The 450 MHz Band

for

the Smart Grid and Smart Metering

By CDG 450 Connectivity Special Interest Group
(450 SIG)

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List of used Acronyms

2G: The **second generation** of wireless communications technology.
3G: The **third generation** of wireless communications technology.
4G: The **fourth generation** of wireless communications technology.
ARPU: **Average Revenue per User,** as the total revenue divided by the number of subscribers.
CAPEX: **capital expenditure** is the cost of developing or providing non-consumable parts for the product or system.
CDMA**:** **Code-Division Multiple Access**; a technology used in wireless communications for second-generation and third-generation wireless networks. It allows many signals to occupy a single transmission channel in order to optimize the available bandwidth, a process called multiplexing.
CDMA EV-DO: A high data rate version of CDMA.
DSO: **Distribution System Operator**; the operator that distributes electrical power from the transmission system and delivers it to consumers.
ECM: **Electromagnetic compatibility;** concerns the reduction of interference in electronic systems.
EU: **European Union**; a group of 26 European countries that participates in the world economy as one economic unit and operates under one official currency, the euro. The EU's goal is to create a barrier-free trade zone and to enhance economic wealth by creating more efficiency within marketplace.
EUTC: European Utilities Telecom Council.
GHz: **Giga Hertz**; a billion (1,000,000,000) Hertz. A measure of bandwidth in an analog transmission system.
GPRS: **General Packet Radio Service**; The 2.5G data service enhancement for GSM host networks. GPRS is a packet-switched service that takes advantage of available GSM time slots for data communications.
GSM: **Global System for Mobile** Communications; A digital cellular phone technology based on TDMA that is the predominant system in Europe, but also used worldwide. Developed in the 1980s.
LTE: **Long Term Evolution**; the next-generation 3G technology for both GSM and CDMA cellular carriers.
M2M: **Machine to Machine;** the automatic communications between devices without human intervention. It often refers to a system of remote sensors that is continuously transmitting data to a central system.
MHz: **Mega Hertz**; A measure of bandwidth in an analog transmission.
NOC: **Network Operations Center**; a centralized location from which a large, complex network and its component sub networks and network elements can be monitored, and faults or performance failures can be identified, diagnosed, isolated, and often corrected.
OPEX: **operational expenditure;** is an ongoing cost for running a product, business, or system. Operating expenditure may include wages, salaries, administrative and research and development costs, but excludes interest, depreciation, and taxes.
TCO: **Total Cost of Ownership**; the purchase price of an asset plus the costs of operation.
QoS: **Quality of Service;** refers to several related aspects of telephony and computer networks that allow the transport of traffic with special requirements.

Introduction

The worldwide and widespread discussions on climate change over the last decade have opened a window of opportunity for governments and other institutions to rethink their climate policies and introduce new visions and strategies for existing and future environmental and sustainability issues. In Europe this debate and subsequent strategy change has deeply affected energy policy and has resulted in, among other things, the so called 'triple twenty by 2020 standard' in which the European Commission and its member states hope to reduce by the year 2020 20% of carbon emissions; 20% of the energy consumption has to come from renewables and by energy efficiency measures, like demand management; and overall energy consumption must be reduced by 20%.

New energy policy calls for new grid strategy by the DSOs

To reach those ambitious goals, demand-side management, decentralized energy production, and increased renewable energy and consumer awareness are necessary building blocks for a more complex and interactive balance of energy flows in the electricity grid, and therefore a challenge for grid operators like DSOs.

This situation gives DSOs the opportunity to rethink their vision and strategy on how their grid should look and has resulted in a common vision of upgrading most of their grids, down to the low voltage grid, with smart sensors and integrated communication. In the centre of all these ambitions and as the key enabler for the modernisation of the grid infrastructure lies the "Smartness" of the Grid, i.e., the combination of actively manageable devices in the field (smart assets) and bi-directional communication with these smart assets.

Communication is an essential part of the Smart Grid

The Smart Grid should increase the ability to manage the flow of electricity by a robust two-way communication system, advanced sensors and intelligent switches with integrated decision mechanisms. With this, the stability and economic advantages are within reach of all parties involved in the electric grid.

As a core requirement for any Smart Grid deployment, a robust and future-proof communication infrastructure is essential. Without the ability to 'see and hear' the status and condition of the grid, not only to the level of the sub-station but even down to the end-consumer who will become the 'prosumer', the utility companies cannot deliver a secure, sustainable and efficient grid network.

Smart Grid requires different communication solutions

DSOs have a long tradition of using communication technologies for operating their grid. With the introduction of the concept of Smart Grids, including the mid and low voltage networks, DSOs have to rethink the communication requirements for different parts of the grid and the possibilities of the various technologies.

DSOs often use expensive fibre optics for communication to a certain percentage of medium voltage stations and to the upper part of the grid because of the extreme low latency needed for signaling and rerouting in case of power disturbances. Because of the very rigorous requirements and the limited number of assets in the upper part of the grid, the fibre optic solution is necessary for this purpose.

This is not the case in the 'lower parts' of the grid where millions of low voltage stations, decentralized power generation, storage units and Smart Meters are located. Here, a communication infrastructure is needed that can address these smart assets securely and reliably, but also economically.

In other words the communication solution in the 'lower parts' meets other or less stringent requirements than in the 'upper part' of the grid and has a different cost-benefit ratio due to its massive scale (in the EU around 240 million Smart Meters).

Cellular communications are the de facto solutions for M2M communication[1]

Taking these requirements into account, smart assets like the Smart Meter are typical Machine-to-Machine communication devices (M2M)[2]. For this reason, it does not come as a surprise that most of the DSOs are looking at cellular communication technologies for their Smart Meters. Where fibre is not widely available and a rollout prohibitively expensive, commercially available fixed line technologies, such as DSL and Cable, face significant disadvantages relating to installation and/or operational costs, coverage issues and the dependency on the customer and network owner. Power line technologies (PLC) have been widely considered and often studied as DSOs could leverage their existing energy network, but trials have shown some serious shortcomings in terms of electromagnetic compatibility (EMC) due to a non-standard technology in a non-exclusive spectrum, limited bandwidth, complex multi-stage system architecture bearing operational risks and costs, coverage issues due to line length limitation, and lack of standardisation.

Cellular connections rely on standardized technology, can provide for the required technical performance, are easier to roll out (lower installation costs and fast implementation), and are generally also economical (several vendors and operators) and reliable (i.e., proven and secure). Less than 20% of all M2M connections worldwide are over fixed-line networks. Forecasts show that in 2021 the figure will be 7%. By that time, 61% of M2M connections will come from the utility sector.[3]

A dedicated cellular network in the lower part of the radio spectrum is the best solution for DSOs

Using commercial cellular services – on existing GSM/GPRS networks or future LTE networks – is not an ideal solution. These networks generate the vast majority of their revenues from mass market customers and the operators do not have the ability to address specific DSO requirements in terms of network coverage, design and operation. The main issues are service levels (given that public networks tend to be congested at certain times), resilience in terms of power back-up and redundant backhaul which is not sufficiently in place and extremely costly to implement, and long-term availability which cannot be guaranteed as commercial networks have to adopt technology trends to serve their mass market customers (customers change devices every two to four years).

Ideally, DSOs should build or use dedicated cellular networks that can address their needs in terms of coverage, service quality, resilience and long-term availability.

Growth in mobile broadband gives DSOs a unique opportunity to use the low 450 MHz frequency spectrum

As mobile phones have entered everybody's life, cellular networks and technologies have become well known and broadly accepted. Mobile phones are a typical mass market device using commercial networks. The market penetration of mobile phones and tablets has grown massively over the years, as has the demand for more bandwidth. 85% of network traffic on the Vodafone network in Germany in 2012 was video.[4] On the Vodafone network in the Netherlands, it was 50%.[5]

This huge demand for bandwidth pushes operators to re-farm existing spectrum and invest in new spectrum to deploy faster, next generation technologies like LTE or 4G. In the last two years operators all over Europe have invested billions of euros in acquiring additional spectrum in the 800 MHz, 900 MHz, 1800 MHz and 2.6 GHz to meet customer need for bandwidth.

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1 For further reading see: "Communication technologies and Networks for the Smart Grid and Smart Metering", Bernd Sörries, 2013

2 For further reading see: "The 450 MHz Band ecosystem", CDG-450 SIG 2013

3 "M2M device connections, revenue and ARPU: worldwide forecast 2011–2021", Analysis Mason, 2012

4 Jens Schulte-Bockum, head of Vodafone Deutschland, Innovation Qualcomm conference in Berlin, 2012

5 Vodafone stated to NU.nl, April 22nd 2013

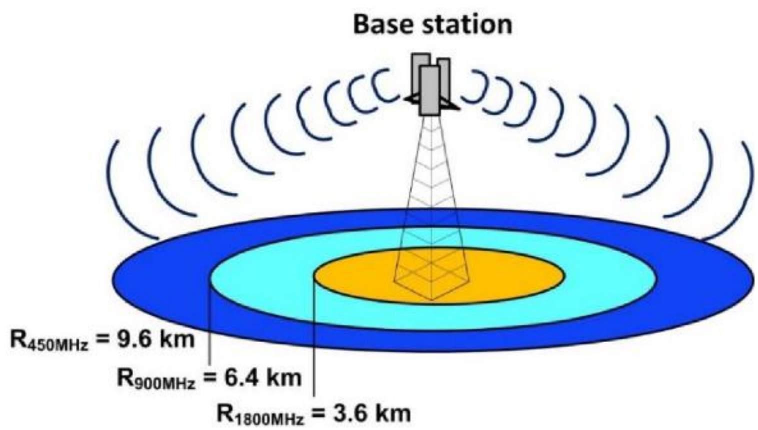
These higher frequency bands offer more and/or larger frequency blocks and therefore more capacity to addresses the mass market compared with the 450 MHz band. This band was first used in Europe for mobile networks in the 1980s.

450 MHz frequency band offers a unique opportunity due to its propagation characteristics

The 450 MHz frequency band was introduced in Europe because of its 'perfect' propagation characteristics. These characteristics are a result of the use of lower frequency. Lower frequencies come with two advantages which are particularly interesting for the Smart Grid:

1. Lower frequency results in larger radio cells. As network costs largely depend on the number of radio sites required for coverage, DSOs could ideally build or use dedicated networks in radio frequencies lower than GSM/GPRS (in 900 MHz) or LTE (in 800 MHz), and benefit from lower investment and operation costs.

   The direct impact of spectrum and coverage is shown in the figure below.

   As rule of thumb, a doubling of the spectrum (and therewith a halving of the radio wave lengths) results in a 3-4 times increase in the number of base stations required.

2. Lower frequency results in better in-building penetration in houses and other types of premises where Smart Meters are located, with a very tangible effect even if compared to the GSM/GPRS cellular network operating at the higher 900 MHz frequency band.

Operators who have 450 MHz spectrum licenses are seeking new business models which fit the beneficial characteristics of the 450 band – best coverage and building penetration of any cellular spectrum, low network cost due to limited number of radio sites – in combination with available standardised 3G/4G technologies that can provide high performing wireless services despite the limited spectrum amount.

450 MHz band for the Smart Grid is getting traction in Europe

In many countries across Europe the 450 MHz frequency band is fully operational. Norway, Denmark, Sweden, Finland, Germany and The Netherlands are examples in the western part of Europe; Latvia, Poland, Czech Republic, Romania, Russia, and Ukraine are examples in the mid and eastern parts of Europe.

In 16 European countries more than 40 networks are operational. Most of these networks are for voice and data. Many of them have a special M2M offering.

There are also countries where the 450 MHz frequency band is not actively used and waits for a business opportunity, or the 450 MHZ band is in the process of being auctioned. For example, in Austria the license was acquired by new owners who explicitly want to use the available spectrum for Smart Grid applications.

In other countries DSOs are establishing their own mobile networks for private use. A good example of this is the DSO Alliander that has acquired the 450 MHz spectrum of telecom operator KPN and is jointly with KPN rolling out a 450 MHz wireless network in The Netherlands.

Acquiring 450 MHz spectrum as a DSO or working closely with an operator that has 450 MHz spectrum is a logical choice given the cost/benefit analyses for DSOs who are looking for low-cost cellular networks with secure, reliable and excellent performance for low band rate communication with their smart assets. There could be a perfect match with operators that have available 450 MHz spectrum seeking new or additional business and/or DSOs who want to own a mobile network for private use.

It is no wonder that European authorities and utilities are focusing their attention on the 450 MHz band to meet their current and future needs. The European Commission, for instance, is currently working with European DSOs to evaluate the need for dedicated spectrum for the utility sector. The 450 band is a good candidate due to the fact that it is already harmonized within Europe and a good match with DSOs' needs.

The European Utility Telecom Council (EUTC) even proposes to harmonize the 450 MHz on a European level and allocate it to the utility sector because "...these bands offer an ideal compromise between coverage and the limited bandwidth requirements of the critically important utility applications."[6]

CDMA450 – technology of choice for M2M to fill the 450 MHz frequency band[7]

But is there an existing mass market radio transmission technology available which can be used in 450 MHz frequency band?

While any 2G, 3G or 4G technology could in principle be used in the 450 MHz band, not all technologies are standardized and commercially available for each spectrum band. To get the lowest total cost of ownership (TCO) and lowest risk possible, an already existing 450 band ecosystem is needed.

Currently, the CDMA (3G) technology standard is available as the dominant and commercially widely available technology of choice for the 450 MHz spectrum. LTE is now being deployed in many countries in Europe, and LTE for the 450 MHz band is currently being introduced in the Brazilian market. However, it is not clear whether LTE will be designed and optimized for M2M use cases.

Although not well-known in Western Europe, CDMA2000 (1xEV-DO) has a long tradition in the 450 MHz band with its own CDMA450 ecosystem. More than 835 million subscribers (voice and data) are connected with the CDMA2000 technology in more than 121 countries throughout the world today.[8] In fact, it is the leading technology in the U.S., China and India. And with an evolution path to LTE services, it will be commercially available for a long time.

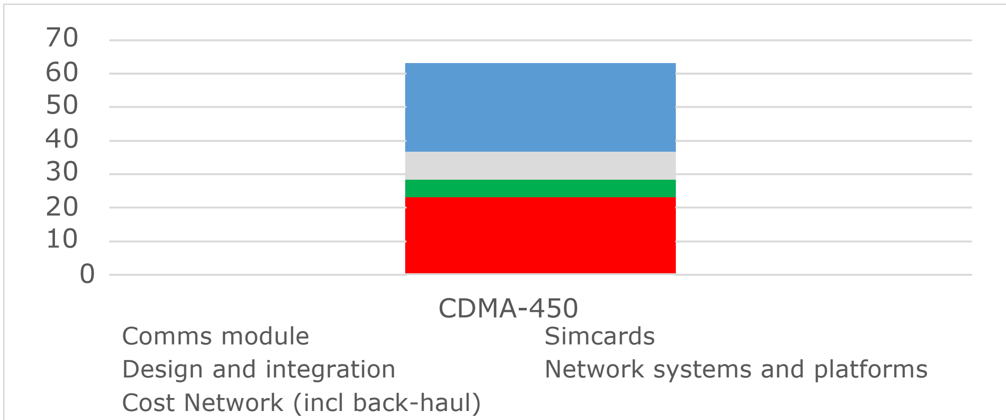
CDMA 450 brings several advantages, especially when it comes to a specific network for M2M connection. Compared with other technologies CDMA2000 is:

- More secure, as it uses spread-spectrum technology developed and used for the military where data is encrypted and encoded in a random sequence and spread over wide channels;
- More efficient due to the use of the spread-spectrum technology by which the channels are more efficiently used allowing a larger number of customers per cell, better use of spectrum and lower energy consumption which will result in lower overall TCO;
- Provides built in TCP and PPP protocols and;
- Is more suitable for critical M2M communication given its lower latency and built-in QoS (CDMA2000 EV-DO).

6 "Spectrum needs for Utilities, EUTC position paper", EUTC, April 2013
7 For further reading see "The 450 MHz Band ecosystem", CDG-450 SIG, 2013
8 "Smart Devices & Services, How CDMA technology is driving the connected age", Harbour Research, 2013

CDMA450 network gives the best TCO[9]

The economics of a CDMA450 communication network have been widely studied by a number of DSOs, operators and consulting companies. Given the low network cost and an established CDMA ecosystem, a combination of CDMA technology and the 450 MHz spectrum results in an overall lower TCO for a communication solution as the following figure shows.



This low TCO can be achieved even in a base scenario Greenfield network. Including synergies like shared backbone infrastructure and Network Operations Center (NOC), contribution margins from other applications on the network or leveraging off existing CDMA450 networks in certain countries can substantially improve the TCO analysis for the CDMA450 solution.

With the opportunity for DSOs to acquire spectrum or redevelop networks with existing operators in the 450 band in many European and non-European countries, and with a communication technology which makes use of all the advantages of the 450 band, the requirements are met for a highly reliable, scalable, secure, long lasting and standardized telecom solution for M2M connections in the Smart Grid with the lowest TCO possible.

Conclusion

To secure a future energy supply which is sustainable, secure and economically feasible, energy networks have to be upgraded to Smart Grids. The Smart Grid can only live up to its expectations if bi-directional, reliable telecommunication is a built-in feature.

The communication technology for low and mid voltage networks must be mature, secure, highly reliable, available long term and cost-effective. As Smart Meters, Public Lighting, electric charging stations, and other smart assets in the Smart Grid are typically M2M applications, cellular networks are preferable because millions of smart assets have to be connected. The best solution would be a private radio network or capacity sharing on a dedicated M2M network where utilities run virtual private networks with quality of service parameters.

Cellular networks based on lower frequencies provide for lower coverage costs and better in-building penetration. The 450 MHz frequency band is an ideally suited spectrum for M2M communication that the DSOs could target to realize a dedicated communication solution. The 450 MHz spectrum has the best building penetration to reach smart meters and has very low network cost.

CDMA, used in the highly available 450 MHz band, is superior due to exceptional indoor penetration, larger cells, and built in security, without the risk of early decommissioning. Less equipment is needed resulting in a substantially lower CapEx and OpEx for a cellular network used for remote sensing and switching in the low and mid voltage energy grid.

9 For further reading see "Economics of the 450 MHz Band for the Smart Grid and Smart Metering". CDG-450 SIG, 2013

If organized in a separate M2M network based on CDMA technology in the 450 band, the DSOs have what they need: a combination of a highly secure, private, reliable telecommunication network with the lowest TCO possible.

For further information

This concept paper is part of a package prepared for DSOs to consider the use of the 450 MHZ frequency band for Smart Grid applications, especially in the lower part of the grid. The various White Papers go into detail on technical and economic aspects of the 450 MHz M2M use case, including telecom requirements for DSOs, an introduction to M2M, communication technologies used in the 450 MHz band, and M2M economics of the use of 450 MHz band. The White Papers are available to DSOs and other interested parties and can be found on the CDG website (www.cdg.org).