TETRA & CRITICAL COMMUNICATIONS ASSOCIATION

Study on the relative merits of TETRA, LTE and other broadband technologies for critical communications markets

Final version 1.1: February 2015

P3 communications GmbH

Am Kraftversorgungsturm 3 (Alter Schlachthof)
52070 Aachen
Germany

www.p3-group.com/en/communications-gmbh-46867.html

Table of contents

Table of figures

1 Executive summary

Background

This report was commissioned by the TETRA & Critical Communications Association (TCCA) and compares the relative merits of TETRA, LTE, and other broadband technologies for current and future critical communications markets. The TCCA is planning for the future of broadband[1] critical communications services, in particular through enhancement of the 3GPP 'Long Term Evolution' (LTE) standards to support features fundamentally required by critical users.

The study reported herein addressed the following aspects with respect to key critical communications market segments, i.e. Public Safety, Transport, Utilities and Industry:

- *The likely evolution of deployed TETRA and LTE technology for two time horizons of three and ten years respectively.*
- *The expected performance and relative strengths and weaknesses of the relevant technologies against the requirements of critical communications markets for both voice and broadband data services.*
- *The relative benefits of standards-based solutions and equivalent risks associated with non-standard, proprietary solutions.*
- *Deployment and delivery options for future critical broadband services.*

Public Safety

Public Protection and Disaster Relief (PPDR), also called 'Public Safety', has traditionally represented the majority share of the TETRA and critical communications market by sector. PPDR / Public Safety user requirements tend to match, and sometimes exceed, those of other critical communications user segments, and thus can be considered to define the requirements of critical communications users more generally.

Voice remains the paramount and "must-have" requirement in the absence of all others for PPDR users, however many agencies predict future requirements for mobile broadband data services in addition. For now it is unclear whether there may ultimately be a 'killer application' for broadband, however services such as video and high-resolution image transmission, as well as real-time database access, telemetry and related high speed data transmission services appear to be increasingly important to the sector.

Over the past few years Standards Development Organisations (SDOs) such as 3GPP and ETSI have been working to enhance LTE mobile broadband standards for critical communications use. Much of this work was initially driven by early Public Safety projects, such as FirstNet in the USA and the UK Home Office Emergency Services Mobile Communications (ESMCP) Programme.

Transport

The transport sector, comprising buses, trams, trains, metros, airports etc., represents a significant and growing market in critical communications. TETRA is widely deployed in transportation markets, except for mainline rail where GSM-R has traditionally been mandated, at least in Europe. Some mainline train markets outside Europe have

[1] **Broadband** data communications generally refers to a high capacity transmission medium or channel with an ability to simultaneously transport multiple signals and traffic types at a high (circa >1 Mbit/s, see ITU report ITU-R M.2033) end-to-end data transfer rate, i.e. a high-capacity communications circuit or path.

enthusiastically adopted TETRA on the basis of its features and facilities for critical applications, and TETRA has been proven in Asia and South America, where it has dominated railway communications.

The European rail sector is currently considering the future technology to ultimately replace GSM-R, however requirements beyond group voice and limited signalling currently satisfied by GSM-R do not appear to be clearly defined for the meantime.

Future road vehicle bandwidth demands are hard to predict for now, and with the exception of narrowband[2] voice and messaging already available from TETRA, no clear use cases for broadband appear to have been established yet. Nonetheless it is expected that the road and rail sectors will use the time whilst critical broadband standards are being specified to develop requirements for future broadband applications.

Reliable and secure communications is vital for airport operations and airports globally have been significant adopters of TETRA. One of the key attractions of TETRA for airports, as well as many other sectors, is its spectrum efficiency and the availability of suitable frequencies in which to operate. A TETRA network can often require just a few 25KHz channels, whilst alternatives such as LTE require dramatically more, i.e. an absolute minimum of 1.4MHz, and typically multiples of 5MHz.

However with airport operators and others in some regions beginning to explore the potential for use of broadband, the significant risks associated with adoption of proprietary non-standardised solutions should not be overlooked.

Utilities

Utility users do not seem for now to be seeking much by way of broadband data services. Additionally, many utilities require direct control of their communications networks, since they are legally obliged to provide reliable services to consumers and thus cannot transfer responsibility for failures to third parties such as commercial Mobile Network Operators (MNOs).

It remains unclear for the meantime whether the utility sector will eventually develop particular requirements for broadband applications in the future. However, LTE could be beneficial for future “Smart Grid” applications.

Industrial

A niche but growing application area in the industrial sector is for Supervisory Control and Data Acquisition (SCADA) and other Machine-to-Machine type telemetry services. Data volumes are generally low, and therefore unlikely to require the bandwidths supplied by LTE, however terminal device volumes are potentially high.

Technologies

TETRA remains the only technology on the market, or indeed the currently visible horizon, demonstrably capable of fully satisfying, securely, reliably and resiliently, the user requirements represented by its target narrowband critical communications markets.

[2] **Narrowband** data communications generally refers to a transmission medium or channel with bandwidth less than or equal to one voice and a slow (circa <25 kbit/s) end-to-end data transfer rate, i.e. a low-capacity communications circuit or path for low speed data applications like e.g. pre-defined status messages.

TEDS (TETRA 2) builds on this heritage to provide wideband[3] services. Analysis of the notionally 'broadband' applications set defined to provide critical communications broadband services for PPDR by the Law Enforcement Working Party (LEWP) Matrix of Requirements demonstrates that the only truly broadband candidate application that could not potentially be met today by either TETRA or TEDS is real time high quality video.

Despite being relatively cheap and easily deployable, **Wi-Fi and WiMAX** have fundamental inherent limitations, including using unlicensed and therefore interference-prone spectrum and not being specified for group communications, which make them generally inappropriate for critical communications applications. One exception to this for the future may be so-called Carrier Wi-Fi Offload (CWO) of critical LTE networks in certain circumstances.

LTE will in future, assuming current standards work is fully completed and implemented, adequately satisfy all the bandwidth and broadband data functionality requirements currently defined by critical communications users. Areas where questions remain for the meantime therefore generally relate to the standardisation and adoption by industry of critical communications features, plus, fundamentally, the availability or otherwise of spectrum for critical broadband deployments.

Timescales

First generation standardised critical LTE products based on 3GPP R13 are not predicted to become available on the market before late 2018, i.e. circa four years hence from the date of this study. Even then, MCPTT (i.e. voice) will be the only 'payload[4]' type standardised by R13. Other data and video related 'payload' type standardisation work is intended to commence, and hopefully complete, in Release 14, for which standards (but not products) might be expected around Q2/18. With a further 18-24 months required thereafter for development before Release 14-based products could be expected to become available on the market, a target date of circa mid-2020 is predicted.

The standardisation and product development process for LTE critical communications features and facilities can be expected to be an on-going process throughout 3GPP R13-15 and beyond as new refinements and features are added over time. In particular, the critical communications user community is currently concerned that the security of an LTE bearer should be assured to at least match, and perhaps even exceed, that currently provided by TETRA.

This does not mean that some critical communications users will not employ LTE in the meantime. Already some users with urgent requirements for broadband data applications are considering, or even actively using, LTE services based on current commercially deployed standards releases.

All such users and operators strongly stress their view that existing TETRA networks will remain the only bearer used for critical voice services for the foreseeable future of at least the next 5-10 years. Indeed, at the time of writing many of the earlier adopters of TETRA are renewing their network infrastructures with a view to maintaining TETRA voice services for a further 10 or more years.

In view of the foregoing the ten year period to 2025 is considered likely to see significant expansion in the critical LTE market globally, particularly during the latter five years 2020-2025. With the first standardised critical LTE products likely to become available on the market by circa late 2018, progressive deployments can be expected subsequently, both by

[3] **Wideband** data communications generally refers to a transmission medium or channel with bandwidth greater than one voice and a medium (several hundred kbit/s, see ITU report ITU-R M.2033) end-to-end data transfer rate, i.e. a medium-capacity communications circuit or path.

[4] **Payload** is defined as: *"The actual information or message in transmitted data."* In other words, the speech, or data, or video, etc. information carried over the radio network.

commercial MNOs wishing to offer services to critical users, as well as for dedicated networks. In the latter case spectrum availability will be fundamental.

Nonetheless it is likely that some user groups may never require critical broadband and will therefore only ever need the facilities offered by TETRA and/or TEDS. Hence there will be an enduring market for TETRA throughout and potentially beyond the ten-year time horizon.

Implementation

There are a variety of alternative means for delivering mission critical services in the future. Just one of several key factors to be taken into account in evaluating the alternatives is that of spectrum. Unless adequate and suitable spectrum is available, all options with the exception of those based on taking service from a third party with access to its own spectrum assets are negated.

Equipment manufacturers are already envisaging and in some cases implementing different mechanisms for increasing co-existence and integration at both the network services and physical radio access levels.

Conclusions

This report concludes that TETRA can expect an enduring market for the foreseeable future of at least 10 years, and will need to coexist and integrate with LTE increasingly, particularly during the latter half of that period and beyond. In the same timeframe the critical LTE market can be expected to grow considerably, but only if and when standards specifications are completed and adopted into products by industry, and if adequate and suitable spectrum can be found in which to operate critical LTE networks for the future.

2 Introduction

This document presents a study commissioned by the TETRA & Critical Communications Association (TCCA) and undertaken by P3 communications GmbH (P3) on the relative merits of TETRA, LTE, and other broadband technologies for critical communications markets.

2.1 Background

The TCCA has been, and remains, closely involved in planning for the future of broadband critical communications services, in particular with respect to the development and standardisation of such services delivered over a 'Long Term Evolution' (LTE) bearer. As such, the TCCA is looking to the future, in particular regarding the types of products and services its members and other stakeholders should be planning for.

For example, members of the Association would like to understand how to promote the relative merits of TETRA, LTE and other broadband technologies as complementary, integrated or competing solutions for various critical communications markets.

The relatively higher data capacity benefits of broadband technologies such as LTE as compared to TETRA and TEDS are clearly understood. However, not all of the other features and services supported by LTE that might eventually benefit critical communications markets are as well defined for the meantime.

Equally, whilst some of the more obvious gaps in the features and capabilities of LTE with respect to critical communications users' needs are currently being addressed in the standards bodies, there may be others that are not as yet being considered.

The TCCA wishes to understand which of the gaps are likely to be resolved, in what timeframes, and which others, for technical or commercial reasons, may never be.

2.2 Study objectives

In view of the foregoing, the TCCA commissioned P3 to undertake this short impartial study on the relative merits of TETRA, LTE and other broadband technologies for critical communications markets. This report arising from the study is seen as a further development of the white paper already published by the TCCA in June 2014 entitled *"TETRA and LTE Working Together"*.

2.3 Scope

The study has addressed the following aspects:

- The Critical Communications market, segmented into Public Safety, Transport, Utilities and Industry.
- Primary focus on TETRA and LTE, but with some consideration of other broadband technologies such as Wi-Fi.
- P3's best judgement on evolution of deployed TETRA and LTE technology for two time horizons, i.e. from today through 2018 and 2025.
- P3's best judgement on performance of the concerned technologies in these time periods against the requirements of the critical communications market, based on ETSI TR 102 022-1 - *User Requirement Specification: Mission Critical Broadband Communication Requirements*. Voice has been understood to be a critical requirement.

- Strengths and weaknesses of TETRA, LTE and hybrid solutions for addressing these markets in the above timeframe.
- The risks of proprietary solutions, wherein reference is made to the TCCA white paper *"What are standards?"*
- Comment on dedicated versus public, shared systems meeting the end user requirements.

In considering the foregoing, P3 has provided some examples as to certain other features of the generic LTE standards that might potentially benefit critical communications users and markets in future.

3 The Critical Communications market by sector

3.1 PPDR / Public Safety

Public Protection and Disaster Relief (PPDR), also generically referred to in many parts of the world as ‘Public Safety’, has traditionally represented the majority share of the TETRA and critical communications market by sector. Most recent figures suggest that PPDR is still the single largest market for TETRA at circa 62%[5] of the total global shipments in 2013.

It has been found through experience that PPDR / Public Safety user requirements tend generally to at least match, and sometimes exceed, those of other critical communications user segments. Thus apart from a few minor exceptions in other specialist markets, PPDR / Public Safety tends to define the high-end needs and expectations of critical communications users more generally.

Whilst strongly asserting that voice remains paramount, and must always represent the lowest common service denominator available even if others fail, PPDR user organisations generally predict that they will require use of mobile broadband capabilities extensively in the future. However each subsector (e.g. police, fire and ambulance) currently appears to have somewhat different views of what the ‘killer application’ for their use of broadband may be.

Video and high-resolution images, as well as real-time database access (e.g. for persons, premises, vehicle and firearms data, etc.) are of growing interest and importance to police and law enforcement users. Fire fighters would like real-time access to building plans and data, but also increasingly aspire to use real-time sensors such as so-called ‘blue force tracking’ infrared cameras and through-the-wall motion detectors. Ambulance and Emergency Medical Services (EMS) also report that they need high-resolution images, and would combine this with real-time medical telemetry for remote assistance in making accurate onsite injury assessments and diagnoses, and commencing in-transit interventions.

Much of the activity over the past few years in Standards Development Organisations (SDOs) such as 3GPP and ETSI on enhancing LTE mobile broadband standards for critical communications use has been catalysed and driven by what may be considered ‘pathfinder’ Public Safety projects, such as the USA FirstNet nationwide public safety broadband initiative, and UK Home Office Emergency Services Mobile Communications (ESMCP) Programme.

Today, the delegates to those SDO’s working groups, and the work items they are tasked with completing, remain predominantly biased towards Public Safety use of LTE as a future broadband bearer.

3.2 Transport

As the second largest market for TETRA globally at circa 14%[5] of 2013 shipments, transport – comprising buses, trams, trains, metros, airports, etc. – represents a significant and growing sector in the critical communications space.

3.2.1 Rail

Traditionally the majority of the mainline rail market, particularly in Europe, has been locked out to TETRA in favour of GSM-R as a result of a historical UIC (International Union of Railways) decision to standardise on GSM-R for ERTMS (European Rail Traffic Management System) projects. However other transport sectors such as metros, trams, buses, etc., as

[5] Approximate market share percentages quoted herein relate to 2013 shipments and installed base as confirmed courtesy of IHS Research.

well as some mainline train markets outside Europe have enthusiastically adopted TETRA on the basis of its features and facilities for critical applications.

TETRA has been proven in Asia and South America, where it has dominated railway communications, and ETCS[6] compliant signalling as well as positive train control have been demonstrated in Asia, the US and South America using TETRA. Moreover, Communication Based Train Control (CBTC) can be seen as a further potential application especially for TEDS. The railway signalling system CBTC requires higher data rate than ETCS (approx. 70 kbit/s). TEDS provides the needed data rate (and higher) and improves security, reliability and cost efficiency.

Narrowband data communications over primarily voice mobile networks based on GSM-R are currently the norm for train control in Europe. However GSM-R is seen as an End Of Life (EOL) technology and organisations such as the UIC and the European Railway Agency (ERA) are currently considering the future replacement technology choice. Furthermore in future the safe movement of express trains may depend more on localised high-speed data transfers associated with use of advanced signalling systems such as the European Train Control System (ETCS).

In P3's view the global rail community does not seem to have developed its thoughts on the applicability or not of broadband generally, and LTE specifically, to the same extent as, for example, the Public Safety community. Rail stakeholders do not appear for the meantime at least to have looked for future rail communications requirements very far beyond current group voice and limited signalling needs satisfied by GSM-R. There is an overall impression that *"more bandwidth will be needed in future"*, but no specific requirements, use cases, etc. defined.

With GSM-R replacement unlikely until circa 2030 there is a potential gap for TETRA to fill. This is an especially compelling option where TETRA coverage exists from existing PPDR networks and operators believe that savings can be made. For example, a recent study carried out by the Finnish VIRVE TETRA operator proposed that the Finnish railways GSM-R network could be superseded in future by the VIRVE service with very few technical issues and quite considerable savings to the exchequer resulting from operating one nationwide network rather than two. At the time of writing this proposal is reported to have been agreed by the Finnish Transport Authority, which will seek a derogation from European Union rail authorities to allow use of TETRA in place of GSM-R for train communications.

In view of the foregoing, it is reasonable to expect that the rail sector particularly, but also the transport sector generally, will use the interim period whilst critical broadband standards are being specified, to develop and refine requirements and use cases for broadband applications that transport sector users will require in the future. In the meantime, TETRA may be able to fill the gap in some circumstances, but there is also a risk that proprietary technologies, including but not limited to so-called 'Trunked LTE', may be seen by users as an early way into the broadband world. See section 7 herein for further commentary on proprietary solutions.

3.2.2 Road

Future road vehicle bandwidth demands are much more diverse and harder to predict. They range from narrowband voice and messaging, typically delivered by TETRA or equivalent bearers today, to broadband vehicle-to-vehicle communications at 5.9 GHz and eCall accident reporting.

[6] European Train Control System (**ETCS**) is a signalling, control and train protection system designed to replace the many incompatible safety systems currently used by European railways, especially on high-speed lines.

With the exception of narrowband voice and messaging already available over TETRA or similar, none of the foregoing applications is particularly relevant to the primary currently available features and services of TETRA, LTE or other critical communications mobile technologies, hence will not be considered further here.

3.2.3 Airports

For airport operators, reliable and secure communications are vital in ensuring efficient operations and optimal coordination of resources across wide and diverse groups of users on the ground, inside buildings and in airside operations such as airport management, government officials, security staff, airline operators and apron control, etc.

Thus airports globally have been significant adopters of TETRA ever since one of the earliest TETRA projects was initiated almost 10 years ago at Oslo Gardermoen airport.

One of the various key attractions of TETRA for airports, as well as many other sectors, is its spectrum efficiency and the availability of suitable frequencies in which to operate on airport and other local area sites. Given that a fully functional and adequately dimensioned TETRA network can in many cases be confined to only a few 25KHz duplex radio channels, alternatives such as broadband technologies including LTE are much more difficult to find adequate spectrum for, since they require dramatically more at an absolute minimum of 1.4MHz duplex channels, and typically multiples of 5MHz duplex (i.e. 5+5MHz, 10+10MHz, etc.).

However airport operators in some regions are beginning to explore the potential for use of broadband applications. It remains to be seen what standards or technologies might be adopted to support such applications, and what spectrum they might be able to operate in. However the significant risks associated with proprietary solutions should not be overlooked in the meantime (see section 7 herein).

3.3 Utilities

Current estimations suggest that circa 8%[5] of TETRA installed base is in the utilities (e.g. water, gas and electricity supply) sector. This is predominantly used for mission critical voice and short data for applications including, but not limited to, service and maintenance teams, for which TETRA and other equivalent PMR technologies are ideally suited.

For the meantime utilities seem generally less interested in using broadband bearers than in reliable wide-area collection of small bursts of Machine-to-Machine (M2M), also known as Device-to-Device (D2D), short data from millions of devices such as consumer meters, substations, solar cells and wind turbines. In the future, Smart Grids will extend two-way communication requirements within and between millions of consumer meters across whole distribution networks, and perhaps add additional services beyond resource distribution.

Utility users do not generally appear for now to be seeking high definition video or high bandwidth data communications services. Most operational data communications require very low data rates of circa 10-64 kbps, but wide geographic coverage and *"exacting availability, latency, jitter and synchronous requirements"*[7]. Video is only needed for security monitoring of remote sites, and most utilities reportedly consider circa 256 Kbps a sufficient data rate for slow scan CCTV in such applications.

Many utilities currently insist on having direct control of their communications networks, since they are legally obliged by national regulatory authorities to provide reliable services to the community. Insofar as they cannot simply transfer responsibility for failures to service

[7] Adrian Grilli, European Utilities Telecommunications Council, 2013

suppliers, they are loath to depend on third parties such as commercial Mobile Network Operators (MNOs) for support of their real-time operational control activities.

In view of the foregoing, it remains unclear for the meantime whether the utility sector will eventually develop particular requirements for broadband applications in the future.

3.4 Industrial

A range of other industrial applications for TETRA, not least extraction and mining at circa 5%[5] of the total global installed base, makes up the remainder of the market.

A niche but growing application area in this sector is for so-called Supervisory Control and Data Acquisition (SCADA) and other M2M / D2D type telemetry services. As for utilities (see 3.3 above), the volumes of data transferred in any such SCADA or other M2M / D2D session are generally low, and therefore unlikely to require the sorts of bandwidth offered by an LTE or equivalent broadband bearer. However the terminal device volumes associated with such usage are potentially enormous given the ever-expanding range of applications coming to market.

Specifically in the extraction sector there are a small number of early examples of LTE deployments for a range of broadband applications, even including in some cases command and control of autonomous driverless vehicles.

4 Technology applicability per market

This section considers the applicability of TETRA, LTE and other broadband technologies against the requirements of the critical communications market, based on ETSI TR 102 022-1 v1.1.1 (Mission Critical Broadband Communication Requirements) as a benchmark. Voice has been understood to be a critical requirement throughout.

4.1 TETRA & TEDS

TETRA was specified, designed and developed specifically to meet the critical voice and narrowband data requirements of user who primarily work in groups, such as are typified by many of those considered in this report. It has proven exceedingly successful and reliable in doing so, and remains *the only technology on the market, or indeed the currently visible horizon*, capable of fully satisfying, securely, reliably and resiliently, the user requirements represented by its target critical communications markets.

Since the requirement defined by ETSI TR 102 022-1 are acknowledged as being for 'Critical **Broadband** Communication', it might be expected that, with the clear exception of voice and a few other lower bandwidth applications, TETRA would be unlikely to meet the needs.

However, on closer analysis, in particular of the applications defined by the LEWP Matrix of Requirements (Annex A to ETSI TR 102 022-1), it becomes less clear as to where a distinct line may be drawn between *narrowband* (e.g. TETRA), *wideband* (e.g. TEDS) and truly *broadband* (e.g. LTE) bearer requirements. In fact, the only clear broadband candidate application that is not already, or could not in future, be met to some degree at least by TETRA or TEDS is **high definition (HD) video in real time**.

4.2 Wi-Fi and other broadband technologies

4.2.1 Wi-Fi

Wi-Fi, based on the IEEE 802.11 standards series, has become virtually ubiquitous in Wireless Local Area Networks (WLANs) since its first introduction in the late 1990s. Almost every home, office and premises globally that has any form of WLAN has an 802.11 router hidden away somewhere, and 802.11 compliant Wi-Fi is the de facto standard WLAN technology incorporated in a huge range of PC, tablet, smartphone and other devices.

Subsequent to 2000, iterations of the standards have introduced improvements, including increased throughput and range, the use of Multiple-Input Multiple-Output (MIMO) antennae and alternative spectrum bands, etc., such that Wi-Fi remains pre-eminent in WLAN applications today.

4.2.2 WiMAX

Until a few years ago, two wireless technologies that are in many ways rather similar, i.e. WiMAX, based on IEEE 802.16 standards, and LTE standardized by 3GPP, were competing for dominance in the 4G sector. This competition started with the advent of the two standards' pre-4G versions: 802.16e for Mobile WiMAX and 3GPP release 8 for LTE, and continued with the release of their truly 4G compliant versions, WiMAX 2.0 based on IEEE 802.16m and LTE-Advanced at 3GPP Release 10.

Subsequently LTE has generally been accepted as the winner of the competition, certainly for the vast majority of commercial carrier mobile network deployments. WiMAX still has niche applications to address, and for example plans are in hand for it to migrate/integrate with LTE in a multiple heterogeneous access technology mode in future.

For fixed network applications WiMAX can offer high-speed broadband connectivity, supporting multicasting and quality of service features as well as cell handover and mesh networks, which should provide highly robust systems. But the lack of standards covering the international spectrum co-ordination of WiMAX is likely to cause fragmentation in the marketplace as different manufacturers focus on different bands.

In any event, the development of user equipment terminal devices (UEs) supporting WiMAX has fallen well behind that of LTE devices, with relatively few mainstream manufacturers deciding to adopt and develop the WiMAX standard. It is therefore considered highly unlikely that WiMAX will ever offer anything other than small-scale niche applications for fixed networking and/or 4G network offloading for any broadband application, including for critical communications.

Both the Wi-Fi and WiMAX standards have fundamental inherent limitations, including using unlicensed and therefore interference-prone spectrum and not being specified for group communications, which make them generally inappropriate for critical communications applications.

4.3 LTE

LTE can already to some extent, or will in future, *assuming current 3GPP standards functional work items are adequately completed and implemented by vendors*, satisfy all the bandwidth and the key functionality requirements defined by ETSI TR 102 022-1.

Areas where questions remain for the meantime therefore relate primarily to the standardisation and adoption processes and timescales, plus of course the omnipresent availability or otherwise of spectrum issue.

4.3.1 LTE features with potential application for Critical Communications

The following capabilities specified within the LTE standards are suggested as having potential utility for some future critical communications implementations of LTE over and above the currently defined enhancements to the standard.

A. Carrier Aggregation (CA)

Carrier aggregation is used in LTE-Advanced (i.e. 3GPP Release 10 and beyond) to increase the bearer bandwidth, and thereby increase the bitrate. Insofar as CA allows for the combination of disparate ‘chunks’ of spectrum, even in sometimes widely different bands, and in both the LTE uplink and downlink, it may be that it has potential for utility in future critical communications LTE implementations.

See Appendix 1 section 11.1 for further details.

B. Carrier Wi-Fi Offload (CWO)

A current focus of increasing interest in the LTE community is for Wi-Fi to be used in so-called Carrier Wi-Fi Offload (CWO) applications. It is considered a reasonable assumption that CWO may also have utility for some future critical communications LTE implementations.

See Appendix 2 section 11.2 for further details.

C. Wi-Fi for Direct Mode Operation (DMO)

Depending on the progress (or not) of standardisation for Proximity Services (ProSe) in LTE, most particularly whether or not so-called ‘relay’ services are eventually adequately implemented, then an alternative device-to-device IP wireless bearer path might be required to implement DMO in practice. Wi-Fi might be one alternative for such a bearer.

5 Estimated deployment timelines for LTE

The following sections present P3's judgement on the likely availability of features and services in LTE to meet the data communications requirements of the critical communications market in the timeframes defined for this study.

5.1 Standardisation & development timelines

A fundamental factor in any consideration of new technology futures is the time required to standardise new features, and thereafter for manufacturers to design, test, prove and implement the standards in chip sets, protocols and software code.

The primary focus of the critical communications sector in terms of technology futures for the past few years has been, and remains, the LTE standards produced by 3GPP. Most recently, The Open Mobile Alliance (OMA) and ETCI TC-TCCE standards bodies have begun formal participation in 3GPP standardisation of critical communications features and functions in LTE via collaboration in the newly formed 3GPP TSG-SA6 working group.

3GPP standards releases occur on a regular 18-24 months cycle, with the next release (R12) expected by the end of Q1/15, i.e. March 2015. Work on specifically critical communications related work items i.e.:

- *Group Communications Service Enablers (GCSE)*
- *Proximity Services – equivalent to TETRA Direct Mode (ProSe)*
- *Isolated E-UTRAN Operation for Public Safety (IOPS)*

began in, and will be at least partially completed by, Release 12 in Q1/15. However completion of these work items, particularly through extensions and enhancements in:

- *Group based Enhancements (GROUPE), and*
- *Extended Proximity-based Services (ProSe_Ext)*

as well as commencement of work on *Mission Critical Push To Talk (MCPTT)*, will not start until Release 13 standardisation begins in circa April 2015.

As the name implies, IOPS (*Isolated E-UTRAN Operation for Public Safety)* is only currently defined for Public Safety specific applications, and the latest indications in 3GPP are that it might never advance to a more generic critical communications implementation due to the complexity of replicating numerous EPS (Evolved Packet System) or 'core' databases within individual eNodeBs. In LTE terms the eNodeB (Evolved Node B) is equivalent to a Radio Access Network (RAN) base station in other networks.

As can be seen from Figure 1 below, given all of the foregoing in relation to standardisation timescales, the earliest that stable standards specifications supporting all the currently defined critical communications features in LTE could be expected to be released is by about the middle to end of 2016. Thereafter, manufacturers will have to decide whether or not to implement the new critical communications features, and if so begin work on development based on the issued specifications.

From past experience, ETSI defines a typical *'from standards to silicon'* (i.e. implemented solutions available on the market) timescale of 18-24 months for this process. On this basis the realistic likelihood of availability on the market for the first Release 13-based products is not earlier than late 2018. Further time would then also clearly be required for conformance and interoperability testing, as well as proving and acceptance in the field.

Also worthy of note in this regard is that MCPTT (*i.e. push to talk voice*) is the only current 'payload' work item approved within 3GPP. Work on other data and video related 'payload' applications is intended to commence, and will hopefully be completed, only in Release 14. Given the 18-24 month 3GPP release cycle mentioned above, Release 14 standards (not hardware) might be expected around Q2/18, with a further 18-24 months required thereafter for development before Release 14-based products might be expected on the market circa mid-2020.

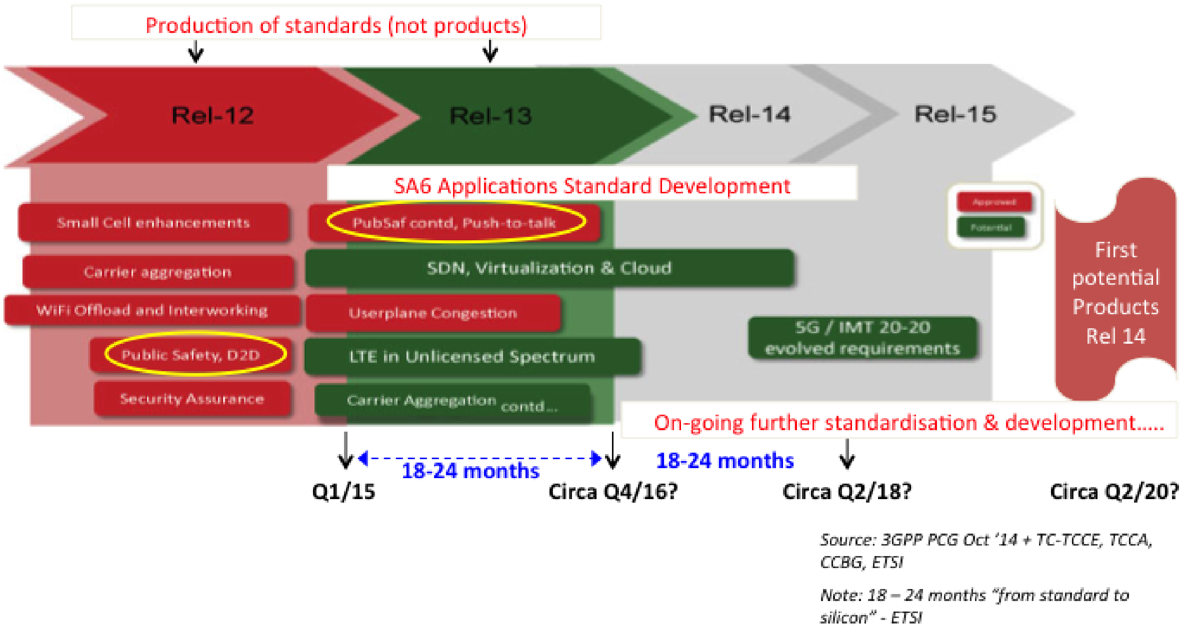

Figure 1: Standardisation & development timelines

As has been the case with TETRA and all other mainstream standardised solutions in the past, the standardisation and product development process for LTE critical communications features and facilities can be expected to be an on-going process throughout 3GPP R13-15 and beyond as new refinements and features are added over time. In particular, the critical communications user community is currently concerned that the security of an LTE bearer should be assured to at least match that currently provided by TETRA.

5.2 Time horizon 2018 (3 years)

With reference to the discussion in 5.1 above, it is not expected that the first standardised critical LTE products will become available on the market much before late 2018, i.e. at least four years from the beginning of 2015.

This is not to say that LTE will not be employed and / or deployed by any critical communications users anywhere in the meantime. Already some users with urgent requirements for broadband data applications are considering, or even actively using, LTE services based on current commercially deployed standards releases (i.e. 3GPP Release 10 or earlier).

For example, the Ministry of Interior (MoI) in the Gulf state of Qatar has implemented a standard commercial LTE network for police and public safety users, accepting the limitations implied by the lack of critical communications features such as group working, etc.

Deployment of such dedicated private networks is clearly fundamentally dependent on the availability (or not) of adequate and suitable spectrum in which to operate them. In the Qatar MoI case the national regulator has licensed 10+10 MHz in the 800 MHz commercial LTE band for public safety use – it has to be said much to the chagrin of the local MNOs. This kind of allocation is currently the exception rather than the rule globally, with only relatively few other national regulators such as in the USA, Canada, Australia, United Arab Emirates and South Korea announcing various amounts of spectrum in a variety of 700 and 800 MHz bands defined locally for dedicated PPDR use.

Others, including the ASTRID and Airwave TETRA operators in Belgium and UK respectively, have established 3G/4G broadband services based on Mobile Virtual Network Operator (MVNO) arrangements with commercial operators. Again these currently have of course to accept all the limitations associated with using commercial networks for critical applications, but they do at least not require regulators to grant additional spectrum since they operate on the commercial MNOs licensed spectrum. Primarily the short-term advantage is to provide some early experience of broadband for those users prepared to work within the constraints imposed.

All such users and operators strongly stress the view that their existing TETRA networks will remain the only bearer used for critical voice services for the foreseeable future of at least the next 5-10 years. Indeed, many early adopters of TETRA, particularly in Europe, are now actively renewing their network infrastructures in order to maintaining TETRA voice services towards a similar time horizon of 10 or more years hence.

5.3 Time horizon 2025 (10 years)

The ten year period to 2025 is considered likely to see significant expansion in the critical LTE market globally, particularly during the latter five years 2020-2025.

With the first standardised critical LTE products becoming available on the market by circa late 2018, progressive deployments can be expected subsequently, both by commercial MNOs aspiring, and in practice able, to offer services to critical users, as well as for dedicated networks. In the latter case, and as mentioned above, availability of suitable spectrum will be fundamental.

The situation on spectrum availability (or not) in nations where regulators have not yet pronounced on critical broadband spectrum licensing will become clearer over the next five to ten years. Beginning with the ITU World Radio Conference (WRC) in November 2015 there are likely to be a number of regulatory initiatives relative to PPDR and other critical broadband spectrum assignments. Decisions on whether deployment of dedicated networks will be practical, or whether commercial MNO services will need to be considered, will depend crucially on these regulatory decisions in different parts of the world.

Whilst these outcomes will clearly directly affect infrastructure vendors, the market for user equipment, applications and other end-user equipment and services can be expected to be less impacted. In other words, whether or not the bearer network is owned and operated by the user organisation, or services are provided by MNOs, users will still require terminal devices, applications, etc.

In a standardised market, competition and innovation, as well as economies of scale resulting from the wider global LTE user equipment ecosystem, can be expected to influence prices. However it is worth noting that a typical high-end smartphone today retails at an undiscounted price not dissimilar to the volume purchase price of a typical TETRA handset. So any expectations that critical users may ultimately benefit from being able to purchase $99 or similarly low priced LTE handsets may be misguided. It is considered more likely that whilst today's TETRA users will not see dramatic price reductions when considering LTE handsets, other more expensive PMR system users, for example such as P25, will see reasonable discounts on the prices they pay today.

With many users wishing to retain TETRA for voice whilst using LTE for data in future there may be a case for vendors to consider development of dual mode terminals during the 5-10 year time window. However attention will need to be focused on potential volumes and the consequent business case before the significant research and development investment necessary is committed. Perhaps in a similar timeframe Software Defined Radio (SDR) will become more of a practical and commercial reality and thereby negate the need for multi mode devices.

Equally, it is considered likely that some user groups and types might never define critical broadband use cases (see for example the discussion under railways - section 3.2.1 above and utilities - section 3.3) and will therefore only ever need or want the capabilities and facilities offered by TETRA. Hence there will be an enduring market for TETRA throughout and potentially beyond the ten-year time horizon.

6 SWOT analysis

The figures in the following sections present P3's judgement on the relative Strengths, Weaknesses, Opportunities and Threats (SWOT) for target technologies to meet critical communications users' needs.

6.1 TETRA

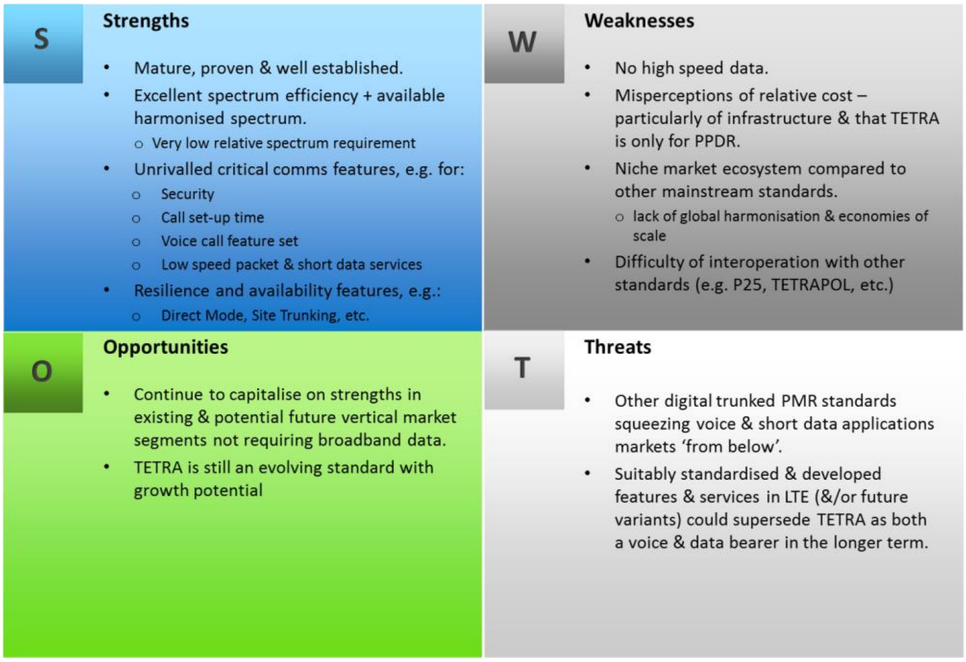

Figure 2: TETRA SWOT analysis

6.2 TETRA 2 - TEDS

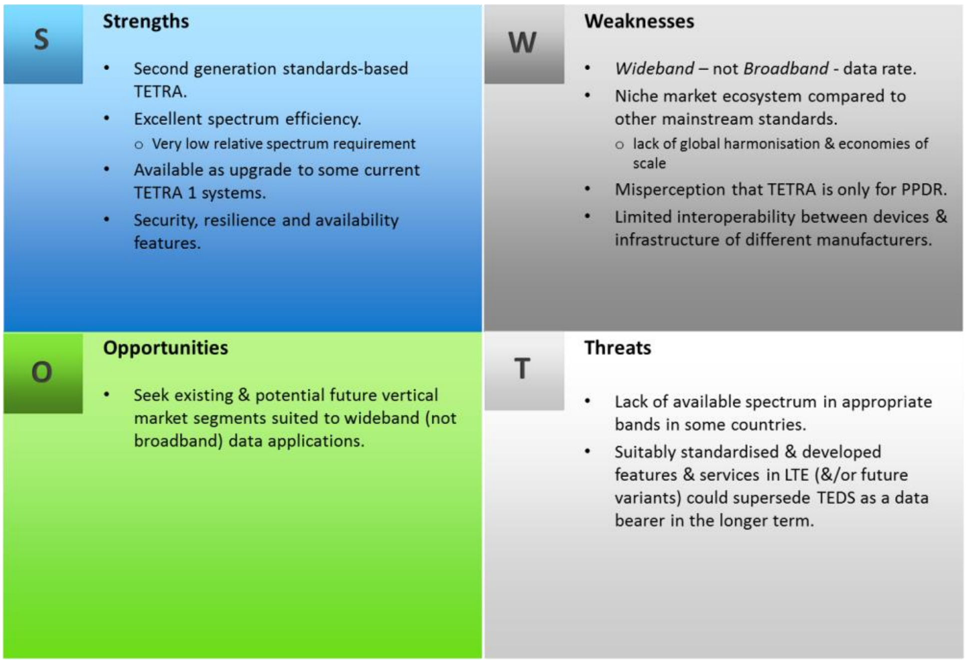

Figure 3: TETRA 2 (TEDS) SWOT analysis

6.3 LTE

Figure 4: LTE SWOT analysis

7 The risks of proprietary solutions

The importance and value of international standards, and consequent risks associated with adopting proprietary alternatives, is made clear in the TCCA white paper *"What are standards?"*

In the context of this current report it is valuable to reiterate that standards support all aspects of conformity and interoperability, and facilitate the implementation of integrated solutions, including compatibility or connectivity with other products, services and systems. They also help reduce unnecessary variety in the marketplace, whilst encouraging competition, diversity of supply and innovation, and reducing prices by enabling economies of scale in what are necessarily larger and more globalised markets.

All of the foregoing has been clearly proven over many years by the success of standards such as TETRA, GSM, UMTS and many others.

As the critical mobile communications sector looks towards a broadband future in LTE, standards retain their vital significance in terms of encouraging competition, innovation, market scale and associated economies through participation in a global ecosystem. The adoption of proprietary solutions during the necessary period required to agree, specify and develop international standards is conversely counter-productive, fragmenting the market and potentially even negating global standardisation efforts by creating 'de facto standards'. Hence why proprietary solutions can be costly in the long term as well as technically risky.

For these reasons the TCCA and its members, including P3, wholeheartedly support and promote the development and adoption of standardised solutions over proprietary, single sourced alternatives.

8 Implementation options: meeting users' requirements

8.1 Network rollout options

In the early period after formation of the TCCA's Critical Communications Broadband Group (CCBG) much valuable time and effort by a range of industry experts was devoted to the development of an 'Implementation Options' White Paper discussing the range of options for delivering future Mission Critical voice and data services. The options discussed in the document include:

- *Taking service from standard commercial networks*
- *Operating as a Mobile Virtual Network Operator (MVNO)*
- *Taking service from a commercially owned dedicated network*
- *Building, owning and operating a dedicated network*
- *Combination (hybrid) approaches*
- *Radio Access Network (RAN) sharing, and*
- *The role of satellite services*

Just one of several key factors to be taken into account in considerations as to how best, most efficiently and cost effectively to deliver mission critical services in the future is that of spectrum. Unless adequate and suitable spectrum is available, all of the above options with the exception of those predicated on taking service from a third party with access to its own spectrum assets are negated.

More recently the Finnish TETRA operator VIRVE has published an article[8] describing a 5-step hybrid approach towards broadband adoption that essentially builds on the options described in the CCBG White Paper and demonstrates a solid model for other operators to develop according to their own needs and timescales.

Accordingly, readers of this current report are strongly encouraged to also reference the CCBG 'Implementation Options' White Paper, since P3 considers that the options described and conclusions reached therein remain entirely valid and current today. Not least in this is the statement made in the White Paper that: *"Commercial networks undoubtedly have a role to play in many Critical Communications solutions and will enable users to experience the benefits in a relatively short time."*

8.2 TETRA / LTE co-existence

In the fullness of time, and as more dual technology implementations are required, TETRA and critical LTE will need to co-exist and integrate for both technical and practical economic reasons.

Network equipment manufacturers are currently envisaging a range of co-existence mechanisms for achieving closer and deeper integration between TETRA and LTE. At the service level these include:

- **Interconnecting gateways**
- **Service integration** - i.e. using a common service server for several different networks / technologies

[8] "Finland's 5 steps to critical broadband" By Jarmo Vinkvist, Tero Pesonen and Matti Peltola

- **Network integration** - i.e. using both a common service server and common Home Subscriber Server (HSS)

In addition, some manufacturers are already integrating equipment at the Radio Access Network (RAN) level, such as by producing single-cabinet TETRA Base Station (TBS) and LTE eNodeB implementations with shared common backhaul.

The TETRA/LTE dual technology can also be expected for terminals. The Project Team (PT) 49 of Working Group Frequency Management (FM) within the Electronic Communication Committee (ECC)[9] predicts these kinds of dual mode terminals between 2018 and 2020.

[9] http://www.cept.org/ecc/groups/ecc/wg-fm/fm-49/

9 Conclusions

Today TETRA/TEDS remain the only technologies on the market, or indeed the currently visible horizon, proven to be capable of fully satisfying, securely, reliably and resiliently, the user requirements represented by their target narrow/wideband critical communications markets.

In the fullness of time, assuming that current standards work is adequately completed and implemented, LTE can be expected to ultimately satisfy all the bandwidth and most of the key functionality requirements currently defined by critical communications users. Areas where questions remain for the meantime therefore generally relate to:

- *the completeness or not of standardisation work,*
- *the ultimate adoption or not by industry of critical communications features, plus, fundamentally,*
- *the availability or otherwise of spectrum for critical broadband deployments.*

The first standardised critical LTE products are considered unlikely to become available on the market before late 2018. For these standards, MCPTT (i.e. voice) is the only current ‘payload’ work item approved within 3GPP. Work on other data and video related ‘payload’ applications is intended to commence, and hopefully complete, only in Release 14 standards, which might be expected around Q2/18.

However in the meantime some critical communications users with urgent needs will likely employ current commercially deployed standards releases of LTE. All such users and operators strongly stress the view that TETRA will remain the only bearer used for critical voice services for the foreseeable future of at least the next 5-10 years. Indeed, many early adopters of TETRA are renewing their network infrastructures and intend to maintain TETRA voice services for a further 10 or more years.

The ten year period to 2025 is therefore considered likely to see significant expansion in the critical LTE market globally, particularly during the latter five years 2020-2025. With the first standardised critical LTE products likely to become available on the market by circa late 2018, progressive deployments can be expected, both by commercial MNOs wishing to offer services to critical users, as well as for dedicated networks. In the latter case availability of adequate and suitable spectrum will be fundamental.

Nonetheless it is likely that some user groups may never require critical broadband and will therefore only ever need the facilities offered by TETRA. Hence there is expected to be a continuing market for TETRA throughout, and potentially beyond, the ten-year time horizon from today.

In conclusion therefore, TETRA can expect an enduring market for the foreseeable future of at least 10 years, and will need to coexist and integrate with LTE increasingly, particularly during the latter half of that period and beyond.

In the same timeframe the critical LTE market can be expected to grow considerably, but only if and when standards specifications are completed and adopted into products by industry, and if adequate and suitable spectrum can be found in which to operate critical LTE networks for the future.

10 Table of Abbreviations

3GPP	3rd Generation (3G) Partnership Project
CA	Carrier Aggregation
CCBG	Critical Communications Broadband Group (of the TCCA)
CCTV	Closed Circuit Television
CWO	Carrier Wi-Fi Offload
D2D	Device To Device
DMO	Direct Mode Operation
ECTS	European Train Control System
EMS	Emergency Medical Services
EOL	End Of Life
EPS	Evolved Packet System
eNodeB	Evolved Node B (LTE RAN base station)
ERA	European Railway Agency
ERTMS	European Rail Traffic Management System
ESMCP	Emergency Services Mobile Communications Programme (of the UK Home Office)
ETCS	European Train Control System
ETSI	European Telecommunications Standards Institute
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
GCSE	Group Communications Service Enablers
GROUPE	Group based Enhancements
GSM-R	GSM-Rail (variant of GSM - Global System for Mobile Communication)
HSS	Home Subscriber Server
IOPS	Isolated E-UTRAN Operation for Public Safety
ITU	International Telecommunications Union
LEWP	Law Enforcement Working Party
LTE	Long Term Evolution
M2M	Machine To Machine
MCPTT	Mission Critical Push To Talk
MIMO	Multiple-Input Multiple-Output
MNO	Mobile Network Operator
MoI	Ministry of Interior
MVNO	Mobile Virtual Network Operator
OMA	Open Mobile Alliance
PMR	Professional Mobile Radio
PPDR	Public Protection and Disaster Relief
ProSe	Proximity Services
ProSe_Ext	Extended Proximity-based Services
R12/13/14/etc.	3GPP standards specification release numbers 12/13/14/etc.
RAN	Radio Access Network
SCADA	Supervisory Control and Data Acquisition
SDO	Standards Development Organisation
SDR	Software Defined Radio
SWOT	Strengths, Weaknesses, Opportunities and Threats
TBS	TETRA Base Station
TCCA	TETRA & Critical Communications Association
TEDS	TETRA Enhanced Data Services (TETRA 2)
TETRA	Terrestrial Trunked Radio
UE	User Equipment
UIC	International Union of Railways
UMTS	Universal Mobile Telecommunications Service (‘3G’)
Wi-Fi	Wireless network conforming to IEEE 802.11x standards
WiMAX	Wireless network conforming to IEEE 802.16x standards
WRC	World Radio Conference

11 Appendices

11.1 Appendix 1: Carrier Aggregation (CA)

Carrier aggregation is used in LTE-Advanced (i.e. 3GPP Release 10 and beyond) to increase the bearer bandwidth, and thereby increase the bitrate. Since it is required to maintain backward compatibility with LTE Releases 8/9 User Equipments (UEs), the aggregation is based on R8/R9 carriers. Carrier aggregation can be used for both FDD and TDD, Figure 5 below illustrates an example where FDD is used.

Each aggregated carrier is referred to as a component carrier, CC. The component carrier can have a bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz and a maximum of five component carriers can be aggregated, hence the maximum aggregated bandwidth is 100 MHz. In FDD the number of aggregated carriers can be different in Downlink (DL) and Uplink (UL), see Figure 5 below. However, the number of UL component carriers is always equal to or lower than the number of DL component carriers. The individual component carriers can also be of different bandwidths.

The easiest way to arrange aggregation would be to use contiguous component carriers within the same operating frequency band (as defined for LTE), so called intra-band contiguous. This might not always be possible, due to available frequency allocations. For non-contiguous allocation it could either be intra-band, i.e. the component carriers belong to the same operating frequency band, but have a gap, or gaps, in between, or it could be inter-band, in which case the component carriers belong to different operating frequency bands, see Figure 6 below.

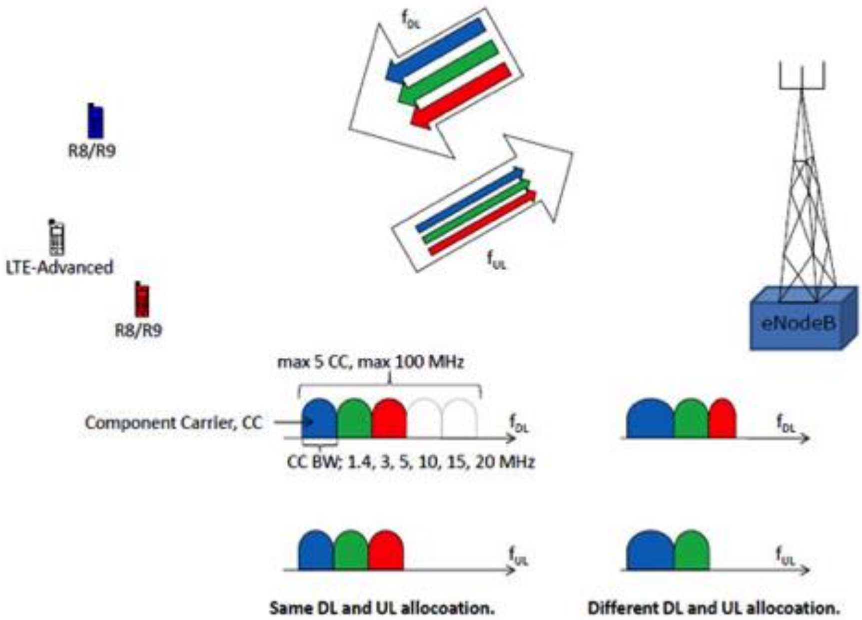

Figure 5: Carrier Aggregation (FDD)

The LTE-Advanced UE can be allocated DL and UL resources on the aggregated resource consisting of two or more Component Carriers (CC), the R8/R9 UEs can be allocated resources on any ONE of the CCs. The CCs can be of different bandwidths. *(Source: 3GPP)*

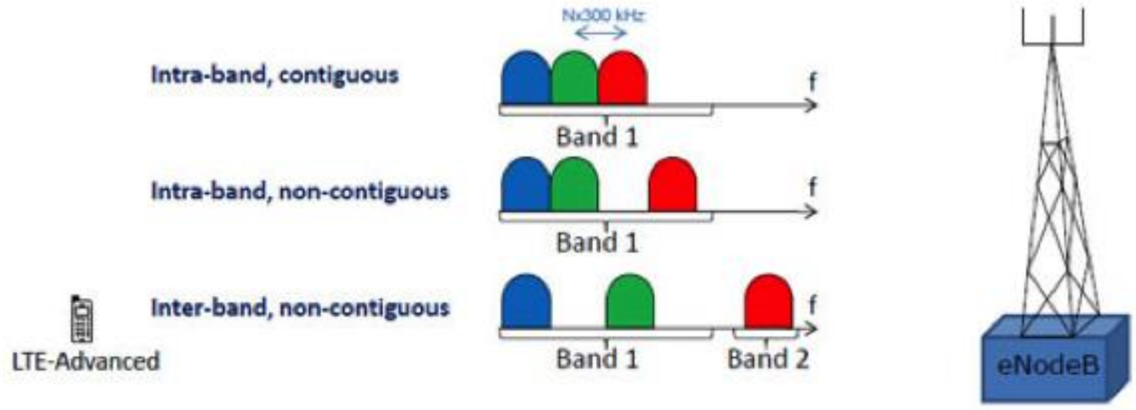

Figure 6: Carrier Aggregation intra-band and inter-band aggregation alternatives

The spacing between the centre frequencies of two contiguous CCs is Nx300 kHz, N=integer. For non-contiguous cases the CCs are separated. *(Source: 3GPP)*

11.2 Appendix 2: Carrier Wi-Fi Offload (CWO)

The current focus of increasing interest in Wi-Fi is for so-called Carrier Wi-Fi Offload (CWO) applications.

Mobile operators are feeling the squeeze with spectrum and data capacity, and consequently seeking alternative options to relieve some of the smartphone-related and other broadband traffic demand and congestion in their networks.

Wi-Fi is embedded in 99% of all smartphones on the market today, and with smartphone Wi-Fi usage climbing, several industry bodies are pushing for standard specifications like Hotspot 2.0[10], which would make Wi-Fi connectivity more seamless and easy to use.

As a result of CWO, demand for carrier Wi-Fi solutions will result in related equipment revenues growing to nearly $8bn by 2019, according to ABI Research.

If Wi-Fi is to have any utility in future critical communications networks, it is therefore considered that CWO may represent the most likely application. This of course pre-supposes that all the traditional critical communications non-negotiable requirements such as reliability and resilience, availability, coverage, capacity, and by no means least, security, can be satisfied in future iterations of standards such as Hotspot 2.0.

[10] Published by The Wi-Fi Alliance. Also known as HS2 and Wi-Fi Certified Passpoint.

12 History

Date	Version	Description	Status
February ‘15	1.0	First issue	First Issue
February ‘15	1.1	Incorporating amendments suggested by TCCA SMEs	Final