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CONGESTION CONTROL SCHEME TO ENHANCE QUALITY OF SERVICE IN WIRELESS SENSOR NETWORKS

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Abstract

With the emerging applications in wireless sensor networks congestion remains a critical problem. The execution of wireless sensor networks is influenced by the application decent variety, unpredictable traffic load, limited processing power and storage capacity among others. The congestion has negative effect on performance of the network such as packet loss etc because of the large number of retransmission and increasing delay. In this paper, a system for congestion control is proposed that is based on fuzzy system to detect and control congestion in the network. When the congestion is identified by the proposed detection mechanism, the notice signal is sent to posterity nodes and the data rate is controlled. In this way proposed approach will improve nature of Quality of Service in the areas of Wireless Sensor Networks.

***Keywords*:** Wireless Sensor Networks, Rate Adjustment, Congestion Score, Congestion Control, Fuzzy Logic System.

1 INTRODUCTION

A wireless sensor network (WSN) is a set of sensor nodes or simply nodes that are embedded with computing devices interfacing with sensors / actuators to sense the physical incident and send the sensed data to the final destination node [10]. The Wireless Sensor Networks utilize short range remote transmitters which act self-sufficiently but helpfully route data towards the central node known as sink. The accomplishment of Wireless Sensor Networks is mainly because of the cutting edge innovative progressions as of late that have empowered minimal effort, low power and moment sensor nodes underway. These modest nodes cooperate adroitly. With the rise of Internet of Things, WSN turns out to be increasingly appealing by their joining in real world of interconnected objects through web [11].

The shared obstruction of wireless connections, asset imperatives of nodes, many-to-one correspondence mode, collision, dynamic changes of topology, all make congestion to effortlessly happen in the systems. The capacity limit and the processing speed are constrained, which will directly results congestion [3]. Congestion enormously impacts the Quality of Service of WSNs, including poor energy effectiveness, low throughput, high packet loss, delay, and so forth [3].

Congestion should be controlled in mission basic applications like military operations, atomic lab, and life basic applications and so on with a specific end goal to have smooth operation [12]. Different techniques are presented by the authors for congestion control and mitigation [17]. The remaining paper is organized as follows: Section II provides methodology used. Section III explains phases of implementation and section IV gives results and conclusion.

2 METHODOLOGY

Congestion control is important to be carried out specifically as congestion has negative impact on overall network performance [7]. A new congestion control protocol based on fuzzy logic system (FLS) is used to overcome the existing problems. Data rate is not reduced; instead a constant data rate is maintained. Every type of data is considered important. No priority is given to any kind of data. FLS is an answer to construct a reaction to unexpected network conditions [9]. The data on network is separated [1] into two types:

(1) Locally Generated data: It is the information created from any source node or any moderate node in a specific period of time.
(2) Transit data: It is the information transmitted through transitional nodes. Since in a system, the travel information needs to venture out many bounces to achieve the sink node. In this manner dropping of such information prompts more vitality dissemination.

To improve QoS, we are utilizing QoS Management Mechanism. The QoS Management Mechanism utilizes two modules [13]:

(1) System Knowledge: In this module, learning of each and every nodes, capacity, and the range of transmission etc is stored. This data is intermittently refreshed, with the goal that latest and genuine conduct of the framework is reflected. It gives the present information of the network system design.

(2) Interface of the Feedback System: The feedback of the network is collected and compared to the known esteems.

The QoS Management Mechanism at that point makes an explanatory examination, and afterward concocts a choice to make any move, for example, rate modification, new path and so on. The proposed fuzzy logic system uses three non-numeric i.e. linguistic variables which defines the congestion level of the system. These variables are LOW, MEDIUM and HIGH.

The given block diagram demonstrates the proposed framework [9]. The input is given to Fuzzy Logic Controller are Fuzzifier, Inference, the Rule Base, Fuzzy Knowledge Base, Type Reduction and the Defuzzifier[7]. Fuzzifier maps the fresh input to comparing fuzzy sets. Inference mechanism comprises of different strategies for inferring the rules. The Rule Base comprises of rules that relate input fuzzy variables with output fuzzy variables. Defuzzifier performs defuzzification. Finally after detecting congestion, the Rate Adjustment Mechanism adjusts the packet rate and gives the constant output rate of packets. Thus all the packets are entertained and no priority is given to any packet. To adjust the packet arrival rate packet processing rate, the Rate Adjustment Mechanism the method that learns on the basis of intelligence from past history and thus enhances the QoS. The input variables which are used for Fuzzifier for congestion detection and mitigation are Net Packet Arrival Rate Pnet and Congestion Score CS.

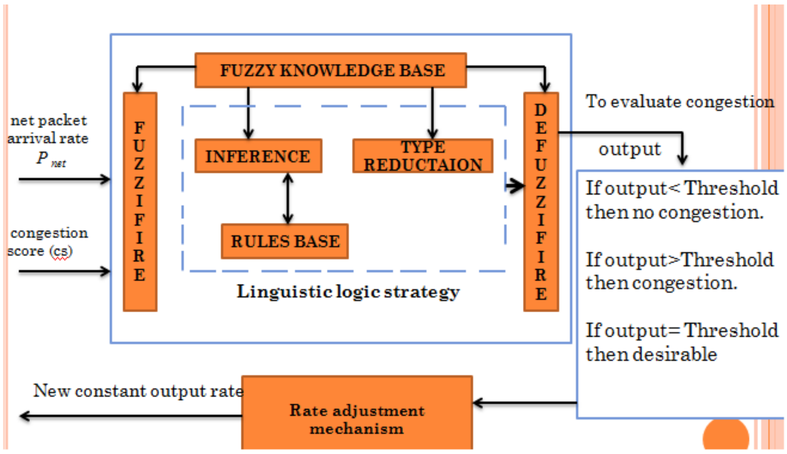

Figure 1: Overall Block Diagram

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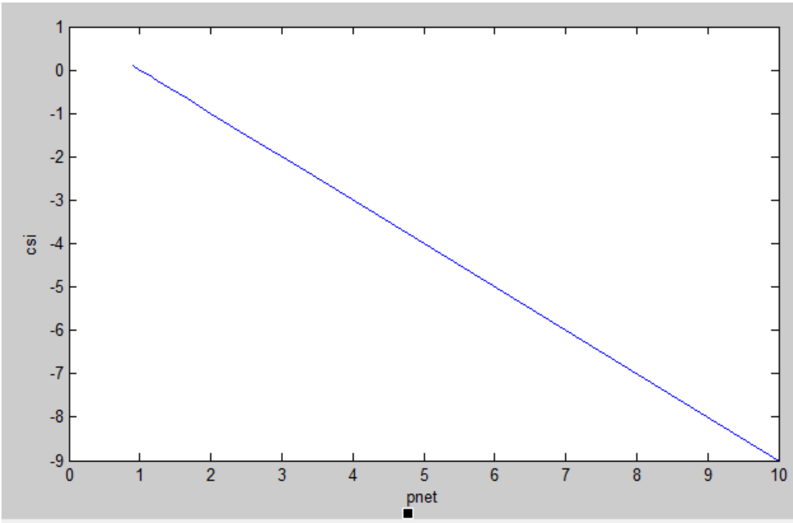

Figure 2: Graph between Pnet and CSi

A. Net Packet Arrival Rate:
At a particular node,

$$P_{net} = \frac{P_{in}}{P_{out}} \qquad (1)$$

P_{in} is incoming packets and Pout outgoing packets at a particular node respectively. Data priority estimator for node i is given by the equation:

$$P_{D(i)} = T_{D(i)} + L_{D(i)} \qquad (2)$$

Where,
$P_{D(i)}$ is Data priority estimator, $T_{D(i)}$ is transit data at current time and $LD(i)$ is locally generated data.[1]

B. Congestion Score: CS
At each node,

$$CS_i = \left(1 - \frac{r^i_{in}}{r^i_{for}}\right) \times T \quad (3)$$

CS_i is the congestion score.

r^i_{for} is the total of all the packet input rate [1]

r^i_{in} is packet forwarding rate

r^i_{in} can be given as:

$$r^i_{in} = R^i_s + R^i_{tr} \quad (4)$$

R^i_s is source traffic rate and

R^i_{tr} is transit traffic rate from its children node.[1]

We can replace the component $\frac{r^i_{in}}{r^i_{for}}$ of (3) by P_net (net packet arrival rate).

Thus (3) can be written as:

$$CS_i = (1 - P_{net}) \times T \quad (5)$$

Or

$$CS_i \alpha (1 - P_{net}) \quad (6)$$

Where time period T is the constant of proportionality. The graph between P_{net} and CS_i is shown in Fig 2.

Occurrence and non occurrence of congestion:

$$CS = \begin{cases} \text{No congestion} & \text{if } 0 < CS < 1 \\ \text{Congestion} & \text{if } CS < 0 \end{cases} \quad (7)$$

C. Proposed Algorithm

INPUT: (N: Net packet arrival rate, CS: Congestion score)
OUTPUT: Constant transmission rate BEGIN

1. WHILE (Event Detected) DO

2. If (P_net, CS) less or equal to threshold, then:
   No Congestion
3. Else:
   Congestion Detected
4. call (Rate Adjustment Function ());
5. END IF
6. Rate Adjustment Function ()
7. Detect R_s^i at node i
8. Detect R_{tr}^i at node i
9. Calculate r_{in}^i of node i using equation (4)
10. Detect r_{for}^i at node i
11. If r_{in}^i greater than r_{for}^i
12. Set the new constant transmission rate given by Rate Adjustment Function
13. Send the new transmission rate to child nodes via implicit message.
14. END WHILE
    END Algorithm

3 IMPLEMENTATION

Membership function (f) is used to convert the input variables into corresponding fuzzy variable. In fig 2, membership functions used for fuzzy variables are shown. It can be seen that three linguistic variables named Low (L), Medium (M), and High (H) are used to provide the level of the net packet arrival rate and congestion score.

Fuzzy Logic System (FLS) converts the crisp inputs to corresponding fuzzy variable using membership function (F). [9]

Pf, Qf is a set of fuzzy input variables obtained after applying membership function. Y represents the present fuzzy data of any

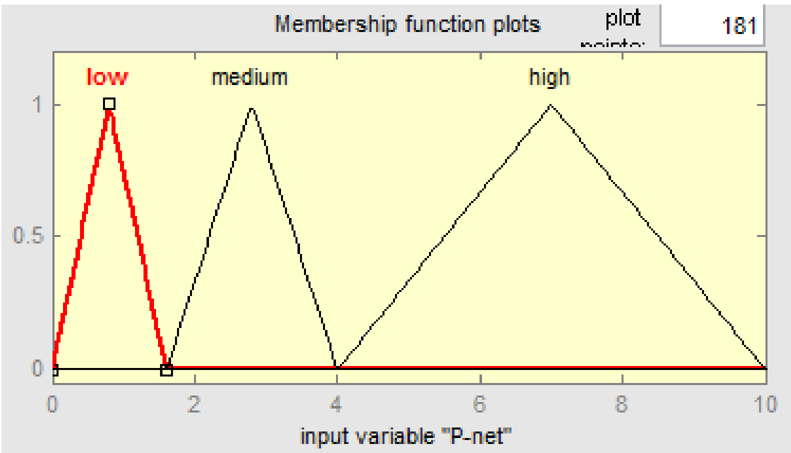

Figure 3: Membership Function Plots

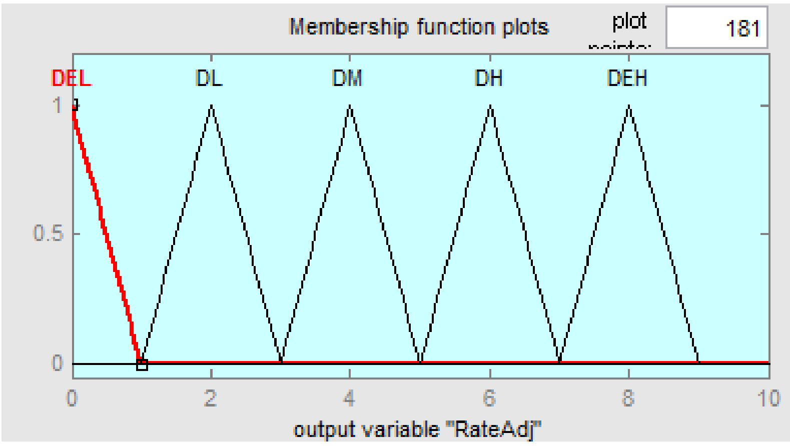

Figure 4: Membership Function Plots

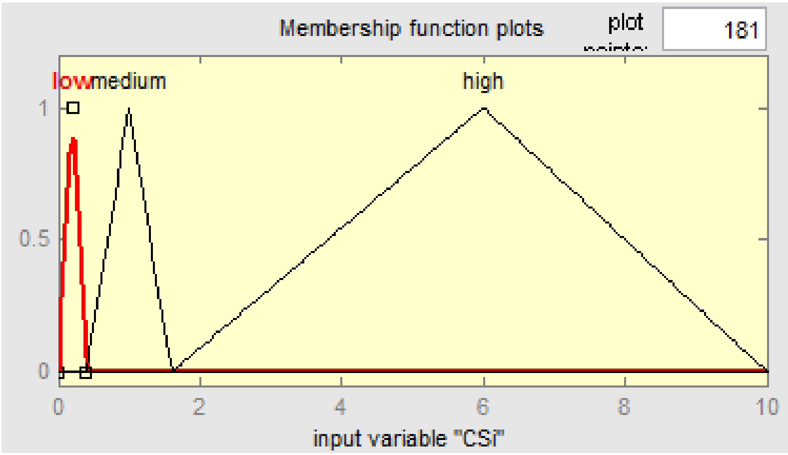

Figure 5: Membership Function Plots

$$F : (P,Q) \rightarrow (Pf, Qf) \quad (8)$$

$$Yf = [ZL(Y), ZM(Y)] \quad (9)$$

input and Z corresponds to P, Q.[7] Membership function Plots are shown in the fig.3, fig 4 and fig 5.

TABLE I. FUZZY DECISION RULES

Rule No.	Input variable		Output
	Net Packet Arrival Rate	Congestion Score	Rate Adjustment
1	L	L	DEL
2	L	M	DL
3	L	H	DM
4	M	L	DL
5	M	M	DM
6	M	H	DH
7	H	L	DM
8	H	M	DH
9	H	H	DEH

DEL: Decrease extremely low
DL: Decrease low
DM: Decrease medium
DH: Decrease high
DEH: Decrease extremely high

TABLE II. COMPARISON OF PACKET DROPS BETWEEN CONVENTIONAL CONGESTION CONTROL METHOD AND PROPOSED METHOD

P-in	P-out	P-net	CSi	Conventional method Rate adjustment	Proposed method Rate adjustment
10	10	1	0	0	0
10	9	1.1111	0.1111	1	0.352
10	8	1.2500	0.2500	2	0.374
10	7	1.4286	0.4286	3	2
10	6	1.6667	0.6667	4	4
10	5	2	1	5	4
10	4	2.5000	1.5000	6	4
10	3	3.3333	2.3333	7	6
10	2	5	4	8	8
10	1	10	9	9	5

The transit data is queued separately and has a certain threshold value. Locally generated data is also queued[1]. The knowledge base uses the knowledge from past history. Also uses Learning Automata Congestion Control Protocol (LACCP) [7, 9]. Rule Evaluation Method is used to create the output of the each rule. The two fuzzy variables Pf, Qf are divided into three ranges (Low, Medium, High), so the rule base contain different rules.[7] Fuzzy Logic System (FLS) uses defuzzifier (G) that always gives a single output. (10)

$$G : E.g \rightarrow E \qquad (10)$$

where E.g is fuzzy variable of E and g = 1,2,310. Fuzzy Logic System FLS gives the output that is uniformly distributed over entire range of Low (L), Medium (M), and High (H) [7]. Rules are evaluated in MATLAB and the rate is adjusted accordingly.

Table 2 shows the comparison of packet drops between conventional congestion control method and proposed method. It can be seen that in proposed method less number of packets are dropped than conventional method in case of congestion. Here the congestion score is normalized to a positive value. It can be clearly seen from the table that in about 70% of the cases the packet drop is minimized and thus energy is conserved and hence quality of service is enhanced.

4 RESULT AND CONCLUSION

A Fuzzy Logic System (FLS) is proposed for congestion detection and control, on detecting congestion the data rate is not reduced, instead a constant data rate is maintained. A congestion detection and control algorithm is proposed which is effectively capable of mitigating congestion, while decreasing the number of packet drops. Actually data rate is maintained by Rate Adjustment Function. Moreover, by applying Congestion Score and Net Packet Arrival Rate to a fuzzy rate controller, the congestion is controlled by altering data transmission rate of the child nodes. Energy efficiency is accomplished through energy-efficient routing and by avoiding packet drops. Thus Quality of Service (QoS) will be enhanced.

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