COMMUNICATIONS REQUIREMENTS FOR SMART GRIDS

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ABSTRACT

In the EU FP7 Project ADDRESS requirements on the communication architecture for a Smart Grid including Active Demand have been developed. In this paper we summarize the methodology applied – a survey and a use case-based analysis, and the results of this specification, as well as the elements of the base architecture. The Traffic Matrix is introduced as a tool for dimensioning the communications.[1]

INTRODUCTION

ADDRESS ("Active Distribution networks with full integration of Demand and distributed energy RESourceS") is a four-year large-scale R&D European project launched in June 2008. The aim of the project is to develop a comprehensive commercial and technical framework for the development of "Active Demand" and the market-based exploitation of its benefits [1], based on the role of the Aggregator as supplier of services using Active Demand.

In ADDRESS, "Active Demand" (AD) means the active participation of domestic and small commercial consumers in the electricity markets and in the provision of services to the other electricity system participants. AD involves all types of equipment that may be installed at the consumers premises: electrical appliances ("pure" loads), distributed generation (such as photovoltaic or micro-turbines) and thermal or electrical energy storage systems. The proposed architecture relies on the concept of aggregation of demand flexibility. The aggregation function gathers the "flexibilities" and contributions (e.g. increase or decrease of consumption) provided by the consumers (and prosumers, i.e. both producers and consumers) to form AD-based services and offers them to the electricity system participants through various markets. The Aggregator is the entity that performs this function. See [2], [3] for a detailed description of the ADDRESS architecture.

In this paper we describe the initial results of the communications activities within the project. The communication architecture must provide the framework for a telecommunication infrastructure between consumers and Aggregators, and then also between each Aggregator and other energy market and system participants in order to enable Active Demand. The goal is to define a guideline for designing and testing the communications architecture for a Smart Grid, with a high penetration of Active Demand.

The paper is organised as follows. In the first section the two key tools of the methodology are described: (i) a survey on the current status of utility communications architectures and the expected developments in the near future, and (ii) a use case-based approach. In the following section, the results are outlined, summarizing the survey results, and some results from the use case analysis. Subsequently, the initial architectural decisions are described. In the conclusion, the results are summarized, along with the next steps in the project.

METHODOLOGY

The overall process adopted for the definition of the telecommunication requirements must take account of the following main elements:

- The ADDRESS model description where all actors, their interactions and business services are defined.
- That the communications infrastructure will usually be implemented based on an existing architecture.

In order to satisfy the first main element, it was decided to follow a use case-based approach, as is known in the standardization communities. In the other ADDRESS workpackages use cases were defined, see [3]. These were then further analysed according to the methodology detailed below.

For the second main element it follows that a survey should be made of the existing communications infrastructure and the developments already planned by utilities. To this end a survey was designed and sent to all Project members and members of the Project advisory group – the Group of Users and Stakeholders (GUS). The survey is described in the second subsection.

It is worth mentioning that the whole process of requirements definition is iterative. It helps to define (from the first iteration) a draft for the generic communications architecture which is be used as input for the rest of research activities to be performed within ADDRESS, and then to iterate as the research activities provide more detail.

Methodology: Use Case Analysis

The overall architecture within the project is described by use cases, e.g. as shown in Figure 1, see [3]. In particular the interactions between the DSO, the Aggregator and the consumers are described for the process of preparing, offering and delivering active demand services. An important result for the project is to model the interactions as UML sequence diagrams, formally being represented using the UML 2.0 modeling language, although it is important to note that in Figure 1 is not fully UML

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compliant. Based on the use case analysis, the messages exchanged between the Entities can be roughly identified. The messages and payloads are then defined in terms of CIM messages in XML, which may then be transmitted by web services. This guarantees interoperability, and possible future standardization. In particular, the analysis of the interactions and messages exchanged provides some of the functional requirements, for example how often messages must be exchanged, and what the latency may be. The requirements and interaction diagrams are considered as an input to deriving the communications architecture.

Methodology: Survey

A survey was conducted with the project participants and the group of users and stakeholders in order to determine the status and expected developments of the current communications system, and perceived specific smart grid requirements. The survey also investigated participants' perceptions of telecommunication requirements in the context of Active Demand.

A total of 18 international organizations answered the survey, including utilities, telecom and electric equipment manufacturers, research institutes, laboratories and consultants from Europe and US. The results provided details concerning utility requirements in diverse areas such as interoperability, physical media constraints, scalability, regulatory issues, standardization, performance (both technical and business), robustness and availability, ease of use, management, upgrading capabilities, security and cost-effectiveness.

The answers received were analyzed to converge to a single set of requirements. For conflicting answers, a discussion and decision process ensured that the result represented the broadest consensus on that requirement.

COMMUNICATION REQUIREMENTS

In this section we summarize the requirements derived from the two methodological steps described above.

Based on the Use Cases and Sequence Diagrams, some basic functional requirements of the telecommunication infrastructure may be derived:

- A static representation of all actors/entities participating in the active demand process (use cases diagrams).
- A dynamic description of the interactions between each of them when interested by a specific service (sequence diagrams).

From the survey, a table was devised for all the relevant requirements. The main key parameters were defined and prioritized for any relevant telecommunication layer. Some of the most relevant requirements are:

- Maximum non-critical data retrieval time between different actors (e.g. Aggregator to Energy Management Box, utility to smart meter) is 15 minutes (loose real time concept)
- Interoperability between vendors and actors must be guaranteed. This is best implemented through open industry-wide standard protocols, including management protocols and firmware upgrades.
- The number of communications interfaces each device presents must be minimized, based on a flexible portfolio of physical media. Simultaneously all devices must allow for remote access based on standards.
- Communications between the smart meter and the Energy Management Box shall be possible, but not mandatory.
- Communication between actors (e.g. Aggregator, utilities, markets…) shall be based TCP/IP, as it is usually Internet-based.
- The architecture shall be designed so that an Aggregator is able to serve at least 100,000 Energy Management Boxes.

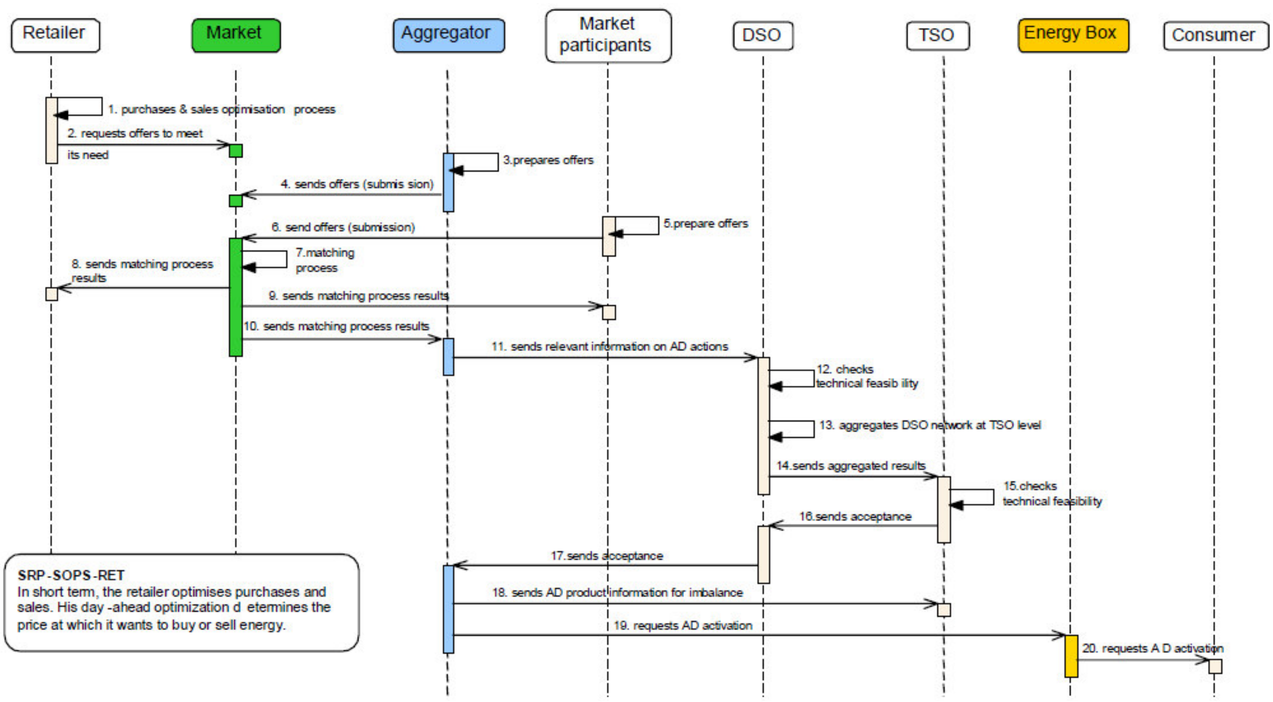

Figure 1. ADDRESS Service Sequence Diagram Sample [SRP-SOPS-RET], see [3] for further details

- Most real time transactions between actors are expected to require 2Mbps over Internet-like connections, with a delay of about 1 second.
- Communication to smart meters is expected to require low speeds in the order of few kbps.
- Communication with Energy Management Boxes connected to Internet providers are required to support at least normal broadband 2Mbps/300kbps throughputs, but the minimum real traffic to be expected is 16kbps.
- Normal utility operations are not to be disturbed, so critical communication paths that could affect utility network stability are required performance close to 100% availability (with redundancy). For market and end-customer transactions a 99,9% is expected, with no outages above one hour per month allowed.
- State-of-the-art security and encryption is to be applied to all ADDRESS systems, so that accountability, authentication and data confidentiality and integrity is guaranteed on a per-customer basis.
- Plug & Play, self-configuration are required, along with full remote configuration capabilities based on open management protocols.
- Aggregators shall be able to prioritize different traffic flows as part of their services.
- An Energy Management Box or a smart meter shall have a maximum real cost of 100€ each.
- Lifetime of any devices greater than 15 years.

DRAFT COMMUNICATION ARCHITECTURE

In addition to the use cases, sequence diagrams, and survey results the following additional aspects were considered in order to focus other relevant features of the communication architecture.
We can define two main concepts, from communication point of view, applicable to each ADDRESS Actor:

1. Access Point: The physical termination where a communication channel ends. E.g. a channel where messages are exchanged between Energy Management Box and Aggregator subtends two access points (one for the Energy Management Box and one for the Aggregator)

Entity	Entity Cardinality	Server Cardinality	Access point Cardinality
Market	Single	1 Server	>1
DSO Nat. Reg. Munic.	[1…5] [1…5] [10…20]	Many	>1
TSO	Single	Many	Many
Aggregator Nat. Reg.	[1…5] [1…2]	Many (>1 each)	>1 each
Market Participants Retailers Traders Producers	[50…100] [100…500] [1000…10'000]	Many (>1 each)	Many
Energy Management Boxes	[10'000…100'000]	N/A	1 each

Figure 2. ADDRESS Communications Key Players

2. Application Server: Different kinds can be considered:
   - Application Servers for Technical issues
   - Application Servers for Billing (where applicable)
   - Application Servers for communication purposes.

Note: For the business and management layers, specific servers must be considered, while for Energy Management Boxes, a single Server instance contains both technical and communication management in the same box.
In Figure 2 the key players in the ADDRESS communication are identified with their cardinality, and the cardinality of the servers and access points, which are key for the design of the communication architecture.
In the ADDRESS Project, the choice was to make use of SOA (Service-Oriented Architecture) and Web Services. A Service-Oriented Architecture is essentially a collection of services. Each function or business process of an actor is represented as a Service - a well-defined, self-contained function, it does not depend on the context or state of other services. These services communicate with each other via Connections. The communication can involve either simple data passing or it could involve two or more services coordinating some activity. Some means of connecting services to each other is needed. This may be done via Web Services, which are defined as an evolving set of protocols used to define, discover, and implement Services over the Web. Detailed descriptions may be found in the rich literature available on the subject, see e.g. [4,5].
The needs, in terms of communications resources, are estimated by first considering the logical flows of data exchanged among each actor as defined in the ADDRESS model. Data flows can be easily represented as in Figure 3, where the numbers of sequence interaction refer to the specific iteration as described into the UML service

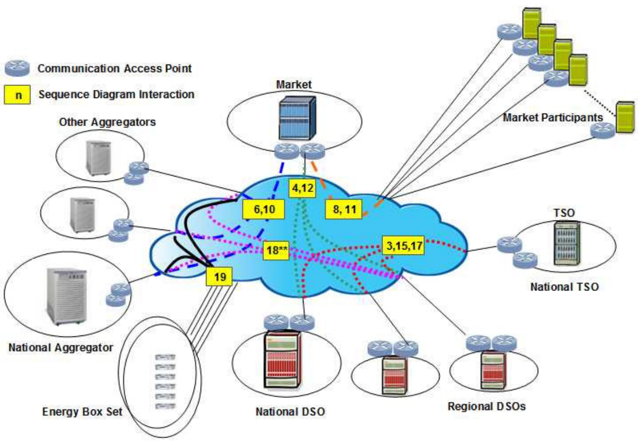

Figure 3. End to End logical connectivity supporting specific business service

Sequence Diagram.
Indeed the aim of preliminary phase devoted to drafting the communication architecture includes the identification of the key characteristics of the interconnections between each access network element in order to guarantee adequate support to each business service to be implemented.

To this end, for each interconnection the set of messages, the data exchanged and related rules of generation and propagation will be highlighted.
Once identified, the traffic on each connection further telecommunication aspects will be addressed: the nature of the messages and the policy for their management.
All elements will be then reported within a synthetic message table, see Figure 4.
Starting from the message it is possible to make an rough estimation of the Matrix of the Offered Traffic. In Figure 5, a sample traffic table is shown, whereby some assumptions have been made in order to add the overhead protocol bits to each application payload message.

TSOack	**Message Payload Short Description**		
From → To (n:m)	TSO → DSO (1:6)	Note:	
Payload (Application Layer)	Data	Lenght (bit)	Note
	Parameter	256	Description
	TimeStamp	64	Standard Reference
	Sender ID	*32*	*Example:*
	Total	**352**	
Traffic	(60;60)	(Frequency Periodicity in second; Max Round Trip Time including channel and Telecommunication Interfaces in seconds)	
Priority	L		Low; High

Figure 4. Message Table

Service	Session #	Total Payload Layer 7 (bit)		*Total Payload + Protocol Overhead L1->L4 (bit)*	
		TSO	DSO	*TSO*	*DSO*
ADDSER01	1	1000	2000	*10000*	*20000*
	2				
	n	500	400	*5000*	*4000*
	TOT	**1500**	**2400**	***15000***	***24000***

Figure 5 : Matrix of the Offered Traffic Sample

Through the aggregation of several traffic matrices it is possible to estimate the capacity of all interconnections to be used in the communication infrastructure.
However the communication architecture should also include other components not directly related to the message payloads to be transported, e.g. the network management system and mechanisms implemented to guarantee the requested security level on each segment of the network. In Figure 6 a layered architecture were several components are depicted is shown.

CONCLUSION

In order to enable Active Demand as developed in the ADDRESS project, a specific Smart Grid Communication Architecture will need to be designed and implemented. In this paper we describe some requirements and preliminary results regarding this communication architecture. Key architectural decisions are to use a Service Oriented Architecture and Web Services to implement the communication, based on generic XML messages, in line with ongoing standardization work. The Traffic Matrix is developed as a key tool for deriving the functional requirements, showing that a distributed architecture is required.
Starting from telecommunication requirements the first draft architecture will be designed, where several decisions and policies on technologies and their collaboration have to be

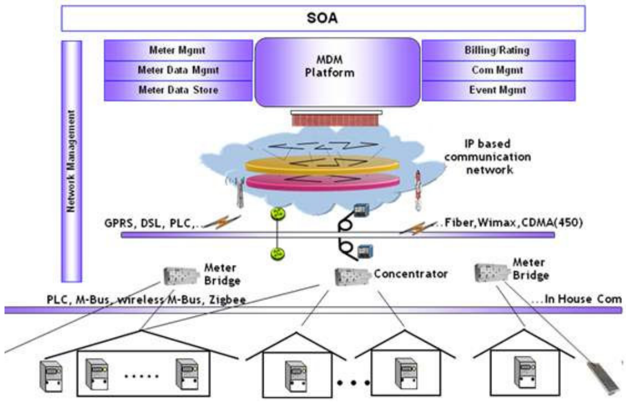

Figure 6. Layered Generic Communication Architecture

made. This preliminary architecture has to be compliant with all requirements even if not yet optimized.
Some key requirements are:

- Flexibility with respect to physical media, e.g. last mile likely to be PLC, wireless, or re-routed via public telecom
- Full interoperability for all network elements
- Secure remote access to all elements of the network
- Implementation to be compatible with TCP/IP and Web Services
- Communication performance should be independent of grid state
- Aggregator and consumer equipment must self-configure.
- Network management: visualization & remote configuration

The results also show the applicability of a use case based analysis for deriving the communications architecture for a smart grid. In further work these requirements and the draft architecture will be detailed to provide guidelines on how to design the overall communications architecture.

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