



Congestion Control by Multiagent in Wireless Sensor Network

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Abstract— In wireless sensor network reliable data transport is one of the most important requirements where different applications have different reliability requirements. The characteristic of wireless sensor network, especially dense deployment, limited processing ability, memory and power supply, provide unique design challenges at transport protocol. A reliable protocol in wireless sensor network must allow data transfer reliably from source to destination with reasonable packet loss. To prolong the lifetime of wireless sensor network efficient transport protocol need to provide congestion control. This paper presents Agent-based Congestion Control Protocol (ACCP) for wireless sensor networks. The traffic rate analysis on each node is based on the priority index and the congestion degree of the node. The parameter such as latency and throughput are investigated.

I. INTRODUCTION

A sensor network is composed of a large number of sensor nodes, which are densely deployed either inside the phenomenon or very close to it. The sensor nodes can sense the physical phenomenon, process the raw information, share the processed information with neighboring nodes and report the information to the sink node. There are mainly two types of traffic downstream traffic and upstream traffic. The downstream traffic is one that is one to many multicast from sink to sensor nodes. The upstream traffic is one that is many to one communication from sensor nodes to sink.

An upstream congestion control has single path routing and multipath routing. In single path routing, a child node can have single parent node and traffic is forwarded from child node to parent node depending on certain policy as shown in fig.1. In multipath routing, a child node can have a multiple parent node depending on certain policy. Fig.2 shows a multipath routing in which nodes 4 and 6 multiple parent nodes.

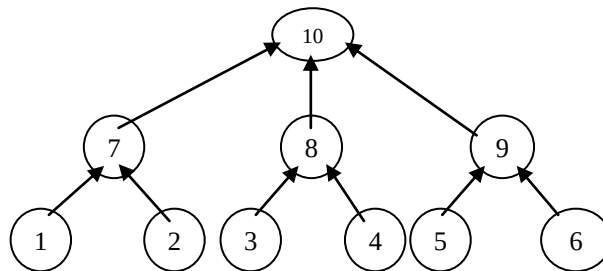


Fig.1 Single path Routing

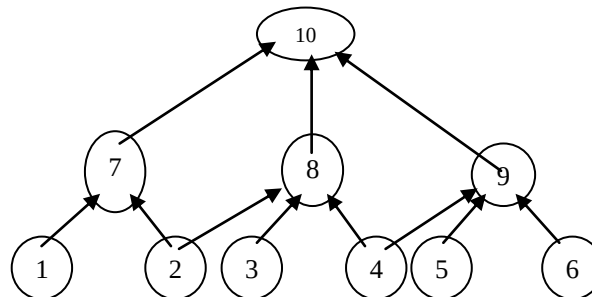


Fig.2 Multipath path Routing

There are mainly two types of congestion that occur in WSNs. The first one is the node level congestion that is caused by buffer overflow in the node and can result in packet loss and increased queuing delay as shown

in fig.2a. Packet loss leads to retransmission and consumes additional energy. The second one is link level congestion that occur when multiple active sensor nodes try to access the channel at same time as shown in fig.2b. Link level congestion increases packet service time, decreases both link utilization and overall throughput and wastes energy at sensor nodes. Both have direct impact on energy efficiency and QoS.

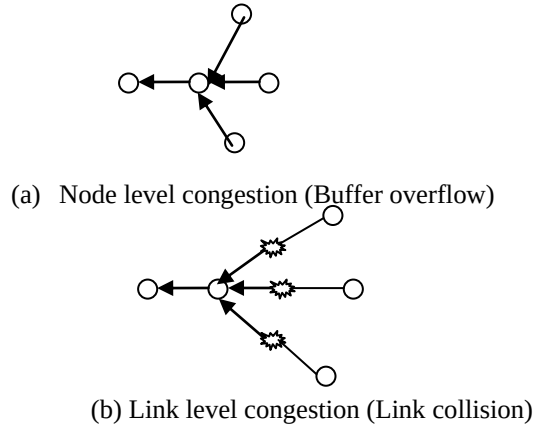


Fig.2 Congestion in wireless sensor networks

There are two general approaches to control congestion. The first approach is network resource management that tries to increase network resource to mitigate congestion when it occurs. The second approach is traffic control that implies to control congestion by adjusting traffic rate at source nodes or intermediate nodes. This approach is helpful to save network resource and efficient when exact adjustment of network resource becomes difficult. Most of the existing congestion control protocols are based on the second approach.

The rest of the paper is the review of different congestion control technique and various protocol to implement the same based on traffic control.

II. PERFORMANCE METRIC

Performance of any transport layer protocol for WSN can be evaluated using congestion metric.

Congestion Metric

Congestion degree, d is congestion detection metric that defined by:

$$d(i) = t_s^i / t_a^i \quad (2.1)$$

where t_s^i is the mean packet servicing time and t_a^i is the mean packet inter-arrival time of node i . Network efficiency refers to how well the transport layer is capable of detecting congestion, mitigating the congestion and maintaining the required level of throughput at the base station. Thus, the number of packet injected by the sensing nodes within a unit time and the number of the packet delivered to the base station is taking into account. Node efficiency or the average delivery ratio is calculated as :

$$\frac{\text{number of packets received by node } i}{\text{number of packets received by } i\text{'s parent}} \quad (2.2)$$

III. LITERATURE REPORTED

Cheng Tien Ee, Ruzena Bajcsy [2], This paper has proposed CCF (Congestion control and Fairness) protocol which states that every node is able to control the rate of its downstream nodes. This allows the root node to reduce the generation rates of all downstream nodes. By measuring and dividing the average rate by the number of downstream nodes, the mean packet generation rate of all downstream nodes are obtained, thus the rate assignment is fair. By reducing the transmission rates of all downstream nodes when this node's queue is full or about to become full, it allows the queue to empty. CCF controls congestion in hop by hop manner and each node uses exact rate adjustment based on its available service rate and child node number. CCF guarantees simple fairness so that each node receives the same throughput. But rate adjustment in CCF depends on packet service time which can lead to low utilization when some sensor nodes do not have enough traffic or significant packet error rate.

ChiehYih Wan, Shane B. Eisenman², Andrew T. Campbell³ [3], The authors proposed Congestion Detection and Avoidance (CODA), that uses a combination of the present and past channel loading conditions, and the current buffer occupancy, to infer accurate detection of congestion at each receiver with low cost. CODA uses a sampling scheme that activates local channel monitoring at the appropriate time to minimize cost while forming an accurate estimate. In CODA a node broadcasts backpressure messages as long as it detects congestion. When an upstream node (toward the source) receives a backpressure message it decides whether or not to further propagate the backpressure upstream, based on its own local network conditions. Nodes that receive backpressure signals can drop packets based on the local congestion policy (e.g., packet drop, AIMD (Additive increase multiplicative decrease), etc.).

C. Wang¹, B. Li², K. Sohraby, M. Daneshmand, Y. Hu In [4], have proposed a new Priority- based Congestion Control Protocol which employs packet based computation to optimize congestion control for a WSN. PCCP uses packet inter-arrival time and packet service time to produce a major of congestion. In WSN sensor nodes might have different priority due to their function or location and hence PCCP guarantees weighted fairness so that the sink can get different but in a weighted fair way, throughput from sensor nodes. PCCP is designed to work under both single path routing and multipath routing scenarios. PCCP results in lower buffer occupancy, achieves high link utilization and low packet utilization and low packet delay.

PCCP consist of intelligent congestion detection based on packet inter-arrival time and packet service time that has not been done in the past. PCCP uses implicit congestion notification to avoid transmission of additional control messages and therefore helps improve energy efficiency.

PCCP designs priority base algorithm employed in each sensor node for rate adjustment, in order to guarantee both flexible fairness and throughput called priority based rate adjustment (PRA).

IV. UPSTREAM CONGESTION CONTROL ALGORITHM

At a particular node i figure 3 shows the queuing model having a single path routing.

The transit traffic from the child node $i-1$ is received by wireless sensor node i through its

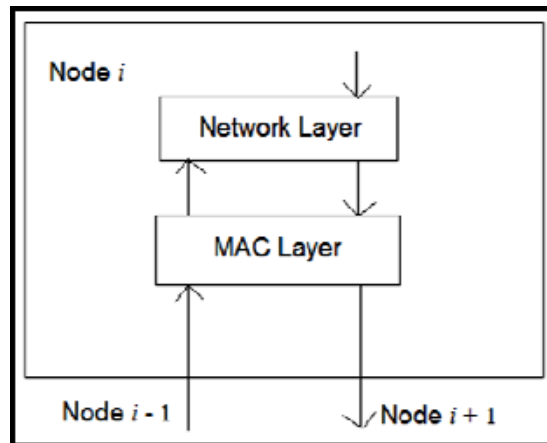


Figure 3. WSN node.

MAC layer and denoted by r_t^i . The source traffic at wireless sensor node i has rate r_s^i . Both the traffics get added at network layer before getting delivered to the node $i+1$ which is the parent node of wireless sensor node

i . The packet forwarding rate of the MAC layer is represented by r_f^i and depends on the MAC protocol alone.

The total input traffic rate r_m^i at the wireless sensor node is given by

$$r_m^i = r_s^i + r_t^i \quad (4.1)$$

Let r_{in}^i be the packet input rate towards the wireless sensor node i from the wireless sensor node $i-1$. r_{out}^i be the packet output rate from the wireless sensor node i to the wireless sensor node $i+1$.

If $r_{in}^i < r_f^i$, then $r_{out}^i = r_{in}^i$, and if $r_{in}^i > r_f^i$, then r_{out}^i is close to r_f^i . Hence the packet output rate at wireless sensor node i can be obtained from the following equation.

$$r_{out}^i = \min(r_{in}^i, r_f^i) \quad (4.2)$$

From equation 4.2 it is clear that the packet output rate at wireless sensor node i can be indirectly reduce through reducing the packet input rate to the wireless sensor node i . In this work, a multi-agent system based intelligent upstream congestion control protocol has been developed.

A new multi-agent system based approach to control the traffic in the upstream congestion is used for single path routing. A Reusable Task-based System of Intelligent Networked Agents (RETSINA) is a multi-agent system that consists of three classes of agents: interface agents, task agents and information agents. Using RETSINA multi-agent an Agent-based Congestion Control Protocol (ACCP) for upstream congestion is proposed. ACCP consists of four components: Execution Monitor, Communicator, Planner and Scheduler. Based on the packet arrival time (ta) and packet service time (ts) at the Medium Access Control (MAC) layer the execution monitor detects the congestion. The packet service time (ts) is the time interval between arrival of packets at the MAC and its successful transmission whereas packet arrival time (ta) is the time interval between two subsequent packets arrived from any source. From this, a congestion index (Cx) is calculated at node i and is given by

$$Cx = ts/ta \quad (4.3)$$

All the notifications at each wireless sensor node, in the packet header to be forwarded by the communicator module. From the congestion index the communicator module computes a global congestion priority index by adding source congestion priority index and the global congestion priority index of the lower level wireless sensor nodes. Through communication message packets the planner receives goals and finds ways to fulfill them. Planning component is reusable and capable of accepting different planning algorithms in an intelligent way. A list of all actions is scheduled by the scheduler and the action with the earliest deadline is chosen for execution.

All modules are executed as separate threads and are able to execute concurrently. Thus almost all the packets are forwarded to the next wireless sensor node without any losses.

V. SIMULATION RESULTS

The simulations are implemented using wireless sensor nodes communicating via IEEE 802.11 MAC layer protocol model. The simulation environment is implemented in the NS-2, a network simulator that provides support for simulating wireless network for 10 nodes. The simulations are carried out using a sensor environment roaming over a simulation area of 300 meters x 300 meters flat space. The buffer size is set to 50 packets.

Performance has been analyzed below for the metrics latency and throughput.

Latency :

Average latency is a measure of the average time between initiating a route discovery for a wireless sensor node to transmit and successfully setting up a route for the data transmission. Figure shows the analysis of latency on ACCP.

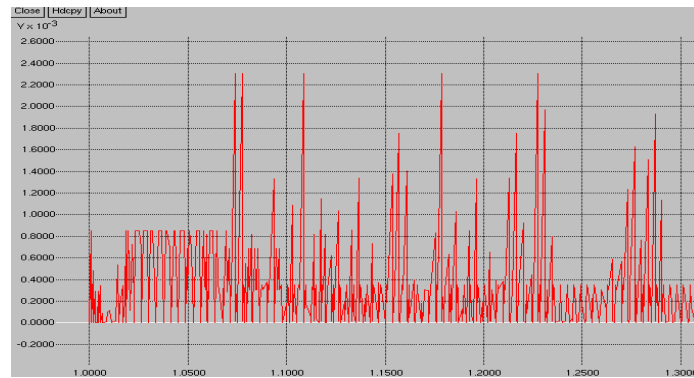


Figure 4. shows latency Vs simulation time.

Throughput

Throughput is the amount of data that is delivered from the source node to the destination node in a network. Figure shows the performance of throughput for the UDP with and without RETSINA agent.

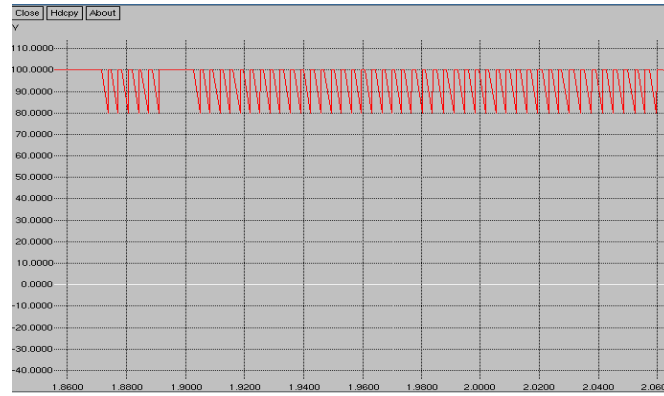


Figure 5.shows throughput Vs simulation time.

VI. CONCLUSIONS

In this paper, an agent-based upstream congestion control protocol is implemented in NS 2. The problem of single-path upstream congestion control in WSNs through the traffic control by introducing a new multi-agent system based application. The algorithm varies the transmission rate of the node and its upstream nodes. This introduces node priority index and is simulated for a single-path routing environment. The simulation shows that the upstream algorithm provides remarkable results and acquires the transmission rate quickly. This work can be extended for multi-path routing environment too.

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