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Traffic Regulation based Congestion Control Algorithm in Sensor Networks

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Abstract. *In order to solve the problem that the node are respond slowly and unsteadily in the existing congestion control algorithms for sensor network traffic control with dynamic changes of network status, an algorithm based on traffic regulation is proposed. In the algorithm, congestion can be avoided and controlled by sending Traffic Regulating Factors from the father node to the children nodes according to the queue size and current traffic arrival rate of the father node. In order to produce traffic regulating factors, pre-assigned rates in bottleneck nodes are considered for the control of packet round-trip delay. At the same time, the Sink node makes reverse transmission of traffic regulating factors one hop-by-hop according to Minimum Event Detection Degrees. Based on the traffic regulating factors, the source nodes can adjust the data packet generation rate adaptively, and the congestion problem can be fundamentally resolved. Simulation results show that the proposed algorithm is an effective algorithm for congestion control, which can raise network throughput, reduce packet loss rate, and stabilize node queue length.*
Keywords: Sensor networks; Traffic regulation; Congestion control; Minimum Event Detection Degrees

1. **Introduction.** As a novel technology for information obtaining and processing, sensor network (SN) is capable of detecting, sensing and collecting information from various environment or to-be-detected objects, which make it very popular in many fields such as national defense, environmental detection and medical care [1]. Of all these applications, SN can be divided into three kinds in principle: periodic information collection, event detection, and mixed application. In periodic information collection, sensor nodes sense information and send it to Sink nodes continuously, and this kind of SN has the characteristics of centralizing data collection, multi-hop data transmission and multiple-to-single communication. The closer is a node to the Sink node, the more data packets will be transmitted via the node, which means a heavier burden for the node. This unbalanced feature of network traffic determines the fact that nodes near the Sink node often become the bottleneck of communication. Congestion of SN will reduce the transmission capability of the network, increase its transmission time-delay, and then cause loss of date packets, so as to cause a great waste of nodes resources and an extremely bad influence on the QOS of network along with the transmitting performance [2].

According to the properties of SN, many methods have been proposed for congestion control, for example, traffic control [3], dynamic routing [4], active queue management [5], etc.. Thereinto, traffic control is an efficient scheme for recovering the network from congestion, and it is the key method to ensure the QOS performance, therefore it plays an important role in the control of network congestion. By limiting the total traffic gathered by all child nodes within the handling ability of father nodes, the traffic control scheme can adjust the production of data packets and their transmitting quantity so as to avoid and control the network congestion. Aiming at the congestion problems in SN, researchers have proposed various traffic control algorithms in recent years. ESRT [6] is one of the earliest algorithms. By calculating the reliability through employing Sink and forecasting the state of network through exploiting the transmission rate obtained via congestion detection, ESRT can control the network traffic between nodes by different methods, and then restore the network to its ideal state. However, ESRT often responds to the changes of network data stream very slowly, and doesn't consider the effects of the transmission delay between nodes during the process of traffic control, so it will cause the fluctuation of the transmission node queue and the instability of the convergence state of the system. FUSION [7] is another traffic control scheme, which provides a cross-layer solution for congestion control. Once congestion is discovered by detecting the buffer queue, the node will transfer this information via a control packet to its neighbor nodes and limit their transmission rates via signal bucket mechanism, and then its influx data will be reduced. Unfortunately, limiting the influx data from local nodes for avoidance of congestion will increase the packet loss rate, and the usage of stop-and-start is also very difficult to handle the change of transmission quantity effectively [8], thus it is of great necessity to optimize the throughput of SN.

In a practical application of SN, owing to various environment interferences, dynamic change of transmission bandwidth, feedback time delay, along with other uncertain phenomenon, analysis and synthesis of the network will be more complicated when the data flow needs to be adjusted adaptively. Feedback time delay is also a main reason for the instability and degeneration in the performance of the system, especially when burst traffic emerges. Thus, aiming at problems such as slow system response, poor handling ability and instable throughput, this paper proposes a new algorithm for congestion control based on traffic regulation (CCTR). Taking the characteristics of production and transmission of SN traffic into account, CCTR adopts the traffic control scheme, predicatively compensates the delay of control packets based on Smith theory, and avoids the congestion in bottleneck nodes by adjusting their transmission modes and the data packet generation rates through a proportional controller. Simultaneously, according to the requirements of event detection rates, the Sink nodes adjust the data production rates of the source nodes adaptively via the reverse notification of the hop-by-hop traffic regulating factors, and provide a fundamental solution for congestion of SN in which the transmission load is beyond its capacity.

2. **Network Model and Problem Definition.**

2.1. **Network Model.**

Different networks often have different frameworks. The network setting considered here is the same as that in [18].As a connected and static network, its topology remains unchanged after deployment. The framework can be seen as a Sink-node-centered hierarchical topology model shown by Fig.1. In this figure, S, M and H denote source nodes, and M, H are called the intermediate nodes, which are the father nodes of the source nodes, and the Sink node is aslo the father node of the intermediate node H.

When several children nodes are transmitting data packets to their father nodes simultaneously, the multi-source aggregation transmission model is formed. The organization of this model is given by Fig.2. In this figure, there are n nodes connected to the father node, and node n transmits the data packet traffic by a rate of $a_j(t)$. Owing to

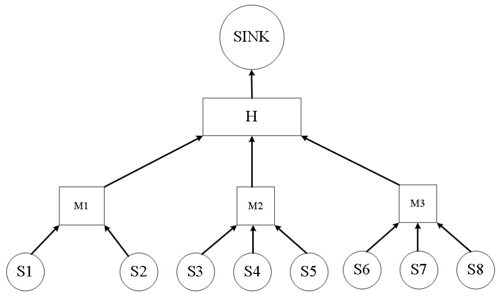

FIGURE 1. Configuration of network

various environment interferences and considering the characteristics of SN, the available bandwidth of $d(t)$ each node is unknown and often satisfies the following condition

$$0 < d_{\min} < d(t) < d_{\max} \tag{1}$$

where $d_{\min}$ and $d_{\max}$ denote the minimum and maximum available bandwidth respectively.

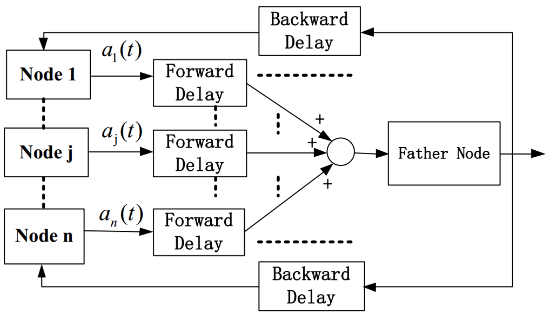

FIGURE 2. Model of data transmission

To obtain a reasonable congestion control model, an issue that can't be ignored is the effect caused by the packet transmission delay. Let T_{fj} be the delay of transmission process between the j-th child node and its father node, which is also called forward delay, and T_{bj} be the corresponding delay of feedback process between these two nodes, which is also called backward delay.

2.2. **Problem Definition.** Due to wide-area deployment and uncertainties of event occurrence, the emergence of SN network traffic is usually paroxysmal and stochastic. However, these traffic bursts always have certain statistical properties. For instance, when SN is applied to the aerial defense field, by identifying and analyzing the sampling data obtained from a target under assault mode [10], it can be proved that the time interval distribution model of the target traffic meets the Blame traffic. By exploiting the time queue model and predicting the traffic data of SN through Kalman traffic predicting algorithm, [11] succeeds in obtaining traffic data almost equal to their origin values ahead of one or even several periods. All these methods for traffic model identification lay the foundation for quantitative analysis of traffic control strategies, and their model parameters can be reflected via node queue length and input rate in real time. However, for reckoning without the traffic production and transmission process, existing traffic control schemes can not determine some of their own parameters accurately, as thus, one of the following three problems may be caused, which are also what this paper wants to resolve.

(1) How to discover congestion in time?

Most of existing algorithms for congestion control are passive, i.e., traffic control will be initiated only when congestion has been confirmed. So the number of data packets is still increasing when detecting congestion, and thus congestion will be worse. Therefore, it becomes the key issues for congestion control whether congestion nodes can analyze the statistical characteristics of input traffic on line and predict the communication traffic of the next stage or not, which requires the real-time interaction between a father node and its child node.

(2) How to assign transmission rates of downlink nodes in reason?

Lack of detailed analysis of models for network transmission and arriving traffic, most of existing algorithms can not assign traffic for downlink nodes in reason. Although the additive increase multiplicative decrease (AIMD) model [12] provides a solution to the fluctuation of data traffic, it can not keep a higher throughput. Hence, how to assign node rates reasonably to ensure a higher throughput is another key issue for congestion control.

(3) How to resolve the congestion problem fundamentally?

Overlarge traffic produced by source nodes may exceed the maximum transmission capacity of the network, which is the main reason for congestion in SN with limited resource and adopting the multiple-to-single communication means. Therefore, it doesn't mean that the more data packets source nodes generate, the better it is. How to adjust the traffic of source nodes adaptively by some means is a problem deserving to research, and it is also a difficulty for solving the congestion problem fundamentally.

3. **Design of Traffic Regulating Algorithm.** A main property of network congestion is a longer buffer queue. The reason for this is that arrival rates of packet data are beyond the node processing abilities. Existing algorithms do not consider the adverse influence caused by the transmission delay of the interactive control packets on the control performance. Based on the feedback control, Smith proposed a predictive compensation principle to enhance the control quality of this kind system [9], which is added a predictive compensation procedure to eliminate pure lag items in the closed-loop equation. Both theory and practice show that Smith's predictive compensation principle can control a system with lag characteristic effectively, see [13] and [14]. However, what they discussed are all control methods in continuous circumstances. Assuming that SN operates in condition of limited bandwidth and father nodes can not interact with children nodes, the paper proposes a Smith control strategy for SN in discrete circumstances. In the strategy, a father node pre-adjusts the traffic from its children nodes according to the dynamic characteristics of its queue, current input rate, and transmission round-trip delay, to avoid and control the congestion. The control process is shown by Fig.3.

According to Fig.3, the child node j connects to the father node f normally and sends detected information to f periodically. When the number of data packets is up to M, j will send a traffic monitor packet (the first kind of control packet) to f. After receiving this packet, f will decide the anticipant uploading rate of j in the next stage according to the buffer state and transmission delay of the control packet by using the queue controller, which is called the second kind of control packet, i.e., traffic regulating factor b_f, and send it back to j. Then j will adjust its output rate based on b_f immediately and decide the traffic factor b_j for regulating the anticipant sending rate of its children nodes.

3.1. **Bottleneck Node Traffic Control.** It has been proved mathematically that, if the information stream on a node can be adjusted according to the traffic characteristics of the network, higher network performance can be guaranteed for application of this information stream [13]. Our traffic regulation method assigns different transmission

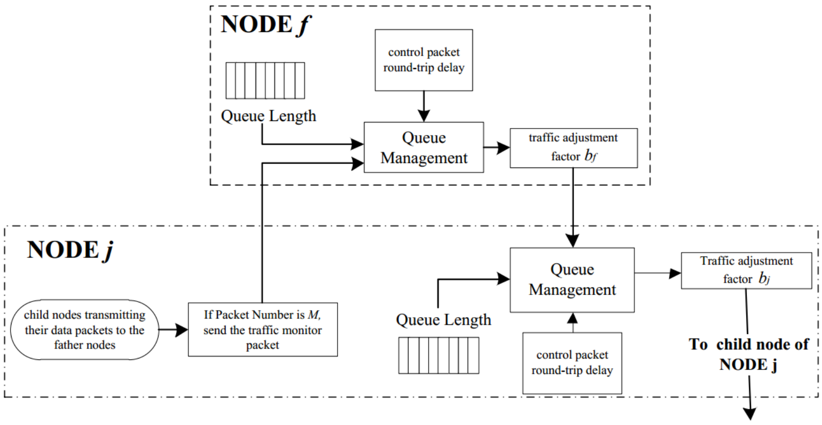

FIGURE 3. The model of the traffic control algorithm

rates to children nodes by stages to adapt the fluctuation of the network resources, which makes the traffic of a children node agree with the traffic model of SN, and it can avoid the congestion caused by outbursts of traffic [15]. To control the traffic of SN more delicately, it is necessary to analyze the transmission model of SN in detail and derive the assignment procedure and method for the transmission rate of child nodes reasonably, so as to maximize the utilization factor of network resources.

The sum of the transmission delay of the monitor packet and that of the regulating factor is given as follows,

$$RTT_j = T_{fj} + T_{bj} \tag{2}$$

Let the data traffic sent from j to f be $h(t)$, which satisfies $0 \le h(t) \le d(t) \le d_{\max}$, then the queue length of f is,

$$x(t) = \begin{cases} 0 & t \le 0 \\ \sum\limits_{j=1}^{n} a_j(\tau - T_{fj})\mathrm{d}\tau - \int\limits_0^t h(\tau)\mathrm{d}\tau & t > 0 \end{cases} \tag{3}$$

where, n is the total number of the children nodes connected with the Sink node, and $a_j(t)$ satisfies the following conditions

$$\underset{j}{\forall}\ \underset{t<0}{\forall}\ a_j(t) = 0 \text{ and } \underset{j}{\forall}\ \underset{t>0}{\forall}\ a_j(t) = b_j(t - T_{bj}) \tag{4}$$

Because of the forward transmission delay, $x(t < T_{f\,\min}) = 0$ before $T_{f\,\min} = \min\limits_{j=0,2,3\cdots n}(T_{fj})$. Let $t_{j,k}$ be the moment that the k-th traffic detecting message belonging to the j-th connection link feeds back to the j-th child node, then

$$\underset{t\in[t_{j,k},t_{j,k+1}]}{\forall} a_j(t) = a_j(t_{j,k}) = b_j(t_{j,k} - T_{bj}) \ = \text{const} \tag{5}$$

Assume that sensor nodes begin data transmission at the moment $t = 0$, and $t_{j,1} = RTT_j$ when $k = 1$, then $t_{j,k+1}$ can be determined by the following equation

$$\int\limits_{t_{j,k}}^{t_{j,k+1}} a_j(\tau - RTT_j)\mathrm{d}\tau = M \tag{6}$$

Noting the moment of each rate readjustment as $\theta_m, m = 1, 2, \cdots$, it can be known that within $\alpha_m = \theta_{m+1} - \theta_m$,

$$\underset{t \in [\theta_m, \theta_{m+1}]}{\forall} \ \underset{j}{\forall} a_j(t - T_{fj}) = a_j(t_{j,k} - T_{fj}) \ = \text{const} \tag{7}$$

Let $a_{\min}$ be the converging rate before a burst of data stream occurs and A denotes the predicted total converging rate in the next stage by using the traffic distribution model. As the network has a present maximum available bandwidth $d_{\max}$, however, the predicted traffic may be larger than the maximum available bandwidth, viz.,

$$a_{\min} \leq h(t) \leq d_{\max} \leq A \tag{8}$$

at this time, one should assign the converging rate of the downlink nodes and endow them with the maximum statistical packet rates, i.e., the bearable well-proportioned rate $a_{\max}$, so as to restrict the transmission packet rates of the child nodes, and when the father node becomes the bottleneck node due to the smooth data stream of its children nodes, it can transmit data stream to the SINK node at the maximum utilization of the network resources without congestion, that is to say, $a_{\max} = d_{\max}$ is just ensured.

Ref. [16] points out that if there are no buffer overflows and bandwidth loss in a detecting period, an ideal queue length exists, which is defined as x_δ. Therefore, to optimize the transmission performance of the network, it is necessary to control the queue length of a node and keep it around x_δ. Define the queue controller as

$$\tilde{a}(t) = \begin{cases} a_{\min} & \text{if} \quad W(t) < a_{\min} \\ W\,(t) & \text{if} \quad a_{\min} \leq W(t) < a_{\max} \\ a_{\max} & \text{if} \quad W(t) > a_{\max} \end{cases} \tag{9}$$

where $a_{\max}$ and $a_{\min}$ denote the maximum rate when there is an outburst of data stream and the smaller rate before the outburst of data stream appears, respectively, and $W(t)$ is the queue control function, which is defined as

$$W\,(t) = K\left[x_d - x\,(t) - \sum_{j=1}^{n} \int_{t-RTT_j}^{t} b_j\,(\tau)\,\mathrm{d}\tau\right] \tag{10}$$

where K denotes the proportion control gain, $x(t)$ is the instant queue length of the father node f, and $\sum\limits_{j=1}^{n} \int\limits_{t-RTT_j}^{t} b_j(\tau)\mathrm{d}\tau$ is the sum of the traffic gathered at f within the round trip time of the control packets. As can be seen from (10), the control function takes the queue length of node, round trip time delay of transmission and converging rate into consideration synthetically. Assuming that $b_j(t)$ is the expected rate of the regulating factor aiming at the converse transmission of the i-th child node, according to the algorithm, the following equation can be got,

$$b_j(t) = \begin{cases} 0 & \text{for } t < -T_{bj} \\ a_{\min}/n & \text{for } -T_{bj} \leq t < T_{fj} \\ \tilde{a}(t_{j,k} - T_{bj})/n & \text{for } t \geq T_{fj} \ \&\ t \in [t_{j,k} - T_{bj}, t_{j,k+1} - T_{bj}] \end{cases} \tag{11}$$

That is to say, during the time interval a_m between any two successful rate changing, the upper limit of the rate changing is $Mn/a_{\min}$. Therefore, combining (2) and (3), the queue control function can be expressed as

$$W(t) = K[x_d - \sum_{j=1}^{n} \int\limits_{0}^{t} b_j(\tau)\mathrm{d}\tau - \int\limits_{0}^{t} h_j(\tau)\mathrm{d}\tau] \tag{12}$$

and the derivative of (12) is

$$\frac{\mathrm{d}}{\mathrm{d}t}\tilde{a}(t) = K[h(t) - \sum_{j=1}^{n} b_j(t)] \tag{13}$$

According to (11) and (12), the maximum changing rate of the queue control function is

$$\frac{\mathrm{d}}{\mathrm{d}t}\tilde{a}(t) \leq K[a_{\max} - \sum_{j=1}^{n} b_j(t)] \leq K[a_{\max} - a_{\min}] \tag{14}$$

and the shortest time for rate changing is $1/K$. If assuming that

$$K \geq [\min(Mn/a_{\min}, \sum_{j=1}^{n} RTT_j/n)]^{-1} \tag{15}$$

the converging traffic can guarantee that the update of the transmission rates of child nodes is able to adapt to the dynamic change of the network bandwidth and the minimum rate required by the traffic model can be satisfied during the transmission delay of the predicted traffic detecting message and the traffic regulating factors. Hence, on basis of analyzing the traffic transmission model, the traffic regulating algorithm can avoid the influence of the pure time delay of the network control packets on the congestion control system by compensation. That is to say, it is able to eliminate the influence of time lag on the stability of the control system.

When congestion occurs, the regulating factor may be thrown away due to the reasons such as competing for signal channel, conflict of data transfer and interruption of links, just as other data packets. If the regulating factor is thrown away, the uplink node will be incapable of sensing the congestion and still send data packets to the congesting area at a higher rate, and it will make the congestion even worse. Hereby, the transmission reliability of the control packet must be ensured. For cable channel, a timer can be used to monitor whether there is a traffic regulating factor or not to judge the occurrence of a congestion. For wireless channel, inspired by [17], here the multi-frequency characteristics of nodes are utilized to solve this problem. While the system predicted that a congestion will happen, it will assign different communication frequencies to the control packets and data packets and thus provide a green channel for the backward transmission of the regulating factor so as to ensure the smooth implementation of the congestion control strategy.

3.2. **Adaptive Adjustment of Transmission Traffic Produced by Source Nodes.** According to the application environment, the relationships among different network packets can be divided into two kinds. The first kind of relationship is irrelevance. Here, different sensor nodes detect entirely different event information, the network throughput is in direct ratio to the total information content of the generate events and thus the optimal application means of this kind of network is to maximize the utilization factor of the network bandwidth. The second kind of relationship is similarity. In this case, the application effectiveness of the network can be measured by minimum event detection degree (MEDD), which denotes the minimum number of packets needed to be received in unit time at the Sink node to meet the requirements of application effectiveness. For instance, when SN is applied to target localization, each of the corresponding three sensors should provide a distance packet at a time. If the total number of packets arriving at the Sink node in unit time is smaller than MEDD, it means the throughput of event packets has not met the requirements of MEDD, and the transmission rates of source nodes should be increased. If the total number of packets arriving at the Sink node in unit time is equal to or greater than MEDD, the related source nodes will not send the redundant packets, the traffic will decrease fundamentally, and thus the congestion can be avoided. When the traffic regulating algorithm is applied to the second kind of network application, to prevent the congestion control from getting in a locally optimum solution like FUSION, firstly the Sink node should determine MEDD according to the application requirements of the network, and then, broadcasts the regulating factor to source nodes by means of backward transmission so as to keep the transmission traffic of source nodes around the network load.

4. **Simulation Experiments.** This paper takes NS2 as the experimental platform and investigates the QOS performance of CCTR, ESRT and FUSION in the respects such as the network throughput, packet loss rate, node queue length. The MAC method and AODV routing scheme in the protocol 802.11DCF are taken as the underlying supporting algorithms of the network simulation platform. Table 1 presents the main configuration parameters. Assuming that there are one hundred randomly distributed sensor nodes, ten of them are chosen as the source nodes, randomly, five kinds of network topological structures can be constructed, and each experimental result is the average of ten simulation results. To distinguish the influence of routing on the transmission performance, all nodes begin to produce and send ABR (Available Bit Rate) stream after the simulation has run for ten seconds and do not update transmission traffic until receiving the feedback rate regulating unit (ESRT, FUSION) or the traffic regulating factor (CCTR).

Table 1. Simulation parameter settings

Simulation parameter	symbol	parameter value	unit
Network size	S	200×200	m^2
Communication radius	R	40	m
Packet size	P	64	Byte
Buffer length of a node	L	120	Packet
ABR average rate	V	30	Packet/s

4.1. **Network Throughput.** The network throughput refers to the number of data packets arriving at the Sink node from all source nodes within unit time. The first experiment compares the dynamic change of the network throughput of the two kinds of network applications mentioned in Section 3.2 when applying CCTR, ESRT and FUSION respectively. Fig. 4 shows the variational curves of the network throughput of the first kind of network application, and Fig. 5 presents the variational curves of the network throughput of the second kind of network application with MEDD equal to sixty Packet/s.

For the first kind of network application, as can be seen from Fig. 4, during the initial stage of the network running, i.e., $t \in [10, 10.4]$, with the increase of time, the network throughput of any of the three schemes increases without exception, and the network throughput of CCTR reaches its maximum at the latest, about eighty -five Packet/s. This is because CCTR is able to pre-assign the average rate according to the predicted traffic, and it can reduce the delay jitter and loss rate of packet transmission by reducing the random fluctuation of the traffic, which is what ESRT and FUSION cannot do. During the period of $t \in [10.4, 10.6]$, the network throughput of ESRT and FUSION lowers sharply when the network load exceeds a certain value, which means a congestion must have happened somewhere for failing to perform congestion control for bottleneck nodes in time. However, in the next period $t \in [10.6, 10.9]$, as ESRT and FUSION have

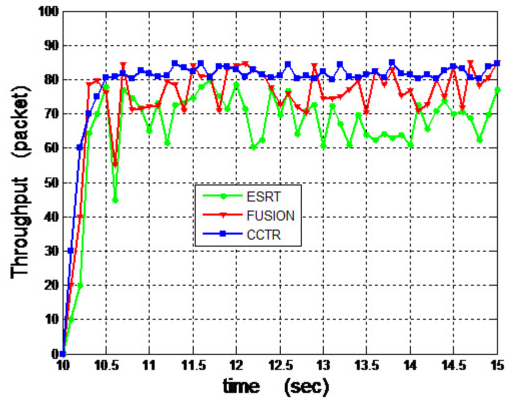

FIGURE 4. Throughput of the first kind of network application

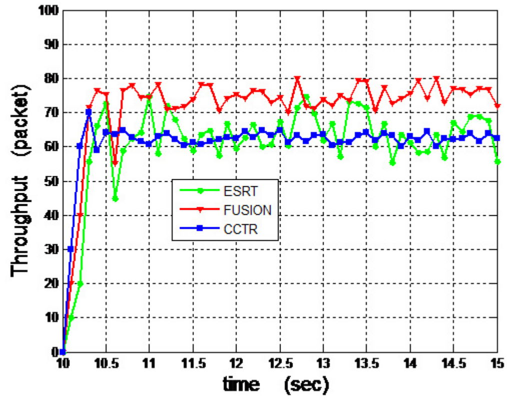

FIGURE 5. Throughput of the second kind of network application

started the congestion control mechanism, the connectivity of the network has been recovered, and thus the network throughput rises gradually. But in the follow- up stage with $t \in [12.3, 15]$, the network throughput of ESRT and FUSION takes on an obvious fluctuation characteristic, however, that of CCTR holds in higher levels and has little fluctuation. Therefore, due to having taken the influence of the feedback time lag into consideration, CCTR improves the control performance in the case of dynamic network state and assures the relative stability of the network throughput.

For the second kind of network application, as can be seen from Fig. 5, during the period of $t \in [10.3, 10.5]$, the network throughput of CCTR continues to decrease by 10 Packet/s when the congestion has been avoided so as to keep the net throughput around MEDD. The reason is that, when the network throughput is greater than MEDD, the Sink node will not stop sending traffic regulating information to its child nodes until the source nodes reduce their transmission traffic. Such regulating strategy can adjust the network throughput to a steady state rapidly and further reduce the possibility of congestion occurrence on basis of satisfying the network application requirements. The average network throughput of ESRT is also around 60 Packet/s, however, due to its control performance of a sort, its network throughput fluctuates more acutely than that of CCTR. As to FUSION, because it has not the function of traffic control, overmuch system resources may be wasted due to redundant transmission.

4.2. **Packet Loss Rate.** Fig. 6 shows the statistical curves of the packet loss rate of the three congestion control algorithms when applied to the first kind of network application. It can be seen from the figure, during the initial stage of running, all the three control algorithms can ensure a lower packet loss rate; after a period of time, the loss rate of CCTR can be kept below 20 percent, however, the performance of ESRT and FUSION goes down quickly, whose loss rates fluctuate around 25 percent. It is obvious that ESRT and FUSION can not control the data traffic effectively, and a lot of packets will be thrown away when the network breakdown occurs or during the slow recovery of the network. However, by means of predicted traffic assignment, CCTR can ensure the network throughput and keep a lower packet loss rate, and thus the network resource can be saved.

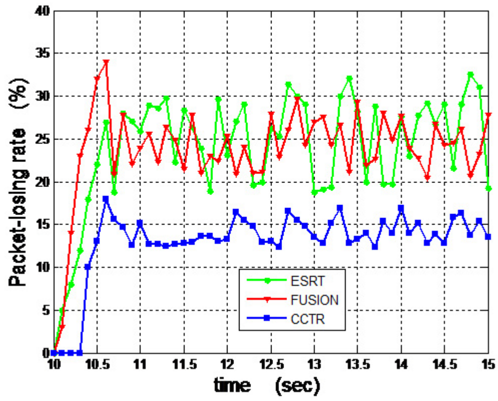

FIGURE 6. Comparison of Packet loss rate

4.3. **Dynamic Change of Node Queue Length.** Tabs. 2 and 3 presents the statistical circumstances of the use of node queues of the three congestion control algorithms when applied to the first kind of network application. As can be seen from the tables, the node queue length of ESRT and FUSION is larger and has a big fluctuation, however, the node queue length of CCTR always swings around the expected length within a small range. This is because CCTR considers the influence of the feedback time lag on the queue control method and offers a good mechanism for traffic assignment by predicting and updating the transmission rate in the next stage, therefore it can produce a smoother output data stream and reduce the delay jitter caused by the queue fluctuation. Moreover, the expected queue length maintained by CCTR also guarantees the availability of the network.

TABLE 2. Average queue lengths of three schemes

	node 1	node 2	node 3
ESRT	86.5500	88.4723	83.3725
FUSION	72.5500	75.4723	68.3725
CCTR	55.9982	63.4961	64.1782

5. **Conclusions.** This paper summarizes the state-of-the-art of the traffic regulating algorithms for congestion avoidance and control from the view point of the reasons for congestion in SN. In allusion to the problems existing in the current mechanism for congestion control, it proposes a new traffic regulating algorithm combining the feedback

Table 3. Variance of queue lengths of three schemes

	node 1	node 2	node 3
ESRT	236.3963	210.3179	225.7488
FUSION	206.684	189.3452	198.245
CCTR	100.9859	121.6673	118.5376

traffic control and the preventive traffic regulation. The proposed algorithm tries to avoid the occurrence of congestion by traffic control in bottleneck nodes and adaptive rate adjustment in source nodes. The experimental results show that, the proposed algorithm is able to keep the network throughput in a high level, reduce the packet loss rate and maintain the stability of the queue. What should be pointed out is that, the proposed algorithm in this paper is best suitable for application cases without frequent change in the network topological structure, and the mathematical- model-free intelligent control algorithm is the work to be investigated in the future.

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