

A Survey and Comparative Study of Routing Protocols in Wireless Sensor Network

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Abstract: Due to real time applications, wireless sensor network is latest research field in computer network. WSN consist of tiny, autonomous low cost, power sensor nodes with sensing and wireless communication capabilities. The design of routing protocols for WSN is influenced by challenging factors like energy consumption, scalability, fault tolerance, quality of service. In this paper, a survey of different routing protocols of WSN is discussed and comparative study is presented. The classification of routing protocols discussed is: location based protocols, layered and in network processing protocols, data centric protocols and mobility based protocols.

Keywords: wireless sensor network, routing protocols, sensor node structure, scalability.

1. Introduction

Wireless Sensor Network is considered as one of the most important technology in today's world. Sensor network is enabled with advances wireless communication technology and embedded with microelectronic mechanical system (MEMS). Sensor nodes are tiny, cheap deployed in physical area and networked with wireless links. A wireless sensor network consists of low cost, power, self-configurable and multifunctional sensor nodes deployed in region of interest. When compared with traditional wireless network, sensor network have following characteristics: dense node deployment, battery powered sensor nodes, severe energy and storage constraint and frequent topology change. Application of Wireless sensor network covered many areas as: environmental monitoring, battlefield monitoring, health care applications, security and surveillance. A sensor node consist of four basic components: power unit, sensing unit, processing unit and communication unit. The power unit contains battery for supplying power to run all other components in sensor nodes structure. The sensing unit consists of sensors and analog to digital converters. The sensors generate analog signals based on performance of network. The processing unit consists of memory and microcontroller /microprocessor which provide control to sensor node. The communication unit consists of radio channels for performing data transmission and reception of data over channel. Thus sensor node structure built with low power consumption and with low cost [1].

Figure 1 show wireless sensor node structure. In this paper, a review of routing protocols classification is discussed and

then comparison is drawn on basis of scalability, quality of service and aggregation of data [2].

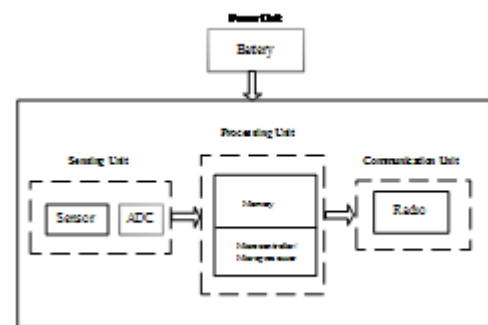


Figure 1: Sensor Node Structure

2. Protocol stack for Wireless Sensor Network

The protocol stack for wireless sensor network contain following layers: physical layer, data link layer, network layer, transport layer, and application layer [1], [3].

The application layer performs various network applications as node localization, time synchronization and includes a variety of application layer protocols. For example: The SMP- sensor management protocol is an application layer protocol that provides software operations to perform various tasks. The SQDP- sensor query and data dissemination protocol provides user applications to send queries respond to queries and collect responses from queries.

The transport layer performs end-to-end data delivery from sensor nodes to sink. Traditional transport protocol cannot be applied directly to wireless sensor network due to energy and

computation constraint of sensor nodes. In this data delivery contains two streams: upstream and downstream, in upstream the sensor nodes transmit sensed data to sink and in downstream data originate from sink such as queries.

The network layer performs routing and sends sensed data from sensor nodes to sink, in wireless sensor network sensor nodes are deployed in sensing area. In general, source node send transmit sensed data to sink via routing methods: single-hop and multi-hop. In single-hop, source node sends sensed data directly to sink and is long-range communication. In multi-hop, source node sends sensed data to sink via intermediate nodes and is short-range wireless communication.

The data link layer protocol performs data stream multiplexing, data frame formation and detection, error control to provide reliable transmission. MAC-medium access control is important function of data link layer and its objective is to efficiently share medium among multiple sensor nodes to get good performance in term of energy consumption, latency. Another important function is error control and it contains two mechanisms: FEC -forward error correction achieves link reliability using error control in transmission and ARQ - automatic repeat request achieves reliable data transmission by retransmitting lost data packets.

The physical layer performs conversion of bit streams from data link layer to signals that are suitable for data transmission over channel. In this layer, medium and frequency selection are an important problems for communication between sensor nodes. Radio and ISM (industrial, scientific and medical) band are options used for medium and frequency selection. Therefore, sender and receiver both communicate with each other within sight distance.

Protocol stack has big impact on energy consumption and network lifetime of wireless sensor network.

3. Design Objectives

3.1 Network Architecture

Wireless sensor network consist of three components- sink or base station, sensor area, and sensor nodes. The sensor nodes must autonomously organize themselves into communication network i.e. should be self-configurable in nature. Most challenging is routing messages and route stability is important in aspect of energy, bandwidth.

3.2 Energy capacity

As, sensors nodes are battery powered and have limited energy. To prolong the network lifetime energy efficiency should be considered as important aspect.

3.3 Reliable Environment

The topology of sensor network changes very frequently due to node failure so nodes should be reliable in nature. As, sensor nodes are linked by wireless medium which are error prone.

3.4 Node capabilities

While deployment of sensor nodes, nodes should be homogenous in nature i.e. have equal computation, communication and power capacity.

4. Routing Protocols in Wireless Sensor Network

Table 1: Classification of Routing Protocols in WSNs

Location- Aided Protocols	GAF, GEAR, SMECN, MECN
Layered and In-Network Processing Protocols	LEACH, PEGASIS, TEEN, APTEEN
Data Centric Protocols	SPIN, Directed Diffusion
Mobility-based protocols	TTDD, SEAD

4.1 Location- Aided protocols

The location information based protocols can be short or long range, energy consumed depends on distance over which data is transmitted. Location based protocols use location information to guide route discovery and data forwarding with proper energy consumption [1], [4].

4.1.1 Geographic Adaptive Fidelity (GAF)

GAF is location based routing protocol proposed for MANETs but also well suited for WSNs, the main mechanism on which GAF is based i.e. turning off unnecessary sensors, radio should be turned off to provide optimize energy consumption. GAF divides a sensor field into grid squares and every sensor node uses location information provided by GPS. Three states of GAF mechanism as shown in Figure 2: sleeping state- turn off radio when not in use, discovery state- sensor exchange discovery messages to know about other sensors and in active state- a sensor periodically broadcast its discovery messages.

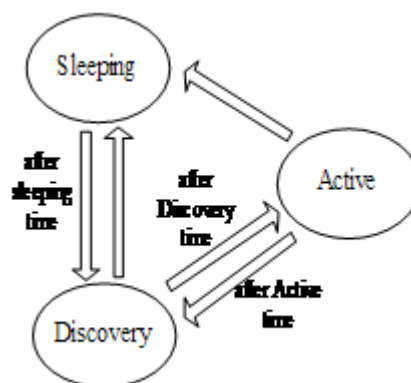


Figure 2: State Diagram of GAF

4.1.2 Geographic and Energy Aware Routing (GEAR)

GEAR is an energy efficient routing protocol and is proposed to route queries to target regions in sensor field. In GEAR also, GPS location hardware is equipped with system to know current positions GEAR uses energy aware routing based on geographical information to select sensors to route a packet towards destination. In this protocol, each sensor keeps an estimated cost that depends on energy consumed and learning cost. GEAR has two phases: forwarding a packet towards its destination and disseminating the packet within destination

region. GEAR also uses restricted flooding which is more energy efficient in nature.

4.1.3 Minimum Energy Communication Network (MECN)

MECN- minimum energy communication Network attempts to set up and maintain minimum energy network with mobile sensors. The main objective of MECN is to maximize battery lifetime of network and minimizing the energy consumption. Also, MECN is self-reconfiguring protocol that maintains network connectivity itself and can dynamically adapt to node failure or adding new sensors. Two main phases of MECN: enclosure graph construction- constructs a sparse graph, selects a relay region (relay region is area where relaying messages to any point through an intermediate node is more energy efficient) and cost distribution- links that are not optimal are simply eliminated.

4.1.4 Small Minimum Energy Communication Network (SMECN)

SMECN construct a minimal graph with respect to minimum energy property and construct a network smaller than MECN. In, SMECN sub graph is constructed and in this every sensor discovers its immediate neighbor by broadcasting discovery messages using initial power and checks whether subset is set of sensors that replied to discovery message otherwise increment power to rebroadcast discovery message.

4.2 Layered and In-Network Processing Protocols

In layered and in-network processing protocol, clustering is done and clustering is an energy efficient communication protocol used by sensors to send sensed data to sink. In Layered protocol, several clusters are formed in network with cluster heads and cluster head is responsible for transmitting sensed data from sensors to sink.

4.2.1 Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH is conventional and first clustering-based routing protocol. LEACH uses data aggregation technique that combines original data into smaller size of data removing redundant data. LEACH is divided into several clusters and is constructed using localized coordination. It also transmits data over short range of communication thus reducing number of transmissions. The mechanism of LEACH is divided into two phases: set up phase and steady phase. In set-up phase, network is organized into several clusters and in steady phase, data transmission to sink is done. In LEACH, cluster head selection is based on probability and sensor decide to become cluster based on desired percentage, current round and set of sensors that have not become cluster head in last $1/p$ round. Thus, LEACH is hybrid approach using short or long range communication and drawback of LEACH is that nodes die very quickly [5].

$$T(n) = \frac{p}{1 - p \left(r \bmod \left(\frac{1}{p} \right) \right)} \quad \text{if } n \in G,$$

$$T(n) = 0 \quad \text{otherwise.}$$

4.2.2 Power- Efficient gathering in Sensor Information system (PEAGSIS)

To improve LEACH performance further, PEAGSIS was proposed that allow only one cluster head to transmit data to

sink in each round. In this protocol, sensors are organized in chain form which can be performed by sensor itself or by sink. The construction phase of this mechanism assume that all sensors have global knowledge about network and in data fusion phase only one leader will transmit data to sink. Hence, PEAGSIS outperforms LEACH in network.

4.2.3 Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN)

TEEN is hierarchical clustering protocol that targets a reactive network and in this sensor within cluster send sensed data to their cluster head; cluster head further send aggregated data to sink. In this mechanism, two threshold values are transmitted i.e. hard threshold and soft threshold. Each cluster head in cluster broadcast a value to its members and that value is hard threshold for sensed attribute when reaching hard threshold value sensor turn on their transmitter to send sensed data to sink and also, cluster head broadcast another value that indicates a small change in value of sensed attribute called soft threshold. Both hard threshold and soft threshold reduces the number of transmissions. TEEN is not suitable for sensing applications which require sensors to report data on regular basis.

4.2.4 Adaptive Periodic TEEN (APTEEN)

To overcome the problem of TEEN, APTEEN was proposed and this protocol combines features of both TEEN and LEACH to achieve better performance. APTEEN is hybrid clustering routing protocol that allows sensors to send sensed data periodically not on regular basis and provide low energy dissipation with larger number of sensors alive. APTEEN works same as TEEN, after cluster formation cluster head broadcast threshold values. However, APTEEN can handle three type of queries- historical, one time and persistent queries.

4.3 Data Centric protocols

In traditional routing protocols, sink sends out a query for collecting data and sensor nodes responds to query by directly sending sensed data to sink. But in data centric protocols, source sensor sends data to sink via intermediate nodes and also perform aggregation. Thus, data centric routing protocols reduce the transmissions and saves energy.

4.3.1 Sensor Protocols for Information via Negotiation (SPIN)

The SPIN protocol improve classic flooding problem and this protocol is resource aware, resource adaptive. SPIN protocol is based on two mechanisms: negotiation- in this sensor negotiates with each other before dissemination of any data occurs and resource adaptation – for energy saving. SPIN is composed of two messages: advertisement (ADV) and request (REQ). In advertisement messages, sensor advertises its data by sending ADV message containing data that it wants to share with other sensors. In request message, if a sensor interested in advertised data then it send back a REQ message to source of ADV that it wants to acquire original data.

However, SPIN protocols are of several types: SPIN-1 or SPIN-PP, SPIN-2 or SPIN-EC, SPIN-BC, SPIN-RL.

4.3.2 Directed Diffusion

Directed diffusion is data centric routing protocol for query dissemination and processing of query. For example- sensor within region A may coordinate to select the best estimate of direction of vehicle movement. In this mechanism, sensor names their generated data by attribute-value pairs and if sensor wants to receive data, it sends interests for named data. Directed diffusion contains key elements: data naming, interest, gradient and data reinforcement. The sensor network in this protocol reinforces one or more small number of paths.

4.4 Mobility- Based Protocols

The existence of path in wireless sensor network is of two types: static or mobile. In static network, both sensors and sink remain in fixed position without any movement thus, have less overhead. In mobile network, sink and sensors are in moving position and thus, have more overhead but mobile network reduces no of transmissions saving energy.

4.4.1 Two Tier Data Dissemination (TTDD)

TTDD protocol was proposed to overcome flooding that occurs in directed diffusion protocol and also, TTDD provides scalable, efficient data delivery. In TTDD, sensors are aware of their locations but sink may or may not be aware of its location. TTDD protocol has three main phases: grid construction, two-tier query data forwarding and grid maintenance. TTDD employs two mechanisms: upstream and downstream dissemination.

4.4.2 Scalable Energy-Efficient Asynchronous Dissemination (SEAD)

SEAD protocol improves performance of TTDD protocol and trade-off between minimizing the forwarding delay and energy savings. SEAD performs data dissemination in which source sensor send its sensed data to multiple mobile sinks and SEAD contain three components: construction of dissemination tree, data dissemination and maintaining linkage to multiple mobile sinks.

5. Other Routing Protocols in WSN

5.1 Hybrid Energy-efficient Routing Protocol (HEE)

HEE was proposed to improve performance of energy consumption when comparing to direct transmission and minimum energy transmission. The HEE protocol proposed is suitable for both large and small size network. HEE is combination of two simple routing techniques i.e. direct transmission and minimum energy transmission. Therefore, HEE provides better energy efficiency regardless of network size and message length [6].

5.2 Distributed Energy efficient Clustering protocol (DEEC)

DEEC is clustering protocol for two or more level heterogeneous network. In this cluster head selection is based on residual energy and average energy of network. The nodes with higher initial, residual energy have more chances to become cluster head. DEEC is proactive protocol and distribute uniform energy [7].

5.3 Hybrid Energy-Efficient Reactive protocol (HEER)

HEER is hybrid routing protocol as it works well both in homogenous and heterogeneous network. HEER is reactive protocol and does not require any global knowledge of energy when electing cluster heads. HEER transmit two threshold values: hard threshold and soft threshold. This protocol performs best for time critical applications and reduces no of transmissions thus, saving energy [8].

6. Comparison of Routing Protocols

Table 2: Comparison of routing protocols in sensor network

Routing Protocols	Data Aggregation	Scalability	Quality of Service
GAF	No	Good	No
GEAR	No	Medium	No
MECN	No	Medium	No
LEACH	Yes	Good	No
PEAGSIS	No	Good	No
TEEN	Yes	Good	No
APTEEN	Yes	Good	Yes
SPIN	Yes	Medium	No
TTDD	No	Good	No
DEEC	No	Medium	Yes
HEER	No	Good	Yes

Classification of routing protocols of Wireless Sensor Network discussed above is compared on parameters scalability, quality of service and aggregation of data provided as shown in Table 2.

7. Conclusion

Routing in WSN is new area of research in network field. To provide low latency, energy efficient and real time guarantees in sensor network is challenging problem but main focus is to achieve better energy consumption. However, routing protocol designed for wireless sensor network should be energy efficient and prolong network lifetime. Hence, in this paper classification of routing protocol is categorized into four types: location based protocols, layered and in network processing

protocols, data centric protocols and mobility based protocols. Also, comparison of routing protocols of wireless sensor network is presented in this paper regarding scalability and quality of service.

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