

Smart Grid Using Wireless Sensor Network's and Routing Protocol

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ABSTRACT: Recent advances in embedded systems and wireless sensor networks (WSNs) made it possible to realize low-cost monitoring and automation systems for smart grids. This paper presents opportunities and design challenges of WSNs for smart grid applications. WSN-based smart grid applications have been introduced, and some WSN standards and communication protocols have been discussed for smart grid applications.

KEYWORDS: Sensor Networks, Grid Networks, Artificial Intelligence, Wireless Network.

I. INTRODUCTION

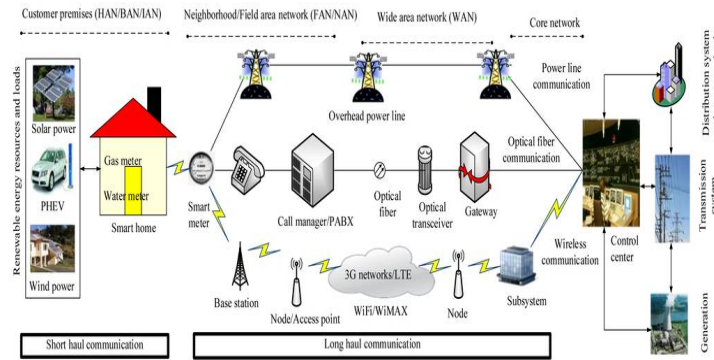
The complex and nonlinear nature of electric power distribution networks and the increasing electricity consumption in most countries have caused serious network congestion problems in recent years. Existing power distribution networks suffer from the lack of effective fault diagnostics, monitoring, automation, and communications. These factors, together with the overstressed situation, increase the possibility of system breakdowns. As a result of the increasing demands for clean, abundant, and sustainable electric energy together with the above-mentioned problems, smart grid concept has emerged. Smart grids are modern electric power grid infrastructures, which provide smooth integration of alternative and renewable energy sources (Renewable energy is generally defined as energy that is collected from resources which are naturally replenished on a human timescale, such

as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energyservices.) Through modern communication and sensing technologies and automated control. The potential benefits of smart grids are numerous and they can be outlined as follows: (i) increased energy consumption information available to consumers, (ii) improved physical and operational security and resilience against attacks or disasters, (iii) increased energy efficiency, (iv) improved reliability and safety, (v) the integration of a higher percentage of renewable energy sources, (vi) easy integration of plug-in electric vehicles, (vii) a reduction in peak energy demand, (viii) several environmental benefits.

Generally, a smart grid network consists of the following three segments. (1) Home area networks (HANs) connect smart meters with on-premise appliances, distributed renewable sources, and electrical vehicles. (2) Neighbourhood area networks (NANs) carry information between customer premises and aggregation points. (3) Wide area networks (WANs) serve as the backbone for communication between the utility data center and aggregation points.

edges followed by thresholding and morphological dilation, erosion operation. Then, connected component labelling is performed to label each object separately. Finally, the set of selection criteria is applied to filter out non text regions. After text detection, text inpainting is accomplished by using exemplar based Inpainting algorithm.

Paper is organized as follows. Section II describes automatic text detection using morphological operations, connected component analysis and set of selection or rejection criteria. The flow diagram represents the step of the algorithm.



Recent advances in Smart Grid (WSN's)

Embedded systems and wireless sensor networking made it possible to implement low-cost monitoring and diagnostic systems for smart grids. These systems receive information from wireless sensor nodes, which monitor critical smart grid equipments and are used to monitor and respond to the changing conditions in a proactive manner. Hence, WSNs have been recognized as a promising and complementary technology for various smart grid applications. Some of the existing and envisaged applications of WSNs in smart grids include load management and control, wireless automatic meter reading (WAMR), equipment fault diagnostics, remote monitoring, electric fault detection, and distribution automation.

II. WSN-BASED SMART GRID APPLICATIONS

Generally, WSN-based smart grid applications are divided into three groups: consumer side, transmission and distribution (T&D) side, and generation side WSN-based smart grid applications.

- **Consumer Side WSN-Based Smart Grid Applications.** Consumer side WSN-based smart grid applications have a direct relationship with different types of customers. Consumer side applications include advanced metering infrastructure, residential energy management, automated panels management, building automation, demand-side load management, process control monitoring, and equipment management and control monitoring.
- **Transmission and Distribution (T&D) Side WSN-Based Smart Grid Applications.** T&D side covers overhead power lines, underground power lines, and substations, and the applications designed for this side play a key role in smart grid, since these systems are responsible for successful power transmission. Some of the transmission and distribution side WSN-based smart grid applications are overhead transmission line monitoring, outage detection, conductor temperature rating systems, underground cable system monitoring, fault diagnostics, overhead and underground fault circuit indicators, cable, conductor and lattice theft, fault detection, and location.
- **Generation Side WSN-Based Smart Grid Applications.** These applications are generally based on monitoring task. Some of them are real-time generation monitoring, remote monitoring of wind farms, remote monitoring of solar farms, power quality monitoring, and distributed generation.
- **Communication and network requirements of smart grid applications** play an important role in implementation of WSN technologies for energy distribution infrastructures.

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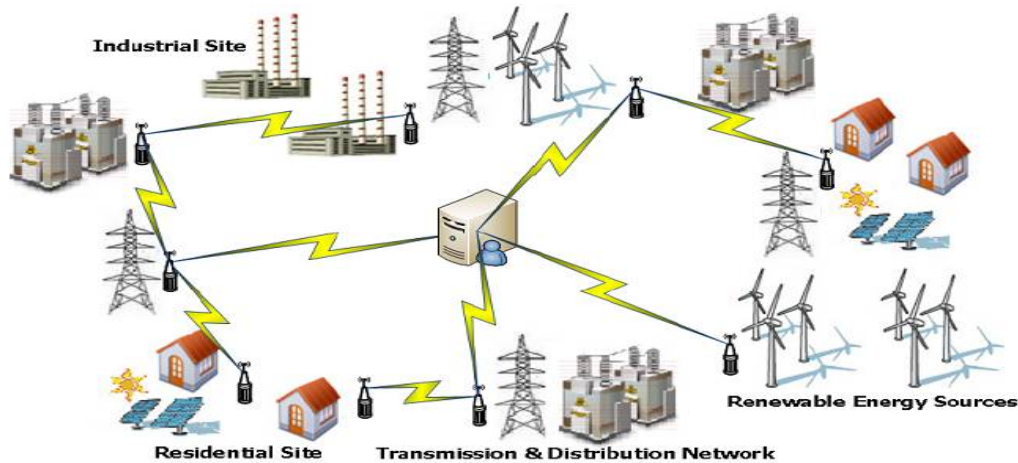


Fig:Design for smart grid transmission

Design Challenges of WSNs in Smart Grids

The major technical challenges for realization of WSN-based smart grid applications can be outlined as follows.

- Resource Limitations of Sensor Nodes. The design and implementation of a WSN is constrained by the hardware resources of sensor nodes due to limited physical size, such as energy, memory, and processing.
- Harsh Environmental Conditions and Dynamic Topologies. In power distribution environments, the connectivity and topology of the network may vary due to varying wireless link characteristics and node failures. In addition, sensor nodes may be subject to different environmental conditions which may cause sensor nodes to malfunction.
- QoS Requirements of Smart Grid Applications. Different QoS requirements and specifications in terms of reliability, throughput, and latency are required for different types of existing and envisaged smart grid applications.
- Packet Errors and Variable-Link Capacity. In electric power system environments, due to noisy environment and obstructions, the bandwidth of wireless links depend on the interference level perceived at receivers, and high bit error rates are observed in communication. Therefore, it is very hard to meet QoS requirements in smart grid applications due to the varying characteristics of wireless links .
- Security. Security is an essential feature in the design of WSN-based smart grid applications in order to provide safe communication by preventing intrusion and denial of service (DoS) attacks .

Since different WSN-based smart grid applications have different requirements and priorities, the tradeoffs among the different parameters can be balanced.

III.COMMUNICATION STANDARDS FOR WSN-BASED SMART GRID APPLICATIONS

This section discusses different communication standards and protocols, such as ZigBee, 6LoWPAN, Z-Wave, WirelessHART, ISA-100, and Wavenis, which can be used in WSN-based smart grid applications. ZigBee was developed by the ZigBee Alliance to meet the specifications of short-range and low-data applications. ZigBee Alliance is very active in the market as an independent organization with more than 340 members.

Zig-Bee protocol stack consists of 4 layers:

1. Physical (PHY) layer,
2. Medium access control (MAC) layer,
3. Network (NWK) layer, and
4. Application (APL) layer.

The IEEE 802.15.4 operates in the 868 MHz, 915 MHz, and 2.4 GHz bands and provides data rates up to 250 Kbps.

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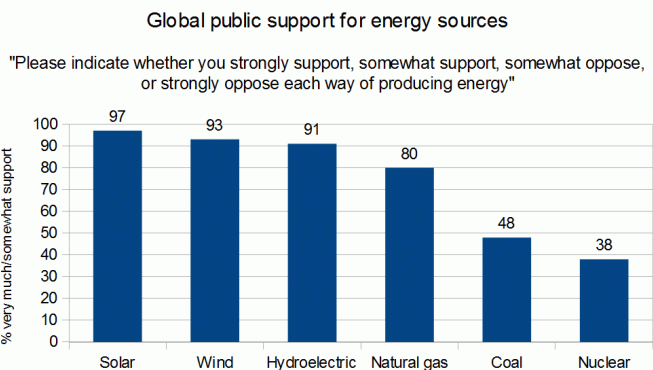
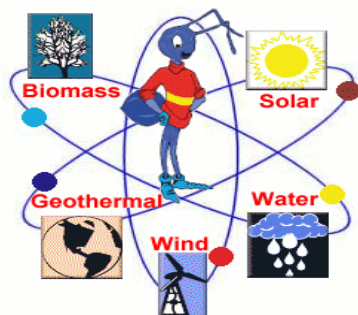
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6LoWPAN. 6LoWPAN was developed by the IETF (Internet Engineering Task Force (IETF)) IPv6 over Low-Power Wireless PAN (6LoWPAN) Working Group. The mechanisms offered by 6LoWPAN are fragmentation, header compression, IPv6 address auto configuration. In the mesh topology, mesh under and route over schemes are used for routing.

IV. DISCUSSION ON COMMUNICATION PROTOCOLS WITH REGARD TO SMART GRID APPLICATIONS

Considering the requirements of smart grid communications, the communication protocol stack of WSN standards is briefly discussed in this section. The details of these discussions are omitted to comply with the page limitations. (i) Physical Layer. IEEE 802.15.4 operates in the 915 MHz and 2.4 GHz bands with multichannel support. Therefore, it is possible to operate in smart grid environments with heavy interference by selecting the less interfered channel if IEEE-802.15.4 based protocols are preferred. Another advantage of IEEE-802.15.4-based protocols over other protocols is better signal-to-noise (SNR) ratios due to phase shift keying (PSK) modulations. Additionally, ZigBee avoids the multipath and narrowband interference by using the spread spectrum techniques. ISA-100 networks use channel hopping to increase reliability and minimize interference. All these features help network designers to meet the requirements of WSN-based smart grid applications. (ii) Link Layer. ZigBee and 6LoWPAN use 16-bit checksums, whereas Z-Wave uses 8-bit checksums to provide reliability. Considering end-to-end delay, ZigBee theoretically provides lower expected latency compared to other protocols. All protocols mentioned in the previous section support acknowledgment and retransmission mechanisms aiming to improve reliability in harsh environments. (iii) Network Layer. Link quality (LQ) metric is an important criterion in smart grid environments with multipath and interference. ZigBee uses the link quality indicator (LQI) offered by IEEE 802.15.4. On the other hand, 6LoWPAN does not require the use of LQI. Wavenis uses a received-signal-strength-indicator- (RSSI-) based LQ estimator which may not be accurate in some cases due to multipath and interference. Z-Wave does not take into account LQ. In general, LQ-aware routing protocols are preferred to ensure reliability in smart grid. (iv) Application Layer. ZigBee, Z-Wave, Wireless HART, and ISA-100 have a set of well-defined attributes, commands for various WSN-based smart grid applications. This can be advantageous while deploying WSNs for smart grid applications.

V. ENERGY HARVESTING FOR WSN-BASED SMART GRID APPLICATION



Source: Ipsos, May 2011

- Main power might be available in some WSN-based smart grid applications. On the other hand, in most implementations, sensor nodes are usually deployed in high voltage environments and require low-voltage power sources due to inappropriate power levels and high costs of wiring and necessary transformers. Due to that the use of batteries as main power sources for the sensor nodes makes periodic battery replacements unavoidable, energy harvesting methods play an important role in the lifetime of WSNs. If there are many battery-operated sensor nodes in the network, then an additional maintenance expense is required to change batteries periodically.

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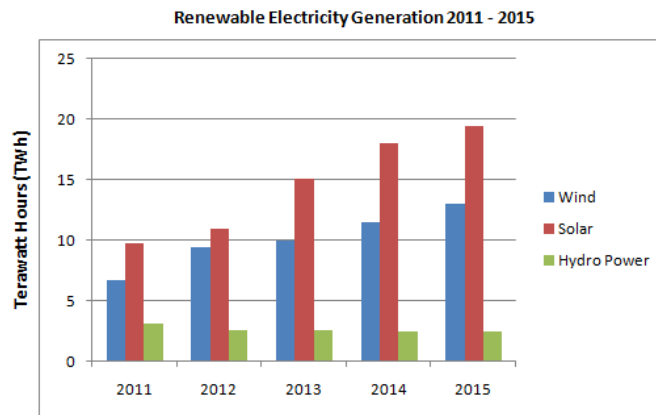
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Although many solutions exist, major energy harvesting techniques that can be used in smart grid applications can be summarized as above.

- **Solar Energy Harvesting.** Solar energy harvesting technique has been around for a long time. With the help of a photo voltaic system, sunlight is converted into electricity. The open circuit voltage and the short circuit current characterize solar panels. Although the value of depends on the amount of incident solar radiation, remains almost constant. Hence, various energy storage elements are used to store the harvested energy and to provide a stable voltage. The problem with this technique is that a continuous supply of sunlight may not be available all the time and solar cells suffer from low energy conversion efficiency. However, various cells are available in the market for both outdoor and indoor environments. Solar energy harvesting can be utilized effectively in outdoor smart grid environments including outdoor substations, transmission and distribution lines, solar farms, and wind farms.



- **Thermal Energy Harvesting.** Thermo generators harvest energy from objects or environments at different temperatures through heat transfer and produce an electrical voltage across difference in temperature between the cold and the hot junctions. Though thermal energy harvesting sounds promising, the maximum efficiency of this method is governed by the Carnot cycle. For instance, a difference of 17°C yields only 5.5% efficiency. This technique may be feasible in the future if thermal energy harvesting for smaller temperature differences is possible.
- **Air Flow Energy Harvesting.** Air flow can be used to produce electric energy. There are different approaches in the literature including micro wind turbines, oscillating wings, and flapping wings for this technique. The effectiveness of this technique depends on the collector area which is a function of required power output, air density, air speed, and conversion efficiency. For practical implementations, it may not be possible to design very small scale and effective converters.
- **Electromagnetic Wave Energy Harvesting.** Theoretically, an electric field of 1 V/m yields 0.26 $\mu\text{W}/\text{cm}^2$. However, such electric fields may only be encountered close to powerful transmitters. Although smart grid environments are energy rich, sensors must be located further away from high voltage conductors to function properly. Instead of this, RF energy can be broadcasted to power electronic devices. But this approach is limited by legal limits set by safety and health implications. This approach is already used in passive Radio Frequency Identification Systems (RFIDs).
- **Modulated Backscattering.** Data transmission is one of the major battery-consuming processes in sensor nodes. A design technique called modulated backscattering (MB) is very promising since by using this technique, wireless sensor nodes send their data just by switching the impedance of their antennas and reflecting the incident signal coming from an RF source. The source of energy is an RF power source which is AC/DC powered. In this technique, an RF source transmits RF power to run wireless passive sensor network (WPSN) nodes and transmits and receives information from the nodes simultaneously. Hence, the expected lifetime of WPSNs utilizing MB is longer than WSNs. On the other hand, the RF coverage provided over the field directly affects the communication

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performance of WPSNs. Another advantage of MB-based WPSNs is that theoretically long-range communication with the WPSN nodes is achievable without increasing the power consumption of the nodes. An important criterion which affects the design of WPSNs is the number of RF sources required for effective MB-based communication.

- **Magnetic Field Energy Harvesting.** The magnetic field near T&D lines can be harvested to power sensor nodes. Most of the magnetic field energy harvesters are based on transformer action, which requires a clamp around the conductor for energy harvesting. This requirement may limit their application.
- **Biochemical Energy Harvesting.** The chemical energy of glucose and oxygen in biofluid can be converted into electricity using an enzymatic biofuel cell (BFC). The highest theoretical voltage which can be obtained from a BFC depends on thermodynamics, and the maximum energy density of a BFC is up to 1 mW/cm^2

VI.CONCLUSION

This paper presents major opportunities and design challenges of WSNs for smart grid applications. WSN-based smart grid applications are introduced, and main WSN standards and communication protocols are discussed for smart grid applications. Importantly, node lifetime and link reliability in wireless sensor networking for smart grid applications have been evaluated. Overall, this paper resulting from inherent properties of WSNs and smart grid propagation environments and show that network designers planning to use WSNs for smart grid applications need to consider important sensor node parameters including transmission power, range, and channel parameters. Future work includes the development of cross-layer communication protocols to address link-quality variations in smart grid environments, QoS provisioning, and coordinated network management for different application types of smart grid. In addition, in order to prove the advantages of energy harvesting techniques for WSN-based smart grid applications.

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