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Study of Routing Techniques in Hierarchical based Structures of Wireless Sensor Networks

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Abstract

In recent years, there is a huge availability of smaller, cheaper and intelligent sensors. These sensors are equipped with wireless interfaces to form a network. This network is well known as Wireless Sensor Network. The applications of wireless sensor networks comprise a wide variety of scenarios and in every scenario, the network composed of a significant number of nodes deployed in an extensive area. Routing techniques are in charge of discovering and maintaining the routes in the network. However, the appropriateness of a particular routing technique mainly depends on the capabilities of the nodes and network architecture to improve Network lifetime expectancy and energy efficiency of WSN. In particular, we systematically analyze routing in hierarchical based structures of WSN and compare these different hierarchical based approaches according to their energy efficiency and network lifetime.

Keywords: WSN, Hierarchical structure, Grid structure, Chain structure, Tree based structure.

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Introduction

Wireless sensor networks (WSNs) have gained worldwide attention in recent years, particularly with the proliferation in Micro-Electro-Mechanical Systems (MEMS) technology which has facilitated the development of smart sensor nodes. Smart sensor nodes are low power devices equipped with one or more sensors, a processor, memory, a power supply, a radio, and an actuator. A variety of mechanical, thermal, biological, chemical, optical, and magnetic sensors may be attached to the sensor node to measure properties of the environment. Since the sensor nodes have limited memory and are typically deployed in difficult-to-access locations, a radio is implemented for wireless communication to transfer the data to a base station (e.g., a laptop, a personal handheld device, or an access point to a fixed infrastructure). The battery is the main power source in a sensor node. The secondary power supply that harvests power from the environment such as solar panels may be added to the node depending on the appropriateness of the environment where the sensor will be deployed.[1] Both power supply requirement is depending on environmental conditions. There is no controlling measure of environmental conditions but there is a possibility of designing network structure and proper routing of sensed information in a designed structure in such a way less environment effective network can make.

A WSN typically has little or no infrastructure. It consists of a number of sensor nodes (few tens to thousands) working together to monitor a region to obtain data about the environment. There are two types of WSNs i.e. structured and unstructured. An unstructured WSN is one that contains a dense collection of sensor nodes. Sensor nodes may be deployed in an ad hoc manner into the field. In a structured WSN, all or some of the sensor nodes are deployed in a pre-planned manner. In an unstructured network, where there are disadvantages like poor managing connectivity and detection failures, structure network has advantages like lower network maintenance and managing cost.[2]

Routing is one of the critical technologies in Wireless Sensor Networks (WSNs). Opposed to traditional *ad hoc* networks, routing in WSNs is more challenging as a result of their inherent characteristics. Firstly, resources are greatly constrained in terms of power supply, processing capability and transmission bandwidth. Secondly, it is difficult to design a global addressing scheme as Internet Protocol (IP). Thirdly, due to the limited resources, it is hard for routing to cope with unpredictable and frequent topology changes, especially in a mobile environment. Fourthly, data collection by many sensor nodes usually results in a high probability

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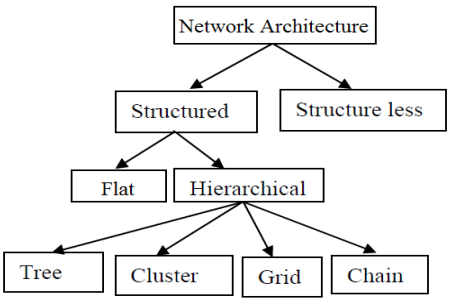

Fig. 1: Network architecture classification

of data redundancy, which must be considered by routing protocols. Fifthly, most applications of WSNs require the only communication scheme of many-to-one, *i.e.*, from multiple sources to one particular sink, rather than multicast or peer to peer. Finally, in time-constrained applications of WSNs, data transmissions should be accomplished within a certain period of time.[3]

This paper analyzes routing in a hierarchical structure based wireless sensor network compare the different hierarchical structure on the basis of routing parameter of WSN: network lifetime and energy efficiency.

Wireless Sensor Network Architecture

Network architecture provides the descriptive view for connection and communication between nodes. Depends upon the architecture, the wireless sensor network can be classified as structured network and structure less network. In this structured network, the specific architecture uses for performing network operation. The architecture can be majorly classified as flat and hierarchical network topology. Hierarchical topology can be divided into tree, cluster, grid and chain architectures. The structure less data aggregation does not use any kind of specific architecture in Fig. 1. So the communication takes place at any node to node in the network.[4]

The structured network can be classified as follows:

Flat network

In flat networks, all the sensor nodes have equal properties and perform the equal role. Mainly, Data centric routing is used in this type of network. In this method, the base station sends a query by means of flooding to all the sensor nodes. If any node has the data matches with the query transmit the response back to the BS. The multi hop path can be used to perform data transmission. So that latency can be increased. Flooding and gossiping SPIN, directed diffusion, rumor routing, gradient based routing are some of the examples of routing protocols performing in flat networks.

Hierarchical Networks

Hierarchical networks overcome the drawbacks of flat networks. It uses clustering, node heterogeneity and reservation based scheduling. In hierarchical (layered)

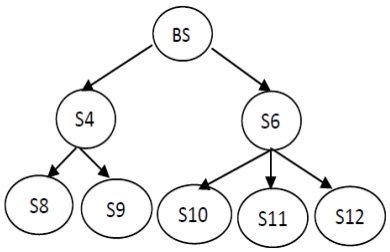

Fig. 2: Tree based structure

architecture, nodes have higher energy are used to process and send the information only while nodes have lower energy are used to perform the sensing only. Hierarchical routing is an efficient way to save energy within a cluster and by performing data aggregation and fusion to decrease the number of transmitted packets to the BS. In Hierarchical structure, there is mainly two-layer routing where one layer is used to select cluster-heads and the other layer is used for routing.

Tree based structure

A tree kind structure is formed to organize sensor nodes. It mainly consists of one root node (BS), intermediate nodes and leaf nodes. Leaf nodes are used to sense the data and the intermediate nodes are used to perform aggregation and transmit to the root node. The main goal is nothing but to build energy efficient tree which performing data aggregation and data transmission. EADAT (Energy-Aware Data Aggregation Tree), E- SPAN (energy-aware spanning tree) and TBC (tree based clustering) are some of the examples for routing in tree based structure.

Cluster based structure

Here, various nodes are grouped into small cluster area. The leader node of a cluster area is called as a cluster head (CH). All nodes in a cluster transmit their sensed information to corresponding CH and these nodes known as member nodes (MNs). CH manages the group communication with the BS. LEACH (Low Energy Adaptive Clustering Hierarchy) is one of the well-known techniques for clustering mechanism.[5]

Grid based structure

In Grid based structure, Network area divide into small and equal sized grid. Sensor nodes are placed in a grid such a way that high energy nodes work as master nodes and low energy nodes work as normal nodes in a grid. Normal nodes are used to perform sensing only and master nodes are used for data aggregation and data transmission. There is also a grid head node which is head of all master nodes and communicates directly to BS (base station). The common grid based structure also employs the sleep-awake mechanism of sensor nodes for improving network lifetime.

Chain based structure

It is one of the hierarchical methods of aggregation which forms chain architecture. In chain architecture, each sensor

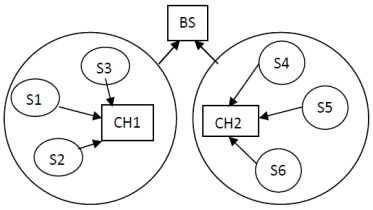

Fig. 3: Cluster based structure

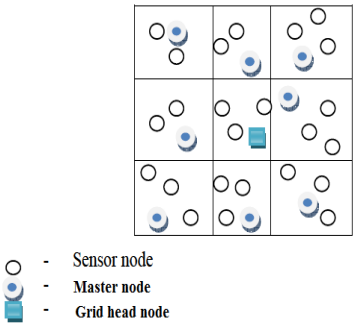

Fig. 4: Grid based structure

node can make a communication with its neighbors and each gets to turn to be the leader for transmitting data to the BS. It uses a token passing approach. After getting the token, each node transmits the data to the aggregator node. Finally it reaches the BS. The Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is well known technique for chain based structure.

Routing protocol based on hierarchical structure

Some commonly used routing protocols in these networks are as follows:

Leach

The low energy adaptive clustering hierarchy (LEACH), is one of the first adaptive clustering-based protocol is introduced by W R Heinzelman, A Chandrakasan, and H Balakrishnan [6]. In LEACH, Randomly deployed nodes organize themselves into local clusters and each cluster has a local base station (cluster head) and many normal or member nodes. Member nodes send the data to cluster head (CH) and CHs send data to sink node (BS). The cluster head selection is based on randomized rotation. LEACH can provide as much as a factor of 8 reductions in energy dissipation compared with traditional routing protocols and double the network lifetime.

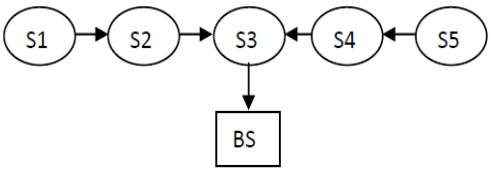

Fig. 5: Chain based structure

Pegasis

The power-efficient gathering in Sensor information systems (PEGASIS), a chain based routing protocol and an enhancement over LEACH is studied by S. Lindsey et. al.[7] Rather than classifying nodes in clusters, the algorithm forms chains of the sensor nodes. Each node transmits to and receives from only one closest node of its neighbors and adjusts the power of their transmission. In this way, nodes formed a chain. A highly improved lifetime (about 100-300%) can be achieved over LEACH. A global knowledge of network is necessary for above work otherwise it cannot be complete and this is the drawback.

Tree based clustering (TBC)

The Tree based clustering (TBC) for energy efficient wireless sensor network is proposed by K T Kim, C H Lyu, S Soo Moon and H Y Youn.[8] In this routing protocol, a root node is selected before data transmission. The root node is basically the cluster-head. Therefore, clustering is done before tree structure constructing. The tree construction consists of two steps. The first step is the determination of the tree level of each member node in the cluster, and the second one is the formation of the tree based on that. The distance of the member nodes to the CH is decided the height of the tree or number of levels in a tree. It effectively reduces and balances the energy consumption among the nodes, and thus significantly extends the network lifetime compared to the existing methods such as LEACH & PEGASIS.

Geographic Adaptive Fidelity (GAF)

This protocol aims at optimizing the performance of wireless sensor networks by identifying equivalent nodes with respect to forwarding packets. Two nodes are considered to be equivalent when they maintain the same set of neighbor nodes and so they can belong to the same communication routes. Source and destination in the application are excluded from this characterization a virtual grid is constructed. This grid is formed by cells whose size allows to state that all the nodes in one cell can directly communicate with the nodes

Table 1: Comparison of different hierarchical structured

Network Architecture/ Factors	*Energy Efficiency*	*Network Lifetime*	*Data Aggregation*	*Node Deployment*
Cluster-based	High	Moderate	Slow	Easy
Chain- based	Moderate	Maximum	Fast	Difficult
Grid-based (without sleep-awake mech.)	High	Minimum	Fast	Difficult
Tree-based	Low	Maximum	Fast	Easy

belonging to adjacent cells and vice versa. In this way, the nodes in a cell are equivalent. Nodes identify equivalent nodes by the periodic exchange of discovery messages with the nodes in their cells. With the information contained in these messages, the nodes negotiate which one is going to support the communications and the other nodes will stay powered off. With this procedure, the routing fidelity is kept that, there is uninterrupted connectivity between communicating nodes. However, the elected node periodically rotates for fair energy consumption to wake up the nodes periodically.[9]

GSSC (Geography-Informed Sleep Scheduling and Chaining Based Routing)

This algorithm in a wireless sensor network is proposed by Poonam Lohan and Rajni Chauhan.[10] In this routing algorithm, Geographical information was used to choose one active node from nodes having same sensing information and other nodes were in sleep mode. Chaining based routing scheme was used to route the sensed data from active nodes to the base station to further reduce the energy consumption. This scheme extends the network lifetime by mixing geography informed sleep scheduling of sensor nodes and chain based routing concept.

In all these protocols, the performance is better when more than two structures are used. Although, these structure are faced complexity.

Comparison of Four Hierarchical Structures

On the basis of various factors affecting routing in WSN, comparison of hierarchical structures is shown in the Table 1.

Conclusion

In this paper following studies has been done on different Routing technique in Hierarchical based structures which shows that first structure based WSN is better than structure less WSN. Second, the use of only one hierarchical structure for any particular WSN application is not enough for desired performance. Finally, this paper concluded that to make the network more energy efficient and also increase network lifetime by using more than two structures in any protocols.

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