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A Survey on Routing Protocol and Performance Metrics in Wireless Sensor Network

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ABSTRACT
A random deployment of the sensor node is referred to as Wireless Sensor Network (WSN), these sensor nodes are able to detect environmental as well as physical conditions. The security of the system depends on WSNs which are used to gather information and construct the communication system. In WSN there are various routing protocols used for finding an efficient route on the basis of distance, network traffic, etc. Routing protocols must be used for the maintenance of the routes as sensor nodes have limited resources such as battery power, transmission range, etc selection of routing protocol is an important issue for a WSN[10]. This paper presents a survey on WSN along with mentioned different routing protocols and performance metrics.

KEYWORDS-WSN, Routing Protocol, Sensor Node, Sink, Flat Routing, Location Base Routing, HierarchicalRouting.

1. INTRODUCTION

Wireless Sensor Networks (WSNs) can be defined as the random deployment of the sensor node. Wireless sensor networks are random self-configured and infrastructure-less networks to monitor physical or habitat conditions, such as temperature, sound, vibration, pressure, motion, or pollutants, and cooperatively pass their data through the network to the main location or sink where the data to be observed and analysed. WSNs are highly scattered network In the wireless sensor network nodes have limited energy, limited computation, sensing, and communication capability.
The wireless sensor network is composed of memory, processors (Base station), sensing element (Node), and battery (power unit) transceiver element.

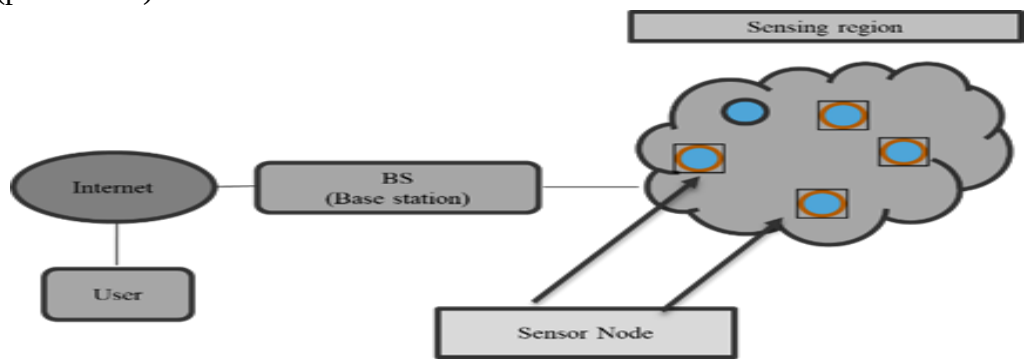

Figure 1. Wireless Sensor Network

A sink or base station acts as an interface between users and the network. One can retrieve required information from the network by injecting queries and gathering results from the sink. Typically, a wireless sensor network contains hundreds of thousands of sensor nodes. The sensor nodes can communicate among themselves using radio signals. A wireless sensor node is equipped with sensing and computing devices, radio transceivers, and power components. [5][6]

Applications of Wireless Sensor Networks [17]

Wireless sensor networks have gained considerable popularity due to their flexibility in solving problems in different application domains and have the potential to change our lives in many ways. WSNs have been successfully applied in various application domains such as:

1. Défense application
2. Area monitoring
3. Transportation
4. Health applications
5. Environmental sensing
6. Structural monitoring
7. Industrial monitoring
8. Agricultural

1.2 Literature Review

Swati Mishra, Rukhsar Bano, Suresh Kumar, Vimal Dixit[1]provide the concept of routing protocol in wireless sensor networks. This paper presents an overview of the WSNs along with their classification and also have a comparison between different routing protocols.

Aarti Kochhar , Pardeep Kaur , Preeti Singh , and Sukesha Sharma[2]provide a detailed discussion on design constraints and classification of routing protocols and as well as their performance parameter analysis .

Noufal.K.P.[3] provide the concept of scalability and its importance in the design of routing protocol KhaeelUllah Khan, M., &Ramesh, K.S. [4] give the concept of the protocol used to detect and prevent the attack on mobile sensor network

Dr. Kanade S,Dr. Joshi S P [5] provide the literature on the development of a wireless sensor network in an agricultural environment to monitor environmental conditions and deduce the appropriate environmental parameters required for the high yield of crop production on given farmland. Among the different technologies for crop monitoring, Wireless Sensor Networks (WSNs) are recognized as powerful ones to collect and process data in the agricultural domain with low-cost and low-energy consumption.

Md Mohinur Rahaman, and Md Azharuddin[6], provide a basic understanding of various agricultural problems and previously used different techniques applied for smart or precision agriculture. Finally, this survey paper also gives the idea to use IoT and deep learning in agricultural WSNs for the next level.

Sallis, P. J. [7] provide the concept of WSN design,development, and function as well as give a brief idea about operating parameters such as power management, reliability, and security.

Hao, L.He Shuang Ding [8] propose a concept of a clustering protocol based on mobile sensor networks which introduce the idea of on-demand routing on mobile WSN to reduce packet loss.

Walter, A., Singh, M., &Sharan, S.[9] this paper describes the concept of an Energy Efficient Clustering and Shortest-Path Routing Protocol (EECSRP) to aid Wireless Sensor Networks (WSNs) by enhancing the lifespan of the network, adequately using the battery power ,minimizing the network overhead anda high packet transmission ratio with minimal delay.

Mishra, S.,Kumar, U.,Sharma, N., &Upadhyay, U[10] provides the literature on the routing protocols based on merits and demerits.

Elsmany, E.F.A.,Wan, M.A.O., &Altahir, A.A.[11]describean energy efficient clustering and hierarchical routing algorithm through which to extend the network life span.

Shrishti Sajan, Chacko, S. J., Mr. Pai, V., &Dr .Pai, K.BH,[12] give an outline of challenges in WSN, requirements of fault detection, and approaches to fault detection technique.

Chuan Xu,Z[13] This paper give the concept of maximization of the network lifetime for WSN and demonstrate the concept of optimization algorithm to search the global optimal path for node.

Kurniawan, A., Kristalina, P., &Hadi, M. Z.S.[14] provide brief performance analysis of AODV(Ad Hoc On-Demand Distance Vector), DSDV (Dynamic Source Distance Vector), and OLSR(Optimized Link State routing) with examination parameter PDR, throughput, packet loss, and transmitting delay.

Heinzelman, W. R., Chandrakasan, A., &Balakrishnan, Hari [15] propose LEACH (Low-Energy Adaptive Clustering Hierarchy), a clustering-based protocol that utilizes randomized rotation of cluster head base stations(cluster-heads) to evenly distribute the energy load among the sensors in the network.

Tang, Jiqiang, Guo, S., &Yang, Y [16] this paper,demonstrate the delivery latency minimization problem (DLMP) in a randomly deployed WSN. To solve this problem, the traversed anchor points on the communication range of sensor nodes shorten the travel route, and then let the sink node move and collect data to reduce the travel time. Also, employ the time division approach to traverse the sensor nodes whose signals cover the same travel segments to full utilization of the channel.

Singh, M. K., Amin, S. I., Imam, S. A., Sachan, V. K., &Choudhary, A [17] describesan introduction to WSNsarchitecture, possible topologies and also give a brief idea about the types of WSN and its applications.

Singh, O., VinayRishiwal, L. K., &Yadav, P [18] provide a detailed discussion on the node's attack and also give the idea that a secure routing approach is needed to securethe entire wireless sensor network. In this paper, SecureEnergy Aware Routing (SEAR) approach is evaluated. SEAR first detects malicious nodes. Then for routing consider the node's trust value, hop length, and residual energy.SEAR evenness the energy consumption, and throughput of the network and transmits the data through trust nodes.

Manikandan, V., &Dr.Sivaram, M. [19] paper discuss the use of the protocol to handle energy consumption by sensor nodes in Wireless Sensor Nodes (WSNs). The main aim is to improve the life span of the network by managing energy consumption. The protocol is so developed that they utilize the energy of the whole sensor node.

Rathi, N.,Saraswat, J., &Bhattacharya, P. P[20] provides the literature on routing protocol in WSNs depending on the network structure.

Dr.Sasi, K., Rani, K., & Ms.Vijayalakshmi, R [21] proposed procedure of mAODV is acquired from the logic of the classical AODV model but instead of using the common transmission and reception it consists of self-initiation features over a mobile network environment and provides a fault free data communication between node, in which the faults are denoted as malicious attacks raised by attackers.

Nasr, S., &Quwaider, M.[22] provide the approach to achieve improvement in the performance of WSN in terms of network lifetime and data transmission time by reducing the packet delay time

2.ROUTING PROTOCOLS [1][2]

Routing protocol means the selection of a suitable path from a number of available paths to transmit data to the sink or the base station. There are several different types of routing protocols that have been developed for WSNs, each with its own set of advantages and disadvantages. Some of the most common types of routing protocols include [20]:

A. Flooding

Flooding is a simple and effective routing protocol that involves broadcasting a packet to all nodes within range. This method is easy to implement and is efficient in cases where the network is sparsely populated. However, it can lead to significant congestion in densely populated networks.

B. Directed Diffusion

Directed Diffusion is a data-centric routing protocol that uses data-centric naming to identify data objects and events of interest. It is useful in applications where data is generated by multiple sources and is consumed by multiple sinks.

C. Low-Energy Adaptive Clustering Hierarchy (LEACH)[22]

In LEACH routing protocol network is dividedinto different clusters and each cluster elected a cluster head which is connected with the sensor node and BS through which further communication is stabilized.

LEACH is a hierarchical routing protocol that organizes nodes into clusters. The cluster head is responsible for forwarding data to the base station, reducing the amount of energy consumed by the individual nodes.

Basically, LEACH is a self-organizing clustering protocol that uses randomization to distribute the energy load evenly among the sensornodes in the network. In LEACH, the nodes organize themselves into local clusters, with one node acting as the base station or cluster head. LEACH includes randomized rotation of the high-energy cluster-head position such that it rotates among the various sensors node in order to not drain the battery of a single sensor node.

D. Geographic Routing

Geographic routing protocols use the location information of the nodes to determine the best path for data packets to take. This method is useful in applications where the nodes are deployed in a known environment and the location of the nodes is known.

C. Energy-Efficient Routing Protocols

Energy-efficient routing protocols aim to reduce the energy consumption of the nodes by selecting paths that minimize the energy consumption of the individual nodes. which is the main concern in the establishment of routes these protocols can include a combination of geographic routing and clustering.

Routing protocols can be classified based on different criteria used as shown in Fig. 3.

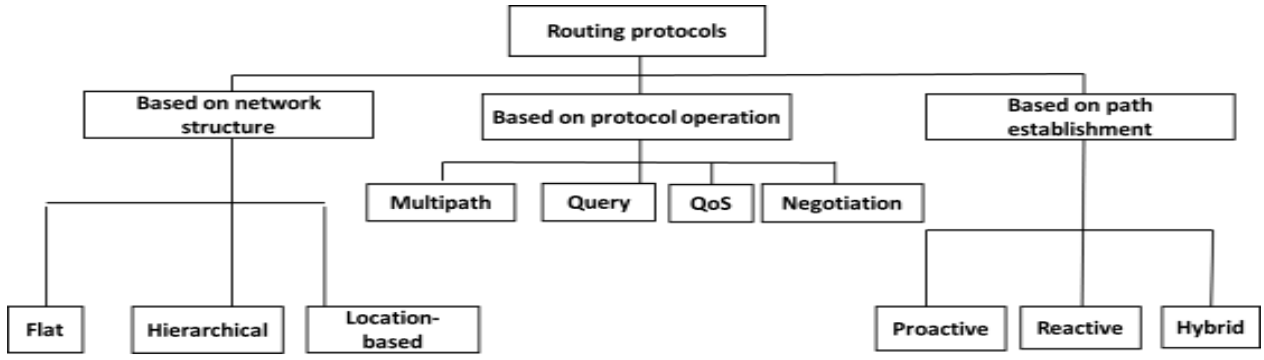

Fig 3: Classification of Routing Protocols[3]

2.1. Routing Protocols Based on Network Structure:

2.1.1. Flat structure routing

All the nodes have the same capacity, i.e. each node is considered as a base station and each node is provided with all information so that the user can send a query to any node to get information. That's why it is named Flat structure routing

2.1.2.Hierarchical structure routing

All nodes have different capabilities and also play different roles in the network. Higher capability nodes perform crucial tasks, whereas less crucial tasks are assigned to nodes withlow capability. It is a level structure. This structure routing is energy efficient. In this scenario, the cluster-head nodes would communicate with "super-cluster-head" nodes and so on until the top layer of the hierarchy, at which point the data would be sent to the base station.

For larger networks, this hierarchy structure could save a large amount of energy.

2.1.3.Location-based routing

Nodes can be addressed based, on where the location of a sensor can be detected using a satellite, provided the system is equipped with a GPS receiver. Another way is to measurethe relative distance of the node from its neighbors based onthe strength of the signal received (by the Doppler effect).

In location-based routing, the nodes have the capability to locate their present location as well as provide some extra services. Examples are [10]:

- SPEED
- Geographical and energy-aware routing (GEAR)
- SPAN

2.2.Routing protocols based on protocol operation:

2.2.1.Multipath routing protocol

In this scheme, the protocol may rely on data on multiple paths. Instead of delivering data from source to destination Multiple paths increase the fault tolerance of the network but increase energy consumption as well as overhead. The path keeps changing whenever the protocol discovers a better path. By using the multipath routing protocol, the reliability of the network can be increased. Here a large packet can be

divided into sub-packets and sent over different paths. A message can be retrieved even if one of the sub-packets is lost due to link errors. Such a path selection approach is known as multipath routing.
Multipath routing protocols are:

- Multipath and Multi SPEED (MMSPEED)
- Sensor protocols for information via negotiation (SPIN)

2.2.2. Query-based routing:
In this routing protocol approach, a node initiates a query and propagates it through all the nodes in the network. After the node receives the query and only the node having data that matches responds. On the other hand, instead of propagating the query throughout the entire network, the node may send it in a random direction and wait for the response. If none of the nodes respond, then the node can propagate it through the whole network. Such query and respond base path establishment approach is called query base routing.
The examples are

- Directed diffusion (DD)
- COUGAR

2.2.3. QoS-based routing
In applications where the routing protocol needs to maintain the quality and specifications of the parameter while delivering data important QoS-based routing protocol is used. The QoS routing protocol is responsible for maintaining energy and other performance metrics parameters like delay, resources, and bandwidth are critical.So when quality is the main concern then QoS-based routing is established
The examples are

- Sequential assignment routing (SAR)
- SPEED
- Multipath and Multi SPEED (MMSPEED)

2.2.4. Negotiation-based routing
The basic concept of the negotiation-based protocol is to avoid the propagation of duplicated packets. Flooding and gossiping create implosion i.e., a single node may receive multiple data copies. To solve this a sequence of negotiation messages is shared among the nodes to transmit redundant data to the next node. It reduces energy consumption, fault, response time, and network congestion.

2.3.Routing protocols based on path establishment:
To deliver data from source to destination, the node must know the path from source to the destination, i.e., path-based routing protocols are established in three ways:

2.3.1.Reactive path establishment
In such protocols,routes are created on a demand basis or we can say routes are event-driven. After a data packet has reached a node, the protocol decides the next node to be taken toward the destination.The decision about the next node may depend upon cache history, but in most cases, the nodes have limited memoryand low computational capability, hence no cache history is maintained.The commonly used reactive routing protocols are as follows:

2.3.1.1. Ad-hoc on-demand distance vector routing system (AODV) [14]

Ad-hoc on-demand distance vector (AODV) is a reactive on-demand protocol. It follows the on-demand routing concept for the formation of routes. The path is established when the source node wants to send data and the route is maintained as long as the source node needs. That's whyit is known as On-Demand. AODV satisfies unicast, multicast, and broadcast routing. AODV allows mobile nodes to pass data packets to thedestination node via nodes of neighbors that are unable to connect links.

AODV chooses the shortest but round-free path from the routing table to transmit data packets whenever required.

2.3.1. 2.. Dynamic source routing (DSR)

Dynamic source routing can be reactive or on demand. As its name suggest that it uses source routing instead of routing tables. Routing in DSR is divided into two parts, route discovery, and route maintenance.

The source node will initiate a route discovery phase and this phase consists of route request and route reply (RREP) messages. In DSR only the destination node will reply with route reply RREP message to the source node unlike in AODV where every intermediate node would reply with route reply message RREP [6, 8]. After this data packet will be transmitted from source node to destination.

2.3.2.Proactive path establishment

Under this scenario, the protocol decides the path to the destination when the data packet is at the first hop or at the node where communication initiates. The commonly used proactive routing protocols are as follows:

2.3.2.1. Optimized link state routing (OLSR)

Optimized link state routing (OLSR) belongs to the category of proactive routing protocols and it uses table-focused practice. The main drawback of OLSR is that it has a massive overhead. To compensate for this delay, multipoint relays (MPRs) are used to overcome the large overhead. For data transmission, three adjutant nodes are used as MPRs by every node.

2.3.3. Hybrid Protocol

This scenario utilizes the quality of both proactive and reactive conventions. These conventions are intended for substantial systems. It keeps up movement stack over the system and every node must have a zone that is predefined and known as a group.

Zone Routing Protocol (ZRP) combines the advantages of proactive and reactive routing.

It takes advantage of pro-active discovery within a node's local neighborhoods (Intra zone Routing Protocol (IARP)) and uses a reactive protocol for communication between these neighborhoods (Inter-zone Routing Protocol (IERP))

3.PERFORMANCE [3]

In the network, many sensor nodesare scattered and each sensor node have battery power The selection of performance metrics for IEEE 802.15.4-based WSNs is important to evaluate the performance of the network. Some of the most common performance metrics include:

3.1. Throughput

Throughput is a measure of the amount of data that can be transmitted through the network in a given period of time.

3.2. Latency

Latency is a measure of the time it takes for a packet to travel from the source node to the destination node. The data delivery latency certainly increases in the data gathering network due to the travel of the mobile sink node[16]

Latency is an important constraint for time-critical applications and needs to be minimized for any network.

3.3. Packet delivery ratio

Packet delivery ratio (PDR) is the ratio of the number of packets delivered in total to the total number of packets sent from the source node to the destination node in the network. As the value of PDR increases the performance of the network also increases [4][8]

3.4. Energy Consumption

Energy consumption is a measure of the amount of energy consumed by the individual nodes during operation.[12][19]

3.5. Scalability

Whether or not the WSN supports the expansion is a very important factor in the design of the protocol Scalability is a measure of the ability of the network to handle an increasing number of

3.6. End-to-End Delay

End-to-end delay is another network performance metric that defines the average sum of the difference in delay of each data packet received by the destination node and the time a data packet is sent by sensor nodes.

4.CONCLUSION

In summary, there are several routing protocols available for IEEE 802.15.4-based WSNs, each with its own set of advantages and disadvantages. The selection of a routing protocol will depend on the specific requirements of the application. Additionally, performance metrics are important to evaluate the performance of the network, including throughput, latency, packet loss, energy consumption, and scalability.

In this paper, we have conducted a review of various routing protocols with respect to the WSN and also a review of various performance parameters of the WSN protocols

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