Congestion Control in Wireless Sensor Network-A Survey

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Abstract—Wireless Sensor network is the network of sensors. The sensors are the nothing but the small devices which have the sensing ability, storage capacity and also the energy or the power storage. The function of the sensors is to sense the environmental conditions like temperature, humidity and send this information to a device or node called sink node or base station. There are number of sensors in the network. All the sensors sense and transmit the data to a single sink node at the same time, which can cause the congestion. This is an important issue because the congestion can cause the data packet loss or delay in the network. It also reduces the system throughput. There are number of protocols which can control the congestion. This paper includes a survey of 3 protocols: "A Fairness-Aware Congestion Control Scheme in Wireless Sensor Networks", "ECODA: Enhanced Congestion Detection and Avoidance for Multiple Class of Traffic in Sensor Networks" and "Upstream Hop-by-Hop Congestion Control in Wireless Sensor Networks".

Keywords— Wireless sensor network, congestion control, throughput.

I. INTRODUCTION

Wireless Sensor Network is network of nodes or devices called sensors which is different from the traditional network [7]. In Wireless Sensor Network, large numbers of sensors are deployed in the sensor field for the specific purpose. The wireless sensor network is highly distributed network.The sensors in wireless sensor network do not have any fixed position. The sensors are very lightweight devices. Also the power or energy with the devices is very limited. The sensors have sensing ability with which it senses the atmospheric or environmental condition. It not only sense but also forwards the data sensed by neighbor. The data storage capacity of the sensors is very less. After sensing, the data sensed by the node or received from the node is forwarded towards final processing device or node called sink node. This nature of network is many to one nature. That means there are number of sensor nodes; all of them senses the environmental conditions and sends the data to a single sink node. When an event occurs, all the sensors become active. And this convergence nature can cause the congestion in the network. If the data sending rate of the sender in much higher than the data handling or processing capacity of the receiver or the buffer space at the receiving node is not enough, then it may get overflow and can cause data packet loss. So the limited bandwidth, high data sending rate, convergent nature of the network, event driven nature of the network all these are important factors that causes the congestion. The congestion control is an important issue because it can reduce the system throughput; data packets can be loss or delay in the network. The energy or power with the sensors is very limited. If data packets get lost and we are using the option of retransmission, then it can be the wastage of the energy. To control the congestion, it should be properly detected; sender should know the status of the congestion in the network so that it can adjust the data sending rate. There are many different protocols whish can control the congestion. Some transport layers provide flow and congestion control service to coordinate the suitable transmission rate between senders and receivers [11].

The computer network architecture is layered i.e. there are different layers like physical layer, Data link layer, Network layer, Transport layer, Session layer, Presentation layer, application layer (from lower layer to higher layer). The lower level protocol provides services to the higher or upped layer. The messages are segmented at the node and transport layer end to end segment transportation [11]. The examples of transport protocols are TCP and UDP. The TCP can be connection oriented or connection less and UDP is connectionless protocol. The transport protocols can be classified into 2 types: elastic and non-elastic. The elastic protocol means data sending rate can be controlled by the sender whereas non-elastic protocol means data sending rate cannot controlled by the sender. The TCP is elastic and UDP is non-elastic. Due to their features, the connectionless protocol cannot provide that much services like connection oriented protocols. And it is less reliable than the connection oriented protocols. It is not possible that all the connection less transport protocols support all the features like Orderly transmission, Flow control, Loss recovery, congestion control, Quality of service, Fairness, Reliability, Energy efficiency. There are number of protocols and these protocols support the above mentioned features depending on the application or the need of the user.

II. RELATED WORK

According to Xiaoyan Yin and Rongsheng Huang, to avoid the wastage of the resources available to the node that is the bandwidth or the energy, transmission of unnecessary packets should be avoided. And to avoid the retransmission, the congestion and data packet loss must be avoided. For this, it is necessary to adjust the data sending rate. The authors Yin, et al. categorized all the sensor nodes into near-sink node and near-source node in his scheme- 'Fairness-Aware Congestion Control Protocol (FACC)' where Near-source nodes maintain a per-flow state and allocate an approximately fair rate to each passing flow by comparing the incoming rate of each flow and the fair bandwidth share. On the other hand, near-sink nodes do not need to maintain a per-flow state and use a lightweight probabilistic dropping algorithm based on queue occupancy and hit frequency [3].

To differentiate between the near-sink node and near-source node, a specific label field is used which is optional according to author. This label field is set by the source node and each forwarder sensor node decrease that label by 1 until it becomes zero. This label field becomes zero when the data packet reaches to the destination.

A queue is maintained to each near-sink node with two thresholds Ql and Qh. If the queue occupancy is less than Ql, the incoming packets will be accepted. On the other hand, if it exceeds Qh, the incoming packets will be dropped. At this time, the data sending rate of all the flows should be reduced. If the queue occupancy is in between Ql and Qh, and the packet is dropped, it indicates the rate of that particular flow is high .Then it is necessary to reduce the data sending rate of that particular flow. To indicate this network status to the particular source node, the near-sink node sends warning message or we can say backpressure message to the source node via the intermediate sensor nodes or he near-source nodes.

When the near-source node receives the warning message, it means that the flow arrival rate is higher than the fair rate or the ideal rate. The near-source node sends the control message to source node indicating that the data sending rate should be updated.

This scheme is useful for congestion control. As compared to no congestion control scheme or the backpressure algorithm, the FACC provides higher throughput. Also the number of packets dropped is less than the other schemes. And energy expenditure is also very less than no congestion control and backpressure algorithm. According to the author, the starving problem for long flows is resolved. As data rate of each incoming flow is controlled, the interference is also reduced. The channels are utilized properly. The better fairness can also be achieved.

But the backpressure messages that is warning message and control messages are used to indicate the network status the source. These messages can increase the traffic which causes the congestion.

L. Q. Tao and F. Q. Yu introduced the protocol: "ECODA: Enhanced Congestion Detection and Avoidance for Multiple Class of Traffic in Sensor Networks". According to the author, for congestion detection, this protocol maintains the queue with duel buffer thresholds and weighted buffer difference. The two threshold values are Qmin and Qmax which maintains three buffer states: accept state, filter state and the reject state. The 'accept state' means the buffer occupancy is less than Qmin in which all incoming packets are accepted. The 'reject state' means buffer occupancy is in between Qmin and Qmax. In this state, if the incoming packets having high dynamic priority then it might be possible that some of the packets with low dynamic priority in the buffer are dropped or overwritten. If the buffer occupancy is greater than Qmax then it is the reject state. Not all but most of the packets of the high priority are dropped to increase the buffer length.

When congestion occurs, packets are dropped to alleviate congestion [1]. The packets in the buffer can be dropped from the tail or any position in the queue. If packets at the tail are dropped and the high priority packet arrives at the tail position,then that high priority packet will be dropped.

The ECODA protocol achieves fairness through Flexible Queue Scheduler. There are two sub-queues maintained with each node: one for local generated traffic and other for route-through traffic. In the route-through traffic, the packets are grouped by the source and arranged by their dynamic priority. The packets from both of the queue sent alternatively and for sending packets from the queue of route-through traffic, round robin policy is used.

Due to convergence nature of the sensor network, though the data sending rate of the near-source nodes is less, there is possibility of congestion to the sink node. To solve this problem, the authors proposed a method called bottleneck node based source data sending rate control. In which, to indicate the path status from a particular node to sink node, own data forwarding delay or parent node's data forwarding delay which is maximum, is piggybacked in the data packets header. And this is computed up to source node so that the path status can be determined. When any source node or forwarding node receives the backpressure message, it reduces its data sending rate or adjusts the rate if there are multiple paths. According to author, if no backpressure message received, the source data sending rate does not increased additively.

Compared to CODA, the throughput provided by the ECODA is higher. There is not too many ACKs sent by the sink node which controls the congestion and also the energy of the node is not wasted in transmission of the ACKs. The end to end delay in the ECODA is less than CODA. It uses the priority of the data packets and provides weighted fairness.

With number of advantages, ECODA has drawback also. If the buffer is in reject state, there is possibility of drop of the high priority data packets.

The last scheme is upstream hop-by-hop congestion control (UHCC) protocol proposed by Guangxue Wang and Kai Liu. The UHCC protocol tries to reduce the packet loss while guaranteeing that priority-based fairness with lower control overhead

[4]. To detect the congestion, congestion index is used which indicate the current congestion level. When the congestion index is greater than or equal to zero, this means that there space in the buffer which can handle more traffic. So that the congestion will not occur. If the congestion index is less than zero, there is no space in the buffer. The buffer cannot handle more traffic which can cause the congestion.

Like other protocol, when the congestion occurs, the data sending rate of the source node should be controlled or the rate should be adjusted. When the congestion index is greater than or equal to zero, there is no need to adjust the rate. If the congestion index of the node i is less than zero, the rate of all the child nodes of node i should be adjusted. And the child node which tends to congest should be allocated more traffic transmission rate [4]. If the congestion tendency of node j is less than zero, that is data sending rate from child node j to its parent node i is suppressed, there is possibility of congestion to the node j. otherwise the congestion will not occur even if the traffic rate from node j to is suppressed. The traffic capacity of node i represent how many packets node i can handle from its child node in the next time interval [4]. If the traffic capacity is greater than or equal to zero, the parent node can handle the packets from the child node. Otherwise the parent node cannot handle packets from its child.

To adjust the data sending rate, the congestion index and traffic capacity are piggybacked in the packet header to the upper layer based on which the new rate of each child node is calculated. And these new rates and the congestion tendency are also piggybacked to notify the parent and child node implicitly [4].

According to the author, both PCCP and UHCC achieve priority based fairness. But compared to PCCP protocol, the UHCC adjust the traffic rate with providing attention towards the priority. As the congestion is controlled, the packet loss is also reduced. Compared to PCCP, the UHCC has less packet loss ratio even with the small buffer size. UHCC achieves higher throughput also.

UHCC adjusts the rate of the upstream traffic only. There is no provision to control the downstream traffic, which can cause congestion.

III. RESULT AND ANALYSIS

This section includes the analysis of all the above mentioned congestion control schemes namely Fairness-aware Congestion Control (FACC) and Enhanced Congestion Detection And Avoidance(ECODA), Upstream Hop-by-hop Congestion Control (UHCC) protocol.

In the given topology the node 2 is away from the sink node whereas the node 6 is near to the sink. From the figure 1, we can say that the interference caused by the hidden terminal and exposed terminal do not affect the throughput of the FACC protocol. Unlike no congestion control, FACC do not favors the shorter flows.

The figure 2 shows the throughput comparison of the CODA and ECODA protocols. ECODA has higher throughput than CODA. When the congestion occurs, the CODA transmits backpressure messages i.e. ACKs. Too many ACKs cause increase in the congestion and also the wastage of the energy or power of the sink node in transmitting the ACKs. ECODA solves this problem by introducing a bottleneck node based source reporting control scheme which is in implicit manner [1]. The delay comparison is given in the figure 3. The end to end delay in the CODA protocol is more than ECODA protocol.

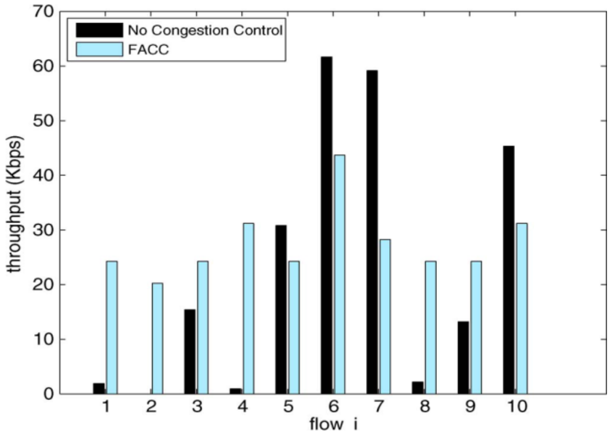

Fig. 1 Throughput with respect to different flows.

The network topology used by the authors in the simulation of the UHCC protocol is shown in figure 4. There are 10 sensor nodes where each of the nodes sense and transmit data towards sink node.

The source traffic priority of nodes 0 to 9 is 1, 1, 1, 1, 1, 1, 2, 3, 1, 2 resp. The figure 5 shows the normalized throughput of the nodes 5, 6 and 7. The source priority of these nodes is 1, 2 and 3 respectively. In the time interval 0 to 100 sec. and 250 to400 sec., the 6 kept off. At that time the throughput of node 6 is 0 whereas 1/12 and 3/12 i.e. 1/4. When the node 6 becomes active at time 100 to 250 sec., the throughput is 1/14, 1/7, 3/14 resp. so we can say that the UHCC achieves priority based fairness.

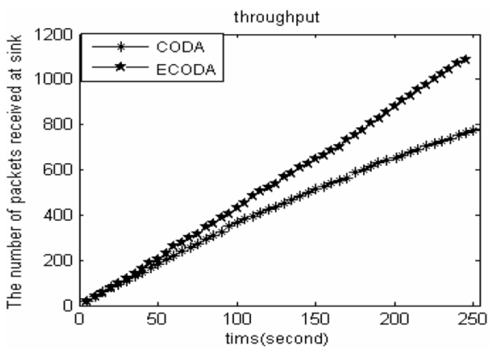

Fig. 2 Throughput comparison

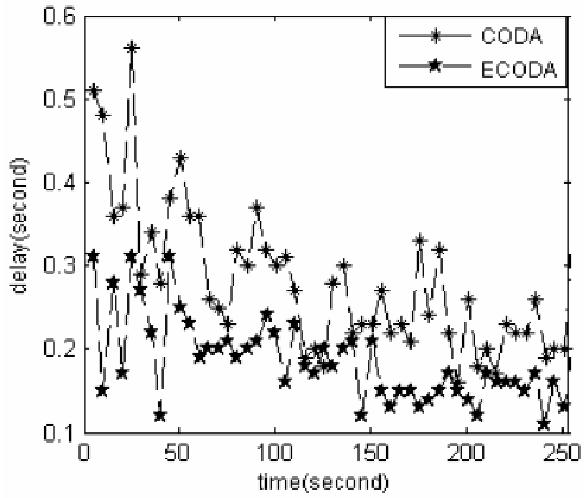

Fig.3 Delay comparison

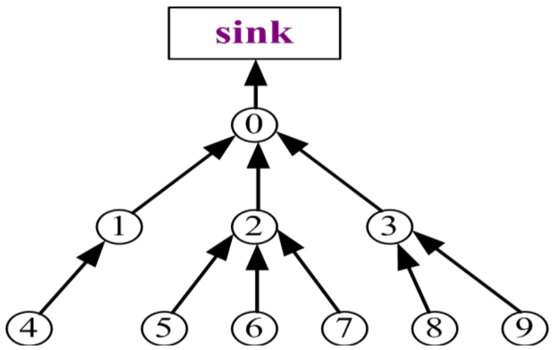

Fig. 4 General network model in WSNs.

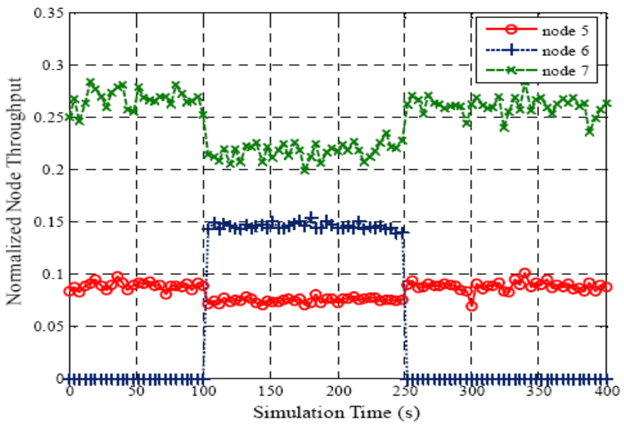

Fig. 5 Normalized node throughput in the UHCC protocol.

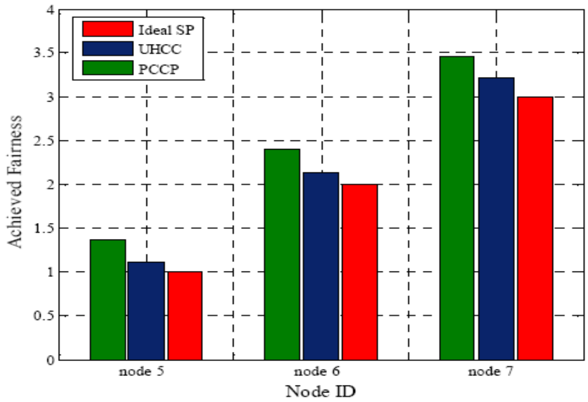

Fig. 6 Achieved priority-based fairness.

The figure 6 shows the fairness achieved by UHCC, ideal SP and PCCP protocols. The PCCP and UHCC protocol achieves priority based fairness. The traffic transmission rate of the PCCP protocol is higher than the UHCC protocol.

IV. CONCLUSION AND FUTURE WORK

There are many conditions that cause congestion in the network like high data transmission rate, event driven nature and busty traffic that result from the detecting the event as well as convergence nature of the wireless sensor network. The congestion lead to packet loss, buffer overflow, large queuing delay, increase in packet service time and also the wastage of the energy. To avoid all this, congestion mitigation is very important. There are different protocols that can be used to congestion control. FACC has better performance in terms of packet loss, and fairness. ECODA can deal with persistent as well as transient congestion. UHCC also mitigate congestion hop by hop based on priority.

But with advantages, the above mentioned protocols have some disadvantages also. These protocols cannot control the congestion 100 percent. Either there is possibility of congestion or it may cause packet loss. We need such a scheme which can control the congestion 100% with packet loss minimum, low power consumption, and less delay. So the future work is to mitigate the congestion 100 percent without affecting the other factors.

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