Data Communication Protocols in Wireless Sensor Network

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***Abstract*—Wireless Sensor Networks (WSNs) are being used in many sectors such as military, human health, and meteorology for collecting and transmitting the data by numerous nodes that are able to sense and contact. Despite these functionalities, the nodes in WSN have a limited lifetime. So, energy efficiency is as important as data collection and transmission. In order to provide this, there are two types of classification, homogeneous and heterogeneous WSN routing protocols. In heterogeneous routing protocol, the nodes have flair abilities for power and sensing. However, in this survey paper, we described some homogeneous routing protocols, in which the nodes are either same or like kind, and their subclasses by definitions, modeling, and comparisons.**

***Keywords*—Homogenous, Wireless Sensor Networks (WSN), Data-Centric, Hierarchical, Location-Based, Quality of Service (QoS)**

I. Introduction

Wireless communication occupies a very important place in today's technology. Tools that use this technology(Wireless Sensors) are very cheap and do not require any infrastructure, making them very useful. Volcano, battlefield monitoring, old building structures are some of the many areas where this technology is used. Wireless communication is done with sensors called wireless sensor communication and resulting network is called Wireless Sensor Network(WSN). These sensors are generally used to measure conditions such as temperature, sound , pollution levels, humidity, wind. Sensors are responsible for carrying these data to a processing centre which is called sink after measuring them. They use multi-hop communication for this transmission. Since these structures are wireless, they need a battery so constantly running this sensors at full power will decrease the lifetime of the battery. Therefore, it is very important to benefit from the sensor node in an energy efficient way. Engineers have developed some protocols to use this technology more effectively. Protocols on how WSNs are used while data communicating are mentioned below.

II. Data-Centric Routing Protocols

Data-centric protocols are based on the query and energy-efficient routing protocol. Fundamentally, this protocol sends the request to sensors that are able to transfer the data.Addresses of the sensors are not in the interest of the data-centric routing. Since there could be numerous sensor nodes in an area, the address assignment for every single node is unsuitable. In addition, data is sent by aggregating, and from neighbor sensor to neighbor sensor. As it is a query-based protocol, there will be less transfer and more energy saved. On the other hand, taking a long time due to complicated inquiries can be considered as a disadvantage. Below, two of important data-centric protocols is explained.

A. SPIN(Sensor Protocol for Information via Negotiation)

SPIN is one of the data-centric routing protocol. Instead of sending data, sending data about the data (metadata) is at the forefront in the SPIN routing protocol. To provide this, three kinds of messages are sent at SPIN protocol for contact, as ADV, REQ, and DATA:

- ADV: Message for advertisement. ADV message contains the metadata of the sensor and is being sent to its neighbor nodes.
- REQ: Message for requesting data. If a node received an ADV message and interested in metadata in that message, it will send a request message to the sender node of ADV.
- DATA: Original data. If a node received REQ, it sends this message to the sender node of REQ.

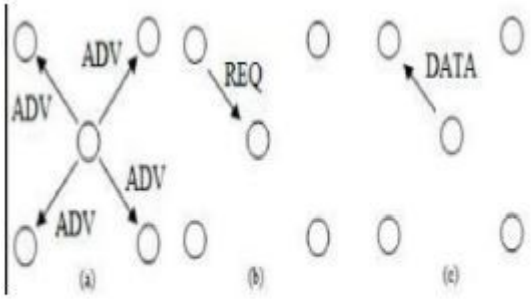
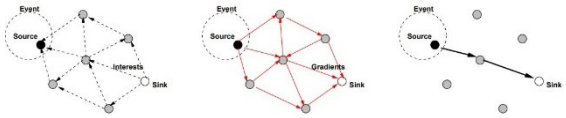


Figure 1-SPIN – (a) Data advertisement (ADV), (b) request (REQ) and (c) transferring of original DATA.

Fig. 1. Modeling of SPIN Protocol[1]

B. Directed Diffusion Protocol

Directed diffusion (DD) is also based on queries. Like SPIN, DD contains special units as interest, gradient, reinforcement, and data message. First of all, the sink node sends its packet, which is interest, to all sensors. Secondly, a tree should be constituted with all neighbor-to-neighbor and towards to sink node links of sensors, which are gradients. After that, in the tree, there could be multiple paths from source to sink. In the end, the shortest path in our tree has to be chosen which is reinforcement and data will be sent.



(a) Interest propagation (b) Initial gradients set up (c) Data delivery along reinforced path

Fig. 2. Modeling of Directed Diffusion Protocol[2]

III. Hierarchical Routing Protocols

Hierarchical routing protocols operate by clustering sensor nodes.The purpose of these protocols are to assign the sensor nodes that make up to the cluster and a cluster head to aggregate the cluster group data and forward it to the target structure. With these methods, sensor nodes do not communicate directly with the base station. Thus, while transmitting data, congestion is prevented and energy consumption is reduced. This protocols generally use multi hop communication. The different protocols in this category are :

A. LEACH(Low Energy Adaptive Clustering Hierarchy)

This protocol is known as the clustering algorithm that transmits single hop between CH(cluster heads).LEACH(low energy adaptive clustering hierarchy) protocol takes place in two phases. The first phase is called the setup phase. In this phase, clusters are regulated and a cluster head is selected. When choosing a node as a cluster head, all nodes receive a random number between 0 and 1. If the value of a node is less than the threshold value, that node is selected as a cluster head. After the cluster head is selected, this node broadcasts an announcement message. In this message it tells other nodes that it is the cluster head selected for this round.after the none cluster head nodes received this message, they decide whether they are part of this cluster or not. They generally determine this according to the signal strength of the incoming message.in other words, nodes that close to the cluster head are more likely to be selected for this cluster.The second phase is known as the steady state phase. At this phase, the actual data transfer to the base station is performed. Here the sensor nodes collect their data and transfer them to the CH. The CH receives this data and transfers it to the base station.

- LEACH-Centralized: In this, destination node regulates cluster formation and determines the CH according to the energy of each node and its distance from the base station. Each node in the network after calculating its energy, transmits this data to the destination node. Destination node collects and averages these energy levels. Then, a sensor node with a higher level of energy than this average is determined as CH.
- LEACH-MF: In this protocol, clusters consists of multiple layers and the distance between sensor nodes and CH is shortened to reduce energy consumption. Ordinary CH's are come together to form a super CH and this super CH transmits data to the base station.

B. PEGASIS(Power Efficient Gathering in Sensor Information Systems)

In this protocol, nodes communicate only with the node closest to itself. The node that furthest from the base station is chosen as the first node of this chain. The node closest to this node is selected as the second node. This chain continues like this. The last node is the node closest to the base station. Nodes combine the data received from the previous node with their own data and transfer it to the next node. PEGASIS(Power Efficient Gathering in Sensor Information Systems) protocol has emerged as an enhancement to the LEACH protocol. In LEACH, Cluster heads are randomly selected, so some CH are close to the base station while others are far away. The furthest CH consumes more energy while transmitting data to the base station. There is only one node that transmits data to the base station and that node is the closest node to the base station.

C. HEED(Hybrid Energy Efficient Distributed)

The HEED protocol was also inspired by LEACH. In the HEED, CHs are selected according to their residual energy and the degrees of the nodes. Node degrees help balance the load between the cluster heads. Clustering process in HEED protocol is performed with iterations. In every iteration, if a node is not covered by a CH, probability of becoming a cluster head for this node is doubled. With this method, cluster heads are distributed quite uniformly in the network. In this way network life is extended

IV. Location-Based Routing Protocols

Location-based routing protocols use their information on knowing locations of themselves and their neighbors. Using greedy algorithms to forward* to the destination, topology requires less energy at the same time. By those nodes, that are no activity, goes sleep. The nodes get the information of location by GPS usually. Below some protocols specified by their GPS ownership.

- Those which needs GPS : MECN,GAF,GEAR,GeRaF
- Those which does not need GPS : IHLAR,SPAN,BVGF
- (*): Greedy algorithms that find the closest path may deviate to side paths. The reason for this inaccuracy is greedy algorithms do not check all the possibilities in the problem even so they are pretty fast.

A. GAF(Geographical Adaptive Fidelity)

In this protocol, each node has GPS sensors in it. From that every node supported to remember itself with a point on the virtual grid. Nodes which are at the same grid managed by the already awaken node. By that each grid stays connected. Hence, GAF can substantially increase the network lifetime as the number of nodes increases.Information about grids edges and their locations given at the figure below."Fig. 3"

GAF uses these three states:

- Discovery. Finding out the other nodes in the same grid.
- Active. The node is participating in the routing.
- Sleep. The radio of the node is turned off.

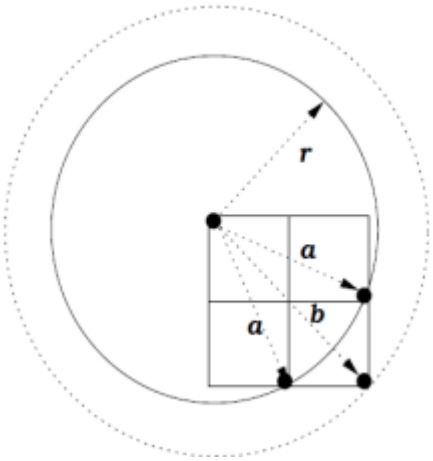


Fig. 3. Grids and edges and their locations[3]

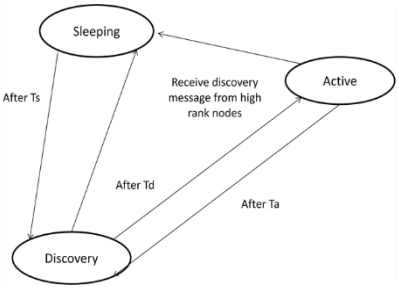


Fig. 4. GAF States[3]

B. GEAR(Geographic Adaptive Fidelity)

Each node in this population, keeps an estimated cost and a learning cost.A hole appears when a node has not got any neighbor node closer it than itself. To avoid this problem. GEAR tracks these costs. Estimated cost by computation from routes can reach to the destination node.Learning cost by tracking real energy expense around holes. For each time a packet reaches the destination node the learned cost is updates itself one hop back, thereby it adjusts the route setup for the next packet. Each node in this protocol knows the location of itselves and their neighbor, also they know the disposable energy for these nodes. By that GEAR algorithm can calculate a heuristic way to destination by recursive forward.

GAF		GEAR	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Optimize the performance of WSN	High overhead	Increase the network lifetime	High overhead
Highly scalable	Doesn't take care of QoS during data transmission	Reduces energy consumption	Doesn't take care of QoS during data transmission
Maximize the network lifetime	Limited mobility		Limited mobility
Limited energy conservation	Limited power managemenet		Limited power management Limited scalability

Fig. 5. GAF and GEAR comparison

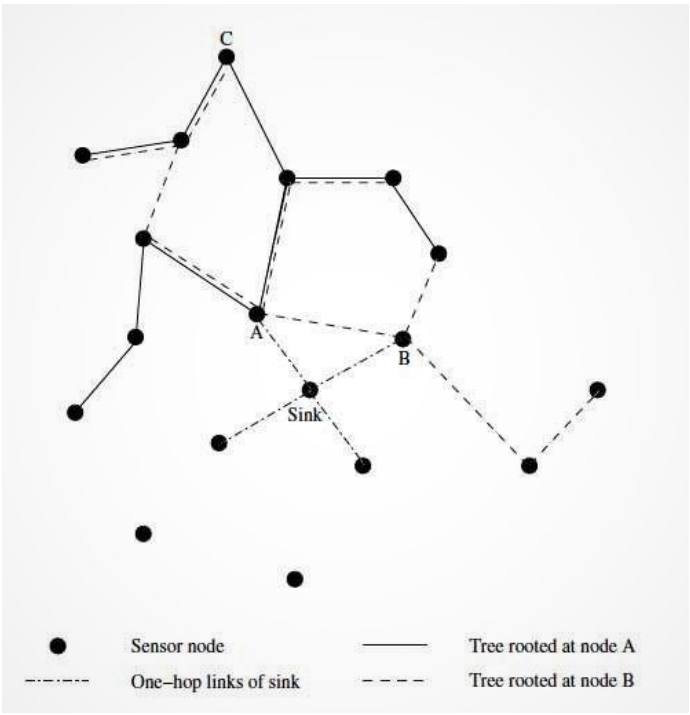


Fig. 6. Sequential assignment routing[4]

V. Network Flow and QoS-Aware Routing Protocols

QoS-aware protocols present as a modular approach, by considering QoS metrics(Delay, jitter, throughput, packet loss) for each module. Our goal is the make less energy consumption and get more data quality, in order to do that we need to consider factors such as delay, energy, bandwidth so that we can use our energy efficiently. These protocols goal to provide higher reliability, lower delay, and higher packet delivery ratio.

A. SAR(Sequential Assignment Routing)

SAR is one of the first protocol that takes into consideration the concept of QoS in routing decisions. It makes routing decisions based on QoS metrics, energy resources, and priority of each packet. Routing trees start from the children of the sink node(one-hop neighbors). Each node knows the routing information of every other node in the network so, in case of any failure, we want to maintain the routing table consistency and any local failure solve its problem locally by creating automatic path restoration. The priority level is an important part of SAR, we want to keep 'priority level * delay' stable. That means if some package with high priority comes, it goes from the low delay route, and package with low priority goes from the high delay route. In SAR many paths are built from the base node according to the criteria that SAR protocol has. So its main setback is 'overhead', during table routing and maintaining states at every sensor node."Fig. 6"

B. SPEED(Stateless Protocol for Real-Time Communication in Sensor Networks)

SPEED protocol is a significant real-time communication protocol with the goal of routing packets at the desired speed for sensor networks. This protocol has 3 types of real-time communication services, if it is about sensing andis about making demands on some end-to-end route area: Multicast. If any response is good for us from any node in the area, it is called area-anycast. Speed uses non-deterministic geographical forwarding to identify routes in order to do that every node should have its neighbor's information(Memory requirements are minimal) and it integrates forwarding with feedback control to get maintenance in delivery speed. SPEED is a good fit if some nodes have scarce resources, it is a localized and stateless protocol that has minimal control overhead.

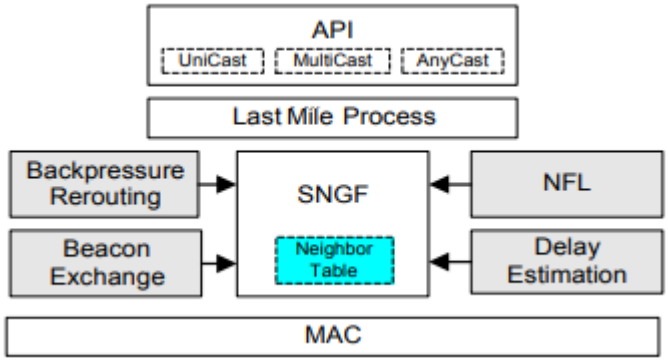


Fig. 7. Speed Protocol[5]

SNGF is responsible for choosing the next node in order to maintain delivery speed.NFL and Back pressure are modules to reduce or split traffic if any congestion occurs. Delay Estimation is for understanding if any congestions occur. Last Mile Process is responsible for supporting three communication semantics. Beacon Exchange supplies the geographic location of neighbors so that SNGF can do the routing.SPEED guarantees the desired delivery speed across the network.

VI. Conclusion

WSNs are limited in communication coverage when we compare nodes with the size of the area that nodes scattered. Therefore, there is multi-hop communication through the source to destination, in order to do that we need to consider nodes are limited in capabilities. Energy is the most important subject in WSNs, in this paper we explained some of the approaches in homogeneous WSNs. At base, all of the routing protocols in this paper are energy-efficient protocols but not all of them put energy efficiency to the top. Such as in QoS classification. In QoS, the quality of data is important but we need to also consider energy consumption. In Hierarchical classification, nodes are unable to communicate to very large distances so we can use hierarchical routing protocol such as LEACH to overcome that problem. In Location classifying, If we have lots of nodes and we know their location by low energy GPS device, we can create an energy-efficient environment since not all of the nodes need to work and some of them can sleep. If we want more event handling, optimal route finder, more user interaction but with high latency, we can use the Data-Centric classification approach. We explained some of the classifications in homogeneous WSNs and their limitations, what these protocols do best based on some of the several specifications.

	Classification	Mobility	Position Awareness	Power Usage	Negotiation based	Data aggregation	Localization	QoS	State Complexity	Scalability	Multipath	Query based
SPIN	FLAT	Possible	No	Limited	Yes	Yes	No	No	Low	Limited	Yes	Yes
Directed Diffusion	FLAT	Limited	No	Limited	Yes	Yes	Yes	No	Low	Limited	Yes	Yes
LEACH	Hierarchical	Fixed BS	No	Maximum	No	Yes	Yes	No	CHs	Good	No	No
PEGASIS	Hierarchical	Fixed BS	No	Maximum	No	No	Yes	No	Low	Good	No	No
GAF	Location	Limited	No	Limited	No	No	No	No	Low	Good	No	No
GEAR	Location	Limited	No	Limited	No	No	No	No	Low	Limited	No	No
SAR	QoS	No	No	N/A	Yes	Yes	No	Yes	Moderate	Limited	No	Yes
SPEED	QoS	No	No	N/A	No	No	No	Yes	Moderate	Limited	No	Yes

Fig. 8. Comparison Table of the in context Protocols[6]

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