A Survey of Energy Efficient Routing Protocols for Wireless Sensor Networks

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Abstract – Wireless Sensor Network (WSN) is a collection of large number of tiny sensor nodes. These nodes are used to monitor the environmental or physical conditions like temperature, sound, pressure, motion, etc. and communicate with other nodes. The most powerful constraint in Sensor nodes is its energy because in WSN have limited power and energy, therefore the power utilization becomes necessary to efficiently use these resources. Power consumption is the vital problem of WSN to overcome this problem there are many approaches were introduced, like flat, hierarchical and location based routing. The basic hierarchical routing protocol for WSN is Low Energy Adaptive clustering Hierarchy (LEACH) and many routing protocols came in existence for low power consumption by WSN. This paper is based on a survey of different routing protocols which suggest the less energy consumption by WSN.

Introduction-

Wireless Sensor Networks (WSN**)** have gained world-wide attention in recent years due to the advances made in wireless communication, information technologies and electronics field.

The "3-any" concept of Wireless Sensor Networks have become popular due to the fact "-any person, anywhere and anytime". A Wireless sensor network is a network of distributed autonomous devices that can sense or monitor physical or environmental conditions cooperatively. The development of low-cost, low-power, a multifunctional sensor has received increasing attention from various industries. Sensor nodes or in WSNs are small sized and are capable of sensing, gathering and processing data while communicating with other connected nodes in the network, via radio frequency (RF) channel. Wireless sensors collaborate with each other to accomplish a common task (e.g. environment monitoring, object tracking etc) and report the collected data through wireless interface to a center node (sink node). The areas of applications of WSNs vary from civil, healthcare, and environmental to military. Examples of applications include target tracking in battlefields, habitat monitoring, civil structure monitoring, forest fire detection, factory maintenance, and health monitoring.

WSNs consist of a large number of small, inexpensive, disposable and autonomous sensor nodes that are generally deployed in an ad hoc manner in vast geographical areas for remote operations. Sensor nodes are severely constrained in terms of storage resources, computational capabilities, communication bandwidth and power supply.

At present, most available wireless sensor devices are considerably constrained in terms of computational power, memory, efficiency and communication capabilities due to economic and technology reasons. That‘s why most of the research on WSNs has concentrated on the design of energy and computationally efficient schemes, and the application domain has been confined to simple data-oriented monitoring and reporting applications. WSNs nodes are battery powered which are deployed to perform a specific task for a long period of time.

Sensor networks are the key to gathering the information needed by smart environments, whether in buildings, utilities, industrial, home, shipboard, transportation systems automation, or elsewhere. Wireless sensors are equipped with data processing and communication capabilities. The sensing circuitry measures ambient conditions and after simple initial processing, reveals some properties of objects and sends collected data to a sink, usually via a radio transmitter.

Recent advances in WSN have led use to search for new routing schemes for wireless sensors where energy awareness is essential consideration. Traditional networks aim to achieve high quality of service (QoS) provisions; sensor network schemes must focus primarily on power conservation. Therefore ad hoc routing techniques proposed in the literature do not usually fit the requirements of the sensor networks. It is necessary to design a special multi hop wireless routing technique between the sensor nodes and the sink node with a focus on energy efficiency.

A typical energy efficient routing protocol can be described as the following three phases:

In the first phase, sink broadcasts the interest or sensor nodes broadcast an advertisement for the available data and wait for a request from the interested sinks.

In the second phase, if the observations of some sensor nodes are matched with the interest list propagated by the sink, then the nodes forward data packets containing the required information to the sink using a certain routing scheme.

In the third phase, the sink infrequently initiates a localized flooding in the network in order to keep all paths alive.

Economic usage of energy is important in WSNs because replacing or recharging the batteries on the nodes may be impractical, expensive or dangerous. In many applications, network life expectancy of a few months or years is desired. Routing refers to determining a path for a message from a source node to a destination node. An optimal path is the need to the gateway in terms of energy consumption and error rate while meeting the end-to-end delay requirements. With the specific consideration of the unique properties of sensor networks such limited power, stringent bandwidth, dynamic topology (due to nodes failures, adding/removing nodes, or even physical mobility), high network density and large scale deployments have posed many challenges in the design and management of sensor networks. These challenges have demanded energy awareness and robust routing designs for the WSN.

Because sensor nodes are usually battery powered, and highly resource constrained, an energy-efficient sensor routing scheme with low latency is critical. In the sensor routing scheme, when each sensor node detects an event, it broadcasts the event to all sensor nodes within 1-hop range. All the sensor nodes within 1-hop, then, repeatedly broadcast the message to the next nodes. These processes are recursively performed until the event reaches the base station. This scheme could lead to excessive drain of limited battery power and increase collisions in wireless transmission.

Efficient utilization of sensor's energy resources and maximizing the network lifetime were and still are the main design considerations for the most proposed schemes and algorithms for sensor networks and have dominated most of the research in this area. The concepts of latency, throughput, packet loss, have not yet gained a great focus from the research community. However, depending on the type of application, the generated sensory data normally have different attributes, where it may contain delay sensitive and reliability demanding data. For example, the data generated by a sensor network that monitors the temperature in a normal weather monitoring station are not required to be received by the processing center or the sink node within certain time limits. On the other hand, for a sensor network that used for fire detection in a forest, any sensed data that carries an indication of a fire should be reported to the processing center within certain time limits. Furthermore, the introduction of multimedia sensor networks along with the increasing interest in real time applications have made strict constraints on both delay and throughput in order to report the time-critical data (in such applications) to the processing center or sink within certain time limits and bandwidth requirements without any loss. These performance metrics (i.e. delay and bandwidth) are usually referred to as Quality of Service (QoS) requirements. Therefore, enabling real time applications in sensor networks requires energy and QoS awareness along with efficient utilization of network resources and effective access to sensor readings.

In this paper, we are providing a brief introduction to different Energy efficient and delay minimization routing scheme for WSNs.

Survey-

A classification of routing protocols for WSN is as given but on the basis of these fundamental protocols there are many energy efficient routing protocols to enhance the energy level of sensor nodes.

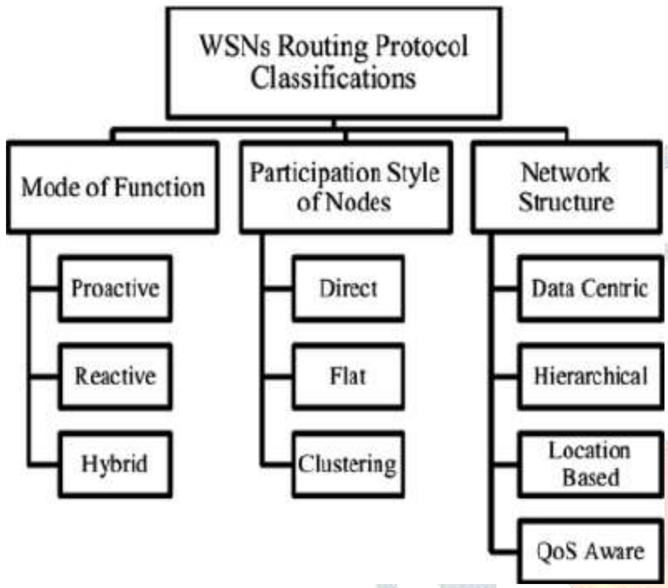

Fig. 1

Akyildiz [1] describes the concept of sensor networks which has been made viable by the convergence of microelectro-mechanical systems technology, wireless communications and digital electronics. First, the sensing tasks and the potential sensor networks applications are explored, and a review of factors influencing the design of sensor networks is provided.

The concept of sensor networks is described by Akyildiz [2] and Jennifer Yick [3] and the issues related are discussed under their related protocol stack layer. Routing in sensor networks has a lot of attention in the recent years and introduced unique challenges compared to traditional data routing in wired networks.

Akkaya and Younis [4] have summarized recent research results on energy efficient data routing in sensor networks.

A simple approach to minimize the average path length is proposed by Jhnoson and Samii [6] where they consider the wireless network of transceiver nodes with a known spatial distribution using a Genetic Algorithm optimization method. Each of the nodes consists of a relatively simple a transceiver (antennas, a receiver and a transmitter). The goal of the optimization is to minimize the average path length from source to destination to minimize the transmitted power. It is assumed that minimizing the average path length from source to destination will reduce the energy consumption.

The data centric approach and present performance analysis of these protocols is given in [5] according to this approach data is the primary parameter for routing protocols.

Q. Li, J. Aslam and D. Rus [7] have proposed a multipath routing protocol for wireless sensor networks that enhances the reliability of WSN by using multipath routing. It is useful for delivering data in unreliable environments. The idea is to define many paths from source to sink and send through them the same sub-packets. This implies that the traffic will increase significantly (not energy aware), but increasing the reliability of the network. The idea is to split the original data packet into sub-packets through each path. This can offer at the end, even with the loss of sub-packets, the reconstruction of the original message. Energy aware consideration is not done which may reduce the lifetime of the sensor network.

The energy awareness in multi path routing is done by J.H. Chang and L. Tassiulas, [8] with consideration of maximum lifetime routing in Wireless Sensor Networks. The protocol routes data through a path whose nodes have the largest residual energy. The path is switched whenever a better path is discovered. The primary path will be used until its energy is below the energy of the backup path. By means of this approach, the nodes in the primary path will not deplete their energy resources through continual use of the same route, thus achieving longer lifetime. A disadvantage for applications that require mobility on the nodes is that the protocol is oriented to solve routing problem in static wireless networks. Better scheme of optimizing end-to-end delay must be considered. Stojmenovic and Lin [9] discussed the importance of designing localized power-aware routing protocols for Wireless Sensor Networks and proposed three (cost aware, energy aware, and a combined cost energy aware) fully localized routing algorithms to minimize the total energy consumption. These algorithms used in this control messages to update positions of all nodes to maintain efficiency of routing algorithms. However these control messages also consume power so the best trade-off for moving nodes is to be established.

A routing scheme proposed by Shah and Rabaey [10] of using lowest energy paths may not be optimal from the point of view of network lifetime and long-term connectivity. To optimize these measures, they propose a new scheme called energy aware routing that uses sub-optimal paths occasionally to provide substantial gains. Selection of suboptimal paths results in increased latency so the trade-off needs to be optimized for better results.

A centralized energy efficient routing protocol for wireless sensor networks is proposed by Siva D. Muruganathan [11], this scheme operates in two phases. In the first phase a suitable node with higher energy level is selected to be the cluster head (CH), while those with low energy can prolong their lifetime by performing tasks that require low energy costs. In the second phase each sensor transmit the sensed information to its cluster head, the cluster head performs data fusion on the collected data and then routed back to the base station via CH-to-CH routing path created by base station. The routing via CH-to-CH can also be made efficient by selecting its neighbor cluster-head with lower cost to the destination.

A new routing algorithm to reduce the energy consumption and the delay of the data transmission in cluster-head based approach is proposed by Guisheng Yin [12] and greedy algorithm is adapted to forward packets between the cluster-head of the target region and the base station. On picking a next hop, a cluster-head tends to choose its neighbor cluster-head with lower cost to the destination (sink as the next-hop node. In terms of intra-cluster routing algorithm, an intra-cluster multi-hop algorithm and the angle limited area are adopted to reduce the energy consumption and the hop count to a certain extent. The latency is reduced in this approach. A simple optimization function is used, the cost function can be improved by considering the bandwidth and failure rate between the links and distribution of network traffic can significantly reduce the power consumption.

A framework based optimizing cost over progress ratio was proposed by Stojmenovic [13] for designing energy-aware routing schemes in wireless networks. The framework is based on optimizing the ratio of the cost of making certain decisions (e.g., selecting a forwarding neighbor for routing) to the progress made in doing so (e.g., reduction in distance to destination). Efficient methods to reduce the communication overhead in maintaining forwarding table and minimizing routing delay needs to be considered.

According to Yang Yang et al. [14] the aspects of accurate signal detection and energy-efficient routing are jointly optimized, he used the scenario of distributed radar-like sensors to detect the presence of an object through active sensing; the problem of energy-efficient routing for signal detection is formulated. Several parallel routes can be found for robustness and reduce the delay in case of failure.

Yahya and Ben-Othman [15] have presented Energy Efficient and QoS aware multipath routing protocol for WSN that provides service differentiation by giving real time traffic absolute preferential treatment over the non real time traffic. The protocol uses the multi-path paradigm together with a Forward Error Correction technique to recover from node failures without invoking network-wide flooding for path discovery. This feature is very important in sensor networks since flooding consumes energy and consequently reduces the network lifetime. Extra computation power is required at every node for error correction code alternate methods to be devised.

A novel online routing scheme is proposed by Haibo Zhang and Hong Shen [16], for loop-free, fully stateless, energy-efficient sensor-to-sink routing at without the help of prior neighborhood knowledge. The scheme ensures to maintain the energy consumption lower when sensor nodes are densely deployed. They assume no packet loss and no failures in the proposed greedy forwarding scheme. By taking the residual energy into account for making forwarding decision, the scheme can be extended to alleviate the unbalanced energy consumption in the network. Another extension is to integrate other energy conserving schemes such as data aggregation to further reduce energy consumption and maximize network lifetime.

The method proposed by Nallusamy [17] covers straight forward address based shortest path routing in Wireless ad hoc sensor networks (WASN). The stress is on energy efficient routing where the network optimizes the energy and thus lifetime of the network by optimizing the length of path between the source to sink. All sensors are assumed to be active all the time, the cost function does not depend on the packet size and the algorithm accepts suboptimal paths.

A modified cost-energy combined scheme for energy efficient routing using a single agent in sensor networks has been proposed in Rahmani et al. [18]. A new parameter has been added to cost-energy combined scheme and obtained better results. By using the proposed scheme, due to lower power consumption, the life time of the sensor network is prolonged by distributing the network traffic to other nodes having higher energy. The communication overhead (each node maintaining forwarding table) is not considered and the algorithm results in increased latency, inefficient route selections.

An investigation of the shortcoming of using a single agent for itinerary planning such as large latency of data collection and global unbalance in energy consumption are being discussed in Wei Cai [19]. A genetic algorithm based multi-agent itinerary planning algorithm is proposed to address the problems that address only the aspect of energy consumption for routing of the agent. However, there is a need to design routing schemes that not only reduces energy consumption but also ensures low task duration and long lifetime of the network.

A modified SPIN (M-SPIN) protocol using hop-count values of sensor nodes for WSNs proposed by Zeenat Rehena et al. [20], according to them only the nodes which are nearer to sink node send REQ packets in response to ADV packet from the source node. Therefore data is disseminated to the sink or neighbor nodes towards the sink node. M-SPIN achieves energy savings by discarding packet transmission to the opposite direction of sink node. But one major problem is that few sensor nodes may be used several times and those nodes may dissipate energy and may be destroyed earlier than other nodes in the network. So, a better solution is desired to solve this problem.

A detailed introduction to WSNs and their properties is done by R. V. Kulkarni, Anna Förster, G.K.Venayagamoorthy [21] a survey of Computation Intelligence (CI) applications to various problems in WSNs from various research areas and publication venues is presented in the paper.

The basic genetic algorithm is improved using the elitism concept [22] to provide the solution to combinatorial optimization problem of finding the energy efficient shortest routing for the wireless sensor networks. The modified GA uses elitist strategy so that the best individual is preserved and carried to the next generation so that there is significant improvement in the convergence. The node energy falling predefined level is restrained from the path based on some probability to increase the overall lifetime of the network. The energy load balancing strategy prevents uneven energy dissipation and thus the network lifetime is prolonged considerably

Clustering is widely used concept to reduce the energy consumption and to improve the stability of the network. The efficient routing protocol in a cluster plays an important role in energy saving and stability of the cluster and its nodes. [23] Enhance Threshold Sensitive Stable Election Protocol **(ETSSEP)** is proposed for heterogeneous wireless sensor network. It is based on dynamically changing cluster head election probability. It selects cluster heads on the basis of residual energy level of nodes and minimum number of clusters per round. It is also found that ETSSEP stability is increased by **33.5** % in comparison to TSEP and more than twice in comparison to SEP. The overall lifetime of ETSSEP is also increased by 37.79% in comparison to TSEP and about thrice in comparison to SEP.

Conclusion-

Network life time and Stability period is one of the key issues for designing the WSN routing protocols. In this paper, a brief introduction of many approaches of WSN routing protocols is discussed and with the comparison of these we can think about the optimized routing protocols to enhance the energy level of sensor nodes.

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