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Comparison of Routing protocols in Wireless Sensor Networks: A Detailed Survey

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----------ABSTRACT----------
Recent advancement in wireless communication has led to the development of low cost, small devices that possess sensing, signal processing and capabilities of wireless communication. WSN consist of two terms i.e. wireless network and sensors. A wireless network is any type of computer network that uses wireless data connections for connecting network nodes and Sensing is a process of gathering information about a physical object, including the occurrence of events (i.e., changes in state such as a drop in temperature or pressure). An object performing such a sensing task is called a sensor. A WSN consist of a large number of sensor nodes having wireless links for communicating. It is a kind of ad-hoc network. Its main aim is to monitor the physical conditions like pressure, temperature. Advancement in technology is mainly due to the decrease in the size of sensors.

KEYWORDS: *GAF, Protocols, SMECN, SPIN, Wireless sensor network,*

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I. INTRODUCTION

A WSN mainly consist of densely distributed nodes in a network. The most important part in wireless sensor network is sensors, popular because of low power, low cost, small size. There are main characteristics of wireless sensor networks - It has mobility of nodes. It is very easy to use. 3. It contains heterogeneity network for nodes. 4. It contains power energy constraints. 5. It has ability to cope up in environmental harsh conditions. Sensor ranges varies from nanoscopic to mesoscopic scale devices. Nanoscopic contains the devices varies from 1 to 100nm in diameter and mesoscopic varies from 100 to 10000nm in diameter. Sensors are mainly self-powered or may be passive. Sensors are mainly of two types –Active sensors- RADAR & SONAR .Passive sensors- video sensor, infrared sensor, seismic sensor, acoustic sensor etc. In WSN, the energy availability is constrained in small sensors and unconstrained in large sensors. WSN can also use large no of wireless technologies such as WLAN, PAN, Bluetooth, wi-max and 3G. [2]
In this paper, a brief description of all the routing protocols is given and then we do the comparison of all the routing protocols.

II. ARCHITECTURE

Architecture of WSN mainly follows OSI model. It consists of hardware and software (Tiny OS). It is a component based. Major components of wireless sensor network are: Sensor field- This Field consists of large number of sensor nodes and sensor nodes are deployed. [3]

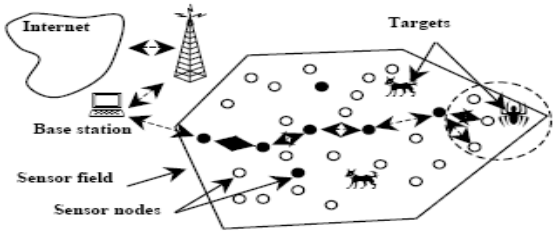

Fig. 1: Architecture of WSN. [5]
Sensor nodes-They are the sensors which are responsible for gathering information and routing information back to the sink.

Base station- it is a centralized point to control the network which is mainly used to extract the information from the network and again passes information back to the network. It is also known as task manager. Communication is done by satellite or internet communication. Sink: it is also a type of sensor node which performs operations like receiving, storing data and processing from the other sensor node. This node reduces the energy requirement.

LAYERS : WSN network architecture mainly consists of large number of layers, five layers and three cross layer plans are also added. It has application layer, transport layer, data link layer, network layer, physical layer and three cross layers are power management plane, mobility management plane and task management plane each layer has its own function. These cross layers increases the efficiency of the network by making the sensors work together these layers also used to manage the network. WSN OSI layers are [5]

Application layer : This layer provides software which translates a data to an understandable form or sends any type of queries for different applications to get certain information. This layer is known as user interface which is responsible for displaying the user information.

Transport layer : This layer is mainly used for the purpose to access other networks when system is organized to do so. It provides reliability & is more energy efficient. It is also responsible for catching and storage. Transport protocols are divided into two parts: [10]

Packet driven: where all the packets sent from the source must reach to the destination.

Event driven: The event is detected, and it is enough that one message reaches the sink.

Network layer: This layer is responsible for routing and faces a lot of challenges and the main challenges are power saving, not self-organized and doesn't have global id they also have limited memory and buffer. Various protocols are used in this layer they are hierarchal routing and flat routing.

Data link layer: It is responsible for data frame detection, MAC and error control, multiplexing data streams. It contains an error and unreliability. The unreliability comes from co channel interference at mac layer and this problem is solved by MAC protocols. Mainly MAC protocol is responsible for energy efficiency and low access delay.

Physical layer: This layer is responsible for modulation, frequency selection signal detection and coding. It provides an interfacing to transmit a stream of bits over a physical medium. These are all lower level operations.

The three cross layers i.e. mobility management is used to detect the movement of sensor nodes. Task management plane is used schedule the given area sensing task and also determine that which node is kept on and off. And power management plane manages the power level of sensors nodes.

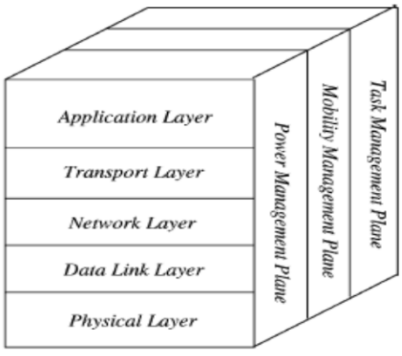

Fig. 2: OSI layer structure [1], [14], [5]

III. DESIGN ISSUES

In case of ireless sensor network, there are many factors which must be considered. Various design issues of WSN are given below. [1], [16].

Fault tolerance: sometimes in network sensor nodes are failed or blocked or some physical damage due to this failure there is no effect on the network. This fault tolerance is the ability of maintain the functionalities of the network after node failure. For e.g. If the sensors are used to keep track the temperature and humidity levels of a house' tolerance may be low since this type of network does not effected or not easily damaged. Mainly tolerance is depending upon the application of the network.

Hardware constraints: Sensor nodes usually scattered in sensor area where the sensor nodes are deployed. Mainly sensor nodes produce information about physical environment of high quality. Every scattered sensor node has the ability of routing and collecting the data from other sensor or from base station. Sensor nodes have limited power and memory. Sensor node consist of four basic components

- Power unit
- Sensing unit
- Processing unit
- Transmission unit

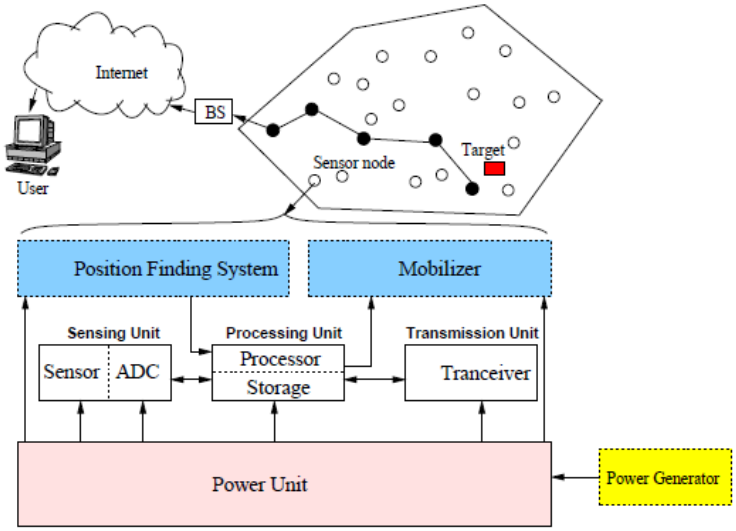

Fig.3: Architecture of sensor node. [14]

Power unit is supported by a power such as a solar cell which is followed by power generator sensor nodes consumes the power for performing various operations like sensing a many more. Power is mainly stored in capacitors and batteries both in rechargeable and non-rechargeable. Supply is mainly needed to support the operation of a network from few minutes to few hours depending upon the application. Sensing unit- It consist of two parts: sensor and analog to digital converter. Sensor produces the analog signals based on observed phenomenon and then converted to digital signals by analog to digital converter. Analog to digital converter is the device that converts input analog voltage to digital voltage. The output of sensing unit is provided to processing unit. Processing unit- the output of sensing unit is the input of processing unit i.e. digital input. This unit consists of small storage and a processor. They are used to handle data manipulation, encryption, digital modulation and many more. Computational requirement mainly ranges from 8- bit microcontroller to 64-bit microprocessor. Transmission unit- its main function is to connects the nodes within the network. It is mainly consist of transceiver. Location finding system and mobilizer- it is mainly used to find out the location and the accuracy of the network the can also move the sensor when the task is given to the network.

3.3 Production cost-sensor network consist of large number of sensors and the cost of each sensor node is required to justify the overall cost of networks. We have to keep the cost of each sensor node to be low. To make the network feasible we have to kept cost less than 1$.

3.4 Transmission media- in multi-hopping sensor network, the communication is done by wireless links and these links are infrared radio media. For global accessing we have to choose the medium that must be available worldwide. Infrared communication is very cheaper, license free and easy to build. Two types of transmission schemes should be there i.e. active transmission and passive transmission. Single channel RF trans receiver operating at 915 MHz must be used in low sensor devices. A line of sight is required between sender and receiver in both infrared and optical media. Communication satellite is also a type of transmission media.

Transmission that can be done from satellite to earth is called downlink and vice –versa is called uplink. They ate used in application like navigation, radio broadcasting etc. A microwave is also a type of transmission media it varies from 3oo MHz to 300 GHz. They are the radio waves which provide a high speed transmission signal.

Quality of services (QoS) - it defines the measure of performances in the network including the throughput and all end to end delay. When sensor sensed the network then it should be delivered within the certain period of time otherwise it can't be used. QOS means the quality services which are required in any application. Selection of Routing protocol will affect this factor.

Node deployment- It mainly affects the routing protocols performance they are mainly of two kinds self-organizing and deterministic. In deterministic, the sensors should be placed manually and data is being routed by pre-determined path. And in self -organizing sensor nodes should be randomly scattered in ad-hoc manner. Route will mainly consist of multi-hopping wireless network.

Data delivery models- its main aim is to determine that when the data is delivered which is collected by the nodes. The data can be continuous, event driven and query driven. In continuous data model each sensor sends data in a periodic manner.in event driven model, when event occurs transmission data is triggering. In query driven, when sink generated a query then data is triggered. Some networks apply a hybrid model also.

IV. ROUTING PROTOCOLS

There are various type of protocols used in wireless sensor network major protocols proposed for sensor network are divided into various categories. [9], [2].

Location based protocols, Data-centric based protocol, Hierarchical protocols, Mobility-based protocols, Multipath based protocols, Heterogeneity based protocols, and QoS based protocols

4.1 Location based protocols: It is a type of protocol which depends upon the location. Means of their location are addressed by sensor nodes. Distance between the two particular nodes can be calculated, for this purpose the location information is required so that estimation of energy consumption is required for sensor nodes.

4.1.1 Geographic adaptive fidelity (GAF) - It is used in wireless sensor network but mainly proposed for MANET and based on the mechanism in which it turns off the sensors which are not in use or unnecessary sensor. GPS provide the information of location to every sensor. It mainly detects the incoming packet presence in sensor nodes. Due to reception and transmission of packets it considers energy consumption and its main aim is to maximize the network lifetime. Sensor fields are mainly divided into grid squares so that entire area is divided into some part each sensor uses the location. With the location information, this routing provides a better way to route the protocols. Geographical locations provide a way to seekers of information. Each node knows about direct neighbor locations within its radio region and also source knows the destination location. Packet delivering could be a single node or multiple nodes. Multiple delivering leads to multiple paths to the destination. It wastes a lot of energy and bandwidth. It also creates robustness. [4]

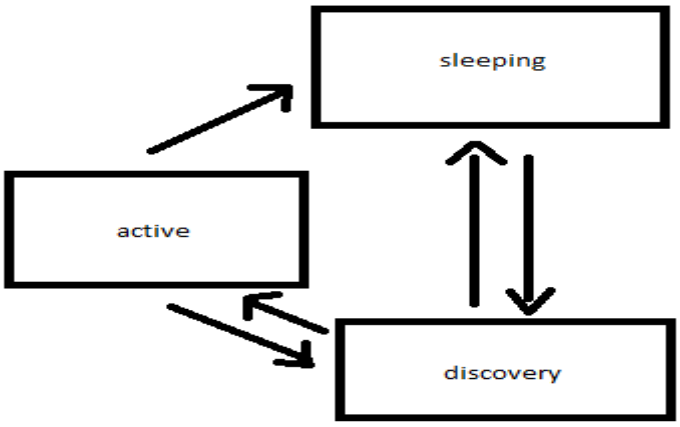

Fig. 4: State transition diagram of GAF. [4]

In this we have three stages i.e. Active, Sleeping and Discovery. In discovery state discovery message is exchange by sensor to know about the sensor in the same grid. It also determines the neighbor in the grid. If there is one or more than one node in the discovery state then a state becomes master which has longest expected lifetime. In sleeping state, when sensor enter in the sleeping state, radio is turned off for saving the energy, to keep the routing fidelity, the sleeping time is adjusted by sleeping neighbor's sleeping nodes has to wake up earlier to take the master node In active state, sleeping mode is wake up before the expiring of the leaving time of the active nodes. Discovery is periodically broadcast by a sensor to inform about its state.

4.1.2 Geographic and energy aware routing (GEAR): It is an energy- efficient protocol which is proposed for routing queries in a sensor field to target the region. Based on the principle of demand driven data delivered model, it faces a problem of limited scalability which is as one of the disadvantage. It can conserve more energy. It has two phases:

- Packets are forwarded towards the target regions.
- Within the target regions, packets are disseminated to the nodes.

4.1.3 SPAN- In this sensor location information is not required and runs with a geographic forward protocol. It is mainly for multi hop ad-hoc network.it is distributed where nodes decided where to join or sleep a forwarding backbone behaves like a co-coordinator. This protocol operates under the routing layer and above the mac and physical layer .it is proactive type in which each node broadcast periodically.it preserves capacity, decreases latency and energy saving protocol. Its energy consumption is not constant.

4.1.4 Minimum energy communication network (MECN) - It is a type of minimum energy network and a self-reconfiguring protocol. When applied to static network it suffers a problem of battery depletion. For transmitting or forwarding sensed data to the sink it uses same type of neighbor and due to this, neighbor would die very quickly thus network disconnected.

4.1.5 Small-minimum energy communication network (SMECN) - It is mainly produced to improve MECN which uses energy efficient property.in this property any sensor associate with network, minimum energy path between them i.e. path having smallest cost in terms of energy consumption. Immediate neighbors are computed analytically of the sensor.

4.2 Data-centric protocols-It is a type of energy saving protocol because it requires less transmission to send the originating data. When data is send from source to sink, immediately sensor can perform some form of aggregation on the data which is originating from multiple sensors and then send this aggregated data.

4.2.1 Directed diffusion (DD) - It mainly meets the requirement of WSN like salability, robustness, and energy efficiency. It is a type of data centric protocol for query dissemination and processing. In the beginning of the process for incoming events, sink specifies a low data rate. Communication is only for named data. It contains a flooding which is energy consuming. Data in a sensor network is a type of physical phenomenon in which data is collected and information is processed. It consists of several elements i.e. gradient, data messages, interest and reinforcement. In gradient, state is created in each node that receives an interest. In data messages, data in a sensor network is the process of collecting or processing information of physical phenomenon. Name of data is given by using attribute value pairs. Interest is a type of query it specifies what user want description of sensing task is contains in interest which is supported by a sensor network. In Reinforce, events flows toward originates of interest sensor network reinforces one or small number of path and provides a node failures which leads to path failures. [13]

4.2.2 Rumor routing(RR)- It is based on the concept of agent (long-lived packet) that transmits a network and informs each sensor it encounters about the events.it takes the shortest path to the event occur in the network. Agent is including by each sensor. Agent encounters a path of the sensor and synchronized. Agent will travel the network for a certain number of hops and then die.

4.2.3 Cougar- In cougar, user doesn't know about which sensor is contacted and how sensed data processed. This problem is solved by cougar. Every sensor is associated with a Query proxy (higher level services) it approaches uses a query layer. If a data which is sensed could be fussed into single then it is significant to the sensor.

4.2.4 Acquire query forwarding in sensor network (ACQUIRE) – It consist of several sub-queries and used for querying named data. An active query in a network is indicated by a sensor that follows either a random or specified trajectory. In this neighboring nodes detect the information of packet and then give message to node. Node selects a neighbor to propagate the query then query resolved into smaller component until solved then query is returned back as the process is completed. It allows in the network to inject a complex query.

4.2.5 Energy aware data-centric routing (EAD) – It is associated with a probability of use of each route. This probability is related to the route of the residual energy of the node. It is a routing protocol responsible for in-network data processing which builds a virtual backbone composed of active sensor. Each sensor is acting as a data source or event source and gateway plays a data sink or event sink role.

4.3 Hierarchical protocols- It uses a concept of clustering. Clustering is a communication protocol that is used by a sensor to inform about the sensed data to the sink. It reduces energy consumption by dividing all nodes into clusters. Each cluster consists of cluster head. Whole network is divided into clustered layers. Data is always transferred from low level to high level. It does hopping from one node to another but it covers a large distance if hops from one layer to another. Different routing differs that how we selects a cluster head and how node behaves in this cluster domain.

4.3.1 Low energy adaptive clustering hierarchy (leach) –it reduces energy consumption. Each cluster head (ch) is used by direct communication for forwarding the data to the base station. It is based on aggregation technique this aggregation technique combines the data in smaller sizes of data in which information is carried for all individual sensor. It doesn't require any global information. it reduces the energy consumption. Communication constant between sensors and their cluster heads is minimized. Network is divided into several clusters to reduce the amount of data which is transmitted to the sink. [6], [16],[13].

4.3.2 Power efficient gathering in sensor information (PEGASIS) – It is the extension of leach It mainly avoids cluster formation. In the network, sensors required global information. Chain is formed from the sensor node. In sensor node, each node transmits and receives from the neighbor and then it selects one node from that chain to transmit to the base station. Topology used in PEGASIS is dynamic. Network lifetime is also increases and is twice to that of leach protocol.

4.3.3 Hybrid, energy-efficient distributed clustering (HEED) – it uses multi-hop network. It is also a clustering protocol. Using residual it uses primary and secondary parameters. In primary, residual energy act as a parameter and in secondary, node degree and node proximity acts as a secondary parameter .Lifetime of the sensor network is limited so more nodes is needed to re-energize the sensor network. Locations of the nodes are unaware. There is similar processing and communication capabilities in the nodes. Heed clustering is done in phases i.e. initialize and finalize in initialize phase the sensor selects the CH and finalize phase in which least common cost is join by each sensor. .it also divides into iterations in which not yet received message from CH, elected to be the probability of CHprop.

4.4 Mobility based protocols- it requires energy efficient protocol for data delivery originated from source sensor toward sink.

4.4.1 Joint mobility and routing protocol – This protocol suffers from a problem of energy sink-hide problems. Sensors which are heavily loaded close to the sink, which deplete their battery power more quickly which is disconnecting the network. Sensors are surrounding to the sink, all the sensors in the network to give the chance to act as data relays thus balance the load.

4.4.2 Data mules based protocol - It is based on three-tier architecture on mobile entities called (MULE) i.e. mobile ubiquitous LAN extensions. It contains layer top layer consist of connected devices of wan for analyzing sensed data. Middle layer has a mobile entity that moves in the sensor field and sensed data is collected from the source. Sensor directly communicates through short range paths. Its architecture has low cost infrastructures.

4.4.3 Scalable energy –efficient asynchronous dissemination (SEAD) - It is self-organizing protocol or minimizing delay to a mobile sink. Sensors should know about the geographic locations.

4.5 Multipath-based protocol- In this transmission of data between source sensor and the sink. Two types of routing are done in this protocol i.e. single path routing and multipath routing. In single path each source sensor

sends data to the sink via shortest path. In multipath routing, each sensor finds first k shortest path to the sink. Its main aim is to balance the traffic load in any network.

4.5.1 Disjoint path- it finds small number of paths primary preference is given to the best available path if failures occurs it remains local and doesn't affect other path.

4.5.2 Braided path- it is partially disjoint path for this path information first computation of primary path is done then decides the best path from source to the sensor. It is constructed in localized manner.

4.6 Heterogeneity based protocol - In heterogeneity, two types of sensors are used and having no energy constraints sensors are having limited lifetime. They use the available energy by minimizing these data communication potential.

4.6.1 Cluster-head relay routing (CHR) – It is a type of sensors which form a heterogeneous network with single sink. Two types of sensors are used i.e. L-sensors and H-sensors commonly known as low-end sensors and high-end sensors. Sensors are aware from the location. It includes a group of sensors that also comprises of L-sensor and H-sensor. L-sensor is responsible for sensing the forwarded packets and h-sensor is responsible for data fusion within the cluster.

4.6.2 Information-driven sensor query (IDSQ) – It is responsible for maximizing the gain. Problem of heterogeneity in WSN is addressed by this protocol. From the whole cluster of sensor a leader sensor is selected, this is the first step of protocol. The sub-set of sensor node needed to be active for conserving the power.

4.7 QOS- based protocol- this protocol aims a kind of quality of service (QOS). QOS is defined as the measure of performance in the network which includes end-to –end delay and throughput. Main aim of this protocol is to find the suitable path between the sender and destination.

4.7.1 Sequential assignment routing (SAR) - it is one of the example of multipath routing. In this multiple trees are created and each is routed at neighbor of sink, for establishing multiple numbers of paths from each node to the sink. It minimizes the average weighted it is mainly used in a network which consist of large sensors. Routing decisions is mainly depending upon factors like energy resources, QOS on each path and the priority level of ach packet.

4.7.2 SPEED- It provides the services to the real-time communication. It requires the geographic location for routing. It uses a re-routing scheme to re-route the packets with minimum control overhead. It contains only immediate neighbor information. It also provides back-pressure to the upper stream. It has three types of real-time communication i.e. real time unicast, multicast and area-any cast. By studying all routing techniques, comparison between these protocols is given below- [15].

Table1: Comparison of routing protocol

Name	Type of protocol	Energy	Redundant data	scalability	Power usage	Reliability	Packet delivery
GEAR	Location based	energy efficient	Limited	Limited	Limited	good	Geo-cast based
SPAN	Location based	Reduced energy consumption	Limited	Limited	Limited	Good	Proactive type
SMECN	Location based	Energy efficient and consumption	Low	Low	Limited	Good	Minimum energy property based
GAF	Location based	High	Limited	Good	Limited	Good	Virtual grid based
SPIN	Data-centric	Low energy consumption	Limited	Limited	Limited	Poor	Meta-data based
DD	Data-centric	Low energy efficient than SPIN	Limited	Limited	Limited	High	Small interval basis
RR	Data-centric	Lower than DD	Low	Limited	Low	High	Long-lived packet
COUGAR	Data-centric	Lower but higher than DD	Low	Limited	Limited	High	Query-proxy based
ACQUIRE	Data-centric	Low	Low	Limited	Low	High	Query- based

LEACH	Hierarchical	High energy consumption	High	Good	High	High	Cluster-head based
PEGASIS	Hierarchical	Max.energy consumption	High	Good	Maximum	High	Chain- based
SAR	QOS based	Less	high	Limited	High	limited	Multipath based
SPEED	QOS based	Energy efficient	low	limited	Low	Low	Re-routing based

V. CONCLUSION

In wireless sensor network, routing becomes the main attention in the recent years and has lot of advantages than the wired networks. This paper is a review which conducts a survey on routing protocols of wireless sensor network then having comparison of all the routing protocols. The main objective behind the protocol is to keep the sensor operating as long as possible.

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