Economics of 450 MHz band for the Smart Grid and Smart Metering

By CDG 450 Connectivity Special Interest Group (450 SIG)

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1. Introduction

Alliander in The Netherlands is the first utility to build and operate a new wireless network in the 450 MHz frequency band to address its communication needs for smart grid and smart metering. A dedicated wireless network in 450 MHz offers several clear benefits to utilities, in particular:

- Superior area coverage and building penetration due to the low frequency
- Security, resilience and service quality of a dedicated network
- Long-term availability and control over network deployment and operations

However, implementing a network infrastructure requires upfront investment and it raises the question of whether a new network is economical compared to other communication infrastructures, in particular those like GPRS or DSL which are already widely available (but cannot offer utilities the benefits of a 450 MHz wireless system as stated above).

This paper addresses the economics of a 450 MHz wireless system by primarily looking at a Make or Buy decision for wireless access based on total cost of ownership (TCO) for a smart grid/smart metering for a reasonable timeframe of 15 years. The "Make" alternative consists – in the base scenario – of building and operating a Greenfield 450 MHz wireless communication network that is solely used for smart grid/smart metering. This is compared to the "Buy" alternative of using capacity from available commercial wireless networks. The by far most competitive commercial solution in Europe is GPRS in 900 MHz as it provides for reasonably good propagation, wide area coverage and low cost modules.

This analysis first establishes the cost of building and operating a 450 MHz wireless system. For this it is assumed that the network uses CDMA EV-DO Rev as this technology is widely used enabling reasonable cost assumptions; alternative technologies include CDMA 1X Rev. F and LTE450. However, the analysis would not result in substantially different conclusions if based on one of these alternative technologies as the biggest impact is the combination of the 450 MHz spectrum with an advanced 3G or 4G wireless technology rather than which of such technology alternatives is considered.

Given that prices for usage of GPRS capacity are set by commercial operators and may vary over time, this analysis can only compare the expected cost of the 450 MHz wireless system per connection to the current or expected prices of using commercial GPRS solutions and showing the "break-even" point. As stated above, there are several additional qualitative arguments for using a 450 MHz wireless network such as building penetration, service quality, and control over a dedicated network that will likely result in much lower lifetime cost versus a commercial system. However, such costs cannot be quantified specifically and will thus not be taken into account in the following analysis. These quantitative benefits should rather justify attributing a premium to 450 MHz wireless systems that could offset a possible cost disadvantage vis-à-vis commercial solutions such as GPRS.

In addition to the base scenario for a 450 MHz wireless communication network (Greenfield build solely for the use of the utility), there are other scenarios that substantially improve the cost of such a system, chiefly (i) lowering cost via synergies or additional usage/revenues or (ii) leveraging an existing commercial CDMA450 network; this will be considered in Section 5.

2. Total Cost of Ownership (TCO) Concept

The Total Cost of Ownership Concept takes into account all relevant costs for a system or technology decision over the assumed usage period. In the case of cellular communication technologies this includes not only the cost of the radio access network but also the cost of elements relating to the device that are inherently linked to the technology. Radio communication systems have a generic basic structure as shown in Figure 1.

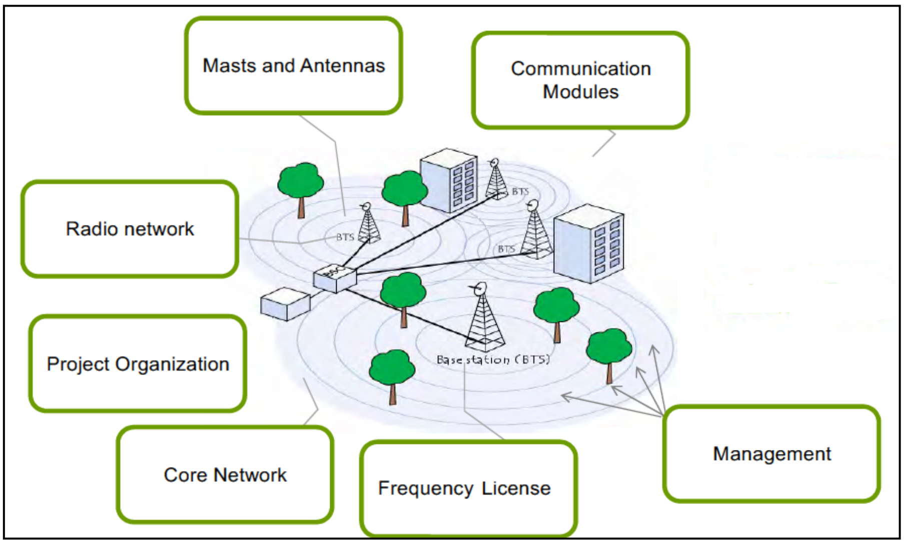

Figure 1: Radio Network, Alliander 2013

The radio communication system consists of several main elements which have to be taken into account in any TCO analysis:

- The radio (access) network consists of the base station transmitting radio signals to and receiving radio signals from devices in the coverage area. Base stations consist of active radio elements (base band unit and radio head) and passive elements (antennas and cables). The base station further needs a power connection and a backhaul communication transmission to the core network which can be microwave or fixed-line.
- The base station is typically installed on a rooftop or mast on which space can be rented. Alternatively, masts can be built on owned or leased ground. The installation of a base station on a rooftop or mast usually requires certain steel works on the site to locate equipment and antennas.

- Each device to be connected to the radio (access) network needs to be linked to or integrated with a communication module that is based on the same technology as the radio network (i.e., in this comparison CDMA450 and GSM/GPRS900)
- The core network consists of the equipment that manages the radio resources of the base stations and the IP connections of the devices. Functionalities of the core network include authentication, service control, routing of data and gateway to other networks.
- Radio communication systems need to be managed and maintained. Management occurs centrally from a Network Operation Centre (NOC) and maintenance via an on-site field service, both of which can be provided internally or outsourced.
- Finally, to operate a radio communication system one needs to have a spectrum license which is issued by a governmental body. Normally, spectrum licenses are restricted for a certain radio frequency, a geographic area and a limited period of time (usually 15 years).

This paper compares the TCO of a CDMA450 wireless connection with the TCO of a GPRS900 connection. In order to compare the TCO of these alternative wireless connections it is imperative that (i) all these elements are considered, either as part of a service fee or as a Capital Expenditures (Capex) or Operational Expenditures (Opex) element, and (ii) over the full system lifetime, here assumed to be 15 years.

3. CDMA450 Greenfield network cost

The costs of building and operating a Greenfield CDMA450 wireless data network are largely related to the number of radio sites. The cost of central equipment and network operation is firstly marginal compared to the Capex and Opex of the radio sites and is secondly scalable in line with the number of sites and wireless connections. The main cost driver, number of radio sites, is determined by the coverage objectives and capacity requirements.

For any given site the network cost is largely fixed, requiring a minimum revenue for break-even. Any investment in a Greenfield network needs to be considered in tandem with the coverage and capacity requirements of the target users, which need to be large enough in "revenue potential" to carry the cost of the network. To establish the unit cost per connection of a Greenfield CDMA450 network, the total network cost is divided by an assumed number of connections. Such unit cost can then be compared to the cost of a commercial GPRS service providing a similar data connection in terms of speed, volume, events and service level.

The following analysis is based on an article published in Germany that looked at the CDMA450 network cost for nationwide deployment in Germany.[1]

The Capex assumptions are as shown in the following table:

[1] Dr Sörries: Article "Wirtschaftlichkeitsanalyse einer Kommunikationstechnologie" in Netzwirtschaft & Recht, 3&4/13, p. 122ff

Total capex per site in Euro				
	Capex per Site	Annual depreciation (over 10 years)	Annual capital cost (at 4.25%)	Annual total cost
Radio equipment/BTS	37.950	3.795	1.613	5.408
Planning/Civil Works	77.050	7.705	3.275	10.980
Core	12.650	1.265	538	1.803
Other	Max. 5% p.a.	2.500	1.063	3.563
(a) Total Capex	152.650	15.265	6.488	21.753

Table 1: Capex CDMA450 Network, Dr Sörries 2013

The main parameters are:

- 1,588 sites for nationwide coverage of Germany (providing in building penetration in most built-up areas);
- CDMA450 – EV-DO Rev. A network with 3-sector/2 carriers per radio site;
- Total Capex of Euro242m or annual cost of Euro34.5m (depreciation + capital cost) assuming average depreciation period of 10 years and capital cost of 8.5% p.a.;
- Including reasonable cost for redundancy and planning reserve of 15%.

The Opex assumptions are as shown in the following table:

Network opex per site per year	
Direct site cost (rent, power, etc.)	10.000
Network operations (incl. frequency fees, microwave operations)	7.200
Equipment maintenance (10% on cumulative equipment capex)	4.500
Outsourced network management/administration	5.000
(b) Total opex per site	26.700
Total annual cost per site (a. capex + b. opex)	48.453

Table 2: Opex CDMA450 Network, Dr Sörries 2013

The main parameters are:

- Assumes backhaul via microwave network and outsourced services
- Includes reasonable cost for redundancy and planning reserve of 10%
- Total network Opex of Euro42.4m p.a.

- Total network cost (including Capex and Opex of Euro77m p.a.)

Assuming 27.5m connections to the network in Germany this implies the following unit cost per connection per month and network capacity utilization.

Unit cost in Euro	
Number sites	1.588
Number of connections	27.500.000
Total annualized capex	34.543.764
Total annual opex	42.399.600
Total annual cost	76.943.364
Capex per connection/month	0,105
Opex per connection/month	0,128
Total cost per connection/month	0,233
Network capacity utilization	38%

Table 3: Unit cost CDMA450 Network, Dr Sörries 2013

The main parameters are:

- 27.5m connections assumed (based on 50% penetration of 55m electricity meters/grid elements in Germany)
- Capacity calculation based on average user profile and 15 minute intervals per connection (with reasonable assumptions regarding various overheads and network loading inhomogeneity)
- Cost per connection/month at Euro0.23 (at average 17k connections per site)

Calculations by other parties (utilities, operators, technology providers and consultants) in other countries obviously come to somewhat different results. The following table compares the results of three different cases.

Scenarios (in Euro)	European DSO plan – full rollout, densely populated country	Dr Sörries, based on Germany as example assuming 50% rollout	European CDMA450 operator plan – limited regulatory rollout, large country	Average
Capex per site	163,812	152,650	159,581	158,681
Annual Opex per site	22,230	26,700	29,315	26,082
Connections per site	17,000	17,317	8,438	14,252
Annual unit cost per connection	1,95	2,13	4,74	2,57
Capacity utilization	40%	38%	18%	32%

Note: Does not include cost of capital deployed as dependent on business model adopted. Capacity utilization not proportional between scenarios as these are based on slightly different usage profiles for the assumed connections.

Table 4: Unit cost European CDMA450 Network, Sörries 2013, data provided by DSO and Operator

As can be seen in the table above, the cases differ in the cost assumptions up to 7% in Capex per site and up to 25% in Opex per site. The unit cost per site differs more than a Factor of 2 as unit costs are driven not only by site related cost but also by connections per site. Connections per site are driven firstly by the extent of the rollout of smart meters (limited to 20% or 50% or full) and population density, as more densely populated areas (more connection potential per site coverage) result in more connections per site. However, lower connections per site result in lower capacity utilization so that more capacity is available for additional connections, be it a more comprehensive smart meter rollout, connecting of further smart assets from utilities or of third parties.

Taking this into account, the following TCO analysis is based on the average network cost per connection as shown above.

4. TCO Comparison CDMA450 versus GPRS900

This TCO analysis compares the TCO per connection over 15 years between a commercially offered GPRS900 MHz wireless connection and a wireless connection via a dedicated built and operated CDMA450 network.

A GPRS900 wireless connection is a service provided by one of the public cellular operators, in Germany for instance, most of which do operate – among others – a GSM/GPRS network in 900 MHz. The service fee will be dependent on requirements in terms of data speed, data volume, communication intervals and service levels, and may either be offered as a fixed fee per connection or as a combination of fixed fee and usage increment. Usage can be either based on volume (number of MBs per month) or time (number of readings, elapsed time, etc.).

While current market offerings for M2M data connections are still priced relatively high (at Euro5 monthly and higher), it is generally expected that the mobile operators will offer substantially reduced rates for smart grid/smart metering given the high number of connections involved. However, the commercial operators also have to consider capacity usage and service level requirements. While M2M connections in off-peak times (at night) and with low service level can be priced very low, this is not the case for M2M connections that require communication in regular intervals (e.g., 15 minute readings) and with higher service levels. These connections take up limited peak hour capacity and compromise service quality for the mass market customers, which, given the importance of the mass market and the overall minute revenue contribution of M2M (even smaller from smart grid/smart metering), is not in the commercial interest of a public mobile operator. Furthermore this capacity competition will increase over time as usage from both mass market customers and M2M solutions grows in number and volume. In this analysis it is therefore conservatively assumed that mobile operators charge on average at least Euro1 per month per connection.

For the CDMA450 wireless connection it is assumed that a new radio communication system has to be built and operated which includes all the above mentioned Capex and Opex elements. Additionally, a cost for the wireless spectrum needs to be assumed to complete the analysis which is set for the basis of this analysis at a one-time cost of Euro5 per connection.

In addition, each device requires a communication module and in the case of GSM/GPRS also a SIM card, which is a mandatory authentication element in the GSM/GPRS system. The prices for communication modules depend on technology and volume. As GSM/GPRS is still the wireless technology with the largest use worldwide, the cost of GSM/GPRS communication modules are expected to have a price advantage against other technologies, including CDMA450. However, this price advantage is limited, as the use of CDMA450 for smart grid/smart metering will provide for volumes of millions of communication modules which will substantially reduce the gap between prices for GSM/GPRS and CDMA450 communication modules. In this analysis it is conservatively assumed that CDMA450 communication modules will be on average Euro10 more expensive.[2] The gap is reduced to Euro9 as GSM/GPRS 900 communication modules additionally require a SIM card which is assumed with an average price of Euro1 per SIM card.

The following chart shows the TCO analysis between GSM/GRPS900 and CDMA450 based on the above outlined assumptions over 15 years. To address the ramp-up phase of the CDMA450 network where network costs are to be carried and users not yet connected, the GSM/GPRS service fee is only taken into account over 12 years.

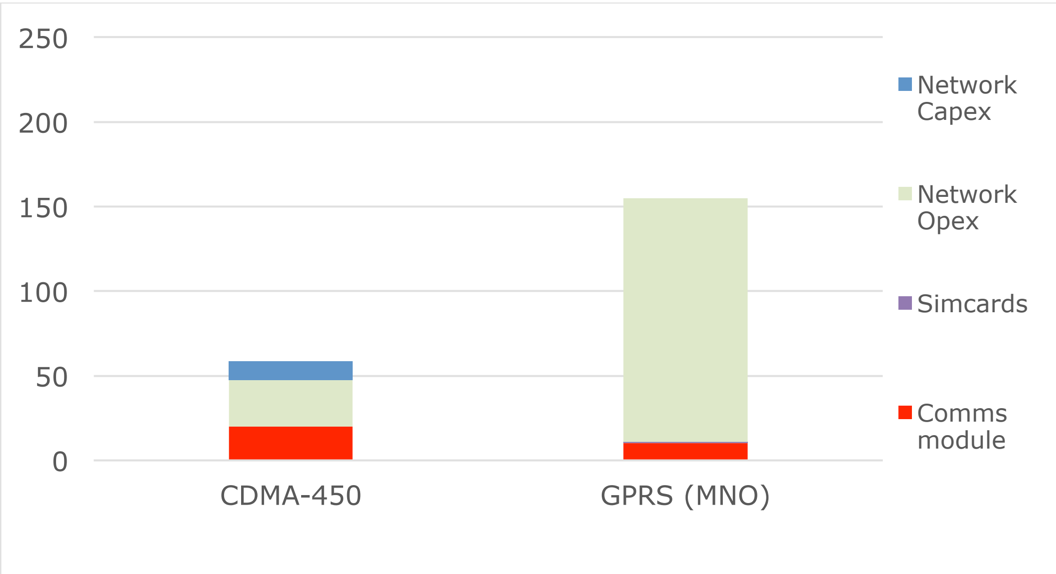

Figure 2: TCO analysis in euro of CDMA450 Network vs GSM/GRPS900

The chart shows total GPRS TCO at Euro144 compared to total CDMA450 TCO cost at 52. The lower network cost per connection of a new CDMA450 network more than compensates the higher cost of the CDMA450 communication module over the 15 year system lifetime.

The benefit of a CDMA450 network increases with a larger number of connections per radio site, lower delta in the cost of communication modules and higher GSM/GRPS fees and vice versa. Given the expected large smart metering rollouts and the increasing capacity and service requirement needs of smart grid/smart metering it seems therefore logical that the above shown advantage for CDMA450 is most likely underestimated.

[2] Price delta applying only to CDMA450 EV-DO Rev. A (data-only) technology; no/much lower increment for CDMA450 1X technology

The TCO benefit of a new CDMA450 network becomes even more evident if one assumes that GSM/GPRS systems will not be available over a 15 year lifetime, as commercial operators will within the next few years start re-farming the GSM/GPRS spectrum to LTE technology to increase data speeds and capacity for their mass market customers. This would require swapping out the installed GPRS communication modules and replacing them with, for example, LTE communication modules. Assuming a modest cost of Euro50 for swapping out the communication module in each meter, the TCO analysis even more clearly shows the TCO benefit of investing and operating a network dedicated for smart grid/smart metering where no technical swap-out has to occur during the system lifetime.

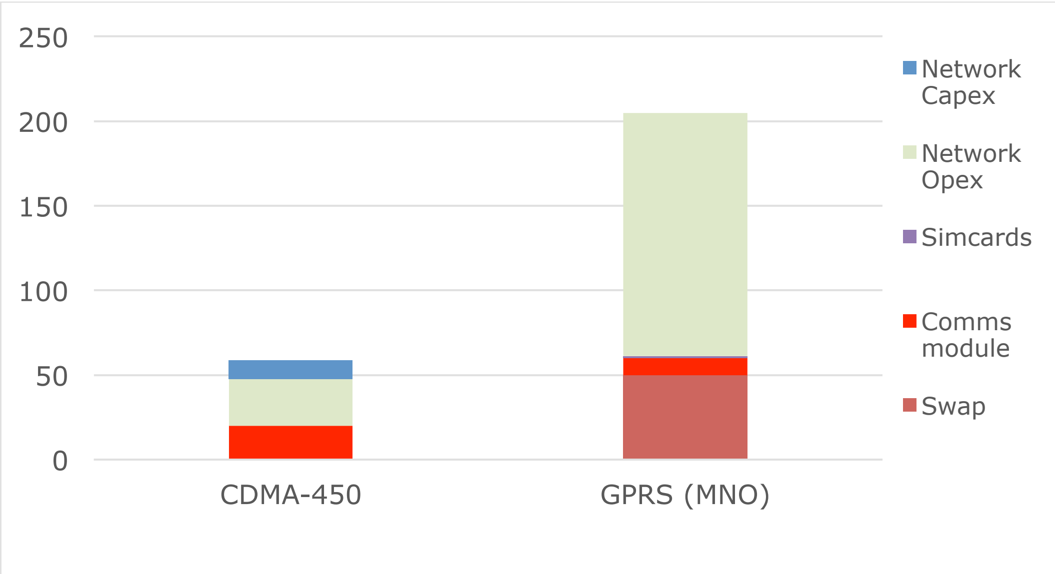

Figure 3: TCO analysis in euro of CDMA450 Network vs GSM/GRPS900

5. <u>Sensitivities for 450 MHz wireless systems</u>

When looking at the cost of using a 450 MHz wireless system in a specific country, the cost of the Greenfield network shown above will likely be reduced in one of two ways, depending on the circumstances in that specific country.

Optimization of economics of Greenfield network

Firstly, a Greenfield build can be optimized in terms of cost and revenues so that the unit cost per smart grid/smart meter connection is further reduced substantially. This includes:

- Realizing synergies in building and operating a new 450 MHz wireless network through use of existing infrastructure and operation of utilities or telecom operators, in particular using existing radio sites/other real estate and backhaul/backbone links as well as existing or external operations for network management, maintenance and administration.
- Utilizing remaining capacity by increasing the number of connections by connecting more “smart assets” from other applications, more utilities or other vertical markets such as transport or health to the network

The extent of synergies and revenue contributions will thereby largely depend on the objectives of the utilities and operators that team up to implement a Greenfield 450 MHz wireless system. The higher the focus is on cost, the more utilities and operators will seek to realize synergies and capacity utilization via additional connections to lower cost per connection and therewith the overall economics of the system.

Reasonable synergies can reach between 10 and 30% of total Capex cost and 20 and 40% of total Opex cost. The higher end of the range assumes that utilities use internally available resources that are provided at cost, not inflated internal transfer prices (Note: In case of higher transfer prices the Greenfield network would bear higher cost but this would be compensated via an additional contribution margin within other parts of the utility operation).

	Average Cost in Euro	Synergies in %		Synergies in Euro		Impact on annual Unit Cost in Euro	
		Min	Max	Min	Max	Min	Max
Capex per site in Euro	158,681	10%	30%	15,868	47,604	0,07	0,22
Annual Opex per site in Euro	26,082	20%	40%	5,216	10,433	0,37	0,73

Table 5: Unit cost CDMA450 Network – Synergies from leveraging DSO/Telco infrastructure and operations

The table above shows that synergies can contribute between Euro 0,42 and 0,95 per connection per month thereby substantially lowering the average cost per connection.

The impact of further connections on capacity utilization and unit cost per connection depends on the pricing assumed for these additional connections. Given that a 450 MHz wireless system is a unique business proposition in terms of coverage, security and quality it has to be assumed that the network operators can offer services to third parties at a substantial premium to unit cost. The following table shows the impact of additional connections and possible premiums on capacity utilization and the unit cost per connection:

	Base Scenario	**Doubling of connections without premium**	**Doubling of connections with 50% premium for additional connections**	**Doubling of connections with 100% premium for additional connections**
Connections per site	14,252	28,503	28,503	28,503
Capacity Utilization	32%	64%	64%	64%
Annual unit cost per connection in base scenario	2,57	1,29	1,03	0,86
Annual unit cost per additional connection	NA-	1,29	1,54	1,71
Rationale	NA	Unit cost down 50% as connections doubled	Unit cost down 60% as additional connections pay 50% premium	Unit cost down 67% as additional connections pay 100% premium

Table 6: Unit cost CDMA450 Network – Impact of additional usage at different price levels

The above table shows that the increase of connections proportionally reduces the unit cost per connection. However, if additional connections can be serviced at a premium, which is reasonable if it is assumed that third parties become users of the 450 MHz wireless system, these new connections can substantially reduce the internal cost for the network operator/main utility users.

Leveraging an existing commercial 450 MHz wireless system

Secondly, smart metering/smart grid applications can leverage existing, commercial 450 MHz wireless systems in certain countries. These networks have to-date largely addressed rural coverage/basic broadband services but are increasingly losing subscribers and need to address new markets, with M2M services for utilities being the most promising. These networks are de facto commercial but due to their limited commercial outlook often offer the opportunity to refocus their business to the M2M/utility market allowing utilities to become the main or anchor customers thereby gaining substantial influence that can be used to implement the utilities' network requirements in terms of security, control, service level and resilience.

In countries with existing 450 MHz wireless systems, instead of deploying a Greenfield network that is cost optimized by using synergies and offering capacity to further applications/3rd parties, here networks have already been built and are in operation with some capacities being used for existing commercial services. In terms of pricing/cost it can be expected that the service is generally in line with the cost of a Greenfield network that benefits from some synergies and capacity utilization from third parties:

- Network already in place and largely depreciated so that overall "Capex cost" is substantially lower than in the Greenfield network case, even if certain investments may need to be made for system upgrade, coverage expansion or resilience.
- Commercial network operator expecting to earn its equity capital cost, i.e., reasonable margins to cover network operation cost, depreciation and overhead.
- Existing and other potential commercial customers provide contribution margins to operator.

A utility as a main customer would only have to pay for part of the network cost that needs to be earned by the commercial operator over the system lifetime, as substantial parts of it have already been paid off or are being paid for by other commercial users. The specific circumstances will change from country to country, as some commercial operators may still have a reasonable business and thus more bargaining power which will be used to seek increased returns, whereas other commercial operators are in need of new business and may offer utilities as anchor customers even more attractive terms.

6. Summary

This economic analysis shows that investing in a new wireless system in the 450 MHz spectrum band not only provides for major benefits in terms of coverage, service quality and control but is extremely economical compared to using a commercially offered wireless service.

This results from the combination of (i) the inherent benefit of the 450 MHz frequency, requiring a very low number of sites for coverage and therewith low network cost with (ii) a substantial number of connections from smart grid/smart metering, ensuring low unit cost per connection.

Commercial networks could only be competitive if they ignore capacity constraints and service level issues to the detriment of their dominant mass market business and forgo the re-farming of their legacy GSM/GPRS900 networks to LTE over the next 15 or more years - neither of which makes strategic or commercial sense to the mobile operators.

In markets where 450 MHz spectrum is available and a new network needs to be built, the economic cost of wireless systems in the 450 MHz spectrum band can be further improved by realizing cost synergies with existing infrastructure and service providers, be it from utilities or telecom operators, and by using spare network capacity for other connections, be it from other utilities or other vertical markets.

Economically, the proposition may be at least as attractive in markets where there is an existing, commercial CDMA450 operator that is looking to develop a new business model, which could enable utilities to become a very substantial stakeholder, as an anchor customer or even a shareholder. The saved investment from the existing network should more than compensate the earnings expectation of the current operator.