Wireless Sensor Networks within the Smart Grid.

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Resumen: En este trabajo de investigación se presenta una revisión del estado del arte sobre Redes de Sensores Inalámbricos (WSN) dentro de la Red Eléctrica Inteligente (SG). El enfoque de este trabajo de investigación incluye comunicaciones inalámbricas y sensado, con aplicación a sensado/monitoreo de líneas de transmisión de energía eléctrica y dispositivos de potencia, estándares y un esquema propuesto.

Palabras Clave: red eléctrica inteligente, red de sensores inalámbricos, comunicaciones inalámbricas, sensado, medidores, medición, AMI, MEMS, RFMEMS, IEEE 802.15.4, ZigBee, estándar.

Abstract: In this research work, a revision on the state of the art of Wireless Sensor Networks (WSN) within the Smart Grid (SG) is presented. The focus of this research work includes wireless communications and sensing, with application to sensing/monitoring electric power transmission lines and power devices, standards and a proposed scheme.

Keywords: smart grid (SG), electric power network, Wireless Sensor Network (WSN), wireless communications, sensing, meter, metering, AMI, MEMS, RFMEMS, IEEE 802.15.4, ZigBee, standard.

Introduction
In this research work, a revisión on the state of the art of Wireless Sensor Networks (WSN) within the Smart Grid (SG) is presented. Providing good quality electricity to consumers, is one of the goals of the SG technology. In order to achieve this, there will be a need to implement sensors in several points in the distribution network and these sensors will need a communications network in order to communicate with different distribution elements and the control center. Sensing will have the ability of detecting misfunctions or normal operational range deviations that would guarantee action.

Further, since in a SG an electricity consuming point can also become a generation point, the sensing process will be closely attached with the metering process. Communications will allow entries from sensors in order to be transmitted to the electric power network control centers, which will generate control messages for transmission to several points in the electric power network, resulting in the proper action. An IP-based network will provide an effective solution for the SG communications needs, where the two most important requirements are latency and a big amount of messages [12].

For example, in order to apply several wireless sensors to one or several electric power transmission lines and having communication wirelessly among each other and towards a central operation module, the wireless sensor networks technology is recommended [1].

Wireless Sensor Networks
Modern communications networks solutions are supported by technologies base on standards, such as IEEE 802.15.4, to provide communications of resilient two-way wireless mesh network to a wide range of control and sensor devices[5-9].

A self-healing intelligent two-way communications mesh infrastructure is considered, that it is base on non-
proprietary standards, high bandwidth industrial enablers (2.4 GHz IEEE 802.15.4) which enable the use of data from many types of devices from a wide range of vendors.

Zigbee Alliance has defined an open standard for metering and communications with in-home appliances (HAN.- Home Area Network) [11], which is based on the Zigbee Pro and IEEE 802.15.4 standards. Zigbee has been standardized as the solution for the electric power utilities’ meters (Figure 1 and Table 1).

**Figure 1.-** A mesh network configuration provides an intelligent communications platform [11].

Wireless sensor networks usually operate under a variety of constraints, different to the traditional wireless networks. Usually, the wireless sensor network objective is to maximize the life time of the network, developing routing protocols which minimize battery usage and being resilient facing PHY layer, data link and network attacks. Some vendors have taken into consideration security when designing their meters, including the AES-128 and 256 advanced encryption standards.

**Table 1.-** Smart grid interoperability standards for Home Area Network [11].

<table>
<thead>
<tr>
<th>Standard</th>
<th>Application</th>
</tr>
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<tbody>
<tr>
<td>OpenHAN</td>
<td>Communication of the Home Area Network device, metering</td>
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<td></td>
<td>and control.</td>
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<tr>
<td>Intelligent Energy Profile</td>
<td>Communications of the Home Area Network device and</td>
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<tr>
<td>ZigBee/HomePlug</td>
<td>information model.</td>
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</table>

As an example, a network of 2500 Zigbee/802.15.4 radios, operating at the maximum data rate of 250 Kbps, being polled every 15 minutes, it will be only able to transmit a file with at most 11,250 bytes corresponding to 88 packets. For a file of this size, each node will be only able to transmit at most 244 packets per second, which only gives to the meter/sensor approximately 4 milliseconds in order to deliver a packet of this size. This was simulated using OPNET (another option is the Network Simulator-2 - NS-2). The radio from the standard IEEE 802.11 was used with as many modifications as OPNET allowed, in order to be similar to the radio IEEE 802.15.4 (DSSS.- Direct Sequence Spread Spectrum, BPSK.- Binary Phase Shift Keying, 250 Kbps y CSMA/CA-Exponential Backoff.- Carrier Sense Multiple Access/Collision Avoidance) [3].

ZigBee as an attractive new wireless network can be used in several applications such as sensor interconection, monitoring and automation different systems at home, hospitals, manufacture industry and agriculture. Characteristics such as low cost, easy extension, reliability, flexibility, security, low energy consumption, etc. make it appropriate to be deployed in the smart grid (intelligent electric power network) [11]. However, it shares the frequency band with Wi-Fi which is widely spread in the world. So, the efficient interference cancellation is a key scheme to assure the ZigBee performance with Wi-Fi present. The frequency agility interference cancellation algorithm has been proposed, including interference detection and intelligent channel selection. Interference detection based on NACK and energy detection as an energy saving and the precise interference detection scheme are adopted. In-sequence energy detection of classified channels is an intelligent method to find the available channel as soon as possible. Active polling assures the channel is not busy for another ZigBee personal area network (PAN). From the real world implementation, this scheme has been validated that it can efficiently cancel interference from Wi-Fi [4].

**Mobility**

Zigbee uses both routing protocols: AODV (Ad hoc On-demand Distance Vector) [2] and Cluster Tree. The cluster tree routing is only used in Reduced Fuctional Devices (RFD), which are usually battery operated or limited resources devices. AODV was created for use in Full Functional Devices (FFD), which are less resources limited than RFDs, because of they are usually plugged in to an electric power source. Cluster...
tree routing suffers from great delays due to the multi-threaded nature of the protocol, where AODV is much faster than cluster tree because the routes are establish as needed. So, it is provided that the routing protocol will be pure AODV [3].

It is proposed that a new layer between the Zigbee routing layer and the MAC 802.15.4 layer is added, similar to the 2.5 layer used in MPLS networks (Multi Protocol Label Switching) in order to reduce the end-to-end delays, for data packets. Label usage enables the electric power utilities’ network engineer to poll meters/sensors and receive responses to 15 minute intervals, without congesting the network during critical-motion situations, when demand starts increasing beyond a system sustainable limit [3].

Wireless Sensor Networks are traditionally composed of a multiplicity of sensor nodes that sense given phenomena and deliver the sensed data to specific sink nodes. In the most of the application scenarios, sensor nodes have been considered motionless. On the contrary, interesting possibilities arise if some sensors are embedded in devices carried by mobile agents as people, cars, animals, etc. Typically in these architectures sinks are cellular phones equipped with sensing devices and short range wireless interfaces like ZigBee. If sinks move within the considered sensor field, they are able to provide both sparse sensing and collecting of data measured by static sensors placed at fixed locations. The goal is to evaluate, through simulations, the impact of sinks’ mobility in a wireless sensor network created by using the topology formation mechanism provided by the IEEE 802.15.4 Standard. To this aim, as a practical case study, we consider a wireless sensor network deployed in a museum used to monitor the presence, the localization and other indications on the interference present on that tree.

An IEEE 802.15.4 WSN is composed of one sink, named Personal Area Network (PAN) coordinator, and a set of nodes that can be Full Function Devices (FFDs), allowing the association of other nodes to the network, or Reduced Function Devices (RFDs), that do not permit the association of other nodes. The sink is always a FFD, intermediate nodes allowing data relay (router) are FFDs too, whereas the RFDs are the leaves of the tree.

The standard defines a set of procedures implemented by the PAN coordinator to initiate a new Wireless Personal Area Network (WPAN) and by other nodes to join an existing one. The PAN coordinator starts by selecting a channel among those specified in the standard. The channel selection is performed by the Energy Detection (ED) scan by means of which the measure of the peak energy in each channel is returned: it gives indications on the interference present on that channel. The procedure adopted by sensor nodes to join a network is named association procedure and it establishes relationships between nodes within the network itself. The operations performed by a node to join a WPAN are: 1) the node searches for the available WPANs, 2) it selects a coordinator belonging to the available WPANs and 3) it starts a message exchange with the selected coordinator to associate with it.

The discovery of available WPANs is performed by scanning the beacon frames broadcasted by the coordinators. Two beacon broadcasting modes are defined in the standard: beacon-enabled and nonbeacon-enabled. In beacon-enabled mode, coordinators transmit beacon frames periodically and the available WPANs can be discovered by eavesdropping the wireless channels (passive scan). In nonbeacon-enabled mode, instead, the beacon frames shall be explicitly requested by a node by means of a beacon request command frame (active scan). In the beacon-enabled mode, the time is divided into a superframe structure. The superframe is bounded by beacon frames that are transmitted periodically and that allow nodes to synchronize.

With their simulations they aimed at measuring [13], in a given case study of IEEE 802.15.4 wireless sensor networks, the effects of sinks’ mobility on connectivity and energy consumption for network formation and reconfiguration. In an IEEE 802.15.4 WSN when a sink moves, sensors that are connected to it can lose the association. They measured the percentage of nodes connected to the network in correspondence to the sinks’ movements and it was shown that network connectivity can be heavily affected. Also, the loss of association due to sinks’ mobility, has an impact on the network energy consumption, because nodes spend energy to continuously restore the associations.

As a general result, they can state that it is important to suitably manage these variations of connectivity and energy consumption, to avoid performance worsening.
For instance, if the application is data loss sensitive, it is recommended to provide nodes with buffers suitably dimensioned to prevent loss during lack of connectivity.

Furthermore, the IEEE 802.15.4 nonbeacon-enabled networks are not as sensitive to sinks’ mobility as beacon-enabled ones. However, performance of nonbeacon-enabled networks must be evaluated when data traffic is considered. In this case mobility affects loss of packets and data transfer delay. Moreover, with these simulations, it was shown that when beacon-enabled networks are used, it is important to choose a suitable value of BeaconOrder, since network performance concerning formation and re-configuration is affected by the value of this parameter [13].

In a mobile ad hoc sensor network (MASNET), mobile sensing nodes intercommunicate without any fixed infrastructure in a dynamic network topology [14]. The severe restrictions on nodes in such an environment are the very limited (as well as hard to refresh) power-budget and scarce medium bandwidth. Any consideration of a routing mechanism should include these limiting factors in addition to the dynamics of the network. Nodes within each other’s transmission range can communicate directly; otherwise they communicate via multi-hop routing mechanisms, through various intermediate nodes. MASNETs are deployed in many civilian and military applications; e.g., in disaster recovery and on the battlefield. In such applications, it is very important to deliver packets quickly and effectively without delay and optimal bandwidth usage, i.e., minimal overhead. Ad hoc on-demand distance vector routing (AODV) is one of the promising protocols for deployment in a MASNET, due to its ability to cope with network dynamic changes and to locally repair broken links in routes [14].

Algorithm from [14] takes advantage of the wireless broadcast environment with the ability to overhear neighbor-to-neighbors transmissions. Passive collection of neighboring node intercommunication will be utilized upon the need to reconstruct any broken link with an immediate neighbor. Hence, they minimize the control packets needed for local repairs with the cost of some local routing tables [14].

They efficiently adapt the prominent Ad Hoc On-Demand Distance Vector (AODV) routing protocol with a reactive Local Link Repair, AODV-LR, for effective deployment in restricted power-budget and bandwidth mobile ad hoc sensor networks (MASNET). They introduce a better replacement mechanism to the local repair phase of the AODV. Their new approach is a preemptive, self-repairing AODV (called AODV-PSR) scheme that is able to find an alternative link to a failing link. The new preemptive protocol achieves better performance than the AODV-LR, due to its avoidance of packet buffering delay and excess use of control messages during link repair. Experimental results show a much lower obtained packet delay, a higher packet delivery ratio, and lower control message overhead. Hence, this mechanism is amenable to deployment in areas of restricted power-budget and bandwidth, such as a MASNET domain [14].

In [15] they present an alternative to an end-to-end wireless network that forwards the motes’ measurements to a back-end database. We propose to use autonomous robots as data mules. These mules visit locations within the communication distance of each of the static motes, download their measurements, and return to a remote base station to offload the collected data. The key benefit of this approach is that motes can conserve energy that otherwise they would use to forward data, thereby prolonging the lifetime of the network. However, to successfully deploy such a hybrid robot/sensor network, new challenges (such as planning robot trajectories) must be overcome (Figure 2).

![Figure 2](image-url)

Figure 2 - Overall system architecture, including a number of sensing motes, multiple robots acting as data mules, and a gateway to which robots offload collected data and receive further commands. Each robot communicates with the sensing nodes and the gateway through a locally connected mote. All collected data are eventually stored in a back-end database for further processing and visualization [15].

Mote radios transmit at rates between 10–250 kb/s; consume about 20 milliwatts when in transmit, receive, or idle listening mode; whereas their range typically is...
measured in tens of meters. Because the robot moves adjacent to the mote, the mote can reduce its radio transmission power, further reducing its energy consumption. The robot moves close to the sensing mote, waits for a beacon message, acknowledges it, and then issues a command to the mote to download (some of) its data. We can further reduce the energy consumption of the mote if the schedule of the robot visits is known. In this case, the robot informs the mote when it will return. An alternative wake-up strategy is to use a lower-power sensor to wake up the node. For example, one could use the mote’s light sensors or even a Reed switch (i.e., an electrical switch operated by an applied magnetic field) to wake up the mote. In this case, the robot could shine a light or carry a magnet that would activate the sensor that in turn activates the sensing mote’s radio for the subsequent download. Once the mote is awake, the robot transmits a request containing the range of collected data it requires to download from the mote.

Wireless communications standards for the smart grid

A revision on wireless communications standards for the smart grid was carried out.

In [16], IEEE P1777 Recommended Practice for Using Wireless Data Communications in Power System Operations, involves several wireless and mobile technologies.

In [17], IEEE P2030 Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System and End-Use Applications and Loads.

In [18], IEEE 802.15.4 Standard for Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs), includes frequency bands, channel numbering, modulation schemes, Ultra Wide Band UWB LR-WPAN (Low Rate) and Communication from a coordinator a beacon-enabled PAN.

In [19], IEEE 802.16 Standard for Local and metropolitan area networks Part 16: Air Interface for Broadband Wireless Access Systems, named as wireless MAN includes coexistence, multihop relay specification and broadband wireless access (BWA).

In [20], IEEE 802.11 Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, named Wi-Fi involves wireless access in vehicular environments and Radio Resource Measurement of Wireless LANs.


In [22], IEEE P802.15.4g WPAN Physical Layer Specifications for Low Data Rate Wireless Smart Metering Utility Networks, specifies modulations and channel parameters.

In [23], IEEE P1815 Standard for Electric Power Systems Communications - Distributed Network Protocol (DNP3).


Information from NETL (National Energy Technology Laboratory), GRIDWISE, U.S. Department of Energy Office of Electricity Delivery & Energy Reliability, and NIST was also revised [25-31].

From above, the IEEE 802.15.4/ZigBee standard is considered for WSN.

On the other hand, MultiSpeak Initiative is an industrial consortium of software vendors in collaboration with the National Rural Electric Power Cooperative Association, which has been actively involved in standardizing the enterprise integration from 2000. The initiative has developed a specification for enterprise integration interfaces, based on a data model documented in XML scheme form and a set of web services that electric power utilities and vendors can use to implement the interface definitions. MultiSpeak specification has been included as one of the standards identified for implementation in the NIST standards framework [10].

WSN applications for the electric power utilities

In order to implement efficient systems, a multidisciplinary research area is required, such as WSNs, where there is close collaboration among users, applications domain experts, hardware designers and software developers. Characteristics such as flexibility, fault tolerant, high fidelity sensing, low cost and fast
deployment of the sensors networks, they create many areas of new and exciting applications for remote sensing. In the future, this wide range of applications areas will do to the sensors networks an integral part of our lives. However, realization of sensors networks needs to satisfy restrictions introduced by factors such as fault tolerant, scalability, cost, hardware, topology changing, environment and energy consuming.

Wireless ad hoc sensor networks have a long-term great economic potential, ability to transform our lives and present many challenges of systems construction. Sensor networks also present a number of new conceptual problems and about optimization. Some of them, such as localization, deployment and tracking are fundamental topics, where many applications are supported in them for the needed information. Coverage in general, answers the questions about Quality of Service (sweep) that can be provided by a particular sensor network. Integration of multiple types of sensors such as seismic, acoustic, optical, etc., in a network platform and the system total coverage study also present several interesting challenges. Also, an integrated scheme for placing sensors that incorporates energy administration and fault tolerance, is required.

The desired basic topology in data collecting WSNs is a expanding tree, due to traffic is mainly of the form of many-to-one flows.

A sensor that efficiently transduces the environment energy in useful electrical energy is an energy harvester. With the refinement of the energy harvesting techniques that are able to gather useful energy from vibrations, from radio energy radiations and similar, autoenergized circuitry is a very real possibility.

Wireless sensors have become an excellent tool for military applications including intruder detection, perimetral monitoring, information gathering and intelligent logistics support in an unknown deployed area. Some other applications are: design of a personal health monitor based on sensors, localization detection with sensor networks and using WSNs to perform movement detection.

Applications in the electric sector are mainly based on monitoring subsystems and power devices. There are some sensors based on MEMS (MicroElectroMechanical Systems) as solutions for the electric sector applications. One of the main aspects from the sensor networks is that solutions tend to be very application specific.

Several applications for the electric power utilities were identified for monitoring: transmission lines, transmission towers, power transformers, lightning arrester, underground cables, underground cables inside pipes, dam wall of electric power generating plants, rotary machines (monitoring and maintenance), and sensors based on MEMs for inspection inside and between pipes (this is already applied to electric power generating nuclear plants using a mini-robot based on MEMS), underground cable displacements (sensors alert engineers), microdisplacements, strain, concrete structure vibrations, event counter, nanoscale strength, and strain gage [1].

A proposed scheme for sensing/monitoring electric power transmission lines and power devices

Applications in the electric sector are based mainly on monitoring subsystems and power devices. There are some sensors based on MEMS and RFMEMS (Radio Frequency) as solutions for the electric sector applications, besides sensors based on IEEE 802.15.4/ZigBee. One of the main aspects from the sensor networks is that solutions trend to be very application specific.

A proposed scheme for sensing/monitoring electric power transmission lines and power devices is that: wireless sensors were self-powered (generating energy from electromagnetic and vibrational environment); wireless microsensors were used (microdisplacements and strain gages, etc.) embedded superficially on the material of lines and devices (considering RF attenuation of the material). Due to WSN has the characteristic of mesh network radio communication and the data aggregation function, these data are sent to a data concentrator radio node, which retransmits these data to the Wide Area Network (WAN), that could be by cellular telephony (GSM/GPRS).- Global System for Mobile/General Packet Radio Service), internet and radio communications. Finally, data from the WSN are received by the central station (a server with a data base).

Future work

For future work, it is proposed a research and development focused on electric power utility applications on sensing/monitoring electric power transmission lines and power devices with WSN.
Conclusion
In conclusion, an state-of-the-art revision on Wireless Sensor Networks (WSN) within the Smart Grid (SG) was carried out. The focus of this research work includes wireless communications and sensing, with application to sensing.monitoring electric power transmission lines and power devices, standards and a proposed scheme.

References


[18] 802.15.4-2006 IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs).


[22] P802.15.4g/d0.2 March 2010 IEEE Draft Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs) - Amendment 4: Physical Layer Specifications for Low Data Rate Wireless Smart Metering Utility Networks.


[25] INTEGRATED COMMUNICATIONS. Appendix B1: A
WHAT IS MISSING IN OUR FUNDAMENTAL KNOWLEDGE OF SMART GRID IMPLEMENTATION? GRIDWISE Alliance, November 9, 2009.

BIographies

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