RTT TECHNOLOGY TOPIC
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5G Public Safety

This month's technology topic summarises the ongoing discussion and debate about the use of LTE for public safety communication and the challenges and opportunities of replacing legacy analogue and digital radio narrow band radio systems with wider channel bandwidth LTE.

If LTE becomes widely adopted by the public safety community there is also an implied need to provide a migration path to 5G.

Previous attempts to migrate public safety radio to cellular network technologies have failed for a number of reasons.

Cellular technologies have not traditionally been designed to deliver press to talk type services and group calling. Cellular networks have not generally been able to provide sufficient rural coverage. Public safety agencies also raise concerns about security and network resilience.

In practice a substantial amount of public safety radio voice and data is carried over commercial cellular networks using standard smart phones on existing cellular spectrum. These services are however supplemented by legacy private radio systems optimised for voice and capable of supporting deep rural coverage.

In Europe the police, fire and ambulance services are supported on either narrow band TETRA networks or (in France) narrower band Tetrapol networks either privately or publicly owned.

The emergency services in the US or 'First Responders' as they are known are supported on more than 10,000 separate private Land Mobile Radio systems or P25 narrow band analogue or digital radios. Most of these systems are incompatible with one another.

This incompatibility was highlighted as a problem during and after the terrorist attacks of 9/11 in September 2001 and substantially increased political awareness of the importance of a unified mobile communications infrastructure, though 15 years on, not a lot of progress has been made.

There is a strong operational rationale for adopting a common unified network technology. The success of LTE globally opens up the possibility that US, European and Asian public safety radio networks could all be supported on a common technology platform which could deliver operational benefits and scale economy.

The present fragmented approach to public safety spectrum allocation however makes it harder for the supply chain to deliver the specific needs of the public safety radio sector and slows market adoption.

In this month's technology topic we review the US approach to resolving this problem, whether it will work and its potential applicability to other markets.

Read on

Past experience

The problem with allocating spectrum for public safety radio is that you have to get different agencies to agree to what they want or think they want and then find enough money to build and operate the network.

As part of the 2007 US 700 MHz auction process it was proposed that a public private partnership would take on the task of building a nationwide interoperable public safety network based on a 5+5 MHz block of spectrum (763-768 and 793 to 798 MHz) with an adjacent 5+5 MHz D block allocation (758-763 and 788-793 MHz) for commercial auction with the winning bidder required to develop a shared wireless broadband network.

The auction was held in early 2008 and failed to produce a viable bid. In May 2010 the Commission adopted a waiver order granting 21 public safety jurisdictions to 'pursue early deployment of state wide or regional public safety broadband networks'. An additional Waiver order determined that these networks should adopt 3GPP Release 8 (LTE) or higher as a common technology platform.

This signalled a reverse from a previous policy of awarding spectrum on a 'technology neutral basis.' On February 22, 2012 the US Congress enabled the Middle Class Tax Relief and Job Recovery Act which allocated D Block spectrum as a 5 by 5 MHz pass band within Band 14.[1]

The legislation directed the Federal Communications Commission to use the spectrum for a public safety nationwide broadband network to be run by a newly created entity known as the First Responder Network Authority (FirstNet).

The commercial challenge was to produce some money to build the network. The 2012 Spectrum Act determined that $7 billion should be allocated to FirstNet to fund network construction. This was to be raised from the auction of H Block of paired spectrum at 1915 to 1920 MHz and 1995 to 2000 MHz, the AWS 3 auction and the 600 MHz incentive auction.

This proved remarkably easy to achieve with $1.5 billion dollars raised from the H Block auction from Dish Networks who are pairing the spectrum with their AWS4 holdings at 2000 to 2020 MHz and 2180 to 2200 MHz and their unpaired lower 700 MHz E block spectrum (for LTE Broadcast). This was followed by the $44 billion raised from the AWS3 auction.

So the money is there but defining how the 60,000 public safety agencies are going to use the FirstNet network is going to take longer with a 46 step process defined for each of the 50 states and six territories involved including Puerto Rico, Guam and the Virgin Islands

The underlying economic rationale is that public safety agencies can re-use base station and user device LTE hardware but this is dependent on getting supply chain support for equipment which is similar but probably not similar enough to standard cellular operator LTE network and user hardware.

Present spectrum issues

An RFP this month from FirstNet for Band 14 LTE user devices highlights the problem.
It seems obvious to add Band 14 to an iPhone or Samsung Galaxy but incrementally adding a band either needs a new switch and filter path or a wider pass band that brings together the reverse duplex Band 13 (Verizon) and Band 14 LTE channels. While this is possible there will be a performance and cost impact on Verizon LTE handsets which although marginal will still be material.

[1] https://www.fcc.gov/encyclopedia/700-mhz-spectrum

There therefore has to be some commercial motivation for Verizon and the supply chain to deliver Band 13 compatible Band 14 LTE user devices.

Verizon could become the 'fall back' network for US public safety agencies and are regarded by some analysts as a natural carrier partner for FirstNet but AT & T would probably regard this as anti-competitive.

Table 1 US 700 MHz LTE Bands including Band 14 Public Safety

Band 12		Band 13 (Verizon)		Band 14		Band 17 AT and T	
Block (a)		Block (c)		Public safety(ps)		Block (b)	
		Reverse duplex		Reverse duplex			
Mob TX	Mob RX	Mob TX	Mob RX	Mob TX	Mob RX	Mob TX	Mob RX
699 716	729 746	777 787	746 756	788 798	758 768	704 716	734 756

The vendor supply chain will therefore be expected to support Band 13, 14 and 17. US Cellular also would like all US LTE user devices to support Band 12 immediately adjacent to high power broadcast TV. Band 17is effectively a sub band of Band 12.

Add these requirements together and a relatively straight forward well behaved low cost RF front end has become a relatively complex badly behaved expensive RF front end.

This is compounded by the differences between the US 700 MHz band plan and the APT 700 Band 28 allocation in Asia (and assumed European implementation).

Table 2 APT 700 Band 28 Band plan

Band	Name	Uplink		Downlink		Bandwidth	Duplex spacing	Guard band
28	700 APT	703	748	758	803	45+45	55	10

Back in the US, Sprint would also argue that if public safety user devices are supporting Band 14 in the 700 MHz band they should also support Band 26 in the 800 MHz band

Table 2 US 800 MHz LTE Bands including Band 26

Band 26 LTE Extended 850 band 850+		Band 27 E SMR	
Mob TX	Mob RX	Mob TX	Mob RX
814 849	859 894	807 824	852 869
Band 5			
824 849	869 894		

This would provide a migration path for business radio users on the legacy Nextel iDEN E-SMR (Extended Specialist Mobile Radio) network based on the now renamed Band 27 with a potential combined (Band 26 + Band 27) mobile TX pass band of 807 to 849 MHz paired with a receive band from 852 MHz to 894 MHz. However this would require the standard 850 (25+25 MHz) pass band to be extended to 42+42 MHz, well beyond the efficient limits of a single acoustic duplex filter.

Again it could be argued that the cost and performance impact of this would be marginal but marginal enough to matter to incumbent operators in Band 5.

The Sprint offering would presumably be aggregated with their mid band FDD and high band TDD LTE offering.

Table 3 Sprint Tri Band LTE

Low Band		Mid Band		High Band	
Band 5	Band 26	Band 2	Band 25	Band 7 FDD	Band 41 TDD
824-849	814-849	1850-1910	1850-1915	2500-2570	2496-2690
869-894	859-894	1930-1990	1930-1995	2620-2690	
	Sprint 5MHz FDD LTE E-SMR/Nextel		Sprint 5 MHz FDD LTE		Sprint 20 MHz TDD LTE Channel plan varies by US region.
	814-824		1910-1915	Band 38 TDD	
	859-869		1990-1995	2570-2620	

Tethering Band 14 to another LTE band or multiple bands superficially makes technical sense but every operator will have a different technology and band combination which will make it hard to translate public safety and E-SMR functionality across similar but different physical networks.

Performance issues

It is therefore debatable as to whether these wider pass bands including 45+45 MHz Band 28 in Asia and or aggregated multi band LTE offerings are going to deliver what public safety agencies are going to need over the next 15 years.

Existing public radio systems are typically narrow band 6.25 KHz, 10 KHz, 12.5 or 25 KHz channel spaced systems within pass bands of typically 3 to 5 MHz. Evolved variants of existing systems such as Release 2 TETRA in Europe also known as TEDS (TETRA enhanced data service) scale to 150 KHz channel spacing but are still relatively narrow band compared to LTE systems where the smallest supported channel is 1.4 MHz with most present systems implemented with 5 MHz or 10 MHz channel spacing with 15 and 20 MHz as additional single channel options.

Release 2 TETRA increases the physical layer range (essentially constrained by ISI) from 58 kilometres to 83 kilometres to facilitate air to ground communication but this also reflects the need from the public safety sector to provide deep rural coverage for voice and data at a level not presently available from LTE networks.

Partly this is due to economics but the commercial challenge of delivering low cost ‘long distance’ LTE is also partly due to the increased channel bandwidth.

This increases capacity due to the additional multiplexing gain, similar in principal to the trunking gain achieved in trunked radio systems but also increases the noise floor both in the RF front end and the ADC (quantization noise, jitter and compression). Voice is intrinsically narrow band; typically 3 to 5 KHz of bandwidth provides adequate quality and thus can be supported on a low bit rate vocoder on a narrow band channel. It is relatively easy to extract a low bit rate channel from a narrow band carrier. It becomes progressively harder to extract a narrow band channel and the baseband content of that channel from progressively wider channels.

LTE Advanced aggregates 10 or 20 MHz channels to support channel bandwidths of up to 100 MHz with longer term ambitions to increase this in bands below 6 GHz to 200 MHz by 2020.

In the centimetre band from 3 GHz to 30 GHz there are a number of 5G engineering studies that are looking to repurpose fixed point to point radio hardware to support 500 MHz bandwidth systems to be deployed from 2025. This would deliver capacity of several hundred Gb/s/per square kilometre.

Similar studies for the millimetre band (30 to 300 GHz) are assuming carrier bandwidths of either 1 or 2 GHz supported typically within 5 GHz pass bands delivering a capacity of terabits per second per square kilometre from 2030.

2030 might seem like a distant future but it is only 15 years away. For some of us, the millennium celebrations don't seem that long ago.

This suggests that evolved 4G and 5G radio systems may get increasingly distant from public safety requirements over the next 15 years, a process of divergence rather than convergence.

It is of course possible to produce variants of LTE that are based on narrow band channels within wide band channels. This is an ongoing process for Internet of Things devices where new categories of LTE (categories 0 and 00) are being standardized to make low bit rate data more power efficient.

It is however hard to see how extension of the existing standards process will realize the supply chain scale economy needed to make public safety LTE and or 5G public safety radio commercially viable particularly if the end product is significantly different from the core LTE product and service offer.

It may of course be the case that public safety agencies and public safety radio users will not need or want to talk to each other in 15 years' time but this seems unlikely.

If there is a serious ambition to make LTE and or 5G suitable for public safety radio then it will be necessary to demonstrate that it is possible to deliver voice service including group calls in large radius cells power efficiently and at low cost. The jury remains out on that one.

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