RTT TECHNOLOGY TOPIC
October 2010

Blue L(i)TE?

Will LTE deliver into the public safety sector?

In this month's technology topic we explore the viability of LTE for the public safety and emergency response sector. Some of the specific public safety requirements and technology options have been covered three years ago in a Technology Topic **'Three Way Radio- Two Way Radio, cellular and broadcast integration'** . This is an update with a broader look at present and future broadband/narrowband integration opportunities.

One of the objectives of LTE is to achieve global scale economy. For this to apply to LTE in the public safety sector implies achieving some commonality between US, European and Asian band allocations and an ability to integrate with or converge with legacy technology standards.

In the US, discussion has focussed on whether or how to deploy LTE for a public safety national wireless broadband network and regional networks in the 700 MHz band. The US debate provides a reference for the discussions that are taking place on LTE public safety networks in Europe, Asia and the rest of the world and provides an insight into some of the spectral and standards issues that need to be resolved in order to translate present market ambition into practical reality.

The LTE 700 MHz public safety band plan

It has been just over nine years since the 9/11 attacks in the US. The attacks prompted a major reassessment of public safety communication needs that have been at least partially reflected in spectral allocation and auction policy and to a lesser extent in technology policy.

The Upper 700 MHz band plan adopted by the FCC on July 1st 2007 allocated a two by 5 MHz duplex band at 763 to 768 and 793 to 798 MHz for a single nation wide public safety broadband network and a second duplex band known as D band/Band 14 at 758 to 763 and 788 to 793 MHz to be auctioned with public safety requirements. Both channel pairs work as reverse duplex with mobile transmit in the upper duplex. This means that the two lower channel pairs supporting base transmit (the downlink) are adjacent to Verizon's ten MHz of C band LTE 700 downlink (Band 13).

There are also proximate 6 MHz allocations for regional and national narrow band networks, dangerously proximate in terms of coexistence between Verizon upper band LTE transmit and the narrow band public safety receive channels. These narrow band allocations are technology neutral but theoretically could support either two by 3 MHz or four by 1.4 MHz LTE channels, not exactly narrow band but relatively narrow band when compared to other LTE networks.

Table 1 Upper Band 700 MHz LTE including the public safety bands

Band description	Frequency MHz	Mob/UE **TX** or **RX**	Bands Used by /Owned by
C (Band 13)	746 to 757	**RX**	Verizon LTE
D (Band 14)	758 to 763	**RX**	Regional public safety LTE broadband
	763 to 768	**RX**	Nation wide public safety LTE broadband
	768 to 776	**RX**	Narrow band public safety
C (Band 13)	776 to 787	**TX**	Verizon LTE
D (Band 14)	787 to 793	**TX**	Regional public safety LTE broadband
	793 to 798	**TX**	Nation wide public safety LTE broadband
	798 to 806 MHz	**TX**	Narrow band public safety

The US LTE 700 MHz band plan between 698 and 806 MHz is unlikely to be adopted in Asia (with very good reason). The most likely band plan in these markets (basically most Asian markets excluding Japan) is a two by (rather ambitious) 45 MHz duplex pair implemented as a standard duplex as per Table 2

Table 2 LTE 700 band in Asia (Region 3)

698	698 - 703	703- 748	748-758	758- 803	803- 806	806-824	
Top of the TV band	5 MHz guard band	45 MHz LTE Mob TX	10 MHz Centre gap	45 MHz LTE Mob RX	3 MHz guard band	PPDR TX P25 or iDEN	

Putting this US regulatory set back to one side, the promise of LTE public safety spectrum in the US market and associated federal funding has prompted infrastructure vendor interest.

In July, Motorola announced a pilot **LTE public safety network in San Francisco** as a broadband overlay to the existing APCO 25/Project 25 narrow band digital radio system. **APCO 25** is a user requirement body overseen by the **A**ssociation of **P**ublic Safety **C**ommunications **O**fficials. Project 25 (P25) fulfils a similar role to the **TETRA Forum** and **ETSI TETRA standards process** in European and ROW markets. P25 radios have overlapping spectrum with analogue and digital two way radios known as **iDEN**. **Motorola** is a dominant vendor of both technologies. There is also a bonded channel variant of iDEN known as **WiDEN.** iDEN and WiDEN products are targeted at the US **S**pecialised **M**obile **R**adio (SMR) market which is similar but different to the European and ROW PMR (**P**rivate **M**obile **R**adio) market or business radio market. The networks and band allocations are also described functionally as **Public Protection and Disaster Relief** (PPDR).

At the **APCO conference** this August there were vendor announcements from **Alcatel** on public safety LTE integration with EADS supply public safety 911 dispatch data systems. EADS also supplies TETRA systems outside the US. Nokia Siemens announced joint projects with **Harris**, a P25 supplier. On September 7th Motorola and **Ericsson** announced they would be working together on LTE public safety solutions

Public safety vendors and regulators have a chequered history when it comes to delivering interoperability. TETRA and P25 radios for example are incompatible both in terms of technology (the air interface) and band allocation. **TETRAPOL** is yet another (narrow band) standard deployed in other bands in Europe.

Within the US and Europe and Asia, legacy analogue networks are still operational. Interoperability can often therefore only be realised by supporting multiple digital and analogue radio systems making scale economy hard to achieve.

In the US, the White Space spectrum in the 700 MHz band has also just been **officially released by the FCC** for 'Super WiFi'. This will introduce complexity and uncertainty when managing multiple radio system co existence particularly if public safety networks are designated as safety critical.

The LTE 700 MHz public safety networks could work completely separately from all other radio systems but from a specialist user perspective it would be sensible to have at least some interoperability with other networks. For example public safety rural data coverage requirements and user expectations would suggest additional infrastructure will be needed in rural areas. Conversely public safety bodies are unlikely to have the finance to build dense urban networks. Public safety users will expect and probably insist on broadband connectivity with the same coverage footprint as existing narrow band voice networks. Economically this means that public safety LTE 700 networks and commercial cellular LTE 700 networks will need to find some way of working together technically and commercially.

Table 1 suggests the obvious starting point for the US market at least would be a dual band radio capable of accessing Verizon LTE upper C band (Band 13).

However this would increase the operational pass bandwidth of the Verizon Band 13 radios by 18 MHz. This will compromise performance and add cost and weight, an unattractive option for Verizon and Verizon subscribers.

The US 800 MHz Public safety band plan

An alternative option is to produce dual band P 25/LTE or iDEN/LTE radios.

In terms of band allocation, legacy APCO 25/P25 radios are implemented with mobile TX at 821 to 824 MHz (immediately adjacent to the US 850 cellular mobile transmit band between 824 and 849 MHz)) and mobile RX at 866 to 869 MHz (immediately adjacent to the US 850 mobile receive at 869 to 894 MHz).

However Release 9 of the 3GPP specifications proposes three extensions/variations to the US 850 band including adding 10 MHz at the lower end of the present Band 5 allocation which includes all of the legacy P25 800 MHz channels and some of the proposed new channels.

P25 radios and iDEN radios are now coming to market capable of supporting the frequency bands shown to the right of the table. This extends P25 and iDEN into channels previously used and still used for analogue two way radio.

Table 3 US 800 MHz public safety – old and new band plan

<table>
<tr><td>806 to 810</td><td>MOB/UE TX</td><td>Conventional PMR</td><td rowspan="4">New Project 25
TX or iDEN
806 to 824 MHz
18 MHz or 8 MHz with no US 850 overlap</td></tr>
<tr><td>810 to 816</td><td>TX</td><td>Trunked PMR</td></tr>
<tr><td>816 to 821</td><td>TX</td><td>iDEN/wIDEN</td></tr>
<tr><td>821 to 824</td><td>TX</td><td>APCO 25</td></tr>
<tr><td>824 to 849</td><td>TX</td><td>US 850 cellular</td><td>Proposed extension down to 814 MHz</td></tr>
<tr><td>851 to 855</td><td>MOB/UE RX</td><td>Conventional PMR</td><td rowspan="4">New Project 25
RX or iDEN
851 to 869 MHz
18 MHz or 8 MHz with no US 850 overlap</td></tr>
<tr><td>855 to 861</td><td>RX</td><td>Trunked PMR</td></tr>
<tr><td>861 to 866</td><td>RX</td><td>iDEN/wIDEN</td></tr>
<tr><td>866 to 869</td><td>RX</td><td>APCO 25</td></tr>
<tr><td>869 to 894</td><td>RX</td><td>US 850 cellular</td><td>Proposed extension down to 859 MHz</td></tr>
<tr><td>896 to 902</td><td>TX</td><td>Trunked PMR</td><td>iDEN SMR 896 to 902 MHz</td></tr>
<tr><td>934 to 940</td><td>RX</td><td>Trunked PMR</td><td>iDEN SMR 934 to 940 MHz</td></tr>
</table>

iDEN radios have 25 KHz channel spacing with a transmit power of up to 1 watt and a six slot QPSK modulated TDMA physical layer.

P25 radios can have 12.5, 20 or 25 KHz channel spacing and an output power of between one and three watts (also QPSK modulated). In car mobiles can have an output power anywhere between 10 and 35 watts. Base stations can be up to 100 watts. This is serious radio, optimized for rural coverage and deep urban in building penetration.

Multi band versions of P25 radios also have to be capable of working at VHF between 136 and 174 MHz and UHF between 380 and 470 MHz.

The theory is that LTE will provide a broadband bridge between these legacy networks and will allow the public safety sector to benefit from global scale economies with an opportunity to amortise research, development and manufacturing investment across billions of user devices per year. From a specialist user experience perspective this should provide an opportunity to source standard form factor phones, smart phones, tablet/slates and lap tops at consumer prices.

Ideally this user equipment would also be able to access commercial LTE networks.

From the tables above it would seem initially attractive to consider integration with the US 850 band rather than LTE 700. Future iterations of P25 could include a 5 MHz LTE channel adjacent to the US 850 commercial networks as or when or if they transition to LTE.

The problem with this from an RF performance perspective is that even extending the US 850 band by 10 MHz to 35 MHz decreases user equipment sensitivity by 1 dB. Here we are suggesting adding 18 MHz to create a pass band of 43 MHz. This would involve at least as much loss again.

Coupling P25 radios with the LTE channel allocations in the 700 MHz band would require a dual mode radio to support P25 TX at 806 to 824 MHz and theoretically at least low band LTE 700 TX down at 698 MHz. This is 126 MHz of operational bandwidth equivalent to a 16% ratio of the centre of the band. The stretch on the RX path would be similar. This is technically challenging and commercially unlikely. In practice the user equipment would be several radios in one box.

A P25 dual mode radio which interoperated just with the LTE national public safety 700 MHz network would be easier to implement and the narrow band public safety bandwidth could be included as well but the devices would still need to stretch on the receive path from 758 MHz to 869 MHz (111MHz) or 746 MHz to include Verizon Band 13 (123 MHz). Either option would still need a dual or triple front end to be sufficiently efficient.

The problem could be solved technically by throwing away the P25 and iDEN radios, reallocating the bandwidth to US 850 operators and just having LTE 700 police and SMR radios. However this would be hard to sell to public safety and specialist mobile radio users. They would quite rightly point to some of the difficulties encountered when Sprint Nextel iDEN users were forcefully migrated on to the Sprint CDMA network.

Alternatively the LTE mobile broadband network could be regarded as a separate network function with legacy networks and new P25 and iDEN radios providing voice coverage and specialist user requirements such as all informed user capability, <250 millisecond press to connect on to channel access times, multi group and wide area broadcast messages, dynamically changeable priority levels, extra secure authentication and encryption, task optimized noise cancellation, storm plans and special event plans, back to back working, ground to air links, surveillance functions and ruggedized user equipment – all that special stuff.

This however implies parallel standards and parallel development, manufacturing and **test processes** and some significant interworking and interoperability challenges.

An alternative would be to use LTE for broadband and narrow band including voice but voice coverage both in rural areas and in terms of urban in building penetration would need to be absolutely as good as existing narrow band specialist radio.

LTE achieves high peak data rates by using wide channels (up to 20 MHz) in a wide variety of wide bands (up to 60 MHz at higher frequencies). However the 'cost' of delivering these high peak data rates is that multi band LTE user equipment will be inherently less sensitive than single band narrow band radios. (See the previous five technology topics for more detail on this).

Specialist mobile radio networks have to support fewer bands, often in the past only one, and have much narrower operational bandwidths and channel spacing. Narrow channel spacing allows for a narrow band IF. A narrow operational band allows for high Q filters and a highly efficient transmit and receive chain. This means that sensitivity and selectivity and transmit and receive efficiency are generally better than wider band devices. As a result voice coverage in specialist radio networks is likely to be better, particularly in rural areas or for deep in building penetration.

The IP voice used in LTE networks introduces additional packet header overheads that have to be taken out with a compression algorithm. Extracting a 12 kbps voice stream from a wideband 20 MHz channel is also computationally expensive. The computational overheads and compression clock cycles will also introduce delay overhead which would be better avoided if press to talk/press to connect needs to be supported. Talk groups and back to back working will also be needed which will require additional standards work.

For applications where high peak data rates are needed, LTE will provide peak data rates that specialist radio networks will find it impossible or at least difficult to match.

For voice and text applications, or where average data rates are more important than peak data rates for example in larger cells, narrow band networks will provide better voice quality and coverage and probably a longer data duty cycle. LTE could compete on coverage and building penetration if the voice or data traffic was heavily error protected but this will compromise spectral efficiency. If the bandwidth is inexpensive this does not matter. If the bandwidth is expensive, it matters a lot. Heavy error protection will also reduce TX and RX efficiency which will compromise the user data duty cycle. This does not matter if the user is attached to a vehicle power supply. It does matter if the user is out on an eight hour shift on foot or bike or horseback (not an uncommon requirement in crowd control situations).

Policy issues and technology economics

So the suitability of LTE for public safety in the US depends partly on spectral allocation and auction policy, partly on technology policy, partly on the application mix and partly on available budgets.

It seems unlikely that LTE 700 MHz networks on their own could meet all the needs of the public safety and or SMR sector. This means that it will be impossible to discontinue either P 25 or iDEN radio and network system development and deployment.

This loads parallel product development manufacturing and test cost on to the sector.

Some of this cost could be reduced if future iterations of P25 and iDEN could be dovetailed into the Release 10 (LTE Advanced) standards process. A 5 MHz channel could be used for LTE leaving sufficient channel bandwidth for narrow band Project 25 voice connectivity.

This would of course be entirely possible but presently improbable due to understandable vested interest both in the specialist radio vendor and specialist user community. Sector procurement policy is also understandably cautious about what might be perceived as relatively radical change.

While it is possible to design military specification radios that can access multiple bands using multiple technologies, these devices are neither low cost nor particularly energy efficient. They are also heavy. Public safety and emergency response user requirements could be best met by flexible radios capable of accessing commercial LTE radio bands and the public safety bands with RF performance at least as good as existing specialist radio products at a price point close to consumer price expectations.

At present it seems unclear as to how this will be achieved.

The US 700 MHz band plan is a salutary example of what happens when spectral allocation and auction policy is decided by economists who ignore engineering advice and abrogate regulatory responsibility by allowing the market to decide technology policy. Out of necessity, operators and vendors have to respond to short term market expectations. These are incompatible with the long term decisions that need to be taken on future technology options.

The US may well end up with well executed and well integrated broadband and narrow band public safety networks but they will be neither technically or commercially efficient unless a much greater degree of user equipment RF front end flexibility can be realized. This in turn requires a level of investment to which the industry presently has limited visibility.

In Europe and the Rest of the World there is an obvious opportunity to use at least part of the LTE 800 band (between 790 and 862 MHz) to support public safety broadband connectivity particularly as these bands overlap the Project 25/ iDEN bands in the US.

This would mean that standard LTE 800 user equipment and network hardware and software could be used in the US public safety market in the APCO band providing the global scale economy needed by the sector.

The (rather major) snag with this is that LTE 800 will probably be deployed as a reverse duplex with mobile RX at 790 to 821 MHz and mobile TX at 831 to 862 MHz. This is because there is concern in the broadcasting community that transmissions from mobile users will interfere with terrestrial TV reception, a process known as ‘hole punching’. Alternatively the band could be deployed as a standard duplex with TV signals retransmitted from cellular base stations. Apart from opening up opportunities for integrated LTE 800/Project 25 public safety networks we would also get reliable digital TV on portable receivers – always handy in a national emergency and particularly relevant in countries presently attempting to reinvigorate **local TV.** It would also make TV more resistant to interference from White Space transmissions. The band plan if implemented with LTE 800 as a standard duplex (mobile TX in the lower paired band) would look something like this.

Table 4 US and European/ROW 800 MHz band plan implemented as standard duplex

	US	**EUROPE/ROW**
	MOB TX P25/iDEN/US850	**MOB TX LTE 800**
		790
806 to 809	**Narrow band P25 or iDEN Could also be two by 1.4 or one by 3 MHz LTE**	
809 to 814	**Broadband P25 LTE or iDEN LTE (5 MHz)**	
814 to 849	**Extended US 850 LTE**	**821**
		MOB RX LTE 800
		831
851 to 854	**Narrow band P25 or iDEN Could also be two by 1.4 or one by 3 MHz LTE**	
854 to 859	**Broadband P25 LTE or iDEN LTE (5 MHz)**	
859 to 894	**Extended US 850 LTE**	**862**
		MOB TX LTE 900
		880
896 to 902	**iDEN SMR TX**	
		915
		MOB RX LTE 900
		925
934 to 940	**iDEN SMR RX**	
		960

As an added bonus it can be seem that LTE 900 overlaps with the upper iDEN bands at 900 MHz which could be implemented as four by 1.4 MHz LTE bands, two by three MHz LTE or one by 5 MHZ LTE with some guard band.

Getting a band plan like this underway would however require a regulatory environment that creates incentives to encourage cooperation between the cellular and broadcasting industry, the public safety radio user ,standards and vendor community and White Space vendors and investors on both sides of the Atlantic, preferably bridging private sector and public sector interest.

An adversarial spectral allocation process designed to maximize income from spectral auctions makes this cooperation harder to achieve. This is compounded by a failure to realise any substantive global harmonisation particularly in the LTE 700 band. A lack of cross sector and or transatlantic let alone global thinking and direction in standards setting also does not help.

International spectral and standards policy together have a direct impact on user equipment cost and performance and user experience value. Regional standards now make very little economic sense. Nationally specific standards make even less sense. Vendor specific standards only make sense to the vendor.

If a local or regional band allocation or adopted standard does not scale on a global basis, this needs to be factored into bid valuation and network **r**eturn **o**n **i**nvestment expectations. This seldom seems to happen.

Ends

A shorter version of this technology topic is published in the September 2010 edition of **Land Mobile Magazine**

RTT have just produced a major new 70 page study on LTE user equipment and LTE network economics. The study is written by RTT with statistics and economic modelling from **The Mobile World** and is sponsored by Peregrine Semiconductor and Ethertronics.

The study, 'LTE User Equipment, network efficiency and value' is available free of charge from the linked web site.

www.makingtelecomswork.com

Information on Peregrine Semiconductor

Information on Ethertronics

The Broadband Bobby on the Beat

It is easy to assume that innovation happens in consumer markets and then translates across into public safety applications. This has not been true in the past. Examples of past police and public safety radio innovation can be found **here.**

Networks and the New Economy – November Workshop in the UK

It is also not correct to assume that future innovation will originate from outside rather than inside the public safety sector. The UK has a particularly positive track record of developing and implementing specialist radio solutions.

The challenge is probably to integrate the better more appropriate parts of LTE into a fit for purpose hardware and software system solution.

This may include integration with geo stationary ATC satellite and low earth orbit satellite systems and other networks (energy, environmental and transport networks).

These integration challenges and opportunities are addressed in a one day workshop, 'Networks and the New Economy' being held in Cambridge on the 9th November.

Speakers include Dan Mercer from Iridium, Andrew Bell from Huawei, Paul Wallace from Oracle, Paul Green from Arkessa, Olivier Andre from Alcatel Lucent, Franck Chevalier from Analysys Mason and Tim Summers from Freescale Semiconductor.

This workshop is free to Cambridge Wireless members or DCKTN members (and the DCKTN is free to join).

More information and registration details are available **HERE**

Makingtelecomswork.com

An additional level of detail on this topic and related topics can be accessed via the **Resources section** of our linked web site **www.makingtelecomswork.com**

www.makingtelecomswork.com provides a cost and time efficient way in which telecommunication engineers, product managers and policy makers can access **technical information and advice not readily available elsewhere in the public domain.**

The web site also provides information on RTT workshops, **Making Telecoms Work Europe**, **Making Telecoms Work Asia** and **Making Telecoms Work in the US.**

The workshops demonstrate how engineering issues can be practically resolved and how performance gains and cost savings can be achieved.

European work shops are held at the Science Museum in Kensington West London**. Information on the next workshop is available here.**

A number of sponsorship opportunities are available linked to the web site and related Science Museum telecom industry educational initiatives.

If you would like more information on these opportunities please e-mail **geoff@rttonline.com** or phone **00 44 208 744 3163**

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Contact RTT
RTT, the **Jane Zweig Group** and **The Mobile World** are presently working on a number of research and forecasting projects in the cellular, two way radio, satellite and broadcasting industry.

If you would like more information on this work then please contact
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