Wireless Technologies for the 450 MHz band

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1. Introduction

Fast uptake of Machine-to Machine (M2M) applications and an installed base of M2M devices driven by smart metering and smart grid deployment in utility markets is expected in the near future. Due to the ease of installation, flexibility and low cost of operation, radio technologies will play a significant role in the connectivity of smart metering and smart grid devices. However, only radio networks operating at low frequency bands are applicable if large radio cells and deep indoor coverage is required. The 450 MHz band is the only low frequency band today with a well-established ecosystem. Therefore, this band is attracting a lot of interest for smart metering and smart grid applications.

Smart metering and smart grid applications require sufficient network capacity for a very large number of M2M devices. The highest number of M2M devices is expected in the smart metering area however the smaller number of smart grid devices will require some additional features (short latency, high availability and security).

Traffic patterns of M2M applications differ from typical traffic patterns in mobile networks. Most M2M applications (like data acquisitions from the field) are characterized by low data volumes but many connections over time. Therefore, particular attention should be paid to the capability of systems in providing capacity for typical M2M traffic in a utility environment. A simplified traffic model for smart metering is introduced in Section 3. A capacity assessment for M2M applications for each considered technology can be made based on this traffic pattern model.

Further, the required technical capabilities for supporting smart metering and smart grid applications will be considered for each technology under study. Also, assessment of timing issues with regard to the availability of technology and to the regulatory environment is of paramount importance. These timing availabilities are essential for proper synchronization with an operator’s roll-out or technology migration plans.

This paper presents the capabilities of various technologies for M2M applications for utilities. Some of these technologies like CDMA2000 1X and CDMA2000 1xEV-DO are already deployed and used in many countries for various applications like mobile and fixed telephony and personal and M2M data communications. Other technologies like LTE in 450 MHz or CDMA 1X Rev. F in 450 MHz are expected to be introduced to the market in the near future.

The results of this study can be used for a technology selection based on local conditions and local utility market demands.

2. Relevance of 450 MHz frequency band

Frequency bands below 1 GHz are often qualified as coverage bands while higher bands (> 1 GHz) are called capacity bands. The reasons for this differentiation are the propagation properties (larger radio cells and better indoor coverage) at lower bands and available amount of spectrum (higher amount is available at higher frequency bands). In some countries the tiny spectrum resources at lower bands are evenly split among a few operators, thus further reducing the available capacity per operator.

The 450 MHz band covering 410-470 MHz spectrum is located at the lower end of standardized bands for terrestrial mobile and fixed communication and therefore furthermost applicable for cost efficient coverage (lowest number of base stations for area coverage) and indoor applications. A well-established ecosystem with many vendors providing standardized infrastructure and a variety of devices exists for this frequency band. In many countries 450 MHz networks are already deployed based on broadband digital technologies like CDMA 1X and CDMA 1xEV-DO. In other countries LTE450 will be introduced soon.

3. Important M2M capabilities

a. Capacity for M2M

An essential technical feature of a network technology in the M2M market is the capability to handle the very specific M2M-traffic, i.e., a massive number of devices, each generating rather small data volumes typically on a regular and sometimes non-regular basis.

One of the advantages of a 450 MHz network is that it uses larger cells which makes it possible to cover a larger number of smart metering or smart grid devices compared with solutions on a 900 MHz network. The traditional method for capacity assessment based on spectrum efficiency figured in terms of throughput per spectrum amount (bps/Hz) is not applicable for the M2M traffic pattern which is characterized by small volume data telegrams, mainly uplink communication and a high share of signalling traffic. The capability of a technology to serve such traffic could be therefore expressed by the maximal number of M2M devices that could be served by one radio cell. Based on the expected large share of smart metering devices, the metering traffic pattern can be seen as representative for M2M capacity analysis.

A simplified smart metering traffic pattern model can be defined in the following way:

- Each meter generates one message of 1kbyte size per 15min

- The read out process is assumed to be deterministic so that instances of the read-outs are scheduled and well synchronized with other meters within one sector for the avoidance of collisions. The guard time of 100ms is assumed for timing accuracy.
- Push mode for data transmission is assumed. The communication modules initiate data calls (call set ups), send data and release the connection.

The goal of a M2M capacity study for each considered technology is to calculate the maximum number of smart meter devices per sector and carrier with the above assumed traffic pattern. The calculation should take into account signalling (i.e., in terms of call set-up times), number of simultaneous connections, etc.

b. Further technical features relevant for M2M

Besides sufficient capacity for a massive number of M2M devices, other common requirements should be considered: reliability, security, long term availability, and vendor support with respect to infrastructure, chipsets and devices that are compatible with very long life cycles in the M2M utility market. Another general requirement named by many utilities is short latency for both call set-up and data transfer times.

Software updates and upgrades for M2M devices have to be done remotely over the air because of the high costs for local downloads. Therefore, a considerable downlink throughput is also important from the operational point of view.

Some other technical features might be very important for local markets, for example, quality of service (QoS) for the provision of differentiated services support. Also, multi-service and multi-flow support could appear as an important feature for some markets.

Since consolidated requirements from utilities are not yet available it is not possible to qualify the best technologies for the M2M utility market. Therefore the technologies under study will be considered separately including some individual technology features that could be useful for the utility market without a comparison on a common, consolidated base of requirements.

c. Non-technical features

The technology choice for M2M applications in the 450 MHz band does not depend on technical capabilities only. In some countries Greenfield deployments are possible because spectrum is just coming to the market (Austria, Lithuania) or is not yet in commercial use (Germany, Netherlands). In other countries networks are already deployed and used for other applications (mobile broadband, WLL or mobile telephony) (Sweden, Norway, Poland, Latvia, etc.). In this last case the capacity analysis can help to better understand residual capacity for M2M applications. Furthermore, it can also be used for business planning purposes (share of M2M services vs. existing applications) including technology migration concepts (e.g., for increasing the share of more profitable applications).

Since the International Telecommunication Union (ITU) has identified this band for mass market mobile and fixed communications, existing mobiles standards like CDMA2000 were extended to this band. Some of the 450 MHz technologies have been already deployed in some countries. However, despite the well-established ecosystem with many infrastructure vendors and variety of devices, this band is still not massively used in Europe. Limited spectrum availability in this band makes it difficult to compete with mobile broadband 3G and 4G offerings in higher bands. The M2M market might appear to be the best opportunity for the operators with 450 MHz spectrum holdings.

In some markets, technology choice for Greenfield deployments or for technology migration is limited due to regulatory constraints. For example, the current usage conditions for 450 MHz in Europe do not allow implementation of LTE450. The situation in Brazil differs in this aspect. The LTE450 standardization initiatives within 3GPP were adopted for specific frequency allocations and applicable bandwidths in Brazil.

The regulatory framework that defines spectrum usage conditions (TX power, spectral masks, guard bands, cross border conditions, etc.) follows the standardization of new technologies and takes into account spectrum usage in neighbour bands. Since neither standardization nor regulatory initiatives for European 450 bands have started yet, the deployment of LTE450 in Europe cannot be planned for some time. The introduction of LTE in this band in Europe could take another two years or more as certain preparatory work is required within the European regulatory body CEPT (Conférence Européenne des Administrations des Postes et des Télécommunications). This time period could be significantly reduced provided strong industry and national regulatory bodies support it. Besides the European regulatory framework for LTE450, some national frequency assignments for European operators have to be extended for the accommodation of broader frequency channels (smallest channel bandwidth of LTE is 1.4 MHz). This will require some more time for the upgrade of national license conditions in addition to the activities within the CEPT.

Another important aspect for a technology choice is the price of communication modules. Due to the high number of M2M devices in some markets module price can have a high impact on the total cost of ownership for the network operator.

4. Overview of possible network technologies

CDMA2000 is a wireless network technology for quality wireless voice and fast, secure data services to mobile workers, enterprises and the mass market, and is currently used by many global operators. It was originally used by the U.S. military for highly secure communications because of its spread spectrum and code division characteristics.

CDMA2000 has been deployed in various licensed frequency bands and operates worldwide in the 450, 850, 1700/2100, 1900 and 2100 MHz bands. Per licensed frequency band, it uses one or more radio frequency carriers of 1.25 MHz each. The technology is standardized in the Third Generation Partnership Project 2 (3GPP2), which was born out of the International Telecommunication Union's (ITU) International Mobile Telecommunications "IMT-2000" initiative, covering high-speed, broadband, and Internet Protocol (IP)-based mobile systems. This effort is further supported by industry groups such as the CDG; founded in December 1993, the CDG is an international consortium of companies who have joined together to lead the adoption and evolution of 3G and 4G wireless systems.

CDMA2000 has gone through various generations of improvements since the commercial introduction of CDMA2000 1X in 2001. Currently, it includes the CDMA2000 1X (1X) and CDMA2000 1xEV-DO (EV-DO) standards.

CDMA2000 1X Radio Transmission Technology (1xRTT or 1X) was the critical first step in improving 2G network performance with increased voice and data capacity. It provides data rates of up to 153 kbps (both uplink and downlink), making it well suited for a variety of M2M applications. 1X Advanced was introduced in 2011, offering three times increased voice capacity in the same 1.25 MHz carrier. The latest addition to the 1X family is 1X Rev. F which is optimized for M2M. It provides five times reduction in signalling load, four times reduction in the amount of data transferred over the air link, and ten times improvement in modem power consumption. Trials for 1X Rev. F are scheduled for Q4’13, followed by commercial availability in 2014.

CDMA 1xEV-DO (Evolution - Data Optimized) introduced new high-speed packet-switched transmission techniques that are specifically designed and optimized for a data-centric broadband network. There have been four steps in the evolution of EV-DO since its commercial introduction in 2002:

> **EV-DO Rev. 0** – offered significant improvements relative to 1X data rates by increasing downlink rates up to 2.4 Mbps by a time multiplexed resource allocation scheme in the DL which supports the bursty traffic nature of data applications. Uplink peak rates remain at 153 kbps. QoS is not supported.
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> **EV-DO Rev. A** – improves Rev. 0 performance by increasing peak data rates in both directions: 3.1 Mbps (downlink) and 1.8 Mbps (uplink). In comparison to Rev. 0, EV-DO Rev. A provides significantly less latency, supports H-ARQ in DL and UL which results in higher mean sector throughput values, and follows an All-IP approach.
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> QoS and VPN concepts are supported.
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> - **QoS:** as of Rev A., QoS is supported. The implemented QoS-scheme allows the definition of QoS for both subscriptions (i.e., companies consuming CDMA services) and service flows (e.g., delay sensitive prior to best effort). This enables the network operator to organize and prioritize the allocation of limited network resources. For instance, delay sensitive applications can be prioritized over non-

delay sensitive applications. QoS allows several Radio Link Protocol (RLP) flows, each having its own characteristic. This allows utilizing the radio network more efficiently.

In comparison to Rev. 0, QoS allows the terminal station to be paged at shorter cycle intervals which reduces call set-up time and increases capacity for M2M applications.

- **VPN:** Virtual private networks are supported and can be established following different approaches. In combination with QoS, VPNs can be used to share limited network resources among several companies.

EV-DO Rev. B or Multi-carrier (MC) EV-DO – combines up to three Rev. A carriers supporting peak rates of 14.7 Mbps (downlink) and 5.4 Mbps (uplink). Similarly to EV-DO Rev. A, QoS and VPN concepts are supported.

EV-DO Advanced – consists of a family of software features that optimize resources, increase capacity, and overall improve the end-user experience.

For **Utilities,** a private CDMA2000 wireless network is a viable option to deliver smart grid services to utility assets that cannot be economically served by wireline technology and to provide voice and data services to the field force. Smart grid services include substation monitoring and control, distribution automation as well as residential smart metering and public lighting control.

Smart Grid and smart metering communication technology is often catalogued under the M2M domain by telecommunication infrastructure vendors. M2M is characterized by time-controlled communication to a large number of fixed, nomadic or mobile devices (rather than persons). There is strong support from the CDMA2000 established ecosystem for M2M since this is projected to be a large growth opportunity for years to come.

LTE is a fourth generation (4G) wireless technology designed for high bandwidth broadband applications. Although not currently available at 450 MHz, the standards for LTE in this band are being developed under 3rd Generation Partnership Project (3GPP) Band 31. The Core network standards were completed in June 2013 and the Radio Access Network (RAN) standards are expected to be finalized by December 2013. The current standard and frequency allocation is specifically focused on the Brazil market for commercial roll-out in 2014. It is not clear today what other countries will allocate LTE450, but more markets are expected to follow Brazil's lead in the coming years.

5. Evaluation of 450 MHz technologies for M2M in the utility market

a. Capacity

The proposed capacity model is based on the calculation of the per read-out intervals available. Sector time is regarded as the available transmission resource and considers the signalling share per read-out event by means of Call Set-up / release times, RLP, etc. The available sector transmission time depends for i) CDMA on the number of CEs being installed in a BTS and for ii) LTE on the number of resource blocks (RB) which are available inside a 1.4 MHz channel.

- CE: the number of CE per sector and carrier (SC) available for traffic channels. It is assumed that CDMA EV-DO BTS is equipped with 192 CE whereby 1/3 is used for control channels (HO, etc.)
- RB: a resource block is regarded as the smallest transmission unit that can be allocated to a single terminal station. Subject to the channel size, the LTE-standard defines a fixed number of RBs.

The table below summarises parameters being used for the deterministic capacity model.

Item	**Unit**	**Value**	**Comment**
Meter per CDMA / LTE Modem		4	
M2M data volume	kByte	1	
Protocol overhead	%	20	Protocol-overhead on MAC layer
Meter read-out period	min.	15	Typical read-out period
RLP inactivity timer	s	0	Devices release connection after the data transmission
Margin	s	0.1	Margin to consider imperfect synchronisation
Channel bandwidth	MHz	1.25 1.4	- CDMA450 - LTE450

Table 01: General assumptions for deterministic traffic model

The next table summarises the capacity figures given as the maximum number of meters per sector carrier (SC) for the considered technologies and outlines the technology specific assumptions for the capacity calculation.

Technology	Parameter			Capacity (max. number of Meters per SC)
	Available Traffic resources in Uplink per SC	Always-on Call Set-up / release time, [s]	Throughput (DL / UL), [kbps]	
CDMA 1X, Rev. F	24 per SC	0.8	250 / 200	15,686
CDMA EV-DO, Rev. A	24 per SC	1	1,200 / 600	32,777
LTE450	6 per SC	0.6	2,400 / 1,400	24,983

Table 02: Number of supported meters per SC and underlying specific assumptions for deterministic traffic model

LTE technology, which is currently optimized for broadband connections, provides much lower simultaneous traffic resources in uplink per SC than the considered CDMA technologies. As a result, the lower number of high data rates channels of LTE provides less capacity than the higher number of simultaneous channels with lower bit rates of CDMA EV-DO Rev. A but higher capacity than the high number of much lower bit rate uplink channels of CDMA 1X Rev. F.

b. Other Features

CDMA EV-DO, Rev. A/B as well as LTE offer QoS features, e.g., to prioritize services, to support certain services with specific bandwidth, delay or jitter requirements. QoS allows sharing of network resources among different users (companies) with differentiated needs by means of VPNs. The economics of network services can be further improved with higher network loads. QoS is important for utilities as it allows for differentiation between delay sensitive smart grid applications and less demanding smart metering communication.

Other technical features might play a role in technology choice. Some utilities require broadcasting/multicasting capabilities for simultaneous communications with installed devices. Broadcast/multicast services for EV-DO are defined in the respective 3GPP2 Standards, however there is so far no respective solution for CDMA450 on the market. CDMA 1X can support the broadcast/multicast services by means of SMS (Short Message Service).

c. Non-technical features

The following table summarize the non-technical features for considered technologies.

Network Technology	**Standardization**		**Regulatory situation**	**Equipment Availability**		**Device Costs**
	Other bands	**450 MHz**		**Infrastructure**	**Devices**	
CDMA 1X	well established, Rev. F under development	well established, Rev. F so far not foreseen for 450 MHz	European Frequency Allocation Table currently allows systems up to 1.25 MHz channel bandwidth based on ECC DEC (04) 06. Many countries adopted ECC DEC(04) 06 decision and allow 1.25 MHz systems in 450 MHz band in their national frequency plans	several vendors, mature technology	several vendors, mature technology	low
CDMA EV-DO	well established, incl. Rev. A and B	well established, incl. Rev. A and B		several vendors, mature technology	several vendors, mature technology	medium
LTE	established	for Brazil under development	Extension of ECC DEC(04) 06 for 1.4 MHz systems in Europe needed; currently 1.4 MHz systems are only allowed in Brazil in this band	some equipment under development, no commercial networks yet	for Brazil, some devices under development	high

Table 03: Summary of considered network technologies and respective non-technical features

6. Summary

This paper describes some relevant network technologies for M2M in the 450 MHz band such as CDMA 1X, EV-DO Rev. A and LTE450. These technologies are introduced with a focus on their applicability for M2M in the utility market. Besides technical characteristics, some non-technical features connected to standardization, regulation, equipment availability and cost are considered.