RTT TECHNOLOGY TOPIC
June 2007

Three way radio - Two Way Radio, Cellular and Broadcast Integration

As it is the TETRA World Congress this month, it seemed good timing to take a look at how specialist user needs are changing and what this means for vendors and operators presently providing products and services to these relatively low volume but high value markets.

In the process we examine present and likely future common interests between the traditional two way radio industry, the cellular industry and broadcast industry and identify areas where positive cross over value can be realised by all parties.

In particular we identify a need for the two way radio industry to establish a closer coupling between two way radio standards and evolving cellular radio and broadcast radio and TV standards - the three way radio proposition.

At the application layer substantial standards commonality is beginning to emerge, for instance the use of MPEG and JPEG encoding and compression schemes and MPEG based content descriptors.

At the transport layer IP protocols are becoming more pervasive and potentially allow much greater transparency across multiple radio bearers.

However the benefits of this transparency can only be realised if a closer commonality between physical radio bearers can be developed over time.

Traditional Specialist user expectations

Specialist users include public safety agencies, fire, police, ambulance, defence users and non emergency users in transport and distribution, energy and small to medium business users.

Traditional expectations in terms of user functionality include open channel working between multiple users based on push to talk functionality, back to back direct mode operation where users can talk to each other directly without a base station in between and ground to air/ air to ground communication, particularly important for military users or event management where aerial surveillance is required.

Latency has always been important and the benchmark generally has been to deliver on to channel times of less than 250 milliseconds.

In terms of radio performance, the most important metric has traditionally been to deliver good rural coverage and good urban in building penetration for two way voice communication.

In Europe this has been achieved by working at VHF or UHF with both the handsets

and base stations working at higher powers than cellular radio. The narrow channel spacing used, typically between 6.25 and 25 KHz and the relatively narrow operational bandwidths, typically 5 MHz or less, makes it possible to deliver good receive sensitivity.

In the USA there are substantial two way radio system deployments in the 800 MHz band. In common with European systems these operate at higher power than cellular systems. APCO 25 portables for example are allowed to produce 5 watts and the base stations can produce up to 500 watts. APCO is unusual in that it is standard developed by a specific user community, the Association of Public Safety Communication Officials.

The table below summarises some typical traditional specialist user needs

Table 1 **Specialist user needs**

Wide area coverage	Better than cellular particularly in rural areas and/or within buildings in urban environments
'All informed' user capability	The ability to hear other users in an 'open' channel
'Instant access' on to available channels	Call set up time has to be less than 250 milliseconds
Multi group announcements	
Wide area broadcast messages	
Dynamically changeable priority levels	
Secure authentication and encryption	
Voice clarity	Includes task optimised noise cancellation, specialist hands free and whisper phones for covert surveillance
Press to talk	With option to work full duplex if needed
Talk groups	Geographical or functional
Inter working/interoperability	Problematic as we shall see later
Storm plans/special event plans	Pre set response to particular events including disaster recovery contingency planning.
Sleeper phones	The ability to stun phones remotely and re enable them as listening or more recently listening and watching and sensing devices.
Ruggedized hand sets	Water proof, dust proof, shock proof fire proof and explosion proof handsets

From the above it can be seen that it is not always easy to move users from a two way radio system on to a cellular system and provide them with sufficiently equivalent functional capabilities. The recent attempted migration of Sprint Nextel iDEN users to Sprint CDMA provides an example of some of the challenges inherent in this process.

Impact of cellular on specialist user expectations

Conversely much of the functionality that we take for granted in cellular handsets,

particularly multi media functionality and the data rates needed to support the real time exchange of multi media content is either not available in a two way radio or commands a substantial cost premium and/or weight and size and/or duty cycle penalty.

Not all specialist users need or want multi media capabilities in their handsets but some do and this present minority will likely increase over time.

Multi media functionality implies audio and video capture bandwidth using high resolution cameras and high resolution display bandwidth using high resolution displays. These functions are only immediately useful if matched with efficient high data rate uplink and downlink radio bearers.

It is not impossible to deliver adequate data rates over two way radio systems. The wider band systems, specifically TETRA and WiDEN are potentially capable of meeting multi media specialist user expectations but substantial engineering effort and investment will be needed to make the handsets and networks work efficiently. The narrow band technologies are optimised for voice or low bit rate data so are inherently unsuitable for real time multi media. These narrow band systems are spectrally efficient but that is of marginal relevance to most specialist end users.

We can illustrate these practical data rate limitations by reviewing firstly the technologies used and secondly the spectrum into which those technologies are presently deployed.

Table 2 **Comparison of present two way radio technologies**

Digital PMR (DMR 446 ETSI)	TETRA TEDS	TETRAPOL	WiDEN	APCO25
6.25 KHz or 12.5 KHz channels or 12.5 KHz with two time slots, 2 level or 4 level FSK, supports peer to peer in unlicensed spectrum or through a repeater or trunked system, typically uses very low bit rate 2 k/bit/s codecs and power output limited to 500 milliwatts	TETRA is a 4 slot 25 KHz channel spaced physical layer, TETRA TEDS is an evolved version with channel spacing scaleable up to 150 KHz and modulation options up to 64 level QAM yielding potential gross data rates of 500 k/bits	Originally developed by MATRA now EADS, a narrow band 12.5 KHz air interface using GSMK, Very good for long range voice, bandwidth limited for multi media	WiDEN an evolved version of iDEN which traditionally uses a 25 KHz channel with 3 or 6 time slots very similar to TDMA cellular where a 30 KHz channel is divided into 3 or 6 time slots, potentially 100 k/bits/sec data rates	12.5 KHz one or two time slot channels or 6.25 KHz channels, QPSK modulation, 9.6 K/bit/s data rate

DMR 446
This is a digital PMR standard developed through ETSI and called 446 as 446 MHz is where some license exempt spectrum has been made available in some countries, for example the UK.

It is neither intended nor suitable for multi media transmission. DMR products are available from Motorola, Icom, Kenwood, Tait and Entel and could potentially be deployed into other UHF and particularly VHF PMR applications. As we shall see later there is a problem of scale economy with these products and their target markets.

TETRA and TETRA TEDS
TETRA is originally a European standard for trunked radio based on 25 KHz channel spacing with a 4 slot frame structure. A more recent extension of the standard , TETRA Enhanced Data Service (TEDS) scales the 25 KHz channel spacing to 150 KHZ and uses 16 level QAM to support up to 500 k/bit/s as a 'close to cell' data rate.

TETRA handsets are available from Motorola, Kenwood, Sepura and Selex. Nokia has not developed handsets for this market since 2005. There are presently no TEDS compliant handsets available from any manufacturer. Even if there were, present TETRA cell densities would mean these higher data rates could only be supported in very limited geographic areas.

This is not presently a major problem. Many specialist user communities are quite rightly hesitant about adopting new technologies or new variants of existing technologies. The recent sale of the TETRA Airwave network in the UK for close to £2 billion pounds proves that good revenues and margins are presently available based on the provision of voice combined with relatively low data rate services. However it is reasonable to expect that this will change over time particularly if the performance gap between TETRA radios and cellular handsets continues to widen which it will for reasons that we explain later.

TETRAPOL
The 'other' European trunked radio standard introduced by Matra, now EADS, based on narrow band 12.5 KHz channels using GMSK. Tetrapol delivers very good range when used for voice services but is bandwidth limited for multi media.

WiDEN is an evolved version of iDEN, the Integrated Digital Enhanced Network standard developed by Motorola in the early 1990's. The frame/slot structure is either 3 slot or 6 slot similar to cellular US TDMA. When combined with 64 level QAM modulation this can deliver per user data rates in the order of 100 Kbit/s but no WiDEN products are presently available.

APCO25
A 12.5 KHz one or two slot air interface using QPSK, good range performance but bandwidth limited for multi media. Manufacturers include Motorola, Tait, Maxon and Bosch.

As can be seen, none of the available two way radio technologies are ideal for multi media. The standards that are capable of supporting the higher data rates needed do

not yet have products available.

Why the performance gap between cellular and two way radio will continue to increase over time
This is not specifically a technology constraint but more a consequence of limited engineering resources. Substantial engineering resources are needed to develop and ratify standards.

Substantial engineering resources are then needed to interpret these standards and translate them into performance competitive cost competitive radio products, handsets and base stations.

This is one reason why the performance gap between cellular phones and two way radios continues to widen. Silicon vendors and handset manufacturers producing GSM quad band chip sets and GSM quad band handsets are servicing a unified market that is now running at over 800 million units per year

Companies like Nokia and the silicon and component vendors supporting Nokia and other Tier 1 cellular handset manufacturers have to treat this dominant market as an absolute priority when deciding on the allocation of engineering development resources. This 'market pull' gravitational effect also helps to focus efforts on meeting other user requirements such as interoperability and roaming.

The opportunity costs of servicing markets that are several orders of magnitude smaller compounded by the 'divide down' effect of needing to support multiple standards for these minority markets makes it extremely difficult to justify investment in two way radio handset or infrastructure radio hardware and software development.

The result is that products come to market more slowly are more expensive and are generally more limited in terms of their radio functionality, at least as far as overall data rates are concerned.

What this means for two way radio network operators
So this tells us two things. Specialist user expectations are changing over time. These expectations are partly driven by personal exposure to rapidly evolving cellular handset form factor and functionality.

These expectations include the assumption that **multi media capabilities** can and should be made available in small form factor portable devices. This expectation extends to include the assumption that multi media capabilities should be available **whenever and wherever voice service is available**.

This is presently a major challenge for cellular service providers but is an even greater challenge for two way radio network operators with networks designed and dimensioned for voice and standards that have been historically driven by voice performance metrics.

Lack of frequency harmonisation as a compounding factor
Two way radio hardware development might be more attractive if there was at least some degree of global commonality in terms of band plan allocation.

Table 3 shows a rather over simplified representation of present European VHF two way radio and radio/TV allocations

Table 3 **European VHF Two way radio and radio/TV allocations**

Low Band VHF	FM radio	High Band VHF	Band 111 Sub bands 1 and 2	Band 111 DAB
30-88 MHz	88-108 MHz	108-174MHz	174-217 MHz	217-230 MHz
	Possibly being repurposed using DRM or DAB		Old black and white 405 line TV	7X1.55 MHz channels

Digital PMR would be a possible candidate technology for upgrading low band and high band VHF radio systems. The DAB allocations can and are used to deliver mobile TV to cellular handsets.

The repurposing of the black and white TV spectrum has been a success in terms of DAB deployment at least in the UK. An attempt to commercialise a trunked network in Band 3 failed due to inadequate economies of scale

Table 4 shows a rather over simplified representation of present European UHF two way radio and radio/TV allocations.

Table 4 **European UHF Two way radio and radio TV allocations**

European public safety and security		European non emergency services			European TV
Tetra and Tetrapol		Tetra and Tetrapol			
380-385 MHz	390-395 MHz	410-430 MHz	DMR446	450-470 MHz	470-872 MHz
		NMT450 now CDMA 450			

The future of the European TV band from 470 to 872 MHz is presently under discussion and may provide opportunities for cellular network deployment proximate to existing TV channels once digital switchover has been achieved. (See our March 2007 Technology Topic on UHFUMTS).

Table 5 shows the present US UHF two way radio and radio TV allocations, specifically the allocations for two way radio in the 800 MHz band.

Table 5 US **UHF Two way radio and radio/TV allocations**

Allocation		Frequencies in MHz	
US TV		512- 806	
Conventional PMR	Mobile TX	806 -810	
Trunked PMR	Mobile TX	810-816	
Trunked SMR iDEN/WiDEN	Mobile TX	816-821	
APCO25	Mobile TX	821-824	
AMPS	Mobile TX	824-849	
Conventional PMR	Mobile RX	851-855	
Trunked PMR	Mobile RX	855-861	
Trunked SMR iDEN/WiDEN	Mobile RX	861-866	
APCO25	Mobile RX	866-869	
AMPS	Mobile RX	869-894	GSM/UMTS900 880-915
Trunked PMR	Mobile TX	896-901	
Trunked PMR	Mobile RX	934-940	GSM/UMTS900 925-960

Some general comments can be made and conclusions drawn from Tables 3, 4 and 5.

Two way radio band allocations are often spectrally proximate to cellular radio allocations.

Two way radio allocations are often spectrally proximate to radio and broadcast TV allocations including VHF and UHF allocations.

There are some present examples of dual band dual mode two way radio handsets that combine two way radio functionality with cellular functionality for example Motorola's dual band Buzz and Blend handsets combining iDEN and CDMA.

If the radio bearer technologies used in present two way radio systems were to be made more similar to cellular then it would be easier to develop and deliver handsets that combined two way radio and cellular functionality.

If the radio bearer technologies used in present two way radio systems were to be made more similar to broadcasting technologies then it would be easier to develop and deliver handsets that combined two way radio and broadcast receive functionality.

This could become more important if present ITU proposals to use DAB or DVB- H or Media FLO to support Public Protection and Disaster Relief contingency planning and response become further developed.

The ITU and ETSI standardisation processes are both actively engaged in developing

next generation standards based on OFDM radio bearers for cellular radio networks.

These are variously described as UMTS LTE (long term evolution) or IMT Advanced. This work has the added advantage of establishing closer commonality between present and proposed WiMax systems, present and proposed WiFi systems and present and proposed multi band UWB systems.

Additionally the standardisation process will establish a closer commonality between cellular and broadcasting radio systems. This commonality will make co existence at radio network level easier to manage and will make it easier to develop and optimise dual mode cellular transceiver and broadcast receiver handsets.

These proposals include 1.25 MHz OFDM channels similar to the 1.5 MHz channels presently used in DAB at 200 MHz and therefore suitable for deployment down into high band and low band VHF.

This brings these systems into line with other OFDM broadcasting standards, specifically Digital Radio Mondiale extending down to medium wave, short wave and long wave frequency allocations.

This suggests that it would be advantageous for vendors presently developing products for the specialist user community to consider how two way radio standards could be harmonised with future cellular and broadcast radio standards.

Harmonisation would make it much easier to deploy integrated radio networks that supported two way radio, cellular and broadcast transmission.

Harmonisation would make it much easier to translate economies of scale across from the cellular and broadcast industries.

From a specialist user experience perspective a developing appetite for wide area access to multi media content and multi media content exchange implies a radical rethink of present two way radio industry technology and engineering constraints.

In this context it is useful to consider that broadcasters are allowed to transmit at EIRP levels of up to 50 kilowatts for digital transmissions, considerably higher than the 500 watts allowed for APCO25 and/or the tens of watts typically transmitted from cellular base stations.

The ability to scale transmission power from 50 kilowatts to a few watts or milliwatts is a consequential benefit of a more harmonised approach to technology standardisation.

The ability to scale frequency band from a few hunded KHz (long wave) to 10 GHz (UWB) is a consequential benefit of a more harmonised approach to technology standardisation.

The ability to scale operational bandwidth from 20 MHz (WiMax or LTE) to 10 KHz (the channel bandwidth used by DRM at long wave) is a consequential benefit of a more harmonised approach to technology standardisation.

The ability to scale operational bandwidth, frequency band and power will be essential to delivering a future specialist user experience that combines wide area and ultra wide area low to high data rates in a small form factor high efficiency portable and mobile device.

The combination of a more harmonised approach to technology standardisation with a more harmonised approach to band allocations would yield even greater end user experience benefits.

This is probably an aspiration too far and over dependent on making regulators realise that technology neutrality is an ill considered experiment. Technology neutrality assumes 'the market' is efficient at taking technology decisions. This would of course only be true if 'the market' had the luxury of being able to take long term decisions.

Despite this obvious disconnect, from an industry self interest point of view a closer coupling between existing two way radio, cellular radio and broadcasting TV and radio standards would yield a clear short term gain for all parties involved.

At engineering level, the two way radio industry has a 50 year heritage of working with the broadcasting industry and a 30 year heritage of working with the cellular industry on common site sharing and back haul provision.

If this engineering common interest could be extended to a standards common interest then remarkable short term benefits would accrue.

Most importantly the RF economies of scale enjoyed by the cellular and broadcast industries could be translated directly across to the two way radio community - delivering the benefits of three way radio.

About RTT Technology Topics

RTT Technology Topics generally reflect areas of research that we are presently working on.

We aim to introduce new terminology and new ideas to clarify present and future technology and business issues.

This is a hazardous process and we welcome comments from our readership who often have definite and better developed views on these subjects.

So do pass these Technology Topics on to your colleagues (using the many sharing algorithmic tools at your disposal), encourage them to join our Push List and encourage them to respond with comments.

Contact RTT

RTT, the Shosteck 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

geoff@rttonline.com

00 44 208 744 3163