Different Congestion Control Methodologies in Wireless Sensor Networks and Reducing Congestion via Alternative Path Routing

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Abstract — The wireless sensor network consists of sensor nodes that have very limited battery power.In order to organize nodes efficiently for a long lifespan, clustering algorithm is demanded in WSNs to reduce redundant data transmissions and to save energy.. The purpose of paper is to achieve good quality of service in terms of increased throughput, low packet delivery ratio, low delay, and improved network lifetime by implementing congestion control techniques. A good quality of service is achieved by forming energy efficient cluster of nodes and selecting one node as cluster head. One cluster head can communicate with another head cluster and to the nodes within cluster to have good connectivity in the network. We proposed an algorithm to have the alternative path within the cluster so that in the event of congestion an alternative path will be available to the node preceding congested node to reduce the effect of traffic either due to congestion or node failure.

Keywords: Cluster Head (CH), Alternative Path Creation (APC), Sensor Networks, Base Station (BS), Hierarchical Tree Creation (HTC)

I. INTRODUCTION

The rapid developments in electronics and radio technologies have advanced Wireless Sensor Networks for many applications. Low cost tiny sensor nodes featured with various sensors can connect with each other to establish a dedicated network for a predefined mission, such as structural health monitoring, hazardous area surveillance and disaster management. Equipped with sophisticated computing algorithms, the WSNs are able to perform persistent monitoring with rapid events identification, situation assessment and even prediction of future events. Despite considerable benefits, there are many challenges when applying WSNs. Firstly, a WSN application often requires a large number of sensors with high sampling rates resulting in huge volumes of data. Secondly,

Limited battery imposes heavy energy constraint in WSN applications for long lifespan. Thirdly, due to long latency in wireless transmission, raw data may expire by the time they reach the sink node and raises the risk of wasting limited resources. To solve these problems, we proposed a clustering algorithm for sensor nodes to optimize energy consumption and to prolong the system lifespan.

In recent years, a considerable number of researches on WSNs have dealt with the issue of energy conservation. Among these works, clustering is a well-established technique for reducing data collection costs in WSNs [6]. In this technique, sensor nodes are grouped into disjoint sets called clusters and a Cluster-Head (CH) is selected among sensor nodes to manage the cluster. The cluster members send their sensed data to their CH... Organizing sensor nodes to form such cluster-based topologies is a widely accepted solution for energy conservation.

II. RELATED WORK

Wan el at proposes CODA, a congestion control system for sensor networks. CODA detects congestion by periodic sampling the channel load and comparing the fraction of time the channel is busy to the optimal channel utilization. The system responds to congestion with a combination of hop-by-hop flow control and closed-loop regulation.

Woo and Culler has given a rate control mechanism that admits traffic into the network using an AIMD controller. When a node hears that a packet it had previously sent was forwarded, it additively increases its transmission rate. When it does not hear a previous transmission being successfully forwarded (presumably after a timeout), it multiplicatively reduces its transmission rate.

Energy Aware Geographic Routing Protocol (EAGRP) for wireless sensor networks to extend the life time of the network. The proposed protocol is an efficient and energy conservative routing technique for multi-hop wireless sensor networks. Location based protocols are most commonly used in sensor networks as most of the routing protocols for sensor networks require location information for sensor nodes. [5-6]. Geographic routing protocols work on the assumption that every node is aware of its own position in the network.

Congestion in WSNs is generally addressed in one of two ways: rate control or packet drop. Rate control protocols, such as RCRT [14], reduce the rate at which packets are generated at the source. Packet drop policies allow congested nodes to selectively drop packets.

Congestion detection is performed at the relay nodes and, if congestion is detected, a notification is sent back to the data source. The source reduces its packet transmission rate by means of data summarization [6]. The rate is dynamically adjusted based on the status of the congested node, while minimum application-level precision is maintained.

Learning Automata-Based Congestion Avoidance Algorithm in Sensor Networks (LACAS). In LACAS [15] the problem of congestion control in sensor nodes are dealt with utilizing an adaptive approach based on learning automata. This protocol causes the rate of processing (rate of entry of data) in nodes to be equivalent to the rate of transmission in them so that the congestion occurrence gradually decreases. An automaton is placed in each node which has the ability of learning. In fact it can be considered as a small piece of code that interacts with environment and makes decisions based on the characteristics of it.

Data aggregation has been put forward as an essential paradigm for routing in wireless sensor networks. The idea is to use a function like average, max or min to combine the data coming from different sources enroute to eliminate transmission redundancy and thus save energy as well as bandwidth.

In WSN, the sensor nodes closer to a sink tend to consume more energy than those farther away from the sink. This is mainly because, besides transmitting their own packets, they forward packets on behalf of other sensors that are located farther away. As a result, the sensor nodes closer to the sink will drain their energy resources first, resulting in energy holes near the static sink [4].

Adaptive Rate Control (ARC). ARC [12] monitors the injection of packets into the traffic stream as well as route-through traffic. Each node estimates the number of upstream nodes and the bandwidth is split proportionally between route-through and locally generated traffic, with preference given to the former. The resulting bandwidth allocated to each node is thus approximately fair. Also, reduction in transmission rate of route-through traffic has a backpressure effect on upstream nodes, which in turn can reduce their transmission rates.

Congestion Control and Fairness (CCF) CCF [13] detects congestion based on packet service time at MAC layer and control congestion based on hop-by-hop manner with simple fairness. CCF uses packets service time to deduce the available service rate and detect the congestion in each intermediate node. When the congestion is experienced, it informs the downstream nodes to reduce their data transmission rate and vice versa.

Fairness Aware Congestion Control (FACC). FACC [14] is a congestion control mechanism, which controls the congestion and achieves fair bandwidth allocation for each flow of data. FACC detects the congestion based on packet drop rate at the sink node. In FACC nodes are divided in to two categories near sink node and near source node based on their location in WSNs. When a packet is lost, then the near sink nodes send a Warning Message (WM) to the near source node.

After receiving WM the near source nodes send a Control Message (CM) to the source node. The source nodes adjust their sending rate based on the current traffic on the channel and the current sending rate. After receiving CM, flow rate would be adjusted based on newly calculated sending rate

The HTAP (Hierarchical Tree Alternative Path) algorithm attempts to solve a congestion situation locally "by- passing" the congested node through the creation of alternative paths form the source to the sink. The algorithm consists of two parts, the Alternative Path Creation (APC) and Hierarchical Tree Creation (HTC)[1]. The philosophy of these two algorithms is similar. Both of them are based on the creation of alternative paths from the source to the sink, when congestion is going to take place

III. METHODOLOGY

It consists of forming the cluster and selecting one node as cluster head. The purpose is to form 'n' number of clusters and select n cluster head. A thorough analysis is made to balance the network lifetime within a cluster and applying same logic to the whole network i.e. a cluster of cluster heads. Cluster head is chosen based on different parameters. The cluster head is aware of all the sensor nodes belonging to that cluster and sink is aware of the cluster head. One cluster head can communicate with another cluster head and finally to the sink node. Thus achieving fairness and stability for the whole network.

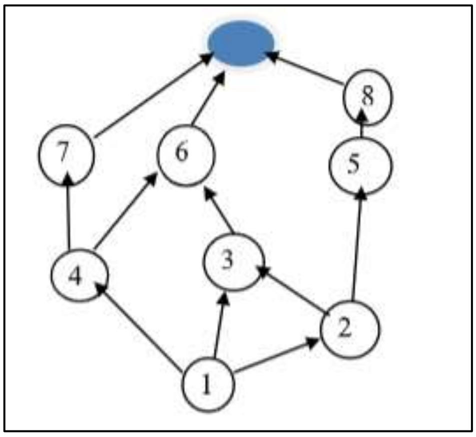

Fig. 1: transmission of data from source to Cluster Head

All the nodes within cluster send data to the cluster head and cluster head will eventually sent the data to the base station. If the base station happens to be far beyond the reach of cluster head then next cluster head is chosen which is near to the base station and it will send the data to base station on the behalf of this cluster head. Thus the cluster head has to be aware of neighboring cluster heads.

It is for this reason the node with highest residual energy only is chosen as the cluster head as all the nodes within cluster communicate to this node and this node further communicate to base station or another cluster head.

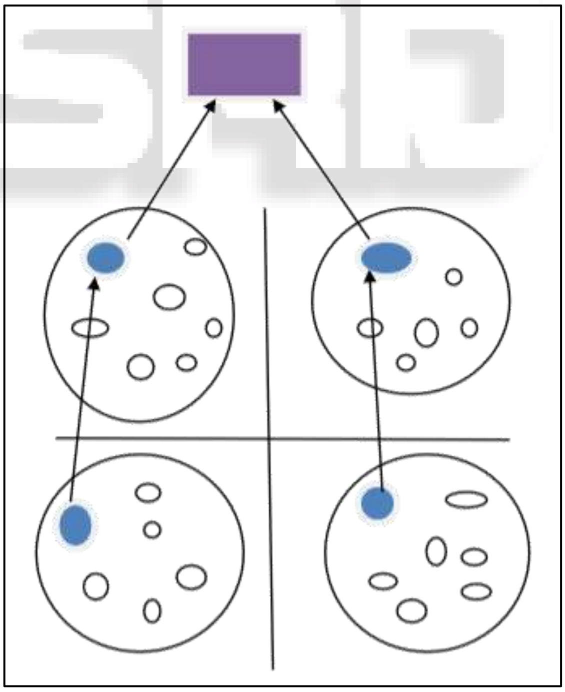

Fig. 2: CH sending data to Base Station (BS). Intercluster and Intracluster communication

IV. IMPLEMENTATION

A. Cluster Formation and Cluster Head selection algorithm:-

A cluster is formed by selecting the node with highest residual energy and lowest residual energy. If their sum is either equal to or less than some threshold which is already computed then a cluster is forms using this node or the next lowest residual node is chosen and the same process is repeated again. In this newly form cluster the node which has the highest residual energy is chosen as cluster head for that cluster. Same procedure is repeated for the remaining node satisfying the same criteria.

Algorithm:

1) N-> number of nodes
2) $\mathbf{E_{total}}$-> energies of all nodes taken together
3) $\mathbf{E_{avg}}$= average energy
4) $\mathbf{C_{size}}$ -> size of cluster
5) $\mathbf{C_{num}}$ ->number of clusters
6) Calculate $\mathbf{E_{avg}} = \frac{\mathbf{E_{total}}}{\mathbf{n}}$
7) Calculate $\mathbf{C_{value}} = \mathbf{C_{size}} * \mathbf{E_{avg}}$
8) Find largest(n)
9) Find smallest(n)
10) For($\mathbf{C_{num}}$ =1; $\mathbf{C_{num}}$ <= $\mathbf{C_{size}}$; $\mathbf{C_{num}}$ ++)
11) If (addittion(largest(n)+smallest(n)))<= $\mathbf{C_{value}}$
12) Then
13) { If (addittion(largest(n)+smallest(n)+smallest(n-1)))<= $\mathbf{C_{value}}$ }
14) Repeat for n=n-2, n-3.........till step(11)is satisfied.
15) else
16) Select CH1= index[largest(n)]
17) Repeat step 10 to 16 with largest(n-1) and smallest(n-3), smallest(n-4)……etc
18) Select CH2 = index[largest(n-1)]
19) Repeat above steps till $\mathbf{C_{num}} = \mathbf{C_{size}}$
20) stop

B. Flooding algorithm with level discovery

The flooding algorithm is used at the first deployment of the network in order for each node to discover its neighbour node and to update their network tables. In order to “assist” the Hierarchical Tree Algorithm a level discovery functionality is also added to this algorithm. After the application of the flooding algorithm, each node is aware of its neighbour nodes

Algorithm

1) Set neighbor_nodes to 0
2) If current _node is source node
3) Set level to 0
4) Broadcast flood_packets with level
5) else if current_node receives flood_packets and is accepting them
6) set current_node to level+1
7) send ack_packet with current_node_id
8) broadcast flood_packet with current_node_id and level
9) ignore subsequent flood_packets
10) else if current_node receives ack_packet
11) neighbor nodes+1

C. HTC: Hierarchical Tree Creation Algorithm

This algorithm consists of two main steps

Route Creation: In this step a hierarchical tree is created beginning at the source node. Each node is assigned a level according to the hierarchical tree. The source node is assigned a level 0 and broadcasts a level discovery packet. Sensors that receive this packet are handed as children to the transmitter and are set as level 1 (they will ignore subsequent level discovery packets). Each of these nodes broadcasts a level discovery packet, and the pattern continues with the level 2 nodes etc. The source when it receives the level discovery packet updates its neighbour table.

Flow Creation: Connection is established between each transmitter and receiver using a 2-way handshake. Packets are exchanged between each transmitter and receiver in the network, in order to get connected. Through this packet exchange, the congestion state of each receiver is communicated to the transmitter. This connection is performed using a 2-way handshake. Having a source node A and a receiver B, node A sends a first packet to B. When node B receives this packet, it sends an ack packet back to A. In this ack packet the node B piggybacks the congestion state at the moment. In this way, the source node is aware of the congestion state of all the children and is also able to forward them data packets. When the congestion state of children changes to a pre-specified limit this node updates its congestion state by sending a packet to the source node

Algorithm

1) if current_node receives hello_message
2) send ack_hello
3) else if current_node sends hello_message
4) wait specific_time
5) if current_node receives ack_hello
6) update neighbor_table
7) else if time_expires
8) re-send hello_message

D. APC: Alternative Path Creation

Algorithm:

A simple hierarchical flooding protocol is used for the formation of the network’s topology. Through this procedure, each node discovers its neighbour nodes and updates its neighbour table. In addition, through this protocol, sensor nodes are theoretically placed in levels from the source to the sink. At each packet transmission each node piggybacks its congestion state (buffer occupancy). The neighbour nodes overhear the packet transmission [6] and update their neighbour tables with this information. During the triggering of an event, the source node begins transmitting data packets creating flows to the sink. If the sending data rate is higher than the rate that the receiving node can transmit, the receiving node will soon face a buffer congestion situation and the results would probably be the random drop of data packets. In order to avoid this situation each candidate congested receiver is sending a backpressure packet to the sender to inform it that if it continues to transmit packets with the same rate it will soon be congested. This way the sender stops the transmission of packets to the candidate congested receiver and searches in its neighbour table to find the least congested receiver in order to continue the transmission of data. The transmitting node begins transmitting the data to the alternative node. The same phenomenon can happen at any level (between the neighbour nodes). The change of receivers leads to the creation of alternative paths

Algorithm

1) if current_node receives ack with congestion_level full
2) update neighbor_table
3) search neighbor_table

4) find node_id with min (congestion_level)
5) send data packet
6) if current_node receives congestion_update_message
7) update neighbor_table
8) else if current_node receives data packet and accepting them
9) Set buffer to buffer+1
10) if buffer+b=full
11) send ack packet with congestion_level full

V. Conclusion

Various congestion notification and congestion control techniques has been studied and a method has been devised to deal with it by forming cluster and making inter-cluster and intra-cluster communication possible. Energy efficiency is also taken into considerations while forwarding data towards sink node. However the future work includes changing the cluster head after some specified time as it may drain out easily due to heavy communication between nodes within cluster and base station

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