A Review: Comparative Analysis of Routing Protocols in Wireless Sensor Network

Prabhdeep Singh[1], Navdeep Kaur[2] and Ravneet Kaur[3]

[1] Department Of Computer Science, Lovely Professional University
Phagwara, Punjab, India
[2]Department of Electronics and Communication, Lovely Professional University
Phagwara , Punjab, India
[3]Department of Electronics and Communication, Lovely Professional University Phagwara, Punjab, India

Abstract- Wireless Sensor networks are recently rapidly growing research area in wireless communications and distributed network. Wireless Sensor Network consists of a large number of low-cost, low-power, and multifunctional sensor nodes with the capability to sense the various types of physical and environmental condition. The sensor nodes have a limited transmission range, and their processing and storage capabilities as well as their energy resources are also limited. Due to these limitations routing is major challenge in wireless sensor network. Routing protocols for wireless sensor networks are responsible for maintaining the routes in the network and ensure reliable multi-hop communication under these conditions. This paper reviews the various routing protocol and their comparison in wireless sensor network.

Keywords: *Wireless Sensor Network, Protocol Stack, Routing Protocols.*

I. INTRODUCTION

A wireless sensor network (WSN) can be defined as a network consists of low-size and low-complex devices called as sensor nodes that can sense the environment and gather the information from the monitoring field and communicate through wireless links; the data collected is forwarded, via multiple hops relaying to a sink (also called as controller or monitor) that can use it locally, or is connected to other networks [1][2]. The WSN structure consists of sensor nodes (SNs) and a sink node, usually called a base station (BS). SNs are placed in the sensing field and BS is usually located further away to collect and analyze the sensing data. Typically, SNs could send data to BS directly or indirectly via other intermediate SN(s). Since SNs usually operate by using limited energy sources such as batteries, it is undesirable to replace or recharge SNs due to high maintenance cost. In this case, Relay Stations (RSs) serve an essential role to receive and forward data from SNs to BS such that the energy-limited SNs can operate for a desired period of the network lifetime. The position of sensor nodes need not be engineered or pre-determined. This allows random deployment in inaccessible terrains or disaster relief operations.[3]

In many WSN applications, the deployment of sensor nodes is performed in an ad hoc fashion without careful planning and engineering. Once deployed, the sensor nodes must be able to autonomously organize themselves into a wireless communication network. Sensor nodes are battery powered and are expected to operate without attendance for a relatively long period of time. In most cases it is very difficult and even impossible to change or recharge batteries for the sensor nodes. WSNs are characterized with denser levels of sensor node deployment, higher unreliability of sensor nodes, and sever power, computation, and memory constraints. Thus, the unique characteristics and constraints present many new challenges for the development and application of WSNs. [4]

Sensor nodes can also be deployed to continually monitor office buildings, hospitals, airports, factories, power plants, or production facilities. Sensor nodes can be used for continuous sensing, event detection, event ID, location sensing and local control of actuators. [2]. Due to the severe energy constraints of large number of densely deployed sensor nodes, it requires a suite of network protocols to implement various network control and management functions such as synchronization, node localization, and network security. The traditional routing protocols have several shortcomings when applied to WSNs, which are mainly due to the energy-constrained nature of such networks. [4].

Unlike Mobile Ad Hoc networks, wireless sensor networks are characterized by asymmetric many-to-one data flows (mainly from sensor nodes to sink node), severe energy constraints and unreliable network nodes. Therefore, most routing protocols proposed for Mobile Ad Hoc networks are not suitable for wireless sensor networks, or cannot be used in wireless sensor networks without any modification. Thus, alternative approaches need to be explored. One of the challenges of wireless sensor network routing protocols is to achieve maximal robustness against path failure with minimal energy consumption.

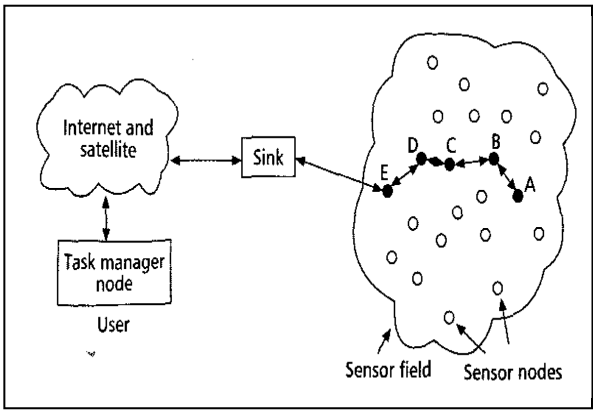

Fig. 1Wireless Sensor Network

Many routing protocols have been designed and developed for WSNs because the routing in WSNs has many challenges which are not there in other form of networks. Few of them are: number of nodes is large, nodes are tightly constrained in terms of energy, processing, and storage capacities, node failure rate is high etc. Hence they need careful resource management. Most of the Routing protocols for WSN support multi-hop routing. Depending on how many copies of one data packet are forwarded to the destination simultaneously, these multi-hop routing protocols can be divided into two categories:

- Single path routing
- Multi-path routing

In single-path routing, for each data packet, there is only one copy traveling along one path in the network. While in multi-path routing, multiple copies of one packet are transmitted in parallel along different paths to the same destination.[5]

II. SENSOR NODE ARCHITECTURE

The basic block diagram of a wireless sensor node is presented in Fig. 2. It is made up four basic components: a sensing unit, a processing unit, a transceiver unit and a power unit. There can be application dependent additional components such as a location finding system, a power generator and a mobilizer. First one, location finding system is required since the user may in need of location with high accuracy and mobilizer may be needed to move sensor nodes to carry out the assigned tasks.

A. *Sensing Unit*

Sensing units are usually composed of two subunits: sensors and analog to digital converters (ADCs). Sensor is a device which is used to translate physical phenomena to electrical signals. Sensors can be classified as either analog or digital devices. There exists a variety of sensors that measure environmental parameters such as temperature, light intensity, sound, magnetic fields, image, etc. The analog signals produced by the sensors based on the observed phenomenon are converted to digital signals by the ADC and then fed into the processing unit.

B. *Processing Unit*

The processing unit mainly provides intelligence to the sensor node. The processing unit consists of a microprocessor, which is responsible for control of the sensors, execution of communication protocols and signal processing algorithms on the gathered sensor data. Commonly used microprocessors are Intel's Strong ARM microprocessor, Atmel‘s AVR microcontroller and Texas Instruments' MP430 microprocessor. The microcontroller’s work is to process and store the sensor output. The transceiver receives command from a central computer or base station and transmits data to the computer or station. Sensor nodes are catered power by a battery. Some sensor nodes include external memory which may be on-chip memory of a microcontroller and Flash memory.

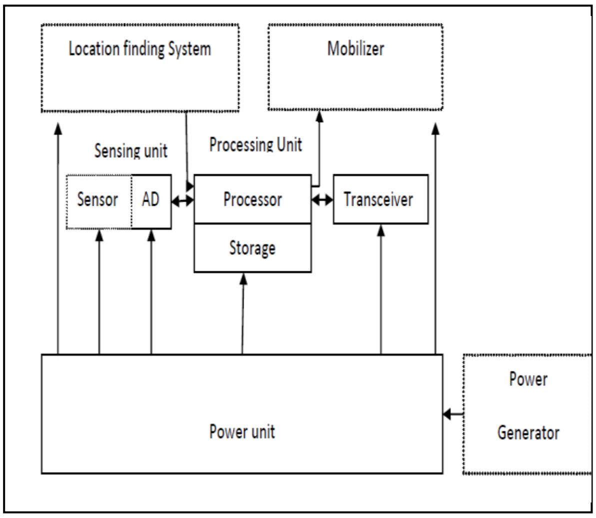

Fig. 2 Sensor Node Architecture

C. *Transceiver Unit*

The radio enables wireless communication with neighbouring nodes and the outside world. It consists of a short range radio which usually has single channel at low data rate and operates at unlicensed bands of 868-870 MHz (Europe), 902-928 MHz (USA) or near 2.4 GHz (global ISM band). There are several factors that affect the power consumption characteristics of a radio, which includes the type of modulation scheme used, data rate, transmit power and the operational duty cycle. At transmitted power levels of -10dBm and below, a majority of the transmit mode power is dissipated in the circuitry and not radiated from the antenna. However, at high transmit levels (over 0dBm) the active current drown by the transmitter is high. The transmit power levels for sensor node applications are roughly in the range of -10 to +3 dBm.

D. Power Unit

The battery supplies power to the complete sensor node. It plays a vital role in determining sensor node lifetime. The amount of power drawn from a battery should be carefully monitored. Sensor nodes are generally small, light and cheap, the size of the battery is limited. AA batteries normally store 2.2 to 2.5 Ah at 1.5 V. However, these numbers vary depending on the technology utilized. Sensors must have a lifetime of months to years, since battery replacement is not an option for networks with thousands of physically embedded nodes. This causes energy consumption to be the most important factor in determining sensor node lifetime.[6].

III. ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORK

Routing in wireless sensor networks is very challenging due to several characteristics that distinguish them from contemporary communication and wireless ad-hoc networks. It is not possible to build a global addressing scheme for the deployment of sheer number of sensor nodes. Therefore, classical IP-based protocols cannot be applied to sensor networks.[7] Minimizing Energy consumption is considered as one of the most important principles in the development of routing protocols for Wireless Sensor Networks (WSN). So the aim of routing in WSNs is to find out and maintain routes in WSNs. Routing challenges with reference to WSNs are Energy consumption without losing accuracy , Node deployment, Link heterogeneity, Data reporting model , Scalability, Network dynamic transmission media, Connectivity, Coverage, Data aggregation, Quality of services. [8] Routing protocols are in charge of discovering and maintaining the routes in the network. Many routing, power management, and data dissemination protocols have been specifically designed for WSNs. [7] Almost all of the routing protocols can be classified into seven categories:

- Location-based Protocols
- Data Centric Protocols
- Hierarchical Protocols
- Mobility-based Protocols
- Multipath-based Protocols
- Heterogeneity-based Protocols
- QoS-based protocols

A. Location-based Protocols

In this kind of network architecture, sensor nodes are scattered randomly in an area of interest and mostly known by the geographic position where they are deployed. Alternatively, the location of nodes may be available directly by communicating with a satellite, using GPS (Global Positioning System), if nodes are equipped with a small low power GPS receiver. In location-based routing, sensor nodes positions are exploited to route data in the network. To save energy, some location based schemes demand that nodes should go to sleep if there is no activity. More energy savings can be obtained by having as many sleeping nodes in the network as possible. The distance between nodes is estimated by the signal strength received from those nodes and coordinates are calculated by exchanging information between neighboring nodes. [9][10] Location-based protocols utilize the position information to relay the data to the desired regions rather than the whole. [7].Location-based protocols are:

- MECN (Minimum Energy Communication Network)
- SMECN (Small Minimum Energy Communication Network)
- GAF(Geographic Adaptive Fidelity)
- GEAR (Geographic and Energy-Aware Routing)
- GEDIR (Geographic distance routing)
- BVGF(Bounded Voronoi Greedy Forwarding)
- GeRaF (Geographic Random Forwarding)
- GOAFR(Greedy Other Adaptive Face Routing)

B. Data Centric Protocols

Data-centric protocols differ from traditional address centric protocols in the manner that the data is sent from source sensors to the sink. In address-centric protocols, each source sensor that has the appropriate data responds by sending its data to the sink independently of all other sensors. However, in data-centric protocols, when the source sensors send their data to the sink, intermediate sensors can perform some form of aggregation on the data originating from multiple source sensors and send the aggregated data toward the sink. This process can result in energy savings because of less transmission required to send the data from the sources to the sink.[4][10] Data Centric protocols are:

- SPIN (Sensor Protocols for Information via Negotiation)
- Directed Diffusion
- Rumor Routing
- COUGAR
- ACQUIRE(Active Query Forwarding in Sensor Networks)
- EAD (Energy-Aware Data-Centric Routing)
- Information-Directed Routing
- Gradient- Based Routing
- Energy-aware Routing
- Information-Directed Routing
- Quorum-Based Information Dissemination

- MCFA (Minimum Cost Forwarding Algorithm)

C. Hierarchical Protocols

The main target of hierarchical routing protocols or cluster based routing is to efficiently maintain the energy usage of sensor nodes by involving them in multi-hop communication within a particular cluster. Cluster formation is generally based on the energy reserve of sensors and sensors proximity to the Cluster Head (CHs). Clustering plays an important role for energy saving in WSNs. With clustering in WSNs, energy consumption, lifetime of the network and scalability can be improved. Because only cluster head node per cluster is required to perform routing task and the other sensor nodes just forward their data to cluster head. Clustering has important applications in high-density sensor networks, because it is much easier to manage a set of cluster representatives (cluster head) from each cluster than to manage whole sensor nodes.

In WSNs the sensor nodes are resource constrained which means they have limited energy, transmit power, memory, and computational capabilities. Energy consumed by the sensor nodes for communicating data from sensor nodes to the base station is the crucial cause of energy depletion in sensor nodes. [8][10] [11]. Hierarchical routing protocols are:

- LEACH (Low-energy adaptive clustering hierarchy)
- PEGASIS (Power-Efficient Gathering in Sensor Information Systems)
- HEED (Hybrid, Energy-Efficient Distributed Clustering)
- TEEN (Threshold Sensitive Energy Efficient Sensor Network Protocol)
- APTEEN (Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol)
- Hierarchical Power-Active Routing (HPAR)

D. Mobility-based Protocols

Mobility brings new challenges to routing protocols in WSNs. Sink mobility requires energy efficient protocols to guarantee data delivery originated from source sensors toward mobile sinks.[4] Mobility-based protocols are:

- SEAD (Scalable Energy-Efficient Asynchronous Dissemination)
- Joint Mobility and Routing
- Data MULES based protocols
- Dynamic Proxy Tree-Base Data Dissemination

E. Multipath-based Protocols

For data transmission between source sensors and the sink, there are two routing paradigms: single-path routing and multipath routing. In single-path routing, each source sensor sends its data to the sink via the shortest path. In multipath routing, each source sensor finds the first k shortest paths to the sink and divides its load evenly among these paths. As its name implies, protocols included in this class provides multiple path selection for a message to reach destination thus decreasing delay and increasing network performance. Network reliability is achieved due to increased overhead. Since network paths are kept alive by sending periodic messages and hence consume greater energy.[4][9]Multipath routing protocols are:

- Sensor-Disjoint Multipath Protocol
- Braided Multipath Protocol
- N-to-1 Multipath Discovery Protocol

F. Heterogeneity-based Protocols

In heterogeneity sensor network architecture, there are two types of sensors namely line-powered sensors which have no energy constraint, and the battery-powered sensors having limited lifetime, and hence should use their available energy efficiently by minimizing their potential of data communication and computation.[4] Heterogeneity-based protocols are:

- IDSQ (Information-Driven Sensor Query)
- CHR (Cluster-Head Relay Routing)

G. Qos-based Protocols

In this type of routing, network needs to have a balance approach for the QoS of applications. In this case the application can delay sensitive so to achieve this QoS metric network have to look also for its energy consumption which is another metric when communicating to the base station. So to achieve QoS, the cost function for the desired QoS also needs to be considered. [9].This protocol extends the routing approach and finds a least cost and energy efficient path that meets certain end-to-end delay during the connection. In order to support both best effort and real-time traffic at the same time, a class-based queuing model is employed. The queuing model allows service sharing for real-time and non-real-time traffic. [4]. Qos-based Protocols are:

- SAR(Sequential Assignment Routing)
- SPEED
- Multi path and Multi SPEED (MMSPEED)

IV. COMPARISON OF ROUTING PROTOCOLS

TABLE I COMPARISON OF ROUTING PROTOCOLS

Routing Protocols	Classifi-cation	Power Usage	Scalability	Overhead	Data Delivery Model	Mobility	Multipath	Position Awareness	State complexity	Query Based
MECN& SMECN	Location -based	Maxim um	Low	N/A	N/A	No	No	No	Low	No
GAF	Location -based	Limite d	Good	Moderate	Virtual grid	Yes	Possible	Yes	Moderate	No
GEAR	Location -based	Limite d	Limited	Moderate	Demand driven	Limited	No	No	No	No
SPIN	Data centric	Limite d	Limited	Low	Event driven	Possible	Yes	No	Low	Yes
COUGAR	Data centric	Limite d	Limited	High	Query driven	No	No	No	Low	Limited
ACQUIR E	Data centric	N/A	Limited	High	Complex query	Limited	No	No	Low	Yes
DD	Data centric	Unlimi ted	Limited	Low	Demand driven	Limited	Yes	No	Low	Yes
Rumor routing	Data centric	N/A	Good	Low	Demand driven	Very limited	No	No	Low	Yes
MCFA	Data centric	N/A	Good	N/A	N/A	No	No	No	Low	No
LEACH	Hierarch ical	Maxim um	Good	High	Cluster	Fixed BS	No	No	CHs	No
PEGASIS	Hierarch ical	Maxim um	Good	Low	Chain based	Fixed BS	No	No	Low	No
TEEN&A PTEEN	Hierarch ical	High	Good	High	Active threshold	Fixed BS	No	No	CHs	No
HPAR	Hierarch ical	N/A	Good	N/A	N/A	No	No	No	No	No
SAR	Qos-based	N/A	Limited	High	Continuo usly	No	No	No	Moderate	Yes
SPEED	Qos-based	N/A	Limited	Less	Geograp-hic	No	No	No	Moderate	Yes
GEDIR	Location -based	N/A	Good	N/A	N/A	Limited	No	No	No	No
GBR	Data centric	N/A	Limited	Low	Hybrid	Limited	No	No	Low	Yes
GOFAR	Location -based	N/A	Limited	N/A	N/A	No	No	No	No	No
TTDD	Hierarch ical	Limite d	Low	N/A	N/A	Yes	Possible	Yes	Moderate	Possibl e
SOP	Hierarch ical	N/A	Low	High	Continuo usly	No	No	No	Low	No
VGA	Hierarch ical	N/A	Good	High	N/A	No	Yes	No	CHs	No
CADR	Data centric	Limite d	Lmited	Low	Continuo usly	No	No	No	Low	Limited
EAR	Data centric	N/A	Limited	N/A	N/A	Limited	No	No	No	Yes

There are several protocols which are compared and comparison is shown in the Table I.This comparision is made on basis of ref [12].

V. CONCLUSION

In this paper the main aspects of wireless sensor network including the sensor node architecture, classification of routing protocol and comparison of various routing protocol are described. The routing protocols can be divided into seven categories: Location-based protocols, Data centric protocols, Hierarchical protocols, Mobility-based protocols, Multipath-based protocols, Heterogeneity-based protocols, Qos-based protocols. In wireless sensor network the sensor nodes operate on limited battery energy so the efficient utilization of energy is very important. The transmission power consumption is closely coupled with the route selection. The main aim of the routing protocol is to enhance lifetime of the wireless sensor network. So routing protocols designed for wireless sensor network should be as energy efficient as possible to prolong the lifetime of individual sensor nodes, and hence the network lifetime.

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