Opportunities and Challenges for SDR in Next Generation TETRA Systems

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Introduction

Software defined radio (SDR) technologies have been long promoted for use in the professional mobile radio (PMR) application domain, as typified by the TETRA standard. The need to retain and enhance compatibility with a proliferation of legacy systems provided the incentive, and the typically very narrowband nature of these communications schemes made SDR appear feasible. In practice the evolution of these standards has moved faster than the development of viable SDR implementations. In recent years, use of PMR radio systems has expanded beyond voice to include data. There is now increasing demand for high speed data access to support applications such as the transmission of high-resolution images (eg maps for emergency services), and video clips. This has resulted in an evolution in the TETRA standard, from the original voice-only service, to an enhanced data version (TEDS) and finally to a proposed new approach which implements a WiMAX subchannel within the TETRA band. This paper will analyse the effect that this evolution in the standards will have on any potential SDR implementation.

TETRA Basestations Demand SDR

As in civilian public mobile radio, cost pressures and resource constraints on the client-side unit are high and this will result in limited opportunities for software defined radio architectures. However at the basestation the situation is different. Ideally a basestation should support existing and legacy devices, be frequency-flexible so that it can be deployed globally, capture the full band so that frequency reuse in different cells can be supported with a single hardware platform, and be software upgradeable to support new standards. These are features that can be offered by reconfigurable radio platforms incorporating software radio. As the original communication schemes are very narrowband (25 kHz channels) with simplistic modulation schemes, software radio systems could be implemented with minimal complexity. As early as 2001, commercial implementations were available demonstrating the flexibility offered by a software radio approach and commercial software based solution for basestations are predicted for deployment in 2009.

Opportunities of the New TETRA Evolutions

A new release of the TETRA standard has just recently been adopted, called the TETRA Enhanced Data Service (TEDS) which provides backward compatibility but allows sub-channel bandwidths of up to 150 kHz, a tuning range of operating frequencies between 350 and 470 MHz, and a number of modulation schemes. TEDS can offer data rates up to 384 kbps (or higher in special cases). Deploying TEDS has been a slow process due to the lack of a unified spectrum allocation, and the concept of a tuning range for devices was proposed. This approach is ideally suited to software-defined radio where a wideband radio front end can be used. The alternative is a multi-band radio which may be acceptable at the handset but is not economical or viable at the basestation. Software defined radios also offer the possibility of dynamically adapting the sub-channel bandwidth (from 25 – 150 kHz) and modulation scheme as needed to support the needs of the users. These two options strongly support the use of SDR techniques.

Beyond TEDS, new broadband TETRA schemes are being considered, including the deployment of a WiMAX stack within a TETRA band, utilizing one or more WiMAX 1.25 MHz channels within the 5 MHz allocation. The benefits of this approach is increased spectral efficiency and the ability to offer individual users a peak data rate of over 3 Mbps as needed. Such a scheme must remain within the frequency constraints of TEDS and once again a tuning range is required. With a given radio front end, assuming a full band (5 MHz) could be captured, an SDR implementation would allow a seamless upgrade path for TEDS devices to any of the newly suggested TETRA evolutions.

Hardware Challenges

The hardware challenges can be grouped into a number of categories: frequency agility; receiver sensitivity; backward compatibility; channelisation; and interfacing with the software engine. The tuning range at up to 120 MHz corresponds to approximately 30% of the centre frequency which is challenging when trying to design selective but wideband filters or achieving low noise oscillators. As a result of these challenges, it is likely that TEDS and broadband Tetra will be initially limited to the range 380-430 MHz. Noise and receiver sensitivity are particular challenges for any TETRA system. The concept is that TETRA networks are light overlays over existing networks providing secure backup communications for low numbers of users in large cells. For this reason receiver sensitivity is very high with tight specifications on adjacent channel interferers and noise. Within a narrowband system (25 kHz) this was achievable but noise and vulnerability to interference will increase with wider channels. Software radio normally implies channelisation in the software domain however this can place excessive requirements on the software, particularly where there are many sub-channels of different sizes within a TETRA band. If channelisation is to be done in software, then this requires the full 5 MHz band to be captured and presented over the PC interface to the software engine. Quick calculations suggest that this is at the limit of current general-purpose-processor capabilities. One alternative is to use a dedicated processor or FPGA on a hardware platform to channelise the data, easing the computational load. Finally the interface between the radio boards and the software engine can also be a major limiting factor. Existing techniques, such as USB2.0 or Ethernet, face difficulties in ensuring sustained latency-free communications of sufficient bandwidth for the full 5 MHz TETRA bandwidth.

Software Challenges

Approximate calculations based on the information from [4] indicate that
the signal processing for a single 1.25 MHz WiMAX channel could be handled by a modern general purpose processor (GPP). For example one core of an Intel Core Duo using a well optimized FFT routine can execute more than 1.5 million 128 point FFTs/sec [5] (equivalent to 192 Msps of raw I and Q data).

Unfortunately TETRA and WiMAX use different channel spacings which makes channelisation more complicated and more compute intensive. Furthermore, existing TETRA and WiMAX stacks use different media access schedules so the radio front end must run in full duplex mode. Taken together these factors suggest that the raw sample rate for even a single 5MHz band would exceed the input/output capabilities of USB and even FireWire 800. Identifying a suitable high speed interface is still a matter of investigation. However, as argued above, it may be more technically feasible to perform the channelisation before input to the GPP although this may result in some loss of flexibility and reconfigurability.

Even with the capability to modulate and channelise the radio waveform, constraining the latency in the input/output and higher level software processing, to the limits required for timely signaling and control, remains a significant challenge.

Conclusions

The technical challenges facing SDR implementations for PMR/TETRA systems are now beginning to approach the complexity of existing mobile telephony systems. Existing low cost SDR platforms and pc-based solutions would find it challenging to support TEDS or the next generation of TETRA, software defined radio architectures present a compelling case for use in TETRA and other PMR systems. As with normal mobile communications, to achieve a viable cost-effective solution a new approach to solving the architectural in the overall platform is required which optimally partitions resources between the radio circuits, dedicated hardware processors, interface systems and the software engine and processor.

Specifications for Tetra Versions

	Tetra	Enhanced Tetra	Broadband Tetra
Frequency (MHz)	380-410	350-470	uses
Spectrum Allocation	Two 5 MHz bands	additional 5 MHz bands	similar
Duplex Spacing (MHz)	10	10	similar
Channel BW (kHz)	25	25-150	1250
Channel Spacing	25	matches channel spacing	50-100
Access Scheme	TDMA/FDMA	TDMA/FDMA	SOFDMA
Modulation	$\pi/4$ DQPSK	$\pi/4$, $\pi/8$ DQPSK up to 64 QAM	QPSK, up to 64 QAM
TX Power	25 W	similar	similar
Maximum ACPR	-60 dBc	similar	similar
RX Sensitivity	-106 dBm	similar	similar
Efficiency (bits/Hz)	1.4 bits/Hz	<3.5	3-4

References

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