A Modified SPIN for Wireless Sensor Networks

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Abstract— Data transmission is one of the major challenges in wireless sensor network (WSN). Different routing protocols have been proposed to save energy during data transmission in WSN. Routing protocols based on data-centric approach are suitable in this context that performs in-network aggregation of data to yield energy saving data dissemination. In this paper we propose a modified version of SPIN protocol named M-SPIN and compare its performance with traditional SPIN protocol using broadcast communication, which is a well known protocol as benchmark. We evaluate the M-SPIN protocol using simulation in TOSSIM environment. We find that, M-SPIN exhibits significant performance gains than traditional SPIN routing.

Keywords- Routing protocols; SPIN; Wireless Sensor Network;

I. INTRODUCTION

Wireless Sensor Network (WSN) [1] [2] consists of large number of sensor nodes which are small in size, low cost and have limited memory size with sensing, computation and wireless communication capabilities.

Sensor nodes measure the ambient conditions from the environment surrounding them. The applications of WSN are various from health monitoring to battle field. The practice of remote sensing has become greatly simplified by useful and affordable sensors as well as required software packages. Additionally, users can monitor and control the underlying environment from remote location.

In order to meet the requirements of different types of applications, it is important to process the collected information from the surrounding environment and relay them appropriately to the destination. So, these are the vital considerations in any routing protocol. The wide ranges of applications that can be deployed on top of WSN make it difficult to develop a single routing protocol. The design of the routing protocol is strictly dependent on the nature of the application requirements. Current trend of research in this area also focuses on routing algorithms designed for achieving better performance and longer network lifetime. Traditional routing protocols are address-centric. Here packets are routed based on unique IP addresses and data payload remains unchanged during the data delivery process. But this type of addressing scheme is not suitable for WSN, because it is hard to globally identify the sensor nodes in the network. Again due to energy and storage constraints of sensor nodes, redundant data are processed before their transmission. Moreover, local data are aggregated and it is also possible to add new data at different levels of hop. As WSNs are qualitatively different from traditional network, they need a different routing approach for their data to route. Data-centric routing is one of them. Since most WSNs are application specific it is relatively advantageous to concentrate on data content rather that address.

In data-centric routing scheme, data are retrieved through querying. Querying the data is based on some of their attributes values. In this type of routing protocol, advertisement or interest for data is propagated throughout the network. There are two popular approaches in this context. These are SPIN [3] [4] family of negotiation protocol and Directed Diffusion [4].

In this paper, we introduce M-SPIN (Modified SPIN protocol), protocol to transmit information only to sink node instead of transmitting throughout the network. The protocol is based on SPIN family of protocol. In this proposed protocol, total number of packet transmissions is less. Therefore a significant amount of total energy can be saved. M-SPIN protocol is implemented using nesC programming language and evaluated using TinyOS mote simulator TOSSIM.

The rest of the paper is organized as follows. In section II, a short description of SPIN family of protocols is given. The proposed M-SPIN protocol is described in section III. Performance analysis of M-SPIN protocol and comparison with SPIN-BC protocol is discussed in section IV. Finally, in section V we conclude the paper with a direction for future work.

II. TRADITIONAL SPIN PROTOCOL

SPIN is a data-centric routing protocol. It fits under event-driven data delivery model in which the nodes sense data and disseminate the data throughout the network by means of negotiation. SPIN nodes use three types of messages for communication [3] [4]:

- ADV- When a node has new data to share; it can advertise this using ADV message containing Metadata.
- REQ- Node sends an REQ when it needs to receive actual data.
- DATA- DATA message contains actual sensor data.

The SPIN family of protocol is made up of four protocols, SPIN-PP, SPIN-BC, SPIN-RL, and SPIN-EC. These are presented in [3]. SPIN-PP used in network for point-to-point communication media and SPIN-BC used in broadcast communication media. SPIN-EC and SPIN-RL are the
modified versions of the first two protocols. SPIN-EC is an energy conserving version of SPIN-PP and SPIN-RL is a reliable version of SPIN-BC. In SPIN-BC, nodes send their ADV message and all nodes within the transmission range receive the message. Upon receiving an ADV, each node checks whether it has already received or requested the advertised data. If not, it waits for a certain amount of predefined time and sends a REQ message out to the broadcast address specifying the original advertiser in the header of the message. On receiving a REQ message, only the original advertiser will respond and send the actual data to the requesting nodes. The negotiation mechanism ensures elimination of redundant data. But it does not establish any path for data transmission and hence data delivery is not guaranteed in SPIN.

Another interesting fact is that energy consumption not only depends on sensing the data but also on processing the sensed data and transmitting or receiving them to or from its neighbor nodes. So if it is possible to control the number of transmission and receipt of messages, a significant amount of energy can be saved. Figure 1 shows an example of a WSN. An event that occurs in the WSN divides the entire network into two regions, A and B. Sensor nodes in region A are on the other side in the network in comparison with the sink node and sensor nodes in region B are on the same side and nearer to the sink node. Sensor nodes of region A can receive data from the event node, however, they will unnecessarily waste their energy in receiving or transmitting the data. In order to reach data to the sink node, data will have to travel more hops if they are sent via the nodes in region A. Thus, when an event occurs, it is always desirable that the data is sent through the nodes in region B. This would save the energy spent for transmission of a piece of data from an event node to the sink node. However, such selective transmission is not supported in the existing SPIN protocols. To overcome this problem, we propose an M-SPIN protocol in the next section.

III. MODIFIED SPIN PROTOCOL

In few applications such as alarm monitoring applications need quick and reliable responses. Suppose in forest fire warning system, quick response is needed before any disaster occurs. In this case, it is desirable that data must be disseminated towards the sink node very quickly. M-SPIN routing protocol is better approach for such type of applications than SPIN.

In our proposed protocol, we add a new phase called Distance discovery to find distance of each sensor node in the network from the sink node in terms of hops. This means that nodes having higher value of hop distance are far away from the sink node. Other phases of M-SPIN are Negotiation and Data transmission. On the basis of hop distance, Negotiation is done for sending an actual data. Therefore, use of hop value controls dissemination of data in the network. Finally, data is transmitted to the sink node.

A. Distance discovery

Figure 2 shows the Distance discovery phase of M-SPIN. Hop distance is measured from sink nodes. Initially the sink node broadcasts Startup packet in the network with type, nodeld and hop. Here type means type of messages. The nodeld represents id of the sending node and hop represents hop distance from the sink node. Initial value of hop is set to 1. When a sensor node receives the Startup packet, it stores this hop value as its hop distance from the sink node in memory. After storing the value, the sensor node increases the hop value by 1 and then re-broadcast the Startup packet to its neighbor nodes with modified hop value. It may also be possible for a sensor node to receive multiple Startup packets from different intermediate nodes. Whenever a sensor node b receives Startup packets from its neighbors a, 1 ≤ i ≤ n, it checks the hop distances and set the distance to the minimum, i.e.

$$\min\{\forall h(a_i, b), i = 1, n\}$$

Where \( h(a_i, b) \) represents hop distances between the nodes a and b and n is the no. of neighbor nodes of node b from which it receives the startup packets.

This process is continued until all nodes in the network get the Startup packets at least once within the Distance discovery phase. After successful completion of this phase, next phase will be started for negotiation. Figure 3 shows some of the variables and structures used by the Distance discovery and Negotiation phase. StartupMsg structure contains three member variables. HopTable structure contains only one member called hop t to store the hop value at each node. Figure 4 shows pseudo code for the Distance discovery phase.

![Figure 2. Distance Discovery Phase](image-url)
B. Negotiation

The Negotiation phase is almost similar to the SPIN-BC protocol. The source node sends an ADV message. Upon receiving an ADV message, each neighbor node verifies whether it has already received or requested the advertised data. Not only that, receiver node also verifies whether it is nearer to the sink node or not in comparison with the node that has sent the ADV message. This is the main difference between the negotiation phase of SPIN_BC and that of M-SPIN. If hop distance of the receiving node (own_hop) is less than the hop distance received by it as part of the ADV message (rcev_hop), i.e. own_hop < rcev_hop, then the receiving nodes send REQ message to the sending node for current data. The sending node then sends the actual data to the requesting node using DATA message. Figure 5 shows pseudo code of the Negotiation phase.

As soon as a node gets data either from its own application or from other sensor nodes, it stores that data in its memory using the function storepkt. Also it uses setCurrent function to specify which data is presently residing in its memory.

When ADV message is received, then each receiving node first checks its record to ascertain whether it already has seen that data using the function chkHistory. Moreover, it calls setDesired to indicate which DATA packet it is waiting for.

The source nodes which receive the REQ use the function getCurrent. It helps to determine whether the received REQ is for the stored data specified by the setCurrent function for which the node has sent the ADV.

When a requesting node receives any data, it immediately checks whether the data is the same for which it has sent the request using getDesired function. The data packet contains the hop distance value along with the information about the event.

C. Data Transmission

Data transmission phase is same as SPIN-BC protocol. After request is received by the source node, data is immediately sent to the requesting node. If the requesting nodes are intermediate nodes other than the sink node then the Negotiation phase repeats. Thus, the intermediate sensor nodes broadcast ADV for the data with modified hop distance value. The sending nodes modify the hop distance field with its own hop distance value and add that in packet format of the ADV message. The process continues till data reaches the sink node. Figure 6 illustrates Negotiation and Data transmission phase.
Figure 6. The M-SPIN protocol. (1) Node 1 starts advertising its data to all of its neighbors. (2) Node 3 responds by sending a request to node 1. (3) After receiving the request, node 1 sends the data. (4) Node 3 again sends advertisement out to its neighbors for the data that it received from node 1.

IV. PERFORMANCE ANALYSIS

We present the performance analysis of both SPIN-BC and M-SPIN by using TOSSIM [7]. Implementation of both protocols has been written in nesC programming language. Here we have compared M-SPIN with SPIN-BC to measure the performance of M-SPIN. For this purpose two metrics are used: (1) Total Number of ADV packets transferred to reach the sink node for an event. (2) Energy consumption of the sensor network with varying numbers of sensor nodes. Size of the network has been varied from 10 to 60 sensor nodes.

Figure 7 and Figure 8 shows the simulation results. Initially, both the protocols have been tested with the same network topology. Figure 7 shows the result of total number of ADV packets generated for an event at each hop level to reach the destination node while the network consists of 30 sensor nodes. In comparison with SPIN-BC, M-SPIN generates lower number of ADV messages, and thus saves the total energy of the WSN. In this way it can prolong the lifetime of the WSN. Figure 8 depicts the energy consumption of SPIN-BC and M-SPIN. Energy consumption increases with the increase in the number of sensor nodes in the network, but M-SPIN performs better in terms of energy saving compared to SPIN-BC. Network discovery costs are included in the results presented in this paper.

V. CONCLUSION AND FUTURE WORK

In this paper, we have proposed a modified SPIN (M-SPIN) protocol using hop-count values of sensor nodes for WSN. Here also negotiation is done before sending the actual data. But in our scheme, only the nodes which are nearer to sink node send REQ packets in response to ADV packet from the source node. Therefore data is disseminated to the sink or neighbor nodes towards the sink node. M-SPIN achieves energy savings by discarding packet transmission to the opposite direction of sink node. But one major problem is that few sensor nodes may be used several times and those nodes may dissipate energy and may be destroyed earlier than other nodes in the network. In future it may be possible to work on this problem associated with M-SPIN protocol and provide a better solution for it.

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