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Spectrum Management and Telecommunications

Consultation on the Spectrum Outlook 2018 to 2022

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1. Intent

1. Innovation, Science and Economic Development Canada (hereinafter referred to as ISED) recognizes that rapid growth of innovative technologies and services are driving the digitization and automation of every sector of the economy. In support of Canada's Innovation and Skills Plan, and with a focus on ensuring that Canadians can benefit from world-class networks and advancements in new digital technologies and services, ISED acknowledges that as the demand for digital connectivity grows, so will the demand for spectrum. Through the release of this document, ISED, on behalf of the Minister, is hereby initiating a consultation on the overall approach and planning activities related to the release of spectrum for commercial mobile services, licence-exempt applications, satellite services and wireless backhaul services over the years 2018 to 2022. In an effort to ensure that Canada is well prepared to meet the spectrum needs associated with these uses, comments are being sought on future technology advancements and associated spectrum demand, as well as on the proposed release of specific spectrum bands, and timing thereof, to meet these future needs.

2. Context

2. The radio frequency spectrum is a unique, finite resource that is an integral component of Canada's telecommunications infrastructure. It provides access to a broad range of private, commercial, consumer, defence, national security, scientific and public safety applications and services that benefit all Canadians. The Minister of Innovation, Science and Economic Development, through the *Department of Industry Act*, the *Radiocommunication Act* and the *Radiocommunication Regulations*, with due regard to the objectives of the *Telecommunications Act*, is responsible for spectrum management in Canada. As such, the Minister is responsible for developing goals and national policies for spectrum utilization and for ensuring the effective management of the radio frequency spectrum resource.

3. Through Canada's Innovation and Skills Plan and its focus on skills, research, technology and commercialization, program simplification, and investment and scale, the Government of Canada is committed to promoting innovation-led growth across all sectors of the Canadian economy. Today's economy is digital. The ubiquity of digital technologies and services across sectors is a defining feature of this digital economy. The information and communications technologies (ICT) sector is an enabler of the digital economy that is embedded in the transformations underway in industries, such as manufacturing, the automotive sector, agriculture and financial services.

4. Canadians rely on wireless applications on a day-to-day basis for a variety of services, such as monitoring their health, mobile transactions and running their households. Spectrum allows Canadians to access high-quality broadband services anytime and anywhere. New wireless technologies, techniques and uses, such as 5th generation mobile (5G), dynamic spectrum access, the Internet of Things (IoT) [1] and small non-geostationary orbit (NGSO) satellites, promise to increase innovation, transform business models and offer consumers advanced products and applications. The growing reliance on wireless

[1] IoT is defined by the International Telecommunication Union (ITU) as a global infrastructure for the Information Society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving, interoperable information and communication technologies.

technologies and the introduction of innovative services are driving demand for ever-increasing amounts of data, which translates into a greater demand for spectrum.

5. ISED is committed to ensuring that Canada has a world-class telecommunications infrastructure and that Canadian consumers, businesses and public institutions continue to benefit from advanced wireless telecommunications services and applications. A robust wireless telecommunications industry drives the adoption and use of digital technologies and enhances the productivity and competitiveness of the Canadian digital economy. ISED is focused on the three pillars that matter to Canadian families and businesses:

- Quality: supporting networks to allow for the latest technologies to be deployed
- Coverage: enabling services available to Canadians where they live and work
- Prices: encouraging services that are affordably priced

6. This consultation will help to inform ISED’s overall approach and planning related to potential spectrum releases in the 2018 to 2022 timeframe. The resulting decision, the Spectrum Outlook, will support the development of and investment in Canada’s digital economy and the objectives of the Innovation and Skills Plan by providing stakeholders with a roadmap of ISED’s approach to ensuring that appropriate spectrum resources are available to meet future demand.

3. Scope

7. The purpose of the Spectrum Outlook is to provide stakeholders with an overview of ISED’s proposed overall approach and planned activities over the next five years. Furthermore, it outlines ISED’s plan to make spectrum resources available to support telecommunications services and applications that are expected to require new or additional spectrum in the coming years.

8. ISED monitors trends in spectrum usage and demand, technology developments and markets in order to make decisions regarding the release of additional spectrum, or the reallocation of spectrum to new uses. The pace of innovation in the telecommunications sector and the resulting increased demand for data are the principal challenges in managing the competing demands for access to the limited radio frequency spectrum supply.

9. Consumer demand for broadband services with faster data rates and more sophisticated applications has been driving an increase in the spectrum requirements for commercial mobile, satellite, and backhaul services, as well as licence-exempt applications. In addition, in the next 5 to 10 years, ISED expects that new technologies, techniques and uses will have a significant impact on spectrum requirements for these services and applications, and will also provide opportunities for new approaches to managing the spectrum. This consultation will seek to validate existing information and evidence derived from various studies as well as to seek additional information from stakeholders to better inform the planning of future activities and priorities set out in the Spectrum Outlook.

10. To promote greater transparency, predictability and therefore investment certainty, section 4 of this consultation discusses a principled approach that will be applied by ISED in its consideration of future spectrum releases.

11. The previous *Commercial Mobile Spectrum Outlook* published in March 2013 (hereinafter referred to as the 2013 Outlook) set out a plan to allocate up to 750 MHz of spectrum specifically to commercial mobile services by the end of 2017, subject to changing priorities, significant technological changes and international developments. In particular, delays in international developments in the 600 MHz and 3500 MHz bands have led to changes in the plan set out in the 2013 Outlook. To date, ISED has made 648 MHz available for commercial mobile services (see table 1). ISED continues to move forward on the release of spectrum previously identified, and will reflect this work in the new Spectrum Outlook.

12. When developing the 2013 Outlook, ISED considered the demand for commercial mobile and backhaul services, as well as licence-exempt applications. At that time, ISED concluded that the release of additional commercial mobile spectrum was a priority and that in general, there was sufficient spectrum for backhaul services and licence-exempt applications. A significant change from the 2013 Outlook is that, in this document, ISED will consider spectrum releases not only for commercial mobile, backhaul and licence-exempt services/applications, but also for satellite services. This reflects the technological developments and growth in demand for spectrum that are occurring in relation to all of these services and/or applications, and the need to take a more holistic view of the resulting demand pressures for available spectrum in order to enable the continued development of a robust wireless infrastructure in Canada. These observations are discussed further in section 5 of the consultation.

13. Finally, when considering future spectrum releases and their timing, ISED also takes into account international spectrum allocations, including those from the International Telecommunication Union (ITU), to take advantage of the economies of scale that result in both more affordable and advanced equipment that is enabled by globally harmonized spectrum use. ISED also considers the progress and development of equipment standards in order to enable access to the latest technologies, and current spectrum usage in Canada to take into account the needs of existing users. Section 6 examines these factors and proposes potential bands for future release for commercial mobile, satellite, backhaul and licence-exempt services and applications.

4. A principled approach to releasing spectrum

14. In developing policies and licensing frameworks to make additional spectrum available, ISED is guided by the policy objectives of the *Telecommunications Act*, and the *Spectrum Policy Framework for Canada* (SPFC), which seeks to maximize the economic and social benefits that Canadians derive from the use of the radio frequency spectrum resource. These objectives, and the enabling guidelines listed in the SPFC, continue to be relevant for guiding the Minister in delivering their mandate of spectrum management.

15. Spectrum is a critical resource for the telecommunications industry and for providing a variety of services to Canadians. ISED recognizes the importance of relying on market forces in spectrum management, to the maximum extent feasible. However, there will also be a need to make spectrum available for a range of services that are in the public interest, but may not be driven by market forces. In particular, spectrum will continue to be made available to meet requirements for sovereignty, security and public safety.

16. Key elements to consider when releasing spectrum include the timeliness of spectrum releases to ensure they are aligned with and reflective of market and technology developments, maximizing the use of spectrum, and fostering innovation.

17. In order to support the efficient functioning of markets, and to be responsive to changing technology and marketplace demands, spectrum should be made available in Canada to keep pace with international markets and global technology development. Releasing spectrum when there is an expected radio equipment ecosystem or when it is clear that there will be global standards will allow Canadians to benefit from access to next generation smartphones and devices that are competitively priced due to the economies of scale that are realized when manufacturers make equipment for many markets.

18. Wireless technology and networks continue to evolve to provide better services and more sophisticated applications across all sectors. Therefore, in support of the Innovation and Skills Plan, the long-term evolution of high-quality services and technologies should be taken into account when releasing additional spectrum.

19. Furthermore, the process for making spectrum available should be open, transparent and reasoned to promote predictability and therefore business and investment certainty for stakeholders. As such, ISED has and will continue to conduct public consultations when making changes to spectrum allocations or when releasing additional spectrum. These consultations offer stakeholders, including service providers, manufacturers, interest groups and Canadians, an opportunity to provide valuable input into the regulatory process. Consultations allow ISED to take into consideration the views and perspectives of different stakeholders, and to validate its assumptions and information on the state of the industry, in its decision-making process.

20. As the spectrum resource is in limited supply, ISED seeks to maximize the use of the spectrum. As demand for spectrum increases, traditional services are competing with new services to use the same spectrum. Today, ISED often chooses to move existing services to another band to free up spectrum for new uses. In the future, this approach will not always be possible given the extent to which spectrum is already being used. However, new technologies and techniques (e.g. cognitive radio, dynamic spectrum access, smart antennas, and radio resource management techniques) are being developed that will change the way spectrum is accessed through intelligent decision-making solutions and geographic/operational awareness of the radio environment. These technologies and techniques provide new opportunities for optimizing the use of spectrum and promise to make it increasingly feasible to share spectrum in real time between multiple different services. ISED will take into account new approaches and the impact of new technology when assessing the potential changes to spectrum allocations and when prioritizing spectrum releases.

21. In addition, ISED may need to examine new approaches to spectrum licensing in order to enable and support the development, adoption, and use of new and future wireless technologies and applications. ISED has recently launched the *Consultation on Releasing Millimetre Wave Spectrum to Support 5G*, in which it sought comments on the development of a flexible use licensing model, and other licensing approaches, to allow new 5G technologies and innovations to evolve without overly prescriptive requirements. Such a discussion, in the context of releasing additional spectrum for commercial mobile, licence-exempt, satellite, and backhaul services and applications, could provide ISED with preliminary insight on the potential need for changes to its licensing regime in the future.

Q1 – What future changes, if any, should ISED examine with regard to the existing licensing regime to better plan for innovative new technologies and applications and allow for benefits that new technology can offer, such as improved spectrum efficiency?

5. Spectrum demand and technology advancement

5.1 Overall demand for data

22. The demand for radio frequency spectrum continues to rise as a result of growth in wireless broadband users, devices and innovative applications. According to the *Cisco Visual Networking Index* (Cisco VNI),[2] by 2021 the number of devices and connections is expected to be three and a half times the world population, compared to just over twice the world population in 2016. Annual global internet protocol (IP) traffic is expected to reach 3.3 Zettabytes (ZB) by 2021, up from 1.2ZB in 2016. Cisco also indicated that the proportion of global IP traffic from Wi-Fi and mobile devices will increase from 48% in 2016 to 63% by 2021. It is also expected that service providers will face increased pressure to meet the demand for access to high-speed, bandwidth-intensive services and applications (e.g. video and music streaming), with Cisco forecasting that average per capita monthly traffic will increase to 35.5 Gigabytes (GB) per capita by 2021, up from 12.9 GB per capita in 2016.

23. This overall demand for data is expected to impact the spectrum requirements for services or applications that provide wireless data services. Therefore, ISED has proactively explored a wide variety of studies that forecast global and domestic radiocommunication traffic growth, technology advances and general spectrum trends to better understand the current and future spectrum management challenges and opportunities related to the expected overall demand for data. These studies show that the volume of data to be carried over various networks is expected to increase between three- and six-fold by 2020 and that the most significant growth in demand for data will be for commercial mobile services, licence-exempt applications (largely Wi-Fi), satellite services and backhaul. Therefore, ISED has focused on these four services and applications in considering future spectrum releases from 2018 to 2022.

24. ISED recognizes that there are several variables that impact spectrum requirements (e.g. technology, traffic growth, network design), and that these can vary significantly for different networks, applications and services. Furthermore, traffic growth for some services and applications can impact the spectrum requirements of other services (e.g. demand for commercial mobile traffic can impact the demand for backhaul spectrum and due to commercial mobile off-loading, can impact the demand for licence-exempt spectrum). Therefore, in the sections that follow, ISED is seeking comments regarding spectrum demand in Canada and the global and domestic technical or operational advancements and market trends that will impact the demand for spectrum over the next five years.

[2] The *Cisco Visual Networking Index* (VNI) is a collection of reports and forecasts, updated annually, regarding global fixed/mobile traffic and Internet trends.

5.2 Commercial mobile services

25. The evolution of mobile communications has had a significant impact on all sectors of the economy and continues to contribute to the economic and social well-being of Canadians. Canadians want high-quality services, ubiquitous coverage and affordable prices from their telecommunication service providers. Smartphones, tablets, wearable devices, machine-to-machine (M2M) devices and the applications that run on them are changing the way that Canadians work, live and play. Mobile communications have become integrated into the daily lives of Canadians as they increasingly rely on mobile services to access a variety of mobile applications, such as multi-media services, social networking and Internet browsing, on a day-to-day basis to do business, connect with others, and to manage finances, health and homes.

26. Commercial mobile services are becoming the preferred communication tool for many Canadians. The Canadian Radio-television and Telecommunications Commission's *Communications Monitoring Report 2015* showed for the first time that more Canadian households subscribed exclusively to mobile wireless services (20.4%) than exclusively to wireline telephone services (14.4%). The *Communications Monitoring Report 2016* shows this trend increasing, with 23.7% of Canadian households subscribed exclusively to mobile wireless services, and only 13.6% subscribed exclusively to wireline telephone services. In addition, the 2016 report indicates that while the majority of Canadians still own and use wireline phones, the data confirms the steady shift away from this technology in favour of wireless services. More Canadian households have mobile phones (85.6%) than landlines (75.5 %) – a big change from only ten years ago, when just over half of Canadian households subscribed to mobile phones (62.9%) and almost all subscribed to landlines (94.0%).

27. Commercial mobile services have evolved significantly over the last 30 years, from simple first-generation mobile voice telephony in the 1980s to complex 4G technology supporting voice and data transmissions in the high-mobility environment of today. In recent years, consumers in Canada and around the globe have increasingly demanded extended coverage, faster data transmission rates and more advanced, data-intensive mobile applications. In response, service providers deployed ubiquitous, high-capacity radio networks based on state-of-the-art technologies. Wireless networks currently cover approximately 20% of Canada's geographic land mass and reach 99% of Canadians with approximately 97.4% of Canadians having access to a long-term evolution (LTE) network, according to the *Communications Monitoring Report 2016*.

28. To date, ISED has made 648 MHz of spectrum available for commercial mobile services. Table 1 below provides details regarding the frequency bands made available and the amount of spectrum in each band.

Table 1: Bands currently available for commercial mobile services in Canada*

Band	Frequency range (MHz)		Amount of spectrum
Mobile broadband service (MBS)	698-764	776-794	68 MHz
Cellular	824-849	869-894	50 MHz
Advanced wireless services (AWS)-1	1710-1755	2110-2155	90 MHz
AWS-3	1755-1780	2155-2180	50 MHz
AWS-4	2000-2020	2180-2200	40 MHz
Personal communication systems (PCS)	1850-1915	1930-1995	130 MHz
Wireless communication services (WCS)	2305-2320	2345-2360	30 MHz
Broadband radio services (BRS)	2500-2690	N/A	190 MHz

* The above table lists the frequency bands currently in use in Canada for commercial mobile service. These frequency bands may also be shared with other services as per the Canadian Table of Frequency Allocations.

29. Commercial mobile spectrum requirements depend on the total amount of traffic and the number of subscribers accessing the network at peak periods, as well as the network design. In addition, commercial mobile networks are often made up of a mix of technologies (e.g. global system for mobile communications (GSM), high speed packet access (HSPA), long-term evolution (LTE)), which have different spectral efficiency in terms of the amount of traffic they can carry over a particular bandwidth. In the future, the response to additional traffic demands is expected to be more challenging, due to the use of more bandwidth-intensive applications, the need to address privacy and security concerns, and innovative uses for mobile spectrum including IoT. Therefore, ISED considered three factors to assess the future spectrum requirements for commercial mobile services: subscribership, traffic growth and technology advancements. These factors are discussed in greater detail below.

5.2.1 Subscribership

30. On a global scale, all regions and markets are expected to continue to experience growth in mobile subscribership. In their report *The Mobile Economy 2017*, the Groupe Spéciale Mobile Association (GSMA) forecasts over 5.6 billion global subscribers in 2020, up from 4.8 billion subscribers in 2016. Specific regions are driving this growth, with the Asia-Pacific region accounting for nearly two-thirds of the 800 million new subscribers expected in the period. Developing markets account for nine out of ten new subscribers expected by 2020, largely due to improving affordability, falling device prices and better network coverage. Subscribership growth in markets where penetration is already high, such as North America and Europe, is expected to be slower, and largely due to adoption of multiple devices by a population that is already fully subscribed.

31. In Canada, there are currently over 30 million[3] mobile wireless subscribers. The slow but steady increase in subscribership has been reported in the *Communications Monitoring Report 2016*, which shows that the percentage of Canadians who subscribed to wireless services has increased from 80% to 82% from 2010 to 2015. However, the subscriber growth rate declined from 5.9% to 3.4% during that same time period. Traditionally, Canada has been an early and heavy adopter of mobile services, unlike other regions which have had lower penetration of mobile devices. Due to the high penetration of mobile devices in Canada, the growth rate between 2016 and 2020 is expected to be below the global rate. However, it is expected that there will still be a steady increase in subscribership between 2016 and 2020 from 30 million to 32.9 million, as Canadians continue to adopt multiple mobile devices.[4]

32. In addition to traditional consumer uses, other sectors have begun to rely on commercial mobile services. For example, the health, automotive and utilities industries are taking advantage of new mobile technologies to increase their productivity and develop new business models. Machine-to-machine (M2M) connectivity is allowing significant advancements in various sectors, enabling innovative uses and applications. Examples of this can be seen in the health sector where new mobile applications allow medical first responders to remotely assess and treat patients and in smart cars that enable drivers to monitor traffic congestion in order to plan more efficient routes.

33. By 2021, the increased use of M2M devices is expected to have a significant impact on commercial mobile subscribership. The *Cisco VNI* estimates that, globally, M2M connections will experience a 4.3-fold increase (from 780 million to over 3.3 billion connections) from 2016 to 2021. However, the total global traffic expected to be generated by these devices will still account for less than 5% of total mobile traffic by 2021. Some M2M applications will be data-intensive, consuming large amounts of bandwidth (such as video streaming for emergency and disaster response support), whereas other uses (e.g. sensors and wearables) will consume much less bandwidth since they will transmit short and intermittent data bursts. Canada has also seen significant growth in M2M subscriptions, with the *Communications Monitoring Report 2016* showing over 7 million M2M connections, an increase of 65% from 2015.

5.2.2 Traffic growth

34. As subscribership continues to increase in all regions, so does global monthly traffic. The Cisco VNI indicates that by 2021, commercial mobile services will experience a seven-fold increase in monthly data consumption to over 41 Petabytes (PB)/month, up from 6 PB/month in 2016.

35. The main driver of mobile data traffic growth is the increasing adoption of smart devices[5] and the bandwidth-intensive applications they enable. According to the *Cisco VNI*, smart devices represented 46% of mobile connections in 2016, but accounted for 89% of mobile data traffic. By 2021, they predict that 74.7% of mobile devices will be smart devices, and they are expected to account for 98% of mobile data traffic. Mobile video applications are a major driver, with video traffic anticipated to increase over nine-fold during in the period 2016-2021. Smartphones are the most used smart devices, accounting for 81% of mobile traffic in 2016 and a projected 86% in 2021. In absolute terms, Cisco

[3] Canadian Wireless Telecommunications Association (CWTA), Facts & Figures, 2017.
[4] TeleGeography, GlobalComms Forecast Service.
[5] Smart devices refer to mobile connections that have advanced multimedia/computing capabilities with a minimum of 3G connectivity.

forecasts that the global average amount of mobile data traffic per smartphone will increase from 1,614 MB per month in 2016 to 6.8 GB per month in 2021.

36. As is the case globally, Canada will experience a substantial increase in demand for commercial mobile data in the coming years. The *Cisco VNI* forecasts that national monthly mobile data traffic in Canada will grow five-fold between 2016 and 2021, from 73.2 PB/month to over 340.9 million PB/month. Studies conducted by Analysys Mason[6] and Ericsson[7] suggest that Canada and the U.S. have the highest monthly data usage rates per device, and that this trend will continue beyond 2020. Ericsson suggests North Americans, on average, will consume over 22 GB/month per device by 2020. This high monthly usage is predicted, in part, due to the fact that a large portion of Canadian mobile subscribers tend to have high-end mobile devices (i.e. smartphones) and many of these subscribers have access to advanced technologies such as LTE. In comparison to other markets where 2G and 3G technology is widely used, Canada is gaining momentum in adopting 4G. Analysys Mason reports that 4G is likely to be the technology of choice for over 80% of all mobile connections in Canada by 2020.

5.2.3 Technology advancements for commercial mobile

37. In response to the projected global mobile traffic growth, the ITU has developed a vision of the future of mobile technologies towards 2020 and beyond.[8] This vision sets the stage for the next generation of commercial mobile systems or “5G” technologies. According to the ITU, there is a need to improve access to and efficient use of spectrum to accommodate the large amount of data traffic that is expected to be generated by advanced mobile devices.

38. 5G will be the next major advancement in mobile telecommunications standards. Forecasted use cases include enhanced/ultra-fast mobile broadband, massive machine type communications, and ultra-reliable/low latency communications, all of which are predicted to drive increased usage and facilitate deployment of integrated verticals such as healthcare, transportation, and smart cities, while leveraging massive IoT growth. A number of other new technologies to support these use cases are emerging or are being researched as part of 5G standards development. These emerging technologies include, among others, the use of massive multiple input, multiple output (MIMO) technology, full-duplexing, and carrier aggregation techniques. These technology advancements, in conjunction with existing technologies, are expected to improve network capacity and spectral efficiency.

39. As with all technologies, access to appropriate frequency ranges is essential for 5G. For example, some applications will require high throughput over short distance (e.g. frequencies above 24 GHz) while others may need high reliability over long ranges (e.g. lower frequencies, below 1 GHz). Consequently, the type and amount of spectrum necessary to deliver 5G services will vary based on usage requirements.

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[6] Analysys Mason, *North America Telecom Market: Trends and Forecasts 2015-2020*, 2015.
[7] Ericsson, *Ericsson Mobility Report*, June 2016.
[8] ITU, Recommendation ITU-R M.2083-0, *IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond*, 2015.

40. As outlined in the Innovation and Skills Plan, ISED recognizes the importance of innovation in digital technologies and is seeking to maximize the benefits of current and emerging digital technologies by positioning Canada at the forefront of wireless communications. As new technologies such as 5G promise to foster innovation among businesses and offer consumers advanced products and applications, Canada will seek to capitalize on these technology advancements to give businesses, research institutions and cities a competitive edge.

5.2.4 Overall impact on commercial mobile spectrum requirements in Canada

41. Mobile technology is constantly evolving to make more efficient use of spectrum in order to meet the increasing traffic demands. However, some technology advancements require new spectrum for reasons other than increased demand. For example, some specific bands may be required due to their ability to accommodate large bandwidths or due to their specific propagation characteristics.

42. Mobile operators have several options available to optimize the use of their spectrum to meet increased traffic demand, such as densifying their networks, deploying efficient equipment and employing more sophisticated traffic management techniques. However, ISED recognizes that the continued growth in data traffic generated by an increasing number of users in various sectors and the data-intensive applications running on mobile networks may not be sustainable with the use of existing mobile spectrum only.

43. The new applications and services that are expected to be made available through 5G technologies will likely need bands in different frequency ranges in order to be realized. 5G networks will require low frequency bands for coverage, mid-range frequency bands to provide both coverage and capacity, and high frequency bands to provide large bandwidths to meet high broadband speeds. When considering spectrum releases for commercial mobile services ISED will also take into account the different frequency ranges needed for the deployment of 5G networks.

Q2 –Do you agree with the above assessment on demand for commercial mobile services in the next few years? Is there additional information on demand, which is not covered above, that should be considered? If so, please explain in detail.

Q3 – What new technology developments and/or usage trends are expected to address traffic pressures and spectrum demand for commercial mobile services? When are these technologies expected to become available?

Q4 – Recognizing the trend of increasing commercial mobile traffic, what operational measures (e.g. densification, small cells or advanced traffic management) are being taken to respond to, and support, increasing traffic? To what extent are these measures effective?

5.3 Licence-exempt

44. Over the past number of decades, licence-exempt spectrum has witnessed a significant increase in use and innovation due to the low barriers to entry, including the low regulatory burden and the low cost of devices. Consumer devices that use licence-exempt spectrum appeared in the 1980s, for example, baby monitors and garage door openers, and have now expanded to include mobile devices such as wireless headphones, Wi-Fi, and remote control drones. In the context of this consultation, discussions on ‘licence-exempt’ will focus mainly on Wi-Fi and IoT applications (e.g. connected wearable devices, connected cars and cities), as these have seen the most significant growth in recent years. However, ISED recognizes that new technologies are emerging, such as LTE-unlicensed (LTE-U), which can also be enabled through the use of licence-exempt spectrum.

45. Today, licence-exempt spectrum is a critical part of mobile connectivity. According to the *Cisco VNI*, in 2015, mobile offload using the licence-exempt spectrum exceeded cellular traffic for the first time ever; more than half of the online activity produced by smartphone users happens over Wi-Fi and this is expected to increase in the years ahead. In Canada, commercial mobile service providers are now looking to the licence-exempt spectrum as a means to support and advance their networks. Wireless service providers have significantly increased the number of publicly available Wi-Fi hotspot locations (free and for-pay) across the country from 14,000 at the end of 2014 to over 21,000 by the end of 2015, according to the *Communications Monitoring Report 2016*. This provides Canadians an additional method of accessing voice and data communication services on their handheld and other wireless communication devices. Wi-Fi hotspots also provide wireless subscribers a means to minimize potential roaming charges.

46. The IoT industry is relatively nascent but is quickly growing. The majority of IoT devices are expected to use licence-exempt spectrum to communicate with computers, smartphones and tablets, as well as to communicate amongst themselves (e.g. M2M). These devices are primarily used for monitoring healthcare, industrial applications, automotive, tracking utility consumption and for safety and security. However, new applications and opportunities are appearing daily.

47. Communications and connectivity have become essential for the digital economy and the use of licence-exempt spectrum is playing a critical role in enabling this connectivity. To date, ISED has made various bands available for licence-exempt use. Table 2 below shows the bands that are currently available in Canada for this use.

Table 2: Bands currently available for Licence-Exempt use (Wi-Fi and IoT only) in Canada*

Frequency range	Use
54-60 MHz 60-72 MHz 76-88 MHz 174-216 MHz 470-608 MHz 614-698 MHz	Television white space Secondary licence-exempt use, based upon a geolocation database (RSS-222)
608-614 MHz 1395-1400 MHz 1427-1429.5 MHz	Medical telemetry (RSS-210 annex C)
13553-13567 kHz 26957-27283 kHz 40.66-40.70 MHz 433.05-434.79 MHz 902-928 MHz 2400-2500 MHz, 5725-5875 MHz 24-24.25 GHz 61-61.5 GHz 122-123 GHz	ISM bands** (RSS-210 annex B, section B.10) (Canadian Table of Frequency Allocations 2014, ITU-R footnote 5.138 and 5.150)
902-928 MHz 2400-2483.5 MHz 5150-5250 MHz 5250-5350 MHz 5470-5600 MHz 5650-5725 MHz 5725-5850 MHz	RLAN bands*** (RSS-247)
57-64 GHz	RSS-210 annex J
4.75-10.6 GHz 22-29 GHz	Ultra-wide band (RSS-220)
46.7-46.9 GHz 76-77 GHz	Vehicular radars (RSS-251)
401-406 MHz 413-457 MHz	Medical devices (RSS-243 and RSS-244)
5.65-10.55 GHz 24.05-29 GHz 75-85 GHz	Level probing radar devices (RSS-211)

* The above table lists the frequency bands currently in use in Canada for Wi-Fi and IoT. These bands may also be used by other licence-exempt devices. These frequency bands may also be shared with other uses, as per the Canadian Table of Frequency Allocations.

** Industrial, Scientific and Medical (ISM) bands are also available for general licence-exempt use for other applications.

*** Radio Local Area Networks (RLANs) include Wi-Fi and similar technologies.

48. Although the demand for both applications is expected to be closely linked, ISED examined the expected demand for Wi-Fi and IoT separately. Given that Wi-Fi is already heavily used in Canada whereas IoT use is relatively new, the forecasted growth of these two applications will be different. In addition, ISED examined the potential impact that new technology advancements would have on future licence-exempt spectrum requirements.

5.3.1 Demand for Wi-Fi

49. Wi-Fi technology originated in the 1980s, was first standardized in the 1990s, and has since evolved from offering megabit to gigabit capacity. The evolution of network technologies has brought internet access to Wi-Fi enabled devices, including smartphones, tablets, laptops, smart televisions, game consoles and more. In addition to the consumer market, Wi-Fi is increasingly being adopted by business, industrial, medical, educational and transport sectors, among others. The low cost of equipment, coupled with improved performance (e.g. lower latency), flexibility of integration with existing technologies and the availability on many devices, makes Wi-Fi ideal for mobile use.

50. The rapid growth of Wi-Fi-enabled devices is putting pressure on the current capacity of bands used for Wi-Fi. Moreover, with the increase in commercial broadband traffic, service providers are also deploying Wi-Fi hot spots to off-load some of the traffic from their commercial broadband networks. According to the *Cisco VNI*, the number of public Wi-Fi hotspots deployed globally is expected to grow from 94.0 million in 2016 to 541.6 million by 2021, representing a five-fold increase. In Canada, Cisco estimates that 71% of mobile data traffic was offloaded to Wi-Fi in 2016 and it is expected to reach 75% by 2021. Wi-Fi traffic was approximately 698 PB/month in Canada in 2015, and it is predicted that it will reach 2.1 EB/month in 2020. The steep data traffic increase is said to be mostly driven by new uses, including growth in IoT, industrial automation in areas from production to inventory control, healthcare and more. Both the proliferation of these devices and the need to off-load broadband traffic are expected to continue in the coming years.

5.3.2 Demand for IoT

51. IoT will see rapid growth over the next five years and beyond, and will evolve to address the increased need for speed, latency and constant connectivity. According to various studies, the focus for IoT over the next five years is expected to be on the consumer market for applications such as home automation, health and fitness, wearables, connected cars, and virtual reality.

52. The estimates for the total number of expected IoT connections and their contribution to the overall demand for data vary significantly. According to the *Cisco VNI*, in 2016, M2M devices alone represented 50% of the 230M networked devices in Canada, and are expected to account for 67% of the 405.2M networked devices in 2020. IoT is expected to be a major driver of data traffic increase in spectrum used for licence-exempt applications for years to come. Cisco forecasts that the average IoT device will contribute to 682 megabytes of data per month by 2021, compared with 266 megabytes per month in 2016.

5.3.3 Technology advancements for licence-exempt

53. It expected that there will be a continued convergence and integration of commercial mobile and Wi-Fi technologies as they both evolve to meet wireless and mobile communications needs. According to the *Cisco VNI*, globally, 60% of mobile data traffic was offloaded onto the fixed network through Wi-Fi or femtocells in 2016 and this will rise to 63% by 2021.This trend to offload traffic to Wi-Fi is expected to continue as commercial mobile services evolve to 5G. Current visions for future 5G networks include the integrated use of both licensed and licence-exempt spectrum to efficiently manage the different types of expected traffic. In addition to offloading, mobile operators can use licence-exempt spectrum for small cell deployments to help increase capacity in areas where large numbers of users are expected and to increase overall capacity of the network through carrier aggregation with licensed spectrum and for connecting to IoT devices.

54. In 2013, in order to support the large amounts of data expected in the future, the Institute of Electrical and Electronics Engineers (IEEE) adopted a Wi-Fi standard that increased the maximum channel size from 40 MHz up to 160 MHz in the 5 GHz band. Equipment with the capability of using these expanded channels became available in 2016. This increased channel size increases available capacity but also reduces the number of available channels in the 5 GHz band, which could lead to congestion in the band in the future. Conversely, to support the large number of IoT devices that require low power, low data rates, low latency and extended range, the IEEE has developed a standard that uses smaller 2-16 MHz channels that will operate in the 900 MHz band. This might help to reduce the impact of the expected increase of IoT traffic on the 2.4 GHz and 5 GHz bands.

55. At the same time, Wi-Fi and IoT technologies are becoming smarter and more cognitive, and even multi-band and multi-protocol based. That means they are evolving their own interference mitigation approaches with more sophisticated spectrum sharing techniques. Thus it is expected that industry will continue to evolve technology to function more effectively in unlicensed bands.

5.3.4 Overall impact on licence-exempt spectrum requirements in Canada

56. There will be a growing demand for spectrum in the licence-exempt bands, largely due to the growth of Wi-Fi devices seeking higher speeds and performance, and the potential volume of IoT devices. Technology advancements are expected that will allow some of the traffic demands to be met by making the use of spectrum more efficient. However, ISED recognizes that the expected growth in the number of devices will put pressure on the existing licence-exempt bands in the next five years. Therefore, there may be a requirement for additional spectrum to fully meet these demands.

57. In addition, licence-exempt devices are expected to be used for a wide variety of applications with various bandwidth, power and transmission range requirements. ISED will take these different requirements into account when considering frequency bands for release.

Q5 – Do you agree with the above assessment of demand for licence-exempt spectrum in the next few years? Is there additional information regarding demand, which is not covered above, that should be considered? If so, please explain in detail.

Q6 – What new technologies and/or sharing techniques are expected to aid in relieving traffic pressures and addressing spectrum demand for licence-exempt applications? When are these technologies expected to become available?

Q7 – What existing licence-exempt frequency bands will see the most evolution in the next five years? Are there any IoT applications that will have a large impact on the existing licence-exempt bands? If so, what bands will see the most impact from these applications?

Q8 – Will the trend for offering carrier-grade or managed Wi-Fi services continue to increase over the next five years? If so, will this impact congestion in Wi-Fi bands and which bands would be most affected?

5.4 Satellite

58. Due to Canada's vast land mass and widely dispersed population, satellite systems play a vital role in providing communications capabilities in rural, remote and northern communities, where terrestrial facilities are limited or non-existent. In these communities, satellite systems provide the backbone for, or direct access to, essential services such as basic telephone, broadcasting and Internet services.

59. In urban areas, satellite systems used to provide direct-to-home (DTH) television services to consumers and underpin Canada's broadcasting system by transferring content from creators into the cable distribution system. In both urban and rural areas, satellite services also play a critical role in times of emergency, such as natural disasters, when terrestrial telecommunications infrastructure may be disabled. Satellite systems are also used extensively by government to support national security and to assist in monitoring the environment.

60. Just as with terrestrial services, ISED has made specific bands available for different types of satellite services. For the purposes of this consultation, ISED is focusing on mobile satellite services (MSS), fixed satellite service (FSS), broadcast satellite service (BSS) and earth observation, including earth exploration satellite service (EESS), as these are the services most widely used in Canada and the most likely to be impacted by overall demand for data services. Other satellite services, such as amateur-satellite service, space research, inter-satellite service, radionavigation satellite services and aeronautical satellite services are not expected to be directly impacted by increased demand for data and are therefore not included.

61. Table 3 below shows the bands that are currently available in Canada for MSS, FSS, BSS, and earth observation.

Table 3: Bands currently available/used for satellite services in Canada*

Frequency range	Use in Canada	Amount of spectrum
Below 1 GHz	Scientific research, Earth observation, mobile satellite (e.g. search and rescue, ship tracking), space operation, etc.	--
1525-1559 MHz paired with 1626.5-1660.5 MHz	Mobile satellite/terrestrial use**	68 MHz
1610-1626.5 MHz paired with 2483.5-2500 MHz	Mobile satellite/terrestrial use**	33 MHz
1668-1710 MHz	Earth observation	42 MHz
2000-2020 MHz paired with 2180-2200 MHz	Mobile satellite/terrestrial use**	40 MHz
2025-2110 MHz paired with 2200-2290 MHz	Satellite operations (command and control of satellite)	175 MHz
2310-2360 MHz paired with 7025-7075 MHz	Satellite radio broadcasting	100 MHz
3700-4200 MHz paired with 5925-6425 MHz	Fixed satellite	1000 MHz
5091-5250 MHz paired with 6875-7055 MHz	Mobile satellite feeder link***	339 MHz
5250-5470 MHz	Earth observation	120 MHz
7250-7750 MHz paired with 7900-8400 MHz	Canadian government use	1000 MHz
10.7-10.95 GHz paired with 13-13.15 GHz and 13.2-13.25 GHz	Fixed satellite, including mobile satellite feeder link***	450 MHz
10.95-11.2 GHz, 11.45-11.7 GHz paired with 13.75-14 GHz	Fixed-satellite, including communication with mobile terminals****	750 MHz
11.7-12.2 GHz paired with 14-14.5 GHz	Fixed-satellite, including communication with mobile terminals**** and DTH broadcasting	1000 MHz
12.2-12.7 GHz paired with 17.3-17.8 GHz	Satellite DTH broadcasting	1000 MHz
17.3-17.8 GHz paired with 24.75-25.25 GHz	Satellite DTH broadcasting	1000 MHz

17.7-20.2 GHz paired with 27.5-30 GHz	Fixed satellite, including communication with mobile terminals and mobile-satellite feeder link***	5000 MHz
20.2-21.2 GHz paired with 30-31 GHz	Canadian government use	2000 MHz
37.5-42.5 GHz	Potential use by future satellite networks	5000 MHz
42.5- 43.5 GHz	Potential use by future satellite networks	1000 MHz
43.5- 45.5 GHz	Canadian government use	2000 MHz
45.5- 47 GHz	Potential use by future satellite networks	1500 MHz
47.2- 51.4 GHz	Potential use by future satellite networks	4200 MHz

* The above table lists only the frequency bands and/or satellite services in use in Canada that are considered or discussed in this consultation. These frequency bands may also be shared with other services as per the Canadian Table of Frequency Allocations.
** Mobile satellite/terrestrial communications refers to the use of a terrestrial network to expand the service area of an MSS network, using the same MSS spectrum.
*** Refers to mobile satellite systems using FSS spectrum for feeder link.
**** Mobile terminals refer to earth stations for aeronautical, maritime or terrestrial use.

62. It should be noted that some additional bands may be in use for satellite services on a secondary basis and/or to receive information from foreign satellites that have earth stations within Canada.

5.4.1 Overall demand for satellite services

63. In 2016, there were approximately 1459 satellites in operation globally.[9] This figure is expected to at least double, with an additional 1450 geostationary satellites expected to be launched globally between 2016 and 2025.[10] The demand for these new satellites comes primarily from developing countries where there is a lack of telecommunication infrastructure and services, or where economic growth is strong. Overall global demand for satellite spectrum is expected to grow significantly between 2017 and 2022.[11] However, the rate of growth varies significantly depending on the region, frequency band and type of application. Key drivers of this growth internationally include commercial broadband applications and satellite broadcasting, specifically DTH broadcasting of 4K TV. For example, Northern Sky Research has predicted that, globally, more than 785 4K TV channels will be available via satellite over the next decade.

64. The introduction of planned non-geostationary satellite orbit (NGSO) satellites for the provision of global connectivity also has the potential to increase demand pressure for satellite spectrum. While

[9] Satellite Industry Association, *State of the Satellite Industry Report*, June 2017
[10] Euroconsult, Satellite Manufacturing & Launch.
[11] Northern Sky Research, Global Satellite Capacity Supply and Demand, 13th Edition.

these NGSO satellites have the potential to offer higher-speed Internet connectivity with full global coverage, they are still in the early stages of development and in many cases have not been specifically considered in the studies that ISED has reviewed.

65. In North America, satellite services are well established with a significant customer base. It is expected that demand for satellite capacity will continue to grow over the next five years due to the increased demand for more bandwidth and ubiquitous connectivity. Consumers and businesses expect to be connected anywhere, anytime, including in areas that are beyond the reach of terrestrial networks. Increased government use (i.e. high resolution imaging, new constellations of global navigation satellites, defence, etc.) is also expected to affect demand. However, growth in North America is expected to be lower in comparison to developing countries, as satellite services are more mature and penetration of terrestrial infrastructure is much higher.

66. The main drivers for the expected satellite capacity demand growth are broadband applications, such as access to the Internet and over-the-top (OTT) video distribution, potential deployment of new NGSO satellites providing connection speeds that could be comparable to terrestrial systems, and the expanding commercial earth observation market (i.e. mapping, climate monitoring and natural resource exploration). The relationship between demand for satellite services and the corresponding spectrum requirements will be impacted by advancements in technology, such as high throughput satellites (HTS). These and other advancements, as well as their potential impact on demand, are discussed in greater detail in subsequent sections.

67. Given the broad array of satellite applications, users, bands, services, and technologies, a general growth projection for satellite spectrum would not give a clear indication of demand in Canada. Therefore, the following sub-sections provide further analysis of the growth projections and potential technology advancements within individual satellite services and associated frequency bands, to determine which services and applications may need additional spectrum in the future.

5.4.2 Demand for mobile satellite service

68. Most of the traditional MSS networks in Canada operate in the L-band (1-2 GHz) and S-band (2-3.5 GHz). Services provided by these MSS networks include satellite telephony and mobile satellite Internet. Some mobile satellite operators have expanded into the M2M market for management of assets in remote areas.

69. Although there is an expectation of global MSS growth of 8% by 2020,[12] existing MSS spectrum is likely sufficient to meet this demand in Canada.

5.4.3 Demand for fixed satellite service and broadcast satellite service

70. There are several FSS telecommunication applications and services, including broadband Internet over satellite and backhaul. Additionally, FSS bands are used for feeder links for other types of satellite services (e.g. transmission of broadcast television to the satellite and feeder links for MSS). Examples of BSS applications include satellite DTH services such as satellite television and satellite

[12] Technavio, Global Mobile Satellite Services Market 2016 – 2020, September 2016.

radio. The demand for FSS and BSS is dependent on the type of applications that will be offered by the satellite system (e.g. high-definition vs. 4K television or narrowband vs. broadband communications). Therefore when assessing how much spectrum would be required over the next few years to meet demand, ISED has taken into consideration the types of applications and services that would be offered and the type of satellite systems (traditional vs. high throughput satellites) that would be used to deliver these services. High throughput satellites (HTS) are communication satellites that have much higher frequency re-use capabilities and can provide up to 20 times more throughput than traditional FSS satellites with the same amount of spectrum. See section 5.4.4, below, for more detail.

71. Currently, there are three major frequency bands used to provide FSS and BSS in Canada: C-band (3.5 GHz – 7 GHz), Ku-band (10 GHz – 18 GHz) and Ka-band (18 GHz – 30 GHz). These bands are the primary bands that are used to provide commercial telecommunication and broadcasting services. Given the different technical properties and current uses in these bands, ISED examined the demand for each band individually, in order to provide a better understanding of where there will be future pressure on existing spectrum.

72. The Northern Sky Research (NSR)[13] *Global Satellite Supply and Demand Study 13th Edition* forecasts demand for these three bands based on the number of transponder equivalents (TPE)[14] for different applications (e.g. broadband access, enterprise data and broadcast distribution). These forecasts give an indication of what services will be more in demand in the future and the overall expected use pattern for the satellites operating in those bands.

73. **C-band:** The C-band has been used extensively in Canada for the delivery of satellite services. It has favourable propagation characteristics that make it less susceptible to rain attenuation (i.e. rain fade), allowing the delivery of much more stable signals to receivers than in other frequency bands. Given this property, satellites operating in the C-band can provide back-up communication services in times of emergency, when the terrestrial telecommunications infrastructure is no longer functional. Additionally, in many remote and northern communities, terrestrial backhaul is not available. In those communities, all communications depend on C-band satellites. However, the C-band is less useful for bandwidth-intensive applications because the spectrum is shared with other services, and because its use requires larger, more costly antennas. Therefore, in Canada, C-band is typically used to transport voice, video and data services to satellite-dependent communities and to distribute content to independent cable operators.

74. According to data from NSR, demand for satellite capacity for traditional systems in the C-band between 2016 and 2025 will have a compound annual growth rate (CAGR) of -2% globally and -2.3% in North America, primarily due to increasing competition from fibre and terrestrial services.

75. NSR expects the demand for C-band applications in Canada to follow this same downward trend and decrease slightly over the next five years. This is also supported by the 2014 CRTC *Satellite Inquiry Report*, which states that at that time, a significant portion of C-band capacity in Canada remained

[13] Northern Sky Research, established in 2000, is a consulting company specialized in growth analysis for satellite industry.

[14] Transponder Equivalent is a measure used by NSR to project the amount of bandwidth (normalized to 36 MHz) that will be used for a given service on satellites operating in a specific frequency band.

available. As a result of these trends, and the expectation of a surplus of C-band capacity in Canada, there is an opportunity to consider how C-band will be used in the future.

76. **Ku-band:** The Ku-band is mostly used for video-related applications (e.g. DTH television); enterprise data services, such as network connectivity for oil and mining companies; and point-of-sale terminals for gas stations and post offices. Signals carried over this band can suffer from some rain fade in heavy downpours but links are maintained in most cases and interruptions are generally for short durations. In comparison with the C-band, this band allows for smaller antennas that are more conducive to consumer use. Given that the spectrum in the Ku-band is allocated exclusively to FSS or BSS, it can support bandwidth intensive applications such as broadband Internet access and high definition video. Currently in Canada, however, the Ku-band is rarely used for voice and data transport or broadband Internet access.

77. Globally, NSR forecasts growth in demand for traditional Ku-band satellite capacity between 2016 and 2025 at 2.1% CAGR for traditional satellites and 28.4% CAGR for new geostationary HTS satellites, driven largely by the uptake of high definition (4K) television. There are two aspects to this demand: higher definition television requires larger amounts of raw satellite capacity, and its availability is expected to increase consumer demand for DTH satellite television service. The impact on Canadian demand may not be as significant, as further explained below. A similar global growth trend is expected for enterprise data, commercial mobility, and government services, with traditional systems seeing slower growth than HTS systems.

78. In North America, NSR forecasts low growth of traditional Ku-band systems in North America for the same period, with DTH satellite television service at a 0.4% CAGR and enterprise data at 2.3% CAGR. Commercial mobility and government services using traditional systems are forecasted to increase at a 9.9% CAGR and 2.8% CAGR respectively, for the same period. In contrast, much higher growth rates are expected for GEO HTS systems. NSR's forecasts estimated growth for enterprise data at 12.8% CAGR and commercial mobility at 39.1% CAGR. Government services are expected to see a 66.1% CAGR, partially due to upgrades to existing satellite systems.

79. In Canada, similar growth trends are forecast for data services, commercial mobile and government services. For DTH satellite television services in the Ku-band, however, subscriber rates may see a slight decline as some existing customers move to Internet protocol television (IPTV) services delivered by the same service providers. This expectation is supported by the *Communications Monitoring Report 2016*, which shows that DTH television subscribers decreased 7.2% between 2014 and 2015. This trend is not expected to result in a significant reduction in spectrum demand, given that satellite operators will still require the spectrum to provide services to existing customers. Further, it is not expected that Canada will see the same uptake of DTH that is expected globally because of the very high penetration rate of cable television. The arrival of 4K TV will, however, increase the demand for raw capacity, which would be only partially offset by new compression technologies, as described below.

80. Given that geostationary Ku band spectrum is heavily used, it is unlikely that more GSO FSS/BSS satellites systems will be deployed, except to replace existing satellite systems with more advanced satellites that could achieve greater efficiencies and higher data rates to meet increasing customer demand. In order to expand services in the Ku-band, some satellite operators plan to provide similar service offerings in this frequency band with non-geostationary (NGSO) satellite constellations in low-Earth orbit. Although deployment of NGSO systems is in its early stages, it is expected that demand for the KU-band will remain strong, because it provides a favourable balance between capacity and propagation characteristics.

81. **Ka-band:** The Ka-band is the newest frequency band to be used to provide satellite services. It is mainly used for the delivery of broadband Internet access, directly to homes and businesses. The Ka-band also features the smallest antennas of any consumer satellite service, making installation easier and less expensive. Although this band is more susceptible to weather-related outages than the C- and Ku-bands, it currently provides the highest capacity given the available spectrum (see table 3). This is partly due to its later commercialization and resulting use of more advanced satellite technologies, including HTS.

82. Globally, the demand for Ka-band capacity is expected to experience significant growth, with NSR forecasting an overall increase of 12.1% CAGR for traditional systems and 23.2% CAGR for GEO HTS systems between 2016 and 2025. Such growth is driven by the demand for broadband Internet access in rural and remote areas. In North America, demand will be high due to the demand for broadband Internet access and data-intensive applications such as OTT television from unserved and under-served areas. This trend is expected to be similar in Canada, as more HTS systems covering Canadian territory will be deployed, both by Canadian and foreign satellite operators in 2018 and onward, with broadband access being a dominating application in terms of bandwidth demand.

5.4.4 Technology advancements for FSS and BSS

83. As described in the preceding paragraphs, one of the most significant developments in satellite is HTS technology, which is based on multiple spot beams, a high level of frequency reuse and advanced coding techniques. These HTS systems can provide at least two times (but typically 20 times in high frequency ranges) the capacity compared to traditional FSS satellites, for the same amount of spectrum. This improvement in spectral efficiency allows for a much lower cost per bit of data transmitted. In other words, service providers can offer more data at lower prices, with some systems capable of providing an affordable high-speed Internet service that is comparable to terrestrial services available in urban areas. Most of the new satellites operating in the Ku-band and Ka-band employ HTS technology, which is compatible with different network architectures.

84. For both the Ku-band and Ka-band, it is expected that there will be an increased demand for earth-stations-in-motion (ESIM) systems in the next five years. ESIM are mobile stations that use FSS frequency bands instead of traditional MSS bands, and have similar operational characteristics to fixed earth stations. Their deployment is being driven by demand for connectivity and mobility. These high bandwidth systems are typically licensed for operation on board vessels or aircraft, to provide for broadband access where terrestrial broadband networks cannot reach. The development of ESIM creates a new and growing unique market segment, uniquely served by satellite operators. Although the use of ESIM has not been factored into the studies that were reviewed in preparation for this consultation, any significant uptake of these systems in the Ku and Ka bands will have a corresponding impact on the demand for these bands.

85. Advances in satellite technology (smaller, less expensive satellites), ground station antennas (electronically steered flat panel vs. mechanically steered parabolic) have led to the emergence of large constellations of low-Earth orbit (LEO) NGSO satellites designed to deliver broadband connectivity. These systems have the potential to enable low-latency, low-cost, high-speed services around the globe, including in areas beyond the reach of geostationary satellites, specifically in polar regions. These advantages, combined with the limited availability of geostationary satellite spectrum in certain bands, have led to significant commercial interest. The large number of satellites in these constellations, and the number of constellations that will be deployed, may put additional pressure on existing satellite bands and may require new satellite spectrum to be identified.

86. Higher resolution broadcasting (e.g. 4K TV) requires a larger amount of raw bandwidth, due to both the amount of data and the number of channels, and is therefore contributing to spectrum demand. Advances in video compression technologies provide improved video quality at the same bit rate, thereby reducing the bandwidth requirement to deliver the same level of video quality by up to 50%. These video compression technologies will be key to delivering 4K (and beyond) video content from FSS and BSS satellites to cable companies and consumers. However, this efficiency gain will only be realized when all high definition channels are delivered using only the new standards, which is not expected within the next five years.

5.4.5 Demand for earth observation applications

87. Earth observation satellites allow the surveillance and imaging of the Earth, providing essential information on the ocean, land mass, climate and atmosphere. These satellites assist in the monitoring and protection of the environment, the management of natural resources, and support the safety and security of Canadians. Images from these satellites are also used by various sectors of the economy for many different applications, for example, to track agricultural production or assist in the planning and development of large construction projects. Satellite imagery and expertise is also used to support global humanitarian efforts and sustainable development.

88. Even with increasing commercialization of earth observation, government satellite systems are expected to remain a major driver of the growth in the number of satellites between now and 2024. The need for high resolution imaging for detailed geospatial information and real-time weather tracking by both governments and commercial entities is increasing. As a result, over 400 civil and commercial Earth observation satellites, excluding meteorology, are expected to be launched for the next decade compared to 163 in the past decade.[15]

5.4.6 Technology advancements for earth observation applications

89. Previously, typical Earth observation satellites could only provide low resolution still images. Modern Earth observation satellites are equipped with high resolution imaging sensors, capable of producing images (e.g. photos, infrared images, etc.) with resolution as detailed as 0.3 metres. Both the resolution of the images and the growth of applications are increasing the bandwidth requirements for these satellites. As an example, an image of a 1000 km^2 area at 50 metre resolution contains 400k pixels. At a 5 metre resolution, the image contains 40M pixels, requiring 100 times the storage capacity.

[15] Euroconsult, *Earth Observation Manufacturing, Data Markets Continue Expansion* , Press release, 2016.

Additionally, some Earth observation satellites have the capability to deliver near real-time video, which has a significant impact on the amount of bandwidth and spectrum required for these satellites.

5.4.7 Overall impact on satellite spectrum requirements in Canada

90. Based on its examination of current demand projections and technical advances for FSS, BSS, and MSS systems, ISED has observed an overall trend towards moving to higher frequencies to better accommodate data-intensive applications that require larger bandwidths (i.e. higher capacity Internet services and high resolution images and video). Based on this expected demand, ISED believes that it would be possible to consider how C-band could be used in the future. For FSS and BSS, the demand for bandwidth-intensive applications, congestion in the Ku-band and the emergence of NGSO systems all lead ISED to believe that there will be a need to consider additional spectrum for these types of satellite services. Similarly, ISED believes that the increasing capacity requirements for higher resolution Earth observation systems require the consideration of additional spectrum for those services.

Q9 – ISED is seeking comments on the above demand assessment for MSS and earth observation applications for the period 2018-2022. Is there additional information on demand, which is not covered above, that should be considered?

Q10 – ISED is seeking comments on the above demand assessment for FSS/BSS for the period 2018-2022. Is there additional information on demand, which is not covered above, that should be considered with regards to the below bands?

a) C-band
b) Ku-band
c) Ka-band

Q11 – What and how will technology developments and/or usage trends aid in relieving traffic pressures and addressing spectrum demand for satellite services? When are these technologies expected to become available?

Q12 – What satellite applications (e.g. broadband Internet, video broadcasting, backhaul, etc.) do you consider a priority for the period 2018-2022?

5.5 Backhaul

91. Backhaul facilities are an essential part of the infrastructure backbone that enables delivery of Internet, as well as data and voice traffic by fixed and mobile broadband networks. Backhaul is also used, for example, to interconnect remote sites and buildings for corporate, health and educational purposes and to support broadcasting undertakings in the transmission of news gathering video.

92. There are multiple backhaul solutions, including fibre optics, microwave radio and satellites. Generally, a combination of backhaul solutions is employed in Canada, with service providers tending to favour a mix of fibre and wireless microwave. The selection of a particular solution is dependent on a

variety of factors and considerations including technical performance, immediacy of deployment, capacity, cost, accessibility and feasibility of other options.

93. Backhaul facilities are an essential part of the telecommunications infrastructure, in both sparsely populated rural areas and densely populated urban areas. Wireless microwave solutions are more prevalent in remote and rural areas, whereas fibre tends to be the solution employed for high-traffic urban cell sites given its capacity and reliability. However, wireless microwave is also used for the fast deployment of small cells in metropolitan markets. Cost-effective, scalable and easy-to-deploy backhaul facilities are also vital for the introduction of microcells to complement existing cell sites. Moreover, wireless microwave solutions are used to support specific enterprise solutions.

94. In 2014, ISED released SMSE-022-14 *Decisions on Spectrum Utilization Policies and Technical Requirements Related to Backhaul* (hereinafter referred to as the Backhaul Decision), which concluded a consultation on spectrum utilization policies and technical requirements related to backhaul spectrum. Based on comments from stakeholders, ISED decided to implement policy (e.g. removing capacity restrictions) and technical (e.g. consider allowing larger channel bandwidths and smaller antennas) changes to promote greater utilization of existing backhaul spectrum and increase flexibility for users to adapt to changing conditions. As part of this process, ISED also made provision for up to 2100 MHz of additional spectrum to be made available to accommodate backhaul-associated applications. The technical and policy changes are currently being implemented and the additional spectrum is further discussed in section 6.2.

95. Given the wide variety of uses and Canada's varied topography, wireless backhaul networks are designed employing a diverse range of frequency bands. The selection of a particular frequency band is primarily dependent on a variety of technical requirements (e.g. low, medium, or high capacity and long-, medium- or short-haul distance), design characteristics and operational practicalities. Currently, there is roughly 24 GHz of spectrum available in Canada for backhaul facilities. Table 4 below provides details regarding the bands currently available.

Table 4: Bands currently available for backhaul in Canada*

Frequency range	Use
953-960 MHz	Studio transmitter links Rural telephone service
1700-1710 MHz 1780-1850 MHz	Studio transmitter links Two-way backhaul Automatic metering infrastructure and automatic meter reading
2025-2110 MHz paired with 2200-2285 MHz	TV pickups Two-way backhaul
3700-4200 MHz	Two-way backhaul
5925-6425 MHz	Two-way backhaul
6425-7125 MHz	Studio transmitter links TV auxiliary services Two-way backhaul
7125-7725 MHz	Two-way backhaul
7725-8275 MHz	Two-way backhaul
8275-8500 MHz	One-way video

	Two-way backhaul
10.55-10.595 GHz paired with 10.615-10.66 GHz	Two-way backhaul
10.7-11.2 GHz paired with 11.2-11.7 GHz	Two-way backhaul
12.7-13.25 GHz	TV pickups Two-way backhaul
14.5-14.875 GHz paired with 14.975-15.35 GHz	Two-way backhaul
14.875-14.975 GHz	Temporary radio links
17.8-18.3 GHz paired with 19.3-19.7 GHz	Two-way backhaul
21.8-22.4 GHz 23.0-23.6 GHz	Two-way backhaul
24.25-24.45 GHz paired with 25.05-25.25 GHz	Two-way backhaul
25.25-26.5 GHz 27.5-28.35 GHz	Two-way backhaul
38.4-38.6 GHz	One-way and two-way backhaul
38.6-40 GHz	Two-way backhaul
71-76 GHz paired with 81-86 GHz	Two-way backhaul

*The above table lists the frequency bands currently in use in Canada for backhaul service. These frequency bands may also be shared with other services as per the Canadian Table of Frequency Allocations or used for other fixed service applications such as fixed wireless access.

5.5.1 Demand for backhaul

96. The demand for backhaul capacity is linked to the demand for other services, including commercial mobile, licence-exempt and satellite systems that are discussed in the previous sections. While wireline backhaul solutions are expected to play a role, demand for these services is expected to put pressure on the spectrum currently available for backhaul facilities. In particular, the different use cases and high data rates anticipated for 5G commercial mobile services are expected to have a significant impact on the future backhaul spectrum requirements.

97. According to the *Ericsson Microwave Outlook*, the global trend towards using fiber instead of wireless microwave for mobile broadband last mile access will start to flatten out by 2021, with an expected 65% of all radio sites being connected by microwave systems by that time. In North America, the share of microwave backhaul is predicted to remain steady at around 20% through to 2021.

98. While there are large regional variations in the demand for different frequency bands, some global trends are evident. The *Ericsson Microwave Outlook* shows that several popular bands (e.g. 15, 23 and 38 GHz) have reached their saturation point. The report indicates that, although these bands still have high volumes of new deployments, their relative shares are not growing and that some bands have started to see negative growth (e.g. 7 GHz). Growth today is mainly seen in the higher bands, given that wider channels are available, which can accommodate the higher throughputs required for current 4G and future 5G services.

99. Over the past several years, similar trends have been seen in Canada with spectrum congestion in many cities and communities in the bands used by commercial mobile operators. This congestion is caused by a variety of factors, including deployment intensity within a geographical area, as well as technical characteristics of the systems (e.g. antenna, power). As part of the Backhaul Decision process stakeholders told ISED that they are experiencing congestion and that it is often difficult to coordinate a suitable frequency for some frequency bands and deployment areas. While some are facing congestion across all traditional backhaul frequency bands, others are primarily encountering difficulties within the 6 GHz bands in rural areas and within the 11 GHz, 15 GHz, 18 GHz and 23 GHz bands in urban and surrounding centres.

100. This congestion may increase in the next five years as the demand for more backhaul capacity is expected to grow to support the large data demands anticipated for 5G networks. Current LTE systems require 90 Mbps of backhaul capacity for a typical site, with some requiring up to 1 Gbps. For 5G networks in 2021, the capacity requirements are expected to be 300 Mbps for a typical site and, for some sites, between 3 and 10 Gbps. By 2025 the anticipated requirements are 600 Mbps and 10-20 Gbps, respectively, according to the *Ericsson Microwave Outlook*. Furthermore, bands used for short hauls may see congestion with the increased density of base stations expected for 5G networks.

5.5.2 Technology advancements for backhaul

101. Wireless service providers have been addressing the increasing demands placed on backhaul spectrum by deploying new links, and upgrading existing ones, with state-of-the-art technologies to improve the speed and capacity of their backhaul networks. To accommodate this, several regulators, including those in the European Union, the United States, New Zealand and the United Kingdom, have initiated backhaul spectrum reviews and have updated rules and policies to allow more flexibility in how backhaul spectrum is used. Similarly, as discussed above, ISED has been working to allow for new deployment approaches and technological advances that will allow operators to improve their networks and support the latest broadband technologies.

102. Similar to carrier aggregation, which is used in commercial mobile systems, microwave backhaul employs radio-link bonding to increase available capacity by combining multiple channels to simulate a single wider channel. This approach has so far been limited to channels in the same frequency band. Backhaul systems are now evolving to allow multiband configurations that will allow higher capacities over longer distances by bonding large bandwidths at higher frequencies with narrow bandwidths at lower frequencies. It is expected that this technology will allow operators to use available spectrum more efficiently, as it could increase the capacity of a microwave backhaul network up to ten-fold.[16]

103. As discussed in the commercial mobile section (see section 5.2), higher frequency bands are being considered for use with 5G technologies. Given the propagation characteristics of some of these bands, there is an opportunity to use them for multiple services. It is expected that these bands could be used to provide small cell backhaul which will be required for dense urban 5G networks and for very short haul links to accommodate the low latency required for some of the 5G use cases (e.g. traffic safety and industrial applications). Some regulators have already begun to allow flexible fixed and mobile use in new bands being released for commercial mobile services. For example, the European Union's decision to allow fixed and mobile in the 3500 MHz band[17] and the proposals and decisions to allow flexible fixed and mobile use of the bands above 24 GHz in the U.S.[18] This flexible use will allow for some of the new network approaches expected for 5G.

5.5.3 Overall impact on backhaul spectrum requirements in Canada

104. Congestion in backhaul frequency bands may continue to be experienced in some urban areas as operators expand backhaul capacity to support the demand generated by commercial mobile service. ISED believes that the technical and policy changes that are currently being implemented and backhaul technology advances will serve to help operators respond to some of this demand. However, the expected capacity requirements and deployment scenarios of 5G will require that some new spectrum be made available in the next five years.

[16] Ericsson, *Ericsson Technology Review Volume 93: Microwave Backhaul Gets a Boost with Multiband*, 2016.
[17] Official Journal of the European Union, Commission Decision of 21 May 2008 on the harmonisation of the 3400-3800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community (notified under document number C(2008) 1873), 2008.
[18] FCC, R&O and Second Further Notice of Proposed Rulemaking (FNPR), Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, April 2015.

Q13 – Do you agree with the above assessment on demand for backhaul in the next five years? Is there additional information on demand, which is not covered above, that should be considered? If so, please explain in detail.

Q14 – Backhaul service in Canada is delivered using a variety of solutions, including fibre optics, microwave radio and satellites. What changes, if any, are anticipated to the mix of backhaul solutions employed?

Q15 – What and how will technology developments and/or usage trends aid in relieving traffic pressures and addressing spectrum demand for backhaul services? When are these technologies expected to become available?

Q16 – Will the demand for commercial mobile, licence-exempt, satellite, or fixed wireless services/applications impact the demand for backhaul spectrum? If so, how and which of these services/applications will create the most impact?

Q17 – Is there a range or ranges of frequencies that will be in higher demand over the next five years? Why is higher demand anticipated for these frequency ranges?

Q18 – Will allowing flexible fixed and mobile services within the same frequency band change how backhaul is planned and used?

6. Potential frequency bands for future release

105. As discussed in section 5, ISED believes that there is a need to consider additional spectrum releases in order to respond to the expected future data and capacity demands of the evolving Canadian telecommunication infrastructure. This section examines frequency bands that could potentially be released in the next five years for commercial mobile, licence-exempt, satellite and backhaul services and applications. In many cases, the potential use of the frequency bands overlap between these four services and applications. Future decisions regarding the use of these proposed bands will be subject to separate and comprehensive consultations with stakeholders and will take into account the proposed principles discussed in section 4.

6.1 Bands contained in the 2013 Outlook

106. The 2013 Outlook set out an objective to make a total of 750 MHz of spectrum available for commercial mobile services by 2017. Three frequency bands considered as part of the 750 MHz have not yet been released, namely the AWS-2, 600 MHz and 3500 MHz bands. In August, 2017, ISED initiated a consultation on the 600 MHz band. ISED intends to consult on the remaining bands in the future; the following provides an update on the status of each of these bands.

107. The AWS-2 band, specifically the frequency range 1915-1920 MHz /1995-2000 MHz (H Block), accounts for 10 MHz of the overall target. Although the H Block was auctioned in the U.S. in 2014, the equipment ecosystem has not yet developed.[19] Therefore, ISED will continue to monitor developments in the AWS-2 band and consult on its future use when an equipment ecosystem is expected.

6.1.1 600 MHz

108. The 2013 Outlook indicated that between 80 to 120 MHz was to be repurposed in the 600 MHz band. The Department released its *Decision on Repurposing the 600 MHz Band* in August 2015, to jointly repurpose the 600 MHz band for fixed and commercial mobile use, in collaboration with the U.S. As determined through the U.S. incentive auction, 84 MHz of spectrum will be repurposed, freeing up 70 MHz of spectrum for commercial mobile services. Existing Canadian and American broadcasters will be transitioned to lower parts of the band, and subsequently, a spectrum auction will be held to award licences for mobile services. In August 2017, ISED released SLPB-005-17, initiating a consultation on a licensing framework for the auction of spectrum licences in the band 614-698 MHz (600 MHz band).

6.1.2 3500 MHz

109. The 2013 Outlook included a potential release of 100-175 MHz of spectrum for commercial mobile services from the 3500 MHz band in the 2016 to 2017 timeframe. However, ISED indicated that there could be some uncertainty for this band based on international developments. In the past few years the potential international use of this band has become clearer with consultation and decision processes underway or completed in several countries, including in Japan, the U.S., the UK and Ireland. In addition, in 2014, ISED released DGSO-007-14, *Decisions Regarding Policy Changes in the 3500 MHz Band (3475–3650 MHz) and a New Licensing Process*, which included a fundamental reallocation of the band 3475-3650 MHz to allow mobile services and indicated that future mobile use would be subject to consultation. ISED recognizes that the 3500 MHz band is being considered as one of the key bands for future 5G networks in many countries and that there have been developments in making the larger 3400-4200 MHz band available internationally. As such, ISED will be considering this when consulting on the 3500 MHz band. See section 6.3.5 for further discussion.

6.2 Bands from the Backhaul Decision

110. As part of the Backhaul Decision, ISED also made provision for additional spectrum to be made available to accommodate backhaul-associated applications. The two frequency bands that were identified for two-way backhaul are the 13 GHz band (12.7-13.25 GHz) and the 32 GHz band (31.8-33.4 GHz). ISED is currently developing the technical standards to enable the licensing and use of these bands.

6.3. Potential frequency bands to be released in the period 2018-2022

111. Canada, like most other countries, participates in the global coordination and harmonization of spectrum management through the ITU. The Radiocommunication Sector of the ITU (ITU-R) serves to

[19] ISED posted a notice of application received for a spectrum licence, Notice of Application Received from TerreStar Solutions Inc. for a Tier 1 Spectrum Licence in the 1695-1710 MHz Frequency Band and in the PCS Block H (1910-1915 MHz/1995-2000 MHz), May 25, 2017.

facilitate the equitable, efficient and economic use of spectrum among all radiocommunication services. The ITU-R maintains the international Radio Regulations, which define the allocation of spectrum bands to various types of services on the basis of the International Table of Frequency Allocations. The Radio Regulations are reviewed and amended at the ITU's World Radiocommunication Conferences (WRCs), which are typically held every three to four years. The last WRC was held in 2015, and the next conference is scheduled for 2019.

112. Canadian operators and consumers benefit from economies of scale for equipment when frequency bands are harmonized either regionally or internationally. As such, ISED takes into consideration the frequency bands that have been harmonized at the WRC as well as frequency bands that other countries have released or are in the process of releasing for which equipment is expected to be made available.

113. It is also important to take into account the work underway by various standards bodies since most consumer devices are based on these standards and the status of the standards can provide information regarding the timing of equipment availability. The 3rd Generation Partnership Project (3GPP) and the IEEE are two of the main standards bodies for these types of devices; 3GPP develops equipment specifications to be used by equipment manufacturers for LTE equipment which is widely used for commercial mobile services. The IEEE develops standards for several different technologies, including Wi-Fi, Bluetooth, WiGig, ZigBee and TV Whitespace, many of which are authorized on a licence-exempt basis. These devices are expected to be used as a large part of IoT connectivity.

114. Therefore, when considering potential frequency bands that could be made available between 2018 and 2022, ISED examined:

- bands opened at the recent 2015 World Radiocommuncation Conference (WRC-15)
- bands being considered at the upcoming WRC-19
- bands that have been released or are being considered for release in other countries
- equipment potentially being made available during the next five years

115. These factors, as well as the Canadian context, are discussed below for each of the frequency bands that could potentially be made available in the next five years for commercial mobile, licence-exempt, satellite and backhaul.

6.3.1 800 MHz

116. ***International context:*** In 2004, the FCC adopted a plan to reconfigure the 800 MHz frequency band to address harmful interference to 800 MHz public safety communication systems caused by high-density commercial narrowband wireless systems. This process is nearing completion. Through this process 14-20 MHz of contiguous spectrum in the bands 814-824 MHz and 859-869 MHz was cleared across the United States. In 2012, the FCC revised their rules[20] for this spectrum such that it can now be used for commercial mobile broadband services and it is currently being used to deploy a LTE network in the United States.

[20] FCC, R&O, Request for Declaratory Ruling that the Commission's Rules Authorize Greater than 25 kHz Bandwidth Operations in the 817-824/862-869 MHz Band, et al, May 2012.

117. In addition, several countries in Asia and Latin America have deployed or plan to deploy LTE networks using spectrum within the frequency range 806-869 MHz.

118. ***Potential equipment ecosystem:*** Currently, there are two 3GPP band classes, Band Class 26 (814-849/859-894 MHz) and Band Class 27 (807-824/852-869 MHz) which overlaps with the spectrum cleared in the U.S. for commercial mobile. At present, there are both mobile devices and network equipment available for this band.

119. ***Current and potential use in Canada:*** Currently in Canada, the 800 MHz band (806-824/851-869 MHz) is not considered commercial mobile broadband spectrum as frequencies are licensed per site on a first-come, first-served basis. The current band plan interleaves various types of users, including commercial public safety and private entity operations. This frequency band is allocated to the mobile and fixed services and is essentially divided in two blocks. The first block (806-821/851-866 MHz) allows the use of fixed point-to-point and land mobile systems. The second block (821-824/866-869 MHz) is designated for exclusive use by public safety systems. The band is highly used in Canada, specifically with a high concentration of public safety licensees within key markets.

120. Similar to the U.S., a large high-density commercial narrowband wireless system was deployed in many urban areas in Canada and is interleaved with other uses throughout the 800 MHz band. Evolution in mobile technology and a market driven by demand for mobile broadband is reducing the need for commercial narrowband wireless systems in Canada.

121. The 800 MHz spectrum is attractive as service provisioned over lower frequencies can reach subscribers at a greater distance from the base station. In addition, by taking advantage of wide radio channels, broadband radio technologies (such as LTE) can accommodate further increases in distance between subscribers and base stations and/or increased data communication speeds. Given that there is an available commercial mobile ecosystem and a reduced demand for commercial narrowband wireless systems, ISED believes that it would be beneficial to review this band for potential commercial mobile services in the next five years. Additionally, harmonizing this band would ease cross-border coordination, interoperability, economies of scale and roaming between countries.

6.3.2 900 MHz

122. ***International context:*** Although limited, there has been some activity internationally regarding the use of portions of the 900 MHz (896-960 MHz) band. The U.S. is considering allowing commercial mobile broadband use in portions of the 869-901/935-940 MHz band, currently used for conventional and trunking mobile systems.[21] Through the 2015 release by the FCC of the *Promoting Spectrum Access for Wireless Microphone Operators* R&O, the U.S. also made available additional licensed spectrum for wireless microphones in the frequency bands 941.5-944 MHz, 952.85-956.25 MHz, and 956.45-959.85 MHz, in addition to the 944-952 MHz band, which had already been available.

123. In 2015, Australia decided to expand the licence-exempt portion from 902-928 MHz to 902-935 MHz in order to support low power, low duty cycle communications (e.g. smart infrastructure) given

[21] FCC, Public Notice, *Wireless Telecommunications Bureau seeks comment on supplement to enterprise wireless alliance and Pacific Datavision, Inc. petition for rulemaking regarding realignment of 900 MHz spectrum*, May 2015.

that the characteristics of this band (i.e. low-power, long-range) make it ideal for Smart Cities, Smart Grids and other IoT applications that require low bandwidth and a long battery life.

124. ***Potential equipment ecosystem:*** ISED is not aware of any standards work or licence-exempt devices that operate in the 928-935 MHz band. However, with the decisions in Australia and with the proximity to the existing licence-exempt band, ISED expects that equipment will become available in this band in the coming five years.

125. In addition, commercial mobile equipment is currently available for the overlapping bands 896-915 MHz and 925-960 MHz for European commercial mobile systems.

126. ***Current and potential use in Canada***: The 900 MHz frequency band has traditionally been used in Canada for land mobile, licence-exempt, paging, multipoint communications systems, narrowband-PCS and fixed services. The demand for these services in this band is low and there are relatively few licences in these bands compared to other land mobile radio bands. The licence-exempt portion is predominantly used for legacy M2M, as well as for basic IoT devices. The 900 MHz has similar propagation characteristics to the 800 MHz band discussed above, which would make it equally attractive for commercial mobile use. Given the demand projections for commercial mobile, licence-exempt, and fixed services, as well as the current low usage of the band in Canada, ISED believes that this frequency band should be reviewed to consider new uses. As such, ISED will soon initiate a consultation process regarding the potential use of wireless microphones in the 940-960 MHz portion of the frequency band.

6.3.3 L-band

127. ***International context:*** The L-band (1427-1518 MHz) is a frequency band that was identified for International Mobile Telecommunications (IMT) at WRC-15.The 1427-1452 MHz and 1492-1518 MHz portions of the L-band were globally identified, whereas, the band 1452-1492 MHz was identified in Regions[22] 2 and 3, and over 50 countries in Region 1.

128. The 1452-1492 MHz portion of the L-band is harmonized and mandated by the European Union for mobile broadband supplemental downlink. Ofcom auctioned 1452-1492 MHz in 2008 to allow the offering of services such as mobile television, wireless broadband and satellite radio. In addition, the Australian Communications and Media Authority (ACMA) recently released its discussion paper, *Future use of the 1.5 GHz and 3.6 GHz bands*, on the possibility of repurposing the 1427-1518 MHz frequency band for enabling 5G mobile broadband.

129. ***Potential equipment ecosystem:*** There are currently four 3GPP band classes that cover portions of the L-band. The bands 1427.9–1462.9 MHz, 1475.9–1510.9 MHz and 1447-1467 MHz are band classes 11, 21 and 32 respectively. In addition, the band 1452-1496 MHz (band class 32) is identified for downlink-only LTE and requires carrier aggregation to be configured.

[22] For the allocation of radio spectrum frequencies, the world is divided into three regions by the ITU: Region 1 - Arab States, Africa, Europe, Commonwealth of Independent States; Region 2 - Americas; and Region 3 - Asia-Pacific. Further details can be found in the Canadian Table of Frequency Allocations.

130. ***Current and potential use in Canada:*** Currently in Canada, the L-band is used for subscriber radio service (SRS), which is limited to rural areas, and Narrowband Multipoint Communication Systems (N-MCS). In addition, the band 1427-1432 MHz is being used for automatic meter reading and rural telephone service while the band 1427-1429.5 MHz is available for licence-exempt medical telemetry in limited geographic areas.

131. In the 2012 policy decision SP 1435 MHz, *Spectrum Utilization Policy Decisions for the Band 1435-1525 MHz*, ISED decided that a review of the 1435-1525 MHz band for flexible mobile and fixed use would be postponed given the international interest in mobile broadband systems at the time. In addition, as part of this decision, the use of aeronautical mobile telemetry in the 1452-1476 MHz band was allowed within two 320 km areas around Downsview and Mirabel airports.

132. Given the fact that the majority of the L-band is expected to be globally harmonized, that there is little current use of this band in Canada and that there is expected to be a global equipment ecosystem, ISED considers that the L-band or portions thereof could be released for fixed and mobile use.

6.3.4 AWS-3 unpaired

133. ***International context:*** The AWS-3 unpaired band (1695-1710 MHz) was also auctioned in the U.S. in 2014 as part of its AWS-3 auction. This block was unpaired and the majority of the licences were won by the same licensee as the H-block.

134. ***Potential equipment ecosystem:*** In the U.S., the H-block, the AWS-3 unpaired spectrum and AWS-4 spectrum are held by the same licensee nationwide. As such, the expected equipment ecosystems for these blocks of spectrum are linked and 3GPP band class 70 pairs the band 1695-1710 MHz (AWS-3 unpaired) with 1995-2020 MHz (upper portion of H-block and lower portion of AWS-4).

135. ***Current and potential use in Canada:*** In Canada, this spectrum is allocated to meteorological aids and meteorological-satellite (space-to-earth) services. Radiocommunication systems, such as meteorological earth stations and weather balloons, are deployed in this band. As well, the frequency band 1700-1710 MHz is used for low-capacity point-to-point microwave systems, such as one-way audio studio transmitter links.

136. Although, to-date there is no equipment available for this band class and the timing of equipment is unknown, given that this band has been licensed in the United States, ISED expects that it will become available within the next five years. As a result, ISED considers that AWS-3 unpaired spectrum could be made available for commercial mobile.[23]

[23] ISED has posted a notice of application received for a spectrum licence, Notice of Application Received from TerreStar Solutions Inc. for a Tier 1 Spectrum Licence in the 1695-1710 MHz Frequency Band and in the PCS Block H (1910-1915 MHz/1995-2000 MHz), May 25, 2017.

6.3.5 3500 MHz

137. ***International context:*** Portions of the band 3400-3800 MHz are being made available for commercial mobile or flexible fixed and mobile use in several countries, such as Japan, the United Kingdom, Ireland, China and Australia. In November 2016, the European Commission's Radio Spectrum Policy Group (RSPG) provided an *Opinion on spectrum related aspects for next-generation wireless systems (5G),* which indicated that they consider the 3400-3800 MHz band to be the primary band suitable for the introduction of 5G services in Europe before 2020, since the band is already harmonized in Europe for mobile networks and consists of up to 400 MHz of continuous spectrum.

138. The United-States has made the 3550-3700 MHz band available for shared wireless broadband use through a dynamic spectrum access system. Furthermore, in July 2017 the U.S. released a Notice of Inquiry entitled *Exploring Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz*, seeking comments on the use of 3700-4200 MHz for expanded flexible use.

139. In June 2016, the U.K's Ofcom closed their *3.8 GHz to 4.2 GHz band: Opportunities for Innovation* consultation indicating that they believe there is potential for further exploration of sharing of this band on a geographic basis with their current and future deployments of fixed and FSS systems. In June 2016, Japan indicated that the band 3600-4200 MHz is a suitable candidate band for 5G.

140. ***Potential equipment ecosystem:*** There are currently three 3GPP band classes that cover the 3400-3800 MHz band. Band class 42 and 43 cover the bands 3400-3600 MHz and 3600-3800 MHz respectively. Band class 48 covers the U.S. band 3550-3700 MHz. In addition, the band 3400-4200 MHz had been identified as a single band for the work underway at 3GPP for 5G New Radio (NR) standards and could result in a new band class covering this entire range. Currently, there is equipment available in the 3400-3800 MHz band and 5G NR equipment is expected to become available as early as 2019.

141. ***Current and potential use in Canada:*** The 3400-4200 MHz frequency band is currently used for radiolocation, fixed point-to-point, fixed wireless access, wireless broadband service (WBS) and the FSS systems. The 3400-3450 MHz portion of the band is reserved for use for aeronautical and maritime radars, although some radars also operate as high as 3650 MHz. The band 3475-3650 MHz is currently being used for fixed wireless access systems; however, as discussed in section 6.1.3, ISED has indicated this band will be subject to a future consultation for mobile use. The band 3650-3700 MHz is available for WBS, which are licensed on a shared basis and can be used for both fixed and mobile applications. There are currently limited fixed point-to-point links in operation in the 3400-3475 MHz and 3700-4200 MHz portions of the band. The band 3700-4200 MHz is primarily used by the FSS for the delivery of broadband services as well as feeder links for television broadcasts. In addition, there are unlicensed broadcast receivers used to receive TV programing from the satellite, which are used to distribute TV programming over cable infrastructure or in broadcast studios to receive multimedia to create programming.

142. Given the international interest in this band for 5G, the expected global equipment ecosystem, and the expected decline in future FSS use in this band, ISED will expand the band for the consultation on 3500 MHz to include a review of 3400-4200 MHz.

6.3.6 5 GHz

143. ***International context:*** Internationally, the 5 GHz range is sub-divided into a number of frequency bands, each allocated to various services. Within this range, the frequency bands 5150-5350 MHz and 5470-5850 MHz are available for licence-exempt applications (e.g. Wi-Fi). Given the variety of incumbent services sharing the bands 5150-5350 MHz and 5470-5850 MHz (e.g. radars, EESS and MSS), there are different measures (e.g. power level restrictions, requirement to use dynamic frequency selection and limitations on outdoor use) in place in these bands to facilitate the coexistence between the licence-exempt devices and other services. WRC-19 agenda item 1.16 will consider whether restrictions in some of these bands can be relaxed to facilitate Wi-Fi use while continuing to ensure coexistence with other services.

144. In addition, in 5 GHz frequency bands that are not currently available to Wi-Fi (i.e. 5350-5470 MHz, and 5850-5925 MHz), WRC-19 agenda item 1.16 will also address whether or not mitigation measures can be adopted to enable the introduction of new Wi-Fi uses, while ensuring protection of other existing and planned services.

145. ***Potential equipment ecosystem***: Should WRC-19 adopt changes for the existing 5 GHz bands or make new bands available, ISED expects that the Wi-Fi industry will make equipment available within two to three years of the WRC.

146. ***Current and potential use in Canada:*** In Canada, the frequency bands 5150-5350 MHz, 5470-5600 MHz, and 5650-5850 MHz are available for licence-exempt applications and the current technical rules align with the international framework (i.e. ITU *Radio Regulations*). ISED is actively participating in the discussion regarding technical changes to these bands and will consult on any changes made at WRC-19. However, ISED has received some expressions of interest from Canadian stakeholders to consider changes to the 5150-5250 MHz band. Therefore, following a consultation, ISED released SMSE-013-17, *Decision on the Technical and Policy Framework for Radio Local Area Network Devices Operating in the 5150-5250 MHz Frequency Band,* which modifies the technical and policy framework for Radio Local Area Network (RLAN) devices operating in the 5150- 5250 MHz frequency band to allow the use of higher power RLAN devices , both indoor and outdoor, under a licensed regime.

147. The 5350-5470 MHz band is used by the Canadian Space Agency's RADARSAT earth exploration satellites. These satellites provide images of the earth from space and allow for mapping, marine surveillance, ice and environmental monitoring and disaster and resource management. The RADARSAT satellites provide data to the Government of Canada, as well as to many agencies in the United States and to private users worldwide. This band has been the subject of years of domestic and international work to find suitable mitigation measures to ensure protection of RADARSAT, and our efforts will continue on this leading into WRC-19. There is currently no primary mobile allocation in this sub-band, and EESS (active) allocations in the bands 5350-5460 MHz and 5460-5470 MHz are essential for Earth-observation programs, including RADARSAT, whose data is vital for reliable and up-to-date information on how our planet and its climate are changing. In addition, the range 5350-5460 MHz is also allocated to the aeronautical radionavigation service (ARNS) and the radiolocation service on a primary basis.

148. In Canada and in the United States, the band 5850-5925 MHz is designated for use by dedicated short-range communications (DSRC) in support of intelligent transport systems (ITS). The ITU defines ITS as systems that utilize the combination of computers, communications, positioning and automation technologies to improve the safety, management and efficiency of terrestrial transportation. Many of the ITS applications require radio spectrum, since they involve communications with moving vehicles. ISED anticipates that DSRC deployment will begin this year. As such, through SAB-001-17 *Displacement of Existing Fixed Service Assignments in the Frequency Band 5850–5925 MHz*, ISED allowed the introduction of vehicle-mounted DSRC devices in the band 5850-5925 MHz and initiated the displacement of fixed service assignments in that frequency range.

149. ISED is actively participating in the work on the bands 5350-5470 MHz and 5850-5925 MHz. Should these bands be made available at the WRC-19 for licence-exempt applications, ISED will consider if they should be made available in Canada at that time.

6.3.7 Earth exploration satellite service bands (7 and 9 GHz)

150. ***International context:*** WRC-15 allocated the bands 7190-7250 MHz, 9200-9300 MHz and 9900-10400 MHz to EESS on a primary basis to allow for earth observation (e.g. the gathering of large amounts of scientific and geological information in areas such as disaster relief and humanitarian aid, land use and large area coastal surveillance). This decision was based on the growing demand for increased radar image resolution, in turn requiring an increase in bandwidth. With this additional spectrum, a total of 1200 MHz of contiguous bandwidth is available for earth observation satellites.

151. ***Potential equipment ecosystem:*** Unlike the other services and applications, earth observation equipment is generally developed for specific uses, there is little standardization and most systems are developed through partnerships. However, given the global allocation and anticipated demand, ISED expects that satellites will be developed to use these bands.

152. ***Current and potential use in Canada:*** The 7 GHz band is currently in use in Canada and is a key frequency range for RADARSAT. Currently, the Canadian Space Agency has not indicated any intention to use the 9 GHz band. However, the satellite imaging industry in Canada is expected to continue its growth. Opening this band may benefit commercial satellite operators providing high resolution satellite imagery or remote sensing services. ISED is currently consulting on adopting the decisions from WRC-15 through SMSE-005-17 *Proposed Revisions to the Canadian Table of Frequency Allocations (2017 edition)* and these bands will be considered as a part of this process.

6.3.8 Bands above 24 GHz

153. ***International context:*** There is a significant interest internationally in using the bands above 24 GHz for all four of the services and applications that are being considered in this consultation. Based on the propagation characteristics of these bands and the expected evolution of technologies and techniques that can facilitate spectrum sharing between different services, there is interest internationally to use these bands by multiple services wherever possible.

154. WRC-19 will consider five different agenda items for different services with studies in overlapping frequency bands above 24 GHz:

- Agenda item 1.5: to consider the use the use of the frequency bands 17.7-17.9 GHz (space-to-Earth) and 27.5-29.5 GHz (Earth-to-space) by Earth Stations in Motion (ESIM) communicating with geostationary space stations in the fixed-satellite service
- Agenda item 1.6: to consider the development of a regulatory framework for non-GSO FSS satellite systems
- Agenda item 1.13: to consider identification of frequency bands for the future development of IMT
- Agenda item 1.14: to consider appropriate regulatory actions for high-altitude platform stations (HAPS)
- Agenda item 9.1 issue 9.1.9: to consider spectrum needs and possible allocation of the frequency band 51.4-52.4 GHz to the fixed-satellite service (Earth-to-space)

155. Table 5 below shows the frequency bands that are being considered under each agenda item and where they overlap.

Table 5: WRC-19 Agenda items related to frequency bands above 24 GHz

Agenda item 1.5 ESIM	Agenda item 1.6 NGSO FSS	Agenda item 1.13 IMT	Agenda item 1.14 HAPS	Agenda item 9.1.9 FSS
		24.25-27.5 GHz	24.25-27.5 GHz (region 2 only)	
27.5-29.5 GHz				
		31.8-33.4 GHz		
	37.5-42.5 GHz (space-to-Earth)	37-42.45 GHz	38-39.5 GHz	
		42.5-43.5 GHz		
		45.5-47 GHz		
	47.2-50.2 GHz (Earth-to-space)	47.2-50.2 GHz		
	50.4-51.4 GHz (Earth-to-space)	50.4-52.6 GHz		51.4-52.4 GHz (Earth-to-space)
		66-76 GHz		
		81-86 GHz		

156. Canada is actively involved, both domestically and internationally, in work related to these agenda items. These frequency bands will be reviewed, based both on their merit toward global spectrum harmonization as well as on their impact on existing users. It is anticipated that WRC-19 will find sufficient spectrum and/or adjust the regulatory framework to support these services.

157. In addition to the work underway at the ITU, several countries have also started to consider or release bands above 24 GHz for fixed service, mobile service and licence-exempt applications in preparation for the 5G applications that require high throughput over short distance.

158. In July 2016, the FCC released the *Spectrum Frontiers Report and Order (R&O) and Further Notice of Proposed Rulemaking (FNPRM)* regarding the use of frequency bands above 24 GHz. As part of the R&O the FCC made the 28 GHz (27.5-28.38 GHz), 37 GHz (37-38.6 GHz) and 38 GHz (38.6-40 GHz) bands available for flexible mobile and fixed use, and the band 64-71 GHz available for licence-exempt use. In the FNPRM the FCC is seeking comment on authorizing fixed and mobile use of the following bands: 24.25-24.45 GHz together with 24.75-25.25 GHz (24 GHz band), 31.8-33 GHz (32 GHz band), 42-42.5 GHz (42 GHz band), 47.2-50.2 GHz (47 GHz band), 50.4-52.6 GHz (50 GHz band), and the 71-76 GHz band together with the 81-86 GHz bands (70/80 GHz bands). In addition, they are seeking comment on the possibility of using some of these bands for licence-exempt, as well as on the use of bands above 95 GHz.

159. In November 2016, the European Commission's RSPG provided an *Opinion on spectrum related aspects for next-generation wireless systems (5G),* which recommended that Europe should develop harmonisation measures for the frequency band 24.25-27.5 GHz before 2020, and that the frequency bands 31.8-33.4 GHz and 40.5-43.5 GHz should not be further encumbered so as not to preclude making them available for 5G in the future. As part of Ofcom's 2016 update of the *Mobile Data Strategy*, they indicated that the bands above 24 GHz are a high priority and that it is examining whether either 24.5-27.5 GHz or 31.8-33.4 GHz could be utilised for early implementation.

160. ***Potential equipment ecosystem:*** Significant work is underway in various forums and standards bodies to define the equipment that will be used in the bands above 24 GHz. The 24 GHz, 28 GHz, 32 GHz and 38 GHz bands have been identified by operators as potential bands for 3GPP's 5G NR. Therefore, it is expected that there will be an equipment ecosystem for the various uses being considered for these bands.

161. ***Current and potential use in Canada:*** The bands above 24 GHz discussed in the preceding paragraphs are currently used for satellite service or fixed service in Canada. Table 3 and table 4 respectively provide details of these uses. In addition, as discussed in section 6.2, ISED recently decided to make the 32 GHz band available for two-way backhaul applications.

162. In June 2017, ISED released SLPB-001-17, *Consultation on Releasing Millimetre Wave Spectrum to Support 5G*, seeking comments on releasing millimetre wave (mmWave) spectrum to support the deployment of 5G in the 28 GHz (27.5-28.35 GHz) and 37-40 GHz frequency bands for flexible fixed and mobile use, and the 64-71 GHz frequency band for licence-exempt use.

163. For the studies leading up to the WRC, in addition to the 37 GHz, 38 GHz and 64-71 GHz bands, which are part of the SLPB-001-17, ISED believes that the significant international interest in the band 24.25-27.5 GHz will make it a priority for study at the ITU. The other bands above 24 GHz being studied for WRC-19 are being proposed as potential bands for future use in Canada for various services. ISED will assess each band and its use when developing positions for the WRC through the normal conference preparation process. In addition, ISED will take into account the decisions of WRC-19 when considering future spectrum releases for the bands above 24 GHz.

6.3.9 Summary of potential frequency bands

164. As discussed above, ISED is continuing work to release the bands from the 2013 Outlook and the Backhaul Decision. In addition, ISED has also begun to consult on some other bands. Table 6 shows a summary of the work that is currently ongoing and that is expected to continue over the next few years.

Table 6: Ongoing and planned spectrum releases

Band	Service/application	Status
600 MHz	Commercial mobile	*Consultation on Technical, Policy and Licensing Framework for the 600 MHz band*
AWS-2	Commercial mobile	Subject to future consultation
3500 MHz	Commercial mobile Fixed	Subject to future consultation
7 and 9 GHz	Satellite – EESS	*Proposed Revisions to the Canadian Table of Frequency Allocations (2017 edition)*
13 GHz	Backhaul	Being implemented as set out in the Backhaul Decision
28 GHz	Commercial mobile Fixed	*Consultation on Releasing Millimetre Wave Spectrum to Support 5G*
32 GHz	Backhaul	Being implemented as set out in the Backhaul Decision
37 GHz	Commercial mobile Fixed	*Consultation on Releasing Millimetre Wave Spectrum to Support 5G*
38 GHz	Commercial mobile Fixed	*Consultation on Releasing Millimetre Wave Spectrum to Support 5G*
64-71 GHz	Licence-exempt	*Consultation on Releasing Millimetre Wave Spectrum to Support 5G*

165. In addition to the bands included in table 6, table 7 shows the bands that ISED believes have potential to be made available, in full or in part, in the coming five years to address spectrum demand for commercial mobile, fixed, satellite and licence-exempt services and applications. It should be noted that these bands are being discussed based on the information available today and are subject to change based on further study, international developments and changes to the expected equipment ecosystem.

166. As discussed above, ISED recognizes that many of the bands listed in table 7 are already in use by various services and applications. Any changes to the utilization of these bands would be subject to future consultations.

Table 7: Potential frequency bands for release between 2018 and 2022*

Band	Potential service/application
814-824 paired with 859-869 MHz (800 MHz)	Commercial mobile
896-960 MHz (900 MHz)	Commercial mobile Fixed Licence-exempt
1427-1518 MHz (L-Band)	Commercial mobile Fixed
1695 – 1710 MHz (AWS-3 unpaired)	Commercial mobile Fixed
24.25-27.5 GHz	Commercial mobile Fixed Licence-exempt
31.8-33.4 GHz (32 GHz)	Commercial mobile Fixed
40-42.5 GHz	Commercial mobile Fixed Satellite
45.5-50.2 GHz	Commercial mobile Fixed Satellite
50.4-52.6 GHz (51 GHz)	Commercial mobile Fixed Satellite
71-76 GHz	Fixed Commercial mobile Licence-exempt
81-86 GHz	Fixed Commercial mobile Licence-exempt
Bands above 95 GHz	Licence-exempt Fixed

* Existing services/applications currently allocated or in use are not necessarily included in this table; detailed use is provided in the discussion of each frequency band above.

Q19 – Provide, with rationale, your view of the above assessments on the bands being considered internationally for commercial mobile, fixed, satellite, or licence-exempt.

Q20 – ISED is seeking comments on the potential frequency bands for release in table 7:

- **a) the proposed services and/or applications for each frequency band**
- **b) the potential timing of releasing for each frequency band**
- **c) the priority of the release of the frequency bands**

Provide supporting rationale for your responses.

Q21 – Are there any other bands that should be considered for release in the next five years for commercial mobile, fixed, satellite, or licence-exempt that are not discussed above? Provide rationale for your response.

Q22 – Are there specific frequency ranges/spectrum bands that should be made available for specific applications?

Q23 – Are there any factors that would impact the potential release of these frequency bands between 2018 and 2022?

7. Next steps

167. ISED will review the comments received and publish a decision on the issues raised in this consultation paper.

8. Submitting comments

168. Respondents are requested to provide their comments in electronic format (Microsoft Word or Adobe PDF) to the following email address: ic.spectrumauctions-encheresduspectre.ic@canada.ca.

169. In addition, respondents are asked to specify question numbers for ease of referencing and to provide supporting rationale for each response.

170. Written submissions should be addressed to the Director, Spectrum Regulatory Best Practices, Innovation, Science and Economic Development Canada, 235 Queen Street, Ottawa, Ontario K1A 0H5. All submissions should cite the *Canada Gazette*, Part I, the publication date, the title and the notice reference number (SLPB-XXX-17). Parties should submit their comments no later than January 9, 2018, to ensure consideration. Soon after the close of the comment period, all comments received will be posted on ISED's Spectrum Management and Telecommunications website.

171. ISED will also provide interested parties with the opportunity to reply to comments from other parties. Reply comments will be accepted until February 8, 2018.

172. All comments, and reply comments will be published, so those making submissions are asked not to provide confidential or private information in their submissions.

173. After the initial comment period, Innovation, Science and Economic Development Canada may, at its discretion, request additional information if needed to clarify significant positions or new proposals. Should additional information be requested, the reply comment deadline may be extended.

9. Obtaining copies

174. All ISED spectrum-related documents referred to in this paper are available on Innovation, Science and Economic Development Canada's Spectrum Management and Telecommunications website.

175. For further information concerning the process outlined in this consultation or related matters, contact:

Innovation, Science and Economic Development Canada
c/o Director, Spectrum Regulatory Best Practices
235 Queen Street
Ottawa, Ontario K1A 0H5
Telephone: 613-219-5436
Email: ic.spectrumauctions-encheresduspectre.ic@canada.ca