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ROUTING PROTOCOLS FOR MOBILE AD-HOC NETWORKS - A SURVEY

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ABSTRACT

Wireless communications and MEMS are the two technologies that have resulted in the development of wireless sensor networks, which are highly distributed networks with the deployment of small, inexpensive nodes. The flexibility of installation and configure ration has greatly improved resulting in a flurry of research activities commencing in the field of sensor networks. This paper studies the routing protocols for WSNs and presents a comparison of the representative routing protocols. At last, several issues that are to be addressed are put forward.

KEYWORDS: Wireless Sensor Networks, Routing Protocols, Data Centric, Negotiation-Based, Hierarchical Protocols, QoS

INTRODUCTION

Wireless sensor networks are highly distributed networks of small, light weighted and inexpensive wireless nodes, deployed in large numbers to monitor the environment or system by measuring physical parameters such as temperature, light, humidity, or pressure [1]. These tiny nodes have some intelligence and can process data as it flows through the network. The latter is being done wirelessly these days using networking principles [2].

Each node of the sensor network consists of three subsystems [3]: the sensor subsystem which performs sensing operation, the processing subsystem which performs local computations on the sensed data, and the communication subsystem which is responsible for the data exchange with neighboring sensor nodes. Further the nodes collaborate and cooperate on their data, resulting in accurate sensing of events in the environment. There are two important operations in any sensor network, data dissemination, that is, the propagation of data/ queries throughout the network, and the data gathering, that is the collection of observed data from the individual sensor nodes to a sink.

Routing protocols that provide the route or the path for the data packets to follow from source node to sink node used in traditional wired networks cannot be used for wireless sensor networks due to their dynamic topology, lack of centralized administration, bandwidth- constrained wireless links, and energy – constrained nodes. A variety of routing protocols has been proposed in the recent past. In this paper, the comparison of routing protocols for wireless sensor networks, their practical limitations, unaddressed issues and future challenges are presented.

The design of routing protocols is influenced by many challenging factors caused by the nature of the Wireless Sensor Networks [1], [4]. Some of these factors are discussed in this part.

- **Data Delivery models**: Data delivery model depends on the application and can be continuous, event-driven, query- driven, or hybrid. In continuous model of delivery, each sensor sends the data periodically. In event-driven

and query driven models, the transmission is triggered by an event or a query- driven data delivery model.

- **Node deployment:** Node deployment can be random, deterministic or self-organizing. For deterministic deployed networks the routes are pre-determined, and for random deployed networks and self-organizing networks route designation have been a challenging subject.
- **Dynamic topology:** For some applications mobility of nodes is required designing the routing protocols for such networks must cater the need for mobility.
- **Fault tolerant:** Failure of nodes should not affect the network operation. So, routing protocol must be designed to make such operation unaffected by node failures.
- **Scalability:** Any routing protocols including any number of nodes should be manageable.
- **QoS:** For time – critical applications, routing protocol with required QoS must be designed.

CLASSIFICATION OF ROUTING PROTOCOLS

There are many ways to classify the routing protocols. They are classified as flat, hierarchical, location based, data centric based, negotiation based, quality of service based [5] [1] depending on the protocol operation. In flat type all nodes are same and play the same role, while hierarchical protocols aim at routing with cluster heads, which perform the job of data aggregation in order to save the energy. For negotiation based protocols, data is transferred after negotiation. Whenever the QoS parameters are to be considered then the protocols like SAR are used for Wireless Sensor Networks.

Routing Protocols

Flooding

This is an old routing protocol in which each node receives a data packet and then sends them to the neighbors by broadcasting, unless the destination of the packet is arrived. However it has the following disadvantages [6].

- Implosion: This is the situation where duplicated data are sent to the same node .This occurs when node receives copies of the same message from many of its neighbors. This is an implosion problem, illustrated in Figure 1.

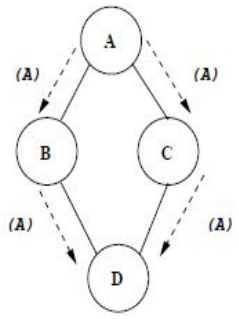


Figure 1: The Implosion Problem

In this graph, node A starts by flooding its data to all of its neighbors. Two copies of the data eventually arrive at node D. This system, wastes energy and bandwidth in one unnecessary send and receive [6].

- **Resource Blindness:** In this protocol, nodes do not modify their activities based on the amount of energy

available to them at a given time. Hence it reduces the network life time.

- **Overlap:** The same event may be sensed by more than one node due to over lapping regions of coverage. This results in their neighbors receiving duplicate messages of same events. This leads to overlap problem, illustrated in Figure 2.

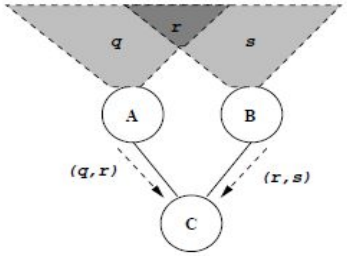


Figure 2: The Overlap Problem. Two Sensors Cover an Overlapping Region. When these Sensors A and B Flood their Data to Node C, it receives Two Copies of the Data Marked r Along with q and s [6]

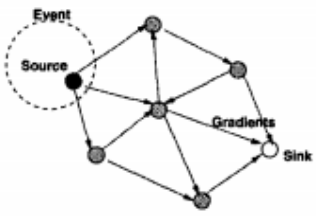
Gossiping

It is an alternate [7] to the Flooding approach that do not uses the broad casting but send the incoming packets to a randomly selected neighbor node. Once the neighbor node receives the data, it randomly selects another sensor node. It may avoid implosion but it does not solve the overlap lap problem. Also, the cost is the long time propagation for sending the messages to all sensor nodes.

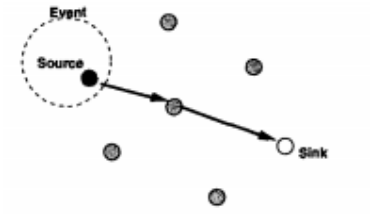
Directed Diffusion

This protocol [8] uses data diffusion using interest gradients. Each sensor node names its data with one or more attributes, and the other nodes express their interest depending on these attributes. Interest is a set of data descriptors for the data for which the querying node is interested. Data is hence propagated along the reverse path of the interest propagation. Each path is associated with a gradient that is formed at the time of interest propagation. While positive gradients encourage the data flow along the path, negative gradients inhibit the distribution of data along a particular path. Figure 3 illustrates the directed diffusion routing method.

(a) Interest Propagation



(b) Initial Gradient Setup



(c) Data Delivery along the Reinforced Path

Figure 3: A Simplified Schematic for Directed Diffusion

Rumor Routing

It is an agent based path creation algorithm [9]. Agents or 'ants' are long lived entities created at random by nodes. These are basically packets which are circulated in the network to establish shortest paths to events that they encounter. The main idea is to route the queries to specific nodes that have observed specific events. When a node detects an event, it adds it to its event table and generates an agent in order to flood through the network and propagate the directed information to the distant nodes. This algorithm works well when the number of queries is large and number of events is small.

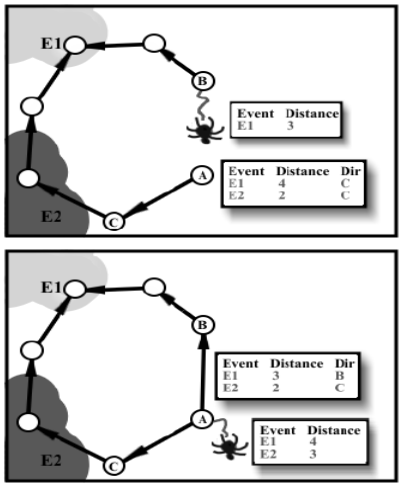


Figure 4: Rumor Routing: The Agent Has Initially Recorded a Path of Distance 3 to Event E1. Node a's Table Shows that it is at a Distance 4 from the Event E1 and 2 from E2 When the Agent Visits Node A, it Updates its Own Path State Information to Include the Path to Event E2. It Also Optimizes the Path to E1 Recorded at Node a to The Shorter Path Through Node B.

SPIN (A 3- Stage Handshake Protocol)

The SPIN (Sensor Protocol for Information via Negotiation) is a simple handshake protocol [6] for data disseminating through a network. It has three messages: ADV-REQ-DATA. ADV is the data advertisement message send by a SPIN node when it has the data to share. REQ is the send by any SPIN node when it wishes to receive data. DATA is the actual sensor data send in the network with a meta- data header.

One of the advantages of SPIN is that topological changes are localized because each node needs to know only its single hop neighbors. Its Meta data negotiation and resource adaptive solves the classic problems of flooding. The

disadvantages are it is not scalable and nodes around the sink could deplete their energy if the sink is interested in too many events. And moreover the SPIN's advertisement mechanism cannot guarantee the delivery of data [5].

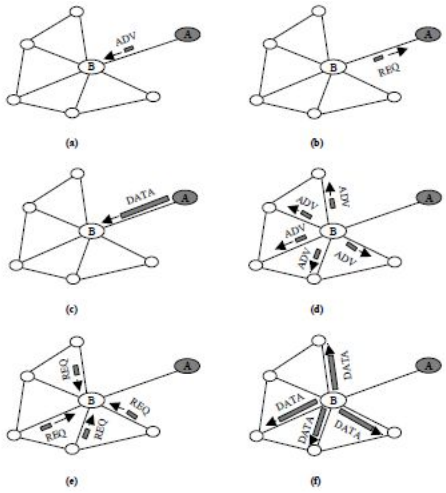


Figure 5: The SPIN Protocol. (a) Node A Starts by Advertising its Data to Node B.
(b) Node B responds by Sending a Request to Node A.
(c) After Receiving the Requested Data,
(d) Node B then Sends Out Advertisements to its Neighbors.
(e) Neighbor Nodes in Turn Send Requests Back to B [6].

LEACH (Low Energy Adaptive Clustering Hierarchy)

This Protocol is a Clustering-based protocol that utilizes randomized rotation of the cluster-heads to evenly distribute the energy load among the sensor nodes in the network. It is the most popular protocol using hierarchical model for routing. The idea is to form clusters of sensor nodes based on the received signal strength and use the local cluster heads to route the data. This will save energy and the transmission is done using only cluster heads rather than all the nodes. All the data processing is local to the cluster. Cluster heads change randomly over the time in order to balance the energy dissipation of the nodes. This decision is made by the node choosing a random number between 0 and 1. The node becomes a cluster head for the current round if the number is less than the following threshold [10]:

$$T(n) = \begin{cases} \frac{P}{1-Ps(r \bmod \frac{1}{P})} & \text{if n} \in \text{G} \\ 0 & \text{otherwise} \end{cases}$$

Where p is the desired percentage of cluster heads, r is the current round and G is the set of nodes that have not been cluster head in the last 1/p rounds.

LEACH provides many good features to the sensor network. It is cluster- based localized coordination and randomized rotation of cluster- heads. But it cannot be applied to time critical applications. And the nodes on the route might drain their energy soon.

PEGASIS (Power Efficient Gathering in Sensor Information Systems)

This protocol is a chain- based power efficient protocol based on LEACH [11]. Each node must have the global knowledge of the network, there by forming the chain is easy using greedy algorithm. It is superior to LEACH by

eliminating the cluster formation; minimizing the distances that the non-head nodes must transmit and the total number of transmission are limited. The main disadvantage of this protocol is that each node must know global information of the network. It does not scale well as SPIN. It is not well for Sensor networks where global knowledge is not easy to get.

SAR (Sequential Assignment Routing)

The SAR [12] [2] algorithm creates multiple trees. The root of each tree is one hop neighbor from the sink. Each tree grows outward from the sink while avoiding nodes with very low throughput/ high delay. One of the paths is selected according to QoS and energy sources. A weighted QoS metric is used to handle prioritized packets, which is computed as a product of priority level and delay. Thus, high priority packets take lower delay paths and low priority packets have paths of greater delay.

COMPARISON OF ROUTING PROTOCOLS

Designing of Routing protocols for Wireless Sensor Networks has attracted a lot of attention in these years and brought unique challenges compared to traditional data routing in wired networks. Every protocol has a relationship with others; Rumor Routing and Directed Diffusion are data centric protocols. So, it is difficult to say that this protocol is better than another one. With respect to the few metrics that are identified, routing protocols that are discussed above are compared.

Table 1: Comparison of Various Routing Protocols

	Directed Diffusion	Rumor Routing	Spin	Leach	PEGASIS	SAR
Classification	Data centric	Data centric	Data centric	Hierarchical	Hierarchical	QoS
Power usage	Limited	low	limited	High	High	High
Scalability	good	Good	limited	Good	Good	Limited
Data aggregation	Yes	Yes	Yes	Yes	Yes	No
Overhead	Low	Low	Low	High	Low	High
Data delivery model	Demand driven	Demand driven	Event driven	Cluster- head	Chain-based	Continuous

CONCLUSIONS

Wireless Sensor Networks have become popular due to the progress made in sensing, communications and computing area. To make, Wireless sensor networks more practical, more effective routing protocols are to be designed. Although efforts are made in routing techniques to suit well for different applications, there are still some challenges that confront effective solutions to the routing problem. As the survey reveals that it is not possible to design a routing protocol which have good performance under all scenario and for all applications.

The further research would be needed to address issues such as QoS pose by the video and audio transmission and also for real time applications [5]. Node mobility, Network topology changes, frequent update information for changing scenario, energy- constraints, multimedia transmission are some of the bottlenecks in wireless sensor network applications. Most of the applications in security and environment monitoring require data to be collected from the sensor node and sending to a server so that further analysis can be done. Since the routing requirements of each environment are different,

further research is necessary for handling these different situations.

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