Memorandum

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Subject: **Preliminary Analysis of the State of Broadband Internet Connectivity in the Durham Region**

Preliminary Analysis of the State of Broadband Internet Connectivity in the Durham Region

By Reza Rajabiun, LLM, PhD

Executive Summary

The Regional Municipality of Durham is in the process of evaluating the state of broadband Internet connectivity available to its residents, businesses, and public-sector organizations, with the objective of using this knowledge to develop a broadband strategy. Based on measurements from a large-scale standards-based network testing platform, this report provides a high-level overview of the state of Internet connectivity and quality of broadband services service providers deliver in the Durham Region. We also benchmark the state of the network in the Durham Region relative to other parts of the Greater Toronto and Hamilton Area (GTHA).

The analysis documents that connection speeds and user quality of experience indicators in some of the urban parts of the Durham Region are among the highest in the GTHA. There are however areas with particularly low service quality both in rural and some urban parts of the Region. Gaps are particularly pronounced in northern and eastern parts of Durham, where average measured connection speeds users experience are about half of those users experience in some of the newer urban areas in the southeast of the Region.

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Preliminary Analysis of the State of Broadband Internet Connectivity in the Durham Region

I. Context, Methodology, and Data:

1. **Motivation:** While Ontario and Canada were recognized as early international leaders in expanding access to high-speed Internet connectivity, over the past decade it has become increasingly clear that Canada is falling behind many other advanced economies in terms of measured broadband speeds, private sector incentives to deploy next generation fiber-to-the-premises (FTTP) technologies, and affordability of high-speed data services.[1] Recognizing these trends, municipal and business stakeholder in the Greater Toronto and Hamilton Area (GTHA) have identified broadband Internet connectivity as a major concern and called on the province to ensure the region develops broadband infrastructure that is at least equal to other globally competitive jurisdictions.[2] At the same time, some communities and regional governments around the GTHA are studying the state of connectivity in their communities to identify and validate gaps with the aim of developing effective strategies for encouraging investments in ultra-high speed next generation fiber-to-the-premises (FTTP) broadband technologies to businesses and residents. Durham Region is currently engaged in a broadband infrastructure mapping and strategy development process.

2. **Scope:** This report provides a high-level overview of the state of broadband connectivity in the Durham Region using data from the large-scale standards-based Internet measurement testing platform developed by Measurement Lab (M-Lab)/Google.[3] Building on previous research conducted by this author on the state of Internet connectivity in Ontario and the GTHA,[4] the analysis of measured/actual connection speeds and service quality levels in Durham complements ongoing efforts by the Region to research and map advertised speeds that Internet service providers claim are available to residents and businesses in particular areas. While likely to be correlated, effective bandwidth and service quality levels that users experience on congestion prone infrastructure tends to vary substantially from advertised maximum speeds that might be theoretically available in a particular area (e.g. due various factors including capacity under-provisioning, distance from the node, availability of legacy copper and fixed wireless/satellite v. faster cable or FTTP "last mile" technologies, etc.). In this report we document measured connection speeds and service quality levels based on user-initiated tests,

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[1] Rajabiun, R., & Middleton, C. (2017). Regulatory Federalism and Broadband Divergence: Implications of Invoking Europe in the Making of Canadian Telecom Policy. *Intereconomics*, *52*(4), 217-225. https://www.ceps.eu/system/files/IEForum42017_5.pdf

[2] See e.g. http://www.occ.ca/wp-content/uploads/OCC-Broadband-Letter-07-18-161.pdf ; http://www.newmarket.ca/TownGovernment/Documents/Mayor%27s%20Speeches%20and%20Presentations/Newmarket%20Chamber%20-%20Mayor%27s%20speech%20-%20April%2022%202016%20-%20Website.pdf

[3] https://www.measurementlab.net/

[4] Rajabiun, R. (2017) State of Broadband Internet Infrastructure and Strategies for Improving Connectivity In The Greater Toronto and Hamilton Area (GTHA). Government of Ontario, Ministry of Infrastructure.

which allows us to benchmark and map the state of connectivity as experienced by Durham residents.

3. **Limitations:** Ideally, to develop an empirically driven approach to broadband infrastructure development policy a combination of indicators capturing inputs (e.g. capital expenditures, distribution and capacity of physical assets) and market outcomes (e.g. quality and affordability) would be required. These indicators can then be mapped in a fine-grained manner in order to identify and address existing and emerging concerns about outcomes, either by operators themselves or through some form of public sector initiative when market forces appear inadequate for delivering the socially desirable outcomes (e.g. targeted supply or demand side subsidies, direct public investment in essential transport and access facilities, structural measures, etc.). In practice, however, disaggregated information about investment inputs, physical assets, and service pricing and quality of service is extremely valuable to operators and considered confidential. This creates an information asymmetry that limits the scope for empirically driven policy decisions, particularly by lower levels of government with limited legal capacity to compel disclosure of material information from private entities regulated under central government jurisdiction.

4. One way of addressing this problem with respect to physical infrastructure is for local authorities to conduct surveys around their communities to be able to benchmark what they have, identify gaps, and plan for the future. While necessary in the design and implementation of broadband initiatives, such surveys are resource intensive and only what can be seen can be mapped independently in the absence of cooperation by operators. As in the case of capital expenditures, maps of physical assets would at best offer an indicator of inputs into the determinants of connectivity and not a reliable measure of market outcomes experienced by users.

5. **"Big data" Internet measurements**: Development of tools and large scale broadband network performance testbeds increasingly allow users, technology companies, and policymakers to overcome this information asymmetry. There is a wide range of such tools available with distinct methodologies, capabilities, and uses. In contrast to financial or technical indicators of inputs that are hard to construct at a disaggregated level due to confidentiality considerations, Internet measurements tests allow those who do not control networks to gain a window into their operations. Users can employ these tools to evaluate speeds their operator is delivering and to compare their options in the market. For telecom investors, network performance indicators offer a method for identifying under-served markets, undervalued/overvalued assets, and to optimize their entry/exit strategies accordingly. This type of information is also highly valuable to technology companies that require high-quality connectivity in order to be able to deliver Internet applications and services from the so-called "cloud" to their customers. For economic policymakers trying to ensure broadband infrastructure of sufficient quality and affordability is available to support the digital economy and information technology intensification, "big data" on the operations of the infrastructure offers a unique window into the evolution of connectivity.

6. Different testing methodologies tend to generate substantially different results in terms of speed measurements across jurisdictions and operators.[5] From an analytical perspective, this is valuable because it suggests they offer distinctive and potentially complementary information about a multilayered and fast evolving world of broadband connectivity. In terms of measured speeds, results from Speedtest/Ookla tend to be substantially higher than those generated by two other commonly cited sources of global speed measurements, Akamai Technologies State of the Internet Report and the Measurement Lab (M-Lab) Network Diagnostic Test (NDT), which is sponsored by Google and various independent research institutions.[6] There are a number of well-known methodological reasons for these differences, which are beyond the scope of this report to discuss in detail.[7]

7. **Open data and multilevel coordination:** In this report, we use data from the M-Lab/NDT test to benchmark and map the state of connectivity in the Durham Region. There are a number of reasons for this, including its standards-based open data approach to the problem of Internet measurements, its widespread use in research and policy debates, and its relatively large sample size for Canada (e.g. approximately 400,000 tests in the GTHA in 2016). The Canadian Internet Registration Authority (CIRA) has adopted the M-Lab testing platform and operates servers that run the NDT tests, data from which is then compiled in the open data repository maintained by M-Lab.[8] Consequently, the open and standardized approach to M-Lab data collection makes it particularly relevant as a basis for policy development that requires mapping and coordination across multiple levels of government.

8. **Potential sources of error:** In terms of absolute measures of average and median speeds, results from M-Lab/NDT tend to be broadly consistent with those from Akamai, a large content and application delivery (CDN) company with a global system of servers. Since Akamai's business is to optimize and accelerate connectivity between its clients and their customers, this suggest the NDT test might be somewhat overestimating speeds. One reason for this might be that crowdsourced measurements such as M-Lab NDT have the potential for a sampling bias as people likely to test their connections tend to be those that care more about the quality of their connections than average users. This sub-group is likely to purchase relatively higher speed packages than the general population. On the other hand, both Akamai and M-Lab approaches represent "off net" measurements that capture connection from users to servers outside of the providers' networks. Consequently, they might be underestimating connection quality for accessing content and applications from within these networks or those the operators are prioritizing. Sample sizes of tests from less densely populated areas can be relatively small, which may create material errors in estimates for these areas. Geolocation of tests is also challenging and adds another source of potential error to the estimates. Combining the data

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[5] Bauer, S. (2016). Improving the Measurement and Analysis of Gigabit Broadband Networks. Research Conference on Communications, Information and Internet Policy 2016 (TPRC 44).
[6] See: https://www.akamai.com/ ; https://www.measurementlab.net/
[7] Bauer, S., Clark, D. D., & Lehr, W. (2010, August). Understanding broadband speed measurements. TPRC. http://people.csail.mit.edu/wlehr/Lehr-Papers_files/bauer_clark_lehr_2010.pdf
[8] https://www.measurementlab.net/data/

provided in this analysis with those the Region is collecting from service providers may offer valuable insights and assist in developing a richer picture of the state of the network and its potential development paths within Durham.

9. **Aggregation and local variation**: In this report we look at connection quality at a relatively high-level of aggregation, which may hide significant local differences in what users actually experience (i.e. we only look at municipal and Industry Canada hexagons, which have an approximately 5 km diameter). For example, service quality/speeds tend to degrade significantly due to distance on legacy copper networks, which means users that are further away from the local fiber node in their area may have a much poorer experience than those residing close to that fiber node. This is one of the key reason why indicators based on maximum theoretical speeds (i.e. up to xMbps) that are available in a particular area are not necessarily very informative as users that are far away from fiber nodes in that area or have to rely on wireless/satellite may be experiencing service quality levels that are far below the theoretical maximum speed that might be "available" to some users in that area. While the level of analysis here should be sufficient for informing the Durham stakeholders as the Region develops a broadband strategy, more fine-grained mapping using network measurements would help pinpoint areas where connectivity is particularly poor, as well that those in which private service providers are investing more to keep up with growing demand for network resources and deploying advanced fiber technologies closer to end user/customer premises.

10. **Aggregation and service provider variation:** Unless otherwise stated, in the analysis that follows we estimate connection quality in aggregating all M-Lab/NDT tests taken by users in Durham Region in 2016. As documented in Figure 1 however, it is important to note that are significant differences in effective speeds large operators deliver, which depends on various factors including their technological endowments, financial, and service provisioning strategies.[9] In Ontario for example, Figure 1 documents a growing gap between median speeds delivered by the two largest fixed infrastructure operators that dominate retail residential markets, with Rogers scaling its network infrastructure capacity to deliver higher speed services compared to its main rival Bell over the past few years. In neighbourhoods where users can access higher capacity/speed cable or FTTP networks, service quality/speed levels that are available to users with demand for higher speed connections are likely to be higher than the average rates analyzed in this report. Where there is limited access upgraded cable networks and FTTP "last mile", residents and businesses may have little option but to rely on long loop DSL services on old copper networks, fixed wireless, or high-latency/low speed satellite services (e.g. those offered by Xplornet). Speed/service quality levels available to users living in relatively remote locations within municipal and hexagonal areas analyzed here are likely be substantially lower than average speeds/latency rates documented in the subsequent section. We abstract away from firm level differences in service/infrastructure quality in Durham in the discussion that follows to focus on geographic variations within the Region and compared to the rest of GTHA.

[9] Rajabiun, R., & Middleton, C. (2018). Strategic choice and broadband divergence in the transition to next generation networks: Evidence from Canada and the US. *Telecommunications Policy*, 42, 1, 37-50. https://www.sciencedirect.com/science/article/pii/S0308596117301143

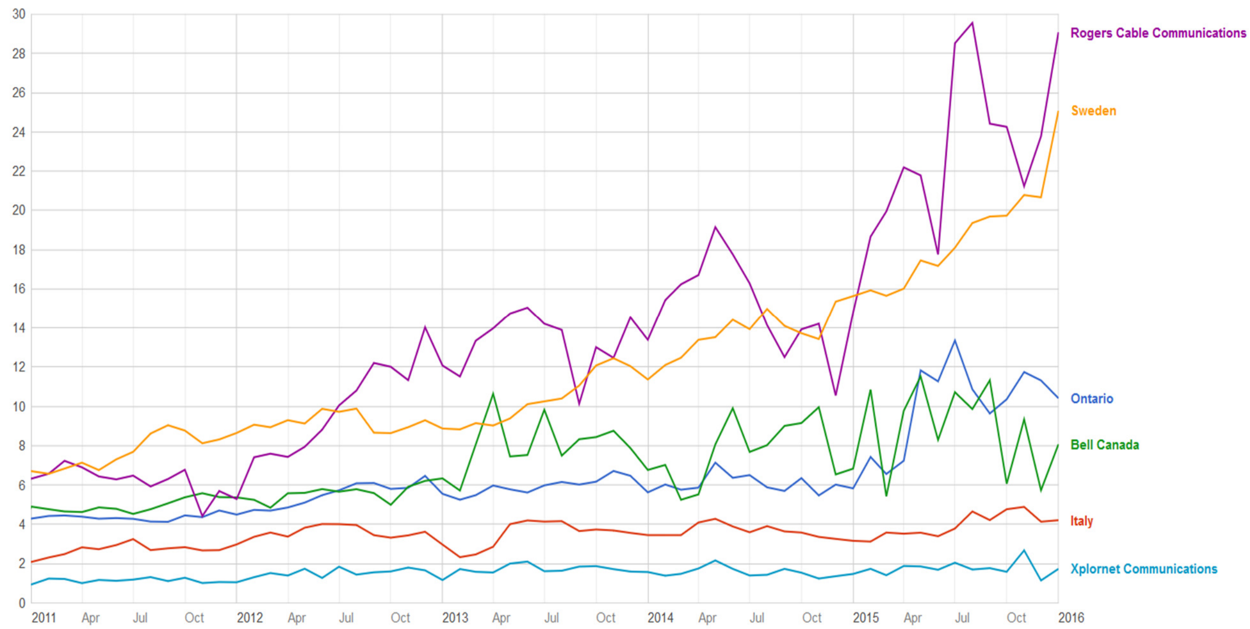
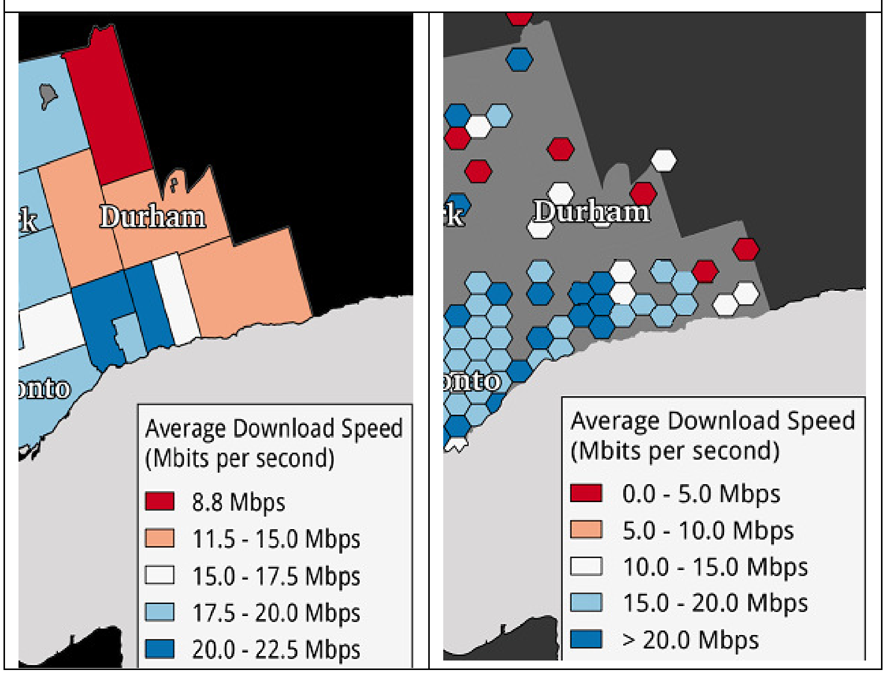


Figure 1: Measured Broadband Speeds in Ontario, differences among dominant service providers, and global benchmarks: Median download speeds 2011-2016 (Mbps); Source Google/M-Lab

II. State of Network Infrastructure in Durham: 2016

11. **Download speeds:** Figure 2 documents the range of average download speeds within Durham Region municipalities and lower level hexagons in 2016. Some of the urban parts in the southwest of the Region had average downstream speeds that lead GTHA, while measured speeds in some of the rural communities in the north and east of Durham Region are relatively poor (below 5 Mbps). However, it is also evident that download speeds in some rural communities in Durham tend to be higher than in some of the more urban hexagons in the southwest of the Region (as well as in the GTA and York Regions). This suggests broadband infrastructure quality concerns tend to cross the urban-rural digital divide as incentives of private sector providers to scale their network capacity in response to demand growth can vary across communities and neighbourhoods. More fine-grained mapping of network infrastructure quality would be needed to identify exactly which areas are falling behind, and where private sector incentives to keep up with demand for high-speed connectivity appear adequate.

Figure 2. Effective Download Speeds in Durham (2016)

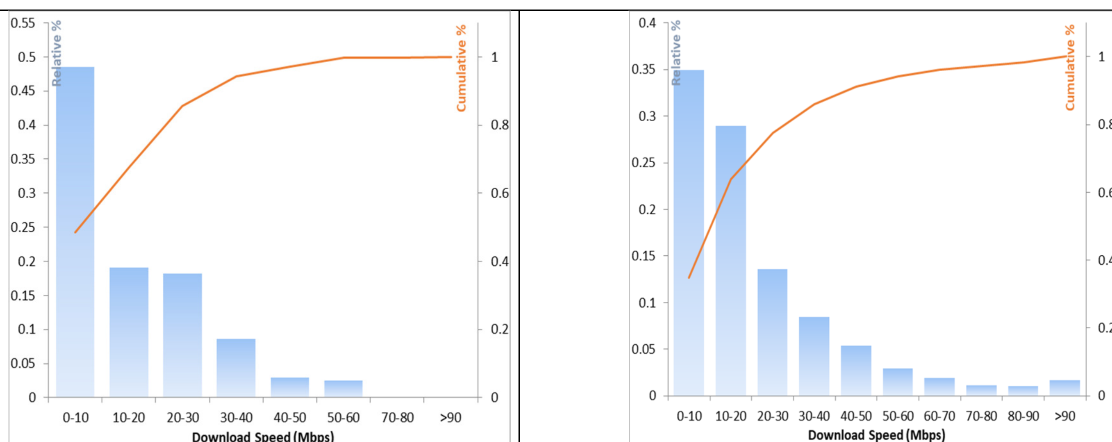


12. **Note on CRTC basic service standards:** In 2016, the federal telecom regulator reclassified high-speed access as a basic telecommunications service and established:

"*the following criterion to assess whether the broadband portion of the universal service objective is achieved: Canadian residential and business fixed broadband Internet access service subscribers can access speeds of at least 50 Mbps download and 10 Mbps upload. These speeds* *are to be the actual speeds delivered, not merely those advertised. That stated, the Commission recognizes that the broadband Internet access service speeds actually experienced by users are affected by a wide range of factors, some of which are outside the control of the network provider.*"[10]

13. The CRTC further estimated that "*82% of Canadians currently **have access to** fixed broadband Internet access services at speeds of at least 50 Mbps download and 10 Mbps upload*."[11] This estimate is based on data from service providers on maximum advertised speeds they claim are available in particular areas of the country (i.e. the hexagons). For various reasons, some of which were noted above, actual measured speeds can vary substantially from these maximum advertised rates that might be theoretically be available sometimes (e.g. low traffic periods late at night/early morning) and to only some users in a particular area (e.g. those close to local fiber nodes/central offices). To help explain the difference between CRTC's approach based on advertised rates that are theoretically "available" and the one used here based on measurements of actual speed/service quality levels service providers deliver, Figure 2 documents the distribution of measured connection speeds in two municipalities representative of urban and rural parts of Durham. Despite significant differences in average service quality, services with speeds higher than CRTC's 50 Mbps basic service standard are theoretically available in certain areas in both communities (e.g. close to the fiber node/central office, in buildings where FTTP last mile networks have been deployed). While effective downstream bandwidth that is available to the large majority of users is below 20 Mbps, in newer/more urban Pickering the proportion of users that can achieve speeds higher than 10 Mbps is substantially higher than in the less densely populated Uxbridge.

Figure 3. Urban/Rural Broadband Divide in Durham
Distribution of effective download speeds

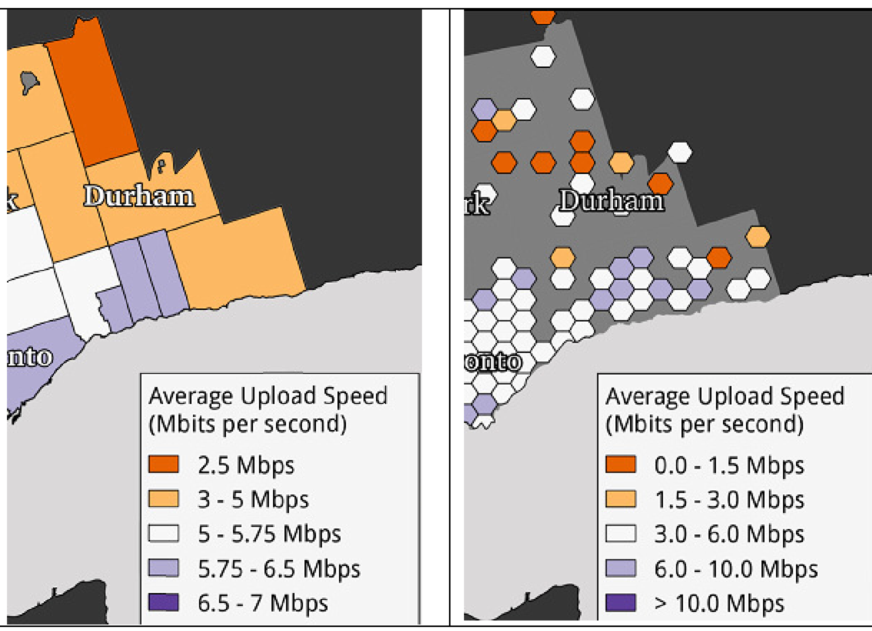


Uxbridge | Pickering

[10] Paragraphs 80 & 81. Telecom Regulatory Policy CRTC 2016-496. https://crtc.gc.ca/eng/archive/2016/2016-496.htm
[11] Ibid. Para 79. Emphasis added.

14. **Upload speeds:** Although effective/measured download speeds are important as an indicator of broadband infrastructure quality, various advanced Internet applications require reliable symmetric connectivity (e.g. voice/video communications, multimedia, applications requiring processing and backup in the "cloud", etc.).[12] Effective bandwidth service providers allocate to upstream capacity can be critical to the ability of users to deploy applications that require more symmetric connections than is needed for media applications that push downstream to end users (e.g. video content, advertising). Figure 3 maps the distribution of average measured upload speeds in Durham in 2016. In terms of the geographic gaps in Durham, this measure broadly confirms insights noted above bases on measured download speeds. The geographic extent of the gaps between the northeast and southwest of the Region in terms of upload speeds appear to be wider than in terms of download speeds noted above. This likely reflects higher access to cable (and potentially some FTTP) access networks in the southwestern parts of the Region which can offer more symmetric connections compared to relatively more rural areas in the north and the east. Notably however, average upload speeds in some rural parts of Durham are on par with the some of urban parts of the Region.

Figure 4. Effective Upload Speeds in Durham (2016)



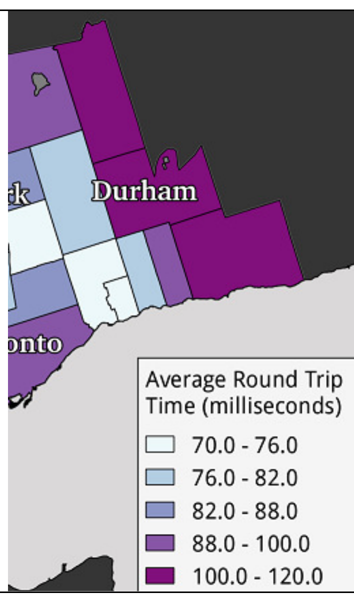
15. **Latency:** In addition to connection speeds and their symmetry, a key measure of broadband infrastructure quality from the perspective of both user experience and network management is the latency/delay in the transmission of data packages. For the usability of some applications latency doesn't really matter (e.g. email), but it can be critical for other basic Internet services

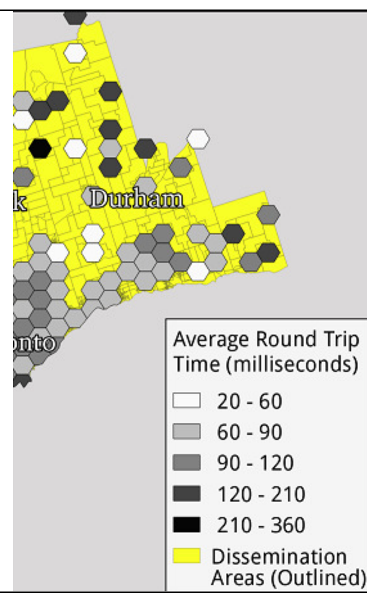
[12] For examples see eBusiness Toolkit for Small and Medium Size Enterprises (SMEs). Eastern Ontario Wardens' Caucus/Eastern Ontario Regional Network; by eFilters Inc. & RDM Management Group (2016). Available at: https://www.edco.on.ca/resources/Documents/EORN_eBusinessToolKit2016_Web%20FINAL.pdf

such as web browsing, voice/video communications, and various latency sensitive applications in the "cloud". As a relevant basic service benchmark, previous research documents that with latency (commonly measured as round-trip-time, RTT) rates over 80-100 milliseconds, delays in simple web browsing become increasingly challenging to the majority of users.[13] Even in areas with relatively high effective measured speeds, when network demand is outpacing supply latency rates can increase exponentially as bandwidth reaches capacity during high-traffic periods, which can substantially degrade service quality (i.e. "congestive collapse" making high speed connections "feel slow"). In terms of network management, latency is usually viewed as a key indicator of emergent congestion on shared links and routers due to growing demand that outpaces capacity supply (i.e. trigger for provisioning more network resources/capacity).

16. Figure 4 presents estimated latency rates in Durham based on 2016 M-Lab data at the two levels of aggregated as above with speeds. While we see some correlation between speeds and latency (which we discuss further below), latency rates appear to offer a richer picture of the complexity of network development across the urban-rural digital divide. Although latency is unacceptably high in some rural parts of the Region, there are rural communities with relatively low latency rates. At the same time, measured average latency rates in some urban parts of Durham (and GTHA more broadly) tend to be higher that most users might find acceptable when engaging in basic Internet applications such as web browsing (i.e. "off-net" websites outside of their service providers network).

Figure 5. Effective Upload Speeds in Durham (2016)





[13] Rajabiun, Reza and McKelvey, Fenwick (2017). Complementary Realities: Public Domain Internet Measurements in the Development of Canada's Universal Access Policies. TPRC 45. Available at SSRN: https://ssrn.com/abstract=2943054

17. **Local variation:** Aggregation of individual network diagnostic tests as above provides an intuitive picture of the state of broadband connectivity, but also may hide substantive diversity at the local level. For example, higher performing municipalities in the southwest of Durham may have newer neighbourhoods and buildings with upgraded networks, but they also contain older and low-income communities where private sector incentives to invest in network resources can be weak (i.e. lower expected return on capacity upgrades). A large number of tests from the newer and more affluent neighbourhoods in the sample is likely obfuscating such local differences. Lower level analysis is therefore required in design and evaluation of particular broadband infrastructure improvement initiatives.

18. **Summary and benchmarking:** To summarize and provide a basis for benchmarking the state of connectivity in Durham, Figures 6 plots the empirical relationship between effective download speeds and latency among GTHA municipalities. Figure 7 plots the same variables, but at the lower Industry Canada hexagonal level of aggregation. Some of the municipalities in the southwest of Durham Region (Pickering and Whitby) are among the leaders in the GTHA in terms of broadband infrastructure quality, but speed/service quality levels in Oshawa and Ajax are substantially below their counterparts in the southwest of Durham. Connection speeds in rural Brock and Scugog were about half of those in the leading municipalities. Somewhat surprisingly, measured network speeds in relatively urban Oshawa where about the same as in rural Uxbridge. This observation documents that some urban areas are also prone to underinvestment and have poor broadband infrastructure quality. As documented in Figure 7 using lower level data, the magnitude of the gaps between leading and lagging areas tend to be substantially higher that is suggested by aggregating the data at the municipal level. An effective broadband infrastructure strategy would recognize that barriers to access and use of the Internet associated with less than adequate service quality levels can be extensive and crosses the urban-rural divide.[14]

[14] Ontario's 2017 Long Term Infrastructure Plan (LTIP) has incorporated this empirical insight to some extent, stating that "The Province is committed to expanding broadband infrastructure and improving connectivity in **both rural and urban communities**, including First Nations….". Page 39; emphasis added. https://www.ontario.ca/document/building-better-lives-ontarios-long-term-infrastructure-plan-2017

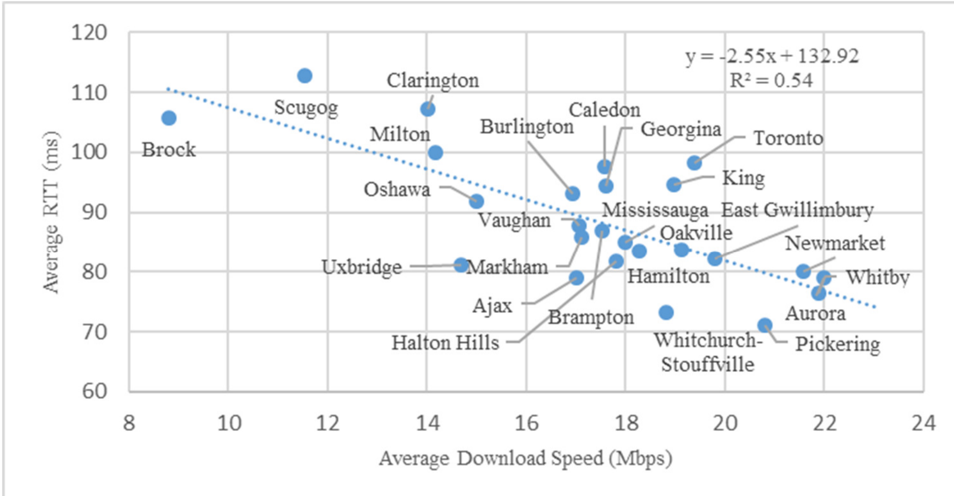


Figure 6: Effective Bandwidth and Connection Quality in GTHA Municipalities (2016)

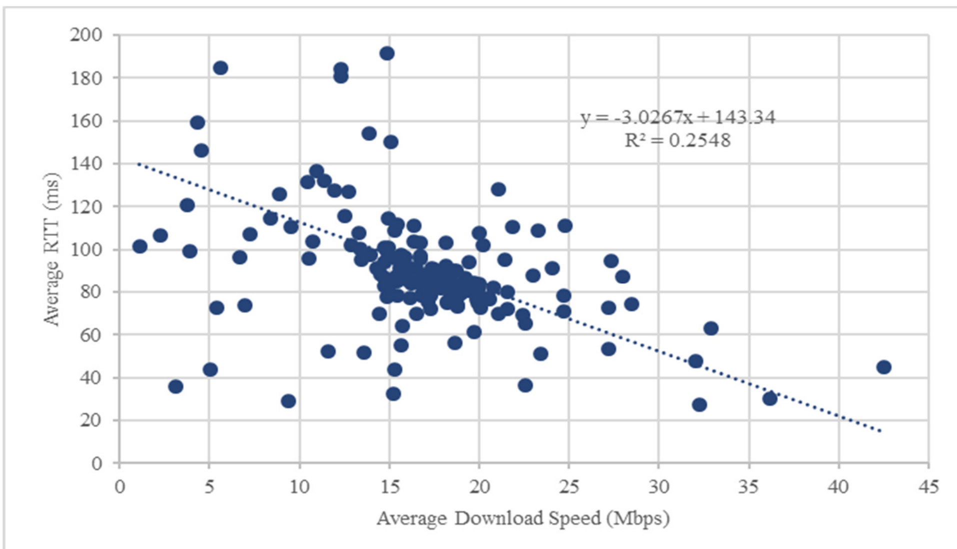


Figure 7: Effective Bandwidth and Connection Quality in GTHA Hexagons (2016)

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