Fuzzy Logic based Congestion Control in Wireless Multimedia Sensor Networks

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Abstract- Network Congestion has become a critical issue for resource constrained Wireless Sensor networks (WSNs), where large volume of data is transmitted through the network. If the traffic load is greater than the available capacity of the sensor network, congestion occurs and it causes buffer overflow, packet drop, deterioration of network throughput which leads to congestion in the network. Congestion in WSN may lead to poor energy efficiency, higher packet loss, lower throughput and increased packet delay. The problems for multimedia transmission over wireless multimedia sensor networks are examined and Transport Protocol for Congestion Control is proposed which provides a fuzzy logic based congestion estimation and a novel congestion mitigation technique which decreases image quality on-the-fly at an acceptable level. When the frames starts to transmit via wireless network, nodes check for congestion. If the incoming frame rate is less than the predefined range, no congestion occurs and hence the frame rate will be maintained same. In case of congestion, it decreases the frame quality and transmits the frames to the sink with lower, but acceptable quality.

Keywords –Wireless Sensor Network, Congestion, Fuzzy

I. INTRODUCTION

Wireless sensor networks (WSN) have drawn the attention of the research community in the last few years, driven by a wealth of theoretical and practical challenges. This growing interest can be largely attributed to new applications enabled by large-scale networks of small devices capable of harvestinginformation from the physical environment, performing simple processing on the extracted data and transmitting it to remote locations [1]. More recently, the availability of inexpensive hardware such as CMOS cameras and microphones that are able to ubiquitously capture multimedia content from the environment has fostered the development ofWireless Multimedia Sensor Networks (WMSNs) i.e., networks of wirelessly interconnected devices that allow retrieving video and audio streams, still images, and scalar sensor data.

Major focus in this paper is on the fuzzy logic based congestion control technique for WSNs. Congestion may occur in many ways [2]. Congestions are of two types: one is node level congestion. This type of congestion occurs due to the buffer overflow or when the packet service time exceeds the packet arrival time. Second is a link level congestion that may occur due to the interference, contention and bit error. Congestion in WSN may lead to packet drops which in turn lead to more energy consumption. Congestion will also degrade the Quality of Service in WSNs. Some of the related works are as follows:

In Ref [3], nodes inform their neighbors in the network about future transmissions shortly before these transmissions begin, so that each neighbor as well as the sending node itself decides whether to send their own outgoing data rate or not.

In Ref [4], It minimizes the packet loss ratio in WMSN by predicting congestion in the network, and adjusting the source nodes output rate before congestion happening.

Ref [5] presents a congestion degree as a ratio of packet inter-arrival time over packet service time. PCCP introduce a priority index to reflect the importance of each sensor node. Based on the introduced congestion degree and node priority index, PCCP utilizes a cross-layer optimization and imposes a hop-by-hop approach to control congestion.

In Ref [6], a lightweight distributed congestion control method is developed to detect congestion in each node by considering the queue lengths and channel conditions observed in the one hop neighborhood. Based on the estimated level of congestion, each node dynamically adapts its packet transmission rate and balanced load among the one-hop neighbors to avoid creating congestion and bottleneck nodes.

The main idea behind Ref [7] is to transmit the maximum number of frames to the sink by decreasing the frame quality to an acceptable level in case of congestion by dropping some packets of the frames in a smart way and thus transmits frames to the sink with lower, but acceptable quality.

In Ref [8], main idea is to reduce the packet drop over intermediate nodes and maximize number of packet send to sink by regulating traffic rate over source or neighboring nodes using fuzzy logic.

Ref [9] takes the advantage of current buffer occupancy and congestion index as congestion level indications. Each upstream traffic rate is adjusted according to the value of congestion degree and can quickly perceive the status and trends of the network load, and adjust quickly to avoid packet loss.

In Ref [10], the congestion of the sensor nodes are controlled by regulating the rate of traffic flow on the basis of the priority of the traffic. The misbehavior of sensor nodes is detected using the concept of trust. The trust value of each individual sensor node is estimated by using a fuzzy algorithm.

In Ref [11], malicious nodes will be detected and isolated to reduce congestion rate contributed by relative packets which in turn removes the traffic ratio overhead of handling packets associated to corrupt or malicious nodes and also analyze the behavior of sensor nodes.

Ref [12] adopts a fuzzy based approach to select energy efficient routes to destination that ensures less packet loss due to various activities such as presence of malicious nodes and congestion each time a demand is received, thus preventing data loss and imparting security at the same line.

The rest of the paper is organized as follows. Proposed Work and algorithm are explained in section II. Results are presented in section III and Conclusion is given in section IV.

II.WORK

The various steps used in Fuzzy based Congestion Control technique are discussed below

A. Fuzzy Inference System

Fuzzy inference (reasoning) is the actual process of mapping from a given input to an output using fuzzy logic. The process involves membership functions, fuzzy operators and if-then rule. FIS consists of 2 types, Mamdani & Sugeno. FIS is depicted in Figure 1. Fuzzification interface performs the function of converting input data into suitable linguistic values which may be viewed as labels of fuzzy sets. Inference Engine is the kernel of FIS, it has the capability of simulation human decision making based on fuzzy concepts and applies a predetermined set of linguistic rule in the Rule base with respect to these linguistic variables, and produces fuzzy outputs. The Rule Base comprised knowledge of the application domain and the attendant control goals. It consists of a data base and a linguistic fuzzy rule base. Defuzzification performs a scale mapping, which converts the range of values of output variables into corresponding universes of discourse.

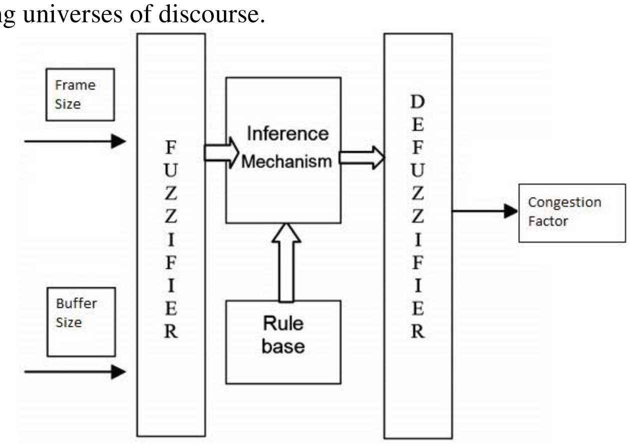

Figure1. Fuzzy Inference System

B. Fuzzy Parameters

Fuzzy controller is used for minimizing uncertainty present in the network due to mobility of hosts or constrained network resources. The proposed scheme employs frame size and buffer size as fuzzy parameters. They have been represented my membership functions are as shown in Figure2.

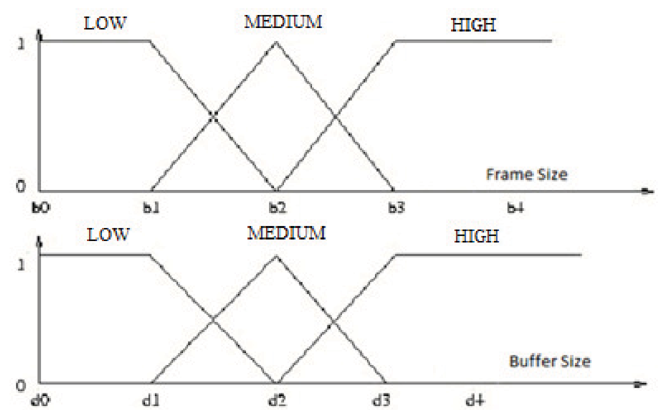

Figure2. Input membership Functions for frame and buffer size

Here b0, b1, b2, b3 refers to 0, 15kb, 30kb, 45kb, 60kb respectively and d0, d1, d2, d3 refers to 0, 15kb, 30kb, 45kb, 60kb respectively (kb=kilobyte).

C. Fuzzification

The fuzzification block matches the input data with the linguistic value present in rule base to determine how well the condition of each rule matches that particular instance. This is a degree of membership for each linguistic term that applies to the input variable. To check congestion, fuzzy sets consists of i) Low ii) Medium iii) High. In this technique we are taking triangular based membership function which takes a centroid value.

D. Inference Engine & Rule Base

After crisp inputs are mapped to the linguistic values through the membership functions in the fuzzification step, the inference rule is applied to determine the output by using rule base. The rule-base is a set of rules that emulates the decision making process of the human expert controlling the system. The rule is written in the form

IF congestion THEN reduce frame quality

Where congestion is a combination of input linguistic values and consequent is reduce frame quality. The rule-base is of form, IF frame size is less and buffer size is more, congestion factor will be Low.

Table 1
Fuzzy Rule Base

Frame Size	Buffer Size	Congestion Degree
L	H	L
L	M	M
L	L	M
M	H	M
M	M	H
M	L	H
H	H	H

We have taken 2 input parameters and 3 linguistic values as Low (L), Medium (M) and High (H). Hence we get a total of 8 Fuzzy Rule which are shown in Fuzzy Rule Base in Table 1.

E. Defuzzification

After getting the fuzzy output from the rule base, the output is mapped to the ordinate and the area for the corresponding fuzzy variable, bounded by the degree of membership value and the abscissa is calculated. Then, using the centroid method, the crisp output is calculated. This output is the summation of the product of the above area and the centroid in the abscissa for the corresponding fuzzy variable divided by the total area.

F. Algorithm

Fuzzy Logic based Congestion Control Algorithm includes the following steps.

Step 1: *Initially set the current value of frame size and buffer size in the sensor nodes.*

Step 2: *Find the shortest path from source node to sink node.*

Step 3: *k=1 to n [n= No. of frames]*

- a) *Initialize the fuzzy controller with frame size, buffer size.*
- b) *Find the values of number of contenders participating, incoming source frame rate and buffer size using the triangular rule (membership functions).*
- c) *Compute the Congestion factor*
- d) *Return*
- e) *Stop*

Step 4: *If the Congestion factor is below the membership function, maintain the flow with same frame rate.*

Step 5: *If the Congestion factor is above the membership function, reduce the frame rate to an acceptable level.*

Step 6: *Go to* ***Step 3***

Step 7: *Stop*

III RESULTS & DISCUSSION

The congestion factor is determined using fuzzy logic. Inputs to determine congestion factor are frame size and buffer size. The algorithm is coded using MATLAB mfile and verified using MATLAB fuzzy logic toolbar using FIS editor.

Fuzzy logic coding using MATLAB includes all the basic steps involved in designing a fuzzy model. These received inputs from a network model and rules are evaluated. The output membership functions are then aggregated and the congestion factor is calculated using the centroid method of defuzzification. MATLAB code for fuzzy scheduler is verified using MATLAB fuzzy logic toolbox. Then the congestion controller is used to maintain the rate of flow. As a result congestion in the network will be maintained.

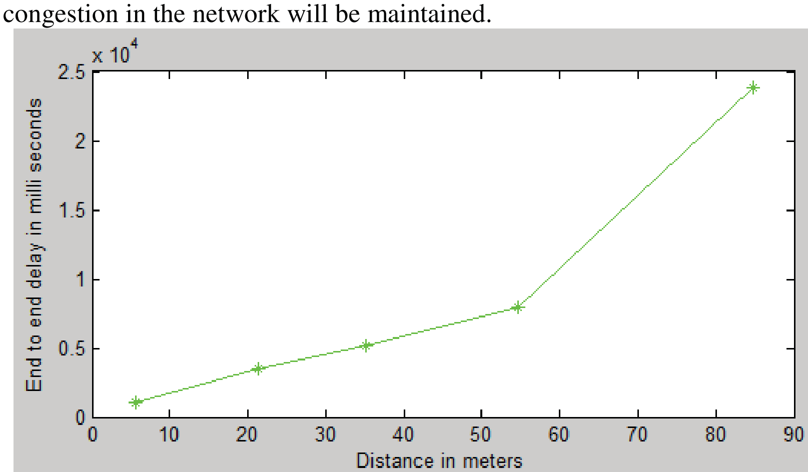

Figure3. End-to-End Delay vs Distance

Figure 3 shows the delay increases with increase in distance from source to sink node. The plot indicates that, as the distance between the nodes increases, there be an increase in delay.

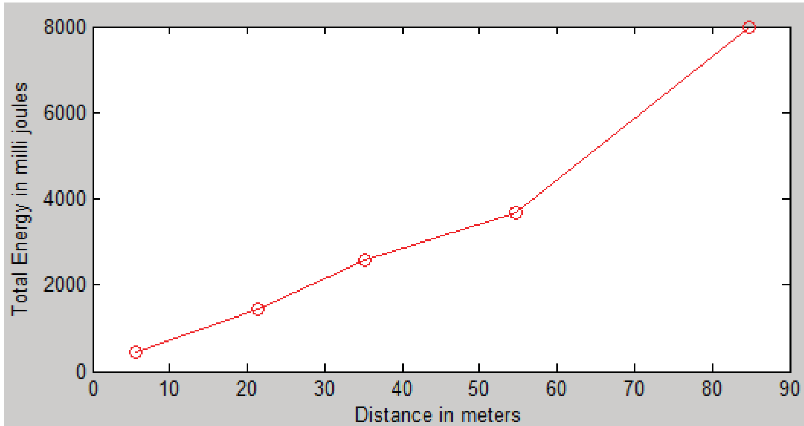

Figure4. Energy Dissipated vs Distance

Figure 4 shows the amount of energy dissipated with respect to distance. The plot shows that if there will be increase in distance between nodes, then the energy dissipation will be more.

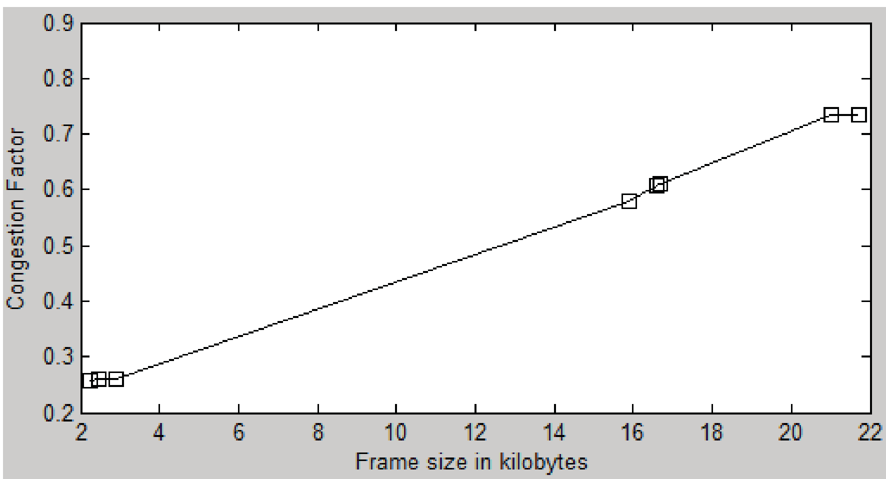

Figure5. Congestion factor vs Frame size

Figure5 shows that higher the frame size larger will be the Congestion factor. This plot shows as the frame size increase, congestion factor will increase linearly.

IV.CONCLUSION

This paper addresses a fuzzy logic based congestion control where the congestion will be identified and will reduce the frame size on-the-fly to ensure the continuous flow of data. The fuzzy controller algorithm combines the input parameters such as buffer size and frame size to find the congestion factor which is calculated by the fuzzy controller based on the above inputs which are derived from the network.

Our future works will consider different parameters like delay, jitter and compare this fuzzy logic based congestion control protocol with other protocols.

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