

A Study on Dynamic and Static Clustering Based Routing Schemes for Wireless Sensor Networks

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Abstract: A Wireless sensor network is an infrastructure comprised of sensing (measuring), computing, and communication elements that gives an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment. The administrator typically is a civil, governmental, commercial, or industrial entity. The environment can be the physical world, a biological system, or an information technology (IT) framework. Routing is very difficult in wireless sensor network due to a large number of sensor nodes. In wireless sensor network, Routing can be divided into Flat Routing, Hierarchical Routing, Location - aware Routing. Hierarchical Routing can be further divided into two parts: Dynamic and Static Hierarchical Routing or Clustering-based Routing. Dynamic Clustering based protocols are those in which the clusters are formed and diminished dynamically. Static Clustering based Routing Protocols are those in which clusters once formed remain same throughout the network lifetime. In our paper, we discuss all Dynamic and Static Clustering based Routing Protocols and its pros and cons.

Keywords: Wireless Sensor Networks, Network Lifetime Routing Protocols, Routing challenges, WSN applications.

I. Introduction

A WSN is a specialized wireless network made up of a large number of sensors and at least one base station. The foremost difference between the WSN and the traditional wireless networks is that sensors are extremely sensitive to energy consumption. Energy saving is the crucial issue in designing the wireless sensor networks [1]. Since the radio transmission and reception consumes a lot of energy, one of the important issues in wireless sensor network is the inherent limited battery power within network sensor nodes. In order to maximize the lifetime of sensor nodes, it is preferable to distribute the energy dissipated throughout the wireless sensor network. So it is essential to design effective and energy aware protocols in order to enhance the network lifetime. A WSN can have network structure based or protocol operation based routing protocol. In this paper, a review on Dynamic and Static Clustering based Routing protocols which are the part of network structure protocol is carried out. Energy consumption and network life time has been considered as the major issues wireless sensor network (WSN) requires an enormous breadth of knowledge from an enormous variety of disciplines, so its study becomes challenging [1]. A wireless sensor network basically consists of small devices called sensor nodes having the capability of sensing the environment around them, computation the task, and performing wireless communications. Sensor networks may also consist of different type of sensors such as seismic, low sampling rate magnetic, thermal, visual, and infrared, radar and acoustic, which monitor a wide variety of ambient conditions that includes [2] habitat monitoring, temperature fluctuation, air pollution control, traffic control. In wireless sensor network, each node is connected to one or more sensors, because it is built of nodes from a few to several hundreds or even thousand. That sensor network node having several parts: a radio transceiver with an internal antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery. An important feature in wireless sensor networks is the battery lifetime of the node. Energy efficiency is a main challenge in wireless sensor networks and energy use is dominated by the energy required. In wireless sensor networks the size and cost of the sensor nodes may vary from micro to macro and from one to few hundred dollars respectively. Battery power decides whether the sensor nodes sense for long time or for short time even the battery cannot be recharged or replaced.

II. Routing Challenges

Routing in Wireless sensor Network is very challenging due to its wireless nature. There are many reasons: a) WSNs have a large number of sensor nodes, it is not possible to apply a global addressing scheme for the deployment of a large number of sensor nodes as the overhead will be high to maintain the IDs of the sensor Network. b) Sensor nodes are tightly constrained in terms of energy, processing, and storage capacity. So there must be some mechanism to manage the resources. There are many challenges and design issues that affect the routing process in Wireless sensor Network.

A. Node Deployment: Node deployment in WSNs is depend on the applications and can be either manual or randomized. In manual deployment, the sensors are manually placed and data is routed through predetermined paths. In random node deployment the sensor nodes are scattered randomly, creating an adhoc routing infrastructure. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy-efficient network operation. Inter sensor communication is normally within short transmission ranges due to energy and bandwidth limitations. Therefore, it is most likely that a route will consist of multiple wireless hops.

- B. Fault Tolerance:** Some sensor nodes may fail due to natural interferences, low battery power, any physical damage. One damaged sensor node can affect the overall performance of the sensor network. If many nodes fail, medium access control (MAC) and routing protocols must accommodate formation of new links and routes to the data collection BSs.
- C. Quality of Service:** In some applications, data should be delivered within a certain period of time from the moment it is sensed, or it will be useless. Therefore, bounded latency for data delivery is another condition for time-constrained applications.
- D. Transmission Media:** In a multihop sensor network, communicating nodes are linked by a wireless medium. The traditional problems associated with a wireless channel (e.g., fading, high error rate) may also affect the operation of the sensor network.
- E. Connectivity:** High node density in sensor networks precludes them from being completely isolated from each other. Therefore, sensor nodes are expected to be highly connected. This, however, may not prevent the network topology from being variable and the network size from shrinking due to sensor node failures.
- F. Scalability:** The number of sensor nodes deployed in the sensing area may be on the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensor nodes. In addition, sensor network routing protocols should be scalable enough to respond to events in the environment.
- G. Heterogeneity:** The existence of a heterogeneous set of sensors raises many technical issues related to data routing. For example, some applications might require a diverse mixture of sensors for monitoring temperature, pressure, and humidity of the surrounding environment, detecting motion via acoustic signatures, and capturing images or video tracking of moving objects.

III. Routing Protocols

In general, Routing in WSNs can be dividing into Flat-based Routing, hierarchical-based routing, and location-based routing depending on the network structure. In flat-based routing, all the nodes are typically assigned equal roles. In hierarchical-based routing nodes have different roles like low energy nodes sense the environment and high energy nodes used to transmit it. The figure (1) depicts the taxonomy of the routing protocols:

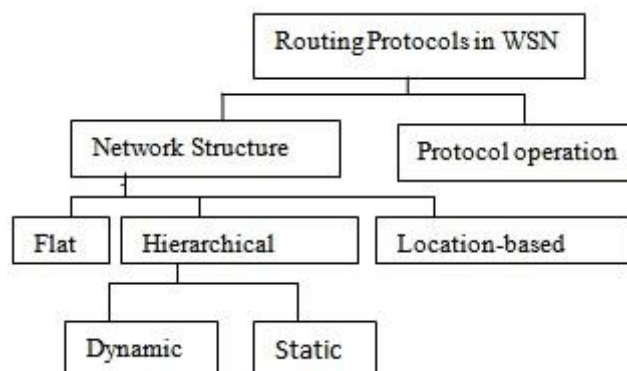


Figure-1 Taxonomy of Routing Protocol

Hierarchical Routing: In hierarchical routing, higher energy nodes can be used to process and send the information, while low-energy nodes can be used to perform the sensing in the targeted area. The creation of cluster can help to achieve scalability, network lifetime, and energy efficiency. Hierarchical routing is two layer routing where one layer is used to select cluster heads and the other for routing. It can be further divided into two parts Dynamic and Static. In Dynamic, cluster are changed with the rounds but in Static, once the clusters are created remain same throughout network lifetime. Following is the explanation of some dynamic and static Hierarchical Routing.

LEACH: It is Dynamic Hierarchical Routing for sensor network, called Low Energy Adaptive Clustering Hierarchy (LEACH). A routing protocol is considered adaptive if certain system parameters can be controlled in order to adapt to current network conditions and available energy levels. LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network. In LEACH, the CH nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the BS in order to reduce the amount of information that must be transmitted to the BS. LEACH uses a TDMA/code-division multiple access (CDMA) MAC to reduce inter-cluster and intra-cluster collisions. However, data collection is centralized and performed periodically. Therefore, this protocol is most appropriate when there is a need for constant monitoring by the sensor network. A user may not need all the data immediately. Hence, periodic data transmissions are unnecessary, and may drain the limited energy of the sensor nodes. After a given interval of time, randomized rotation of the role of CH is conducted so that uniform energy dissipation in the sensor network is obtained. The operation of LEACH is separated into two phases, the setup phase and the steady state phase. In the setup phase, the clusters are organized and CHs are selected. In the steady state phase, the actual data transfer to the BS takes place. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead. During the setup phase, a predetermined fraction of nodes, p , elect themselves as CHs as

follows. A sensor node chooses a random number, r , between 0 and 1. If this random number is less than a Threshold value, $T(n)$, the node becomes a CH for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a CH, the current round, and the set of nodes that have not been selected as a CH in the last $(1/p)$ rounds denoted as G . It is given by

$$T(n) = (p/(1-p(\text{mod}(1/p)))) \text{ if } n \in G$$

Where G is the set of nodes that are involved in the CH election. All elected CHs broadcast an advertisement message to the rest of the nodes in the network that they are the new CHs. All the non-CH nodes, after receiving this advertisement, decide on the cluster to which they want to belong. This decision is based on the signal strength of the advertisement. The non-CH nodes inform the appropriate CHs that they will be a member of the cluster. After receiving all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the CH node creates a TDMA schedule and assigns each node a time slot when it can transmit. This schedule is broadcast to all the nodes in the cluster. During the steady state phase, the sensor nodes can begin sensing and transmitting data to the CHs. The CH node, after receiving all the data, aggregates it before sending it to the BS. After a certain time, which is determined a priori, the network goes back into the setup phase again and enters another round of selecting new CHs. Each cluster communicates using different CDMA codes to reduce interference from nodes belonging to other clusters.

Limitation: It is not applicable to networks deployed in large regions. It also assumes that nodes always have data to send, and nodes located close to each other have correlated data. It is not obvious how the number of predetermined CHs (p) is going to be uniformly distributed through the network.

B. EECS (Energy Efficient Clustering Scheme): EECS is a LEACH-like clustering scheme, where the network is partitioned into a set of clusters with one cluster head in each cluster. Communication between the cluster head and BS is direct (single-hop). In the *cluster formation* phase, we will use this distance to balance the load among cluster heads. In the *cluster head election* phase, well distributed cluster heads are elected with a little control overhead. And in the *cluster formation* phase, a novel weighted function is introduced to construct load balanced clusters. In the *cluster head election* phase, the cluster head is elected by localized competition which is unlike LEACH and with no iteration which differs from HEED. The optimal value of competition range produces a good distribution of cluster heads. Further in the *cluster formation* phase, plain nodes join clusters not only taking into account its intra-cluster communication cost, but also considering cluster heads' cost of communication to the BS. EECS is autonomous and more energy efficient, and simulation results show that it prolongs the network lifetime much more significantly than the other clustering protocols.

C. PEGASIS (Power-Efficient Gathering in Sensor Information Systems): The protocol, called Power-Efficient Gathering in Sensor Information Systems (PEGASIS), is a near optimal chain-based protocol. The basic idea of the protocol is that in order to extend network lifetime, nodes need only communicate with their closest neighbors, and they take turns in communicating with the BS. When the round of all nodes communicating with the BS ends, a new round starts, and so on. This reduces the power required to transmit data per round as the power draining is spread uniformly over all nodes. Hence, PEGASIS has two main objectives. First, increase the lifetime of each node by using collaborative techniques. Second, allow only local coordination between nodes that are close together so that the bandwidth consumed in communication is reduced. Unlike LEACH, PEGASIS avoids cluster formation and uses only one node in a chain to transmit to the BS instead of multiple nodes. To locate the closest neighbor node in PEGASIS, each node uses the signal strength to measure the distance to all neighboring nodes and then adjusts the signal strength so that only one node can be heard. The chain in PEGASIS will consist of those nodes that are closest to each other and form a path to the BS. The aggregated form of the data will be sent to the BS by any node in the chain, and the nodes in the chain will take turns sending to the BS. The chain construction is performed in a greedy fashion. Simulation results showed that PEGASIS is able to increase the lifetime of the network to twice that under the LEACH protocol. Such performance gain is achieved through the elimination of the overhead caused by dynamic cluster formation in LEACH, and decreasing the number of transmissions and reception by using data aggregation. Although the clustering overhead is avoided, PEGASIS still requires dynamic topology adjustment since a sensor node needs to know about the energy status of its neighbors in order to know where to route its data. Such topology adjustment can introduce significant overhead, especially for highly utilized networks. Moreover, PEGASIS assumes that each sensor node is able to communicate with the BS directly. In practical cases, sensor nodes use multihop communication to reach the BS. Also, PEGASIS assumes that all nodes maintain a complete database of the location of all other nodes in the network. The method by which the node locations are obtained is not outlined. In addition, PEGASIS assumes that all sensor nodes have the same level of energy and are likely to die at the same time. Note also that PEGASIS introduces excessive delay for distant nodes on the chain. In addition, the single leader can become a bottleneck. Finally, although in most scenarios sensors will be fixed or immobile as assumed in PEGASIS, some sensors may be allowed to move and hence affect the protocol functionality.

Static Hierarchical-based Routing Protocol: Static clustering based routing protocols are those in which once the cluster is created remain same throughout the network lifetime. We discuss some static clustering based routing protocol.

EEPSC (Energy Efficient Protocol with Static Clustering): EEPSC, partitions the network into static clusters, eliminates the overhead of dynamic clustering and utilizes temporary-cluster-heads to distribute the energy load among high power sensor nodes; thus extends network lifetime. The operation of EEPSC is broken up into rounds, where each round consists set-up phase, responsible node selection phase and steady-state phase.

Setup phase: cluster formation is performed only once at the beginning of network operation. For this aim, base station broadcasts $k-1$ different messages with different transmission powers, which k is the desired number of clusters. By broadcasting the $k=1$ message all the sensor nodes which hear this message (are in the radio range of this message) set their cluster ID to k and inform the base station that they are member of the cluster k via transmitting a join- request message (Join-REQ) back to the base station.

Responsible Node Selection Phase: After the clusters are established, network starts its normal operation and responsible nodes (temporary-CH and CH) selection phase begins. At the beginning of each round, every node sends its energy level to the temporary-CH in its time slot. Afterward, temporary-CH choose the sensor node with utmost energy level as CH for current round to collect the data of sensor nodes of that cluster, perform local data aggregation, and communicate with the base station; and the node with lowest energy level as temporary-CH for next round and sends a round-start packet including the new responsible sensor IDs for the current round. This packet also indicates the beginning of round to other sensor nodes. Since every sensor node has a pre-specified time slot, changing the CHs has no effect on the schedule of the cluster operation.

Steady State Phase: The steady-state phase is broken into frames where nodes send their data to the CH during pre-allocated time slots. These data contain node ID and the measure of sensed parameter. The duration of each slot in which a node transmits data is constant, so the time to send a frame of data depends on the number of nodes in the cluster. To reduce energy dissipation, the radio of each non-cluster head node is turned off until its allocated transmission time, but the CHs must be awake to receive all the data from nodes in the cluster.

Advantage:

- EEPSC benefits a new idea of using temporary-CHs and utilizes a new setup and responsible node selection phase.
- EEPSC utilizes static clustering scheme, therefore eliminates the overhead of dynamic clustering.

EEEPSC (Enhanced Energy Efficient Protocol with Static Clustering): Enhanced Energy-Efficient Protocol with Static Clustering (E3PSC) which is basically a modification of an existing routing scheme, Energy-Efficient Protocol with Static Clustering (EEPSC). In EEEPSC, cluster-head selection is performed by taking into account both the spatial distribution of sensors nodes in network and their residual energy with an objective to reduce the intra-cluster communication overhead among the nodes making the scheme more energy-efficient base station computes the mean positions of node-distribution (P_{mean_i}) of every cluster where i is cluster id which help in reducing the inter-cluster communication.

IV. Conclusion

Routing in sensor networks is a new area of research, with a limited but rapidly growing set of research results. In this article we present a comprehensive survey of Dynamic and static Clustering based routing techniques in wireless sensor networks that have been presented in the literature. They have the common objective of trying to extend the lifetime of the sensor network while not compromising data delivery. Overall, the routing techniques are classified based on the network structure into three categories: flat, hierarchical, and location-based routing protocols. Furthermore, these protocols are classified into multipath-based, query-based, negotiation-based, and QoS-based routing techniques depending on protocol operation. Although many of these routing techniques look promising, there are still many challenges that need to be solved in sensor networks. We highlight those challenges and pinpoint future research directions in this regard.

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