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First Step Towards a Smart Grid Communication Architecture for the Brazilian Federal District

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Abstract: Most electrical grids worldwide employed are outdated, and this includes the electrical grid of the Brazilian Federal District (DF). In order to cope with new technological requirements that arise from an increasingly automated devices of power and communication systems, the concept of smart grid has spread. Smart grids involve completely integrated systems allowing better control of data as well as the improvement of energy efficiency. This work proposes a Smart Grid Communication Network (SGCN) in the context of the DF, in Brazil. Firstly, the present work gathers demographic and electric power meters information from the DF region. Afterwards, the data capacity requirements are calculated based on the joint information. Finally, suitable communication technologies for each subnetwork of the SGCN are suggested. This work is a first step towards the implementation of a SGCN on the DF.

Keywords: Smart grid, communication system.

1. INTRODUCTION

The world's perception of electrical energy has changed significantly over the last decades. Climate changes and greenhouse gases have become a significant problem and balancing energy supply and demand is more complex than ever. In addition, the utilization of renewable energy sources comes with barriers when we consider our current electrical grid. In this context, the concept of smart grid comes into scene to fit these aspects.

Current electrical grids operate as *broadcast* grids according to Fang et al. (2012). Therefore, the energy is generated in different sites and manners, as from nuclear to hydroelectric power plants, being in sequel transmitted to the consumers, i.e. houses and industries. Since energy storage is generally expensive and inefficient, it is necessary to control the amount of energy generated in a way that it is totally consumed. This task has become more complex than ever and, as a consequence of the high instantaneous levels of electric power demand achieved, has resulted into black-out in certain regions.

Another drawback in our current electrical grid is the lack of support, appropriateness and use of renewable energy sources, since the energy is continuously provided. Considering the necessity of employing increasing amounts of power by means of renewable resources and the inadequacy of the current grids to cope with intermittent generators, improvements on the structure of the current power grids are required.

In order to adjust in real-time the energy supply and consumption, the electric grid should be monitored. By monitoring the network, near-real-time energy pricing and consumption information can be provided. Hence, smart grids imply into improving the system reliability, reducing the ecological impact and improving operational and electrical efficiencies of the grid as shown in Flynn (2009).

Since smart grids allow the full integration and connection of the whole system, a relevant part of their conception comes from the use of communication technologies and the development of a smart grid communication network (SGCN). The basic idea of the SGCN is to create a network connecting the consumers and the utility company. According to Wollenberg and Amin (2005), from a refinement of the National Institute of Standards and Technology (NIST) Smart Grid System Architecture, the basic elements of the SGCN can be outlined. More detailed

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information about the structure of a SGCN can be found in NIST (2009).

For energy management applications, a communication network must provide some essential qualities, such as high reliability and availability, high coverage and distances, security, low delays, among others as shown in M. A. Hammoudeh (2012). On the other hand, the different types of information being carried have distinct requirements and delay tolerances. T. Otani (2010) presents tables that summarize the communications requirements of information coming to and from customer's gateway.

Each network carries different volumes of information and within different ranges. Therefore, they present different communication technologies. In the context of the Brazilian Federal District (DF), we are going to focus on three of these subnetworks, namely Neighborhood Area Network (NAN), Field Area Network (FAN) and Wide Area Network (WAN).

The rest of this work is organized as follows. In Section 2, we analyze the demographics and the data capacity requirements for the DF. In Section 3, we propose a SGCN based on the requirements defined on the previous Section and on cases of other SGCN already implemented in different cities. Finally, in Section 4, conclusions are drawn.

2. DEMOGRAPHICS AND DATA CAPACITY REQUIREMENTS FOR THE DF

In this section, we primarily analyze and categorize the regions that compose the DF and, afterwards, from this perspective, we calculate the required data capacity for the SGCN architecture.

As described by Moura (2009), the administrative regions on DF can be classified into four categories, namely, dense urban, urban, suburban, and rural. The dense urban regions have a population density greater than 2500 inhabitants per km^2, while urban regions, the population density ranges between 800 and 2500. The population density of a suburban region varies between 100 and 800 inhabitants per km^2, while for rural regions, this value is up to 100 inhabitants per km^2.

Table 1 provides information about the number of electric power consumption meters (EPCM) in each demographic category, according to the local electric power company, in portuguese, Companhia Energética de Brasília (CEB), and the IBGE Census 2010. Note that the vast majority of the consumers still use the conventional mechanical energy meters.

Table 1. Population density and amount of EPCM in each region on DF

Region	Pop. Density (inhab./km^2)	# EPCM	EPCM per km^2
Dense Urban	4528	368 779	1842
Urban	1594	414 954	643
Suburban	316	173 959	126
Rural	51	72 924	21
Global	444	1 048 616	184

Based on Table 1, we can estimate the amount of data capacity required by each of the four demographic categories on DF.

The Smart Grid Networks Deployment Modeling Framework, developed by the OpenSG Networks Working Group, and the Wireless Modeling Engine, developed by SGIP PAP02 NIST (2015a), merged to form the Smart Grid Framework and Wireless Modeling Tool (SGFWMT) NIST (2015b). This tool consists of a spreadsheet that uses demographic information, such as demographic area requirements and the quantity of EPCM, to estimate the data volume requirement for a certain region. The SGFWMT is a tool to provide initial estimates of network base station requirements to fit coverage, data volume, and latency requirements in a wide range of deployment venues.

The information in Table 1 is used as the input for the SGFWMT, which then calculates the average data throughput as shown in Table 2, where UL stands for Uplink and DL for Downlink, both in kbps/km^2. Based on the data capacity requirements, the communication technologies for each network and subnetwork can be chosen as shown in Section 3. Table 2 shows the average data throughput, as a data density in kbps/km^2 for each demographic category.

Table 2. Estimated required data troughput in kbps/km^2 for the DF

		Dense Urban	Urban	Suburban	Rural
Avg. Baseload Requirements	UL	0.9720	4.7506	1.3572	0.3153
	DL	0.0095	2.4799	0.4439	0.0267
Avg. Highload Requirements	UL	16.3183	14.2304	12.0384	1.7829
	DL	36.0084	34.4577	22.3997	5.3917

The average baseload requirements and the average highload requirements are, respectively, the minimum and maximum network traffic loads. They are fundamental parameters and are considered in order to propose SGCN with appropriate technologies. More details regarding the baseload and highload can be found in Gray (2015).

3. PROPOSED SMART GRID COMMUNICATION NETWORK

Based on the required data capacity for the DF and on the available infrastructure, we propose a SGCN architecture for the DF in this section.

As shown along this section and illustrated in Figure 1, the proposed SGCN for the DF is based on a fiber-optic WAN backbone and a private wireless broadband network, including a WiMAX FAN combined with a 900 MHz wireless mesh NAN. The 900 MHz wireless mesh network collects all the smart EPCM data from the consumers in a neighborhood. The WiMAX base stations, which are installed near the transmission lines as depicted in Figure 1, then, establish the connection between the information coming from the NAN and the fiber-optic backbone. Finally, the fiber-optic backbone delivers all the collected information to the utility company, i.e. CEB.

For the wireless part of the SGCN architecture, we propose to use private wireless networks, since, as shown in Grid-