RTT TECHNOLOGY TOPIC
April 2012

Machine to Machine and Machine to Network Connectivity

This month's technology reviews past and present implementations of machine to machine radio networks also known as machine to network networks and reflects on how past experience can be used to validate proposed future systems. This includes Wi Fi based systems and the new PHY and MAC being developed by the **Weightless Special Interest Group.**

If you require more information on the Weightless specification a new book, 'Understanding Weightless' is available authored by William Webb and published by Cambridge University Press.
The book can be ordered from Amazon via the **RTT book shop.**

We also draw on **information provided from InterDigital on their spectrum harvesting products**

The past experience reference material is drawn from RTT's book Data over Radio published in 1992. The topic is also addressed in detail in RTT's latest book '**Making Telecoms Work- from technical innovation to commercial success'** published In January 2012. Chapter 18, 'Network Software - energy management and control. Will the pot call the kettle back?' has particularly relevance.
All of these can be ordered from Amazon via the **RTT book shop.**

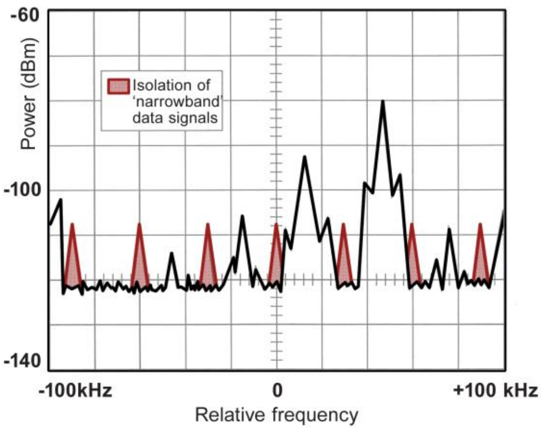
Machine to Machine Twenty Years Ago

Twenty years ago data was delivered over wireless systems using simple though expensive FSK modems. These networks were generically described as mobile data networks given that they supported data communications with subscribers and data communications between machines or from machines to and from a network.

Legacy VHF or UHF trunked radio systems used a 1200 baud FFSK bit stream to support 184 bit short data messaging on a signaling channel or a continuous 1200 baud on a 12.5 KHz traffic channel and were the basis for the first generation data systems for motoring organizations and utilities.

Vodafone used a modem with proprietary error correction known as CDLC (cellular data link control) in a 25 KHz ETACS channel which was claimed to be able to deliver up to 9600 bps or 2400 bps at 70 miles per hour for mobile telemetry applications.

In the US Motorola and IBM established the Ardis network in 1985 to provide wireless data links to IBM's 20,000 service engineers. In parallel a study was made of the practicality of implementing a packet data system based on 3 KHz data channels interleaved into the guard bands either side of AMPS 30 KHz voice channels. This was an autonomous 'secondary network' co existing with the primary cellular network with the client devices making their own channel availability decisions based on local measurements.



Narrow band cellular 'white space' with autonomous client devices circa 1990

This then evolved into a time domain equivalent called CDPD developed by IBM and six of the seven Regional Bell Operating companies. Designed to be compatible with legacy AMPS analogue systems and the evolved digital IS136 DAMPS system this was effectively a network within a network with the data devices sensing whether or not a voice channel was in use and then acquiring that channel, hopping to another channel as and when a voice assignment was made. Both of these were effectively early examples of cellular network white space cognitive systems with autonomous client devices. The CDPD network was shut down by AT and T Wireless and Cingular Wireless in 2005.

Over in Sweden, Ericsson started the first Mobitex network in 1986, originally as a 1200 baud rate system then 4800 then 8000 baud and deployed over the following years into low band VHF (80 MHz), high band VHF (160 MHz), and UHF at 450 and 900 MHZ in 12.5 and 25 KHz channels.

In the UK, twenty five year licenses were issued in 1992 to Cognito Group Ltd, Hutchison Mobile Data Ltd and RAM Mobile Data Limited. These replaced temporary licenses issued in 1989. Paknet, a Racal/Chubb/Mercury joint venture also received a license and targeted the electronic point of sale market.

RAM Mobile Data adopted Mobitex technology both for the UK and US market and other markets. Hutchison used MDI/Motorola technology. Cognito used a proprietary three level FSK modem and five watt radios in the lower sub band of Band 111 at 189 MHz, a band made available when black and white TV was discontinued. Paknet implemented a VHF underlay to the Vodafone network transmitting at 159.7 to 159.9 MHz and receiving at 164.2 to 164.4 MHz

The Cognito network was discontinued in 2003 and re-engineered to use GPRS modems. The company now concentrates on **mobile workforce solutions.** Paknet still exists and is promoted as **'the UK's only dedicated M2M network'**. Information on the present status of Mobitex networks is available **here** and **here**.

It would be fair to say that these mobile data licenses were issued twenty years ago with good intention and attracted substantial infrastructure investment but in practice had business models that were frustrated by an oversupply of technology choice and an undersupply of globally harmonised spectral allocation. This meant that the scale economy needed to support mass market rather than specialist market adoption was never achieved.

The early experience with data over cellular was also mixed both technically and commercially. The CDPD concept never translated across into GSM and therefore could never achieve the scale needed to realise the cost targets needed to support mass market applications. GPRS has had more success and is now reasonably widely deployed but is not presently helped by mixed messages as to its likely long term future. If the technology choice was bewildering to potential customers in 1992 it is even more so today and any perceived time limit on availability is a major disincentive to deployment.

This being the telecoms industry, the answer to having too much technology choice is naturally to introduce even more choice both in terms of the standards available and the spectrum available.

However we are going to suggest that after 20 years some lessons may have finally been learnt and we may be close to resolving the technology and spectrum disconnects that have prevented the development of low cost machine to machine and machine to network connectivity.

This does not mean that present solutions will disappear and many specialist applications will remain well served by legacy VHF and UHF systems but the challenge going forward is to scale devices down to a dollar and service costs down to a point of indifference where price is no longer a barrier to mass market adoption.

This can only be achieved by leveraging existing scale or creating a new scaling opportunity. Theoretically LTE networks would be able to exploit legacy cellular scale but it is hard to see how machine to machine or machine to network revenues on a per device basis can ever fit comfortably into business models that remain focussed on high per user data rates.

A second option is to leverage existing Wi Fi market volume and cost points. From a technology standards perspective Wi Fi has arguably all of the basics either already in place or closely visible both at the physical and MAC layer and in terms of higher layer support, including for example IP mobility and IP security protocols. The IEEE standards process is robust and responsive to specific vertical market needs. In terms of spectrum, Wi Fi has a more or less global availability at 2.4 GHz, 5 GHz and potentially 60 GHz for low cost high bandwidth applications. The only missing ingredient is range.

The range issue can be at least partially solved by extending Wi Fi into the UHF TV White space bands. Most countries globally are presently repurposing this band. For example **analogue TV transmission from Alexandra Palace in London will be discontinued on the 18th April.**

There has always been unused or at least under used spectrum in the TV band which in its original entirety stretches from 470 to 790 MHz. This is a consequence of the need to plan terrestrial TV coverage on a worst case basis for anomalous propagation conditions. For example transmissions from a 50 kilowatt tower can easily travel 100 kilometres and sometimes further but these conditions will rarely apply all of the time in all places and will constantly change as propagation conditions change. Additionally the shift to digital has released more bandwidth, a function of digital compression and improved signal to noise performance.

Terrestrial TV networks are traditionally implemented as multi frequency networks. The alternative more spectrally efficient alternative is to implement as a single frequency network but this translates frequency planning complexity into time domain planning complexity as large time domain guard bands are needed in areas of equal signal strength. The alternative here is to have more closely spaced lower power TV transmission sites but this would require broadcasters to cooperate more closely with the cellular and mobile broadband operator community.

Additionally the World Radio Congress in January 2012 decided that a regionally based review of the practicality of a second digital dividend should be investigated for possible ratification at WRC 2015. This would mean (probably) that most countries would have two mobile broadband duplex spaced bands which would occupy the UHF band between 692 to 790 MHz

This would mean TV channels would need to be more densely spaced in the frequency domain which would mean less White Space spectrum. In parallel a shift to super high definition TV would imply an increase in flux density. The view could be taken that all TV will shift to fibre, cable, copper and satellite but terrestrial TV remains politically important as a physical way of communicating with the voting population and it is hard to see this changing.

Even so there should be enough UHF white space spectrum available to be useful and the narrower bandwidth (470 MHz to 690 MHz) will make transceiver design simpler than a ‘whole band’ (470 MHz to 790 MHz) transceiver. However it is going to be necessary commercially to find some mechanism by which white space devices can be positioned as adding rather than subtracting value from TV broadcasting and other users in the band including wireless microphones.

This is not impossible. A direct analogy is the way that the Wi Fi community is developing technology and business solutions for offloading unwanted broadband traffic. **InterDigital** has a cellular augmentation platform which allows operators to use White Space spectrum. Note that in this context White Space spectrum would not necessarily be confined to the UHF TV band but could include the UHF mobile broadband spectrum including guard bands and theoretically at least any other band visible to the RF front end of the client device.

As with CDPD, this gives a mobile broadband operator access to 'no cost'(unlicensed) or 'low cost' (lightly licensed) spectrum which from past experience is a pre-condition for delivering the per device service pricing needed to enable viable mass market machine connectivity, the other precondition being of course low cost devices. This second pre-condition is potentially deliverable by leveraging existing Wi Fi device scale.

Why and how terrestrial TV broadcasters would benefit from access to devices is open to debate but a low cost or no cost wireless return channel that had more range than existing systems and or could be independent of a cable, copper or fibre return path could transform or at least enhance existing terrestrial TV business models.

Wi Fi and in particular White Space Wi Fi is a perfectly plausible candidate technology for this transformation process and an embedded existing presence in home hubs and domestic appliances provides an interesting starting point. White Space 6, 7 or 8 MHz channels could be aggregated together to deliver equivalent throughput rates to existing 20 MHz Wi Fi channels. Lower data rate exchanges could be accommodated by using some of the legacy Wi Fi modulation and coding schemes which include simple FSK modulation and direct sequence spreading.

But Wi Fi is not the only option and consumer device connectivity is not the only target market. Another alternative is to start from scratch with an M2M optimised physical layer and MAC layer and a network offer that can be delivered at a coverage cost at least an order of magnitude lower than a cellular or mobile broadband network. The inherent cost and performance advantage of such an approach then has to be leveraged into global scale in order to realise sufficiently low client device costs.

This is the objective of the Weightless Special Interest Group. Rather than rehearse the technical detail of how this is to be accomplished we recommend you either buy the book referenced at the beginning of this article and/or visit the **Weightless web site**.

As a summary, the physical layer uses conservative modulation options to minimise ACLR and reduce power drain on the transmit path. The uplink is sub divided into narrow band channels to reduce the received noise floor at the base station by 18dB and spreading codes are used to deliver up to 30dB of coding gain for low bit rate data exchanges. Network functions such as billing, session management, authentication and encryption are realised within a cloud hosted virtual machine. The client devices and the base stations meet the ACLR requirements for White Space. Frequency hopping at the frame rate (which for MAC efficiency reasons is set at 2 seconds) randomises out inter system and intra system interference. A super frame interval is set at 15 minutes

Low data rate exchanges (2.5 k/bit per second) can be supported with a 1023 spreading factor code to give up to 10 kilometres of range. The super frame interval allows for long power down cycles to maximise battery life. At the other extreme a 6, 7 or 8 MHz downlink can be modulated with higher level modulation to deliver up to 16 M/bits of peak single user throughput.

Many in fact most of the characteristics of the PHY and MAC layer bear an uncanny resemblance to the original Bluetooth specification which is hardly a surprise as the start-up team for the weightless SIG are from the team that founded Cambridge Silicon Radio.

The devices are White Space friendly and can be driven from a data base that determines available spectrum by location by time.

As with Bluetooth, the weightless SIG needs robust vendor support and applications that pull through early market volume. For Bluetooth the vendor was Ericsson and the application initially was cordless handsets and then hands free legislation.

The potential size of the market and the diverse vertical market segmentation suggests that this does not need to be an 'either or' battle between weightless and Wi Fi. Both could be collaborative rather than competitive enablers of M2M and M2N markets.

A diary note to revisit this topic twenty years from now.

About RTT Technology Topics
RTT Technology Topics reflect areas of research that we are presently working on. We aim to introduce new terminology and new ideas to help inform present and future technology, engineering, market and business decisions although as you can tell we sometimes stray into more philosophic territory. There are over 130 technology topics **archived on the RTT web site**. Do pass these Technology Topics and related links on to your colleagues, encourage them to join our **Subscriber List** and respond with comments.

Contact RTT
RTT, the Jane Zweig Group and **The Mobile World** are presently working on a number of research and forecasting projects in the mobile broadband, 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