Volume 3, No. 2, February 2012

Journal of Global Research in Computer Science

ISSN-2229-371X

REVIEW ARTICAL

Available Online at www.jgrcs.info

A REVIEW ON HIERARCHICAL CLUSTER BASED ROUTING IN WIRELESS SENSOR NETWORKS

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Abstract: The use of Wireless Sensor Networks (WSNs) is expected to bring enormous changes in data gathering, data processing and data dissemination for different applications and environments. The network life for wireless sensor network plays an important role in survivability. Energy efficiency is one of the critical concerns for wireless sensor networks. Sensor nodes are strictly constrained in terms of storage, board energy and processing capacity. For these reasons, many new protocols have been proposed for the purpose of data routing in sensor networks. These protocols can be classified into three main categories: data-centric, location-based and hierarchical. This paper mainly deals with 'Hierarchical Routing' in which nodes are grouped into squads which perform data aggregation and multi hop communication. By performing the above process, the number of transmitted messages to the base station is reduced for the benefit of system scalability and energy efficiency. This paper mainly focuses on the energy-efficient hierarchical cluster-based available routings for Wireless Sensor Network.

INTRODUCTION

Wireless Sensor Networks (WSNs) is renowned as one of the emerging technologies of the 21st century. They are expected to develop interaction between humans and environment to a new level. However the technology is still in its infancy and undergoing rapid evolution with a tremendous amount of research effort in the networking community. The main purpose of a WSN is to assist in monitoring a physical phenomenon by gathering and delivering information to the interested party. Sensor nodes deploy a particular field and helps in tracking and conveying information to a base station. The main success of the operation can be attributed to the recent development of micro-electronic-mechanical systems (MEMS) and this technology have enabled the production of powerful micro sensor nodes.

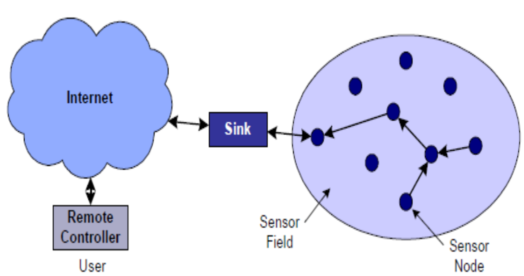

Figure 1. Wireless Sensor Networks

WSN can be applied to any field in which monitoring is necessary e.g. military applications, security surveillance, traffic monitoring, health applications environmental applications, home applications. WSN are poised to become an integral part of our lives with the above given applications. Despite being a fascinating topic, there still exist some challenges to be resolved in wireless sensor networks. For example, Nodes on a WSN are severely constrained by energy. The sensor node battery can hardly accommodate adequate energy, which affects its storage capacity, lifespan and computing power of sensor node. One of the crucial questions is how to extend the lifetime to such a long time in face of these limitations.

ENERGY EFFICIENCY IN ROUTING

More research works have already been done in routing in WSN, since energy efficiency is more important for wireless sensor networks than any other networks. In wireless communication, data transmission consumes more power than data processing. The battery power of the node will be reduced whenever they transmit more number of data proportionately. In order to reduce the data size we can prefer techniques like data fusion or aggregation. Data fusion is that in which the sensed data are fused at certain point for transmitting data at reduced size. There are two types of aggregation in which the first type of data aggregation will data gathered from different sources will be fused and sent in reduced size. But the problem is, it lacks in precision and accuracy of data from various sensor nodes. In the second method both the data under the single header are combined together and forwarded to the base station. Here header packets consolidates and pass it to the base station without any modification to the original data from the sensors. Thus accuracy can be improved.

In order to prolong the lifetime of the WSN, designing efficient routing protocols is critical. It has been established that most of the energy consumption in a WSN comes from data reception and transmission. A good routing protocol therefore can reduce the number and size of unnecessary transmissions that take place, thus helping alleviate the energy crisis in WSNs. Hierarchical routing algorithms are techniques with special advantages related to scalability and efficient communication. The main aim of hierarchical routing is to optimize energy consumption of sensor nodes by arranging the nodes into clusters. Data aggregation and fusion is performed within the cluster in order to decrease the number of transmitted messages.

ENERGY EFFICIENT HIERARCHICAL ROUTING

Among the issues in WSN the consumption of energy is one of the most important issues. Regarding energy efficiency Hierarchical routing protocols are found to be the best. By the use of a clustering technique they minimize the consumption of energy greatly in collecting and disseminating data. Hierarchical routing protocols minimize energy consumption by dividing nodes into clusters. In each cluster, a node with more processing power is selected as a cluster head, which aggregates the data sent by the low-powered sensor nodes.

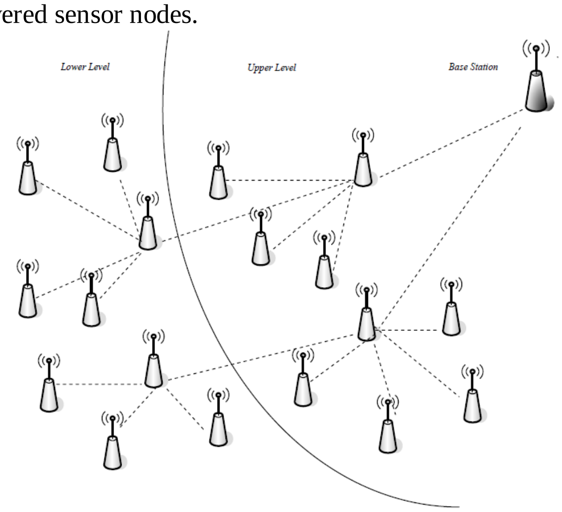

Figure 2. Hierarchical Routing

The primary motive of hierarchical routing is to maintain the consumption of energy by sensor nodes as an efficient one through multi-hop communication that too in a particular cluster, by doing fusion and data aggregation to decrease the number of transmitted messages to the sink. Formation of cluster is mainly based on the sensors' energy reserve and proximity to the cluster head.

LEACH:

Low-energy adaptive clustering hierarchy (LEACH) is one of the most popular hierarchical routing algorithms for sensor networks. Now the motive is to form sensor nodes clusters based on incoming signal strength and then local cluster heads are used as routers to the sink. As transmissions are done by those clusters alone, instead of sensor nodes, energy will be saved here. It is estimated that 5% of total nodes will be the optimal amount for cluster nodes. To balance the dissipation of energy from nodes with respect to time Cluster heads are changed randomly, which is done through choosing a random number between 0 and 1, by the node.

The sensor nodes elect themselves to be CHs at any given time with a certain probability. The decision of whether a node elevates to cluster head is made dynamically at each interval. The elevation decision is made solely by each node independent of other nodes to minimize overhead in cluster head establishment. This decision is a function of the percentage of optimal cluster heads in a network (determined a priori on application) in combination with how often and the last time a given node has been a cluster head in the past. Expression for threshold function is mentioned below.

$$T(n) = \begin{cases} \frac{P}{1-P(r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Where n is the given node, P is the a priori probability of a node being elected as a cluster head, r is the current round number and set of nodes which haven't been chosen as cluster heads in the recent 1/P rounds is G. Each node during cluster head selection will generate a random number between 0 and 1. If the number is less than the threshold (T (n)) the node will become a cluster head.

LEACH achieves over a factor of 7 reduction in energy dissipation compared to direct communication and a factor of 4–8 compared to the minimum transmission energy routing protocol. Dynamic clustering improves the lifetime of system and nodes die randomly. LEACH requires no global knowledge of network and is completely distributed. However, LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. So that is not the case for networks installed in large regions. Extra overhead is brought by dynamic clustering e.g. advertisements, head changes, etc., which diminishes the improvement in consumption of energy.

PEGASIS and Hierarchical-PEGASIS:

Power-efficient Gathering in Sensor Information Systems (PEGASIS) is an improvement of the LEACH protocol. Rather than forming multiple clusters, PEGASIS forms chains from sensor nodes so that each node transmits and receives from a neighbor and only one node is selected from that chain to transmit to the base station (sink). Collected data is moved from one node to another node, then aggregated and is sent to base station.

c0□ c1□ c2□ c3□ c4
. □
BS

Figure 3. Token Passing Approach

As shown in Fig 3. Node c0 will pass its data to node c1. Node c1 will then aggregates node c0_s data of its own and then will transmit it to the leader. After node c2 has passed the token to node c4, node c4 will again transmit its data to node c3. Node c3 will aggregate node c4_s data with its own and then transmits to the leader.

Node c2 will finally wait and receive data from both neighbors and then aggregates its data with its neighbors_ data. Finally, node c2 transmits one message to the base station. The main difference from LEACH is, it uses multi-hop routing and one node to transmit to the base station instead of using multiple nodes. PEGASIS has been shown to outperform LEACH by about 100–300% for different network sizes. The performance gain is achieved mainly through the elimination of overhead caused by dynamic cluster formation in LEACH and by decreasing the number of reception and transmissions by using data aggregation. However, PEGASIS will introduce excessive delay for distant node on the chain.

Hierarchical-PEGASIS is an extension to PEGASIS, which aims to decrease the delay of packets during transmission to the base station and suggests a solution to the data gathering problem by considering energy delay metric. Simultaneous transmissions of data messages are pursued in order to reduce the delay in PEGASIS. Two approaches have been investigated to avoid collisions and possible signal interference among the sensors. The first approach is to incorporate signal coding, e.g. CDMA and the in second approach nodes that are spatially separated are allowed to transmit at the same time.

The non-CDMA based approach creates a three-level hierarchy of the nodes and the interference effects are carefully reduced by scheduling simultaneous transmissions. Such chain-based protocol will perform better than the regular PEGASIS scheme by a factor of about 60. Although the PEGASIS approach avoids the clustering overhead of LEACH, since sensors energy is not tracked they still require dynamic topology adjustment. For example, every sensor needs to be aware about the status of its neighbor and only so it knows where to route that data. Such topology adjustment will introduce significant overhead for highly utilized networks.

TEEN and APTEEN:

A hierarchical protocol, Threshold sensitive Energy Efficient sensor Network protocol (TEEN) is designed to be responsive to sudden changes in temperature. TEEN pursues a hierarchical approach and it uses data-centric mechanism. The sensor network architecture is mainly based on a hierarchical grouping in which closer nodes will form clusters and this process goes on the second level until base station (sink) is reached.

The cluster head broadcasts two thresholds namely hard and soft thresholds to the nodes after the clusters are formed. Hard threshold is the minimum threshold used to trigger a sensor node to switch on its transmitter and transmit the cluster head. Thus, the hard threshold will perform transmission only when the sensed attribute is in the required range and reduces the number of transmissions significantly. Once a node senses a value at or beyond the hard threshold, the data is transmitted only when the attribute changes by an amount greater than or equal to the soft threshold. As a consequence, soft threshold will further reduce the number of transmissions if there is no change or little change in the value of sensed attribute.

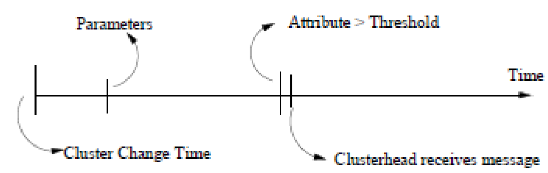

Figure 4. Time Line for TEEN

The hard and soft threshold values can be adjusted to control the number of packet transmissions. Since the user may not get any data at all if the thresholds are not reached, TEEN will not suit for many applications where periodic reports are needed. The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) is an extension to TEEN and it uses same architecture as TEEN. It aims at both reacting to time critical events and capturing periodic data collections. When the base station forms the clusters, the cluster heads will broadcast the attributes and the transmission will be scheduled to all nodes. Cluster heads will also perform data aggregation in order to save energy. APTEEN supports three different query types: historical, to analyze past data; and persistent to monitor an event for a period of time and one-time, to take a snapshot view of the network.

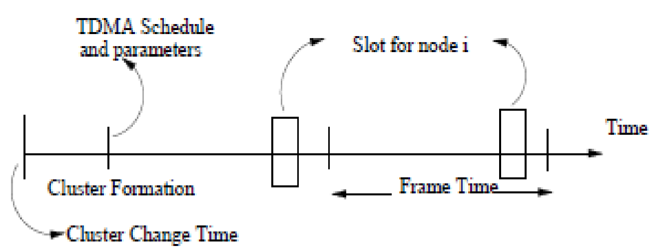

Figure 5. Time Line for APTEEN

The node that senses the environment continuously, will also sense a data value beyond the hard threshold transmit. After sensing it will transmit the data when the value of that attributes changes by an amount greater than or equal to the ST. If a node does not send data for a time period equal to the count time, it is forced to retransmit the data after sensing it. A TDMA schedule is used and each node is assigned with a transmission slot. Hence modified TDMA schedule is used by APTEEN to implement the hybrid network. The main features of the APTEEN scheme include the following. It combines both reactive and proactive policies. In addition it also offers lot of flexibility by allowing the user to set the threshold values and count-time interval (CT) in order to control the energy consumption by changing the count time as well as the threshold values. The main drawback of the scheme is the additional complexity required to implement the count time and threshold functions. Simulation of APTEEN and TEEN has shown that these two protocols outperform LEACH. The experiments have confirmed that APTEENs performance is somewhere between LEACH and TEEN in terms of network lifetime and energy dissipation. TEEN decreases the number of transmissions and hence best performance is achieved with TEEN. The main drawbacks behind the two approaches are complexity and the overhead associated with forming clusters at multiple levels and how to deal with attribute-based naming of queries.

COMPARISON BASED ON NETWORK LIFETIME

In LEACH the first node death will occur 8 times later than the conventional methods and hence the network lifetime will increase considerably. TL-LEACH which was the improvement of LEACH will increase the lifetime of network to 30% than the former one and whereas EECS will improve the lifetime to 35%. But Simulations have confirmed that PEGASIS will give a 100% to 300% improvement in network lifetime when compared to standard LEACH.

APTEEN guarantees lower energy dissipation and the Simulation of TEEN and APTEEN has clearly shown them to outperform LEACH. Experiments have demonstrated that APTEEN.s performance will be between LEACH and TEEN in terms of energy dissipation and network lifetime. In LEACH, the sensors will continuously transmit data to the sink and in APTEEN the sensors will transmit their sensed data based on the threshold values. The best performance can be achieved with TEEN since it decreases the number of transmissions. The main drawbacks of the two approaches are its complexity and overhead of forming clusters in multiple levels.

Table I. Comparison of some selected protocols

PROTOCOL	Latency in the sensor network	Mobility support	Cluster Stability	Data Aggregation
Direct Approach	Low	Nil	N/A	No
LEACH	Acceptable	Fixed BS	Moderate	Yes
PEGASIS	Higher	Fixed BS	N/A	No
TEEN	Acceptable	Fixed BS	Good	Yes
APTEEN	Acceptable	Fixed BS	Good	Yes

CONCLUSION AND FUTURE RESEARCH

The energy efficiency is one of the main challenges in the design of protocols for WSNs due to the scarce energy resources of sensors. The vital objective behind the protocol design is to operate sensor as long as possible, to extend the network lifetime. The surveyed and summarized recent research works focus mainly on the energy efficient hierarchical cluster-based routing protocols for WSNs. This paper has covered only few sample of routing protocols since this is a vast area under research. The protocols discussed in this paper will have both advantages and disadvantages with it. The protocol and routing strategies can be applied based on the topology. The process of data aggregation and fusion among clusters is also one of an interesting problem to explore.

It is needed to satisfy the constraints introduced by factors such as fault tolerance, topology change, cost, environment, scalability, and power consumption for realization of sensor networks. Since these constraints are highly specific and stringent for sensor networks, new wireless ad hoc networking techniques will have to be explored further. Further research would be needed to address issues related to Quality of Service (QoS) though the performance of the protocols discussed here is promising in terms of energy efficiency.

The protocol like LEACH, TEEN, APTEEN and PEGASIS are showed to be energy efficient than its previous models but the main drawbacks in these protocols are that nodes are assumed to be stationary and static. Future works will focus mainly on achieving better energy efficiency in routing mechanism for mobile wireless sensor nodes.

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