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Scientific Letter

Bandwidth Requirements for Day-to-Day Operations on Canada’s 700 MHz Public Safety Broadband Network

Background

In 2010, the Federal Government of Canada launched a consultation on the technical framework that would enable a future public safety broadband network (PSBN) in Canada. Essentially, a PSBN is a nationwide broadband cellular network for public safety use. A reason for this important initiative is that the nature of the demand for data communications for first responders differs markedly from the data communications demand of consumers. The communications profile of first responders consists of two distinct factors: (i) the day-to-day (DTD) contribution which is assumed to be uniformly distributed over an operating area and (ii) an intense incident-level demand concentrated in a small geographic area—a fraction of the overall operating area. As such, the network design and implementation of a public safety broadband network (PSBN) would not follow the same approach used to design commercial mobile broadband networks. In the latter case, networks are designed to maximize the use of the total spectrum available during normal DTD operation. Hence, during the peak periods of the day when demand is much greater than DTD, the level of service to end users is impacted. Conversely, a public safety broadband network is designed to maximize the availability of spectrum during incidents rather than DTD. Consequently, a public safety broadband network will have unused capacity available for significant periods of time when only DTD requirements need to be satisfied.

In response to the 2010 consultation, Defence Research and Development Canada – Centre for Security Science (DRDC CSS), published a report in February 2011 that presented the results of an analysis to estimate the bandwidth required to deliver broadband services to Canadian first responders during typical incidents of varying degrees of severity [1]. The study considered the composition of the response team for three emergency events, namely a chemical plant explosion, a multi-vehicle accident, and a riot at a sports event. When emergency services respond to an incident their ability to access the information they need and share it among themselves enhances their situational awareness and becomes vital to the success of the mission. The communications needs at each event, and for each responder agency, were determined as well as the data throughput required for each application expected to be delivered over a 700 MHz broadband network. The study also considered the average spectral efficiency of long term evolution (LTE) technology in the uplink and downlink directions and possible improvements with advanced technologies that had not yet been commercialized at the time.

The 2011 study used a similar methodology that other researchers followed prior to, and subsequent to it [2, 3, 4]. In all cases the conclusions of those studies are that 2x10MHz of bandwidth would be required to support the data communications needs of first responders during incidents of moderate to moderately severe intensity.

While understanding the incident-level bandwidth requirements of a PSBN is vital to its successful implementation, the DTD bandwidth requirements are equally as important. The 2011 study [1] focused on the demands for data during periods when the need would be most acute and critical but it did not address DTD demand. DTD demand consists of data communications requirements for normal daily operations such as routine traffic stops, background checks, vehicle telemetry, emergency medical dispatch, automatic license plate readers, etc., and is the subject of this report.

This report, requested by the Director General of DRDC CSS is intended to inform the public safety community and other stakeholders of the 700 MHz RF bandwidth that would be needed to support public safety typical DTD operations with broadband wireless communications services. As indicated above though, bandwidth requirements for DTD operations are not the basis for a public safety broadband network implementation, but an understanding of this baseline is required to determine potential collaborative operational models for a PSBN. Determining the potential collaborative operational models is outside the scope of this report.

Methodology

The data used in this analysis is taken from the report published in 2011 on the RF bandwidth requirements for public safety wireless broadband [1]. That study focused on demands for broadband data that are expected to arise during typical incidents. The methodology used in this report consists of removing the incident-driven demands from the response profiles that were considered in that study. All other factors, formulae, and considerations remain unchanged.

Assumptions

The data used in this analysis does not consider the impact of future developments that either increase the demand for data on wireless networks or deliver additional wireless capacity. On the one hand, the growing interest in the Internet of Things (IoT) portends a massive increase in the demand for data[1]. Indeed, the interest in 5G[2] to address the potential 1000x increase in capacity is, in part, aimed at the IoT revolution. Significant developments in this area include wireless offloading, heterogeneous networks and small cell underlays. On the whole, it is expected that the overall wireless ecosystem will evolve in a manner that addresses the potentially massive impact of the IoT, and any other disruptive development for that matter. Because of this, it is too early to gauge how these emerging developments may impact the public safety broadband network in one way or another. Hence, IoT and 5G effects are not considered in this report.

[1] The article by McKinsey & Company provides an notional overview of the IoT: http://www.mckinsey.com/insights/high_tech_telecoms_internet/the_internet_of_things.

[2] The white paper from 5G Americas (previously branded as 4G Americas) provides an overview of market drivers, recommendations for requirements and solutions for 5G [5].

The assumptions that are used in this analysis are the same as those that were used in the original study [1]. They cover:

- The downlink (DL) and uplink (UL) throughput requirements of the various applications that are expected to be used by users (Table 1).
- The response profile for DTD operations as represented by the number and types of users (Table 2).
- Variables such as cell radius, size of the territory for DTD operations, over-booking factors, frequency reuse mechanisms, etc. (Table 3).

***Table 1**: Throughput requirements for applications [1].*

	data rates (kbps)			data rates (kbps)	
	DL	UL		DL	UL
Video applications			Database access and records upload		
Surveillance video HR	1536	0	GIS information	50	20
Surveillance video LR	64	0	License Plate Reader	50	256
Tactical video LR	64	64			
Tactical video HR (monitor)	1152	1152	Monitoring		
Ambulance patient video (LR)	0	64	Automated Vehicle Locating	5	10
Ambulance patient video (HR)	0	768	Blue Force Tracking	5	10
Public Transit video (LR)	64	64	Vital signs monitoring	5	10
Public Transit video (HR)	384	384	Automotive telemetry	5	10
Video conferencing	384	384	Tracking evacuees	5	10
News feeds	768	0	CBRNE sensors	5	10
			Sum of monitoring applications	30	60
Collaborative tools					
Emergency Management System	incl.	incl.	Messaging		
Computer-Aided Dispatch	incl.	incl.	SMS, MMS, email	40	20
Records Management System	incl.	incl.			
Sum of collaborative tools	50	50			

Table 2 also contains the throughput requirements for each type of user in DTD operations taken from [1], which are illustrated in relation to each other in the pie chart of Figure 1. The aggregate throughput is for the entire region and is pro-rated for a single sector of an LTE base station. It is the per-sector demand from which the bandwidth requirement is derived.

***Table 2**: Response profile for DTD operations and throughput requirements [1].*

			Average data rate (kbps)	
			DL	UL
1	No. of fire-fighting assets and vehicles	20	2,367	1,812
2	No. of tactical cameras, sensors	12	60	386
3	No. of Emergency Medical assets and vehicles	154	19,388	9,997
4	No. of police assets and vehicles	484	69,250	50,646
5	Utilities, municipal services, govt civil agencies assets and vehicles	1320	19,140	39,705
			110,205	102,546
6	organic growth of assets (per year)	3%	4,188	3,897
7	demand growth from new apps (net of efficiencies)	5%	7,665	7,132
			122,058	113,575
8	Area served by the PSBN (sq.km)	630		
9	Cell radius (km)	2	Average data rate (kbps)	
10	No. of sectors in a cell	3	per sector	
	area served by one sector (sq.km)	4.2	811	755

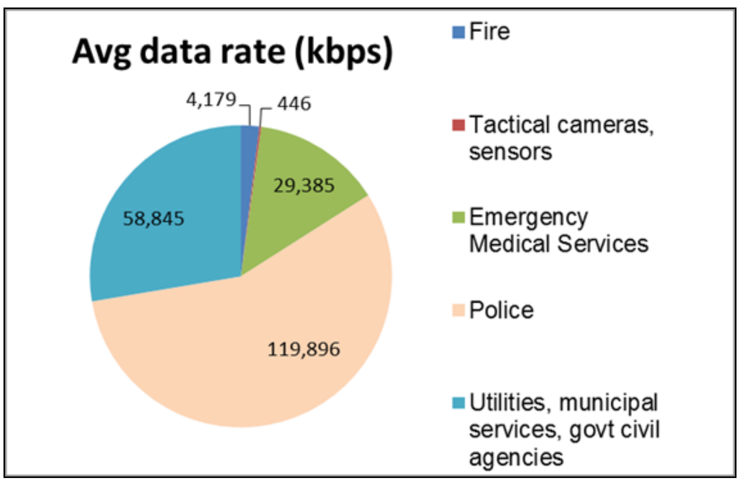

***Figure 1**: Breakdown of throughput requirements by type of user over the entire territory of DTD operations.*

***Table 3**: Variables used in the demand and capacity modeling [1].*

	Variables	Incident scenarios	Day-to-Day Operations
A	Number and types of responders at an incident.	see Incident Profile tabs	see "Day-to-Day Operations tab
B	Applications used by the responders at an incident	see "Data Rates" tab	see "Data Rates" tab
C	Datarates	see "Data Rates" tab	see "Data Rates" tab
D	**Video management policy**	**Incident scenarios**	**Day-to-Day Operations**
	Number of simultaneous HR feeds that can be viewed at EOC	8	8
	Number of simultaneous LR feeds that can be viewed at EOC	balance of feeds	
	Number of simultaneous HR feeds that can be viewed at MCV	2	2
	Number of simultaneous LR feeds that can be viewed at MCV	10	10
	Number of simultaneous HR feeds that can be viewed by selected 1st Responders	1	1
	Number of simultaneous LR feeds that can be viewed by selected 1st Responders	3	3
	Number of simultaneous video conferencing participants	4	4
	Number of Patient Videos that can be viewed simultaneously at med.ctr.	4	40
E	Number of fixed Surveillance video cameras (not backhauled with LTE)	4	100
F	Number of live News feeds	1	6
G	Multicast Broadcast Multimedia Services (MBMS) overhead	10%	10%
H	**Statistical Gain**		
	streaming video	4	20
	video conferencing	10	20
	interactive applications	4	20
	background polling application	1	1
I	**Growth variables**		
	Penetration rate for mobile broadband services (per year)	10%	10%
	Growth of the user community - assets and people (per year)	0%	3%
	Introduction of new and as-yet uknown applications and devices (annually, after year-3)	5%	5%
J	**Area of Operations**		
	size of the territory (sq.km)		630
	radius of a cell (km)		2
	number of sectors in a cell		3

Discussion of Results

Table 2 contains the expected data demand for all users in DTD operations spread over a territory measuring 630 km^2. The model assumes a uniform distribution of users in the territory, which is contrary to the way the analysis is performed using an incident-based approach. In the latter case, it is expected that users will converge to a relatively small area in response to the incident. This has the effect of driving up the demand in a small portion of the public safety broadband network (PSBN) serving the territory. In the DTD case, the throughput is calculated for one sector covering ≈ 4.2 km^2. As with the original study, the bandwidth requirements have been calculated for a 20-year period. The results are captured in Table 4. It shows the projected growth in spectral efficiency due to advances in LTE technology and improvements in coding efficiencies versus the demand for data. This comparison is shown in the chart of Figure 2.

The rise in demand from Yr-1 to Yr-10 is attributed to the penetration of services among the user community. The inflection of the demand at Yr-10 is due to having saturated the penetration of the user community at that time.

***Table 4**: Results of the analysis of DTD operations in terms of data demand and bandwidth requirements.*

	Avg. spectral efficiency/sector (b/s/Hz/sector)		Data Demand		RF bandwidth requirements		
	DL	UL	DL (kbps)	UL (kbps)	DL (MHz)	UL (MHz)	Sum
Yr-1	0.69	0.30	311	289	0.45	0.96	1.42
Yr-2	0.69	0.30	352	327	0.51	1.09	1.61
Yr-3	0.69	0.30	387	361	0.56	1.20	1.77
Yr-4	0.86	0.38	448	417	0.52	1.11	1.63
Yr-5	0.86	0.38	494	460	0.57	1.23	1.80
Yr-6	0.86	0.38	546	508	0.63	1.35	1.99
Yr-7	1.06	0.46	602	560	0.57	1.23	1.80
Yr-8	1.06	0.46	665	619	0.63	1.36	1.98
Yr-9	1.06	0.46	734	683	0.69	1.50	2.19
Yr-10	1.33	0.65	811	755	0.61	1.16	1.77
Yr-11	1.33	0.65	815	758	0.61	1.16	1.78
Yr-12	1.33	0.65	818	761	0.62	1.17	1.78
Yr-13	1.92	1.05	822	765	0.43	0.73	1.16
Yr-14	1.92	1.05	826	768	0.43	0.73	1.16
Yr-15	1.92	1.05	830	772	0.43	0.74	1.17
Yr-16	2.40	1.49	834	776	0.35	0.52	0.87
Yr-17	2.40	1.49	839	781	0.35	0.53	0.88
Yr-18	2.40	1.49	844	785	0.35	0.53	0.88
Yr-19	2.85	1.74	849	790	0.30	0.45	0.75
Yr-20	2.85	1.74	854	794	0.30	0.46	0.76

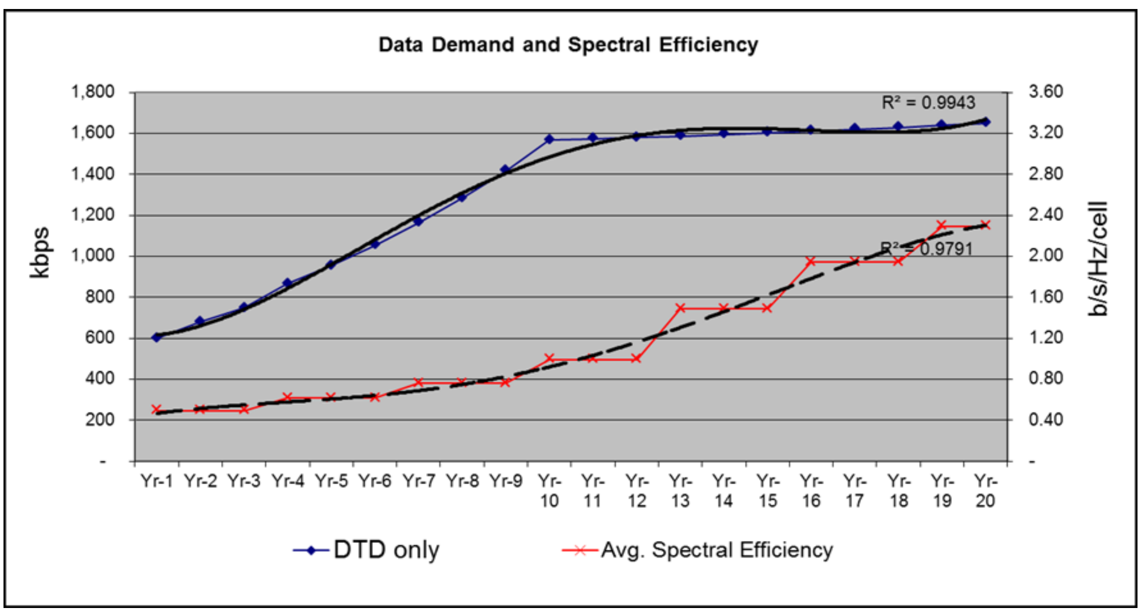

***Figure 2**: Comparison of the growth in data demand for DTD operations versus the increase in spectral efficiency.*

Figure 3 illustrates the variation in usable bandwidth over time and the predicted bandwidth requirements for DTD operations on a per-sector basis. The large step increase in usable bandwidth at Yr-4 represents the shift from sector-based RF planning to one where the entire cell's capacity can be flexibly allocated to any location in the cell's footprint. Further improvements in spectral efficiency are obtained by better interference control and implementation efficiencies. At Yr-13 and beyond, the model shows that the usable bandwidth is greater than 90% of the channel bandwidth.

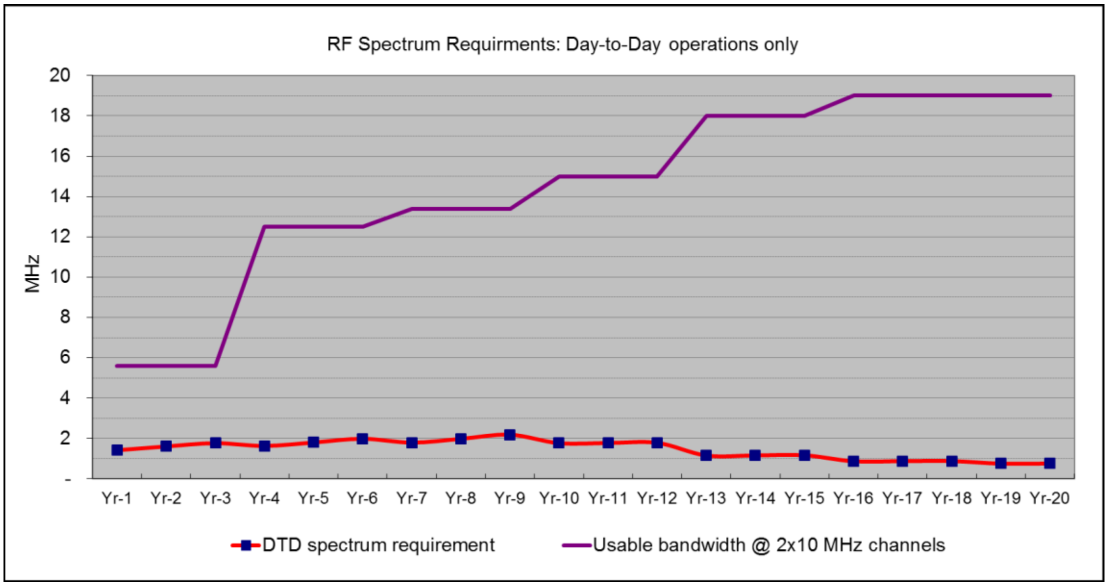

***Figure 3**: Comparison of the usable bandwidth versus the bandwidth requirements for DTD operations.*

Conclusion

The following interpretations and conclusions can be drawn from the results of the analysis.

- DTD demand for 700 MHz bandwidth is shown to be up to 2.2 MHz (year 9), which is significantly less than what was shown to be needed for commonly occurring incidents in [1].
- The LTE technology's spectrum efficiency is expected to out-pace the increase in DTD demand. This means that over time and for a given amount of bandwidth, the capacity of LTE is expected to increase at a faster pace than the demand for broadband data from the public safety community for DTD operations.
- Notwithstanding the bandwidth needed for DTD operations, the PSBN should be designed to support incident-level demand rather than DTD data requirements.
- Excess capacity can be available on the PSBN in those locations beyond the cell sites serving the incident areas for the types of incidents used as benchmarks in [1]. Stated differently, typical incidents are not expected to utilize the capacity of the PSBN over its entire coverage area. When and where the PSBN is not used to satisfy the data demands for first responders engaged in responding to incidents, the balance of the PSBN's capacity would be unused and, therefore available for other purposes. According to the analysis presented in this report, there could be 17.8 MHz of channel bandwidth available for other purposes when and where incidents are not occurring. This assumes that the PSBN capacity is based on a 2x10 MHz allocation of spectrum.

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References

[1] C. Lucente, "700MHz Spectrum Requirements for Canadian Public Safety Interoperable Mobile Broadband Data Communications," Defence R&D Canada, DRDC CSS CR 2011-01, February 2011.

[2] "700 MHz Broadband Public Safety Applications and Requirements," City of New York, February 2010.

[3] "Public Safety Capacity Requirements Analysis," Motorola – Presentation to FCC, April 9, 2010.

[4] "User requirements and spectrum needs for future European broadband PPDR systems (Wide Area Networks)," European Conference of Postal and Telecommunications Administrations (CEPT) – Electronics Communications Committee (ECC), Report 199, May 2013.

[5] "5G Americas, '4G Americas' Recommendations on 5G Requirements and Solutions," October 2014.