Study of Wireless Sensor Networks its Routing Challenges and Available Sensor Nodes

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Abstract

Wireless sensor network requires an extremely large broad of knowledge from an extremely large variety of disciplines so its study become challenging. The wireless sensor network consists of small nodes having sensing, computation, and wireless communications capabilities or it may also consists of spatially distributed anomalous sensor to monitor physical or environmental conditions, such as pressure, temperature, sound, etc. In wireless sensor network, each node is connected to one or more sensors, because it is built of nodes from a few to several hundreds or even thousands. In this paper we also highlight the advantages of ideal WSNs, characteristics of WSNs and its application. Several routing challenge and design issue are also described in this paper. In this article a list of sensor nodes and its features are also tabulated.

Keywords- *Wireless Sensor Networks, The sensor node, Wireless Sensor Network application, Routing challenges, Available Sensor Nodes.*

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1. Introduction

The wireless sensor network (WSN) requires an enormous breadth of knowledge from an enormous variety of disciplines, so its study becomes challenging [1]. A wireless sensor network basically consists of small devices called sensor nodes having the capability of sensing the environment around them, computation the task, and performing wireless communications. Sensor networks may also consist of different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared, radar and acoustic, which monitor a wide variety of ambient conditions that includes [2]:

- Temperature
- Humidity
- Vehicular movement
- Lightning condition
- Pressure
- Soil makeup
- Noise levels
- The presence or absence of certain kinds of objects
- Mechanical stress levels on attached objects
- The current characteristics such as size of an object, its speed and direction also

In wireless sensor network, each node is connected to one or more sensors, because it is built of nodes from a few to several hundreds or even thousands as shown in figure 1**.** That sensor network node having several parts: a radio transceiver with an internal antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery.

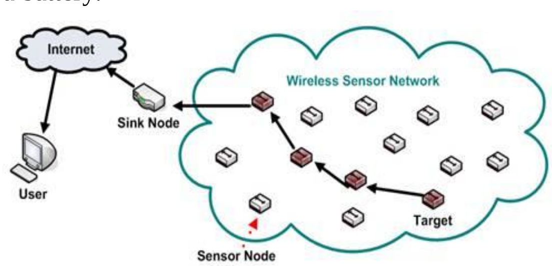

Figure 1. Wireless sensor network configuration

An important feature in wireless sensor networks is the battery lifetime of the node. Energy efficiency is a main challenge in wireless sensor networks and energy use is dominated by the energy required to keep the nodes active and running. In wireless sensor networks the size and cost of the sensor nodes may vary from micro to macro and from one to few hundred dollars respectively. Battery power decides whether the sensor nodes sense for long time or for short time even the battery cannot be recharged or replaced.

2. Node and the Sensor Node

A node is any device which is connected to a computer network. Nodes can be computers, personal digital assistants (PDAs), cell phones, or various other network appliances [3]. A node is also a connection point, either a redistribution point or a communication end point in communication network

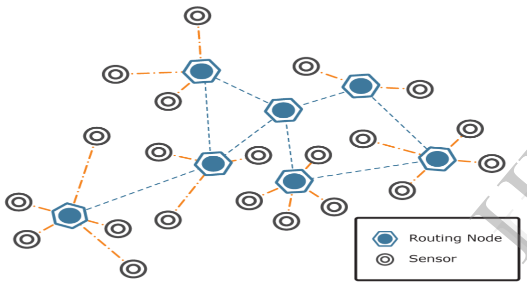

Figure 2. Routing nodes and sensors

The sensor nodes are devices having the capability of sensing, gathering, storing, transmitting information and communicating with other connected nodes in the network. A sensor node is also known as a mote (chiefly in North America) [3]. A mote is a node but a node is not always a mote.

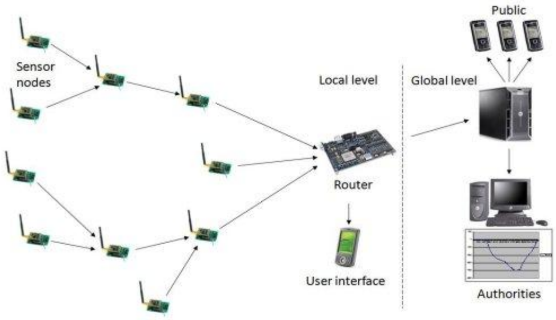

Figure 3. Sensor nodes connection

2.1 Components of sensor node

There are different component in wireless sensor networks, but the main components of a sensor node contains [4]

- Power unit
- Sensing unit
- Processing unit
- Transmission unit

In the **power unit,** the sensor node consumes power for sensing, communicating and data processing. Power is stored either in batteries or capacitors. Batteries, both rechargeable and non-rechargeable, are the main source of power supply for sensor nodes.

The **battery** supplies power to the complete sensor node plays an important role in determining sensor node lifetime. The amount of power that is drawn from a battery should be carefully monitored in WSNs. Batteries normally store 2.2 to 2.5 Ah at 1.5 V. However, these numbers vary depending on the technology utilized. For example, Zinc–air-based batteries have higher capacity in Joules/cm³ than lithium batteries. Alkaline batteries have the smallest capacity, normally around 1200 J/cm³.

In the **sensing unit,** two major components are sensor and analog-to-digital converter (ADC). To change in a physical condition like temperature or pressure sensors are hardware devices that produce a measurable response. Three types of sensor used are passive, Omni-directional sensors; passive, narrow-beam sensors; and active sensors. Sensors measure physical data of the parameter to be monitored. The continual analog signal produced by the sensors is digitized by an analog-to-digital converter and then it sent to controllers for further processing.

In the **processing unit,** two major components are processor like microcontroller and storage device like memory. A microcontroller is often used in many embedded systems such as sensor nodes because of its low cost, flexibility to connect to other devices, ease of programming, and low power consumption. A general purpose microprocessor generally has higher power consumption than a microcontroller; therefore it is often not considered a suitable choice for a sensor node. On-chip memory of a microcontroller and Flash memory off-chip RAM are the most relevant kinds of memory that are used. Flash memories are used due to their cost and storage capacity. Two categories of memory based on the purpose of storage are: user memory used for storing application related or

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personal data, and program memory used for programming the device. Program memory also contains identification data of the device if present.

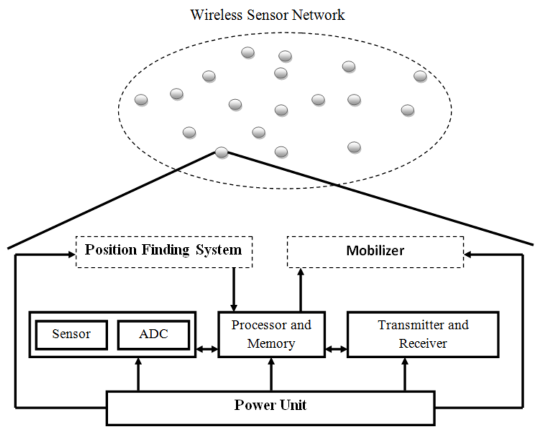

Figure 4. Components of sensor node

In transmission unit, the transmission media are Radio frequency (RF), Optical communication (Laser) and Infrared. The functionality of both transmitter and receiver are combined into a single device known as transceivers. Radio frequency based communication is the most relevant that fits most of the WSN applications. WSNs tend to use license-free communication frequencies: 173, 433, 868, and 915 MHz, and 2.4 GHz [3]. Lasers require less energy, but need line-of sight for communication and are sensitive to atmospheric conditions. Infrared, like lasers, needs no antenna but it is limited in its broadcasting capacity.

2.2 Characteristics of WSNs

The wireless sensor networks are characterized by different parameters that play important roles. The main characteristics of a wireless sensor networks includes

- Power consumption constrains for nodes using batteries or energy harvesting
- Ability to cope with node failures
- Mobility of nodes
- Communication failures
- Heterogeneity of nodes
- Scalability to large scale of deployment
- Ability to withstand harsh environmental conditions
- Power consumption

2.3 Applications of WSNs

In 2012, according to a new report from research, the home market for Wireless Sensor Networks (WSN) will reach US$6 billion. In 2013, World predicts the market for "Home Area Network" (HAN) energy management solutions to reach 20 million homes worldwide. Applications of WSNs are found in many fields in [5]. It plays an important role in health, home, environment, military etc. Some categories of their applications are listed below.

- Environmental applications
- Health applications
- Home applications
- Military applications
- Other commercial applications

In **Environmental applications**, mainly the sensor networks monitor environmental conditions that affect crops and livestock and the movements of birds, and small animals are tracking, It also includes earth monitoring and planetary exploration, earth and environmental monitoring in marine, soil, and atmospheric contexts, chemical/ biological detection and precision agriculture, forest fire detection, flood detection [6], bio complexity mapping of the environment [7], geophysical or meteorological research and pollution study.

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In **Health applications** the sensor networks includes patient monitoring, diagnostics, monitoring of human physiological data, tracking and monitoring doctors and patients inside a hospital. It also includes drug administration in hospitals. Monitoring of human physiological data: In which the sensor network collect physiological data that can be stored for a long period of time and can be used for medical exploration. Tracking and monitoring doctors and patients inside a hospital: Each patient has small and light weight sensor nodes having its specific task. For example, one sensor node may be detecting the heart rate while another is detecting the blood pressure. Drug administration in hospitals: The chance of getting and prescribing the wrong medication to patients can be minimized if sensor nodes can be attached to medications. Since the sensor nodes identify the allergies and required medications of the patients.

In **Home applications** sensor nodes can be applies as vacuum cleaners, micro-wave ovens, refrigerators, and VCRs [8]. These sensor nodes inside the domestic devices can interact with each other and with the external network via the internet or satellite. The sensor nodes can be embedded into furniture and appliances, and they can communicate with each other and the room server. The room server can also communicate with other room servers to learn about the services they offered, e.g., printing, scanning, and faxing.

In **Military applications**, the wireless sensor networks play an important role. It can be an integral part of military command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting (C4ISRT) systems. Since sensor networks are based on the dense deployment of disposable and low-cost sensor nodes, destruction of some nodes by hostile actions does not affect a military operation as much as the destruction of a traditional sensor. Some of the military applications of sensor networks are monitoring friendly forces, reconnaissance of opposing forces, battlefield surveillance, battle damage assessment, targeting, biological and chemical (NBC) attack detection and reconnaissance.

Commercial applications of sensor network containing toys, museums, machine diagnosis, monitoring product quality, monitoring and detecting car thefts, managing inventory, environmental control in office buildings, robot control and guidance in automatic manufacturing environments, factory instrumentation, factory process control and automation, transportation, local control of actuators, vehicle detection and tracking, and instrumentation of semiconductor processing chambers, wind tunnels.

3. Routing Challenge and Design Issue in WSNs

WSNs have several restrictions, such as limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes even they have innumerable applications. One of the main design goals of WSNs is to carry out data communication while trying to prolong the lifetime. Routing challenges and design issues in WSN plays an important role during the routing process. The routing challenges and design issues in [9], that affect the routing process in WSNs are summarize below.

- Node deployment
- Energy consumption without losing accuracy
- Data reporting method
- Node/link heterogeneity
- Fault tolerance
- Scalability
- Network dynamics
- Transmission media
- Connectivity
- Coverage
- Data aggregation
- Quality of service

Node deployment: Node deployment in WSNs is application-dependent. It can be either manual or randomized. In manual deployment, the sensors are manually placed and data is routed through predetermined paths, while in random node deployment, the sensor nodes are scattered randomly, creating an ad hoc routing infrastructure. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy-efficient network operation. The reliability $R_k(t)$ or fault tolerance of a sensor node is modeled in [10] using the Poisson distribution to capture the probability of not having a failure within the time interval (0; t): $R_k(t)=\exp(-\lambda_k)$, where λ_k and t are the failure rate of sensor node k and the time period, respectively.

Energy consumption without losing accuracy: Sensor nodes can use up their limited supply of energy performing computations and transmitting information in a wireless environment. As such, energy-conserving forms of communication and computation are essential. Sensor node lifetime shows a strong dependence on battery lifetime [11]. In a multi hop WSN, each node plays a dual role as data sender and data router.

Data reporting method: It is also application-dependent method and also depends on the time criticality of the data. Data reporting can be categorized as either time-driven, event driven, query-driven, or a hybrid of all these methods. The time-driven delivery method is suitable for applications that require periodic data monitoring. As such, sensor nodes will switch on their sensors and transmitters, sense the environment, and transmit the data at constant periodic time intervals.

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Sensor nodes react immediately and drastic changes in the value of a sensed attribute due to the occurrence of a certain event, or respond to a query generated by the base station as in case of event-driven and query-driven methods.

Node/link heterogeneity: The existence of a heterogeneous set of sensors raises many technical issues related to data routing. For example, some applications might require a diverse mixture of sensors for monitoring temperature, pressure, and humidity of the surrounding environment, detecting motion via acoustic signatures, and capturing images or video tracking of moving objects. Either these special sensors can be deployed independently or the different functionalities can be included in the same sensor nodes. For example, hierarchical protocols designate a cluster head node different from the normal sensors.

Fault tolerance: Some sensor nodes may fail or be blocked due to lack of power, physical damage, or environmental interference. The overall task of the sensor network should not affected by failure of sensor nodes. This may require actively adjusting transmit powers and signaling rates on the existing links to reduce energy consumption, or rerouting packets through regions of the network where more energy is available. Therefore, in a fault-tolerant sensor network multiple levels of redundancy may be needed.

Scalability: A system is said to be scalable if its effectiveness increases when the hardware is put-on and proportional to the capacity added [12]. Routing schemes make efforts with the vast collection of motes in WSNs which should be scalable enough to talk back to the events take place in the environment.

Network dynamics: In many studies, sensor nodes are assumed fixed. However, in many applications both the BS or sensor nodes can be mobile [13]. As such, routing messages from or to moving nodes is more challenging since route and topology stability become important issues, in addition to energy, bandwidth, and so forth. Moreover, the phenomenon can be mobile (e.g. - target detection/ tracking application). On the other hand, sensing fixed events allows the network to work in a reactive mode (i.e.- generating traffic when reporting), while dynamic events in most applications require periodic reporting to the BS.

Transmission media: In a multi hop sensor network, communicating nodes are linked by a wireless medium. The traditional problems associated with a wireless channel (e.g., fading, high error rate) may also affect the operation of the sensor network. In general, the required bandwidth of sensor data will be low, on the order of 1–100 kb/s. Related to the transmission media is the design of MAC.

Connectivity: Sensor nodes are expected to be highly connected. This, however, may not prevent the network topology from being variable and the network size from shrinking due to sensor node failures. In addition, connectivity depends on the possibly random distribution of nodes.

Coverage: In WSNs, each sensor node obtains a certain view of the environment. A given sensor's view of the environment is limited in both range and accuracy; it can only cover a limited physical area of the environment. Hence, area coverage is also an important design parameter in WSNs.

Data aggregation: The main goal of data aggregation algorithms is to gather and aggregate data from different sources by using different functions such as suppression, min, max and average to achieve energy efficient and traffic optimization in routing protocols so that network lifetime is enhanced.

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Quality of service: Bounded latency for data delivery is another condition for time-constrained applications. However, in many applications, conservation of energy, which is directly related to network lifetime, is considered relatively more important than the quality of data sent. As energy is depleted, the network may be required to reduce the quality of results in order to reduce energy dissipation in the nodes and hence lengthen the total network lifetime. Hence, energy-aware routing protocols are required to capture this requirement.

4. Routing protocols in WSNs

From the protocols used in other fixed networks the routing protocols used in the sensor networks are unique. Since energy awareness is an essential design issue, many routing protocols have been proposed for WSNs based on network structure and protocol operation. Based on network structure routing protocols are categories into location-based routing , data-centric routing and hierarchical routing as shown in figure 5. In data-centric routing, all nodes are assigned equal functionality or roles. In hierarchical-based routing, nodes will play different roles in the network. However, In location-based routing, sensor node's positions are make used to route data in the network.

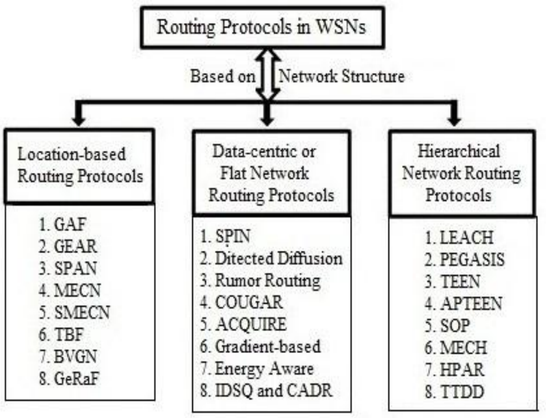

Figure 5. Routing protocols based on network structure

while based on protocol operation routing protocols are divided into coherent-based routing, negotiation -based routing, multipath-based routing, QoS-routing and query-based routing as shown in figure 6. Furthermore, multipath-base routing protocols are divided into three categories depending on how the source finds a route to the destination. They are proactive, reactive, and hybrid protocols. In proactive protocols or table drim protocols, all routes are computed bepending upon incremental update and full dump, while in reactive protocols, routes are computed on demand basis. Hybrid protocols use a combination of these two protocols, that is proactive and reactive.

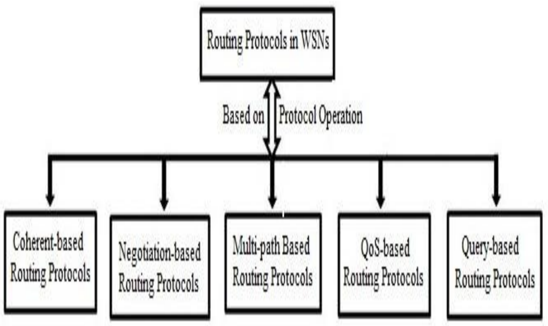

Figure 6. Routing protocols based on protocols operation

Another class of routing protocols is called the cooperative routing protocols. In cooperative routing, nodes send data to a central node where data can be aggregated and may be subject to further processing, hence reducing route cost in terms of energy use.

5. Wireless Sensor Networks are Different from Ad Hoc networks in the following manner.

Although many protocols and algorithms have been proposed for traditional wireless ad hoc networks, they are not well suited for the unique features and application requirements of sensor networks. The differences between sensor networks and ad hoc networks [14] are summarizing below:

- The number of sensor nodes in a sensor network which are data centric can be several orders of magnitude higher than the nodes in an ad hoc network which are address centric.
- In case of sensor network the batteries are not rechargeable or replaceable where as batteries can be replaced in case of ad hoc networks.
- Sensor nodes are prone to failures and densely deployed even its topology changes very frequently.
- Sensor nodes mainly use broadcast communication paradigm whereas most ad hoc networks are based on point-to-point communications.
- Sensor nodes are limited in power, computational capacities, and memory. So the routing protocols used in ad hoc networks usually cannot be used in sensor networks even different routing mechanisms are used in sensor networks.
- Because of the large amount of overhead and sensors, Sensor nodes may not have global identification (ID). So unique addressing is not possible in case of sensor networks.

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6. List of wireless sensor nodes

The available prototype and the commercial sensor nodes are listed in the following tables [15, 16, 17].

Sensor Node Name	**Microcontroller**	**Transceiver**	**Program+ Data Memory**
Arago systems Wi SMode Dev	MSP430 F5437	CC2520	RAM:16 KB,flash:256 KB
Arago systems Wi Smote Mini	ATMEGA128 RFA2	ATMEGA 128 RFA2	RAM:16KB,flash:128 KB
BTnode	ATMEGA128L	CC1000	64+180 KB RAM
COOKIES	ADUC841,MSP430	ETRX2 TELEGESIS	4 Kbytes + 62 Kbytes
Dot	ATMEGA163		1 KB RAM
EPIC mote	MSP430	250Kbit/s, 2.4 GHz. 802.15.4	10 KB RAM
Eyes IFX	MSP430 F149	TDA5250 (868MHz)	
Flat Mesh FM1	16 MHz	802.15.4-comlpiant	
GW node	PIC18LF8722	BIM(173 MHz)FSK	64 KB RAM
Imote	ARM 12MHz	Bluetooth range 30m	64 KB RAM
I Mote 2.0	Marvell PXA271	TICC2420 802.15.4	32 MB SRAM
Iris Mote	ATMEGA 1281	AT86RF230	8 KB RAM
K Mote	TI MSP430	250Kbit/s, 2.4 GHz, 802.15.4	10 KB RAM
Mica	ATMEGA 103	RFM TR1000 radio 50 kbit/s	128+4 KB RAM
Neo Mote	ATMEGA 128L	TI CC2420 802.15.4	4 KB RAM
Nymph	ATMEGA 128L	CC1000	64 KB EEPROM
Preon32	ARM cortex M3	AT86RF231 (2.4 GHz)	RAM:64KB+Flash:256KB
Rene	ATMEL8535	916 MHz radio with bandwidth 10 kbit/s	512 bytes RAM
Shimmer	MSP430 F 1611	TICC2420 802.15.4 shimmer RS7	10 KB RAM, 48 KB Flash
Tiny node	MSP430	Semtech SX1211	8KB RAM
Ubimote1	CC2430	TI’s CC2430	8KB RAM
Ubimote2	MSP430 F 2618	TI’s CC2430	8KB RAM
VE mesh	TI MSP430	SX1211/1231	512 KB RAM
Wireless RS495	ATMEGA 128L	CC2420 802.15.4	4 KB RAM
Wasp mote	ATMEGA 1281	ZigBee/802.15.4/DigiMesh/RF	8 KB SRAM
XM1000	MSP430 F 2618	TI’s CC2430	8 KB RAM
XYZ	ARM/THUMB	CC2420	32 KB RAM
Zolertia Z1	MSP430 F 2617	CC2430 (2.4GHz), 802.15.4	8 KB RAM

Following table listed the gateway sensor nodes

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Sensor Node Name	Microcontroller	Transceiver	Program + Data Memory
ADVANTIC SYS SG1000	D525 2x1.8 GHz	802.15.4-compliant	
DWARA CS 03A30	ATMEG A 128L	802.15.4 compliant	128 KB Flash
Shimmer Span	MSP439 F 1611	802.15.4 Shimmer RS7	10 KB RAM 48 KB Flash
Star gate	PXA255	802.11	64 MB SDRAM
Flat Mesh FMG-S	16 MHz	802.15.4-compliant	
VE Mesh	TI MSP430	SX1211/123	2KB RAM + 16 KB Flash

7. Conclusions

The enabling applications of wireless sensor networks were not practical previously. Today low power systems are continually developed and new standards-based networks are released. Now we will start to see the widespread deployment of wireless sensor networks. The sensor networks having characteristics like flexibility, high sensing fidelity, low-cost, fault tolerance, rapid deployment etc that creates many new and exciting application areas for remote sensing. In the future, this wide range of application areas will make sensor networks an integral part of our lives. However, the constraints introduced by factors such as scalability, fault tolerance cost, hardware, topology change, power consumption and environment satisfy the needs of the realization of sensor networks. Since these constraints are highly stringent and specific for sensor networks.

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