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Developing an Epidemic Routing Algorithm to Extend the Lifetime of Wireless Networks

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Abstract: Most of the smart wireless devices may act as servers, collectors of data and/or delivers the data at real time to users in a certain collaborative fashion. These devices (nodes) possess several source limitations like storage capacity, power limitation, data processing, radio limitation, etc. Thus, several routing algorithm have been adopted to manage the energy strategy of WSNs. Gossiping is a well-defined multi-hopping as an epidemic routing algorithm. Gossip algorithm uses random selection process to find the intermediate nodes during packet path construction, thus leads to its inefficiency. In this study, DGossip algorithm is proposed to develop Gossip algorithm. Network lifetime improved by considering the information of nodes location, energy and their distance to the base station. The simulation executed in MATLAB and the results of the proposed algorithm prove that it's more efficient than Gossip and prolong the overall network lifetime.

Key words: Gossip, epidemic routing algorithm, DGossip, network life time, MATLAB

INTRODUCTION

Many of tiny sensor devices can be used to configure wireless networks for various applications such as environmental, military, or health applications. Highly effective communication telecommunication protocols are needed to achieve the existing and potential applications for wireless sensor networks (Norouzi *et al*., 2011). Each sensor device is composed of a microcontroller for local data processing, transceiver for transmission/receiving of data, external memory for local storage, power source for supplying energy and one (or more) sensors for data acquisition from the physical environment (Mukherjee and Mukherjee, 2013).

Sensor nodes suffer from several limitations such as power supply, bandwidth for communication, processing speed and memory space, thus making researchers to concentrate on the maximizing the utilization of limited sensor resources. The deployed sensors sense the information from the interesting environment. Then, these data are sent toward the Base Station (BS) for more processing and taking appropriate action (Mudgule and Ganjewar, 2014).

The nodes in wireless sensor networks are cheap, disposable and expected to continue till all their energy is drained. So, energy is an important issue for WSNs and it is required to manage in a better method. Data routing in WSN is a significant issue and considerable amount of energy can be conserved if routing can be implemented tactfully (Sarma *et al*., 2010).

In multi-hop communication, selection of the intermediate nodes in the route is the most important issue. These intermediate nodes are selected such that a best path is realized with minimized needed energy and successfully delivery of the data to the BS. Consequently, the wireless network can work for longer time. In many wireless network situations, changing or recharging node devices is occasionally impossible. Therefore, a lot of protocols have been introduced to prolong network lifetime (Norouzi *et al*., 2011).

Network lifetime relies on several factors such as network protocols and structure, the initiation of data aggregating, definition of life span, models of channel and approach of the energy drain (Chen and Zhao, 2005). Energy consumption in communication subsystem is higher than that of computation subsystem. Even transmitting the single bit may consume more energy than processing it (Mukherjee and Mukherjee, 2013).

This research introduces a development for Gossip routing algorithm called DGossip protocol. Gossiping is a data-relay protocol, based on a Flooding protocol and does not need routing tables or topology maintenance. It was produced as an enhancement for Flooding and to overcome the drawbacks of Flooding, or implosion.

Related review: Many approaches have been introduced to enhance the Gossip protocol. Zhang and Cheng (2004), introduced a combination of two approaches, the Flooding and Gossiping routing protocols called

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FLossiping. Their proposed work uses Gossiping mode during transmission and flooding mode during broadcast processing. Each sender selects and stores a threshold within the header of the packet. Then a neighbor will be chosen to send and receive this packet in a gossip mode. The neighbors that harken to this packet and produce random numbers less than the threshold will forward it in flooding fashion. Their simulation showed that the FLossip algorithm improves the issues of packet overhead and lateness in flooding and gossiping, respectively. Yen *et al.* (2008) adopted Single Gossiping together with Directional Flooding (SGDF) algorithm in their proposed routing protocol. The SGDF includes:

- Initializing the network by assigning each node with a value representing its remoteness to the sink in terms of hops number
- Routing step by exploiting single Gossiping and directional Flooding approaches to transfer messages. Their simulation results showed that SGDF realizes shortest route to the sink and increases packet delivery ratio

Kheiri *et al.* (2009), proposed in their research a scheme whose adopted Gossip algorithm with concentrated on the position of all nodes in the network (LGossiping). During packet transmitting, the node selects a node at random within radius of its Transmitting (TR). Once it receives this packet, the node repeats the procedure and so on till the sink (base station) is found. According to their results, although they saw that the latency issue can be solved to some extent, the sink still couldn't receive many messages. In addition, the energy which is consumed by the network is inversely proportional to TR.

Norouzi *et al.* (2010), in their proposed algorithm employed power of the node and the remoteness between the node and the sink (ELGossiping) to deliver messages from a sender to a Base Station (BS). A node whose has a message to be sent elects next node in its radio range with the shortest way to the sink. The same procedure repeats for the next node selection until the packet reaches the BS. As a conclusion, their proposed method solves the issue of delay in terms of number of hops and the reliability of packet that reaches the BS in more acceptable degree.

In Gossiping the receiving node sends the packet to a neighbor that is randomly selected which picks another random neighbor to transfer the packet to and so on (Hedetniemi *et al.*, 1988). The problem of implosion in flooding algorithm has been overcome by using Gossiping due to the selection of a random node to send the packet rather than broadcasting.

MATERIALS AND METHODS

Gossip as a biologically inspired model: In wireless networks, the process of information dispensation is complex when the nodes have knowledge limitation about network's properties. Thus, problems will rise when certain information requires accessing a particular node or whole nodes within entire the network. Epidemic algorithms have such characteristics. They obey the nature's model through employing unpretentious rules for propagating information by adopting a local environment viewing. Based on this fact, execution of these algorithms is simple and warrants spreading messages within anisotropic areas and is not whole time consistent environments (Shah, 2009).

Gossip is a biologically inspired paradigm of contagion inspired from behavior of the disease infection process. The concept is based on the means of spreading this disease in which an infected person A wants to provide a connection with an uninfected person B in order to infect him with a high probability. It is a data-relayed protocol, utilizing the procedure of flooding without requirements for maintenance of topology or routing tables. It made development for flooding protocol and beat of the flooding issues, i.e., collapse.

Gossiping protocol utilizes a probabilistic theory, where it determines sending the packet with a probability p to its own neighbors and rejects the packet with a probability (1-p). It therefore can decrease the degree of traffic and accomplish power preservation by randomization. The Gossiping technique solves the implosion issue of Flooding but does not the overlap and resource blindness issues.

Radio model system and energy: In general, the transmitter consumes energy for running the radio electronics plus the power amplifier while the dissipation energy of the receiver is based only on running the radio electronics. The channel models use the multipath fading and the free space (d^{α} power loss), where d is the sender to the receiver distance, α is path loss exponent which depends on the wireless fading environment, its value is usually (2 for short d, 4 for long d). The power amplifier can be conveniently set corresponding to this loss by using power control where threshold distance (d_0) is adopted in which if (d_0) is greater than the distance then free space (fs) paradigm must be used, otherwise, multipath (mp) paradigm is utilized.

An acceptable signal to noise ratio (SNR) can be achieved using (Heinzelman *et al.*, 2000).

$$E_{tx} = \begin{cases} E_{elect} \times k + E_{fs} \times k \times d^2 & \text{if } d < d_0 \\ E_{elect} \times k + E_{mp} \times k \times d^4 & \text{if } d \geq d_0 \end{cases} \quad (1)$$

Where:

E_{tx} = The transmission energy consumed for (k) bits
d = Acts the remoteness of the sender node to the receiver one
E_{elect} = Energy dissipated per bit
E_{fs}, E_{mp} = Depend on the modality of the transmitter amplifier

The consumed energy (E_{rx}) due to receiving the message is given by:

$$E_{tx} = E_{elect} \times k \quad (2)$$

Gossip model adopts Eq. 2 to calculate the receiving of power consumed and Eq. 3 for consuming power due to transmitting a packet.

$$E_{tr} = E_{elect} \times k + E_{fs} \times k \times d^2 \quad (3)$$

The proposed algorithm: This section, presents the proposed algorithm (DGossip) which involves the following phases:

- Phase-1: establishing node's gradient to the sink
- Phase-2: a request message has been sent to other nodes within its radio range to receive the information about other member's node
- Phase-3: DGossiping calculates the factor (F) as follows:

$$F = \frac{e_{cn}}{E_0} + \left(1 - \frac{d_i}{d_t}\right) \quad (4)$$

Where:

e_{cn} = The current nodes energy
E_0 = The initial nodes energy
d_i = The i-th nodes distance from the sink
d_t = The total distance from the starting source to the sink

The Factor (F) possesses sufficient effect on selecting the candidate node to be the next transmitter corresponding to the radio range of the sender node. Figure 1 illustrates the general procedure used in DGossip algorithm to construct a route from the data birthplace node to the sink node.

Figure 1 represents the general form of the developed algorithm (DGossip) which includes the following steps:

- Predisposing: specifies the location of start node and location of sink node, packet size (in bits), maximum number of rounds, number of nodes, radio range and threshold energy that represents the amount of energy needed to transmit one packet through using Eq. 3. Also, calculates the distance (d_i) of each node to the sink node by using Euclidian distance

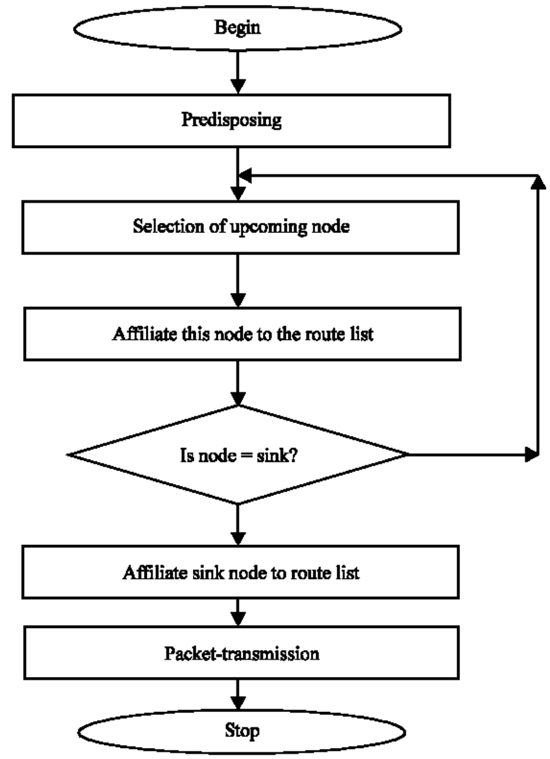

Fig. 1: DGossip procedure

- Selection of upcoming node: In this step, the sender node finds all nodes that are in its radio range and out of sinks radio range which can possess energy more than the threshold energy. Then the Factor (F) is calculated for each node by using Eq. 4. Then, the node with large F can be selected to be the next (recipient) node
- The selected node is added to the route list and a packet transmission will be done. Then the transmission and recipient power consumed are computed according to Eq. 3 and 2, respectively
- Check whether the selection node is the sink node or not. If yes, it is added to the route list and the first path is found for one round. Otherwise steps (a-c) are repeated
- For all rounds, the above procedure can be repeated

RESULTS AND DISCUSSION

In this study, the comparison between DGossip and the traditional Gossip is produced in terms of the average remaining network's energy, number of nodes still alive, cumulative simulation time and the latency(in number of hops) for each round by utilizing MATLAB R2013a as simulation software. The following assumptions are

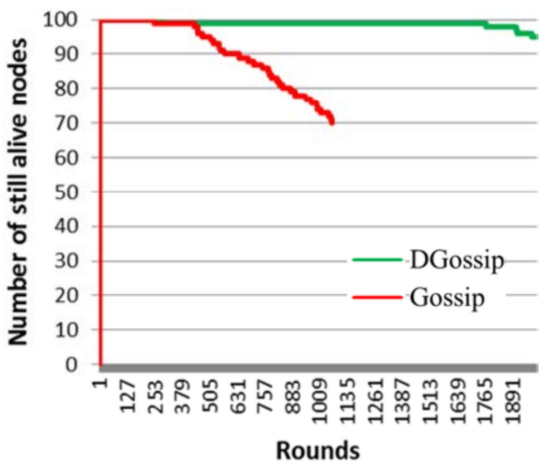

Fig. 2: Live nodes vs. rounds

Table 1: Parameter setting

Parameters	Values
Packet size	100 bits
E_{fs}	10 pJ per bit per m^2
Radio range	25 m
E_{mp}	0.0013 pJ/bit/m^4
EDA	5 nJ/bit/signal
Round	2000 pkt
E_{elec}	50 nJ per bit
No. of nodes	100
Area	100×100 m
Location of Bs	90, 90

adopted for this model: all sensor nodes have the same ability in terms of battery capacity, computation and communication ability. In addition the links are symmetrical between nodes. The used sensor nodes were deployed randomly.

Table 1 indicates the parameters that have been used as implementation parameters in implementing this simulation approach.

Nodes still alive: Figure 2 illustrates the network's live time in terms of number of nodes still alive in both DGossip and classical Gossip.

As shown in Fig. 2, the nodes in Gossip start to die after 254 rounds while after 300 rounds in DGossip. in addition, after all rounds the number of node that still alive are 95 in DGossip and 70 after 1065 rounds in Gossip. Therefore the DGossip algorithm has significantly risen the lifetime of network comparing to Gossip algorithm.

Increased average network's energy: The average remaining energy for overall network can be used as a criterion adopted for energy efficiency of DGossip and Gossip. Figure 3 explains the comparison between both algorithms.

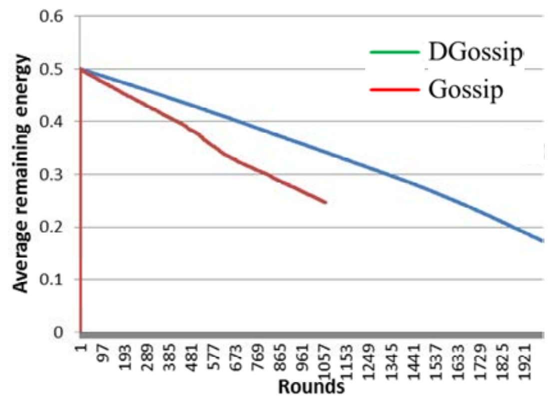

Fig. 3: Average remaining energy vs. round

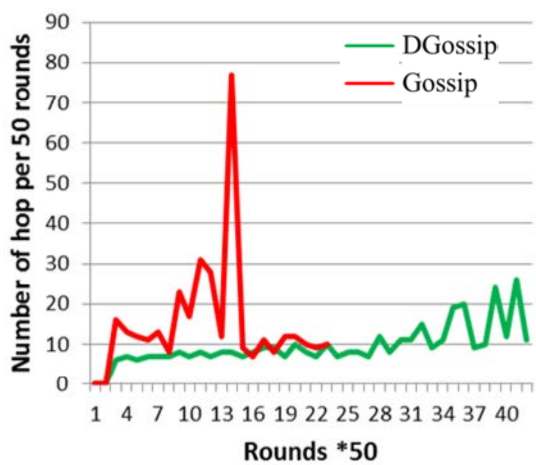

Fig. 4: Number of hops vs. rounds

A node consumes more energy when transmits a packet to another node for long distance. Hence, with DGossip the intermediate nodes are selected heuristically as in Eq. 4 while in Gossip is randomly without considering the distance. So, as shown in the above figure, the average remaining energy for the suggested DGossip algorithm presents a better solution for energy consumption than traditional Gossip algorithm by a high degree.

Decreased number of hops: For both algorithms the average number of hops per 50 rounds has been calculated in our simulation for traveling packets from the starter node to the sink node (BS). Since DGossip select the best route (with a little number of intermediate nodes) to reach the BS. Thus, DGossip investigates a low latency (in number of hop) to deliver a packet from the sender to the BS. Figure 4 clarifies that the number of hops for Dgossip is reduced compared with Gossip, thus leading to the fact that with few number of hops, reducing the latency of packet delivery can be achieved.

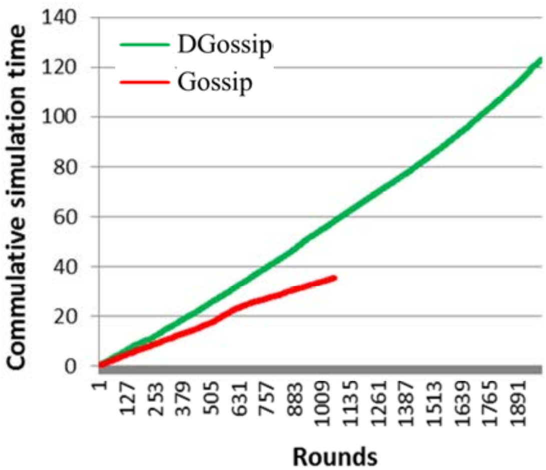

Fig. 5: Cumulative simulation time vs. rounds

Cumulative simulation time: Figure 5 illustrates the comparison between Dgossip and Gossip in term of cumulative simulation time. As can be noticed, the DGossip algorithm outperforms the traditional.

CONCLUSION

In this study, examination of Gossip algorithm as an epidemic routing approach for multi-hop algorithm is introduced and introduced a new procedures called Dgossip. By considering node's position, node’s residual energy and the selection process of the next node which affect the network’s dissipation energy and improve the algorithm’s efficiency can be overcoming the Gossip's shortcomings. According to the simulation results, the performance of both Dgossip and Gossip protocols are conducted in terms of number of nodes still alive, average remaining energy of the network, the number of hops (latency) and cumulative simulation time. As a result, it is concluded that outstanding performance of DGossip is over traditional Gossip. Consequently, prolonged network lifetime and decreased packet's delivery latency can be achieved.

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