Barristers & Solicitors

WeirFoulds LLP

June 14, 2013

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VIA EMAIL

Kirsten Walli
Board Secretary
Ontario Energy Board
Suite 2701
2300 Yonge Street
Toronto ON M4P 1E4

Dear Ms Walli:

**Re: Toronto Hydro-Electric System Limited/
Application for an Order Pursuant to Section 29 of the Ontario Energy Board Act**

We are counsel to Toronto Hydro-Electric System Limited ("THESL"). On behalf of our client we enclose herewith the following:

1. A Notice of Application for an application seeking an order pursuant to section 29 of the *Ontario Energy Board Act 1998*;

2. The Pre-Filed Evidence of THESL, dated June 13, 2013;

3. The Expert Report of Dr. Jeffrey Church, dated June 13, 2013;

4. The Expert Report of Dr. Charles Jackson, dated June 11, 2013.

With the original of this letter we will provide copies of the enclosed material, enclosed in an Application Record.

Yours truly,

WeirFoulds LLP

Robert B. Warren

RBW/dh
cc: Toronto Hydro-Electric System Limited
Attention: Rob Barrass
5502349.1

ONTARIO ENERGY BOARD

IN THE MATTER OF the Ontario Energy Board Act, 1998, S.O. 1998, c.15 (Schedule B);

AND IN THE MATTER OF an application by Toronto Hydro-Electric System Limited for an order pursuant to section 29 of the Ontario Energy Board Act, 1998.

NOTICE OF APPLICATION

TORONTO HYDRO-ELECTRIC SYSTEM LIMITED ("THESL") will make an application on a date and at a time to be fixed by the Ontario Energy Board (the "Board"), at the Board's Chambers at 2300 Yonge Street, Toronto, Ontario.

PROPOSED METHOD OF HEARING: THESL proposes that the application be heard orally.

THE APPLICATION IS FOR THE FOLLOWING ORDERS:

1. An order, pursuant to section 29 of the *Ontario Energy Board Act, 1998* (the "Act"), that the Board refrain from regulating the terms, conditions and rates for the attachment of wireless telecommunications devices ("wireless attachments") to THESL's utility poles.

2. Such further and other orders as the Board may require.

THE GROUNDS FOR THE APPLICATION ARE:

1. THESL is required by Decision and Order dated March 7, 2005 to allow access to its utility poles for Canadian carriers' and cable companies' wireless attachments at a regulated rate.

2. THESL proposes to charge a competitive rate for wireless attachments to its utility poles.

3. The public interest relevant to assessing whether competition is sufficient is the interest of THESL's ratepayers.

4. Ratepayers would not be harmed by allowing THESL to charge a competitive rate for wireless attachments to its utility poles. On the contrary, allowing THESL to charge a competitive rate for wireless attachments to those poles would benefit those ratepayers.

5. In the alternative, if the public interest relevant to assessing whether competition is sufficient is the public interest in wireless markets, competition will be sufficient to protect that public interest.

6. Such further and other grounds as counsel may advise.

THE FOLLOWING DOCUMENTARY EVIDENCE will be used at the hearing of the application:

1. The Pre-Filed Evidence of THESL dated June 13, 2013;

2. The Expert Report of Dr. Jeffrey Church, dated June 13, 2013;

3. The Expert Report of Dr. Charles Jackson, dated June 11, 2013; and

4. Such further and other material as counsel may advise and the Board permit.

Dated June 13, 2013

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ONTARIO ENERGY BOARD

IN THE MATTER OF the Ontario Energy Board Act, 1998, S.O. 1998, c.15 (Schedule B);

AND IN THE MATTER OF an application by Toronto Hydro-Electric System Limited for an order pursuant to section 29 of the Ontario Energy Board Act, 1998.

PRE-FILED EVIDENCE OF

TORONTO HYDRO-ELECTRIC SYSTEM LIMITED

JUNE 13, 2013

ONTARIO ENERGY BOARD

IN THE MATTER OF the Ontario Energy Board Act, 1998, S.O. 1998, c.15 (Schedule B);

AND IN THE MATTER OF an application by Toronto Hydro-Electric System Limited for an order pursuant to section 29 of the Ontario Energy Board Act, 1998.

PRE-FILED EVIDENCE OF TORONTO HYDRO-ELECTRIC SYSTEM LIMITED

1. THESL owns approximately 175,000 poles in its distribution system.

2. THESL's poles serve different functions, and individual poles may serve more than one function. The poles can be grouped roughly in four broad categories, as follows:

   (a) Poles whose principal function is to support primary distribution. These poles may also support secondary distribution. These poles can, depending on the circumstances, accommodate wireless telecommunications equipment ("wireless attachments") and wireline telecommunications equipment ("wireline attachments"), but not as a general proposition on the top of the poles;

   (b) Poles whose principal function is to support secondary distribution. These poles can, depending on the circumstances, accommodate both wireless attachments and wireline attachments;

   (c) Streetlighting poles, which either have or can have a distribution function. Under THESL's current standards, streetlighting poles do not accommodate wireline attachments but can, if modified or replaced, accommodate wireless attachments;

   (d) Streetlighting poles that are "decorative" or "historic". Such poles generally do not accommodate either wireless attachments or wireline attachments.

3. Whether any individual pole can be used for wireless attachments depends on the circumstances of that pole, the size of the proposed attachments, and where on the pole the devices are to be attached. THESL now reserves, and would continue to reserve, the right to preclude wireless attachments on any of its poles based on the circumstances of those poles.

4. THESL has no knowledge of the economic significance that the location of poles has to the attacher. As a result, that factor plays no role in THESL's decision whether to permit wireless attachments on a pole or poles.

5. Although THESL's poles are located throughout its distribution system, the majority of its distribution poles are located outside the downtown core. The majority of distribution services in the downtown core are provided through underground ducts. THESL's poles in the downtown core are primarily streetlighting poles.

6. Attached as Appendix A is a map showing the location of THESL's poles, by type, in THESL's service territory.

7. There are approximately 119,000 poles in THESL's system available for wireless attachments. Given that number of poles in THESL's system, and given the broad geographic dispersion of those poles within that system, THESL can accommodate reasonable demands for wireless attachments to its poles.

8. In addition to THESL's poles, there are approximately 23,000 poles owned by THESL's affiliate, Toronto Hydro-Electric Services Inc. ("THESI"). All of THESI's poles are streetlighting poles, which do not under current standards accommodate wireline attachments but which can, if modified or replaced, accommodate wireless attachments. Some of THESI's poles are "historic" or "decorative" and as such generally do not accommodate either wireless or wireline attachments.

9. THESL owns approximately 40,000 streetlighting poles. As set out in the preceding paragraph, THESI owns approximately 23,000 streetlighting poles. Approximately 25% of the streetlighting poles in the downtown core of Toronto are historic or decorative.

10. Wireless attachments are in two categories. One is for WiFi services. The other is for cellular services.

11. There are now wireless attachments on 130 of THESL's poles, and 61 of THESI's poles. Of the wireless attachments on THESL's poles, 128 are for WiFi services, and 2 are for cellular services. Of the wireless attachments on THESI's poles, 52 are for WiFi services and 9 are for cellular services.

12. In his report dated June 13, 2013, Dr. Jeffrey Church distinguishes between incumbent wireless service providers and new entrants. There are no wireless attachments on THESL's or THESI's poles from any of the new entrants.

13. Since the date of the Board's Preliminary Decision and Order in EB-2011-0120 there have been 19 permit applications, from two providers, for wireless attachments on THESL and THESI's poles. To date, one permit has been issued. Of those applications, 18 are for cellular services on 18 THESL poles. The remaining application contemplates WiFi attachments on 2 THESL poles.

14. With the exception of wireless attachments for Wi-Fi, the THESL and THESI poles on which there are wireless attachments, or for which applications for attachments have been made, are all located outside the downtown core.

15. Were the Board to refrain from regulating the terms, conditions, and rates for the wireless attachments on its poles, there would be no harm to THESL's distribution system.

16. As a result of the Decision and Order of the Ontario Energy Board dated March 7, 2005, THESL is authorized to charge $22.35 for each pole attachment. That figure is intended to cover THESL's direct and indirect costs. THESL's direct and indirect costs for pole attachments are higher than that.

17. THESL proposes to charge a competitive rate for wireless attachments to its poles. Doing so will improve THESL's ability to recover its true costs, and provide a benefit to its ratepayers and to its shareholder.

Dated June 13, 2013

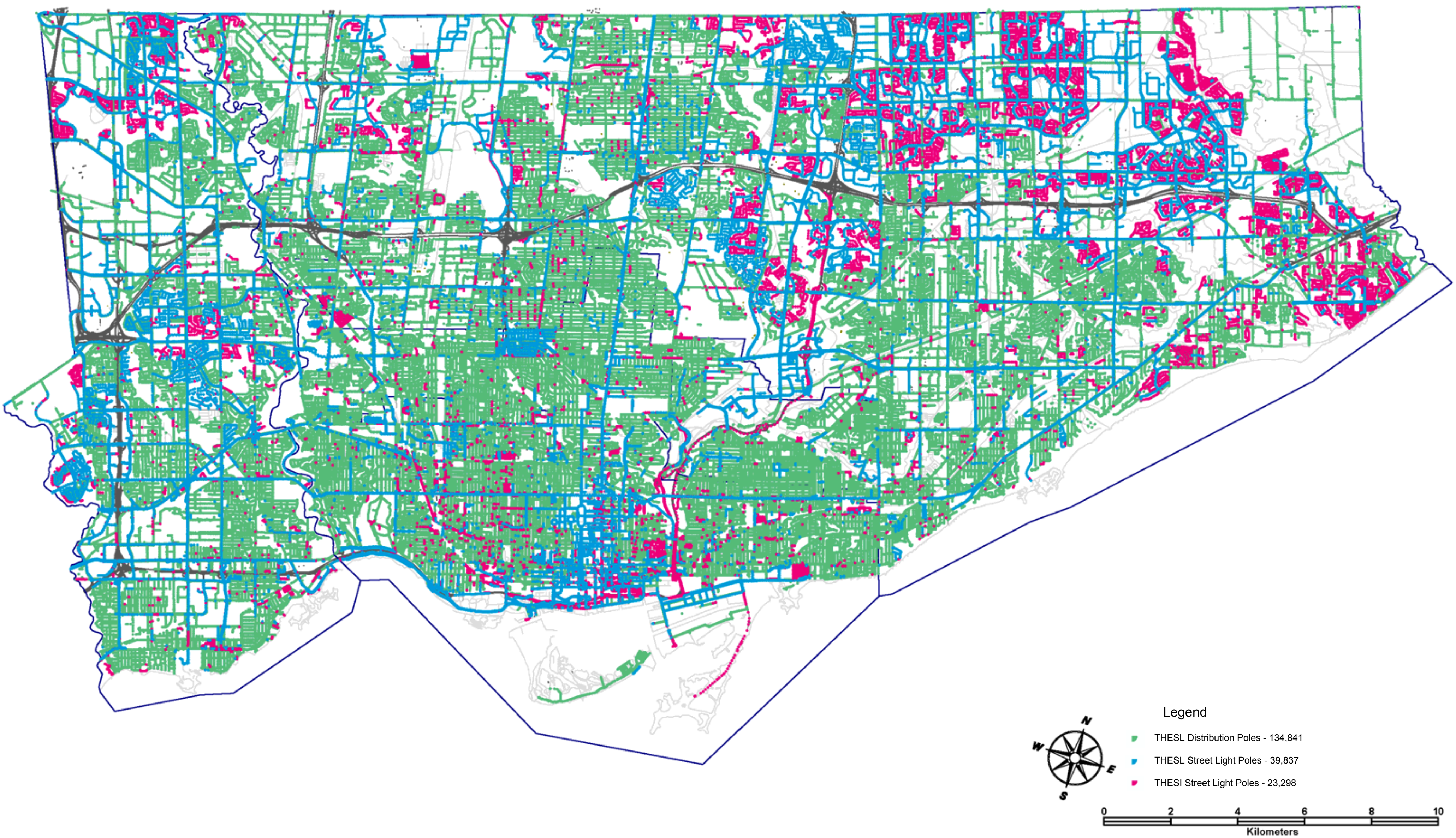
5499441.1

APPENDIX A

TO THE PRE-FILED EVIDENCE OF TORONTO HYDRO-ELECTRIC SYSTEM LIMITED

DATED JUNE 13, 2013

All Toronto Hydro Poles



ONTARIO ENERGY BOARD

IN THE MATTER OF the Ontario Energy Board Act, 1998, S.O. 1998, c.15 (Schedule B);

AND IN THE MATTER OF an application by Toronto Hydro-Electric System Limited for an order pursuant to section 29 of the Ontario Energy Board Act, 1998.

EXPERT REPORT OF

JEFFREY R. CHURCH

JUNE 13, 2013

Regulatory Forbearance for Toronto-Hydro-Electric System's Provision of Pole Access for Wireless Attachments

Expert Report

Jeffrey Church

Professor
Department of Economics
University of Calgary

June 13, 2013

Table of Contents

1 Introduction

1.1 Overview of the Application for Forbearance by THESL

1. Toronto-Hydro Electric System Limited ("THESL") is owned by the City of Toronto. THESL is the local electric distribution company ("LDC") in the City of Toronto. One component of the electric distribution system owned, maintained, and operated by THESL is a network of hydro (or power) poles. These poles are an example of a support structure used by THESL to provide distribution services. THESL has a number of different types of poles, with the type of pole determined by its requirements. Some poles support both primary and secondary distribution of electricity, wireline attachments of the telecommunications and cable television providers, and streetlights. Other poles have a much more limited function, primarily supporting streetlights but available to provide distribution services.[1]

2. The Ontario Energy Board (OEB) confirmed in decision EB-2011-0120, the *CANDAS* decision,[2] that access to THESL's poles for wireless telecommunication carriers was mandated by its previous decision (the *CCTA* decision) requiring access for attachments by telecommunications carriers and cable operators.[3] Under the *CCTA* decision the regulated rate for an attachment was set at $22.35 per year. The *CCTA* decision provided for ex post regulation of terms and conditions: the telecommunication carriers and cable operators could appeal to the OEB for regulatory relief if they were unable to negotiate satisfactory terms and conditions of access.[4]

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[1] *In the Matter of the Ontario Energy Board Act, 1998, and in the Matter of an application by Toronto Hydro-Electric System Limited for an order pursuant to section 29 of the Ontario Energy Board Act, 1998, Pre-filed Evidence of Toronto Hydro-Electric System Limited,* June 13th, 2013 at ¶2. ("THESL Evidence.")

[2] *In the Matter of an application by Canadian Distributed Antenna Systems Coalition for certain orders under the Ontario Energy Board Act, 1998,* Preliminary Decision and Order, EB-2011-0120, 13 September 2012, p. 6. ("CANDAS Decision").

[3] *In the Matter of the an Application pursuant to section 74 of the Ontario Energy Board Act, 1998 by the Canadian Cable Television Association for an Order or Orders to amend the licenses of electricity distributors*, RP-2003-0249 7 March 2005 ("CCTA Decision").

[4] The CCTA Decision provided for the terms and conditions of attachments to be negotiated between the concerned parties (e.g., the electric utility and the telecom or cable companies) once the Board had determined the appropriate rate. See CCTA Decision, p. 10. In a typical contract, these other terms and conditions might, among other things, specify any restrictions on the attachments permitted (e.g., for safety or operational reasons), the rights of third-parties making attachments, duration of the contract, force majeure provisions etc.

3. THESL has applied for regulatory forbearance under Section 29 of the *Ontario Energy Board Act* for wireless attachments. Section 29 of the *Ontario Energy Board Act* provides that the OEB shall forbear from regulation "if it finds as a question of fact that a licensee, person, product, class of products, service or class of services is or will be subject to competition sufficient to protect the public interest."[5]

4. The key issue in assessing regulatory forbearance is whether, in the absence of regulation, competition is sufficient to discipline the exercise of market power, in this case in the provision by THESL of pole access for wireless attachments. At the foundation, therefore, of a forbearance application is a market power analysis.

5. The goal of a market power analysis is to determine the extent to which a firm, in this case THESL, can profitably offer a service, in this case pole access for wireless attachments, at rates in excess of competitive levels. If THESL cannot exercise market power in the provision of pole access for wireless attachments, then in the absence of some other compelling reason to continue regulation, competition is sufficient to protect the public interest.

6. Even though the firm is an exclusive supplier of its product, it may not have market power if it competes with differentiated products.[6] Whether it competes with differentiated products depends on the ability and willingness of its customers to substitute to the products of other suppliers.

7. The rationale for price and entry regulation is typically a two step justification. First the technology is typically assessed to be a normative natural monopoly. This means that the cost of service is minimized if there is a single supplier. To minimize costs of service entry is restricted: there is a designated supplier. To control the presumed market power of this

[5] *Ontario Energy Board Act* Section 29(1). Section 29 applies to any licensee and "any product or class of products supplied or service or class of services rendered within the province by a licensee or a person who is subject to this Act." See Sections 29(2)(a) and (b) of the *Ontario Energy Board Act*. As an LDC in Ontario, THESL is required to have a license by Section 57 of the *Ontario Energy Board Act*.

[6] See the discussion of intermodal competition, as well as differentiated products and market power in J. Church and R. Ware, (2000), *Industrial Organization: A Strategic Approach,* McGraw-Hill, San Francisco, at p. 764 and p. 30, respectively.

supplier, however, requires regulation of its rates.[7] But if that supplier does not have market power in the provision of a service, then regulation to control its market power is not required.

8. In the case of THESL's provision of pole access for wireless attachments, it is not competition from other pole networks that is the issue. Instead the issue is whether wireless service providers can, and will, substitute to other inputs sufficiently to discipline any exercise of market power by THESL in the provision of pole access for wireless attachments. That is, when the price of pole access for wireless attachments increases can, and will, wireless service providers reduce their use of pole access for wireless attachments sufficiently and instead utilize other inputs, for example a side of building to mount the wireless attachment or split an existing cell by adding another antenna tower and base station.

9. To summarize: if regulation is based on the premise that it is in the public interest to control the exercise of market power by a firm, then a finding that competition is sufficient to discipline its market power suggests that regulation of rates, and associated terms of service, are not required to protect the public interest. Regulation is not necessary to replace competition to discipline the firm's market power.

10. The objectives of this report are the following:

    - Present an analytical framework to determine the potential for the exercise of market power and its effects.

    - Apply that analytical framework to the provision of pole access for wireless attachments by THESL.

11. Furthermore, a finding that THESL has market power in the provision of pole services to wireless communication providers is only a necessary condition, but not a sufficient one, for continued regulation. As explained in this report, both economic efficiency and distributional

[7] See J. Church and R. Ware, (2000), *Industrial Organization: A Strategic Approach,* McGraw-Hill, San Francisco, at p. 760.

concerns also likely justify forbearance of THESL's poles for the purposes of wireless attachments, even if THESL has market power in the relevant market.[8]

12. Some exercise of market power in the provision of pole access for wireless attachments is likely appropriate on efficiency and distribution grounds. Efficiency considerations mean wireless attachments should contribute to the revenue adequacy of THESL by paying a rate that exceeds the marginal cost of making an attachment. The efficient allocation of the burden of ensuring THESL's financial viability should be spread across all of the services it provides. Moreover, on distributional grounds the OEB might determine that some of the burden of financial viability for THESL should be borne by those making and benefiting from wireless attachments instead of THESL ratepayers.

1.2 Questions Addressed

13. Counsel for THESL requested:

> The preparation of a written report (the "Report"), to be filed as evidence with THESL's application to the OEB, assessing the extent to which wireless telecommunications in THESL's service territory is, or will be, competitive if the OEB refrains from regulating the rates, terms and conditions upon which access for wireless telecommunications services is made available by THESL.

This request is in support of an application by THESL requesting the OEB to forbear, or refrain, from regulating the attachment of wireless communications devices to its poles.

14. This question is addressed by considering the following two questions:

- Does THESL have market power in the provision of pole access for wireless attachments?
- Could THESL's exercise of market power result in a substantial lessening of competition in the relevant downstream market?

15. The answer to both of these requires as an initial step identifying two relevant markets:

[8] See Section 7.

- What is the relevant upstream market to assess whether THESL has market power in the provision of pole access for wireless attachments?

- What is the relevant downstream market to assess (i) whether THESL has market power in the provision of pole access for wireless attachment and (ii) the effect of any exercise of market power by THESL?

1.3 Summary of Opinion

1.3.1 Does THESL have market power in the provision of pole access for wireless attachments?

16. It is very unlikely that THESL has market power in the provision of pole access for wireless attachments.[9] Market power analysis requires a careful consideration of the ability and willingness of the customers of a firm to substitute. The consideration of what constitutes "reasonable substitutes" typically involves defining the relevant market. Market definition involves identifying the set of substitutes that constrain the exercise of market power. An analysis of the willingness and ability for substitution away from pole access for wireless attachments by wireless service providers is consistent with the conclusion that there is not a relevant market defined by provision of pole access for wireless attachments. THESL's position as an exclusive supplier of pole access for wireless attachments does not mean that it has market power in a relevant market.

17. *Upstream Product Market Definition*: The economic interest in the regulation of access to poles by firms wishing to make wireless attachments is linked to demand for such pole access by (cellular) wireless service providers in Toronto. While some parties might also wish to make wireless attachments to poles for providing other types of services—e.g., Wi-Fi or highly localised wireless networks—the economic importance of these is likely limited.[10] Demand for pole access for wireless attachments arises because poles can be used as a site to deploy small cell technologies and Distributed Antenna Systems ("DAS"). Wireless service providers can utilize a number of alternative inputs to small cell wireless technologies and

[9] The concern is with whether THESL has significant and durable market power. As explained in Section 4 significant market power is the ability to profitably raise prices above competitive levels, which typically means pricing above average cost and the firm earns monopoly profits.
[10] Section 5 establishes that the appropriate economic focus is on wireless service providers such as Bell, Rogers, Telus, WIND Mobile, etc. who use licensed spectrum to provide wireless services to consumers.

DAS deployments that use pole access to provide outdoor coverage and capacity. Wireless service providers can also utilize alternative siting facilities for small cell and DAS deployment, such as the side of a building. These possibilities for substitution suggest that there is a broad upstream "input market", and not a market defined by monopoly control over the input provision of pole access for wireless attachments. Consequently, the fact that THESL may be an exclusive supplier in the provision of pole access for wireless attachments does not mean that it has market power in a relevant upstream market.

18. *Downstream Product Market Definition:* The relevant downstream market is a wireless service that meets both nomadic and mobile demand by users in Toronto, with an emphasis on high speed data transmission.[11] Wireless services in the relevant market are likely to utilize Long Term Evolution ("LTE") technology to deliver increasingly high speed data transmission services, aimed at supporting the needs of smartphone and tablet users.

19. *Upstream and Downstream Geographic Market Definition*: The geographic market for both the provision of the input upstream and the provision of the service downstream is at least as extensive as the City of Toronto.

20. Market definition involves identifying substitutes that constrain the exercise of market power. If the relevant market was (on the product dimension) pole access for wireless attachments and (on the geographic dimension) a specific pole, then THESL would have market power. That the market is much broader—defined over other inputs and other sites and a broader geographic region than a particular pole—strongly suggests that THESL is unlikely to be able to exercise market power in the provision of pole access for wireless attachments. Even though THESL is the only supplier of pole access for wireless attachments at a particular location, its exercise of market power is disciplined by the ability and willingness of wireless service providers to substitute to other inputs and sites, as well as the ability and willingness of wireless consumers to substitute to wireless services that do not use pole access.

[11] Nomadic demand refers to demand for connectivity across a variety of locations in which users tend to make the most use of devices such as smartphones, tablets and laptops, e.g., homes, offices, libraries, cafes. Mobile demand refers to demand for connectivity when users are mobile, e.g., walking, driving, in trains etc. Most users are more nomadic than they are mobile, but might occasionally have need for true mobile connectivity.

21. The key to the conclusion that THESL is very unlikely to have market power in the provision of pole access for wireless attachments is recognition of the limited role that pole access for such attachments will have in the deployment of high speed (broadband) wireless networks. The network architecture of broadband wireless networks required to meet the capacity and coverage requirements of increased data demand will involve a combination of traditional macrocells (typical base stations and large antennas) with small cells and DAS deployments. Small cells and DAS can be installed on poles, but need not be, to provide outdoor coverage, and pole access is important primarily for providing outdoor service. Importantly, these small cells and DAS will be used to augment capacity or provide coverage in targeted areas, and not to provide "blanket" outdoor and indoor coverage.

22. There are three sources of substitution that will discipline the exercise of market power by THESL in the provision of pole access for wireless attachments:

- Wireless service providers can often substitute to alternative sites rather than use small cells and DAS mounted on poles to enhance their outdoor coverage. Indeed power and backhaul requirements suggest that outdoor coverage is more likely to be provided by small cells installed on the exterior of buildings or indoors.

- Wireless service providers can often substitute to alternative inputs rather than use small cells and DAS to augment the capacity and coverage of their networks outdoor. For instance, wireless service providers can mitigate the demands on their wireless networks by offloading traffic to fixed line networks using femtocells and Wi-Fi, and using data management practices such as pricing, traffic shaping, and data compression. Wireless service providers can also increase the capacity of their wireless networks by, for example, acquiring more spectrum, splitting macrocells, adopting technology that economizes on spectrum, and sharing spectrum and cell sites, perhaps by roaming. The substitution might be circuitous: outdoor capacity and coverage in a particular geographic area can be enhanced by reallocating macrocell capacity away from providing indoor usage by installing DAS and small cells indoors.

- Because pole access does not result in either a significant cost advantage or quality advantage, consumers do not distinguish between wireless services that utilize pole access as an input and those that do not. Hence downstream substitution to wireless services that do not use pole access is an important source of indirect substitution that would discipline the exercise of market power by THESL.

23. Small cell deployment on poles is likely to be considered to augment the capabilities of a macrocell network's outdoor coverage for users who are non mobile and have significant demand for data transmission.[12] In these circumstances there are likely to be alternative sites, in particular a structure (or structures) which has (or have) attracted subscribers and likely has (or have) both power and fibre access and/or alternative combinations of inputs that address the coverage and capacity issue from large data demand. Both of these make demand for pole access for wireless attachments relatively price responsive and suggest that THESL will not have market power.

24. The analysis of the extent to which wireless service providers can and will substitute to alternative inputs and sites is supported by the fact that at regulated rates, the use of THESL poles for wireless attachments to provide wireless services is extraordinarily small.[13, 14]

25. There are likely only a very limited number of locations where using small cells or DAS mounted on poles is the sole option for wireless service providers to implement outside data coverage and capacity. But, these localized circumstances are not likely to be known by THESL. Hence it is unlikely that THESL can exercise market power in those locations: if it cannot distinguish the locations where it has market power from those where it does not, then the relevant geographic area is no smaller than the footprint of its entire pole network. THESL does not know the value of pole access at a given location to a wireless service provider and hence cannot discriminate if rates were forborne.

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[12] Non mobile means that the wireless user is not traveling at sufficient speed that dropped calls are an issue when small cells are used to provide capacity and coverage.
[13] Recall that wireless services in this report means a service that supports both nomadic and mobile access, i.e., that provided by licensed spectrum users who operate cellular networks.
[14] THESL Evidence at ¶11 and ¶13.

1.3.2 Could THESL's exercise of market power result in a substantial lessening of competition?

26. Even if THESL does have market power in the provision of pole access for wireless attachments, an important consideration is whether this exercise has a negative effect on competition in the relevant downstream market. The exercise of market power by THESL in the provision of pole access for wireless attachments could result in a substantial lessening of competition in downstream wireless broadband markets if:

- the exercise of market power by THESL raises the costs of deploying wireless services, resulting in higher prices and lower quality service in the downstream market.
- the exercise of market power by THESL affects wireless service providers asymmetrically, and in doing so, preserves, creates, or enhances the market power of some wireless service providers in the downstream market.

27. The incumbent wireless service providers in Toronto are Bell, Rogers, and Telus. Mobilicity, WIND Mobile, and Public Mobile are the entrants. They acquired spectrum in 2008 and have launched services in Toronto. The incumbent wireless service providers in Toronto already serve the great majority of customers, and it is very unlikely (given that only these firms offer the most data-intensive devices and LTE high speed data networks) that they will have a smaller share of data traffic. Because the expected increase in demand for capacity is likely attributable to increased demand for data, it is most likely to materialise almost exclusively on the networks of these carriers. Consequently, a significant impact on consumer welfare would arise primarily if THESL were able to exercise market power at the expense of incumbent wireless service providers. If THESL had market power with respect to these incumbent firms, it could raise their costs and this increase in costs could manifest itself in the form of higher consumer prices and lower output in the downstream market.

28. Pole access services for wireless service providers is not likely, and is not likely to be, an appreciable element of downstream costs for the major wireless firms in Toronto. Because of this the ability of the incumbent firms to deploy new networks and services cannot be significantly impacted by the price for pole access for wireless attachments. THESL is not in

the position of a firm that can exercise market power in a way that creates substantial harm in the downstream market by raising the costs of the incumbent wireless service providers.

29. The only negative effect, therefore, in the downstream market from any market power THESL might have (such market power is not indicated by the analysis) must arise from the potential for THESL's exercise of market power to maintain or create market power in the downstream market. The only firms in the downstream market who *might* have market power are the incumbents. Any hypothesis regarding THESL's ability to maintain or create market power in the downstream market must, however, require that the facts be consistent with *all* of the following:

- the exercise of market power by THESL has a greater effect on the costs of entrants than on incumbents;
- but for this asymmetric impact on costs the entrants would have been able to more effectively discipline the exercise of market power by the incumbents; and
- the incumbents have market power.

30. The analysis indicates that the facts do *not* support the hypothesis that if THESL exercised market power, it would create, maintain, or preserve market power in the downstream market. First, the analysis strongly suggests that incumbents do not exercise (inefficient) market power. Second, pole access at regulated rates is unlikely to materially, if at all, affect the competitive constraint the entrants have on the incumbents. Therefore any exercise of market power by THESL cannot create, enhance, or maintain market power in the downstream market.

1.4 Organization of this Report

31. The remainder of this report is organized as follows:

- Section 2 provides background on THESL's network of poles;

- Section 3 spells out the generally accepted analytical framework used to evaluate the case for regulatory forbearance and its relationship to whether THESL has market power;

- Section 4 provides some basic antitrust economic concepts used extensively in the analysis of market power;

- Section 5 provides an antitrust analysis of market power—that is, it defines relevant upstream and downstream markets, and evaluates whether THESL can exercise market power—has a dominant position—in the upstream market;

- Section 6 evaluates whether in the absence of regulated rates for pole access THESL's pricing and terms of access for pole access for wireless attachments would result in a substantial lessening of competition in the relevant downstream wireless services market;

- Section 7 develops the hypothesis that even if THESL can exercise market power in providing pole access for wireless attachments forbearance might still be appropriate.

1.5 Background and Qualifications

32. I am a Full Professor in the Department of Economics at the University of Calgary. I received a Ph.D. in economics from the University of California, Berkeley in 1989, and have been continuously employed in the Department of Economics at the University of Calgary thereafter, teaching courses in industrial organization, competition policy, regulatory economics, and microeconomics. I am also the Program Director of the Digital Economy Program (DEP) in the School of Public Policy at the University of Calgary. The focus of DEP's research program is on policy and regulation of telecommunications and broadcasting in Canada. I am the coauthor of a book on the regulation of natural gas pipelines in Canada, a text in industrial organization, and a monograph on the competitive implications of vertical and conglomerate mergers. A complete list of my publications is included in my curriculum vitae, which is marked and attached hereto as Appendix A. I have acted as an expert on a wide range of regulatory and competition policy matters. I have been accepted as an expert in

proceedings before the National Energy Board, the Alberta Energy Utilities Board, the Canadian Radio-Television and Telecommunications Commission ("CRTC"), the Competition Tribunal, the Federal Court of Australia, the Federal Court of Canada, and the Supreme Court of British Columbia. Appendix B and the footnotes in this report document the material relied upon for the analysis.

33. I have extensive experience with telecommunications issues in Canada. For more than ten years I was involved in the preparation of numerous submissions with the Competition Bureau in regulatory proceedings before the CRTC on issues such as restructuring local telecommunications, forbearance, and wholesale access. I recently submitted reports to Industry Canada on spectrum policy and foreign ownership in the telecommunications sector, as well as an expert report on the economics of usage based billing for the CRTC.

2 THESL's Pole Network

34. It is useful to adopt a four category classification of THESL's poles. There are:[15]

- poles whose principal function is to support primary distribution ("primary distribution poles"). These poles might also support secondary distribution.
- poles whose principal function is to support secondary distribution ("secondary distribution poles").
- streetlighting poles that support a streetlight but also have, or can have, a distribution function ("streetlighting poles").
- decorative or historic streetlighting poles.

35. Primary voltage poles can be used to support attachments used to provide wireline telecommunications services and cable services.[16] Poles that provide secondary distribution can also support wireline telecommunications and cable services.[17] Under certain circumstances both primary and secondary distribution poles can support wireless

[15] THESL Evidence at ¶2.
[16] THESL Evidence at ¶2.
[17] THESL Evidence at ¶2.

attachments.[18] As a general proposition, however, primary distribution poles cannot support pole-top attachments.[19]

36. Under THESL's current operating standards streetlighting poles do not support wireline attachments.[20] However streetlighting poles may be used for wireless attachments.[21] If they are used for hosting wireless attachments, however, streetlighting poles typically require modification or replacement.[22] Decorative and historic streetlighting poles generally cannot accommodate wireless attachments.[23]

37. The total number of THESL poles of all kinds across the entire City of Toronto is 175,000.[24] THESL has some 40,000 streetlighting poles across the City of Toronto, while its affiliate Toronto Hydro Energy Services Inc. ("THESI") has some 23,000 streetlighting poles across the City.[25] THESL estimates that of its 175,000 total poles, 119,000 are poles (including streetlighting poles) to which wireless attachments can be made, perhaps with modification or replacement.[26]

38. The majority of THESL's poles are not in the downtown core.[27] The majority of its distribution system in the downtown core is underground and its poles in the downtown core are primarily streetlighting poles.[28] Of these THESL estimates that approximately 25% of its poles in the downtown core are historic or decorative. [29]

39. It is important to note that because of the characteristics of its pole network, THESL has significant numbers of poles that do not naturally lend themselves to wireline or wireless attachments in the downtown core of Toronto. Its poles in the the downtown core are primarily streetlighting poles to which wireless attachments can be made (but not typically

[18] THESL Evidence at ¶2.
[19] THESL Evidence at ¶2.
[20] THESL Evidence at ¶2.
[21] THESL Evidence at ¶2.
[22] THESL Evidence at ¶2.
[23] THESL Evidence at ¶2.
[24] THESL Evidence at ¶1.
[25] THESL Evidence at ¶9.
[26] THESL Evidence at ¶7.
[27] THESL Evidence at ¶5.
[28] THESL Evidence at ¶5.
[29] THESL Evidence at ¶9.

wireline), but which require modification or replacement in order to make such attachments, or are historic or decorative poles that generally do not accommodate telecommunications attachments of any kind.

3 Overview of the Analytical Framework: Essential Facilities and Market Power

40. This section provides a brief overview of the analytical framework that is developed and applied to the analysis of forbearance in this case. This analytical framework establishes that regulation is only warranted if it is the case that THESL enjoys the ability to exercise market power in the provision of pole access for wireless attachments, and that the exercise of this market power produces a substantial negative effect in the downstream market for wireless services.

41. The key issue with respect to THESL's application is whether the rates that THESL can charge wireless service providers to make attachments on its poles should be regulated by the OEB. The rationale for that regulation is a concern that THESL can exercise market power and that such access is essential for competition. In its *CCTA* decision, the OEB considered the general issue of pole access for cable and telecommunications providers, although its primary focus was on wireline attachments by cable television providers. The OEB ordered access at regulated access charges to all power poles owned by local electric distribution companies in Ontario.[30] The OEB's rationale was that power poles were essential facilities and that the local distribution companies had exercised monopoly power.[31]

42. The essential facilities framework and the exercise of monopoly power are related, but distinct. The essential facilities framework is an antitrust concept that was developed to determine when refusal by a vertically integrated incumbent to provide access could be an antitrust violation. The focus of an essential facilities analysis is on the effect on competition in the downstream market if access is mandated to the facility, where the services the facility provides are in an upstream market. The analysis involves a comparison

[30] CCTA Decision at pp. 3-4.
[31] CCTA Decision at p. 3.

between the outcome in the downstream market with and without mandated access: the difference will depend on the extent of THESL's market power in the upstream market.

43. The essential facilities framework captures this "but for" analysis and defines a facility as essential if the services provided by the facility are an input to a product, where the input is in an upstream market and the product is in a downstream market, and[32]

- the firm that provides the input is dominant in both an upstream and a downstream market.
- the withdrawal of access to the input results in exit or contraction of competitors from the downstream market [or alternatively that providing access would result in entry or expansion of competitors in the downstream market].
- the exit or contraction results in a substantial lessening of competition [or alternatively that entry or expansion results in a substantial increase in competition] in the downstream market.

44. The dominance requirement means that the vertically integrated firm has market power both in the market for the input and the market downstream (the market for the product that uses the input). The inability to economically duplicate the facility or otherwise find substitutes for the services provided by the facility must result in a substantial cost disadvantage for competitors in the downstream product market. Finally, the cost disadvantage and its effect on competitors in the downstream market must substantially and negatively affect competition in that market. Within the essential facilities framework a substantial lessening of competition means a substantial increase in market power. This is consistent with the first

[32] This is the definition of an essential facility developed by the Competition Bureau in its submissions to the Canadian Radio-television and Telecommunications Commission ("CRTC") in response to CRTC PN 2006-14. See *Evidence of the Commissioner of Competition,* March 15th, 2007, in response to CRTC Telecom Public Notice PN 2006-14 ("*Review of Regulatory Framework for Wholesale Service and Definition of Essential Facility"*) at pp. 22-23. The definition adopted by the CRTC in its decision is similar except that the CRTC did not explicitly adopt the requirement of dominance in the downstream market. See CRTC, *Revised regulatory framework for wholesale services and definition of essential service,* Telecom Decision 2008-17, March 3, 2008 at ¶¶20-27 and ¶¶36-37. The CRTC did not adopt the downstream dominance requirement because of concerns regarding a potential inconsistency with the criteria for forbearance of local exchange services set down in Telecom Decision CRTC 2006-15, *Forbearance from the regulation of retail local exchange services* and *Order Varying Telecom Decision CRTC 2006-15*, Order in Council P. C. 2007-532. See CRTC Telecom Decision 2008-17 at ¶21-22.

bullet above: the vertically integrated firm is able to exercise market power in the downstream market when access to competitors is denied.

45. However, if the owner of the alleged essential facility is not vertically integrated, i.e., not active in the downstream market, then the issues are (i) whether it can exercise market power in the market for the services of the facility and (ii) the effect of that exercise of market power in the downstream market. If it is able to exercise market power then price will be elevated above competitive levels in the upstream market. The effect of this elevation in price from the exercise of market power will be two-fold: (i) some downstream firms will purchase access, but the effect of the exercise of market power is to raise their costs of production in the downstream market; and (ii) some downstream firms, who would have demanded access at the competitive price, no longer demand access when market power is exercised. Firms that no longer choose to access the services of the facility when market power is exercised are effectively denied access. If the owner of the alleged essential facility is not vertically integrated, then mandated access at cost based rates to control its market power in the upstream market is only warranted if the owner of the facility has market power upstream and the effects of its exercise in the downstream market are substantial.

46. When the focus is on a denial of access by a vertically integrated firm the concern in the downstream market should be the extent of market power created or maintained. In this case the definition of a substantial lessening of competition is typically informed by competition policy with its focus on the preservation, maintenance or enhancement of market power. When the focus is on the exercise of market power by the facility owner—which is typically not a competition policy concern, but a regulatory concern—the definition of a substantial lessening of competition is broader. In this case the concern is on the effects of the exercise of market power in the upstream market on the downstream market.[33]

[33] When the exercise of market power raises public policy concerns, the response is to control that exercise by regulating the firm, i.e., subjecting its pricing and other decisions to ex ante regulation under which it must receive permission from a regulator to implement its pricing and other decisions. The policy concern addressed by competition law is very different. Competition law and policy is an ex post approach under which firm conduct is subject to challenge if it creates, enhances, or maintains market power, but the mere exercise of market power is *not* reachable, typically, under competition law. This is the case in Canada. The *Competition Act* does not contain provisions against the mere possession or mere exercise of market power.

47. Determining whether THESL has substantial and durable market power in the provision of pole access for wireless attachments involves, therefore, determining the following:

- Defining the relevant upstream market that includes THESL's provision of pole access for wireless attachments. This involves identifying reasonable substitutes for THESL's pole access for wireless attachments.

- Defining the relevant downstream market. This involves determining the set of reasonable substitutes for wireless services that use THESL's pole access for wireless attachments.

- Assessing THESL's market power in the relevant upstream market.

- Assessing the extent of competition in the relevant downstream market and the impact of the exercise of market power (if any) by THESL in the upstream market on competition in the downstream market.

48. In the absence of either market power in the upstream market *or* a substantial negative effect from its exercise in the downstream market the condition for forbearance is likely satisfied. If regulation is premised on protecting the public interest because of the exercise of market power, a finding that competition is sufficient to discipline the firm's exercise of market power suggests that competition should be sufficient to protect the public interest. The techniques and principles involved in defining markets and establishing the existence of market power are discussed next, as are the principles relevant to assessing the potential for a substantial lessening of competition.

4 Context and Key Economic Concepts

49. In this section some key concepts are defined that will be relevant to determining whether regulatory forbearance is merited in the case of pole access for wireless attachments The section begins with a discussion of market power and related concepts, in particular principles of market definition and the distinction between the exercise of market power and conduct that creates, maintains, or enhances market power.

4.1 Market Power

50. Market power is typically defined as the ability of a firm to profitably raise price above competitive levels.[34] Firms with market power may exercise it by being able to profitably alter characteristics of their products or other aspects of their behaviour away from competitive levels. For instance a firm with market power may find it profitable to not only raise price above competitive levels, but to reduce the quality of its products, its product variety, its level of customer service, or expenditure on research and development below competitive levels.[35]

51. The substitution alternatives available to the customers of a firm determine its market power. The extent of demand substitution depends on whether consumers can, and will, switch to other products in response to a price rise (or other manifestation of market power) or alternative suppliers in a different geographic location. In addition, the set of demand-substitutable products may increase as firms not currently producing demand-substitutable products respond to a price rise (or other manifestation of market power) by changing their product offerings and introducing a demand substitute.[36] Supply substitution involves other firms expanding the set of demand substitutes when a firm attempts to exercise market power and raise its price. The extent to which a firm can unilaterally exercise market power depends on the extent of demand and supply substitution. If these possibilities for substitution are

[34] See the Competition Bureau, *Merger Enforcement Guidelines* March 2011 at 2.3 or more generally G. Niels, H. Jenkins, and J. Kavanagh (2011) *Economics for Competition Lawyers,* Oxford University Press at p. 116 or D. Carlton and J. Perloff (2005) *Modern Industrial Organization,* Pearson at p. 783. Economists typically define market power as the ability to profitably raise price above marginal cost, the price that would prevail in perfectly competitive markets. However the definition used by economists is less useful for policy analysis since many firms will be able to exercise market power based on this definition—indeed any firm whose demand curve is downward sloping—but they will not be able to raise price above average cost levels, i.e., earn greater than a competitive return. Indeed if a firm's unit cost declines as it expands output, the firm will have to be able to profitably raise price above marginal cost in order to break even. The ability to profitably raise prices over competitive levels implies the ability to raise prices above average cost, a level that reflects the requirement of firms to break even and is a useful definition of a competitive market even when firms are not perfectly competitive. An alternative, and equivalent distinction, is to adopt the economic definition of market power and distinguish between the inefficient and efficient exercise of market power. Only the exercise of market power that raises the price above long run average cost levels is inefficient. The exercise of market power should also be durable if there is to be regulation. Durable means that a firm can exercise market power without attracting entry and hence its exercise can persist in the long run.

[35] See Competition Bureau, *Merger Guidelines* March 2011 at 2.2 or the U.S. Department of Justice/Federal Trade Commission, *Horizontal Merger Enforcement Guidelines* August 2010 at p. 2.

[36] See F. Fisher, (2008), "Economic Analysis and 'Bright-Line' Tests," *Journal of Competition Law and Economics* 4: 129 at 134.

limited, and are likely to remain so, for an extended period of time, a firm will be able to exercise market power.

52. Fundamental to the exercise or market power is demand substitution. Customers discipline, and thereby constrain, the exercise of market power by a firm by substituting away from a firm's products when it raises its price. When a firm increases its price, it gains increased revenues from its higher price on infra-marginal sales (sales it continues to make), but loses the profits on marginal sales (sales no longer made). A price increase will be profitable if the gain in revenues from the infra-marginal units exceeds the loss on marginal units. The loss on marginal units equals the product of the reduction in volume from consumers substituting to other alternatives and the profit margin. When these losses at the margin are sufficient, substitution by consumers will limit the ability of the firm to raise its price. The decrease in sales of a product when a firm increases its price is determined by its elasticity of demand.[37]

53. Even if demand substitution is initially limited, a firm may not be able to exercise market power if there is supply substitution. In response to higher prices, if suppliers can easily enter and produce substitutes, then the demand substitution alternatives available to its consumers could expand sufficiently that the market power of a firm is limited.

4.2 Market Definition

54. The reason to define markets is usually to identify market power and to identify if the conduct at issue harms competition in a market. The relevant market has both a product and a geographic dimension. The product dimension involves identifying competing products, while the geographic dimension involves identifying the location and identity of competing suppliers of the relevant product.

55. The functional dimension of the market involves identifying the levels of the supply chain or the different vertical levels of production that are relevant for assessing market power. The functional dimension is often taken into account, either implicitly or explicitly, when defining the product and geographic dimensions of the market. However, in the case of

[37] The own price elasticity of demand (which when there is no possibility of confusion with cross price elasticity is sometime referred to as the elasticity of demand) for a firm is the percentage decrease in its sales volume (quantity) from a one percent increase in its price. The smaller is the change in sales volume, the more inelastic is demand.

markets for inputs, the ability to exercise market power at an upstream level may well depend on the substitution alternatives of downstream consumers. Hence explicit consideration of the supply chain and the functional dimension may well be warranted. In any event, the potential for market power in an upstream stage of a vertical chain of supply will typically be informed by, and depend on, demand considerations in downstream stages.

56. One of the roles of market definition is to identify alternative suppliers and products that constrain the exercise of market power by the supplier of a product in a particular location. Too narrow a market definition excludes substitutes that impose important competitive constraints. Too broad a market definition will lead to the inclusion of products or suppliers from other regions that are not close substitutes and do not exert significant competitive constraints. Antitrust markets are an attempt to define markets appropriately so that they include substitutes and alternative suppliers that are important in constraining the exercise of market power by a supplier, but exclude those that are not. As a consequence in an antitrust market, market shares are potentially reflective of market power. Proper market definition enables market shares and statistics on concentration to be used as proxies for market power.

57. Concentrated markets will only be a necessary condition for the inference of market power. Whether they are in fact indicative of market power depends on barriers to entry. The combination of high barriers to entry and high market shares is often presumed to indicate market power.

4.2.1 Principles of market definition

58. In this section principles of market definition are considered. The discussion of those principles is organized around the Hypothetical Monopolist Test, the product dimension, the geographic dimension, and derived demand.

Hypothetical Monopolist Test (HMT)

59. A common method to determine the boundaries of antitrust markets for sellers which emphasizes demand substitution is the hypothetical monopolist test ("HMT"). The Competition Bureau's *Merger Enforcement Guidelines* defines the HMT as:[38]

> Conceptually, a relevant market is defined as the smallest group of products, including at least one product of the merging parties, and the smallest geographic area, in which a sole profit-maximizing seller (a "hypothetical monopolist") would impose and sustain a small but significant and non-transitory increase in price ("SSNIP") above levels that would likely exist in the absence of the merger. In most cases, the Bureau considers a five percent price increase to be significant and a one-year period to be non-transitory. Market characteristics may support using a different price increase or time period.

60. In principle the HMT can be adapted to other conduct, besides a merger, that raises concerns that it created, enhanced, or maintained market power. This is done, conceptually, by redefining the HMT to be the smallest group of products and the smallest geographic region such that a hypothetical monopolist of those products in that region would find it profitable to raise prices by a small, but significant and non-transitory (a "SSNIP") amount over competitive levels.[39]

61. Following the HMT, the process of defining the relevant market begins by choosing an initial product and an initial production location. Products and locations are progressively included that are "next-best" substitutes for the initial product choice and geographic locations from which "production is the next-best substitute" for production in the initial location until the HMT is satisfied. The relevant antitrust market is defined (typically) as the smallest set of products in the smallest geographic region that includes the initial product and location such that a hypothetical monopolist of those products in that region would find it profit-maximizing to implement a SSNIP.

62. If for a group of products in a region the HMT does not hold, that means the substitution possibilities for consumers are—in aggregate—sufficient to make the imposition of a SSNIP not profit maximizing. Consumers can discipline the hypothetical monopolist sufficiently by

[38] See Competition Bureau, *Merger Enforcement Guidelines*, March 2011, at 4.3, footnote omitted.
[39] See Competition Bureau, *The Abuse of Dominance Provision Enforcement Guidelines*: *Sections 78 and 79 of the Competition Act*, September 2012 at p. 3.

substituting to either other products or sourcing the same product from suppliers in other geographic regions.

Product Dimension

63. The product dimension of the relevant market is found by considering the willingness and ability of customers to substitute to different products in response to a SSNIP. Products to which it appears that consumers are readily willing to substitute in the face of higher prices are included in the market. Substitutes are often identified by the requirement of functional interchangeability, which means that substitute products have similar qualities that enable the same end use. The issue of whether products are reasonable substitutes, in aggregate, is resolved by the HMT and the threshold for the SSNIP.

64. The key to implementing the hypothetical monopolist test is determining the costs and benefits from exercising market power. When the hypothetical monopolist increases its price, it gains increased revenues from a higher price on inframarginal sales—sales it continues to make—but loses profits on marginal sales—sales no longer made to consumers that substitute away, and for which there was a positive margin over marginal cost. The question of whether the extent to which consumers can, and will, substitute is enough to constrain a profit-maximizing hypothetical monopolist to raise its price by less than a small, but significant and non-transitory increase in price (the SSNIP) depends on both the own price elasticity of demand and the price-marginal cost margin at prevailing prices.

65. Recall from the previous discussion that the own price elasticity of demand summarizes all substitution possibilities: it shows for a one percent increase in price the percentage loss in quantity. Hence it measures the extent to which sales are lost at the margin.[40] The firm's

[40] As indicated the own price elasticity of demand summarizes all of the substitution possibilities available to consumers. The cross-price elasticity of demand shows, in the case of substitutes, the percentage increase in the quantity demanded of good *X* when the price of good *Y* increases by 1%. The market power of a firm does not depend on any single cross-price elasticity of demand. Pair-wise comparisons based on a cross-price elasticity do not give the right answer because cross-price elasticity is the answer to the wrong question. Instead of how demand will shift to consumption of a substitute when the price of a good increases, the relevant question for the ability of a firm to exercise market power is how much will its consumers reduce their demand. As indicated in the text, the own-price elasticity summarizes all of the substitution possibilities of consumers when a product's price increases. However, there is a close relationship between the own price and cross-price elasticities. The greater the number of products for which a firm has high cross-price elasticities, the greater the own price elasticity. Hence, especially in

price-cost margin determines the implications for profits of the reduction in demand: it determines the lost profit per unit of sales no longer made.

66. As discussed below the assessment of THESL's market power in pole access for wireless attachments will depend on the willingness of two sets of customers to substitute to alternative products. The downstream product market will be defined by the willingness and ability of wireless customers to substitute for wireless services that use pole access. The upstream product market will be defined by the willingness and ability of wireless service providers to substitute to other inputs in place of pole access for wireless attachments.

Geographic Dimension

67. When defining the geographic dimension, it is usual to begin by selecting the initial location of production and/or sales and then examining the ability of a hypothetical monopolist to profitably implement a SSNIP in that region. Whether it is profitable depends on the ability of consumers to substitute to other regions. The location of sellers is typically an important consideration where, for example, transportation costs are significant; there is a need for localism (e.g., after-sales care) in the provision of products or services; or where institutional barriers (tariffs, national boundaries etc.) impede the flow of goods from one region to another. Geographic market definition, starting from the location of production and sales, identifies a set of locations for suppliers that must be under the control of the hypothetical monopolist for a SSNIP to be profit maximizing. Without control of all of the suppliers at these locations, consumers would be willing and able to substitute sufficiently to the excluded regions to make a SSNIP non-profit maximizing.

68. Less typically there are cases where buyers or customers require delivery of the product to their location: the sellers must come to the buyers. In these circumstances the ability to deliver the product to the geographic location of the customers defines the set of relevant suppliers. In these circumstances it is not the region in which the supplier is located that is identified by the geographic dimension, but instead the ability of the supplier to supply at the

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the absence of information regarding own price elasticity, cross-price elasticities can provide useful information regarding the substitution possibilities for consumers.

particular location of a buyer. The geographic market dimension in this case identifies the set of suppliers that can provide the good or service at the location of a buyer.

69. An example of when consumers require delivery of a product at their location is broadband internet access. They are unlikely to substitute to broadband access at a different location when the price of service at their existing location rises by a SSNIP—at least not in the short run. Of course this might mean that each location in a city is a unique market. However, the competitive conditions at many, if not most of the locations in a city are likely identical, allowing for aggregation.

70. Markets may be aggregated together if the choices faced by consumers across different geographic markets are very similar—for example, the market for telephone service might be local since consumers may not substitute telephone service at another location for service that they receive at their own location. Yet if the choices facing consumers at location *A* are identical to the choices that they face at location *B*, then location *A* and location *B* can be aggregated into a single market. However, what this means is that the competitive conditions in those markets are the same and hence the analysis of market power and competitive effects is likely identical, not that consumers at location *A* will substitute to location *B* for service.

71. In the case of wireless mobile services—the subject of this report—consumers require coverage and capacity to be provided at a variety of locations. Some consumers, for example, are highly mobile—they travel across different areas of Toronto frequently and require network presence all across the city. Other consumers are more nomadic than truly mobile, and require coverage and capacity at a set of usually predictable locations that they frequent, (although in most cases, they will at least occasionally require mobile coverage also).

Derived Demand

72. In input markets, where the product is not sold to consumers, but other firms that use the product as an input, the demand for the input is said to be derived. It is said to be derived because the demand for the input by firms depends upon the demand for the product it is used to make or the service provided.

73. In general the benefit to a firm of employing another unit of an input is its marginal revenue product. The marginal revenue product of an input equals its marginal product (the increase in output from using another unit of the input) multiplied by the change in the firm's revenues from selling that output, i.e., its marginal revenue. Its marginal revenue is the price it receives in the downstream market where it participates less any reduction in revenue received on infra-marginal units. The revenue from infra-marginal units might fall if the firm has to lower its price to induce sales of the marginal unit.

74. The price the firm receives for the output produced from using more of the input depends on demand in the downstream market, as does the reduction in price (if any) required to induce buyers to purchase the additional input. Hence demand downstream for the product produced by the firm that uses an input is a key determinant of its demand for that input.

75. For a product that is an input there are two sources of substitution that are relevant to disciplining its exercise of market power. The direct source of substitution is by firms in the downstream market who substitute to alternative inputs when the price of an input rises. The second, indirect, source of substitution occurs when the rise in the price of an input raises the costs of downstream firms, downstream firms pass that cost increase onto their customers by raising prices in the downstream market, to which downstream customers respond by reducing their demand in the downstream market. With less demand for the output, downstream firms respond by utilizing less of the input.[41]

[41] The elasticity of derived demand was initially discussed by A. Marshall (1920), *Principles of Economics* 8th edition, MacMillan, at Book VI, Chapter 5 pp. 385-386. It was refined by A. Hicks (1963), *The Theory of Wages* 2nd edition, MacMillan, at pp. 241-247. Modern textbook discussion can be found in M. Trebilcock, R. Winter, P. Collins, and E. Iacobucci (2002) *The Law and Economics of Canadian Competition Policy,* University of Toronto Press at pp. 84-85 and M. Katz and H. Rosen (1994) *Microeconomics,* 2nd Irwin at pp. 375-376. A modern formulation and discussion is R. Chirinko and D. Mallick (2011), "The Elasticity of Derived Demand, Factor Substitution and Product Demand: Corrections to Hicks' Formula and Marshall's Four Rules," *Labour Economics,* 18: 780. Marshall's four rules for the elasticity of demand for an input are (i) the greater the extent to which substitution to other inputs is possible; (ii) the more elastic the supply of other inputs; (iii) the greater the elasticity of the good downstream; and (iv) the higher the share of input in total cost, the greater the elasticity of derived demand. However these results depend on the cost share of an input being fixed. In general it is not fixed when input proportions are variable, but is endogenous and depends on the other three factors. As discussed below because wireless service providers have flexibility in substituting different inputs the cost share of an input, including pole access for wireless attachments, is unlikely to be fixed.

76. In the case of easy substitution, demand for the input will fall as the user of the input substitutes to other inputs.[42] For instance, if the price of peanuts purchased by airlines for snacks rises, their demand for peanuts is likely to fall significantly as airlines can easily substitute to other snacks to serve passengers.

77. If demand for the final product is relatively elastic (small changes in its price result in large changes in the quantity demanded), then for a given increase in marginal cost of production downstream from a rise in an input price:

- the firm that uses the input will find that when it passes this cost on in the form of increased prices for its product, demand will fall relatively substantially;
- resulting in much less need for the input;
- resulting in a reduction in demand for the input;
- and hence demand for the input will also be relatively elastic.

78. For instance, if the downstream products are differentiated in part by their use of different inputs, then the willingness and ability of consumers downstream to substitute between downstream products will be an important determinant of the elasticity of demand for these products, and hence derived demand for an input. As an example, consider a local telephone network that provides wholesale access to its network. Assume that only the local telephone network provides access to entrants required for them to provide broadband service to their residential retail customers. Under this assumption the local telephone network operator is the sole provider in the wholesale market for network access. However, demand by entrants for access may be quite elastic if they face competition from other networks. In these circumstances, demand for wholesale access may be elastic if homeowners are sufficiently able and willing to substitute to broadband access over an alternative network, such as a cable television network or a wireless network. An increase in the wholesale price, to the

[42] Though see R. Chirinko and D. Mallick (2011), "The Elasticity of Derived Demand, Factor Substitution and Product Demand: Corrections to Hicks' Formula and Marshall's Four Rules," *Labour Economics,* 18: 708 with regard to the generality of the ease of substitution. They show that if the cost share of the factor were to rise significantly when the ease of substitution decreases, the elasticity of demand for the input could actually rise if the price elasticity of demand downstream exceeds the elasticity of substitution.

extent it is passed on by entrants to downstream consumers, will raise the entrants' price, and result in consumers substituting to the other networks.

Pass Through

79. The extent of indirect substitution depends on the extent of pass through. The rate of pass through is the extent to which downstream firms increase their prices when their costs increase. The greater the rate of pass through, the greater indirect substitution, holding the elasticity of downstream product demand constant.

80. The pass through if the downstream firms do not have market power depends on the elasticity of downstream demand and the elasticity of supply.[43] Pass through will be very high if downstream demand is inelastic or supply downstream is very elastic. It will be complete when demand is perfectly inelastic or supply perfectly elastic.

81. If the market downstream is imperfectly competitive, i.e., the downstream firms have market power, then the pass-on rate depends not just on the elasticity of demand and the behaviour of marginal costs, but also on the extent to which the elasticity of downstream demand increases as the downstream price rises.[44] If the elasticity of demand rises very quickly as price increases—indicating that consumers are becoming much more price sensitive—then firms will find it optimal to lower their mark-ups as price increases and their pass through will be less than that of a competitive firm. If the elasticity of demand does not rise as quickly, then the pass through rate of firms with market power will be greater than it is for competitive firms.

4.3 Substantial Lessening of Competition

82. The definition of a substantial lessening of competition depends on whether the concern is the exercise of market power or the creation, enhancement, or preservation of market power.

[43] See T. Van Dijk and F. Verboven, (2008), "Quantification of Damages," W. Collins, eds., *Issues in Competition Law and Policy*, Vol. 3, American Bar Association: 2331 at 2342.
[44] See T. Van Dijk and F. Verboven, (2008), "Quantification of Damages," W. Collins, eds., *Issues in Competition Law and Policy*, Vol. 3, American Bar Association: 2331 at 2341-2343.

4.3.1 Exercise of Market Power

83. There are two effects from the exercise of market power in the upstream market. The first is a transfer of profits from downstream firms to the upstream supplier on inframarginal units—the units that the downstream firms continue to purchase even though price has risen. The second is the loss in economic value as downstream firms reduce their purchase of the input. The downstream firms reduce their demand for two reasons. First as the price of the input rises, they may substitute to alternative inputs. Second, to the extent they pass through the price increase of the input to their customers, downstream demand will fall, reducing the demand for the input by the downstream firms. The lost value as firms and consumers in the downstream market substitute to their second best choice when the price of the input rises is called the deadweight loss.

84. The harm in the downstream market—the lost value based on the reduction in output in that market—has been shown to depend on the increase in downstream marginal costs from the increase in the input price, the extent of competition downstream, the pass through rate, the size of the market and the utilization level of the input.[45] The economics literature finds the following relationships:[46]

- The greater the effect of the increase in input price on marginal costs, the greater the harm in the downstream market.

- The extent of competition in the market is measured by the product of the downstream price cost margin and the downstream elasticity of demand.[47] The greater the product of these the less competitive the downstream market and the less competitive the downstream market the greater the harm in the downstream market.

- The greater the pass through rate, the greater the harm downstream.

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[45] T. Van Dijk and F. Verboven, (2009), "Cartel Damages Claims and the Passing-On Defense," *Journal of Industrial Economics* LVII: 457 at 484.
[46] See T. Van Dijk and F. Verboven, (2009), "Cartel Damages Claims and the Passing-On Defense," *Journal of Industrial Economics* LVII: 457. They develop these relationships by looking at only small price increases upstream, i.e., marginal price increases.
[47] For a monopolist this would equal one: the price cost margin for a monopolist is equal to the inverse of the elasticity of demand. If competition was perfect downstream this would equal zero; for Cournot competition it equals the inverse of the number of firms.

- The larger the size of the market, the greater the harm downstream.

- The larger the utilization of the input, the greater the harm downstream.

85. The two key relationships utilized in the analysis of the potential for a substantial lessening in competition are the extent of usage of the input and the effect of its price on marginal cost. The smaller the usage of the input (in this case pole access for wireless attachments) then the smaller is the effect of the price of pole access for wireless attachments on the cost of providing wireless service, and the less the harm in the downstream market from the exercise of market power—if it has any—by THESL in the provision of pole access for wireless attachments.

4.3.2 Enhancement, Creation, or Preservation of Market Power

86. The ability of firms to exercise market power depends on the substitution alternatives of their customers, as explained above. Conduct that enhances, creates or maintains market power—the usual definition of a substantial lessening of competition in a competition policy case—has this effect only if it reduces the extent to which its customers are willing or able to substitute. Only by reducing the attractiveness of some firm or firms' products in the downstream market; raising the costs of some firm or firms; or both, will a firm's conduct create, enhance, or preserve market power.

87. Increases in a firm's marginal cost will typically make it less willing to expand output in response to a reduction in output or increase in price by its rivals. The Competition Bureau recognizes this in their discussion of what constitutes a substantial lessening of competition in its *Abuse of Dominance Guidelines*:[48]

> Generally speaking, a substantial lessening or prevention of competition creates, preserves, or enhances market power. A firm can create, preserve, or enhance market power by erecting or strengthening barriers to expansion or entry, thus inhibiting competitors or potential competitors from challenging the market power of that firm. In examining anti-competitive acts and their effects on entry barriers, the Bureau focuses its analysis on determining the state of competition in the market in the absence of these acts. If, for example, it can be demonstrated that, but for the anti-competitive acts, an effective competitor or group of

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[48] See Competition Bureau, *The Abuse of Dominance Provision Enforcement Guidelines*, September 2012 at p. 13.

> competitors would likely emerge within a reasonable period of time to challenge the market power of the firm(s), the Bureau will conclude that the acts in question result in a substantial lessening or prevention of competition.

88. The Competition Bureau notes the relationship between the effect of the conduct and ability of rivals to restrain market power:[49]

> In general, the Bureau is not concerned with conduct that forces competitors to be more effective, but rather with conduct that makes it more difficult for competitors to be effective. Exclusionary conduct is designed to make current and/or potential rivals less effective at disciplining the exercise of a firm's market power, to prevent them from entering the market, or to eliminate them from the market entirely. Such conduct often does so by raising rivals' costs.

and[50]

> All such activities can, in certain circumstances, serve to increase a rival's costs and may force that rival to raise its prices, which may make it more difficult for the rival to compete or result in its exclusion from the market. This may allow the dominant firm to maintain or increase its prices, which can be profitable if the costs of the exclusionary strategy are offset by the ultimate increase in revenue, or by the preservation of revenues that would otherwise be lost, owing to competitive entry or expansion.

89. The harm from conduct that enhances, creates, or maintains market power flows from the effects of exercising market power (as discussed above). THESL cannot create, enhance or maintain *its* market power in the downstream market, as it does not participate in this market. It can, if it has market power in the provision of pole access, merely exercise that market power. By exercising that market power it might, however, differentially affect competitors in the downstream market and hence *market power downstream*.

90. For instance some wireless service providers maybe more likely to utilize pole access for wireless attachments than others. If those wireless service providers were the entrants, then the exercise of market power by THESL would have an asymmetric impact on participants in the downstream market. But for THESL's exercise of market power it might be posited that one or more of the entrants would have emerged as effective competitors in the downstream market to challenge the national incumbents. Hence the effect of the exercise of market

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[49] See Competition Bureau, *The Abuse of Dominance Provision Enforcement Guidelines,* September 2012 at p. 11.
[50] See Competition Bureau, *The Abuse of Dominance Provision Enforcement Guidelines,* September 2012 at p. 11.

power might be to create, enhance or maintain the market power of those providers who are less reliant on pole access for wireless attachments, in this case the incumbents. The harm is, as usual, ultimately attributable to the effects on consumers in the downstream market. In this case these effects are higher prices and lower levels of deployment of advanced wireless networks because the exercise of market power by the incumbents is preserved. This hypothesis depends on the following facts: (i) an asymmetric impact on costs; (ii) that but for this asymmetric impact on costs the entrants would have been able to more effectively discipline the exercise of market power by the incumbents; and (iii) the incumbents have market power.

91. Sections 5 and 6, apply the concepts of market definition, market power and substantial lessening of competition developed in the foregoing discussion to THESL's provision of pole access for wireless attachments.

5 THESL's Market Power in Pole Access for Wireless Attachments

92. In this section THESL's ability to exercise market power in the market that includes pole access for wireless attachments is considered. The assessment of THESL's market power in the provision of pole access for wireless attachments involves consideration of the following:

- Section 5.1 is a discussion of the supply chain relationship between the upstream activity (THESL's provision of pole access for wireless attachments) and the downstream activity (wireless services). This section establishes that pole access for wireless attachments is a derived demand based on using small cell and DAS to augment the capacity and coverage of wireless service providers.

- Section 5.2 is a brief discussion of wireless service provision, with a focus on the different technologies that might use pole access. An important fact established is the flexibility that wireless service providers have to substitute inputs to increase their capacity and coverage.

- Section 5.3 establishes the relevant upstream product market is wider than pole access for wireless attachments.

- Section 5.4 defines the relevant downstream market as wireless services and establishes that wireless services provided with, and without, pole access for wireless attachments are in the same relevant downstream market.

- Section 5.5 delineates the relevant upstream and downstream geographic markets.

- Section 5.6 concludes the analysis with a summary of the relevant upstream and downstream markets followed by a discussion of why THESL is very unlikely to have market power in the provision of pole access for wireless attachments.

5.1 Wireless Services and Derived Demand for Pole Access

93. The starting point of the analysis is a description of the supply chain relationship between THESL's poles (the upstream input) and the wireless services that might utilise these poles. Understanding this supply chain relationship helps in understanding the sources of substitution that constrain market power arising from the provision of pole access.

94. Wireless service providers in Toronto might seek to place certain attachments on poles in order to facilitate the provision of services to consumers. In this report the term "wireless services" refers to the services that wireless service providers seek to offer. Wireless services involve the provision of network coverage and capacity to consumers who wish to make voice calls and consume data services ranging from Internet downloads to simple SMS text messaging, from a multiplicity of locations. These consumers use "wireless" devices such as handsets, smart-phones and tablets that have cellular radio functionality built into them. Wireless service providers in Toronto compete with each other to meet both mobile demand and nomadic demand. Mobile demand can be thought of as demand for the provision of wireless voice and data services everywhere, including when the customer is travelling (e.g., in a car). Nomadic demand is demand for access by customers who consume voice and data services from a handful of distinct (and often predictable) locations and they are not traveling or at least not too quickly at the time of access. Most customers are not particularly mobile over the course of a typical day (although some are) but equally most consumers will experience the need for universal coverage and mobility at least occasionally. The ability to provide the mobility option distinguishes wireless service providers from those—such as

firms which provide Wi-Fi hotspots—who serve only nomadic demand.[51] An effective wireless service that serves both types of demand (mobile and nomadic) will always use cellular radio access networks,[52] but the provision of cellular network capacity can be enhanced by encouraging the off-load of traffic to Wi-Fi networks, or by technologies such as femtocells which leverage fixed broadband connections.[53]

95. The immediate demand for the pole access input arises from the fact that there are certain cellular wireless network deployments that might use poles as a siting resource for putting up antennae or even micro base stations in outdoor locations. Outdoor Distributed Antenna Systems (DAS) and small cell deployments (antennae and mini-base stations, respectively) are examples of such technologies that might be mounted on poles, among other mounting sites.[54] Small cells are essentially low-powered base stations in their own right, which are linked (as is the case with "normal" base stations) by a backhaul connection (usually fibre at present) to a base station controller, communications hub, or mobile wireless centre.[55] DAS

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[51] An accessible discussion of the characteristics of users of mobile cellular networks is provided by Das et al, "Understanding Traffic Dynamics in Cellular Data Networks." This paper shows that relatively few users are actually highly mobile, many more are nomadic, and a small proportion of users accounts for the great majority of data consumption on cellular networks. See http://www.wings.cs.sunysb.edu/~upaul/paper/Infocom11-final-version.pdf.

[52] Dr. Jackson's Report points out the distinction between cellular networks that provide universal coverage and supported a high degree of mobility, and a service that only addresses the needs of stationary users, which he describes as "Wi-Fi-like." In Dr. Jackson's view, "any commercial wireless system operating on licensed spectrum can be expected to use macrocells to provide universal coverage." See Expert Report of Charles L. Jackson, "Wireless Networks and Utility Poles", *In the Matter of the Ontario Energy Board Act, 1998, and in the Matter of an application by Toronto Hydro-Electric System Limited for an order pursuant to section 29 of the Ontario Energy Board Act, 1998* , June 11th, 2013, also referred to as the "Jackson Report" or Dr. Jackson's Report, at p. 28.

[53] Data provided by Cisco Systems shows that smart-phone users in North America consumed more than twice as much data over Wi-Fi connections than they did over cellular or "mobile" connections. For tablets, the ratio is even more skewed towards Wi-Fi connections. Source: Cisco Data Meter, available from http://ciscovni.com/data-meter, accessed April 9th, 2013. It is interesting to note that in Calgary, Shaw Communications is only offering service that provides access for nomadic customers. Shaw has optioned its spectrum—acquired in the 2008 AWS auction—to Rogers and instead have an extensive Wi-Fi network in downtown Calgary. Dr. Jackson's Report also discusses the benefits of Wi-Fi, which operates on unlicensed spectrum, at p. 20 of his Report.

[54] The U.S. Federal Communications Commission's (FCC) *16th Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services*, March 21st, 2013 ("FCC 16th Annual Report") dealing with competition in the wireless sector specifically mentions the FCC's efforts to facilitate pole attachments by wireless service providers for purposes of deploying DAS and small cell networks, which it says are especially useful in the context of broadband services. See FCC 16th Annual Report at ¶77.

[55] DAS Forum, "DAS and Small Cells Distinguished", February 4th, 2013, p. 3. Small cells might also be able to use an IP connection for backhaul purposes, e.g., data from such small cells can be dumped onto DSL or cable broadband connections from where the data are routed to the wireless operator's core network. See also Jackson Report, pp. 13-19 and also p. 29. If an existing broadband Internet connection can be used for backhaul purposes, the economics of small cells that can leverage such connections are very favourable from the wireless operators'

networks are a system of antennas that are linked to a common base station, usually by a feeder fibre, and the base station is then linked to the base station controller, communications hub, or mobile wireless centre.[56]

96. However, the demand (if any) for such deployment is driven by downstream demand for services provided by wireless service providers, particularly data services. Thus, in the context of attachments made by wireless service providers, pole access is an input, the demand for which is ultimately derived from the demand for downstream wireless services. The purpose of outdoor small cell and outdoor DAS deployments is to enhance the provision of wireless services by improving the capacity and coverage of the cellular wireless networks used to provide those downstream wireless services. The focus of these efforts is substantially on facilitating the provision of broadband data services, which place a far greater burden on network capacity and spectrum resources than do voice services.

97. In assessing THESL's potential market power, there are two sources of substitution that might discipline its exercise of market power, direct and indirect. The direct sources of substitution are the alternative inputs to which wireless providers would divert their demand when confronted with a price increase for wireless attachments on THESL's poles. These alternative inputs include not just alternative siting facilities, but more broadly other inputs that minimize the use of outdoor siting facilities for small cells or DAS. Indirect substitution arises if firms who use pole access compete in the same downstream market as firms who do not use pole access. A provider of pole access may find it difficult to exercise market power in the provision of pole access if this strongly reduces demand in the downstream market for services based upon that pole access, because of a high willingness and ability of consumers to substitute between services provided with and without pole access.

98. The definition of the appropriate downstream market is therefore important because pole access is a derived demand and the elasticity of derived demand can only be discussed in the context of the potential elasticity of downstream demand. Defining the downstream market is not only necessary to determine THESL's market power, it is also important in assessing the

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perspective. This is the case with the technology described in Section 3.4.1 of the Jackson Report.
[56] See the Jackson Report at pp. 13-19.

benefits of access to poles for wireless attachments at regulated rates. If the effect on competition of such mandated access is not substantial in the downstream market, the case for regulated access is difficult to sustain.

5.2 Wireless Services, Capacity Management and the Role of Poles

99. This subsection discusses the capacity and coverage challenges that wireless service providers in Toronto face, the solutions available to meet those challenges, and the potential role of pole access in the range of solutions available.

100. Wireless service providers currently operating in Toronto meet their customers' demand for voice and data coverage and capacity by operating an extensive cellular radio network. All the wireless service providers (the major incumbent firms as well as the entrants) in Toronto have deployed the traditional cellular network architecture: a "macrocell" deployment.[57] This involves the division of the relevant geographic region into various "cells." Coverage across these cells is provided by relatively high-powered transmitters that feed antennas deployed on cell towers, but (in downtown Toronto) also frequently on rooftops. Typically, these antennae provide coverage over a relatively large area. Wireless service providers using licensed spectrum to offer services have access to a finite amount of spectrum. The cellular networks overcome this issue by re-using frequencies: for example, a cell covering geographic area C can operate using the same spectrum bands as cells covering geographic area A.[58] However, as traffic grows, wireless service providers frequently meet the increased capacity burden caused by increased traffic by further splitting existing cells into smaller cell areas, essentially intensifying the re-use of frequencies. Thus where previously there may have been only one rooftop antenna provisioned to meet the needs of a given area, wireless service providers might place another antenna on another rooftop within the original area. In a dense urban area such as downtown Toronto, this means that cell sites have become much more numerous, but the radius of the average cell has declined, and cells

[57] See the discussion at pp. 4-7 of Dr. Jackson's Report.

[58] The geographic re-use of frequencies is discussed at pp. 6-7 of Dr. Jackson's Report. In traditional cellular systems such as those using the GSM technology that was popularized in the 1990s and early 2000s, adjacent cells would be required to operate at slightly different frequencies to avoid interference, but cells that were far apart could operate on identical frequencies. Subsequent technologies handle interference without even this constraint on frequency re-use.

are now utilising lower-powered transmitters.[59] Evidence from the United States suggests that up to the present time the addition of cell sites or "cell splitting", together with migration to more spectrally efficient technologies and the release of additional spectrum by regulators,[60] has been an effective solution to keep up with the increased demand for cellular capacity.[61]

101. The rapid development of smart cellular-enabled devices—smart-phones and (to a lesser degree) tablets—has resulted in significant additional burdens driven by users downloading applications from the web, streaming videos, etc. Many observers believe that dramatically increased demand for cellular data services in the recent past and into the near and medium-term future will mean that solutions in addition to traditional "cell splitting" will need to be utilised to meet increased demand.[62] A basic but easily appreciated difficulty with continuing to deploy cell towers and obtrusive antennas arises from civic opposition to such deployment on largely aesthetic grounds (although there are also concerns about radiation levels from cellular facilities),[63] to say nothing of the increase in capital costs. Consequently, other techniques for boosting capacity and improving coverage, and also techniques and strategies that increase the efficiency of spectrum and network resources, are increasingly important to wireless service providers.

[59] The maps of downtown coverage provided in Dr. Jackson's Report at pp. 5-6 illustrate this phenomenon as they show a very great density of cell sites in the core downtown area of Toronto. These cell sites typically cover a much smaller radius than do macrocell sites in the rest of the Toronto region.

[60] Mobile telecommunications technologies have evolved from first-generation (1G) analogue technologies to 2G and then 3G digital technologies. Each technological leap has improved spectral efficiency, which is essentially measured by the amount of spectrum required to support a function such as a voice call or the transmission of a given amount of data. The movement to fourth-generation wireless technologies is expected to significantly enhance spectral efficiency, especially when the LTE-Advanced (LTE-A) technology is deployed.

[61] See Clarke, Richard, (2013), "Expanding Mobile Wireless Capacity: The Challenges Presented by Technology and Economics," pp. 19-20. Available at SSRN: http://ssrn.com/abstract=2197416.

[62] An example of the industry consensus regarding rapid growth in mobile data traffic is provided by the often-cited periodic publication by Cisco Systems which projects out mobile data usage over a five-year time period. For the latest projections, see Cisco Systems, *Cisco Virtual Networking Index: Global Mobile Data Traffic Forecast*, 2012-17, available at http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf ("*Visual Networking Index*"). See Clarke, "Expanding Mobile Wireless Capacity: The Challenges Presented by Technology and Economics" *supra* at p. 1 for an example of how these forecasts are interpreted as supporting the need for additional spectrum and also for other frequency re-use techniques including small cells.

[63] For example, the siting of cell towers appears to have become a significant community issue in Montreal's suburbs. Rogers Communications was forced to withdraw plans for a 22.5 m cell tower in a park in the district of Pointe-Claire because of community opposition. See http://westislandgazette.com/news/story/2013/03/06/reaction-mixed-to-new-protocol-for-cell-tower-installations/.

102. At present, the major wireless service providers in Toronto have rolled-out fourth generation ("4G") wireless services using a technology that is called Long-Term Evolution ("LTE").[64] On the one hand, LTE is a more spectrally efficient technology so that the amount of spectrum used to provide a given level of user experience within a geographic area is substantially less than was the case with third-generation ("3G") wireless data technologies such as UMTS or CDMA-2000.[65] However, because LTE already offers data transfer speeds that equal or even exceed that of many fixed-line broadband technologies such as DSL, deployment of LTE might encourage even greater utilisation of cellular data networks. The deployment of LTE is being accompanied by concurrent enhancements in the attractiveness of wireless-enabled handsets and tablets, which is also likely to stimulate use of cellular data networks. There is a virtuous circle: increases in the power and capabilities of devices increases demand for faster networks, while faster networks increases demand for more capable devices. Demand for data service will be less if networks are slow or devices are not very powerful in terms of their capabilities or processing speed.

103. Wireless service providers have for a number of years been using other technologies to augment their cellular network deployments. Since many customers have devices sold to them by the wireless service providers that also incorporate Wi-Fi functionality, Wi-Fi access in the home and at public locations (airports, train stations, office buildings, and very importantly, cafes such as Starbucks and Second Cup) reduce the burden on cellular networks. In Toronto, leading wireless service providers such as Rogers and Bell Mobility

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[64] Rogers began rolling out LTE wireless services in Toronto in late September 2011. See http://redboard.rogers.com/2011/rogers-lte-network-now-live-in-toronto-montreal-and-vancouver/. Bell began to roll out LTE service in Toronto in September 2011 as well, two weeks before Rogers. See Howard Solomon, "Bell Beats Rogers to Toronto with LTE Service", available at http://www.itworldcanada.com/news/bell-beats-rogers-to-toronto-with-lte-service/143943. Telus' LTE network in the Greater Toronto Area went live in February 2012. See "Telus 4G LTE Wireless Service Goes Live in Toronto and the GTA", http://about.telus.com/community/english/news_centre/news_releases/blog/2012/02/09/telus-4g-lte-wireless-service-goes-live-in-toronto-and-the-gta.

[65] Research commissioned by the U.K.'s telecommunications regulator, Ofcom, suggests that spectrum efficiency in deployed networks will grow by approximately 5.5. times between 2010 and 2020. See http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2011/4G-Capacity-Gains/. While this spectral efficiency improvement might not be enough to keep up with demand, accelerated deployment of 4G networks means that spectral efficiency gains can be realized sooner and will partially mitigate the need for more spectrum or deployment of capital-intensive technologies for frequency re-use.

also own and operate an extensive network of Wi-Fi hotspots.[66] Wireless service providers can also reduce the demands on their cellular capacity by providing femtocells (miniature base stations) to consumers for in-home use. These femtocells switch traffic from the cellular network to a fixed-line network by utilising the consumer's home broadband connection.[67] In the subsequent discussion in this section, these techniques are considered as part of the expanding array of solutions that wireless service providers will use (and are already using) to meet the challenges of capacity and coverage in the near future.

5.2.1 DAS, Small Cells, and Poles

104. Small cells and DAS technologies are being discussed as part of a larger set of partial solutions that can be used to meet the challenges faced by wireless service providers as they roll out ever-more-advanced wireless data networks. Small cell deployments and DAS deployments are similar to traditional cell splitting in that they increase capacity by reusing frequency.

105. Consumers armed with smartphones and with devices such as tablets are consuming ever-increasing amounts of cellular data and demand and expect high-quality coverage in a wide variety of locations. Much of the capacity and coverage burden on cellular data networks is generated by indoor use of such networks, and this proportion is likely to increase in the future.[68] DAS and small cell technologies are as much "indoor" solutions as they are outdoor solutions.[69] Outdoor deployments of DAS and small cell technologies might not be effective in meeting indoor demand. Yet only the outdoor deployments of DAS and small cells, and

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[66] Access to wireless hotspots is often free at certain locations (e.g., Starbucks) or could be included in the price that wireless service providers charge for home Internet subscriptions or even wireless subscriptions. Bell, for example, offers free Wi-Fi access at public locations as part of the Internet packages that it sells to Ontario consumers. See http://www.bell.ca/Bell_Internet/Bell_Internet_WiFi_Access. See also Dr. Jackson's Report at p. 20.
[67] Also see Dr. Jackson's Report at 3.4.1 for a discussion of such cells.
[68]See Cisco Systems *Visual Networking Index*, *supra*, for evidence on mobile traffic growth. Also see http://www.cisco.com/en/US/solutions/collateral/ns341/ns524/ns673/solution_overview_c22-642482.html, which says that 80% of mobile data usage is indoors. This figure—suggesting that most mobile data usage is nomadic and indoors—is also repeated at Cisco's "Small Cell Solutions" website at http://www.cisco.com/en/US/netsol/ns1178/networking_solutions_solution_category.html ("Analytics show that the majority of mobile data usage— close to 80 percent —is indoors and nomadic, rather than truly mobile.").
[69] See, for example, George Malim, "Small Cells and DAS: A Widely Distributed Choice," *Wireless*, February 22nd, 2013 available at http://www.wireless-mag.com/Features/24320/Small_cells_and_DAS_-_A_widely_distributed_choice.aspx. The article cites commentators who believe that DAS has not made a case for itself in outdoor applications, and that DAS does not provide the capacity augmentation of small cells. Some of the commentators cited in the article argue that DAS is heavily reliant on fibre connectivity and that reliance on fibre connectivity weakens the business case for DAS.

possibly some large-scale outdoor Wi-Fi deployments (which would only serve nomadic demand), would potentially utilise utility poles, but there are other outdoor siting alternatives (as discussed below). Indoor deployments can be leveraged to provide outside or street coverage without using poles.[70]

106. The use of utility poles by wireless service providers in Toronto to date is *very* limited. According to evidence filed by THESL in this proceeding, there are wireless communications attachments on some 130 of *its* poles.[71] Of these attachments, however, some 128 are attachments made to support Wi-Fi deployment, not the outdoor cellular deployments that wireless service providers use.[72] Only 2 attachments have been made by wireless service providers. On poles owned by THESI, there are only 9 attachments made by wireless service providers, and 52 attachments made to support a Wi-Fi network.[73] Although access to THESL poles has been available at regulated rates since the Ontario Energy Board's decision in EB 2011-0120, since that date only some 19 permit applications for wireless attachments have been made: of these there are 18 applications made by wireless service providers for attachments on 18 THESL poles, and a permit application by another telecommunications provider that is not a "wireless service provider" for Wi-Fi attachments on 2 THESL poles.[74]

107. In the future, wireless networks might utilise utility poles, but likely only in the context of particular technologies (DAS and small cells) that will be part of a series of solutions that wireless service providers use to meet capacity and coverage challenges. A key issue is how important pole access is for the deployment of these technologies and how important these technologies are for alleviating capacity and coverage challenges. Dr. Jackson observes that going forward modern wireless networks will likely be heterogeneous: they will likely be a mix of macro and small cells. Macrocells are required for universal coverage and for mobility.[75]

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[70] See Jackson Report at p. 12 and also Table 2 at p. 32.
[71] THESL Evidence at ¶11.
[72] THESL Evidence at ¶11.
[73] THESL Evidence at ¶11.
[74] THESL Evidence at ¶13.
[75] See the discussion in the Jackson Report at (for example) at pp. 25-26 and p. 28.

108. There are two important distinctions between small cell technologies and DAS deployments. First, as explained by Dr. Jackson, DAS deployments are relatively simple. Essentially, they consist of antennas that have a direct connection to a base station.[76] Each antenna simply repeats the same signal from the base station. Hence a dedicated fibre or coaxial connection between each of the antennas and the base station is important.[77] On the other hand, small cells have more flexibility in the way in which backhaul connections can be routed, and these deployments include a base station. For example, small cells can sometimes be deployed in ways that utilise local area networks that connect directly to the Internet for backhaul purposes.[78] Second, small cells are generally more effective at expanding capacity than DAS deployments.[79] Given the historic experience with the costs of electronics and their likely trajectory in the future, it is Dr. Jackson's opinion that the circumstances when DAS deployments will be economic are limited and declining relative to small cells.[80]

109. What is not an issue, at least anymore, is the use of pole networks to support either DAS or wide scale deployment of small cells to provide blanket coverage: that is coverage that does not use macrocells.[81] Small cells alone cannot provide blanket coverage since they cannot provide adequate mobility.[82] DAS networks, in distinction to small cells and Wi-Fi networks, can provide blanket outdoor coverage because they handle seamless hand-off between customer locations (thus making them suitable, for example, to serving the needs of mobile customers travelling in a car). However, all wireless service providers in Toronto already have macrocell networks in place, and this macrocell network provides both mobility

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[76] See Jackson Report at pp. 14-16.
[77] See Jackson Report at pp. 14-16 and p. 33.
[78] See Jackson Report at p. 17
[79] See Jackson Report at p. 18 and p. 27. See also Figure 11.
[80] See Jackson Report, pp. 13-19, which discusses some of the distinctions between small cells and DAS.
[81] The advantages of pole access in providing blanket coverage arose in the CANDAS proceeding. See, for example, *Reply Comments of Johanne Lemay on the Evidence Submitted by THESL and CEA in the OEB Matter Related to CANDAS' Application, In the Matter of the Ontario Energy Board Act, 1998, and In the Matter of an Application by the CANDAS Coalition for Certain Orders under the Ontario Energy Board Act, 1998*, EB 2011-0120, dated October 11th, 2011, at p. 13 ("Lemay Reply Evidence"). Hereafter this proceeding is denoted as EB 2011-0120. See also "Reply Evidence of Tormod Larsen", in EB 2011-0120 at pp. 2-3 ("Larsen Reply Evidence"). Both emphasize that the key distinction between DAS and small cells is that DAS currently can be used to provide outdoor blanket coverage. They also state that were the other technologies debated in that proceeding—small cells including femtocells and picocells—to become suitable for providing blanket coverage, then they would also benefit from pole access. They do not claim that pole access will be essential where the goal is merely to augment macrocell coverage with targeted small cell deployments.
[82] See Jackson Report at pp. 25, 28 and 34.

and geographic coverage (in areas where demand is less) that small cells and Wi-Fi cannot match. As Dr. Jackson observes:[83]

> As noted above, some appear to hold the view that a commercial wireless system could be build using only distributed antenna systems. Such an architecture would be unable to provide cost-effective service along highways, in urban areas, on waterways, and other locations where macrocells provided the best mix of cost and coverage. Similarly, such a system would have far less capacity than would a system in which small cells replaced many or most of the antennas of the distributed antenna system.

110. Thus the attractiveness of any "blanket coverage" property of DAS technology to wireless service providers in the Toronto area is currently highly limited. Instead the issue is how to provide coverage and capacity using a mix of small cells, DAS, and macrocells, with macrocells targeting outdoor coverage and mobility, and small cells deployed primarily to provide indoor capacity and coverage. Outdoor capacity and coverage in a particular geographic area can be enhanced by reallocating macrocell capacity away from the burden of indoor usage by installing small cells and DAS indoors. Indoor small cell installations also augment outdoor coverage.[84]

5.2.2 Fixed vs. Variable Proportions of Production

111. A key consideration to understanding the demand for pole access by wireless providers is that demand for pole access will arise by a decision to use a small cell or DAS to increase capacity or coverage. However, what is of interest is how the wireless operator will implement its network to achieve desired speed, capacity and coverage, i.e., its quality of service. Given its desired quality in a geographic area it will implement the network that achieves this objective at lowest possible cost. This means that given the demand, topography, and other relevant characteristics it will choose the cost minimizing mix of inputs. These inputs include not just small cells and DAS on poles, but small cells and DAS on alternative sites, macrocells, use of spectrum, offloading to fixed networks using femtocells and Wi-Fi, and choice of wireless technology. The key to determining the elasticity of demand for poles is the willingness, at the margin, of wireless service providers in a particular geographic area to substitute to other inputs rather than use poles in response

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[83] Jackson Report at p. 28.
[84] See p. 12 and Table 2 of the Jackson Report.

to an increase in the price of poles. These considerations mean that wireless service technology is characterized by variable proportions. Wireless carriers can, and will, choose the relative usage of different inputs, including pole access, based on minimizing costs.

112. This is in contrast with wireline telecommunications services and cable services where the technology does not have nearly the same extent of flexibility to substitute for a physical connection with the premise where service is demanded: provision of wired services is much closer to fixed proportions between other inputs and such a connection. When cable networks were being built, cable network operators had no choice but to use wires to connect central hub facilities such as cable head-ends with end-user premises. At best, the cable operators had a choice between using poles and using other facilities which would permit the stringing of wires. Wireless networks have never had to place equipment at end-user premises and have considerably more flexibility in terms of where they can place their equipment in relation to the area or premises that they would like to cover. Wireless service providers not only have typically a greater choice of siting alternatives, but they can rely on a whole range of other techniques to meet capacity and coverage challenges.

113. For a given quality of service, wireless service providers will roll out a network architecture that minimizes costs. The actual quality of service provided by a wireless service provider will be based on a comparison of the marginal revenue and marginal cost of changing its service quality, for instance its capacity, coverage, and speed. If demand for higher quality does not exist then it will not incur the costs of increasing its quality.

114. In summary, wireless service providers can vary the intensity with which they need to make wireless deployments that utilise the small cell technologies discussed previously. Only outdoor-focused deployments of these small cell technologies might require pole access, and even for these deployments there may be alternative siting structures available, as discussed in the next section.

5.3 Upstream Product Market Definition

115. The issue of pole access for wireless attachments is discussed in terms of a potential siting facility for outdoor DAS or small cell technologies. The purpose of using these technologies is to provide a high-quality service so that users experience strong signals and

high data transfer speeds. This means there are two sources of substitution that must be considered. The first is whether there are other technological inputs or capacity management techniques that can be used to provide similar quality service—i.e., *a similar end-user experience*—as might be achieved by deploying outdoor DAS or small cell technologies.[85] The second is whether there are alternative sites that can be used to deploy DAS or small cells.

116. In defining the relevant upstream market for pole access for wireless attachments, one must remember that pole access is a derived demand. As per the discussion in Section 4, the elasticity of derived demand—the relevant "own-price" elasticity that summarises the substitution possibilities—depends on the willingness and ability of wireless service providers to substitute to other inputs, including other siting facilities, and also on the elasticity of downstream demand for wireless service incorporating the pole access input.

5.3.1 Substitution to alternative upstream inputs

117. Table 1 lists a number of techniques that wireless service providers can use to meet capacity and coverage challenges in providing high-quality wireless services (data services in particular, as these are more capacity intensive).[86] Table 1 in Dr. Jackson's Report also lists a range of techniques that can be used to manage capacity and coverage challenges, and their relationship to pole access.[87] Wireless service providers can use a mix of different inputs or capacity management techniques to provide high-quality services. The mix of inputs does not have to be in fixed proportions. Different wireless service providers can use varying levels of each type of input or technical solution and provide the same level of service.

Offload to fixed line networks

118. Wireless service providers can limit their need to deploy outdoor DAS or small cell networks by managing their capacity burden through a mixture of offloading to indoor Wi-Fi and femtocell networks, deploying indoor DAS and small cell networks, splitting macrocells to the extent feasible, or utilising more spectrum (if they have access to such). The majority

[85] In this section it is assumed that wireless services provided with extensive pole access is in the same downstream market as wireless services that do not. See below at Section 5.4 for discussion.
[86] All Tables and Figures are in Appendix C.
[87] See Jackson Report at p. 30.

of mobile data use takes place in indoor locations, not outdoor locations.[88] Since this is the case, there is potential for further increasing the amount of data offloaded to fixed networks via indoor Wi-Fi or femtocells.[89] Fixed line broadband networks are ubiquitous throughout Toronto, and have more capacity than wireless networks. Further leveraging these networks should not require deployment of much new infrastructure. In the case of femtocells, the economics for the operator are highly favourable since the user is already paying for a fixed-line broadband connection in most cases. An interesting feature of the Toronto market is that the two largest wireless service providers, Bell Mobility and Rogers Wireless Partnership, also own ubiquitous fixed-line networks, which increases the opportunities and incentives for them to leverage these networks in support of their wireless data networks.

Indoor deployments of small cells and DAS

119. A major cost-affecting characteristic of outdoor small cell and DAS technologies is that they require the provisioning of backhaul and power to the relevant site.[90] Where provisioning backhaul (and power) to an outdoor site is problematic, the attractiveness of indoor small cell and DAS deployments relative to their outdoor counterparts is enhanced. Indoor small cells and DAS networks might be easier to set up and more effectively achieve the aim of providing boosts to capacity where and when it is needed most than their outdoor counterparts. This is because in most buildings there is already an accessible power supply and broadband network that can be used for backhaul purposes. In large office complexes in Toronto, buildings will frequently have fibre connections or the ability to very easily have fibre extended to the building. An "inside-out" deployment of small cells and DAS might do a better job of providing coverage indoors, and once the wireless service provider has access to a building for purposes of providing indoor coverage it will be relatively convenient for such a provider to place small cells (particularly) on a building wall to provide augmented outdoor coverage and use the in-building infrastructure for backhaul than to deploy outdoor

[88] See http://www.cisco.com/en/US/solutions/collateral/ns341/ns524/ns673/solution_overview_c22-642482.html. See also Jackson Report at p. 28.
[89] Cisco Systems' various forecasts of future levels of mobile data traffic take account of the offload to Wi-Fi and femtocells. According to Cisco, mobile data traffic grew more slowly in 2012 than they had forecast, precisely because wireless service providers had consciously promoted strategies such as Wi-Fi and femtocell offload. See Cisco Systems, *Visual Networking Index*, *supra* at p. 4.
[90] See Jackson Report at pp. 13-19.

small cells on utility poles.[91] Use of indoor DAS and small cells augments indoor coverage and capacity, of course, but also outdoor capacity and coverage.[92] Since small cell deployments and deployments of cells with distributed antenna systems involve the placement of base stations closer to the end-user demand, they can be seen as a form of "cell splitting": use of such deployments intensifies the re-use of frequencies.[93] By intensifying the re-use of frequencies, these deployments add to the capacity of the outdoor macrocell network. Adding capacity by deploying small cells or an additional cell using a DAS indoors can also augment capacity available for outdoor coverage since it releases macrocell capacity that can be used to provide service outdoors.[94]

Spectrum acquisition, spectrum sharing and technical advancement

120. Wireless service providers can obviously add capacity by utilising more spectrum. Two of the major wireless providers in Toronto, Rogers and Bell, have access to licensed spectrum in the Cellular (800 MHz), AWS (1700 and 2100 MHz), PCS (1800 and 1900 MHz), and BRS (2500 and 2600 MHz) bands.[95] Both Bell and Rogers have access to a considerable amount of BRS spectrum that has traditionally been "underutilized" but which can now be used to provide LTE service for data.[96] As Dr. Jackson documents "the 2500 megahertz band is well suited for expanding capacity in urban areas."[97]

121. While it is difficult to say whether or not the spectrum holdings of the incumbents are sufficient to meet present and future needs, the availability of greater amounts of spectrum to

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[91] See Ubiquisys, "Small Cell Hotspots: Outside or Inside?", http://ubiquisys.com/small-cells-blog/small-cell-hotspots-inside-or-outside/. Ubiquisys is a British firm that specializes in small cells, and which was recently acquired by Cisco Systems for $310m as part of Cisco's push into the small cell domain. See also the Jackson Report at p. 12, and Table 2 at p. 32.
[92] See Jackson Report p. 12, and also Table 2.
[93] See, for example, Jackson Report, Figure 11. In this case, both the DAS deployment and the small cell deployment involve the placement of a base station transmitter (or rather four transmitters in the case of the small cell deployment) within the building. These placements are, effectively, additional cell sites. See also the discussion in Clarke, "Expanding Mobile Wireless Capacity: The Challenges Presented by Technology and Economics" *supra,* at p. 23.
[94] See Jackson Report at pp. 24-25 and p. 34.
[95] Industry Canada, *Consultation on a Policy and Technical Framework for the 700 MHz Band and Aspects Related to Commercial Mobile Spectrum*, November 30, 2012, at Section 4.2, and Figures 4.1 to 4.6. The document is available from http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09949.html#s4.2.
[96] See Telegeography.com, "Rogers Expanding LTE to 44 New Markets this Spring, Including 2600 MHz Coverage", available at http://www.telegeography.com/products/commsupdate/articles/2013/03/27/rogers-expanding-lte-to-44-new-markets-this-spring-including-2600mhz-coverage/.
[97] See Jackson Report at p. 23.

these wireless service providers, as well as the fact that they have spectrum in different frequency bands, limits the need to augment capacity using small cells, DAS, Wi-Fi offload, etc. relative to the needs of smaller wireless service providers. Wireless service providers can (per Table 1) also achieve efficiencies by sharing spectrum with each other or with government agencies.[98] Further, the LTE standard incorporates technologies such as carrier aggregation and MIMO that help network providers better utilise their existing spectrum assets by, for example, permitting use of a greater number of channels across different bands of spectrum to secure higher end-users speeds, or using multiple antennas at both ends of a data signal to boost performance.[99]

Pricing, traffic shaping, and data compression

122. Wireless service providers can also use techniques that do not involve any infrastructure deployment in order to relieve the traffic burden on their macrocell networks. For example, wireless service providers can engage in traffic-shaping where they can de-prioritise certain interactions (e.g., transfer of very large files from sites using Bit Torrent) that impose disproportionate burdens on the network at certain hours. Wireless service providers are already using tiered data plans wherein consumers are given a monthly allowance of data as part of their monthly service payment, but must pay extra when they go over those allowances. Such pricing has likely stimulated the use of Wi-Fi and femtocells. Further, wireless service providers can throttle back consumer speeds or restrict downloads when the monthly allowance is exceeded instead of charging more for exceeding the data allowance. This will further accelerate the trend towards offload as well as preventing capacity overloads. Wireless service providers might also be able to benefit from developments in technologies that optimise and compress content to make it suitable for transmission over

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[98] See Goldstein, Philip "AT&T/Verizon/T-Mobile to Forge Pact to Explore Spectrum Sharing with Government", Fierce Wireless, January 31st, 2013. In Canada, Industry Canada has no objections to wireless operators sharing network resources and spectrum resources, so long as they remain robust downstream competitors. See, for example, ¶¶202-205 of Industry Canada's *Licensing Framework for Mobile Broadband Services—700 MHz*, March 7th, 2013. See also ¶199, where Industry Canada recognizes that spectrum and network sharing can promote efficiencies in the use of limited spectrum resources.

[99] See Lawson, Stephen, "11 Ways Around Using More Spectrum for Mobile Data", *Computer World*, August 16th, 2012. Available at http://www.computerworld.com/s/article/9230345/11_ways_around_using_more_spectrum_for_mobile_data.

wireless networks. If these techniques are used more intensively, they will reduce the need to augment macrocell capacity by (for example) deploying outdoor DAS and small cells.

Cell splitting and Deployment of Spectrally Efficient Technology

123. Wireless service providers can, to some degree, continue to split cells, thereby substituting macrocell deployment for pole access, i.e., instead of using pole access wireless service providers may invest in additional capital. Wireless service providers can also relieve capacity constraints by accelerated deployment of more spectrally efficient technologies such as HSPA+, LTE and (especially) LTE-Advanced. Canada's leading wireless service providers have been quicker than most of their international counterparts to move to such technologies.[100]

Roaming and Site Sharing Mandates

124. Canadian wireless policy requires all wireless service providers—both those who have been established for decades and those who entered the business following the auction of Advanced Wireless Services (AWS) spectrum in 2008—to provide their rivals with the ability to "roam" on their networks. Canadian policy also requires that wireless service providers share cellular sites (e.g., cellular towers, antenna sites) with their rivals. The roaming policies were initially applied only to the infrastructure of the incumbent established wireless service providers, but have now been applied symmetrically. In practice however, these roaming and site sharing policies are designed to enable wireless entrants who have less of their own infrastructure to utilize the networks and cellular sites of the incumbents.[101]

125. For example, wireless entrants who lack ubiquitous coverage through their own network facilities can have their customers "roam" onto incumbent networks in areas where they lack their own facilities. Site-sharing policies are also designed to reduce the barriers to entry for entrant wireless service providers—for example, in Toronto many building rooftops already have antennas placed by incumbent wireless service providers. Site-sharing policies are

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[100] See RCR Wireless, "North America Early Leader in LTE", December 7th, 2011. Available at http://www.rcrwireless.com/article/20111207/carriers/report-north-america-early-leader-in-lte/.

[101] Industry Canada, *Conditions of License for Mandatory Roaming and Antenna Tower and Site Sharing and to Prohibit Exclusive Site Agreements*, CPC-2-0-17, March 2013. Further detail of the background to the roaming and site sharing mandates is available at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf10290.html. The roaming policies were intended initially to be in place for only a five-year period, but have been extended indefinitely.

designed to obviate the need for wireless entrants to negotiate access to hard-to-acquire placement sites.

126. The presence of these roaming and site-sharing policies allows entrants to leverage existing infrastructure, and thus reduces demand for siting facilities—including poles—by entrants.

127. Additionally, incumbent network operators in Canada and elsewhere have entered into network and infrastructure sharing agreements with each other.[102] This also has the consequence of reducing demand for siting facilities—for example, if Bell and Telus use the same sites to place their antenna, this reduces demand for new sites and it also overcomes some of the barriers frequently raised to placement of new antenna on aesthetic and environmental grounds. Just recently, Rogers and Videotron announced a plan to share network infrastructure and spectrum in Quebec and Ottawa.[103] The economics of infrastructure sharing are attractive as sharing existing facilities avoids costs such as those associated with rental of sites and with construction of structures such as cell towers.

5.3.2 The Importance of Pole Access for DAS and Small Cells

128. The importance of pole access is not the same for outdoor small cells and DAS deployments. Outdoor DAS deployments are more likely to depend on pole access than outdoor small cells. In an earlier proceeding before the OEB, experts testifying for the CANDAS coalition made the point that DAS networks are as much wired as they are wireless and that it is more economically efficient and technically easier to use poles to not just mount the antennae, but to string fibre and secure power supply.[104] It might be easier to

[102] Bell and Telus entered into roaming and resale agreements as long ago as 2001, and in 2008, agreed to share network resources to construct an HSPA+ network across Canada. See "Bell Signs Wireless Network Sharing Agreement with Telus", http://www.thewhir.com/web-hosting-news/bell-signs-wireless-network-sharing-agreement-with-telus, October 18th, 2001 and P. Hoffman, "No spectrum sharing involved in Bell-Telus LTE infrastructure deal," Cartt.ca, February 14, 2012 online at http://www.cartt.ca/news/FullStory.cfm?NewsNo=13196.
[103] See CBC News, "Rogers, Videotron to Share New LTE Network," http://www.cbc.ca/news/technology/story/2013/05/30/business-rogers-videotron-lte.html. Rogers stated that "This network and spectrum-sharing agreement . . . will allow even more consumers to experience the superior connectivity and incredibly fast speeds that LTE delivers".
[104] See Larsen Reply Evidence, EB 2011-0120, October 11th, 2011, at p. 3. See also Table 1 at p. 30 of Dr. Jackson's report and the discussion at pp. 31 and 33.

attach fibre overhead between poles, in the public right-of-way, as opposed to digging up the ground to provide buried fibre connections.

129. Small cells however afford much greater flexibility. They can be deployed in targeted ways that can leverage a wider variety of backhaul infrastructure. For example, an indoor deployment of small cells can be used to provide street-level coverage, or a wireless service provider that has access to a building can mount a small cell on the exterior of the building and utilise local area networks in the building for backhaul purposes.[105]

130. Pole access might have been particularly important for entrants deploying a DAS network to provide blanket outdoor coverage. But in a world in which targeted deployments of small cells and DAS will be used by wireless carriers to extend the coverage and capacity of their macrocell network (and not blanket coverage), then deployment will be primarily small cells, and demand for pole access will be more elastic and the demand for pole access less than if extensive DAS deployments were anticipated. As noted by Dr. Jackson above, the declining costs of electronics, the relative ease of backhaul, and increased capacity all suggest that small cell deployment will dominate DAS deployments.[106] Indeed Dr. Jackson identifies only one set of circumstances under which a DAS deployment using pole access would be superior to a small cell not mounted on a pole.[107] The example is to fill in coverage on a

[105] See the comparative discussion of DAS and small cells at pp. 13-19 of Dr. Jackson's Report, and also the discussion at p. 33 following Table 2. These discussions make it clear that small cells can more easily leverage resources such as in-building local area networks, for example. This is one factor that strongly suggests flexibility in terms of the siting of such cells.

[106] In the CANDAS proceeding, technology experts for CANDAS argued that where the goal of wireless deployment was "to achieve blanket coverage over small or wide geographic areas using small cell wireless technologies, utility poles…are a necessary support structure for antenna mounting." (Lemay Reply Evidence, EB 2011-0120 at p. 13). They argued, however, that DAS was the only technology that could currently handle blanket coverage because it allowed for "seamless hand-off." (Lemay Reply Evidence at p. 13). They argued that small cell (femtocell, metrocell and outdoor Wi-Fi technologies) could not currently provide for blanket coverage, but that when they evolved so as to provide for blanket coverage, they too would require pole access (Larsen, Reply Evidence, EB 2011-0120 at pp. 2-3). However, I am not aware of any wireless service provider that will serve the Toronto market in the near future by deploying primarily DAS (not macrocells) to provide outdoor coverage for any reasonably large area of Toronto. As discussed by Dr. Jackson, outdoor coverage and mobility will be provided primarily by macrocells, while small cells will be used to increase capacity. See Jackson Report, pp. 25-26, p. 28 and p. 34, for example, which discuss the role of macrocells and small cells in the heterogeneous networks of the future.

[107] Jackson Report at p. 33.

sunken highway: mobility requirements mean that a DAS deployment is preferred to a small cell and pole access provides a line of sight.[108]

5.3.3 Alternative Siting Facilities to Poles

131. In addition to utilising technologies that substitute for outdoor DAS and small cells, wireless service providers can continue to use outdoor small cell (and perhaps outdoor DAS) services but use alternative siting facilities to poles.

132. The difficulty with using poles for small cells is that they require both power and backhaul connections. These are likely to be available at significantly less cost if the small cell is located on the side of a building instead of a pole. In addition mounting small cells on the outside of buildings does not involve some of the costs and difficulties associated with using power poles.[109] In Dr. Jackson's analysis the only advantage of pole access is its superior outdoor coverage. But as he notes in geographic regions where demand justifies installation of a small cell, usage is likely to be indoors or there will be buildings to which attachments can be made—likely at lower cost in terms of providing backhaul connections and power.

Relevant characteristics of Toronto's urban core increase elasticity of substitution, support broad upstream market

133. In the dense urban core of Toronto, there are a number of specific considerations that likely limit the potential for pole access for wireless attachments to be the relevant market. First, there may be areas that lack THESL distribution poles. The majority of THESL's distribution services in the downtown core are provided underground.[110] The downtown core is precisely the kind of high-density, high-traffic zone that generates significant capacity and coverage issues. This is especially true because unlike many North American cities, downtown Toronto is not only a place where people work, but it is also increasingly a place where people live. In the last five years, Toronto's downtown core has seen faster employment growth and faster population growth than its suburbs.[111] The downtown core is

[108] Jackson Report at p. 33.
[109] See, for example, Jackson Report at p. 31 and also Table 2 at p. 32.
[110] THESL Evidence at ¶5.
[111] See http://news.nationalpost.com/2013/01/22/downtown-torontos-pace-of-population-growth-triples-outpacing-suburbs-as-echo-boomers-flock-towards-urban-centre-report/.

particularly attractive to younger people and higher-income people who typically are the most intensive users of wireless data services.[112]

134. The poles available may also only be streetlighting poles. On such poles, wireless service providers may be able to make attachments, but making an attachment may require modification or replacement of the pole.[113] If they do require modification or replacement, this reduces any hypothetical relative cost advantage of using poles. Thus poles are not necessarily an easy and ready-to-use resource that wireless service providers can rely upon.[114] Such considerations point to poles not necessarily being the preferred siting resource where other siting resources such as traffic signs, buildings, and other street furniture occur in high density, as is the case in urban Toronto.

135. Rogers, Bell, and Telus[115] all own fibre networks in downtown Toronto. Rogers and Bell provide fixed broadband coverage to almost all locations in Toronto, including residential areas. Both firms have fibre extended out to at least the neighbourhood street cabinets or cable head-ends all over Toronto. They also are deploying fibre-to-the-premises in several residential locations, especially where there is new development.[116] Allstream owns and operates fibre facilities in Toronto as well.[117] Cogeco acquired the assets, including fibre-

[112] See for example, TD Economics, "Toronto – A Return to the Core", available at http://www.td.com/document/PDF/economics/special/ff0113_toronto.pdf and City of Toronto, "Living in Downtown and the Centres", available at http://www.toronto.ca/opreview/pdf/living_in_downtown_and_the_centres.pdf. Survey evidence suggested that smartphone ownership was 1.46 times the national average level among households with more than $100,000 in income. It also found that the ownership of smartphones was more skewed towards the 18-34 age group, whereas the ownership of cellphones was skewed towards the 35-64 age group. See Magazines Canada, *Digital Magazines Factbook 2012*, at slide 46. Available at http://www.magazinescanada.ca/uploads/File/AdServices/FactBooks/2012/DigitalFactbook2012_EN.pdf.

[113] THESL Evidence at ¶2.

[114] This corresponds with Toronto Hydro Telecom's experience in using Toronto Hydro's streetlight poles for One Zone. In rolling out this Wi-Fi network some poles were found not to have twenty four hour power and in other areas poles were not available. See Neil Sutton, "Police concerns, poor street light poles snarl Toronto Wi-Fi project," itbusiness.ca, July 20, 2006, online at http://www.itbusiness.ca/news/police-concerns-poor-street-light-poles-snarl-toronto-wi-fi-project/8860.

[115] In 2000, Telus entered into a joint venture with Metromedia Fibre Networks to construct a 225 km fibre ring in Metropolitan Toronto. "Telus Begins Construction of Canada's Largest Metropolitan Fibre Network", October 11th, 2000, available at http://about.telus.com/community/english/news_centre/news_releases/blog/2000/10/11/telus-begins-construction-of-canadas-largest-metropolitan-fibre-network.

[116] See http://www.theglobeandmail.com/globe-investor/tv-providers-lay-on-the-love-for-toronto-condo-owners-hearts/article6583581/.

[117] See http://www.allstream.com/about-us/ipnetwork/

optic assets, of Toronto Hydro in 2008.[118] Consistent with multiple providers of fibre, the CRTC determined in 2008 that the market for wholesale fibre-based transport and access services was competitive, and thus phased out essential facilities regulation applied to these services.[119] One can only reasonably expect the Toronto market for supply of such services to be the most competitive in Canada.

136. It should be comparatively easier in the urban core of Toronto, particularly for firms that have large amounts of fibre in their own networks, to provision backhaul using buried fibre that is already in place. To the extent that small cell and DAS deployments is directed towards outdoor uses, the presence of buried fibre in close proximity to numerous potential sites—street signs, building sides, etc.— improves the economics of outdoor deployments, but also reduces the relative advantage of poles comparative to the situation in which fibre was difficult to provision and overhead stringing of fibre between poles was the cheapest and easiest answer. This is another reason for why utility poles might not be a natural "first choice" siting alternative in the urban core of Toronto.[120]

137. The large wireless service providers, through their existing wireless and business-oriented telecommunications services, already have relationships with many building owners in Toronto. This should make it relatively easy for such wireless service providers to gain access to buildings for purposes of making small cell installations. This would be another factor that would reduce the hurdles and the costs associated with using alternative siting facilities. If there is competition among building owners for business and residential customers, they will be relatively keen to facilitate the quality of wireless coverage on and around their premises.[121]

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[118] Montreal Gazette, "Cogeco Buys Toronto Hydro Telecom", June 13th, 2008 at http://www.canada.com/topics/news/national/story.html?id=d43b8b28-349a-4d47-822f-b68ffaa78d8c.

[119] See CRTC, *Revised regulatory framework for wholesale services and definition of essential service,* Telecom Decision 2008-17, March 3, 2008, at ¶¶ 117-119, pertaining to "fibre-based access and transport products".

[120] Dr. Jackson's Report makes a similar observation at footnotes 50 and 51.

[121] Ubiquisys also notes that competition among business owners should facilitate the ease of indoor siting: "Many of these owners have a commercial incentive to provide their customers with a better mobile experience." See Will Franks, "Small Cell Hotspots: Inside or Outside", http://ubiquisys.com/small-cells-blog/small-cell-hotspots-inside-or-outside/. Dr. Jackson also cites to recent studies which point to the high cost of provisioning outdoor sites such as utility poles, at footnote 49 of his report. Also the noted advantage of poles in terms of having firms deal with only one counter-party (the municipality or a utility such as THESL) can be achieved without regulating the rates at which access to poles is offered.

138. The entrants may face relatively higher hurdles in terms of being able to use alternative techniques or rely on alternative siting facilities relative to the large incumbent wireless service providers. However, even for these entrants, the relative disadvantages from not having access to poles are likely not particularly significant:

- The comparison of Toronto and Montreal (see below) indicates that access to poles in Montreal has not had a great impact on the fortunes of the smaller wireless service providers, nor on the overall extent of competition in the provision of wireless services.[122]

- The relatively large number of competing fibre networks in downtown Toronto suggests a relatively competitive wholesale market. The competing fibre networks can be expected to compete to provide backhaul service to the entrants and assist in facilitating building access.

In any event the competitive significance of the smaller entrant service providers, with or without pole access (at regulated rates), is destined to be very limited, for reasons explained below on the potential for a substantial lessening of competition.

139. The evidence is consistent, therefore with the hypothesis that, in urban Toronto, especially in its downtown core, the availability of upstream alternative inputs, and in particular alternative sites to pole access, is likely to be substantial, and the elasticity of substitution between different inputs is likely to be high.

5.3.4 Implications for Product Market Definition

140. The foregoing discussion makes it apparent that the relevant product market is very unlikely to correspond *only* to the provision of pole access for wireless attachments. Pole access is an input that might be useful in the context of particular kinds of outdoor technologies (DAS and small cell). But those technologies are themselves one of a set of options that wireless service providers have at their disposal, in their quest to provide capacity and coverage in Toronto. These wireless service providers have the flexibility to use

[122] A bigger factor that could ultimately generate differences between the Montreal and Toronto markets is that one of the entrants is Videotron, the incumbent cable company which has access to 40 MHz of AWS spectrum and is able to provide bundles of services (telephony, broadband, cable television, and wireless service).

these technologies in varying proportions with other capacity and coverage augmenting techniques. This flexibility arises from the fact that small cells and DAS are unlikely to be used to provide blanket outdoor coverage, and much more likely to be used to augment capacity and coverage of the macrocell networks that wireless service providers already have in place. As well, wireless service providers have the ability to use alternative siting facilities to poles, even if they choose to deploy small cells or DAS.

141. To summarize pole access is likely only important for:

- augmenting the capabilities of a macrocell network's outdoor coverage and capacity
- deploying small cells
- for users who are not moving too quickly (i.e., in a vehicle)
- to augment capacity attributable to large data demand.

142. But in these circumstances there are likely to be:

- alternative siting possibilities, in particular a structure (or structures) which has (or have) attracted subscribers and likely has (or have) both power and fibre access and/or
- alternative combinations of inputs that address the coverage and capacity issue from large data demand.

143. Pole access for wireless attachments is not likely a relevant input market in its own right, but an input that is part of a broader relevant market. That pole access for wireless attachments is therefore not likely the relevant upstream market, based on the possibilities for direct substitution, is reinforced by the possibilities for indirect substitution, attributable to competition in the downstream product market, considered in the next section.

5.4 Downstream Product Market Definition

144. The indirect source of substitution arises from pass through of pole access rates for wireless attachments to wireless services that use pole access for attachments as an input.

This section confirms that wireless services provided using extensive pole access are in the same market as wireless services that do not use extensive pole access. The conceptual experiment required is to assume there is a wireless service provider who has exclusive access to the pole network of THESL and consider whether the services it was able to offer would be in the same market as the wireless services offered by wireless service providers who did not have access to THESL's poles.

145. For purposes of the market definition exercise, the smallest candidate product market to consider is a wireless service that makes use of attachments placed on poles. A hypothetical monopolist in this context might be a firm that somehow has exclusive or preferential access to poles in Toronto and provides a service using small cell and DAS networks that utilise pole access. The wireless service aims to serve the demand for voice and particularly data services of mobile and nomadic users. It is assumed that since wireless services of the first, second and third generation (1G, 2G, and 3G services) provided in Toronto have not utilised poles in any significant way, then the wireless services of interest are based on the networks being freshly deployed right now, which use 4^{th}-generation LTE technology. While consumers demand both voice connectivity and data connectivity, the deployments of LTE technology are geared towards meeting demand for data connectivity.[123] In this section, it is assumed that near-term competition in the wireless service market (most especially for data purposes) will involve deployment of 4^{th}-Generation LTE technology, even though all wireless service providers will continue to maintain and operate 3G networks over the foreseeable future.[124] The findings in this section can be generalised to competition between 3G networks as well.

146. In this section the market definition question is assessed in terms of services that do, and do not use pole access, but in practice the question is likely to be one of how extensive the

[123] In the near-term, most wireless service providers will operate LTE networks and 3G networks simultaneously. The 3G networks will run on different frequencies to the LTE networks. All LTE-enabled devices are backwards compatible and will switch to the 3G network where LTE connectivity is not available, or for handling voice calls.

[124] It would appear that a wireless service provider that was not able to upgrade to LTE would face substantial hurdles in competing in the data marketplace, not least because of the branding disadvantage suffered by being identified as lacking the latest technology. At best, such an operator could carve out a niche serving particular price-sensitive groups of consumers. But this may not leave it with enough scale to sustain its operations for any significant period of time. Also, the major incumbent wireless service providers in Toronto are all already deploying 4G LTE technology. As explained subsequently, it is these wireless service providers that are important for competition.

use of pole access might be. It might be the case that a network makes no use of pole access except in an extremely limited number of circumstances where suitable alternative sites are not available, or it is difficult to use other techniques to manage the problems of capacity (discussed above) effectively. In this case, while there is some use of pole access as an input, there is not extensive use in general. That is, to serve customers located in most areas, wireless service providers will generally not utilise pole access. This is in contrast to the other extreme where wireless carriers use extensive pole access to provide blanket outdoor coverage. The key issue, regardless of the issue of the extent to which pole access is utilized, in terms of the downstream product market, is whether pole access provides a wireless service provider with a persistent and significant advantage in the downstream market.

147. It should be clear from the discussion of the upstream choices available to carriers that pole access is very unlikely to provide a wireless carrier with a persistent and significant advantage in the downstream market. To do so pole access would have to allow the carrier with it to have significantly lower costs or a significantly higher quality of service. The evidence is not consistent with either of these propositions: pole access is not likely to significantly lower costs or enable a higher quality service.

5.4.1 Canadian "natural experiment" supports broad market definition

148. There is a natural experiment from the Canadian market that supports the market definition analysis offered above. Public Mobile (using the DAS system put in place by DASCom) and Videotron have utilized outdoor DAS networks in Montreal using the pole infrastructure of local utilities whereas that has not been the case in Toronto.[125] Table 2 shows a number of wireless services metrics for both Montreal and Toronto. Despite the deployments of DAS using pole access in Montreal, the Quebec market shows no signs of featuring more advanced technologies, significantly different pricing by Public Mobile (whose operations in Ontario and Quebec are effectively in Toronto and Montreal only), or a marked difference in the extent of competitive pressure on the incumbent wireless service providers. Ontario has far higher wireless and smartphone adoption than Quebec, as well as a greater availability of LTE. LTE was rolled out in Toronto at exactly the same time as in

[125] These are 3G networks utilizing AWS spectrum. See *Written Evidence of Tormod Larsen*, July 26th, 2011 in EB 2011-0120 at p. 12 and Lemay-Yates Associates, *The Deployment of Distributed Antenna Systems on Utility Poles, Report Presented to CANDAS,* EB 2011-0120 at pp. 26-27.

Montreal. The pricing of Public Mobile—the wireless service provider that was seeking to deploy networks using pole access in Toronto— has, if anything, higher prices for its data plans in Montreal than in Toronto.

149. Market share data are not available at the city level in Canada, but at the provincial level, new entrant service providers have not been able to gain, in absolute terms, substantially more market share in Quebec than in Ontario. Smartphone users tend to have much higher usage and to generate much higher Average Revenue per User (ARPU) than other wireless service users.[126] Despite the upsurge in smartphone adoption since 2007 (around the time that smartphones began to be widely available), ARPU in Ontario has fallen over the 2007-2011 period. Indeed, ARPU has fallen more appreciably in Ontario, compared to Quebec (See Figure 1). As with the market share data this is not consistent with greater competitive pressure on the incumbents: it might have been expected that the ARPU differential between Ontario and Quebec should have increased, given the difference in smartphone adoption.

150. If wireless services that use pole access were really a distinctive product that conferred substantial advantages on end users, one would expect to see a stronger impact of the wireless service providers using these technologies on the Montreal market. Instead the fact that wireless service providers in Montreal are only operating some 250-odd nodes in a metropolitan region of some 3.4 million people suggests that pole access is a minor input used to support localised deployments in certain areas.[127]

5.4.2 Fixed broadband and wireless broadband are not in the same market

151. Elements of fixed networks are leveraged by technologies such as Wi-Fi and femtocells which can be used to augment the provision of cellular-based wireless services in order to alleviate capacity and coverage problems. But this does *not* mean that wireline services are

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[126] See Jeff Fan, "Canadian Wireless Myths and Facts," *Equity Research Daily Edge,* Scotiabank, March 7, 2013, at p. 5. Available online at http://blog.telus.com/wp-content/uploads/2013/03/SC-Canadian-Wireless-Myths-and-Facts.pdf.

[127] See Lemay-Yates Report, in EB 2011-0120, at pp. 26-27 and *Written Evidence of Brian O'Shaughnessy* (Public Mobile), EB 2011-0120, July 26, 2011, at p. 7. These documents suggest an initial plan to utilize 700-800 utility poles in Toronto. It appears that Videotron at the time of the CANDAS proceeding was using only a handful of Hydro-Quebec utility poles in Beaconsfield, Quebec DAScom had made attachments to around 259-odd utility poles in Montreal on lamp-posts and streetlights. Public Mobile's submitted evidence also makes it clear that limitations on the amount and characteristics of the spectrum that Public Mobile had were a key determinant of Public Mobile's initial interest in DAS technology. These limitations do not apply to other providers, especially not the incumbents.

close economic substitutes for the wireless services discussed in this section. These services do not offer the mobility element that wireless services offer and hence they are not in the same downstream market. However wireless service providers can use fixed-line offload more intensively as a substitute for technologies that might utilise pole access in the upstream input market.[128, 129]

5.4.3 Relevance of Other Wireless Attachments

152. The focus of the preceding discussion has been on wireless service providers who meet both nomadic and mobile demand by deploying extensive cellular radio networks (using licensed spectrum), and augmenting these deployments with technologies such as Wi-Fi. It is possible that there are some parties that wish to make attachments to THESL poles while providing wireless service of a more limited sort, e.g., firms that might wish to provide localised Wi-Fi service. A firm might wish to utilise THESL's poles to provide outdoor Wi-Fi service similar to that provided by One Zone, the Wi-Fi network that was constructed by Toronto Hydro Telecom and acquired by Cogeco.

[128] In the acquisition of Microcell Communications by Rogers in 2005, the Competition Bureau ruled that wireline communications was not a constraint on wireless pricing. At the time, voice services and text messaging were by far the dominant services provided over wireless networks. In 2011 there was extensive market definition and market power analysis submitted by several parties in the wake of the proposed acquisition of T-Mobile USA by AT&T. None of the parties suggested that wireline and wireless data services were in the same market. See Competition Bureau, "Acquisition of Microcell Telecommunications Inc. by Rogers Wireless Communications Inc.," *Technical Backgrounder*, April 2005. In the AT&T/T-Mobile case the positions of the parties are summarized in the Federal Communications Commission's (FCC) staff report of November 29, 2011, at ¶¶ 29-31, where the FCC and Applicants (T-Mobile and AT&T) appear to agree that there is a mobile telephony/broadband market consisting of mobile voice and data services, including broadband data services provided over advanced mobile networks. See Federal Communications Commission, *Staff Analysis and Findings*, November 29th, 2011 in WT Docket No. 11-65 available online at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-11-1955A2.pdf.

[129] Experts for the CANDAS coalition in EB 2011-0120 suggested that there was a market for "ubiquitous, high-quality communications services." The supporting evidence for such a market definition consists of strategy documents prepared by the CRTC that do not make use of the hypothetical monopolist test. CANDAS' expert, Ms. Kravtin, also suggests that Bell Mobility and Rogers' wireless division do not participate in the relevant downstream market for ubiquitous data communications services as they are not of sufficiently high quality. But she says that Bell and Rogers wireline services, do participate in the market for ubiquitous, high-quality telecommunications services. It seems very unlikely, as explained above, that the downstream market for broadband mobile services includes fixed broadband: that is that a SSNIP for a hypothetical monopolist of mobile broadband would not be profit maximizing because of substitution to fixed broadband. Ms. Kravtin's position on Bell and Rogers' wireless divisions not participating in the relevant market are spelled out in CANDAS' *Responses to the Interrogatories of Toronto Hydro-Electric System Limited***,** in EB 2011-0120 , January 20th, 2012 and in the *Reply Report of Ms. Patricia D. Kravtin*, in EB 2011-0120, December 16th, 2011, at ¶19. In the Joint Written Statement of July 20th, 2012, CANDAS' experts claim that Canada's telecommunications regulator, the CRTC, has "repeatedly recognized" that there is a relevant output market in which wireless carriers compete with incumbent wireline carriers. The supporting citation is to a CRTC strategy document called *Navigating Convergence*. See *Joint Written Statement of Johanne Lemay, Adonis Yatchew, Patricia Kravtin and Michael Starkey*, EB 2011-0120, July 20th, 2012 at p. 14.

153. However, it is likely that the same considerations developed for cellular radio attachments by wireless service providers apply to Wi-Fi and other deployments. In particular there may well be lots of other sites that are good substitutes for pole access. But more importantly, downstream substitution is likely to result in substantial discipline of the exercise of market power in pole access for Wi-Fi or other attachments.

154. An outdoor Wi-Fi service, for example, is a service that is only capable of serving nomadic demand at a few locations. This service would not constitute a relevant downstream market in its own right. A monopolist that controlled the provision of such services in Toronto would have to compete with the service proposition that is offered by the leading wireless service providers and wireline broadband providers of hotspots for Wi-Fi access.

155. For example, Bell and Rogers provide both cellular and fixed broadband services in Toronto. Both provide access to hotspots to their Internet subscribers for no additional charge.[130] Between the numerous 3G cellular data networks, the user's home and office broadband connections, and the Wi-Fi access often freely available at indoor locations, the opportunity for a hypothetical monopolist of outdoor Wi-Fi provided using pole access to exercise market power would appear to be negligible. Consumers would simply substitute to alternatives in the downstream market. The wide scope for indirect substitution in the downstream market means that THESL is unlikely to have market power in the provision of pole access for Wi-Fi and other non cellular wireless attachments.

156. Conversely, the limited nature of a Wi-Fi-like service means that substitution away from cellular service subscriptions towards this kind of service is most unlikely to constrain the exercise of market power in the provision of pole access to wireless service providers that utilise cellular networks. The economically relevant analysis needs only to focus on the possibilities of substitution, either directly or indirectly, by the wireless service providers (who use licensed spectrum to provide nearly universal and mobile service) away from pole access to other inputs if THESL attempts to exercise market power for wireless attachments.

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[130] See http://your.rogers.com/store/cable/internet/wifi/overview.asp. Prior to December 31st, 2010, Rogers attempted to charge a monthly subscription fee for Wi-Fi access, but abandoned that policy.

5.4.4 Conclusion on Downstream Product Market

157. The relevant downstream product market likely consists of wireless services that utilise a range of capacity management techniques and a range of siting facilities to serve downstream consumers. A wireless service that extensively used pole access to deploy its LTE technology would not have market power because of either a cost advantage or a quality advantage over wireless service providers who used inputs to deploy LTE other than pole access. Were the price of access to utility poles raised significantly above competitive levels, wireless service providers who provide service using pole access would likely not be able to pass this increase in cost on to their customers without significant loss attributable to substitution to wireless service providers who do not utilize pole access (or do not utilize pole access as extensively). Consumer switching to these close economic substitutes will discipline the ability of a firm that is a hypothetical monopolist providing the only pole-deployed wireless service to elevate prices above a competitive level.

158. The broad downstream market for wireless services suggests that indirect substitution to services that do not utilise the pole access input is an important factor that increases the elasticity of demand for pole access. Indeed, the discussions of both direct and indirect substitution for pole access for wireless attachments suggest that demand for pole access for wireless attachments is relatively elastic. This implies that a SSNIP test for pole access for wireless attachments would likely not be passed: the product market for pole access for wireless attachments is broader than just pole access for wireless attachments.

5.5 Geographic Market Definition

5.5.1 Downstream Geographic Market Definition

159. In the downstream wireless market, and in particular wireless broadband service, the competition between wireless services is between their networks. Subscribers select a service provider based on a number of characteristics or attributes of the network, including price, speed, handsets, and coverage.

160. Coverage refers to the geographic area in which customers can receive service. For geographic market definition, the relevant geographic area is defined by where customers would like to receive service, i.e., make and receive calls, or transmit and receive data. Hence

the geographic market is defined by the usage patterns of consumers. A service provider serving location *B* but not location *A* cannot serve the demand of a consumer whose greatest share of usage occurs in location *A* and hence it is not in the relevant geographic market defined around service in *A*.

161. However, over the area of THESL's pole network all three major wireless carriers and most of the smaller ones provide service.[131] In general Industry Canada regulations mean that the new wireless entrants can roam onto the networks of these three incumbent wireless service providers.[132] Hence all carriers in the same product market are able to provide wireless service over THESL's pole network footprint.

162. In such circumstances where there is homogeneity of competition across potentially distinctive geographic markets and where there is no price discrimination across different geographic locations, the market can be defined by aggregating up these markets. The process of aggregation continues until the conditions of homogeneity in competition and pricing are no longer satisfied. For this reason, the relevant geographic market in which competition for provision of wireless services takes place is at least as big as the city of Toronto. That there are not "local" geographic markets is consistent with the fact that while wireless carriers do compete on their coverage (and the price of extended coverage), they do not price discriminate across different locations in Toronto based on the extent of competition in a particular area.

5.5.2 Upstream Geographic Market Definition

163. The discussion of the upstream product market indicated that there are other upstream alternatives or inputs that limit the importance of the pole access input and that the pole access upstream input likely does not form a relevant antitrust product market. This does leave open the possibility for localised circumstances in which pole access might be vital.

[131]The site http://www.cellmapper.net/map provides locations and coverage maps for each provider all over Canada.
[132] Industry Canada first announced regulations pertaining to mandated roaming in 2008 and these have been subsequently revised, with a new set of rules being published in March 2013. The right to roam and share sites applies to all networks, but in practice, it is the customers of the smaller entrant wireless providers who will roam onto the networks of the incumbent operators. See http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09081.html#p1. See also M. Lally and M. Anderson, "Industry Canada Makes Significant Announcements Impacting the Wireless Industry," March 8, 2013 online at http://www.osler.com/NewsResources/Industry-Canada-Makes-Significant-Announcements-Impacting-the-Wireless-Industry/.

These localised circumstances might suggest that the geographic dimension of the input market be treated in a disaggregated fashion. Indeed, there are some areas in which poles are present and others in which they are not present; some areas may have plenty of alternative sources of fibre, others may be more limited in this regard; mixed-use business and residential areas and the core business districts of Toronto might have especially rich siting options, purely residential areas less so. However, given the range of alternative techniques and combinations of techniques identified, as well as the range of siting alternatives present, there is only a limited likelihood that wireless service providers will lack for options to provide outside data coverage for non mobile users using small cells mounted on poles.

164. Importantly these localized circumstances are not likely to be known by THESL. Hence it is unlikely that THESL can exercise market power in those locations: if it cannot distinguish which locations where it has market power from those that it does not, then the relevant geographic area is no smaller than the footprint of its entire pole network. THESL does not know the value of pole access at a given location to a wireless service provider and hence cannot discriminate if rates where forborne.[133]

165. If THESL cannot price discriminate then the profitability of raising pole access rates for wireless attachments will depend on the usual trade off: increased revenues from poles that are accessed, but lost profits from poles that would have been used for wireless attachments at a lower price, but are not at a higher rate. As discussed above in the context of providing wireless service for the entire City of Toronto, the wireless service providers will have a great deal of flexibility to substitute away from poles. The use of small cells mounted on poles to provide coverage and capacity is a relatively expensive alternative given that it involves not only the cost of the small cell, but also the cost of providing the small cell with power and backhaul and the rental of the pole.[134]

5.6 Market Definition and THESL's Market Power in Pole Access for Wireless Attachments

166. The foregoing analysis suggests the following:

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[133] THESL Evidence at ¶4.

[134] See the discussion in Dr. Jackson's Report at p. 29 and also p. 31.

- Upstream product market: The fact that wireless service providers can vary the extent to which they use wireless attachments that require pole access, as well as the availability of alternative siting facilities for such attachments, suggests that there is a broad upstream "input market", and not a market defined by monopoly control over the provision of the pole access input. Consequently, the fact that THESL maybe an exclusive supplier in the provision of pole access for wireless attachments does not mean that it has market power in a relevant upstream market.

- Downstream product market: The relevant downstream market is wireless services that provide a high quality user experience that meets the needs of mobile and nomadic consumers in Toronto. Wireless services in the relevant market are likely to utilize LTE technology to deliver increasingly high speed data transmission services, aimed at supporting the needs of smartphone and tablet users.

- Geographic markets (Upstream and Downstream): The geographic market for both the provision of the input upstream and the provision of the service downstream is at least as big as the city of Toronto.

167. Recall that market definition involves identifying substitutes that constrain the exercise of market power. These broad geographic and product markets suggest that THESL is unlikely to be able to exercise market power in the provision of pole access for wireless attachments.

168. This conclusion is supported by the frequency of use of THESL poles to host wireless attachments. As discussed above THESL presently provides pole access for wireless attachments made by wireless service providers on a very small number of poles.[135] This is so even though access is available at a regulated rate. Clearly this indicates that at the regulated rate the extent of substitution identified in our analysis is sufficient that demand for pole access for wireless attachments is minimal at present.[136] The analysis suggests that the demand in the future will be sufficiently elastic that THESL's market power will be limited.

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[135] See THESL Evidence at ¶11.

[136] Hence it is not necessary to look at either measures of market concentration or barriers to entry, as would usually be done in a market power analysis.

6 Substantial Lessening of Competition

169. The previous analysis suggests that there are usually alternatives to pole access in the upstream input market and that it is likely that wireless service providers can provide services that are economic substitutes to services based on pole access in the downstream market using these alternatives. Especially for the major incumbent wireless service providers in Toronto, the set of alternatives and options seems substantial, especially when one considers the relatively dense business and mixed-use districts of downtown Toronto.

170. The immediate implication of this is that THESL does not have market power in the provision of pole access for wireless attachments. In this section the analysis is extended to show that even if it did exercise *some* market power in the upstream market, there would not be a substantial lessening of competition in the relevant downstream market or, equivalently, mandated access for wireless attachments at regulated rates would not result in a substantial increase in competition in the relevant downstream market.

171. The exercise of market power by THESL in the provision of pole access for wireless attachments could result in a substantial lessening of competition in downstream wireless broadband markets if either of the following hypotheses is supported by the facts:

- the exercise of market power by THESL raises the costs of deploying wireless services, resulting in higher prices and lower quality service in the downstream market.

- the exercise of market power by THESL affects wireless service providers asymmetrically, and in doing so, preserves or creates market power for some wireless service providers in the downstream market.

172. This section demonstrates that neither hypothesis is consistent with the facts:

- With respect to the exercise of market power on the prices and quality of downstream services, pole access services for wireless service providers is not and cannot be an appreciable element of downstream costs for the major wireless firms in Toronto. Because of this the ability of the incumbent firms to deploy new networks and services at affordable prices to consumers will not be impacted by the price for pole access for wireless attachments. THESL is not in the position of a firm that can exercise market power in a way that creates substantial harm in the downstream market.

- Two important considerations mean that the potential for the exercise of market power by THESL to preserve, create, or enhance market power in downstream wireless markets is not likely. These are (i) that the evidence is not consistent with the exercise of market power in downstream wireless markets; and (ii) the competitive significance of entrants is minimal, THESL's poles are not being used presently by the entrants to provide service, and providing entrants with pole access at regulated rates will not enhance their competitive significance.[137]

6.1 Potential Impact of THESL's Exercise of Market Power on Incumbent Firms

173. In this section, the hypothesis considered is whether the exercise of market power by THESL (if it had any) could harm consumers in the relevant downstream market. The conclusion is that even if THESL could exercise market power in the provision of pole access for wireless attachments, the facts are not consistent with the hypothesis that this exercise would materially harm consumers in the relevant downstream market. The section proceeds by explaining why it is the potential for the exercise against the incumbents that is important, why it is unlikely that THESL can exercise market power against the incumbent wireless service providers, and even if it could the effect on downstream wireless consumers would be immaterial. The incumbent wireless service providers in Toronto already serve the great majority of customers, and it is very likely (given that only these firms offer the most data-intensive devices and LTE networks) that an even greater share of data traffic travels over their networks. The expected increase in demand for capacity is likely to materialise almost exclusively on the networks of these operators.

[137] There is a third hypothesis. It is that THESL can exercise market power against the entrants and that by raising their costs prices in downstream markets and/or quality of service are negatively impacted even if the incumbents do not exercise (inefficient) market power. If, however, the competitive significance of the entrants is minimal and not enhanced by pole access for wireless attachments at regulated rates, then this potential benefit of mandated access at regulated rates will also not be realized.

174. One of the main reasons for this contention is that only the incumbent networks support the latest and most advanced cellular-enabled devices, most notably Apple's iPhone. Data consumption by iPhone and other high-end device users tends to be much greater than data consumption by other consumers and none of the entrants are able to offer the iPhone.[138]

175. Second, deployment of LTE networks—which has been done by the incumbent wireless firms only—also appears to have a very substantial impact on data consumption. A recent news story notes that North American LTE users use an average of 46 MB of mobile data daily, compared to 17 MB for 3G network users.[139] It is very unclear at present regarding which, if any, of the crop of Canadian wireless entrants who entered the market in 2008 will remain in business or deploy extensive LTE networks.[140]

176. Third, the entrants into the Canadian wireless market appear to have focused on talk and text, and not on data.[141] Their focus has been on providing low priced voice and text packages.

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[138] In 2010, iPhone users were found to consume five times as much cellular data as users of other smart devices. In early 2013, iPhone users on major U.S. networks were still using more data than users of Android phones. As Android devices span a wide range from inexpensive to very expensive, it is reasonable to suppose that users of Android phones that are in the same price range as iPhones have usage levels closer to that of iPhone users. See http://www.macrumors.com/2010/02/12/average-iphone-consumer-data-usage-pegged-at-five-times-that-of-blackberry/ for evidence from 2010, and http://bgr.com/2013/03/20/iphone-android-data-usage-study-387882/ for evidence from 2013.

[139] Tammy Parker, "Alcatel-Lucent: LTE Drives 168% Higher Daily Mobile Data Consumption", *Fierce Wireless*, April 24th, 2013. Available at http://www.fiercebroadbandwireless.com/story/alcatel-lucent-lte-drives-168-higher-daily-mobile-data-consumption/2013-04-23. The higher usage on LTE networks could reflect both an "encouragement effect" wherein higher speeds encourage users to up their data consumption relative to previous levels, and a "migration effect" wherein the highest-intensity users of 3G data networks have migrated to 4G networks rapidly. In either case, this suggests a higher load on LTE networks—like those deployed by Canada's incumbent wireless operators—compared to older 3G networks. In wireless networks, it is well known that a small proportion of users generate a disproportionate amount of data traffic. See also Deloitte, "TMT Predictions 2013: A Strong Year For LTE Adoption", http://www.deloitte.com/view/en_GX/global/industries/technology-media-telecommunications/tmt-predictions-2013/tmt-predictions-2013-telecommunications/77ca7f7d2c1eb310VgnVCM2000003356f70aRCRD.htm. .

[140] All three of the "entrants" in Toronto face deeply uncertain futures: all are, or were, for sale. Public Mobile has been acquired by private investors. Telus had a deal to acquire Mobilicity that was denied by Industry Canada. It is difficult to see how there will not be further consolidation that eliminates some of the entrants. See CBC News, "Telus Agrees to Take Over Mobilicity for $380m", May 16th, 2013. See also Telegeography.com, "Public Mobile, Mobilicity Put Up for Sale Besides Wind, Report Says", April 15th, 2013, available at http://www.telegeography.com/products/commsupdate/articles/2013/04/15/mobilicity-public-mobile-up-for-sale-alongside-wind-report-says/ and "Private equity firms scoop up Public Mobile, aim for more deals," *Wire Report,* June 6, 2013.

[141] See Sean Silcoff, Boyd Erman and Rita Trichur, "How Ottawa's Plan to Foster Wireless Competition Sank", *Globe and Mail*, May 18th, 2013, which states "the new entrants were partly to blame for their own misfortunes…they underestimated the impact of the Smartphone revolution….the business model quickly shifted from talk and text on flip phones to data consumption…on devices like the iPhone."

This is reflected in their relatively low average revenue per user and relatively small share of postpaid subscribers relative to the three incumbents.[142] These differences are likely attributable to a large difference in the importance of data service for the incumbents relative to the entrant. Despite their low data prices, the market shares of the entrants are very low thus suggesting that they are not important providers of data services and it is data capacity that is likely at the heart of the demand for pole access.[143] The relative lack of importance of the entrants in providing data services is reflected in a comparison of some relevant financial results.

177. For instance in the first quarter of 2013:[144]

- Bell reported that 84.5% of its wireless customers were postpaid, data revenue accounts for 39.3% of its total wireless revenue, 68% of its postpaid subscribers use smartphones, and its monthly average revenue per user was $55.92.

- Rogers reported that 84% of its wireless customers were postpaid, data revenue accounts for 43% of its total wireless revenue, 71% of its postpaid subscribers use smartphones, and its monthly average revenue per user was $59.68.

- Telus reported that 85.7% of its wireless customers were postpaid, data revenue accounts for 43% of its total wireless revenue, 68% of its postpaid subscribers use smartphones, and its monthly average revenue per user was $60.04.

178. In contrast Wind Mobile's monthly average revenue per user in the first quarter of 2013 was $27.60[145] and in large part because of its initial focus on the prepaid market, postpaid subscribers accounted for only 40% of its subscriber base as of early 2012.[146]

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[142] Post paid customers pay in advance and are on a contract. Pre paid customers pay as they go.
[143] See CRTC, *Communications Monitoring Report 2012,* Table 5.5.10 at p. 174. The average reported rate differential between the entrants and the incumbents is 33% for 2 GB per month and 35% for 5 GB per month.
[144] See "BCE reports first quarter 2013 results" at http://www.bce.ca/news-and-media/releases/show/bce-reports-first-quarter-2013-results?page=1&perpage=10&year=&month=&keyword= and "Bell, Telus chipping away at Rogers' lead in postpaid wireless," *Wire Report,* May 9, 2013.
[145] See *Orascom Telecom Holding First Quarter 2013* at p. 12 available at http://www.rns-pdf.londonstockexchange.com/rns/7479E_-2013-5-15.pdf.
[146] See "Expanding a NEW Mobile Network," *Telecom Review,* November-December 2012 available online at http://www.telecomreviewna.com/index.php?option=com_content&view=article&id=274:expanding-a-new-mobile-

179. The competitive effect of the entrants is reflected, in part, by the decline in the voice average revenue per user for the incumbents of $10-$18 over the period 2008 to 2012. On the other hand the rise in smart phone penetration and increased data usage has raised the monthly data average revenue per user for the incumbents from $12-$14 over the same time period, leaving the monthly average revenue per user for the incumbents relatively unchanged.[147]

180. Consequently, a significant impact on consumer welfare would arise primarily if THESL were able to exercise market power at the expense of incumbent wireless service providers. If THESL had market power with respect to these incumbent firms, it could raise their costs and this increase in costs could manifest itself in the form of higher consumer prices and lower output in the downstream market.

181. However, as discussed in the previous section, it is very unlikely that THESL can exercise market power against the incumbents. To recap—with a focus on the incumbent wireless service providers in Toronto—THESL is unlikely to be able to exercise significant market power against the incumbents for the following reasons:

- These firms are sophisticated and well-capitalized, and are well-acquainted with the other techniques that are available at their disposal to augment capacity and coverage.

- Given their large macrocell networks, and their spectrum holdings, these firms will only use small cell technologies for fill-in purposes for outdoor coverage, thus reducing the urgency of pole access.

- Buildings are an attractive and feasible siting alternative for poles, even for those instances in which outdoor small cell technologies are used. These firms have access to their own buried fibre networks in Toronto, or will be in a favourable bargaining position with respect to wholesale fibre providers in Toronto, thus reducing the importance of poles as a relatively convenient resource for purposes of

network&catid=44:novembre-decembre-2012&Itemid=88.

[147] See Jeff Fan, "Canadian Wireless Myths and Facts," *Equity Research Daily Edge,* Scotiabank, March 7, 2013, online at http://blog.telus.com/wp-content/uploads/2013/03/SC-Canadian-Wireless-Myths-and-Facts.pdf, p. 3.

routing fibre connections between antenna/small-cells and the larger communications network.

These firms may already have relationships with building owners, as they might already be providing buildings with business broadband services, or might already have a relationship with building owners because they have placed wireless equipment on building rooftops. For example, Industry Canada's antenna database reveals that Bell had at least 133 unique addresses within a 5 km radius of the CN Tower, on which it had installed wireless antennas in the 800-1000 MHz range alone. Rogers had 177 unique addresses, and Telus had 49 unique addresses, in this frequency range alone. While it is impossible to be absolutely determinative, it stands to reason that the majority of these addresses at which equipment have been placed reflect rooftop constructions and not free-standing structures.[148] In any case, such operators will have powerful incentives to improve in-building coverage and capacity, and so will anyway have an interest in negotiating access to buildings.

182. The incumbent wireless service providers are large and sophisticated parties. They are unlikely to plan an extensive small cell network that depends upon access to THESL poles without first having negotiated access to poles. In those negotiations, if THESL attempts to price pole access at very high levels, this is likely to reduce the demand for poles to the limited set of circumstances where even the incumbent wireless firms lack effective economic substitutes. Even if wireless service providers could not avoid using THESL poles entirely, they would appear to certainly have the flexibility to greatly reduce their reliance on this infrastructure, limiting the profitability of exercising market power.

[148] This is likely the case because the area searched was downtown Toronto where erecting free-standing structures (e.g., a free-standing cell tower) would be difficult and uneconomic. Across Canada, in 2004, it was estimated some 33% of cell sites were roof-top sites. See Industry Canada, *Report on the National Antenna Tower Policy Review*, Section D, December 2004, available at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08352.html.
In the dense urban core of Toronto, that proportion is surely significantly higher. As well, most of the sites that were identified within a 5 km radius of the CN Tower have street addresses corresponding to buildings in Toronto. The Toronto Community Housing Association lists several hundred of its buildings on which it says that rooftop antennas have been mounted. In "downtown", some 53 buildings owned by the Association serve as antenna sites. See http://www.torontohousing.com/commercial/antenna/downtown.

183. Consequently, the cost share of the pole input relative to all the other costs that these wireless service providers incur is never likely to be significant. The share of pole access in the aggregate costs of providing service is likely rather small. For instance, if a major wireless operator such as Rogers used only a few hundred poles in Toronto, unless the poles cost hundreds of thousands of dollars per year to rent, the share of such pole access in overall operating costs that run into several billion dollars per year would be negligible.[149] Rogers and other large wireless carriers tend to price their services on a national basis. If Rogers had to pay several hundred thousand dollars or even a few million dollars additional to serve one of its most significant markets—Toronto—the impact on pricing and costs would be negligible.

184. Therefore the cost of pole access for wireless attachments is unlikely to make a material difference to the pricing that consumers face. Nor is the lack of pole access likely to materially impact on the deployment plans of major wireless service providers. THESL cannot, through its choice of the access price, significantly impact upon the costs and prices of the major wireless service providers. If it cannot significantly impact on the incumbent wireless service providers and their customers, then it almost certainly cannot significantly impact the level of consumer welfare in the downstream market.

185. Moreover, it is clear that the effect on the incumbents from any exercise of market power by forbearing from regulating rates to pole access for wireless attachments cannot result in a substantial negative effect at present since their use is minimal.[150] The analysis suggests that even in the future there will not be a substantial negative effect because of their elasticity of demand and minimal cost share of pole access.

186. Any possibility of a significant negative impact from the exercise of market power by THESL on the downstream market will therefore be attributable to its effect on the new

[149] For example, Rogers' wireless division had annual operating costs of $2.677 billion and equipment costs of $1.585 billion in 2012. See Rogers' Annual Report for 2012 at p. 35, available at http://www.rogers.com/cms/investor_relations/pdfs/2012_Annual-Report.pdf. Bell's reported wireless operating costs were $3.463 billion in 2012. See BCE Annual Report 2012 at p. 41.

[150] See THESL Evidence at ¶11, which suggests that very few attachments have been made by wireless service providers on either THESL or THESI poles. The preponderance of current "wireless" attachments is for Wi-Fi services, which presumably have been made for the purposes of the One-Zone Wi-Fi deployment.

wireless service providers. But the analysis in the next section suggests that this will not be the case.

6.2 Potential Impact of THESL's Exercise of Market Power on Market Power in Wireless Markets

187. The only negative effect therefore in the downstream market from any market power THESL might have (which is not indicated) must arise from the potential for its exercise of market power to maintain or create market power in the downstream market. The only firms in the downstream market who might have market power are the incumbents. Whether this hypothesis is true requires that *all* of the following be supported by the facts:

- the exercise of market power by THESL has a greater effect on the costs of entrants than on incumbents;
- but for this asymmetric impact on costs the entrants would have been able to more effectively discipline the exercise of market power by the incumbents; and
- the incumbents have market power.

188. In what follows in this section, it is demonstrated, first, that incumbent wireless service providers do not appear to exercise inefficient market power. Second, it is shown that pole access for wireless attachments at regulated rates is unlikely to make any difference on the ability of the entrants to constrain the market power of the incumbents. Hence neither of the last two bullets are supported by the facts and hence the hypothesis that if THESL could and did exercise market power in the provision of pole access for wireless attachments it would create, maintain, or enhance market power in wireless markets is not valid.

6.2.1 Market Power in the Wireless Markets in Toronto

189. By the very nature of their costs, wireless service providers cannot price at short run marginal cost as competitive firms would. Instead they must price at levels in excess of short run marginal cost. However, it would be wrong to expect that pricing above short run marginal cost is a useful measure of market power. Firms must be able to price so that they recover at least their average long run cost of production, given the fixed costs associated

with operating in the industry. The exercise of market power by firms whose costs are characterized by economies of scale is problematic only if it is means that prices exceed long run average cost.[151]

190. Because of the nature of the technology of wireless networks—significant sunk capital that must be recovered by markups over short run marginal cost—there is a minimum gross margin required for the marginal wireless service provider to be just profitable. The number of wireless service providers will adjust in the long-run to ensure this margin is realized. If there are too many networks in the short run, the competitive price will reflect short run costs and firms will not break even. In the long run, consolidation and exit will occur until firms are at least able to raise price over short run costs sufficient to break even.

191. Thus the traditional approach used in competition policy analysis to identify market power, involving defining markets and inferring the exercise of market power from market share and margins must be applied with caution. High margins and a concentrated market might indicate market power is a concern, but this could easily be a false positive. For firms to price in excess of average cost and be viable, concentration and gross margins might both be relatively high. The margins earned over short run marginal costs create quasi-rents, not profits. Quasi-rents are the difference between revenues and short run avoidable costs: they exclude sunk costs.[152] In order for a firm to break even in the long run, quasi-rents must at least equal sunk costs.

192. The traditional measures of assessing market power cannot recognize when concentration and high gross margins are consistent with competition and not the exercise of market power. There are two alternative approaches that do distinguish between competition and the exercise of market power when the industry is characterized by significant economies of scale. The two approaches are the internal rate of return on investment and international comparisons of market structure.

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[151] See discussion above in Section 4.1.

[152] See Church, Jeffrey and Roger Ware (2000), *Industrial Organization: A Strategic Approach* (McGraw-Hill), p. 23 for a definition and discussion of quasi-rents.

The Internal Rate of Return and Monopoly Profits

193. Understanding the implications of significant sunk fixed costs means that the appropriate measure of market power involves considering the net present value (NPV) of total cash-flow generated over the life-cycle of the wireless service provider's investment. In the start up phase cash flows will be small or negative—both because the market is new and because of the requirements for investment. Once the business is established—if it survives and becomes established—cash flows will be positive as investment requirements are reduced and demand is established. If the investment is successful high margins in later years will compensate the firm for its capital costs and losses in early years. Only if firms are able to realize returns that are substantially above their opportunity cost of capital over the life-cycle of an investment project can one even begin to draw conclusions about abnormal levels of profitability and market power.[153] Market power is consistent with returns in excess of the cost of capital.

194. Rogers is the largest wireless incumbent in Canada and has been the market leader for some time. In the early 2000s, Rogers was considered a highly risky financial investment, with Moody's credit rating service expressing concern about its ability to quickly generate cash flows that would compensate investors for the cash that the company had consumed to get its networks up-and-running.[154] To assess the significance of market power for its financial performance from 1986-2012 it is possible to estimate Rogers' internal rate of return on investments made in its wireless operations.[155] Over the period 1986-2012, the

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[153] Even if it appears that firm earnings exceed the opportunity cost of capital, care must be exercised to determine if the excess returns are attributable to market power or are Ricardian rents. Ricardian rents are really returns to superior factors of production that provide a firm with an apparent cost advantage. They are not a result of the firm exercising market power.

[154] See Moody's Investors Service, *Rating Action: Moody's Lowers Rogers Wireless Inc.'s SR Secured Ratings to Ba3 and SR Sub. Ratings to B2; Continues Review for Possible Downgrade* July 12, 2001. Available online at http://www.moodys.com/research/MOODYS-LOWERS-ROGERS-WIRELESS-INCs-SR-SECURED-RATINGS-TO-Ba3--PR_57805.

[155] Cantel, Rogers Wireless' predecessor, commenced service on July 1, 1985. See Ian Marlow, "A phone so big it came with its own luggage," *Globe and Mail* 2 July 2010 online at http://www.theglobeandmail.com/report-on-business/a-phone-so-big-it-came-with-its-own-luggage/article1389639/#dashboard/follows/. Because cash flow is not available before 1986 and capital expenditure (capex) for 1986 and before is not available, the IRR calculations assume a value of $60 million for capex in1986. This represents undepreciated cumulative capex for all years before 1987. The value of $60 million is based on the fact that as of financial-year end 1987, Rogers had invested over $110 million in Cantel, which it had acquired at the beginning of financial year 1986, and investment in 1987 was $52 million.

internal rate of return in nominal terms was 12.68%. The year 2008 is very significant since it was then that Industry Canada decided to take affirmative measures to boost competition in the wireless industry by setting aside significant amounts of AWS spectrum for entrants. It was also the year that the iPhone launched on Rogers' network, and the new data-centric wireless market was born. Up until that inflection point in the development of the market, Roger Wireless' IRR over the period from 1986-2008 was only approximately 6.4%, likely below any reasonable estimate of the nominal pre-tax cost of capital. In constant 1986 dollars, cumulative cash flow did not turn positive for Rogers Wireless until 2007. Even the more reasonable IRR achieved over the entire 1986-2012 period is an ex-post realised rate of return, which does not reflect the significant risk that Rogers would fail to last the course.[156] See Table 3 for details.

Natural Limits on the Extent of Competition

195. An important implication of extensive economies of scale and scope is that there will be an upper bound on the number of wireless service providers that can be supported. This upper bound is determined by the extent to which the wireless service providers must be able to price above short run marginal cost sufficiently to breakeven. An implication is that market power would be indicated if the number of competitors was below this natural limit.

196. The more extensive economies of scale and scope the fewer the number of firms that can be supported. Whether or not market size makes much of a difference to concentration in a given industry may depend on both the nature of the "set-up" costs associated with entry and their relative magnitude. The relationship between concentration and market size (e.g., available demand) depends also on the relationship between market size and "set-up" costs.

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[156] The year 2004 is a key year for Rogers. In 2004 Rogers acquired Microcell for $1.5 billion, another risky investment that Rogers made in its business-building phase. Unlike the other Canadian mobile service providers, Rogers opted for the GSM standard in the early 2000s, spending hundreds of millions of dollars annually to build out a GSM network. Rogers suffered nearly two decades of low or negative cash flow returns, but was rewarded in the mid and late-2000s, when it reaped the benefits both of its acquisition of scale and spectrum with the Microcell purchase, but also with its adoption of the technology that became the global standard. Most notably, Rogers was able to secure an exclusive iPhone distribution contract, as the iPhone was initially built only to support GSM and its successor standards (e.g., UMTS). Bell and Telus subsequently were forced to join forces and switch to using the 3rd-Generation GSM technology, HSPA+, in order to sell the iPhone.

When set-up costs are relatively large in relation to total demand, concentration will tend to be similar across markets of different size.[157]

197. Table 4 is a cross-country comparison of market structures across the world. It shows the Herfindahl-Hirschman Index (HHI), the share of the market held by the top two firms, and the number of competitors by country.[158] These data suggest that it is difficult for a national wireless market to sustain more than four competitors, and that in many cases, two or three firms dominate the market. Few markets have more than four nationwide competitors, and even in ones that do, two or three competitors have overwhelming market shares, suggesting that the fourth competitor is marginal. The striking feature of the data in Table 4 is how similar the market structure is across the different markets. The data in Table 4 suggests that the scope for entry is exhausted relatively quickly. Consistent with the large set up costs involved in constructing wireless networks, the number of competitors appears to be limited.

198. The exercise of market power might be suggested if the market structure in Canada was more concentrated than elsewhere, but this is not the case. To the contrary the evidence in Table 4 is not consistent with the exercise of market:

- the HHI in Canada is similar to other countries.
- the two firm concentration ratio in Canada is less than most other countries.

6.2.2 Competitive Significance of Pole Access for Wireless Entrants

199. The key observation is that pole access for wireless attachments at regulated rates will not materially affect, if at all, the competitive significance of wireless entrants. This is true for a number of reasons.

200. First, no wireless service provider in Toronto currently uses THESL's poles in any significant way to provide wireless service. In fact, none of Wind, Public Mobile and

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[157] The definitive framework for analyzing the relationship between technology, market size and equilibrium market structure can be found in Sutton, John, (1991), *Sunk Costs and Market Structure: Price Competition, Advertising and the Evolution of Concentration*, Cambridge, MA: MIT Press.

[158] The HHI is the sum of squared market shares. See Church, Jeffrey and Roger Ware (2000), *Industrial Organization: A Strategic Approach* (McGraw-Hill) at p. 239.

Mobilicity has made any attachments to THESL or THESI poles to date.[159] There is currently only very limited use of streetlighting poles. Public Mobile has claimed that it uses utility poles to provide wide-area coverage in Montreal. Public Mobile also had plans to use 730 DAS nodes to meet the needs of its Toronto area customers for a four-to-five year time period.[160] It originally intended to use THESL poles for 90% of those nodes but claims that it was thwarted by THESL's refusal to accommodate wireless attachments. Indeed, even though Public Mobile has had access to THESL poles at regulated rates for several months, it has not made any applications for wireless attachments to such poles. Despite the alleged lack of pole access in Toronto at the time that it sought to launch its service offerings in Toronto, it deployed a macrocell network and it offers the same services in Toronto as in Montreal at prices that for plans that include data and music appear around $5 per month cheaper.[161] Toronto area customers have about as great a choice of wireless services as anyone in Canada with Bell, Telus, Rogers, Wind, Public Mobile and Mobilicity all deploying facilities in the region. Moreover, since the entrants do not use pole access to mount wireless attachments in Toronto,[162] it is clear that the effect on entrants from any exercise of market power by forbearing from regulating rates to pole access for wireless attachments cannot result in a substantial negative effect.

201. Second, the entrants are not in the data intensive part of the market, and it is primarily to enhance capacity for data purposes that small cells will be deployed. The Canadian entrants have mostly focused on deep discounting and voice, not on deploying the latest networks and smartphones.[163] The entrants are already almost two years behind the incumbent firms in

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[159] THESL Evidence at ¶¶11-12.
[160] See Lemay-Yates Report at pp. 26- 27.
[161] See Table 2.
[162] THESL Evidence at ¶12
[163] See Peter Nowak, "Public Mobile Lowers Price for Launch", http://www.cbc.ca/news/technology/story/2010/05/25/public-mobile-launch-wireless-plans.html,which mentions Public Mobile's launch plans and their focus on voice. The Globe and Mail recently noted that "[A]fter three years, the new entrants have captured less than 6 percent of the market, having spent their early days focused on the low-budget pre-paid customer." Sean Silcoff, Boyd Erman and Rita Trichur "How Ottawa's Plan to Foster Wireless Competition Sank," *Globe and Mail,* May 18th, 2013. The article notes that in 2012, the entrants began to attempt to shift their strategies, but this is against the backdrop of imminent exit or takeover by larger firms. The same article also notes that the entrants were side-stepped by the shift in the nature of the wireless business model that was induced by smartphones, most particularly the iPhone. The CEO of Public Mobile was quoted in the same article as saying that the "talk and text" model that his firm hoped to market was outdated much more quickly than Public Mobile had anticipated. See also the discussion above in Section 6.1.

deploying LTE networks. The recent launch of the latest iPhone model in Canada, accompanied by LTE capability that only Bell, Telus and Rogers have deployed, underscores that the entrants are likely irrelevant to the data-hungry consumers whose usage is likely to strain network capacity. Rogers signed up about as many iPhone customers in one week following the launch of the latest model than Wind Mobile typically signs up in an entire quarter.[164]

202. Third, there are two important aspects of competition in the downstream market that place the entrants at a disadvantage and these disadvantages cannot be redressed by regulated rates for pole access. These are

- Competition is over bundles of services. The incumbents are typically able to offer both triple and quad plays involving not just the provision of wireless service, but also local telephony, broadband, and television.

- Competition in mobile broadband is increasingly between "ecosystems". Wireless service providers compete over not just the characteristics of their wireless network (coverage, capacity, and speed), but also over handsets, applications, and content. Ecosystems are typically sponsored by the handset manufacturer. All Canadian wireless service providers, entrants and incumbents, are relatively small in comparison to international and U.S. giants such as Vodafone, AT&T and Verizon Communications. They are consequently in an unfavourable bargaining position in relation to handset makers such as Apple, which might be able to demand higher shares of revenues and greater up-front subsidies.[165] At best only the larger Canadian

[164] See Jamie Sturgeon, "Super-Smart Phones, Faster Networks Tighten Squeeze on New Wireless Carriers", *Financial Post*, September 26th, 2012.

[165] The iPhone is most often sold as part of a bundle alongside airtime and data. The wireless service providers typically subsidize the up-front price of the handset—thus at $700 handset might be sold for $100 or $200 (or even free), with the subsidy recovered through the pricing of airtime and data services. While no evidence specific to Canada is available, it is well known that Apple is able to demand more favourable conditions from smaller operators such as Sprint than it is able to from operators such as Verizon and AT&T. It appears that Sprint made a purchase commitment of $15.5 billion with Apple to secure the rights to sell the iPhone. Ina Fried, "Sprint's Chief: iPhone Was Worth the Billions", AllThingsSD.Com, August 7th 2012 at http://allthingsd.com/20120807/sprints-chief-iphone-was-worth-the-billions/. Sprint is much larger than any of the Canadian incumbent operators, let alone the Canadian entrants.

incumbents are likely to be able to offer the most desirable handsets and satisfy the needs of the most data-hungry consumers.

203. Fourth, as indicated above Public Mobile and Videotron access to poles in Montreal does not appear to have resulted in better outcomes for wireless consumers in Montreal than in Toronto. This is especially illuminating because Videotron, with pole access in Montreal, has a number of advantages that entrants in Toronto do not have, including the ability to bundle and substantially more spectrum.

204. Especially in the wireless services of primary concern, high speed data transmission based on deployments of LTE technology, whatever policies are adopted with respect to pole access are unlikely to affect the competitive significance of the wireless entrants. Although these entrants acquired a market share of 5% of Ontario subscribers by 2011, even this modest market share probably overstates their competitive significance to consumers who have high levels of data consumption, given their lack of attractive devices and their lack of LTE deployment.

7 Market Power and Regulation of Wireless Attachment Rates

205. Assessing the potential for THESL to exercise market power is not the only consideration that is relevant to evaluating the case for forbearance or continued regulation of its rates for wireless attachments to its poles. A finding that THESL has market power in the provision of pole services to wireless communication providers is only a necessary condition for continued regulation, it is not a sufficient condition. Even if THESL has market power in the relevant market both economic efficiency and distributional concerns also likely justify forbearance of THESL's poles for the purposes of wireless attachments.

206. Some exercise of market power by THESL in the provision of pole access for wireless attachments is likely appropriate on efficiency and distribution grounds.[166] Efficiency considerations mean wireless attachments should contribute to the revenue adequacy of THESL by paying a rate that exceeds the marginal cost of making an attachment. The

[166] In what follows in this section, with its focus on economic efficiency and efficient pricing, market power refers to the ability to profitably raise prices above marginal cost or the perfectly competitive level. See Section 4.1 and footnote 34.

efficient allocation of the burden of ensuring the financial viability of THESL should be spread across all of the services it provides. Moreover, on distributional grounds the OEB might determine that some of the burden of financial viability for THESL should be borne by those making and benefiting from wireless attachments instead of THESL ratepayers.

7.1 Efficient Pricing by a Multiservice Firm

207. Firms often produce more than one product or output. Multi-product firms arise because of indivisible inputs—inputs that provide for a certain level of capacity. Multi-product firms might be seen as arising because firms will produce whatever products they can to maximise capacity utilisation. Notice, however, that there must be indivisibilities in the common input. An indivisibility exists if it is not possible to scale the cost of the input in the same proportion as output is scaled. THESL's pole network and rights of way are examples of inputs that are indivisible below a certain level and which because of a fixed capacity can be used to produce more than one product. For example, parts of THESL's distribution plant are used to provide electricity during different times of the day and to different types of users.

208. Common costs are those costs that are incurred once, but which do not have to be re-incurred to support the production of additional products. Common costs for a firm are defined as the difference between the firm's total costs and the sum of the incremental costs for each of the products that the firm produces. There might also be fixed common costs. Such costs are common costs whose level does not vary with the output of the firm. Much of THESL's general and administrative expenses—its overhead—are likely fixed common costs.

209. A normative natural monopoly industry is one in which costs of production are minimised when output is produced by a single firm rather than by a multiplicity of firms. Fundamentally, natural monopoly is driven by economies of size. If economies of scale and economies of joint production are sufficient it will be cost minimizing to have production by a single supplier.[167] Economies of scale and joint production mean that it is inefficient to duplicate the electric distribution plant of THESL.

[167] See J. Church and R. Ware, (2000), *Industrial Organization: A Strategic Approach,* San Francisco, McGraw-Hill, Chapter 24 for discussion of normative natural monopoly.

210. Economies of scale and joint production typically mean that pricing at marginal cost is not viable. In the simplest case of a single product firm characterized by economies of scale, pricing at marginal cost will result in the firm not recovering its costs (including the opportunity cost of its capital), since economies of scale mean that marginal cost is less than average cost. A similar problem usually arises for multiproduct firms characterized by economies of scale and scope. In such circumstances efficient pricing—in the absence of a subsidy—involves a trade off between revenue adequacy and efficiency.

211. The trade off is illustrated in the case of a single product firm that incurs a fixed cost of production and has a constant variable unit cost of production. If its price is set equal to its variable cost per unit it will not recover its fixed costs. The same revenue inadequacy arises for a multiproduct firm that has two products with constant variable unit cost of production and a common fixed cost.

212. Raising rates above marginal costs reduces demand and services provided to ratepayers, as well as raising the amount they pay for continued service. But at the same time their increased payments provide needed revenue for the firm. The cost in terms of reduced economic activity is reduced to the extent that prices are raised for services where demand by customers is relatively insensitive to price. These will be services where the firm has relatively more market power.

213. Some exercise of market power in pricing pole access for wireless attachments to provide a contribution to THESL's revenue adequacy will be efficient if THESL has market power in pole access. The extent of the mark up—the gap between price and marginal cost— will depend on its market power in providing pole access for wireless attachments. Efficiency considerations mean that the greater THESL's market power in providing pole access for wireless attachments, the greater should be the mark up on pole access for wireless attachments.

214. The benefits and costs of rate regulation depend on the extent to which the OEB can determine the efficient rate. This will involve the direct costs of regulation, but also the costs associated with resource misallocation from not setting the efficient price to pole access for wireless attachments. Because of imprecise information, determining the efficient rate for

wireless attachments is likely to be very difficult: some exercise of market power will be warranted, but not too much. Errors in setting the access price will induce regulatory distortions in economic activity and associated economic costs.

7.2 Costs and Benefits of Regulating Rates of Pole Access for Wireless Attachments

215. The case for forbearance can be summarized as follows (based on the premise that regulation of pole access for wireless attachments is based on controlling THESL's market power):

- THESL is very unlikely to have market power in the provision of pole access for wireless attachments.

- The exercise of any market power by THESL in the provision of pole access for wireless attachments is very unlikely to have any effect on competition in downstream wireless markets and, consequently, is unlikely to have adverse impacts on the welfare of wireless consumers, especially broadband wireless users in Toronto.

- If THESL did have market power then the small negative effects in downstream wireless markets could easily be outweighed by the positive effects of reducing rates for other THESL services as well as the reduction in the costs of regulation. The benefits of reduced rates accrue to THESL's distribution customers.

7.3 Distributional Considerations

216. Finally, it may be appropriate for THESL to exercise market power in the provision of pole access for wireless attachments—if it has any—not because it is efficient, but because of distributional considerations. That is, there might also be distributional considerations that dovetails with the economic efficiency perspective adopted above.

217. Not only might it be economically efficient to place a relatively high share of the burden of financial viability and common cost recovery on the pole access service, but it might be *desirable* from a distributional perspective. For instance, it might be, depending on the weight placed on distributional factors by the OEB, more desirable to have relatively high

mark ups on pole access for wireless service providers instead of loading the burden onto residential electricity rates.

8 Appendix A: Curriculum Vitae of Jeffrey Church

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Citizenship

Canadian

Education and Professional Qualifications

- Ph.D., Economics, University of California, Berkeley 1989, specialization in Industrial Organization and International Trade. Supervisory Committee Richard Gilbert, Michael Katz, and Jeffrey Perloff.
- B.A. First Class Honours (Economics), University of Calgary 1984.
- Qualified as an expert witness before the Competition Tribunal, the National Energy Board, the Alberta Energy Utilities Board, the Canadian Radio-Television and Telecommunications Commission, the Federal Court of Canada, the Federal Court of Australia and Supreme Court of British Columbia.

Positions Held

Academic Appointments

- Professor, Department of Economics, University of Calgary (since July 1, 2001).
- Program Director, Digital Economy Program, School of Public Policy, University of Calgary (from May 1, 2013).

- IAPR Professor, Institute for Advanced Policy Research, University of Calgary, *Coordinator of the Markets, Institutions, and Regulation* Working Group (July 1, 2006 to June 30, 2009).
- Associate Professor, Department of Economics, University of Calgary (1994-2001).
- Assistant Professor, Department of Economics, University of Calgary (1989-1994).

Other Appointments

- Chairperson, Terra Nova Reference Price Committee, Newfoundland (2007 and 2010-).
- Founding Academic Director, Centre for Regulatory Affairs in the Van Horne Institute for International Transportation and Regulatory Affairs, University of Calgary (1998-2001).
- T.D. MacDonald Chair in Industrial Economics, Competition Bureau, Industry Canada, Hull, Quebec (1995-1996).
- President, Church Economic Consultants Ltd. (1992-).
- Director, Berkeley Research Group (2010-2011).
- Member, C.D. Howe Institute Competition Policy Council (2011-).

Academic Awards and Distinctions

Teaching Awards

- Faculty of Social Science Distinguished Teacher Award, University of Calgary 1994 and 2004.
- Superior Teaching Award, Department of Economics, University of Calgary, 1997, 1999, 2000, 2002, 2003, 2004, 2011.
- Students' Union Teaching Excellence Award, University of Calgary 1994-95.

Major Academic Distinctions

- Faculty of Social Sciences Gold Medal, University of Calgary 1984.
- Listed as one of the leading competition economists in the world in the Directory of Competition Economists in *The International Who's Who of Competition Lawyers and Economists*. London: Global Competition Review 1998 onwards.

Research Interests

- Industrial Organization

- Economics of Regulation
- Competition Policy

Publications

Refereed Journal Articles

- "Direct and Indirect Network Effects are Equivalent: A Comment on "Direct and Indirect Network Effects: Are They Equivalent?" (with N. Gandal), *International Journal of Industrial Organization* 30: 708-712, 2012.
- "Indirect Network Effects and Adoption Externalities." (with N. Gandal and D. Krause) *Review of Network Economics* 7: 325-346, 2008.
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- "Integration, Complementary Products and Variety." (with Neil Gandal) *Journal of Economics and Management Strategy* 1, 651-675, 1992.
- "Network Effects, Software Provision and Standardization." (with Neil Gandal) *Journal of Industrial Economics* XL, 85-104, 1992.

Invited Papers

- "Too Many Tweets: Internet Billing Practices in Canada," *Policy Options* May 2011: 54-59.
- "Trade-Dress and Pharmaceuticals in Canada: Efficiency, Competition and Intellectual Property Rights," (with Roger Ware) *Policy Options* 18: 9-12, 1997.

Books and Monographs

- *The Impact of Vertical and Conglomerate Mergers on Competition* Brussels: European Commission, 2004 at http://bookshop.europa.eu/en/the-impact-of-vertical-and-conglomerate-mergers-on-competition-pbKD7105158/. Published as European Commission, 2006, *The Impact of Vertical and Conglomerate Mergers on Competition* Luxembourg: Office for Official Publications of the European Communities.
- *Industrial Organization: A Strategic Approach* (with Roger Ware) San Francisco: IRWIN/McGraw-Hill, 2000. Second edition forthcoming from Cambridge University Press.
- *Traditional and Incentive Regulation: Applications to Natural Gas Pipelines in Canada* (with Robert Mansell) Calgary: Van Horne Institute, 1995.
- *Econometric Models and Economic Forecasts: A Computer Handbook Using MicroTsp* New York: McGraw-Hill, 1990.

Chapters in Books

- "Conglomerate Mergers." in W.D. Collins ed., *Issues in Competition Law and Policy* Volume 2 Chicago: American Bar Association, pp. 1503-1552, 2008.
- "Vertical Mergers." in W.D. Collins ed., *Issues in Competition Law and Policy* Volume 2 Chicago: American Bar Association, pp. 1455-1502, 2008.
- "Platform Competition in Telecommunications." (with N. Gandal) in M. Cave, S. Majumdar, and I. Vogelsang eds., *Handbook of Telecommunications* Vol. 2 Amsterdam: North-Holland, pp. 119-155, 2005.
- "Mergers and Market Power: Estimating the Effect on Market Power of the Proposed Acquisition by The Coca-Cola Company of Cadbury-Schweppes' Carbonated Soft Drinks in Canada." (with A. Abere, O. Capps, Jr. and H.A. Love) in D. Slottje ed., *Economic Issues in Measuring Market Power*, Contributions to Economic Analysis, Vol. 255, Amsterdam: North-Holland, pp. 233-294, 2002.

- "The Economics of Coordinated Effects and Merger Analysis." in D. Houston ed., *CBA Competition Law Conference 2000* Juris Publisher: Yonkers, N.Y., pp. 561-575, 2001.
- "Network Industries, Intellectual Property Rights, and Competition Policy." (with Roger Ware) in N. Gallini and R. Anderson eds., *Competition Policy, Intellectual Property Rights and International Economic Integration* Calgary: University of Calgary Press, pp. 227-285, 1998.

Papers and Proceedings

- "The Interface Between Competition Law and Intellectual Property in Canada: An Uneasy Alliance or Holy War?" on CD-ROM, *2005 Annual Fall Conference on Competition Law*. Ottawa: Canadian Bar Association, 2005.
- "The Economics of Exclusionary Contracts and Abuse of Dominance in Canada." on CD-ROM, *2003 Annual Fall Conference on Competition Law*. Ottawa: Canadian Bar Association, 2003.
- "Competition Policy and the Intercity Passenger Transportation System in Canada." in M. Duncan, ed. *Directions: A New Framework for Transportation* Calgary: Van Horne Institute, pp. 21-25, 1993.
- "Commodity Price Regulation in Canada: A Survey of the Main Issues." (with Robert Mansell) *Papers and Proceedings of the Fifth Annual Regulatory Educational Conference,* Canadian Association of Members of Public Utility Tribunals, 1991.

Public Reports

- *Transmission Policy in Alberta and Bill 50* (with William Rosehart and John MacCormack). School of Public Policy, University of Calgary Research Paper, 2009.
- *Buyer Power: Background Note*. Competition Committee, Directorate for Financial and Enterprise Affairs, OECD, Paris, 2009, Available at http://www.oecd.org/dataoecd/38/63/44445750.pdf.
- *Vertical Mergers: Background Note*. Competition Committee, Directorate for Financial and Enterprise Affairs, OECD, Paris, 2007. Available at http://www.oecd.org/dataoecd/25/49/39891031.pdf.
- *An Evaluation of Traditional and Incentive Regulation for Canadian Natural Gas Pipelines*. (with Robert Mansell) Study submitted to, and available from, the National Energy Board of Canada, 1992.

- *Methodology for Evaluating Natural Gas Transmission System Reliability Levels and Alternatives*. (with Robert Mansell) Study prepared for, and available from, the Canadian Petroleum Association, 1991.

Public Regulatory Interventions

- Submission of The Director of Investigation and Research to Industry Canada re: Canada Gazette Notice No. DGTP-008-95 Review of Canadian Overseas Telecommunications and Specifically Teleglobe Canada's Role October 27, 1995 (with David Smith).
- Reply Comments of The Director of Investigation and Research to Industry Canada re: Canada Gazette Notice No. DGTP-008-95 Review of Canadian Overseas Telecommunications and Specifically Teleglobe Canada's Role December 11, 1995 (with David Smith).
- Submission of The Director of Investigation and Research to The Canadian Radio-Television and Telecommunications Commissions re: Telecom Notice CRTC 95-36 Implementation of Regulatory Framework, Local Interconnection and Network Component Unbundling January 26, 1996 (with Cal Gundy and Patrick Hughes).
- Final Argument of The Director of Investigation and Research to The Canadian Radio-Television and Telecommunications Commissions re: Telecom Notice CRTC 95-36 Implementation of Regulatory Framework, Local Interconnection and Network Component Unbundling October, 1996 (with Cal Gundy and Patrick Hughes).
- Final Oral Argument of The Director of Investigation and Research to The National Energy Board in PanCanadian Petroleum Limited application dated 26 July 1996 for an order requiring Interprovincial Pipe Line Inc. to transport natural gas liquids for PanCanadian Petroleum Limited from Kerrobert, Saskatchewan (MH-4-96) November 1996 (co-author).
- Opening Statement to the Alberta Utilities and Energy Board in Federated Pipe Lines Ltd. Application to Construct and Operate a Crude Oil Pipeline from Valhalla to Doe Creek, Alberta Energy and Utilities Board March (Decision 98-12) March 1998.
- Final Argument of The Director of Investigation and Research to The Canadian Radio-Television and Telecommunications Commissions re: Telecom Notice CRTC 98-10 Local Competition Start-Up Proceeding November, 1998 (with Cal Gundy).
- *Commissioner of Competition Intellectual Property Enforcement Guidelines,* Hull, Quebec: Competition Bureau. External member Commissioner of Competition's

Drafting Team, first draft released in June 1999, second draft released April 2000, final version released September 2000.

- Final Argument of The Commissioner of Competition to The Canadian Radio-Television and Telecommunications Commissions re: Telecom Notice Public Notice 2001-37 - Price Cap Review and Related Issues October 2001 (with Cal Gundy).
- Comments of The Commissioner of Competition to The Canadian Radio-Television and Telecommunications Commissions re: Telecom Notice Public Notice 2001-47 Framework for the expansion of local calling areas and related issues November 2001 (with Cal Gundy and Masood Qureshi).
- Written Comments of the Competition Bureau to the Alberta Electricity Industry Structure Review February 2002 (with David Krause and Mark Ronayne).
- Final Submission of the Commissioner of Competition to the Ontario Energy Board's Natural Gas Forum Consultation on the Ontario Natural Gas Market November 2004 (with Mark Ronayne).
- The Commissioner of Competition Evidence, Final, and Reply Argument, The Canadian Radio-Television and Telecommunications Commissions re: Telecom Notice Public Notice 2005-2, Forbearance from Regulation of Local Exchange Services June, September, and October 2005 (part of the Competition Bureau's drafting team).
- *Market Power and the Mackenzie Gas Project,* Evidence filed before the National Energy Board, Mackenzie Gas Project, GH-1-2004, June 2005.
- The Commissioner of Competition Evidence, Supplementary Material, Final Argument, and Reply Argument, The Canadian Radio-Television and Telecommunications Commissions re: Telecom Notice Public Notice 2006-14, Review of Regulatory Framework for Wholesale Services and Definition of Essential Service 2007 (part of the Competition Bureau's drafting team).
- Commissioner of Competition, *Abuse of Dominance Provisions as applied to the Telecommunications Industry,* Hull, Quebec: Competition Bureau. External member Commissioner of Competition's Drafting Team, first draft released September 2006, final version released June 2008.
- *Foreign Ownership Restrictions of Canadian Telecoms: An Analysis of Industry Canada's Proposals* (with assistance of BRG), re Industry Canada Consultation on Opening Canada's Doors to Foreign Investment in Telecommunications: Options for Reform, July 2010. Available online at http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/Rogers.pdf/$file/Rogers.pdf.
- Spectrum Policy as Competition Policy: A Good Choice for Canada? (with

assistance of BRG) re Industry Canada Consultation on a Policy and Technical Framework for the 700 MHz Band and Aspects Related to Commercial Mobile Spectrum Gazette Notice SMSE-018-10, February 2011. Available online at http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/smse-018-10-jeffreychurch-rogers.pdf/$FILE/smse-018-10-jeffreychurch-rogers.pdf.

- *Economic Principles and Usage Based Billing,* The Canadian Radio-Television and Telecommunications Commissions re: Telecom Notice of Consultation CRTC 2011-77 Review of billing practices for wholesale residential high-speed access services March 2011. Available online at https://services.crtc.gc.ca/pub/ListeInterventionList/Documents.aspx?ID=156065&Lang=e.
- *The Competitive Effects of Vertical Integration: Content and New Distribution Platforms in Canada* (with assistance of BRG), The Canadian Radio-Television and Telecommunications Commissions re: Broadcasting Notice of Consultation CRTC 2010-783 Review of the regulatory framework relating to vertical integration, April 2011. Available online at https://services.crtc.gc.ca/pub/ListeInterventionList/Documents.aspx?ID=156953&Lang=eDocuments.aspx?ID=156065&Lang=e.
- *In the Matter of a Complaint by Imperial Oil with Respect to Enbridge Southern Lights GP (ESL) Tariffs No. 1 and 2 Expert Evidence* (with assistance of BRG), The National Energy Board, Hearing Order RH-1-2011, July 2011 and *Reply Evidence* September 2011. Available online at https://www.neb-one.gc.ca/ll-eng/livelink.exe?func=ll&objId=704264&objAction=browse and https://www.neb-one.gc.ca/ll-eng/livelink.exe?func=ll&objId=718914&objAction=browse.
- *Western Alberta Transmission Line Application Evidence of Dr. Jeffrey Church and Mr. John MacCormack,* Application No. 1607067, Proceeding ID 1045, Alberta Utilities Commission, September 2011.
- *Critical Transmission Review Committee Request for Information*, Submission of Dr. Jeffrey Church and Mr. John MacCormack, January 2012.

Public Expert Competition Filings

- *Expert Report of Jeffrey Church* in *The Commissioner of Competition v. Visa Canada Corporation and MasterCard International Incorporated*, The Competition Tribunal CT-2010-010, April 2012. Available online at http://www.ct-tc.gc.ca/CMFiles/CT-2010-010_Expert%20Report%20of%20Jeffrey%20Church_239_45_4-10-

2012_4211.pdf

- *Expert Report of Jeffrey Church* in *The Commissioner of Competition v. The Toronto Real Estate Board,* The Competition Tribunal CT-2011-003, July 2012. Available online at http://www.ct-tc.gc.ca/CMFiles/CT-2011-003_Expert%20Report%20of%20Jeffrey%20Church_202_53_7-27-2012_7764.pdf

Book Reviews

- *Competition Policy: A Game -Theoretic Perspective* (by Louis Phlips) for *The Economic Journal,* 107, 1590-1592, 1997.

Websites

- *Industrial Organization: A Strategic Approach*. URL: http://www.econ.ucalgary.ca/iosa/
- *Industrial Organization: A Strategic Approach Instructor's Manual*. URL: http://www.econ.ucalgary.ca/iosa/IM/

Research In Progress

- "Network Externalities, Technological Progress, and Competitive Upgrades." (with Michael Turner) Mimeo, Department of Economics, University of Calgary 2002.
- "Direct and Indirect Strategic Effects: A Taxonomy of Investment Strategies." (with L. Moldovan) Mimeo, Department of Economics, University of Calgary 2006.
- "Market Power in the Alberta Red Meat Packing Industry." (with D. Gordon) IAPR Technical Paper 07-004, Institute for Advanced Policy Studies, University of Calgary 2007.
- "Exclusive Provision and Standardization in a Two-Sided Market." (with J. Mathewson) Mimeo, Department of Economics, University of Calgary 2009.
- "Asymmetries, Simulation and the Assessment of Input Foreclosure in Vertical Mergers." (with A. Majumdar and M. Baldauf) Mimeo, Department of Economics, University of Calgary 2010.
- "Capacity Constraints in Durable Goods Monopoly: Coase and Hotelling." (with John Boyce and Lucia Vojtassak) Working Paper 2012-07, Department of Economics, University of Calgary 2012.

Presentations

- "Spectrum Policy as Competition Policy." Workshop on Auction Design and Competition in Canadian Wireless Markets, Centre for Digital Economy, University of Calgary, Ottawa, September 2011.
- "Issues in the Economic Regulation of Pipelines in Canada." Canada's Pipeline and Energy Transportation Infrastructure, C.D. Howe Institute, Banff, June 2011.
- "Competition Issues in Network Industries." CBA Competition Law Spring Forum 2011: Focus on Civil, Toronto, May 2011.
- "Regulatory Governance and the Alberta Integrated Electric System." 11th Annual Alberta Power Summit, Calgary, November 2010.
- "Asymmetries, Simulation and the Assessment of Input Foreclosure in Vertical Mergers." Bates White Seventh Annual Antitrust Conference, Washington, D.C., June 2010 and Annual Meeting of the Canadian Economics Association, Ottawa, June 2011.
- "The Competition Act and the Fair Efficient and Open Competition Regulation." Workshop for the Alberta Utilities Commission, Calgary, April 2010 (with Barry Zalmanowitz).
- "Transmission Policy in Alberta and Bill 50." School of Public Policy Workshop, Electricity Transmission Policies: Issues and Alternatives, Calgary, October 2009 and the National Energy Board, Calgary, February 2010.
- "Economics of Vertical Mergers." British Institute for International and Comparative Law, 7th Annual Merger Conference, London, November 2008.
- "Telecommunications in Canada: Market Structure and the State of the Industry." 2008 Telecommunications Invitational Forum, Landgon Hall, Ontario, April 2008.
- "Cartel Cases Under Section 45: Is Proof of Market Definition the Achilles Heel?" Panelist, Competition, Crime and Punishment, Canadian Bar Association National Competition Law Section Spring Conference, Toronto, April 2008.
- "Forbearance of Local Telecommunications in Canada: One Back, Two Forward?" Telecommunications and Broadcasting Current Regulatory Issues and Policy Insight Communications Conference, Ottawa, April 2007.
- "The Economics of Non-Horizontal Merger Guidelines." ENCORE Workshop on the Assessment of Non-Horizontal Mergers, The Hague, April 2007.
- "Stumbling Around in No Man's Land is Dangerous: Competition Policy, the CRTC, and Deregulation of Local Telecom in Canada." Competition Policy in

Regulated Industries: Principles and Exceptions, C.D. Howe Institute Policy Conference, Toronto, November 2006.

- " Competition in Local Telecommunications in Canada: Grading the CRTC." Delta Marsh Annual Conference, Department of Economics, University of Manitoba, Winnipeg, October 2006.
- "Grading the CRTC: Forbearance from the Regulation of Retail Local Exchange Services Telecom Decision 2006-15." part of the Panel on Local Competition at the Annual Meetings of the Canadian Economics Association, Montreal, May 2006.
- "The Interface Between Competition Law and Intellectual Property in Canada: An Uneasy Alliance or Holy War?" Presented at the Canadian Bar Association Annual Fall Conference on Competition Law, Gatineau, November 2005.
- "Game Theory and Industrial Organization: An Introduction." Competition Tribunal, Knowlton, Quebec, October 2005.
- "The Impact of Vertical and Conglomerate Mergers on Competition: An Overview of the Survey And Implications for Competition Policy." DG IV European Commission, Brussels, July 2004, UK Competition Commission, London, September 2005, British Institute of International and Comparative Law/Competition Law Forum, Brussels, September 2005 and Conference on Economics in Competition Policy, Ottawa, April 2006.
- "The Economics and Competition Policy of Exclusionary Agreements." Competition Bureau, Gatineau, April 24-25, 2005.
- "Intellectual Property Issues and Abuse: The IP/Competition Policy Interface in Canada." 2004 Competition Law and Policy Forum, Langdon Hall, Cambridge, Ontario, April 2004.
- "Efficiencies Gained and Paradise Lost? Or the Inverse? Comments on the Propane Case." Economics Society of Calgary Seminar Regulation vs. Competition: Different Shades of Grey, Calgary, October 2003.
- "The Economics of Exclusionary Contracts and Abuse of Dominance in Canada" Presented at the Canadian Bar Association Annual Fall Conference on Competition Law, Hull, October 2003.
- "Network Externalities, Technological Progress, and Competitive Upgrades" Presented at PIMS-ASRA Alberta Industrial Organization Conference, Calgary, November 2002.
- Panelist, The Changing Competition Law Landscape, Osler, Hoskin & Harcourt, Calgary, June 2002.

- Panelist, Efficiencies in Mergers Under the Competition Act, Annual Meeting of the Canadian Economics Association, Calgary, June 2002.
- "Specification Issues and Confidence Intervals in Unilateral Price Effects Analysis" Presented at the Annual Meeting of the Canadian Economics Association, Calgary, June 2002.
- “The Economics and Econometrics of Unilateral Effects Analysis.” Competition Bureau, Gatineau, January 7th and 8th, 2002 (with Oral Capps, Jr. and H. Alan Love).
- “Economics and Antitrust of Network Industries.” Competition Bureau, Gatineau, January 2001.
- "The Economics of Coordinated Effects and Merger Analysis." Presented at the Canadian Bar Association Annual Fall Conference on Competition Law, Ottawa, September 2000.
- "Network Externalities, Technological Progress, and Competitive Upgrades." Presented at the Annual Meeting of the Canadian Economics Association, Vancouver, June 2000.
- "Competition Policy for Network Industries." Presented at Centre for the Study of Government and Business New Challenges for Competition Policy Panel, Annual Meeting of the Canadian Economics Association, Vancouver, June 2000.
- "Applying Antitrust Concepts in IT Industries." Presented at Roundtable on Reassessing the Role of Antitrust in Mega-Mergers and IT Industries Faculty of Law, University of Toronto, June 2000.
- "The Economics of Electricity Restructuring: The Case of Alberta." Canadian Law and Economics Conference, Toronto, September 1999.
- "Refusals to License and the IP Guidelines: Abuse of Dominance and Section 32." McMillan Binch Symposium on Intellectual Property Rights and Competition Policy, Toronto, June 1999.
- "The Economics of Electricity Restructuring: The Alberta Case." presented at Economic Society of Calgary conference Alberta's Electricity Market—Moving Towards Deregulation, Calgary, May 1999.
- "Competition in Natural Gas Transmission: Implications for Capacity and Entry." presented at Van Horne Institute conference The New World in Gas Transmission: Regulatory Reform and Excess Capacity, Calgary, April 1999.

- "Bill 27: The Regulatory Framework." presented at Canadian Institute of Resources Law conference on Restructuring Alberta's Electricity System: How will It Work?, Calgary, June 1998.
- Panelist, Antitrust and Telecommunications, Global Networking '97 Conference, Calgary, June 1997.
- "Network Industries, Intellectual Property Rights, and Competition Policy." presented at Author's Symposium on Competition Policy, Intellectual Property Rights and International Economic Integration, Ottawa, May 1996.
- Panelist, Symposium on Barriers to Entry, Bureau of Competition Policy, Ottawa, March 1995.
- "Branded Ingredient Strategies," presented at the Summer Conference on Industrial Organization, University of British Columbia, Vancouver, August 1994.
- "Equilibrium Foreclosure and Complementary Products," the Annual Meetings of the European Association for Research in Industrial Economics, Tel-Aviv, September 1993, the Annual Meeting of the Canadian Economics Association, Ottawa, June 1993 and the Mini-Conference on Network Economics at Tel Aviv University, July 1992.
- "Competition Policy and the Intercity Passenger Transportation System in Canada," presented at the Van Horne Institute for International Transportation and Regulatory Affairs symposium on *The Final Report of the Royal Commission on National Passenger Transportation,* The University of Calgary, February 1993.
- "Integration, Complementary Products and Variety," presented at the Annual Meeting of the Canadian Economics Association, Prince Edward Island, June 1992 and Telecommunications Research Policy Conference, Solomons Island, MA, September 1991.
- "The Role of Limit Pricing in Sequential Entry Models," presented at the Twenty-Fifth Annual Meeting of the Canadian Economics Association, Kingston, June 1991.
- "Commodity Price Regulation in Canada: A Survey of the Main Issues," presented at the Fifth Annual Regulatory Educational Conference, Canadian Association of Members of Public Utility Tribunals, May 1991.
- "Complementary Network Externalities and Technological Adoption," at the Twenty-Fourth Annual Meeting of the Canadian Economics Association, Victoria, June 1990 and at the Fifteenth Canadian Economic Theory Conference, Vancouver, June 1990.

Invited Seminars

- Department of Economics, University of Montreal, June 2011.
- Faculty of Commerce and Business Administration, University of British Columbia, April 2002
- Department of Economics, University of Toronto, March 2002
- School of Business & Economics, Wilfred Laurier University March 2002
- Competition Bureau, January 2002
- Department of Economics, University of Laval, April 1996
- Department of Economics, Carleton University, Ottawa, January 1996
- Stern School of Business, New York University, December 1995
- Bureau of Competition Policy, Industry Canada, Ottawa, March 1994
- Department of Economics, Simon Fraser University, November 1992
- Department of Economics, University of Victoria, November 1992
- Department of Economics, University of Toronto, October 1991
- Department of Economics, Queen's University, Kingston, October 1991
- Department of Economics, University of Alberta, February 1990

Refereeing

American Economic Review, Canadian Journal of Agricultural Economics, Canadian Journal of Economics, Canadian Journal of Political Science, Canadian Public Policy, C.D. Howe Institute, Energy Journal, European Economic Review, FCAR, Information Economics and Policy, International Economics and Economic Policy, International Economic Review, International Journal of the Economics of Business, International Journal of Industrial Organization, Israel Science Foundation, Journal of Econometrics, Journal of Economic Behavior and Organization, Journal of Economic Education, Journal of Economic Psychology, Journal of Economics, Journal of Economics and Business, Journal of Economics and Management Strategy, Journal of Industrial Economics, Journal of International Economics, Journal of Law, Economics, & Organization, Management Science, Marketing Science, National Science Foundation, RAND Journal of Economics, Journal of Economic Surveys, Review of Industrial Organization, Review of Network Economics, Routledge , SSHRC, University of Cambridge Press.

Professional Service

- Chair, Canadian Bar Association National Competition Law Section Economics and Law Committee, 2005-2007.
- Vice-Chair Canadian Bar Association National Competition Law Section Economics and Law Committee, 2004-2005.
- Juror, James M. Bocking Memorial Award, Canadian Bar Association National Competition Law Section, 2006, 2007, 2008, 2009, 2010, 2011, and 2012.
- Co-Editor, *Journal of Economics & Management Strategy,* 2001-2007.
- Editorial Board, *Canadian Journal of Economics*, 1993-1996.
- Theme Head Economics Sessions and Programme Committee, International Telecommunications Society and the International Council for Computer Education Global Networking '97 Conference, Calgary, June 1997.
- Organizer, Roundtable on Vertical Mergers, Competition Committee, Directorate for Financial and Enterprise Affairs, OECD, Paris, 2007. See http://www.oecd.org/dataoecd/25/49/39891031.pdf
- Organizer, Roundtable on Buyer Power, Competition Committee, Directorate for Financial and Enterprise Affairs, OECD, Paris, 2008. See http://www.oecd.org/dataoecd/38/63/44445750.pdf
- External Examiner for E. Croft Ph.D., Policy Programme, Faculty of Commerce and Business Administration, University of British Columbia, April 1999, B. Isaacs Ph.D., Department of Economics, Simon Fraser University, May 2000, J. Landa Ph.D., Department of Economics Carleton University, May 2001, J. Latulippe Ph.D, Department of Economics, University of Montreal, June 2011.
- House of Commons Standing Committee on Industry, Science and Technology Roundtable Participant on Competition Policy, December 2001.
- House of Commons Standing Committee on Industry, Science and Technology, Deregulation of Telecommunications, February 2007.

Teaching Experience

Graduate

- Ph.D. Micro Theory
- Industrial Organization
- Regulatory Economics
- Markets and Public Policy (School of Public Policy)

Undergraduate

- Regulatory Economics
- Competition Policy
- Honours Micro Theory
- Industrial Organization
- Intermediate Microeconomics

Professional

- Regulatory economics through the Centre for Regulatory Affairs.
- Principles of Microeconomics, Industrial Organization and Competition Policy for the Competition Bureau.

Graduate Student Supervision/Examination

Completed

- Supervisor, M. Ec. Programme, Mark Larsen, "Calgary Crossfield Sour Gas: A Case Study in the Costs of Regulation," Department of Economics, University of Calgary, 1993.
- Supervisor, M. A. Programme, George Given, "The Dynamics of Industries Characterized by Complementary Network Externalities," Department of Economics, University of Calgary, 1994.
- Supervisor, M. Ec. Programme, R. Allan Wood, "Subsidies to Municipal Golfers in Calgary, AB. ," Department of Economics, University of Calgary, 1995.
- Supervisor, M. A. Programme, Marcy Cochlan, "Branded Ingredient Strategies," Department of Economics, University of Calgary, 1995.
- Supervisor, M. Ec. Programme, Shaun Hatch, "Optimal Pricing and the Allocation of Water Under Uncertainty: A Stochastic Nonlinear Programming Approach," Department of Economics, University of Calgary, 1995.
- Supervisor, M. A. Programme, Denelle Peacey, "Priority Pricing," Department of Economics, University of Calgary, 1995.
- Supervisor, M.A. Programme, Michael Turner, "Analysis of Product Upgrades in Computer Software," Department of Economics, University of Calgary, 1999.
- Supervisor, M.A. Programme, Kurtis Hildebrandt, "Market Dominance and Innovation in Computer Software Markets," Department of Economics, University of Calgary, 1999.

- Supervisor, M.A. Programme, Alex Harris, "Optimal Multiproduct Tolling on an Oil Pipeline," Department of Economics, University of Calgary, 2000.
- Supervisor, M.A. Programme, Noelle Bacalso, "Conceptual Hazards Associated with Power Purchase Arrangements," Department of Economics, University of Calgary, 2000.
- Supervisor, M.A. Programme, Laura Jolles, "Antitrust Logit Model," Department of Economics, University of Calgary, 2005.
- Supervisor, M.A. Programme, Mohamed Amery, "The Procurement of Ancillary Services in Alberta," Department of Economics, University of Calgary, 2007.
- Supervisor, M.A. Programme, Graham Thomson, "Optimal Price Cap Regulation," Department of Economics, University of Calgary, 2008
- Supervisor, M. A. Programme, Kevin Wipond, " Market Power in the Alberta Electrical Industry," Department of Economics, University of Calgary, 2008.
- Supervisor, M.A. Programme, Nicholas Janota, "Introducing Competition into Regulated Network Industries: From Hierarchies to Markets in Canada's Railroad Industry," Department of Economics, University of Calgary, 2009.
- Supervisor, M.A. Programme, Cory Temple, "A Beggars' Banquet? Copyright, Compensation Alternatives, and Music in the Digital Economy," Department of Economics, University of Calgary, 2010.
- Supervisor, M.A. Programme, Susan Baker, "Loyalty Programs: A Review of the Competition Commissioner versus Canada Pipe Case," Department of Economics, University of Calgary, 2011.
- Supervisor, M.A. Programme, Michael Ata, "A Bayesian Approach to Antitrust Liability: Exclusive Dealing and Predation," Department of Economics, University of Calgary, 2011.
- Supervisor, Master of Public Policy Programme, Jennifer Rumas, "Economic Evaluation of Wind Power in Alberta," School of Public Policy, University of Calgary, 2012.
- Supervisor, Ph.D. Programme, David Krause, "Internalizing Network Externalities," Department of Economics, University of Calgary, 2002.
- Supervisory Committee, Ph.D. Programme, Lucia Vojtassak, "Equilibrium Concepts in Exhaustible Resource Economics." Department of Economics, University of Calgary, 2006.
- Examination Committee Member, M. Ec. Programme, Murray Sondergard, "An Examination of the Efficient Markets Hypothesis for the Toronto Stock Exchange," Department of Economics, University of Calgary, 1992.

- Examination Committee Member, M.A. Programme, Denise Froese, "Auctioning Private Use of Public Land," Department of Economics, University of Calgary, 1993.
- Examination Committee Member, M.Ec. Programme, Merrill Whitney, " Economic Espionage as a Form of Strategic Trade Policy" Department of Economics, University of Calgary, 1994.
- Examination Committee Member, M.Ec. Programme, Robert Richardson, "North-South Disputes Over IPRs" Department of Economics, University of Calgary, 1994.
- Examination Committee Member, M. Ec. Programme, Eva Cudmore, "The Viability of New Entry into the Alberta Electrical Generation Industry," Department of Economics, University of Calgary, 1997.
- Examination Committee Member, M. A.. Programme, Geok (Suzy) Tan, Course Based M.A, Department of Economics, University of Calgary, 1997.
- Examination Committee Member, M.A. Programme, Kris Aksomitis, "Strategic Behaviour in the Alberta Electricity Market," Department of Economics, University of Calgary, 2002.

Current

- Supervisor, M.A. Programme, Greg Belyea and Richard Kendall-Smith, Department of Economics, University of Calgary.
- Supervisor, Ph.D. Programme, Hongru Tan, Department of Economics, University of Calgary.

University Service

- University Research Grants Committee 1994/95
- Dean's Academic Appointment Committee, Department of Mathematics and Statistics 2001
- ISEEE Tier II Chair in Energy and Climate Change Search Committee 2005/06
- Faculty of Social Sciences Academic Program Review Committee 2000/01
- Faculty of Social Sciences Executive Council 2002/03
- Department of Economics, Ad Hoc Outreach Committee 2001/02
- Curriculum Fellow, Department of Economics, 2001
- Department of Economics Representative on Van Horne Institute Sub-Committee on Centre for Regulatory Affairs 1997/98

- Department of Economics Advisory Committee 1997/98
- Department of Economics Undergraduate Curriculum Committee 1993/94, 1994/95, 1996/97, 1997/98, 1999/00, 2000/01, 2001/02, 2010/11
- Department of Economics Honours Advisor 1992/93, 1993/94, 1994/95, 2006/07
- Department of Economics Hiring Committee 1990/91, 1991/92, 1994/95, 1998/99, 1999/00, 2002/03, 2003/04, 2004/05, and 2005/06
- Department of Economics Computer Committee 1992/93, 1993/94, 1996/97, and 1997/98
- Department of Economics Ph.D. Ad Hoc Committee 1990/91 and 1992/93
- Department of Economics Ad Hoc Committee on the Status of Women 1991/92
- Department of Economics Striking Committee 1991/92
- Department of Economics Guest Lecturers Committee 1990/91 and 1991/92
- Department of Economics Graduate Curriculum Committee 1989/90
- Department of Economics Library Coordinator 2006/07
- Department of Economics Graduate Studies Committee 2007/08 and 2008/09
- Department of Economics Fund Raising Coordinator 2006/07, 2007/08, and 2008/09
- University of Calgary Appointment Appeals Committees 2008
- Haskayne School of Business, Academic Appointment Review Committee 2007/08, 2008/09
- Haskayne School of Business, Advisory Decanal Selection Committee for the Dean, 2011/2012
- General Promotions Committee, University of Calgary 2008/2009, 2010/2011

Consulting Experience

President of Church Economic Consultants Ltd., for whom I have written consulting reports and provided advice on issues in regulatory and antitrust economics for Alberta Beef Producers, Apotex, Australian Competition and Consumer Commission, Bell Canada Enterprises, Bayer CropScience, BC Ferries, BP Canada Energy Company, the Canadian Association of Petroleum Producers, the Canadian Cattlemen's Association, the Canadian Competition Bureau, The Coca-Cola Company, The Conference Board of Canada, Enbridge Pipelines, ENMAX, EPCOR, European Commission, Foothills Pipelines, Google Inc., James Richardson International Limited, Mackenzie Explorers Group, Maple Leaf Foods, MasterCard, Microcell, Nokia, Nova Gas Transmission, OECD Competition Division, Pacific Gas & Electric, Pan Alberta Gas, PanCanadian Petroleum, Peace

Pipe Line, Perimeter Transportation, Rogers Communications, Superior Propane, Toronto Real Estate Board, TransAlta, TransCanada Pipelines, Williams Energy, Visa, and eight major motion picture film studios.

Other

- 3M National Coaching Certification Program Level 1 Softball January 2002
- 3M National Coaching Certification Program Coach Level Hockey November 2002
- 3M National Coaching Certification Program Level 1 Baseball September 2003

9 Appendix B: Sources and Documents Relied Upon in the Report

Regulatory Orders , Decisions, Acts and Guidelines

1. Ontario Energy Board*: In the Matter of an application by Canadian Distributed Antenna Systems Coalition for certain orders under the Ontario Energy Board Act, 1998,* Preliminary Decision and Order, EB-2011-0120, 13 September 2012, p. 6. ("CANDAS Decision").
2. Ontario Energy Board*: In the Matter of the an Application pursuant to section 74 of the Ontario Energy Board Act, 1998 by the Canadian Cable Television Association for an Order or Orders to amend the licenses of electricity distributors*, RP-2003-0249 7 March 2005 ("CCTA Decision").
3. Ontario Energy Board: *Ontario Energy Board Act*, 1998.
4. Canadian Radio-Telecommunications Commission (CRTC): *Revised regulatory framework for wholesale services and definition of essential service,* Telecom Decision 2008-17, March 3, 2008.
5. CRTC: Telecom Decision 2006-15, *Forbearance from the regulation of retail local exchange services*
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10 Appendix C: Tables and Figures

Table 1: Techniques to Improve Capacity and Coverage in Advanced Wireless Data Networks

	Technique	Relation to Pole Access
1	Expand number of cell sites	Cell splitting of macro-cells, does not use poles
2	More Spectrum, Spectrum Sharing, Spectrum Re-farming	None
3	Indoor Small Cells and DAS	None, as indoor siting is more effective
4	Outdoor Small Cells and DAS	Poles are a potential siting resource especially for DAS
5	Deploy Advanced LTE Technology	None
7	Compression, Caching, Traffic Shaping	None
8	Pricing and Data Caps	None
9	Wi-Fi Offload	None for Indoor Wi-Fi, some for Outdoor Wi-Fi
10	Femtocell offload	None, as technology is used indoors

Sources: Jackson Report (Table 1); Stephen Lawson, "11 Ways Around Using More Spectrum For Mobile Data", *Computer World*, August 16th, 2012; and Amdocs, "10 Ways to Deal with Mobile Data Capacity Crunch", http://www.amdocs.com/Whitepapers/OSS/WhitePaper-MobileDataCapacityCrunch.pdf.

Table 2: Comparison of Ontario/Toronto with Quebec/Montreal

	Ontario/Toronto	**Montreal/Quebec**
Market share of entrant service providers[168]	5%	7%
Smartphone penetration (2011)[169]	38%	27%
Total cellular phone penetration (2011)[170]	81%	65%
LTE coverage[171] (% of population)	61%	48%
Public Mobile "Talk + Text" plan[172]	Unlimited provincial calls, unlimited texts for $25 pm, unlimited long distance.	Unlimited provincial calls, unlimited texts for $25 pm, unlimited long distance.
Public Mobile "Talk, Text + Data" plan[173]	Unlimited provincial calling and text, 3G data for $30 p.m. Current offer for free Canadian long-distance.	Unlimited provincial calling and text, 3G data for $35 p.m. Current offer for free Canadian long-distance.

[168] CTRC, *Communications Monitoring Report 2012*, Table 5.5.5.
[169] CTRC, *Communications Monitoring Report 2012*, Figure 4.5.22. (Data pertain to 18+ age group).
[170] CTRC, *Communications Monitoring Report 2012*, Table 5.5.11.
[171] CTRC, *Communications Monitoring Report 2012*, Table 5.5.11.
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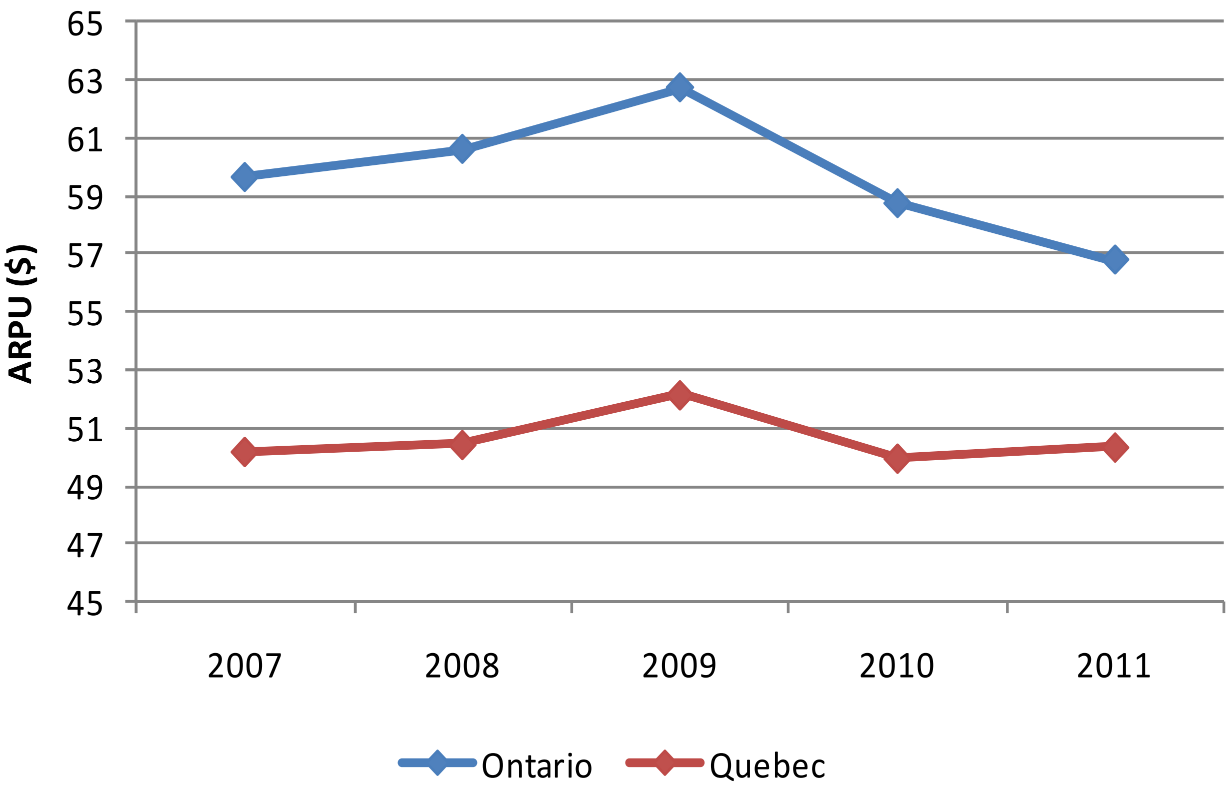
Figure 1: Trend in Wireless ARPU



Source: CTRC, *Communications Monitoring Report 2012*, Table 5.5.6.

Table 3: Roger Wireless Internal Rate of Return

Year	EBITDA	Capex	Other cash investments	Free cash flow	Deflator (Jan 1986 = 100)	Real cash flow (1986 $)	Cumulative cash flow (1986 $)
1986	-$12,804	$60,000		-$72,804	1.025	-$71,039	-$71,039
1987	-$1,771	$52,651		-$54,422	1.071	-$50,794	-$121,833
1988	$17,797	$91,646		-$73,849	1.113	-$66,330	-$188,163
1989	$30,026	$261,328		-$231,302	1.172	-$197,296	-$385,459
1990	$76,156	$456,847		-$380,691	1.241	-$306,840	-$692,299
1991	$99,605	$152,632		-$53,027	1.287	-$41,193	-$733,492
1992	$129,452	$237,613		-$108,161	1.315	-$82,238	-$815,731
1993	$198,600	$181,400		$17,200	1.337	$12,865	-$802,865
1994	$289,900	$149,100		$140,800	1.340	$105,070	-$697,796
1995	$315,600	$185,600		$130,000	1.363	$95,353	-$602,443
1996	$351,100	$553,800		-$202,700	1.393	-$145,528	-$747,971
1997	$395,700	$604,700		-$209,000	1.404	-$148,889	-$896,860
1998	$395,100	$301,300		$93,800	1.418	$66,163	-$830,697
1999	$422,300	$401,000		$21,300	1.455	$14,639	-$816,057
2000	$410,900	$526,000		-$115,100	1.502	-$76,654	-$892,711
2001	$411,900	$654,500	$396,800	-$639,400	1.512	-$422,766	-$1,315,477
2002	$527,700	$564,600		-$36,900	1.570	-$23,505	-$1,338,982
2003	$727,600	$411,900		$315,700	1.602	$197,007	-$1,141,975
2004	$950,400	$439,200	$1,501,800	-$990,600	1.637	-$605,262	-$1,747,238
2005	$1,337,000	$585,000		$752,000	1.671	$450,082	-$1,297,156
2006	$1,987,000	$684,000		$1,303,000	1.699	$767,031	-$530,125
2007	$2,589,000	$822,000		$1,767,000	1.739	$1,016,025	$485,900
2008	$2,806,000	$929,000	$1,008,000	$869,000	1.759	$493,942	$979,842
2009	$3,042,000	$865,000		$2,177,000	1.783	$1,221,244	$2,201,086
2010	$3,173,000	$937,000		$2,236,000	1.825	$1,225,518	$3,426,604
2011	$3,036,000	$1,192,000		$1,844,000	1.866	$987,967	$4,414,571
2012	$3,063,000	$1,123,000		$1,940,000	1.882	$1,030,825	$5,445,396
Real IRR				1986 - 2008			4.14%
				1986 - 2012			10.33%
Nominal IRR				1986 - 2008			6.41%
				1986 - 2012			12.68%

Source: Rogers Communications (RCI) Annual Reports for financials, and Statistics Canada. Table 326-0020 - Consumer Price Index (CPI), 2011 basket, annual (2002=100 unless otherwise noted). We used EBITDA or similar measure of income before depreciation and amortization. Capital expenditures correspond to “additions to property plant and equipment” for Rogers Wireless in recent annual reports. “Other cash investments” that we have included are (a) the acquisition of PCS spectrum in 2001 and AWS spectrum in 2008 (we report the total cash expenditure for the latter), (b) the acquisition of Microcell for a net cash outlay of $1.5 billion (including cash received from Microcell and cash expended to pay Microcell’s creditors). There are other cash outlays on a smaller scale such as outlays pertaining to spectrum for Inukshuk Wireless (a joint venture in which Rogers has a 50% stake) and smaller acquisitions (e.g., City-Fone Wireless) that are not included in either the capital expenditure or “other” columns. The reported capital expenditure for 1986 is an estimate, based on reported cumulative investment *by Rogers* of $110m at the end of FY 1987. Note that the 1990 financial year is from August 1989 to December 1990, and that previous financial years (1989 and before) were August-to-August. August price levels used for 1986-89 and December price levels (based on the CPI Index) used over the period 1990-2012. All dollar values in thousands.

Table 4: HHI and Market Concentration Statistics, Year-End 2011

Country	Number of competitors[174]	Share of Top Two Firms	HHI
Canada	3	64%	2840
US	4	64%	2440
UK	4	67%[175]	2850
France	3	76%	3230
Germany	4	64%	2700
Italy	4	67%	2880
Japan	3	75%	3480
Australia	3	76%	3550

Source: *FCC 16th Wireless Competition Report*, Table 68 and ¶409 (for HHIs) and CRTC *Communications Monitoring Report 2012*, Table 6.1.4. (for 2-firm market shares and number of competitors, adjusted for U.K. merger between T-Mobile and Orange). The CRTC Monitoring Report lists the number of 'major providers', effectively nationwide competitors. The international comparisons in the FCC report rely upon national-level HHIs from Merrill Lynch's Global Wireless Matrix. These HHIs are calculated based on national market shares of all carriers.

[174] The CRTC Monitoring Report lists the UK as having 5 competitors, but this does not take account of the merger of T-Mobile and Orange's UK operations, a merger that was announced in 2010.

[175] The reported two-firm market share and HHI reflects the merger of T-Mobile UK and Orange UK, who now operate as "Everything Everywhere." If the two operators are treated separately then the UK's HHI falls to 2210. See FCC 2013, Table 68 and ¶409. The two-firm market share falls to 54% if these two firms are treated separately. See CRTC *Communications Monitoring Report 2012*, at Table 6.1.4. The two-firm market share of 67% for the U.K. was calculated by us based on year-end 2011 company data.

ONTARIO ENERGY BOARD

IN THE MATTER OF the Ontario Energy Board Act, 1998, S.O. 1998, c.15 (Schedule B);

AND IN THE MATTER OF an application by Toronto Hydro-Electric System Limited for an order pursuant to section 29 of the Ontario Energy Board Act, 1998.

EXPERT REPORT OF

CHARLES L. JACKSON

JUNE 11, 2013

Wireless Networks and Utility Poles

Charles L. Jackson

June 11, 2013

This study was prepared at the request of WeirFoulds LLP.

Table of Contents

1 Introduction and Overview

Counsel asked me to address the following four questions regarding wireless infrastructure:

> What coverage challenges, if any, do wireless network operators currently face or are likely to face in providing high-speed wireless voice and data services in densely populated urban areas?
>
> If there are, or are likely to be, such coverage challenges, describe whether and if so how operators use outdoor small cell technologies and distributed antenna systems to meet these coverage challenges.
>
> Does the importance of these technologies in operators' deployment plans vary, and if so, how? And if so, to what extent does their importance depend upon on factors such as: the operators' access to spectrum, the existence of macro-cell networks, and the ability to use technologies that offload voice and data traffic to fixed broadband networks?
>
> Is access to utility poles necessary in order to facilitate the deployment of small cell and distributed antenna system networks in urban areas and, if so, to what extent? Are there alternatives to utility poles to facilitate that deployment and, if so, please assess the relative advantages and disadvantages of each alternative (including utility poles).

The report begins with an overview of modern wireless technology with an emphasis on those aspects of the technology that provide the basis for answering those four questions. Following that background material, the report addresses each of the four questions. Initially, though, I set out below brief responses to the four questions.

Regarding the first question, the two primary challenges relate to the provision of reliable service and the provision of service to rapidly moving users. As wireless systems mature, the primary coverage challenge is to provide sufficient capacity to serve consumer demand. Generally speaking in urban areas, basic coverage—the ability to make and receive calls—has been extended to almost all geographic areas. Because physics and regulation limit the amount of radio spectrum wireless service providers can use, a primary tool in expanding capacity is the use of smaller cells.

As to the second question, operators use small cells extensively in their networks to expand capacity. Small cells are used indoors and out. For example, AT&T, one of the largest wireless carriers in the United States, recently announced that it will install 40,000 small cells in the next few years. Relatedly, AT&T will also install some distributed antenna systems, but, AT&T will install only one distributed antenna system for every 40 small cells that it installs. Distributed antenna systems are used for a variety of coverage enhancements in which their special properties make them superior to small cells.

Regarding the third question, the importance of small cells to operators varies depending upon the nature of an operator's licence (in particular, the bandwidth the licence makes available to the operator) and the demand growth forecast by the operator.

Regarding the fourth question, generally speaking access to utility poles is not necessary for the deployment of small cell and distributed antenna systems. No doubt there will be a few locations, such as a stretch of road with no other structures, where utility poles will be the best location for a small cell site or an antenna of a distributed antenna system. But, in most areas where small cells or distributed antenna systems will be needed, utility poles are one of many possible locations for such systems. Other locations include the sides of buildings and other structures or inside buildings.

Attachment A is a list of materials considered in the preparation of this report.

2 About the Author

I am an electrical engineer and have worked extensively in communications and wireless. I have done both digital design and systems and applications programming. Currently, I work as a consultant and as an adjunct professor at George Washington University, where I have taught graduate courses on computer security, networking and the Internet, mobile communications, and wireless networks. I consult on technology issues—primarily wireless and telecommunications. I served for three terms on the FCC's Technological Advisory Council. I have provided expert testimony before the CRTC and for the Telecommunications Policy Review on behalf of TELUS. Earlier, I worked at both the FCC and the House Commerce Committee. I hold two U.S. patents. I received the PhD degree in Electrical Engineering from MIT.

A professional biography is Attachment B to this report.

3 Background on Wireless

As with many fields, the wireless industry has developed its own jargon and specialized definitions. This section provides an overview of key concepts essential to understanding wireless technology and explains some of the most important terms used when discussing wireless. Topics considered include spectrum and bandwidth, the structure of modern wireless systems, the problem of expanding capacity in wireless systems, small cell technologies, Wi-Fi, and the properties of different spectrum bands.

3.1 Spectrum and Bandwidth

Two often used terms in wireless are *spectrum* and *bandwidth. Spectrum* is used to refer to the entire set of radio frequencies—starting from below the AM radio band up beyond the radio frequencies used for satellite communications.[1] For example, radio station CFTR (680 News) transmits a signal centered on 680 kilohertz and CFTO-DT (CTV) transmits a signal in the band of frequencies ranging from 186 megahertz to 192 megahertz.[2] That 6-megahertz band is known as TV channel 9. *Bandwidth* is used to refer to size of a range of frequencies. Thus, TV channel 9 has a bandwidth of 6 megahertz.

Similar to the way that CTV is licenced to use channel 9, wireless carriers are licenced to use blocks of frequencies. For example, Bell Mobility operates in Toronto on the cellular A block. Bell cellular phones transmit in the range 835–845 megahertz; base stations transmit in the range 880–890 megahertz.[3] Just as a TV signal occupies a block of frequencies, so do transmissions from cellular phones. For example, the original FM cellular standard transmitted a signal that occupied about 30 kilohertz of bandwidth. Consequently, the entire cellular A block, which had 10 megahertz of bandwidth in which cellular phones would transmit, could carry no more than about 300 conversations at any one location.

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[1] The radio spectrum is a portion of the much larger electromagnetic spectrum, which includes radio waves, visible light, and x-rays. See https://en.wikipedia.org/wiki/Electromagnetic_spectrum for a more detailed discussion.

[2] *Hertz* is the measure of frequency—just as seconds are a measure of time.

[3] These are the original frequencies for sub-band A in the cellular band. Currently, sub-band A includes some other frequencies—but including those in the discussion would add complexity without adding any expository value.

3.2 Structure of Modern Wireless Systems

Modern wireless systems are astoundingly complex and beautiful systems—they are invisible cathedrals in the air. Nevertheless, the basic structure of a wireless system is easy to understand. Wireless calls require both a wireless handset and a matching wireless network. Wireless networks consist of cell sites that contain antennas, radios, and communications connections to a switching center where calls are processed and sent on to other subscribers, a local telephone company, or a long-distance company.

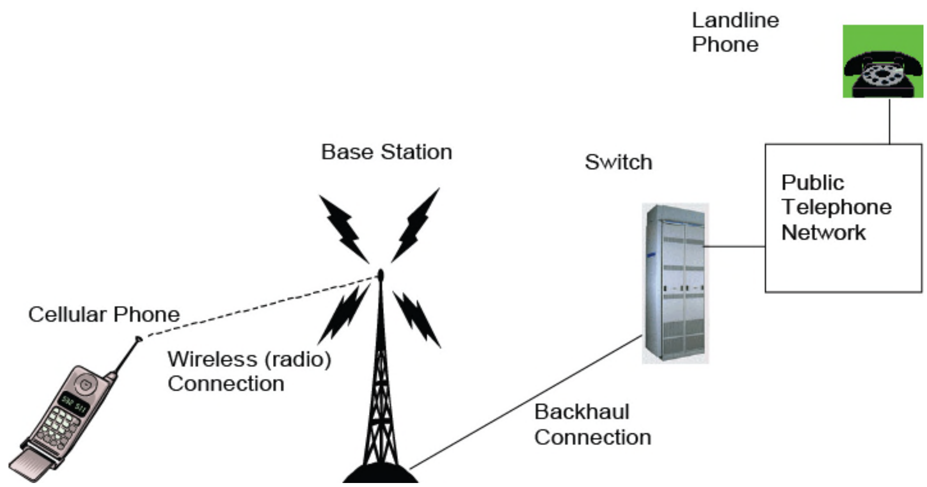

Figure 1. Elements of a Wireless Network

Figure 1 shows the basic elements of a wireless network: (1) the user's device, (2) the base station that consists of an antenna and electronics for controlling communications, formatting messages, and generating radio signals, (3) a backhaul connection such as a microwave link, a fiber link, or a service purchased from the local telephone company, and (4) a switching center that routes traffic between users or to other networks. However, wireless networks do not use a single base station as shown in Figure 1. Rather, they contain many base stations, with each station serving a relatively small area—often as small as a few hundred yards in diameter. These small areas are called *cells*, and the terms *cellular* and *cellular wireless* are derived from this cellular concept. Figure 2 illustrates a wireless network with multiple base stations.

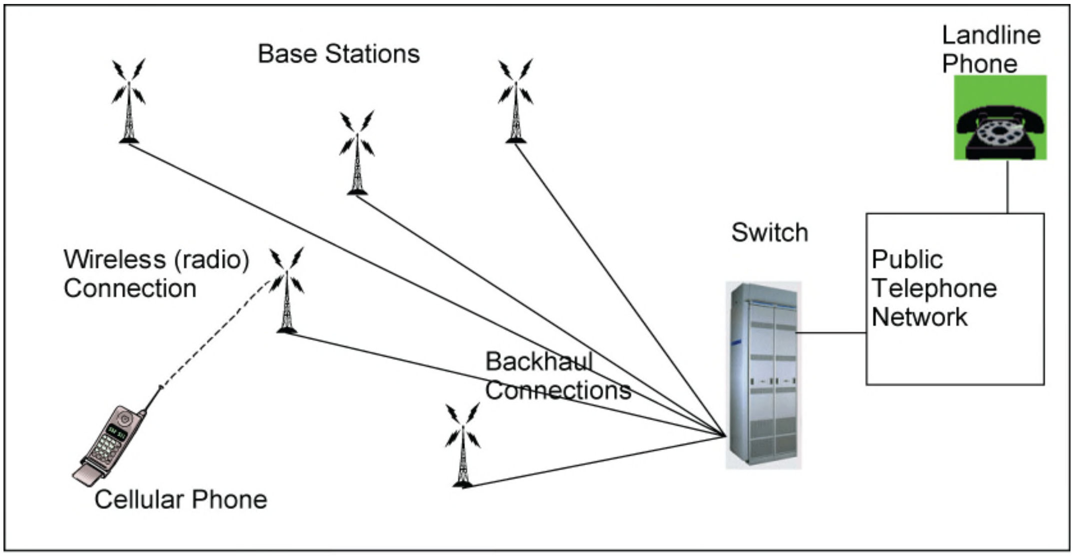

Figure 2. Multiple Base Stations

Carriers such as Bell and Rogers have many hundreds of cells, each with its own base station, in the Toronto area and thousands across Canada. Figure 3 is a map showing the location of Bell's base stations in the Toronto area. As can be seen from Figure 3, the typical base station serves an area roughly a kilometer or two in radius.

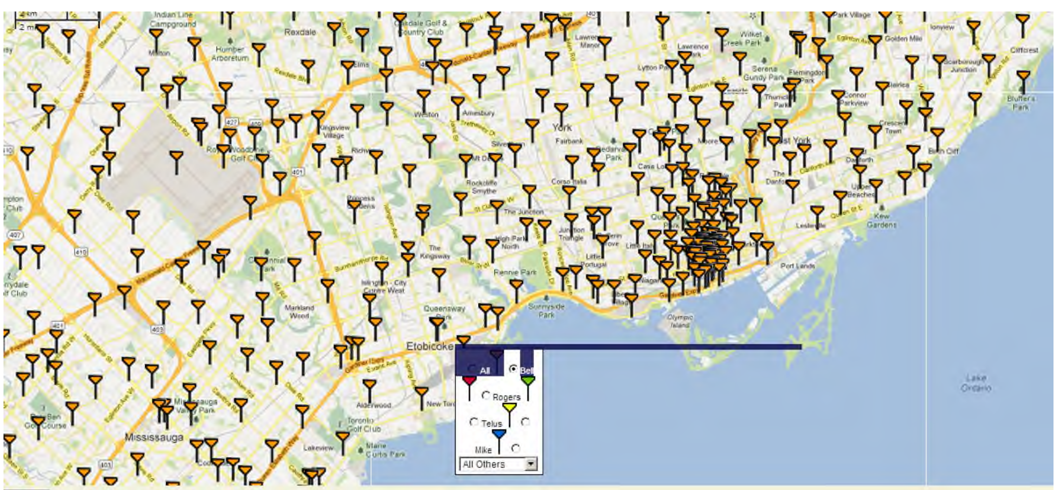

Figure 3. Map of Bell Towers in Toronto[4]

4 From http://www.ertyu.org/steven_nikkel/cancellsites.html, with permission.

However, if one zooms in on the Financial District, one sees that many base stations are within two or three hundred meters of another base station. These densely packed base stations serve smaller areas.

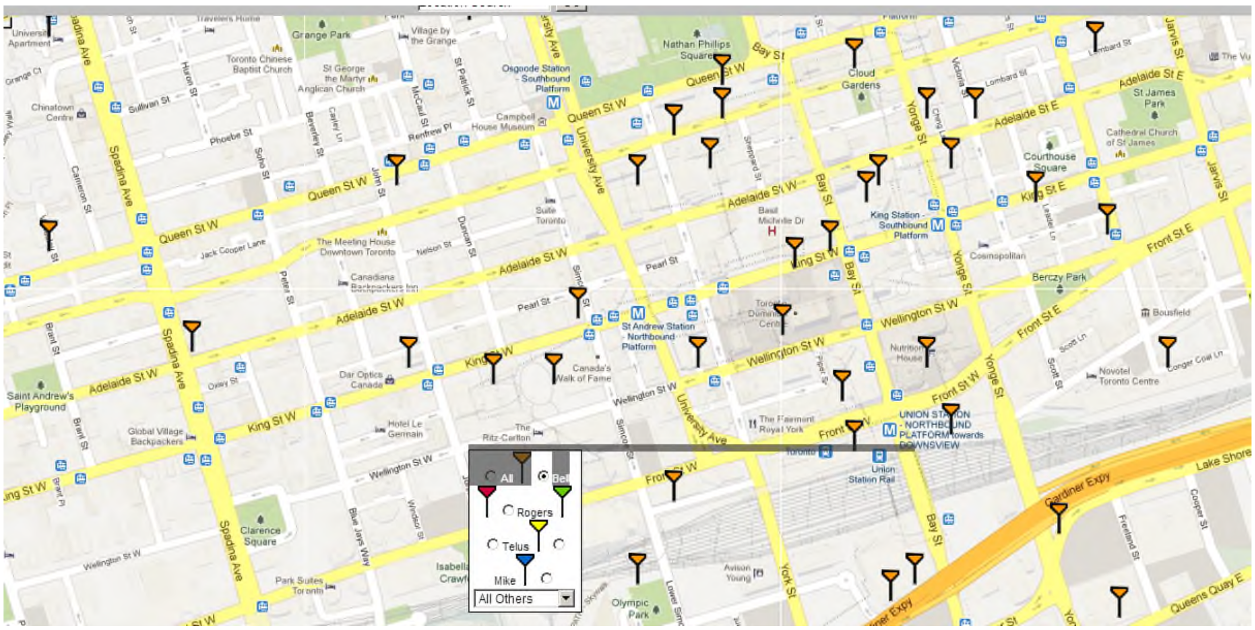

Figure 4. Bell Cell Towers in the Financial District of Toronto[5]

One great advantage of the cellular approach is that the radio spectrum—the channels that actually carry the calls—can be used in multiple cells.   Such reuse can be illustrated by a similar process in broadcasting. In the analog television days, CBC broadcast on channel 5 in both Toronto and Edmonton (stations CBLT and CBXT, respectively). Toronto and Edmonton are sufficiently separated that the TV transmissions in each city did not interfere with reception in the other—thereby allowing TV channel 5 to be used in Toronto and used again in Edmonton. Much the same kind of reuse occurs in cellular—cell phones located in different cells can transmit on the same frequencies. Another advantage of the limited size of cells is that handsets need only transmit relatively weak signals—thus preserving battery life.

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5 From http://www.ertyu.org/steven_nikkel/cancellsites.html,with permission.

Smaller cells allow more reuse of the spectrum. Consequently, the Bell wireless network in the Financial District can carry far more calls per square kilometer than can the Bell network in the suburbs where cells are bigger.

Cellular reuse causes one problem that has no counterpart in broadcasting. As a user moves about, the handset moves out of the coverage of one cell and into the coverage of another cell. The wireless system must detect when this occurs and direct both the base station and the wireless handset to adjust their transmissions to match the new configuration. This process is called *handoff* or *handover*. Handoffs impose a burden on the wireless network's infrastructure. Perhaps more important, sometimes the handoff process fails and the call is dropped.

3.3 The Problem of Expanding Capacity in Wireless Systems

The modern wireless industry began in the early 1980s with the first cellular systems that used analog technology. Cellular service turned out to be more popular than most people had forecast. Within a few years, the capacity available on the cellular licences was close to exhaustion in some large cities. There were two responses to this pending exhaustion: (1) The industry pressed efforts to develop technologies that could fit more calls into spectrum currently available to the service providers and (2) regulators looked for additional radio spectrum (radio channel space) that could be made available for wireless services.

Technological progress has been truly amazing. The bandwidth occupied by a telephone call has fallen enormously since the 1980s—probably by a factor of between 20 and 100. Capacity expanding innovation is continuing.

There are both physical and social limits to the amount of spectrum that can be devoted to wireless service. Physics limits the spectrum that can be used for wireless. With today's technology, the spectrum between about 500 megahertz and 3000 megahertz (3 gigahertz) is best suited for providing wireless services. But, there are a host of other uses for this block of spectrum as well—air traffic control, satellite audio broadcasting, satellite navigation systems, and myriad other applications. Consequently, regulators have to make difficult tradeoffs between alternate spectrum uses. There has been substantial regulatory action, and several additional bands have been made available for wireless service.

Wireless carriers seek additional spectrum when the opportunity arises. For example, Industry Canada auctioned off licences for the Advanced Wireless Service (AWS) in 2008. Bell Mobility and Rogers each purchased licences for 20 megahertz of spectrum in Toronto. Bell and Rogers are deploying the most recent wireless standard, LTE, in this new spectrum thereby combining the advantage of improved technology with expanded spectrum.

Growth in the use of wireless has kept up with the expansion in capacity. Once, wireless service was expensive and used only by a few; today, Canadian wireless carriers have about 26 million subscribers and a significant fraction of households have only wireless telephone service.[6] [7] New technologies, such as smartphones and wireless data services, have expanded the demand for wireless services.

There is a third approach to expanding capacity called *cell splitting* or more formally, closer geographic reuse. Cell splitting refers to wireless carriers shrinking the size of cells and using more but smaller cells to provide service. The small cells shown in Figure 4 are the result of splitting cells several times. As a general strategy for expanding a carrier's capacity in a large region such as the Greater Toronto area, cell splitting is more expensive and less desirable than adopting improved technology or operating on additional spectrum if either of those latter choices is available.[8]

3.4 Small Cell Technologies

As the above discussion makes clear, cells in wireless systems come in a variety of sizes. The largest cells cover a few hundred square kilometers, while the smallest cover a small room. The industry has developed a variety of names for cells that are considerably smaller than the

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[6] CWTA Facts, available at http://cwta.ca/wordpress/wp-content/uploads/2013/01/SubscribersStats_en_2012_Q3.xlsx-Legal.pdf.

[7] In 2010, more than 13% of households had only wireless telephone service. See *Residential Telephone Service Survey*, December 2010, Statistics Canada. Available at http://www.statcan.gc.ca/daily-quotidien/110405/dq110405a-eng.htm.

[8] The underlying economic model leading to this conclusion is quite simple. New spectrum and new radio technology can be exploited by deploying radio equipment on service provider's existing cell sites. In contrast, cell splitting requires access to new cell sites as well as the deployment of additional radio equipment at those new cell sites. A typical macro cell site requires a tower, equipment shelter, fence, power connection, backhaul connection, and site acquisition or lease costs. The cost of these non-electronic systems usually exceeds the cost of the electronics at the cell site.

traditional urban cells. These smaller cells are often denoted microcells, picocells, and femtocells—meaning small coverage area, even smaller, and very small indeed. I use the terms *small cell* as a generic term to refer to cells in these various categories of small cells, regardless of whether the coverage provided by the cell extends 100 meters or 10 meters from the antenna. I use the term *macrocell* to refer to the larger, more traditional cells.

Macrocells have antennas on towers or near the top of taller buildings. Small cell antennas providing outdoor coverage are positioned much lower—such as on the side of an office building at the second story level, in a window, or on the ceiling of a large, open building such as a train station. Figure 5 illustrates an office building with small cells on each floor. The equipment on each floor is a complete base station with signal processing electronics, transmitter, and antenna. That base station must be connected to a backhaul network that connects the base station to the mobile switching center. For the smallest of cells, that connection is often the public Internet.

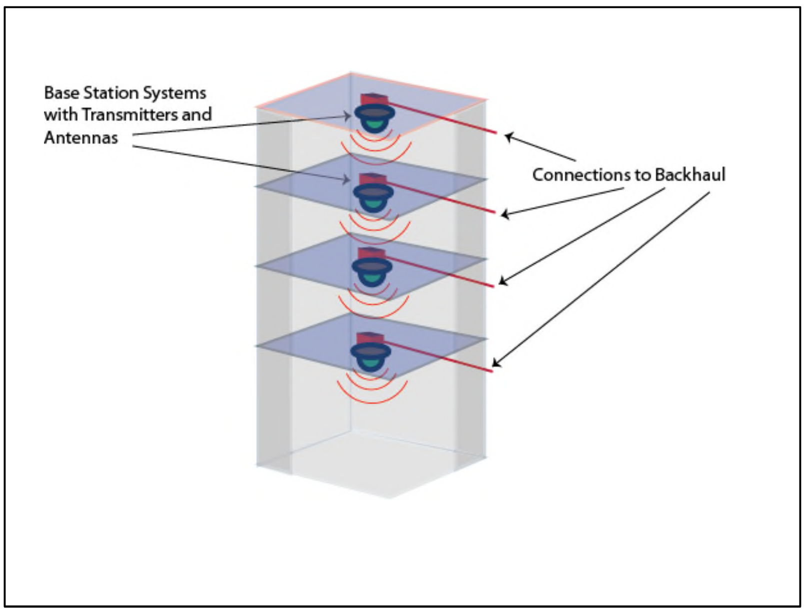

Figure 5. Small Cells Serving an Office Building

Below I discuss very small cell technology, small cells used by network service providers, Wi-Fi access points, and distributed antenna systems.

3.4.1 Very Small Cells

The smallest cells serve users within about 10 meters from the base station antenna. Figure 6 shows one such base station. It is the Samsung unit that provides wireless coverage inside my home.[9] The unit is connected to the router for my cable modem service. That cable modem service provides the backhaul connection—a connection over the public Internet; the yellow cable in the picture is the Ethernet cable running from the base station to the cable modem. I bought the unit from my carrier and installed it myself. I provide electrical power and pay for the backhaul connection. It operates on the licenced spectrum of my wireless service provider; it does not use the Wi-Fi band. The transmitted power ranges from 10 microwatts to 30 milliwatts, and the unit supports only three or fewer connections at the same time.[10]

Figure 6. Samsung Home Base Station (network extender)

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9 See http://www.samsung.com/us/mobile/cell-phones/SCS-26UC4.

10 http://support.verizonwireless.com/pdf/network_extender_user_manual.pdf at p. 21

3.4.2 Small Cells used by Network Service Providers

Figure 7 is an illustration taken from an Alcatel-Lucent marketing brochure showing a small cell mounted on the outside of a building. Alcatel-Lucent calls these products *metro-cells.* The transmitted power from these cells is higher than in the home small cell illustrated above—ranging from 250 milliwatts to 5 watts.[11] These higher power levels allow network service providers to serve many more subscribers and to serve subscribers at substantially longer distances than the very small cell discussed above.

Alcatel-Lucent metro cells deployed where capacity is needed

Figure 7. Illustration from an Alcatel-Lucent Marketing Brochure

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[11] *Alcatel-Lucent Metro Cells: Placing Coverage and Capacity Where It's Needed*, Alcatel-Lucent, 2012. Power levels specified on p. 6.

Alcatel-Lucent also sells a small cell for indoor use in public places. It is about 25 cm square and 5 cm thick and weighs less than 2 kilograms. One unit supports up to 32 simultaneous users and transmits at powers up to 250 milliwatts.[12]

Of course, it is not necessary to mount a small cell base station on an outside wall to create outside coverage—signals from indoor small cells will travel outside the building. Figure 8 shows a research small cell network operated by QUALCOMM. I have used circles to emphasize their observation that indoor cells provide substantial outdoor coverage. I have also circled a photo of one of the base stations showing it positioned in front of a window.

Figure 8. Research Small Cell Network[13]

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[12] Datasheet for Alcatel-Lucent 9363 Metro Cell Indoor V2, 2011.

[13] *Neighborhood Small Cells and UltraSON Open for LTE*, QUALCOMM Technologies, 2013, at p. 8. Available at http://www.qualcomm.com/media/documents/files/qualcomm-research-neighborhood-small-cells-ultrason-open-for-lte.pdf. Emphasis added.

3.4.3 Wi-Fi Access Points

Wi-Fi access points are similar to small cells. Many modern wireless devices such as the iPhone or Galaxy Note can connect over Wi-Fi. Such devices can be configured to automatically use Wi-Fi networks when those are available. When so configured, a Wi-Fi network provides connectivity as if it were a small cell. The wireless industry is developing standards that permit calls to be handed between Wi-Fi access points and commercial wireless networks.[14]

3.4.4 Distributed Antenna Systems

Distributed antenna systems (DAS) are related to small cells but with one big difference—each small cell is a separate base station, but a cell with a distributed antenna system is built by connecting several antennas to a single base station.[15] Figure 9 illustrates a distributed antenna system serving a building.

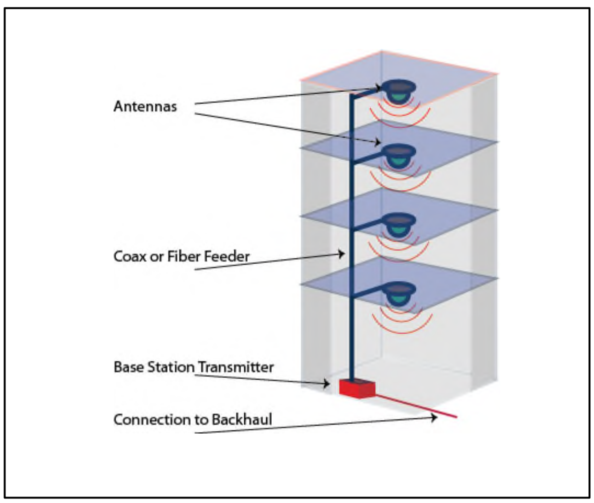

Figure 9. Illustrative Distributed Antenna System

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[14] See *The Wi-Fi Evolution*, April 2013, available at http://www.qualcomm.com/media/documents/wi-fi-evolution.

[15] Usage varies. Some use the term *small cell* system to refer to a cell with a distributed antenna system. Others distinguish distributed antenna systems from small cell systems. See, for example, http://www.smallcellforum.org/newsstory-femto-forum-becomes-small-cell-forum-as-femtocell-technology-extends-beyond-the-home.

An important distinction between small cells and cells with distributed antenna systems is the difference in the connection between the antennas of a distributed system and its associated base station and the connection between the small cell base station and the switching center of the mobile network. (Note, following common usage I will often use the term *distributed antenna system* to refer to *cells with distributed antenna systems.* This economy of language is potentially misleading because it uses a term describing part of a system to refer to the entire system. But it has become the accepted usage.) Figure 10 compares a the physical structure of a small cell with that of a single cell that operates using a distributed antenna system. The small cell is contained in a single enclosure. Running from the enclosure are a power connection and a connection to a backhaul facility. Inside the enclosure is a cable that runs from the electronics to the antenna. The cell with a distributed antenna system is quite similar. It also has electronics that are connected to power and backhaul. The big difference comes in the connection to the antennas. The antenna cable leaves the enclosure and goes to multiple antennas that provide overlapping regions of coverage to serve an area. The connection between the antennas and the enclosure is an appropriate antenna cable—a cable that is, generally speaking, quite different from the cable providing the backhaul connection.

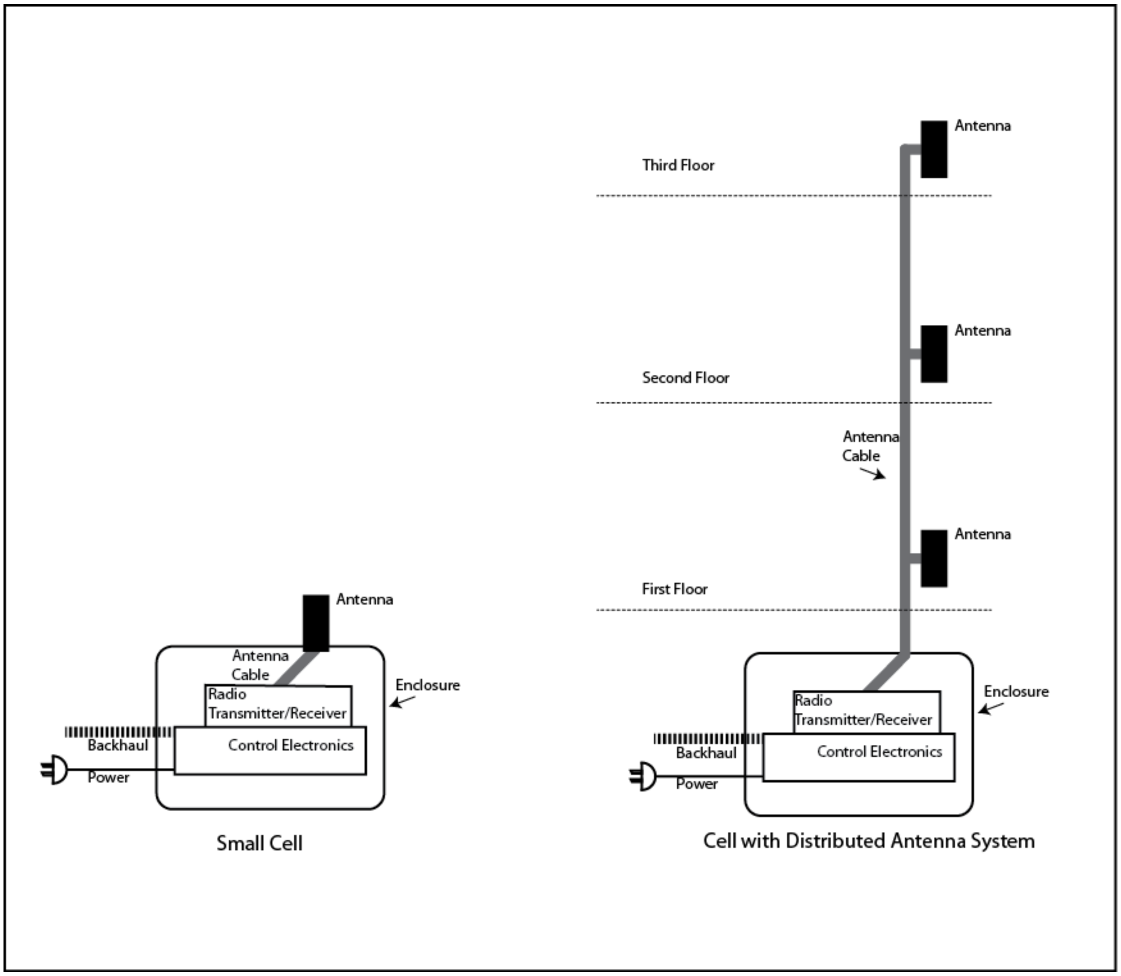

Figure 10. Small Cell versus Distributed Antenna System

The connection from the transmit/receive electronics to the antenna corresponds to the wiring in a residence that runs from a rooftop antenna to a TV set. The antenna is a passive device and needs no electrical power—the radio signal itself carries the power.[16] In contrast, a small cell's base station needs both electrical power and a connection to the backhaul network, which is often the Internet. In some circumstances the two connections can be provided over a single cable by

16 More recent distributed antenna systems use a variation on this basic idea. The signal from the base station is transformed into an optical signal that is sent over optical fiber cable to the antenna. At the antenna the electrical signal is converted back to an electrical signal, amplified, and transmitted. Such fiber-fed distributed antenna systems require an electrical power connection at the remote unit as well as the fiber connection back to the base station.

using power-over-Ethernet (PoE).[17] The signals transmitted between the small cell's base station and the switching center are digital and are identical in concept to the signals transmitted between the base station of the cell with the distributed antenna system and the switching center.

Figure 11 compares the use of a distributed antenna system and the small cell base stations illustrated above to serve a single building. That comparison makes it easy to see the capacity difference between the systems—one has a single base station, the other four base stations. The system with four base stations will have four times the capacity.[18]

Distributed Antenna System
One Unit of Capacity

Corresponding Four Small Base Stations
Four Units of Capacity

Figure 11. Comparison of a Distributed Antenna Systems and Small Cells

Before the advent of modern wireless, distributed antenna systems were used to provide reliable radio coverage in mines, subway tunnels, and similar locations where the signal from a single antenna could travel only a short distance before it was blocked.[19] When handheld wireless phones came into use, it was found that wireless coverage was often poor inside office buildings. Distributed antenna systems were found to provide a good tool for extending wireless coverage

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[17] The Alcatel-Lucent small cell product can use PoE. See http://www.alcatel-lucent.com/solutions/lightradio-metro-cell-express/details.

[18] This capacity comparison assumes that the base stations of the two systems have similar capacity.

[19] See, for example, "The Design and Implementation of a UHF Radio System Using Distributed Antennas, Passive Reflectors and Two-way Signal Boosters in a Room and Pillar Limestone Mine," Isberg, R.A.; Cawley, J.C.; Chufo, R.L., Vehicular Technology Conference, 32nd IEEE, 1982, pp. 259–267. Digital Object Identifier: 10.1109/VTC.1982.1623028.

inside office buildings, thereby providing service at locations where the signals from outside the building could not penetrate.[20] For example, a single base station serving the inside of an office building might have an antenna on each floor. The same signal would be transmitted on each floor. The multiple antennas provide a reliable signal on each floor. Providing an equally reliable signal with a single transmitter located in the middle of the building might be impossible. If not impossible, it would require a much higher power transmission that would create interference outside the building. Distributed antenna systems have been used extensively to provide wireless coverage in office buildings. They have also been used to provide coverage outside in a variety of circumstances.

One factor key to the economics of distributed antenna systems is that the remote units are antennas—simple enough to be affordable when built with the electronics of the 1970s. Originally, they consisted of nothing but antennas connected back to the transmitter by coaxial cable and an electrical circuit that divided the transmitted signal among the antennas. Today, many distributed antenna systems use more complex remote units that include a low-power transmitter. But, the complex signal processing is done at the central base station—the remote units have limited capabilities. Such units require special, dedicated links from the remote unit back to the central base station. Typically those dedicated links must be able to carry a relatively wideband analog or digital signal. The bit rate needed on such a connection might be several hundreds of megabits per second—a rate far higher than can be accommodated over a public Internet connection. Thus, unlike the backhaul connection for a small cell base station discussed above, distributed antenna system remote units cannot use a local area network having Internet connectivity for the required connection to their associated base station. The need for these dedicated links makes it difficult to install distributed antenna systems that serve more than a single building or campus.

As electronics have improved, the economics of distributed antenna systems relative to small cells have changed. QUALCOMM now offers a chipset that provides most of the capabilities

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[20] See "Distributed Antennas for Indoor Radio Communications," Saleh, A.A.M,; Rustako, A.J.; Roman, R., *IEEE Transactions on Communications,* 1987, Vol. 35, No. 12, pp. 1245–1251. Digital Object Identifier: 10.1109/TCOM.1987.1096716.

needed for a small cell base station, as do other manufacturers.[21] A recent examination of the economics of small cells and distributed antenna systems for in-building coverage concluded that, under most circumstances, small cells provide more capacity at lower cost than do distributed antenna systems.[22] Given that electronic technology is expected to get better and less costly and that improvements in electronics will lower the cost of small cells more than they will lower the cost of distributed antenna systems, it is to be expected that small cells will have an increasing cost advantage over distributed antenna systems.

A possible source of confusion arises with the use of the terms *distributed antenna system* and *DAS.* A distributed antenna system is exactly that—an antenna of a wireless system is electrically distributed—spread out—over many locations. An ideally illustrative example of a distributed antenna is a leaky cable run through a tunnel. However, some use these two terms (*distributed antenna system, DAS*) to refer to hypothetical wireless systems built using cells each of which is implemented by a distributed antenna system.[23] Those same sources indicate that it would be not only possible but practical to build a commercial wireless system using exclusively or primarily distributed antenna systems as the technology in each cell.

To summarize, distributed antenna systems are one form of cell technology. They were and are widely used to improve wireless coverage inside facilities such as office buildings, sports stadiums, and subways. However, improvements in electronics have made base stations for small cells sufficiently inexpensive that small cells appear to be becoming economically dominant. Two additional factors push toward the use of small cells rather than distributed antenna systems: (1) the need for dedicated cabling in distributed antenna systems and (2) the fact that distributed antenna systems do not expand system capacity in the fashion that small

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21 See QUALCOMM press release, "QUALCOMM Now Sampling Industry's Most Comprehensive Femtocell Chipsets, FSM9xxx-Series Chipsets Offer Unprecedented Performance, Interference Management and More," San Diego, California, June 22, 2010 Available at http://www.qualcomm.com/media/releases/2010/06/22/qualcomm-now-sampling-industrys-most-comprehensive-femtocell-chipsets.

22 See "Economical Comparison of Enterprise In-Building Wireless Solutions Using DAS and Femto," Zhen Liu; Kolding, T.; Mogensen, P.; Vejgaard, B.; Sorensen, T., *IEEE Vehicular Technology Conference (VTC Fall),* 2012, pp. 1–5. Digital Object Identifier: 10.1109/VTCFall.2012.6399316.

23 For example, at page 21, the July 26, 2011 report of Lemay-Yates Associates states "Distributed Antenna Systems or DAS networks are comprised of a network of small antennas linked together via a high-speed fibre optic network to provide the link between the antennas and base stations situation [in hub locations]." That sentence treats *Distributed Antenna Systems* and *DAS Networks* as synonyms.

cells do. Thus, in most situations, small cells will be found to be economically superior to distributed antenna systems—they will cost less and do more. This superiority is illustrated by a recent statement by AT&T, the second-largest wireless carrier in the United States, outlining their plans for expanding their wireless network:

> To expand access to high-speed Internet service and new mobile services to customers, AT&T launched Project VIP, an initiative to deploy more than 10,000 macro sites, 1,000 distributed antenna systems and 40,000 small cells.[24]

3.5 Wi-Fi

The expression *Wi-Fi* is the trademarked name for wireless local area networks that use the IEEE 802.11 standard.[25] Because the 802.11 standard has come to dominate the wireless local area network market, some people use Wi-Fi to refer generically to wireless local area networks. Wi-Fi is commonly used to interconnect computers, printer, and other devices in offices and homes.

Wi-Fi, being a modern wireless technology, shares many technological features with the modern wireless services offered by carriers. However, Wi-Fi has a completely different economic and regulatory model than does wireless.[26] [27] Two important aspects of the regulation of Wi-Fi are (1) it is restricted to quite low powers and (2) use of Wi-Fi does not require a licence—it is a licence-exempt use of the radio spectrum.[28] The restriction to low power restricts the range that can be served by a Wi-Fi access point (the Wi-Fi equivalent of a wireless base station). For most practical purposes, the range of Wi-Fi is limited to between 10 and 100 meters.

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24 "AT&T Investment Drives Service Improvements,' 2013. Available at http://www.att.com/Common/about_us/pdf/network_investment_infographic.pdf. 2013.

25 See http://www.wi-fi.org/about/wi-fi-brand.

26 For background on the development of Wi-Fi and unlicenced wireless more generally, see *INFO*, Special Issue August 2009, INFO Volume 11, Issue 5, from *Genesis of Unlicenced Wireless Policy: How Spread Spectrum Devices Won Access to Licence-Exempt Bandwidth*, held on April 4, 2008. See also http://iep.gmu.edu/conference-the-genesis-of-unlicenced-wireless-policy-how-spread-spectrum-devices-won-access-to-licence-exempt-bandwidth/.

27 The relevant power limits are specified in *RSS-210 – Licence-exempt Radio Apparatus (All Frequency Bands): Category I Equipment*, Issue 8, December 2010, Spectrum Management and Telecommunications Radio Standards Specification, Industry Canada.

28 See *Low-power Licence-exempt Radio Communications Devices — Frequently Asked Questions* at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08655.html

The lack of licencing permits one to buy a Wi-Fi router and install it in one's home or office without having to jump through any regulatory hoops. The downside of this flexibility is that there is no protection against interference. Thus, operation of a neighbor's Wi-Fi system might degrade the performance of Wi-Fi in one's home. However, because Wi-Fi signals are quite low power and travel only limited distances, the lack of interference protection is often not a problem. The combination of the limit to low power and the lack of interference protection makes it impossible, both technically and economically, to build Wi-Fi macrocells with current technology.

Wi-Fi operates in different portions of the spectrum than does commercial wireless. A substantial amount of spectrum has been made available for use by Wi-Fi—indeed more than is currently available for licenced for use by all wireless carriers combined.[29]

Not surprisingly, wireless carriers have found a variety of ways to incorporate Wi-Fi into their operations. One approach is public hot spots—locations where a user can access the Internet using Wi-Fi. For example, Bell operates about 4,000 hot spots across Canada in locations such as Tim Horton's or McDonalds.[30] The second approach is to facilitate subscriber use of Wi-Fi instead of the wireless network. For example, my commercial wireless handset also has a Wi-Fi capability. It is configured to use Wi-Fi for data communications whenever Wi-Fi is available. This takes traffic off the service provider's network—it is as if the Wi-Fi access point were another cell in the network. However, not only do Wi-Fi hotspots serve as small cells that can be an integral part of a wireless system, but they also give service providers access to large blocks of spectrum—albeit spectrum that cannot be used in macrocells. These large blocks of spectrum expand capacity and support higher data rates than are possible with commercial wireless technologies.

A presentation prepared by QUALCOMM, one of the major wireless hardware companies, provides a useful and accessible overview of the integration of Wi-Fi with commercial

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[29] See RSS-210. This comparison of the amount of licenced and licence-exempt spectrum omits the licence-exempt spectrum at frequencies above 6 GHz. That spectrum has different physical properties, and such a comparison could be misleading.

[30] See http://www.bell.ca/Bell_Internet/Bell-Wifi-Internet-Locations.

wireless.[31] That presentation has 32 slides so it cannot be summarized in one or two sentences. However, it makes the following relevant points:

> The newest step in Wi-Fi evolution, 802.11ac, will significantly improve speed and capacity.
>
> Wi-Fi is being integrated into cellular networks. Switching between the two networks can be seamless and automatic. Automatic access to Wi-Fi access points will replace the sometimes confusing manual procedures used today.

3.6 Properties of Different Spectrum Bands

Everyone is familiar with the concept of the AM radio band, the FM radio band, and the TV band. Everyone, at least on reflection, is also familiar with the fact that radio signals in these bands have vastly different physical properties. For example, when one drives into a parking garage, an AM signal is lost almost immediately but an FM signal often remains useful unless one enters an underground portion of the garage. Similarly, FM signals can be picked up only within about 50 or 60 kilometers or so of the transmitter. In contrast, AM740 (CFZM-AM) claims that its signal reliably reaches Parry Sound to the north, Windsor/Detroit to the west, and Pittsburg to the south—locations more than 300 kilometers from the station's transmitter.[32]

3.6.1 Wireless Bands

The commercial wireless industry uses three principle bands—the cellular band, the PCS/AWS band, and the soon-to-be-available 700 megahertz band.[33] The 700-megahertz band was used for analog TV channels 52–69 before the digital transition.[34] The cellular band is slightly above the 700-megahertz band. The PCS and AWS bands are considerably above the 700-megahertz and cellular bands—being located at about 2000 megahertz. There is another band, known as the

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[31] See *The Wi-Fi Evolution*, April 2013. Available at http://www.qualcomm.com/media/documents/wi-fi-evolution.

[32] AM740 media kit at p. 8. Available at http://www.zoomerradio.ca/wp-content/uploads/2013/02/AM-740-2013-Media-Kit_Jan29.pdf.

[33] The PCS and AWS bands are often spoken of as separate. However, the PCS and AWS bands are in similar spectrum and, generally speaking, radio waves in those bands have similar properties. The band plans for 700 megahertz, PCS, and AWS are available at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08748.html. The band plan for cellular can be found at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf08104.html.

[34] See http://digitaltv.gc.ca/eng/1297877456613/1298648705530.

broadband radio service (BRS) band, at 2500 megahertz. However, a convoluted series of regulatory decisions limited the development and use of this band. Only recently have wireless carriers begun to use it for mobile service. For example, in March, 2013 Rogers announced plans to provide LTE service using its BRS band spectrum in 44 markets.[35] Rogers stated that the LTE service in this band will provide higher speeds—up to 150 megabits per second—than do wireless services in other bands.

3.6.2 Bands near 2 Gigahertz versus Bands below 1 Gigahertz

Because they are at lower frequencies, both the 700 megahertz and cellular bands, particularly the 700 megahertz band, are regarded as being better suited for large cells such as would be useful for coverage in rural areas. In contrast, the PCS and AWS bands are often regarded as providing better capacity in urban areas.

Industry Canada summarized this difference saying,

> Spectrum in the 2500 MHz band is also expected to be in high demand to help service providers address future capacity constraints. Although the propagation properties of the spectrum are not ideal for mobile systems covering large rural and remote areas, the spectrum is expected to be highly useful in expanding the wireless capacity of mobile systems in urban areas and may also be deployed for fixed wireless systems in rural areas.[36]

A study done by the Communications Research Center of Industry Canada made the following observations regarding the relative ability of radio signals at 700 megahertz and 2500 megahertz to penetrate into or out of buildings:

> Based on empirical results (Table 5), average building penetration losses in residential areas are estimated to be 3.9 dB lower at 700 MHz than at 2,500 MHz; as a result, indoor coverage near cell boundaries in such environments is expected to be comparatively better at 700 MHz. In industrial/commercial environments, on the other hand, average building penetration losses are estimated to be 4.3 dB higher at 700 MHz, leading to decreased indoor coverage performance with respect to 2,500 MHz.[37]

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[35] http://redboard.rogers.com/2013/rogers-lte-network-expanding-to-a-market-near-you-this-spring/.

[36] *Policy and Technical Framework, Mobile Broadband Services (MBS) — 700 MHz Band, Broadband Radio Service (BRS) — 2500 MHz Band*, Industry Canada, SMSE-002-12, March 2012, at p. 5.

[37] *Comparison Of Radio Propagation Characteristics at 700 And 2,500 MHz Pertaining To Macrocellular Coverage*, Communications Research Centre Canada, Ottawa, April 2011, at p. iv.

It is often asserted that, all other things being equal, a signal at 700 megahertz provides better coverage at a distance than does a signal at 2500 megahertz; relatedly, the 700-megahertz band is sometimes referred to as beachfront property.[38] That assertion of better coverage rests on the use of a particular model of radio transmission.[39] That model implicitly assumes that the 700-megahertz radio uses a much bigger antenna than does the 2500-megahertz radio. And, it ignores the option to use a recently developed technology, MIMO, which is generally expected to work better at 2500 megahertz than at 700 megahertz.

The 700-megahertz and 2500-megahertz bands have different physical properties. Each is superior to the other in some uses. The fact that MIMO works better at 2500 megahertz (in most circumstances) supports the view that the 2500-megahertz band is well suited for expanding capacity in urban areas. The coverage benefits of 700 megahertz make it best suited for providing rural service and large cells more generally.

3.6.3 Wi-Fi

Wi-Fi operates in two bands—2.4 gigahertz and 5 gigahertz (2400 and 5000 megahertz respectively).[40] The 5-gigahertz band is regarded as having poorer signal coverage, but it covers a much wider bandwidth; consequently, it supports more capacity and higher speeds.

4 Coverage Challenges

Counsel posed the following question:

> *What coverage challenges, if any, do wireless network operators currently face or are likely to face in providing high-speed wireless voice and data services in densely populated urban areas?*

The two primary challenges relate to the provision of reliable service and the provision of service to rapidly moving users.

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38 Ibid at pp. 3–4, and Appendix A. But see the caveats at the end of Appendix A.

39 The relevant model is described by the Friis equation.

40 There is also a Wi-Fi alternative at 60 gigahertz, but that has very limited range. See, for example, http://www.economist.com/blogs/babbage/2013/04/gigabit-wi-fi.

Two keys aspects of a wireless system are necessary for the provision of reliable service. First, the wireless system must provide coverage—an acceptable radio signal at the vast majority of the locations where customers desire service. Second, the wireless system must provide capacity—sufficient capacity to allow users to place calls or access the Internet most of the time at most locations. I discuss coverage and capacity in turn and then address the challenges posed by rapidly moving users in very small cells.

4.1.1 Coverage

Building a system that provides good wireless coverage faces two challenges—the limits of radio propagation and economics. Radio waves tend to travel in straight lines—so providing coverage in small valleys or behind hills may require building extra cells to fill in coverage. Also, radio waves weaken as they penetrate buildings or foliage. The construction of a building affects how much such penetrating radio waves weaken. Typically, a building with many windows lets in more radio waves than a building with few. A building with wooden siding lets in more radio waves than does a building with aluminum siding.

The other limit to coverage is economics. It is simply too expensive to provide coverage everywhere. For example, Bell provides extensive wireless coverage in southern Ontario; but, as one goes north, Bell's coverage thins out and is focused on highways and towns.

4.1.2 Capacity

Some locations require far more capacity than others. One can imagine a service provider needing to cope with hundreds of simultaneous wireless calls occurring at the Rogers Centre; in contrast, a similar-sized area in rural Ontario might generate only a few dozen calls for that carrier at the busiest time.

As discussed above, there are three routes to expanded capacity—improved technology, more spectrum, and increased geographic reuse. Increased reuse is usually the most expensive of these three alternatives—but sometimes it is the only choice.

There are also non-technical tools to deal with demand, such as usage caps, time-of-day or cell-by-cell pricing, and other forms of demand management. For example, many wireless carriers do not charge for evening and weekend calls.[41] Phrasing it another way, many wireless carriers charge only for calls during the day—the period at which capacity is most likely to be strained and any reduction in demand from charging for calls reduces the needed capacity. There also has been limited use of dynamic pricing in which the price for calling varies as a function of the load on specific cells.[42]

4.1.3 Service to Rapidly Moving Users

Handsets that are moving rapidly create two problems for wireless systems. First, transmitting to a handset in motion creates a variety of problems that make radio reception more difficult.[43] Second, a rapidly moving handset passes from cell to cell quickly: each transition between cells requires the call to be handed off from one base station to the next. Such handoffs create system overhead (additional administrative traffic on the backhaul network), reduce system capacity, and sometimes cause dropped calls. An automobile traveling 50 kilometers per hour would spend only seven seconds in a cell 100 meters in diameter. In such circumstances, a handoff would be needed every seven seconds and about 40 error-free handoffs would be needed to complete a five-minute call.

The reception problems created by motion are mostly dealt with at the equipment design stage or in the definition of the wireless standard (GSM, CDMA, etc.). The problem of rapid handoffs in very small cells is harder to deal with. One solution is to operate a network with two types of cells denoted *macrocells* and *small cells.* Macrocells serve relatively large areas; perhaps three or four kilometers in diameter in urban areas and 10 or 20 kilometers in diameter in rural areas. Small cells serve much smaller areas; perhaps less than a hundred meters in diameter.

If a handset served by small cells is found to require several handoffs in rapid succession, it is likely that the handset is in rapid motion. In such a case, the system recognizes such rapid motion

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41 See http://www.bell.ca/Mobility/Cell_phone_plans/Voice_plans for one example. Bell states, "All plans include unlimited local nights (6 p.m. - 7 a.m.) and weekends (6 p.m. Fri - 7 a.m. Mon)."

42 See http://www.thehindubusinessline.com/todays-paper/now-locationbased-mobile-tariffs/article1069058.ece?ref=archive.

43 These problems include Doppler shift, Doppler spread, and rapid fading. Motion also has a benefit—a moving radio does not stay in locations with particularly poor signal strength for long.

and hands off the call to the macrocell serving the same geographic area. Because macrocells are much larger, it takes more time for the handset to move from one side of a cell to the other side. Consequently, far fewer handoffs are needed for a rapidly moving handset served by a macrocell than if the handset is served by a succession of small cells. Conversely, a call being communicated over a macrocell to a handset that is not in motion can be transferred to a small cell, if one is available, in order to free up capacity in the macrocell.

4.1.4 Summing Up

The biggest challenges to providing wireless service are providing adequate coverage and capacity. Large cells are used for widespread and affordable coverage; improved technology, additional spectrum, and smaller cells are used to expand capacity.

5 Use of Small Cell Technologies

The second question posed by counsel is:

> *If there are, or are likely to be, such coverage challenges, describe whether and, if so, how operators use outdoor small cell technologies and distributed antenna systems to meet these coverage challenges.*

Service providers have long used small cells to provide service at locations where a large concentration of users can be expected, such as at busy intersections. Future demand growth will require much more extensive use of small cells. The wireless industry has recognized the need for many small cells. For example, the recently adopted LTE Advanced standard (Release 10) included features to improve the coordination between traditional macrocells and smaller cells.[44]

The industry coined the term *heterogeneous network* (*hetnet*) to describe a network with a mix of macrocells and many small cells.[45] Without careful coordination, operation of small cells will degrade the service provided by macrocells and vice versa. The most recent wireless standards include several features that make operation of networks with many small cells more efficient.

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[44] See the discussion of small cells and LTE Advanced at http://www.qualcomm.com/research/projects/lte-advanced. See also *Mobility Enhancements in Heterogeneous Networks*, 3GPP TR 36.839 V11.1.0 (2012-12), and the documents referenced there.

[45] See "Heterogeneous Cellular Networks: From Theory to Practice," A. Ghosh et al., *IEEE Communications Magazine*, June 2012, p. 54.

5.1 Observations on Small Cells and Distributed Antennas

Small cells are one of several techniques for expanding the coverage and capacity of wireless systems. Distributed antenna systems are generally used for expanding coverage; typically, a distributed antenna system does not expand capacity as much as would a corresponding set of small cells.

Small cell technology will be used increasingly in the future to expand wireless system capacity in regions with significant concentrations of users. Small cells also are a way to provide reliable coverage inside buildings. One market research firm offered the following forecast:

> HetNets are a gradual evolution of cellular topology, not a distinct network unto itself. Driven by this evolution, ARCchart forecasts annual unit shipments of 1.4 million macrocells, 5 million small cells and 11.5 million Wi-Fi access points by 2017, representing a global market value of $42 billion.[46]

Clearly small cells are an important aspect of the wireless landscape and will remain so for many years. Distributed antenna systems do not provide the increase in system capacity associated with conventional small cells. Given the relative affordability of conventional small cells and the widespread availability of connections to the public Internet, it appears unlikely that wireless carriers would deploy significant quantities of distributed antenna systems in the future. It is also the case that carriers will deploy far fewer outdoor distributed antenna systems than indoor distributed antenna systems due to several factors, including the significantly higher cost of hardware and backhaul connections of outdoor systems and the concentration of demand for wireless data services indoors.[47]

6 Factors Influencing the Use of Small Cell Technologies

The third question posed by counsel is:

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[46] http://www.arcchart.com/reports/heterogeneous-networks-hetnets-report.asp

[47] Hardware for outdoor use is more expensive because it must be weatherproof and must tolerate far greater temperature variations; it must also resist vandalism, theft, insects, and small animals. For example, Lucent specifies that their outdoor small cells will work in ambient temperatures between -40 C and +55 C. In contrast their home cells are specified to work within the temperature range -5 C to +45 C.

Does the importance of these technologies in operators' deployment plans vary and, if so, how? And if so, to what extent does their importance depend upon on factors such as: the operators' access to spectrum, the existence of macro-cell networks, and the ability to use technologies that offload voice and data traffic to fixed broadband networks?

The importance of small cell technologies to a service provider varies with the amount of spectrum available to the service provider and the service provider's business model. Roughly speaking, a service provider with twice as much spectrum needs half as many base stations to provide adequate capacity. Thus, the more spectrum a service provider is licenced to use, the less the need for small cells.

Macrocells are necessary to provide universal coverage and to provide service to rapidly moving users. Only if a wireless service provider did not offer support for mobility or universal coverage could that service provider avoid the need for both macrocells and small cells. As noted above, some appear to hold the view that a commercial wireless system could be build using only distributed antenna systems. Such an architecture would be unable to provide cost-effective service along highways, in urban areas, on waterways, and other locations where macrocells provided the best mix of cost and coverage. Similarly, such a system would have far less capacity than would a system in which small cells replaced many or most of the antennas of the distributed antenna system.

One can imagine a wireless service that used only small cells, that was designed to provide service only to stationary users, and that lacked coverage outside of built-up areas. However, such a service would be much like modern Wi-Fi hotspot services such as those offered by Rogers or Bell Canada. But, if a carrier wants to offer a Wi-Fi-like service, there is no point in paying for licenced spectrum—unlicenced spectrum provides acceptable service and is free. Thus, any commercial wireless system operating on licenced spectrum can be expected to use macrocells to provide universal coverage and coverage to users.

The most important small cells are those inside commercial buildings and residences. They are located near the places where most high-speed data communications and telephone calls occur.

The option of allowing customers to roam onto other operators' networks is another possible substitute for small cells in some circumstances.

7 Antenna Site Choices

The fourth question posed by counsel is:

> *Is access to utility poles necessary in order to facilitate the deployment of small cell and distributed antenna system networks in urban areas and, if so, to what extent? Are there alternatives to utility poles to facilitate that deployment and, if so, please assess the relative advantages and disadvantages of each alternative (including utility poles).*

No, as a general matter access to utility poles is not necessary or essential to the deployment of small cells. No doubt there will be a few locations, such as a stretch of road with no other structures, where utility poles will be the best location for a small cell site. But in most areas where small cells will be needed, utility poles are one of many possible locations for small cell antennas. Other locations include the side of buildings and other structures or inside buildings. Putting small cells on or inside buildings has several advantages:

- Most buildings today have high-speed Internet connections that can be used for backhaul from the cell site to the switching center.
- Buildings are wired for electrical power.
- Buildings often provide easy access to base stations for service or replacement. (In contrast, servicing equipment on a utility pole requires sending a truck to the site and staff trained in operation of a bucket truck or pole climbing as well as trained on safety procedures for working on poles.)
- Small cells within buildings provide better in-building coverage.
- Equipment inside buildings is protected against extremes of temperature and weather.

Table 1 displays small cells in the context of other methods for expanding capacity, along with the relationship of each method to utility pole access.

Table 1. Wireless Capacity Growth and Pole Access

Method of Expanding Capacity	Implications for Utility Pole Access
Cell Splitting with Macrocells	Reduces need for pole access
Additional Spectrum	Reduces need for pole access
Improved Technology	Reduces need for pole access
Indoor Small Cells	Reduces need for pole access
Indoor DAS	Reduces need for pole access
Outdoor Small Cells	Benefits from pole access
Outdoor DAS	Benefits significantly from pole access; benefits more than small cells.
Demand Management (pricing or usage caps)	Reduces need for pole access
Wi-Fi Offloading (Indoors)	Reduces need for pole access
Wi-Fi Offloading (Outdoors)	Benefits from pole access

Another claimed benefit of pole access is that it affords access to a regular, uniform, and contiguous set of support structures. It is true that uniformly spaced transmitter sites make radio coverage planning easier. However, radio-propagation is a complex process, and radio coverage depends on many factors—land cover, topography, building type and location, whether cars or trucks are parked on the street, and so on. Uniform physical spacing of transmitters does not mean that the coverage from each transmitter is identical.

Although planning for randomly located transmitter sites is more difficult than for evenly spaced sites, small cell deployments in offices and residences is essentially random—at least random from the point of view of a network planning engineer. Given that service providers must deal with such irregular small cell locations, the industry has developed tools to deal with such random deployments. The wireless industry uses the term *self-organizing networks* (SON) to refer to tools and capabilities for efficient utilization of randomly located small cells complementing a macro cell network. The Wikipedia article on self-organizing networks provides an overview of this technology and pointers to further references. SON technology, part of the LTE standard since Release 8, more than makes up for any advantage of regularly spaced over randomly spaced small antenna systems. The earlier cited paper by Ghosh et al. also provides an overview of SON technology.

Ghosh and his co-authors address the use of small cells on utility poles (they use the term *street poles*). They noted two main benefits of small cells on utility poles: (1) proximity to pedestrians in areas where people tend to congregate and (2) negotiating with a single property owner.[48] They also identify difficulties with using utility poles, the most important of which were the cost of backhaul and the difficulties in supplying power; esthetic impacts were a third issue.[49]

Recall that distributed antenna systems require a dedicated connection—fiber or coaxial cable—between the antenna and the base station transmitter. Installing such dedicated connections for distributed antenna systems inside a single building is relatively easy. Fiber or coaxial cable can be run in the building's risers and above the ceiling. In contrast, there is no similarly easy way to install the necessary dedicated connections for a distributed antenna system intended to serve an outside area.[50]

Utility poles supporting cables often offer a convenient way to provide the direct connections back to the transmitter needed by distributed antenna systems. For example, it may be possible to run fiber from pole to pole in the communications space on the poles. In contrast, running fiber from one building to another may require trenching or tunneling as well as penetration of the building walls. Such tasks are costly. Thus, access to such utility poles appears to provide advantages with respect to distributed antenna systems when compared to installing the antenna units of distributed antenna systems on the outside of buildings.[51] Some utility poles, such as

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48 Ghosh et al., op cit. at p. 61.

49 They stated, "but providing wired backhaul using fiber from street level picos [small cells] to the core network may be cost prohibitive compared to wireless backhaul. However, wireless backhaul has its own set of issues which are described below." And, "However, two vexing issues associated with street pole pico [small cell] deployments are: electric power and aesthetics" (p. 61).

50 This statement is not true for firms, such as Bell, that have an extensive fiber network that they can connect to at outside locations. Note also that such fiber networks do not naturally pair with utility poles. Telecommunications cables and electrical cables are usually routed in different conduits and are accessed at separate manholes. Running communications fiber to a pole not already connected to the communications network may be as difficult as running fiber to a new building.

51 As noted, firms that have existing fiber networks with spare capacity could use those networks to connect antennas back to the transmitter. Such firms would benefit less from the option to run fiber in the communications space than would an entrant that did not have a fiber network.

street lights fed by underground electricity and not used to support wire and cables, do not provide this advantage because the lack of aerial cable connections makes backhaul more costly.

Table 2 compares the attributes of several locations for small cells.

Table 2. Comparison of Alternate Sites for Small Cells

Attribute	Utility poles	Inside residences and commercial buildings	Outside residences and commercial buildings	Wireless towers
Indoor coverage	Adequate	Superior	Adequate	Adequate
Outdoor coverage	Superior	Usually adequate[52]	Superior	Superior
Access to backhaul	Inferior. May require installation of fiber or microwave backhaul equipment.[53]	Superior	Superior	Superior
Access to electric power	Variable. Inferior if battery storage or a step-down transformer is required.[54]	Superior	Superior	Superior
Backhaul cost	Higher[55]	Lower	Lower	Lower
Hardware cost	Higher	Lower	Higher	Higher
Installation and servicing costs	Highest[56]	Low	Higher[57]	Higher

52 See note 13 above.

53 See Ghosh et al., op. cit. at p. 6. Note that access to backhaul may not be difficult at jointly-used utility poles that already carry fiber for a cable system or a telephone company. In such situations, the cable company or telephone company may find the option of placing small cells on utility poles attractive.

54 Some street lights are bank switched—a single switch turns off power to many poles at once. Wireless equipment located on poles with such bank switched power need either a separate source of power or a battery that can be charged while the street lights are on and that can power the equipment while the street lights are off during the day. See also Ghosh et al.

55 See Ghosh et al.

56 Installation and servicing of units mounted on utility poles typically requires use of a bucket truck or other equipment for working on poles and technicians trained to work safely on utility poles. See the various requirements for technician qualifications, preapproval of designs, inspection, and recordkeeping in *Guideline for Third Party Attachments,* Ontario Regulation 22/04, Electrical Safety Authority, October 5, 2005.

57 This cost varies greatly. Putting a small cell 15 feet above ground on the side of a two-story wooden building would be relatively low cost. Putting one 60 feet above ground on the side of a larger building would be much more expensive.

This table shows that utility poles are inferior to the alternative choices for small cell sites on many important attributes including the cost of installation, the cost of service, and the cost of backhaul. There is no attribute for which small cells mounted on utility poles are superior to small cells mounted on the sides of buildings (or put in a window).

A similar analysis could be done for distributed antenna systems and it would reach the same general conclusions. The analysis for distributed antenna systems would also need to take into account the organization of a distributed antenna system. Recall that the antennas of a distributed antenna system need to be connected back to the base station using dedicated fiber or cable. This connection is not comparable to the backhaul connections of small cell base stations. Rather, it must be a high-bandwidth link—one capable of carrying the analog radio signals from the base station transmitter. Thus, these connections between the DAS antenna and the DAS base station must be fiber or coaxial cable that runs between the antenna and the base station. Connections that could be used with small cell base stations such as those provided by local area networks or the public Internet will not suffice. Thus, it will be the case that distributed antenna systems are far more likely to require purpose-built connections between the antenna and the base station. In contrast, the base stations of small cells will often be connected to existing data networks.

There are likely to be instances in which in which poles might be more valuable for a distributed antenna system than is indicated by the general analysis of Table 2. One such situation would be if a wireless service provider could run fiber or coaxial cable from pole to pole in the communications space in order to provide the dedicated connections needed between the antennas and the base station. And, there might be situations in which a distributed antenna element could be used to fill-in the coverage of a cell. In some such cases, say along a sunken highway, a utility pole or two overlooking the highway might be a more useful site than indicated in the above analysis for small cells.

Nevertheless, given the analysis shown in Table 2, one would expect to rarely find wireless firms installing small cells or the antennas of distributed antenna systems on utility poles in situations in which an alternative was available. As noted above AT&T's announced construction plan will build small cells and distributed antenna systems at a forty to one ratio—small cells are by far the preferred solution.

8 Observations and Conclusions

Small cells are important building blocks in wireless networks and are expected to become more important in the future. Small cells are not a substitute for macrocells; rather they complement macrocells. Macrocells provide widespread, essentially universal coverage in urban areas. Macrocells also provide connectivity to handsets in cars or trains that are moving too fast to be served from small cells. Small cells reduce the load on macrocells, permitting macrocells to be used for those applications for which they are best suited. Small cells also allow the use of other spectrum, such as that used by Wi-Fi, that is unsuitable for macrocells.

Utility poles are one of many possible places to locate small cells. But, in most locations where used density is high enough to justify the use of small cells, alternative sites are available that provide more convenient access to power and backhaul connections. The most important potential locations for small cells are inside buildings where backhaul and electric power are available and where much of the demand for wireless services occurs. Small cells mounted in windows or on the sides of buildings can provide coverage outside the building. The use of utility poles as locations for small cells faces significant issues with respect to power, backhaul, and esthetics.

Attachment A Materials Considered

https://en.wikipedia.org/wiki/Electromagnetic_spectrum

http://www.ertyu.org/steven_nikkel/cancellsites.html

http://cwta.ca/wordpress/wp-content/uploads/2013/01/SubscribersStats_en_2012_Q3.xlsx-Legal.pdf.

Telephone Service Survey, December 2010, Statistics Canada.

http://www.samsung.com/us/mobile/cell-phones/SCS-26UC4.

http://support.verizonwireless.com/pdf/network_extender_user_manual.pdf

*Alcatel-*Lucent *Metro Cells: Placing Coverage and Capacity Where It's Needed*, Alcatel-Lucent, 2012.

Datasheet for Alcatel-Lucent 9363 Metro Cell Indoor V2, 2011.

Neighborhood Small Cells and UltraSON Open for LTE, QUALCOMM Technologies, 2013

The Wi-Fi Evolution, April 2013, QUALCOM. .

http://www.smallcellforum.org/newsstory-femto-forum-becomes-small-cell-forum-as-femtocell-technology-extends-beyond-the-home.

"The Design and Implementation of a UHF Radio System Using Distributed Antennas, Passive Reflectors and Two-way Signal Boosters in a Room and Pillar Limestone Mine," Isberg, R.A. ; Cawley, J.C. ; Chufo, R.L., Vehicular Technology Conference, 1982. 32nd IEEE, Digital Object Identifier: 10.1109/VTC.1982.1623028. 1982, pp. 259–267.

Distributed Antennas for Indoor Radio Communications," Saleh, A.A.M. ; Rustako, A.J. ; Roman, R., IEEE *Transactions on Communications*, 1987, Vol. 35, No. 12, pp. 1245–1251, Digital Object Identifier: 10.1109/TCOM.1987.1096716.

QUALCOMM press release, "QUALCOMM Now Sampling Industry's Most Comprehensive Femtocell Chipsets, FSM9xxx-Series Chipsets Offer Unprecedented Performance, Interference Management and More," San Diego, California, June 22, 2010.

"Economical Comparison of Enterprise In-Building Wireless Solutions Using DAS and Femto," Zhen Liu; Kolding, T.; Mogensen, P.; Vejgaard, B ; Sorensen, T., *IEEE Vehicular Technology Conference (VTC Fall)*, 2012, pp 1–5, Digital Object Identifier: 10.1109/VTCFall.2012.6399316.

http://www.att.com/Common/about_us/pdf/network_investment_infographic.pdf. 2013.

http://www.att.com/gen/press-room?pid=23971.

http://www.wi-fi.org/about/wi-fi-brand.

*RSS-*210 – *Licence-exempt Radio Apparatus (All Frequency Bands): Category I Equipment*, Issue 8, December 2010, Spectrum Management and Telecommunications Radio Standards Specification, Industry Canada.

Low-power Licence-exempt Radio Communications Devices — Frequently Asked Questions at

http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08655.html

http://www.bell.ca/Bell_Internet/Bell-Wifi-Internet-Locations.

Affidavit of Dr. Adonis Yatchew sworn September 1, 2011
Toronto Hydro-Electric System Limited
Notice of Motion, Volume 1, Exhibit 2
Filed September 2, 2011
EB-2011-0120

Affidavit of Michael Starkey sworn September 1, 2011
Toronto Hydro-Electric System Limited
Notice of Motion, Volume 1, Exhibit 1
Filed September 2, 2011
EB-2011-0120

Evidence of Ms. Johanne Lemay,
Lemay-Yates Associates Inc.;
Prefiled Evidence of CANDAS
Filed July 26, 2011
EB-2011-0120

Reply Evidence of CANDAS
"Reply Comments on the Evidence presented by THESL and CEA in the OEB Matter Related to the CANDAS Application REPORT Presented to CANDAS"
by Ms. Johanne Lemay,
Lemay-Yates Associates Inc.
Filed October 11, 2011
EB-2011-0120

Ontario Energy Board Decision On Preliminary Issue And Order, EB-2011-0120 dated September 13, 2012

Reply Evidence of CANDAS
"Reply Evidence of Tormod Larsen"
Filed October 11, 2011
EB-2011-0120

Canadian Cable Television Association Proceeding (March 7, 2005), RP-2003-0249, online: Ontario Energy Board http://www.ontarioenergyboard.ca

“Outdoor Distributed Antenna Systems and their role in the Wireless Industry,” LCC International Inc., evidence of the Canadian Electricity Association (the CEA) in EB-2011-0120, September 2, 2011.

In addition to the materials listed above, I performed a number of search on the IEEE Digital Library for terms such as “small cell,” “distributed antenna system,” and “tunnels.”

I performed web searches using the Google search tool for similar terms.

I performed searches on the Industry Canada website for similar terms.

Attachment B   Professional Biography of Dr. Charles L. Jackson

Dr. Jackson received a B.A. degree from Harvard College in Applied Mathematics and the degrees of M.S., E.E., and Ph.D. in Electrical Engineering from the Massachusetts Institute of Technology. At MIT, he specialized in operations research, computer science, and communications. While a graduate student at MIT, he held the faculty rank of Instructor, was a teaching assistant in graduate operations research courses, and codeveloped an undergraduate course in telecommunications.

Dr. Jackson began his career as a computer programmer and worked as both a systems programmer and digital designer. In government, he worked at the Federal Communications Commission and as staff engineer for the Communications Subcommittee of the U.S. House of Representatives. Since leaving government, he has worked as a consultant and a professor. Currently, Dr. Jackson provides consulting services as JTC, LLC, and is an adjunct professor at George Washington University.

Dr. Jackson has written extensively on radio spectrum management and policy, and has consulted on radio spectrum management for the governments of New Zealand, Germany, and Panama.

Dr. Jackson has provided a wide variety of expert witness services, primarily in patent litigation and telecommunications regulation. His expert witness testimony has included analyses of computer software to determine whether patent-infringing elements exist in that software and to determine the relatedness of various bodies of software in copyright/trade secret disputes.

Dr. Jackson has authored or coauthored numerous studies on public policy issues in telecommunications and has testified before Congress on technology and telecommunications policy. Over the last several years, he has also directed or participated in projects on acquisition analysis, market planning, and product pricing. He has written for professional journals and the general press, with articles appearing in publications ranging from *The IEEE Transactions on Computers* to *Scientific American* to *The St. Petersburg Times*. He holds two U.S. patents. Dr. Jackson was appointed by the Secretary of Commerce to the Commerce Department's Spectrum Planning and Policy Advisory Committee and by the Chairman of the FCC to the FCC's Technological Advisory Council (TAC).

Dr. Jackson is a member of the IEEE, the American Mathematical Society, and Sigma Xi. He is an adjunct professor of computer science at George Washington University, where he has taught graduate courses on mobile communications, wireless networks, computer security, and the Internet and an undergraduate course on programming. From 1982 to 1988, he was an adjunct professor at Duke University.

EDUCATION

Massachusetts Institute of Technology
Ph.D., Electrical Engineering, 1977
M.S. and E.E., Electrical Engineering, 1974

Harvard College
B.A., Honors in Applied Mathematics, 1966

EMPLOYMENT

1997–present	**Consultant.** Provides consulting services in telecommunications and information technologies and public policy, and expert witness services in litigation. Also an adjunct professor in the Department of Computer Science at George Washington University.
	Strategic Policy Research, Inc. (SPR), Bethesda, MD
1992–1997	**Principal.** Provided telecommunications and public policy consulting services for a variety of clients in the telecommunications industry.
	National Economic Research Associates, Inc. (NERA), Washington, DC
1989–1992	**Vice President.** Provided telecommunications and public policy consulting services for a variety of clients in the telecommunications industry.
	Shooshan & Jackson Inc., Washington, DC
1980–1989	**Principal.** Provided telecommunications and public policy consulting services for a variety of clients in the telecommunications industry.
	Communications Subcommittee, U.S. House of Representatives, Washington, DC
1977–1980	**Staff Engineer**. Was responsible for common carrier legislation and spectrum-related issues.
	Common Carrier Bureau, Federal Communications Commission, Washington, DC
1976–1977	**Special Assistant to Chief**. Was responsible for technological issues and land mobile policy.
	Federal Communications Commission, Washington, DC
1975–1976	**Engineering Assistant to Commissioner Robinson.**
	CNR, INC., Boston, MA
1973–1976	**Consultant.** Worked on the implementation of digital communication systems over dispersive channels.

	Massachusetts Institute of Technology, Cambridge, MA
1973–1976	**Instructor.**
1971–1973	**Research and Teaching Assistant.**
	Signatron, Lexington, MA
1968–1971	**Research Engineer**.
	Stanford Research Institute, Menlo Park, CA
1966–1968	**Programmer.**

PROFESSIONAL ACTIVITIES

Member, Sigma XI, Institute of Electrical and Electronics Engineers (IEEE), IEEE Computer Society, IEEE Communications Society, IEEE Information Theory Society, American Association for the Advancement of Science, and the American Mathematical Society.

Member of the examination drafting committee for the IEEE Wireless Communications Technologies (WCET) examination (2008–present).

Conference Organizer, *The Genesis Of Unlicensed Wireless Policy: How Spread Spectrum Devices Won Access to License-Exempt Bandwidth*, held at George Mason Law School, April 4, 2008.

Guest Editor of special issue on spectrum resource optimization, *Journal of Communications Networks* (JCN), 2006.

Member, Federal Communications Commission Technological Advisory Committee. (1998–2004). Chair, Spectrum Working Group (1998–2000).

Member, U.S. Department of Commerce Spectrum Planning and Policy Advisory Committee. (1995–2002).

Executive Committee Member, University of Florida's Public Utility Research Center (PURC) (1991–2007).

Chairman, IS/WP1 (Policy and Regulation) of the FCC's Advisory Committee on Advanced Television. (1989–1992).

From 1987–1988, served on the Board of Directors of the Telecommunications Policy and Research Conference. Chairman of the Board, 1988.

RECENT PUBLICATIONS and REPORTS

"Coase and the New Zealand Spectrum Reforms," *Journal of Law and Economics*, Vol. 54, No. 4, November 2011, pp. S189-S205, DOI: 10.1086/661940

With Robert W. Crandall, "Antitrust in High-Tech Industries," *Review of Industrial Organization,* Vol. 38, No. 4, June 1, 2011. Doi: 10.1007/s11151-011-9298-4. An earlier version was a Technology Policy Institute Report, January 5, 2011.

"Wireless Efficiency versus Net Neutrality," FCLJ Special Issue on Integrating Engineering Principles into Internet Policy Debates, *Federal Communications Law Journal,* Vol. 63, No. 2, March 2011.

Letter to the Editor, *IEEE Communications Magazine,* Vol. 48, No. 1, p. 18, January 2010.

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"The Genesis of Unlicensed Wireless Policy," Guest Editorial, *info*, Vol. 11, No. 5, August 2009.

The Significance of Next Generation Networks Reconsidered, prepared for TELUS, July 29, 2008.

Equipment Operator Personalization Device, U.S. Patent 7,096,619. Describes a means for securing a piece of hand-held equipment so that it is easily activated by an authorized user while, at the same time, individuals without proper authorization cannot easily active the equipment.

With Michael M. Marcus, Fredrick Matos, William Webb, and K. J. Wee. "Spectrum Resource Optimization in Context," *Journal of Communications and Networks,* Vol. 8, No. 2, June 1, 2006 (Guest Editorial).

Wireless Handsets Are Part of the Network, International Telecommunications Society, 16th Biennial Conference, June 2006, Beijing, China.

With Raymond Pickholtz and Dale Hatfield. "Spread Spectrum Is Good—But It Doesn't Obsolete NBC v. US!," *Federal Communications Law Journal,* April 2006, Vol. 58, No. 2.

Dynamic Sharing of Radio Spectrum: A Brief History, IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks, November 9, 2005. Baltimore, MD.

Limits to Decentralization: The Example of AM Radio Broadcasting or Was a Common Law Solution to Chaos in the Radio Waves Reasonable in 1927? Telecommunications Policy Research Conference, September 24, 2005, Arlington, VA.

With Tarek Saadawi et al. *Telecommunications Liberalization Policy in Egypt*, prepared for the Egypt Ministry of Communications and Information Technology, August 2005.

Quantifying the Cost of Radio Interference, 2004 WNCG Wireless Networking Symposium, October 20–22, 2004, Austin, TX.

Limits to the Interference Temperature Concept, prepared for Verizon, April 4, 2004.

An Overview of VoIP, prepared for TELUS, June 18, 2004.

A Quick Introduction to Voice over Internet Protocol, University of Florida Public Utilities Research Center, February 2004.

With Robert W. Crandall. "The $500 Billion Opportunity: The Potential Economic Benefit of Widespread Diffusion of Broadband Internet Access," in *Down to the Wire: Studies in the Diffusion and Regulation of Telecommunications Technologies*, Allan L. Shampine, Ed., Nova Science Press, 2003.

"Wired High-Speed Access," Chapter 5 of *Broadband Should We Regulate High-Speed Internet Access?* Robert W. Crandall and James H. Alleman, Eds., AEI-Brookings Joint Center for Regulatory Studies, 2002, ISBN 0-8157-1591-9.

CLECs' Choices for Local Switching. Prepared for Bell South, July 2002.

With Christopher Weaver. "Boss Hogg and the Out-of-Town Geek," *ZDNet*, August 23, 2001.

The Likely Evolution of Local Communications. Prepared for TELUS, July 15, 2001.

RECENT SPEECHES AND PRESENTATIONS

Implications of Technical Issues for Auction Design, Presented at Stanford Institute for Economic Policy Research, Conference on the FCC Incentive Auction, Stanford University, Stanford California, February 26, 2013.

Observations on the Promise and Problems of Strategic Plans: From the Spectrum Policy Task Force to the PCAST Report, Presented at Looking Back to Look Forward: The Next Ten Years of Spectrum Policy a Silicon Flatirons Center conference, Pew Charitable Trusts Conference Center, Washington DC, November 13, 2012.

Spectrum Markets: Challenges Ahead. Presented at Spectrum Markets: Challenges Ahead, a workshop at Kellogg School of Management, Northwestern University, Evanston, IL. June 3, 2011.

Observations on Networking. Presented at Information Technology and Innovation Foundation Hill Staff Briefing on Network Neutrality, Washington, DC. February 11, 2011.

Antitrust in High-Tech Industries. Presented jointly with Robert Crandall at The Technology Policy Institute Conference Antitrust and the Dynamics of Competition in High-Tech Industries, Washington DC. October 22, 2010.

Participated in panel discussion at Regulatory Developments and Unlicensed Operations in the Television Broadcast Band, Federal Communications Bar Association, CLE session, Washington, DC. October 12, 2010.

Observations on "Neutrality" and Priority. Presented at Role of Managed Services on Broadband Networks, Information Technology and Innovation Foundation, Washington, DC. October 1, 2010.

Observations on Wireless and "Neutrality." Presented at Rough Consensus and Running Code: Integrating Engineering Principles into the Internet Policy Debates, Center for Technology, Innovation, and Competition, University of Pennsylvania Law School, Philadelphia, PA. May 7, 2010.

Coase and the New Zealand Spectrum Reforms. Presented at Markets, Firms and Property Rights—A Celebration of the Research of Ronald Coase, University of Chicago, Chicago, IL. December 4, 2009.

Observations on Network Regulation. Presented to the Information Technology and Innovation Foundation's What Will the Internet of the Future Look Like? Washington, DC. November 2, 2009.

Control of Prison Cell Phones. Presented to the Federal Communications Bar Association Wireless Committee, Washington, DC. October 25, 2009.

Wireless Industry Overview. Presented to the Telecom, Media & Tech Boot Camp, presented by Stifel Nicolaus, Washington DC. September 17, 2008.

A Quick Introduction to Voice over Internet Protocol (VoIP) Presentation to the FCBA's State and Local Practice Committee, Washington, DC. October 22, 2008, *Encouraging Broadband Internet Access in the TV White Space: The Licensed Option,* with Dorothy Robyn, Telecommunications Policy Research Conference (TPRC), Arlington, VA. September 30, 2007.

Licensed Access: The Smarter Policy for TV White Space and Broadband Internet Access, with Dorothy Robyn, Conference on Smart Radio: Smart Markets and Policies, Arlington, VA. April 6, 2007. Also presented at IEEE CrownCom, Orlando, FL. August 2, 2007.

The Cost of Interference, Working Level Group (WLG) E of the President's Spectrum Policy Initiative, Washington DC. April 12, 2005.

Status of Telecom Reform and the Telecom Industry in the United States, National Telecommunications Regulatory Authority, Ministry of Communications and Information, Cairo, Egypt. April 4, 2005.

The Cost of Interference, Interdepartmental Radio Advisory Committee (IRAC), Washington, DC. February 23, 2005.

Observations on Interference Temperature and Underlay Operation, Telecommunications Policy Research Conference, Arlington, VA. October 3, 2004.

Quantifying the Cost of Interference, FCC Technological Advisory Council, Washington, DC. July 28, 2004.

Observations on VoIP, ICT Seminar, Johns Hopkins University. June 22, 2004.

A Quick Introduction to Voice over Internet Protocol, PURC 2004 Annual Meeting, Gainesville, FL. February 12, 2004,

Spectrum Management in Telecommunications, PURC/World Bank Ninth International Training Program on Utility Regulation & Strategy, Gainesville, FL.
January 15–26, 2001.

TESTIMONIES

Witness statements and testimony regarding U.S. Patent Nos. 7,706,830 and 8,009,636 and U.S. Patents Nos. 7,970,127 and 7,536,013, International Trade Commission Investigation No. 337-TA-800, February 12-20, 2013.

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Declaration of Charles L. Jackson in *Re Patent Application Serial No. 12/630,323, Method For Signal Processing And An Apparatus Therefore,* U.S. Patent and Trademark Office, July 6, 2011.

Telephonic testimony of Dr. Charles Jackson in *Alaska Communications Systems v. Department of Education and Early Development, OAH No. 11-0120-PRO*, Before the Alaska Office of Administrative Hearings, June 21, 2011.

Affidavit of Dr. Charles Jackson in *Alaska Communications Systems v. Department of Education and Early Development, OAH No. 11-0120-PRO,* Before the Alaska Office of Administrative Hearings, June 8, 2011.

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Satellite Service Can Help to Effectively Close the Broadband Gap, Attachment to *Comments of ViaSat Inc. in FCC Dockets 10-90, 09-51, 07-135, 05-337, 01-92, 96-45, and 03-103,* April 18, 2011.

Observations on Pole Access for Wireless Carriers, attachment to *CTIA Ex Parte Communication, in FCC WC Docket No. 07-245,* March 18, 2011.

Deposition testimony in WI-LAN, Inc. v. Acer, Inc, et al., CASE NO. 2:07-CV-473-TJW, United States District Court for the Eastern District of Texas, Marshall Division, December 29, 2010.

Deposition testimony in Transcom Enhanced Services, Inc. v. Qwest Corporation. Case No. 4:09-cv-755-A, United States District Court for the Northern District of Texas, Fort Worth Division, December 15, 2010.

Expert witness report in WI-LAN, Inc. v. Acer, Inc, et al., CASE NO. 2:07-CV-473-TJW, United States District Court for the Eastern District of Texas, Marshall Division, December 8, 2010.

Wireless Terminals Are Part of the Network (Updated and revised), attachment to Comments of CTIA to the FCC In the Matter of Preserving the Open Internet Broadband Industry Practices, in GN Docket No. 09-191, WC Docket No. 07-52, Oct 12, 2010.

Review of Transcom's Voice Termination *Service*, expert report in *Transcom Enhanced Services, Inc.* v. *Qwest Corporation.* Case No. 4:09-cv-755-A, United States District Court for the Northern District of Texas, Fort Worth Division, September 13, 2010.

Deposition testimony in Jon Coble and 8Jax Inc. v. Bagli et al. Case CL07-3061, Circuit Court, Henrico County, VA, August 3, 2010.

Testimony in Broz v. Commissioner, U.S. Tax Court Docket No. 21629-06. February 17, 2010.

Testified as a telecommunications and information technologies expert regarding measurements of the levels of cell phone signals in the Georgetown area of Washington, DC. Superior Court of the District of Columbia, January 25, 2010.

Testimony in the Markman Hearing in N2IT Holding B.V., v. M-Audio LLC, Civil Action No. 2:08-cv-00619-HCM-TEM, U.S. District Court for the Eastern District of Virginia, November 6, 2009.

Report on the Validity of the *'184 Patent,* expert report in N2IT Holding B.V., v. M-Audio LLC, Civil Action No. 2:08-cv-00619-HCM-TEM, U.S. District Court for the Eastern District of Virginia, October 30, 2009

Statement on the Meaning of Time-Code Signal as that phrase is used in U.S. Patent 7,201,184, Expert Report in N2IT Holding B.V., v. M-Audio LLC, Civil Action No. 2:08-cv-00619-HCM-TEM, U.S. District Court for the Eastern District of Virginia, October 13, 2009.

Classifying the Plant and Equipment of a Cellular Telephone Carrier for Purposes of Depreciation Accounting, expert report in Broz v. Commissioner, US Tax Court Docket No. 21629-06.

Report on M-Audio's Torq Product, expert report in N2IT Holding B.V., v. M-Audio LLC, Civil Action No. 2:08-cv-00619-HCM-TEM, U.S. District Court for the Eastern District of Virginia, September 24, 2009

Engineering a Reliable and Efficient Internet: Priority Scheduling, Congestion, and Security, attachment to Reply Comments of Verizon and Verizon Wireless on a National Broadband Plan, FCC Docket GN No. 09-51, July 21, 2009.

Technological Considerations Regarding Jamming Wireless Telephone Service, January 6, 2009, attachment to CTIA's Petition for Reconsideration and Request for Referral to the Full Commission, January 6, 2009.

With several others, *ex parte comments regarding Service Rules for Advanced Wireless Services in the 2155-2175 MHz Band and Service Rules for Advanced Wireless Services in the 1915-1920 MHz, 1995-2000 MHz, 2020-2025 MHz and 2175-2180 MHz Bands,* filed in FCC Proceeding 07-195, October 20, 2008.

With David Shively, Ahmad Armand, Randy Leenerts, and Yasmin Karimli, *Ex Parte Comments regarding Testing of AWS-1/ASW-3 Interference,* September 9, 2008, filed in FCC Proceeding 07-195.

The Supply of Spectrum for CMRS, August 19, 2008. Attachment to Joint Opposition to Petitions to Deny and Comments of Verizon Wireless, FCC Docket WT 08-95, August 19, 2008

With Dorothy Robyn and Coleman Bazelon, *Unlicensed Use of the TV White Space: Wasteful and Harmful, August* 20, 2008, comments filed in FCC Proceeding 04-186.

Unlicensed TV White Space Wireless Cannot Provide Substantial Rural Broadband Access, comments filed in FCC Proceeding 04-186, October 22, 2008

Wireless Handsets Are Part of the Network, report attached to CTIA's Opposition to Petition for Rulemaking titled "Petition to Confirm A Consumer's Right to Use Internet Communications Software and Attach Devices to Wireless Networks," FCC RM-11361, April 30, 2007.

Comments of Charles L. Jackson and Dorothy Robyn *In The Matter of Unlicensed Operation in the TV Broadcast Bands*, FCC-ET Docket No. 04-186, January 31, 2007.

Testimony of Dr. Charles L. Jackson in Inline Connection Corporation v. Earthlink et al., C.A. No. 02-477-MPT, C.A. No. 02-272-MPT, United States District for the District of Delaware, February 2007.

Reply comments of Charles L. Jackson and Dorothy Robyn *In The Matter of Unlicensed Operation in the TV Broadcast Bands*, FCC-ET Docket No. 04-186, March 2, 2007.

Statement of Charles L. Jackson in Support of ACS's Ex Parte Submission Filed November 30, 2006, FCC WC Docket No. 05-281, November 30, 2006.

Statement of Charles L. Jackson In Support Of Petition of ACS of Anchorage, Inc.
For Forbearance from Sections 251(C)(3) And 252(D)(1), FCC WC Docket No. 05-281, September 8, 2006.

Deposition of Dr. Charles L. Jackson in Inline Connection Corporation v. Earthlink et al., C.A. No. 02-477-MPT, C.A. No. 02-272-MPT, United States District for the District Of Delaware, July 20–21, 2006.

Deposition of Dr. Charles L. Jackson In the matter of Certain Baseband Processor Chips and Chipsets, Transmitter and Receiver (Radio) Chips, Power Control Chips, and Products Containing Same, including Cellular Telephone Handsets Inv. No. 337-TA-542, U.S. International Trade Commission, May 24, 2006.

Report of Dr. Charles L. Jackson In the matter of Certain Baseband Processor Chips and Chipsets, Transmitter and Receiver (Radio) Chips, Power Control Chips, and Products Containing Same, including Cellular Telephone Handsets Inv. No. 337-TA-542, U.S. International Trade Commission, May 19, 2006.

Declaration of Dr. Charles L. Jackson Regarding Infringement of the ’596, ’446, and ’585 Patents, Inline Connection Corporation v. Earthlink et al., C.A. No. 02-477-MPT, C.A. No. 02-272-MPT, United States District for the District Of Delaware, April 18, 2006.

Testimony of Dr. Charles L. Jackson in Inline Connection Corporation v. Earthlink et al., C.A. No. 02-477-MPT, C.A. No. 02-272-MPT, United States District for the District Of Delaware, March 7, 2006. (Hearing re application of confidentiality order)

Statement of Charles L. Jackson In Support Of Petition of ACS of Anchorage, Inc.
for Forbearance from Sections 251(C)(3) and 252(D)(1), FCC WC Docket No. 05-281, February 23, 2006.

Answers of Dr. Charles L. Jackson incorporated in the submission of TELUS to the Telecommunications Policy Review Panel (Canada), August 15, 2005.

Observations on Bidding Rules, reply comments in FCC WT Docket No. 04-356, May 24, 2005.

Deposition of Dr. Charles L. Jackson, Wireless Telephone Services Antitrust Litigation, 02 Civ. 2637(DLC), Southern District of New York, December 20, 2004.

Report of Dr. Charles L. Jackson, Wireless Telephone Services Antitrust Litigation, 02 Civ. 2637(DLC), Southern District of New York, December 20, 2004.

Declaration of Dr. Charles L. Jackson, *PCS Handset Vulnerability to H-Block Transmissions Interpreting the Test Results,* filed by CTIA in FCC Dockets WT 04-356 and WT 02-353, December 8, 2004.

Testimony in Gerald E. Frugoli, v. Douglas V. Fougnies; et al., CIV 02-957-PHX-RC, United States District Court District of Arizona, June 27, 2004.

Declaration of Dr. Charles L. Jackson Regarding Infringement of the ‘596, ‘446, and ‘585 Patents, in Inline Connection Corporation v. Earthlink et al., C.A. No. 02-477-MPT, C.A. No. 02-272-MPT, United States District for the District Of Delaware, April 16, 2004. (Confidential)

Declaration of Dr. Charles L. Jackson, in Inline Connection Corporation v. Earthlink et al., C.A. No. 02-477-MPT, C.A. No. 02-272-MPT, United States District for the District Of Delaware, April 5, 2004.

Affidavit of Dr. Charles L. Jackson, in Proceedings related to the Public Utility Commission’s February 16, 2004 Section 34(3) Notice to Cable Bahamas Limited.

Declaration of Dr. Charles L. Jackson, in Inline Connection Corporation v. Earthlink et al., C.A. No. 02-477-MPT, C.A. No. 02-272-MPT, United States District for the District Of Delaware, February 9, 2004.

Declaration of Dr. Charles L. Jackson , in Cellco Partnership (d/b/a Verizon Wireless) v. Nextel Communications, Inc., Civil Action No.: 03 CV 839-A**,** United States District Court for the Eastern District of Virginia, January 12, 2003

Rebuttal report of Dr. Charles L. Jackson, in Cellco Partnership (d/b/a Verizon Wireless Firm) v. Nextel Communications, Inc., Civil Action No.: 03 CV 839-A**,** United States District Court for the Eastern District of Virginia, December 22, 2003.

Deposition testimony in Freedom Wireless Inc. vs. Boston Communications Group Inc. et al., 00-12234-EFH , United States District Court, District of Massachusetts, December 19, 2003

Report of Dr. Charles L. Jackson in Response to the Expert Reports of Dr. Richard C. Levine and Mr. Charles Gholz in Freedom Wireless Inc. vs. Boston Communications Group Inc. et al., 00-12234-EFH , United States District Court, District of Massachusetts, August 29, 2003

Report of Dr. Charles L. Jackson Regarding Processing of Incoming Calls as Described in U.S. Patent 6,157,823, in Freedom Wireless Inc. vs. Boston Communications Group Inc. et al., 00-12234-EFH, United States District Court, District of Massachusetts, June 23, 2003

Deposition testimony in Gerald E. Frugoli, v. Douglas V. Fougnies; et al., CIV 02-957-PHX-RC, United States District Court District of Arizona, June 17, 2003

Second report of Dr. Charles L. Jackson in Gerald E. Frugoli, v. Douglas V. Fougnies; et al., CIV 02-957-PHX-RC, United States District Court District of Arizona, June 2, 2003

Testimony in GE-Harris Railway Electronics, L.L.C., and GE-Harris Railway Electronics Services, L.L.C., v. Westinghouse Air Brake Company, Civil Action No. 99-070 GMS, U.S. District Court for the District of Delaware, May 13, 2003.

Deposition testimony in GE-Harris Railway Electronics, L.L.C., and GE-Harris Railway Electronics Services, L.L.C., v. Westinghouse Air Brake Company, Civil Action No. 99-070 GMS, U.S. District Court for the District of Delaware, April 24, 2003.

Testimony of Dr. Charles L. Jackson in CBS Broadcasting et al. v. EchoStar Communications et al., Case No. 98-2651-CIV-Dimitrouleas/Seltzer, U.S. District Court For the Southern District of Florida, April 21, 2003.

Report on Inventorship in Gerald E. Frugoli, v. Douglas V. Fougnies; et al., CIV 02-957-PHX-RC, United States District Court District of Arizona, April 1, 2003.

Report of Dr. Charles L. Jackson, GE-Harris Railway Electronics, L.L.C., and GE-Harris Railway Electronics Services, L.L.C., v. Westinghouse Air Brake Company, Civil Action No. 99-070 GMS, U.S. District Court for the District of Delaware, March 21, 2003.

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Testimony in BSC de Panamá, S.A. contra Tricom Panamá S.A., March 7, 2003, Panamá, March 13, 2003.

With Ramón Mouynés, Informe Pericial, BSC de Panamá, S.A. contra Tricom Panamá S.A., March 7, 2003, Panamá. (In Spanish)

Testimony of Dr. Charles L. Jackson Regarding Xentex's Flip-Pad Voyager Computer in Xen Investors, LLC v. Xentex Technologies, In the Court of Chancery for the State of Delaware in and for New Castle County, C.A. No. 19713 NC., March 5, 2003.

Deposition of Dr. Charles L. Jackson Regarding Xentex's Flip-Pad Voyager Computer in Xen Investors, LLC v. Xentex Technologies, In the Court of Chancery for the State of Delaware in and for New Castle County, C.A. No. 19713 NC., February 26th, 2003.

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Summary of Opinions of Dr. Charles L. Jackson in CBS Broadcasting et al. v. EchoStar Communications et al., Case No. 98-2651-CIV-Dimitrouleas/Seltzer, U.S. District Court For the Southern District of Florida, February 7, 2003.

Deposition testimony of Dr. Charles L. Jackson In re: IN-SYNC INTERACTIVE/MONTEREY, INC., Debtor-in-Possession. IN-SYNC INTERACTIVE/AKRON, INC., et al., v. FEDERAL COMMUNICATIONS COMMISSION, Defendants Case No. LA 01-42617-ES Chapter 11, Adversary No. AD 01-02529-ES, January 30, 2003.

Deposition testimony of Charles L. Jackson in Isp.Net Llc D/B/A IQuest Internet V. Qwest Communications International, case No. IP01-0480-C B/S United States District Court, Southern District Of Indiana, Indianapolis Division, January 24, 2003.

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Statement on personal communications service (PCS) before the Federal Communications Commission Personal Communications Services Task Force Meeting, Docket 90–314. April 12, 1994.

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Testimony on Freedom of Expression and the Electronic Media: Technology Issues before the Committee on Commerce, Science and Transportation, U.S. Senate. September 28, 1982.

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Testimony on Electronic Mail before the Postal Operations and Service Subcommittee, U.S. House of Representatives. May 5, 1977.

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