Enhanced Flooding overlay Structure for WSN

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***Abstract*— Data transmissions in the sensor network are mostly based on flooding. The original flooding result in the implosion and the overlap problems, so flooding results in the reduction of network lifetime of the sensor network with limited resources. In order to reduce the overhead by flooding, the flooding overlay structure (FOS) was used, which uses the concept of the overlay network so that the overhead caused by flooding is reduced. We have modified the FOS mechanisms to increase the life time of the sensor network, the Enhanced centralized flooding overlay structure (ECFOS) and the Enhanced distributed flooding overlay structure (EDFOS). ECFOS is for the static sensor network in which the sink can select forwarding nodes more effectively. And EDFOS is proposed for the dynamic sensor network environment. We have carried out simulations for our ECFOS and EDFOS mechanisms, and shown that our ECFOS and EDFOS mechanisms are performing well compared to the original FOS mechanism.**

Keywords*— Flooding Overlay Structure, Enhanced Centralised Flooding Overlay Structure, Enhanced Distributed Flooding Overlay Structure, Enhanced Flooding Overlay Structure.

I. Introduction

The wireless sensor network is the network composed of wireless sensor nodes distributed over a specific area to monitor the environmental condition within that area. Sensor nodes sense and measure some requested event, and send the sensed data to the sink via the wireless channel. The sink collects and analyzes data from sensor nodes. The sensor network is different from the mobile ad hoc network (MANET) in the sense that sensor nodes have lower mobility, limited energy and denser distribution.

One of the most important issues in the sensor network is network lifetime. In general, the network lifetime is defined as the time when for the first time any sensor node experiences energy depletion. Most of the energy consumption is for radio communication. For example, the amount of the energy consumed for the delivery of 1 bit to a place located 100 m apart is almost the same as the energy required for the execution of 3000 commands [1]. However, most of the packet transmissions in the sensor network are based on flooding, which causes unnecessary energy consumption. For example, the sink to query other sensor nodes about the occurrence of events (such as the dissemination of the INTEREST packets in the directed diffusion [2]) or a sensor node to notify the sink of the occurrence of events uses the flooding mechanism for the dissemination of its data.

The Enhanced flooding overlay structure (EFOS) which adopts the concept of the overlay network to reduce the overhead caused by frequent packet flooding within a sensor network. The Enhancement for the FOS mechanism are, Enhanced centralized FOS (ECFOS) and Enhanced distributed FOS (EDFOS). Here we are analyzing the pros and the cons of both mechanisms. Their performance will be analyzed by carrying out simulations.

The rest of this paper is organized as follows: in section 2, the previous works on FOS mechanisms trying to reduce the overhead of the original flooding are mentioned. In section 3, our proposed FOS mechanisms are described in detail. Section 4 presents the performance comparisons of the original FOS(CFOS and DFOS) and the proposed FOS mechanisms (ECFOS and EDFOS). Section 5 concludes this paper.

II. RELATED WORK

1. Routing Protocols In WSN

Depending on the network structure routing in WSNs can be divided into flat-based, hierarchical-based and location-based. In flat-based routing, all nodes have equal roles or functionality. In hierarchical-based routing, nodes are having different roles in the network. In location-based routing, position of the sensor nodes is used to route data in the network

A routing protocol is considered adaptive if some system parameters can be controlled in order to adapt to the current network and the available energy levels. Protocols can be classified into multipath-based protocols, query-based protocols, negotiation-based protocols, QoS-based protocols, or routing techniques depending on the protocol operation. In addition to that,, routing protocols can be classified into three categories, namely, proactive, reactive, and hybrid protocols based on how the source sends a route to the destination[3]. In proactive protocols, routes are computed before they are really needed, in reactive protocols, routes are computed on demand basis. Hybrid protocols use a combination of proactive and reactive protocols. When sensor nodes are static, it is good to have a table driven routing protocols than reactive protocols. A significant amount of energy is used in route discovery and in the setting up of reactive protocols. Another class of routing protocols is cooperative routing protocols. In cooperative routing, nodes send data to a central node where data can be aggregated and may be subject to further processing, hence reducing route cost in terms of energy usage[3].

2. Energy Constraints In WSN

In WSN, sensors dissipate energy mainly during transmission and reception of data as compared to data sensing and processing, while a significant amount of energy is wasted with regard to data communications is mentioned below[3].

- Data Collision: Data packets collide when a node receives more than one at the same time resulting in all the packets that caused this collision being discarded which will in turn necessitate retransmission of the discarded packets causing significant energy waste.
- Data Overhearing: Although a node is not transmitting, it will eventually listen to transmissions destined for other nodes causing continuous energy waste.
- Idle Listening: This phenomenon occurs when a node keeps listening to an idle channel in search of a data packet destined for it.
- Interference: Energy is wasted as each node within the transmission and interference range receives a packet but cannot decode it.
- Control Packet Overhead: Control packets usually synchronize the whole data transmission phase but don't carry any user data. Therefore, it is always a design goal that minimal number of control packets be generated to reduce the energy consumption by these non-data packets.

3. Energy Efficient Routing Protocols In WSN

In most of the practical applications, we do not want any coverage gaps to arise. The main aim of an Energy Efficient Routing (EER) is to maximize network lifetime by minimizing energy consumption in end-to-end transmission. WSN are highly application-specific which means the routing protocols are also dependents on the applications.

In general, routing in WSNs can be divided into flat-based routing, hierarchical-based routing, and location-based routing depending on the network structure. In flat-based routing, all nodes are typically assigned equal roles or functionality. In hierarchical-based routing, however, nodes will play different roles in the network. In location-based routing, sensor nodes' positions are exploited to route data in the network [3].

The main research issue regarding Energy Efficient protocols is how to develop a communication path so that the energy consumption and contemporary communication metrics such as latency is optimized.

In ECFOS, the BS select some of the nodes as FOS nodes and they are taking part in the forwarding of packets. And in EDFOS the nodes itself recognize that whether it will become a FOS node that is based on the Notice Delay. The problem with the CFOS and DFOS [4] mechanism are its Network lifetime. But the Network lifetime is considerably increased with EECFOS and EDFOS

III. ENHANCED FOS MECHANISM

In this paper, we propose Enhancements for FOS mechanisms, the Enhanced centralized FOS (ECFOS) and the Enhanced distributed FOS (EDFOS), for the purpose of increasing the Network lifetime of the actual FOS mechanism.

In ECFOS, the BS collects the topology information from all sensor nodes and, from the collected information; it selects the FOS nodes which are going to participate in data forwarding. Determining FOS nodes at the BS is reasonable since the BS is usually not limited in power and computing capabilities, and this can make each sensor node exempted from the duty of deciding whether to participate in flooding or not. Since ECFOS utilizes the entire network topology information, ECFOS is more effective in determining FOS nodes than EDFOS. Since in ECFOS the sink collects topology information only once, that is at the starting of the network, ECFOS works better when the network is static.

On the other hand, in EDFOS, each node determines whether it becomes a FOS node or not based on the entire network topology, but on its own local information. Therefore, EDFOS adapt well to the dynamic network environment, but it requires an additional mechanism to provide the network connectivity so that all sensor nodes are assured to receive broadcast packets. EDFOS works efficiently in the sensor network since the neighbour information exchange (like the exchange of HELLO messages in MANET) among sensor nodes is not required for the construction of a FOS. The neighbour information exchange usually used in MANET flooding mechanisms will consume plenty of wireless link resources and sensor node power, which implies that those efficient flooding mechanisms proposed for MANET are impossible to be used in the sensor network environment

- ECFOS
  - At first, the Base Station requests the location information from every sensor node by broadcasting a Location Discovery (LD) message to the entire network.
  - Upon receiving the LD message, each sensor node sends a Location Response (LR) message which contains the topology information of the sensor node, such as the number of neighbour nodes and the list of neighbour node IDs, to the BS.
  - The sink constructs the topology information from the collected LR messages and determines FOS nodes based on the topology information. The FOS nodes are those which can participate in the forwarding of packets. In this case, the most challenging problem is how to provide the network connectivity so that all sensor nodes can receive broadcast packets. The problem to select the optimal set of FOS nodes to provide the network connectivity is the connected dominating set problem
  - The sink broadcasts a FOS packet with the list of the selected FOS nodes.
  - Each sensor node receiving the FOS packet knows whether it is a FOS node or not. If it is present in the FOS list then, it participates in the forwarding of packets.
  - If the remaining energy of a FOS node falls below some pre-specified amount, the FOS node notifies its neighbours by sending a Ready-to-Die (RD) packet via 1-hop flooding.
  - Up on receiving the Ready to Die (RD) packet each sensor node sends a Response (RD_ACK) message which contains remaining energy level information and position information of the sensor node.
  - Based on the values of the position coordinates in RD_ACK message, dyeing FOS node set some of the 1-hop nodes as FOS nodes. And send the FOS list via 1 hop flooding.

- EDFOS
  - The sink broadcasts a Location Discovery (LD) packet to the entire network.
  - Each sensor node receiving the LD packet sends a LD_ACK packet to the sink. If a sensor node receives the LD_ACK packet a given number of times from other sensor nodes, the sensor node becomes a FOS candidate node.
  - Each FOS candidate node determines the notice delay based on the number of its neighbour nodes. A FOS candidate node which has not received a Notice_packet from any of its neighbours during the pre determined notice delay, then it can change its status to a FOS node, and sends a Notice_packet to its 1-hop neighbours via flooding to inform that it becoming a FOS node. This is how the network connectivity is maintained in EDFOS.
  - A node which is not a FOS candidate node can be a FOS node, if it has not received a Notice_packets from its neighbours during a pre-specified time. Then the node changes to a FOS node and sends a Notice packet to its neighbours via 1-hop flooding
  - If the remaining energy of a FOS node falls below the threshold value, the FOS node notifies its neighbours by sending a Ready-to-Die (RD) packet via 1-hop flooding.
  - Up on receiving the (Ready_to_Die) RD packet each sensor node sends a Response (RD_ACK) message which contains position information of the sensor node.
  - Based on the values of the position coordinates in RD_ACK message, dyeing FOS node set some of the 1-hop nodes as FOS nodes. And send the FOS list via 1 hop flooding.

IV. PERFORMANCE EVALUATION

We have performed simulations using the NS-2 simulator [5] with the NRL sensor network extension package [6]. Our simulations were carried out for the sensor network with randomly distributed 50 nodes in the area of 1000 x 1000m. By adjusting the transmission radius of each node, the network node density varies from 7 to 12. The node density is calculated by dividing the average number of neighbor nodes of each node by the size of the transmission area. The initial node energy is set to 10J(Joule) and the buffer can store up to 50 packets. If the available node energy lower than 10-4J, it is assumed to be insufficient for the proper operation of node. Events are generated uniformly within the given sensor network. We have analyzed the following aspects:

- Network Lifetime Vs Node Density
- Number Of Packets Transmitted Vs Node Density(ECFOS and EDFOS)

Fig. 1 shows the network lifetime vs node density. Network lifetime means the time till a node becomes dead due to energy drain. When the node density increases, the network lifetime of the original FOS mechanism decreases since when the energy of a transmitting node decreases, all neighboring nodes will starts to transmit. ECFOS yields longer network lifetime for higher node density since ECFOS allows only FOS nodes to transmit broadcast packets in order to reduce the number of duplicate packets and when the energy of a FOS nodes falls below some threshold value, then only a few nodes will change its status to FOS as specified . EDFOS gives slightly shorter network lifetime than ECFOS for higher node density due to the increased number of control packets such LD_ACK and Notice packets.

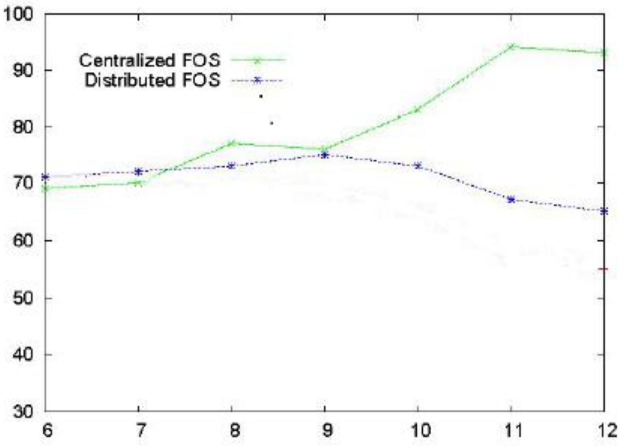

Fig-1 Network Lifetime vs. Node Density

Fig. 2 shows the number of packets transmitted vs node density. Here, the number of packets implies the number of control and data packets. In original FOS mechanism, when the energy of an FOS node fall below the threshold value, then all neighbouring nodes will change its status to FOS node. Which will gradually increasing the packet overhead. ECFOS shows the better performance compared with EDFOS. Since ECFOS selects FOS nodes based on the entire network topology information collected from all sensor nodes, EDFOS shows slightly leaser better performance than ECFOS, which determines FOS nodes in a distributed manner. When comparing with the original FOS mechanism, packet transmission in ECFOS and EDFOS are considerably decreased. This is because when the energy of FOS nodes falls below some threshold value, then only a few nodes will change its status to FOS.

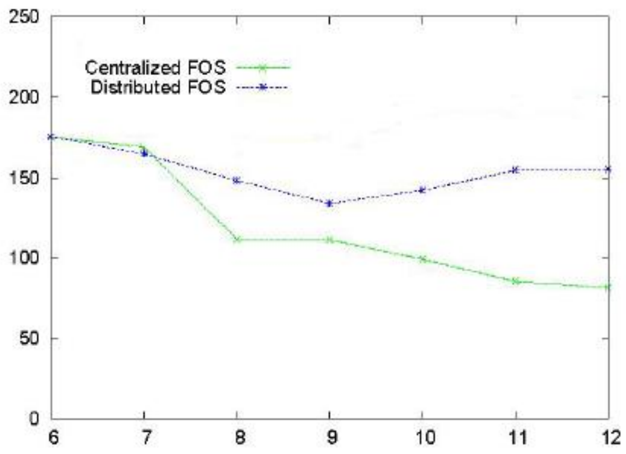

Fig-2 Number of Packets Transmitted per Second vs. Node Density

V. CONCLUSION

One of the most important issues on the sensor network with resource-limited sensor nodes is prolonging the network lifetime by effectively utilizing the given energy. Most of the data transmissions in the sensor network are based on flooding. The original flooding causes the implosion and overlap problems, so flooding may result in the reduced network lifetime of the sensor network with limited resources. Therefore, in this paper, we are enhancing flooding overlay structure (FOS) which adopts the concept of the overlay network so that the overhead can be reduced. We proposed two types of FOS mechanisms, the Enhanced centralized FOS (ECFOS) and the Enhanced distributed FOS (EDFOS).ECFOS is for the static sensor network in which the sink can select forwarding nodes more effectively. And EDFOS is proposed for the dynamic sensor network. For the provision of the network connectivity in EDFOS, the notice delay was used. We performed simulations for our proposed mechanisms, and showed that our Enhanced FOS mechanisms performing well compared to the original FOS mechanism in terms of network lifetime and the packet overhead.

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