A Review on Routing Protocols For Wireless Sensor Network

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***Abstract*— Latest development in wireless sensor networks (WSN) have led to several new protocols particularly intended for sensor networks where knowledge about energy is a necessary consideration. Most of the attraction, still, has been provided to the routing protocols since they might differ based on the network architecture and application. This paper studies latest routing protocols for sensor networks and introduces a classification for the many approaches followed. The three major classes explored in this paper are data-centric routing Protocol, hierarchical and location-based routing protocol. Every routing protocol is explained and talked about under the suitable category. Furthermore, protocols utilizing latest methodologies such as QoS and network flow modeling are also talked.**

Keywords: WSN, QoS, MEMS, OPNET, SPIN.

I. Introduction

Latest developments in micro-electro-mechanical systems (MEMS) and highly integrated and low power digital electronics have led to the advancement of micro sensors [1][2][3][4][5]. Such sensors are usually fitted with communication capabilities and data processing. Networking unattended sensor nodes are required to have substantial effect on the efficiency of various civil and military applications i.e. security and disaster management, combat field surveillance. These systems process data collected from various sensors to monitor events in an interested area of interest. Intrusion detection and criminal hunting are security applications of sensor networks.

Sensor nodes are constrained in bandwidth and energy supply. When these constraints combined with a distinctive deployment of large number of sensor nodes, several challenges to the design and management of sensor networks have presented. These challenges require knowledge about energy at all layers of networking protocol stack.

Routing in wireless sensor networks is very challenging because of various characteristics that differentiate them from wireless ad-hoc networks and present communication. First of all, it is impossible to make a global addressing strategy for the deployment of sheer number of sensor nodes. Thus, classical IP-based protocols cannot be employed to sensor networks. Second, in opposite to distinctive communication networks almost entire applications of sensor networks require the flow of sensed data from various sources (regions) to a specific sink. Third, produced data traffic has important redundancy in it since various sensors may produce same data within the locality of a process. Such redundancy requires to be exploited by the routing protocols to enhance bandwidth and energy utilization. Fourth, sensor nodes are tightly restrained in terms of on-board energy, transmission power, processing and storage capacity and thus need suitable resource management.

Because of these differences, several new algorithms have been suggested for the problem of routing data in wireless sensor networks. These routing processes have considered the characteristics of sensor nodes along with the architecture and application needs. All routing protocols can be categorised as data-centric, hierarchical or location-based routing protocol.

II. System Architecture and Design Issues

Based on the application, various system architectures and design objectives/constraints have been considered for sensor networks.

Network Dynamics: The sensed event can be either static or dynamic based on the application [13]. For example, in a tracking/target detection application, the event is dynamic while forest monitoring for early fire prevention is an instance of static events. Monitoring static events permits the network to function in a reactive mode, simply producing traffic when reporting. In most applications, Dynamic phenomenon need periodic reporting and therefore produces significant traffic to be propagated to the sink.

Node Deployment: other consideration is the configuration deployment of nodes. This is application based and influences the routing protocol performance. The deployment is either self-organizing or deterministic. In deterministic conditions, the sensors are placed manually and data is propagated via pre-determined routes. While in self-organizing situations, the sensor nodes are distributed randomly generating an infrastructure in an ad hoc way. In that infrastructure, the

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location of the cluster head or sink is also important in terms of performance and energy efficiency. When the scattering of nodes is not uniform, optimal clustering becomes a important issue to enable energy efficient network procedure.

Energy Considerations: at the time of production of an infrastructure, the process of determining the routes is highly affected by energy considerations. However, multi-hop routing presents significant overhead for medium access control and configuration management.

Data Delivery Models: The routing protocol is greatly affected by the data delivery model, particularly with regard to the minimization of route stability and energy consumption.

Node Capabilities: various functionalities can be linked with the nodes in a sensor network. In latest works, all sensor nodes are considered to be homogenous, having equal capacity in terms of communication, computation and power. Involvement of heterogeneous set of sensors increases various technical issues concerned with data routing. These heterogeneous environment build routing of data more challenging.

III. Related Work

The developing interest in wireless sensor networks and the continuous growth of new architectural technologies inspired some previous attempts for studying the applications, characteristics and communication protocols in such a technical environment. The objective of [1] is to make a detailed study of design issues and techniques for sensor networks explaining the physical restraints on sensor nodes and the protocols suggested in all layers of network stack. Several applications of sensor networks are also talked about. A number of routing protocols for sensor networks are discussed.

This work provides a high level explanation of a typical sensor network architecture along with its components. Sensor networks are categorized by taking many architectural factors i.e. the data delivery model and network dynamics. Such categorization helps a designer to choose the suitable infrastructure for his/her application. Our work is a devoted study of the network layer, explaining and classifying the various methods for data routing. In summation, we explain several architectural design issues that may influence the performance of routing protocols.

IV. Data-centric protocols

In data-centric routing, the sink routes queries to particular regions and waits for data from the sensors positioned in the chosen regions. Since data is being requested by queries, naming based on attribute is essential to define the properties of data. There are many Data-centric Routing protocols:

Flooding and Gossiping**:** In flooding, every sensor node obtaining a data packet distributes it to all of its neighboring nodes and this process pursues until the packet reaches at the destination node or the maximum number of hops for the packet is arrived. On the other side, gossiping is a nearly improved version of flooding where the obtaining node routes the packet to a randomly chosen neighbor nodes, which chooses another random neighboring node to propagate the packet to and so on.

Though flooding is very easy to implement, it has various withdraws. Such withdraws involve *implosion* caused by redundant messages routed to same node, *overlap* when two nodes observing the same region route same packets to the same neighboring node and *resource blindness* by taking large amount of energy without considering the energy constraints [25]. Gossiping neglects the problem of implosion by just choosing a random node to route the packet instead of broadcasting. However, this cause delays in routing of data through the nodes.

Sensor Protocols for Information via Negotiation: **(SPIN)** [25] is a data-centric routing protocol. The concept behind SPIN is to naming the data by utilizing high level meta-data or descriptors. Before transmission, meta-data are interchanged between sensors through a data advertisement procedure, which is the primary characteristic of SPIN. Each node upon obtaining new data, advertises it to its interested neighboring nodes such that those who do not have the data, fetch the data by sending a request message. SPIN's meta-data discussion solves the classic problems of flooding i.e. overlapping of sensing areas, redundant information passing, and resource blindness therefore attaining a lot of energy efficiency.

One of the benefits of SPIN is that configuration changes are localized since every node requires to know only its single-hop neighboring node. However, SPIN’s data advertisement procedure cannot assure the delivery of data. SPIN is not a good selection for applications i.e. intrusion detection, which need reliable delivery of data packets in periodic intervals of time.

Directed Diffusion: Directed Diffusion is a significant milestone in the data-centric routing research of sensor networks. The concept goals at diffusing data through sensor nodes by utilizing a naming strategy for the data. The primary reason behind employing such a strategy is to get rid of unessential operations of network layer routing in order to preserve energy.

Direct Diffusion is greatly energy efficient since it is on demand based and there is no requirement for preserving global network configuration. However, directed diffusion cannot be employed to all sensor network applications since it is query-driven data delivery model based. The applications that need continuous data delivery to the sink will not work effectively with a query-driven on demand data model. Thus, Directed Diffusion is not a well choice as a routing protocol for the applications i.e. environmental monitoring. In summation, the naming strategies utilized in Directed

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Diffusion are application dependent. Furthermore, the matching process for queries and data might need some additional overhead at the sensors.

V. Hierarchical protocols

The primary objective of hierarchical routing is to effectively preserve the energy consumption of sensor nodes by including them in multi-hop communication within a specific cluster and by performing data fusion and aggregation for decreasing the number of transmitted messages to the sink. LEACH is one of the first hierarchical routing protocols for sensors networks. Several hierarchical routing protocols are also talked about, while some protocols have been independently formulated.

LEACH: Low-Energy Adaptive Clustering Hierarchy (LEACH) [14] is one of the most appropriate hierarchical routing algorithms for sensor networks. The concept is to build clusters of the sensor nodes dependent on the obtained signal strength and utilize local cluster heads as routers to the sink. This will preserve energy since the transmissions will only be performed by these cluster heads instead of all sensor nodes. Optimal number of cluster heads is calculated to be 5% of the total number of nodes. LEACH is totally distributed and needs no world knowledge of network. However, LEACH utilizes single-hop routing where every node can route immediately to the sink and cluster-head. Thus, it is not relevant to networks distributed in large areas.

PEGASIS & Hierarchical-PEGASIS: Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [20] is an enhancement of the LEACH protocol. Instead of constructing multiple clusters, PEGASIS builds chains from sensor nodes so that every node transmits and obtains from a neighboring node and only one node is chosen from that chain to transmit to the sink (base station). Collected data travels from node to node, combined and finally sent to the sink (base station). The chain construction is carried out in a greedy way. The difference from LEACH is to utilize multi-hop routing by constructing chains and choosing only one node to transmit to the base station instead of utilizing multiple nodes. PEGASIS performance is better than to LEACH by approx. 100 to 300% for different network configurations. Such performance gain is obtained by removing the overhead occured by dynamic cluster construction in LEACH and by decreasing the number of receptions and transmissions by employing data aggregation. However, PEGASIS represents unreasonable delay for distant node on the chain. In summation, the single leader can become a bottleneck.

TEEN and APTEEN: **T**hreshold sensitive **E**nergy **E**fficient sensor **N**etwork protocol (TEEN) [16] is a hierarchical protocol planned to be reactive to fast changes in the sensed dimensions i.e. temperature. Responsiveness is significant for time-critical applications, in which the network controlled in a reactive mode. TEEN follows a hierarchical approach along with the utilization of a data-centric process. The **A**daptive **T**hreshold sensitive **E**nergy **E**fficient sensor **N**etwork protocol (APTEEN) [35] is an enhancement to TEEN and goals at both catching periodic data collections and responsing to time-critical phenomenon.

VI. Location-based protocols

Some routing protocols need location information of sensor nodes for sensor networks. In most situations location information is required in order to evaluate the distance between two specific nodes so that energy consumption can be formulated. Because, there is no addressing strategy for sensor networks i.e. IP-addresses and they are spatially distributed in an area, location information can be used in routing data in an energy effective manner. For example, if the area to be felt is known, utilizing the position of sensors, the query can be disseminated only to that specific area which will remove the number of transmission importantly.

MECN and SMECN: Minimum Energy Communication Network (MECN) [39] arranges and preserves a minimal energy to network for wireless networks by using low power GPS. Although, the protocol considers a mobile network, it is best relevant to sensor networks, which are not mobile. A minimal power configuration for static nodes involving a master node is detected. MECN considers a master-site as the information sink, which is ever condition for sensor networks. The small minimal energy communication network (SMECN) [40] is an enhancement to MECN. In MECN, it is considered that each node can transmit to each another node, which is not possible each time. In SMECN possible obstructions among any pair of nodes are assumed. However, the network is still considered to be completely linked as in the situation of MECN. The sub network build by SMECN for minimal energy relaying is obviously smaller (in terms of number of edges) as compared to one build in MECN if broadcasts messages are capable to arrive to entire nodes in a circular area across the broadcaster. As a result, the number of hops for transmissions will decrease. Simulation results indicate that SMECN utilizes less energy as compared to MECN and cost of maintenance of the connections is less. However, discovering a sub-network with less number of edges presents more overhead in the algorithm.

GAF: Geographic Adaptive Fidelity (GAF) [38] is an energy-aware location-based routing algorithm planned mainly for mobile ad hoc networks, but as well may be suitable to sensor networks. GAF preserves energy by turning off unessential nodes in the network without influencing the level of routing accuracy. It builds a virtual grid for the covered area. Every node utilizes its GPS-indicated location to relate itself with a point in the virtual grid. Nodes linked with the same point on the grid are assumed equivalent in terms of the packet routing cost. This equivalence is exploited in maintaining some nodes positioned in a specific grid area in sleeping state for

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preserving energy. Therefore, GAF can considerably enhance the network lifetime period with increment in number of nodes.

GEAR: Yu et al. [43] have proposed the utilization of geographic information while diffusing queries to suitable regions since data queries usually involves geographic attributes. The protocol, namely Geographic and Energy Aware Routing (GEAR), utilizes energy aware and geographically informed neighbor selection heuristics to send a packet towards the destined region. The concept is to limit the number of interests in Directed dissemination by only assuming a particular region instead of sending the interests to the whole network. GEAR compliments Directed Dissemination in this manner and therefore preserves more energy.

Conclusion

In this paper, we have summed latest research results on routing of data in sensor networks and categorized the protocols into three major classes i.e. data-centric, hierarchical and location-based routing protocols. Some other protocols adopted the QoS simulating methodology and traditional network flow. Still, we have also noticed that there are few hybrid protocols that are suitable for more than one category. We also observed whether the protocol is using data dissemination or not, since it is a significant assumption for routing protocols in terms of traffic optimization and energy saving.

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