Effect of Multiple Sinks on the Performance of Wireless Sensor Networks

Gajendra Sanjay Vyas, Vivek S. Deshpande

Abstract: Wireless Sensor Network is a collection of sensor nodes. These nodes are to able sense the surrounding environment and based on changes in environment sends data to destination which is called as Sink in sensor networks. When any event occur each sensor node try to disseminate data to sink. Due this congestion becomes the primary problem of network which must be solved, the retransmission of data packet also increased. Due to congestion the other quality of service parameters (like reliability, throughput) gets decreased. There are two techniques by which congestion can be reduced which are: either by reducing the data sending rate of source or by providing extra resources. Reducing data sending rate will decreases the network throughput. In this paper we proposed the multiple sink mechanism in which sensor nodes are able to deliver data to multiple sink in the network. Simulation result shows that proposed congestion control mechanism improve the packet delivery ratio, reliability, throughput of the network and also reduces the packet loss ratio which reduces the number of retransmission, saves the energy of sensor node . This will improve the network lifetime. It will also able to handle the "Black Hole Problem" in the wireless sensor network.

Keywords: Congestion Control, Wireless Sensor Network, Packet Delivery Ratio, Multiple Sink, and Reliability

I. INTRODUCTION

Wireless Sensor Networks (WSNs) is a collection of large number of tiny sensor nodes which are also has the capabilities of sensing the environment, data processing, and communicating ability [1]. The sensed data is then sending through intermediate sensor nodes to the destination which is also called as Sink in WSNs. WSNs large range of application such as Mobile health monitoring [2], habitat monitoring [3], Military and Security. The data sense by the sensor nodes is of two types: Event Driven Data and Periodic Data. Event driven data means the data which is generated on an occurrence of any particular event. For example the sensor monitoring the fire detection in forest will send data to sink immediately after the huge rise in temperature. Periodic data means data which is send after equal amount of time interval. For example the sensor monitoring humidity of city will send data of humidity after every 6 hours to sink.

The event driven nature leads to huge traffic in the network [4]. Initially network is in idle load and suddenly become active when any event is detected. However the generated data has very high importance. Since all sensor nodes sends data then congestion is primary problem of network.

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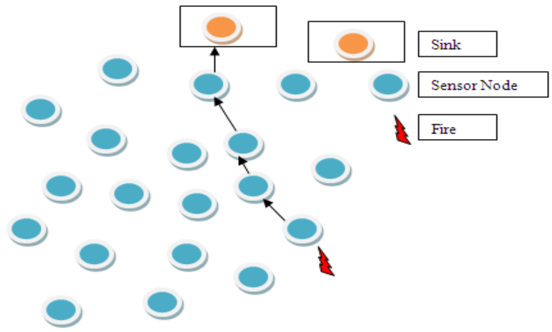

Figure 1.General Architecture of Wireless Sensor Network

Figure 1 show the general architecture of wireless sensor network in which various sensor nodes are deployed in region. These sensor nodes are able to sense the surrounding environment. The event is occur near the sensor node then that node sense data and sends it to the sink through various intermediate nodes. The flow of data shown with the help of directed arrow. This figure clearly helps us to understand the working of the wireless sensor network.

Congestion in wireless sensor networks has as unenthusiastic impact on energy consumption, throughput and reliability [5]. Basically there are two types of congestion can happen in WSNs. These are node level congestion and link level congestion [6]. As the node are tiny in size so they also have small buffer size, when this buffer of node gets full and still there are incoming packets to the node then the node level congestion happen. Due to the node level congestion the packet loss of the network is increased, also the throughput and reliability of the network gets minimized. Link level congestion occurs when multiple active sensor nodes try to infuse the traffic in channel at the same time. Due to the link level congestion the packet service time gets increased and decreases link utilization of network.

This congestion problem makes the great impact on other quality of service parameter (like energy, throughput, reliability and delay).So one must have to control congestion in WSNs because they deal with most of real time application where human life comes in picture.

In WSNs any congestion control mechanisms has following steps: Congestion detection, congestion notification and reporting rate adjustments [7]. Solution given in many standard literature controls the congestion in network by reducing the data sending rate of the source which ultimately reduces the network throughput [8].There are some basic causes of congestion such as input/output flow rate, node density, processing time of node, unbalanced distribution of load [9].

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In this paper we propose a solution that sufficiently alleviating the congestion with the help of multiple sinks. "Black Hole" is predicament in WSNs. This means that the sensor nodes which are one hop away from sink is very congested and sensor node utilize all amount of energy and become inactive. If these one hop away node become inactive then the data to the will never delivered. So the entire network gets useless because we don't get the data because the communication link gets deleted. So to overcome this problem suggested mechanism help a lot. Suppose that the communication link between one sink lost then we able to deliver data to another sink. Due to this mechanism the purpose of sensor network gets satisfied. Simulation result shows that we have improved the packet delivery ratio and throughput of network without any compromise with the reporting.

The rest of the paper is organized as follows: Section II shows the related work which is carried out to control the congestion in wireless sensor network. Section III described the experimental results of proposed mechanism. Finally Section IV concludes the paper.

II. RELATED WORK

Swastik Brahma et. al. [10] has proposed a congestion control mechanism which provides a fair and efficient data sending rate to each node. The proposed mechanism runs on each individual node separately and monitors its input and output data sending rate, based on these differences the node decides whether to increase (if output rate is more) or to decrease (if input rate is more) the bandwidth allocable to flow originating from itself and to those being routed through it. They used utility module and fairness module. The utility module control the utilization of the network and the fairness module assign the fair and efficient data sending rate to each and every node. The main advantage of this proposed mechanism is that, it is independent of the underlying routing topology. The mechanism is also able to adapt itself to the changes in underlying routing technology. The disadvantage of this is that it introduced the feedback delay in flow of network. The feedback delay of flow is time interval, measured starting from the time node *i* starts transmitting flow f_i at rate r_a to the time the control signal arrives and changes the rate to r_b.

In Congestion-Aware and Rate-Controlled Reliable Transport in Wireless Sensor Networks (CRRT) author propose the rate control mechanism to control congestion in network [11]. To achieve high one hop reliability of network CRRT uses the efficient MAC (Media Access Control) retransmission and end to end retransmission for loss recovery purpose. CRRT uses NACK to inform that the packet is loss. For congestion detection the author uses buffer occupancy by using two threshold value, lower-threshold and the upper-threshold. When buffer occupancy is more than upper-threshold the CN (congestion notification) bit is set in all forwarding packet, so that the neighbor knows that congestion going to happen. CN bit is of two-bit. Congestion is control by using the rate control method. Rate control method used in CRRT is of two types: Distributed Rate Control and Central Rate Control. In distributed rate control CRRT uses the Weighted Proportional Back off (WPB) instead of binary exponential back off. In central rate control, it is determined that the rate at which the sink is able to receive the data from source without congestion level. If sink receives the CN bit as 11 then sink decreases the rate and again increase rate. To increase and decrease of rate sink us the AIAD (Additive Increase Additive Decrease) mechanism. Performance results of CRRT show that it has achieved good energy efficiency and transmission efficiency. The mechanism runs on sink so that it is somewhat slower and the energy of sink gets more consumed.

Charalambos Sergiou et. al. [12] has designed the Hierarchical Tree Alternative Path (HTAP) algorithm for congestion control in wireless sensor network. The HTAP algorithm is one of the resource control algorithm. Most algorithms designed for congestion control are based on traffic control (reporting rate control). HTAP is dynamic congestion control algorithm that uses packet switching decision based on local information, such as congestion state of its neighbor. HTAP divides work into four parts which are: Topology, Hierarchical tree creation, Alternative path creation and Handling of powerless nodes. In Topology they used Local Minimum Spanning Tree algorithm (LMST). LMST algorithm finds the neighbor nodes of each node. In LMST each node builds its local minimum spanning tree using Prime's algorithm and tree keep those node which are one hop away from its self. In Hierarchical tree creation consists of two main steps: Path creation and Flow establishment. During Path creation point each source node is self assigned as level 0 and sends level discovery message to its neighbor. Like this continues until level discovery message arrive at sink. In Flow establishment, a two-way handshaking connection is established between each transmitter and receiver. When a higher level node receives a packet from lower level node then it sends back ACK packet which consists of its current congestion state. In alternative path creation when congestion gets happen then locally lightweight congestion detection algorithm runs on each node. It uses buffer occupancy for congestion detection. Once congestion is detected the alternate path are find and packets are send through that alternative path. The bigger advantage of this algorithm is that it is very simple and doesn't add any overhead to the congested network. Apart from this due to alternate path delay gets increased to reach the packet to sink.

III. PROPOSED MECHANISIM

A) Simulation Parameters:

To evaluate the performance Network Simulator 2 (NS-2) is used. In simulation uniform random network topologies with multiple sink nodes are considered. A network of area 1000 m * 1000 m is used. The simulated traffic is Constant Bit Rate (CBR). Simulation consists of 30 sensor nodes; packet size is of 50 bytes, reporting rate is 10 packets per second, MAC layer protocol is IEEE 802.11 and Ad-hoc On Demand Distance Vector (AODV) is used as routing protocol for packets in network. Initial energy of all nodes is 1 Joule.

B) Performance Merits :

Received Packets are the packets which are successfully delivered to the sink. Drop Packets are the packets which are get dropped due to congestion in the network. Performance qualities such as Packet Delivery Ratio (PDR) which is the ratio of number of received packets at destination sink to the number of packets send.

Packet Loss Ratio (PLR) which is the ratio of number of drop packets to the number of send by CBR source. Throughput is the number of processed packet per unit time.

C) Performance Evaluation:

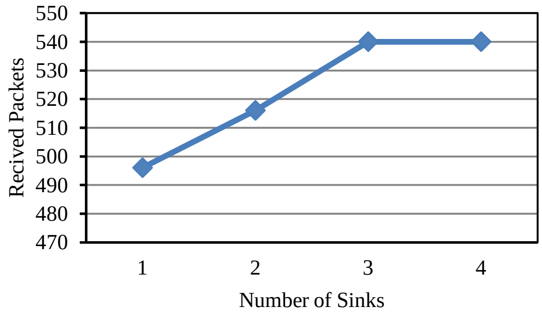

Figure 2: Received Packets as Function of Number of Sinks

Figure 2 shows the received packets as a function of number of sinks. Figure clearly shows that as you increase the number of sinks the received by the sink are also increases linearly. This occurs because as you increase the number of sink the chances of getting data delivered to sink is also increases. After a specific point the received packets are become constant after increases in number of sink because at that point all the data is delivered to the sink.

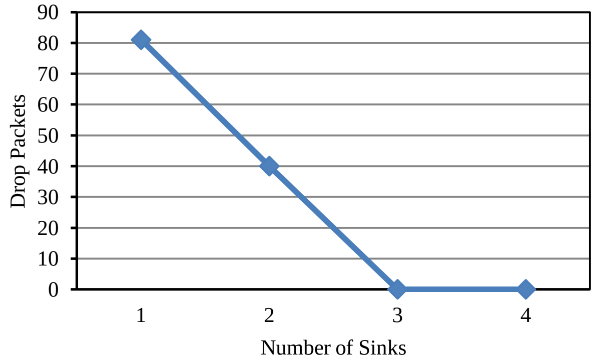

Figure 3: Drop Packets as a Function of Number of Sinks

Figure 3 shows the drop packets as a function of number of sinks. As you increase the number of sink the drop packets are decreases linearly. After increase in number of sink the probability of packet loss becomes less because nodes are able to deliver data to different sink. After a point we get drop packet count as zero (0) because at that point all generated packets are delivered to sink and still there are some packets which are neither dropped nor delivered to sink. These are present in the input buffer of sensor nodes.

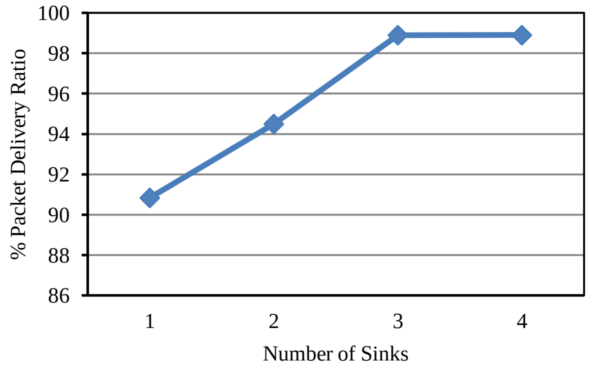

Figure 4: Packet Delivery Ratio as a Function of Number of Sinks

Figure 4 shows the packet delivery ratio as a function of number of sinks. It shows that as the number of sink increases the packet delivery ratio also gets linearly increased. After a specific threshold it remains constant. This happens because of number of sink. Due the congestion in the network the packet delivery ratio is lower when uses one sink, as we increases the number of sink the PDR also gets increases because the probability of delivering data gets increased. As PDR increases the overall reliability of the network gets increased and the congestion in the network gets control.

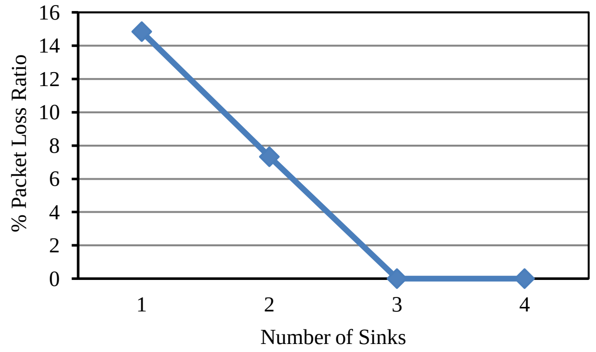

Figure 5: Packet Loss Ratio as a Function of Number of Sinks

Figure 5 shows the Packet Loss Ratio as a Function of Number of Sinks. It shows that as we increases the number of sink the packet loss ratio is decreases drastically. When we use one sink then due to the congestion the dropped packets are more. But as we increases the number of Sink the probability of getting sink increases due to which ultimately the drop of packets gets decreases. As the packet loss ratio decreases the number of retransmission are also gets reduced which saves the energy of the sensor nodes and overall network lifetime. We get zero percentage of PLR (0%) because at the end of simulation there are some packets which lie in buffer of sensor node which are neither delivered to the sink nor dropped by sensor node. They are present in the input buffer of the sensor node which is not considered as dropped packets.

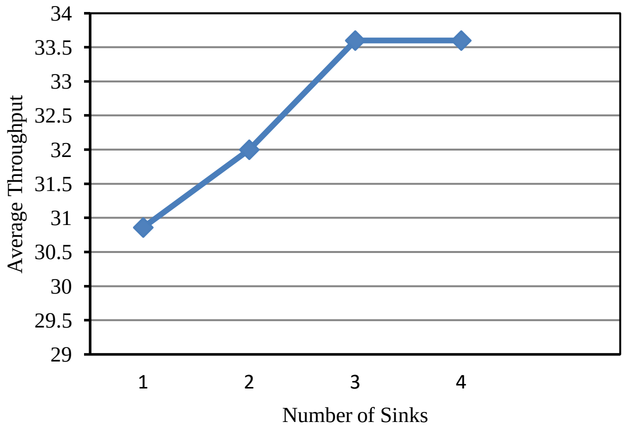

Figure 6: Average Throughput as a Function of Number of Sinks

Figure 6 shows the average throughput as a function of number of sinks. For minimum number of sink we get lower throughput. As we increases the number of sink the throughput also gets increases linearly to some threshold but after that it remains constant, this is happen because the chance of getting the destination for packet gets increased.

IV. CONCLUSION

Proposed mechanism alleviates the congestion in wireless sensor network. In WSNs the congestion causes the unnecessary retransmission of the packet and decreases the other quality of service parameter. So we must have to control congestion in WSNs, due which the quality of service parameter of network gets increased. In our proposed mechanisms the congestion is reduced by using the multiple sink but after number of 3 sinks the results are constant. So you can increase the number of sink up to 3 for better performance of network and still if you increases the number sinks then it will add more overheads and it is wastage of resource. As a result we get improved packet delivery ratio which also increases the reliability of the network and average throughput of the network. The proposed mechanism is also able to handle the black hole problem of WSN. Proposed mechanism shows good results for AODV routing protocol which means that it will also shows good results for Dynamic Source Routing (DSR) and Destination Sequenced Distance-Vector (DSDV) routing protocol.

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