A Brief Survey on Clustering Routing Protocols for Wireless Sensor Networks

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Abstract— Since past few years use of Wireless Sensor Network or Sensor Network has been increased and has been the wide and powerful research area compared to others. This review paper presents total review of wireless sensor network, its routing protocols, architecture of WSNs and applications. This review paper also describes the objectives, characteristics and challenges of WSNs. Due to the characteristics of sensor nodesfa and the working requirements of wireless sensor network, there have been many challenges in developing routing protocols. Clustering routing protocols satisfies these constraints and challenges to the greater extent and hence has become the most powerful area of research. This paper summarizes some of the approaches of clustering routing protocols.

Key words: Wireless Sensor Network, Routing Protocols, Clustering Routing Protocols, Cluster Head, LEACH, DSC, FT-DSC, FT-EEC

I. INTRODUCTION

A wireless sensor network (WSN) can be generally described as a network of sensor nodes that cooperatively sense and may control the environment enabling interaction between persons or computers and the surrounding environment [1]. Wireless sensor network are network of large number of tiny sensor nodes that senses the data and sends this data to the base station (BS) for further processing based on the application. The data to be sensed and send depends purely on the application for eg., if the WSN is to deployed for detecting the intensity of earthquake then, the data to be sensed is the intensity of the seismic waves inside the earth's core. Also, the tiny sensor nodes have particular characteristics: low energy, low cost and self-organizing. These sensor nodes are to be deployed in the large geographical area via variety of modes of deployment and they have to work under harsh environment and unattended. Due to these characteristics and working requirement, there is high requirement for developing energy efficient and fault tolerant routing protocol so that data can be communicated between BS and sensor nodes in a reliable way. Also, Routing protocols in WSN are very application specific. Hence, a routing protocol applicable to one specific application may or may not be applicable to another.

II. APPLICATION OF WSN

WSN have a wide range of applications.

Area	Applications
Military	Military situation awareness. Sensing intruders on basis. Detection of enemy unit movements on land and sea. Battle field surveillances.
Emergency situations	Disaster management. Fire/water detectors. Hazardous chemical level and fires.
Physical World	Environmental monitoring of water and soil. Habitual monitoring. Observation of biological and artificial systems.
Medical and health	Sensors for blood flow, respiratory rate, ECG (electrocardiogram), pulse oxymeter, blood pressure and oxygen measurement. Monitoring people's location and health condition.
Industrial	Factory process control and industrial automation. Monitoring and control of industrial equipment.
Home networks	Home appliances, location awareness. Person locator.
Automotive	Tire pressure monitoring. Active mobility. Coordinated vehicle tracking.

Table 1: Applications of WSN [2].

III. ROUTING CHALLENGES

Routing in WSN has more challenges compared to traditional ad hoc networks:

- WSN is made up of large number of sensor nodes which makes very difficult to implement traditional IP-Based protocols in WSNs.
- WSN applications require the flow of communication from multiple nodes to the particular BS.
- WSN require careful resource constraints
- Nodes in most of the WSN applications are stationary after deployment.
- WSN are application-specific.
- WSN requires the location awareness of nodes in order to be efficient.
- There is a high probability that data sent by nodes to BS are redundant.

IV. CLUSTERING CONCEPT

The clustering phenomenon was introduced to solve above problems to some extend. In this phenomenon, the area of interest is divided into the group of small areas called clusters. Each cluster contains the head called cluster head (CH) which performs the task of data aggregation and data fusion. Nodes other than CH are called non-CH nodes or mobile nodes (MN) whose task are to send the data to the CH periodically or in the given time slot assigned by the CH based on the routing protocol. The CH aggregates the received data and sends the fused data to the base station (BS) which reduces the redundancy of data.
This concept has many advantages:

- More scalability
- Data aggregation and data fusion
- Fewer loads
- Less energy consumption
- More robustness
- Collision avoidance
- Latency reduction
- Load balancing

Challenges in clustering routing protocols are :

- Fault-tolerance
- Guarantee of connectivity
- Maximizing network lifetime
- Energy hole avoidance
- Quality of service

V. RELATED WORK

Jagtar singh et. al addresses the review of wireless sensor network [1]. Here they discuss about wireless sensor network, its introduction, architecture, protocol design of WSNs and its application. In this paper author was talking about various applications of WSNs like Habitat Monitoring, Manufacturing and Logistic, Environmental Observation and Forecast system, Military applications, Health, Home and Office applications etc. and conclude that there are some problems regarding routing protocols and security of wireless sensor networks. For all kind of Network, security is the main and major part. In future, some other features like fault tolerance, scalability, reliability, cost, topology change can be introduced in WSNs.

Classification and comparison of routing protocols in wireless sensor network was introduced by Rajshree. V. Biradar et al [2].In this paper, authors have described basic architecture and components used in WSN. They have compared MANETS with WSN and have also described the applications of WSN. Also they have discussed the classification of various routing protocols. They have briefly stated about the design characteristics of wireless sensor network and have given comparison table of various routing protocol based on the design characteristics and their classification.

A Fault Tolerant Dynamic Classification Protocol of Wireless Sensor Networks by Lutful Karim et al. [3] addressed one method which is based on Dynamic Static Clustering protocol. Fault Tolerant is of utmost importance in Wireless Sensor Network. In WSN various protocol discussed by the authors. All of these are LEACH, TEEN, ATEEN, GAF, Sec-LEACH, GS-LEACH, LESCS, DSC. All these protocol does not facilitate fault tolerance mechanism. In this paper, fault – tolerance mechanism is applied to the DSC protocol and is named as FT – DSC. This paper provides fault tolerance to:

A. Non – CH Nodes:

Every Non-CH will transmit either sensed data or special packet to the CH of the corresponding cluster in its time slot. If CH does not receive any data in particular time slot, it will consider that nodes to be down.

1) CH Nodes:

At the end of each round if, BS does not receive any information from CH of cluster. It will perform following steps.

- Sets timer
- Send “Hello” packet to CH and waits for “ACK” packet.

If “ACK” does not arrives to BS within the time limit, BS considers that CH to be dead and assigns new CH based on residual energy level of other cluster nodes [3].

Dynamic/ Static Clustering protocol for Wireless Sensor Network by Faud Bajaber et al. [4] addressed large number of small, low-cost and low-power nodes which is coordinate with each other for environmental sensing. This paper introduced to a new protocol that is mixture of dynamic and static protocol. Hence, the name dynamic-static clustering protocol.

Survey on Clustering Protocol for Homogeneous and Heterogeneous wireless sensor network by Jaskikaran Kaur et al [5] addressed various performance characteristics that can be considered while designing a protocol or algorithm for WSN. They have focussed on the technique used to aggregate data in sensor networks of all those techniques; they have designed cluster based techniques and classified them into two types:

- Homogeneous
- Heterogeneous

Also, they have explained various protocols that belong to these classifications. Lastly, they have compared various homogeneous as well as heterogeneous protocol based on few design principles.

Hierarchical Cluster Based Routing Protocol with High Throughput for Wireless Sensor Network by Tripti Singh et al [6] addressed new methods for WSN. In this paper they have classified routing protocols for WSN based on network organization, route discovery and the protocol operation: flat – based, Hierarchical and Location – based. They have focused on basically on hierarchical based routing protocol as it is superior to the rest of two and bestow maximum energy efficient protocol. They have briefly explained various hierarchical based routing protocolsand have described LEACH and its variant in detail. They have proposed an enhancement on LEACH protocol called LEACH-IT which had resulted in an improved throughput by decreasing the packet loss.

Lutful Karim et al addresses A Fault Tolerant Energy Efficient Clustering Protocol of a Wireless Sensor Network [7]. In their paper [7], they have proposed fault tolerant and energy efficient clustering protocol named FT-EEC. This protocol very smartly reduces the probabilities of sensing hole in the network to the greatest extent and also provides fault tolerance mechanism for CH as well as Non-CH nodes. Also, CH and BS subscribes themselves to Non-CH nodes of a cluster to be notified only when an event of interest occurs, and so the Non-CH nodes do not need to send data to the CH in every time slot of a frame allocated to them which reduces energy consumption [7]. The simulation results and performance shows:

- FT-EEC is more energy efficient as compared to LEACH and DSC.
- It requires less no of control packets compared to DSC hence reduces communication overhead.

– FT-EEC provides fault-tolerance and hence is more reliable compared to LEACH and DSC.

Xuxun Liu [8] addressed A Survey on Clustering Routing Protocols in Wireless Sensor Networks. This survey paper outlines the introduction of WSN and routing challenges of WSN. He have classified the routing protocols based on the network structure into two categories: flat and hierarchical/clustering routing protocols. He have explained the concept of clustering, its advantages, objectives and design characteristics of WSN in detail. He have presented a extensive survey on clustering protocols in WSN. He has developed a novel taxonomy of clustering methods for WSN based on rather detailed clustering attributes. Also, he has analysed few classical WSN clustering routing protocols in detail and compared all these protocols based on primary metrics (energy-efficiency, cluster stability, scalability, delivery delay, load balancing, and algorithm complexity). Finally he has classified all of these protocols based on the novel taxonomy developed by him.

VI. VARIOUS CLUSTERING ROUTING PROTOCOLS

A. LEACH Protocol (Low Energy Adaptive Clustering Hierarchy)

LEACH is one of the clustering based hierarchical routing protocols. LEACH works well for homogeneous networks, where every node has the same initial energy [6]. It employs localized control for data transfers, randomized, adaptive and self-organizing techniques for cluster formation and cluster head selection. LEACH works in rounds. Each round is divided into two phases: Set-up phase followed by Steady phase.

– Set-Up phase: This phase is divided into two parts CH Selection and CH Formation
– CH Selection: In this part, clusters are organized using a distributed algorithm. Following steps are then performed :-

1) The decision to select a node as a CH is based on a threshold value T(n). Threshold value is given by :-

(6.1)

$$T(n) = \frac{p}{1 - p\left(r \bmod \frac{1}{p}\right)}$$

Where, p = desired percentage of CH
r = round number
n = number of sensor nodes.

2) Each sensor node then selects the random number between 0 and 1.
3) A particular node becomes a CH for current round if random number (ran) generated is less than the threshold value. i.e., ran < T(n).

– CH Formation: Following steps are performed in this phase:-

1) After CH selection, each CH node broadcasts advertisement (ADV) message.
2) All non-CH nodes join one of the CH based on the received signal strength indicator (RSSI) of the advertisement from each CH and transmits join request message (JOIN_REQ).
3) CH set-up and transmit a TDMA schedule to assign separate time slots to each of its MN.

– Steady Phase: This phase consists of transmitting data from MN to their respective CH during their assigned time slots. Furthermore, the radio is turned off after transmission. The CH aggregates the data received and forwards it to the BS

B. DSC Protocol (Dynamic Static Clustering)

This protocol has two cases: Dynamic and Static. In dynamic case, DSC forms the clusters while in static case, the clusters are fixed for 10 rounds and CH position rotates among the nodes within the clusters [4].

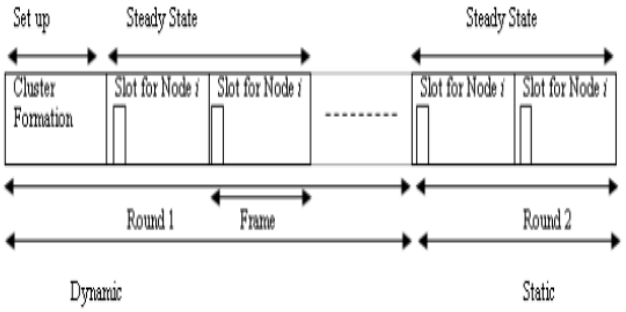

Fig 1: Set-up and steady phase of DSC [3]

These two cases are as follows:-

1) Dynamic Case:

In this case, clusters are formed and CH are selected. The operation is divided into rounds and each round is divided into two phases: Setup phase and Steady-State phase. Each round starts with the setup phase in which clusters are formed and CH are selected while in steady phase, the CH collects data from MN and sends it to BS.

– Setup Phase:

1) Each node sends it energy status and location to the BS.
2) BS uses this information to find the number of CH also it makes sure that only nodes with enough energy are participating in the CH selection
3) BS selects the CHs and broadcasts a message containing the CH ID for each node. If CH ID = node's own ID, then the node is itself a CH. Otherwise it is a non-cluster head node.
4) The CH determines the TDMA scheme for the nodes belonging to their cluster and broadcasts the scheme. Each node is assigned a unique slot during which it can transmit its data to the CH.

– Steady Phase:

This phase is divided into frames, nodes starts sensing events and transmitting data to the CH according to the TDMA scheme. Once the CH receive all the data, CH aggregates the received data and transmit the fused information to the BS. At the end of steady-state phase, the CH receive data and energy status from sensor nodes. The CH aggregates the received data and transmits it to the BS also CH use energy status to select new CH for next round and inform BS.

Now, the dynamic case completes and static case starts.

2) Static Case:

The operation of static case is divided into rounds and each round contains Steady-State phase only.

- Steady-State Phase: This phase is divided into frames, nodes starts sensing events and transmitting data to the CH according to the TDMA scheme. Also, sensor nodes send energy status to CH if round number is less than 10 rounds. Once the CH receives all the data, CH aggregates the received data and transmits the fused information to the BS.
- If round number is less than 10 rounds, the current CH selects the new CH with enough energy for next round and informs the BS.
- If round number is equal to 10 rounds, then at the end of round all nodes sends energy status and location to BS and setup phase starts to form clusters.

The advantage of DSC protocol is that it reduces setup phase overhead which increase the system throughput, prolong the network lifetime and also allow new nodes to be added to the network.

C. FT-DSC Protocol (Fault Tolerant – Dynamic Static Clustering)

In this protocol, CH subscribes events to the non-CH nodes. Each non-CH node A will send either the sensed data (i.e., subscribed events) or the special packet to the CH in its allocated time slot [3]. Special packets inform CH that the particular node is still alive in case of no subscribed events occurs for the particular node in its allocated time slot. If CH does not receive any packet, it assumes the node to be failed and exclude it from the TDMA scheme.

At the end of round, if BS does not receive any data, it will send "hello" message to the CH and turns the timer on. If any "ACK" packets are not received to BS before the timer expires, it assumes the CH to be failed. BS then selects the node with highest residual energy and makes it as CH.

D. FT-EEC Protocol (Fault Tolerant – Energy Efficient Clustering)

This protocol is divided into two phases: Setup phase and Steady Phase

1) Setup Phase:

1) BS selects number of nodes as CH based on following criteria – initially, BS selects a node A randomly as a CH and then it selects another node B as CH which is out of the coverage area of node A.
2) CH broadcasts their IDs to the network.
3) Non-CH nodes join the cluster of CH based on RSSI (Received Signal Strength Indicator).
4) A set of minimum number of active nodes are selected by CH based on sensing and communication range.
5) Each cluster is divided into several small squares with each square having at least one active node. This resolves the problem of sensing hole as an active node has the sensing coverage of all the neighbouring squares.

2) Steady Phase:

In this phase, number of frames constitutes a round, where each node has a time slot allocated to it in a frame using a TDMA scheme [7].

- Each active node selected in setup phase sends either data sensed or special packet to CH in its time slot.
- All other nodes remain in sleep mode by turning their radio off.
- If CH does not receive any packet, it will assume that particular node has failed and CH will exclude that node from time slot.
- At the end of frame, if BS does not receive any data, it will send "hello" message to the CH and turns the timer on. If any "ACK" packets are not received to BS before the timer expires, it assumes the CH to be failed. BS then selects the node with highest residual energy and makes it as CH.

Dynamism can be obtained by setting the variable number of frames to form a round based on the energy status of the nodes of network.

VII. COMPARISON OF PROTOCOLS

The comparison of various protocols discussed so far is as shown in the table:

Features	LEACH	DSC	FT-DSC	FT-EEC
BS forms clusters	Yes	Yes	Yes	Yes
BS subscribes for events of interest to CHs and Non-CH nodes	No	No	Yes	Yes
CH subscribes for event of interest to Non-CH nodes	No	No	Yes	Yes
Non-CH nodes send data to CH in every time slot of a frame (using TDMA scheme)	Yes	Yes	No	No
Non-CH nodes send special packets to notify that they are still alive	No	No	Yes	Yes
BS sends "hello" message to a CH if CH does not send aggregated data to BS at the end of a round	No	No	Yes	Yes
Variable number of frames in a round	No	No	Yes	Yes
Avoid redundant coverage	No	No	No	Yes
Avoid redundant data	No	No	Yes	Yes
Resolves sensing hole problem	No	No	No	Yes
Fault tolerance	No	No	Yes	Yes

Table 2: Comparison of various clustering routing protocols

VIII. SUMMARY AND CONCLUSION

In this review paper, we have referred about the wireless sensor network, its architecture, application, routing challenges, clustering concept, its advantages and challenges to be met while developing clustering routing protocols. Also, we have described various clustering routing protocols

in brief and lastly we have compared all of them against various features that are present and absent among them.

Routing protocols in WSN have many challenges compared to the traditional ad hoc networks. And clustering concept fulfils this constraint as well as challenges to the greater extent so it is a wide and powerful research area at present. Most of the traditional routing protocols implemented earlier do not support fault-tolerance. Hence making these protocols fault tolerant makes them as reliable protocols and also while doing that we can reduce the energy consumed by the base protocol.

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