Survey of Wireless Sensor Network Protocols

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***Abstract*—Wireless sensor networks need to be energy-efficient, time-efficient and reliable. Various protocols have been devised to achieve these goals. Each protocol has strong and weak points. We try to give a survey of some of the protocols used in wireless sensor networks.**

***Index Terms*—sensor, protocol**

T-MAC

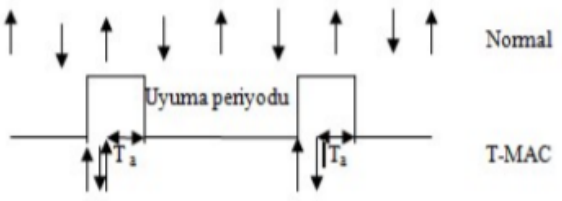

Fig. 1. T-MAC Timeline

Timeout Medium Access Control (T-MAC) is a CSMA based protocol. It has been developed influenced by the S-MAC protocol. According to S-MAC, it is frugal in energy expenditure. In T-MAC, neighboring nodes wake up sequentially by communicating with each other. Therefore, they do not spend much energy, but it may cause delays.

If a node is idle for a certain period of time, it will sleep. In cases where data is received from sensors for a long time, it will lose its advantage. Once active, it will remain active as the data continues to come. When there is no data for a certain period of time, it will go back to sleep and wake up periodically. [1] [2] [3] [4]

COUGAR

COUGAR is a data-centric protocol that treats the network like a database. In this protocol, nodes collect data and transmit them to the leader node via their intermediary. There is a query layer located between the network and application layers. Query plan is created to make data flow and calculations. How to select the leader node in the query plan is also determined. This protocol provides in-network computing capability for sensor nodes. Although it is connected to the leader node, it saves energy in situations with frequent and large data flow.

To look at the disadvantages of the COUGAR protocol:

It causes an increase in energy consumption and memory usage due to the query layer added to the nodes. There is a high probability of malfunction. To transfer data to the leader node, the nodes must be synchronized. [5] [6] [7]

LEACH

Low-Energy Adaptive Clustering Hierarchy (LEACH) is a clustering based protocol that uses a randomized rotation of local cluster base stations.

LEACH is the first and most favored hierarchical clustering protocol in wireless sensor networks (WSNs), which is energy efficient, meanwhile it is one of the distributed cluster-based protocols.

LEACH was proposed for reducing power consumption and also to increase the lifetime of the wireless sensors, in the same time the life time of the network with using clusters. Because in WSNs it is not efficient to change the battery of sensors..

In LEACH routing protocol, sensor nodes organize themselves into clusters. For every cycle, this protocol executes self-organizing and re-clustering functions.

Also, it eases the nodes with more leftover energy have more chances to be selected as cluster leader, or head.

Energy load must be equally distributed among all sensor nodes, in order to prolong the lifetime of the whole sensor network, so that the energy at a single sensor node or a small set of sensor nodes will not be exhausted very soon.

In clusters, one of the sensor node acts as cluster-head and remaining sensor nodes as member nodes of that cluster. In order to communication to sink, member nodes must use cluster-head as intermediate route. Only cluster-head can directly communicate to sink.

Cluster -head has additional responsibilities, like collecting data from all the nodes, aggregate those data and route all meaningful information to sink.

Because of these additional responsibilities Cluster-head consumes more power and if it remains cluster-head permanently it will die quickly as happened in case of static clustering.

LEACH solves this problem by randomized rotation of cluster-head. We must do this if we want to save the battery of each node.

LEACH maximizes life time of network nodes and also reduces the energy consumption which caused by sending data, by compressing the data before transmitting to cluster-head.

Leach requires the global knowledge about the network. Because, it is a protocol which is completely distributed . In order to accomplish the design purpose, the key tasks performed by Leach are as follows,

- Randomized rotation of the cluster heads and the corresponding clusters.
- Global communication reduction by the local compression.

- Localized co-ordination and control for cluster setup and operation.
- Low energy media access control.
- Application specific data processing.

The Leach operation is divided into different parts and each of these parts having mainly two phases and these are called,

- Setup phase For the process of organizing the whole network into different intra-clusters Advertisements of the cluster heads to its different individual cluster members Transmission of the schedule that has been created during the setup phase only
- Steady state The process of data aggregation within the different clusters of the network Compression of the sensed information that is being sensed by the sensor node into its different cluster head within the cluster only Transmission of the compressed data to the sink via different cluster heads.

Advantages of LEACH:, It provides scalability in the network by means of limiting most of the communication inside the different clusters of the network. The cluster heads aggregates or fuses the information that is been collected by the sensor nodes and this helps in to limit high amount of traffic generated within the network. By this means, a large-scalable network without traffic overload can be deployed and by this also better energy efficient network topology can be achieved as compared to the flat-topology. We can able to save the energy of the network, because single-hop routing is possible from sensor node to cluster head. It does not require the information of location of the sensor nodes in the network to create the clusters. Therefore it is very powerful routing protocol and it is very much simple.

Disadvantages of LEACH: Failure of the cluster heads can cause robustness issues. Because, LEACH significantly relies on cluster heads rather than cluster members of the cluster for communicating to the sink. LEACH is not best suited for large-scale networks that interns require single hop communication with sink. There is no inter-cluster communication in the network because CHs directly communicate with sink. This process requires high range of transmission power in the network. It incurs additional overheads due to the process of cluster head changes in each iterations of the communication of information. It also incurs overhead due to calculations which leads to the energy inefficiency for dynamic clustering in large scale networks. CHs can be located at the edges of the cluster, because in LEACH CHs are not uniformly distributed within the cluster. It does not work well with the applications that require large area coverage along with multi-hop inter-cluster communication. [8] [9] [10] [11] [12]

SPIN

Sensor Protocols for Information via Negotiation (SPIN) is a flat network routing protocol that disseminates all the information at each node to all nodes in the network, assuming that all nodes in the network are potential base stations. Thus, an user can get the required information immediately, by querying any node. These protocols make use of the trait that nodes in close proximity have similar data, and so only the data which other nodes do not posses needs to distribute. To be sure that there is no unnecesary data sent throughout the network, the SPIN family of protocols uses data negotiation and resource-adaptive algorithms. Nodes running SPIN assign a high-level name to fully define their collected data (called meta-data) and perform metadata negotiations before any data is transmitted. The semantics of the meta-data format is application-specific and not specified in SPIN. For example, sensors might use their unique IDs to report meta-data if they cover a certain known region. Besides, SPIN has access to the current power 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 intended to point out the deficiencies of classic flooding by negotiation and resource adaptation. The SPIN family of protocols is designed based on two main 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, sensor and image nodes must monitor the changes in their energy resources.
2) Conventional protocols like flooding or gossiping-based routing protocols [11] waste bandwidth and energy when sending extra and redundant 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 send similar packets to the same neighbor, and resource blindness in consuming large amounts of energy without consideration for energy constraints. Gossiping avoids the problem of implosion by just selecting a random node to which to send the packet rather than broadcasting the packet blindly. However, this causes delays in propagation of data through the nodes. SPIN's meta-data negotiation fixes the classic problems of flooding, thus achieving a lot of energy efficiency.

Sensor nodes use three types of messages, ADV, REQ, and DATA to communicate, thus we can say that SPIN is a three-stage protocol. ADV is used to advertise new data, REQ to request data, and DATA is the actual message itself. The protocol starts when a SPIN node obtains new data it is willing to share. It does so by broadcasting an ADV message containing meta-data. If a neighbor is interested in the data, it sends a REQ message for the DATA and the DATA is sent to this neighbor node. The neighbor sensor node then repeats this process with its neighbors. As a result, the entire sensor area will receive a copy of the data.

The SPIN family of protocols includes many protocols. The main two are called SPIN-1 and SPIN-2; they incorporate negotiation before transmitting data in order to ensure that

only useful information will be transferred. Also, each node has its own resource manager that keeps track of resource consumption and is polled by the nodes before data transmission. The SPIN-1 protocol is a three-stage protocol, as described above. An extension to SPIN-1 is SPIN-2, which incorporates a threshold-based resource awareness mechanism in addition to negotiation. When energy in the nodes is rich, SPIN-2 communicates using the three-stage protocol of SPIN1. However, when the energy in a node starts approaching a low threshold, it reduces its participation in the protocol; that is, it participates only when it believes it can complete all the other stages of the protocol without going below the low energy threshold.

In conclusion, SPIN-1 and SPIN-2 are simple protocols that efficiently disseminate data while maintaining no per-neighbor state. These protocols are well suited to an environment where the sensors are mobile because they base their forwarding decisions on local neighborhood information. Other protocols of the SPIN family are ([3, 7] for more details):

- SPIN-BC: This protocol is designed for broadcast channels.
- SPIN-PP: This protocol is designed for point to point communication (i.e., hop-by-hop routing).
- SPIN-EC: This protocol works similar to SPIN-PP, but with an energy heuristic added to it.
- SPIN-RL: When a channel is lossy, a protocol called SPIN-RL is used where adjustments are added to the SPIN-PP protocol to account for the lossy channel.

One of the benefits of SPIN is that topological changes are localized since each node need know only its single-hop neighbors. SPIN provides more energy savings than flooding, and metadata negotiation almost halves the redundant data.

On the other hand, disadvantages of SPIN is, it's data advertisement mechanism cannot guarantee delivery of data. To see this, consider the application of intrusion detection where data should be reliably reported over periodic intervals, and assume that nodes interested in the data are located far away from the source node, and the nodes between source and destination nodes are not interested in that data; such data will not be delivered to the destination at all. [13] [14] [15]

	SPIN	LEACH	Directed diffusion
Optimal route	No	No	Yes
Network lifetime	Good	Very good	Good
Resource awareness	Yes	Yes	Yes
Use of meta-data	Yes	No	Yes

Fig. 2. Comparison of SPIN and LEACH

TEEN

TEEN (Threshold sensitive Energy Efficient sensor Network protocol) is the first routing protocol that has developed for reactive networks.

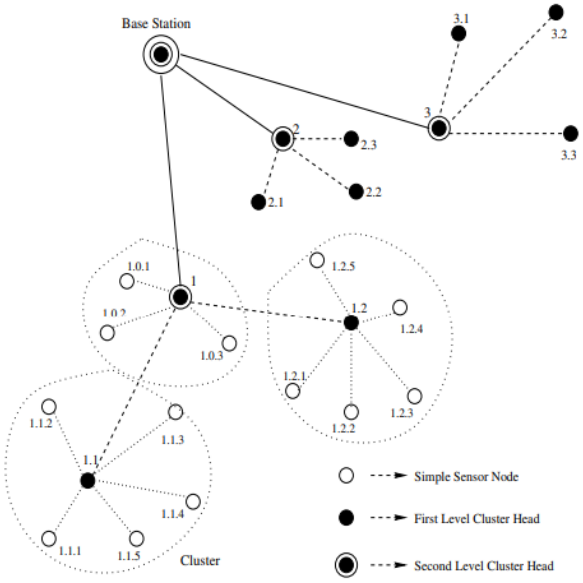

Fig. 3. Hierarchical Clustering

- **Functioning:** There are two thresholds in this protocol. First one is Hard Threshold (HT) and the other is Soft Threshold (ST). If the sensed absolute value is higher than Hard Threshold, node reports it to its cluster head. If there is a small change that trigger Soft Threshold, node switches on its transmitter. Nodes transmit data when either sensed value is higher than HT or current value differs from sensed value by at least Soft Threshold. After the trasnmittion, sensed value is set to current value.
- **Important Features:** Since the data arrival is fast, this protocol is suitable for time-critical applications. The amount of energy consumed by sensing data is far less than message transmission, so it consumes much less energy than a proactive network. Accuracy of data is adjustable by the value of Soft Threshold.

Main disadvantage of this protocol is that if sensed value never exceedes thresholds there will be no data received by user so it's not suitible for applications that need data transmition on regular basis. [16]

PEGASIS

Wireless Sensor Network is sensors that deployed in a region for purposes such as monitoring temprature, presure, wind speed, traffic, health etc.

1) Establishing the chain: The chain establishment starts from the base station, then every link is selected based on nodes' wave intensity. Nodes that are already selected can't be linked again so that a single bond consists of all the links can be created.

2) Selection of the Leader Link: In order to maintain strong detector network, irregular link chooses the leader which locates at irregular place. Since it's important to ensure equal weight of strength consumption, a new leader is chosen each circular.

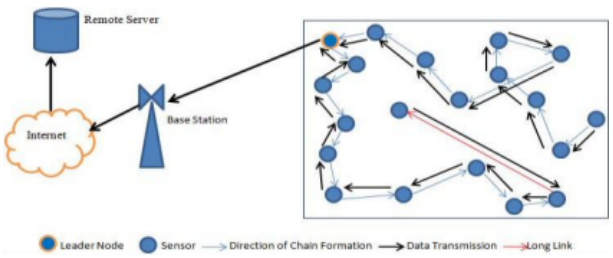

Fig. 4. Wireless Sensor Network Illustration with PEGASIS without connecting bonds.

3) Data Forwarding: If the leader is at the beginning of bond as shown in 5, N1 passes token all the way to the N7. After N7 transfers data, N7 passes the token to N6 and it goes like this until N1 receives the token back. When N1 receieved the token, it transfers its data. If the

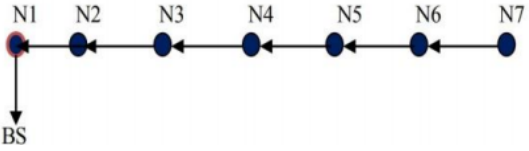

Fig. 5. Data forwarding illustration in bond at the beginning of the bond with the leader.

leader link is in the middle of leader bond as shown in 6, N4 passes the token to one of the directions. After data transfers done in that direction and N4 receieves token back, it passes the token to other direction. When N4 receieves token back again, it transfers its own data too.

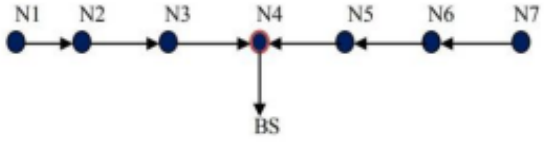

Fig. 6. Any intermediate node is an illustration of information forwarding in the leader bond.

4) Conclusion: PEGASIS based communication protocols have big time delays which makes them inappropriate for real time apps,. They also got greedy chain formation. Other problem is that the have bad capacity for weight balance. However, they are effective in terms of resistance but surely weighting ability and performance of delivery are still need to be improved for these protocols.

[17]

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