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## Conference Paper

# Analysis of regulatory, market and cost structure aspects for deployment of private or shared Mobile networks for high quality M2M communications

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**Title:  
Analysis of regulatory, market and cost structure aspects for deployment  
of private or shared Mobile networks for high quality M2M communications**

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## 1. Introduction and motivation of work

New communication solutions for the energy sector are often called smart energy networks or a smart grid [1]-[4]. This includes to control the energy distribution and transport network at all levels as well as to collect metering data. Recently mobile operators and telecom vendors have presented white papers and propose use of mobile networks and LTE for energy applications and smart grids [7][8].

In order to control energy networks high requirements are put on availability, reliability and delay [1][2]. Energy companies want to have this high quality service guarantees but these may be difficult to integrate into a commercial mobile operator network. Some actors in the utility sector have discussed this with operators and claim that mobile operators do seem reluctant to offer special service classes suitable for control of power substations.

So what can the energy company do in order to be able to control their power networks using wireless communications? As mentioned, one option is that mobile network operators offer specific service classes to be used for traffic with “high” requirements within the traditional LTE networks. Another solution is that energy companies themselves acquire spectrum and deploy an “own” network.

A solution “in between” is that a new type of operator offers high quality services to companies and organization with these kind of needs, e.g. electric power and oil companies, railway companies and public safety users. One example of this type of actor is Texas Energy Networks (<http://www.texasenergynetwork.com/>) who acquire spectrum<sup>1</sup> and together with telecom vendors offer solutions to energy companies<sup>2</sup>.

*“Texas Energy Network (TEN), a provider of communication services to the oil and natural gas industry, has announced that it has purchased an allocation of 700MHz A and B block wireless spectrum in the south Texas region known as the Eagle Ford Shale, from Verizon Wireless”*

In this paper we will investigate and compare the different network options an energy company has to provide wireless communication solutions for control of its energy networks. The comparison will be based on cost structure analysis and by analysing options for use of non-licensed spectrum bands, mainly TV white spaces (TV WS).

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<sup>1</sup> <http://www.telegeography.com/products/commsupdate/articles/2012/05/29/oil-be-damned-texas-energy-network-snaps-up-verizon-lte-spectrum/>

<sup>2</sup> <http://www.fiercewireless.com/story/energy-firm-proposes-private-lte-network-oil-and-gas-firms/2010-08-19>

## **2. Research questions, objective and outline of paper**

In this paper we will analyse business feasibility of the three different solution options introduced above. In the paper we will call the solutions options as follows.

***Operator networks*** where mobile network operators offer specific service classes to be used for traffic with “high” requirements within the traditional networks.

***Own network*** where energy companies acquire spectrum and deploy an “own” network

***Special machine communication network*** where a new type of operator offers high quality services to companies and organization with these kind of needs, e.g. electric power and oil companies, railway companies and public safety users.

The overall ongoing study includes 4 - 5 countries with different market and regulatory conditions but in this paper we will present findings from two countries; Germany and Sweden. The research questions are:

1. What are the main limitations for energy companies to deploy and operate an own mobile network for own applications only? And why is it a limitation?
2. Is there a business case for mobile operators offering special services classes for M2M traffic with special requirements
3. Is there a business case for a new type of operators operating special mobile networks carrying M2M traffic with special requirements?

In the next two sections related work and methodology is presented. Next, modelling and design are described for both radio access network (RAN) and for the core network. In section 7 cost structure modelling and results are presented. Analysis and discussion is found in section 8. In last section with conclusions we provide answer to the research questions and some notes on future work.

### 3. Related work

There is a wide range of recent and ongoing work in the smart energy / smart grid area. The availability of efficient, low-cost and secure communication technologies and components enable supervision and control of all parts of the power grid: home appliances, smart meters, substations and power generators. Overviews of technology, the smart grid components, security and standardisation are found in [1] – [4].

Different communication technologies for the smart grid are further studied in [5][6]. 3GPP communication systems (GSM, 3G and LTE) have a number of important advantages including ubiquity, economy of scale and security aspects. Mobile operators and vendors have presented white papers on use of mobile networks and LTE [7][8][9].

Security, integrity and privacy aspects are important for all parts of the smart grid. For home appliances and smart metering privacy and fraud are important aspects. For power generators and substation automation, cyber-attacks could lead to disastrous consequences. Security aspects are studied in [2], [5] and [6].

Issues related to private wireless networks (*own network*) has been analysed in some papers; use of TD-LTE technology is discussed in [10] and quality of service for smart grids is discussed in [11]. Secondary use of spectrum (TV white spaces) for smart grids is discussed in [12].

Techno-economic analysis of network deployment and spectrum costs are analysed in [13] where both licensed and TV WS spectrum is considered for existing and greenfield mobile operators. Spectrum prices and valuation of spectrum is discussed in [14]. Business model aspects for smart grid networks can be found in some papers, operator driven networks is discussed in [15] and business models for demand response systems is discussed in [16].

The contribution in this paper is the comparison of the three options for an energy company to control the energy grid using wireless communication, the options are:

- to use an operator network
- to deploy and operate an own network
- to use special machine communication network)

#### 4. Research approach

The analysis of the network options (operator networks, own network and special machine communication network) is based on an analysis of the costs to deploy an *own network* assuming that spectrum can be acquired. The level of the estimated costs of an *own network* on one hand provides insights about what is required by the energy company. On the other hand it provides information what can be gained by the energy company by sharing with others and also what energy companies would be prepared to pay when using a network of another operator.

The dimensioning of an *own network* consider two country cases, Germany and Sweden, with different number of sites. The dimensioning considers coverage and capacity but coverage is the main driver. The cost structure of the *own network* of the energy company include the following main components [13]

- Investments in radio access network
- Running costs for the radio access network
- Investments and running costs for the core network
- Costs for acquiring spectrum

Different options to deploy and operate an *own network* are considered with use of licensed or non-licensed spectrum, the latter implies no spectrum costs. In addition, we consider both to build own base station sites and to rent space at sites of mobile operators.

As complement to the qualitative network cost analysis we also include a qualitative part in order to estimate cost levels and for the trade-off consideration between different options. Here we have had discussions with representatives for Ericsson, Siemens and the Swedish regulator PTS. These findings are used as basis for the analysis in section 8.

## 5. Radio Access Network Modelling and Design

For this paper two countries have been chosen as case studies; Sweden and Germany [20], where both these two countries have a relative high level of penetration for telecommunication in the Utility sector. Germany with around 4% urban land is compared with Sweden with 2.8% urban area (of the country). On the other hand, Sweden has a higher ratio of uncovered rural land (i.e. area of country where there is no coverage for electricity networks at all) which is 50%, compared to Germany with 15%.

For dimensioning the telecommunication network for these “smart” grids the following assumptions have been considered:

- Density of substations: Urban area: 20 per km<sup>2</sup>; Rural area: 1 per km<sup>2</sup>
- Broadcasting from central node of the distribution (high voltage/power) ring
- Cell size: 7 km radius in LTE 800 MHz [19]
- Bandwidth: Average 10 Kbit/s ; Maximum 1 Mbit/s [9]
- Latency < 2s [9]

| SWEDEN                             | rural                  | urban                | Sum                     |
|------------------------------------|------------------------|----------------------|-------------------------|
| Coverage area                      | 202332 km <sup>2</sup> | 5672 km <sup>2</sup> | 208 004 km <sup>2</sup> |
| Number of nodes                    | 202332                 | 113440               | 315 772                 |
| Number of sites (coverage limited) | 1349                   | 38                   | 1384                    |
| Capacity per site                  | 1400 Kbps              | 30 Mbit/s            | ~                       |

Table 1. Network dimensioning for Sweden

| Germany                            | rural                   | urban                  | Sum                     |
|------------------------------------|-------------------------|------------------------|-------------------------|
| Coverage area                      | 343 353 km <sup>2</sup> | 13 815 km <sup>2</sup> | 357 168 km <sup>2</sup> |
| Number of nodes                    | 343 353                 | 276 300                | 619 653                 |
| Number of sites (coverage limited) | 2289                    | 92                     | 2381                    |
| Capacity per site                  | 1500 Kbps               | 73 Mbit/s              | ~                       |

Table 2. Network dimensioning for Germany

## 6. Core Network Modelling and Design

EPC, Evolved Packet Core, is the core network for LTE. Only packet core network nodes are included – there is no circuit switched core network as in 2G/3G. The LTE packet data network is designed to be highly scalable - from small to very high capacity.

### *General about a dedicated core network*

The core network of a MNO is used to connect a large number of end-users via a large number of base stations. The core network then connects to a number of services, applications and external networks. In our case, the core network is a dedicated network, it is only to be used for one or a small number of power companies. Therefore, a large part of the nodes and functionality of the core network are not needed.

- Voice services are of course not needed, but neither is deep packet inspection
- Most of the subscriber data will never need to be updated.
- Functionality for charging and billing is not needed
- Since the power grid is stationary, mobility is not necessary, so the handover testing and tuning can be minimized or switched off.
- No need for international roaming of own users and no visiting users

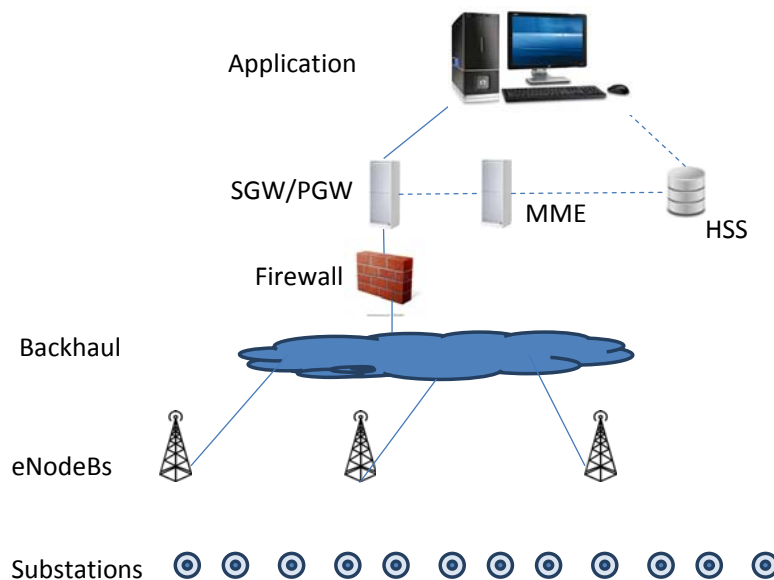


Figure 1 Overview of networks nodes



### ***Included nodes and functionality***

The following nodes are included in the suggested core network for LTE smart grid:

- i) SGW/PGW (Serving gateway/Packet Data Network Gateway)  
These nodes are separate entities in the 3GPP specifications, but most vendors have combined the functionality to a single node. The SGW handles the (IP) connectivity to the eNodeBs and the PGW the connectivity to the external IP networks.
- ii) MME (Mobility Management Entity)  
The functionality of the MME is similar to the SGSN in 2G/3G networks. It is the main control node in EPC and its tasks includes bearer setup, idle mode and signaling.
- iii) HSS, SIM cards and provisioning  
HSS is the subscriber registry where data about all end-users (in this case substations) is stored. For each SIM card there is a data record in the HSS. The HSS needs to be integrated with the power companies' application for provisioning, activation and administration of SIM cards.
- iv) Operation and Maintenance system  
The O&M system is typically vendor specific and performs Alarm Handling, Element management and Performance Management.
- v) Redundancy and robustness  
It can however be considered to have full geographic node redundancy depending on the requirements of the power companies' applications.

### ***Excluded nodes and functionality***

In case the LTE network is a dedicated network for one or a few power companies, the following nodes and functionality can be excluded.

- i) LTE does not include a circuit switched core network as in 2G/3G. Voice is specified to be carried over IMS/VoLTE, but the IMS nodes (CSCF, MRFP, IMS applications Servers, etc) are not needed in our case.
- ii) PCRF (Policy and charging rules function) handles deep packet inspection and bandwidth control for subscribers. PCRF is not needed in a dedicated network.
- iii) The prepaid or postpaid charging system is a large and complex area for an MNO. In the dedicated network, neither pre-paid (real-time) charging or post-paid billing is needed. There is enough statistics in the system to be used for a usage based split of cost in case several power companies are sharing the network.
- iv) Connections to external networks do not have to be made, which simplifies the services scope. And as discussed above, (international or national) roaming agreements or connections are also excluded.

## 7. Cost Structure Modelling and Analysis

In the cost structure analysis we consider the following four different deployment cases that can be considered when an energy company wants to build an own network:

- The energy company make use of licensed spectrum and build own sites
- The energy company make use of licensed spectrum and rent site space by others
- The energy company make use of TV white spaces and build own sites
- The energy company make use of TV white spaces and rent site space by others

These cases are then used as basis for the comparison with the options to buy network capacity from mobile operators or the share network with other energy companies.

### *Assumptions*

The major components of the cost structure are the following

- Investments in radio access network (RAN capex)
- Running costs for the radio access network (RAN opex)
- Investments and running costs for the core network (CN capex and opex)
- Costs for acquiring spectrum (Spectrum costs)

For deployment and operation of the radio access network the cost assumptions are summarized in table x and is based on recent data from the Swedish regulator PTS. The costs for leasing space at a site are set the same as the annual cost to operate the site but include also the tenant's (i.e. the energy company) share of carrying costs for investments in the site. The capex and opex of core network nodes are estimated to be 10% of the cost for the RAN. This is a high level estimate since the core network of an energy network has reduced functionality compared to a network with human traffic and subscribers, see section 6 on core network modelling. The higher level is anyway used in order to indicate upper limit. These numbers are used for both Germany and Sweden, the differences are the number of sites and the price of spectrum.

The spectrum costs assuming use of 2 MHz are estimated based on a high price level in Germany (100 M€per MHz) and a lower level in Sweden (10 M€per MHz). These levels are similar to the 800 MHz spectrum auctions (Mölleryd and Markendahl, 2011).

|                                     |      |
|-------------------------------------|------|
| Total investment cost per site (M€) | 0,09 |
| Radio cost per site (M€ )           | 0,01 |
| Opex per site                       | 0,01 |
| Leasing cost per site               | 0,01 |

Table 3. Assumptions used for cost structure analysis

The results presented below assume investments and operation for 10 years using a simple model with zero interest rate, no depreciation and no price erosion.

### *Estimates for Sweden*

For these cases the major cost component is the operation of the radio access network. To rent sites and/or site space will decrease the cost. The spectrum cost is relatively low so the use of TV white spaces will not result in any major savings of costs.

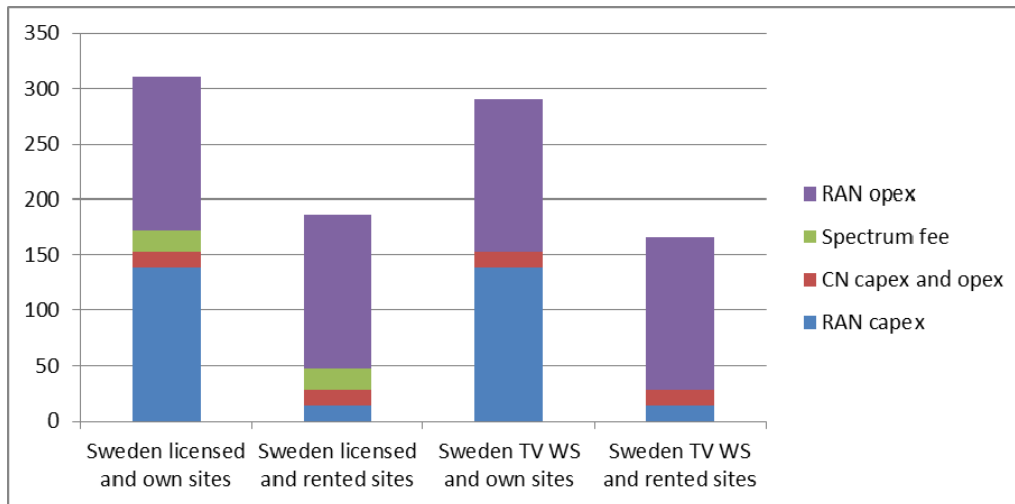


Figure 2. Cost structure for Sweden cases, capex and opex for 10 years

### *Estimates for Germany*

For Germany the spectrum prices are higher. The use of TV WS is included for the cost comparison but from a reliability perspective it questionable if it can be used. Even with TV WS we see that that the total costs are of the same order of magnitude for all cases, the major cost driver is the RAN capex.

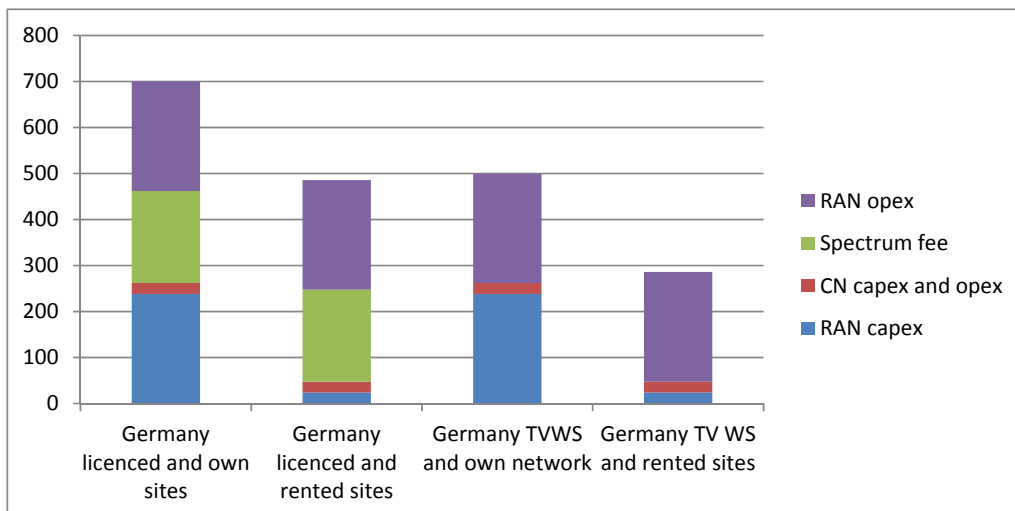


Figure 3. Cost structure for Germany cases, capex and opex for 10 years

## **8. Analysis and discussion**

The three major cost components are network investments, network operation and costs for acquiring spectrum. The major network costs come from the radio access network and the base station sites, the more sites the higher costs. The core network nodes represent a minor part of all costs. To lease sites space or to share sites will reduce costs but the RAN opex is still a major cost component for all cases.

The results for the Germany case illustrate the cost drivers. For the case of Germany where an energy company acquire licensed spectrum and build an own network the main drivers are RAN capex, RAN opex and spectrum costs. For our assumptions the costs are roughly 200 M€ each for 10 years. To share sites will reduce cost but the order of magnitude of costs is still the same.

Compared to a mobile network operator these network costs and investments are not balanced by expected revenues from uses. For an energy company the motivation is to improve efficiency and performance in the operation of the energy networks. The option to deploy an own network does not seem to be so attractive. In addition the energy company needs to acquire spectrum which may not be feasible. Regulators may not allow other actors than mobile operators to acquire spectrum. In addition, mobile operators usually have financial resources in order to buy all spectrum.

Hence, for energy companies the two other options seem to be more attractive:

- To share a machine traffic network with other energy companies
- To agree with a mobile network operators (MNO) to buy capacity using special service classes to be used for traffic with “high” requirements

The option to share network with other energy companies have some interesting implications. Besides being able to share cost multiple energy companies would have larger possibilities to acquire spectrum. Multiple companies have more financial resources and in addition the regulator may see a benefit that energy companies join forces to provide a common solution.

The cost analysis indicate that energy companies have a strong incentive to avoid building an own mobile network. Hence, mobile operators are in a good position to offer network capacity to energy companies. Our view is that agreements with energy companies would be beneficial and with low risk. The actors in the utility sector are big companies and agreements would be long term and would generate stable revenues.

## **9. Conclusions and future work**

### ***Answers to research questions***

*RQ1. What are the main limitations for energy companies to deploy and operate an own mobile network for own applications only? And why is it a limitation?*

To deploy and operate an own mobile networks is associate with very costs. These costs cannot be recovered by new sources of revenues like a mobile mobile operator can do. In addition an energy company may not be able to acquire and “own” license. The prices at an auction may be very high and/or the regulator may not allow energy companies to acquire spectrum for “own” use only (“spectrum should be used for public access”).

*RQ2. Is there a business case for mobile operators offering special services classes for M2M traffic with special requirements?*

We would say yes due to the cost analysis of mobile networks owned by an energy company. Operators need to consider the savings and value offered to energy companies and not base the pricing on the data volumes (as for consumers and “human” traffic)

*RQ3. Is there a business case for a new type of operators operating special mobile networks carrying M2M traffic with special requirements?*

Also here we would say yes due to the cost analysis of mobile networks owned by an energy company, especially if mobile operators would be reluctant to provide good offers. . A new actor focusing on machine type of communication can also offer taylor made solutions to multiple utility and transport companies with special needs.

Operators need to consider the savings and value offered to energy companies and not base the pricing on the data volumes (as for consumers and “human” traffic)

### ***Future work***

An obvious way of improving the business case for a dedicated network for substation automation would be to use the dedicated network also for residential and corporate smart meters. As can be seen in for example [12] and [13], 3GPP wireless systems (like LTE) are well suited as communication media for smart meters. And as calculated in [16], the number of power meters that can be handled by a single cell is very large.

This work is part of ongoing study where detailed analysis will be made in three areas;

- to make detailed study of network deployment options in different countries
- to look into country specific regulation with relevance for energy companies
- to make interview with major stakeholders about possible business solutions

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## **Appendix: Inter Site Distance (ISD) on LTE 800 MHz**

Based on the authors' experiences, we have used 7 km as an Inter Site Distance (ISD) in rural areas. We also studied [19], which is a report made for PTS (the Swedish Telecom regulator) in 2010, as an input to the LTE 800 MHz frequency spectrum auction. An aim from PTS was to assure that the process resulted in providing mobile broadband coverage for rural households which did not (at the time of the report) have mobile coverage.

The report discusses the foreseen site density when planning for full rural coverage in areas differing from dense forest to more open mountain areas. Different inter-site distances of between 3,2 and 8,1 km are discussed. The requirements in the PTS report are aiming for mobile broadband connections of 1Mb/s as peak and 0,75Mb/s as an average during 24 hours. We have assumed that the substations would require less capacity needs than that – thereby allowing for a somewhat larger ISD. It should also be possible to have external antennas in substations close to cell edges.