Adaptive Protocol for Critical Data Transmission of Mobile Sink Wireless Sensor Networks

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***Abstract*—The sensors in sensor networks have limited energy and energy preserving technique are important. Network lifetime is a key issue of the sensor network. Sensor Protocols for Information via Negotiation (SPIN), that efficiently disseminates information among sensors and provide the surety to deliver the data towards the sink node in mobile sink sensor network. Which is a negotiation based multicast routing protocol. Here we show how SPIN protocol is working in the mobile sink wireless sensor network, where our assumption is that all the sensor nodes are static other than the sink node. We apply the SPIN property to check the data delivery to the mobile sink and mathematically proved the cost taken to deliver the data. Routing protocols for wireless sensor networks are responsible for maintaining the routes in the network and have to ensure reliable multi-hop communication to sink under every condition. We prove that mobility of the sink doesn't matter, cost depends on the distance from the source to sink node. We show SPIN is the efficient protocol for the mobile sink wireless sensor network. Also provide the random mobility model of the sink in sensor network. This is moving randomly within the restricted area.**

***Index Terms*—WSN, mobile sink, GIT, SPIN.**

I. Introduction

Wireless sensor network (WSN) is becoming an increasingly important technology that will be widely used in a variety of applications such as public safety, environmental surveillance, disaster surveillance, medical, home and office security, transportation, and military[1]. Routing protocol in sensor network is very pivotal. SPIN protocol is a basic data-centric routing protocol of wireless sensor networks [3]; though many new algorithms have been proposed for the problem of routing data in static sensor networks not for the mobile sink [9]. Our goal is to show the random mobility model of sink in sensor networks by using SPIN protocol.

In traditional WSN, both sensor nodes and sinks are fixed once they are deployed. Many protocols for routing are deployed based on static WSN, which prolong network lifetime in deferent levels. However, it is very difficult to deploy a new routing protocol to prolong network lifetime further because of the limit that both sensor nodes and sinks are fixed. Furthermore, some practical applications of WSN are dynamic. According to our assumption all nodes are static, whereas sink node is dynamic having infinite energy. Mobile-sink node is roaming over the field randomly as figure. 3 to collect the data and to prolog the network lifetime. Therefore, a dynamic wireless sensor network gradually becomes a new hot issue of research for Wireless Sensor Network.

In this paper we focus on random mobility model of sink and SPIN protocol. SPIN protocols can deliver 60% more data for a given amount of energy than conventional approach [2]. Here mathematically in equation. 5 proved that it doesn't take the extra cost for the mobility of the sink node.

Mobile sink WSN is proposed for energy saving and prolonging the lifetime of the network. When sink is at position it broadcast the beacon frame about its presence and initializes the sensor node to send the data packet, which are in the range of transmission. After the specified pause time sink changes its position. Before sink changes its position, it sends another beacon frame to reinitialize the sensor nodes in-order to avoid the packet loss. This mechanism is energy efficient method for sensor networks.

Figure 1 shows our proposed model of static sensor network with mobile sink. Sink moves randomly within the specified range of service area to collect the data. If there is some critical level of data arises and sinks is not at its one hop distance then sensor node routs data towards the sink by using SPIN protocol.

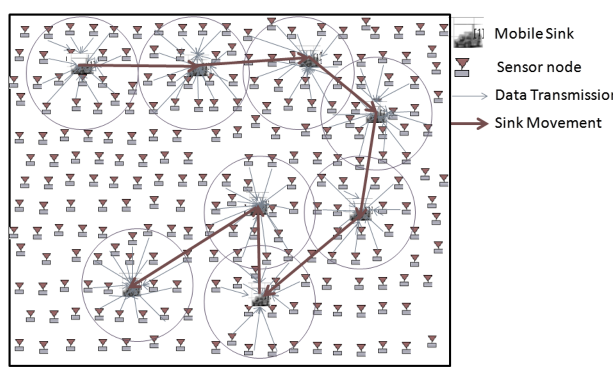

Fig. 1. Sensor network model.

WSN is mainly deployed for risk management like disaster surveillance, environmental surveillance and military etc. So we need to route the critical data to sink which will transfer the data to the base station immediately.

The demerit of this method is when a sensor node senses a critical data and sink is not in its transmission range. At that time node can't wait till sink come in its range. It needs to route the packet immediately to the sink node. For this situation in mobile sink Wireless Sensor Network, SPIN can works efficiently, which our goal is to prove that the cost is not depends on sink mobility rather it depends on distance between source and sink.

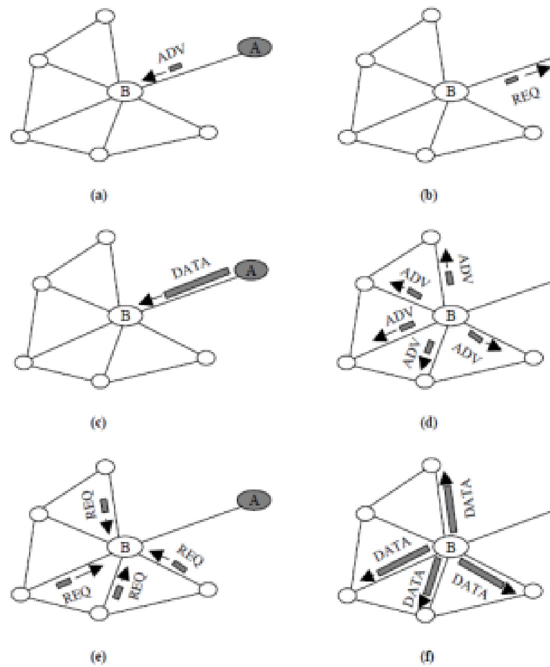

Fig. 2. The SPIN-PP protocol [2].

Wireless Sensor Network with mobile sink is an emerging field for current research. There are many mathematical models have proposed but there is the need of efficient protocol which can efficiently deliver the data to the sink [4], [5]. As sink moves randomly in the specified range, according to our assumption SPIN protocol can work efficiently to deliver the data to the sink.

The performance of SPIN is better than that flooding, gossiping and ideal protocol for energy and bandwidth consumption [2]. The other three protocols function as comparison protocols: (i) flooding, which broadcast the packet among all of its neighbors; (ii) gossiping, a variant on flooding that sends messages to random sets of neighboring nodes; and (iii) ideal, an idealized routing protocol that assumes perfect knowledge and has the best possible performance.

The traditional protocols which establish a path before transmit the data are also not suitable for the mobile sink. Because each time sink is changes its position. It needs to flood the data in order to reach at the sink node.

Sensor Protocol for Information via Negotiation Protocol (SPIN) has four types: SPIN-PP, SPIN-EC, SPIN-BC, and SPIN-RL [2]. In our work, we consider SPIN-PP as the best protocol. In SPIN-PP, Nodes use three types of messages ADV, REQ and DATA to communicate [3]. ADV is used to advertise new data, REQ is also to request for data and DATA is the actual message. The protocol starts when a SPIN node gets new data that it is willing to share on on-demand basis. It does so by broadcasting an ADV message containing meta-data. Meta-data size is very small as compared to the size of the DATA. If a neighbor is interested in the data, it sends an REQ message for the DATA and the DATA is sent back to this neighbor node. The neighbor sensor node then repeats this process to its neighbors till reach at the sink node.

Figure 2 [2] shows an example on how this protocol works. It starts by advertising its data to node B from Node A(a). Node B responds by sending a request to node A (b). After receiving the requested data (c), node B then sends out advertisements to its neighbors (d), who in turn send requests back to B (e, f).

The strength of this protocol lies in its simplicity. Each node in the network performs little decision making when it receives new data, and therefore wastes little energy in computation. Furthermore, each node only needs to know about its single-hop network neighbors.

The remainder of the paper is organized as follows. Section II motivates the importance of sink mobility models and SPIN working model. Section III specifies the objective of the data transmission. Our proposed mathematical model is described in detail in section IV and finally section V offers some concluding remarks and future work.

II. Mechanism of sink routing

Our work mainly focused on mobile sink wireless sensor network, where all the sensors are static in nature. Only the sink node dynamically changes its position. Mobility is restricting within the sensing bounded area. Which is a cause to the prolog of network lifetime. Our intension is to show the mobility model of sink node and how efficiently SPIN can work in the mobile sink WSN.

In our assumption all nodes are static other then the sink node. Sink node moves randomly in the field. We propose a random mobility model of sink in the Section-IV. Where speed, direction and position calculates randomly in Equation 2,3,1 after each step of moving.

According to SPIN characteristics, sensors communicate with the sink via negotiation. When sensor node starts send the data to the sink node, each time it finds the path following negotiation based approach to reach at sink as described above. Because SPIN protocol doesn't establish the path to the sink node while going to send. It is a three step process to communicate with sink node.

Figure 3 shows the data transmission to the mobile sink according to the SPIN characteristics. Here K1 to K6 are the static nodes and S is the mobile sink node. Form figure.2 node k1 sends the packet to the sink node when it is at P1 and deliver the data to the sink when it is at the position P2. Sink move from the position P1 to P2 during the data transmission.

SPIN is the better protocol then those traditional protocols which first establish the path then transmit the data to sink. In this situation sink always changes the position dynamically as derived in the Equation 1, so it is not feasible to establish the path and follow to transmit the data to the sink. As per the mathematical derivation Equation 5 SPIN works efficiently in mobile sink WSN. Which proved in the next Section-IV and it is better than the flooding, gossiping and ideal protocol for energy and bandwidth consumption [2].

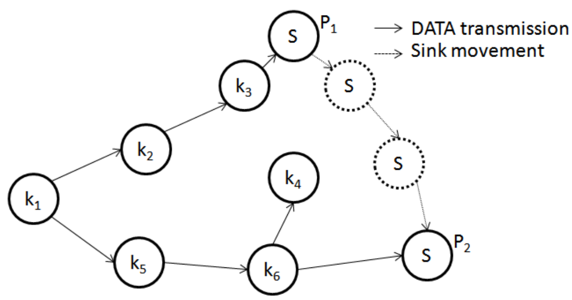

Fig. 3. Data transmission with mobile sink.

III. SYSTEM MODEL

A. Mobility model of sink

Our proposed mixed mobility model which is the combination of random way point and modified Gauss-Markov model. Gauss-Markov mobility model is initially proposed for PCS [6]; and this model has been used for an ad hoc network protocol [7]. Here we describe how it works for mobile sink in the WSN.

i. Modified Gauss-Marko model

Assume that at time t_1 sink is at position $p_1(x_1, y_1)$. Initially it needs to specify the position of the sink. Then it starts movement with the based on previous position, speed and direction. At the n^{th} position:

$$\begin{aligned} \mathrm{x_n} &= \mathrm{x_{n-1}} + \mathrm{s_{n-1}}\cos(\mathrm{d_{n-1}}) \\ \mathrm{y_n} &= \mathrm{y_{n-1}} + \mathrm{s_{n-1}}\sin(\mathrm{d_{n-1}}) \end{aligned} \tag{1}$$

Where $(\mathrm{x_n}, \mathrm{y_n})$ and $(\mathrm{x_{n-1}}, \mathrm{y_{n-1}})$ are the current and the previous position of the sink node respectively. s_{n-1} and d_{n-1} are the speed and direction of the previous $(\mathrm{x_{n-1}}, \mathrm{y_{n-1}})$ position.

The Gauss-Markov Mobility Model was designed to adapt to different levels of randomness. More specifically, the value of speed and direction at the n^{th} instance is calculated based upon the value of position, speed and direction of the $(n-1)^{th}$ instance and a random variable shown in the following equations:

$$\mathrm{s_n} = \alpha \mathrm{s_{n-1}} + (1-\alpha)\mathrm{s}' \sqrt{(1-\alpha^2)}\mathrm{s_{xn-1}} \tag{2}$$

$$\mathrm{d_n} = \alpha \mathrm{d_{n-1}} + (1-\alpha)\mathrm{d}' \sqrt{(1-\alpha^2)}\mathrm{d_{xn-1}} \tag{3}$$

Where s_n and d_n are the new speed and direction of the sink at time interval n, s' and d' are constants representing the mean value of speed and direction as $\mathrm{n} \to \infty$; $0 \leq \alpha \leq 1$, is the tuning parameter used to vary the randomness, and s_{xn-1} and d_{xn-1} are random variables from a Gaussian distribution. As the proposed model's assumption is the random motion of the mobile sink, so that it is according to values of α, s_{xn-1} and d_{xn-1} are taken randomly. Total random values obtained by setting $\alpha = 0$ and linear motion is obtained by setting $\alpha = 1$. Intermediate levels of randomness are obtained by varying the value of α between 0 and 1.

When sink reach at the boundary then it returns back to the previous position. For that each time sink needs to save the previous position to calculate the next position calculation and return back when it heats boundary.

ii. Random Waypoint Mobility Model A mobility model that includes pause times between changes the position. Here sink is staying at in a location for a certain period of time (pause time). At each step sink node stays for a fixed amount of time. Once pause time expires, it moves towards the newly chosen position at the selected speed.

iii. Mixed mobility Model Speed, direction and position calculate at Gauss-Markov model, random waypoint only gives the pause time. Here we use pause time because sink needs to collect the packet/data before change its position and here we have taken long pause time is 10 second.

We implemented the proposed mixed mobility model for sink in MatLab. It randomly covers the maximum area within the specified region for data collection. Before changes its position it halts for a fixed amount of time (i.e. 10 seconds).

B. Mathematical model for data transmission

Figure 4 shows the data transmission to the sink when sink at the P_1 hop distance from source (a) and P_2 hop distance from source (b). Source starts to send the data with multicasting according to the SPIN property. Each time it starts with the greedy incremental tree (GIT) to reach at the sink.

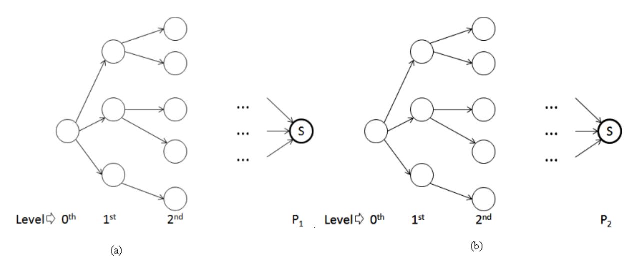

Fig. 4. Transmission of data when sink is (a) at P1 hop distance (b) P2 hop distance from source.

Each node in the tree (except the sink) makes the transmission till reach at the sink. So GIT starts from source node.

In this case number of transmission should be equal to number of edge of the tree. And number of the edge of the tree is the cost for transmission.

Assume the distance from source to sink is D_x, cost to transmit the data with distance D_x is C_x and each node can disseminate the maximum 'n' number of packets.

When sink is at position P_1.shown in Figure 4(a), the maximum number of packet dissemination to reach at the sink

node at distance:
Can be formulated as

$$C_1 = \frac{n^{p_1} - n}{n-1} + k \tag{4}$$

Where $\mathrm{k} < \mathrm{n}$, number of packets at last step of flowing to reach at the sink.

For the distance (D_1) is directly proportional to cost i.e $D_1 \propto C_1$

Similarly at the position of sink at P_2 is $D_2 \propto C_2$; In general

$$D_x \propto C_x \tag{5}$$

Cost depends on distance between the sources and sink node not the position and the direction. Here it shows the position means the distance of sink position from the source node. This shows the following equations; i.e. $p(x_1, y_1)$ = distance form sink to position (x_1, y_1)

if $\mathrm{P}(\mathrm{x}_1, \mathrm{y}_1) > \mathrm{P}(\mathrm{x}_2, \mathrm{y}_2)$
then $\mathrm{D}_1 > \mathrm{D}_2, \mathrm{C}_1 > \mathrm{C}_2$
if $\mathrm{P}(\mathrm{x}_1, \mathrm{y}_1) < \mathrm{P}(\mathrm{x}_2, \mathrm{y}_2)$
then $\mathrm{D}_1 < \mathrm{D}_2, \mathrm{C}_1 < \mathrm{C}_2$
And if $\mathrm{P}(\mathrm{x}_1, \mathrm{y}_1) = \mathrm{P}(\mathrm{x}_2, \mathrm{y}_2)$
then $\mathrm{D}_1 = \mathrm{D}_2, \mathrm{C}_1 = \mathrm{C}_2$

Thus the increase in delay is approximately proportional to:

$$\text{(Distance between farthest source and sink)} - \text{(Distance between closest source and sink)} \tag{6}$$

Cost depends on distance between source and sink, not on the directions and speed using the SPIN protocol.

IV. Conclusion and Future work

In this paper we mainly present the random mobility model of sink in Equation 1 and SPIN efficiency in the mobile sink wireless sensor network. We mathematically proved as per Equation 6 SPIN is efficient for mobile sink data delivery. It doesn't depend on direction or position; it depends on the distance between the source and destination.

Our proposed protocol for mobile sink wireless senor network can be simulated. Here also proved mathematical that SPIN protocol doesn't depend on mobility of sink. This can be further enhancing to probably efficient and secure routing protocol.

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