Design of Congestion Control Protocol for WMSN

Supriya Pansare, C. V. Kulkarni

Abstract- A Wireless Multimedia Sensor Network (WMSN) is formed with a large number of distributed embedded devices equipped with camera modules. These devices are able to retrieve multimedia content from the environment and are able to extract video and audio streams, still images as well as the scalar sensor data from the multimedia content. WMSNs have generated much interest in recent years due to their huge applications such as surveillance systems, traffic control systems, environment monitoring, control of manufacturing processes in industry., Multimedia traffic produces busty high-load traffic in the network. Therefore probability of congestion in WMSNs is higher than traditional Wireless Sensor Networks (WSNs). It causes a waste of communication which reduces energy efficiency. In addition, it negatively affects reliability due to the packet losses and degrades overall performance of the network and quality of- service (QoS) of the application. To address this challenge, we propose a novel energy efficient congestion control scheme for sensor networks, called ECODA (Enhanced congestion detection and avoidance)which comprises three mechanisms: 1) Use dual buffer thresholds and weighted buffer difference for congestion detection; 2) Flexible Queue Scheduler for packets scheduling; 3) A bottleneck-node-based source sending rate control scheme.

Keywords: Wireless Sensor Networks; multimedia; Congestion; QOS

I. IINTRODUCTION

After detecting the congestion, neighbor sensor nodes should be informed about it. Two common methods are used for this issue. Congestion can be informed explicitly or implicitly. Protocols which perform notification process explicitly send a message to relevant sensor nodes .Other protocols perform this step implicitly by inserting a congestion notification flag into the header of outgoing packets as a piggyback. Explicit notification brings an extra communication overhead to the network. Implicit notification requires fewer packet transmissions, but takes longer to effect. For congestion mitigation, various methods are proposed. These methods are adapting data transmission rate, redirecting data traffic to different sensors, using backpressure techniques to inform neighbor sensor nodes not to forward data, decrease the image quality by dropping the relevant packets or by using integration of hop by hop flow control, source rate limiting and Prioritized MAC. The event-driven nature of Wireless Multimedia Sensor Networks leads to unpredictable network load. Typically, WMSNs operate under idle load and then suddenly become active in response to a detected event. When the events have been detected, the information in transit is of great importance. However, the heavy traffic that results from the detected events can easily cause congestion in the networks.

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***Correspondence Author(s)**
Mrs. Supriya Pansare, MIT College of Engineering, Pune, India.
Prof. C. V. Kulkarni, MIT College of Engineering, Pune, India.

When congestion happens, the network throughput and coverage fidelity are penalized. So, congestion control is a critical issue in sensor networks. Congestion is a main factor which affects the overall network performance in Wireless Sensor Network. So we will study congestion in detail. Congestion in a Wireless Multimedia Sensor Networks (WMSN) can cause missing packets, low energy efficiency, and long delay. Moreover, some applications, e.g. multimedia and image, need to transmit large volumes of data concurrently from several sensors. These applications have different delay and QoS requirements. Congestion problem is more urgent in such application. Congestion can be defined as when the demand for resources exceeds the capacity, congestion occurs. Resources are Input Buffer, Output Buffer, Processing Capacity, Memory Capacity, Energy, Bandwidth. Types of Congestion are Node Level congestion, link level congestion, Local level congestion, Network level congestion, Transient Congestion, Persistent Congestion. Causes of congestion are input /Output data flow rate, Node Density, Non Linear or unbalanced Load Distribution, Processing or service time of the node, Reliability of the network. Congestion can be detected by monitoring buffer occupancy and channel occupancy. Congestion can be controlled by mechanisms such as back pressure, ACK, packet scheduling, Rate control.

II. RELATED WORK

In the literature, many works have been conducted on congestion control, congestion mitigation, and reliable transmission in WSNs. Existing works can generally be classified into three categories. The first category consists of transport protocols that provide end-to-end reliability without congestion control. Reliable multi segment transport (RMST)[12] is an example of these protocols. RMST is a hop-by-hop reliable transport protocol specially designed to run on top of directed diffusion in which packet loss is recovered hop by hop using caches in the intermediate nodes. RMST guarantees reliability but is designed for more capable sensor nodes. In addition, in RMST, the node's transmit rate is manually set by a system administrator. The second category consists of protocols with centralized congestion control schemes. ESRT[2] classifies a network into five regions. It adjusts source packet data sending rate such that network stays in a state where sufficient number of packets arrive at a sink without producing congestion. ESRT's rate allocation is centrally computed i.e., the base station periodically counts the number of received sensor readings and re tasks the sensors by broadcasting a new transmission rate. Due to the drawbacks of centralized scheme, ESRT cannot deal with transient congestion efficiently.

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RCRT[13] is another centralized transport protocol in which all functionalities including congestion detection, rate adaptation, and rate allocation are implemented at sink node. Although RCRT's performance is good, it can't differentiate flows unconstrained in bottleneck regions. Also, RCRT's convergence is too slow when the network has highly varying RTTs. The third category consists of protocols with distributed congestion control schemes. Fusion[7] uses hop-by-hop flow control, rate limiting, and prioritized MAC to alleviate congestion. With this combination, Fusion achieves higher good put and better fairness with heavy loads than previous schemes. Congestion detection and avoidance (CODA)[3] in sensor networks is another congestion mitigation strategy, it provides a comprehensive discussion on congestion control and proposes an open-loop hop-by-hop backpressure mechanism and closed-loop multi-source regulation scheme. For transient congestion, each sensor monitors channel utilization and buffer occupancy level to detect congestion. For persistent congestion, source requires sink's feedback to maintain its data rate. Unlike Fusion, CODA doesn't explicitly focus on per-source fairness. IFRC[14] and CCF[6] are both congestion control protocols to ensure fairness. In IFRC, every node adopts multi-level buffer thresholds. When a node's buffer exceeds the threshold, it asks its neighbors to decrease data sending rate and maintain its buffer utilization less than a predefined level. In CCF, two schemes are proposed to ensure fairness: probabilistic selection and epoch based proportional selection. However, IFRC and CCF both try to ensure absolute fairness among every node. For congestion control ESRT protocol uses centralized congestion control scheme. It will monitor the local buffer occupancy of nodes for congestion detection. If buffer overflows it will set congestion notification bit (CN bit) of the packets before forwarding the packets to the sink. When the sink receives packets with congestion notification bit set, sink infers the congestion and broadcasts a new transmission rate for all the nodes. Nodes will send packets with the new rate and thus the congestion is minimized. It does not monitor the Channel occupancy hence can not deal with congestion which occurs due to link variations i.e. transient Congestion. Drawbacks of ESRT Protocol are same transmission rate for all nodes decreases throughput as every node's contribution to the congestion is different and decreasing data sending rate of all nodes with the same value will definitely decrease throughput. ESRT is not efficient for transient type of congestion as it does not monitor the channel occupancy to avoid transient congestion. ESRT is more focused on reliability. Sensor networks come in a wide variety of forms, covering different geographical areas, being sparsely or densely deployed, using devices with a variety of energy constraints, and implementing various sensing applications. One of the applications of sensor networks is the reporting of conditions within a region where the environment suddenly changes due to an observed event, such as in habitat monitoring, target detection, earthquakes, floods, or fires. Sensor networks typically operate under light load and then suddenly become active in response to a detected or monitored event. Depending on the application this can result in the generation of large, sudden, and correlated impulses of data that must be delivered to a small number of sinks without significantly disrupting the performance (i.e., fidelity) of the sensing application. Although a sensor network may spend only a small fraction of time dealing with impulses, it is during this time that the information it delivers is of greatest importance. The transport of event impulses is likely to lead to varying. CODA uses three mechanisms for congestion control Receiver based congestion detection, Open loop hop by hop backpressure mechanism, Closed loop multi source regulation mechanism. Drawbacks of CODA Protocol are backpressure message intensify congestion Explicit ACK waste much energy. Loss of ACK affects N/W throughput. CODA can not find bottleneck node. To address this challenge, we propose a novel energy efficient congestion control scheme for sensor networks, called ECODA[1](Enhanced congestion detection and avoidance)which comprises three mechanisms: 1) Use dual buffer thresholds and weighted buffer difference for congestion detection; 2) Flexible Queue Scheduler for packets scheduling; 3) A bottleneck-node-based source sending rate control scheme.

III. ECODA PROTOCOL OVERVIEW

1. Use of dual buffer thresholds and weighted buffer difference for congestion detection.

The Protocol uses dual buffer thresholds Q Min and Q Max to detect congestion. If single threshold is used suppose the it is set at 60 then the slight changes such as threshold at 58 or 62 will cause the change in data sending rate . thus due to slight changes in threshold the data rate will change continuously and this will cause degradation in network throughput. Hence the protocol uses dual thresholds. These thresholds will divide the buffer in three states Accept State , Filter State and reject state. 0 To Q Min all Packets are accepted. Q Min to Q Max the packets are filtered according to their static and dynamic properties. After Q Max is reached some low

2. Flexible queue scheduler for packet scheduling at intermediate nodes

When congestion occurs generally packets are dropped from tail. With tail dropping high priority packet may be dropped due to queue overflow. Hence to control congestion flexible queue scheduler is used. In flexible queue scheduler there are two queues one for route through traffic and other for locally generated traffic. In route through traffic queue packets are grouped according to sources. For every source packets are sorted by dynamic priority from high to low. For sending next packet round robin algorithm is adopted. Hence the source will send the packets by scanning the route through queue and the locally generated queue. The high priority packet will be sent first weather it is locally generated or route through.

3. Bottleneck node based source data sending rate control scheme

The explicit or implicit backpressure messages of distributed hop-by-hop congestion control can finally reach the source node and source data sending rate is adjusted to mitigate congestion which happens at the sink side. It can not accurately adjust source data sending rate. In the proposed method every node can determine routing path (from itself to sink) status.

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The forwarder can find better path to forward data and the source data sending rate can be adjusted more accurately and efficiently.

IV. ECODA PROTOCOL DESIGN

Proposed protocol uses three mechanisms;

1 Use of dual buffer thresholds and weighted buffer difference for congestion detection.

2 Flexible queue scheduler for packet scheduling at intermediate nodes.

3 Bottleneck node based source data sending rate control scheme.

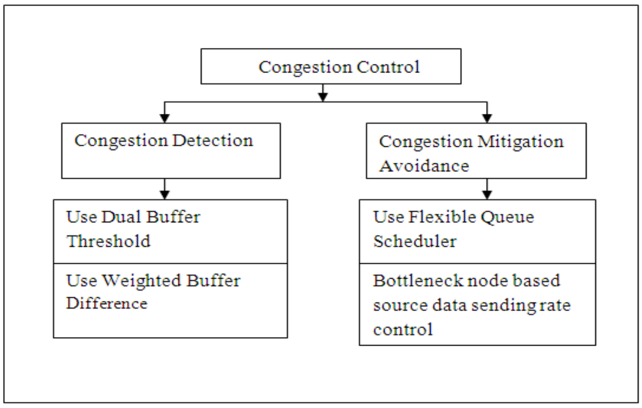

Fig. 1 Block Diagram

As per the block diagram for controlling the congestion we have to implement the various mechanisms taking into consideration the Wireless Multimedia Sensor Network. The multimedia traffic produces bursty high-load traffic in the network. Hence we have to first detect the traffic using congestion detection procedures such as use of dual buffer thresholds for monitoring buffer occupancy and use of weighted buffer difference to filter the packets according to their Priorities. The congestion can be minimized by using flexible queue scheduler for packet scheduling and bottleneck based source data sending rate control. We will use the NS2 Network Simulator and Nam network animator to design and test the protocol.

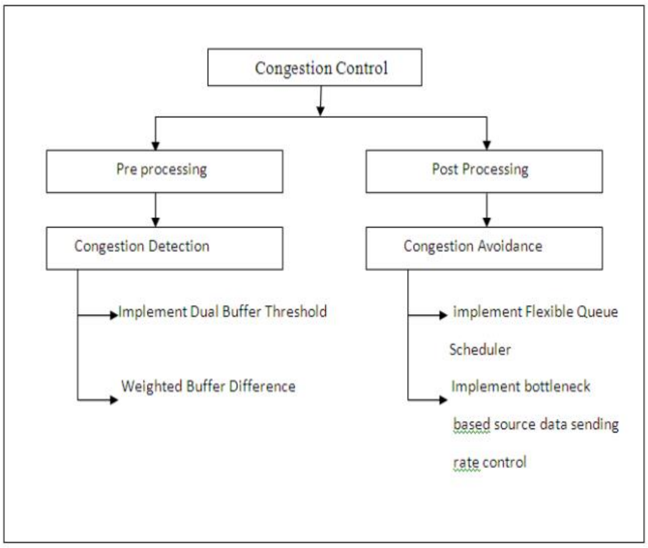

Fig. 2 Design Flow

The flow of the project is in two phases:

1. **Pre-Processing**-Congestion Detection.
2. **Post-Processing** – Congestion avoidance.

Congestion Detection involves Use of dual buffer thresholds and use of weighted buffer difference to detect congestion till we do not detect congestion and % of congestion we cannot minimize it.

It includes:-

1. **Use of Dual buffer thresholds and Use of weighted buffer difference for congestion detection**:

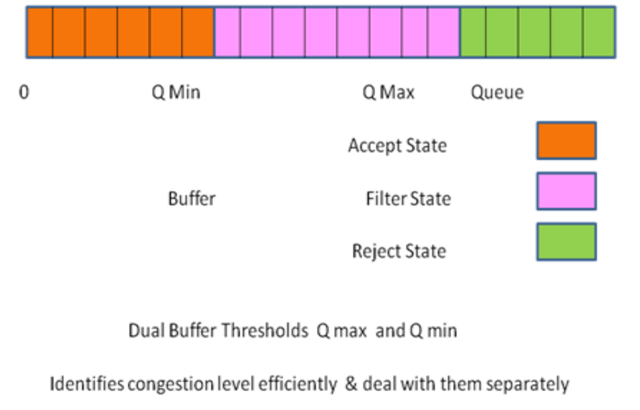

Fig. 3 Buffer state[1]

The Protocol uses dual buffer thresholds Q_Min and Q_Max to detect congestion If single threshold is used suppose the it is set at 60 then the slight changes such as threshold at 58 or 62 will cause the change in data sending rate . thus due to slight changes in threshold the data rate will change continuously and this will cause degradation in network throughput. Hence the protocol uses dual thresholds. These thresholds will divide the buffer in three states Accept State , Filter State and reject state. 0 To Q Min all Packets are accepted. Q Min to Q Max the packets are filtered according to their static and dynamic properties. After Q Max is reached some low priority packets are rejected and high priority packets are accepted. The formulae for the priorities are as follows. Every Packet has two types of priorities Static and dynamic. Static Priority is represented as an integer & lowest SP(packet)=0

Dynamic priority changes with the no. of hops and delay

$$DP(Packet) = \frac{\alpha * hop + SP(packet)}{1 + \beta * delay}$$

Where α and β are two parameters for tuning system performance.

Hop is the no. of hops to sink.

SP is packet static priority.

Delay is the time from packet generation to current.

Buffer changing rate R = BO-BI

Weighted Buffer changing rate

WR = DP(BO) – DP(BI)

$$\text{Weighted Queue Length } WQ = \sum_{j=1}^{N} DP(Packet)$$

Where N is the total No. of packets in the buffer.

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Node having data to send will monitor its buffer and piggybacks its WR & WQ In outgoing packets. If Nodes buffer occupancy exceeds threshold and data has higher priority among neighborhood CN bit in the outgoing packet header is set . Other nodes will slow down data sending rate to minimize congestion.

Congestion Avoidance involves the use of flexible queue scheduler and bottleneck based source data sending rate control

It includes:

2. Use of flexible queue scheduler:

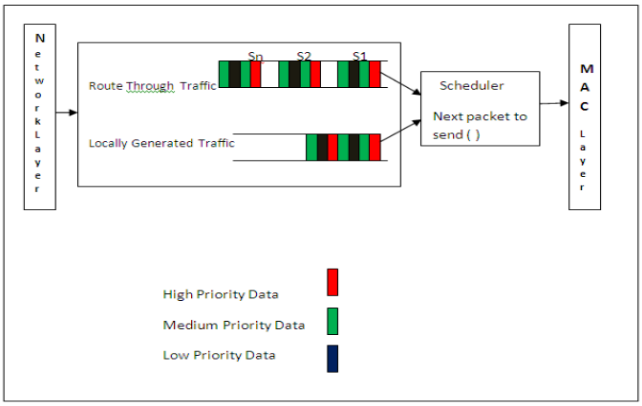

Fig. 4 Flexible Queue Schedular[1]

When congestion occurs generally packets are dropped from tail. With tail dropping high priority packet may be dropped due to queue overflow. Hence to control congestion flexible queue scheduler is used. In flexible queue scheduler there are two queues one for route through traffic and other for locally generated traffic. In route through traffic queue packets are grouped according to sources. For every source packets are sorted by dynamic priority from high to low. For sending next packet round robin algorithm is adopted. Hence the source will send the packets by scanning the route through queue and the locally generated queue. The high priority packet will be sent first weather it is locally generated or route through.

3. Use of bottleneck based source data sending rate control:

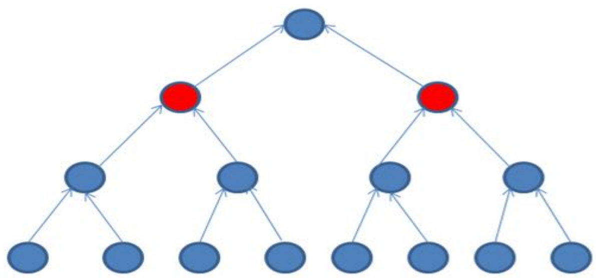

Fig. 5 Bottleneck source

Bottleneck node based source sending rate control scheme includes two methods

a. Determination of routing path from certain node to sink node piggybanks data forwarding delay D(i)

Child node overhears this information and compares its own delay with parents as

D max (i) = MAX {D(p), D(i) }

child sends data with D max(i) piggybacked in packet header. D max (i) is the path status from node to sink.

b. Bottleneck node detection and data sending rate control child overhears data from parent node extracts delay information from parent

set data sending rate Gs = 1/D max (p)

In forwarder node

If no backpressure message Additively increase data forwarding rate. If backpressure message Multiplicatively decrease data forwarding rate.

In Source Node

If one hop delay set data sending rate 1/D max

If backpressure message Multiplicatively decrease data forwarding rate.

V. EVALUATION AND COMPARISON

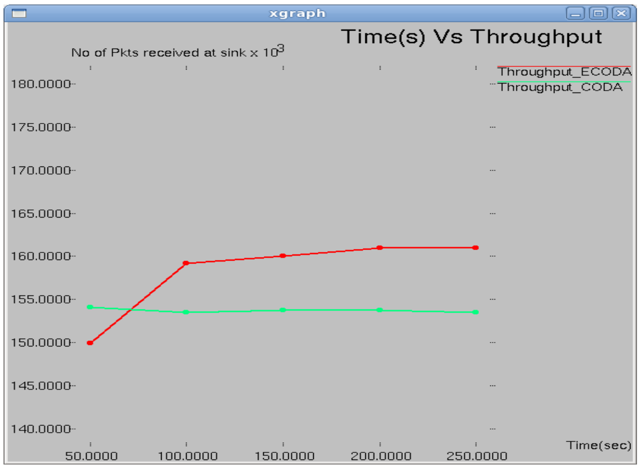

Fig. 6 Throughput Comparison

Throughput and delay are simulated and shown in Fig. 6 and 7 respectively. From Fig. 6, one can see that ECODA has higher throughput than CODA. Since CODA adopts queuelength-based scheme for congestion detection, every time when buffer length exceeds a threshold, congestion is reported. However, when many nodes exceed the buffer utilization threshold simultaneously, nodes which have the highest data priority send congestion information, leading to CODA's low efficiency. When persistent congestion happens,CODA needs feedback from sink to maintain its sending rate, which has two drawbacks: 1) Too many ACKs cause extra energy consumption; 2) ACKs may be dropped due to some reasons (congestion, link variation) and cannot reach the source. ECODA solves this problem by introducing a bottleneck node based source reporting control scheme which is in implicit manner. It costs no extra energy and is more robust than CODA's closed loop multi-source regulation scheme.

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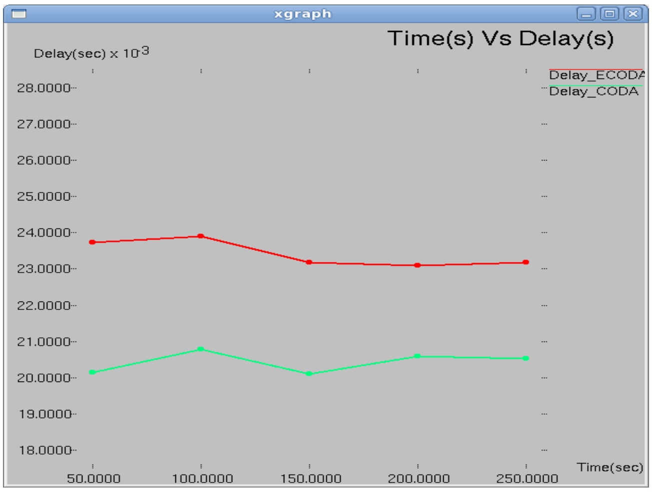

Fig. 7 Delay Comparison

The average delays of CODA and ECODA are presented in Fig. 7. packets experience much long delay in CODA than in ECODA ,as CODA resolves persistent congestion inefficiently and cannot deal with the situation that several buffers exceed threshold simultaneously. ECODA uses dual buffer thresholds to detect congestion, which measures channel loading indirectly.

VI. CONCLUSION

In this paper congestion control protocol ECODA is proposed. In this protocol congestion can be detected by monitoring the local buffer occupancy of each node and channel occupancy and using Dual Buffer thresholds and Weighted buffer difference. In ECODA congestion is controlled by mechanisms such as Back Pressure, Acknowledgement , flexible Packet Scheduling and bottleneck based source data sending Rate Control. It can reduce packet loss and lower delay.

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