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Event Driven Routing Protocols For Wireless Sensor Networks

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Abstract

This paper introduces a comparative study for the two most popular event-driven routing protocols used in wireless sensor networks, Directed Diffusion (DD) and Sensor Protocol for Information via Negotiation (SPIN). These protocols are analyzed using varying mobility models to reveal the important features that need to be taken into consideration while designing and evaluating a new event-driven routing protocol for wireless sensor network.

Keywords— wireless sensor networks, event-driven routing protocols, simulation, performance comparison.

INTRODUCTION

Wireless Sensor Networks are networks that consist of distributed sensors in required area. These sensors work with each other to sense some physical phenomenon and then the information are gathered to get relevant results. They consist of protocols and algorithms with self-organizing capabilities. Wireless sensor networks are applied on many applications to monitor an object or an area or both of them. There are many applications for monitoring area such as, environmental and habitat, agriculture, indoor climate control, military and intelligent alarms [1].

An event-driven routing protocol is considered a data centric routing protocol because it can find routes from multiple sources to a single sink, and allows data aggregation. However, data centric is more general which includes application-specific, time-driven, event-driven, and query-driven methods [2], [3]. This paper evaluates the performance of two event-driven routing protocols Directed Diffusion(DD) and Sensor Protocol for Information via Negotiation (SPIN) using different performance metrics and mobility models. NS2 Simulator [4] is used to simulate and analyze the important features needed to be taken into consideration while using SPIN and DD routing protocols under dynamic manipulation. The performance metrics that are used in the comparison included Energy Ratio, Packet Delivery Ratio, delay, energy consumption, throughput and Network Lifetime for two different mobility models Random waypoint and RPGM

This paper is organized as follows. Section 2 provides a brief overview of the event-driven routing protocols and discusses the background information related to these protocols. Section 3 describes the results through performance comparison of random way point mobility model. Section 4 describes the performance comparison of RPGM. Section 5 describes the performance comparison of Manhattan mobility model, and analyzes the simulation results for SPIN and DD routing protocols.

EVENT-DRIVEN ROUTING PROTOCOLS

DD and SPIN are event-driven routing algorithms. Directed diffusion key features are named attribute value pairs and path reinforcement. It is a reactive routing protocol which creates paths based on need, not ahead of time. Sensed data is stored in attribute-value pairs. When a node known that a sink node wants information about a particular attribute, it broadcasts interest messages to its neighbors. These interest messages are flooded through the network added to each node's interest cache. Each interest record in this cache has one or more gradients which correspond to neighbor nodes that transmitted the interest. The gradient also stores the rate at which data is desired, the duration of the interest, and a timestamp. When a node generates data that matches an interest in its cache, it sends the data back to the source along the gradients. The data is sent to the sink through the gradients. The sink node may reinforce the shortest path (i.e., the one with the fastest response) by sending an interest with a higher data rate along that path. Intermediate nodes propagate the reinforcement by examining a local cache of recently sent data messages. [5, 6].

The SPIN protocol is controlled flooding protocols. The design goal for the SPIN protocol was to address the broadcast storms, overlap problems, and resource blindness of traditional flooding protocols. The SPIN protocol uses data negotiation and resource-adaptive ideas. Nodes running SPIN perform metadata negotiations before each data transmission. This ensures that no redundant data is transmitted. The SPIN protocol starts with a source broadcasting an ADV message containing metadata for its data. Each node in its transmission range will then respond with a REQ message if it is interested in the data. The DATA is then sent to the interested nodes. The process is recursive; as a result, all the nodes in the network that are interested in the data will eventually receive a copy. [7, 8*]*

SIMULATION SETUP

The network grid is 220x220 meters. The nodes are randomly distributed and the movement is generated by Bonnmotion [9]. The base station is placed at the origin of the network topology, at location x = 0, y = 0. All sensor nodes start with a fixed amount of energy 100j. Number of nodes is (10, 25, 50, 75, 100 and 150). Data size is 1000 byte. Transmission range is 250 m. Disseminating interval is 20.0 second. Transmission energy consumption is 36 mw. Reception energy consumption is 24 mw and simulation time is 500 second.

RANDOM WAYPOINT MOBILITY MODEL

In this section, different performance metrics are taken into account such as energy ratio, packet delivery ratio, delay, energy consumption, throughput, and network lifetime. In what follows, each performance metric is measured by sets of experiments.

A. Packet Delivery Ratio

Packet delivery ratio is calculated by the ratio of the number of routing messages propagated by every node in the network and the number of data packets successfully delivered to all destination nodes. In Fig. 1, the graph shows that the total dropped packets by SPIN are lower than DD. The maximum SPIN packet delivery ratio occurred at 10 sensor nodes at which the ratio is 93%.

The maximum DD packet delivery ratio occurred also at 10 sensor nodes at which the ratio is 87.6%. And when the number of the nodes increased the packet delivery ratio decreased for both protocols. The minimum SPIN packet delivery ratio occurred at 250 sensor nodes at which the ratio is 89.3%. And the minimum DD packet delivery ratio occurred at 250 sensor nodes at which the ratio is 81.2%. Another result is based on the packet delivery ratio graph is that the packet received by nodes decreases from the first 10 nodes. This is because nodes in DD that links to the shortest path nodes and the gradient links generate overhead and reduce the life time of the nodes in the network.

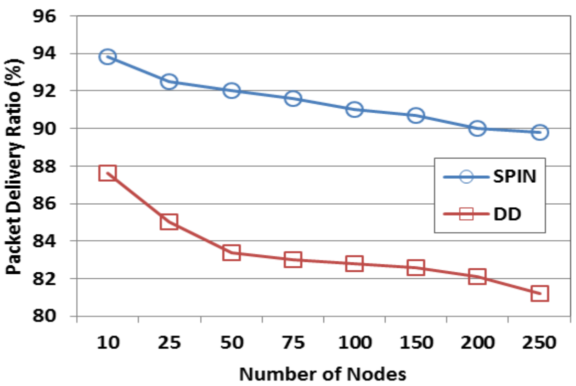

Figure 1 Packet Delivery Ratio at Random Waypoint Mobility Model

When the nodes move under random waypoint, the topology and links for every node will change. The distance for transmitting and receiving packet will be a bit larger and will consume a lot of energy. In case of SPIN the packet delivery ratio are actually higher than the directed diffusion because having meta-data actually increase the efficiency of a network using SPIN protocol as the sensor nodes will transmit almost zero redundant data packet and decrease the operation of sending wasted data packets.

B. Routing overhead

Routing overhead is calculated by the ratio of the number of routing messages propagated by every node in the network and the number of data packets successfully delivered to all destination nodes. Figure 2 shows that SPIN and DD performance is particularly the same, delivering over 100 nodes.

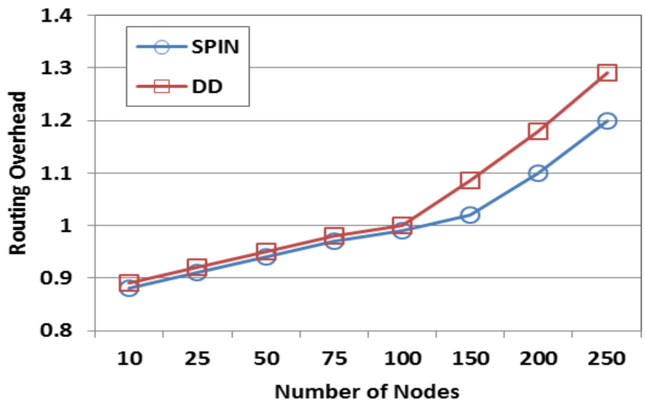

Figure 2 Routing Overhead at Random Waypoint Mobility Model

When the nodes number exceeds 100 nodes, the SPIN protocol showed better routing overhead than DD. This is because DD has overhead to find new paths, because the nodes are moving in different ways. When existing paths are not found there is overhead and this leads to the lose of the event, which is reflected on the performance as a whole. SPIN show better performance than DD because it has no specific route that all the nodes depend upon as DD has.

C. End-to-End Delay

The average delay measures the average one-way latency observed between transmitting an event and receiving it at each sink. Fig. 3 shows End-to-End Delay results for Random Way Point mobility model. Both protocols continued to increase the average delay after 50 nodes. The delay of SPIN as compared to DD is approximately the same during the first 50 nodes then after that the DD delay is increased at certain limit over the SPIN. The results show that the DD perform well as compared to SPIN because the packet delivery ratio for SPIN is higher than DD.

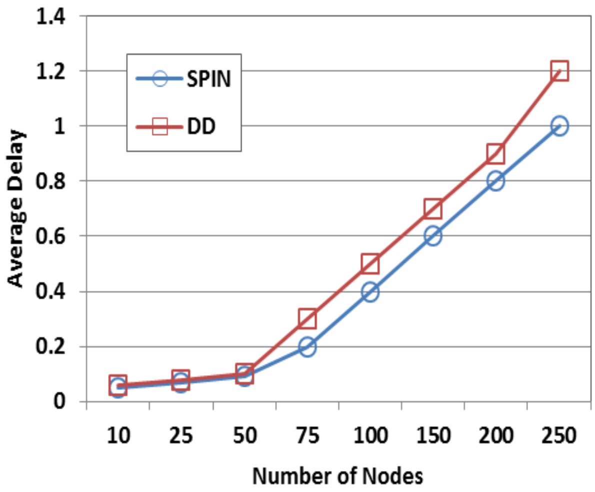

Figure 3 End-to-End Delay at Random Waypoint Mobility Model

D. Throughput

In Fig. 4, SPIN throughput achieves higher values than DD. This happened because delay constrained the throughput in each of the two protocols. As shown in Fig. 4, DD gives higher average delay than SPIN. This leads to lower throughput. The more nodes are added to the network area the lower the throughput because data centric protocols enable sensor data to be disseminated from data sources to sinks with low delay. In addition, dissemination also requires high bandwidth and delivery ratio, which cannot be guaranteed by a single path.

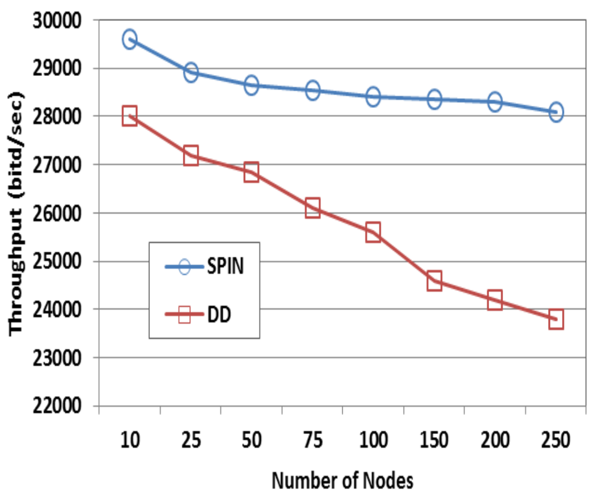

Figure 4 Throughput at Random Waypoint Mobility Model

E. Energy consumption

In Fig. 5, the energy consumption of the network increases rapidly with increasing the number of nodes. This is because the effect of transmitting and receiving data in the network. In DD, the sensor node will find the shortest path, and then later it is set to the appropriate gradient for the path which enables the node to transmit and receive the appropriate packet or data. The rapid uses of the gradient path also contribute to decrease the energy because this rapid use is due to the node only transmitting and receiving data packet with one gradient path which is the main basic operation for this routing protocol. Also the node has to make sure that the transmitting and receiving duplicate data or packet can be eliminated over this gradient path. On the other hand, SPIN with the same parameters, the energy decreases at a much slower rate. This proves that having meta-data actually increase the energy efficiency of a network because SPIN will start with advertising its interest, then waiting a request from any node before start transmitting data again. The result proves that meta-data negotiation keeps SPIN nodes from sending out even a single redundant data packet in a network so consume less energy. Based on these results some of the desirable features of a good energy efficient routing protocol for sensor network are Random path selection. If a routing algorithm can support multiple paths to a destination with low overhead, it could help in balancing the network load and data grouping. If nodes could classify and aggregate data, it helps in efficient query processing, and decrease network overhead. In conclusion, as referring to data centric routing, SPIN having slower rate in decreasing energy which is much better than directed diffusion. This proves the fact that having meta-data negotiation increases the energy efficiency of a network.

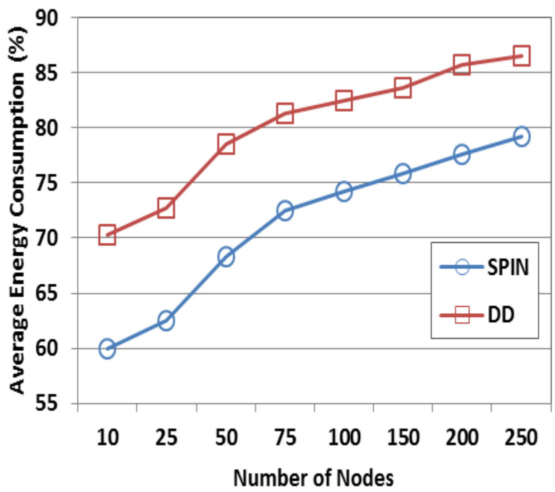

Figure 5 Energy Consumption at Random Waypoint Mobility Model

F. Network lifetime

Sensor node lifetime shows a strong dependence on the battery lifetime However, in many applications, conservation of energy, which is directly related to network lifetime, is considered relatively more important than the quality of data sent. As the energy gets depleted, the network may be required to reduce the quality of the results in order to reduce the energy dissipation in the nodes and hence lengthen the total network lifetime. In wireless sensor nodes aggregation, eliminating redundancy, minimizing the number of transmissions are factors which save network energy and prolonging its lifetime.

As shown from Fig. 6 it is obvious that the SPIN lifetime is better than DD because the energy depletion was more in DD than in SPIN. The maximum value of the SPIN is 231 alive nodes and for DD is 206 alive nodes at 250 nodes and the minimum value for SPIN is 10 alive nodes and for DD is 9 alive nodes at 10 nodes. As a result the random way point decreased the performance of the DD than of the SPIN because the geographic forwarding direction is not continuously corrected based on distributed destination mobility knowledge among nodes in the routing path, so a source may fail to find a route to a mobile sink. Also, it is overload to keep updating a neighbor table to deal with mobility, and an inadequate update usually leads to failure of data forwarding. Neighbor location usually changes, so in case of DD there is a fixed gradient path so when neighbor nodes move their locations, a new path should be made. In contrary to SPIN that doesn't have fixed routing path.

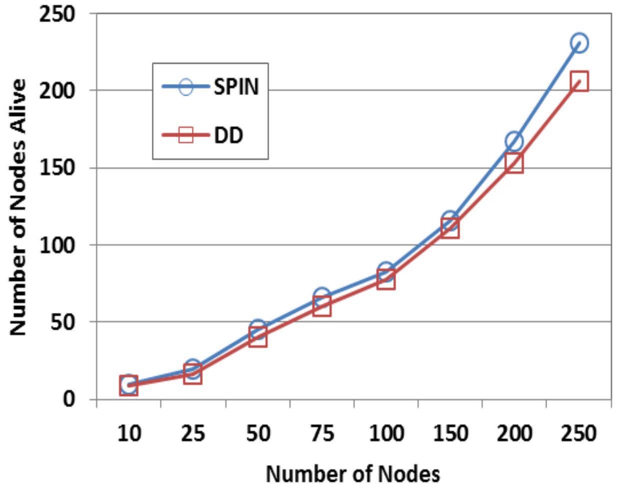

Figure 6 Network Lifetime at Random Waypoint Mobility Model

RPGM BASED PERFORMANCE COMPARISONS

A. **Packet Delivery Ratio**

In this mobility model, DD performed better than SPIN as shown in Fig. 7 where DD is dependent on the mobility pattern and has a fixed path between nodes. For RPGM the nodes move in groups so each gradient path remain most the time the same which benefit in delivering the packets. The distance for transmitting and receiving packet will remain the same most of the time.

B. **Routing overhead**

Both SPIN and DD performs well under RPGM mobility models in terms of Routing Overhead compared to Random Way Point. DD incurs same routes and it has no overhead to find new paths, because the nodes are moved in groups so the same rout path still exist. When existing paths are still found there is no overhead and this leads to maintaining the same event and not losing it, which is reflected on the high performance as a whole.

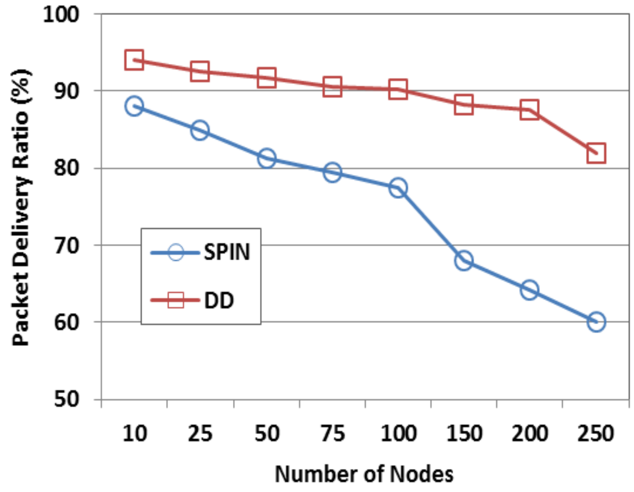

Figure 7 Packet Delivery at RPGM Mobility Model

The RPGM increases the performance of SPIN and DD. But SPIN show lower performance than DD because it has no specific route that all the nodes depend upon as DD has, but its algorithm can manage under any change of the nodes area.

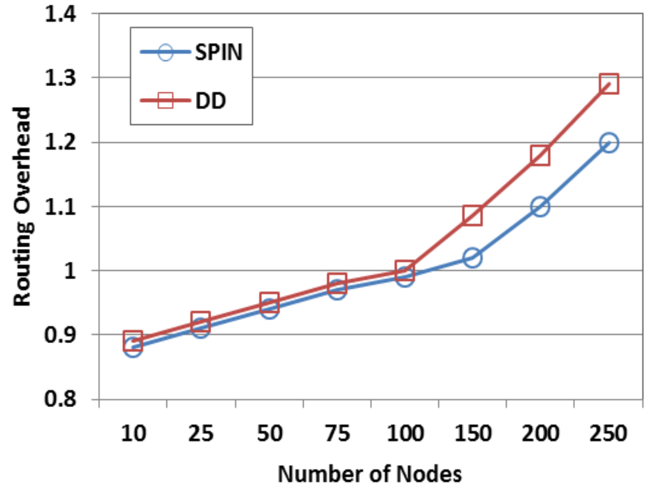

Figure 8 Routing Overhead at RPGM Mobility Model

C. **End-to-end delay**

The minimum average end to end delay for both the protocols occurred at 10 nodes the minimum value for SPIN is 0.032 S and for DD is 0.031 S. Accordingly, they both continued to increase the average delay. The maximum value for SPIN is 0.16 S and for DD is 0.15 S at 250 nodes. The delay of SPIN as compared to DD has increased at certain limit over the DD. It results that the DD perform better than SPIN because the shortest path is also the lowest delay path.

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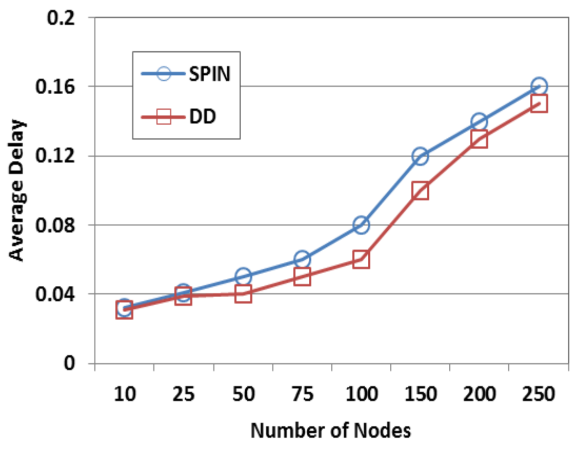

Figure 9 delay at RPGM mobility model

D. Throughput

Figure 10 shows that DD throughput achieves higher values than SPIN. This happened because delay constrained the throughput in each of the two protocols. As shown in Fig. 10, SPIN gives higher average delay than DD. This leads to lower throughput. The more nodes are added to the network area the lower the throughput because data centric protocols enable sensor data to be disseminated from data sources to sinks with low delay.

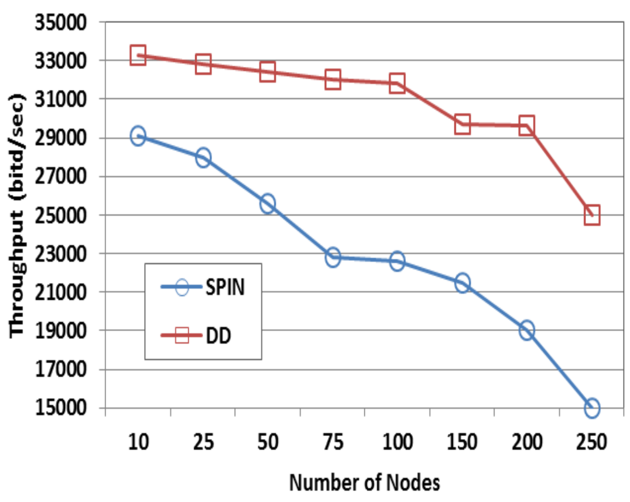

Figure 10 Throughput at RPGM mobility model

E. Energy consumption

In Fig. 11, DD the sensor node will find the shortest path, and then later it is set the appropriate gradient for the path which enables the node to transmit and receive the appropriate packet or data.

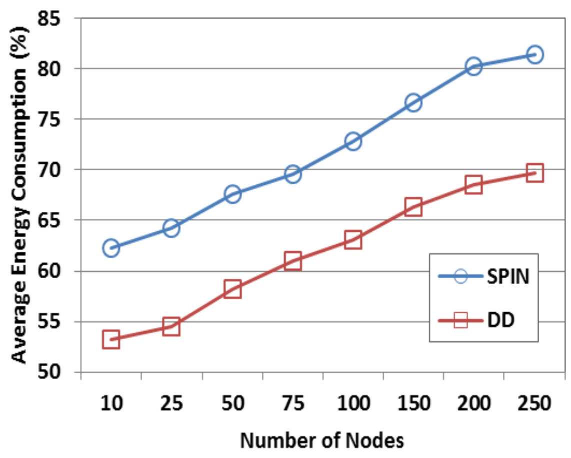

Figure 11 Energy Consumption at RPGM Mobility Model

DD incurs same routes and it has no overhead to find new paths, because the nodes are moved in groups so the same rout path still exist. When existing paths are still found there is no energy loss and this leads to maintaining the same event and not losing it, which is reflected on the higher performance as a whole. But losing the energy of the sensors in case of RPGM has decreased more than in Random Way point so RPGM gives longer lifetime for the network. As a result the RPGM is recommended to be used than Random Way Point.

F. Network lifetime

As shown from Fig. 12 the maximum value for SPIN is 179 alive nodes and for DD is 197 alive nodes at 250 nodes.

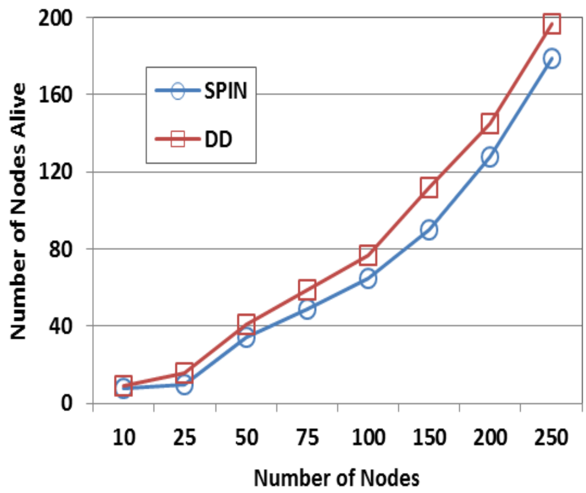

Figure 12 Network Lifetime at RPGM Mobility Model

The minimum value for SPIN is 8 alive nodes and for DD is 9 alive nodes at 10 nodes. It is obvious that the DD lifetime is better than SPIN because the energy depletion was more in SPIN than in DD. As a result the RPGM decreased the performance of the SPIN than of the DD because the geographic forwarding direction is not continuously corrected based on distributed destination mobility knowledge among nodes in the routing path, so a source may fail to find a route to a mobile sink. Also, it is overload to keep updating a neighbor table to deal with mobility, and an inadequate update usually leads to failure of data forwarding. Neighbor location usually changes.

CONCLUSION

This paper introduces a comparative study for the two most popular event-driven routing protocols used in wireless sensor networks, Directed Diffusion (DD) and Sensor Protocol for Information via Negotiation (SPIN). It is revealed that directed diffusion is not a good choice for dynamic applications, where continuous data delivery is important. Moreover, the query types as well as the interest matching procedures need to be defined for each application. Finally, the matching process for data and queries causes some overhead at the sensors. On the other hand, SPIN protocol suffers from the uncertainty of the data delivery. In another word, if the nodes that are interested in the data are far away from the source node and the nodes between source and destination are not interested in that data, such data will not be delivered to the destination at all. Therefore, SPIN is not a good choice for certain applications. In the future, a new event driven routing protocol will be proposed to alleviate the drawbacks of Directed Diffusion and SPIN routing protocols.

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