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A Comprehensive Study on Optimal Energy Efficient Routing Protocols for Life Time Conservation of Wireless Sensor Networks

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Abstract

In General, energy efficient routing protocols in WSN are the precise domain which enables the designer to deploy variety of protocols. WSNs are an integration of multi functional nodes which are tiny, low powered and smaller in size. Moreover, energy efficiency among sensor nodes is one of the important issues that need to be solved in WSN for attaining good quality of service. Hence, it is vital to save sensor node energy while meeting the requirements of the user either by changing energy source or can be recharged. The life time of WSN can be increased based on optimal routing protocols that accentuate data dissemination and bandwidth constraints. WSN has design techniques or routing protocols that contribute the trade-off between energy, latency, security, data aggregation, stability factors and other metrics for the focus of QoS. This paper presents an extensive survey of state-of-the-art of the modern routing protocols to facilitate robustness. Further, in this paper the performance metrics, main advantages and disadvantages of each routing algorithm are compared and scope of future enhancement is discussed.

Keywords— *Energy Efficiency in WSN, Data Cycling, HEED, DECA, PEGASIS, WSN Routing, EAP, LEACH*

I. INTRODUCTION

Wireless Sensor Networks (WSN) is a collection of small, low powered and cheap sensor nodes which are capable of sensing the environment for collecting and processing the data that can able to communicate with other fellow nodes [1]. Since, WSN contains high tolerance level and autonomous, they have been recognized as a powerful tool for extensive data collection in remote and hazardous areas. The each unit in the sensor nodes are

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assigned for distinct multitasking functionalities. Thereby the lifetime of the individual nodes are to be evaluated for stable service.

Ideally, there are two factors that determine the overall lifetime of the sensor nodes: energy depletion and often device failure. The accumulated energy consumption mainly depends on the number of switching activities of each component in the sensor node, which are mainly determined by the network management schemes [2]. It is obvious that sensor nodes have to work in long durations and power bank of sensor node is very small. Generally wireless communication consumes much energy and to transmit 1kb for example, may need 100m, which is equivalent to executing 3 million instructions. Moreover, a sensor node has to sense and compute the data apart from communications, which adds additional energy load to wireless sensor nodes. It is also not possible to recharge the batter of sensor nodes as it is difficult to implement [3]. Hence it is important to emend the energy efficiency of the sensor nodes thereby elongating the life time of a sensor. This gives screech to design the protocols that are energy efficient, and requires low complexity and low transmission power. Another advantage of minimizing complexity is that it will proportionately reduce hardware cost. Here, the main aspects of WSN are accounted for designing the specific routing protocols such as., energy efficiency, security, scalability, latency, data aggregation, fault-tolerance, accuracy and QoS. The above mentioned trade-off metrics are the primary challenges for WSNs establishment. All the constraints are influenced by the characteristics of individual sensors, network behavior, and the nature of sensor fields. Hence, many traditional routing protocols such as the shortest path algorithms may failed.

In this paper, a survey on various energy efficient techniques for wireless sensor networks is presented. The paper is organized as follows. Introduction about the wireless sensor networks and the need for energy efficiency is discussed in section I. Various sources of energy wastage in wireless sensor networks are discussed in section II. Section III provides information about traditional energy saving schemes in WSNs. Proper routing of packets in WSN can save lot more energy. Hence energy efficient routing protocols such as LEACH, HEED, DECA, EPA are PEGASIS elaborately analyzed in section IV with their advantages and disadvantages. The paper ends by defining the lucid conclusion.

II. SOURCES OF ENERGY WASTAGE IN WSNS

Another way by which energy efficiency can be achieved is to identify the energy wastage sources and avoiding it. By this way, we can manage energy of a sensor node in a wise manner [4]. Major sources of energy wastage in WSN include

[1] Collision – This occurs when the transmitted packets of two or more sensor nodes colloid. All the packets involved in collision are discarded and fresh transmission is needed, which is a major source of energy wastage. Moreover, collision increases latency also.

[2] Overhearing–When the packets are picked by nodes that are not destinated to it, overhearing problem occurs.

[3] Packet Overhead – In order to maintain network, control packets are transmitted regularly. This transmission becomes overhead and consumes lot more energy.

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[4] Idle Listening–Sensor nodes listening to receive possible traffic that is not to be transmitted. If nothing is sensed, nothing to be transmitted and sensor nodes will be idle in these situations. This is the major source of energy wastage in WSNs. Hence the main objective of any MAC protocol is to overcome these pitfalls in order to improve energy efficiency.

III. APPROACHES FOR ENERGY EFFICIENCY IN WSN

Before discussing about general approaches for energy efficiency in wireless sensor networks, it is important to understand the layout of a sensor node and energy consumption of each sub system. Sensor node consists of four main components viz. sensing sub system, processing sub system, radio sub system and power supply unit [5]. Apart from these, additional sub systems can be added based on applications. Examples of additional sub systems location finding system which determines physical location, mobilize sub system which changes location or configuration, etc. Communication sub system consumes much energy than other sub systems [5]. Radio sub system performs reception and transmission, and energy requirement is little bit higher than sensing sub system. Another significant source of energy consumption is at sensing sub system. Hence any energy efficiency scheme must minimize communication, sensor nodes need to put in sleep during idle state and power minimization during sensing operation.

Based on the above facts, energy efficiency schemes of WSN are broadly classified into three categories viz. data cycling, data-driven approaches and mobility approaches.

Putting the radio transceiver to sleep mode whenever communication is not performed is the basic principle of data cycling method. When there is no need to send / receive data, the radio should be switched off, thereby gaining energy efficiency. It is something like sleep/wakeup scheduling algorithm that need to be applied to all the sensor nodes in the network to minimize energy consumption [6]. Duty cycling algorithm is basically distributed and allows neighbouring nodes to be active at the same time, thus achieving feasible data communication.

Avoiding sensor nodes to send redundant data to the sink is the basis of data-driven approaches. These approaches reduce the data by avoiding unneeded samples. Few data-driven approaches also aim to reduce energy spent by the sensor system. In order to reduce the amount of data transmitted to the sink, data aggregation can be done in the intermediate nodes. By doing this, data is reduced and concept is said to be in-network processing [6].

Data compression can be done to reduce the amount of data transmitted. For this, encoding of data is done in the source sensor node and decoding at destination sink node. Selection of specific data compression technique is application-specific. Another method of data driven approaches is data prediction. This method builds an abstraction of sensed phenomenon, with certain error bounds. Data prediction technique can predict the data in sensor node as well as in sink node[6]. Here the communication between sensor node and sink happens only when the prediction model's data is not accurate enough. This method reduces the number of information sent.

Mobility approaches conserve energy by controlling the mobility of sensor nodes. Sensors can be equipped with mobilizers to charge their location [7]. Generally mobilizers are expensive and energy consumption for

mobility is huge. Hence, instead of allowing mobility for all the nodes, it can be limited to selected nodes. And also, sensors can be placed on mobile elements so that nodes are in mobility. By these two ways energy conservation can be achieved. A special node called mobile data collector collects all the data from sensor nodes and sends to sink. By this way, ordinary nodes can save energy.

IV. ENERGY EFFICIENCY THROUGH ROUTING

In WSN, energy efficiency is one of the most important parameter which affects the lifetime of the network during data processing and transmission. Energy efficient routing protocols can be broadly classified into clustering approach and tree based approach. In clustering approach, whole sensor network is divided into small, manageable units called clusters. A cluster consists of some sensor nodes and a cluster head. Sensor nodes gather information and send the information to the corresponding cluster head [8]. The selection of cluster head is based on some criteria. Cluster head can perform data aggregation to reduce data size and can send to sink node. Clustering based routing algorithms are efficient way of energy conservation in wireless sensor networks and this method improves scalability of WSN. Since clustering based routing algorithm uses data aggregation before data transfer, it avoids redundant message transfer and provides efficient route setup among clusters [8].

A. LEACH

Low Energy Adaptive Clustering Hierarchy (LEACH) is a routing protocol which authenticates the achievable quality of service and energy-aware communication in WSN. Forming clusters and electing cluster heads are done randomly. All the nodes in the cluster transmit the data to the cluster head. LEACH is self adaptive and self-organized protocol and uses round as unit. The steps involved in each round are advertisement phase, cluster setup phase, schedule creation phase and data transmission phase. In the first phase, eligible cluster heads advertise itself to the fellow nodes and nodes will respond with reply. The acceptance of advertisement by the node is based on Received Signal Strength (RSS). In cluster setup phase, the nodes will be responding to their cluster heads. Schedule creation phase uses Time Division Multiple Access (TDMA) and cluster members are intimated when they have to transmit information to the cluster head [9]. Finally, individual sensor nodes perform data transmission within their stipulated time interval to the cluster head. The cluster head aggregates, compress and forward the data to the sink node (base station). By using stochastic algorithm, each node determines when it will become cluster head [10]. If a node becomes cluster head, it has to wait for p rounds to become cluster head again, where ‘p’ is the desired percentage of cluster heads. Since all the nodes will become cluster head at one point or another, balanced energy consumption is achieved among all the nodes thereby increasing the life time of the network. Advantages of LEACH are that it performs better than traditional routing protocols, easy to configure and network life time is increased. Since LEACH uses TDMA, a node can be alive only during its time interval and put to sleep for remaining time thereby achieving energy efficiency. LEACH also contains certain drawbacks. Since it uses single-hop routing, it is not recommended for networks that are spread over vast regions. LEACH assumes that all nodes are isomorphic and all nodes have same amount of energy. Such an assumption is impractical in most application scenarios.

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A variation of the above algorithm, called LEACH-C, uses sink node to form clusters. The sink node receives information about location and energy level of each node in the network. Sink node selects few clusters and cluster heads using the above information. The advantage of LEACH-C is that sink node uses global knowledge about network in forming clusters and number of cluster heads are fixed where as it is dynamic in LEACH.

*B. **HEED***

Hybrid Energy Efficient Distributed (HEED) is an energy efficient clustering protocol and uses residual energy as a primary parameter. HEED is the extension of traditional LEACH protocol and clustering process is divided into number of iterations [11]. During each iteration, nodes that are not covered by any cluster head becomes cluster head. HEED protocol works in three phases viz. initialization phase, repetition phase and finalization phase [11]. In initialization phase, each node in the network will calculate its probability to become cluster head.

Repetition phase repeats the above process until cluster head is located. If the node fails to find the appropriate cluster head, then the concerned node becomes cluster head. The selection of cluster head is finalized in finalization phase. Everyone elects the cluster head with least communication cost and joins it. As usual, cluster head sends the aggregated data to the base station in a multi-hop fashion rather than single-hop fashion as in the case of LEACH. The advantages of HEED protocol is that it is a distributed method and selects cluster head by two important parameters viz. residual energy level and communication cost. HEED provides cluster head chance to all the nodes in the network uniformly and load balancing is also achieved [12]. Since the communication between cluster head and base station takes place in multiple hop fashion, more energy saving and scalability is achieved. However, HEED also contains certain limitation. The tentative cluster head used in repetition phase that do not become actual cluster head leaves some unclustered nodes. Selection of cluster head in each iteration adds computational overhead to the network. Moreover, HEED needs several iterations to form clusters.

*C. **DECA***

Distributed Efficient Clustering Algorithm (DECA) is differ from HEED in decision making and score computation concepts [13]. DECA forms clusters in the first phase where all the nodes compute their score. Hence, all the nodes send their score to other nodes. If a node receives score value higher than its score, it accepts the sender node as cluster head and responds with a message. This step is said to be receive cluster message. When the above step is over, newly elected cluster head sends its cluster head ID to all the nodes in the cluster and score value is broadcasted. Finally, the selection process is finalized. The selected node becomes the cluster head.

*D. **EAP***

Energy Aware routing Protocol (EAP) introduces a new clustering parameter for cluster head selection. This allows better handling of heterogeneous energy capacities and area coverage problem can be solved using intra cluster method [14]. EAP algorithm believes that sensor nodes are location unaware. EAP gets location information of sensor nodes by using global positioning systems, directional antenna and positional algorithms. EAP uses TDMA and operation is divided into rounds. Cluster head must be rotated along with other nodes so that energy

consumption of cluster head can be minimized. Each node in the network needs to maintain a table to store information about its neighbouring nodes[14]. Every node broadcast E-message and other nodes receive and update neighbouring table. After exchange of e-messages, each node computes broadcast time delay 't'.

E. ***PEGASIS***

It is a tree based approach in which aggregation points are selected which resembles tree structure. In this tree structure, sink node is represented as root node and remaining nodes as leaves. Power Efficient Gathering in Sensor Information System, acronym for PEGASIS, is an improvement over LEACH protocol and forwarding of packets is done only to its neighbours[15]. It forms a chain like structure from leaf node to sink node. By transmitting data to its neighbours, energy efficiency is achieved. Nodes perform data fusion before transmitting to its neighbour nodes. All the nodes perform data fusion before forwarding it to the neighbour node and all nodes get a change to send the data. During chain construction, some nodes may have relatively distant neighbours in the chain. These nodes require more energy than other sensors. The performance of PEGASIS can be improved by not allowing such nodes to be leaders of chain. This can be done by setting the threshold distance between two neighbour nodes.

The performance of PEGASIS can still be enhanced by applying threshold adaptive to the remaining energy levels in nodes[16]. This threshold can be updated whenever there is a node removal from chain. PEGASIS is better than LEACH and it saves energy in several stages. First it saves energy by allowing local gathering, the small distance used by neighbour nodes for data transfer. Secondly, the leader of the chain receives only two messages whereas it is much higher in LEACH. Finally, only one node transmits data to the base station during each round of communication which greatly improves energy efficiency. There are several extensions of PEGASIS protocol is available. Energy Efficient PEGASIS Based (EEPB) is a variation of PEGASIS[17]. It saves energy by setting thresholds and balances the energy consumption of all sensor nodes. PEGASIS-ANT is another protocol uses ANT colony algorithm instead of greedy algorithm to construct data chain[18]. H-PEGASIS decreases the transmission delay of packets to the sink node. It uses CDMA to avoid collisions and node transmits data to other node of upper hierarchy [19]. PDCH, which is an abbreviation for PEGASIS with Double Cluster Head, uses two cluster heads in a single chain and forms a hierarchical structure. This method eliminates dynamic cluster formation, reduces distance between nodes, reduces message sending between nodes and allows only one transmission to the base station per round[20]. Improved Energy Efficient PEGASIS Based (IEEPB). This method is an improvement over EEPB, compares the distance between two nodes twice and finds the shortest path to link adjacent nodes[21]. IEEPB considers node's energy level and distance between sink and nodes. These parameters are normalized and different weight coefficients are assigned. The node with minimum weight becomes leader.

F. ***Comparison of various Energy Efficient Routing Protocols***

Protocols	**Energy**	**Data Aggregation**	**Scalabi**	**Latency**	**Advantages**	**Disadvantages**

			lity			
LEACH	High	Yes	Good	High	Minimizes unwanted communication and improves scalability It allows single-hop routing from node to cluster thereby saving energy	Less robustness when there is a cluster head failure. This method is not well suited for applications that cover a large area.
HEED	Good	Yes	Good	High	Extends life time of nodes within the network and stabilizes the neighbouring nodes does not require special node capabilities such as location awareness	It requires high communication overhead as the cluster heads are selected randomly Periodic election of cluster heads need extra energy to rebuild clusters
DECA	Good	Yes	Accepta ble	Mod erate	It works for mobile nodes It terminates quickly It has low computational overhead It generates non-overlapping clusters	The algorithm is applicable to multi-hop wireless networks only Maintenance of neighbour list requires additional processing power, memory

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						and extra communication High probability of wrong cluster head selection
E AP	o o d	o	o	o d e r a t e	Th is method introduces the idea of area coverage to reduce the number of working nodes within cluster in order to prolong network lifetime	U sage of GPS and directi onal antenn a method s will lead to an increas e in the cost of sensors node. P osition al algorit hms that need to exchan ge a large quantit y of messag

						es to compute the nodes location information will also result in high energy consumption
PEGASIS	igh	es	o	igher	This method is having the capacity to work on dissimilar network sizes and topologies It decreases the unwanted data transmission The energy level in the network is isolated	This method is incompatible for networks with a time fluctuating topology The communication undergoes extrem

					equally	e delays caused by single chain T he networ k is not scalabl e becaus e all nodes must have whole networ k inform ation

V. SUMMARY

Routing in wireless sensor network is a more competitive and quite imperative part of information transmission. This paper summarized study of existing research contributions in data routing to save energy of sensor network. Latency, Data aggregation and Security are the open issues in sensor network routing protocols in terms of energy harvesting and optimization. Also, in this paper, need for energy efficiency and various sources of energy wastage in wireless sensor networks are discussed in a detailed manner. The three traditional energy saving schemes such as duty cycling, data driven and mobility approaches were discussed. Putting the transceiver to sleep mode when communication is not performed is the basic idea of duty cycling approach. Avoiding sensor nodes to send unwanted data is the principle behind data driven approaches and mobility approaches achieve energy efficiency by controlling the mobility of nodes. It is obvious from the survey that efficient routing can conserve lot more energy and extend the lifetime of WSNs. The table summarizes the various energy efficiency routing protocols viz. LEACH, HEED, DECA, EAP, PEGASIS were analyzed along with their merits and demerits based on experimental study developed in NetSim-2. Further, the extension of research would require revealing issues

related to secure routing under the mobility for resource constrained WSN. The study may help to orient the development of future proposals well adapted in the area of security issues in routing protocols for WSNs. There are still many problems need to be addressed in WSN such as architecture, security and scalability. The main objectivity of the future technology revolution can solve all the issues to bridge the gap between design requirements and commercial needs.

REFERENCES

1. Cheng, Zhao, Mark Perillo, and Wendi B. Heinzelman. "General network lifetime and cost models for evaluating sensor network deployment strategies." Mobile Computing, IEEE Transactions on 7.4 (2008): 484-497.
2. Patel, Ashish, Rutvij Jhaveri, and Kruti Dangarwala. "Wireless Sensor Network–Theoretical Findings and Applications." International Journal of Computer Applications 63.10 (2013): 25-29.
3. Anastasi, G., Conti, M., Di Francesco, M., & Passarella, A. (2009). Energy conservation in wireless sensor networks: A survey. Ad hoc networks, 7(3), 537-568.
4. Demirkol, Ilker, Cem Ersoy, and Fatih Alagöz. "MAC protocols for wireless sensor networks: a survey." Communications Magazine, IEEE 44.4 (2006): 115-121.
5. Baldauf, Matthias, Schahram Dustdar, and Florian Rosenberg. "A survey on context-aware systems." International Journal of Ad Hoc and Ubiquitous Computing 2.4 (2007): 263-277.
6. Stojčev, Mile K., Mirko R. Kosanović, and Ljubi AR Golubović. "Power management and energy harvesting techniques for wireless sensor nodes." Telecommunication in Modern Satellite, Cable, and Broadcasting Services, 2009. TELSIKS'09. 9th International Conference on. IEEE, 2009.
7. Zhao, Wemi, Mostafa Ammar, and Ellen Zegura. "Controlling the mobility of multiple data transport ferries in a delay-tolerant network." INFOCOM 2005. 24th annual joint conference of the IEEE computer and communications societies. Proceedings IEEE. Vol. 2. IEEE, 2005.
8. Baronti, Paolo, et al. "Wireless sensor networks: A survey on the state of the art and the 802.15. 4 and ZigBee standards." Computer communications 30.7 (2007): 1655-1695.
9. Yadav, Rajesh, Shirshu Varma, and N. Malaviya. "A survey of MAC protocols for wireless sensor networks." UbiCC journal 4.3 (2009): 827-833.
10. Thein, Ma Chaw Mon, and Thandar Thein. "An energy efficient cluster-head selection for wireless sensor networks." Intelligent systems, modelling and simulation (ISMS), 2010 international conference on. IEEE, 2010.
11. Mamalis, Basilis, et al. "Clustering in wireless sensor networks." RFID and Sensor Networks: Architectures, Protocols, Security and Integrations, Y. Zhang, LT Yang, J. Chen, eds (2009): 324-353.

Received: 27 Mar 2020 | Revised: 20 Apr 2020 | Accepted: 05 May 2020

12. Singh, Shio Kumar, M. P. Singh, and D. K. Singh. "A survey of energy-efficient hierarchical cluster-based routing in wireless sensor networks." International Journal of Advanced Networking and Application (IJANA) 2.02 (2010): 570-580.

13. Li, Jason H., et al. "A scalable key management and clustering scheme for ad hoc networks." Proceedings of the 1st international conference on Scalable information systems. ACM, 2006.

14. Ramesh, K., and Dr K. Somasundaram. "A comparative study of clusterhead selection algorithms in wireless sensor networks." arXiv preprint arXiv:1205.1673 (2012).

15. Muruganathan, Siva D., et al. "A centralized energy-efficient routing protocol for wireless sensor networks." Communications Magazine, IEEE 43.3 (2005): S8-13.

16. Bhuvaneswari, P. T. V., and V. Vaidehi. "Enhancement techniques incorporated in LEACH-a survey." Indian Journal of Science and technology 2.5 (2009): 36-44.

17. Yu, Y. Ch, and Gang Wei. "An improved PEGASIS algorithm in wireless sensor network." Acta Electronica Sinica 36.7 (2008): 1309-1313.

18. Guo, Wenjing, Wei Zhang, and Gang Lu. "PEGASIS protocol in wireless sensor network based on an improved ant colony algorithm." Education Technology and Computer Science (ETCS), 2010 Second International Workshop on. Vol. 3. IEEE, 2010.

19. Waware, Sanjay, Dr Nisha Sarwade, and Pallavi Gangurde. "A review of power efficient hierarchical routing protocols in wireless sensor networks." International Journal of Engineering Research and Applications (IJERA) 2.2 (2012): 1096-1102.

20. Kumar, Vinay, Sanjeev Jain, and Sudarshan Tiwari. "Energy efficient clustering algorithms in wireless sensor networks: A survey." IJCSI International Journal of Computer Science Issues 8.5 (2011).

21. Sen, Feng, Qi Bing, and Tang Liangrui. "An improved energy-efficient pegasis-based protocol in wireless sensor networks." Fuzzy Systems and Knowledge Discovery (FSKD), 2011 Eighth International Conference On. Vol. 4. IEEE, 2011.

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