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A SURVEY OF HYBRID CLUSTER-BASED ENERGY-EFFICIENT ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORK

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ABSTRACT

Wireless Sensor Networks (WSNs) is one of the most rapidly evolving scientific domain, which is mainly due to the development of advanced small and low-cost sensor nodes with capability of sensing various types of physical and environmental conditions, data processing, and wireless communication. WSNs have many sensor nodes which have restricted battery power and these nodes have to transmit sensed data to the Base Station which dissipate high energy of these nodes. Therefore reliable routing of packets from sensor nodes to its base station is the most important task for these networks. There are many routing protocols developed for the efficient use of energy resources to improve the network lifetime. Along with some conventional Energy-Efficient routing protocol, some hybrid routing protocols are also proposed for different applications. In this paper, we give a survey of hybrid routing protocols for Wireless Sensor Network and compare their strengths and limitations.

Keywords: Clustering, Energy efficiency, Hybrid Routing, Wireless Sensor Network.

I. INTRODUCTION

Wireless sensor networks (WSNs) have been of interest in a wide range of applications, for example, Home security surveillance, military surveillance, disaster management, environmental monitoring, industrial automation, emergency medical response ,[1]-[3] so on. A typical WSN consists of a large number of tiny sensor nodes distributed over a large area of interest with one or more powerful sinks or base stations which collect information from these sensor nodes. All sensor nodes are equipped with information sensing, data processing and wireless transmission capabilities, but have limited power supply or source (battery) , so the most critical aspects in WSNs is efficient usage of power source as most of sensor nodes are typically installed in an inaccessible remote area or is hard to replace. In addition to this depletion of battery source of a sensor node can has a substantial impact on the lifetime of an entire network.

Routing is one of the critical technologies in WSNs. Opposed to traditional *ad hoc* networks, routing in WSNs is more challenging as a result of their inherent characteristics [4],[5]. 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. Thirdly, data collection by many sensor nodes usually results in a high probability of data redundancy, which must be considered by routing protocols. Finally, in time-constrained applications of WSNs, data transmissions should be accomplished within a certain period of time. So latency for data transmissions must be considered.

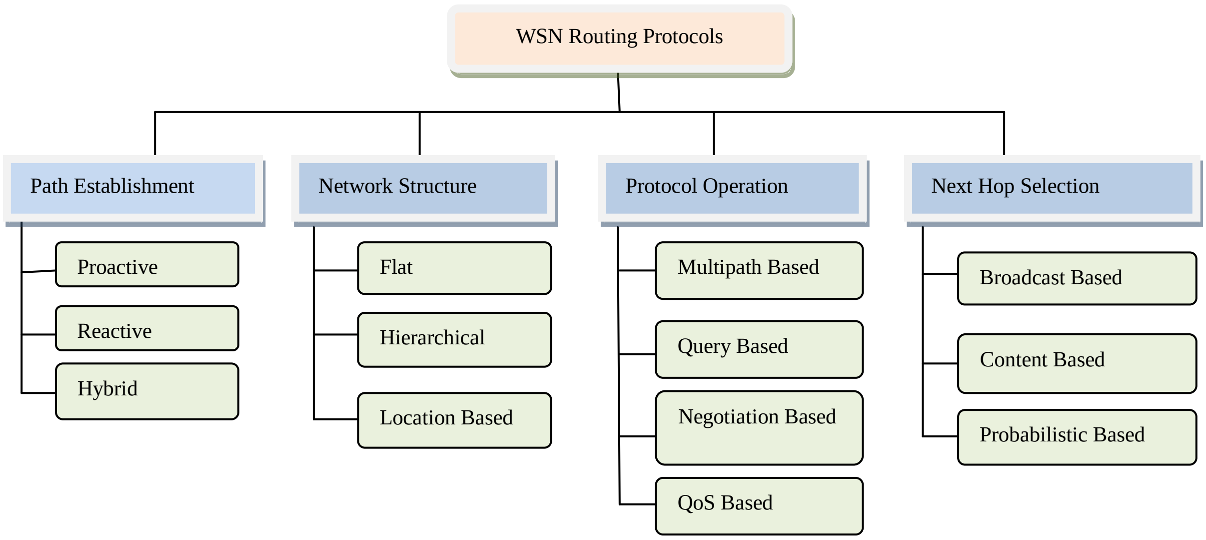

Fig. 1. Categorization of Routing Protocol in WSN

Based on path establishment as shown in Fig.1, routing protocols in WSNs can be of three types, namely proactive, reactive or hybrid. In proactive networks, all routes between source and the sink are computed and maintained before they are really needed regardless of the data traffic. Once a message arrives, it travels through a predetermined route to the sink. In contrast, no predetermined routes exist in reactive networks, in which the routing is chosen when a message needs to be delivered from source to the sink. Hybrid approaches use a combination of the above two ideas.

Based on network structure, routing protocols in WSNs can be divided into two categories: flat routing and hierarchical routing. In a flat topology, all nodes perform the same tasks and have the same functionalities in the network. Data transmission is performed hop by hop usually using the form of flooding. On the other hand, in a hierarchical topology, nodes perform different tasks in WSNs and typically are organized into lots of clusters according to specific requirements or metrics[4]. Generally each cluster comprises a leader referred to as cluster head (CH) and other member nodes (MNs) and the CHs can be organized into further hierarchical levels. In general, nodes with higher energy act as CH and perform the task of data processing and information transmission, while nodes with low energy act as MNs and perform the task of information sensing.

Clustering routing[6] is becoming an active branch of routing technology in WSNs on account of a variety of advantages, such as more scalability, data aggregation or fusion, less load, less energy consumption, more robustness, etc.

In the last few years, a relatively large number of clustering routing protocols have been developed for WSNs. This paper is an attempt to comprehensively review and critically discuss the most prominent hybrid clustering routing algorithms that have been developed for WSNs. The goals of this survey can be summarized as follows: (1) To make a large audience aware of the existence and of the usually good performance of a number of hybrid clustering routing protocols in WSNs; (2) To highlight their strengths and weaknesses.

II. HYBRID ROUTING PROTOCOLS

According to the proactivity of clustering routing, clustering routing methods can be grouped into proactive, reactive, and hybrid ones. Hybrid approaches use a combination of proactive and reactive ideas. These hybrid routing protocol are developed either to improve stability, network lifetime or to reduce traffic levels etc. But all the protocols result in improve energy efficiency. Some of hybrid routing protocols are APTEEN, HRP, HEED, ANHR etc,

2.1 Adaptive Periodic Threshold-Sensitive Energy Efficient Sensor Network Protocol (APTEEN)

APTEEN [7] has been proposed as an improvement to TEEN [8] in order to overcome its limitations. The nodes in APTEEN network not only react to time-critical situations, but also give an overall picture of the network at periodic intervals in a very energy efficient manner. Thus, APTEEN is a hybrid clustering-based routing protocol that allows the sensor nodes to send their sensed data periodically and also to react to sudden change in the value of the sensed attribute by reporting the values to their Cluster heads (CHs). In APTEEN, once the cluster head (CH) are elected based on [9]Low Energy Adaptive Clustering Hierarchy (LEACH), the CH broadcast four different parameters to its member nodes (MN). These parameters are:

a) Attributes (A): a set of physical parameters in which user has interest.
b) Thresholds: a parameter which consist of a hard threshold (H_T) value and a soft threshold (S_T) value. H_T is predefined value of an attribute above this value a node can be transmit data packets. S_T is a small deviation in the attribute value which can forces a node to transmit data again.
c) Schedule: which assigning a time slot based on TDMA schedule to each MN
d) Count Time (T_c): Count Time is the maximum time required to transmit the data from node to CH.

When value is sensed by MN and if that sensed value is equal to H_T, then the transmitter is turned on and value is transmitted. A register is used to store this value and is called as sensed value (SV). In a same cluster period, the next transmission is done only, if the SV and current sensing value difference is equal to or greater than ST. Thus APTEEN supports three different query types namely: 1) Historical query, to analyze past data values, 2) One-time query, to take a snapshot view of the network, 3) Persistent queries, to monitor an event for a period of time. The distinctive features of APTEEN is its ability to shift between proactive and reactive modes to transmit data by setting the count time and threshold values.

2.2 Hybrid Energy-Efficient Distributed Clustering (HEED)

HEED extends the basic scheme of LEACH as it periodically selects cluster heads according to a hybrid of the node residual energy and a secondary parameter, such as node proximity to its neighbors or node degree [10]. It operates in multihop networks, using an adaptive transmission power in the inter-clustering communication. HEED was proposed with four primary goals namely.

1) To increase network lifetime by distributing energy consumption among the nodes,
2) Terminating the clustering process within a constant number of iterations,
3) Minimizing control overhead, and
4) Form well-distributed CHs and compact clusters.

HEED protocol periodically selects CHs according to a combination of two clustering parameters. The primary parameter is their residual energy of each sensor node which is used in calculating probability of becoming a CH and the secondary parameter is the intra-cluster communication cost as a function of cluster density or node degree (i.e. number of neighboring nodes). The primary parameter is used to decide an initial set of CHs while the secondary parameter is used for breaking ties among them. Every round is long enough to receive messages from any neighbour within the cluster range. As in LEACH, an initial percentage of CHs in the network(C_{prob}) is predefined but in HEED the parameter C_{prob} is only used to limit the initial CH announcements and has no direct impact on the final cluster structure. Hence each sensor node sets its probability CH_{prob} of becoming a CH as:

$$CH_{prob} = C_{prob} \times E_{residual} / E_{max}$$

Where $E_{residual}$ is the estimated current residual energy in the node and E_{max} is a reference maximum energy (corresponding to a fully charged battery), which is typically identical for all nodes.

During each round of HEED, every sensor node that never heard from a CH elects itself to become a CH with probabilityCH_{prob}. Then these newly decided CHs are added to the current set of CHs. If a sensor node is selected to become a CH, it broadcasts an announcement message as a tentative CH or a final CH. A sensor node hearing the CH list chooses the CH with the lowest cost from this set of CHs. Every node then doubles its CH_{prob} and goes to the next step. If a node completes the HEED execution without electing itself to become a CH or joining a cluster, it announces itself as a final CH. A tentative CH node can become a regular node at a later iteration if it hears from lower cost CH. Here, a node can be selected as a CH at consecutive clustering intervals if it has higher residual energy with lower cost. In HEED, the distribution of energy consumption extends the lifetime of all the nodes in the network. Nodes also automatically update their neighbour sets in multi-hop networks by periodically sending and receiving messages. The HEED clustering improves network lifetime over LEACH clustering because LEACH randomly selects CHs (and hence cluster size), which may result in faster death of some nodes. The final CHs selected in HEED are well distributed across the network and the communication costs minimized.

2.3 Hybrid Routing Protocol (HRP)

HRP [11] is a hybrid protocol which divides the network into number of zones, these zones form a hierarchical protocol as the protocol ZHLS (zone-based hierarchical link state).HRP is base on GPS (Global positioning system), which permit each node to recognize its physical position before mapping an area with table to identify it to which it belongs. The number of information exchanged in high ZHLS is what influences the occupation of the bandwidth. HRP reduces the amount of information exchanged, hence increasing network performance and service life.

In HRP each zone contains multiple nodes i.e Level node, Level Getaway and Level Cluster Head. Each node deploys a relocation method to find its physical location and determines its zone ID by mapping its physical location to the zone map. Once zone ID is known, then node can start the intra-zone (level of node) clustering and then the inter-zone (level of getaway) clustering procedures to form its routing tables. A link request is broadcasted by each node which gets response from other nodes; other nodes send its zone ID along with its node ID to sender node. Once the reply messages are received, the node LSP is created by each node. The node LSP contains the information about neighbours node ID of same zone and neighbour zone ID of different zones. HRP works in rounds, each round is divided into two phases, the Setup phase and the Steady State [11]. A node that has a packet to send first checks whether the destination is within its local zone. In that case, the packet can be routed proactively. Reactive routing is used if the destination is outside the zone.

2.4 A New Hybrid Routing Protocol (ANHR)

A New hybrid routing Protocol [12] combines the simple routing protocols with hierarchical routing protocols and find out the present state of last hop node and the present residual energy according to the received signal strength of the node. Thus this protocol uses two-way query mechanism based on destination node query and source node detection. Each node communicates with the other nodes in the network such that it optimizes effort to send data and help to create an adaptive dynamic cluster head. This protocol has a higher cluster head formation efficiency and reliable data delivery which effectively reduce the network load and energy consumption.

Table 1: Comparision of different Hybrid protocols

Protocols	Energy Efficiency	Scalability	Algorithm complexity	Goal	Advantage	Disadvantage
APTEEN	Low	Low	Very High	To Support both reactive and time critical applications	1)Guarantees lower energy dissipation as load is divided uniformly, 2) It ensures that a larger number of sensors are working or alive	1)High overhead and complexity of forming clusters in multiple levels, 2)Implementing threshold-based functions is complex task
HEED	Moderate	Moderate	Moderate	To increase scalability and network lifetime	1) Improves network lifetime by distributing energy consumption, 2) Minimizing control overhead, and 3) Producing well distributed CHs and compact clusters.	1)The cluster selection deals with only subset of limited parameters

HRP	High	Low	Low	To decrease Probability of nodes failure and extend network lifetime	1) Reduces energy consumption of the HRP relative ZHLS in heterogeneous settings. 2) The Gateways reduces energy consumption and extends the lifetime of the cluster heads.	1) Only the zone radius is configurable parameter 2) Number of messages exchanged depends on number of nodes and the number of zones.
ANHR	High	Moderate	Low	To improve Cluster head selection and reduce network load.	1) successful packet delivery rate 2) Network load of ANHR is relatively small.	1) There may be chances that cluster node may run out of energy

III. CONCLUSION

Recent developments in wireless communications have trigger the development of low-cost, low-power WSNs for wide range of applications. Minimizing energy consumption and increasing the network lifetime are key requirements in the design of optimum wireless sensor network protocols. Node clustering is a useful energy-efficient approach to reduce the communication overhead and exploit data aggregation in sensor networks.In this survey, we discussed different types of hybrid routing protocols used in WSNs which have certain advantages, and also limitations. APTEEN protocol is appropriate for a time critical application in both proactive and reactive scenario; however increases variety of overheads and additional complexity in Implementation. A HEED protocol is employed which reduce control overhead and iteration for cluster formation. HEED has better scalability then others. In HRP, network period is exaggerated by utilizing gateways with the restriction in zone radius. ANHR provide successful packet delivery with small network load .Finally, it can be concluded from this survey that still a new hybrid protocol is needed for higher energy efficiency in order to increase the network lifetime.

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