Overview of Cluster Based Routing Protocols in Static and Mobile Wireless Sensor Networks

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Abstract Wireless Sensor Network (WSN) is one of the hottest research areas now days. WSNs can be used to monitor environmental conditions like light, sound, temperature, pollution, humidity, wind speed and direction, pressure, and many more. Also WSNs are used in industrial process monitoring and control, machine health monitoring, traffic monitoring, space exploration, disaster management etc. Cluster based WSN provide much better support, functionality, advantages and results in ample variety of applications, because of this, many cluster based routing protocols have been developed for WSN. This paper focus on concise study of the clustering based routing protocols. In this paper, brief overview of the cluster based routing techniques for Static WSN where, the sensor nodes are fixed, i.e. not moveable, and for Mobile WSN, where the sensor nodes are fixed and/or mobile in nature, i.e. they can move from one location to another, is presented.

Keywords Cluster based routing · Wireless sensor networks · Static nodes · Mobile nodes

1 Introduction

Wireless Sensor Network [1–3] is one of the hot areas in research now days. It is consist of a group of spatially distributed and dedicated autonomous cooperative tiny, low cost, small battery powered static and/or mobile sensor nodes which have

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capability to sense, actuate, compute, move from one location to another and communicate with each other. WSNs can be used to monitor environmental conditions like light, sound, temperature, pressure, pollution levels, humidity, and many more. Development of WSN was motivated by military applications but, nowadays, WSNs applications has been extended to traffic monitoring, health monitoring, industrial process monitoring and control, machine monitoring, etc.
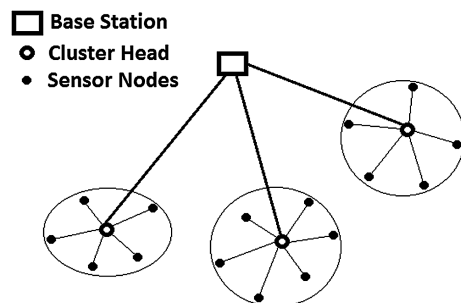
Sensor nodes are deployed densely in the region of interest for monitoring of any desired data, where there is no network infrastructure, so the nodes must cooperate to accomplish communication, global control and information aggregation. WSN aims to collect data from a desired region of interest and sometimes control an environment. Generally in the basic operations performed in WSN, like sensing, computing, communication, moving from one location to another and routing the sensed data, carried out during the lifetime of the wireless sensor network, battery of the sensor nodes may ruin quickly, due which the desired operations may not be completed and the network may fail. To avoid such situations and to prolong the lifetime of the operation and the network, the battery life of the sensor nodes is considered as one of the key issues. It is must to find out the factors affecting the battery life of the sensors and ways to reduce the energy consumption of sensor nodes and that is one of the main challenges in Wireless Sensor Networks.

Cluster Based Routing (CBR) [4] is one of the most popular routing schemes used in static as well as mobile WSN. In this type of routing protocols the sensors are grouped into different clusters, in each cluster there is a Cluster Head (CH) which collects data from each of the member nodes in its cluster. The CH may collect data from the sensors periodically or TDMA scheduling may be done for collecting the data from the sensors. Figure 1 illustrates the cluster based routing in WSN.

Cluster based routing protocols have a variety of advantages compared with flat routing protocols [5, 6], such as more scalability, less load, less energy consumption, Data Aggregation/Fusion, Collision Avoidance, more robustness, Load Balancing, Maximizing of the Network Lifetime, Quality of Service etc.

In this paper we are classifying the WSN into two categories i.e. Static Wireless Sensor Network (SWSN) and Mobile Wireless Sensor Network (MWSN). The SWSN generally consist of the sensor nodes, which are static in nature i.e. once the nodes are deployed in the field their position is fixed, they do not have the

Fig. 1 Cluster based routing in wireless sensor networks

capability to move from one location to another. Whereas MWSN consist of sensor nodes which are static and/or mobile in nature i.e. once the nodes are deployed in the field, they can move from one location to other [7]. The routing of data from the sensor to the BS in MWSN is more complicated than that of SWSN, as because of the mobility of the sensor nodes, the topology changes rapidly in MWSN.

2 Cluster Based Routing Protocols in SWSN

This section presents the discussion on routing protocols in Static Wireless Sensor Networks (SWSN), which works only on static sensor nodes. Summary of studied protocols is presented in tabular manner.

Low Energy Adaptive Clustering Hierarchy (LEACH) protocol [8] is a self organizing, adaptive clustering protocol for Wireless Sensor Networks (WSNs) which uses the concept of randomization to distribute load among the nodes in WSN. Operation of LEACH protocol is alienated into rounds where each round composed of two phases: set-up phase in which clusters are formed and CH is selected for each cluster using the residual energy of the nodes and steady phase in which using TDMA the nodes sends data to their CH during time slots allocated to them.

Hussain and Matin [9] have discussed Hierarchical Cluster based Routing protocol (HCR) in which each cluster is managed by a set of associates known as head-set and uses round-robin technique. Cluster Head (CH) receives messages from the cluster members, aggregates the message and transmits it to the Base Station (BS). All the transmissions are single-hope and CHs transmit long range broadcast messages and the Cluster Members (CM) transmits short range broadcast messages. After a specific number of transmissions cluster reformation is done, called as a round. The simulation is performed on versions of HCR (HCR-1, HCR-2) and LEACH and found that HCR-1 shows a minor improvement over LEACH but for HCR-2 the improvement is enhanced.

Another cluster-based routing protocol for sensor networks is discussed in [10] by Lee et al., where the sensor nodes do not know their location. According to the conditions of the network, it uses the remaining energy of sensor networks and wanted number of CHs. For the proposed protocol simulation was carried out with two initial energy levels and it was found that the protocol improves the data rate and lifetime of the sensor networks compared to LEACH.

WSNs are similar as that of a Neural Network of human beings, which is a cluster of firmly related individual units and carry outs a special function, discussed by Guo et al. [11]. The authors have proposed Dynamic Clustering Reactive Routing (DCRR) algorithm based on the architecture and principle of neural network in which the sensor nodes are event driven. The performance of DCRR is compared with TEEN, and found that DCRR algorithm attains significantly better balance in battery power distribution and increases the energy efficiency and the lifetime of the network.

Threshold sensitive Energy Efficient sensor Network (TEEN) [12] is LEACH based hierarchical routing protocol used for time critical application domains in WSN. It uses LEACH's method to form the cluster. It has simple nodes with first-level CHs which are form away from BS and second-level CHs which are formed near to BS. The CH sends two types of data to neighbor nodes, one is Hard Threshold (HT) mode where the nodes transmit data if sensed data attributes are of interest, second is Soft Threshold (ST) mode where any minor change in the sensed value of the attribute is transmitted further.

TEEN has main assumptions [13, 14]: BS can transmit data to all nodes directly, it uses two-tier architecture for CHs and BS with all sensor nodes has same initial energy. TEEN has weakness too: Node has to wait for time slot for data transmission, if node has no data to transmit the time slot is wasted and CH has to keep its transmission on always for data from nodes.

The comparative analysis of some of the cluster based routing algorithm in Static Wireless Sensor Network is summarized in Table 1.

3 Cluster Based Routing Protocols in MWSN

This section presents the discussion on routing protocols in Mobile Wireless Sensor Networks (MWSN), which works on both, static and mobile sensor nodes. Summary of studied protocols is presented in tabular manner.

One of the main challenges in MWSN is Packet loss due to the mobility of the sensor nodes and it comes in parallel with energy consumption. In paper [15], authors propose adaptive TDMA scheduling and round free cluster head protocol called Cluster Based Routing (CBR) protocol for Mobile Nodes in WSN. The performance of the proposed protocol is evaluated using MATLAB and it is found that it reduces the packet loss by around 25 % compared to LEACH Mobile protocol. It is seen that the protocol is also energy aware, shows significant improvement in the data transfer success rate in the mobility environment compared to LEACH-Mobile protocol.

To reduce the complexity of sensors and the cost of construction of WSN, Duan et al. [16] have designed three-layer mobile node architecture. They proposed a Shortest Path (SP) routing protocol to save energy of nodes. The simulation results show that Shortest Path routing protocol outperforms LEACH by redefining the function of nodes, keeping most of the time some nodes in sleeping mode and transmitting data packets through the shortest path to the sink.

A routing protocol is proposed by Ying and Yang [17] for MWSN. It has both fixed and mobile sensor nodes in the same network. It is called as Energy-efficient Chain-cluster Routing protocol (ECRM). The static nodes whose battery are difficult to be recharged, are set into the communication backbone to maintain the basic connectivity of network, and the mobile nodes, whose battery can be recharged, are set as CH to prolong the fixed node's lifetime and improves the energy efficiency.

Table 1 Comparative analysis of various routing algorithm in SWSN

Refs.	Concept	Assumptions	Phases	Working	Remark
[8]	Self organizing, adaptive clustering	BS is fixed and far away	Set-up	CH is selected using residual energy of nodes	Uses data fusion at CH
	Uses randomization to distribute load	Nodes have enough power to communicate with BS directly	Steady	Using TDMA nodes sends data to CH	Improves lifetime of network
[9]	Round Robin cluster head selection	Single hop transmission	Election	Nodes self-organized into new set of cluster, and cluster contains a head-set	HCR-1 shows minor improvement over LEACH but for HCR-2 improvement is enhanced
	Clusters are maintained for short duration called round	Members perform short range, CH performs long range broadcasting	Data transfer	Head-set members performs long range transmission to BS	
[10]	BS changes desirable no. of CHs	Sensor nodes do not-necessarily know their own position	Construction / Communication	Uses remaining energy of sensor networks and desired number of CHs	Improves data rate and life-time of networks compared to LEACH
[12]	LEACH based hierarchical routing protocol	BS and all sensor nodes have same initial energy	Set-up	CH selected using residual energy of nodes	Uses data fusion at CH
	Used for time critical application	Uses two-tier architecture for CHs	Steady	Using TDMA nodes sends data to CH	Improves network lifetime compared to LEACH
[13]	TEEN based hierarchical routing protocol	BS and all nodes have different initial energy	Set-up	CH is selected using residual energy of nodes	Uses data fusion at CH
	Uses hybrid network	Uses two-tier architecture for CHs	Steady	Using TDMA nodes sends data to CH	Improves lifetime compared to TEEN
[11]	Selects temporary CH according to similarity and isochronisms of local on-the-spot data	Based on architecture and principle of neural network	Excite	Node monitors sudden change in environment	Performance of DCRR is remarkably better compared with TEEN
		Nodes are event driven	Transmit	Transmits excitement info. to other nodes	
		Self-organizing multi-hop network	Receive	Node receives excitement information from other nodes	

Table 2 Comparative analysis of various routing algorithm in MWSN

Refs.	Concept	Assumptions	Phases	Working	Remark
[4]	Zone based information	Homogeneous and location aware Nodes	Route creation	Combined updating mechanism including periodic and event based	Acts as a hybrid routing protocol
	Cluster like communication between nodes	BS is stationary, mobile nodes	Route prevention		
[15]	Cluster based routing	Mobile nodes	Cluster and CH formation	Sends data to CH in efficiently	Energy aware
	TDMA scheduling concept	BS is far away	TDMA scheduling, data routing	Based on received signals	Adaptive scheduling, improved data rate
[16]	Multi-layer	Mobile nodes are of 3 types	Neighbor discovery	Data collection, routing table maintenance	Reduces complexity and construction cost
	Cluster based	Sensor, fusion, control nodes	Shortest path construction	Data processing placed in different nodes	Save energy of nodes
[17]	Energy efficient chain-cluster routing (ECRM)	Fixed mixed with mobile homogeneous nodes	Backbone setup, cluster formation	Fixed nodes considered, CH at each layer is chosen	Save energy consumption and overheads produced
	Uses efficient CH selection criteria	Nodes transmit data to BS continuously, BS is far away	Steady communication	Data flow to BS via communication link	Robust to network size and energy efficient
[18]	Based on LEACH	Homogeneous nodes, communicate directly to BS	Set-Up	Randomly rotates CH, activities are equally shared	Reduces energy dissipation, doubling lifetime
	Randomization for distributing energy load	BS is fixed and far away, One CH work as local BS	Steady	Compression at CH, divides operation into rounds	Distribute energy evenly
[19]	Data centric braided multipath algorithm	Nodes are homogeneous	Path establishment, data forwarding	Uses previous information, detecting loops and dismantling	Good performance in high data delivery rate
	Uses multipath interleaving routing	Nodes are mobile	Route maintenance, localized path refresh	Monitoring data delivery	Low overhead,
	Reverse path based forwarding algorithm	BS is far away	Loop handling	Maintaining braided multiple paths	Loop avoidance

An Energy-Efficient Communication Protocol for Wireless Micro-sensor Networks is discussed by Heinzelman et al. [18]. It uses the concept of LEACH and randomization for distributing energy load among sensor nodes in the network. Simulation results show that the algorithm is better as it reduces the energy dissipation doubles the lifetime for networks and it is able to distribute energy dissipation evenly throughout the sensors.

In [19] the Multipath Algorithm for MWSN is discussed by A. Aronsky and A. Segall. It uses Data Centric Braided Multipath (DCBM) algorithm with multipath interleaving routing and Reverse Path Based Forwarding algorithm. The algorithm achieves good performance in terms of high data delivery rate and low overhead, it also helps in avoiding loop formation in the network.

Cluster Based Routing Protocol for MSN is discussed in [4], which is based on Zone Based Information and there is cluster like communication between nodes. The basic assumptions are: all nodes are homogeneous, all nodes are location aware, BS is stationary and sensor nodes are mobile. It uses a combined updating mechanism, including periodic and event based updates. It acts as a hybrid routing protocol.

The comparative analysis of various cluster based routing algorithm in Mobile Wireless Sensor Network is summarized in Table 2.

4 Conclusion and Discussion

WSN consist of a set of spatially distributed and dedicated autonomous cooperative tiny, low cost, limited battery powered static and/or mobile sensor nodes deployed densely in a region of interest. The sensor nodes have the capability to sense, actuate, compute, move from one location to another, communicate with each other and send data to sink or base station using single hop or multi hop communication with the help of various routing protocols available for WSN. Cluster based routing is one of the best approaches for routing of data to the sink or BS, it has many advantages over a direct communication or a flat WSN. In this paper various clusters based routing protocols for Static and Mobile WSNs are discussed and analyzed. The basic assumptions, working environment, advantages, limitations, and working style of various clusters based routing protocols for Static and Mobile Wireless Sensor Networks is also discussed in this paper.

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