

Wireless Sensor Network: A Survey

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ABSTRACT-Wireless sensor networks (WSNs) is a distributed real time system. It plays an important role in today's research area also provides several advantages over networks. There are various challenges in WSNs i.e. energy consumption, communication between the nodes, scalability, utilization of sensors, large scale co-ordination and so on. Many researches take place to overcome such limitations. Various protocols and algorithms are exist and also some are proposed for efficient routing in Wireless sensor network. The protocols are classified on the basis of location, mobility, quality of service (QoS), multipath, and heterogeneity and so on. In this paper we surveyed different routing protocols and also provide a comparative analysis of that protocols on the basis of some key points like scalability, mobility, localization, aggregation, load balancing, lifetime, delay etc. The goal of routing protocols is to provide the better way for transmitting the data between sensors and also source node to destination node. Here we discuss about fundamentals of wireless sensor networks, routing, and application and design objectives.

KEYWORDS - Wireless sensor network, Routing protocols, Comparison of routing protocols, Applications.

I. INTRODUCTION

A wireless network referred as a network without any wired connection means the network does not contain any physical link between any pair of nodes. It is named as WSN because the transmitting of data between sensors is done in a wireless fashion. It is the network that primarily works as the data gathering from physical environment. There are two most fundamental nodes named as: Sensor node and Base station. Sensors are battery powered and short range transceiver equipment that sense the environment and then transmit the data to the base station. Base station gathered sensed data to the sensor node also called a sink node, it has more computational power. Wireless sensor networks are mostly a self organized network, here self organized means any time anyone insert a new node or automatically joins the network without manual intervention. It is also a collection of tiny and scattered devices which provide some essential functionality-

1. It has the ability how to monitor the physical and environmental condition, generally in real time applications.
2. The ability how to operate devices such as motors, switches etc.
3. The ability how to provide a efficient and reliable communication via wireless network.

A wireless sensor network consists of a large number of low cost, low power, and multifunctional wireless sensor nodes, with sensing wireless communications and computation capabilities [1]. These low cost sensor nodes can be arranged either randomly by dropping from an airplane or manual deployment. Capability of each sensor node has a limitation but the aggregate power of whole network is adequate to complete the task. Different applications of WSNs are: Real time traffic monitoring [3], Military surveillance [4], Health care [5], civil structure monitoring [6], Forest fire detection [7], Fire rescue [8], Remote sensing & Weather monitoring.

II. DESIGN OBJECTIVE

Different design objective has been considered, as follows –

- **SELF CONFIGURABLE**- WSNs are inclined to dynamic network behavior, that includes node power ON or OFF, joining of new nodes, being disconnected, dropping of node and so on therefore sensor networks necessitate to self configure themselves without knowing about the network topology.
- **TOPOLOGY CHANGE**-For the reason of energy depletion, channel fading, node failure and for any type of damage the network topology changes constantly (again and again).
- **LIMITED ENERGY AND STORAGE CONSTRAINTS**-In WSN, sensor nodes have limited energy and also limited storage constraints, but the aggregate power is sufficient to complete the task.
- **NODE WITH BATTERY POWERED**-It is very difficult in wireless sensor network to change and recharge the batteries, sensor nodes are generally organized in a hostile environment.
- **FAULT TOLERANCE**-Sensor networks are fault tolerant and has an ability of self testing, self recoument, self repairing. Fault tolerance indicates the ability to continue sensor network function without any interruption.
- **SECURITY**-Sensor networks suffer several attacks such that denial of service attack, Sybil attack, Wormhole attack, acknowledgement spoofing, hello flood attack, sinkhole attack and selective forwarding thus for preventing the data information network should follow several security mechanism.
- **SCALABILITY** - Scalability is the ability of the computer to continue the network functionality when size and data changed. In WSN the sensor nodes are in the range of hundreds and thousands so that the protocol design must be scalable.

- **HETEROGINITY**-The sensor nodes which are deployed may be of different kinds so here demand to collaborate with each other effectively.
- **ADAPTABILITY**-The sensor network must be adaptive for several changes like node may fail, node may move, node may join means the density of network is changed.
- **RELIABILITY**-There are various kinds of network protocols for WSNs. They provide error control, correction mechanism that assures reliable data delivery.

III. ROUTING IN WIRELESS SENSOR NETWORK

Routing is the technique for moving the information from one node to another node or from source to destination. Routing is the act of moving information across an inter-network from a source to a destination. We can also say that routing is the process of selecting the optimal (best) path in the network from source to destination. Routing in WSNs is very important and totally different from other network because here no wired connection, sometimes sensor nodes may fail and also very typical energy saving requirements.

A. ROUTING PROTOCOLS- There are various types of protocol under this section. The major categories are

Table 1: WSN Routing Protocol Categories

Category	Protocols
Location based	GEAR, GAF, SPAN, MECN, SMECN ETC.
Data Centric based	DD, ACQUIRE, RUMOR ROUTING, COUGAR, SPIN ETC.
QOS based	SPEED, SAR ETC.
Heterogeneity based	CHR, IDSQ ETC.
Mobility based	SEAD, Dynamic Proxy Tree Base Data Dissemination, Joint Mobility and Routing, Data MULES etc.
Multipath based	QEMPR, REEM,MRMS, REER, CAMP, HMRP, EBMR ETC.
Hierarchical based	HEED, LEACH, PEGASIS, TEEN, APTEEN ETC.

1. LOCATION BASED PROTOCOL

The location based protocol uses information related to location for route discovery and maintenance. The sensor nodes are manipulated based on their location. Sensor nodes are required for sensor networks to calculate the distance between two particular nodes so that energy consumption can be estimated [1].

- **GEOGRAPHIC AND ENERGY AWARE ROUTING (GEAR)** – GEAR [9] uses energy awareness which is based on the location information for selecting the sensors to move a packet towards a destination. In GEAR learning cost and estimated cost are conserved by each node to reach towards the destination. It uses a recursive

geographic forwarding algorithm to propagate the packet inside the required region.

- **GEOGRAPHIC ADAPTIVE FIDELITY (GAF)** – GAF [10] is used in WSN for energy conservation basically it is proposed for MANETS. GAF is based on the concept of taking out the non essential sensors while keeping an unvarying level of routing fidelity. It has three states- In sleeping state sensor prevents its radio to save the energy. In discovery state sensor exchange the discovery message in the same grid, at last in active state sensor broadcasts its own discovery message to inform other sensors about its state.
- **SPAN** – SPAN is the protocol used for energy consumption of nodes, It turn off the radio when time is idle. SPAN easily runs with geographic forwarding protocol without knowing about the location of sensor. Sensors join forwarding backbone topology as coordinator which can forward packet of the place of other sensors. Election rules are required so that every sensor advertise its status, neighbors and coordinators when used with a geographic forwarding.
- **MINIMUM ENERGY COMMUNICATION NETWORK (MECN)** - MECN [11] is used for achieving minimum energy, it has two phases: First is enclosure graph construction, in this phase a directed graph is constructed that contains every sensor and its vertex. Second is cost distribution here the link is eliminated which is non optimal, the resulting graph has a directed path between every sensor and sink, the cost is broadcasted to the neighbor.
- **SMALL MINIMUM ENERGY COMMUNICATION NETWORK (SMECN)** - SMECN [12] protocol is introduced to improve the MECN protocol, sensor discovers its neighbor with the help of neighbor discovery message. Sensors starts broadcasting a neighbor discovery message with some initial power p and checks whether the theoretical set of immediate neighbors is a subset of the set of sensors that replied to that neighbor discovery message [1].

Other protocols under this category are Trajectory based forwarding [13], Bounded voronoi greedy forwarding [14], and Geographic random forwarding [15].

2. DATA CENTRIC PROTOCOLS

In data centric protocols, when the source sensor sends data to the sink intermediate sensors performs some form of aggregation on the data originating from multiple source sensors and send the aggregated data towards the sink [1]. Some protocols under this section are –

- **DIRECT DIFFUSION** – Direct diffusion is energy efficient, scalable and robust protocol. At the starting for incoming events a low data rate is specify by sink node then sink reinforce a selected sensor node for sending the events with high data rate.

- **ACTIVE QUERY FORWARDING IN SENSOR NETWORKS (ACQUIRE)** - ACQUIRE is a type of query mechanism, basically works for querying named data. Every query consists sub queries, queries must be answered on the basis of presently stored data. Sensors inject the query into the network via ACQUIRE even complex query are also injected. It uses query optimization technique for answer the query.
- **RUMOR ROUTING** – Rumor routing used the ‘Agent’ concept, it is packets that traverse in the whole network and give the information to other sensors which came into existence at the time of network traversing. Every sensor even agent maintains a list. List contains events and the distance in the number of hops to the event from currently visited sensor. Agent will synchronize the event list with the sensor which it has encountered on the path. Rumor Routing is a logical compromise between query flooding and event flooding app schemes [2].
- **COUGAR** – In Cougar users have not any information about the contacted sensor, how can sensed data compute the queries, and how results are sent to the user. It follows database approach and uses query layer in which sensors are associated with query proxy, also provide high level service. Generally the protocol is not used due to some limitations. Cougar is more useful if the sensed data is associated in a single unit.
- **SENSOR PROTOCOLS FOR INFORMATION VIA NEGOTIATION (SPIN)** – SPIN protocol has two mechanisms: they are negotiation and resource adaptation. The protocol used for overcome the problem of implosion and overlap, here sensors compute the energy consumption and uses Meta data that prevents the overlapping. The size of corresponding sensor data must be greater than the size of Meta data. Two protocols presented by SPIN are –
 - *SPIN PP Or SPIN 1* – Negotiation mechanism is used by SPIN 1 protocol for reducing the consumption of sensors. It is a type of handshake protocol and most suitable for the network where two sensors are communicate directly without disturbing the other sensors.
 - *SPIN EC Or SPIN 2* – It uses the resource aware mechanism and has one to many communications. With the help of single shared channel sensors are communicate to each other.

3. QOS BASED PROTOCOL

Quality of service (QOS) in terms of delay, reliability and fault tolerance plays important role for energy consumption. The protocols under this section are –

- **SPEED** – SPEED is a protocol which ensures end to end guaranty. It uses geographic forwarding

algorithm for discovery of multiple paths, the protocol also provides the congestion avoidance. The advantages of this protocol are the total transmission energy is less, control packet overhead is less, and also more realistic as compared to other protocol.

- **SEQUENTIAL ASSIGNMENT ROUTING [SAR]** – SAR protocol has the responsibility to maintaining tables and states because it follows table driven multipath approach. It creates a tree and with the help of tree it forms a multiple path, now some path is selected for transmitting the data on the basis of energy resources and QOS on the path. Failure recovery is done and ensures fault tolerance.

4. HETEROGENITY BASED PROTOCOL

As the name heterogeneity – It implies that one or more type of sensors is used in this type of protocol, like live powered sensors and battery powered sensors. The protocol under this section are-

- **CLUSTER HEAD RELAY ROUTING (CHR)** – In CHR routing protocol sensors are in static behavior and also aware about its location. It uses two types of sensors to form a heterogeneous network with a single link: a large number of low end sensors denoted by L- sensors and a small number of powerful high end sensors denoted by H - sensors [1]. Sensors are responsible for sensing the physical environment and transmitting the data packets of all L sensors towards their cluster head. The H sensors are responsible for collection of data with in clusters and transmit the aggregate data packet towards the sink with the help of only cluster heads.
- **INFORMATION – DRIVEN SENSOR QUERY (IDSQ)** The initial step of IDSQ protocol is to find a sensor as a leader from the cluster of sensors, On the basis of some measures leader selects a optimal sensors. It addresses the problem of heterogeneous WSNs of maximizing information gain and minimizing detection latency energy consumption for target localization and tracking through dynamic sensor querying and data routing [1]. For conserving the power there is no need to activate the all sensors only subset of sensors must be activated.

5. MOBILITY BASED PROTOCOL

On the basis of mobility some more protocol are describe. They are –

- **SCALABLE ENERGY EFFICIENT ASYNCHRONOUS DISSEMINATION (SEAD)** – In SEAD protocol, source sensor forwards its data (which is sensed by sensor) to many mobile sinks. Each source sensor maintains its dissemination table, nodes have information about its geographic location. The behind SEED protocol is to decrease the delay between mobile sinks and energy savings. It addresses three main

components: dissemination tree construction, data dissemination and to preserve links.

- **DYNAMIC PROXY TREE BASED DATA DISSEMINATION** – The whole network is established by stationary sensors and mobile hosts work as sink. Sensors are find and examine some mobile targets and mobile hosts gather information or data from sensors. Due to mobility source changed and a new sensor became a source. The protocol maintains a tree for linkage between source sensors and sinks. Remember that at any time source and sink nodes are changed or moved. Both source and sink have proxies. Proxy is changeable only when the distance between source and its available proxy exceeds a threshold, similarly for sinks.
- **JOINT MOBILITY AND ROUTING PROTOCOL** – Static sink network have a problem that sensors around the static sinks are mostly used for transmitting the data, this problem is called as energy sink hole problem. The sensor which is mostly used is decreased the power of battery so that network is disconnected. As a solution of this problem mobile sinks are used so that the sensor around the sink is changed time to time and give chance to another sensor to transmit the data this helps to balancing the node. In shortest path routing strategy trajectories of the sink mobility belongs to concentric circles so that the average load of data routing is reduced.
- **DATA MULES BASED PROTOCOL** – This protocol is used for decreasing the energy consumption of the sensors. It contains static wireless sensors, WAN connected devices and MULES (mobile ubiquitous LAN extension) it is a mobile entity. Static wireless sensors used for sensing the environment, WAN connected devices and some repositories are used for examine the sensed data, MULES moved in the whole sensor field and collects the sensed data. MULE has low infrastructure cost and sensors directly communicate to MULES. If a MULE fail then latency is increased and data success rate is decreased, MULE has an undesirable delay for time critical applications.

6. MULTIPATH BASED PROTOCOLS

In multipath routing protocols many routes are find between source node and destination node and loads are divided in that multiple paths. The goals of multipath routing protocols are data security, data reliability and load balancing. On the basis of features and specification it is also categories into three types such as –

6.1 INFRASTRUCTURE BASED PROTOCOL

When a specific infrastructure is build before transmitting the data then it is called Infrastructure based protocol, it provides reliable and fast data transmission. It must be clear that specific infrastructure is not a guaranty for reliability, load balancing, and security.

- **QOS AND ENERGY AWARE MULTIPATH ROUTING (QEMPR)** – In QEMPR [16] each node has a unique ID and also nodes have the ability of calculating the probability (packet receiving as well as packet sending). By message broadcasting many paths are discovered, packets are transferred on the basis of sequence number. Sequence number and hops are associated with each other, this protocol helps to increasing the network lifetime.
- **RELIABLE AND ENERGY EFFICIENT MULTIPATH [REEM]** – REEM constructs the multiple paths on the basis of reliability and energy level. Base station constructs the path by message broadcasting also evaluate the reliability of path which is based on the neighbor information.
- **MULTIPATH ROUTING IN LARGE SCALE SENSOR NETWORK WITH MULTIPLE SINK NODES [MRMS]** – MRMS protocol is beneficial to save energy, path cost metric is used for selection of multiple paths. Path cost metric is calculated with the help of distance between neighbors and hop count.
- **HIERARCHY BASED MULTIPATH ROUTING PROTOCOL [HMRP]** – HMRP protocol ensures the scalability, also extends the life of network. Paths are constructed via broadcasting the message to neighbors, each receiving node also forward the broadcasted message to its neighbor and mark them as a child node. Destination node sends acknowledgement after receiving the message and after that message is deleted from the buffer.
- **ENERGY BALANCING MULTIPATH ROUTING PROTOCOL [EBMR]** - EBMR protocol is based on the client server architecture, all the processing done via two type of message- DATA ENQUIRY MESSAGE (DE) and DATA ENQUIRY REPLY (DER). When base station requires to query data it broadcasts a DE message, nodes reply back using DER. DER message received by base station and it calculates the shortest path by calculating the amount of energy consumes for transmitting the package.

6.2 NON INFRASTRUCTURE BASED PROTOCOL

If without constructing any infrastructure a data is transmitted then it is considered as non infrastructure based protocol. Here path is discovered when data packets move forward. The advantage of this protocol is that it does not require path maintenance.

- **EECA-** EECA is the multipath routing algorithm designed for collision free multipath. Let the transmission range be R, contains N nodes each node already knows about the location of destination node. Before sending data packets source selects two groups of nodes (neighbor).On

the basis of some conditions source node sends the data to destination node.

The conditions are-

- Nodes are near to the destination.
- The distance of nodes which corresponds to different group is more than R/2 from the source destination line.
- **MMPRSF**- MMPRSF is the approach of multipath routing, it uses a meshed route. Initially the location information of each node is spread across the network, nodes are static. Meshed routes help to find the multiple paths. When source has the data to forward it applies selective forwarding approach in which packets are distributed into the multiple paths, thus it provide load balancing.
- **ReInForm** – ReInForm is used to prevent congestion and packet loss. It has a special queue for transmitting and receiving a data. Every packet has a priority; by priority the packets are selected for transmission thus congestion is in control.

6.3 CODING BASED PROTOCOL

The coding based protocol breaks the data packets into fragments then these fragments are transmitted into the separate paths, some fragments are used to complete the decoding process. Several coding schemes are – Erasure coding, Network coding, XOR based coding.

- **MULTIPATH ROUTING USING ERASURE CODING [MREC]** – MREC protocol uses on demand routing algorithm; a path is constructed when required. Message is broadcasted into the whole network for the construction of multiple paths. After receiving the message destination

node reply via route reply message. The original data is divided into P packets and redundancies of M-P data packets are added. At last with the help of discovered multiple path these P packets are transferred.

- **CODING AWARE MULTIPATH ROUTING PROTOCOL [CAMP]** – CAMP uses network coding scheme for data reliability and security. It has two phases – In the first phase multiple paths are constructed via message broadcasting technique. In second phase, data packets are transmitted using network coding, after receiving the packets nodes check which path provide high flexibility and reliability, data packets should be transmitted using these paths.
- **ROBUST AND ENERGY EFFICIENT MULTIPATH ROUTING [REER]** – REER protocol is based on XOR coding scheme. REER follows two approaches for allocation of traffic. Firstly it uses single path to transfer data and secondly it uses multipath with XOR based scheme. The protocol uses HELLO message for selecting multiple paths. It has a version like REER-1 and REER-2.

COMPARISON OF MULTIPATH ROUTING PROTOCOLS

Table 2: Comparison of Multipath Routing Protocols

Protocol Name	Lifetime	Delay	Route Setup Time	Load Balancing	Packet Delivery Rate	No. of paths	Path length	Traffic amount
QEMPR	Good	Low	Mid	Good	Good	Low	Mid	Low
REEM	Fair	Low	High	Good	Good	Low	Mid	Mid
MRMS	Very good	Low	High	Good	Very good	Low	Low	Low
REER	Very good	Low	Mid	Good	Good	High	Low	Low
CAMP	Very good	Low	Mid	Good	Good	High	Low	Mid
MREC	Fair	Low	Mid	Good	Good	High	Low	High
ReInForm	Poor	Mid	Mid	Fair	Poor	Low	Mid	High
MMPRSF	Very good	Mid	High	Fair	Good	High	Mid	Low
HMRP	Fair	Low	Low	Fair	Fair	Low	Low	Mid
EBMR	Fair	Low	Mid	Fair	Fair	Low	Low	Low

7. HIERACHICAL PROTOCOLS

Hierarchical based protocol divides the network into clustered layer, every node belongs to a cluster with a cluster head. Data travelling takes place by lower cluster layer to high cluster layer and uses the cluster optimization technique. The protocol under this section is as follows

- **HYBRID, ENERGY EFFICIENT DISTRIBUTED CLUSTERING (HEED)** – The HEED protocol has several goals such as increasing the lifetime of network, terminates the clustering process, minimize the overhead of network and producing clustering heads. It uses a multihop networks also selects cluster heads by some parameters like residual energy of each sensor node and intra cluster communication cost. It selects a initial set of cluster heads, final selected cluster heads are distributed on the whole network. It also imposes some constraints to the system.
- **LOW – ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)** – In LEACH protocol each cluster head communicates directly for forwarding the data to the base station. Network divides into many clusters it gives chance to other sensors that act as a cluster head. It has two phases: A setup phase and a steady state phase. The algorithm is based on the aggregation technique, it uses a single hop routing. LEACH clustering terminates in a finite number of iterations, but does not guaranty to good cluster head distribution and assumes uniform energy consumption for cluster heads [1].
- **POWER EFFICIENT GATHERING IN SENSOR INFORMATION SYSTEM (PEGASIS)** – In PEGASIS routing protocols, at the time of construction it assumes that every

sensors have knowledge about the position. At the place of forming the cluster it use one node to forward the data at the base station. It forms a chain so that node forwards the data and receives the data from the neighbor but only one node forwards to the base station, Protocol follow the greedy approach. Due to some problem if sensor fails then again chain is formed by using the same greedy approach. The advantage of PEGASIS protocol is it avoids cluster formation and also increase the life time of the network. It is the extension of LEACH protocol.

- **THRESHOLD SENSITIVE ENERGY EFFICIENT SENSOR NETWORK PROTOCOL (TEEN)** – TEEN protocol also forms a cluster, every sensor belongs to a cluster. Sensor give the sensed data to the cluster head, then cluster head also forward the data to the high level cluster head whenever it not reaches to the sink. TEEN protocol also uses a data centric approach. If periodic reports are needed and time sharing applications are required then TEEN protocol is not suitable. The protocol is useful where user controls the energy efficiency, data accuracy and response time.
- **ADAPTIVE PERIODIC THRESHOLD SENSITIVE ENERGY EFFICIENT SENSOR NETWORK PROTOCOL (APTEEN)** – APTEEN comes with improvement in TEEN, it overcome the drawback of TEEN such that it works well when periodic reports are needed and suitable for real time applications. On the basis of architecture TEEN and APTEEN both are same. It also supports query like persistent query, historical query and one time query.

IV. COMPARISON OF PROTOCOLS

Table 3: Comparison of Protocols

Protocol	Type	Localization	Scalability	Data aggregation	Power usage	Position awareness	mobility
SPAN	Location based	NO	Ltd.	Yes	Ltd	No	Ltd
GAF	Location based	NO	Ltd.	No	Ltd	No	Ltd
GEAR	Location based	NO	Good	No	Ltd	No	Ltd
MECN & SMECN	Location based	NO	Low	No	Max	No	No
D.D	Data centric	YES	Ltd	Yes	Ltd	No	Ltd
ACQUIRE	Data centric	NO	Ltd	Yes	N/A	No	No
COUGAR	Data centric	NO	Ltd	Yes	Ltd	No	Ltd
SPIN	Data centric	NO	Ltd	Yes	Ltd	No	Possible
RUMOR ROUTING	Data centric	NO	Good	Yes	N/A	No	Very ltd
GBR	Data centric	NO	Ltd	Yes	N/A	No	Ltd

VGA	hierarchical	YES	Good	Yes	Low	No	No
TEEN & APTEEN	Hierarchical	YES	Good	Yes	High	No	Fixed B.S
LEACH	Hierarchical	YES	Good	Yes	High	No	Fixed B.S
PEGASIS	Hierarchical	YES	Good	No	Max	No	Fixed B.S
SPEED	QOS based	NO	Ltd	No	Low	No	No
SAR	QOS based	YES	Ltd	Yes	High	No	No

V. CONCLUSION

This paper presents a brief analysis of WSN routing protocols into seven main categories – Data centric based, location based, QOS based, mobility based, heterogeneity based, hierarchical, and multipath based protocols. The purpose behind the routing protocols is to increase the utilization of sensor as long as possible. Even lots of routing protocols are proposed and worked but still some challenges arises which is need to be solved. Like security of routing protocols, bandwidth utilization, become sensor node self configurable. We can think of expanding the sensor mote network by adding more motes, this would allow the development and testing of advanced network layer function. We can think of alternative energy sources to extend the battery life which may include solar cells and rechargeable batteries, these system could provide a long term, maintenance free and wireless monitory solution.

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