

Examining Different Data Dissemination

Schemes for WSN

Amanpreet Kaur¹, Gurpreet Singh²

¹Assistant professor, University College of Computer Applications

Guru Kashi University, Talwandi Sabo, Bathinda (India)

²Associate Professor, Department of Computer Sc. & Engg.,

Punjab Institute of Technology, Rajpura, MRSPTU, Bathinda (India)

ABSTRACT

A wireless sensor network (WSN) consists of no. of autonomous devices equipped with sensors to cooperatively monitor certain physical or environmental phenomena, such as pressure, temperature, vibration, or pollutants at different locations. These devices called sensor nodes (SNs) have sensing, computation and wireless communication capabilities. One of the significant features of SNs is their limited battery power and it is sometimes not feasible to recharge or replace the batteries. Thus, efforts must be employed at all layers to minimize the power consumption so that the network lifetime is increased. Many routing, power management, and data dissemination protocols have been specifically designed for WSNs where energy awareness is a key design issue. The focus, however, has been on the routing protocols which differ depending on the application and network architecture. In this paper, we present a survey of the state-of-the-art routing methodologies in WSNs. We first outline the design challenges for routing protocols in WSNs followed by a comprehensive survey of different routing techniques.

Keywords: WSN, Routing Protocol, LEACH, SPIN, PEGASIS, TEEN, Energy Efficiency

I. INTRODUCTION

Recent technological advances made the manufacturing of small and low cost sensors technically and economically feasible. The sensing electronics measure conditions related to the environment surrounding the sensor, such as temperature, pressure etc. and transform them into an electric signal. A large number of these disposable sensors are generally networked in many applications that require unattended operations. A Wireless Sensor Network (WSN) [1] contains huge numbers, sometimes hundreds or thousands, of these sensor nodes. These sensors have the ability to communicate either among each other or directly to an external base-station (BS). A greater number of sensors allows for sensing over larger geographical regions with greater accuracy. Figure 1 shows the schematic diagram of sensor node components. Basically, each sensor node comprises sensing, processing, transmission, mobilizer, position finding system, and power units (some of these components are optional). The same figure shows the communication architecture of a WSN. Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed. Sensor nodes coordinate among themselves to produce high-quality information about the physical environment.

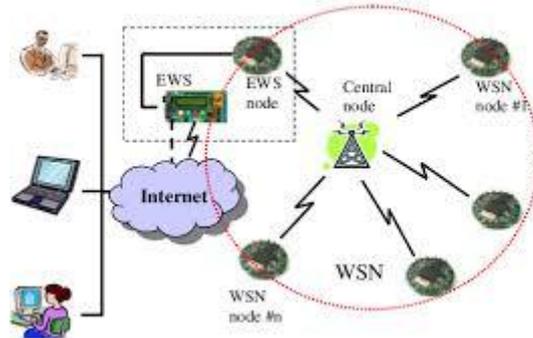


Figure1. Block Diagram of WSN

Each sensor node bases its decisions on its mission, the information it currently has, and its knowledge of its computing, communication, and energy resources. Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external base station(s). In the past few years, an intensive research that addresses the potential of collaboration among sensors in data gathering and processing and in the coordination and management of the sensing activity were conducted. However, sensor nodes are constrained in energy supply and bandwidth. Thus, innovative techniques that eliminate energy inefficiencies that would shorten the lifetime of the network are highly required. Such constraints combined with a typical deployment of large number of sensor nodes pose many challenges to the design and management of WSNs and necessitate energy awareness at all layers of the networking protocol stack. For example, at the network layer, it is highly desirable to find methods for energy-efficient route discovery and relaying of data from the sensor nodes to the BS so that the lifetime of the network is maximized. Routing in WSNs is very challenging due to the inherent characteristics that distinguish these networks from other wireless networks like mobile ad hoc networks or cellular networks. Due to the relatively large number of sensor nodes, it is not possible to build a global addressing scheme for the deployment of a large number of sensor nodes as the overhead of ID maintenance is high. Thus, traditional IP-based protocols may not be applied to WSNs. Furthermore, sensor nodes that are deployed in an ad hoc manner need to be self-organizing as the ad hoc deployment of these nodes requires the system to form connections and cope with the resultant nodal distribution especially that the operation of the sensor networks is un-attended.

Routing Challenges and Design Issues in WSNs :

Despite the innumerable applications of WSNs, these networks have several restrictions [3], e.g., limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes. One of the main design goals of WSNs is to carry out data communication while trying to prolong the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques. The design of routing protocols in WSNs is influenced by many challenging factors. These factors must be overcome before efficient communication can be achieved in WSNs. In the following, we summarize some of the routing challenges and design issues that affect routing process in WSNs.

Node deployment:

Node deployment in WSNs is application dependent and affects the performance of the routing protocol. The deployment can be either deterministic or randomized. In deterministic deployment, the sensors are manually placed and data is routed through pre-determined paths. However, in random node deployment, the sensor nodes are scattered randomly creating an infrastructure in an ad hoc manner. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy efficient network operation. Inter-sensor communication is normally within short transmission ranges due to energy and bandwidth limitations. Therefore, it is most likely that a route will consist of multiple wireless hops.

Energy consumption without losing accuracy

sensor nodes can use up their limited supply of energy performing computations and transmitting information in a wireless environment. As such, energy- conserving forms of communication and computation are essential. Sensor node lifetime shows a strong dependence on the battery lifetime [1]. In a multihop WSN, each node plays a dual role as data sender and data router. The malfunctioning of some sensor nodes due to power failure can cause significant topological changes and might require rerouting of packets and reorganization of the network.

Data Reporting Model

Data sensing and reporting in WSNs is dependent on the application and the time criticality of the data reporting. Data reporting can be categorized as either time-driven (continuous), event driven, query-driven, and hybrid [3]. The time-driven delivery model is suitable for applications that require periodic data monitoring. As such, sensor nodes will periodically switch on their sensors and transmitters, sense the environment and transmit the data of interest at constant periodic time intervals. In event-driven and query-driven models, sensor nodes react immediately to sudden and drastic changes in the value of a sensed attribute due to the occurrence of a certain event or a query is generated by the BS. As such, these are well suited for time critical applications. A combination of the previous models is also possible. The routing protocol is highly influenced by the data reporting model with regard to energy consumption and route stability.

Node/Link Heterogeneity

In many studies, all sensor nodes were assumed to be homogeneous, i.e., having equal capacity in terms of computation, communication, and power. However, depending on the application a sensor node can have different role or capability. The existence of heterogeneous set of sensors raises many technical issues related to data routing. For example, some applications might require a diverse mixture of sensors for monitoring temperature, pressure and humidity of the surrounding environment, detecting motion via acoustic signatures, and capturing the image or video tracking of moving objects. These special sensors can be either deployed independently or the different functionalities can be included in the same sensor nodes. Even data reading and reporting can be generated from these sensors at different rates, subject to diverse quality of service constraints, and can follow multiple data reporting models.

Scalability: The number of sensor nodes deployed in the sensing area may be in the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensor nodes. In addition, sensor network routing protocols should be scalable enough to respond to events in the environment. Until an event occurs, most of the sensors can remain in the sleep state, with data from the few remaining sensors providing a coarse quality.

Transmission Media: In a multi-hop sensor network, communicating nodes are linked by a wireless medium. The traditional problems associated with a wireless channel (e.g., fading, high error rate) may also affect the operation of the sensor network. In general, the required bandwidth of sensor data will be low, on the order of 1- 100 kb/s. Related to the transmission media is the design of medium access control (MAC). One approach of MAC design for sensor networks is to use TDMA based protocols that conserve more energy compared to contention based protocols like CSMA (e.g., IEEE 802.11). Bluetooth technology can also be used.

II. ROUTING PROTOCOLS IN WSNS

In this section, we survey the state-of-the-art routing protocols for WSNs. In general, routing in WSNs can be divided into flat-based routing, hierarchical-based routing, and location-based routing [4] depending on the network structure. In flat-based routing, all nodes are typically assigned equal roles or functionality. In hierarchical-based routing, however, nodes will play different roles in the network. In location-based routing, sensor nodes' positions are exploited to route data in the network. A routing protocol is considered adaptive if certain system parameters can be controlled in order to adapt to the current network conditions and available energy levels. Furthermore, these protocols can be classified into multipath-based, query-based, negotiation-based, QoS-based, or coherent-based routing techniques depending on the protocol operation. In addition to the above, routing protocols can be classified into three categories, namely, proactive, reactive, and hybrid protocols depending on how the source finds a route to the destination.

Sensor Protocols for Information via Negotiation (SPIN): Heinzelman et.al. in [8] proposed a family of adaptive protocols called Sensor Protocols for Information via Negotiation (SPIN) that disseminate all the information at each node to every node in the network assuming that all nodes in the network are potential base-stations. Figure 2 show the diagram of SPIN. This enables a user to query any node and get the required information immediately. These protocols make use of the property that nodes in close proximity have similar data, and hence there is a need to only distribute the data that other nodes do not possess. The SPIN family of protocols uses data negotiation and resource-adaptive algorithms.

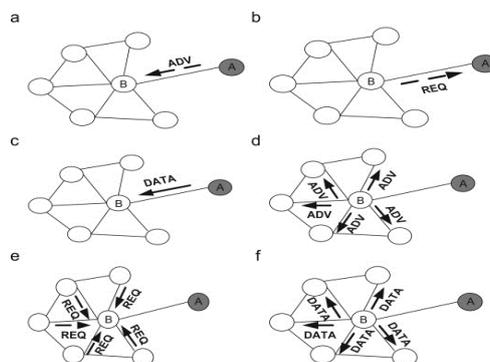


Figure2. Block Diagram of SPIN

Nodes running SPIN assign a high-level name to completely describe their collected data (called meta-data) and perform meta-data negotiations before any data is transmitted. This assures that there is no redundant data sent throughout the network. The semantics of the meta-data format is application-specific and is not specified in SPIN. For example, sensors might use their unique IDs to report meta-data if they cover a certain known region. In addition, SPIN has access to the current energy level of the node and adapts the protocol it is running based on how much energy is remaining. These protocols work in a time-driven fashion and distribute the information all over the network, even when a user does not request any data. The SPIN family is designed to address the deficiencies of classic flooding by negotiation and resource adaptation. The SPIN family of protocols is designed based on two basic ideas:

1. Sensor nodes operate more efficiently and conserve energy by sending data that describe the sensor data instead of sending all the data; for example, image and sensor nodes must monitor the changes in their energy resources.

2. Conventional protocols like flooding or gossiping based routing protocols [6] waste energy and bandwidth when sending extra and un-necessary copies of data by sensors covering overlapping areas. The drawbacks of flooding include implosion, which is caused by duplicate messages sent to the same node, overlap when two nodes sensing the same region will send similar packets to the same neighbor and resource blindness by consuming large amounts of energy without consideration for the energy constraints. Gossiping avoids the problem of implosion by just selecting a random node to send the packet to rather than broadcasting the packet blindly. However, this causes delays in propagation of data through the nodes.

Rumor routing: Rumor routing [6] is a variation of directed diffusion and is mainly intended for applications where geographic routing is not feasible. In general, directed diffusion uses flooding to inject the query to the entire network when there is no geographic criterion to diffuse tasks. However, in some cases there is only a little amount of data requested from the nodes and thus the use of flooding is unnecessary. An alternative approach is to flood the events if the number of events is small and the number of queries is large. The key idea is to route the queries to the nodes that have observed a particular event rather than flooding the entire network to retrieve information about the occurring events. In order to flood events through the network, the rumor routing algorithm employs long-lived packets, called agents. When a node detects an event, it adds such event to its local table, called events table, and generates an agent. Agents travel the network in order to propagate information about local events to distant nodes. When a node generates a query for an event, the nodes that know the route, may respond to the query by inspecting its event table. Hence, there is no need to flood the whole network, which reduces the communication cost. On the other hand, rumor routing maintains only one path between source and destination as opposed to directed diffusion where data can be routed through multiple paths at low rates. Simulation results showed that rumor routing can achieve significant energy savings when compared to event

flooding and can also handle node's failure. However, rumor routing performs well only when the number of events is small. For a large number of events, the cost of maintaining agents and event-tables in each node becomes infeasible if there is not enough interest in these events from the BS. Moreover, the overhead associated with rumor routing is controlled by different parameters used in the algorithm such as time-to-live (TTL) pertaining to queries and agents.

Hierarchical Routing Hierarchical or cluster-based routing, originally proposed in wire-line networks, are well-known techniques with special advantages related to scalability and efficient communication. As such, the concept of hierarchical routing is also utilized to perform energy efficient routing in WSNs. In a hierarchical architecture, higher energy nodes can be used to process and send the information while low energy nodes can be used to perform the sensing in the proximity of the target. This means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way to lower energy consumption within a cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the BS. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster-heads and the other layer is used for routing. However, most techniques in this category are not about routing, rather on "who and when to send or process/aggregate" the information, channel allocation etc., which can be orthogonal to the multihop routing function. **LEACH protocol:** [1] introduced a hierarchical clustering algorithm for sensor networks, called Low Energy Adaptive Clustering Hierarchy (LEACH). LEACH is a cluster-based protocol, which includes distributed cluster formation. As shown in figure 3

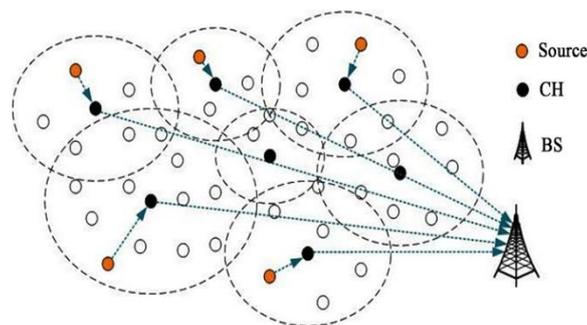


Figure3. Block Diagram of LEACH Protocol

LEACH randomly selects a few sensor nodes as cluster-heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network. In LEACH, the cluster head (CH) nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station. LEACH uses a TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collisions. However, data collection is centralized and is performed periodically. Therefore, this protocol is most appropriate when there is a need for constant monitoring by the sensor network. A user may not need all the data immediately. Hence, periodic data transmissions are unnecessary which may drain the limited energy of the sensor nodes. After a given interval of time, a randomized rotation of the role of the CH is conducted so that uniform energy dissipation in the sensor network is obtained. The authors found, based on their simulation model that only 5% of the nodes need to act as cluster heads. The operation of LEACH is separated into two phases, the setup phase and the steady state phase. In the setup phase, the clusters are organized and CHs are selected. In the steady state phase, the actual data transfer to the base station takes place. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead. During the setup phase, a predetermined fraction of nodes, p ,

elect themselves as CHs as follows. A sensor node chooses a random number, r , between 0 and 1. If this random number is less than a threshold value, $T(n)$, the node becomes a cluster-head for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last $(1/P)$ rounds, denoted by G . It is given by:

$$T(n) = \frac{p}{1 - p(r \times \text{mod}(\frac{1}{p}))}, p \in G$$

where G is the set of nodes that are involved in the CH election. Each elected CH broadcast an advertisement message to the rest of the nodes in the network that they are the new cluster-heads. All the non-cluster head nodes, after receiving this advertisement, decide on the cluster to which they want to belong to. This decision is based on the signal strength of the advertisement. The non cluster-head nodes inform the appropriate clusterheads that they will be a member of the cluster. After receiving all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule and assigns each node a time slot when it can transmit. This schedule is broadcast to all the nodes in the cluster.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS): In [7], an enhancement over LEACH protocol was proposed. The protocol, called Power-Efficient Gathering in Sensor Information Systems (PEGASIS), is a near optimal chain-based protocol. The basic idea of the protocol is that in order to extend network lifetime, nodes need only communicate with their closest neighbors and they take turns in communicating with the base-station. When the round of all nodes communicating with the base-station ends, a new round starts and so on. Figure 4 show the diagram of PEGASIS

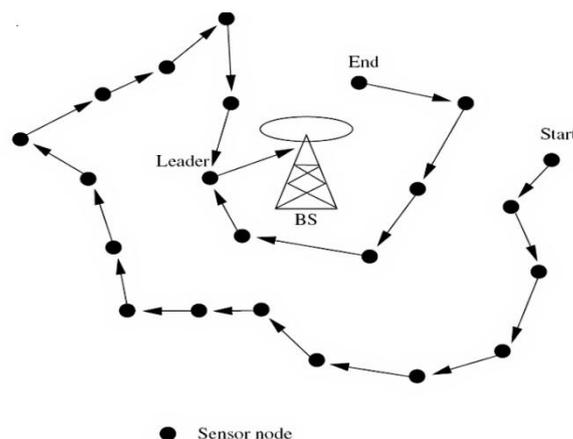


Figure 4. Block Diagram of PEGASIS

This reduces the power required to transmit data per round as the power draining is spread uniformly over all nodes. Hence, PEGASIS has two main objectives. First, increase the lifetime of each node by using collaborative techniques and as a result the network lifetime will be increased. Second, allow only local coordination between nodes that are close together so that the bandwidth consumed in communication is

reduced. Unlike LEACH, PEGASIS avoids cluster formation and uses only one node in a chain to transmit to the BS instead of using multiple nodes.

Threshold-sensitive Energy Efficient Protocols (TEEN)[5]: Two hierarchical routing protocols called TEEN (Threshold-sensitive Energy Efficient sensor Network protocol), and APTEEN (Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network protocol) are proposed in [5]. These protocols were proposed for time-critical applications. In TEEN, sensor nodes sense the medium continuously, but the data transmission is done less frequently. A cluster head sensor sends its members a hard threshold, which is the threshold value of the sensed attribute and a soft threshold, which is a small change in the value of the sensed attribute that triggers the node to switch on its transmitter and transmit. Thus the hard threshold tries to reduce the number of transmissions by allowing the nodes to transmit only when the sensed attribute is in the range of interest. The soft threshold further reduces the number of transmissions that might have otherwise occurred when there is little or no change in the sensed attribute. A smaller value of the soft threshold gives a more accurate picture of the network, at the expense of increased energy consumption. Important features of TEEN include its suitability for time critical sensing applications. Also, since message transmission consumes more energy than data sensing, so the energy consumption in this scheme is less than the proactive networks. The soft threshold can be varied. At every cluster change time, a fresh parameters are broadcast and so, the user can change them as required.

III.CONCLUSION

This paper represents few of the existing routing protocols which are both flat and hierarchical in nature. The future directions can be drawn as follows: 1. Exploit redundancy: typically a large number of sensor nodes are implanted inside or beside the phenomenon. Since sensor nodes are prone to failure, fault tolerance techniques come in picture to keep the network operating and performing its tasks. Routing techniques that explicitly employ fault tolerance techniques in an efficient manner are still under investigation. 2. Tiered architectures (mix of form/energy factors): Hierarchical routing is an old technique to enhance scalability and efficiency of the routing protocol. However, novel techniques to network clustering which maximize the network lifetime are also a hot area of research in WSNs. 3. Exploit spatial diversity and density of sensor/actuator nodes: Nodes will span a network area that might be large enough to provide spatial communication between sensor nodes. Achieving energy efficient communication in this densely populated environment deserves further investigation. The dense deployment of sensor nodes should allow the network to adapt to unpredictable environment. 4. Achieve desired global behavior with adaptive localized algorithms (i.e., do not rely on global interaction or information). However, in a dynamic environment, this is hard to model

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