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Energy Conservation in SPIN Using Leaky Bucket Algorithm

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Abstract: **Wireless sensor networks (WSNs) are large networks made of a numerous number of sensor nodes with sensing, computation, and wireless communications capabilities. Recently various routing, power management, and data disseminating protocols have been designed for WSNs. SPIN (Sensor Protocols for Information via Negotiation) is a family of adaptive protocols for WSNs. Their design goal is to avoid the drawbacks of flooding protocols by utilizing data negotiation and resource-adaptive algorithms. In this paper, we have proposed two schemes for enhancing SPIN. The first scheme makes use of token leaky bucket for message management for avoiding congestion in SPIN protocol. Second scheme focuses on strategy for fetching information from nearest node. Simulation result shows the effect of proposed scheme on energy consumption for different number of sensor nodes involved sensor node.**

Keywords: **adaptive algorithms; data negotiation; energy consumption; SPIN; token leaky bucket.**

I. INTRODUCTION

Wireless sensor networks are providing tremendous benefit for a number of industries. The ability to add remote sensing points, without the cost of running wires, results in numerous benefits including energy and material savings, process improvements, labor savings, and productivity increases. Furthermore deployment of application specific protocols, which focus on energy constrain is adding value to WSN.

Wireless sensor networks (WSNs) can be seen in various fields like disaster management, battle field surveillance and border security surveillance since last few years [1]. In such applications, a large number of sensor nodes are deployed in extremely hostile environment, which are often unattended and work autonomously [2].

Sensor senses the information from the surrounding environment and active suddenly and transforms the information to the base station leading to the traffic congestion. Degradation of channel, increased in packet loss rate, rise in delays and confusion in what data should transfer to the node are the impact of the congestion in network.

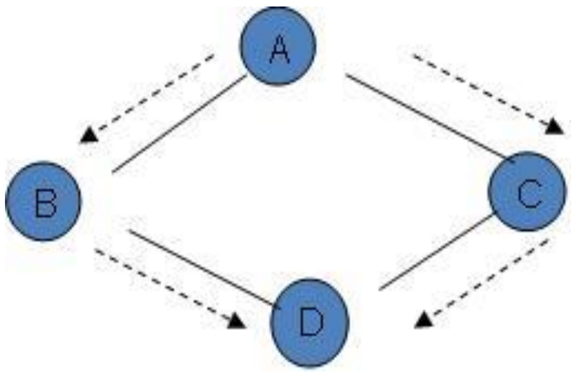

Fig 1. Data received from multiple nodes

WSNs are confined with communication, computational capabilities and battery power. Energy dissemination is one of the major hindrances in prolonging network life time [3] [4] .The load distribution is uneven in many cases and thus has a strong impact on energy dissemination. Also the deployment of sensor nodes is in hostile environments wherein periodical charging or replacement of batteries is not feasible [5] [6] accordingly many algorithms have been proposed focusing on the energy dissemination of wireless sensors.

Generally following deficiencies with data dissemination protocols are observed:

- Implosion – It is function of only network topology, one node getting same data from different nodes. As in figure1, node A starts flooding its data to all of its neighbours. Two copies of the data eventually end at node D. Consequently the system wastes energy and bandwidth[7]

- Overlap – It is function of both topology and mapping of observed data to sensor nodes, overlapping of geographical region by 2 sensor nodes and both sensing same data and disseminating it to one node again. This leads to wastage of energy in computation and communication processes. Two sensors cover an overlapping graphic region. When the sensors flood their data to node, the node receives two copies of the data[8]

- Resource blindness – Sensor nodes are not aware of its own energy level, hence no adaption to communication and computation by its energy resources. Resources do not modify their activities based on the amount of energy they have [9][10]

SPIN (Sensor Protocols for Information via Negotiation) is a family of adaptive protocols for WSNs. [11] Their design goal is to avoid the drawbacks of flooding protocols by utilizing data negotiation and resource-adaptive algorithms. Negotiation overcomes implosion, metadata overcomes overlap and energy resource overcomes resource blindness. [12] SPIN nodes poll their energy resources before data transmission; each node has its own resource manager that keeps track of resource consumption. SPIN is designed based on two basic ideas –

- to operate efficiently and to conserve energy by sending metadata(i.e., sending data about sensor data instead of sending the whole data that sensor nodes already have or need to obtain), and

- Nodes in a network must be aware of changes in their own energy resources and adapt to these changes to extend the operating lifetime of the system. SPIN has three types of messages, namely, ADV, REQ, and DATA.

ADV: when a node has data to send, it advertises via broadcasting the message containing meta-data (i.e., descriptor) to all nodes in the network.

REQ: an interested node sends this message when it is in state to receive some data.

DATA: It contains the actual sensor data along with meta-data header.

SPIN is based on data-centric routing where the sensor nodes send ADV message via broadcasting for the data they have and wait for REQ messages from interested sinks or nodes. The semantics of SPIN's metadata format is application dependent and not supported by SPIN. In another words; SPIN uses application specific metadata to name the sensed data. Although, SPIN has some advantages, such as solving the problems associated with classic flooding protocols, and topological changes are localized, it has its own drawbacks like; scalability, SPIN is not scalable, if the sink is interested in too many events, this could make the sensor nodes around it deplete their energy, and SPIN's data advertisement technique cannot guarantee the delivery of data if the interested nodes are far away from the source node and the nodes in between are not interested in that data.

II. LITERATURE REVIEW

In [13] proposed fuzzy based approached to control the congestion in efficient manner. Proposed scheme take input as node degree, queue length and the data arrival rate for congestion detection and produces output in the form of fuzzy variables indicating level of congestion. This novel scheme produced perfect results in measuring the congestion in network. Extensive simulation is carried out to prove the effectiveness of the proposed scheme.

The performance of computer network degrades due to hot spot traffic congestion. In [14] author proposed to reduce the impact of the hot spot traffic in high bandwidth, low latency and lossless computer networks, a novel scheme name as Speculative Reservation Protocol (SRP) is developed. This scheme uses proactive method to avoid the congestion. SRP control the congestion in network with the help of light-weight endpoint reservation scheme and speculative packet transmission. The proposed scheme provides better results which are proved by extensive simulation. SRP also control the congestion on benign traffic patterns.

The SPIN family of protocol is made up of four protocols, SPIN-PP, SPIN-BC, SPIN-RL, and SPIN-EC[15].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 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.

A. SPIN-PP: Point-to-Point Protocol:

The first SPIN protocol, SPIN-PP, is optimized for a network using point-to-point transmission media, where it is possible for nodes A and B to communicate exclusively with each other without interfering with other nodes. In such a point-to-point wireless network, the cost of communicating with n neighbors in terms of time and energy is n times the cost of communicating with 1 neighbor.

The SPIN-PP protocol works in three stages (ADV-REQ-DATA), with each stage corresponding to one of the messages in SPIN messages. The protocol starts when a node advertises new data that is willing to disseminate. It does this by sending an ADV message to its neighbors, naming the new data (ADV stage). Upon receiving an ADV, the neighboring node checks to see whether it has already received or requested the advertised data. If not, it responds by sending an REQ message for the missing data back to the sender (REQ stage). The protocol completes when the initiator of the protocol responds to REQ with a DATA message, containing the actual data (DATA stage).

B. SPIN-EC: SPIN-PP with a Low-Energy Threshold:

The SPIN-EC protocol adds a simple energy-conservation heuristic of the SPIN-PP protocol. When energy is plentiful, SPIN-EC nodes communicate using the same 3-stage protocol as SPIN-PP nodes. When a SPIN-EC node observes that its energy is approaching a low-energy threshold, it adapts by reducing its participation in the protocol. In general, a node will only participate in a stage of the protocol if it believes that it can complete all the other stages of the protocol without going below the low-energy threshold. This conservative approach implies that if a node receives some new data, it only initiates the 3-stage protocol if it believes it has enough energy to participate in the full protocol with all of its neighbors. Similarly, if a node receives an advertisement, it does not send out a request if it does not have enough energy to transmit the request and receive the corresponding data. This approach does not prevent a node from receiving, and therefore expending energy on, ADV or REQ messages below its low-energy threshold. It does, however, prevent the node from ever handling a DATA message below this threshold.

C. SPIN- BC: Broadcast protocol:

In broadcast transmission media, nodes in the network communicate using a single, shared channel. As a result, when a node sends out a message in a broadcast network, it is received by every node within a certain range of the sender, regardless of the message's destination. If a node wishes to send a message and senses that the channel is currently in use, it must wait for the channel to become idle before attempting to send the message. The disadvantage of such networks is that whenever a node sends out a message, all nodes within transmission range of that node must pay a price for that transmission, in terms of both time and energy. However, the advantage of such networks is that, when a single node sends a message out to a broadcast address, this node can reach all of its neighbors using only one transmission. One-to-many communication is therefore 1/n times cheaper in a broadcast network than in point-to-point network, where n is the number of neighbors for each node.

D. SPIN- RL: Reliable Version of SPIN-BC:

SPIN-RL can disseminate data efficiently through a broadcast network, even if the network loses packets. The SPIN-RL protocol incorporates two adjustments to SPIN-BC to achieve reliability. First, each SPIN-RL node keeps track of which advertisements it hears from which nodes, and if it doesn't receive the data within a reasonable period of time following a request, the node re-requests the data. It fills out the originating-advertiser field in the header of the REQ message with a destination, randomly picked from the list of neighbors that had advertised that specific piece of data. Second, SPIN-RL nodes limit the frequency with which they will resend data. If a SPIN-RL node sends out a DATA message corresponding to a specific piece of data, it will wait a predetermined amount of time before responding to any more requests for that piece of data.

III. PROPOSE ENHANCING SPIN PROTOCOL'S: MESSAGE MANAGEMENT USING TOKEN LEAKY BUCKET

In this section we describe the incorporation of Token Leaky Bucket algorithm to enhance SPIN. Token Leaky Bucket algorithm focuses on constant bit rate , this is achieved by first buffering the incoming data and the maintaining a steady out flow[16].Proposed scheme contains negotiation messages(ADV, REQ, DATA) as in SPIN with slight modifications.

Each node consists of two checklists, one for sending ADV msgs and one for sending REQ msgs. ADV checklist will have the data/metadata which has to be advertised by the node, i.e. data which has to be sent to other nodes and the REQ checklist will have the data/metadata which it has to request for, i.e. data which it has to get from other nodes. While advertising, the ADV node sends (multicasts/broadcasts) the ADV messages along with its id, its location information, and metadata. While advertising ADV messages the nodes will check their ADV checklist and advertises only those metadata which is present there in the given list, once the ADV checklist is completed (i.e. once all the metadata in the checklist is advertised) the node will go to sleep mode thereby conserving energy. When ADV message is received by the other nodes, the nodes will check its REQ checklist and if the received ADV is having metadata that matches the REQ checklist then the node send the REQ message to the advertised node for the actual data. Once the REQ checklist is completed (i.e. once all the metadata/data in the checklist is received) the node will go to sleep mode for conserving energy. Once the REQ message is received at the advertised node, the node will send the actual data through the DATA msg. Furthermore when the REQ checklist of each node is completed then it will unicast its ready message to the base station, i.e. the nodes are ready with their data and it will go to sleep mode for conserving energy.

In the novelty SPIN we have two checklists for each node, i.e. advertisement checklist (ADV checklist) and request checklist (REQ checklist).

TABLE I. CHECKLIST TABLE

Node Number	ADV checklist	REQ checklist
Node 0	a,b,y	c,d,l
Node 1	m,d,z	o,n,y
Node 2	n,l,c	x,y,o
Node 3	a,d,z	m,b,x
Node 4	n,a,o	m,c,z
Node 5	m,b,x	l,p,d
Node 6	c,d,y	n,o,a

Fig. c.1. Wireless Sensor Network: Nodes – 0, 1, 2, 3, 4, 5, 6. Data – a, b, c, d, l, m, n, o, p, x, y, z (data/metadata to be sensed by the sensor nodes and exchanged all over the network). It's a Node 0 ADV phase: Node 0 has y in its ADV checklist, so it is advertising y

Fig. c.2. Node 0 ADV phase Node 0 REQ phase: When ADV(y) arrives at node 1, it checks its REQ checklist whether to accept or reject the advertised message, in this scenario since y is there in the REQ checklist of node 1 it accepts the ADV(y).

Fig. c.3**.** Node 0 REQ phase:Node 0 DATA phase

Fig. c.4. Node 0 DATA phase:Node 1 ADVphase. Node 1 has x in its ADV checklist, so it is advertising x

Fig. c.5**.** Node 1 ADVphase. Node 1 REQ phase

When ADV(x) arrives at nodes 2, 3, 4, 5 it checks its REQ checklist whether to accept or reject the advertised message, in this scenario since x is there in the REQ checklist of nodes 2, 3 it accepts the ADV(x) and sends the request for the actual data.

Fig. c.6. Node 1 REQ phase Node 1 DATA phase. Node 1 DATA phase. Node 1 sends the actual data to the requested nodes.

Fig. c.7. Node 1 DATA phase. If the message management for traditional SPIN and novelty SPIN for the same sensor network is noticed, it is apparent that the total number of messages required for traditional SPIN is 16 and for novelty SPIN its 12 which is less than the traditional SPIN. Consequently the total energy consumption is affected by the scheme proposed.

BACKUP PLAN FOR ENHANCING RELIABILITY:

When a particular node gets ADV messages from many different nodes for the same data, then the node has to decide to which node it has to send the REQ message (i.e. from which node it has to accept data). At this instance the node calculates the distances of all the advertised nodes from which it has got the ADV message and selects the minimum distance node and sends the REQ message to it. For calculating the distance it makes use of location information of the ADV node which has been attached in the ADV msg. By any chance if the requested data has not not been sent by the advertised node or has not been received by the requested node then it will lead to problem or loss of data, hence the requesting node will send REQ message to two nodes with minimum distances as a back up and accepts the data from the one which reaches first.

Let us consider the following network shown in Figure8 where more than one sensor node has the same data to advertise.

Fig. c.8**.** Sensor network: We will consider the same above checklist as used for explaining novel SPIN. Node 1 and node 5 ADV phase.Both the nodes 1 and 5 have data m in their ADV checklist and both have advertised it to some of the same/common nodes.

Fig. c.9**.** Node 1 and Node 5 ADV phase. Node 1 node 5 REQ phase. When ADV(m) arrives at nodes 2, 3, 4, 6 it checks its REQ checklist whether to accept or reject the advertised message, in this scenario since m is there in the REQ checklist of nodes 3, 4 it accepts the ADV(m) and sends the request for the actual data.

Fig. c.10**.** Node 1 Node 5 REQ phase. Nodes 3 and 4 have m in their checklist but it has got ADV(m) from two different nodes, so nodes , 4 calculates the distance from itself to the advertised nodes and sends the request to the node with minimum distance. For backup plan it sends request to two nodes with least distances.

Node 3 calculates 3-1, 3-5 and node 4 calculates 4-1, 4-5. Let's assume minimum distances are 3-1 and 4-1 and for back up reason it sends request for node 5 also.

Fig. c.11**.** Node 1 Node 5 REQ phase.Node 1 and Node 5 DATA phase. Node 3 and node 4 gets the actual data from both node 1 and node 5 but it selects the one which arrives first.

Fig. c.12**.** Node 1 Node 5 DATA phase

IV. SIMULATION

We made use of Glomosim an open source WSN simulator. We performed simulation for different number of nodes for both Traditional and novel SPIN with different levels of threshold and tabulated the total energy consumption for each instance and plotted the graph accordingly.

Threshold here signifies the number of messages permitted in the checklist for an individual sensor.

TABLE II. ENERGY CONSUMPTION FOR NOVEL SPIN

Energy consumption (mWhr)					
No of nodes	***Traditional SPIN***	***Novel SPIN(25% threshold)***	***Novel SPIN(30% threshold)***	***Novel SPIN(40% threshold)***	***Novel SPIN(50% threshold)***
10	2.5	1	1	1.25	1.5
30	6.502	2.251	2.501	3.251	4.001
50	12.503	3.501	4.001	5.251	6.502
70	14.254	4.751	5.502	7.252	9.003
90	16.254	5.752	7.002	9.252	11.503
100	21.506	6.502	7.752	10.253	12.753
120	25.257	7.752	9.253	12.253	15.254
150	31.759	9.753	11.503	15.254	19.004
175	35.26	11.253	13.503	17.755	22.256
200	41.511	12.753	15.254	20.256	25.257

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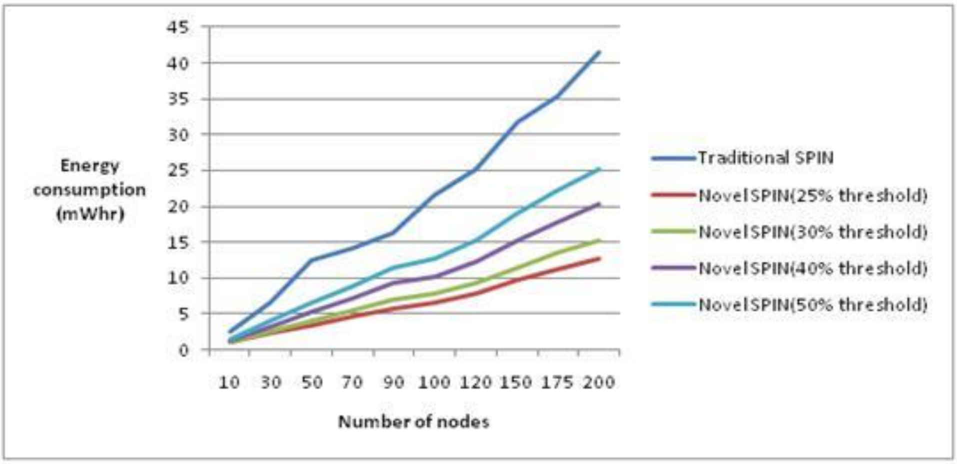


Fig. (b). Energy Consumption graph for Novel SPIN

From Fig (b) and Table II, we can observe the energy consumption in traditional SPIN is high than the energy consumption in novel SPIN.

V. CONCLUSION

In this paper we have proposed two schemes to modify SPIN. The first scheme focuses on message management by incorporating leaky bucket algorithm for each sensor node. Second scheme aims selecting nearest node in case same data is available at different nodes within the network. Simulation results put forth the effect of novelty in the proposed schemes on the energy consumption. In future we would like to analyze the effect of proposed scheme on congestion in the network

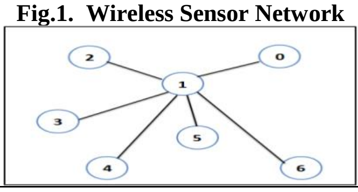
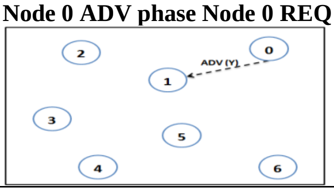
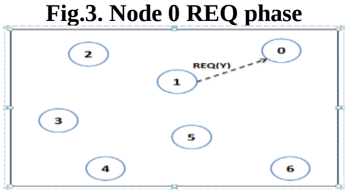
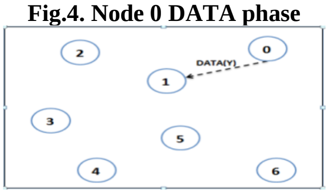
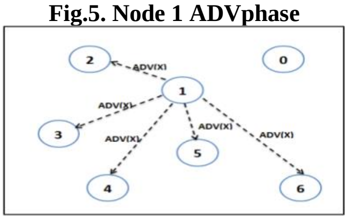
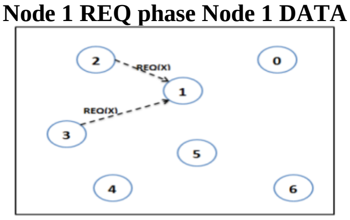
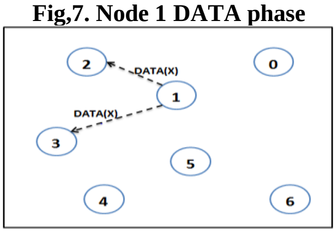
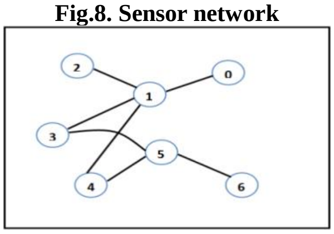
Fig.1. Wireless Sensor Network 	**Fig. 2. Node 0 ADV phase Node 0 REQ phase** 
Fig.3. Node 0 REQ phase 	**Fig.4. Node 0 DATA phase** 
Fig.5. Node 1 ADVphase 	**Fig.6. Node 1 REQ phase Node 1 DATA phase** 
Fig,7. Node 1 DATA phase 	**Fig.8. Sensor network** 

Fig.9. node 1 and node 5 ADV phase

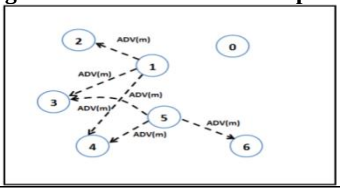


Fig.10. Node 1 node 5 REQ phase

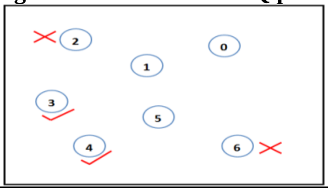


Fig.11. Node 1 node 5 REQ phase

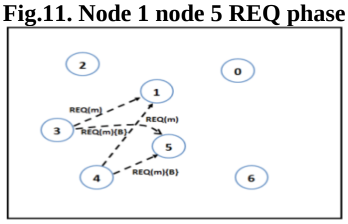


Fig12. Node 1 node 5 DATA phase

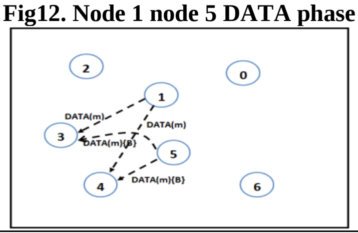


Fig. (c). Different phases of proposed scheme

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