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ENERGY EFFICIENT ADAPTIVE BROADCASTING SCHEME FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

Energy-efficiency is a critical issue in wireless sensor networks (WSNs), since sensors are battery operated with limited life time. Energy efficient broadcasting will have a direct impact on network lifetime. Since the minimum energy broadcasting schemes are affected by broadcast storm problem, it has to be addressed to improve the energy efficiency. To overcome the broadcast storm problem, probabilistic schemes have been proposed in the literature to make a rebroadcast decision. However, the random assessment delay (RAD) in probabilistic broadcasting schemes results in poor reachability and increased end to end delay in the congested networks. In the proposed work, the probabilistic scheme adapts its RAD based on network congestion level. The simulation results reveals that the new scheme outperforms the existing schemes in term of saved-rebroadcast, packet delivery and routing overhead.

Keywords: Wireless sensor networks, Energy efficient broadcasting, Broadcast storm problem, Random assessment delay, Probabilistic broadcasting.

1. INTRODUCTION

Wireless sensor networks (WSNs) are employed in many applications including healthcare monitoring, environment monitoring, and battlefield surveillance. WSNs allow computer systems and to remotely interact with the outside world. WSNs will transform the way we manage our homes, industries, and environment. WSN comprises of spatially distributed sensor nodes that cooperatively monitor environmental conditions. Two types of WSN nodes are sink nodes and sensor nodes. While sensor nodes collect environmental information using sensors, sink nodes are in charge of link between the Internet and sensor nodes. Since sink nodes act as a gateway, it has powerful components for the high reliability. Conversely, sensor nodes are normally equipped with low-end components to reduce cost, as thousands of sensor nodes are needed for a WSN to provide the secure environment monitoring function [1]. Sensor nodes are tiny devices with one or more sensors, transceiver, storage resources and actuators.

One of the most critical issues in the WSNs is energy efficiency, because sensor nodes are operated by battery power. Due to battery limitations, WSNs are commercialized based on ZigBee [2] or IEEE 802.15.4 [3], which are current standards for low power communication. The energy conserving resources are highly attractive, as they have a direct influence on network lifetime. Network lifetime is generally defined as the time period the network is able to perform the sensing functions and to send information to the sink. During the network lifetime, some nodes may become unavailable and additional nodes might be deployed. To reduce power consumption, a popular mechanism is to schedule the sensor node activity such that redundant nodes have to enter into the sleep mode as often as possible. Another method is to minimize the sensing range, while the sensing coverage objective is satisfied. Adapting the sensing range leads to minimization of sensing range and the sensor communication range [4]. Power savings are highly possible when communication range is minimized while maintaining the connectivity requirements.

In wireless sensor networks, broadcasting is a well known mechanism for sending message from one identified source node to all other nodes. Broadcasting is widely used in various scenarios, such as network topology discovery processes, network configuration processes, routing processes, and so on. Besides, broadcast operations in wireless sensor networks are performed without any additional cost on the sender side. Therefore, broadcasting is a common operation in WSNs for frequent route judgment and routing solutions. The simplest broadcasting mechanism is blind flooding in which every node rebroadcasts a message when the message is received at the first time [5]. However, numerous articles [6–8] revealed that blind flooding is not a good idea since it introduces lots of duplicate messages and results in collision in wireless networks, which is widely referred to as broadcast storm problem [9]. Several techniques have been proposed in the literature for reducing the broadcast storm problem [10–12].

Since energy consumption is an important issue in wireless sensor networks, it is vital to deal with broadcast storm problems seriously. As mentioned, sensor nodes are concerned with limited energy in WSNs, energy cost is determined during the transmission process. Radio is a main source of energy consumption in WSNs, which comprises of transmission power, reception power and idle power [13]. To improve the energy efficiency and to solve the broadcast storm problem, an energy efficient adaptive broadcasting scheme is proposed in this work.

2. LITERATURE REVIEW

The minimum-energy broadcast problem in wireless sensor networks has received significant attention over the last few years. The characteristics of the broadcast algorithms have become a major research area. Flooding is the simplest method for broadcast operation, but may end up with well known broadcast storm problem [9]. Many flooding mechanisms have been presented to mitigate the effect of broadcast storm problem. The rebroadcast of duplicate packets are contained using network information such as location, retransmission probability [14]. In dynamic probabilistic broadcasting approach, the packet counter was used in counter-based approaches to adjust the probability of forwarding [15]. In case that one node was located in a dense area, it could receive a large amount of rebroadcasts from its neighbors, and thus the calculated packet counter was rather high; accordingly this node shall decrease the re-broadcast probability.

Hanashi et al. [16] proposed another dynamic probabilistic approach, which assign the value of the rebroadcast probability for every host node in relation to its neighbor's information. Jeong et al. [17] proposed an adaptive broadcasting method that utilized the neighbor type information. Many distance based schemes were proposed for broadcasting. DB (distance based) was one of the schemes used to minimize the effects of the broadcast storm problem when disseminating information in wireless networks [9]. It made use of the distance between the source node and the receiver. The main idea of DB was that a node received a broadcast message for the first time would compute the distance to the source node. If this distance was small, the contribution to the dissemination performing this forwarding was negligible, and the message was not rebroadcast. Ruiz et al. [18] enhanced the DB approach by minimizing the transmission power every node used for the broadcasting process in order to save energy and reduce the number of collisions. They added energy efficiency features to the DB approach by reducing the transmission power of the source nodes, and analyzed the influence that reducing the transmission power had over other nodes in terms of the number of collisions or the interference level. In addition, they studied the behavior of the algorithm according to the setting of the delay.

The probabilistic broadcast includes counter-based, location-based, distance-based and hybrid-based schemes. In counter-based schemes, messages are rebroadcasted only when the number of copies of the message received at a node is less than a threshold value. In the location-based scheme, messages are rebroadcasted only when the additional coverage concept [11] determines the location of the mobile nodes to broadcast. In distance-based scheme, the decision made between the relative distance of mobile node and the previous sender. In cluster-based scheme, the network is divided into number of clusters; each cluster has a single cluster head and several gateways. Each cluster head, in turn, acts as a source for rebroadcast within its own cluster and the gateways can communicate with external clusters and are responsible for transmitting the broadcast message externally. Hybrid schemes [12] combine between the advantages of probabilistic and counter-based schemes to achieve the performance improvement.

3. THE PROPOSED SCHEME

Literature review reveals that probabilistic counter schemes are the superior to all the existing schemes to make a rebroadcast decision. However, the random assessment delay (RAD) in probabilistic broadcasting schemes results in poor reachability and increased end to end delay in the congested networks. Our scheme is used to reduce the contention and collision problems associated with conventional probabilistic counter based approaches. It achieves efficient broadcasting by adaptive threshold with a forwarding probability *'p'* which can be fixed based on the local density information. In the existing dynamic probabilistic flooding, the retransmission probability is adjusted according to the number of duplicate packets received within a period of time. On the other hand, the proposed method utilizes the neighbor node information to determine the retransmission probability. The counter identifies nodes with duplicate data packet using threshold values and node removes the redundant message.

This probabilistic approach does not need global topological information of the network to make a rebroadcast decision. Here every node is allowed to rebroadcast a message. This neighbor information, however, is more detailed than the previous neighbor-information-based methods. In the previous schemes, each node has just the neighbor node list to check whether all its neighbors have received broadcast packets already. If any neighbors have not received a broadcast packet, the packet is retransmitted. Using the node densities at various regions in the network, a new probabilistic route discovery approach is suggested in this paper.

For a given topology scenario, if N is the number of nodes in the network and Ni is the number of neighbours at a node x_i at a particular time instant, the average number of neighbours $\bar{n}$ at a node in the network at that time instant is defined by the relation

$$\bar{n} = \frac{\sum_{i=1}^{N} N_i}{N} \quad (1)$$

The initial probability at a node in Group-*i* can be obtained by

$$p_i = \frac{1}{i} p_t \quad (2)$$

Here, *pi* is an initial probability depending on the node density. Assume that the initial probability threshold is p_t.

Each node independently chooses which group it belongs to by using its local node density and sets its forwarding probability that satisfies the condition

$$\sum_{i=1}^{N} p_i N_i < 1 \quad (3)$$

The algorithm for the proposed probability based adaptive broadcasting scheme is shown in Figure-1. The proposed algorithm is composed of three steps. First, nodes obtain neighbor information through the Hello messages. Second, they determine their level within the topology tree and compute the relation with their all neighbors. After that, each node rebroadcasts a packet according to its retransmission probability.

1. On hearing a route request at node X:
2. Get the neighbour information
3. Obtain the number of neighbours of node X;
4. If packet m received for the first time then
5. Get the number of neighbours Nj at node j
6. Generate a random number rd between [0, 1]
7. Compute the relation among the neighbours
8. Decide the transmission probability
   If rd>p
      Send packet
   Else
      Drop packet
   End if
9. While (the message not hearing to start the transmission)
10. Wait for a random number of slots until the transmission actually starts.
11. Node rebroadcasts a packet according to its retransmission probability.
12. End while
13. After the broadcast is completed, node 1 counts the number of nodes belonging to each type. Increment the counter_threshold
14. If (counter_threshold< threshold) Go to 8
15. Else exit algorithm

Figure-1. Algorithm for the proposed adaptive broadcasting scheme.

The use of a rebroadcast probability stems from the fact that packet counter value does not necessarily correspond to the exact number of neighbours of a node, since some of its neighbours may have suppressed their rebroadcast according to their local rebroadcast probability. Therefore to adapt T_{max} to congestion levels, each node keeps track of the number packets received per second. Thus, each host will use a threshold C depending on its current value of n to determine whether to rebroadcast or not. There should be a neighbor discovery mechanism to estimate the current value of *n*. This can be achieved through periodic exchange of 'HELLO' packets among mobile nodes. Each host now executes the following steps

We evaluate the broadcast schemes using the following performance metrics:

- Saved Rebroadcast (SRB) – This is defined as *(r – t)/r*, where *r* and *t* are the number of nodes that received the broadcast message and the number of nodes that transmitted the message respectively. a mobile host rebroadcasts every routing request packet if received for the first time. Consequently, there are *N*-1 possible rebroadcasts, where *N* is the total number of mobile nodes.
- Routing overhead - The total number of route request packets transmitted during the simulation time. For multiple hops, each transmission over one hop is counted as one transmission.
- Packet delivery ratio- The packet delivery ratio is defined as the ratio between the number of packets sent by constant bit rate sources and the number of received packets at destination.

4. PERFORMANCE ANALYSIS

In order to verify the outcome of the proposed adaption scheme, numerous simulations have been performed. We compare the proposed scheme with AODV, fixed probabilistic (FP) and probabilistic counter (PC) methods. The simulation scenarios consist of three different settings, each specifically designed to assess the impact of a particular network operating condition on the performance of the protocols. First, the impact of network density or size is assessed by deploying 50 to 300 mobile nodes. After the node reaches its destination, it again stops for a pause-time interval and chooses a new destination and speed. This cycle repeats until the simulation terminates. The simulation is allowed to run for 200 seconds for each simulation scenario. Other simulation parameters that have been used in our experiment are shown in Table-1.

NS-2 simulator has been used in the network range of 1000x1000m. The numbers of CBR connections that are considered in the experiments are nodes 50,100,150,200,250,300. When the speed is high the traffic load is concentrated on some nodes leads to congestion.

Table-1. Simulation parameters.

Simulation Parameter	**Parameter Value**
Simulator	NS-2 (v.2.29)
Transmission range	250 meters
Bandwidth	2 Mbps
Packet size	64 byte
Traffic type	CBR
Packet rate	1 packet/ 5sec
Network range	1000 m x 1000 m
Number of nodes	50 to 300
Number of trials	30
Simulation time	200 sec
RAD T_{max}	0.01 Seconds
MAC protocol	IEEE 802.11

The packet rate is assumed as 1 packet per 5 seconds. The number of trials allowed for the experiment is 30. The maximum random assessment delay is 0.01 seconds.

Figure-2 shows the values obtained for the saved rebroadcast vs. the network sizes (number of connections) for all the three schemes. When the traffic load increased, there exist many connections between any nodes used to

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reach to the destination, so we choose one of these connections

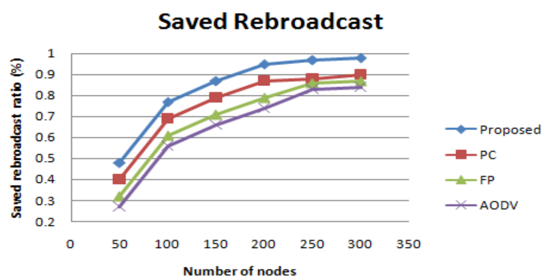

Figure-2. Saved rebroadcast ratio vs. the network size

Figure-3 represents the routing overhead of all schemes for different traffic loads. The routing overhead is increased as the traffic load grows. The number of packets transmitted on the network has a considerable impact on overhead. Most of the generated data packets and connections are dropped resulting from collisions and contention. Nevertheless, our proposed scheme will decrease the NRL over the traffic load percentage against other schemes and shows better performance up to 11.5%.When the number of CBR connections increases the number of collisions, contentions and redundant rebroadcast packets grows. Thus, this leads to more retransmissions of packets towards the destination and, hence, resulting in growing delay. Figure-3 shows that flooding incurs higher end-to-end delay. This is owing to the higher number of redundant rebroadcasts of RREQ packets with collisions and contention caused by many RREQ packets that fail to reach the destination.

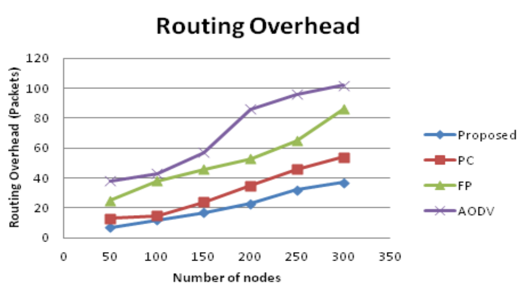

Figure-3. Routing overhead Vs Number of nodes.

Figure-4 illustrates the packet delivery ratio (PDR). This is the ratio of nodes that have received the packet after broadcasting is finished. The PDR is the most important performance metric for broadcasting schemes, considering that the goal of broadcasting is to deliver packets to all nodes. The PDR tends to be increased in proportion to the node density as a single transmission can cover more nodes in a denser network. From the Figure-4, the proposed scheme achieves the packet delivery of 98.5% which is higher than all other existing schemes

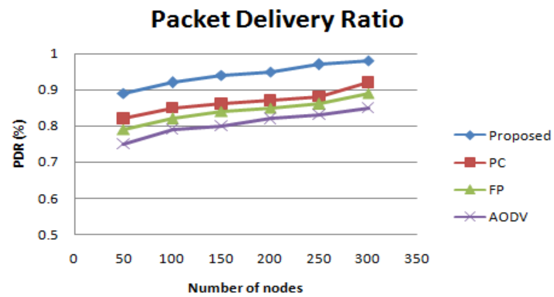

Figure-4. Packet delivery ratio Vs Network size.

Meanwhile, the PDR of the fixed probabilistic is much different depending on the number of nodes as the retransmission probability is fixed at 0.6 all the time. On the other hand, the probabilistic counter method adjusts its retransmission probability to the node density, so it can achieve PDR greater than 90% at the node density of 300. The proposed algorithm has the better PDR than the other probabilistic methods, being greater than 90% for all cases of network density. It can more adaptively determine the retransmission probability compared with the others.

5. CONCLUSIONS

This work proposed an energy efficient broadcasting scheme to accomplish efficient broadcasting by adaptive threshold value. The proposed approach adaptively sets the value of the rebroadcast probability according to its neighbour's information. Simulation results disclose that saved rebroadcast ratio is high and maximizes delivery ratio to 98. 5%, and thus achieves superior performance in terms of reachability and routing overhead over the other schemes. The RAD setting in the proposed method based on network congestion level greatly reduces the routing overhead. Simulation results conclude that the proposed scheme outperforms the existing schemes in term of saved-rebroadcast, packet delivery and routing overhead.

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