



DIGITAL COMMUNICATIONS KNOWLEDGE TRANSFER NETWORK

Cooperative networks positioning paper

Wireless Technology & Spectrum Working Group

The Digital Communications Knowledge Transfer Network has been established by an industry-led group of leading players, with funding from the Technology Strategy Board. We seek to bring competitive advantage to the UK by promoting collaboration and knowledge sharing between the users and providers of Digital Communications, and helping to drive innovation in the sector.

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Digital Communications KTN
Russell Square House
10–12 Russell Square
London WC1B 5EE

Email: info@dcktn.org.uk

Website: www.dcktn.org.uk

Telephone: +44 (0) 20 7331 2056

Contact points for positioning paper

Stuart Revell DCKTN Wireless Technology & Spectrum group chair

07836 512787

stuart.revell@dcktn.org.uk

Mark Waddell

BBC R&D, Kingswood Warren

01737 839528

mark.waddell@rd.bbc.co.uk

Geoff Varrall

RTT Programmes

0208 744 3163

geoff@rttonline.com

The opinions and views expressed within this positioning paper have been reviewed by the members of the Digital Communications Knowledge Transfer Network Wireless Technology & Spectrum working group. The views and opinions do not necessarily reflect those of the individual members of the DCKTN or the Working Group or the organisations that the members represent.

DCKTN Wireless Technology & Spectrum Working Group

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2. Abbreviations and Definitions

Abbreviation	Definition
3GPP	3 rd Generation Partnership Project
ATC	Ancillary Terrestrial Component
ATSC	Advanced Television Systems Committee
C/I	Carrier to Interference (Ratio)
CAPEX	Capital expenditure
DAB	Digital Audio Broadcasting
DC-KTN	Digital Communications Knowledge Transfer Network
DRM	Digital Radio Mondiale
DTT	Digital Terrestrial Television
DVB SH	Digital Video Broadcasting - Satellite services to Handhelds
DVB T	Digital Video Broadcasting — Terrestrial
DVB T2	Digital Video Broadcasting – Second Generation Terrestrial
FDD	Frequency-Division Duplex
FFT	Fast Fourier Transform
G I	Guard Interval
GSM	Global System for Mobile communications
IMT	International Mobile Telecommunications
ISI	Inter Symbol Interference
kbps	Data rate - Kilobit per second
LOS	Line of Sight
LTE	3GPP Long Term Evolution
Mbps	Data rate - Megabit per second
MBSFN	Multi Cast Broadcast Single Frequency Network
OFDM	Orthogonal Frequency Division Multiplex
PFD	Power Flux Density
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase-Shift Keying
SFN	Single Frequency Network
TDD	Time-Division Duplex
UHF	Ultra High Frequency

3. Executive Summary

Broadcasters and the cellular industry are facing unprecedented economic and technical challenges both nationally in the UK and internationally. For mobile and portable TV services, there are currently 5 competing standards with no clear leader and matters are further complicated by regional and national differences in frequency allocation. The current focus is the development of new services using UHF spectrum. For MNOs, the LTE standard, featuring the MBSFN broadcast mode in the new European-harmonized band, is a key ingredient for next generation services. For broadcasters, the new DVB-T2 standard, launched as part of Digital Switch Over, offers improved capacity and SFN performance allowing efficient delivery of new services, including HDTV to the DTT platform.

The industries' combined interests in UHF spectrum could unlock opportunities for cooperative networks allowing hybrid delivery of portable and mobile TV content. Next generation mobile phones and dongles will have 700 and 800 MHz LTE transceiver functionality and it is therefore conceivable to increase receiver bandwidth to accommodate DTT transmissions. Furthermore, new LTE-800MHz macro cell sites will often need to rebroadcast DTT signals to protect TV reception from interference caused by the dense cellular network exceeding the C/I budget for TV receivers on the sparse DTT network. Rebroadcasting of national and local TV from cellular transmitters would allow HDTV to be delivered to portable receivers without the need to connect portable devices to a fixed antenna. Since video services consume an increasing fraction of cellular radio traffic, making use of the broadcast networks, enhanced by cellular sites, would also reduce the traffic load on the LTE data networks.

The coupling of local and national linear TV broadcasting with mobile broadband would unlock new direct and indirect revenue streams both for the broadcasters and cellular operators and would provide the basis for developing innovative mass market consumer electronic products that could be clearly differentiated from present product and service offerings.

4. Purpose of this Positioning Paper

The purpose of this paper is to provide the basis for discussion amongst all interested stakeholders as to how a deeper collaboration both at standards level and engineering level between the cellular community, broadcast community and the public safety communications community could deliver significant fiscal benefit.

The broadcasting industry in the UK, and in particular the BBC, has a unique global brand value combined with very significant intellectual assets and experience in terrestrial OFDM broadcast network design and implementation.

The UK is also home to the multinational operator, Vodafone who presently support nearly 300 million subscribers worldwide. Partner networks bring this total to over 1 billion subscribers.

The UK has a telecoms regulator that is globally respected for innovative forward looking thinking and two industry associations, the Digital Television Group and the GSM Association, both of whom have significant global influence.

The UK thus has a unique opportunity to leverage the knowledge and experience resident in these national organisations to change the way in which the world delivers digital TV, digital cellular and public safety radio communications, a digital Britain with a potentially pivotal role in a digital world.

5. Market – Landscape & Considerations

The television industry has had to engineer a transition to digital transmission within challenging time scales within a constrained budget.

The public safety radio communications industry has undergone a similar transition and has the additional problem that its present technology base is bandwidth constrained.

The cellular industry has had to manage the roll out of third generation digital networks into the core IMT band at 1.9/2.1 GHz. This has proved to be technically challenging and has not as yet realised an adequate ROI.

There is an expectation that similar technologies will be deployed into the current GSM bands and the top end of the UHF band adjacent to digital TV transmission, as well as other IMT expansion bands such as 2.6 GHz that are becoming available.

The cellular industry has spent considerable amounts of time and money on mobile TV standardisation and network and handset development with to date no commensurate fiscal return.

It has been difficult to realise a return on investment partly due to competing standards, (there are currently at least five¹) and partly due to network and handset development limitations and performance constraints compounded by regional and national differences in mobile TV frequency band allocation.

Although mobile TV has been successful in some markets, for example Japan, it has failed to date to achieve global scale and in most markets there has been a marked reluctance for consumers to pay for mobile TV content.

The longer term economics and effectiveness of hybrid satellite and cellular networks such as DVB SH in Europe or ATC (ancillary terrestrial component) hybrid satellite and terrestrial networks in the US also remain unproven.

In parallel the global cellular industry has been developing one of the most technically and economically ambitious set of radio standards that the world has ever seen, described generically as Long Term Evolution (LTE).

¹ DVB H, MediaFLO, the DMB variant of DAB, DVB-SH and MBMS mobile broadcast and multicast service.

6. LTE and Broadcast Networks

The LTE standard includes a detailed specification for a new generation of Multi Cast Broadcast Single Frequency Networks, MBSFN, to be deployed into existing cellular radio spectrum and or potentially into future 700 and 800 MHz spectral real estate.

This might be perceived as a threat to the broadcast community but in reality the spectrum working group of the DCKTN consider that MBSFN and or the integration of MBSFN with DVB T and DVB T2 presents a substantial opportunity for the broadcasting and cellular community to achieve future cost savings and to realise new revenue streams which would deliver fiscal benefit to all involved parties.

This would be achieved through the development of a cooperative radio and broadcast network platform that would leverage the unique and complementary capabilities already available from terrestrial TV and cellular mobile broadband connectivity into a collaborative proposition that would release significant additional user experience value.

Additionally a combined network proposition could have significant longer term value for other radio user communities including public safety and disaster relief agencies, for example by using hilltop TV transmitters to provide extended cellular coverage.

7. Digital Broadcast, LTE & MBSFN: Technical details

i. Sub Carrier Spacing & Cyclic Prefix

MBSFN is based on a 7.5 kHz sub carrier spacing rather than the 15 kHz used in standard LTE. This doubles the symbol length from 66.7 microseconds to 133.4 microseconds and allows the cyclic prefix to be increased from 4.69 microseconds to 33.33 microseconds.

The cyclic prefix provides a time domain guard band between symbols to compensate for delay spread in the radio channel. A 4.69 microsecond cyclic prefix allows a delay spread of 1.5 km; a 33.33 microsecond cyclic prefix allows a delay spread of 10 kilometres. The delay spread is the difference in path length caused by multi path in cellular networks. In SFN broadcast networks, the delay spread is also a function of receiving the same signal from more than one transmitter. The 33 microsecond cyclic prefix means that TV transmissions can

be broadcast simultaneously from multiple enhanced node B cellular base stations without causing inter carrier symbol interference in the receiver.

ii. Technical Comparison of Broadcast and LTE Networks

Table 1 compares DRM, DAB, DVB broadcast networks with LTE and LTE MBSFN.

Table 1 Technical comparison of DRM, DAB, DVB, LTE and MBSFN

	Broadcast Wide Area			Cellular	Cellular broadcast
System	DRM	DAB	DVB-T	LTE	LTE MBSFN
Frequency	<30 MHz	100 MHz, 220 and 1400 MHz	700 MHz	Between 700 and 2.6 GHz	Between 700 and 2.6 GHz
ISI-free LOS Range	500 km	74km	67km	1.4 km	10 km
Channel bandwidth	9 kHz	1.536 MHz	7.6 MHz	1.4, 3.0, 5, 10, 15, 20 MHz	5 MHz
Max gross data rates	25 kbps	2.304 Mbps	5 to 31.7 Mbps depending	10 to 30 Mbps or above depending on cell size	10 to 30 Mbps or above depending on cell size
Modulation	QAM	QPSK	QPSK 16 QAM 64 QAM	QPSK 16 QAM 64 QAM	
Number of sub carriers	204	1536	1705, 6817	300 across 4.5 MHz	600 across 4.5 MHz
Sub carrier spacing	41.66 Hz	1 kHz	4.464kHz, 1.116 kHz	15 kHz	7.5 kHz
Symbol duration in microseconds	26,660	1246	1120	66.7	133.4
Guard interval in microseconds	2660	246	7 to 224	4.69	33.33

iii. Solving the Historical problems

In practice a number of DVB-T networks were implemented as 2K rather than 8K networks due to receiver chip set limitations, for example in the UK where initial implementation was realised in 1998. This prevented the roll out of a single frequency DVB-T network and legacy issues continue to constrain DSO plans². Although the LTE MBSFN is described as a single frequency network, it could be deployed as a cluster of SFN enhanced node B base stations with frequency re use from cluster to cluster.

Present standards work is focused on either FDD or TDD implementation, known as Downlink Optimized Broadcasting within existing cellular allocations, for example the TDD bands within Band I at 2 GHz.

This however fails to capitalize on some potential major cost saving and enhanced revenue opportunities which together could become major drivers for MBSFN investment.

These can be identified by analysing the problems that the broadcasting and cellular industry have to solve.

As can be seen from table 1, the 8K sub carrier OFDM used in DVB-T allows very large cells to be deployed. This means that DVB-T broadcast networks can be very cost economic.

However to provide adequate coverage, low power in-fill sites have to be deployed which add capital cost and running costs. Traditionally, these sites have been planned using white space spectrum which reduces overall broadcast spectral efficiency.

Although this provides adequate coverage at an adequate link budget for TV's (including high definition TV's) with a roof top aerial, there is generally not enough signal strength to support portable receivers.

DVB-T is already included in some cellular handsets in some markets, for example in [Germany](#). However in most countries signal levels are not sufficient to deliver a sufficiently consistent user experience to support mass market

² Factors preventing the efficiency benefits of national SFNs include the requirement to carry region-specific content and the legacy of developing the original digital services alongside an existing analogue MFN service whilst ensuring reception was compatible with the existing installed base of narrow sub-band antennas. Coordinating international plans for national SFNs with broadcasters and regulators has been the final barrier and effectively rules out national SFNs for the foreseeable future in the UK and many other countries. Regional SFNs remain an interesting technical possibility and would offer some of the improvements in spectrum efficiency particularly beneficial for new white space applications.

adoption. Deployment of high density SFNs based on existing cellular infrastructure would overcome this problem.

Portable receivers have been the Cinderella of the TV industry for many years but the availability of lap tops and netbooks with DVB or ATSC embedded modems or plug in dongles will potentially result in a much broader market reach. The top of the range high definition [Sony Vaio](#) is one example

The problem is that portable DVB-T devices do not work well unless connected to an outdoor aerial as the existing terrestrial networks have been planned for fixed reception. This limits the portability of the device.

A roof mounted antenna has about 12 dBi of directional gain. A built in broad band TV antenna in a lap top will usually have negative gain (typically -7dBi) and will be looking for a signal severely attenuated by height loss (12dB), additional building penetration loss (7dB) and location variation due to standing waves (14dB), resulting in a received signal up to 52dB lower than the value planned for fixed outdoor reception.

It would be prohibitively expensive to increase flux levels from the existing terrestrial broadcast networks to support acceptably ubiquitous portable TV reception, particularly portable HDTV reception.

iv. The Co-Operative Networks and User Platform Proposition

Cellular base stations, particularly cellular base stations designed to support the 700 and 800 MHz cellular bands could function as relay repeaters and provide a cost effective alternative to dedicated TV repeaters.

Cellular handsets or at least some cellular handsets and mobile broadband devices including lap tops with embedded LTE modems or dongles will have 700 and 800 MHz LTE transceiver functionality.

It is therefore not inconceivable to increase LTE 700 and 800 MHz receiver bandwidth to accommodate DVB-T transmissions, albeit this will create some challenges to antenna designers.

Operators might question the point of including DVB-T reception in mobile broadband devices particularly given that many of the services are available free to air. This however ignores the indirect revenue gain that is potentially achievable from coupling free to air TV reception with two way mobile broadband and is pragmatically probably the only way in which cellular operators will ever achieve a return from 700 and 800 MHz cellular infrastructure and spectral

investment. The ability to receive broadcast TV off-air would also reduce the traffic load on the LTE data networks.

The CAPEX cost of deploying DVB-T repeaters at 800MHz cellular sites to enable portable DVB-T and DVB-T2 at first site looks quite prohibitive. However, it may be necessary to do this in any case as DTT receiver C/I performance issues are a major concern for 800MHz LTE deployments. The requirement to protect DTT as part of the 800MHz spectrum license regulation looks set to limit the permitted PFD levels for cellular 800MHz deployments, limiting LTE coverage, particularly at the DTT coverage edge. One technique to enable improved LTE coverage would be to deploy DTT active repeater technology at the base station sites to repair the DTT network (to mitigate the effect of hole punching) and simultaneously provide DTT reception to portable terminals. This would allow higher-power cellular 800MHz networks to be deployed with larger, more economical cell sizes, whilst simultaneously enabling improved reception of DTT to portable terminals.

The move from 2k mode to 8k mode for DSO potentially enables the deployment of mini SFN, DVB-T repeaters at cellular sites, as the guard interval increases with the longer FFT. A full interference analysis is needed to check that the 1/32 G.I mode used for DSO would permit ISI-free, DTT reception with mobile network enhancement, but the technique is promising.

Broadcasters and transmission providers may be nervous about sharing part of the responsibility for network coverage to cellular operators, but the opportunity for portable DTT reception is very attractive.

Different classes of applications are emerging that would be suited to either MBSFN or DVB-T networks. Lower resolution (QCIF or CIF), fully mobile services, for example video on demand clips or mobile video streams for sporting events could be supported on the mobile IP network on a pay-per-view basis. Higher resolution broadcast services to portable netbooks, including HDTV using DVB-T2, would be more appropriate on an enhanced DVB network using cellular site enhancement to the broadcast network.

MBSFN cannot replace DVB-T/T2 on a large cell broadcast SFN because of guard interval issues. The new MBSFN technical standard has a 33us guard interval and an active symbol of 133.4us. This can accommodate a delay spread of 10km, which may be appropriate for IMT broadcast networks at 1.9/2.1GHz, but implies a risk of inter symbol interference in a UHF SFN. The efficiency of the system, defined in terms of the ratio of active symbol to total symbol length is 80% ($133.4 \text{ us} / 133.4 + 33.33 \text{ us}$). DVB-T SFN deployments using 8k GI $\frac{1}{4}$ have an active symbol of 1120us and a guard interval of 224us. This allows a much larger delay spread of 67km to be tolerated, with an overall efficiency of 80%.

In DVB-T2, a 32K FFT mode has been introduced to further improve SFN capability. The 32K mode has an OFDM active symbol four times greater than the 8K mode of DVB-T. Guard intervals of between 1/4 and 1/128 are supported by the standard.

Comparing SFN performance of DVB-T with DVB-T2, a T2 system 32K FFT and GI 1/8 has a guard interval twice the length of a DVB-T 8K GI 1/4 system and the efficiency is improved from 80% to 88%. The 1/4 GI mode of DVB-T2 permits networks up to 270km at 80% efficiency.

8. Summary

The proximity of cellular receive and transmit bands at 700 and 800 MHz to UHF broadcast TV channels opens up the possibility of supporting digital TV transmission via cellular base stations and digital TV reception in handsets and mobile broadband devices without significant additional hardware cost.

Rebroadcasting of national and local TV from cellular transmitters would allow HDTV to be delivered to portable receivers without the need to connect portable devices to a fixed antenna.

Cellular site and hardware costs including backhaul overheads could be amortised across cellular **and** broadcast services.

There would be no need to ring fence or repurpose TDD bandwidth at 2 GHz for broadcasting. These channels could be used as originally intended for bi directional mobile broadband access.

The coupling of local and national linear TV broadcasting with mobile broadband would unlock new direct and indirect revenue streams both for the broadcasters and cellular operators and would provide the basis for developing innovative mass market consumer electronic products that could be clearly differentiated from present product and service offerings.

The combination of the additional revenues realisable from a more broadly based user experience combined with more broadly amortized costs could significantly improve profitability for all involved parties.