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A literature review on Wireless Sensor Networks (WSNs) and its Diversified Applications

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Abstract: Development in the technology of sensor such as MEMS, wireless communications, embedded systems, distributed processing and wireless sensor applications have contributed a large transformation in Wireless Sensor Network (WSN) recently. It assists and improves work performance in our daily life. Routing is a critical issue in WSN and hence the focus of this paper is on WSNs, its routing protocols classification, sensor network applications, performance characteristics, metrics, application of these routing protocols in diversified application like military surveillance, environmental monitoring, traffic control etc. The objective of this paper is to understand the classification of the WSN routing protocols, to identify the representative examples of each class of routing protocols based on route selection, architecture and operation.

Keywords: WSN; sensor node; performance characteristics; performance metric; communication architecture

I. INTRODUCTION

Research on sensor networks was originally motivated by military applications. Early research was done by military using sensor networks for defense dealing with events at contiguous levels. Around 1980 modern research on sensor networks started with the distributed sensor networks program at the US Defense Advanced Research Projects Agency (DARPA). During this period Universities and Institutes did an intensive research in technology components for sensor networks about designing acoustic sensors, protocols to link processes of working on a common application in a network, self-location algorithms, distributed software and developing test beds. In 1990s there was an important shift of sensor network research due to advances in computing and communications. Small size, low cost sensors are designed to be based upon Micro Electro Mechanical Systems (MEMS) technology, wireless networking and low power processors, which make sensors possible to be deployed in a wireless fashion. This leads and influences the latest research on networking and information processing techniques of sensor networks.

A WSN can be generally described as a network of nodes that cooperatively sense and may control the environment enabling interaction between persons or computers and the surrounding environment. Today, Wireless Sensor Networks are widely used in the commercial and industrial areas such as for e.g. environmental monitoring, habitat monitoring, healthcare, process monitoring and surveillance. For example, in a military area, we can use wireless sensor networks to monitor activity. If an event is triggered, these sensor nodes sense it and send the information to the sink node by communicating with other nodes. The use of WSNs increasing day by day and at the same time it faces the problem of energy constraints in terms of limited battery lifetime. As each node depends on energy for its activities, this has become a major issue in WSNs [5]. The failure of one node can interrupt the entire system or application. Every sensing node can be in active (for receiving and transmission activities), idle and sleep modes. In active mode nodes consume energy when receiving or transmitting data. In idle mode, the nodes consume almost the same amount of energy as in active mode, while in sleep mode, the nodes shutdown the radio to save the energy.

This paper is structured as follows. Section 2 shows the basic features of WSN while Section 3 describes the classification of routing protocols in WSN. In Section 4, we present the most popular performance characteristics of WSN and protocol metrics in Section 5. Section 6 outlines the classification of sensor network application and Section 7 summarizes the most diversified WSNs applications. Finally, Section 8 draws the conclusions of this survey work.

II. WIRELESS SENSOR NETWORKS

A WSN can be defined as a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless links. The data is forwarded, possibly via multiple hops, to a sink (sometimes denoted as controller or monitor) that can use it locally or is connected to other networks (e.g., the Internet) through a gateway. The nodes can be stationary or moving. They can be aware of their location or not. They can be homogeneous or not. This is a traditional single-sink WSN. Almost all scientific papers in the literature deal with such a definition.

This single-sink scenario suffers from the lack of scalability: by increasing the number of nodes, the amount of data gathered by the sink increases and once its capacity is reached, the network size cannot be augmented. Moreover, for reasons related to MAC and routing aspects, network performance cannot be considered independent from the network size. A more general scenario includes multiple

sinks in the network. Given a level of node density, a larger number of sinks will decrease the probability of isolated clusters of nodes that cannot deliver their data owing to unfortunate signal propagation conditions. In principle, a multiple-sink WSN can be scalable (i.e., the same performance can be achieved even by increasing the number of nodes), while this is clearly not true for a single-sink network. However, a multi-sink WSN does not represent a trivial extension of a single-sink case for the network engineer. In many cases nodes send the data collected to one of the sinks, selected among many, which forward the data to the gateway, toward the final user. From the protocol viewpoint, this means that a selection can be based on a suitable WSN performance criteria e.g. minimum delay, maximum throughput, minimum number of hops, etc. discussed in section V. Therefore, the presence of multiple sinks ensures better network performance with respect to the single-sink case (assuming the same number of nodes is deployed over the same area), but the communication protocols must be more complex and should be designed according to suitable criteria [1],[2]. This is shown in Figure 1.

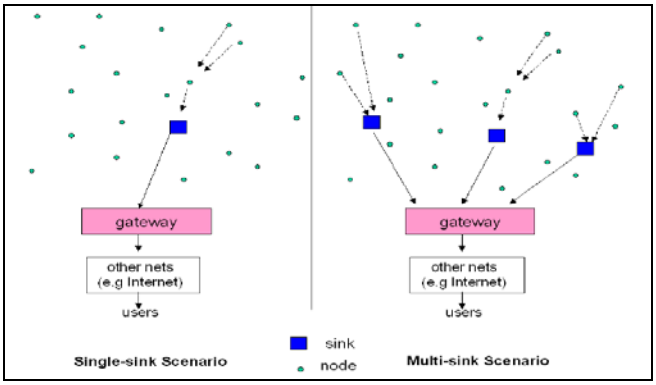

Figure 1: Single sink and multiple sink WSN

A. Components of WSN:

The components of WSN are the sensor node along with its functional units, and the sink node.

a. Sensor Node and its Functional Units:

In WSN, every sensor node has capabilities of sensing, processing and communicating data to the required destination. To perform these operations the basic entities in sensor nodes are sensing unit, memory unit, power unit, processing unit and communication unit. This is shown in Figure 2.

b. Sensing Unit

Sensors play an important role in sensor networks by creating a connection between physical world and computation world. Sensor is a hardware device used to measure the change in physical condition of an area of interest and produce response to that change. Sensors sense the environment, collect data and convert it to fundamental data before sending it for further processing. It converts the analogue data to digital data and then sends it to the microcontroller for further processing. There are different categories of sensors which are available and can be used depending on the nature of the intended operation. A typical wireless sensor node is a micro-electronic node with less than 0.5 Ah and 1.2 V power source. Sensors size and their energy consumptions are the key factors to be considered in selection of sensors.

c. Memory Unit:

This unit of sensor node is used to store both the data and program code. In order to store data packets from neighboring (other) nodes Random Only Memory (ROM) is normally used. And to store the program code, flash memory or Electrically Erasable Programmable Read Only Memory (EEPRM) is used.

d. Power Unit

For computation and data transmission, the corresponding units in sensor node need power (energy). A node consist a power unit responsible to deliver power to all its units. The basic power consumption at node is due to computation and transmission where transmission is the most expensive activity at sensor node in terms of power consumption. Mostly, sensor nodes are battery operated but it can also scavenge energy from the environment through solar cells.

e. Processing Unit:

Sensor node has a microcontroller which consist a processing unit, memory, converters (analogue to digital, ATD) timer and Universal Asynchronous Receive and Transmit (UART) interfaces to do the processing tasks. This unit is responsible for data acquisition, processing incoming and outgoing information, implementing and adjusting routing information considering the performance conditions of the transmission.

f. Communication Unit:

Senor nodes use radio frequencies or optical communication in order to achieve networking. This task is managed by radio units in sensor nodes that use electromagnetic spectrum to convey the information to their destinations. Usually each sensor node transfers the data to other node or sinks directly or via multi hop routing.

g. Base Station:

The sink is also referred as a cluster head is an interface between the external world i.e. the Internet and computational world e.g. sensor network. It is normally a resourceful node having unconstrained computational capabilities and energy supply. There can be single or multiple base stations in a network. Practically, the use of multiple base stations decreases network delay and performs better using robust data gathering. Base station in a network can also be stationary or dynamic. The dynamic base stations can influence the routing protocols greatly because of its changing position which will be not clear to all the nodes in a network. This is called as mobility of base station.

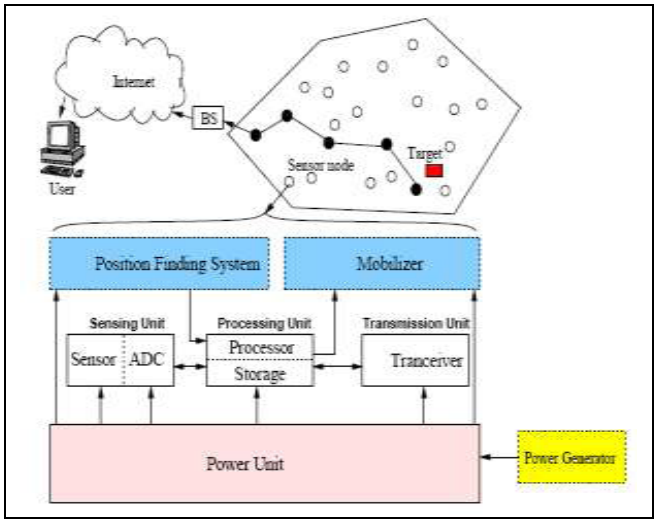

Figure 2: Components of WSN

B. WSN Operation:

Generally, operation of WSN involves communication between sensor node and base station. The sensor node senses environment, perform some computation, if required and report gathered information to the base station. If base station is connected with some actuator which triggers the alarm for human intervention in case of an event of interest. Although sensor nodes are identical devices but their characteristics varies with the network structures. Sensor deployment, coverage, transmission power, computation, reporting, addressing and communication pattern greatly affects the routing protocol operation both at nodes and at base stations [5]. Routing protocol used for WSN communication support unicast (one-to-one), multicast (one-to-many) and reverse-multicast (many-to-one).

a. Node-to-Node :

In a multihop communication data needs to be passed by intermediate nodes in order to reach to destination. Node to node communications is used to pass data from one node to other till the destination. Generally, this type of communication is not required in WSN communication.

b. Node-to-Base Station:

When sensors node want to send responses back to base station, this communication pattern is used. This is a reverse-multi path communication which means that more than one node can communicate to base station directly or indirectly. This communication pattern can also be unicast if there are multiple base stations or there is a special node (group leader), who is responsible to gather sensed information and transmit it to base station [11].

c. Base Station-to-Node:

This type of communication is required when base station wants to request data from nodes. Typically, the mode for communication is anycast (one-to-many) which means any sensor node having the requested date can respond to the base station. This pattern of communication can also be multicast or unicast if the identification of nodes is unique by their IDs or locations etc.

A functional block diagram of a versatile wireless sensing node is provided in Figure 3. 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 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 [6].

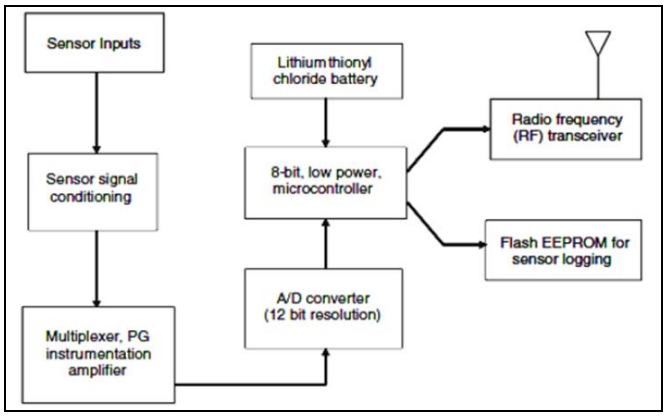

Figure 3: Functional working of sensor node

C. Network Layer in WSNs:

Sensor nodes are constrained by energy supply and bandwidth. Such constraints combined with the deployment of a large number of nodes are challenges to the design and maintenance of the network. Energy-awareness needs to be considered at all layers of a protocol stack. Physical and data link layers, which are generally common for all kind of applications, also need to consider these limitations. Thus research on these layers has focused on radio communication hardware, energy-aware Medium Access Control (MAC) protocols. The main aim at the networking

layer is to find the route to transmit data from sensor nodes to the sink in an energy-efficient and reliable manner in order to maximally extend the lifetime of the network.

Routings in sensor networks are challenging due to several characteristics distinguishing from established wireless communication networks in following areas.

a. It is not possible to build a global addressing scheme for a large number of sensors deployed. The addressing scheme, e.g. Internet Protocol (IP), needs to maintain routing tables for the global topology. Updating in a dynamic environment of a typical sensor network's application leads to heavy overhead in terms of time, memory and energy. Therefore a classical IP-based protocol is not applicable to sensor networks.
b. Compared to a typical communication network, e.g. mobile communication networks, almost all applications of sensor networks require the flow of sensed data from different sources to the same sink. Most prevalent wireless networks today, e.g. cellular network, are based on cells which are regions divided geographically. A mobile terminal in a cell only communicates with the base station serving the cell. A peer-to-peer communication between two mobile terminals doesn't exist. Communications are established through different base stations. However sensor nodes in WSNs send data to the sink based on a multiple hop routing composed by distributed networking and control functions in sensor nodes.
c. Data traffic generated by sensor nodes has significant redundancy because multiple sensors with a similar distance to the phenomena may generate the same data. Such redundancy needs to be eliminated by using proper routing protocols to improve energy and bandwidth utilization.
d. Different resource management protocols in the stack have to consider constrains of sensor node in terms of its transmission power, residual energy, processing and storage capacity [4].

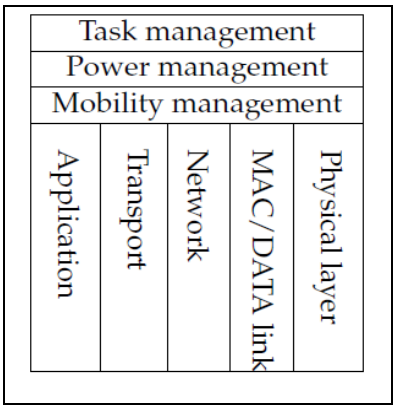

Figure 4: Protocol stack in sensor network

D. Communication Architecture of a WSN:

A typical WSN contains a large number of sensor nodes, which send collected data via radio transmitter to a sink. The decrease in both the size and the cost due to the development of MEMS has led to smart disposable micro sensors, which can be networked through wireless connections to the Internet. Sensor nodes are capable of organizing themselves, and collect information about the phenomenon and route data via neighboring sensors to the sink. The gateway could be a fixed or mobile node with an ability of connecting sensor networks to the outer existing communication infrastructure, such as Internet, cellular and satellite networks. Depending on applications to reveal some characteristics about phenomena in the area, sensor nodes can be deployed on the ground, in the air, under water, on bodies, in vehicles and inside buildings. Publications and current applications have shown these connected sensor nodes have the potential in both consumer and military applications summarized in section VII. Deployment of these sensor nodes can be in a random fashion like dropping from a helicopter in a disaster management application for environment surveillance, or manually [4].

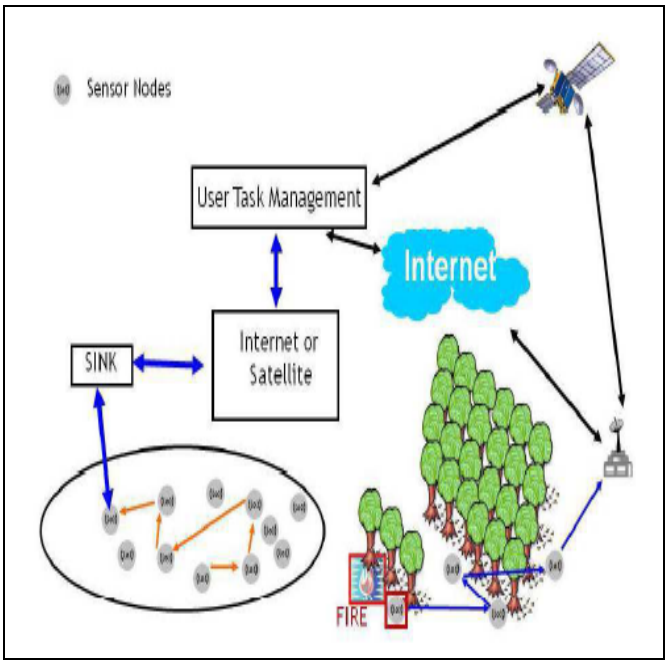

Figure 5: Communication architecture of a WSN

E. Types of Sensor:

Sensor can be selected on the basis of different aspects, including technological aspects, detection means, their output signals and sensor materials and field of application. Sensors can be categorized in to following categories [1].

a. Active Sensors:

Active sensors stimulate the environment in order to do the measurements. For example seismic sensors, laser scanners, infrared sensors, sonar's etc.

b. Passive, Directional Sensors:

These sensors can monitor the environment without disturbing the environment. Examples of these sensors are: thermometers, humidity sensors, light sensors and pressure sensors etc.

c. Narrow Beam Sensors:

This is the type of passive sensors requires a clear direction in order to measure the environment (medium) e.g. camera and ultrasonic sensors.

F. Sensor Platforms:

Researchers and developers use widely some of the following Sensor platforms available easily for comparative studies on WSN.

a. MICA Motes:

MICA mote is a commercially available product that has been used widely by researchers and developers. MICA motes use an Atmel Atmega 128L microcontroller to provide bidirectional communication at 50 kbps and a pair of AA batteries to provide energy. The operation system (OS) cooperating with the MICA is called the TinyOS ,which is currently widely used.

b. Rockwell WINS:

Rockwell WINS uses a StrongARM 1100 CPU running at 133 MHz, 1 MB of FLASH memory, 1 MB of RAM, a 100 kbps radio, and has to operate on two 9V batteries. This is considered to be towards the high end of sensor network devices.

c. Smart Dust:

Smart Dusts are densely deployed tiny nodes used to float in the air and organize themselves into a sensor network to achieve a surveillance task. It has more strict constraint with energy consumption and a simply undivided architecture. Currently sensor networks are considered to evolve toward this small dust if technological advance permits such miniaturization and copes with other existing limits

d. PC-104 based nodes:

Nodes based on PC-104 are much larger than Mica motes. They are widely used as parent nodes in hierarchical sensor networks. The PC-104 based testbed is mainly funded by DARPA SenseIT program. It is built upon off-the-shelf PC-104 based products. Each node has an AMD ElanSC400 CPU,16MB RAM and 16MB IDE Flash Disk [4],[12].

III. CLASSIFICATION OF ROUTING PROTOCOLS IN WSN

Different routing protocols are designed to fulfill the shortcomings of the recourse constraint nature of the WSNs. The deployed WSN can be differentiated according to the network structure or intended operations. Therefore, routing protocols for WSN needs to be categorized according to the nature of WSN operation and its network architecture.WSN routing protocols can be subdivided into two broad categories, network architecture based routing protocols and operation based routing protocols [1],[3],[4],[7]. This is shown in Figure 6.

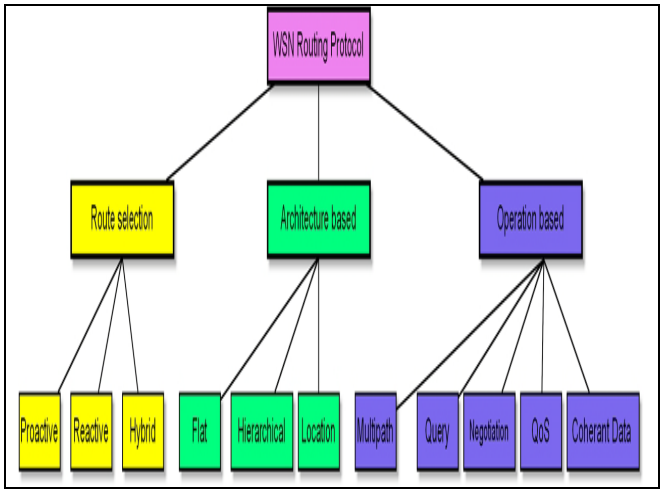

Figure 6: Classification of protocols in WSN

A. Route Selection Base Classification of Routing Protocols :

The WSN routing protocols can be further classified on the method used to acquire and maintain the information, and also on the basis of path computation on the acquired information. This classification of protocol is based on how the source node finds a route to a destination node.

a. Proactive Protocols :

Proactive routing protocols are also known as table driven protocols which maintains consistent and accurate routing tables of all network nodes using periodic dissemination of routing information. In this category of routing all routes are computed before their needs. Most of these routing protocols can be used both in flat and hierarchal structured networks. The advantage of flat proactive routing is its ability to compute optimal path which requires overhead for this computation which is not acceptable in many environments. While to meet the routing demands for larger ad hoc networks, hierarchal proactive routing is the better solution.

b. Reactive Protocols :

Reactive routing strategies do not maintains the global information of all the nodes in a network rather the route establishment between source and destination is based on its dynamic search according to demand. In order to discover route from source to destination a route discovery query and the reverse path is used for the query replies. Hence, in reactive routing strategies, route selection is on demand using route querying before route establishment. These strategies are different by two ways: by re-establishing and re-computing the path in case of failure occurrence and by reducing communication overhead caused by flooding on networks.

c. Hybrid Protocols :

This strategy is applied to large networks. Hybrid routing strategies contain both proactive and reactive routing strategies. It uses clustering technique which makes the network stable and scalable. The network cloud is divided

into many clusters and these clusters are maintained dynamically if a node is added or leave a particular cluster. This strategy uses proactive technique when routing is needed within clusters and reactive technique when routing is needed across the clusters. Hybrid routing exhibit network overhead required maintaining clusters.

B. Architecture Based Routing Protocols:

Protocols are divided according to the structure of network which is very crucial for the required operation. The protocols included into this category are further divided into three subcategories according to their functionalities. These protocols are discussed below:

a. Flat-Based Routing :

When huge amount of sensor nodes are required, flat-based routing is needed where every node plays same role. Since the number of sensor nodes is very large therefore it is not possible to assign a particular Id to each and every node. This leads to data-centric routing approach in which Base station sends query to a group of particular nodes in a region and waits for response. Examples of Flat-based routing protocols are Energy Aware Routing (EAR), Directed Diffusion (DD), Sequential Assignment Routing (SAR), Minimum Cost Forwarding Algorithm (MCFA), Sensor Protocols for Information via Negotiation (SPIN), Active Query forwarding In sensor network (ACQUIRE) etc.

b. Hierarchical-Based Routing:

When network scalability and efficient communication is needed, hierarchical-based routing is the best match. It is also called cluster based routing. Hierarchical-based routing is energy efficient method in which high energy nodes are randomly selected for processing and sending data while low energy nodes are used for sensing and send information to the cluster heads. This property of hierarchical-based routing contributes greatly to the network scalability, lifetime and minimum energy. Examples of hierarchical-based routing protocols are Hierarchical Power-Active Routing (HPAR), Threshold sensitive energy efficient sensor network protocol (TEEN), Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN), Power efficient gathering in sensor information systems (PEGASIS), Minimum energy communication network (MECN) etc.

c. Location-Based Routing:

In this kind of network architecture, sensor nodes are scattered randomly in an area of interest and mostly known by the geographic position where they are deployed. They are located mostly by means of GPS. The distance between nodes is estimated by the signal strength received from those nodes and coordinates are calculated by exchanging information between neighboring nodes. Location-based routing networks are Sequential assignment routing (SAR), Ad-hoc positioning system (APS), Geographic adaptive fidelity (GAP), Greedy other adaptive face routing (GOAFR), Geographic and energy aware routing (GEAR), Geographic distance routing (GEDIR) etc.

C. Operation Based Routing Protocol Classification:

WSNs applications are categorized according to their functionalities. Hence routing protocols are classified according to their operations to meet these functionalities. The rationale behind their classification is to achieve optimal performance and to save the scarce resources of the network. Protocols classified to their operations are discussed below:

a. Multipath Routing Protocols:

As its name implies, protocols included in this class provides multiple path selection for a message to reach destination thus decreasing delay and increasing network performance. Network reliability is achieved due to increased overhead. Since network paths are kept alive by sending periodic messages and hence consume greater energy. Multipath routing protocols are Multi path and Multi SPEED (MMSPEED), Sensor Protocols for Information via Negotiation (SPIN) etc.

b. Query Based Routing Protocols:

This class of protocols works on sending and receiving queries for data. The destination node sends query of interest from a node through network and node with this interest matches the query and send back to the node which initiated the query. The query normally uses high level languages. Query based routing protocols are Sensor Protocols for Information via Negotiation (SPIN), Directed Diffusion (DD), COUGAR etc.

c. Negotiation Based Routing Protocols :

This class of protocols uses high level data descriptors to eliminate redundant data transmission through negotiation. These protocols make intelligent decisions either for communication or other actions based on facts such that how much resources are available. Negotiation based routing protocols are Sensor Protocols for Information via Negotiation (SPIN), Sequential assignment routing (SAR), Directed Diffusion (DD) etc.

d. QoS Based Routing Protocols:

In this type of routing, network needs to have a balance approach for the QoS of applications. In this case the application can delay sensitive so to achieve this QoS metric network have to look also for its energy consumption which is another metric when communicating to the base station. So to achieve QoS, the cost function for the desired QoS also needs to be considered. Example of such routing are Sequential assignment routing (SAR), SPEED, Multi path and Multi SPEED (MMSPEED) etc.

e. Coherent Data Processing Routing Protocol:

Coherent data processing routing is used when energy-efficient routing is required. In this routing scheme, nodes perform minimum processing (typically, time-stamping, suppression etc) on the raw data locally before sending for further processing to other nodes. Then it is sent to other nodes called aggregator for further processing known as aggregation. Data processing in non-coherent processing involves three phases. In first phase target detection, its data collection and preprocessing of its data takes place. Then for

the cooperative function the node needs to enter in phase 2 where it shows its intention to neighboring nodes. Here all neighboring nodes must be aware of the local network topology. Finally, in step 3 a center node is selected for further refined information processing. Therefore central node must have enough energy resources and computation abilities.

IV. THE PERFORMANCE CHARACTERISTICS OF WSN

The performance of wireless sensor networks is based on the following characteristics [5],[6]:

A. Latency:

Latency is defined by how much time a node takes to sense, or monitor and communicate the activity. It also depends on the application at hand. Sensor nodes collect information, process it and send it to the destination. Latency in a network is calculated based on these activities as well as how much time a sensor takes to forward the data in heavy load traffic or in a low density network.

B. Scalability:

Scalability is an important factor in wireless sensor networks. A network area is not always static, it changes depending upon the user requirements. All the nodes in the network area must be scalable or able to adjust themselves to the changes in the network structure depending upon the user [4].

C. Energy Awareness:

Every node uses some energy for activities like sensing, processing, storage and transmission. A node in the network should know how much energy will be utilized to perform a new task that is submitted, the amount of energy that is dissipated can vary from high, moderate to low depending upon the type of functionality or activity it has to perform.

D. Node Processing Time:

This refers to the time taken by the node in the network for performing all the operation starting from the sensing activity to processing the data or storing data within the buffers and transmitting or receiving it over the network.

E. Transmission Scheme:

Sensor nodes which collect the data transmit it to the sink or the base station either using the flat or in multi hop routing schemes.

F. Network Power Usage:

All the sensor nodes in the network use a certain amount of network power which helps them to perform certain activities like sensing or processing or even forming groups within the network area. The amount of energy or power utilized by the sensor nodes or a group of sensors within the network is known as network power usage.

V. WSN PROTOCOL METRICS

Following performance metrics are considered to evaluate the QoS in WSNs [3],[12].

A. Packet delivery Ratio:

Packet delivery ratio is calculated by dividing the number of packets received by the destination through the number of packets originated by the application layer of the source. It specifies the packet loss rate, which limits the maximum throughput of the network. The better the delivery ratio, the more complete and correct is the routing protocol.

B. Routing Overhead:

He routing overhead describes how many routing packets for route discovery and route maintenance need to be sent in order to propagate the Constant Bit Rate (CBR) packets. It is an important measure for the scalability of a protocol. It for instance determines, if a protocol will function in congested or low-bandwidth situations, or how much node battery power it consumes. If a protocol requires for sending many routing packets, it will most likely cause congestion, collision and data delay in larger networks.

C. End-to-end Delay:

End-to-end delay indicates how long it took for a packet to travel from the CBR source to the application layer of the destination. It represents the average data delay an application or a user experiences when transmitting data.

D. Hop Count:

Hop count is the number of hops a packet took to reach its destination.

VI. CLASSIFICATION OF SENSOR NETWORK APPLICATION

Wireless sensor networks can be deployed for various type of applications. The demands of applications vary according to application nature, data delivery types, and application objectives. A requirement variation has been observed in terms of data collection, delivery, and delay etc. There are different application classes with different transmission demands. These application classes with different delivery requirements make both software and hardware design of WSN more challenging. Therefore it is required to classify WSNs application in classes in order to understand their nature and requirements. Generally, WSN applications can be classified into following four classes[1],[12],[13].

A. Event Detection and Reporting:

This class of WSN application consists of sensor nodes which are used rarely. These sensor nodes are inactive most of the time and come to life when a certain event occurs. When the event is detected, individual node sends event report to the sink which may contain some information about the nature of the event and location. The application nature is sensitive in terms of reliability and delay. As soon as an event is detected, WSN reports to sink within no time. A

major challenge in this kind of network at application level is to minimize false reporting of the event. Also routing of event to the sink is a design issue from networking point of view. Examples of such applications are Intruder detection in military surveillance, Quality check at product line/ anomalous behavior, Detection of forest fire/ Floods, Seismic activity detection, Detection of ocean environment etc.

B. Data Gathering and Periodic Reporting:

The functional behavior of sensor nodes in these applications is of continuous nature. In these applications continuous monitoring of some activity is recorded and sent to the sink individually like point-to- point communication. But in case of large network, sink is more interested in distributed computation on gathered data rather than individual node reading in order to avoid traffic volume at sink. Sometimes these sensors can be attached with actuators. The sink might need to store the geographical information of the sensor nodes in the area of interest. Monitoring of humidity in a glass house is an example of such applications. Crucial requirement of these applications is efficient utilization of energy. Examples are Monitoring humidity, temperature and light, Environmental conditions monitoring, Home/office smart environments, Health applications etc.

C. Sink-Initiated Querying:

In this case sink has the ability to send a query to a group of sensor nodes for their reading rather than the periodic reporting of the individual node. This allows the sink to gather information of different locations and also helps in validity of the measurements in order to take a decision e.g. trigger an actuator or raise an alarm. Examples of these applications are environmental control in buildings, Soil condition monitoring, Biological attack detection, Weather monitoring, fire alarming etc.

D. Tracking Based Application:

This class of WSN applications consist some of the characteristics of the previous three classes. Tracking applications involve both the detection as well as location information. When a target is detected at any location by a sensor node, it has to notify the sink promptly where accuracy is the main concern. Now, the sink may require initiating queries to the specific set of sensor nodes in order to get the location information of the target. It also helps to verify the measurements of that individual node about the target detection. The decision of triggering actuator or raising an alarm for human intervention is based on the readings received by this set of sensor nodes. Examples of these applications are Targeting in intelligent ammunition, Tracking of doctors and patients in hospital, Tracking of inhabitant in a building, Tracking of animal in forest, Tracking and controlling the people in park and building etc.

VII. WSNS DIVERSIFIED APPLICATIONS

As the costs for sensor nodes and communication networks have been reduced, many potential applications have emerged in military and civil engineering. The following are a few examples [8].

A. Military surveillance:

The original motivation behind the research into WSNs was military application. Examples of military sensor networks include large-scale acoustic ocean surveillance systems for the detection of submarines, self-organized and randomly deployed WSNs for battlefield surveillance and attaching micro sensors to weapons for stockpile surveillance.

B. Environmental Monitoring:

Environmental monitoring can be used for animal tracking [9], agricultural management [10], disaster monitoring [11], forest surveillance, flood detection, and weather forecasting. It is a natural candidate for applying WSNs, because the variables to be monitored, e.g. temperature, are usually distributed over a large region.

C. Traffic Control:

Sensor networks have been used for vehicle traffic monitoring and control for some time. At many crossroads, there are either overhead or buried sensors to detect vehicles and to control the traffic lights. Furthermore, video cameras are also frequently used to monitor road segments with heavy traffic. However, the traditional communication networks used to connect these sensors are costly, and thus traffic monitoring is usually only available at a few critical points in a city. WSNs will completely change the landscape of traffic monitoring and control by installing cheap sensor nodes in the car, at the parking lots, along the roadside, etc. Sensor network inbuilt technology helps drivers to find unoccupied parking places and avoid traffic jams. The solutions provided by WSNs can significantly improve the city traffic management and reduce the emission of carbon dioxide.

D. Industrial Sensing:

As plant infrastructure ages, equipment failures cause more and more unplanned downtime. Sensors nodes can be deeply embedded into machines in WSNs make it economically feasible to monitor the "health" of machines and to ensure safe operation. Aging pipelines and tanks have become a major problem in the oil and gas industry. Monitoring corrosion using manual processes is extremely costly, time consuming, and unreliable. A network of wireless corrosion sensors can be economically deployed to reliably identify issues before they become catastrophic failures. WSNs have also been suggested for use in the food industry to prevent the incidents of contaminating the food supply chain.

E. Infrastructure Security:

WSNs can be used for infrastructure security and counter terrorism applications. Critical buildings and facilities such as power plants, airports, and military bases have to be protected from potential invasions. Networks of video, acoustic, and other sensors can be deployed around these facilities. The installation of a WSN-aided intrusion prevention system is useful to deter any unexpected intrusions.

F. Security:

While the future of WSNs is very prospective, WSNs will not be successfully deployed if security, dependability and privacy issues are not addressed adequately. These issues become more important because WSNs are usually used for very critical applications. Furthermore, WSNs are very vulnerable and thus attractive to attacks because of their limited prices and human-unattended deployment.

VIII. CONCLUSION

A detail study of WSN and routing protocols is carried in this paper to focus on the common issues for understanding and equip to work on WSNs. This is first step to prepare for our future work to implement different protocols classified based on architecture and operation. We understood the importance of WSNs in diversified applications e.g. military surveillance, environmental monitoring traffic control, industrial sensing and security etc. We have discussed WSN protocol performance metrics i.e. packet delivery ratio, routing overheads, end-to-end delay, and hop count. We have studied brief descriptions of these metrics that affect the working of WSN routing performance protocols and useful to diversified applications. We will use these metrics to draw conclusions about the functioning and comparison of some of the routing protocols to be studied in our future work.

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