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Defining a convergence network platform framework for smart grid and intelligent transport systems

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ABSTRACT

The challenges faced by electricity grids suggest smart grids will have to coordinate its operation with other important initiatives in areas such as transportation. The smart grid relies on the use of network platforms where meter readings and data can be transmitted. On the other hand, concerning transportation systems the need to achieve a reduction of road congestion and traffic accidents among the increasing use of electric vehicles has consolidated the importance of ITS (intelligent transport systems). Given the magnitude of the challenges faced by both the smart grid and ITS, the aim of this work is to identify the elements comprising a convergence platform capable of supporting future services for data traffic associated to smart grid operations as well as ITS-related commercial service applications and road traffic safety messaging. A seaport terminal scenario is used to present a convergence network platform incorporating WSN (wireless sensor network) theory. The results of the simulation of the proposed network confirms the suitability of WSN to be used in the transmission of data traffic associated to meter readings which is required for effective energy consumption and management policies in industrial environments comprising equipment with high energy demands.

1. Introduction

The continuous challenges faced by electricity grids including the continuous rise in electricity consumption, the need for renewable generation of electricity, the need for efficient transmission and distribution, the need to recover quickly from natural disasters and more recently the increase in the use of electric vehicles suggest the smart grid will continue to receive substantial attention in the future. The smart grid relies on the use of network platforms where meter readings and data can be transmitted. The smart grid has been defined as an 'electricity network that can cost efficiently integrate the behavior and actions of all users connected to it in order to ensure an economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety' [1]. The U.S. Department of Energy defines the smart grid as 'a fully automated power delivery network that monitors and controls every customer and node, ensuring a two-way flow of electricity and information between the power plant and the appliance, and all points in between' [2]. The definition found in Ref. [2] also adds that 'the smart grid's distributed intelligence, coupled with broadband communications and automated control systems, enables real-time market transactions and seamless interfaces among people, buildings, industrial plants, generation facilities, and the electric network'.

The European Commission in its European Energy Strategy 2020 has acknowledged the need to work towards the deployment of the future European electricity networks using the latest technology [3]. In the view of the European Commission electricity will be delivered where and when needed, and consumers will be able to monitor their electricity consumption in real time.

In Europe, over €5.5 billion has been invested in about 300 Smart Grid projects since the year 2001 [3] and of all that amount of money spent around €300 million has come from the EU budget. At present current EU-funded smart grid projects cover wind and other renewable electricity sources, infrastructure to support the

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achievement of a reliable, competitive and sustainable electricity supply and guidelines for more efficient integration of renewable energy into future infrastructures among others. The European Commission is careful to highlight that the EU is still in the early stages of the actual deployment of smart grids and that today, only around 10% of EU households have some sort of smart meter installed, although most do not necessarily provide the full scale of services to consumers [3]. However, the European Commission points out that those consumers with smart meters have reduced their energy consumption by as much as 10%. Furthermore, the adoption of the smart grid relies heavily on ICT (information and communication technology) developments. Indeed, the importance of ICT is evident as research work on smart grid has concentrated on customer involvement including areas such as technical operation systems, economic incentives to facilitate flexible demands including the development and design of proper information and communication systems and electric vehicles [4]. Fig. 1 depicts a smart grid architecture with various elements comprising: power generation like thermoelectric and nuclear plants and renewable sources like wind, power transmission, power distribution and smart grid IP (internet protocol) backbone/smart grid data management processing where meter readings and data can be transmitted. Users include electric/plug-in hybrid vehicles from private and freight/cargo transport, residential, offices, factories and warehouses. The size of power generators found may include domestic ones at kilowatt levels to large hydroelectric plants with capacity of several megawatts.

Recent developments in smart grid research have anticipated the connection of electric vehicles into the power network and the myriad of technical challenges that need to be addressed properly [5]. Nonetheless, it has been recognized that electric vehicles with vehicle-to-grid capabilities can reduce emission from the transportation industry [5]. Furthermore, transportation systems need to achieve a reduction of road congestion and traffic accidents and make transport networks more secure and resilient has consolidated the importance of ITS (intelligent transport systems). ITS is based on the use of advanced information and communication technology to achieve a reduction of congestion and accidents while making transport networks more secure by reducing their impact on the environment [6]. The European Union has supported ITS research with the purpose of improving the efficiency of the road network comprising coordinated traffic control ramp metering, variable message signs, and traffic and incident detection systems which have been implemented across places in Europe to monitor road conditions and provide quick and smooth journeys [7].

Both the smart grid and ITS represent a unique challenge in terms of the convergence of network platforms to be used in the deployment of future services. The urge for convergence can be seen in the increase in the use of electric and plug-in hybrid vehicles which need public and private remotely metered recharging stations to recharge their batteries. The ability to monitor the energy state of vehicles in real time can help future energy management to mitigate the negative effect of vehicle charging such as variable electricity costs and battery degradation among others. On the other hand electric and plug-in hybrid vehicles meter readings can be transmitted using an ITS platform based on VANETs (vehicle adhoc networks) in addition to the use of available technologies such as cellular networks, Wi-Fi or 3G. Moreover, ITS applications supported by VANETs are expected to grow and evolve with the ultimate goal of achieving an accident-free driving environment [8]. VANETs can handle different types of service applications, including the transmission of both safety and non-safety messages into two modalities: V2V (vehicle to vehicle) and V2I (vehicle to infrastructure). In the near future the importance of the convergence platform is expected to grow as new technological developments continue to take place. For example, the next generation of grid-based electric vehicles will be characterized for not only drawing energy from the smart grid, but also the storage of energy to the grid and allowing various data communication [8].

The next sections provide a review of the elements comprising the smart grid and VANET-based ITS which is followed by a framework that addresses the need for a convergence network platform based on commonalities such as systems security and electrification of the transport infrastructure. A seaport terminal scenario is used to discuss the characteristics of a convergence network platform followed by a model based on WSN (wireless sensor network) theory to simulate the operation of a common network platform for the smart grid and ITS. Future work opportunities are also discussed.

2. A review of smart grid and VANET-based ITS elements

The European Commission Task Force for the Implementation of Smart Grid into the European internal market highlights that existing grids and related infrastructure have already elements of intelligence or smartness [9]. Furthermore, the European Commission also emphasizes that the smart grid of the future will rely on innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies. According to the European Commission [9] the use of the smart grid will make possible to:

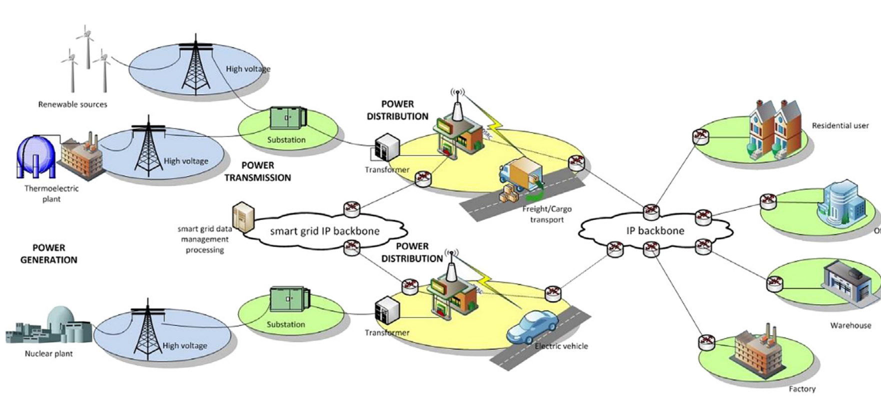

Fig. 1. The smart grid configuration.