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Architectural Design issues and Challenges-WSN

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Abstract- Wireless sensor network (WSN) is an infrastructure less, low cost, dynamic topology, application oriented, Multi hoping network design with small, low power, sensing wireless distributed nods. WSN designing become more complex due to characteristics of deploying nodes, security, authentication and its operation scenario. This paper presents an analytical view on WSN architecture design issues, its objectives and implementation challenges.

Keywords- Wireless sensor network, Architecture, power unit, WSN design challenges.

I. INTRODUCTION

Wireless networks are broadly divided into infrastructured and infrastructureless network where infrastructured network consists of wireless node with a network backbone and infrastructureless network consist with distributed independent, dynamic topology, low-power, task –oriented wireless node as shown in the figure1.In this figure, ***cellular wireless network*** falls under the category of infrastructure network whereas ***ad-hoc*** and ***wireless sensor network(WSN***) are the part of infrastructureless network In adhoc mode, the wireless devices integrated and communicated to each other by making an on-support dynamic wireless link. WSN consist with hundred/thousand wireless node distributed with geographical area; all wireless nodes collect information and supply towards central node for further processing. The common part of these network forms ***hybrid wireless network (HWN)*** which adopt the characteristics of both network i.e. architecture of HWN is based on cellular wireless network and communication is performed by using infrastructureless network. In WSN, the distributed nodes sense the activity/current status of its region and supply to the next upper node which collects different information from different nodes. The final information is supplied to the central node to remove the redundant information and further.

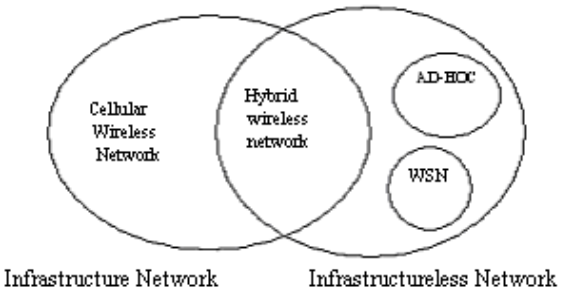


Fig1- Classification of wireless network

II. CHARACTERISTICS OF SENSOR NODE

Energy –efficiency

Energy is scarcest resource that must be utilized properly because it is impossible to recharge each node so it must be energy efficient as possible as.

Low-cost

As it is collection of hundred and thousands sensor nodes, so cost of each node should be node minimum so that overall cost of network should also be minimum.

Distributed-Sensing

As large numbers of node are distributed in sensor network so each node can capable of collecting and storing data. Thus distributed sensing provides robustness to the system.

Wireless

Sensor node should be wireless as many application do not require/ install infrastructure for communication. In that case, sensor node will use wireless communication channel.

Multi-hop

As large number of sensor are deploying in WSN, so it is not feasible for each node to reach the base station. It may be require intermediate node to reach the base station. Thus the solution is multi-hop.

Distributed processing

Each node in WSN can collect and process local data, perform aggregation on same data and then transforming it to information basis of sensing range basically two type of set or group of node are exist- ***homogeneous group of node and heterogeneous group of node***. A Group in which all nodes are identical and have same capability is known as homogeneous

group of node. Example of homogeneous group is layered architecture. On the other hand, a group in which all the nodes are not identical and do not have same capability i.e. some node are more powerful than others. Example of heterogeneous group is cluster architecture in which node form a cluster head and gather data from less powerful node.

Application-oriented

Due to the wireless nature of sensor network, they are used in major variety of application such as military, environmental and health care etc. Nodes are deployed randomly and spanned depending upon the type of application used. ***Small Size node***

Sensor nodes are generally small in size where range of each node is restricted about 30m.Due to small size of node; energy is limited which makes processing capability low.

Dynamic Network Topology

Mostly sensor nodes are deployed in the infrastructure less area as a result the network topology always changes due to the addition of new nodes, failure of nodes, and mobility. So, it is a very challenging task to maintain the topology of sensor network. Thus, the topology is responsible for affecting the sensor network characteristics such as latency, capacity, robustness, complexity and processing of data.

III. APPLICATION POTENTIALS

Depending upon the requirement and characteristics of system, wide variety of applications are there which require constant monitoring and detection of specific event.

Military Applications Sensor networks are applied very successfully in the military sensing. WSN can be an integral part of military command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting systems, detection of mass destruction and explosion and enemy movement, Biological, nuclear and chemical attack detection reconnaissance and military situation Awareness.

Environmental Applications

Nowadays sensor networks are also widely applied in habitat monitoring, agriculture research include sensing of pesticide, soil moisture, PH levels, habitat Exploration of Animals, forest Fire and Flood detection, traffic control and ocean monitoring includes monitoring of fish.

Structural health monitoring

Health monitoring is a very hot research topic for industry and academia. The amount of raw data that can be gathered and transported for such application is of the order of 1-10 Mbps. Thus only useful information is transmitted by using complex algorithms like wavelet transformation, auto regressive models etc.

Heavy Industrial monitoring

Industrial applications require highly reliable operation in harsh environment, in warehousing, industrial applications, manufacturing monitoring, industrial automation and factory process control.

Health or Medical Applications

Sensor networks are also widely used in health care such as monitoring patient physiological data such as blood pressure or heart rate, to control the drug administration, unconsciousness detection, exercise monitoring and noninvasive health monitoring.

Home Application

Home application will step into our normal life in the future. In home application, sensor node can be embedded into furniture and home appliances, monitoring product quality, managing and monitoring inventory system and automatically control the temperature and airflow of the room.

IV. ARCHITECTURE DESIGN OBJECTIVES

1. Identifying Requirements for Typical Sensor Node Application

On the basis of target application a new architecture can be developed and in case of sensor network it is important to find the nature of future Sensor Node applications but qualitative analysis of an application will greatly provide identification of more accurate design goals.

2. Identifying Relevant Technological Trends

WSN systems are heterogeneous and complex, therefore it is important to estimate the design and cost bottlenecks and which ones will be resolved due to technological progress. Importance of technological trends is important during architecture design for maximize the power optimization. Depending on future ratios of computation, communication and storage cost, very different types of algorithms will be developed for WSN.

3. Balanced Design

For the maximum utilization sensor node, it is important to optimize each and every component of sensor node to the maximum extend.

4. Techniques for Design and usage of the Components.

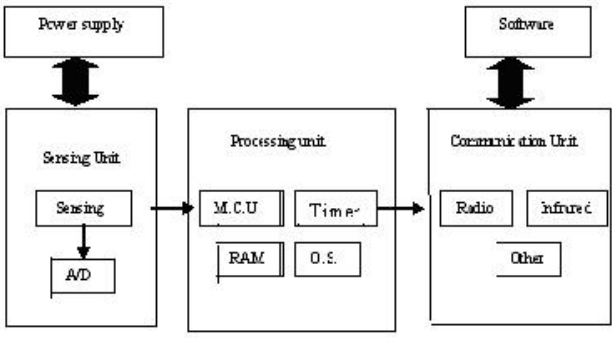
The components of WSN node can be grouped in two categories according to their maturity. Power supplies, in particular, storage and power supply, are considered as mature technologies. On the other hand, ultra low power wireless communication, sensors, and actuators are technologies waiting for major technological revolutions. It is important to identify which techniques, architectures, and tools can be reused and where the new design effort is required.

5. Survey of technology, components and sensor nodes

Special focus of sensor node architecture is to provide both qualitatively and quantitative analysis. For this, we must consider the state-of- sensor nodes, technology and components and then evaluate decision for designing the architecture.

V. ARCHITECTURE DESIGN

Architecture of node focuses to reduce cost, increase flexibility, provide fault-tolerance, improve development process and conserve energy. The sensor node consists of sensing unit, processing unit (MCU-micro controller unit), communication unit, and power supply as shown in Figure inwhich node is divided into five major blocks where each block performs some specific task. First block is ***Power supply*** block composed of power battery and DC-DC which is responsible for giving energy to the node. Battery can not replace every time so proper and efficient utilization of power must be necessary. Second block i.e. ***Communication block (transceiver)*** provide communication channel which may use radio, laser or optical and infrared. Third block is ***Processing block*** which has memory (RAM), microcontroller, operating system and timer which are responsible for storing, processing and executing the events respectively. Fourth block is ***Sensing unit*** composed of collection of sensor which produces the electric signal by sensing physical environment and analog to digital converter (ADC) which transforms the signal. The type of sensor being used in a sensor node will depend on the application.



2 **Figure A Sensor Node Architecture**

A. Processing Unit

It is responsible for collecting data from various sources then processes it and stores it. The central process unit of sensor node determines energy consumption and computational capabilities of a node. In order to provide the flexibility for CPU implementation, large number of micro-controller, microprocessor and FPGAs (field programmable gate arrays) are available.

1. Microcontroller

It is general purpose processor used for processing. It is not only consists of memory and processor but also non-volatile memory and interfaces. It helps to reduce the requirement of wiring, extra hardware, circuit board space and energy. For saving of power, microcontroller should have three states-active, sleeps, idle.

2. FPG

As Field Programmable Gate Arrays is used for testing. However, it has two disadvantages i.e. it can not reduce their energy consumption. Secondly, it is not feasible to make separate block for it. But it does not mean that it can not be used in sensor. In near future, if ultra-low power will be developed, it will eliminate the deployment cost due to reprogrammable and reconfigurable feature.

3. Timer/Clock

Timer is a special type of clock. As it is asynchronous technology but for sequencing of sequence, it need timer. Timers are of different types such as electronic, electromechanical, mechanical and digital. It has also low volume and low power consumption.

4. Operating System

WSN uses less complex operating system as compared to general –purpose operating system inthe sense that it uses few thousands of lines for coding the system whereas general-purpose consist of millions of lines of codes. Some WSN node operating systems are TinyOS, Contiki, MANTIS, BTnut and SOS etc. TinyOS is the mostfamiliar operating system in sensor network which is event driven and calls the appropriate event handler for execution.

5. Memory

Here, we use RAM as an internal memory for storing information in microcontroller. We can also use flash memory which is used for storing program code. However, Size of memory can affect consumption of power and cost. Thus, selecting the appropriate size of memory is important and can be selected according to application.

B. Power Unit

Power block are responsible for providing energy to the sensor node for monitoring the environment at low-cost and time. It takes energy from power generator and pass to other component of node. Life of sensor node depends upon battery

so battery is the important component that must be distribute properly. Power unit are required due to the following reasons provide long life, provide stability of voltage, has capacity under load, has ability to recharge under low current, has low self

discharge.

Battery

Batteries can be dividing into primary and secondary i.e. rechargeable or non-rechargeable and design of sensor node depend upon the battery. Non-rechargeable battery is good solution since it has high density. To manage energy basically two type of technique are used- demand power management (DPM) and dynamic voltage scheduling (DVS). In DPM, microcontroller has 3 states- active, sleep and idle. By using these states, devices shut down when not needed and waked up when needed in order to save energy. It also supports embedded O.S. which is used to provide switching between states. In DVS, power can be reduced by processor by reducing its operating voltage. It charges the power to match the workload and avoid idle cycles.

C. Communication or Transceiver Unit

A transceiver is a unit in which transmitter as well as receiver is sharing same circuitry on single board. It receives command from processing unit and passes it to the other node of the network. Communication is performed through communication channels. This phase provide some network protocol in order to perform communication. Three type of communication are discussed under this

1.Optical Communication

An optical communication is a telecommunication system in which transmitter convert signal into optical form at sender side and convert optical signal into original signal at receiver side. Advantages of optical communication-Takes less energy than radio frequency, No requirement of antenna, No broadcast is used so no need of security. Disadvantages of optical communication- It support line-of-sight communication i.e. transmitter must be line up with receiver during communication, Sensible to atmospheric conditions.

2.Infrared

The communication is omni directional within plane but every time node requires to be aligning within a plane. It requires no antenna and has short-range of 1m.

3.RF (Radio-frequency)

It is based on electromagnetic waves and to optimize communication, antenna must be at least where is the wavelength of carrier frequency. Radio also plays an important role in power conservation. Because it has four operating mode- transmit, receive, idle, and sleep. In order to conserve power, it is necessary to shut down the radio when no needed since radios operating in idle mode take power equal to receive mode. Advantages-Easy to use, provide integrity, well established in commercial place. The main challenge in RF is size of antenna. In WSN communication among various nodes depends upon wireless standards such as is a set of standard used for WLAN computer and communication is carried out at 2.4, 3.6 and 5GHZ frequency bands. All components connected in wireless medium in a network are known as station. Basically wireless network is divided into two categories (as shown in fig4) ***- Basic service set BSS and extended service set ESS***.

Basic service set is set of station where all the station communicates with each other. Basically BSS is of two type- ***Independent Basic service set (IBSS)*** is also called ad-hoc network in which access point are not used i.e. one BSS is not connected to any other BSS and ***infrastructure BSS*** communicate with other station with the help of access point.

Extented service set(ESS) is a set of connected BSS in which access point are connected by using a distributed system where distributed system connect access point in extended service set.

D. Sensing Unit

* *A/D converter*-It is used for converting the analog signal into digital signal. It takes an analog signal from sensor and converts it into digital signal and relay to microcontroller for further processing.

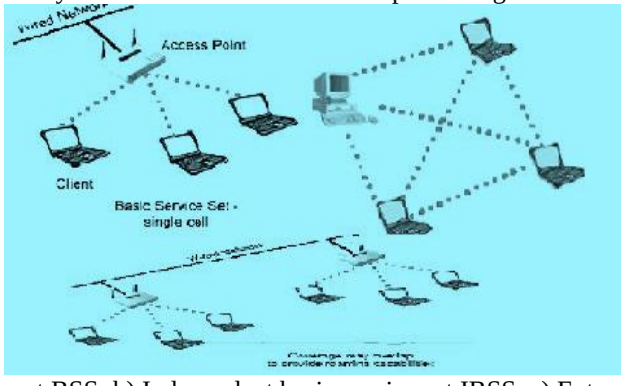


Fig4 a) Basic service set BSS; b) Independent basic service set IBSS, c) Extended Service set ESS

** Sensors*

WSN consists of large number of sensor nodes where each node contains more than one sensor at the same time depending upon the application. There are different types of sensors like acoustic sensor, resonant temperature sensor, magnetic field sensor etc. Basically sensor is device that sense physical phenomenon such as pressure, motion, speed etc and transform it into analog signal and the same signal are processed by analog to digital converter. Now-a-days sensors are used in machines, medicine, cars, manufacturing etc. Sensor may be directional or omni-directional and may be active or passive. An active sensor is sensor that senses the phenomenon with active manipulation. Example of active sensor is radar. A passive sensor is sensor which senses the environment without active manipulation. Examples of passive are thermometer, light, hygrometer, microphones etc. There are large number of commercial sensor nodes are available such as BT nodes, Eyes nodes, scatter web etc. Each of the above nodes has specific hardware component.

E. Software

It provides four services such as i)sensor manager which provide access to sensors and manage the delivery of sensor data, ii)storage is responsible for providing the persistent storage for data streams, iii)query manager performs query processing and manages active queries, iv) integrity services is used for access control.

VI. DESIGN CHALLENGES OF WSN

1.Scalable and flexible architecture

In the sensor network the number of sensor nodes deployed may be order of hundred, thousands or millions so that we can easily extend the network size. The communication protocols must be designed in such a manner that deploying many nodes in the network does not affect clustering and routing. In other words, the network must preserve its stability. Introducing more nodes into the network means that additional communication messages will be exchanged, so that these nodes are integrated into the existing network. The density of network can be calculated as:-

2. Error-prone wireless medium

Since sensor networks can be deployed in different situations, the requirements of each different application may vary significantly. We should consider that the wireless medium can be greatly affected by noisy environments. An attacker interferes knowingly and causes enough noise to affect the communication.

3.Fault tolerance and adaptability

Fault tolerance means to maintain sensor network functionalities without any interruption due to failure of sensor node because in sensor network every node have limited power of energy so the failure of single node doesn't effect the overall task of the sensor network. Adaptable protocols can establish new links in case of node failure or link congestion. Network can able to adapt by changing its connectivity in case of any fault. In that case, well- efficient routing algorithm is applied to change the overall configuration of network.

4. Infrastructure

Sensors network are infrastructure less in which nodes can communicate directly with base station. It utilizes multi-hop radio relaying and number of base station depends upon area covered by node and its radio range.

5.Node Deployment

Sensor network can be deployed randomly in geographical area. After deployment, they can be maintained automatically without human presence. In sensor network node deployment falls into two categories either a dense deployment or a sparse deployment. In dense deployment we have relatively high number of sensor nodes in the targeted field while in a sparse deployment we have fewer nodes and it is used when the cost of sensor nodes increases and prohibited the use of dense deployment. The dense deployment is used when it is important to detect the every moment or when we have multiple sensors for covering an area.

6.Real –time

Achieving Real-time in WSN is difficult to maintain. It must support maximum bandwidth, minimum delay and several QOS parameters. This issue can affect time synchronization algorithm.

7.Dynamic changes

As in sensor network nodes are deployed without any topology and they are adaptable to changes due to addition of new nodes or failure of nodes. Thus, unlike traditional networks, where the goal is to maximize the channel throughput or minimize the node deployment, but in a sensor network focus is to extend the system lifetime and the system robustness.

8. Power Consumption

Wireless sensor node is microelectronic device means it is equipped with a limited number of power source. Nodes are dependent on battery for their power. Hence power conservation and power management is an important issue in wireless sensor network. Due to this reason researchers are focusing on the design of power aware protocols and algorithm for sensors network.

9. Production cost

As the name suggests production cost, we know that in the sensor network we have large no of nodes deployed, so if a single node will be very high then the cost of over all network will be very high. As a result the cost of each sensor node has to be kept low. In order to make sensor network feasible the cost of sensor node should be less. As a result the cost of sensor nodewill be a very challenging issue.

10.Short Range Transmission

In WSNs we should consider the short transmission range in order to reduce the possibility of being eavesdropped. As in long range transmission we need high transmission power due to the point to point transmission between the nodes to reach the destination which increases the chance of being eavesdropped.

11.Hardware design

While designing any hardware of sensor network, it should be energy-efficient. Hardware such as micro-controller, power control, and communication unit should be design to consume less energy.

12. Limited computational power and memory size

It is another factor that affects WSN in the sense that each node stores the data individually and sometime more than one node stored same data and transferred to the base station which waste the power and storing capacity of nodes so we must develop effective routing schemes and protocols to minimize the redundancy in the network

13. Operating environment

Sensor nodes are deployed densely either very closed or inside the phenomenon which is to be observed. These nodes may work under-busy interaction, at the bottom of an ocean, in the interior of a large machinery, on the surface of an ocean during a tornado, in a home or large building and in a large warehouses.

14. Simplicity

Simplicity is an important point in the wireless sensor network since sensor nodes are small and there is restriction on the utilization of energy as they are energy dependent so the computing and communicating software used in the nodes should be computation efficient and less in size than the traditional software in the network

15.Quality of Service

It means data should be delivered within time period. Some real time sensor applications are based on time means if data should not be delivered on time from the moment it is sensed; the data will become unusable for e.g. fire detection requires good quality of services.

16. Unattended operation

In wireless sensor network, nodes are deployed randomly, without any topology. Once these nodes are deployed they don't require human intervention. Hence the nodes are responsible for reconfiguration in case of any modification i.e. addition of new nodes or failure of any node. Nodes is independent of each other so there maintenance needs to be autonomous.

17.System Architecture

There is no stable, unified and mature networking and system architecture to build different applications. Most of the applications and research prototypes are integrated in order to maximize performance

18. Initial connecting process

In WSNs nodes are deployed randomly in the region to monitor the environment and transfer the gathered data to the base station .In order to inform the base station about the status of sensor nodes like consumption of power, transmitter rate, address of sensor node and reliability of gathered data it requires efficient connection process.

9.Security

Security is very important parameter in sensor network since sensor networks are data centric so there is no particular id associated with sensor nodes and attacker can easily inserted himself into the network and stole the important data by becoming the part of network without the knowledge of sensor nodes of the network. So it is difficult to identify whether the information is authenticated or not.

VII. CONCLUSION

Wireless sensor networks become more popular these days because of its low cost, less power requirement, performance and high potential application areas. This paper elaborates the deploy node characteristics and functioning of each module of WSN architecture. Security issues and design challenges are analyzed and enlisted. Although a great work has been done in relation with wireless sensor networks, till date and still many efforts are needed in the direction of design and security of WSN.

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