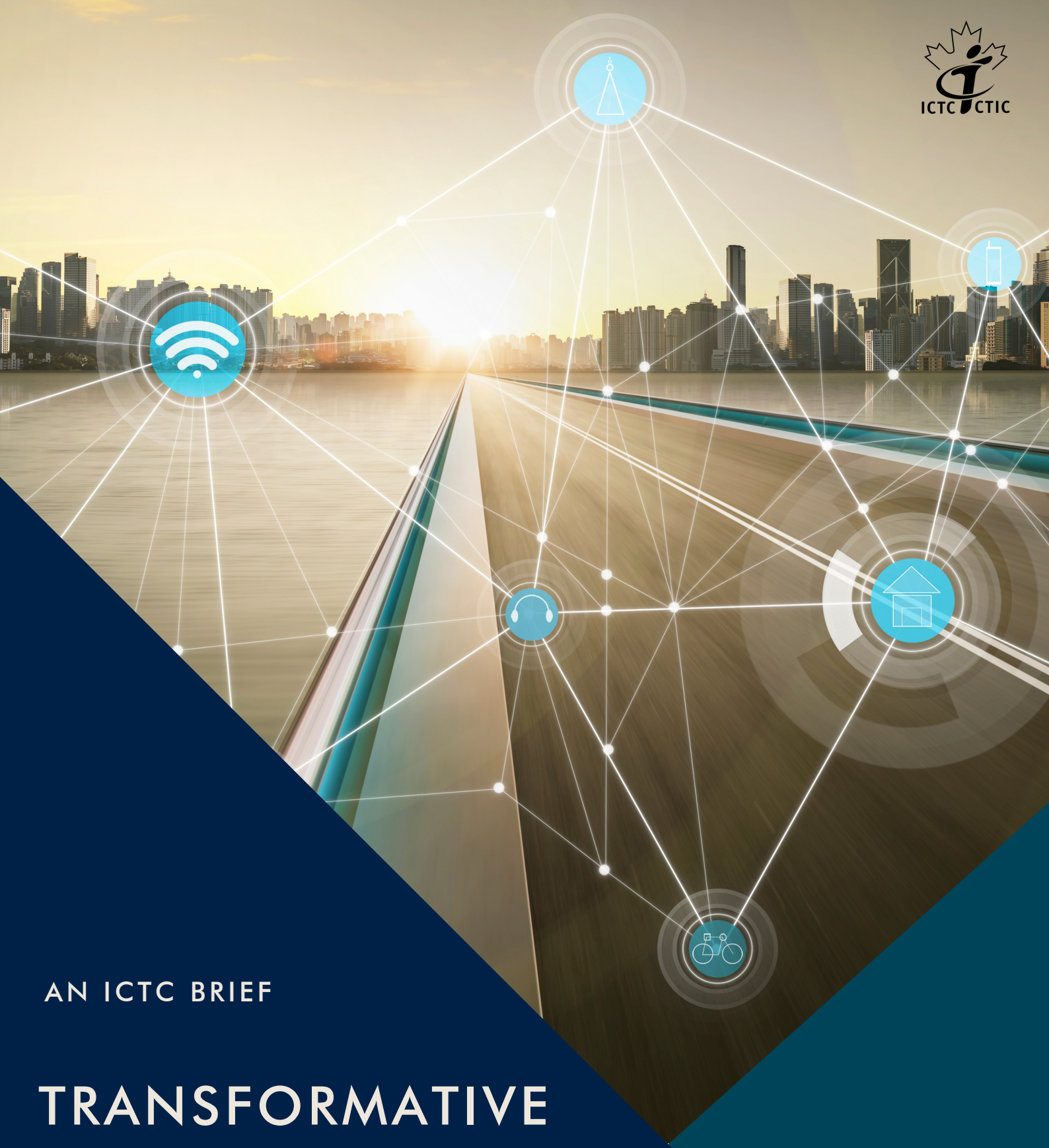

AN ICTC BRIEF

TRANSFORMATIVE TECHNOLOGIES

For Smart Canadian Cities

A Brief by the Information and Communications Technology Council of Canada

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Preface

ICTC is a national centre of expertise for the digital economy. With over 25 years of experience in research and program development related to technology, ICTC has the vision of strengthening Canada's digital advantage in the global economy. Through forwardlooking research, evidence-based policy advice, and creative capacity building programs, ICTC fosters innovative and globally competitive Canadian industries, empowered by a talented and diverse workforce.

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Transformative Technologies for Smart Canadian Cities

Canadian municipalities of all sizes are facing unique challenges to do with population, distance, and public services. Large and growing urban centers need improved ways to deal with congestion, mobility, and sustainability, while smaller and more remote communities face barriers to accessing high-quality infrastructure and social support. One way to solve this is to help our cities and regions become more informed, efficient, and "smart."

What is a Smart City?

A "smart city" is not defined by size, affluence, or even integration of smart devices. Instead, a smart city uses all of its resources, including information and communications technology (ICT), to communicate with citizens, collect and analyze data in a secure manner, and deliver long-lasting, evidence-based services for all. Smart cities emphasize accessibility, effectiveness, and sustainability, in terms of both longevity and environmental friendliness. Common resources and services are supported by digital interconnectedness and vice-versa, where people, governments, companies, and the environment around them are able to exchange mutually intelligible information, form plans, and make decisions.

Smart Cities in Canada

In 2017, more than 200 municipalities across Canada responded to Infrastructure Canada's Smart Cities Challenge with comprehensive proposals that leveraged new technologies and insights in support of economic opportunity, empowerment and inclusion, environmental quality, healthy living and recreation, mobility, and safety and security.[1] Beyond the challenge, over the past five years, Canadian municipalities from Calgary to Kitchener (and above and beyond) have created digital strategies and plans for transforming their urban spaces to be more interconnected, efficient, and sustainable.[2] Furthermore,

[1] "Smart Cities Challenge Finalists," Infrastructure Canada, January 21 2019, https://www.infrastructure.gc.ca/cities-villes/finalists-finalistes-eng.html
[2] Canadian Urban Institute, "Smart Planning our Smart Cities: A Best Practices Guide for Building our Future Cities," June 2018, https://static1.squarespace.com/static/546bbd2ae4b077803c592197/t/5b2bbd44aa4a9970b3cff95f/1529593163251/CUIPublication.SmartPlanningOurSmartCities.June2018.pdf.

these plans frequently rely on private sector partnerships and create new avenues for companies and start-ups to come to Canada, grow, and improve prosperity for citizens.

The following technologies are being used in Canada and around the world to support smart and interconnected cities. While many of these technologies are designed to be integrated into one urban system, no city is an island: many Canadian smart city proposals, technologies, and technology vendors in fact create connections and new digital and physical infrastructure with benefits that extend far beyond municipal borders, recognizing the relationships between and within regions.[3]

COLLECTING DATA, CONNECTING PEOPLE: TECHNOLOGIES FOR COMMUNICATION

Smart cities use networks of sensors and crowd-sourcing mechanisms to gather interoperable information about everyday urban patterns, like mass-transit use.

The Internet of Things (IoT) and Connective Technologies

The IoT is made up of everyday physical objects connected to the internet and each-other.

While smart cities conversations almost always discuss the importance of IoT as a foundational requirement for interconnected, efficient urban spaces, IoT itself is not a technology but an idea enabled by a wide variety of technologies, including hardware (such as embedded sensors or chips), software, and communications technology. One could, for example, implement short-range wireless communication between devices using Bluetooth or near-field communication (NFC), two technologies with different applications within the bigger IoT bucket. IoT hardware uses everything from short-range "multi-hop" communication, to the more efficient use of fourth- and fifth-generation (5G) cellular networks, to commercial long-range, low-power wireless technologies.[4]

[3] The Nunavut communities' proposal to the Smart Cities Challenge, for example, suggests a series of makerspaces that will connect youth across the 25 communities of the territory both physically and digitally. For more information, visit: https://www.infrastructure.gc.ca/alt-format/pdf/cities-villes/exec-summaries-resume/Nunavut_ExecSummary.pdf.
[4] See Lorenzo Vangelista, Andrea Zanella, and Michele Zorzi, "Long-range IoT technologies: the dawn of LoRaTM" Proceedings of the 1st EAI Conference on Future access enablers of ubiquitous and intelligent infrastructures (Fabulous 2015). Sept 23-25, 2015, Ohrid, Republic of Macedonia.

Canadian cities are working with numerous IoT technologies to support their networks of objects,and many of these projects are creating new private sector opportunities through a proliferation of public data and connectivity. The following list highlights several projects across the country with a focus on communication.

Low Power Wide Area Network (LPWAN) Technology

LPWAN technology is used to create a wireless network that can transmit small amounts of data, such as a small sensor's location, over a wide region with little energy required.

LPWAN technologies include numerous commercial products that typically use low radio-frequency bands for wireless networks with wide coverage, with the first LPWAN technology for IoT emerging in 2009.[5] LPWAN technologies are applied when connected sensors only need to communicate small quantities of data, as inexpensive and low-energy alternatives. For example, smart agriculture often requires sensors with long battery lifetimes and long range, and many rural areas lack cellular coverage, making LPWAN technology an ideal fit for any low-maintenance, low-power system.[6]

Multiple types of low-power, long-range networks have been launched across Canada: in April 2019, a comprehensive Canadian IoT LPWA network was launched by Sigfox Canada, with 693 live devices and numerous network base stations from St. John's, NL, to Vancouver, BC.[7]

The cities of Calgary, AB and Fredericton, NB have both partnered with communications companies to deploy LoRaWAN™ IoT networks, one type of LPWA public network. In Fredericton, this partnership will permit smart water metering, intelligent parking, flood detection, and air quality monitoring,[8] while Calgary is leveraging its new network to monitor lighting conditions in the city's Devonian Gardens, track pace of play at the Shaganappi Point Golf Course, and monitor noise levels across the city.[9]

[5] Vangelista, Zanella, and Zorzi, "Long-range IoT technologies: the dawn of LoRa™."
[6] Kais Mekki, Eddy Bajic, Frederic Chaxel, and Fernand Meyer, "A comparative study of LPWAN technologies for large-scale IoT deployment," ICT Express 5, no. 1, March 2019, pp. 1-7.
[7] Stephen Law, "Sigfox Canada unveils coast-to-coast IoT network," Electronic Products and Technology, April 11, 2019, https://www.ept.ca/2019/04/sigfox-canada-unveils-coast-to-coast-iot-network/.
[8] Eleven-x, "City of Fredericton and eleven-x Partner to Deploy Intelligent City Solutions," November 20, 2018 https://eleven-x.com/city-of-fredericton-and-eleven-x-partner-to-deploy-intelligent-city-solutions/; Claire Swedberg, "Canadian City Plans IoT Pilots with New LoRa Infrastructure," RFID Journal, January 15, 2019, https://www.rfidjournal.com/articles/view?18187/.
[9] Semtech, LoRa Technology: How Calgary Built and Utilizes One of the First City-owned LoRaWAN™-based Networks, November 2018.

Broadband and 5G Connectivity

Broadband refers to transmission techniques that permit multiple signals and large amounts of data, and it often is simply used to mean a fast internet connection. The term "5G" refers to cellular network technology that will provide faster mobile broadband and allow for numerous machine-to-machine (M2M) communications.

Much like IoT, 5G is not a single technology so much as it is a useful category, identifying an upcoming wave of coordinated technologies that will allow for unprecedented bandwidth (the amount of data transmitted per second) and reduced latency (the delay in data delivery). In addition, 5G can support a significantly higher density of connected devices than previous generations of cellular technology, with some estimating that it will allow for one million networked devices per square kilometer.[10] This shift is key for enabling IoT connectivity in high-density urban areas. In Canada and around the world, 5G promises to revolutionize the opportunities provided by IoT devices through features like improved M2M data transfer.

As a nation comprised of numerous remote communities, the rollout of 5G will not likely reach much of rural and northern Canada for numerous years, and broadband access in all its forms has the potential to revolutionize community planning and infrastructure.[11] Service providers like Xplorenet and SSi Micro direct their services at rural and northern community access, with SSi network QINIQ providing 4G LTE services to 25 communities in Nunavut in 2017.[12] Nunavut has extensive satellite-dependent coverage but is the only territory to have almost no broadband service exceeding 5 Mbps.[13] The potential for broadband delivery from low Earth orbit (LEO) satellites is an emerging conversation in Canada, and Telesat's LEO network is expected to deliver full service in four years. Better broadband would bring many benefits the region, including e-governance, teleworking for remote communities, and telehealth services.[14]

[10] Information and Communication Technology Council (ICTC), "5G: Jumpstarting our Digital Future," 2018 https://www.ictc-ctic.ca/wp-content/uploads/2018/12/ICTC_5G-Jumpstart-our-Digital-Future_EN-12.4.18.pdf; "5G Changing the World," (E) BrandConnect, n.d., https://worldin2019.economist.com/5gchangingtheworld.
[11] For a map of existing broadband connections in Canada, see Government of Canada, "National Broadband Internet Service Availability Map," March 3 2019, https://www.ic.gc.ca/app/sitt/bbmap/hm.html?lang=eng
[12] QINIQ, "What is QINIQ?", Accessed June 04, 2019, https://www.qiniq.com/company.
[13] Canadian Radio-television and Telecommunications Commission, Communications Monitoring Report 2018, 2018, https://crtc.gc.ca/eng/publications/reports/policymonitoring/2018/cmr3c.htm.
[14] See: Caleb Henry, "Telesat outlines spending plan for Canadian government's LEO constellation investment," Space News, August 7, 2019, https://spacenews.com/telesat-outlines-spending-plan-for-canadian-governments-leo-constellation-investment/; Clare Liddy et al., "Improving access to specialists in remote communities: a cross-sectional study and cost analysis of the use of eConsult in Nunavut," International Journal of Circumpolar Health 76, no. 1, 2017, DOI: 10.1080/22423982.2017.1323493.

CRTC map of satellite-dependent communities; inhabited areas without 50/10 Mbps fixed broadband access; without LTE; and with neither broadband nor LTE. Satellite-dependent residents often have broadband services but may also experience satellite service disruption, as has occurred in Nunvaut in the past. [15]

Image Source: Canadian Radio-television and Telecommunications Commission. https://crtc.gc.ca/cartovista/northcombinedye2018_en/index.html

First Mile, an organization that supports and researches remote and rural First Nation use of ICT, features stories from Indigenous communities about community development of infrastructure for connectivity.[16] Numerous communities across Canada, such as Fisher River Cree Nation, MB, have developed community-managed broadband that can be used to deliver services such as digital education and tele-health.[17]

Regional projects aim to connect multiple communities to high-speed telecommunications. One such is the Mackenzie Valley Fibre Link, commissioned by the Government of the Northwest Territories, which will connect McGill Lake, Inuvik, and Tuktoyaktuk, NT, along with the communities in between.[18] Another is Western Valley, NS, where the local government took the initiative to lay over 186km of fiber-optic cable connecting towns in the region to Halifax, NS, attracting new business and enterprise while providing improved digital skills training for youth.[19]

"Full stack" IoT products: Cellular network providers and other businesses also offer a number of top-to-bottom smart cities solutions, such as smart kiosks that are able to provide interactive information about events, routes, and other public information, while offering city wireless access and collecting data on pedestrian flow and user choices.[20] A Bell Canada Smart Kiosk prototype was installed in 2018 in downtown Whitehorse, YT, by Northwestel.[21] With the rollout of 5G, it is likely that similar services and devices will continue to appear in Canadian cities.

Whitehorse Smart Kiosk. Image source: Northwestel on Twitter [22]

[15] Jim Bell, "The connected territory? Nunavut still waits," ᓄᓇᕗᑦ (Nunatsiaq News), April 1, 2019, https://nunatsiaq.com/stories/article/the-connected-territory-nunavut-still-waits/.
[16] See FirstMile.ca for more information on the organization's work in research, outreach, and policy.
[17] First Mile, "Stories from the first mile," 2018, http://firstmile.ca/wp-content/uploads/Stories-from-the-First-Mlle-2018.pdf, p. 17.
[18] "The Mackenzie Valley Fibre Link," Accessed May 14, 2019, https://mvflproject.com/.
[19] "Western Valley of Nova Scotia," Intelligent Community Forum, Accessed May 14, 2019, https://www.intelligentcommunity.org/western_valley_nova_scotia.
[20] For more information, visit: https://business.bell.ca/shop/medium-large/internet-of-things/smart-cities/smart-kiosk?EXT=MOBBUS_PDL_Google_kwid=p39218993149&gclid=EAIaIQobChMIhOztqP2R4gIVBNRkCh0kLgKLEAAYASAAEgLwoPD_BwE&gclsrc=aw.ds
[21] For more information, visit: https://www.cbc.ca/news/canada/north/smart-kiosk-information-northwestel-whitehorse-1.4737577
[22] For original post, visit https://twitter.com/northwestel/status/1015018287074340865

CREATING INSIGHTS: TECHNOLOGIES FOR ANALYSIS

Smart cities use machine learning, computer vision, natural language processing, and other technologies to interpret data efficiently and correctly.

Artificial Intelligence: Machine Learning, Vision, and Speech, and Natural Language Processing

Machine Learning (ML), Machine Vision, and Natural Language Processing (NLP) are all significant subsets of Artificial Intelligence (AI), which aims to develop computer systems capable of tasks that typically require human intelligence, including visual perception and decision-making.

While many kinds of sensor networks have the ability to collect immense quantities of instantaneous data, synthesizing and analyzing that data is another matter. Without the help of powerful AI technologies, only a tiny fraction of all collected data would be leveraged to its full extent, and even ML has a long way to go before it can efficiently label, interpret, and leverage all of a smart city's available information.

Canada is well-placed to become a leader in ML and AI, with internationally renowned research centers in Edmonton, AB,[23] including a team of researchers who helped found the field of computational reinforcement learning, Montreal, QC,[24] and Toronto, ON[25] among numerous other successful programs and businesses across Canada's provinces and territories.

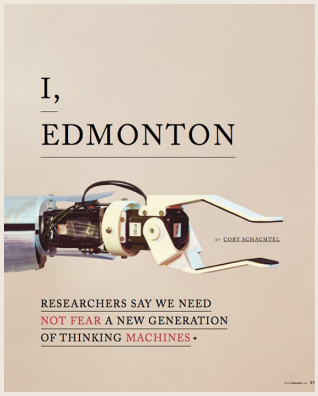

Image Source: Cory Schachtel, "I, Edmonton," Avenue Magazine Edmonton, September 1, 2018

[23] This includes the Alberta Machine Intelligence Institute (Amii) and its partnered labs at the University of Alberta, (for more information, consult https://www.amii.ca/about-us/). Edmonton, Alberta is also the site of "DeepMind Alberta," the Google-affiliated project's first research office outside of the United Kingdom (see https://deepmind.com/blog/deepmind-office-canada-edmonton/).
[24] This includes the Quebec Artificial Intelligence Institute (Mila, formerly the Montreal institute for learning algorithms) and its numerous partners (for more information about this, https://mila.quebec/), as well as the Institute for Data Valorization (IVADO) and Element AI.
[25] According to Invest in Canada, Toronto has the highest concentration of AI start-ups in the world, including companies such as the Vector Institute, NextAI, and the Creative Destruction Lab (Canada—A Leader in Artificial Intelligence (AI), n.d., https://www.international.gc.ca/investors-investisseurs/assets/pdfs/download/Niche_Sector-AI.pdf).

The field of ML identifies and improves on methods for teaching computers to interpret and act on many different types of data, including, increasingly, language and images. As such, the interconnected IoT and "smart infrastructure," when paired with ML algorithms, can collect information, analyze it, and make decisions, such as dimming a streetlight or identifying a water leak.

Smarter Transportation

Many of us already use AI or ML technology in our daily lives—for example, the navigation applications Waze and Google Maps use AI to predict commute times and suggest faster routes. This kind of existing application makes it not too far a stretch to imagine ML-run smart traffic: interconnected traffic lights communicating with our vehicles and transit systems, driven or driverless.

More Efficient Energy Systems

Real-time tracking and interpretation of energy use data should allow for ML-informed "smart grids" that respond efficiently and precisely to consumer demand without wasting electricity where it isn't needed. In addition, the supply of energy that is made more complex by user-generated solar or wind power can be more easily managed by AI, allowing the grid to absorb excess energy from creators.

The city of Summerside, PEI, has recently partnered with BluWave-ai, a Canadian clean energy company with an ML platform that communicates with IoT sensors. [26] Summerside's wind and solar resources will be predicted and their use optimized by this platform, creating significant savings for the city and improving the efficient use of renewable energy sources.

Côte Saint-Luc, QC proposed a set of technologies intended to assist the city's aging population in quality of life, safety, and social connectedness. Their project suggests that smart automation for seniors, including wearable and at-home devices, allows AI to analyze situations and trigger alerts (such as calling health personnel if a fall is detected) or responses (such as a social robot intended to keep older adults conversational and alert).[27]

[26] BluWave-ai and City of Summerside, "Summerside Smart Grid Taps BluWave-ai to Shrink Energy Costs and Maximize Use of Renewable Sources," February 13, 2019, https://www.bluwave-ai.com/press-releases---summerside-smart-grid-taps-bluwave-ai-to-shrink-energy-costs-and-maximize-use-of-renewable-sources

[27] Ville de Côte Saint-Luc, The VillAGE Initiative: The Future of Aging in Community, Smart Cities Challenge Final Proposal, March 5, 2019. https://docs.wixstatic.com/ugd/c4d649_7d3a1328afa949879c7ad17d93709cae.pdf

SECURING INFORMATION: TECHNOLOGIES FOR SECURITY AND PRIVACY

Smart cities guard individual privacy and maintain strict security guidelines through both technology and policy.

IoT Cybersecurity Technologies

Cybersecurity has become a key consideration for IoT technologies. Internet-enabled devices with poor security can allow a hacker to connect to both a device and its network, increasing the number of vulnerable access points in a home or workplace.

A variety of software and hardware solutions to IoT security issues have entered the marketplace and are constantly being refined and improved. These technologies work with encryption, behaviour analysis and machine learning (to detect anomalous behaviour, for example), hardware access verification, and improved network security systems (such as traditional firewalls or antivirus software).

In Canada, in coordination with a multi-stakeholder consultation on the nation's IoT security,[28] the Canadian Internet Registration Authority (CIRA) has developed a Secure Home Gateway (SHG) project. Its features include a Per Device Access Policy (PDAP), which identifies a new IoT device in a network (such as a new internet-enabled television in someone's home) and restricts it to particular functions: it also monitors devices and can quarantine them should they demonstrate unusual behaviour.[29]

Distributed Ledger Technology

The parent category of the much-discussed blockchain technology, distributed ledger technology (DLT) is a database or ledger that is not hosted in any one centralized location but "distributed," or duplicated across many users or servers.

[28] Led by Innovation, Science and Economic Development Canada (ISED) and other partners, the Canadian multistakeholder process for IoT security has published its results at iotsecurity2018.ca at the time of writing, accessed June 03 2019.
[29] Canadian Internet Registration Authority (CIRA). "CIRA Secure Home Gateway," accessed June 03, 2019, https://cira.ca/labs/cira-secure-home-gateway.

While blockchain has received significant attention due to its affiliation with bitcoin, the broader category of DLT is relatively novel. As a spreadsheet, database, or ledger duplicated numerous times and hosted by a wide array of servers, DLT has the potential to communicate the same information instantaneously to numerous readers and may mitigate potential fears about a centralized body, such as a government or business, collecting and owning citizen data.[30] The features that DLT promises include enhanced security and user control of data, improved interoperability of different types of data, and simultaneous communication for different industries or organizations working with the same information. All of these are immensely relevant to smart cities.

Canadians have demonstrated that they care about how their data is used, and by whom, through many public conversations such as those regarding the Quayside development (a proposed Smart Community) in Toronto.[31] This concern is worldwide, and the cities of Amsterdam and Barcelona have begun to work with project DECODE (decentralized citizen-owned data ecosystems), funded by the European Commission. The pilots in these two cities experiment with DLT-based secure digital wallets and support citizens to gain control over their data, deciding what to share, when, with whom, and how, and withdraw that permission whenever necessary.[32]

Canada, and particularly Toronto, ON, has become a hub for blockchain and DLT innovation. One of the first blockchain protocols that allowed developers to build applications and smart contracts, Ethereum, was born in Toronto, and the city continues to host conferences and nurture start-ups in blockchain technology for secure fintech, e-health, and more.[33]

[30] Peter Sloly, "Safe, smart cities: Enormous Potential but significant challenges," Deloitte, 2019, https://www2.deloitte.com/ca/en/pages/public-sector/articles/safe-smart-cities.html.
[31] "Sidewalk Labs's vision and your data privacy: A guide to the saga on Toronto's waterfront," December 7, 2018, https://www.theglobeandmail.com/canada/toronto/article-sidewalk-labs-quayside-toronto-waterfront-explainer/
[32] "Pilots," Decode, accessed May 14, 2019, www.decodeproject.eu/pilots.
[33] For more information, consult news and updates from organizations like the Toronto-based Blockchain Research Institute (BRI) at https://www.blockchainresearchinstitute.org/.

DELIVERING SERVICES: TECHNOLOGY FOR SHARED GOOD

Smart cities use their insights to design and deliver smart services in accessible and effective ways. Services improve both urban efficiency and quality of life for all.

Autonomous Electric Vehicles

While the vast majority of Canadians are already familiar with the idea of driverless cars, the commitment to having these cars be connected, autonomous, shared, and electric has led numerous smart cities conversations in both policy and industry.

Driverless cars, or autonomous vehicle (AV) technology is rapidly progressing in sophistication and is expected by some to be launched on a commercial scale within the next decade.[34] A recent OECD report noted that AV initiatives attract about a third of all the venture capital investment dedicated to AI start-ups.[35] While driverless vehicles seem intimidating to some Canadians, significant research has found that the vast majority of car accidents are caused by human error and that AVs, even imperfect AVs, would save lives.[36]

AVs function most effectively with a "smart" environment, making them a natural complement to smart cities. Several of the technologies discussed in this brief support the effective implementation of AV technology: 5G will enable cars to use faster network speeds for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2X) communication.[37] AI and Machine Learning in turn enhance AVs' safety and efficiency. Previous ICTC research has outlined a number of human occupations that will be displaced and/or require upskilling with the advent of autonomous electric vehicles (AEVs), particularly in industries that currently involve human drivers, such as long-haul shipping. However, it has also forecasted an increase in the number of ICT sector jobs.

[34] Namwoo Kang, Fred Feinberg, and Panos Papalambros, "Autonomous Electric Vehicle Sharing System Design," Journal of Mechanical Design 139, January 2017, https://pdfs.semanticscholar.org/34a6/07617da235a3d7faa9c5f096637174d7bcff.pdf, p. 011402-9.
[35] OECD, Private Equity Investment in Artificial Intelligence, 2018, https://www.oecd.org/going-digital/ai/private-equity-investment-in-artificial-intelligence.pdf, p. 3.
[36] Black & Veatch, "2018 Strategic Directions: Smart Cities & Utilities Report," 2018, https://www.bv.com/insights/expert-perspectives/autonomous-cars-poised-transform-connect-smart-communities.
[37]ICTC, "Autonomous Vehicles and the Future of Work in Canada," 2018, https://www.ictc-ctic.ca/wp-content/uploads/2018/01/ICTC_-Autonomous-Vehicles-and-The-Future-of-Work-in-Canada-1-1.pdf, p. 14.

Accordingly, the advent of AEVs operating within smart cities must be paired with a focus on new types of professional development that help people transition into new, high-quality jobs.[38]

The EZ10 Driverless Shuttle in Surrey, BC 2019. From February to March 2019, the EZ10 Driverless Shuttle (commonly known as ELA), a 100% electrical vehicle that holds 12 passengers, ran demos in the Surrey, BC Civic Plaza and Vancouver Olympic Village, BC with 1661 and 2826 total passengers, respectively. ELA has previously carried passengers in Edmonton, AB to the Grey Cup, around the city's neighbourhood of Old Strathcona, and at the Calgary, AB zoo.

Image Source: Ridewithela.ca instagram.[39]

Why Electric?

Many have argued that the benefits of AV technology will be heightened if these vehicles adopt sustainable energy sources and are shared—thus, the smart city of the future may well see a fleet of AEVs without single owners, enabling radical reorganizations of commutes, distributions of goods and services, and beyond. Furthermore, many cities that are preparing for AVs are also preparing electric vehicle (EV) infrastructure; Toronto, recently ranked 10th in a global list of cities preparing for future mobility technology, has introduced regulation to support widespread EV charging stations in multi-resident buildings.[40]

[38] Idem, p. 41.
[39] https://www.instagram.com/p/BtosLcDANla/
[40] WSP, "Top 10 Cities in Future Mobility Technology," January 7, 2019, https://www.wsp.com/en-GL/insights/top-10-cities-in-future-mobility-technology.

Enhancing Access and Mobility

The rapidly aging populations of OECD countries may find increased mobility in driverless cars, as might those with disabilities that prevent them from driving. [41] AEVs will be incorporated into services like Uber and Lyft (and already are so in Boston and Pittsburgh). At the same time, they will allow mass transit to become safer, cheaper, and more widespread, reducing traffic and congestion. [42]

A Cleaner Environment

AEVs will both transform and be transformed by smart city technologies: as improved electric charging infrastructure and remote sensing technologies allow AEVs to operate as efficiently as possible, so too will the number of cars on the road decrease, permitting shorter commutes and improved urban air quality.

While Regina, SK's Smart Cities Challenge proposal was not selected by Infrastructure Canada, the city has stated an intention to move forward with its plans for enhancing transportation efficiency, including an exploration of autonomous buses connecting new suburbs to existing public transit.[43]

NAVYA is an electric stand-alone shuttle that will transport passengers from the bus terminal to their work places in Candiac, QC, in mixed traffic. An operator will be on board to educate passengers about AVs, but it is not anticipated that operator interception will be necessary. This project is co-sponsored by organizations including Keolis Canada and Propulsion Quebec, the latter of which has a mission to make the province of Quebec a leader in electric, intelligent transportation, in addition to projects that build out electric charging infrastructure.[44]

[41] ICTC, "Autonomous Vehicles and the Future of Work in Canada," p. 26.
[42] Black & Veatch, "2018 Strategic Directions: Smart Cities & Utilities Report."
[43] Economic Development Regina, "Embracing Technology for a Smarter City," August 8, 2018, https://economicdevelopmentregina.com/news/embracing-technology-for-a-smarter-city.
[44] Keolis Canada, "A Canadian First in Candiac – Autonomous Electric Shuttle Project on Public Roads," Newswire, August 10, 2018, https://www.newswire.ca/news-releases/a-canadian-first-in-candiac---autonomous-electric-shuttle-project-on-public-roads-690560721.html.

DESIGNING SUSTAINABLY: TECHNOLOGIES FOR HOLISTIC PLANNING AND LASTING USE

Smart cities use versatile and interconnected technologies to design systems that reduce waste and enhance the efficiency of shared infrastructure.

Geolocation, Information, and Positioning System Technologies

Technologies for geolocation and positioning enable users to identify or estimate objects' locations through a variety of methods, including radio frequency locations, cellphone tower triangulation, IP address location, or crowdsourcing. These technologies have countless smart city-related applications, and they are often used to enhance energy efficiency and environmental sustainability.

Geolocation, positioning, and intelligence services allow urban planners to visualize inefficiencies and identify the causes of pollution and waste. Frequently used in transportation mapping, for example, ArcGIS offers tools that allow governments to examine transportation data from diverse sources through maps and improve their traffic and transportation design.[45] Canada has a long track record in using geolocation technologies for environmental management, and its expertise in this field also extends to the urban landscape. For example, the Canadian research organization Geothink studies the interactions between the geospatial web and government–citizen interactions, including the ability of citizens to correct and edit government-hosted data.[46] Urban planning and long-term, sustainable design can benefit significantly from the ability to source and visualize spatial data.

Cities across Canada are increasingly maintaining websites with open data, which is available to the public free of charge, reusable, and machine-readable. [47]

[45] "Smart Planning for Sustainable Communities," esri, accessed May 14, 2019, https://www.esri.com/en-us/smart-communities/sustainable-communities.
[46] Peter A. Johnson, "Models of direct editing of government spatial data: challenges and constraints to the acceptance of contributed data," Cartography and Geographic Information Science 44, no. 2, 2017, pp. 128-138, DOI: 10.1080/15230406.2016.1176536.
[47] The Government of Canada offers a federal database dedicated to open data: https://open.canada.ca/en/open-data.

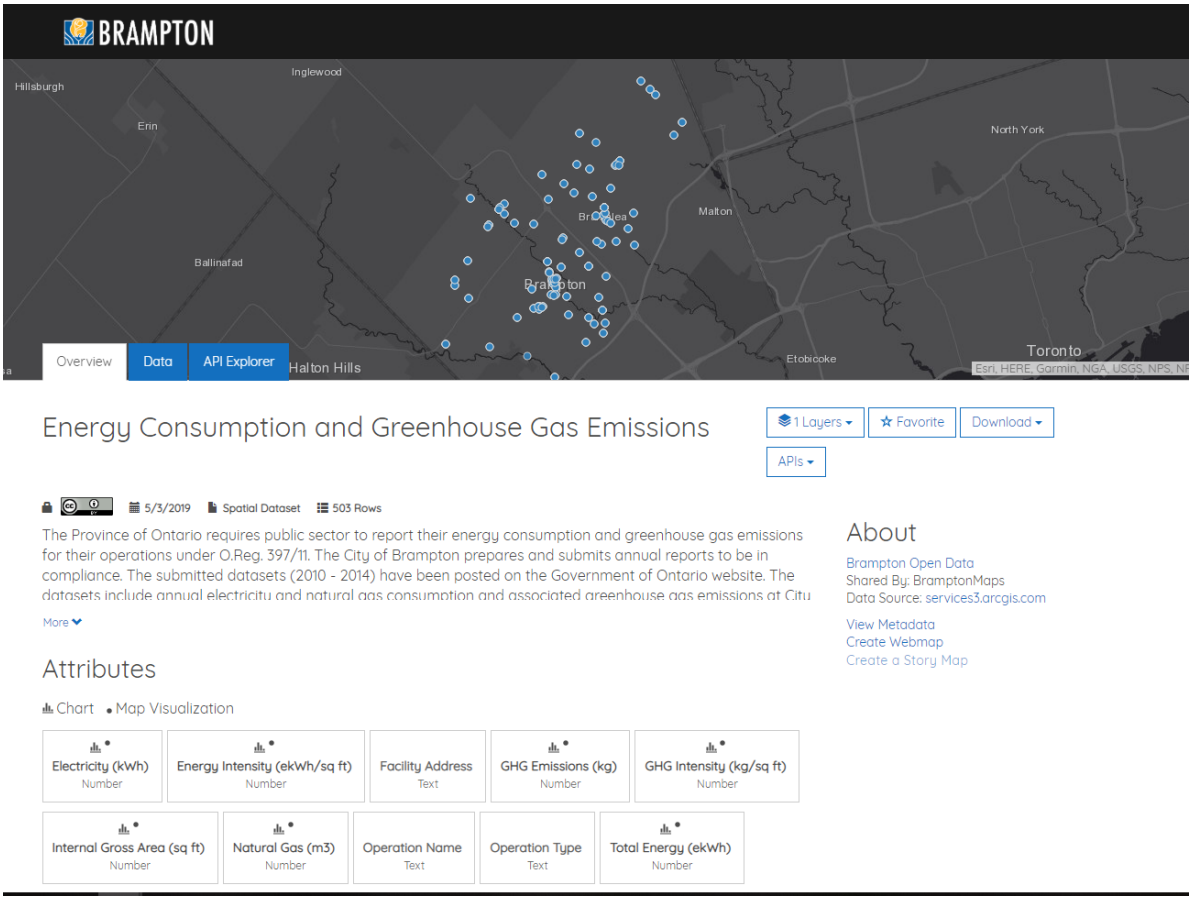

Image Source: City of Brampton, Energy Consumption and Greenhouse Gas Emissions Open Data, updated May 3, 2019.

The City of Brampton, ON has a GIS & Open Data team, responsible for creating and maintaining a wide variety of maps that portray environmental and other data, from public sector greenhouse gas emissions to average weekly traffic.[48]

In 2013, a University of Calgary, AB team won an award at an MIT climate conference for a technology that maps heat loss and its cost in homes.[49] That same technology, based on Geographic Object-Based Image Analysis (GEOBIA),[50] offers free residence heat maps of cities across Alberta, as well as Nelson, BC and Hamilton, ON. These maps are intended to provide homeowners and policymakers with data on energy loss and incentivize retrofitting for more energy-efficient homes.[51]

[48] To view the data made available by the city of Brampton, visit http://geohub.brampton.ca/pages/data.
[49] Climate CoLab, "Press Release: Contest Winners Confront Climate Challenge," MIT Centre for Collective Intelligence, November 7, 2013, https://news.climatecolab.org/2013/11/press-release-contest-winners-confront-climate-challenge/.
[50] For more information, see https://www.ucalgary.ca/f3gisci/GEOBIA.
[51] Interactive city maps are available at the time of writing at https://myheat.ca/.

Smart Lighting

A modest concept with big environmental impact, smart lighting includes everything from more efficient bulbs to motion-activated streetlights, with atmospheric data sensors, automatic outage reporting, and solar recharging as a few of many potential additions.

A city can achieve immensely greater efficiency in its lighting simply by replacing old incandescent bulbs with fluorescent lights or LEDs; Burnaby, the first Metro Vancouver municipality to convert all of its streetlights from sodium bulbs to LED, cut lighting energy use by 60%.[52] Further Canadian smart lighting pilot projects in cities such as Lloydminster, AB/SK, and Yellowknife, NT have sought to reduce light pollution by dimming lights when no motion is detected, improving residents' sleep and enhancing views of Canadian skies at night.[53]

The next frontier in smart street lighting includes solar power, internet-enabled lights, and wireless connectivity, and projects around Canada are beginning to take this challenge on. A collaboration between Clear Blue Technologies, Tymat Solutions, and the City of Hamilton, ON, looks to install off-grid solar powered lights that use a cloud-based software for remote management, reducing the need for expensive grid extensions.[54] In turn, Quebec-based DimOnOff recently announced the development of a product that can be installed onto existing LED lights to sense air quality, monitor sewer and river levels, distinguish the sounds of a car accident, or indicate vacant parking spaces.[55] These and other Canadian innovations and partnerships will continue to forge through issues caused by our unique climate[56] to bring increased energy efficiency to smart cities across the country.

[52] "Burnaby first city in Metro Vancouver to complete conversion to LED streetlights," Vancouver Sun, April 18, 2019, https://vancouversun.com/news/local-news/burnaby-first-city-in-metro-vancouver-to-convert-to-led-streetlights/
[53] Kaila Jefferd-Moore, "High-tech lampposts have Yellowknife in the running for $5M prize," CBC News, June 5, 2018, https://www.cbc.ca/news/canada/north/yellowknife-smart-lamp-posts-1.4691568.
[54] Isabelle Kirkwood, "Clear Blue Bring Solar-Powered IoT Streetlights to Hamilton," betakit, April 4, 2019, https://betakit.com/clear-blue-brings-solar-powered-iot-streetlights-to-hamilton/.
[55] DimOnOff Inc. "Dimonoff unveils the future of intelligent outdoor light control with its new product: The H3," itbusiness.ca, https://www.itbusiness.ca/press-release/dimonoff-unveils-the-future-of-intelligent-outdoor-light-control-with-its-new-product-the-h3.
[56] "LED traffic lights trouble in winter because they don't melt snow," CBC News, February 26, 2016, https://www.cbc.ca/news/canada/windsor/led-traffic-lights-trouble-in-winter-because-they-don-t-melt-snow-1.3465301.

Conclusion

On May 14, 2019, Infrastructure Canada released its Smart Cities award winners to the public, including a plan for a local energy economy in Bridgewater, NS, a set of digital makerspaces for youth engagement across Nunavut, a circular food security plan in Guelph, ON, and integrated mobility services in Montreal, QC. In their ultimate presentations, many of the other smart cities finalists pledged to continue with their work with or without award funding, and the representation from across Canada made it clear that there is significant smart cities momentum nationwide.

The examples contained in this brief include and exceed the submissions to Infrastructure Canada's challenge; while this exciting competition has raised significant interest in smart cities, population centres across Canada have been working with advanced technologies in innovative ways for a long time. Canada's strengths in research, industry, and public application will continue to grow as interest in smart technology builds: technologies for data collection and connection, analysis, ethical and secure use, public services, and long-term planning and sustainability all work in concert to improve quality of life for people across Canada. In the future, ICTC will follow this brief with an in-depth report on smart city technologies, their potential applications, and their economic impact in Canadian cities.

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