Research Project 2:

Dutch Advanced Metering Infrastructure

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Abstract

This paper discusses advanced metering infrastructure (AMI) in the Netherlands. The Dutch AMI has been deployed in reaction to EU request. Implementation of it is desirable in facilitating the transition from the current fossil fuel centric energy production to the use of more renewable energy resource. Moreover, implementation of Dutch AMI is necessary to accommodate the expected significant increase in the need for electrical transmission capacity. This descriptive research aims to systematically describe Dutch AMI by identifying the specifications from legal and technical perspectives, major stakeholders and their corresponding task domains, and the metering information flow between these stakeholders. Research findings were drawn from desk research on the relevant legal documents and published research papers and interviews with major stakeholders. This research provides readers with a clear overview on Dutch AMI and hopefully, leads to a higher transparency and higher social acceptance of the implementation of Dutch AMI.

Acknowledgements

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Last but not least, a special thanks to my dear girlfriend, Annie.

Contents

Chapter 1

Introduction

Advanced metering infrastructure (AMI), also known as smart metering infrastructure, is *an electricity network that can intelligently integrate the behavior and actions of all users (i.e. generators, consumers, and those play both roles e.g. prosumers) connected to it in order to efficiently deliver sustainable, economic, and secure electricity supplies* [1]. Prosumers are the consumers who do not only consume energy but also produce energy through solar panel or other technologies which make use of renewable resources. It is believed that with the implementation of smart meters, the amount of prosumers will rapidly increase [2].

Smart meters enable bi-directional communication between the meters and the systems of various players, *e.g.* grid operators (GOs) and supplier companies (SCs). This makes remote monitoring as a service, enables remote controlling of home appliances and better reallocation of energy consumption easier - not only leverages the awareness of energy being consumed but also better facilitates in energy saving, leading to emission reduction.

AMI has gained a lot of enthusiasm and attention in both research and practice in the recent years, as it is considered to be the solution to the emerging trend of energy saving and CO2 emission reduction. Moreover, it is not only desirable to implement AMI in order to facilitate the transition to the use of renewable natural energy resources buy also necessary to accommodate the expected high increase in electrical transmission capacity. With the help of AMI, the current grids can better accommodate and balance the transmission load in order to fulfill the transmission needs without major reinforcement[3]. Grid reinforcement can involve high cost which might lead to increase in connection and transmission costs.

There are numerous studies on AMI, addressing different perspectives, such as security and organizational changes [4][5][6]. In addition, live implementations have been carried out in the world, such as NYSEG [7] and Italian smart grid[1].

In 2005, European Union (EU) parliament requested all its member states to implement AMI. By 2015, 80% of Dutch households should be connected to smart grid in order to fulfill the EU long term target: 90% reduction of $CO2$ emission by 2050 [8]. In reaction to this request, the Dutch government decided to completely liberalize the Dutch energy market and implement AMI all over the Netherlands [9].

As every market is different and has its own specific requirements and policies, the discussion and compromise made between different stakeholders from different interest groups result in different details, such as legislation, technical requirements, and performances of the AMI system [7][9].

Therefore, this study is motivated to investigate into the details of Dutch AMI. Particularly, the scope of this research focuses on the network formed by smart meters and its connectivity to and among the major stakeholders. The objective of this research is to systematically describe Dutch AMI from three dimensions. The first dimension is the specifications from both legal and technical perspectives. Subsequently, major stakeholders and their task domains are identified. Finally, the metering information in Dutch AMI is examined. Accordingly, the research questions are put forth:

[1] `http://www.businessweek.com/globalbiz/content/nov2009/gb20091116_319929.htm`

- RQ1: *What are the specifications of Dutch AMI from legal and technical perspectives?*
- RQ2: *Who are the major stakeholders and what are their corresponding task domains in Dutch AMI?*
- RQ3: *How does metering information flow between different stakeholders within Dutch AMI?*

As a result, this study is expected to contribute to the increase of transparency of Dutch AMI to the society, and therefore, leads to a higher social acceptance of the deployment of Dutch AMI and smart meters.

The structure of this paper is as follows. First, a brief background of Dutch AMI is presented. Afterward, the infrastructure of Dutch AMI is reviewed. Subsequently, the research findings are elaborated based on the evidence drawn from both desk research and interviews. Finally, the paper is concluded by answering the three research questions and recommendations on the future research.

Chapter 2

Background of Dutch AMI

In reaction to the EU request for AMI, Dutch Ministry of Economic Affairs commissioned "Nederlands Normalisatie-instituut", NEN, to draft a document that describes the needs and requirements focusing on Electricity (E) and Gas (G) [4][5][9].

NEN delivered a technical agreement, *i.e.* NTA 8130 [10], in April 2007 [4][5]. In this document, the required functionality of the smart meter are described in a high level and abstract way. The purpose of this document is not only to provide the implementer, *i.e.* GOs, with a clear guideline but also to give them enough room and freedom to better utilize their knowledge and specialization as they know the market well and will be the operators of the system.

With regard to legislation, Dutch Ministry of EL & I started developing Algemene maatregel van Bestuur "Besluit op afstand uitleesbare meet- inrichtingen" (AMvB) on smart meters [9]. This document defines the legal position of NTA 8130 and the smart meter manufactured, purchased and rolled out according to NTA 8130. The AMvB was finalized in March 2011.

The two aforementioned ministries together assigned the task of drafting the detailed requirements for Dutch smart meters to NetbeheerNederland[1] , the

[1] `http://www.energiened.nl/Content/Home/HomePublic.aspx?MenuItemID=1`

umbrella organization of all the Grid Operators (GO) in the Netherlands. Furthermore, GO is assigned to be the core stakeholder of AMI and the actual owner and operator of the entire AMI, including smart meters, medium voltage and low voltage power grid for E (Figure 2.1), up to 8 bar gas grid [2], and the

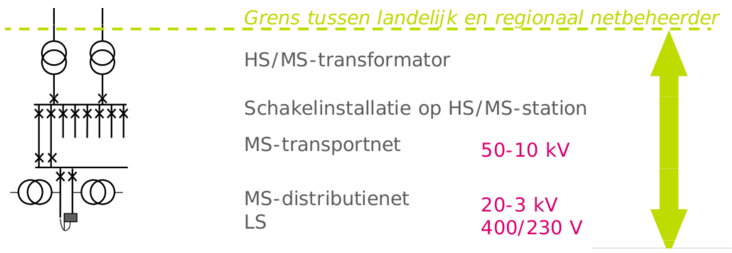


Figure 2.1: GOs as the Owners of Medium-to-Low Voltage Electricity Network [11]

operational system with database store.

According to NTA 8130 and the corresponding AMvB, a document, *i.e.* Dutch Smart Meter Requirements (DSMR), was drafted by NetbeheerNederland. Multiple stakeholders were involved in the creation of DSMR. Different interests from different stakeholders were considered, discussed and compromised. However, the development of this document is a continuous process. Since the final policy of the Dutch energy market is still under debate, technology and market needs keep changing, there have been already several versions of DSMR. By the time of writing this report, the version being used was 4.3.

Nevertheless, multiple versions of DSMR are being used for purchasing and rolling out the smart meters. By the time of writing, all rolled out smart meters have been in compliance with DSMR version 2.2 and above. From 2013, version 4 is expected to be applied [2].

Chapter 3

Infrastructure

This chapter explains the infrastructure of Dutch AMI. Figure 3.1 illustrates Dutch AMI. As the figure shows that there are multiple parties and compo-

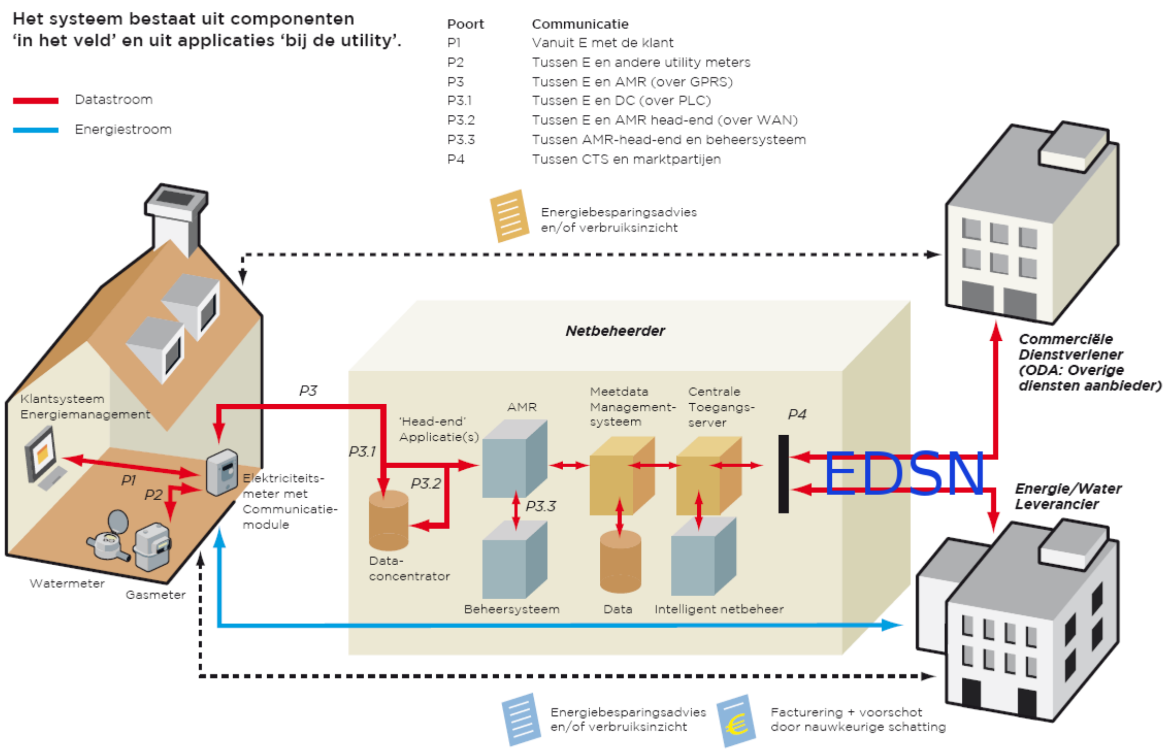


Figure 3.1: Overview of Dutch AMI with its Major Stakeholders and Connectivity among them [2]

nents in Dutch AMI. Among them, the smart meter is the fundamental part of the entire system, entailing two functions: (1) As a measuring device, a smart meter measures and records the energy consumption at a regulated frequency, *i.e.* once every 15 minutes, and stores the data read by GO; and (2) together with the integrated networking module, either GPRS or PLC, smart meters form a large and complex network to transfer metering data.

P4 is a virtual port run by EDSN. ISP and SC can only request metering information through this port. P4 accepts only message level request and separates the whole AMI from outside world [2]. By working at higher level using messages to pass requests and get responses, the lower layers of the infrastructure are wrapped, hence not to be touched even by accident by parties from outside of GO.

Within the P3 related network, there are three types of elements, *i.e.* SM, DC and GO. This network can be viewed as LAN (Local Area Network), though it is a very large national wide network. This network is owned by GO - no any other party should be able to access to it, even though part of the network relies on telecommunication provider's network. GOs give access to EDSN through namely P3. This P3 used by EDSN to request data for SC and ISP is an extension to the P3 on the smart meter according to the high level abstraction model, *i.e.* DLMS (Distribution Line Message Specification) used in the AMI. Only GOs can access to their own smart meter's P3 - no any other stakeholder else should be able to access to the smart meter. Multiple smart meters in a neighborhood can form another type of network, *i.e.* NAN (Neighborhood Area Network). This formation increases the reliability of the network by creating redundant routes and simplifies the network topology as some of the smart meters can relay data for others. Like the situation shown in Figure 3.2, the link to DC of neighborhood one is temporarily unavailable, instead of getting stuck and separated from the rest of the infrastructure, the smart meters will detect the connection failure and change the topology of the neighborhood network. Another smart meter will be used as hub for the whole disconnected neighborhood and route the traffic through another NAN.

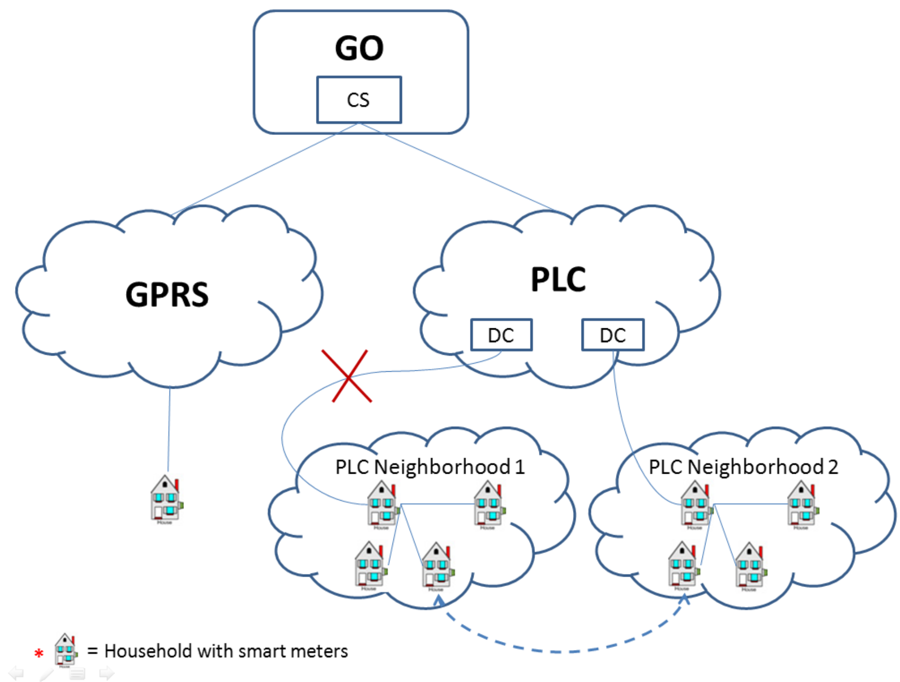


Figure 3.2: Smart Meters Relaying Data for Other Neighbors

If we zoom in the network and take a close look at a consumer's house, we can see that at this level, a HAN (Home Area Network) can be formed through P1. A consumer can connect different types of devices to the smart meter through port P1 to control and monitor his or her consumption better. For example, a custom made device can watch a consumer's consumption and remind him or her that certain device used too much electricity as it should. Thus, the consumer may take further actions.

If we further zoom in, we reach the smart meters. Figure 3.3 and Figure 3.4 show the two communication profiles selected for P3 in DSMR P3 Companion [9], GPRS and Ethernet, respectively. As they are the only two communication profiles chosen and described in DSMR, it can be argued that GPRS based profile is used by smart meters with GPRS module and Ethernet based profile is used by smart meters with PLC module. Starting from layer three and above,

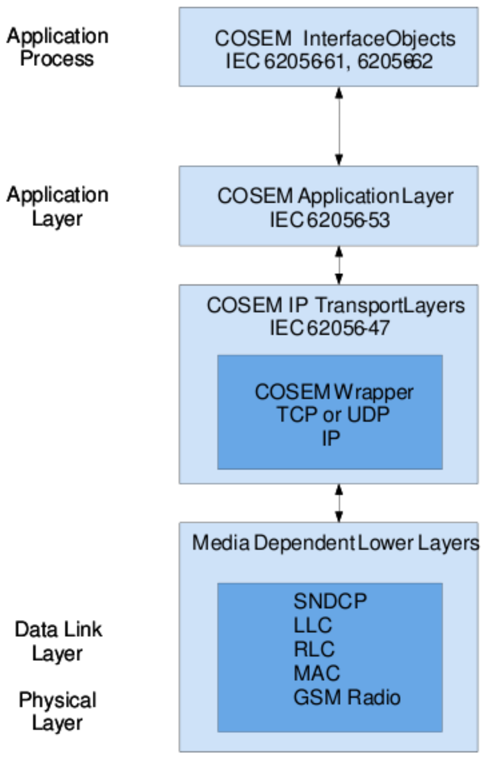


Figure 3.3: GPRS based Profile [12]

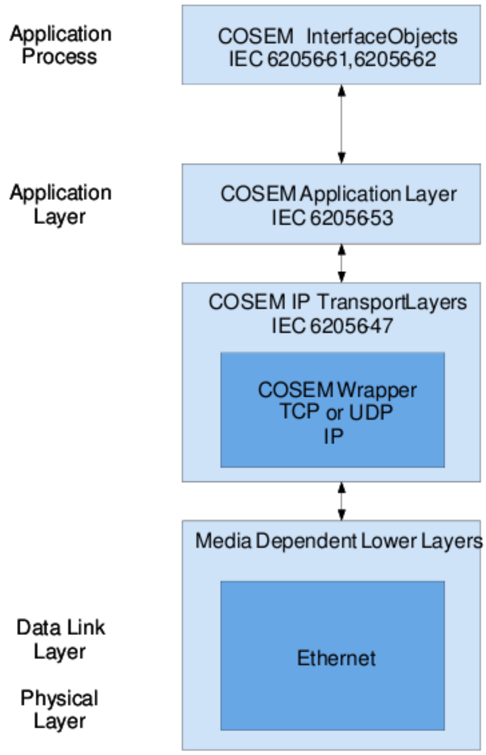


Figure 3.4: Ethernet based Profile [12]

both profiles use COSEM/DLMS as defined in IEC62056[1] to shield the lower layer technical details and give a unified upper layer support.

Though IPv6 (Internet Protocol Version 6) is discussed often, it is not mentioned in particular by DSMR. IPv4 (Internet Protocol Version 4) is mentioned and said to be used in "DSMR version 4 final P3 Campanion" [9]. The two popular PLC standards mentioned by OPENMETER project[2] are PRIME[3] and G3PLC[4]. The OPENMETER project is financed by European Commission (EC) and "*strongly coordinated with the smart metering standardization*

[1] IEC 62056 is a set of standards for Electricity metering `http://en.wikipedia.org/wiki/IEC_62056`

[2] Official site of OPENMETER project: `http://www.openmeter.com/`

[3] Official site for PRIME `http://www.prime-alliance.org/`

[4] Official site for G3 PLC `http://www.g3-plc.com/`

mandate given by the European Commission to the European Standardization Organizations, CEN, CENELEC and ETSI"[5]. It aims to remove barrier to the wide scale adoption of smart metering in Europe and lead to an open standard which accepted and widely supported by all the stakeholders. Both PRIME and G3-PLC support IPv4 according to DSMR. PRIME declares that it will start supporting IPv6 in the next version. However, G3 PLC already supports IPv6 in the current version. It remains unclear which version of IP will be used by Dutch smart meters. It might be the case that IPv4 is used now and IPv6 can be rolled out later through a firmware update.

[5]Objective of OPENMETER project `http://www.openmeter.com/?q=node/8`

Chapter 4

Research Findings

This research adopted two methods *i.e.* desk research and interviews. The findings have been drawn on the results from both methods, which can verify each other [13]. Desk research states theoretically "what" should be done and the interviews reveal "what" have been done [14]. It is also intriguing to see if there is a difference between them.

The research findings are presented in accordance with different aspects, such as legislation, stakeholders, and their roles in the Dutch AMI. In the following passages, these findings are elaborated, respectively.

4.1 Legislation

The desk research on DSMR [9] revealed that the legalization process of DSMR follows two origins. As illustrated in Figure 4.1, on one hand, the legislation originated from the EU parliament call to the member states on implementing AMI. As the reaction to this EU call, Dutch Ministry of EL & I, made AMvB on smart meters to give smart meters a legal position in the society. As a result, this legal document AMvB was issued in March 2011. On the other hand, Dutch Ministry of Economic Affairs appointed NEN, the Dutch standardization institute, to make technical guidelines. This document of technical guidelines was finalized in April 2007 and called NTA8130. NetbeheerNederland, in turn, combined the aforementioned two independent documents and crafted out a synthesized document, *i.e.* DSMR. This DSMR is a deliverable of NetbeheerNederland's work and regulates both legal and technical requirements.

The requirements of Dutch AMI are considered comprehensive and detailed. For instance, the major requirements described in DSMR do not entail only general requirements and requirements of access and security but also specific requirements derived from NTA8130. DSMR [9] further points out that once a conflict is encountered between legal and technical requirements, the legal requirements derived from AMvB should be followed.

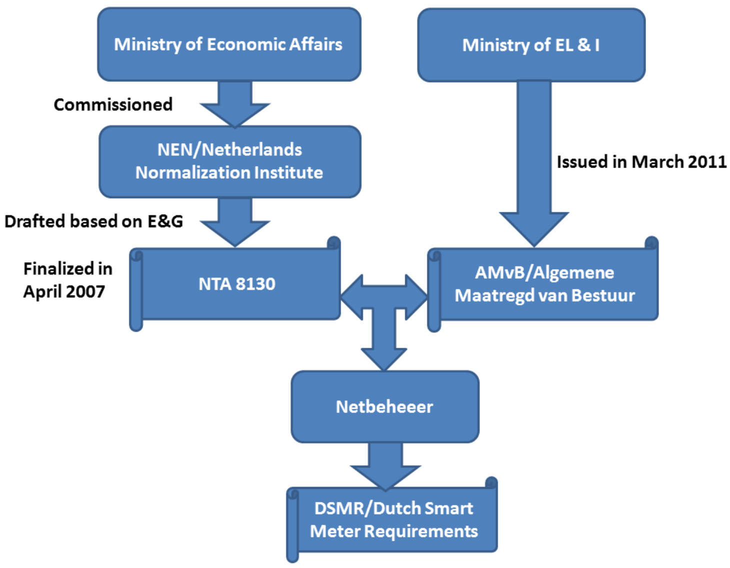


Figure 4.1: The Origin of DSMR (Dutch Smart Meter Requirements)

4.2 Stakeholders

Nationwide design and implementation of AMI is undoubtedly a large and time consuming project. Therefore, numerous stakeholders are involved. Table 4.1 lists the stakeholders of Dutch AMI.

These stakeholders can essentially be categorized into several groups, such as governmental institutions, corporations, non-governmental organizations, and consumers. For instance, governmental institutions, such as Energie Kamer and Ministry of Economic Affairs, are mainly involved in the legislation of Dutch AMI. Corporations, such as smart meter manufacturers and data communication suppliers, are often providers of various resources and services.

However, some of them may have contradictory interests with each other. According to the news[1], the Dutch parliament had attempted to make smart meters compulsory and issue a fine in case of denial of installation so as to ensure the deployment of smart meters in the entire country. Nevertheless, consumers immediately started fighting against this imperative.

4.3 Major Stakeholders

4.3.1 Identification of Major Stakeholders

Stakeholders are entitled to different functions and responsibilities in Dutch AMI. As Figure 4.2 displays that stakeholders together are considered as a network, in which GOs are identified as the core of this network and other stakeholders are positioned around the core. However, the distances between the core and each stakeholder in the network are varied.

According to this figure, GOs, as the core stakeholders, are located in the center. There are five stakeholders are positioned on Ring 0 till Ring 1, most inner rings, including SC, EDSN, ISPs, Data communication suppliers, and Consumers with smart meters. These entities are in fact major stakeholders, as they have direct or indirect access to the AMI and are directly impacted by AMI. The entities on the outer rings, such as ICT suppliers on Ring 1 to Ring 2 and Consumer organizations on Ring 2 to Ring 3, are considered as minor stakeholders. However, it does not necessarily mean that these minor stakeholders are not important. As a

[1] http://www.tilburguniversity.edu/research/institutes-and-research-groups/tilt/news/archive/2009/04/

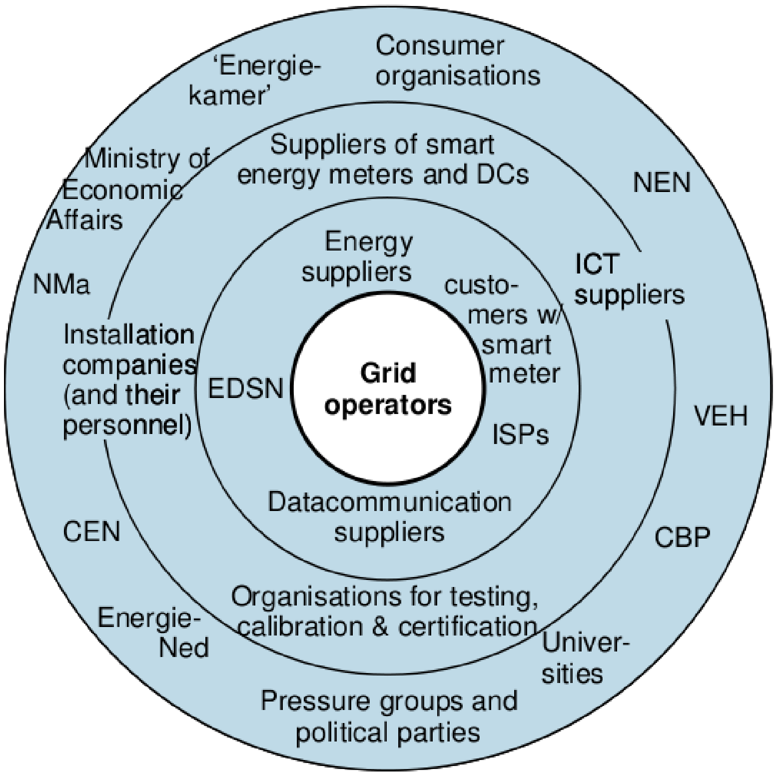


Figure 4.2: Major Stakeholders of Dutch AMI [6]

matter of fact, the implementation of Dutch AMI is driven by these stakeholders.

The metering data information particularly flows among the following stakeholders:

1. Grid operators (GOs) - periodically collect the technical data, and collect the metering data on request of SCs and ISPs [2];
2. Consumers - have the smart meter installed and produce metering data;
3. EDSN - facilitates the Dutch energy market;
4. Supplier companies (SCs) - sign energy supply contracts with consumers and use the metering data with consumers' permissions;
5. Independent service providers (ISPs) - provide consumers with value-added services concerning energy consumptions instead of energy, like

usage monitoring and remote management on energy consumption; and

6. Telecommunication providers - provide data transportation service to GOs, if needed.

Moreover, as the GO interviewee mentioned, among these stakeholders, telecommunication providers are not allowed to directly or indirectly operate AMI. They only provide network connectivity, if needed by GOs. GOs are allowed to choose their own data communication providers. To become or continue functioning as SC or ISP, an organization needs to be certified by NMa [2]. Only SC and ISP fully certified can continue operating in energy sector and request metering data through P4.

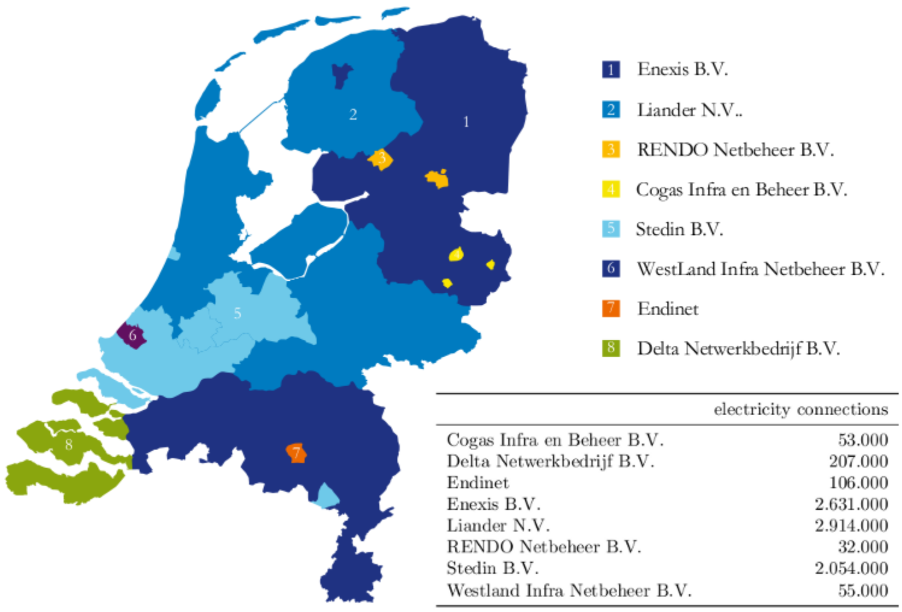
4.3.2 Roles of Major Stakeholders

As discussed in Chapter 2, according to the regulation, GOs are the owner and operator of the entire infrastructure. Moreover, they are the owner of smart meters, though smart meters are installed on customers' locations. When consumers move to another location, they are not allowed to carry the smart meters with them.

Furthermore, there are a number of GOs in the Netherlands, *e.g.* Stedin and Liander. Some large GOs operate in more geographical regions within the Netherlands on E (Electricity) and G (Gas) comparing to smaller sized GOs. (See Figure 4.3) [11][15]

According to the GO interviewee, consumers are the actual producers of the metering data. When a consumer consumes or produces energy and sends it onto the grid, the smart meter will capture the data and the supplier company will store the data for later billing.

As discussed in DSMR [9], EDSN is a nonprofit organization, playing the role of market facilitator and communication center. According to the GO interviewee, GOs are the only players who have direct access to the smart meters from outside of consumers' houses. However, when other players would like to get the



	electricity connections
Cogas Infra en Beheer B.V.	53.000
Delta Netwerkbedrijf B.V.	207.000
Endinet	106.000
Enexis B.V.	2.631.000
Liander N.V.	2.914.000
RENDO Netbeheer B.V.	32.000
Stedin B.V.	2.054.000
Westland Infra Netbeheer B.V.	55.000

Figure 4.3: Operational Regions and Number of Electricity Connections of Dutch GOs [16]

metering data, they have to request it from EDSN. EDSN will then check the request and relay it to the corresponding GO for further process. The metering data reading procedure will be elaborated in Chapter 4.5.1.

Nevertheless, the interview with the GO interviewee revealed that even though SCs and ISPs can request data from EDSN, consumers are entitled to deny the request. The fundamental difference between SCs and ISPs is that SCs provide energy to consumers but ISPs do not. However, it is possible for a SC to register as an ISP; and vice versa.

4.4 Smart Meters

4.4.1 Design of Smart Meters

The smart meters follow a port based design, as illustrated in Figure 4.4

- P0 is the configuration terminal, used by the mechanics.
- P1 is used by consumers to connect compatible home appliances.

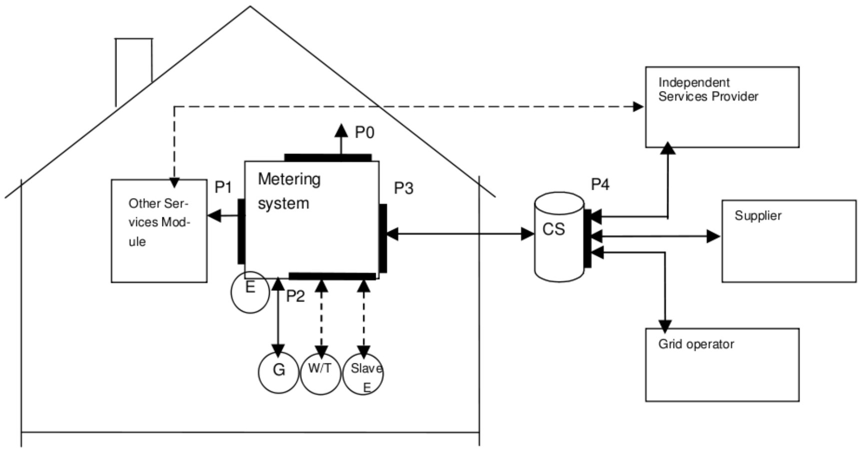


Figure 4.4: Smart Meter: Port Based Design [9]

- P2 is used to connect to other meters. Since E meter is used as communication hub for the other meters, it should be able to store and submit other meters' data.
- P3 is the connection to GOs, used for controlling and metering data reading.
- P4 is a virtual port. It is not on the meter but rather be seen as an extension to P3 through which other players can read the data and communicate.

The end-to-end communication is encrypted with at least Advanced Encryption Standard (AES) 128[2]. In order to be future proof, AES 256 and Elliptic Curve Cryptography (ECC)[3] are considered in DSMR [6].

To ensure that the metering data is safely stored and accessible, DSMR defines [9]:

- Smart meter's life time is 20 years (DSMR-M 4.3.4).
- Smart meter stores 15-minutes' read out for E and hourly read out for G (DSMR-M 2.3.1 & 2.3.2).

[2]Information on AES: http://en.wikipedia.org/wiki/Advanced_Encryption_Standard
[3]Information on ECC: http://en.wikipedia.org/wiki/Elliptic_curve_cryptography

- Internal clock survives 5 days in case of electricity outage (DSMR-M 4.3.6).
- E meter should keep the recent 10 days' interval read outs [2].
- E meter should keep the recent 40 days' day read outs (DSMR-M 4.5.2).
- E meter should keep the recent 13 months' monthly read outs (DSMR-M 4.5.3).

4.4.2 Communication Technology of Smart Meters

There are two types of smart meters based on the Port 3 communication technology, *i.e.* Power Line Communication (PLC) [4] and General Packet Radio Service (GPRS) [5] These two technologies do not co-exist on the same meter - either GPRS or PLC, but never both (See Figure 4.5).

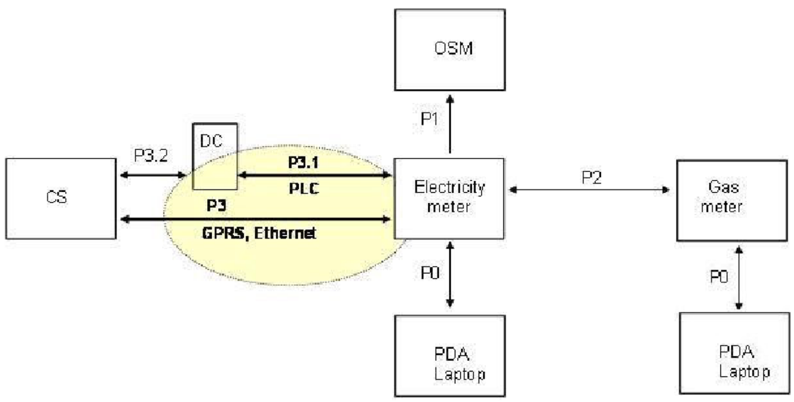


Figure 4.5: Smart Meter: P3 Technology [12]

The advantages of PLC include: (1) no additional cost incurs as PLC is already there; and (2) GOs have full control over PLC, as they own it. The disadvantage is that the transformer station destroys the PLC signal. Thus, in every substation there must be a data concentrator (DC). Moreover, other technology should be used to transfer the data back to the central system or a converter

[4] http://en.wikipedia.org/wiki/Power_line_communication
[5] http://en.wikipedia.org/wiki/Gprs

ought to be adopted to convert PLC signal from low voltage network to medium voltage network.

In case of GPRS, GOs have to rely on telecommunication provider's network to transfer metering data. This might result in higher cost, less control over the infrastructure, and endangering the metering data as it will travel through public network.

Currently, both PLC and GPRS are used based on different versions of DSMR [2]. Depending on the location and other criteria (such as line noise interference), one may work better than the other.

4.5 Metering Data

Essentially, there are two types of metering data, *i.e.* personally identifiable information (PII) and technical information [6].

- PII or privacy-sensitive data is information that identifies or describes an individual and includes at least the following items:[6]
    - Personal information, such as name, sex, age, etc.;
    - Connection information, including address, town/city, connection type and EAN Code. This information can be traced back to a specific location and specific person(s);
    - Consumption information ('measurement data') at the level of detail of quarterly, daily or weekly readings. This may contain information about the private sphere;
    - Monitoring information, provided that this contains the kind of details or is sent with such a frequency that information about the private sphere can be derived.
- Technical information includes the following parts: [7]

[6]Definition from [6]
[7]Definition from [6]

- Connect and disconnect commands and commands that limit ('restrict' or 'reduce') supply, which can be used to control the supply to a specific connection;
- Software, including firmware on smart meters, data concentrators, network devices, routers and servers, which can be used, amongst other things, to determine the operation and degree of security of the advanced metering infrastructure;
- Keys and passwords required to guarantee the authenticity and confidentiality of information and to gain access to systems or the content of messages;
- Device settings, including firmware configurations, time settings and volume units, which, amongst other things, determine how the meter stores and processes information;
- Other information at application level, such as non-privacy-sensitive monitoring information, instructions to check whether the meter can still be accessed, tariff structures, registration of events, etc.

Depending on the part of the metering data, different ownership applies [6]. PII is owned by the consumer who produces it. Technical information is owned by the GO to better maintain and leverage the service quality.

4.5.1 Metering Data Reading

As the GO interviewee explained that since EDSN serves as the communication center, it runs two databases directly under its own possession, *i.e.* Central Connection Registry (C-AR) and Other Service Registry (ODA). The request for metering data is either handled by C-AR or ODA, depends on the requesting party. Particularly, C-AR is used by SC and ODA for ISP.

GOs currently run their local AR (local connection registration). The connection and meter information is stored in the local AR. However, this situation is expected to change in the near future, as all the GOs are registering all the contents within their local ARs into the C-AR. In the current situation, when SC or ISP requests the data, EDSN has to check it, lookup the GO, then pass the message to GO. The GO looks up the meter, reads the data, then sends it back to EDSN. By 2014 all the connection information will be available in C-AR. The lookup procedure can be done already at EDSN.

In practice, there are two different situations as shown in Figure 4.6. In the first situation where GOs have both electricity and gas connections, the smart meter

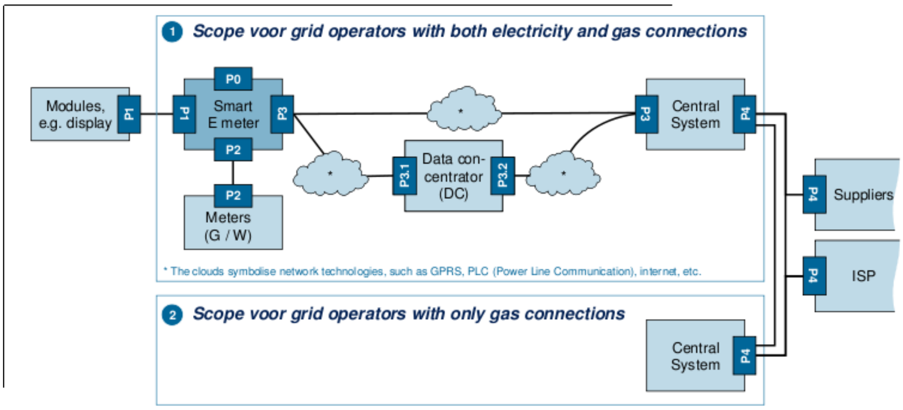


Figure 4.6: Metering Data Reading in Two Cases: 1) GOs with both Electricity and Gas Connections 2) GOs with only Gas Connections [6]

stores consumption data in 15-minutes' interval for electricity and for other meters once per hour. When ISP or SC requests, the metering data can be pulled through EDSN and GO. The data is transmitted through a data concentrator in case of PLC or directly to the central system of GOs in case of GPRS. In the other situation where GOs have only gas connections, they have to rely on other GOs' E meters to transmit the data. This is because DSMR defines that E meters, as smart meters, should provide other meters with network connectivity.

By regulation, the lower limit of data reading is 6 times a year, *i.e.* once every two months [9]. However, consumer can choose to "opt-in" or "opt-out". In case of "opt-in", the contracted parties, SC and ISP, can read particular consumer's 15-minutes' interval smart meter read outs once every day. In case of "opt-out", no one, neither SC nor ISP, can read the data at all. It is a bundled permission, either 6 times according to the regulation for SC and ISP, or daily 15-minutes' read outs, or completely no read out for any one (consumers can still read from the integrated reading panel and P1 as shown in Figure 4.6).

The metering data reading behavior is monitored by Dutch Competition Authority (NMa) and Chamber of Energy. EDSN is the actual party which checks every request and then forwards the request to GO for further process, if and only if the party is allowed to read the specific data. However, with regard to how often the metering data can be requested, it is not checked at all. This is the part that SC and ISP both need to be audited by the third party every year. Additionally, the auditing report should be checked and archived by GOs [2].

4.5.2 Metering Data Volume

We do not know the size of the metering data, neither the size of the request nor the size of the response. It is also difficult for us to know the exact layout of the signaling message the GOs are going to use. However, based on the existing figures and technical specifications, we may roughly estimate the metering data volume.

The following estimates are based on the number of households in the Netherlands in 2011 which is 7.4 million, though this number is expected to increase remarkably in the coming decades[8]. Based on the default annually 6-times' metering data reading, the frequency for all the households is approximately:

$$\frac{1\, read\, out \times 7.4\, million\, households}{61\, days(\approx 2\, month) \times 24\, hours \times 60\, minutes \times 60\, seconds} = 1.4\, Hz$$

About three requests are sent in every two seconds through out the whole year, despite that the technical part is not included yet in the calculation. We are not sure if the pulling of technical data and metering data can be combined. They mostly follow a different pulling schedule by default *e.g.* once per two months for metering data and once per hour for technical data.

If every household choose to "opt-in", the frequency is approximately:

$$\frac{1\, read\, out \times 7.4\, million\, households}{24\, hours \times 60\, minutes \times 60\, seconds} \approx 85.6\, Hz$$

[8] Article by CBS - Statistics Netherlands `http://www.cbs.nl/en-gb/menu/themas/bevolking/publicaties/artikelen/archief/2011/2011-3365-wm.htm`

About 86 requests are sent every second, again despite the technical data part. If we add in also the technical part, in total it will be:

$$85.6\,Hz + 85.6\,Hz \times 24\,messages\,/\,day = 2140\,Hz$$

The calculation above is at message level. At packet level, a response to a periodic meter read request on E meter contains 4 register values *e.g.* two for consumption with different rates and two for production [9]. As we mentioned before, consumers can also produce energy, and therefore this volume should also be captured. The data included in the estimation is only the register value. Other data, such as indicator of consumption or production, is not included. Hence, this estimation only shows the minimum possible data volume. The assumption is that a single register value contains a 6-digit figure as presented on display panel of the E meters being used nowadays. A 6-digit figure can be stored in 3 bytes. One single response, with pure metering data part, is then 12 bytes. For metering data part, approximately 86 responses will be sent per second which yields:

$$86\,Hz \times 12\,bytes \approx 1032\,bytes$$

The technical part contains various information, it is difficult to estimate the size of the data. However, taking into account that there are all kinds of information, *e.g.* voltage, error report and etc. This part of data could be several times larger in size than the actual metering part.

Considering the overhead of TCP segment, IP packet and AES cryptography suite, the size of a response can easily add up to 1500 bytes which equals to 12 kbits. The maximum speed of G3-PLC is 33.4 kbps. PRIME is more than three times faster, 128.6 kbps [17]. The calculation above assumes that the requests are smoothly scheduled and evenly spread throughout the whole year time frame. In reality, the DSMR requires that within 6 hours, a national wide pull of metering data should be accomplished which makes the task even tougher [9].

4.5.3 Privacy

Prior research has revealed that AMI may possibly endanger consumers' privacy [18][19]. As shown in Figure 4.7 and Figure 4.8, when the sampling rate of energy consumption taken by a smart meter is small enough, privacy related

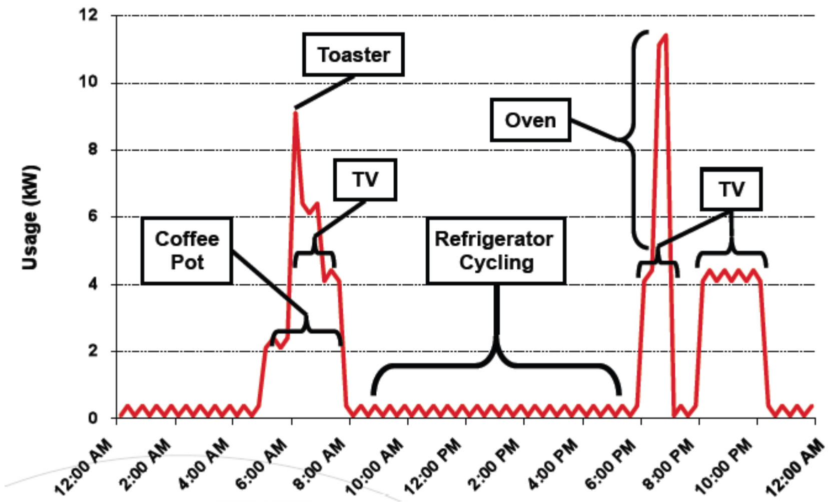


Figure 4.7: Identification of Home Electronic Appliances and Deduction of Indoor Personal Activities based on Line Noise [20]

information (such as personal activities inside the house and personal electronic appliances) could be deduced based on the technical data, such as line noise. Since technical data are owned by GOs, GOs are allowed to store and use them. In order to avoid this type of privacy issue, the interval that smart meters store metering data is regulated [6].

As privacy is a major concern on the implementation of AMI, to better protect consumers' privacy, the meters are not allowed to push data actively. On contrary, the metering data can only be pulled based on particular request. Even GOs have to pull the data, as the meters will not actively push data to any party.

Furthermore, consumers can opt-in or opt-out for metering data reading as discussed in Chapter 4.5.1.

Stakeholder	Name	Description
GO	grid operator	Owner of the network, AMI, smart meter. They transfer the energy to consumers
GOG	grid operator for gas	GO who transfers gas
GOE	grid operator for electricity	GO who transfers electricity
ISP	independent service provider	They are independent from GO and SC and provide services by using the metering data
SC	supplier company	They sell energy to the consumer; They are not producing nor transporting energy
EDSN	energie data service nederland	Facilitator for energy market, owner of the central registration system for GOs. Responsible for P4 message traffic and associated process model
Netbeheer Nederland	umbrella organization of GOs	This is the organization which defines smart meter requirements
Consumer	consumer	Who uses energy according to the contract with a SC
Telecommunication Provider	Data communication supplier	Provide communication network (GPRS) for transferring metering data or other information flow
NEN	Dutch standardization organization	Standardize requirements according to Dutch market or give new standard according to Dutch specific requirements.
Energie-Nederland	Sister organization of NetbeheerNederland	Assist NetbeheerNederland
NMa	Netherlands Competition Authority	NMa enforces fair competition between businesses in the marketplace.
NEDU	Netherlands Energy Data Exchange Association	
Chamber of Energy	Regulator of Dutch energy market	Regulator of Dutch energy market

Table 4.1: Stakeholders of Dutch AMI and Description of their Task Domains

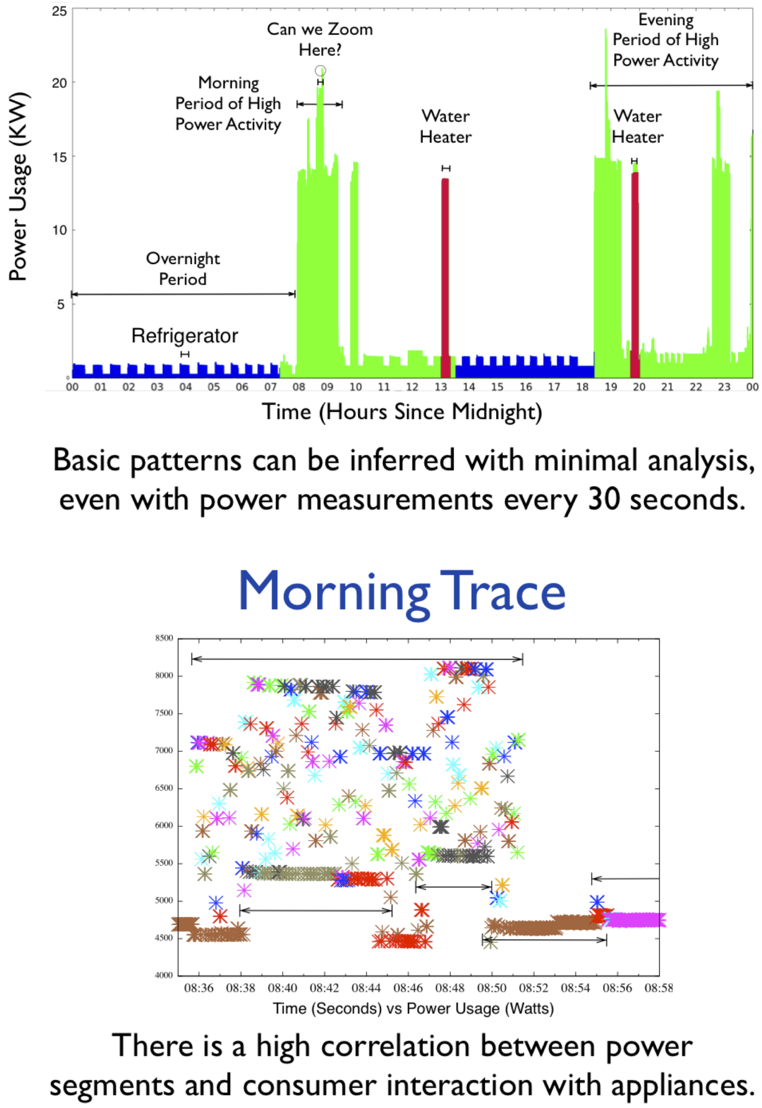


Figure 4.8: Deduction of a Consumer's Schedule based on Consumption Data [21]

Chapter 5

Conclusions and Recommendations

5.1 Conclusions

In reaction to EU request and to fulfill the increase demand in energy capacity, the Netherlands has started the liberalization of its energy market and the deployment of its own AMI. This descriptive research aims to systematically describe Dutch AMI by identifying its specifications, major stakeholders and their corresponding task domains, and the metering information flow between these stakeholders.

First, this study reveals that DSMR identifies the comprehensive specifications of Dutch AMI. This is a synthesized requirement document, constructed based on two independent legal and technical requirement documents, *i.e.* AMvB and NTA8130, respectively. The specifications of Dutch AMI consist of general requirements, requirements of access and security, and specific requirements derived from NTA8130. In case of a contradiction between legal and technical requirements, the legal requirements derived from AMvB should always be followed.

Second, numerous stakeholders with different interests are involved in Dutch

AMI. Five major stakeholders and their corresponding roles are specifically identified in this research, including (1)GOs, the owner of the infrastructure; (2) Consumers, producer of usage data; (3) EDSN, market facilitator; (4) telecommunication providers, provider of GPRS network; and (5)ISP, provide value-added services to consumers. Figure 3.1 illustrates the overview of Dutch AMI system which consists of the aforementioned major stakeholders.

Moreover, there are two key information flows between stakeholders within Dutch AMI, including: (1) The communication between GO and the consumer (smart meter) either uses PLC or GPRS - PLC requires data concentrator to facilitate the communication between different voltage networks; and GPRS uses telecommunication provider's network to transfer data; and (2) EDSN runs both C-AR and ODA to let SC and ISP access to metering data through them respectively. While the infrastructure of both databases is maintained by EDSN, the contents of both are maintained by GOs through their local databases.

5.2 Recommendation

The research findings have drawn our attention to the following issue. The performance of the system can be fine tuned. According to the research findings, the current route of information flow of the metering data reading follows this pattern: 1) the requesting party sends a request to EDSN; 2) EDSN checks the message to ensure that the requesting party has the right to read, then sends it to the corresponding GO; 3) the GO receives the message and looks up the meter then pulls the metering data; 4) after the GO gets the information, it sends the information back to EDSN for relaying; and 5) EDSN receives the information and relays it to the requesting party. This "EDSN relays every bit" model could have been discussed over and over among different stakeholders, all kinds of thoughts and compromises could have been made to form it. However, in step 4) and 5) EDSN is still relaying data while it does not have to since GO can directly push the data back to the requesting party. For the sake of better performance, Dutch AMI could use a concept similar to "TCP-handoff". TCP-handoff can pass the duty of serving TCP connections to another selected replica[1]. The load of one server can be offloaded to other servers. The "middle man", in this case EDSN, checks the incoming request and let GO push the response directly back to the requesting party. As illustrated in Figure 5.1, the information flow, marked with dotted green lines, follows a triangular pattern instead of two times the bi-directional routing, marked with dotted red lines.

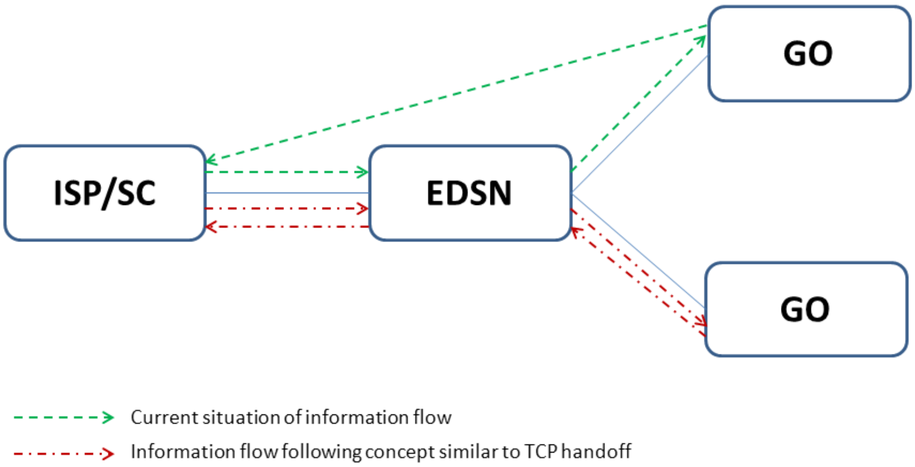


Figure 5.1: Information Flow With TCP handoff and Information Flow in the Current situation

But this setup should be carefully tested to see if the performance enhancement worths the trouble breaking the "physical isolation" of GO's network to the outside world.

5.3 Limitations

Four limitations are concerned in this research. First, due to the unavailability of interviewee from EDSN, we could not conduct interview with this major stakeholder. As EDSN facilitates and coordinates the entire AMI, the data collected from it could substantiate and supplement our research findings.

Second, due to the time constraint, we only had a single interviewee of each major stakeholder, *i.e.* consumers and GOs. Due to the different background

[1] TCP handoff explained `http://students.mimuw.edu.pl/SR/prace-mgr/szymaniak/node5.html`

of consumers, such as income, education level, gender, and different operation locations of GOs, the findings could be slightly different from more respondents. To increase the generalizability of the research findings, it is ideal to interview more respondents and draw the conclusions based on more extensive data.

Third, this research lacks a field study, such as observation on site of GOs. The field investigation of the Dutch AMI system can show a concrete picture about how the system works at operational level.

Last, due to the limited time frame of the study, we cannot conduct a simulation of AMI. The performance, behavior and topological change of the meter network were not verified. If a simulation can be conducted, we may provide more comprehensive recommendations based on a deeper understanding of Dutch AMI.

5.4 Future Research

Corresponding with the aforementioned limitations, we suggest future research interviewing the rest major stakeholders identified in this study, collecting data from more representative samples, and conducting field study. Particularly, as stakeholders may have contradictory interests, the discussions with more different stakeholders may help understand the system more comprehensively, find out the crucial problems, and develop corresponding solutions to keep optimizing the Dutch AMI and facilitating the liberalization of Dutch energy market.

Moreover, technical research on the communication technologies of the AMI system would be of great fun to carry out. This research may potentially be combined with a Monte Carlo simulation to better illustrate the system in reality.

Appendix A

Interview with stakeholders

This interview question list was applied to the interviews with different stakeholders. The data collected from the different stakeholders were compared to see if their opinions and understanding of the Dutch AMI is consistent.

A.1 Questions for interview

1. The big picture of the electricity network (relationships between among EDSN-consumer-supplier-regional grid operator-energy generator) in your view

2. How the consumption/production is measured? (metering data communication)

3. How to deal with the energy consumers put back onto the grid

4. Who is the owner of the metering data, where is it stored for how long. Who can view/change it?

5. What is C-AR, CAS (I know C-AR and CAS, but how exactly it is going to be used)

    (a) Who owns the C-AR, system, infrastructure and legally? Who operate it, manage it and maintain it.

    (b) Who initiate the registration, and what has to be logged in C-AR.

(c) Rights on the C-AR, who can read/write what.

6. Some use cases of AMI, like meter reading and permission assigning

   (a) User switch supplier within the same region (no GO change)

   (b) User switch supplier in another region (user moved, GO change)

   (c) User move to another region, stay with same supplier (GO change)

   (d) User move to another region, switch to another supplier (supplier change and GO change)

A.2 Interview report

- Background

  1. GO operates $\leq$50KV for electricity and 8 Bar for gas grid.

  2. GO owns the whole infrastructure including the meters.

- Metering Data

  1. By law the low limit for metering data reading is 6 times per year. This can be increased on consumer's request or denied by the consumer at all. Metering data is available at meter in 15 minutes interval for electricity and 60 minutes interval for gas and read by GO every day (when necessary), higher frequency is possible.

  2. The metering data consists of two parts: technical part (technical data) and personal part (usage/billing data).

  3. Technical part contains electricity quality, outage information and etc. The owner of the technical part is the GO, and GO use/stores it for the purpose of better facilitating the network and leverage service quality.

  4. The personal part contains the meter readout which can contain personal information (usage/billing data, due to privacy law considered as personal data). GO will only store 40 days reading and 10 days' interval readout in order to let SC and ISP read the information.

- Communication

1. EDSN, is the communication hub between GO and SC/ISP for smart meter messages. Every communication has to go through it. GO checks every message (*e.g.* via C-AR or ODA-register).
2. EDSN runs C-AR which contains the information from all the local (GO) ARs. Technical maintenance of C-AR is done by EDSN, the information is maintained by GO's and SC's
3. ODA-register is a local database of the GO. Technical maintenance is done by GO and information is provided by ISP.
4. By 2013, every connection should be in C-AR. Till then both C-AR and local AR are used.
5. SC and ISP do not have direct access to the smart meter. They can only access the data through a virtual interface: P4.
6. SC/ISP accesses the smart meter data (usage/billing data) through the virtual P4 interface.
7. NMA/Chamber of Energy carries the responsibility for checking if parties do follow the rules of the electricity en gas law (in this case specific: correct handling of smart meter data reading/exchange)
8. CBP is responsible for checking if parties do follow privacy law
9. GO, SC and ISP have to be certified to be able to function as the roles on the virtual port P4.
10. GOs demanding a yearly audit from SC and ISP on the reading behavior to prove that the readings are well regulated and within the permission of the consumer. Hence during the reading only the permission, whether the requester is allowed to read the data, is checked. But the extra contract, how often the data can be read, is not checked.
11. Consumer asks SC or ISP for the metering data, the SC or ISP forward the request to EDSN on P4, EDSN checks it (is the message from a certified party) then forward it to corresponding GO, GO checks the message (several checks) and GO give back the reading via EDSN to the SC/ISP.

12. The communication happens at message level.
13. The EAN code is used as the ID when requesting the data. The EAN to MID (meter ID) lookup is done at local AR by GO. By 2013, this could be done at EDSN means every connection and MID in C-AR.

- Meter Specification

  1. At this moment there are two types of smart meters according to the communication technology used: PLC and GPRS. They do not co-exist on one single meter.
  2. Both PLC and GPRS meters are being used.
  3. PLC uses DC (data concentrator) at transformer station.
  4. GO can choose telecommunication provider for GPRS
  5. The currently rolled out smart meter are manufactured according to DSMR 2.2+
  6. All the Dutch smart meters carry the same specification according to DSMR (exception: older smart meters. They are not manufactured according to DSMR). But DSMR has different versions.
  7. The meters can come from different suppliers.
  8. As of 2013, GOs are purchasing meters according to DSMR version 4.
  9. By 2015 DSMR will hit version 5, this might be comply to the might be EU meter standard.
  10. EU meter standard is being developed.
  11. Kill switch is available on every smart meter (functionality is not used at the moment, foreseen in 2013). From 2013 the energy sector is planning to start using the switch function.

- Legislation

  1. In long term, the SC should be the single contact point for consumer, consumer only get single bill from them. From April-2013, only one bill of both usage and transportation for one consumer.

Appendix B

Glossary

AES	Advanced Encryption Standard
AMI	Advanced Metering Infrastructure
C-AR	Centraal Connection Registration
DSMR	Dutch Smart Meter Requirements
ECC	Elliptic Curve Cryptography
EDSN	Energy Data Service Netherlands
GO	Grid Operator
GPRS	General Packet Radio Service
ISP	Independent Service Provider
NMa	Netherlands Competition Authority
NEN	Dutch standardization organization
ODA	Independent Service Registration
PLC	Power Line Carrier
SC	Supplier Company

Table B.1: Glossary

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