Stochastic Modelling and Computational Sciences

COMPREHENSIVE ANALYSIS OF WIRELESS SENSOR NETWORKPROTOCOLS

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ABSTRACT
Wireless Sensor Network (WSN) is an emerging technology consisting of spatiallyscattered independent devices using sensors to observe physical and environmental conditions. Sensor nodes are instilled with a minimum of resource and the quantity of sensed information is also huge. Hence, maintenance of network and efficient mechanism for resource usage is essential in WSN. It is initiated with the basic features of wireless sensor networks and issues taking place in practical applications also discussed in this article.Additionally, the basic mechanism of WSN and their functionalities are discussed. In this article, various types of WSN protocols are discussed along with their mechanism. Energy consumption and routing is a huge issue in WSN protocols that is identified from the review of various research work across different period.

Keywords: Location information, energy consumption, routing, data packet, nodes, GRP and WSN.

1. INTRODUCTION
Wireless sensor network (WSN) is composed of large number of tiny nodes with no infrastructure. All the nodes will collect the information and transmit it to another node [1, 2].WSN consists of four major parts namely, Power Unit, Sensing Unit, Processing Unit and Communication Unit. Initially, the power is generated from the nodes and it is send to the processing unit [3]. Here the power is passed to the sensing unit, where the information is collected by the sensors and the output signal is produced. The input analog signal is converted in to output digital signal by the Analog and Digital Converter (ADC). Now the signal is fed into the processing unit, which consumes low power [4]. A memory is placed in the processing unit for storage purpose. A tiny OS will support C programming language that provides services and applications. The transceiver will act as a transmitter and receiver and the information is passed to the mobilizer [5]. Figure 01 illustrates the Architecture of WSN.

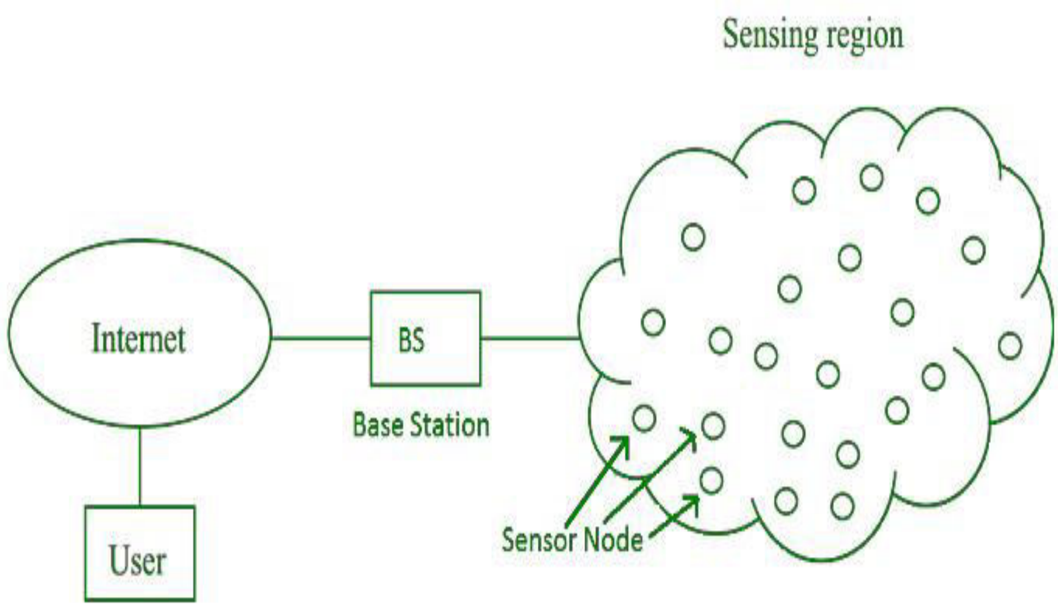

Figure. 01. Architecture of WSN

The number of sensor nodes will form a network and perform the operation inside the network. The sink node is connected to the base station and it will provide the service to the users. The routing processes in WSN are divided into many categories such as flat-based routing, hierarchical-based routing and location-based routing [6]. In flat-base routing, all the nodes are assigned with same functions. Here, Sensor Protocol for Information Negotiation (SPIN) takes place. It will send large collections of data to the neighbour nodes. It avoids redundant data transmission. By saving the node energy, it will increase the network lifetime. By diffusion, the base station sends the query to the remaining nodes [7].

The transmitted data will send back to the base station to find the optimal route path. Minimum cost forwarding algorithm (MCFA) is designed to obtain the shortest path for data transmission. By this technique, the energy is saved and multiple routes are also established. The propagated interest describes the multipath for transmission from sink to source for data transmission towards BS. After this process, the set up gradients will flow from source to sink for data transmission. Finally, it will send data at the shortest path and the path also gets reinforcement [8].

In hierarchical-based routing, nodes with high energy are used for sending information and nodes with low energy are used for sensing [9, 10]. The main operation is to create cluster in the network and perform special operations. It will improve the system performance and energy efficiency. Fusion takes places in reducing the transmitting data to the base station. It is a two layer routing in which it is used for cluster and routing process [11]. In location based routing, the nodes are specified with the ID and it is addressed by location. The information is exchanged between the neighbour nodes. To find the location, communication is done with the help of GPS. It will determine the positioning of the node. Sleeping node technique is used here to save the energy. This article discusses WSN protocols and their drawbacks [12]. The figure 02 illustrates the different roles and activities of WSN.

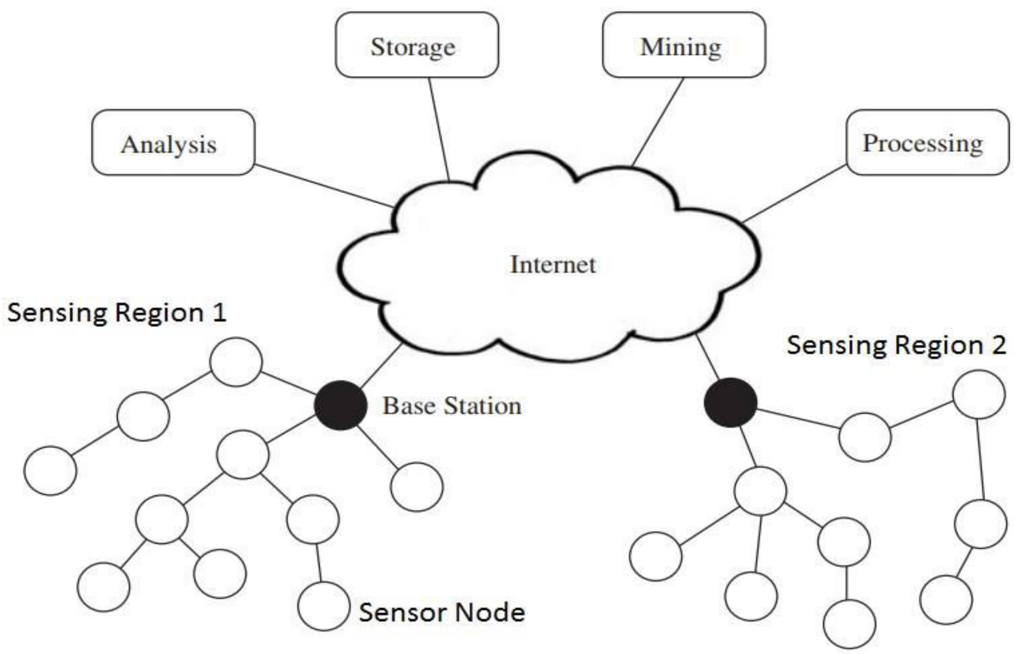

Figure. 02. WSN different roles and activities

Motivation for Wireless Sensor Networks

The recent developments in engineering, communication and networking has led to new sensor designs, information technologies and wireless systems. Such advanced sensors can be used as a bridge between the physical world with the digital world. Sensors are used in numerous devices, industries, machines and environment and help in avoiding infrastructure failures, accidents, conserving natural resources, preserving wildlife, increase productivity, provide security etc. The use of distributed sensor network or system has also been contributed by the technological advances in VLSI, MEMS and Wireless Communication.

With the help of modern semiconductor technology, you can develop more powerful microprocessors that are significantly smaller in size when compared to the previous generation products. This miniaturization of processing, computing and sensing technologies has led to tiny, low-power and cheap sensors, controllers and actuators.

Classification of Wireless Sensor Networks

Wireless Sensor Networks are extremely application specific and are deployed according to the requirements of the application. Hence, the characteristics of one WSN will be different to that of another WSN. Irrespective of the application, Wireless Sensor Networks in general can be classified into the following categories.

- Static and Mobile WSN
- Deterministic and Nondeterministic WSN
- Single Base Station and Multi Base Station WSN
- Static Base Station and Mobile Base Station WSN
- Single-hop and Multi-hop WSN
- Self – Reconfigurable and Non – Self – Configurable WSN
- Homogeneous and Heterogeneous WSN

Static and Mobile WSN

In many applications, all the sensor nodes are fixed without movement and these are static networks. Some applications, especially in biological systems, require mobile sensor nodes. These are known as mobile networks. An example of mobile network is animal monitoring.

Deterministic and Nondeterministic WSN

In a deterministic WSN, the position of a sensor node is calculated and fixed. The pre-planned deployment of sensor nodes is possible in only a limited number of applications. In most application, determining the position of sensor nodes is not possible due to several factors like harsh environment or hostile operating conditions. Such networks are nondeterministic and require a complex control system

Single Base Station and Multi Base Station WSN

In a single base station WSN, only a single base station is used which is located close to the sensor node region. All the sensor nodes communicate with this base station, in case of a multi base station WSN, more than base station is used and a sensor node can transfer data to the closest base station.

Static Base Station and Mobile Base Station WSN

Similar to sensor nodes, even base stations can be either static or mobile. A static base station has a fixed position usually close to the sensing region. A mobile base station moves around the sensing region so that the load of sensor nodes is balanced.

Single-hop and Multi-hop WSN

In a single-hop WSN, the sensor nodes are directly connected to the base station. In case of multi-hop WSN, peer nodes and cluster heads are used to relay the data so that energy consumption is reduced.

Self – Reconfigurable and Non – Self – Configurable WSN
In a non – Self – Configurable WSN, the sensor networks cannot organize themselves in a network and rely on a control unit to collect information. In most WSNs, the sensor nodes are capable of organizing and maintaining the connection and work collaboratively with other sensor nodes to accomplish the task.

Homogeneous and Heterogeneous WSN
In a homogeneous WSN, all the sensor nodes have similar energy consumption, computational power and storage capabilities. In case on heterogeneous WSN, some sensor nodes have higher computational power and energy requirements than other and the processing and communication tasks are divided accordingly.

Applications of Wireless Sensor Networks:
Theoretically speaking, the possible applications of Wireless Sensor Networks are unlimited. Some of the commonly used applications of wireless sensor networks are listed as follows: Air Traffic Control (ATC), Heating Ventilation and Air Conditioning (HVAC), Industrial Assembly Line, Automotive Sensors, Battlefield Management and Surveillance, Biomedical Applications, Bridge and Highway Monitoring, Disaster Management, Earthquake Detection, Electricity Load Management, Environment Control and Monitoring, Industrial Automation, Inventory Management, Personal Health Care, Security Systems, Tsunami Alert Systems and Weather Sensing and Monitoring

Advantages of Wireless Sensor Networks (WSN):

- **Low cost:**

WSNs consist of small, low-cost sensors that are easy to deploy, making them a cost-effective solution for many applications.

- **Wireless communication:**

WSNs eliminate the need for wired connections, which can be costly and difficult to install. Wireless communication also enables flexible deployment and reconfiguration of the network.

- **Energy efficiency**

WSNs use low-power devices and protocols to conserve energy, enabling long-term operation without the need for frequent battery replacements.

- **Scalability**

WSNs can be scaled up or down easily by adding or removing sensors, making them suitable for a range of applications and **environments.**

- **Real-time monitoring**

WSNs enable real-time monitoring of physical phenomena in the environment, providing timely information for decision making and control.

Disadvantages of Wireless Sensor Networks (WSN):

- **Limited range**

The range of wireless communication in WSNs is limited, which can be a challenge for large-scale deployments or in environments with obstacles that obstruct radio signals.

- **Limited processing power**

WSNs use low-power devices, which may have limited processing power and memory, making it difficult to perform complex computations or support advanced applications.

- **Data security**

WSNs are vulnerable to security threats, such as eavesdropping, tampering, and denial of service attacks, which can compromise the confidentiality, integrity, and availability of data.

- **Interference**

Wireless communication in WSNs can be susceptible to interference from other wireless devices or radio signals, which can degrade the quality of data transmission.

- **Deployment challenges**

Deploying WSNs can be challenging due to the need for proper sensor placement, power management, and network configuration, which can require significant time and resources.

Attacks on WSNs

There are different types of attacks on WSNs which affects the performance of the WSN. The attacks on WSNs are classified into three categories as illustrated in figure 03.

- **Legitimate Based Attacks**

Legitimate base attacks are classified into two categories such as external attacks and internal attacks. External attacks are caused by the sensor node which is not part of the given network. Internal attacks occur due to the internal node of the given network. Internal attacks can be more easily detected than external attacks. Internal attacks are more hazardous than external attacks.

- **Interaction Based Attacks**

Interaction based attacks are classified into types such as active attacks and passive attacks. Passive attacks do not disturb data transmission in the network. They intercept and capture the data to read the information from the network. The detection of passive attacks is difficult. Passive attacks can be avoided using encryption. Active attack deletes, disturb, alter, inject, or destroy the data, which is being transmitted over the networks, therefore these attacks are more hazardous than passive attacks. Active attacks can be generated due to internal or external sources.

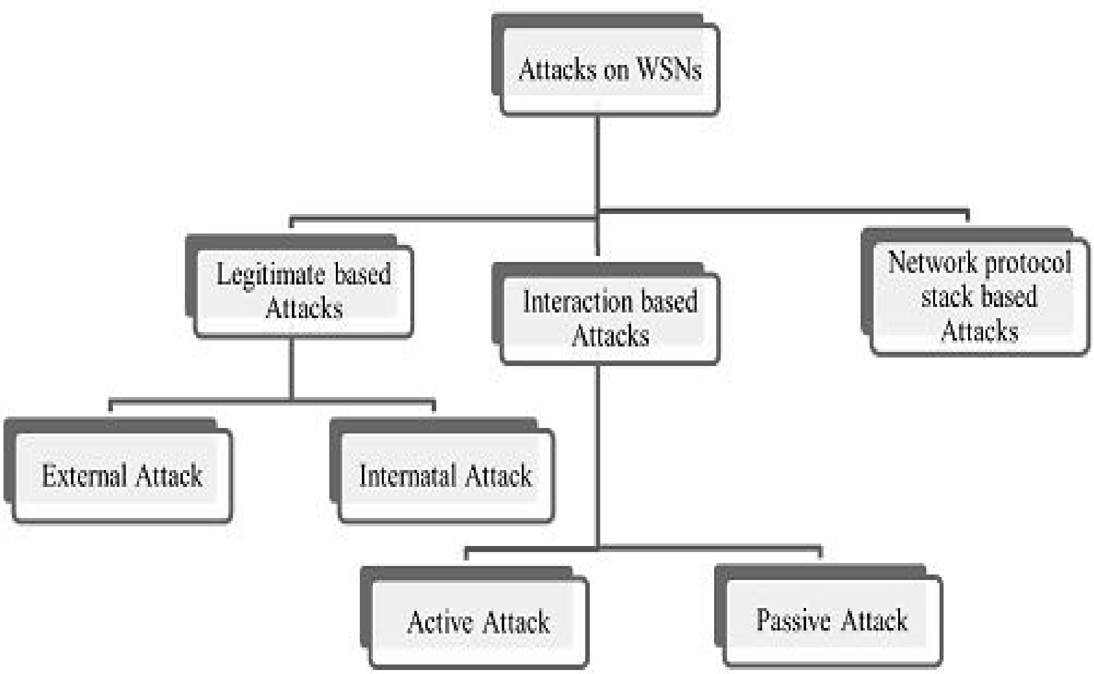

Figure. 03. The attacks on WSNs

- **Network Protocol Stack Based**

In this, the types of attacks are classified based on the affected layer OS the OSI model. Some of the attacks may affect any layer of OSI model supported by WSN such as Denial of Service attack, Impersonation attack, Replay attack, Man-in-the-middle attack, etc.

The remainder of the article is organized as follows: various research on WSN protocol is discussed in Section 2, the challenges faced in WSN protocol is discussed in Section 3 and the article is concluded in Section 4.

2. WSN PROTOCOLS: A CRITIQUE

WSN faces numerous issues during data transmission and routing. Due toadvancement of technology, WSN has grabbed wide attention and researcher also focuses on WSN protocols. Table 01, describes the comparative analysis between the existing numerous WSN protocols.

3. CHALLENGES IN WSN PROTOCOLS

The IoT devices are generally resource constrained, as it has low power, low processing and low memory capacity. Extending the network lifetime has become one of the primary objectives in IoT. Therefore, the energy efficient technique is developed in IoT networks, during the data communication to reduce energy utilization in the network.. Designing an effective routing protocol has undergone many challenging factors that can affect the whole network performance [43-45]. The routing protocol takes these challenges into consideration in order to achieve effective network communication.

- **Energy Efficiency**

As the nodes are autonomously deployed and powered by the battery in the network. Therefore, energy conservation is mandatory to enhance the network's lifetime. The routing protocol plays a very important role in energy conservation. The efficient route selection process conserves the energy during data packets transmission and it increases the network lifetime.

- **Limited power and energy:**

WSNs are typically composed of battery-powered sensors that have limited energy resources. This makes it challenging to ensure that the network can function for long periods of time without the need for frequent battery replacements.

- **Limited processing and storage capabilities:**

Sensor nodes in a WSN are typically small and have limited processing and storage capabilities. This makes it difficult to perform complex tasks or store large amounts of data.

- **Security**

WSNs are vulnerable to various types of attacks, such as eavesdropping, jamming, and spoofing. Ensuring the security of network and the data it collects is a major challenge.

- **Interference**

WSNs are often deployed in environments where there is a lot of interference from other wireless devices. This can make it difficult to ensure reliable communication between sensor nodes.

- **Reliability**

WSNs are often used in critical applications, such as monitoring the environment or controlling industrial processes. Ensuring that the network is reliable and able to function correctly in all conditions is a major challenge.

- **Node Deployment**

In IoT, the deployment of nodes can be either deterministic or self-organizing approach based on application requirements. In the deterministic approach, the nodes are deployed manually and it transmits the data on the pre-determined route. In self-organizing approach, the nodes are deployed randomly and create an ad-hoc infrastructure to transfer the data.

- **Data Reporting Model**

It is based on IoT applications and it is categorized into four types, namely query-driven, time-driven, event-driven and hybrid model. Periodic data monitoring applications use the time-driven model to send sensor data to the sinknode periodically. The query-driven and event-driven model is suitable for time- critical applications. The node transmits the data to the sink node when a sudden change occurs in the sensor data. The hybrid model uses the combination of the reporting models for the data transfer.

- **Coverage Area**

In IoT, there is a communication range in the physical environment for each sensor node. The coverage area is one of the significant factor for designing an IoT routing protocol.

- **Fault Tolerance**

Fault tolerance plays a vital role in data transfer. If sudden node failure occurs due to battery drain or by any physical damage. It affects entire network performance. In such cases, there is a need to reconstruct route with immediate effect to avoid packet-loss in networks.

- **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.

- **Scalability**

It is a fundamental requirement for large-scale networks. Hence, therouting protocol must support the scalability of the network. WSNs often need to be able to support a large number of sensor nodes and handle large amounts of data. Ensuring that the network can scale to meet these demands is a significant challenge.

- **Aggregation**

It is a method of obtaining and aggregating data packets from different sensor nodes using an aggregate function. Thus, it minimizes the number of data transmission in the network.

- **Quality of Service**

The sensor nodes need to transfer the data to the sink quickly in time-constrained applications. Otherwise, the IoT application will not meet the conditions and requirements. Hence, the Quality of Service (QoS) is one of the most significant factors in the design of a routing protocol.

- **Geographic Routing**

A routing principle known as "geographic routing" is based on geographic position data. It is primarily suggested for wireless networks and is predicated on the notion that, rather than utilising the network address, the source transmits a message to the destination's geographic position.

- **Sensor Holes**

A routing hole is an area within the sensor network where nodes are either not available or cannot participate in the actual data routing process for a variety of reasons. The identification of holes is particularly difficult because most wireless sensor networks are made up of low-capacity, lightweight nodes that have no idea where they are in relation to other nodes.

- **Coverage Topology**

The coverage problem shows how well sensors track or monitor a given area. In recent years, the research community has paid close attention to the issues of coverage and connection in sensor networks. Determining whether every site in the sensor network's service area is covered by at least k sensors—where k is a predefined parameter—can be framed as a choice problem.

- **Network Data Traffic**

It indicates the quantity of network data packet moves around the network at a specific point of time. The routing protocol supports bidirectional data transmission. In IoT, the traffic pattern varies from application to application.

- **Mobility**

Mobility support is hardcore challenging tasks in IoT. It is mainly due to the wireless nature and path may break frequently due to mobility. In such a case, it is needed to re-discover the route.

- **Heterogeneity**

Depending on application, sensor nodes vary their role and capacity. The heterogeneity of the nodes may raise technical challenges during the routing process. For instance, some application possesses the combination of different sensors to monitor the environment. WSNs often consist of a variety of different sensor types and nodes with different capabilities. This makes it challenging to ensure that the network can function effectively and efficiently.

- **Transmission Media**

The sensor node uses either infrared or radio frequency to communicate wirelessly to transmit the sensor data from one node to another. These two ways are associated with the problems of multi-path propagation, high error rate, reflection and fading.

4. CONCLUSION

The advancement in technology and wireless network has grabbed huge attention of researchers. WSN is a self-organizing protocol and decentralized that doesn't need anyframework for their functionality. Nodes in WSN are instilled with limited amount of energy and due to this nature energy consumption is high. The effective routing mechanism can enrich the performance which in turn minimizes the energy consumption. Various researchers developed diversified protocols and mechanism for WSN routing. The drawbacks in the existing system are considered and it is suggested to use optimization approaches for thecluster based mechanism. Moreover, routing via shortest path and energy preserving is initiated by the optimization as well as advanced computational approaches.

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