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A Survey on Network Structure Based Routing Protocol in Wireless Sensor Network

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ABSTRACT

In WSN (Wireless Sensor Network) the large number of sensor nodes is deployed in the environment which collects the data from the environment and forwards it hop by hop to the sink (or base station). The dynamic topology and the distributed nature of WSNs present the requirement to design the special type of routing protocols which can efficiently handle the energy of the sensor nodes in the network. The design of the routing protocols must focus on the extension of the network's lifetime and the energy consumption. The paper presents the classification of routing protocols on the basis of network structure. The routing protocols belonging to this category are classified into three categories: Flat, Hierarchical and Location based. The routing protocol belonging to the first category can be further classified as proactive, reactive and hybrid. The challenges which affect the design of routing protocol are also discussed in this paper.

Keywords: WSN, Routing Protocols, Energy Efficiency, Sensor Nodes, Network Structure

1. INTRODUCTION

Wireless Sensor Networks is self-organized, distributed, sensing and data propagation networks. WSN is a group of wireless sensor nodes that has limited energy resource; these sensor nodes may be stationary or mobile and can be deployed randomly on a dynamically changing environment. In middle of the 70s the first WSNs were designed and developed by the military and defense department [4], these sensor networks are used for detecting the enemies in the dense areas. The wireless sensor network has some limitations such as limited energy capacity, large size of the sensor and limited network capability. Wireless sensor networks also called as WSN which is the combination of the three words: sensor, network and wireless. The tiny devices which sense the physical quantities and convert them into electrical signals are known as sensors. The sensors can communicate with each other which signify the word network and the communication take place in the wireless medium which denotes the wireless [1]. So WSN contains the number of sensor nodes which sense their surroundings and communicate the sensed information with each other or to the sink (base station) as in figure 1.

A sensor node has a sensing component, processing, communication, storage capabilities and limited battery power as shown in figure 2. Thus due to these components, a sensor node is not only responsible for data collection, but also used for network analysis, correlation, and aggregation of its own sensed data and data from other sensor nodes [6]. Sensor nodes communicate with base station using wireless radio allowing them to forward their data for remote processing, analysis and storage. The wireless sensor network has some characteristics which include: dense node deployment, sensor nodes with batteries as power source,

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self-configurable, data redundancy and frequent topology change etc. For each and every operation that is performed by the sensor nodes requires the battery power. So in wireless sensor network energy efficiency is one of the major design issues [5]. Other design issues that are in the wireless sensor network include limited hardware resources, dynamic and unreliable environment, diverse applications, random deployment of sensor node. Wireless Sensor Networks can be used in collecting data of massive field at a low cost and less manpower, traffic and wildlife monitoring, healthcare system, military also for the surveillance of property and pollution control. Due to sensor nodes deployment model, the sensor node has non-renewable energy source although some nodes are be able to scavenge resources from their environment [6]. Routing protocols that are used in the wireless sensor network are needed to use the energy resource efficiently.

Wireless Sensor Networks are composed of sensor nodes that are resource constrained and more resourced base station. The routing protocols in wireless sensor network are classified into four main categories:

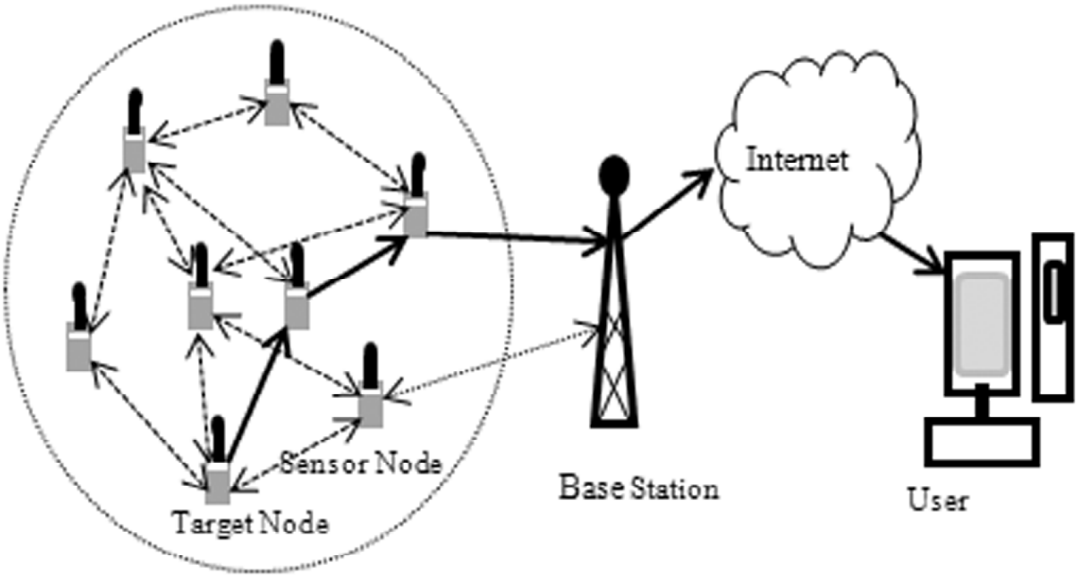

Figure 1: Wireless Sensor Network

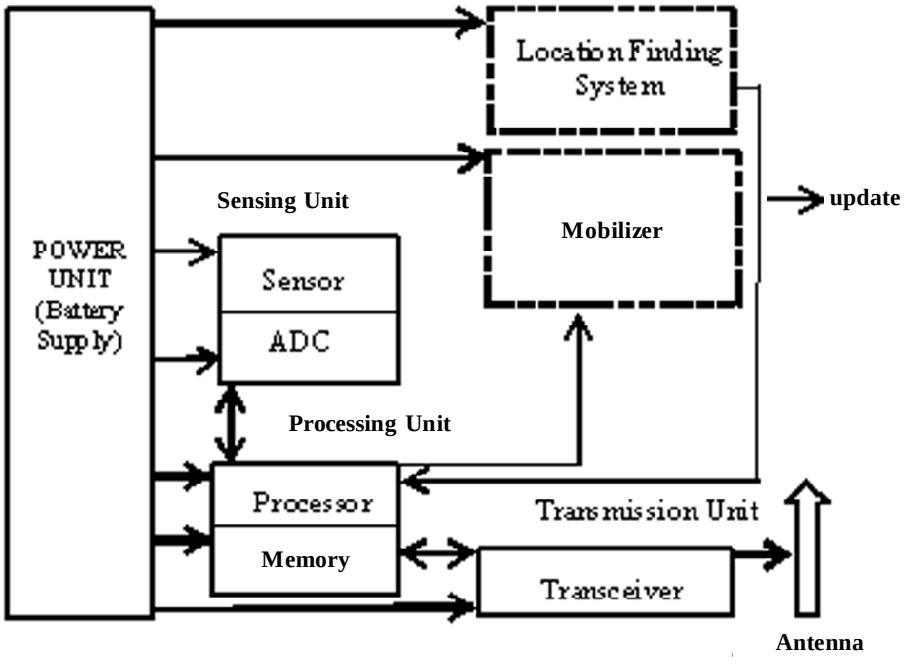

Figure 2: Sensor Node

Network Structure based, Communication Model based, Topology Based and Reliable Routing [4]. The remaining paper is organized as follows: In section II, the challenging factors affecting the routing protocol design in WSNs is presented. In section III, classification of routing protocols based on network structure in WSNs is discussed. In section IV, some of the application area of wireless sensor network is presented. Finally, in section V, we conclude the paper.

2. CHALLENGING FACTORS AFFECTING THE ROUTING PROTOCOL DESIGN

Some factors that affect the routing protocol design are [23]:

2.1. Node Deployment

Node deployment can be deterministic or self-organizing. It affects the performance of routing protocol. The deterministic means that the sensors are placed manually and pre-determined path is used for routing the data. The self-organizing means that the sensor nodes are randomly scattered and form the ad hoc network [7].

2.2 Node/Link Heterogeneity

The presence of heterogeneous set of sensors arise many technical problems in case of data routing and they should be overcome.

2.3 Data Delivery Model

Data sensing, measurement and reporting in sensor networks depend upon the time criticality and the application of the data reporting. Data reporting can be categorized as query-driven, event driven, time-driven (continuous) and hybrid.

2.4 Energy Consideration

There is a great need for preserving the energy required for data communication and processing. The process of finding the routes is influenced by energy. So there is need to efficiently use of the energy.

2.5 Scalability

The routing protocols in wireless sensor network are scalable enough in order to respond to events, example the large increase in the sensor nodes [13].

2.6 Network Dynamics

There are three main components in the wireless sensor network. They are sink, sensor nodes and monitored events. In some setup the sensor nodes are mobile [2]. Some network architecture considers that the sensor nodes are fixed or stationary and on the other hand supports the mobility of cluster-heads or the sinks.

2.7 Fault Tolerance

The sensor nodes cover only the limited physical area of the environment and also limited in range and in accuracy.

2.8 Coverage

The sensor nodes cover only the limited physical area of the environment and also limited in range and in accuracy.

2.9. Quality of Service-

In wireless sensor network, the conservation of energy is more important than the quality of data because the life of the network is depends upon the energy. Hence, routing protocols are required which consume less energy.

2.10. Data Aggregation-

The data aggregation is the process of combining the data from different data sources by the use of aggregation function. The sensor nodes generate the redundant data, so similar packets are aggregated to reduce the number of transmission [3].

3. CLASSIFICATION OF ROUTING PROTOCOL BASED ON NETWORK STRUCTURE

The network structure can play important role in the routing protocol operation in wireless sensor network. The network structure can be classified on the basis of the node uniformity. The main feature of this type of routing protocols belonging to this category is how the nodes are connected and they communicate the information based on the architecture of the network [1]. These protocols can further be classified into three Categories which are: Flat, Hierarchal, Location based routing protocols as shown in figure 3.

3.1. Flat Routing Protocol-

In flat routing protocol each node in the sensor network typically play the same role and all sensor nodes combines together to perform the sensing task. The Flat routing protocols can further be classified into three categories [4]:

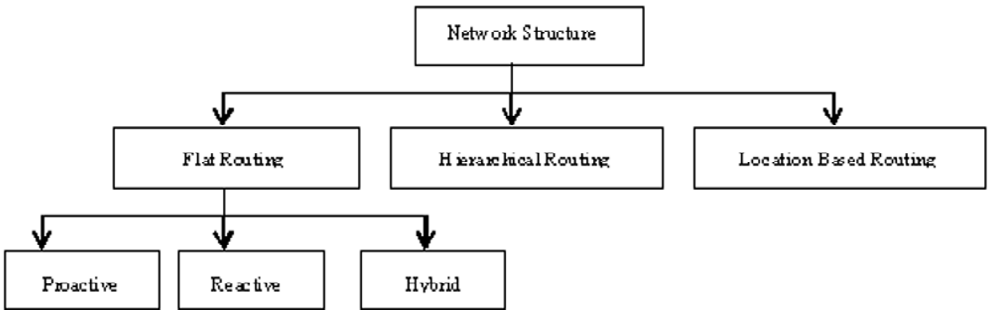

Figure 3: Classification of Routing Protocols on the basis of Network Structure

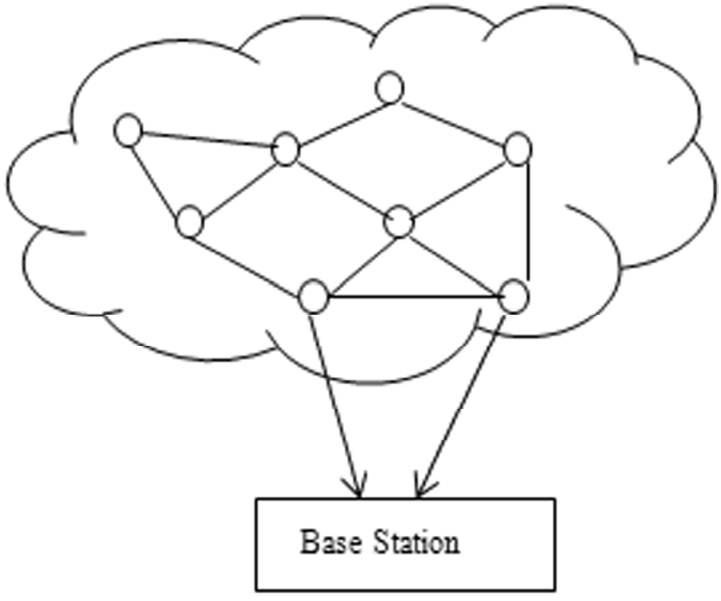

Figure 4: Flat Architecture

3.1.1. Proactive or Table-Driven Routing Protocol

Proactive routing protocol working is based on the exchange of the routing information periodically in between the different sensor nodes. Each node maintains its own routing table which contains the path from source to destination. Whenever there is any change in the network topology they send the updates throughout the network and therefore maintain consistent network information. When a source node needs the path to the destination node or we can say when a packet needed to be sending the path is already known [7]. Therefore no extra time is needed for route discovery however a large bandwidth is required for keeping the updated information of the network which causes faster energy dissipation. Some of the following proactive routing protocols are:

a) WRP: Wireless Routing Protocol is a table-based routing protocol. The WRP maintains updated information of the network by maintaining a set of tables at each node. Whenever the link changes mobile nodes inform each other by the help of updated messages. An update message contains the list of updates that is send to the neighboring nodes and a list of responses is reported by all its neighbors. WRP contain few table updates but great processing power and large memory is required by the nodes of WSN. When the link between the two nodes is break then update message is send to its neighbors and find new path among the other nodes then they change their routing table accordingly. WRP is not suitable for the large wireless sensor network [20].

b) TBRPF: The Topology Dissemination Based on Reverse Path Forwarding Protocol is based on the concept of the broadcasting the link-state updates in the spanning tree in the reverse order from all the nodes to the source node of the update [21, 22]. The routing table at each node in the tree has more update information of the topology. The protocol transmits only the changes between the current network topology and the previous network topology. So the messages that are transmitted in the protocol has small in size and thus they can be transmitted more frequently. The updated link-state information that is received through the broadcasting in the spanning tree is used for calculating min-hop path. Each source node in the network broadcast the updates through the outgoing paths in the tree that is rooted at the source. Each source node has its separated broadcast tree. A node can only accept the link-update information that is originated at the source node only if the node receives the link-update information from its parent node only and has greater sequence number.

3.1.2. Reactive or Source Initiated On Demand Routing Protocol

The Reactive routing protocol uses the different approach from the proactive protocols, they begins the route discovery when it is needed. When the path to the destination from the source node is needed start the global search. These protocols doesn't request for the constant updates of information to be sent through the wireless network. In some of the case the sensor node maintains some desired routes in their cache memory, so no extra delay for the route discovery [4]. Some of the following reactive routing protocols are discussed below:

a) RR: Rumor Routing protocol is developed by D. Braginsky et al. (2002) [19]. In this routing techniques send queries to the sensor nodes that have sensed a particular event instead of flooding to the entire network. In order to flooding the information of the events through the network, routing algorithm use long-lived packets called agents. When a sensor node sense an event, it adds that event to its local table, called events table and an agent is generate. Agent travels the network in order to send the information of the local event to base station. When a sensor node generates a query for the sensed event the nodes that knows the path to the base station responds to the query by inspecting the event table of the sensor node.

Rumor routing significantly saves energy when it is compared to event flooding and handle the nodes failure. Rumor routing technique doesn't work well in case of large number of nodes in the network because

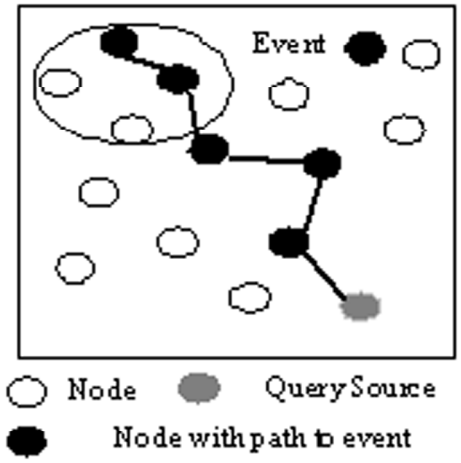

Figure 5: Rumor Routing

the agent's maintenance cost and the cost of event table at each in very high [6]. The rumor routing is shown in figure 5.

b) TORA: The Temporarily Ordered Routing Algorithm is highly adaptive distributed loop free routing technique which has minimum communication overhead for multihop network to topological changes [11]. It is a reactive or source initiated on demand routing protocol for wireless network with some additional features of the proactive routing. In TORA each node j in the network has the knowledge of its own height and the height of the neighboring node k which are directly connected to node j in the network. Thus to provide energy efficiency TORA routing protocol sends the control messages locally to the set of nodes that are near to the topology change [18,24]. In TORA each node is assigned it height on the basis of its location in the network with respect to the destination node. The link between the pair of node (i, j) are marked as upstream or downstream on the basis of the neighboring node j height is greater or less than node i height respectively as shown in figure 6.

3.1.3. Hybrid Routing Protocols

Hybrid routing protocol takes the advantages of both type of protocol that is proactive and reactive protocols. These protocols use the proactive protocol locally and reactive protocol inter locally. When the path fails

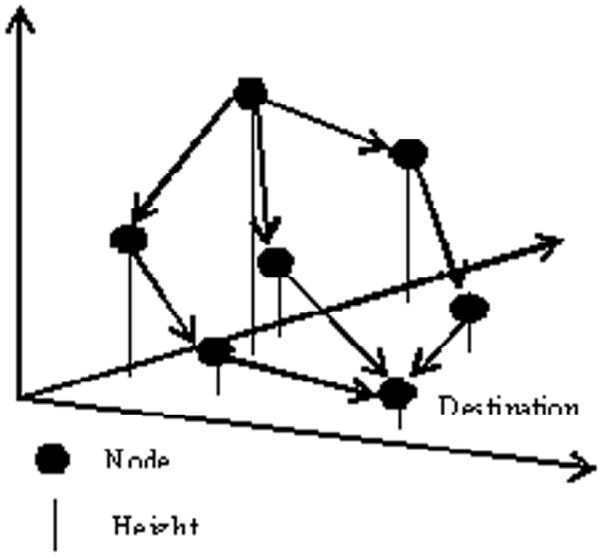

Figure 6: TORA Routing Protocol forward the data to the destination in downward direction

between the nodes or a node disappeared other part of the wireless network it only affects the local neighboring nodes, the sensor nodes on the other part of the wireless network are not get affected [8]. Some of the following hybrid routing protocols are discussed below:

a) ZRP: Zone Routing Protocol is a hybrid routing protocol that combines the features (advantages) of both the reactive and proactive routing protocol. According to the ZRP the sensor network is divided into parts known as zone and the topology of each zone is maintained proactively and when the topology of the network change there is no periodic exchange of the changes that occur in the network. Only the neighboring nodes get the information after periodic intervals [17]. In ZRP if there is need to search a node i, then route query is initiated and broadcast to its neighboring node in its zone. If the node is not found in the same zone the inter zone routing is used, in which node broadcast the route request to the node that are present on the border of this zone. On receiving this request these node checks the intra zone routing table if there is route they send the reply if not another route request is broadcast in its zone. Procedure is repeated until the node is found. The advantage of the ZRP is that each node maintain small amount of information due to which there is less traffic, but there is high chances of delay and overheads.

b) HRP: It is a hybrid routing protocol developed by V. Safdar et al. (2012) [8]. It is an enhancement done in the RPL by considering mobile sink, the sink maintain DAG up to some zone limit. The source node that wants to sends some data check whether it is the active member of DAG, if it is the member of active DAG it send data to sink else if not it broadcast route request with in the zone limit and wait for some interval of time. If the sink/member of active DAG found send reply to the source, if not increase the zone limit. In case no sink found up till maximum number of tries, the route request will broadcast to entire network as shomn in figure 7 [8].

3.2. Hierarchical Routing Protocols-

Hierarchical routing protocols are different from flat routing protocols, the nodes are not similar and they play different role. In hierarchical protocol nodes which have higher energy level can be used for processing data and for sending the information whereas the nodes which have lower energy level used for sensing [5]. In this type of protocols nodes are organized in clusters. The cluster has the cluster head which are elected by using different cluster head election techniques. The cluster head are used for the special task i.e. for high level communication. They provides better scalability, increase in the network lifetime and energy efficiency [1]. The architecture is shown in figure 8. Some of the following hierarchical routing protocols are discussed below:

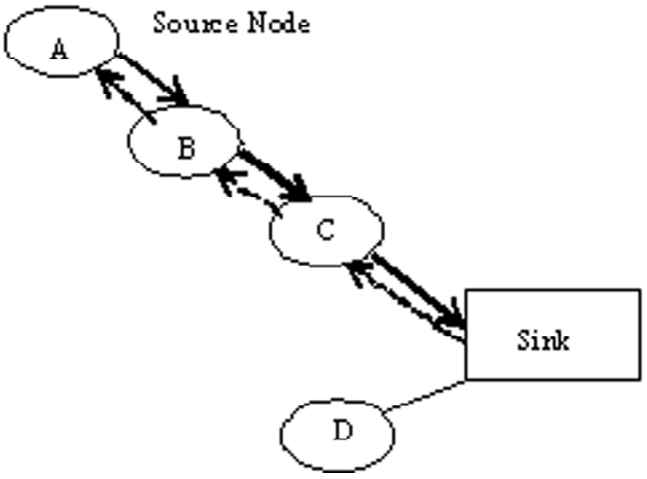

Figure 7: Source node A communicates with sink via DAG links

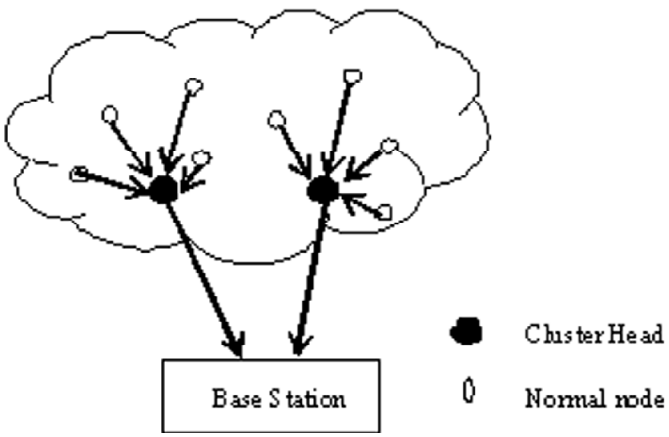

Figure 8: Cluster Architecture

a) LEACH: Low Energy Adaptive Clustering Hierarchy is the first routing protocol proposed for hierarchical clustering, developed by W. B. Heinzelman et al. (2000) [9]. The operations in LEACH are divided into two phases: setup phase and steady phase. In LEACH for becoming cluster head each node is independent for taking the decision. For becoming the cluster head each node select a random number and compares the randomly selected value with the threshold value. The Threshold value is calculated as:

$$P(s) = \begin{cases} \dfrac{k}{1 - k * \left(r \bmod \dfrac{1}{k} \right)} & if s \in G \\ 0 & otherwise \end{cases} \quad (1)$$

Where k denotes the desired percentage of cluster heads in the sensor network, r denotes the current round number; G denotes the set of nodes that have not been cluster heads in the last 1/k rounds. If the random value is smaller than the threshold value the node become the cluster head. Each cluster head then broadcast a message to all the nodes in its range through which each node decides to join which cluster head for the current round. In this way the clusters formation takes place. The cluster head selection is done random fashion and in LEACH the number of cluster head in each round varies. After the setup phase the steady phase begins in which the data communication starts. Each node forward its sense data to cluster head in the given schedule, cluster heads performs data aggregation on the data it receive from different nodes and compression and sends the data to base station. The steady state phase time period is longer than the setup phase time period in order to minimize overhead.

b) SEECH: Scalable Energy-Efficient Clustering Hierarchy routing protocol is developed by Mehdi Tarhani et al. (2014) [10]. SEECH is a distributed algorithm, before starting the first round the protocol perform the start phase. In the start phase each sensor node collects the some useful information such as its neighboring nodes and its distance to the base station. In SEECH protocol each round is divided into two phases: set-up and steady phase. In the set-up phase the network topology is determined that means the cluster head selection, relay nodes selection and the cluster formation take place. The cluster head election is taken place on the basis of the energy level and the degree of the node i.e. the nodes with high level of energy and high degree and they are rotationally changed. Another set of high energy level and low degree is elected as the relay nodes. In steady state the sensor nodes senses the data the sensed data is collected and aggregated by the cluster. The aggregated data is send by the relay node to the base station on the basis of the topology determined for that round.

3.3. Location Based Routing Protocol

In Location based routing protocols acknowledge by distance between the neighboring nodes and distribution of the sensor nodes in the network area. These protocols are based on two assumptions [7]: 1) It is assumed that every node in the network have the knowledge of the neighboring node position in the network. 2) The message is the source of information about the destination node position. The hello messages are periodically transmit by the nodes for gathering the information about the neighbor node position. Therefore, once the destination node location is known all the operations are performed locally. Some of the following location based routing protocols are discussed below:

a) GAF: Geographical Adaptive Fidelity is a Location based routing protocol developed by the Y. Xu et al. (2001) basically for the MANET [15]. Firstly the network field is divided into the same size zones and they form a virtual grid. It associates the node inside each zone and collaborate them with each other so that each node play a different role. In this protocol all node inside each zone selects one node that is responsible to stay awake for some period of time and the other node in the zone go to sleep. The node that is awake for that certain period of time is responsible for monitoring the zone and for reporting the information to the base station. All the nodes inside the zone adjust their sleeping time so that continuity is maintained. So before the awaking of the active node, the node that is on sleep gets wakeup and then become the active node for some duration. In GAF each node has a GPS system to locate its position in the virtual grid are equivalent in terms of the routing cost [6]. Geographical Adaptive Fidelity turning the unnecessary nodes in the sleeping state so the energy is conserved without affecting the routing. Therefore, GAF can increase the network lifetime.

b) *SPAN:* It is a location based routing protocol developed by Benjie Chen et al. (2002) [16]. SPAN is a distributed, randomized routing protocol in which nodes locally takes the decision about either they go into the sleeping state or they work as coordinator in the forwarding backbone. Some of the sensor nodes in the network are selected as the coordinator on the basis of their positions. The coordinator nodes are used for forwarding messages in the network and they form the network backbone. If the two nodes can't reach each other neither directly or via one hop or two hop (coordinator) then the neighboring non-coordinator became the coordinator node [7]. It is not necessary that the existing and new coordinator nodes are neighbors.

4. COMPARISON OF ROUTING PROTOCOL

In this paper we compared the following routing protocols on the basis of their classification, scalability, periodic message type and route metric [4, 6-11]

Table 1 show the comparison of the routing protocol based on the network structure.

Table 1
Network Structure Based Routing Schemes Comparison

Routing Protocol	*Classification*	*Scalability*	*Periodic Message Type*	*Route Metric*
WRP	Flat (Proactive)	Limited	Table exchange	Shortest Path
TBRPF	Flat (Proactive)	Limited	Hello messages	Shortest Path
RR	Flat (Reactive)	Good	Hello messages	Shortest Path
TORA	Flat (Reactive)	Good	IMEP control	Shortest Path
ZRP	Flat (Hybrid)	Limited	The Best route	The Best Route
HRP	Flat (Hybrid)	Good	DIO messages	Shortest Path
LEACH	Hierarchical	Good	None	Shortest Path
SEECH	Hierarchical	Good	None	Each node send data to the CH, CH sends the data to relay node then relay node to the sink.
GAF	Location-Based	Good	Hello messages	The node serves as leader, which conveys data to the other nodes in each grid area.
SPAN	Location-Based	Limited	Hello messages	The coordinator from network backbone that is used to forward the message.

5. WSN APPLICATIONS

In this section various applications of wireless sensor network are covered which are as follows [14].

5.1. Healthcare

In health care system, to receive the significant information from the research community the wireless sensor network is used. The two types of healthcare-oriented system are identified and they are remote health-care surveillance and vital status monitoring. Some of the applications of wsn in healthcare system are: monitoring of human physiological data, Sensors for blood flow, ECG [2].

5.2. Industry: Manufacturing and Smart Grids

The automation of control and monitoring systems is important for many utility companies in water treatment, electrical power distribution, manufacturing and oil and gas refining [1]. The WSNs is integration in Data Acquisition systems and Supervisory Control and Smart Grids.

5.3. Transportation Systems

The integration of the sensor network and the transportation systems include real-time safety and traffic monitoring systems share bandwidth with commercial services.

5.4. Public Safety and Military Systems

WSNs help to anticipate and manage the unpredictable events, like man-made threats or natural disasters. The military and public safety applications are categorized into passive supervision and active intervention. Some of the applications of WSN in military system are [2]: Sensing intruders on basis, nuclear and chemical attack detection, detection of enemy unit movements on land and sea, battle field surveillances.

5.5. Environment and Agriculture

WSNs are well suited to open-space monitoring and agricultural applications. A variety of applications have been developed in environmental monitoring, flood detection, precision agriculture, forest fire detection and cattle monitoring [12].

5.6. Underground and Underwater Sensor Networks

Underground and underwater sensor networks consist of sensors that are buried in dense materials like soil or concrete and provide communication through dense materials. Such networks can be used for infrastructure supervision, intrusion detection, soil moisture reporting in agriculture and transport systems. Underwater sensor networks are used in many applications like disaster prevention, surveillance, ocean supervision, water quality monitoring and pipeline monitoring.

5.7. Home Network Application

As the technology is advancing, the sensor nodes are also used in home appliances, person locator and location awareness. These smart sensor nodes inside the home appliances can communicate with each other and the external environment through satellite or internet. With the help of these smart networks the user may be able to manage these home appliances locally as well as from the distant location [1].

6. CONCLUSION

In wireless sensor network (WSN) the energy efficiency is the most important term. So, in WSN such routing protocols are required which can efficiently use the energy to send the sensed data by the sensor

nodes to the base station. In recent years the routing techniques in sensor network has drawn the lot of attention and introduce various challenges as compared to the traditional routing techniques. The routing protocols play an important role to deliver the sensed data to the base station with the less use of energy and also increase the lifetime of the network. This paper discusses many energy efficient routing protocols which are mainly classified on the basis of network structure. The network structure based routing protocols are classified into flat, hierarchical and location-based routing protocols. The flat routing protocol is classified into proactive, reactive and hybrid routing protocols. The research is still going on in routing protocols to fulfill challenging factors such as fault tolerance, flexibility, high sensing fidelity, rapid deployment and low cost in WSN.

REFERENCES

[1] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "Wireless sensor networks: a survey", Computer Networks 38 (2002) 393–422.

[2] Satvir Singh, Meenaxi, "A Survey on Energy Efficient Routing in Wireless Sensor Networks", International Journal of Advanced Research in Computer Science and Software Engineering Volume 3, Issue 7, July 2013.

[3] Kemal Akkaya, Mohamed Younis, "A survey on routing protocols for wireless sensor networks", Ad Hoc Networks 3 (2005) 325–349.

[4] Nikolas A. Pantazis, Stefanos A. Nikolidakis and Dimitrios D. Vergados, "Energy – Efficient Routing Protocols in Wireless Sensor Networks: A Survey", IEEE Communications Surveys & Tutorials, VOL. 15, No. 2, Second Quarter.

[5] Agam Gupta, Anand Nayyar, " A Comprehensive Review of Cluster-Based Energy Efficient Routing Protocols in Wireless Sensor Networks", International Journal of Research in Computer and Communication Technology, Vol 3, Issue 1, January-2014.

[6] Sujee.R, Kannammal.K.E, "Routing protocols based on network structure in wireless sensor networks -A survey", SSRG International Journal of Computer Science and Engineering (SSRG-IJCSE) – volume 2 issue 4 April 2015.

[7] Ritika Sobti, "A Comparative Study on Network structure based Routing Protocol and its Variants in Wireless Sensor Networks: A Survey", International Journal of Computer Applications (0975 – 8887) Volume 117 – No.12, May 2015.

[8] Safdar, V., Bashir, F., Hamid, Z., Afzal, H., & Pyun, J. Y. , "A hybrid routing protocol for wireless sensor networks with mobile sinks", In Wireless and Pervasive Computing (ISWPC), 7th International Symposium on Dalian (pp. 1–5).

[9] W. B. Heinzelman, A. P. Chandrkasan, and H. Balakrisnan, "An application-specific protocol architecture for wireless microsensor networks", IEEE Trans. Wireless Commun., vol. 1, no. 12, pp. 660–670, Oct. 2002.

[10] Mehdi Tarhani, Yousef S. Kavian, and Saman Siavoshi, "SEECH: Scalable Energy Efficient Clustering Hierarchy Protocol in Wireless Sensor Networks", IEEE Sensors Journal, Vol. 14, No. 11, November 2014.

[11] Anand Pandey, Dinesh Kumar and Shailendra Kumar Singh, "Performance Evaluation of TORA Protocol with Reference to Varying Number of Mobile Nodes", International Journal of Application or Innovation in Engineering & Management Volume 2, Issue 12, December 2013.

[12] Mohamed Younis and Kemal Akkaya, "Strategies and techniques for node placement in wireless sensor networks: A survey", Ad Hoc Networks 6 (2008) 621–655.

[13] Ahmed M. Shamsan Saleh, Borhanuddin Mohd Ali, Mohd Fadlee A. Rasid and Alyani Ismail, "A survey on energy awareness mechanisms in routing protocols for wireless sensor networks using optimization methods", TRANSACTIONS ON EMERGING TELECOMMUNICATIONS TECHNOLOGIES Trans. Emerging Tel. Tech. (2013) Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/ett.2679.

[14] Tifenn Rault, Abdelmadjid Bouabdallah and Yacine Challal, "Energy E_ciency in Wireless Sensor Networks: a top-down survey", Computer Networks, Elsevier, 2014, 67 (4), pp.104-122. <hal-01009386>.

[15] Y.Xu, J.Heidemann, D.Estrin 2001, "Geography-informed Energy Conservation for Ad-hoc Routing", In Proceedings of the Seventh Annual ACM/IEEE International Conference on Mobile Computing and Networking, pp. 70-84.

[16] Benjie Chen, Kyle Jamieson, Hari Balakrishnan and Robert Morris, "Span: Energy Efficient Coordination Algorithm for Topology Maintenance in Ad Hoc Wireless Networks",Wireless Networks, ACM, Volume 8, Issue 5.

[17] Z.J. Haas, "A New Routing Protocol for the Reconfigurable Wireless Networks", In Proc. 6th International Conference on Universal Personal Communications Record, San Diego, CA, 1997, Vol. 2, pp. 562-566.

[18] S. Bali, "Performance Comparisons of DSR and TORA", WirelessNetworks and Mobile Computing, South Carolina, 2001, pp. 10-15.

[19] D. Braginsky, D. Estrin, “Rumor Routing Algorithm for Sensor Networks”, In Proc. 1st ACM International Workshop on Wireless Sensor Networks and Applications, USA, Atlanta, 2002, pp. 22-31.

[20] S. Murphy, L. Aceves, “An Efficient Routing Protocol for Wireless Networks”, Mobile Networks and Applications, ACM Journal, USA, Hingham, 1996, Vol. 1, Issue 2, pp. 183-197

[21] B. Bellur, R. Ogier, “A Reliable, Efficient Topology Broadcast Protocol for Dynamic Network”, In Proc. IEEE INFOCOM ’99, New York, USA, 1999, vol.1, pp.178-186.

[22] R. Ogier, F. Templin and M. Lewis, “Topology Dissemination Based on Reverse-Path Forwarding (TBRPF)”, RFC Editor 2004.

[23] L. Junhai, X. Liu and Y. Danxia, “Research on Multicast Routing Protocols for Mobile ad-hoc Networks”, Computer Networks, 2008, Vol. 52, Issue5, pp. 988-997.

[24] D. Park, S. Corson, “A Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Networks”, In Proc. 16th Conference on Computer and Communications Societies, Japan, 1997, pp. 1405-1413.