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SOME BACKGROUND STUDIES ON WIRELESS SENSOR NETWORKS: ARCHITECTURE, TOPOLOGY, APPLICATIONS, ISSUES AND CHALLENGES

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Abstract:

The day to day development in data communication system has provided a chance of using new modern devices for network communication. The size of Wireless Sensor Network (WSN) is very small, due to its size it can be easily deployed in different remote locations and applications. In wireless network almost all nodes are distributed over a network and are logically inter connected with each other. Logically inter connected nodes are useful to increase reliability and fault tolerance of wireless sensor network. In this study we conducted detailed literature survey on wireless sensor node hardware and software components, studied related applications of wireless sensor nodes, reviewed the various issues and challenges of wireless sensor networks and we discussed different category of topologies suitable for WSN. At the end we described sensor single node architecture view, hardware components and properties of sensor node.

Key words: Sensor node, Wireless networks, Quality of service, network topologies, energy consumption, and Applications.

I. Introduction

Sensor networks are an advanced technology of semiconductor or communication networks. Because of sensor node size (small) it can be easily deployed in small tools or geographically located areas. Sensor network is a network has interconnected nodes swapping sensed information by using wired or wireless network. Sensor network consists of number of sensor nodes and all are logically connected to centralized processing device to process sensed data [1]. Existing wired communication network devices are replaced with wireless device due to less expensive, it is very easy to use, and it can be easily deployed to monitor and controlling applications. At present many applications are developed based on wireless sensor network concept [2]. These type of applications use more number of sensor nodes

and are deployed across geographical locations[3]. All these nodes are equipped with battery, small processing unit, memory, and sensor components.

Sensor node is simply hardware device and has sub components like sensor (s) and other component (s) which is useful to process sensed data and communicating collected information over a network to another node [4]. In general more number of sensor nodes are distributed and interconnected to cooperate with each other for smooth communication.

Each sensor node has sensors (to sense data), processor (to process sensed signals), transceiver, and battery source. In wireless networks more number of small sensor nodes is distributed over a network to monitor or control by considering parameters like humidity, pressure, and current temperature. Lunching Sensors will make a chance of upgrading MEMS (Micro Electro Mechanical Systems) techniques[5]. The rest of the discussions about this paper is outlined as in section II we described related applications of WSN, in section III discussed the important issues and challenges to be considered when implementing WSN, in section IV we depict the different topologies suitable for WSN, and in section V we deeply elaborate sensor single node architecture.

II. Applications

Now a day in many applications sensor nodes are deployed, here we are discussed some of the applications.In military to arrange self organizing communication general use wireless sensor networks. *Mielke et al.* developed an array of sensor nodes are formed into a group and are distributed to detect radiation signals. In their proposed system they used less expensive sensors, and which are useful to detect and transmitting signals [6]. *Simon et al.* conducted research to find shooter location in urban places, in their research work they used acoustic method, which is useful to gather sensor signals from various sensor nodes and process these signals to detect the location of shooter point. To achieve this task they deployed sixty sensor nodes within one meter range [7]. But deploying large number of sensor nodes will raise practical difficulty.

Booke et al. are conducted practical experiment with sensor nodes and they deployed these nodes in agriculture field to observe day to day environment and functions [8]. These nodes are sensed information about environment to collect details about temperature, moisture, climate, and activities of workers in the field. After collecting all these data analyze and based on analysis summary report is generated about production.*Heart et al.* designed a Glacsweb to observe environment using probe which is placed inside [9]. The sensors which are placed are automatically detect day to day readings over designed time period but sometimes it is tough to deploy sensor network in harsh

environments. *Haller et al.* used image processing technique to capture video stream about environment using sensors and collected data is transmitted to server over a network [10].

Mann et al. proposed a Gator Tech for smart house using wireless sensor network with an objective to assistive for living [11]. In their work used number of sensor nodes is distributed in house to monitor and control house, and they mainly focus on self organizing of wireless network to achieve their task of gathering data from sensors. Here smart house is constructed with objective to provide programmable environment after collecting data from sensor nodes.In addition above mention applications sensor nodes can be used in many applications like Habit monitoring, climate study, industrial monitoring, Security monitoring, health care, building automation, and consumer electronics. Some of the applications of wireless sensor networks are shown in figure 1.

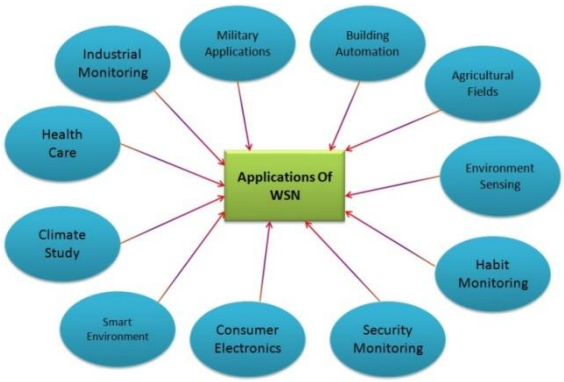


Figure 1: Applications of WSN.

III. Issues and Challenges

In general large number of sensor nodes is placed in a single application, for humans it is impossible to access all of the nodes, and deploying sensors dynamically will increase the use of self organizing networks. In self organizing network energy consumption is almost proposition to square of the distance between source and destination node. So to reduce energy consumption in wireless networks choosesad-hoc networks which are appropriate network to provide communication between nodes. All nodes which are neighbor to sensor node will self organize to route the information between sender and receiver [12].

Sensor nodes must aware of all other sensor node positions to transfer sensed data. Many researchers still work on self organizing and data aggregation challenges in WSN. The main use of self organizing protocol is to establish connection for data can be disseminated, topological positions of nodes, and data aggregation. If the nodes are self organized into a network this will help us to reduce maintenance cost, support fault tolerance facility and provide better communication [13]. Estrin st al. discussed privacy methods like dense instrumentation and how to provide secure real time access. Security is less when we using sensor nodes in some applications like environment

monitoring and agriculture. The users of data are responsible for security concern. In some cases there is a chance of varying usage data because humans are not having knowledge over applications, and moreover many human activities take place in such applications [14].

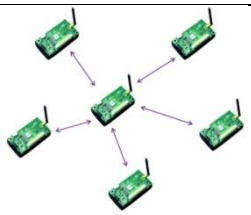
Most of the single hop communication base wireless applications (ecological control and monitoring) are not practical because the sensed signals must be travel miles together to reach destination. Single hop networks are also not energy efficient because power is proposition to square of distance between source and destination. Some of the dynamic node properties are mobility in the network environment, less reliable because power problem and for these kind of situation static routing protocol offer better communication but most widely used protocol is multi hop ad-hoc routing protocol provide efficient communication. Callaway et al. proposed to use cluster tree method which has power gateway as root node of the tree and nodes are allowed to communicate with each other using TCP/IP protocol [15].All nodes are grouped to form hierarchical tree and serve as route for data aggregate or disseminate messages to and from gateway node. They also discussed about how clusters are used for load balancing cloud computing.

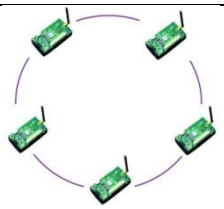
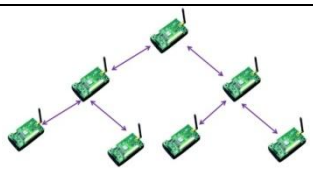
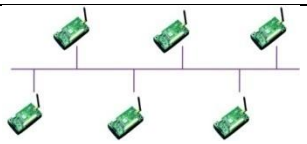
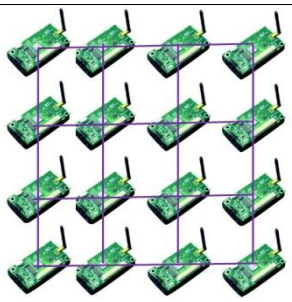
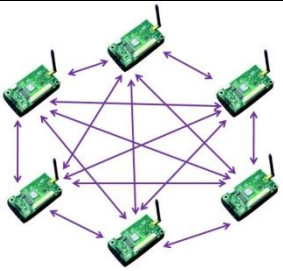
Power is most essential component of sensor node. Managing power in sensor is a big issue, in order to accomplish this task sensor node should be enter into standby mode if it is not performing any kind of operations like sensing data or communicating sensed data to other nodes. Managing power means when power is low sensor will automatically send warning message before turn off and with remaining power available it can complete minimum functions or at least complete current communication [14]. Some software are specially designed to improve battery life which includes compression of data to reduce power consumption during transmission,data collected from multiple sensor nodes must be aggregated, and use less power sensors for processing if needed then only use high power consumption sensor nodes.

IV. WSN Topologies

In Table 1 we listed the different network topologies used for establishment of wireless sensor network.

Table 1: List of WSN Topologies.

Topology	Example	Definition
Star		All sensor nodes are capable to maintain connection with center node to exchange data.

Ring		All sensor nodes are connected like ring here there is no sink node and all are communicating in a single direction
Tree		All sensor nodes are arranged like a tree and which has root node, branches
Bus		All sensor nodes are connected using a bus and which broadcast data to all nodes
Mesh		All sensor nodes are distributed like mesh and sensor node only have capability to communicate with neighbor sensor nodes
Fully Connected		Any sensors node has direct connection with rest of the nodes. As and when nodes are increase automatically connections are increased

V. Sensor Single Node Architecture

Architecture of single sensor node is depicted in figure 2. Each sensor node has four sub components and they are battery component, processing component, sensor component, and transceiver component.

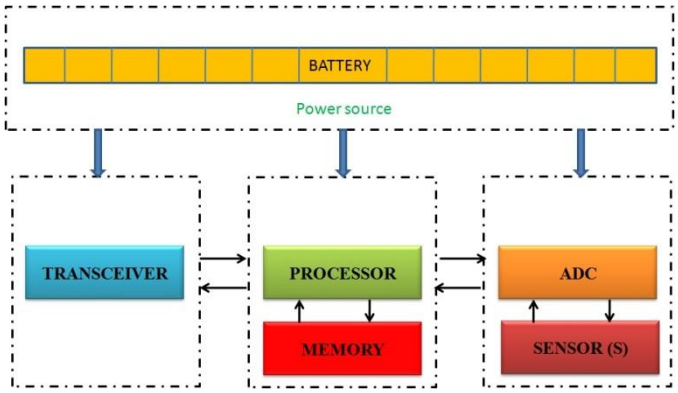


Figure 2: Single node Architecture.

Battery component is a major component of sensor node provides energy to other components like processing, sensing and transceiver components. The entire operation of a sensor node is depends on supply of reliable

uninterrupted power from these component. Generally non rechargeable batteries deployed in sensor nodes and some cases non renewable sources are used to charge battery using photo voltaic panels.

Processing Component is a processing component consist of two sub components, they are processor and memory. After sensing data or for communication to other sensor node or received signals are processed by this component and also it is collaborating with other components of sensor for synchronous communication. The operation on this component is depends on the operating system in delivering and receiving instructions from the sensor and communication components through drivers. Power is consumed when instructions are executed by the processor. The drivers may be cause leakage of power even absence of any computation and its magnitude can also be high as 50% of the total computing power [16].

Sensing components has sensors and Analog to Digital Converters (ADC). The main function of sensor is to collect data from environment or field. ADC component is useful to convert sensed analog signal to digital and which is send to processing unit.The Communication component has transceiver which is accountable for transmission and reception of signals between sensor node and base station. Sensor node is a small size device and a simple sensor node is shown in figure 3.

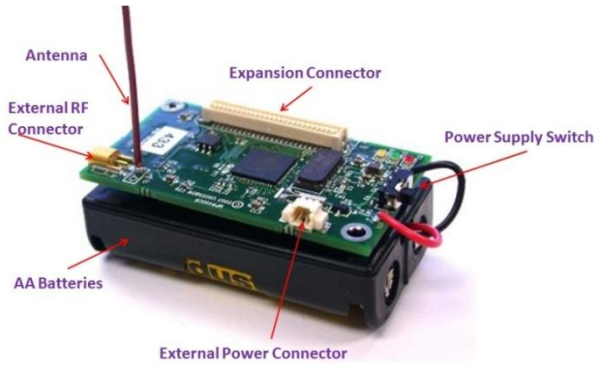


Figure 3: A simple Sensor node Hardware elements.

Sensor nodes are only communicated with another sensor node if it is there in its same radio frequency range. Some of the important elements are mention in the figure like antenna, external radio frequency (RF) connector, Central Processing Unit (CPU), Sensors, AA batteries. For any sensor node utilization of its power is an important task because it has only limited power. A sensor nodes life span is based on its battery lifespan and a sensor node can be used to generate data r simply acting as a router. Sensor node consumption energy in three different cases, first one is at the time of communication, second one is at the time of processing, and finally when it is sensing data. Energy consumption of a sensor node when it is communicated with other sensor node is calculated by using following equation.

$$E_C = E_{RX} + E_{TX} + E_O$$

Where, E_C = Total energy consumption for communication; E_{RX} = Energy consumption of receiver;

E_{TX}= Energy consumption of transmitter; E_O= Energy consumed to display output

Energy consumption of a sensor node when it is performed computation is calculated by using following equation.E_P = $C_T * V_S^2$ * F + Energy loss because of current leakage

Where, E_C = Total energy consumption for Processing sensed data

C_T = Capacitance of switching; V_S = Swing voltage; F = frequency of switching

Energy consumption of a sensor node when it is sensing data is based on application and purpose of sensing. In our survey we come to know that most of the sensor nodes follow the standard properties listed in table 2.

Table 2: Sensor node properties.

Services	HTTP, UDP, IPV4, IPV6, TCP, RPL, API, CoAP
Memory	RAM, Data Memory, Flash, Program Memory
APPS	SDK, OTAP
Energy	Voltage, Nominal, Sleep, Radio RX and Radio TX
Sensors	Luminosity, Accelerometer, CO2, Motion, Humidity, Acoustic, Pressure, Gyroscope, Image, Sonar, Battery level indictor, Voltage Sensing, Magnetic Field, Conductivity, Heat, Leaf wetness, Ultrasonic, Vibration, ECG, CO, Dust, Force, Load, Heart Rate, Smoke, Alcohol, Radio Spectrum, Color, Power, and etc.
Interfaces	SPI, UART, GPIO, USB, ADC, DAC, USART, Timers, JTAG, 12C/TWI
Connectivity	ZigBee, Wi-Fi, 802.15.4, Bluetooth, XBee, 6LoWPAN, Wireless HART
Operating System	TinyOS, ContikiOS, MicroC/OS, YATOS, BSNOS, PEEROS, Nano-RK RTOS, FOS, MicrosensusOS,

Energy consumption of sensor node is classified into useful energy consumption and useless energy consumption. It is listed in table 3 elaborately.

Table 3: Energy Consumption of a sensor node	
Useful Consumption	**Useless Consumption**
i) when sensor node sensing data	i) at the time of listing network channel sensor simply idle to get

	required traffic
ii) when sensor node processing data	ii) Overhearing of data whether it is belonging to it or not.
iii) when a sensor node communication with other nodes	iii) sending retransmission request due to collision of packets.
	iv) For generating and monitoring control messages.

VI. Conclusion

Wireless sensor networks are an important class of networks which find extensive applications in monitoring and data collection systems. However, the networks based on the sensor nodes have certain limitations in terms of their power consumption, reliability, lifetime in mission critical applications. In this paper we conduct literature survey on wireless sensor networks, architecture, applications, issues, challenges, and network topologies. The basic architecture of the wireless sensor node has enabled the researcher to understand the conditions on the applicability of wireless sensor network for various applications. Similarly, the discussion on the issues and challenges highlight the research problems that sill needed detail investigation and extensive research in the field of wireless sensor networks.

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