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Design and Energy Consumption Issues in Wireless Sensor Network

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ABSTRACT

In this paper Design and energy Consumption Issues in wireless Sensor network is focussed. Energy consumption is the most important factor to determine the life of a sensor network because usually sensor nodes are driven by battery. Sometimes energy optimization is more complicated in sensor networks because it involved not only reduction of energy consumption but also prolonging the life of the network as much as possible. The optimization can be done by having energy awareness in every aspect of design and operation. This ensures that energy awareness is also incorporated into groups of communicating sensor nodes and the entire network and not only in the individual nodes.

Keywords: Wireless Network, Sensor Nodes, Sensor Network.

Introduction: Wireless Sensor Networks (WSNs) can be defined as a self-configured and infrastructureless wireless networks to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location or sink where the data can be observed and analysed. A sink or base station acts like an interface between users and the network. One can retrieve required information from the network by injecting queries and gathering results from the sink. Typically a wireless sensor network contains hundreds of thousands of sensor nodes. The sensor nodes can communicate among themselves using radio signals. A wireless sensor node is equipped with sensing and computing devices, radio transceivers and power components. The individual nodes in a wireless sensor network (WSN) are inherently resource constrained: they have limited processing speed, storage capacity, and communication bandwidth. After the sensor nodes are deployed, they are responsible for self-organizing an appropriate network infrastructure often with multi-hop communication with them. Then the onboard sensors start collecting information of interest. Wireless sensor devices also respond to queries sent from a "control site" to perform specific instructions or provide sensing samples. The working mode of the sensor nodes may be either continuous or event driven. Global Positioning System (GPS) and local positioning algorithms can be used to obtain location and positioning information. Wireless sensor devices can be equipped with actuators to "act" upon certain conditions. These networks are sometimes more specifically referred as Wireless Sensor and Actuator Networks as described in (Akkaya et al., 2005).

Wireless sensor networks (WSNs) enable new applications and require non-conventional paradigms for protocol design due to several constraints. Owing to the requirement for low device complexity together with low energy consumption (i.e. long network lifetime), a proper balance between communication and signal/data processing capabilities must be found. This motivates a huge effort in research activities, standardization process, and industrial investments on this field since the last decade (Chiara et. al. 2009). At present time, most of the research on WSNs has concentrated on the design of energy- and computationally efficient algorithms and protocols, and the application domain has been restricted to simple data-oriented monitoring and reporting applications (Labrador et. al. 2009). The authors in (Chen et al., 2011) propose a Cable Mode Transition (CMT) algorithm, which determines the minimal number of active sensors to maintain K-coverage of a terrain as well as K-connectivity of the network. Specifically, it allocates periods of inactivity for cable sensors without affecting the coverage and connectivity requirements of the network based only on local information. In (Cheng et al., 2011), a delay-aware data collection network structure for wireless sensor networks is proposed. The objective of the proposed network structure is to minimize delays in the data collection processes of wireless sensor networks which extends the lifetime of the network. In (Matin et al., 2011), the authors have considered relay nodes to mitigate the network geometric deficiencies and used Particle Swarm Optimization (PSO) based algorithms to locate the optimal sink location with respect to those relay nodes to overcome the lifetime challenge. Energy efficient communication has also been addressed in (Paul et al., 2011; Fabbri et al. 2009). In (Paul et al., 2011), the authors proposed a geometrical solution for locating the optimum sink placement for maximizing the network lifetime. Most of the time, the research on wireless sensor networks have considered homogeneous sensor nodes. But nowadays researchers have focused on heterogeneous sensor networks where the sensor nodes are unlike to each other in terms of their energy.

Design Issues of A Wireless Sensor Network : There are a lot of challenges placed by the deployment of sensor networks which are a superset of those found in wireless ad hoc networks. Sensor nodes communicate over wireless, lossy lines with no infrastructure. An additional challenge is related to the limited, 6 Wireless Sensor Networks – Technology and Protocols usually non-renewable energy supply of the sensor nodes. In order to maximize the lifetime of the network, the protocols need to be designed from the beginning with the objective of efficient management of the energy resources (Akyildiz et al., 2002). Wireless Sensor Network Design issues are mentioned in (Akkaya et al., 2005), (Akyildizet al., 2002), (SensorSim; Tossim, Younis et al., 2004), (Pan et al., 2003) and different possible platforms for simulation and testing of routing protocols for WSNs are discussed in (NS-2, Zeng et al., 1998, SensorSim, Tossiim). Let us now discuss the individual design issues in greater detail. Fault Tolerance: Sensor nodes are vulnerable and frequently deployed in dangerous environment. Nodes can fail due to hardware problems or physical damage or by exhausting their energy supply. We expect the node failures to be much higher than the one normally considered in wired or infrastructure-based wireless networks. The protocols deployed in a sensor network should be able to detect these failures as soon as possible and be robust enough to handle a relatively large number of failures while maintaining the overall functionality of the network. This is especially relevant to the routing protocol design, which has to ensure that alternate paths are available for rerouting of the packets. Different deployment environments pose different fault tolerance requirements. Scalability: Sensor networks vary in scale from several nodes to potentially several hundred thousand. In addition, the deployment density is also variable. For collecting highresolution data, the node density might reach the level where a node has several thousand neighbours in their transmission range. The protocols deployed in sensor networks need to be scalable to these levels and be able to maintain adequate performance. Production Costs: Because many deployment models consider the sensor nodes to be disposable devices, sensor networks can compete with traditional information gathering approaches only if the individual sensor nodes can be produced very cheaply. The target price envisioned for a sensor node should ideally be less than $1. Hardware Constraints: At minimum, every sensor node needs to have a sensing unit, a processing unit, a transmission unit, and a power supply. Optionally, the nodes may have several built-in sensors or additional devices such as a localization system to enable location-aware routing. However, every additional functionality comes with additional cost and increases the power consumption and physical size of the node. Thus, additional functionality needs to be always balanced against cost and low-power requirements. Sensor Network Topology: Although WSNs have evolved in many aspects, they continue to be networks with constrained resources in terms of energy, computing power, memory, and communications capabilities. Of these constraints, energy consumption is of paramount importance, which is demonstrated by the large number of algorithms, techniques, and protocols that have been developed to save energy, and thereby extend the lifetime of the network. Topology Maintenance is one of the most important issues researched to reduce energy consumption in wireless sensor networks. Transmission Media: The communication between the nodes is normally implemented using radio communication over the popular ISM bands. However, some sensor networks Overview of Wireless Sensor Network 7 use optical or infrared communication, with the latter having the advantage of being robust and virtually interference free. Power Consumption: As we have already seen, many of the challenges of sensor networks revolve around the limited power resources. The size of the nodes limits the size of the battery. The software and hardware design needs to carefully consider the issues of efficient energy use. For instance, data compression might reduce the amount of energy used for radio transmission, but uses additional energy for computation and/or filtering. The energy policy also depends on the application; in some applications, it might be acceptable to turn off a subset of nodes in order to conserve energy while other applications require all nodes operating simultaneously.

Structure of A Wireless Sensor Node : A sensor node is made up of four basic components such as sensing unit, processing unit, transceiver unit and a power unit which is shown in Fig. 5. It also has application dependent additional components such as a location finding system, a power generator and a mobilizer. Sensing units are usually composed of two subunits: sensors and analogue to digital converters (ADCs) (Akyildiz et al., 2002). The analogue signals produced by the sensors are converted to digital signals by the ADC, and then fed into the processing unit. The processing unit is generally associated with a small storage unit and it can manage the procedures that make the sensor node collaborate with the other nodes to carry out the assigned sensing tasks. A transceiver unit connects the node to the network. One of the most important components of a sensor node is the power unit. Power units can be supported by a power scavenging unit such as solar cells. The other subunits, of the node are application dependent. A functional block diagram of a versatile wireless sensing node is provided in Fig. 6. Modular design approach provides a flexible and versatile platform to address the needs of a wide variety of applications. For example, depending on the sensors to be deployed, the signal conditioning block can be re-programmed or replaced. This allows for a wide variety 10 Wireless Sensor Networks – Technology and Protocols of different sensors to be used with the wireless sensing node. Similarly, the radio link may be swapped out as required for a given applications' wireless range requirement and the need for bidirectional communications. Using flash memory, the remote nodes acquire data on command from a base station, or by an event sensed by one or more inputs to the node. Moreover, the embedded firmware can be upgraded through the wireless network in the field. The microprocessor has a number of functions including:

- Managing data collection from the sensors
- performing power management functions
- interfacing the sensor data to the physical radio layer
- managing the radio network protocol

A key aspect of any wireless sensing node is to minimize the power consumed by the system. Usually, the radio subsystem requires the largest amount of power. Therefore, data is sent over the radio network only when it is required. An algorithm is to be loaded into the node to determine when to send data based on the sensed event. Furthermore, it is important to minimize the power consumed by the sensor itself. Therefore, the hardware should be designed to allow the microprocessor to judiciously control power to the radio, sensor, and sensor signal conditioner (Akyildiz et al., 2002).

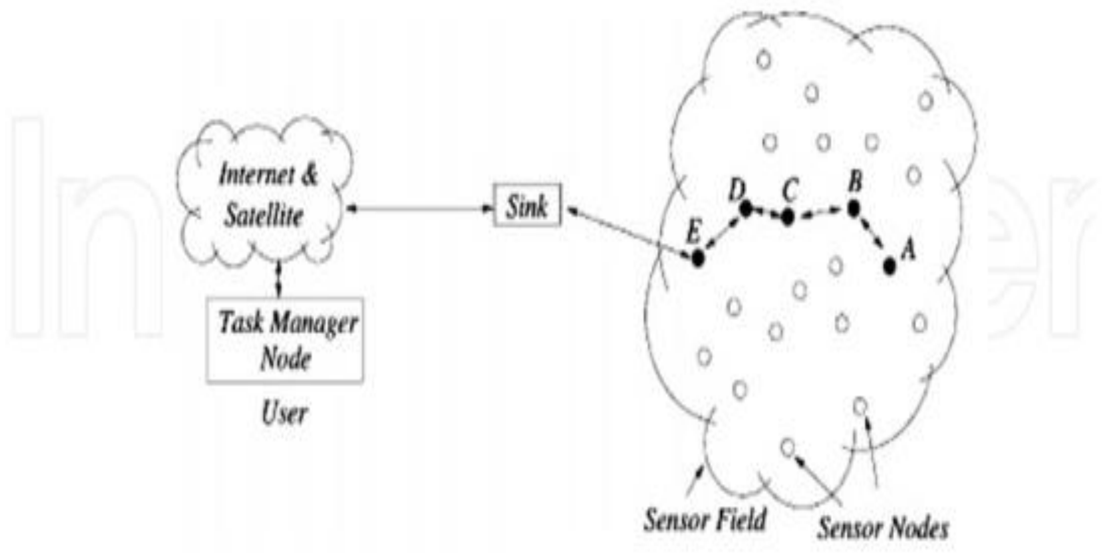

Figure (1). A typical Wireless Sensor Network

Energy consumption issues in wireless sensor network:

Energy consumption is the most important factor to determine the life of a sensor network because usually sensor nodes are driven by battery. Sometimes energy optimization is more complicated in sensor networks because it involved not only reduction of energy consumption but also prolonging the life of the network as much as possible. The optimization can be done by having energy awareness in every aspect of design and operation. This ensures that energy awareness is also incorporated into groups of communicating sensor nodes and the entire network and not only in the individual nodes (Bharathidasan et al. 2001). A sensor node usually consists of four sub-systems (Bharathidasan et al. 2001):

• a computing subsystem : It consists of a microprocessor(microcontroller unit, MCU) which is responsible for the control of the sensors and implementation of communication protocols. MCUs usually operate under various modes for power management purposes. As these operating modes involves consumption of power, the energy consumption levels of the various modes should be considered while looking at the battery lifetime of each node.

• a communication subsystem: It consists of a short range radio which communicate with neighboring nodes and the outside world. Radios can operate under the different modes. It is important to completely shut down the radio rather than putting it in the Idle mode when it is not transmitting or receiving for saving power.

• a sensing subsystem : It consists of a group of sensors and actuators and link the node to the outside world. Energy consumption can be reduced by using low power components and saving power at the cost of performance which is not required. Overview of Wireless Sensor Network 13

• a power supply subsystem : It consists of a battery which supplies power to the node. It should be seen that the amount of power drawn from a battery is checked because if high current is drawn from a battery for a long time, the battery will die faster even though it could have gone on for a longer time. Usually the rated current capacity of a battery being used for a sensor node is less than the minimum energy consumption. The lifetime of a battery can be increased by reducing the current drastically or even turning it off often. To minimize the overall energy consumption of the sensor network, different types of protocols and algorithms have been studied so far all over the world. The lifetime of a sensor network can be increased significantly if the operating system, the application layer and the network protocols are designed to be energy aware. These protocols and algorithms have to be aware of the hardware and able to use special features of the micro-processors and transceivers to minimize the sensor node's energy consumption. This may push toward a custom solution for different types of sensor node design. Different types of sensor nodes deployed also lead to different types of sensor networks. This may also lead to the different types of collaborative algorithms in wireless sensor networks arena.

Conclusion : The aim of this paper is to discuss few important issues of WSNs, from the application, design and technology points of view. For designing a WSN, we need to consider different factors such as the flexibility, energy efficiency, fault tolerance, high sensing fidelity, lowcost and rapid deployment, above all the application requirements. We hope the wide range of application areas will make sensor networks an integral part of our lives in the future. However, realization of sensor networks needs to satisfy several constraints such as scalability, cost, hardware, topology change, environment and power consumption. Since these constraints are highly tight and specific for sensor networks, new wireless ad hoc networking protocols are required. To meet the requirements, many researchers are engaged in developing the technologies needed for different layers of the sensor networks protocol stack. Future research on WSN will be directed towards maximizing area throughput in clustered Wireless Sensor Networks designed for temporal or spatial random process estimation, accounting for radio channel, PHY, MAC and NET protocol layers and data aggregation Overview of Wireless Sensor Network 21 techniques, simulation and experimental verification of lifetime-aware routing, sensing spatial coverage and the enhancement of the desired sensing spatial coverage evaluation methods with practical sensor model. The advances of wireless networking and sensor technology open up an interesting opportunity to manage human activities in a smart home environment. Real-life activities are often more complex than the case studies for both single and multi-user. Investigating such complex cases can be very challenging while we consider both single- and multi-user activities at the same time. Future work will focus on the fundamental problem of recognizing activities of multiple users using a wireless body sensor network. Wireless Sensor Networks hold the promise of delivering a smart communication paradigm which enables setting up an intelligent network capable of handling applications that evolve from user requirements. We believe that in near future, WSN research will put a great impact on our daily life. For example, it will create a system for continual observation of physiological signals while the patients are at their homes. It will lower the cost involved with monitoring patients and increase the efficient exploitation of physiological data and the patients will have access to the highest quality medical care in their own homes. Thus, it will avoid the distress and disruption caused by a lengthy inpatient stay.

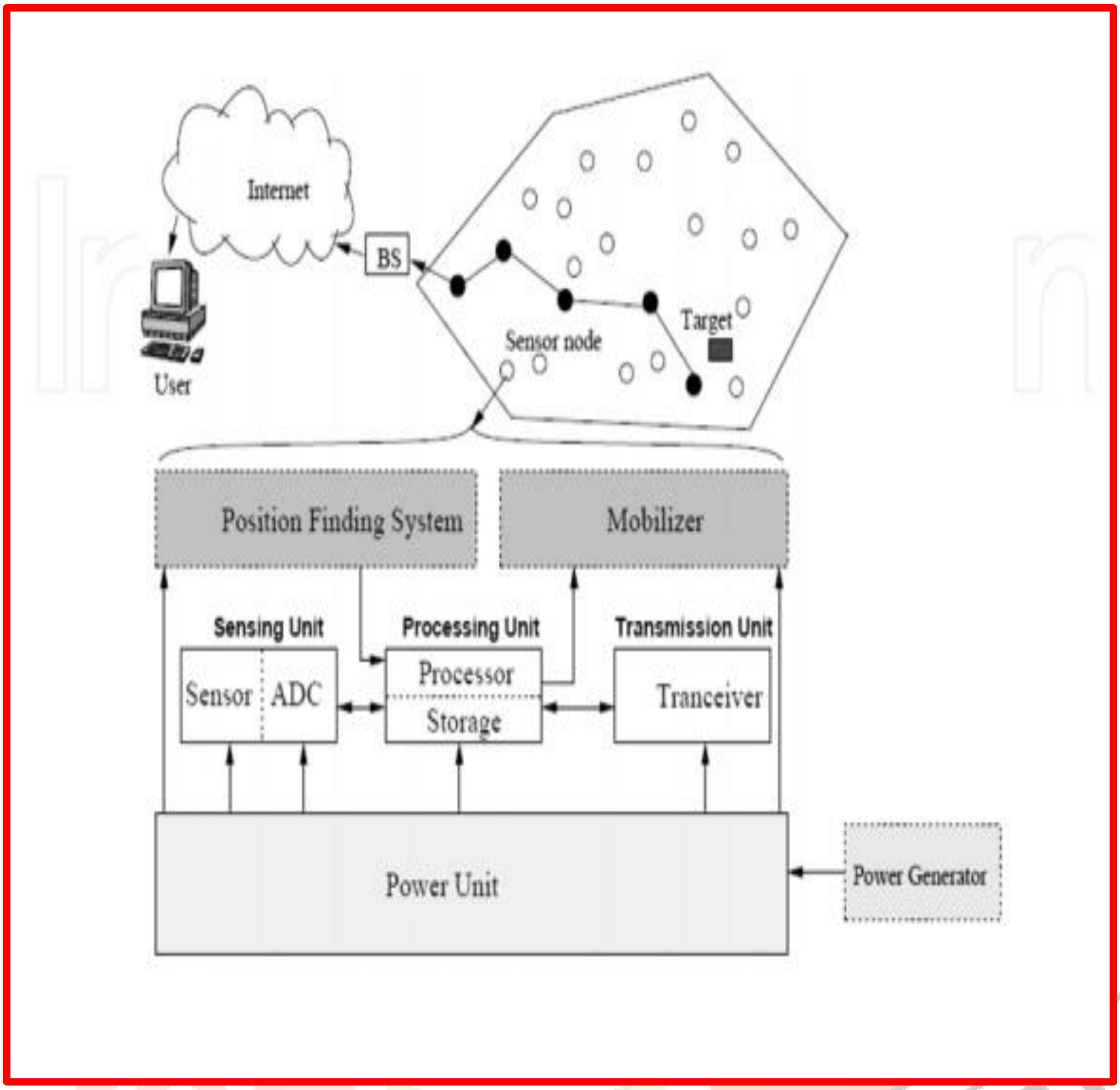

Figure 2. The Components Of A Sensor Nodes

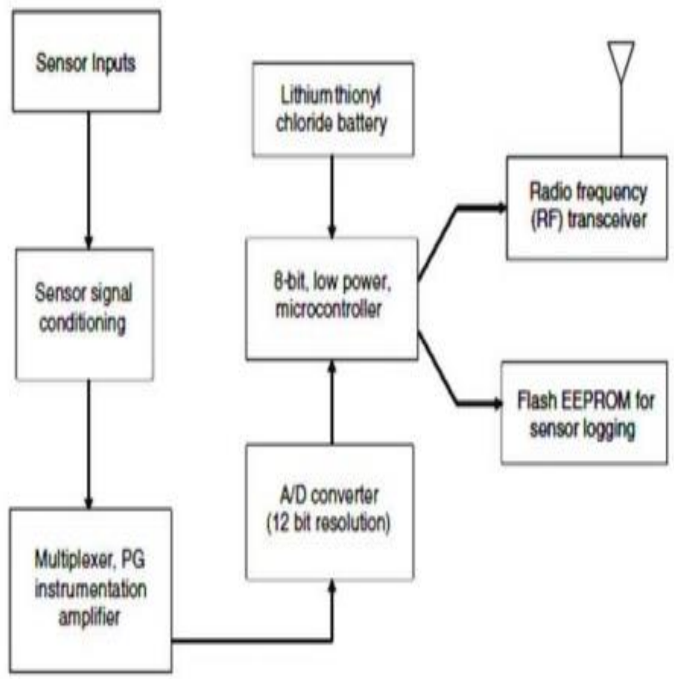

Figure 3. Functional Block Diagram Of A Sensor Node

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