Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 1, Number 6; October, 2014 pp. 94-98

http://www.krishisanskriti.org/jbaer.html

Opportunistic Routing in Wireless Sensor Networks: A Comparative Analysis

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Abstract: **Wireless Sensor Networks (WSNs) are the networks in which many sensor nodes are deployed in the application area to form a network. The sensor nodes collect the information about physical or chemical phenomenon and transfer this information towards the base station for further processing. To accomplish the task of transferring data sensor nodes require the routing protocols. Routing protocols for WSN are used for finding the best path to establish communication in the networks. Routing in WSN is a challenging task due to the nature and abilities of sensor nodes in WSN like energy, communication architecture and deployment of nodes. Many researchers have proposed routing protocols of various categories like Data Centric Routing, Hierarchical Routing, Location-based Routing and Opportunistic Routing. The use of routing protocols depends on the requirements of applications of WSN and also the capabilities of sensor nodes. In order to achieve a high throughput in unreliable wireless links, Opportunistic Routing (OR) collaborate all the sensor nodes in the path while forwarding the data packets.**

This paper presents a study and comparative analysis of opportunistic routing algorithms which are Ex-OR (Exclusive OR), EEOR (Energy Efficient OR), SOAR (Simple Opportunistic Adaptive Routing), EAOR (Energy Aware OR) and EFFORT. The comparative analysis has been done on the basis of power usage, data aggregation, scalability, data delivery model and QoS. The analysis of OR protocols will enable us to identify the capabilities and the effects of OR on the performance of WSNs.

Keywords: **WSN, Routing, Opportunistic Routing.**

1. INTRODUCTION

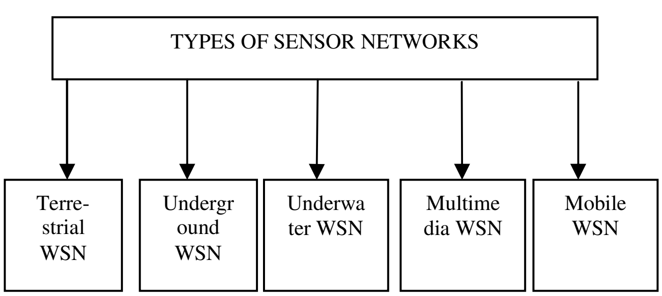

Fig. 1: Type of sensor networks

WSN can have thousands of tiny sensor nodes. Large number of sensor nodes allow for sensing larger geographical area with greater accuracy. There are five types of the sensor network. Classification of different type sensor networks has been shown in figure 1.

WSN have wide range of applications. Classification of these applications is shown in figure 2.

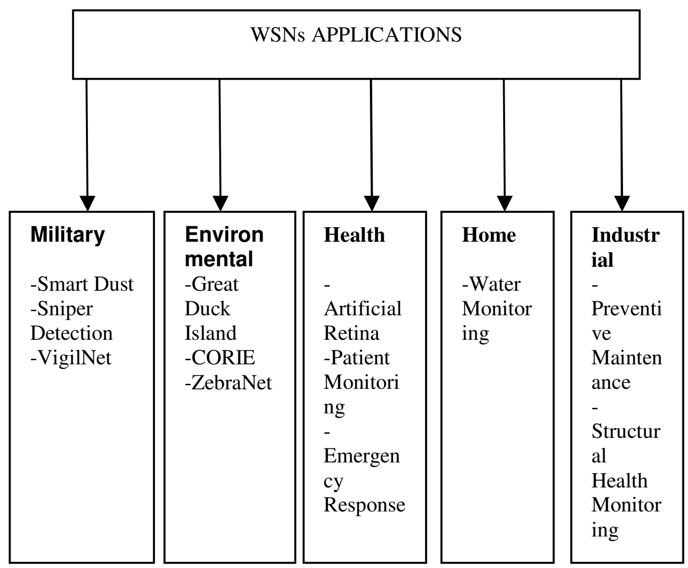

Fig. 2: Main categories of WSN application and examples.

To accomplish the task of transferring data, sensor nodes require routing protocols. Routing protocols for WSN are used for finding the best path to establish communication in the networks. Routing in WSN is a challenging task due to the inherent characteristics of WSN like energy, communication, architecture and deployment of nodes. Many researchers have proposed routing protocols.

The rest of the paper is organized as follows. Section 2 discuss challenges and designing issue for routing in WSNs, Section 3 presents classification of routing protocols, Section 4 discuss various Opportunistic routing protocols for WSNs, Section 6 will give a comparative analysis of various Opportunistic routing protocols in WSNs and section 7 concludes the paper.

2. CHALLENGES AND DESIGNING ISSUE FOR ROUTING IN WSNS

Routing is the most complicated process in WSNs. The design of routing protocols in WSNs is inclined by many testing factors. Efficient communication is dependent on these testing factors. In the following, we précis some of the routing challenges that influence routing process in WSNs [12].

2.1. Node deployment

Node deployment is dependent on the application and effect the performance of WSNs. The deployment can be either deterministic or randomized. In deterministic deployment, the sensing elements are manually identified and data is routed through pre-defined routes. However, in random node deployment, the sensor nodes are spotted randomly creating WSNs. If the consequent distribution of sensor node is not uniform, optimally clustering becomes necessary to allow connectivity and enable energy efficient network performance. Inter-sensor communication is normally within short communication ranges due to energy and bandwidth restrictions. Thus, it is most probable that a route will consist of multiple wireless hops.

2.2. Energy consumption

The main task of the routing protocols is efficient delivery of data from source to destination. Energy consumption is the major concern in the development of routing protocols for WSNs. Sensor node has limited energy resources and information or data want to be delivered in an energy efficient way without compromising the correctness of the information. The main reason of energy consumption for routing in WSNs is neighborhood discovery and data aggregation.

2.3. Scalability

A large number of sensor nodes are scattered in the application area, i.e. thousand or more numbers of node. Routing protocols work with large number of sensor nodes. WSN routing protocols must be an adequate amount of scalable to act in response to events in the network [8, 5]. If an event occurs, then sensor nodes are responsible or handle that event.

2.4. Fault Tolerance

A few sensor nodes can crash due to lack of power, physical damage, or environmental interference. The crash of sensor nodes must not influence the overall task of the WSNs. If a large number of nodes crash, MAC and routing protocols must lodge formation of new links and routes for communication in the network. This may need more power for new link formation and route these new links in the sensor network [16]. Therefore, several levels duplication can be needed in a fault tolerant sensor network.

2.5. Data Aggregation

Sensor nodes can produce duplicate data from different regions. Data aggregation techniques combine data from various nodes, according to a definite aggregation function, e.g., duplicate repression, minima, maxima and average. Data aggregation is used to meet energy efficiency and data transfer optimization in all routing protocols.

2.6. Quality of Service

In many applications, data must be delivered in a definite period of time from the instant it is sensed, otherwise the data will be of no use. Therefore restricted latency for data delivery is another situation for time-constrained applications. Since, the energy gets exhausted, the network has to degrade the performance.

3. CLASSIFICATION OF ROUTING PROTOCOLS

Many researchers proposed routing protocols for WSN. In general, all the routing protocol for WSNs can be divided into data centric protocols, Hierarchical Protocols, location based protocol and opportunistic routing protocols [13, 15]. Classification is shown in figure 2.

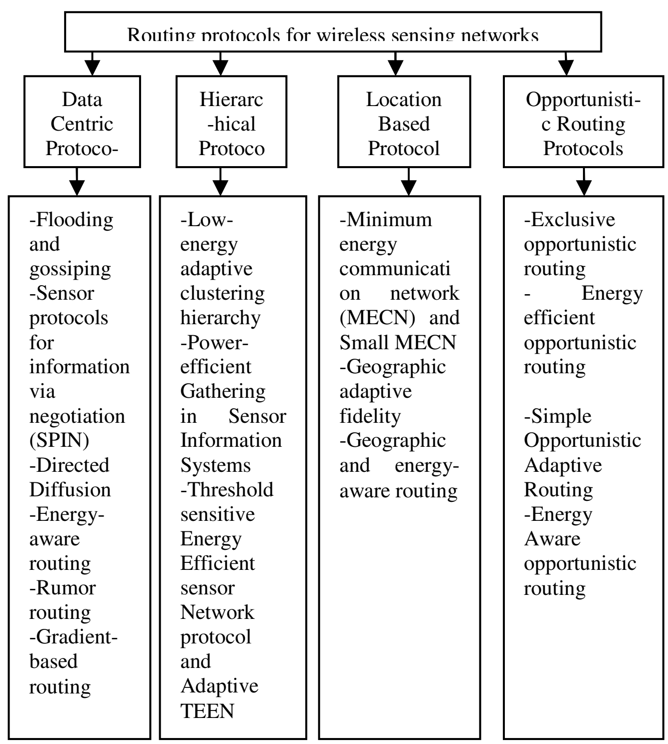

Fig. 3 Classification of routing protocols

3.1. Data Centric Protocols

Data Centric routing protocols are used to manage the redundancy of data, it happens for the reason that sensor nodes do not have global identification which identifies them uniquely. Therefore, data sent to every node is having significant redundancy. In data centric routing, the destination demand for data by sending the question then the nearby sensor node sends the data selected relating to the query [14]. SPIN is the first data-centric protocol, which considers between nodes in order to eliminate redundant data and maintain energy. Later, Directed diffusion has been modernized and has become a breakthrough in data-centric routing.

3.2. Hierarchical Routing Protocols

Standardized to a cellular phone network, sensor nodes in a hierarchical routing approach send their information to a key cluster-head and the cluster head then forwards the information to the desired receiver. The primary purpose of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by taking them in multi-hop communication within a particular cluster and by performing data collection and fusion in order to lessen the number of communicating messages to the destination. Among numerous of hierarchical routing protocols LEACH and PEGASIS are mostly used protocols [14].

3.3. Location Based routing Protocol

The estimation of location-based protocols is using an arena instead of a node identifier as the object of a packet. Any node that positions within the given area will be acceptable as a destination node and can obtain and process a message. From the perspective of sensor networks, such location-based routing is important to request sensor data from any region. Since there is no addressing method for sensor networks like IP-addresses and they are spatially deployed in a neighborhood, location information can be used in routing data in an energy-efficient manner. For example, if the region to be sensed is identified, using the location of sensor nodes, the question can be disseminated only to that particular region which will eradicate the number of transmission significantly. The location-based routing protocols obtain into report the mobility of sensor nodes and execute very well when the density of the network increases. Merely, the execution is very pitiful when the network deployment is sparse and there is no data aggregation and further dealing out of the header node. For example, GEAR [14] is one of the location-based protocols.

4. OPPORTUNISTIC ROUTING IN WSNS

Challenged networks where network contacts are intermittent or where link performance is highly variable and there is no complete path from source to destination for most of the time [10]. The path can be highly unstable and may change or break quickly [10]. To make communication possible intermediate nodes may take keeping of data during the blackout and forward it when the connectivity resumes [10]. Opportunistic Routing used broadcast transmission to send packets through multiple relays. Opportunistic routing archives higher throughput than traditional routing. First protocol was designed by Biswas and Morris in 2004 [9]. The main idea behind Opportunistic Routing is select a subset of the nodes between the source and the destination node and the node closest to the destination will first try to retransmit packets. The main two steps are [11]-

1. Selection of the forwarder sets: Selecting only the potential nodes between the source and destination to increase the routing efficiency.

2. Prioritization among these forwarders: The highest priority forwarder should be the closest one to the destination.

4.1. Exclusive opportunistic routing (ExOR)

ExOR is an incorporated routing technique. ExOR broadcasts each packet, selecting a receiver to forward only after learning the set of sensor nodes which really received the packet. Delaying forwarding decisions pending after reception allows ExOR to try multiple long, but radio lossy links at the same time as, resulting in high estimated progress per transmission. Unlike supportive diversity schemes, but a single ExOR sensor node forwards each packet, so that ExOR works with existing radios. The central challenge of realizing ExOR is ensuring that only the best receiver of each packet forwards it, in order to avoid redundancy. ExOR operates on sets of packets in order to cut the communication cost of the accord. The source node contains in each packet a list of candidates Forwarders prioritized by close to the destination. Receiving nodes buffer effectively received packets and wait for the end of the batch.

The maximum priority forwarder then broadcasts the packets in its buffer, as well as its copy of the “batch map" in each packet. The batch map includes the sender's excellent estimate of the highest priority node to have received each packet. The residual forwarders then send out in order, but only send packets which were not acknowledged in the batch maps of higher priority nodes. The forwarders maintain to cycle in the course of the priority list until the destination has 90% of the packets. The remaining packets are transferred with traditional routing. The advantage of this ExOR is the choice of forwarders to provide throughput gains of a factor of two to four. Another advantage of this ExOR improves performance by taking advantage of long-distance, but lossy links which would otherwise have been avoided by traditional routing protocols. ExOR is likely to increase total network capacity as well as individual connection throughput

4.2. Energy Efficient Opportunistic Routing (EEOR)

EEOR is an algorithm which works on the basis of selecting forwarders' list and prioritizing the nodes in it [17]. Two scenarios have been presented in the paper for adjusting the power of the nodes during transmission. EEOR have been tested on TOSSIM simulator.

In first scenario it is assumed that the sensor nodes cannot adjust the power available with them. In other case the transmission power can be adjusted by the sensor node for each transmission.

When the forwarder list has been formed the expected cost of transmission has been recorded against each forwarder node entry. Initially the cost will be zero for all nodes. Distance vector routing [17] has been used to decide the routes after the expected cost has been calculated. The advantage of this EEOR is the end-to-end delay is smaller than EXOR routing, As well as better in terms of the packet loss ratio , energy consumption, and the average delivery delay

4.3. Energy Aware Opportunistic Routing (EAOR)

Energy Aware Opportunistic Routing follows a same transmission method as the opportunistic routing. But, the main diversity of this approach is the next relay node selection criterion. The communicate node that will respond first to an RTS packet is different than that of opportunistic routing. In energy aware opportunistic routing, a sensor node checks its energy level. If the energy level is low, then it does not respond with CTS. In this manner, the lifespan of each client is increased. When a node has high power usage, the probability to get a DATA packet is more depressed. But, the sensor node can still involve you in some of the DATA packet transmissions. If a neighboring node has a high energy level, but it is not that close to the destination in comparison with other neighboring nodes, it will start participating in packet transmissions when some of the neighboring nodes consumed too much energy. Energy aware opportunistic routing tries to send the packets over nodes that are near to the destination and also accept a high energy level. In this manner, it can discover more routing paths compared to the opportunistic routing. These paths do not always consist of a similar number of hops that the opportunistic paths, however, they consist of nodes that have not been used that much and have high energy levels. EOAR does not use beaconing mechanism, for that reason it avoids the disadvantages of beaconing and this is the advantage of this EOAR protocol

4.4. Simple Opportunistic Adaptive Routing (SAOR)

SOAR is a proactive link state routing protocol. Each sensor node periodically calculates and distributes link quality in terms of ETX. According to this information, a sender chooses the default path and a list of next-hop that are suitable for forwarding the data. It then broadcasts a data packet together with this information. Upon consideration the transmission, the nodes was not present on forwarding list, just discard the packet. Nodes were present at the forwarding list store the packet and set forwarding timers based on their nearness to the destination. Smaller timer is set if the node is closer to the destination and forward the packet earlier. Upon examining this transmission, the other nodes will eliminate the resultant packet from their queues to avoid redundant transmissions. Similar to all the existing opportunistic routing protocols, SOAR broadcast data packets at a fixed PHY data rate. The advantage of SOAR is promising to achieve effectively support multiple simultaneous flows and high efficiency

4.5. EFFORT

EFFORT is another opportunistic routing protocol for WSNs. EFFORT based on the OEC (Opportunistic End-to-end Cost) metric, which represents the predictable end-to-end scarcity energy cost for each data transmission. Effort having three main components is:

- Method for OEC computation,
- Select Candidate and relay priorities
- Data forwarding and OEC is updating.

The first component enables each sensor node to calculate its optimal OEC in a dispersed manner. The second component lets every sensor node put its optimal forwarding set of its neighbors and verify the relay sequence. The third component tells how the chosen forwarders help with each other to relay data and update the OEC value consequently. Main advantage of this EFFORT routing, i.e., the improvement of transmission reliability and path diversity, to develop a distributed routing scheme for keeping up the network-lifetime of a WSN.

5. COMPARISON TABLE AND ANALYSIS

In this paper, we have compared the following routing protocols according to their design characteristics and the results are described in table 1:

Table 1 Comparison of various ORP

Name of Protocol	Power Usage	Data Aggregation	Scalability	Data delivery model	QoS
ExOR	Moderate	YES	Poor	Continuous	NO
EEOR	LOW	YES	Moderate	Event Driven	YES
SAOR	LOW	NO	Poor	Continuous	NO
EAOR	LOW	YES	Good	Event Driven	YES
EFFORT	LOW	YES	Good	Active	YES

6. CONCLUSION

Opportunistic Routing in sensor networks is a new area of research, with a limited, but quickly rising set of research results. In this paper, we presented a comprehensive survey of opportunistic routing techniques for WSNs. Overall; the routing techniques are classified based on the network structure into four categories: data centric, hierarchical, location based and opportunistic routing protocols. We also discuss various opportunistic routing protocols, and the design tradeoffs between energy and communication overhead savings in some of the routing paradigm, with the advantages and disadvantages of each opportunistic routing technique. Although several of these opportunistic routing techniques look promising, there are still many challenges that need to be solved in the WSN. We highlighted those challenges and pinpointed future research directions in this regard.

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