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An evaluation of two-way communication means for advanced metering in Flanders (Belgium)

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Abstract *– Advanced meters for electricity and gas require two-way communication to upload commands to, and download measuring data from the meters. With a specific emphasis on the means for two-way communication, this research starts from an analysis of the amount of data to be transmitted and its real time requirements, and it evaluates different communication means for smart metering for suitability, penetration rate, exploitation costs, flexibility and dependability – focused on Flanders' case.*

Keywords *– advanced metering, smart meter, communication, AMR/AMM*

I. INTRODUCTION

In the context of the liberalisation of the European electricity markets, several countries are currently in the process of installing advanced meters residentially at each household: Italy [1], The Netherlands [2], Denmark, Sweden, etc. [3]. There are ongoing standardisation activities concerning meters and their communication: The Netherlands recently proposed a standard for advanced meters including local and remote communication interfaces [4], the IEC and Europe are proposing standards for communication protocols for metering and object representation [5, 6], CIRED is identifying communication interfaces and protocols [7], etc.

The case of communication for smart metering applications in Flanders (the northern region of Belgium in which 60% of its population is living) is specific, because of its high population density (440 inhabitants/km^2), a high penetration of broadband internet access (60%) and of cable TV (95%) and exploitation of advanced communication means (UMTS, terrestrial trunked radio, etc.)

Advanced meters for electricity and gas require two-way communication to upload commands to, and download measurement data from the meters. With a specific emphasis on the means for two-way communication, this research starts from an analysis of the amount of data to be transmitted and its real time requirements, and it evaluates different communication means for advanced metering for suitability, penetration rate, exploitation costs, flexibility and dependability – focused on Flanders' case [8].

II. FROM AMR TO SMART METERING

Advanced metering can be implemented with different levels of *intelligence* associated to the meter. Typically three types can be distinguished, in order of increasing interaction level and feature contents.

- AMR (*automated meter reading*) implies the remote reading of the measurement registers of a (electricity, gas, water, …) meter without physical access to the meter. It can be implemented via a temporary RF (radio) link to the meter from a car passing by in the street while interrogating the meters, or as an (always connected) communication link to the meter from the data collecting devices. Such link may use wireless or wired communication media.
- AMM (*automatic meter management*) extends AMR with the ability to manage meters remotely. For instance, it allows for disconnection of customers, for dimming their usage (e.g. down to a socially acceptable 6A or 10A for non-paying customers) or for reconnection of customers (except for gas because of safety issues).
- *Smart metering* extends AMM with control abilities. For instance, it allows to shut down several customers simultaneously on short notice – in order to balance the grid in case of an incident –, or for demand side management – for usage flattening or load shifting –, or for integration in home automation systems – for automatic response to varying prices in real time pricing or time-of-use pricing scenarios –, etc. As such, smart meters are an indispensable enabler in a context of smart grids which deploy advanced information and communication technology to control the electrical grid [9].

Many different types of advanced meters are on the market, from classic electromechanical Ferraris meters with an external pulse output to fully digital electronic power and energy meters [10]. Some manufacturers completely integrate the communication module into the meter (allowing for easier certification and tamper-resistance), while others provide a separate communication module via a dedicated communication port (using or not a standard, such as M-bus EN 13757 [5]).

In the context of the presented study, an advanced meter has been considered [8] which is able

- to store multiple measurement registers (e.g. for consumption and generation of energy during different tariff periods) and to archive this data;
- to send measurement registers periodically (at least monthly) as well as on demand (typically once per year, e.g. if a consumer want to change suppliers);
- to be remotely (dis)connected and to reduce electricity or gas supply and to act as a budget meter;
- to undergo remote modification of tariffs and tariff periods;
- to have its firmware upgraded remotely, e.g. to incorporate new functionality;

♦ to send on demand power quality data (e.g. surges, outages, …) and to send automatic fraud alarms.

This set of requirements is conform to the Dutch standard NTA 8130 [4], which additionally requires that a group of meters can be reduced or disconnected as a whole, e.g. in order to cope with grid problems.

Hence, according to these specifications, the meter rather belongs to the class of AMM-meters, than to the one of *smart* meters. In the rest of this paper, we firstly consider the above specifications, but also allow for future usage for smart meter purposes.

III. ADVANCED METER COMMUNICATION REQUIREMENTS

If advanced metering is only used to transfer data from the measurement registers, a smallband communication medium is sufficient and no real time constraints are involved. However, if demand side management is required, it is necessary to address the smart meters within a given time period and hence *real time* constraints need to be satisfied [11, 12]. Often, this implies that some type of broadcasting needs to be supported by the communication medium [13]. If – besides the classical measurement registers – also much additional data is to be transmitted (e.g. concerning power quality or load profiles) a *broadband* connection is required. Table 1 summarises the time and data size requirements for some typical transactions with advanced meters.

In Flanders, there are about 3 million electricity meters (2.6 million residential) and 1.6 million gas meters (1.44 million residential). Hence, for approximately 3 million advanced meters this requires about 0.5 MiB per meter per year for reading measurement registers monthly. This is negligible with respect to internet traffic, but still results in 1.28 TB raw data per year for Flanders. If not only monthly measurement registers need to be transferred, but also 15 min profile data needs to be send daily or if detailed power quality data needs to be transmitted, then the amount of data per meter can increase with 2 or 3 orders of magnitude.

Furthermore, if a message needs to be sent to all meters within one hour sequentially, only 1.2 ms is available if broadcasting is not supported. Hence, a hierarchical or parallel approach is required to send out commands to the meters to which a response is needed in a short time frame. Three communication architectures can be envisaged.

♦ A *direct connection* is set up between the meter and the data collection point via a dial-in modem over the public switched telephone network (PSTN) or via a mobile data connection (GSM/GPRS).

♦ A *dedicated intermediate communication infrastructure* is deployed between the meters and a concentrator, e.g. for power line carrier (PLC), or low power radio frequency (RF) communication solutions.

♦ An *existing intermediate communication infrastructure* is used to connect the meters to the data collection points, e.g. by providing the meters with an internet address and using existing broadband internet connections of cables or phone lines.

IV. SUITABLE COMMUNICATION MEANS

Three categories of communication media to smart meters have been studied in detail [8]: power line carrier, communication over telephone and cable infrastructure, and wireless communication (mobile phone, RF, PMR), discussing technical aspects and the concerned situation in Flanders. The following sections elaborate major advantages and disadvantages of these communication media for advanced metering applications.

A. Power Line Carrier

Power line carrier, or power line telecommunication, uses the power grid for data communication [14, 15]. Digital data is modulated on a carrier at a specific frequency. Its usage is standardized and limited to specific spectra (EN 50065-1) [16]. The spectrum reserved in Europe for PLC lies between 3 and 148.5 kHz, in which the A-band (3-95 kHz) has been reserved for utility communications. This allows smallband communication only; realistic communication bandwidths reach up to about 4 kbps (kilobit per second). PLC has already been used for a long time for lower bandwidth applications e.g. to switch public lighting or to switch between tariff periods.

Each advanced meter requires a PLC modem which communicates with data concentrators which are often located in medium/low voltage substations.

In Flanders, a typical distance of the meter to the substation transformer is about 400 m. In city areas, each transformer serves about 400 households; in rural areas this is often less [17]. Hence, many concentrators will be required to serve all meters.

Table 1: time and data size requirements per transaction type per meter

transaction type	time critical	response (min/typ/max)	#times/yr	#data (min/typ/max)
command store measurement registers	yes	immediate / 5 min / 1 h	1	0.5 KiB / 1 KiB /16 KiB
send **measurement registers** (periodically + on demand)	no	immediate / 10 min / 2 h	13 (12+1)	1 KiB / 32 KiB / 16 MiB
command reduce load	yes	immediate / 5 min / 1 h	1	0.5 KiB / 1 KiB / 16 KiB
adjust **parameters**	no	immediate / 10 min / 2 h	2	0.5 KiB / 1 KiB / 16 KiB
upgrade **firmware**	no	10 min / 2 h / 1 day	0,2	0.5 KiB / 1 KiB / 512 KiB
send **alarms**	no	immediate / 10 min / 2 h	0,2	0.5 KiB / 1 KiB / 16 KiB

By using *repeaters* the communication reliability can be improved. Nevertheless, it seems that large European PLC-based deployments are not able to reach 1 to 5 % of the meters. Also, when certain power problems occur (e.g. interrupted distribution cable), the communication medium is not available neither.

Its main advantage is that no additional cabling is required, as the meter is already connected to the communication medium. Also, a concentrator can broadcast messages to all connected meters.

B. Smallband Communication over Telephone Lines

For analog telephony and Integrated Services Digital Network (ISDN) (digital telephony), a connection is made over the public switched telephone network between an advanced meter and the data collection point. The modem at the meter needs to be connected to the telephone line, which is often not in the same place.

Communication bandwidth is up to 56 kbps (analog) or 128 kbps (ISDN) for a duplex connection. Setting up a connection (dialling in) takes a non-negligible time. The communication medium is very reliable, but multicasting is not supported. Flanders has a very high penetration rate of telephone (45 connections per 100 inhabitants), hence about 98% of the meters are connectable. This communication network remains functional in case of power problems, if the modem does not need a grid-connected power supply.

C. Broadband Connection over Phone Line or TV Cable.

The Digital Subscriber Line (DSL) technology provides a broadband connection over a PSTN line, while a cable based connection uses the cable that carries television and radio signals to bring data communication to the home. These implementations allow for a bandwidth of hundreds of kbps to several Mbps. When this communication medium is already *existing* in a home, it can be shared with the metering application. It is operated by a telecom provider or internet service provider (ISP). For research purposes, we also include a *dedicated* broadband connection that is used for advanced metering only. In both cases, it is required to make a connection from the meter to the phone or cable equipment. Cable based broadband also allows for broadcasting data to all meters on the cable segment. Flanders has a high penetration rate for television cable, which serves about 95% of the households. If this is coupled with the high penetration of telephony, it is clear that it is a potentially widely available communication medium for smart metering. The reliability is assumed to be somewhat lower than smallband communication over telephone lines.

D. 2nd or 3rd Generation Mobile Telephony and Data

GSM (Global System for Mobile Communications) provides the standard for 2nd generation digital mobile telephony; it is a circuit-based connection [18]. GPRS (General Packet Radio Service) is the corresponding packet-switched standard for data communication in the same frequency band [19]. GSM, GPRS and their variants or evolutions have a medium bandwidth (tens of kbps), and a complete coverage of Flanders; however reception in cellars and alike (where the meters are often located) is not guaranteed. Third generation mobile telephony (UMTS) is being deployed in Flanders with a coverage of about 60% for outdoor purposes. UMTS allows a broadband connection of several hundreds of kbps. The advanced meter needs to be equipped with a GPRS or UMTS modem, and the communication takes place over the network of the mobile operator, to whom a subscription fee has to be paid. Operators do not guarantee the availability of these networks for the foreseen lifetime of the meters (15 years). These cellular communication systems have a lower reliability than (landline) telephone connections.

E. Non-licensed RF in ISM band

Low-power radio uses the non-licensed ISM (industrial, scientific and medical) band for RF communication often around 433 or 860 MHz. Each meter is equipped with a RF transmitter that allows communication to the data concentrator directly, or to other meters with RF transmitters which act as repeaters or forward the data, e.g. in a meshed network configuration. Also, an antenna infrastructure is required at the concentrators; this is typically not operated by a third party, but can be owned by the metering company or distribution system operator. Reliability of non-licensed RF is high, especially if there is a large penetration, such that the repeater functionality can be exploited [20]. It typically provides a smallband communication (up to some kbps).

F. Licensed RF

PMR (Professional Mobile Radio) is a group name for mobile radio systems that use licensed bands of the frequency spectrum. Typical implementations (besides walkie-talkies) include PAMR (Public Access Mobile Radio) and terrestrial trunked radio. PMR has been build for group communication (e.g. used by emergency services), but it is also standardised for utility services. Its main advantages are that it is a very reliable communication means with a vey good coverage (also in cellars), that also provides broadcasting with a fast communication setup. It allows medium bandwidth communication (up to some tens of kbps). The network is operated by an independent operator.

The author is not aware of advanced metering implementations that use these communication means, which seems however quite well suited in terms of reliability and responsiveness.

WiMAX is a novel RF communication technology of the fourth generation that used the licensed 2.5 or 3.5 GHz band or the non-licensed 5.8 GHz band. It is standardized as IEEE 802.16a with a potential range up to 50 km and a broadband connection up to 100 Mbps.

V. COST ANALYSIS

Different studies have tried to identify costs and benefits of advanced metering [2, 3, 12, 21, 22]. These studies show that the chosen medium for communication only plays a certain role in the overall business case; nevertheless, due to the uncertainty related to estimating the communication costs, its influence is non-negligible.

Based on cost elements from other studies, and our own estimations (detailed figures for the different cost elements can be found in [8]), a cost analysis has been made for several scenarios of communication means. Figure 1 provides a comparison of initial costs (such as the communication module of the advanced meter and the possible connection to

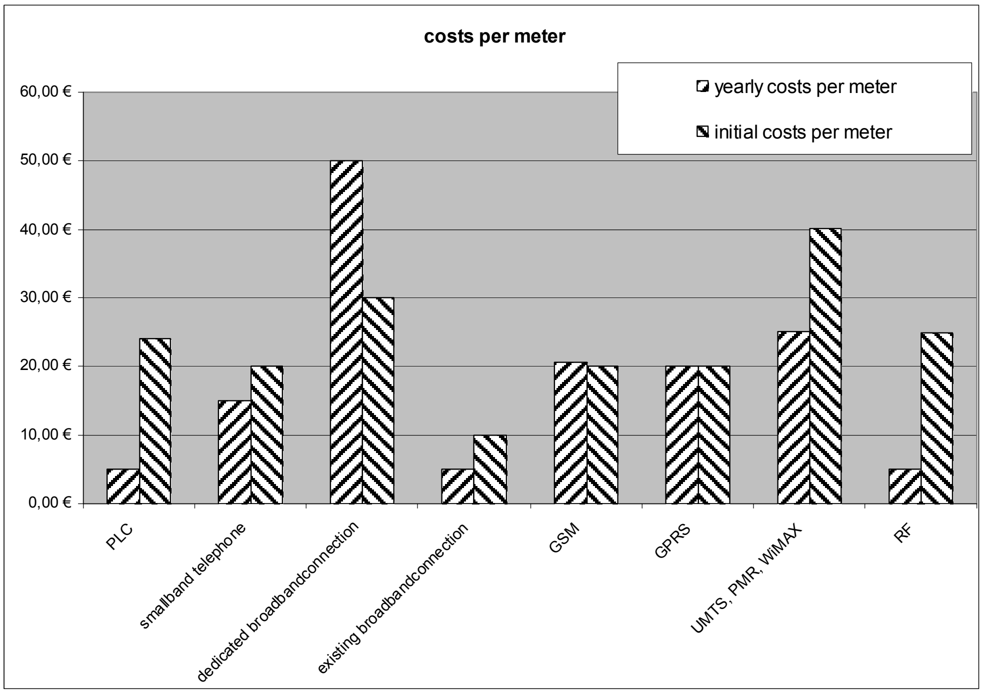

Figure 1: initial and yearly costs per meter

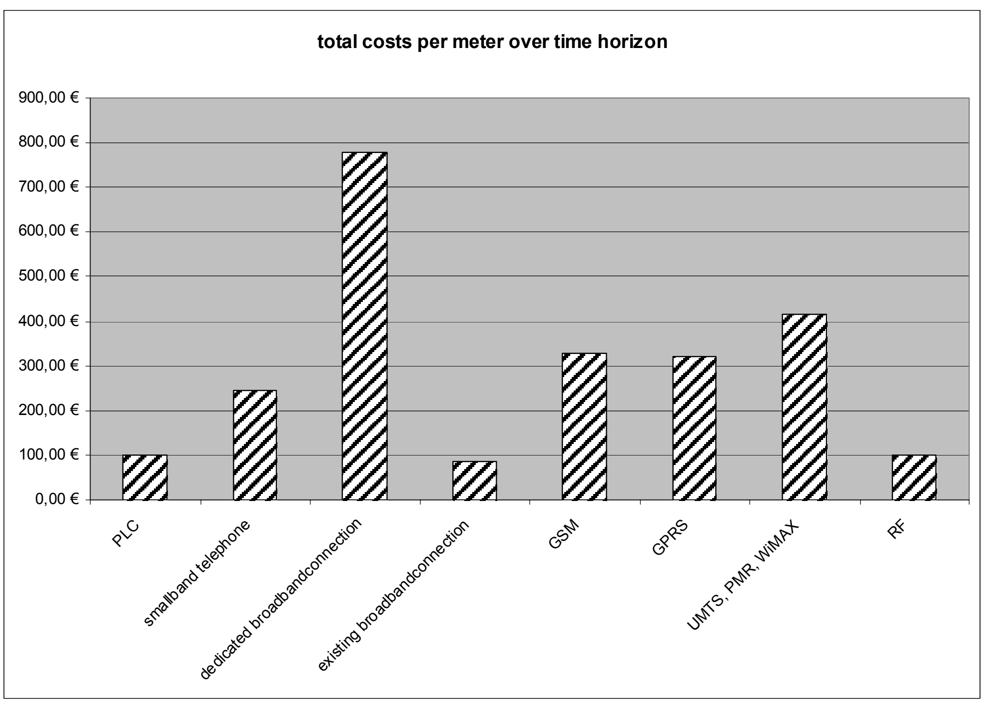

Figure 2: costs per meter over time horizon

the medium) and recurring costs (such as connection costs and subscription fees) for the different communication means. These costs include concentrators where necessary, but they exclude the backbone ICT infrastructure (e.g. between the concentrators and the central data collection points), and the installation costs. For newer technologies (UMTS, PMR, WiMAX) costs are considered equal – due to uncertainty. Figure 2 aggregates these costs over a 15-year time horizon, which is assumed to be the lifespan of the smart meter.

This analysis shows that communication based on existing broadband connections is the least expensive, shortly followed by PLC and RF. Next follows smallband telephony and GSM/GPRS. Novel communication means (such as PMR) do not seem to be significantly more expensive. A dedicated broadband connection is the most expensive.

VI. CONCLUSION

Table 2 provides a summary of the attributes reachability, costs, operator, flexibility, reliability and suitability for advanced metering applications for the different communication means discussed above.

The final decision on the best suited communication medium for advanced metering applications first needs to answer whether a solution which is only suited for AMM will be chosen, or if also future smart metering applications need to be supported. Besides, such decision has to consider both technical and non-technical requirements.

If a future-proof *smart* meter is required that allows for detailed and frequent consumer data (power quality data, quarter-hour profiles), a significant larger bandwidth is required than when only a monthly remote reading is required for AMM purposes. This indicates that broadband internet-based solutions or 3rd generation mobile telephony would be a suitable communication infrastructure.

When it is necessary that a set of meters is reached within a given time span as for smart metering control applications (real time requirements), then the medium shall support a form of broadcasting or parallelism. This favours solutions such as PLC or RF, or other wireless solutions (PMR, UMTS).

When costs are an important issue, PLC/RF and existing internet solutions are preferable for advanced metering applications.

Besides, communication media operated by parties external to the energy markets (like telecom operators or internet service providers) provide some potentially undesired level of dependence. This indicates PLC or RF as suited media.

Concerning flexibility and reliability, all communication media fulfil the basic requirements for AMM meter applications.

However for future-proof smart meter applications, it is clear that no single communication means on its own will be able to meet all requirements. It will then be necessary to go for hybrid, combined communication solutions to ensure a suitable simultaneous fulfilment of broadband, real time and reliability requirements.

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Table 2: summarizing table

	power line carrier	cable		wireless			
		internet	telephone	GSM, GPRS	UMTS	RF	PMR/trunked radio
reachability	95%	Dedicated, D 95% / Existing, E 60%	98%	97%	60%	100%	100%
costs	medium	D: very high E: medium	medium to high	high	high	medium	high
operation	own	D: telecom-provider E: ISP	telephone operator	mobile phone operator	mobile phone operator	own	own or PMR-operator
addressability of the meter	via concentrators	directly	directly	directly	directly	via concentrators	directly or via concentrators
suitability (bandwidth, BW)	functions with low BW	functions with high BW	functions with medium BW	functions with medium BW	functions with high BW	functions with low BW	functions with medium BW
suitability for real time applications	yes	D: yes / E: no	no	no	yes	yes	yes
flexibility	medium	high	medium / high	medium / high	high	medium	medium / high
reliability	high	medium / high	very high	high /very high	medium / high	high	very high

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