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Optimistic Technique for Smart Grid Infrastructure Using Sensor Network

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Abstract:
Smart grid integrates electrical grids and communication infrastructures and forms an intelligent electricity network working with all connected components to deliver sustainable electricity supplies. Smart grid (SG) is an intelligent control system over sensors and communication. A communication is an essential part to the success of the smart grid. For that cognitive radio (CR) networks to reduce the communication interferences and improve the bandwidth efficiency for smart grid communication. There is an essential need to use the CR communication to support large-size and time-sensitive delivery for future smart grid system. In this paper, develop smart grid infrastructure the grid is primarily radial built for centralized power generation and is dependent on manual restoration. First, the design scheme of a conventional power distribution system configuration that adopts distribution automation is introduced. The possibility to store energy, to exchange power and information on demand and production among grids allows us to achieve an active distribution, which can forecast demand and production and are able to exchange power in order to enhance the quality of service. And further the project propose a priority-based approach for CR communication infrastructure based smart grid system according to the various traffic types of smart grid such as control commands, multimedia sensing data and meter readings.

Key words: *cognitive radio (CR), Smart grid (SG), channel allocation, traffic scheduling, grid infrastructure, prioritized network*

1. Introduction

Today's electricity grid was designed and constructed to meet the requirements in the last century. The grid is primarily radial, built for centralized power generation, and is dependent on manual restoration. In addition, reliability of traditional electric grid is ensured mainly by having excessive power capacity in the whole system, with one-way power flow from power plants to consumers. Although lots of newly-developed information and communication technologies have dramatically affected the other industry sectors, the electric systems generally remain to operate in the same way for decades.

The smart grid concept is aimed at increasing the level of automation of the power distribution system. Among the immediate effects, there are, for instance, the improved quality of the delivered energy and the efficient integration of renewable energy resources. The smart grid has been imagined to improve the strength and efficiency of traditional power grid networks with the help of modern communication technologies. It is allowed by the technological advances in sensing, measurement, and control devices capable of two-way communications among system managers, electricity production, and transmission, distribution, and consumption parts of power grids by exchanging information about the grid states to system users, operators, and automated devices. State estimation is a key function in building real-time models of electricity networks in energy management centers.

The smart grid is an intelligent power delivery system, which utilizes the communication platform to exchange the information and optimizes the operation of interconnected power units to improve the efficiency, reliability, and sustainability of electricity services. Typically, a two-way communication infrastructure is required to exchange the real-time information between the utilities and consumers. The information exchange enables many new functions and services for smart grid such as remote meter reading, control, and detection of unauthorized usage. Smart grid controls intelligent appliances and diagnoses problems in consumers' houses or business buildings to reduce the energy cost and increase the system reliability, efficiency and safety. It ranges from traditional central generator and/or emerging renewal distributed generator to industrial consumer and/or home users with their thermostats, electric vehicles, and intelligent appliances.

Wireless sensor networks (WSN) have been identified as a connected and intelligent monitoring system platform for smart grid systems. For example, low-cost wireless sensor nodes can be distributed over wild fields where the power plants are located and can enhance utility asset monitoring capabilities. The control center can collect the information from remote wireless sensors to detect the behavior of the power equipment and manage the stability of the power grid. WSNs will play an important role in automatic meter reading, remote system monitoring, remote home/customer site monitoring, equipment fault diagnosing and etc. Further, wireless multimedia sensor networks (WMSNs) using sensors such as video and acoustic sensors can enhance the reliability, safety and security of smart grid system by providing rich surveillance information for grid failure detection and recovery, energy source monitoring, asset management, etc. For example, using smart camera sensors for monitoring solar power plants (e.g., the light intensity and direction) can predict the amount of generated energy and thus efficiently scheduling the power distribution.

On the other hand, the application of CR technology in smart grid communications has drawn much attention due to its excellent capability to improve the spectrum usage. In addition, the application of cognitive radio network can also alleviate the burden of purchasing licensed spectrum for utility providers. These advantages make cognitive radio networks a necessary component for smart grid communication infrastructure. The growing needs of multimedia sensor applications for smart grid system require wireless huge amount of bandwidth and network resources, it is critical to use the CR to support various traffic types including multimedia for future smart grid system.

A key point for the success of smart grid system is how to meet the heterogeneous communication requirements such as high reliability and low latency requirement, especially under harsh environmental conditions. Smart grid requires high quality of services (QoS) and resource efficiency as well as the system expenses and bandwidth. The communication challenge demands further research and customized solutions for smart grid applications.

2. Smart Grid

The smart grid concept is predicated on a two-way flow of energy-and information-between electricity generators and end users. The system not only delivers power to end users as needed, depending on demand; it also gathers power from end users that produce their own homes and businesses that generate solar, wind or geothermal power themselves, when they have more than they need.

Smart grid applications improve the ability of electricity producers and consumers to communicate with one another and make decisions about how and when to produce and consume electrical power. This emerging technology will allow customers to shift from an event based demand response where the utility requests the shedding of load, towards a more 24/7 based demand response where the customer sees incentives for controlling load all the time. Although this back and forth dialogue increases the opportunities for demand response, customers are still largely influenced by economic incentives and are reluctant to relinquish total control of their assets to utility companies.

Smart grid describes a set of related technologies, rather than specific technology with a generally agreed-on specification.

- **Two-way integrated communications**: allow for real-time control, information and data exchange to optimize system reliability, asset utilization, and security
- **Sensing and measurement:** evaluate congestion and grid stability, h congestion and grid stability, monitor equipment health, detect energy theft, and support control strategies support.

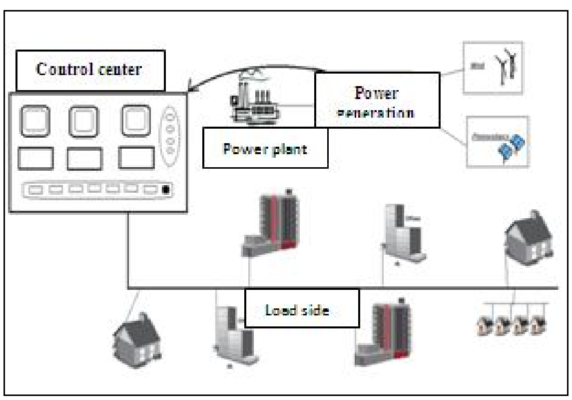

Figure 1 Smart Grid Network

3. Cognitive Radio

Smart grid networks have to carry reliable and real-time information to the control centers of the utilities. Due to the unique challenges imposed on the smart grid, the existing communications network is infeasible and cannot be applied trivially. Revolutionary communication architecture is urgently demanded. In this article, we propose a cognitive radio based communication architecture for the smart grid. Cognitive radio refers to the potentiality that wireless systems are context-aware and capable of reconfiguration based on the surrounding environments and their own properties. In the same frequency range, there are two coexisting systems: the primary system and the secondary system.

The primary system refers to the licensed system with legacy spectrum. This system has exclusive privilege to access the assigned spectrum. The secondary system refers to the unlicensed cognitive system, which can only opportunistically access the spectrum holes that are not used by the primary system. We call the subscriber in the primary system the primary user (PU) and the subscriber in the secondary system the secondary user (SU).

4. Proposed System

To start the process of a simple meter reading a command is sent from the server at the office. The command travels through our radio communication link from the office to the substation. At the substation a signal is injected onto the power lines. The signal travels to every meter connected to that particular substation. The signal is received and decoded by the meter. The meter replies with the information that was requested from the server and sends a signal back to the substation. The substation injection equipment relays the information back to the server at the office via the radio. It takes approximately 3 to 6 seconds for the process to be completed.

Generally, meters are read in groups during certain times of the day, but they can also be read anytime it becomes necessary. The data from each meter is archived and can be retrieved at any time for review. The information has already proven to be useful in addressing some customer concerns about high usage. “Real-time” data is a great tool for helping customers and understand how much electricity they are using and when it is being used.

5. Smart Grid Structure

Recently, diverse communication and information technologies have been identified to realize SG. In this section, first we will introduce a general SG architecture, and then we will discuss those recently developed technologies according to their functionalities in electricity delivering processes, including electricity transmission and distribution systems. A transmission system is often regarded as the section in an electricity grid that moves a great amount of power over very long distances, and thus it is distinguishable from a distribution system, which is usually considered as the section that delivers electric energy from a high voltage transmission grid to user-end premises such as a residential district or commercial center.

6. Priority-Based Traffic Scheduling For Smart Grid

- **Multimedia Communication in Smart Grid Systems**
  In smart grid systems, real-time multimedia surveillance of the critical assets, substations and the household appliances is performed by the smart meters in order to observe security and network health conditions. In case of electricity outage, not only can the real-time monitoring information diagnose which asset in the smart grid system is out of work, but it can also indicate the way that asset is damaged. Moreover, the application of smart camera in wind power plants can help monitoring the light intensity and direction so that the administrators can adjust the direction of solar panels. Video surveillance around and inside of consumers’ house can provide intrusion identification and monitoring of the household appliances (e.g., TV set, audio system, oven, washer, and dryer). Overall, the video surveillance of smart meters can provide better security and visual inspection of the distributed equipment and household appliances. Accordingly, efficient multimedia transmission techniques are of most importance and essential to fulfill the duty of smart grid systems.
- **Prioritized Network System**
  To achieve effective SG communication, modern communication technologies must be able to offer multiple services and meet service requirements of heterogeneous applications. The need to prioritize the traffic types is just as important as the capability to adapt to varying network conditions in real time. In smart grid applications, a typical traffic type is the control commands with small packet size. In the proposed CR network for SG system, the data traffic is prioritized into three classes:
- **The vital messages:**
  The vital messages are mainly for control; protection and management of the SG (e.g., notification of a sudden voltage drop, a switching command for an actuator) are classified into the highest priority for the emergency notification. This type of traffic is characterized by the message transmitted from nodes to the control center or vice versa.
- **System monitoring information from sensors:**
  The monitoring information including multimedia surveillance is classified into the second highest priority due to the possibility that the power plant/device may be destroyed by natural disaster, severe weather or accidents such as animal damage.
- **The meter readings:**
  The various meter reading is classified into the third highest priority, which is less time-sensitive and transmitted in certain time period depending on the network requirements.

7. The CR Network Architecture for Smart Grid

In our study, a spectrum band consists of P orthogonal channels with identical bandwidth. These channels are shared by primary users (PUs) and N secondary users (SUs). The N SUs are further prioritized into classes. As shown in Figure. 2, in this network system, all the SUs send information to the CR base station. All the users in the CR network system are categorized into (S+1) priority levels, in which PU’s priority level is 0 (the lower number of the users have higher priority).

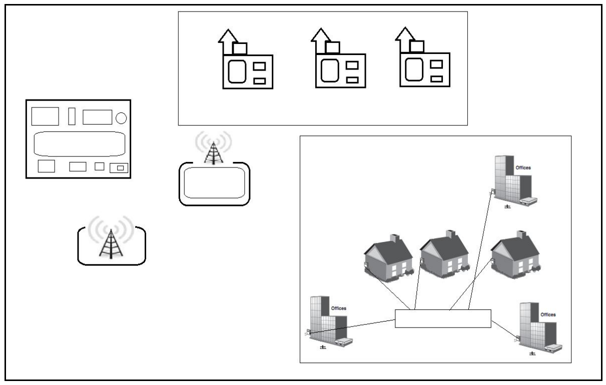

Figure 2: Priority Based Network

In Figure 2, the CR network architecture with three priority classes for SG is presented, where three types of traffic is illustrated as shown by P0, P1, and P2. Based on the available resources, the base station will make spectrum decision and inform each SU their available channel resource according to their priority. At each SU node, there is an information queue which buffers source packets according to the priority of a packet. While utilizing free spectrum resources, each SU should be aware of the PU reappearance and could be dropped off from this channel immediately. In our proposed scheme, encoded packets are transmitted through selected sub channels from the spectrum pool based on quality requirement.

We consider a single-hop CR network system here, which is characterized by a topology graph Ω (P, N) that has a set of PU's $P=\{p_1,p_2,\ldots.p_p\}$ a set of SU nodes $S=\{n_1,n_2,\ldots.n_N\}$ which are connected to the base station as long as the node and free channels are available at the same time. Assume the number of channels is exactly the number of PUs, which means there are P channels. There are a total of N SU nodes, which could function as source or destination nodes, and the SUs are classified into S priority classes from high to low: $(SU_1,SU_2,\ldots..,SU_s)$. According to the priority class of SUs, the available channels are sorted according to their quality.

The lower index of the SUs represents the higher access ability to the available channels. The packets of each priority of SUs are further classified into M priority classes, where M represents the importance of that packet (the lower the more important). The available resource matrix for SU priority class SU_n is represented by R_n. Whether a channel is available for SU_n depends not only on the connectivity, but also on the interference coming from other SUs, sensing errors, and channel switching interferences.

8. Priority Based Communication

To start the process of a simple meter reading a command is sent from the server at the office. The command travels through our radio communication link from the office to the substation. At the substation a signal is injected onto the power lines. The signal travels to every meter connected to that particular substation. The signal is received and decoded by the meter. The meter replies with the information that was requested from the server and sends a signal back to the substation. The substation injection equipment relays the information back to the server at the office via the radio. It takes approximately 3 to 6 seconds for the process to be completed.

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9. Snapshot

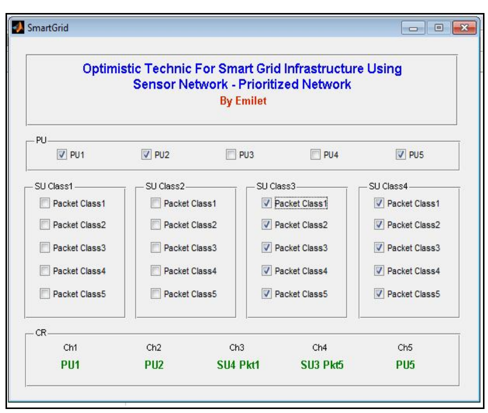


Figure 3: Third Priority Messages Pass

In prioritized communication simulation output the primary unit (PU) allocate the free channel for unlicensed spectrum, through that all meter reading has been sent which are third priority message. If suddenly first or second priority message is weighted to transmit means that channel will allocated to pass through that channel first

Normally in every time third priority that is meter reading value is transmitted through the allocated channel continuously. It has been transmitted continuously till any interrupt will occur such that second priority and third priority messages

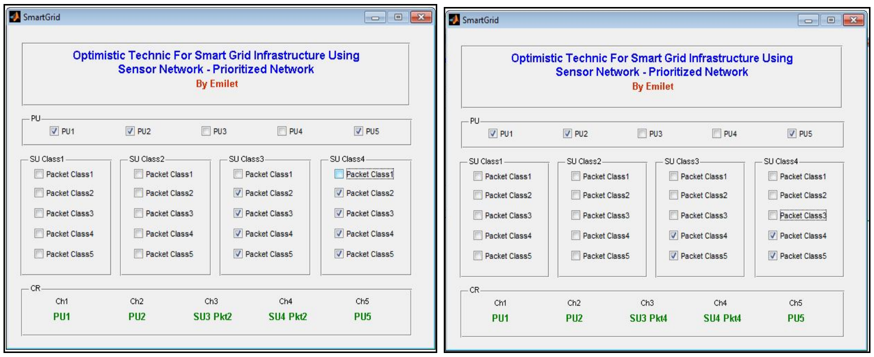


Figure 4(a,b)

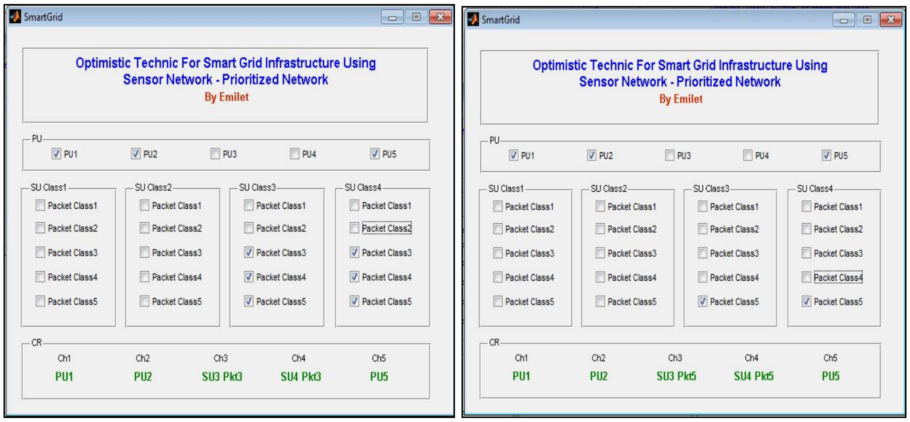
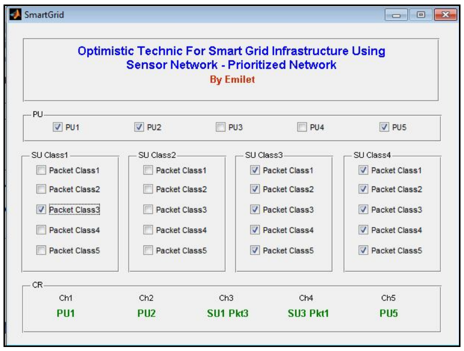


Figure 5(a,b):Third Priority Message Pass Continosly



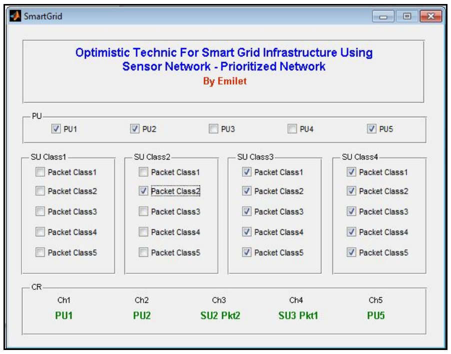


Figure 6: First Priority Message Pass *Figure 7: Second Priority Message Pass*

To achieve effective SG communication, modern communication technologies must be able to offer multiple services and meet service requirements of heterogeneous applications. The need to prioritize the traffic types is just as important as the capability to adapt to varying network conditions in real time. In smart grid applications, a typical traffic type is the control commands with small packet sizes. In the proposed CR network for SG system, the data traffic is prioritized into three classes:

The vital messages: The vital messages are mainly for control; protection and management of the SG (e.g., notification of a sudden voltage drop, a switching command for an actuator) are classified into the highest priority for the crisis notification. This type of traffic is characterized by the message transmitted from nodes to the control center or vice versa.

System monitoring information from sensors: The monitoring information, including multimedia surveillance is classified into the second highest priority due to the possibility that the power plant/device may be destroyed by natural disaster, severe weather or accidents such as animal damage.

The meter readings: The various meter readings are classified into the third highest priority, which is less time-sensitive and transmitted in a certain time period depending on the network requirements.

10. Conclusion

In this paper, we have investigated the application of CR network on SG systems. This develops a smart grid infrastructure and priority based network. The different traffic types in SG are classified and prioritized for traffic scheduling of the SUs in a CR network system. An SG communication system peak load problem has been formulated to obtain the optimal SG communication resource utilization through choosing the optimal CR network channel selection strategy. This paper opens a new vista of future smart grid communications and has great potential in enhancing the flexibility and adaptability, and reliability of SG system.

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