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Comparative Study of Tree Based Routing Protocols for WSNs

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Abstract: ***The quick growth in network multimedia equipments have allow additional real-time digital services such as video-conferencing, online games and distance education to grow to be the conventional internet tasks. WSNs have become major area of research in computational theory due to its wide range of applications. But due to limited battery power the energy consumption has become major limitations of WSNs protocols. Though many protocols has been proposed so far to improve the energy efficiency further but still much enhancement can be done. In this paper, a survey on various tree based routing protocols has been discussed. From the survey, it has been concluded that none of the protocol performs effectively in all fields. Therefore the paper ends with the future scope to overcome these issues.***

Keywords: WSNs, CLUSTERING, GSTEB

I. INTRODUCTION

A Wireless Sensor Network (WSN) contains large number of small sensor nodes with restricted computation capacity, low memory, limited power, and limited range communication device. All nodes send their data to a Base Station (BS) or sink, which performs calculation and decision-making, and can be compared with the functionalities of server or in some cases as a gateway in a computer network. These sensor nodes are deployed over a large geographical area to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. WSN has emerged as an important area for research and development. They are presently at an accelerated deployment stage, with huge potential for numerous applications. So it won't be reasonable to state that they are expected to cover a substantial part of the world in the coming decade.

A wireless sensor network is made up of large number of tiny sensor nodes, each node has a radio transceiver, a microprocessor and a sensor. Such sensor nodes are able to form a network on their own, sensed information is transmitted through this network. Each node has processing capacity, data is processed as it passes through network. Given the limitations of the equipment and the physical environment and levels of high demands with which the nodes must operate, algorithms and protocols must be designed to provide strong and efficient energy consumption. The design of the physical layer and communication technologies and the information coding still represent significant challenges for the emerging field of sensor networks.

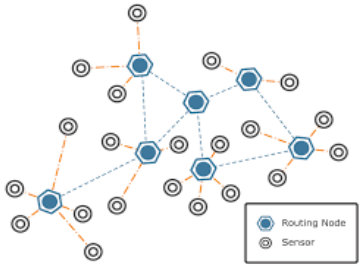

Figure 1: A sensor network

Components of WSN

Sensor nodes

The Sensor Node is a basic element of WSN and it consists of Sensing, Computation and wireless Communication unit. Therefore sensor nodes are able to observe physical phenomenon, process the observed and received information and communicate the observed or processed information to the nearby sensor nodes to form a network of sensor nodes called Wireless Sensor Networks (WSNs). The wireless networking capability of the sensor enabled nodes, have resulted in various interesting applications ranging from surveillance, smart homes, precision agriculture, disaster detection and supply chain management applications. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.

A typical sensor node consists of four components:

- A power unit, responsible for supplying energy to other components;
- A sensing unit, that actually contains the sensor, for instance, of light, humidity, temperature, etc;
- A processing unit, composed of RAM and flash memories and a processor that typically uses a set of analog-to-digital converters (ADCs) to obtain data from sensors and communications protocols;
- A communication unit, used to send and receive radio signals.

Components of a sensor node are:

- **Power Unit:** Power is stored either in batteries or capacitors. Batteries, both rechargeable and non-rechargeable, are the main source of power supply for sensor nodes. The sensor node consumes power for sensing, communicating and data processing.
- **Sensing Unit:** Sensors are hardware devices that produce a measurable response to a change in a physical condition like temperature or pressure. A sensor node should be small in size, consume extremely low energy, operate in high volumetric densities, be autonomous and operate unattended, and be adaptive to the environment. Sensors measure physical data of the parameter to be monitored.
- **Processing Unit:** A processing unit, composed of RAM and flash memories and a processor.
  - Microcontroller**:** The controller performs tasks, processes data and controls the functionality of other components in the sensor node. Some characteristics of microcontroller are: low cost, flexibility to connect to other devices, ease of programming, and low power consumption.
  - External Memory**:** From an energy perspective, the most relevant kinds of memory are the on-chip memory of a microcontroller and Flash memory—off-chip RAM. Two categories of memory based on the purpose of storage are: user memory used for storing application related or personal data, and program memory used for programming the device.
- **Communication Unit:** The functionality of both transmitter and receiver are combined into a single device known as a transceiver. The operational states are transmit, receive, idle, and sleep.

Sensor nodes can be imagined as small computers, extremely basic in terms of their interfaces and their components. They usually consist of a processing unit with limited computational power and limited memory, sensors or MEMS (including specific conditioning circuitry), a communication device (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery. Other possible inclusions are energy harvesting modules, secondary ASICs, and possibly secondary communication interface (e.g. RS-232 or USB).

Base Station (BS)

The base stations are one or more components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end user as they typically forward data from the WSN on to a server. Other special components in routing based networks are routers, designed to compute, calculate and distribute the routing tables.

Characteristics of WSN:

The main characteristics of a WSN include:

- Power consumption constrains for nodes using batteries or energy harvesting
- Ability to cope with node failures
- Mobility of nodes
- Communication failures
- Heterogeneity of nodes
- Scalability to large scale of deployment
- Ability to withstand harsh environmental conditions

Platforms

Hardware

Major challenge in a WSN is to make cheap and small sensor nodes. There are an increasing number of small companies producing WSN hardware and the commercial situation can be compared to home computing in the 1970s. Many of the nodes are still in the research and development stage, particularly their software. Also they need to use energy efficient methods for signal transmission and data gathering. In many applications, a WSN communicates with a Local Area Network or Wide Area Network through a gateway. The Gateway acts as a bridge between the WSN and the other network. This enables data to be stored and processed by devices with more resources, for example, in a remotely located server.

Software

WSN nodes are usually deployed in remote areas so it is not feasible to recharge them often so these nodes mostly suffer energy constraints as a result in a WSN energy is the scarcest resource and it decides the network. For this reason, algorithms and protocols need to address the following issues:

- Lifetime maximization

- Robustness and fault tolerance
- Self-configuration

Lifetime maximization: Energy/Power Consumption of the sensing device should be minimized and sensor nodes should be energy efficient since their limited energy resource determines their lifetime. To conserve power the nodes normally turn off the radio transceiver when not in use. Different protocols such as LEACH, HEED, PEGASIS and GSTEB etc. are developed so as to achieve even distribution of load among nodes and maximize network lifetime.

Operating system

Operating systems for wireless sensor network nodes are typically simpler as compared to general-purpose operating systems. They mostly resemble embedded systems because of two reasons. First, wireless sensor networks are typically deployed with a particular application in mind, rather than as a general platform. Second, a need for low costs and low power leads most wireless sensor nodes to have low-power microcontrollers ensuring that mechanisms such as virtual memory are either unnecessary or too expensive to implement.

Applications :

- Area monitoring

  The most straightforward application of wireless sensor network technology is to monitor remote environments for low frequency data trends. For area monitoring, the WSN is located over an area where some event is to be examined. Examples include use of sensors to detect enemy invasion in military or we can consider the geo-fencing of gas or oil pipelines.
- Health care monitoring

  Medical applications can be classified into: wearable and implanted. WSNs can be used for both kinds of medical applications. Body-area networks can gather information about an individual's fitness, health and energy expenditure.
- Environmental data collection

  The term Environmental Sensor Networks has evolved to cover many applications of WSNs to earth science research. This includes sensing volcanoes, oceans, glaciers, forests etc. Some of the major areas are air pollution monitoring, landslide detection, forest fire detection etc.
- Machine health monitoring

  WSNs have been developed for machinery condition-based maintenance (CBM) as they offer significant cost savings and enable new functionality. In wired systems, the installation of enough sensors is often limited by the cost of wiring. Previously inaccessible locations, mobile assets, and hazardous or restricted areas, and can now be outreached with wireless sensors.
- Data logging

  WSNs are used for compilation of data for observing environmental information. This can be as basic as the monitoring of the temperature in a fridge to the level of water in overflow tanks in nuclear power plants. The statistical information can then be used to show how systems have been working.

II. A GENERAL SELF-ORGANIZED TREE-BASED ENERGY-BALANCE ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORK (GSTEB)

General Self-Organized Tree-Based Energy-Balance routing protocol (GSTEB) constructs a routing tree by means of a method in which, for every round, Base station (BS) chooses a root node and broadcasts this choice to each node. Then, every node chooses its parent node by taking into consideration just itself and its neighbor's information. This makes GSTEB a dynamic protocol. Goal of GSTEB is to increase network lifetime of different applications. There are two definitions for network life time and two extreme case of data fusion are considered in the paper under consideration which are described as follows:

- Network lifetime can be defined in two ways:

a) The time from the beginning of the operation until first node dies.
b) The time from the beginning of the operation until last node is dead.

- Also two cases in data fusion are considered:

a) **Case (1)** The data among sensor nodes can be completely fused. Every node transmits the same amount of data regardless of the amount it receives.
b) **Case (2)** The data cannot be fused. Each relay node sends data which is an addition of its individually sensed data and data received from its child nodes.

III. LITERATURE SURVEY

Stephanie Lindsey et al. [1] proposed a protocol named PEGASIS . It is near optimal chain base protocol and is better than LEACH protocol. In the proposed protocol each sensor node communicates with a neighbor only and sends data to the BS in turns, hence minimal energy is spent in each round. As load is distributed between nodes network lifetime and quality of network is improved. Results in the paper show that PEGASIS perform better as compared to LEACH.Wendi B. Heinzelman et al. [2]developed and analyzed low energy adaptive clustering hierarchy (LEACH) protocol for WSN

that combines the ideas of energy-efficient cluster-based routing and media access together with application-specific data aggregation to improve network lifetime and quality. LEACH is based on a distributed cluster formation technique that is capable of self-organization of nodes, algorithms for adapting clusters and rotating cluster head positions for even distribution of the -+-load among nodes, and techniques to enable distributed signal processing to save communication resources. Results in the paper show that LEACH can improve system lifetime by an order of magnitude compared with general-purpose multihop approaches. When designing protocol architectures for wireless micro sensor networks, it is important to consider the function of the application, the need for ease of deployment, and the severe energy constraints of the nodes. These features led to the design of LEACH protocol in which local computation is done so as to minimize the amount of data transmission, network configuration and operation is done using local control, and media access control (MAC) and routing protocols enable low-energy networking. Results from experiments show that LEACH provides the high performance needed under the tight constraints of the wireless channel. Huseyln Ozgur Tan et al. [3] proposed two new algorithms named PEDAP (Power Efficient Data gathering and Aggregation Protocol), which are near optimal minimum spanning tree based routing schemes, where one of them is the power-aware version of the other. PEDAP-PA promote it further and attempts to balance the load. Low energy consumption and even distribution of load among sensor nodes improves system lifetime. This is confirmed through simulations. Simulations show that if keeping all the nodes working together is important, PEDAP-PA performs best among others, regardless of the position of the base station. On the other hand, if the lifetime of the last node is important or the nodes are not power-aware, PEDAP is a good alternative. Proposed algorithms also perform well when the base station is inside the field. There have been no approaches so far for this scenario except direct transmission. Younis et al [4]proposed a novel distributed clustering approach for long-lived ad hoc sensor networks. Proposed approach does not make any assumptions about the network infrastructure or about node potential, other than the existence of the multiple power levels in nodes. A protocol named HEED (Hybrid Energy-Efficient Distributed clustering) is proposed in the paper, that 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. A key feature of this approach is that it exploits the availability of multiple transmission power levels at sensor nodes. Simulation results demonstrate that HEED prolongs network lifetime, and the clusters it produces exhibit several appealing characteristics. HEED parameters, such as the minimum selection probability and network operation interval, can be easily tuned to optimize resource usage according to the network density and application requirements. This can be achieved by recursive application at upper tiers using bottom-up cluster formation .Weifa liang et al. [5] considered an online data gathering problem in sensor networks. It is assumed that there is a series of data gathering queries arriving one by one. The system constructs a routing tree for responding to each arriving query. Paper presents a generic cost model of energy consumption for data gathering queries if a routing tree is used for the query evaluation. Then it is shown that the online data gathering problem is NP-complete if the length of the message transmitted by each relay node varies, so heuristic algorithms for the problem are projected. The experimental results showed that algorithm MNL performs far better than the other algorithms proposed such as MDST, MMRE, SPT, and BT. Liu, Zhaowei et al. [6] introduced several different phases in a round of a clustering protocol and how to determine the number of the clusters, analyzed the CH election approaches of three classical clustering protocols, interpreted how CH distributing influence the energy consumption, how to reduce the clustering overhead and the energy consumption in data communication phase, then proposed the design principle of CH election. Zheng, Jun et al. [7] proposed an efficient fault-prevention clustering protocol for improving the lifetime and robustness of underwater sensor networks (UWSNs). The proposed clustering protocol takes into account both the reliability and residual energy status of each sensor node during clustering, and attempts to select those healthy nodes as cluster heads through failure prediction, cost evaluation, and clustering optimization. The simulation results displays that the proposed clustering protocol can not only significantly prolong network lifetime, but also improves network robustness and capacity compared with existing clustering protocols. Dilip kumar et al. [8] introduced an energy efficient heterogeneous clustered scheme for WSN founded on weighted election probabilities of each node to be chosen as a cluster head (CH) according to the residual energy in each sensor node. Main advantages of Hierarchical or cluster-based routing are scalability and efficient communication. Low-energy adaptive clustering hierarchy (LEACH) is one of the widely accepted distributed cluster-based routing protocol in WSN. Further this paper presents a model of heterogeneous wireless sensor network and explains the effect of heterogeneous resources. The energy efficiency and ease of use make EEHC an advantageous protocol for WSN. EEHC has increased the lifetime of the system by 10% as compared with LEACH in the same network environment. The proposed system increases the reliability and network lifetime. Basma M. Mohammad El-Basioni et al. [9] studied A hierarchical clustering routing protocol introduced for data assembling software in WSN called Energy-Aware routing Protocol (EAP) which fulfills various significant necessities for a clustering algorithm. EAP has various advantages, it is proven that it increases network lifetime significantly. So, this protocol should be considered for big interest therefore in this paper authors evaluate EAP in connection with network lifetime, end to end delay, packet loss percentage, and throughput, and introduces an improved protocol that performs better. It is shown in the paper that the modified protocol performs better than EAP in terms of packet loss percentage by an average of 93.4%, and also improves throughput and delay. Tripathy, Asis Kumar, and Suchismita Chinara [10] proposed a staggered clustering protocol to prolong the stable region of WSNs. Compared with classical clustering protocols, this protocol can maintain efficient load balancing of networks, and extremely prolong the network lifetime. Zhu, Jiang et al. [11] proposed a hybrid clustering protocol - Hybrid Distributed Hierarchical Agglomerative Clustering (H-DHAC) - which uses both quantitative location data and binary qualitative connectivity data in clustering for WSNs. Our simulation results show that H-DHAC has a lower percentage of compromise in performance in terms of network life

time and total transmitted data compared to similar approaches that use complete location data. However, H-DHAC still outperforms the well known clustering protocols, e.g., LEACH and LEACH-C. M.J. Shamani et al. [12] studied heterogeneous multi-domain WSNs. These are the systems in which different networks are members of different domains and sensor nodes are deployed at the same physical location and their topology is heterogeneous. It seems that, domains life time can be maximized by mutual aid in packet forwarding; but selfishness is unavoidable from rational viewpoint. Paper shows that proposed approach can remove irrational feedback, suspicious strategy and increase network lifetime. B. Manzoor et al. [13] stated that now a days WSNs are used for long lasting monitoring of fields and are required to work without sudden changes. Additionally, it is preferred to obtain better coverage of area. In view of these requirements new protocol Quadrature-LEACH (Q-LEACH) is developed which is more efficient in terms of network lifetime and stability. In this protocol nodes are deployed in the region. Network is divided into four quadrants to improve clustering. Consequently, nodes are well distributed within a particular cluster and this causes efficient energy consumption. Above mentioned notion of localized organization is applied in each sectored region of the proposed concept. Alnuaimi, Mariam et al. [14] highlighted the challenges in clustering a large scale WSN, discuss some of clustering protocols, and classify them based on the clusters technique formation and the way that data is aggregated to the base station. They further considered the case of border monitoring and simulate these protocols and compare their performance results using different scenarios. T.N. Qureshi et al. [15] studied that Clustering is an efficient method to improve energy efficiency. Generally, heterogeneous protocols use two or three energy levels of nodes. However actually, heterogeneous WSNs have large number of energy levels.. In this protocol Cluster Heads (CHs) are selected by considering residual energy level of nodes. In the paper BEENISH is proved more efficient than other protocols such as DEED, DDEEC and EDEEC for all types of WSNs in regard to stability period, network lifetime and throughput. Said, Jihed Eddine et al. [16] introduced a velocity-based clustering algorithm and implement a relay placement technique in order to maintain seamless network connectivity. Simulation results show that the packet loss rate of the proposed algorithm is much lower than the existing LEACH and HEED clustering protocols. Kumar, Dilip [17] proposed and evaluated two new clustering-based protocols for heterogeneous WSNs, which are called single-hop energy-efficient clustering protocol (S-EECP) and multi-hop energy-efficient clustering protocol (M-EECP). To analyse the lifetime of the network, the authors assume three types of sensor nodes equipped with different battery energy. Finally, simulation results indicate that the authors protocols prolong network lifetime, and achieve load balance among the CHs better than the existing clustering protocols. Zhao han et al. [18] proposed General Self-Organized Tree-Based Energy-Balance routing protocol (GSTEB) which constructs a routing tree by means of a method in which, for each round, BS selects a root node and broadcasts this selection to every sensor node. Then, every node chooses its parent bearing in mind only itself and its neighboring nodes information, hence allowing GSTEB to be a dynamic protocol.

IV. COMPARATIVE ANALYSIS

Table 1 displays the comparison of various protocols.

Table 1: Comparison of various protocols.

REF	AUTHORS	YEAR	TECHNIQUE/METHODS	FEATURES	LIMITATIONS
[1]	Lindsey, Stephanie, and Cauligi S. Raghavendra	2002	PEGASIS	Better than LEACH protocol, network lifetime and quality of network is improved	The GSTEB is homogeneous in nature, but many WSNs comes up with the different level of heterogeneity
[2]	Heinzelman, Wendi B., Anantha P. Chandrakasan, and Hari Balakrishnan	2002	application-specific protocol	improve system lifetime , minimize the amount of data transmission	The GSTEB is proactive protocol so the use of reactivity i.e. hard and soft thresholding to reduce the number of communications between the sink and the member nodes
[3]	Tan, Huseyin Ozgur, and Ibrahim Korpeoglu	2003	Power Efficient Data gathering and Aggregation Protocol	improves system lifetime, balance the load	The effect of the mobile sink on the GSTEB has been neglected.
[4]	Younis, Ossama, and Sonia Fahmy	2004	HEED	Maximizes network lifetime, exploits the availability of multiple transmission power levels at sensor nodes	The GSTEB is homogeneous in nature, but many WSNs comes up with the different level of heterogeneity
[5]	Liang, Weifa, and Yuzhen Liu	2007	MNL	performs far better than the other algorithms such as MDST, MMRE, SPT, and	The effect of the mobile sink on the GSTEB has been neglected

				BT	
[6]	Liu, Zhaowei, Bo Yang, Hongjian Chen, Chang Liu, and Yan Zhang.	2008	Different phases in a round of a clustering protocol	reduce the clustering overhead and the energy consumption	The GSTEB is proactive protocol so the use of reactivity i.e. hard and soft thresholding to reduce the number of communications between the sink and the member nodes
[7]	Zheng, Jun, Pu Wang, Cheng Li, and Hussein T. Mouftah	2008	An Fault-Prevention Clustering Protocol	prolong network lifetime, but also improves network robustness and capacity	The GSTEB is homogeneous in nature, but many WSNs comes up with the different level of heterogeneity
[8]	Kumar, Dilip, Trilok C. Aseri, and R. B. Patel	2009	EEHC	scalability and efficient communication , has increased the lifetime of the system by 10% as compared with LEACH	The effect of the mobile sink on the GSTEB has been neglected
[9]	Mohammad El-Basioni, B. M., Abd El-kader, S. M., Eissa, H. S., & Zahra, M. M	2011	optimized energy-aware routing protocol	improves throughput and delay	The GSTEB is proactive protocol so the use of reactivity i.e. hard and soft thresholding to reduce the number of communications between the sink and the member nodes
[10]	Tripathy, Asis Kumar, and Suchismita Chinara.	2012	Staggered clustering protocol	can maintain efficient load balancing of networks, and extremely prolong the network lifetime	The GSTEB is homogeneous in nature, but many WSNs comes up with the different level of heterogeneity
[11]	Zhu, Jiang, Chung-Horng Lung, and Vineet Srivastava	2013	H-DHAC	lower percentage of compromise in performance in terms of network life time and total transmitted data	The effect of the mobile sink on the GSTEB has been neglected
[12]	Shamani, M. J	2013	Adaptive Energy Aware Cooperation Strategy	remove irrational feedback, suspicious strategy and increase network lifetime	The GSTEB is proactive protocol so the use of reactivity i.e. hard and soft thresholding to reduce the number of communications between the sink and the member nodes
[13]	Manzoor, Basit	2013	Q-LEACH	efficient energy consumption, considerably improves network parameters	The GSTEB is homogeneous in nature, but many WSNs comes up with the different level of heterogeneity
[14]	Alnuaimi, Mariam, Khaled Shuaib, K. A. Nuaimi, and Mohammed Abdel-Hafez	2013	Clustering protocols	highlighted the challenges in clustering	The effect of the mobile sink on the GSTEB has been neglected
[15]	Qureshi, T. N., Nadeem Javaid, A. H. Khan, Adeel Iqbal, E. Akhtar, and M. Ishfaq	2013	BEENISH	efficient than other protocols such as DEED, DDEEC and EDEEC for all types of WSNs in regard to stability period, network lifetime and throughput	The GSTEB is proactive protocol so the use of reactivity i.e. hard and soft thresholding to reduce the number of communications between

					the sink and the member nodes
[16]	Said, Jihed Eddine, Lutful Karim, Jalal Almhana, and Alagan Anpalagan	2014	Heterogeneous mobility and connectivity-based clustering protocol	packet loss rate of the proposed algorithm is much lower than the existing LEACH and HEED	The GSTEB is homogeneous in nature, but many WSNs comes up with the different level of heterogeneity
[17]	Kumar, Dilip	2014	S-EECP and M-EECP	prolong network lifetime and achieve load balance among the CHs	The effect of the mobile sink on the GSTEB has been neglected
[18]	Han, Zhao, Jie Wu, Jie Zhang, Liefeng Liu, and Kaiyun Tian	2014	A General Self-Organized Tree-Based Energy-Balance Routing Protocol	extends network lifetime by 100% to 300%	The GSTEB is proactive protocol so the use of reactivity i.e. hard and soft thresholding to reduce the number of communications between the sink and the member nodes

V. CONCLUSION AND FUTURE SCOPE

In this paper, the review has shown that the majority of algorithms has the limitations like the GSTEB is homogeneous in nature, but many WSNs comes up with the different level of heterogeneity. Moreover the GSTEB is proactive protocol so the use of reactivity i.e. hard and soft thresholding to reduce the number of communications between the sink and the member nodes. Also the effect of the mobile sink on the GSTEB has been neglected. Therefore to overcome these issues, in near future, an on demand three level of heterogeneous GSTEB routing protocol can be proposed to enhance the results further.

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