무선 센서 네트워크 환경에서 실시간 트래픽에 대한 비트율 제어 기법

모하마드 무스타파 모노워 O, 엠디 오베이둘 라만, 홍충선
경희대학교 컴퓨터공학과
{monowar, rupam}@networking.khu.ac.kr and cshong@khu.ac.kr

An Rate Control Protocol for Real Time Traffic in Wireless Sensor Network

Muhammad Mostafa Monowar O, Md. Obaidur Rahman and Choong Seon Hong
Department of Computer Engineering, Kyung Hee University,

Abstract

Wireless Sensor Network typically incorporates various real time applications that must meet timing constraints under severe resource limitations. Due to the high data rate and burst traffic for that type of applications, occurrence of congestion is very common. Ensuring the end-to-end deadline under congested scenario is quite challenging. In this paper we propose a hop-by-hop rate control algorithm which avoids the congestion as well as ensures that the real time traffic will meet the end-to-end deadline by guaranteeing the meeting of local deadline at intermediate hop. Finally, simulation has demonstrated the effectiveness of our approach.

1. Introduction

The recent advances in wireless sensor network communication protocols [1] and low power hardware devices such as CMOS camera and microphones have elevated the proliferation of various sensor network applications i.e. battlefield surveillance, disaster and emergency response, environmental monitoring, industrial process control etc. These applications deal with various kinds of real time constraints in response to the physical world. In comparison with the traditional distributed systems, the real time guarantee for sensor network is more challenging due to the diverse transmission rates, unpredictable spatiotemporal properties of the physical events in the real world and the severe resource limitations in the sensor network.

In WSN, usually tens or thousands of sensor nodes are deployed scattered way in an area with one or more sinks. Because of the high data rate and unpredictable burst traffic nature of the real time application, occurrence of congestion is more likely. When congestion occurs, the strict timing requirements of this type of application are seriously hindered. Therefore, an efficient rate control mechanism is necessary that guarantees the timing requirements even in the congested scenario.

In this paper, we have proposed a hop-by-hop rate adjustment technique that avoids the congestion as well as ensures that the real time traffic will meet the end-to-end deadline by guaranteeing the meeting of local deadline at intermediate hop. We have introduced per hop entailed delay for congestion detection that facilitates the adjustment of rates by the sensors before missing the local deadline of the real time packet.

The rest of the paper is organized as follows. Section 2 presents several related works on congestion control techniques. Subsequently section 3 describes the design considerations for our proposed scheme. Section 4 represents our proposed protocol in detail. Section 5 describes the simulation and finally section 6 concludes the paper.

2. Related Work

In the present research train lots of works is going on the congestion control for wireless sensor network. But a very few of them considered the real time delivery of packets. PCCP [2] is a recent congestion control protocol which takes into account the QoS of the multimedia applications. It introduces an efficient

This research was supported by the MKE under the ITRC support program supervised by the IITA"(IITA-2008-(C1090-0801-0002))

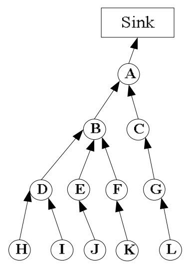
congestion detection technique addressing both node and link level congestion but can't guarantee the end-to-end deadline of the real time packets.

DART [3] is another current transport protocol for wireless sensor networks. The protocol simultaneously addresses the congestion control and timely event transport reliability. But it is not suitable for the application where each packet needs to be delivered within strict time requirements and due to the sink initiated congestion control the reporting rate adjustment also incurs extra delay for the sources far away from the sink. SUPORTS [4] is one of the most promising real time traffic management protocols for Sensor Network. It is based on traffic regulation and end-to-end scheduling approach which uses hop-by-hop approach for traffic regulation and reject packets which is supposed to miss the deadline. The idea of this protocol inspired us to design our protocol but our contribution is regulating the outgoing rate of the offspring nodes instead of dropping the packets which can miss the deadline.

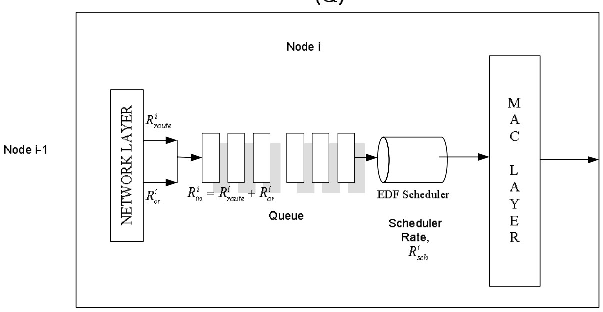
Besides these, CODA[5], CCF[6], SIPHON[7], FUSION[8] etc are the remarkable congestion control for wireless sensor networks but none of the explicitly considered the real time traffic.

3. Design Considerations

This section describes the network and node model we considered for our protocol.



(a)



(b)

Figure 1. (a) Network Model (b) Node Model

Network Model: In this paper, we consider the rate control for many-to-one multihop single path routing. The network model is shown in Figure 1(a) where each node can function as a source node as well as forwarding node and each node transmits the real time packets periodically. All nodes are supposed to use CSMA like MAC protocol. We assume that a predetermined route has been established by any routing protocol and path establishment is out of the scope of this paper. We further assume that the routing protocol will provide the local estimate delay for each node. When a sensor node transmits its data to the upstream direction then the node is called child node and the node to which it transmits is called its parent node.

Node Model: Figure 1(b) depicts the node model on a particular node, i for single path routing. The route data comes from the child nodes at a rate R^i_{route} and the originating data at R^i_{or}. Therefore, the total input rate is $R^i_{in} = R^i_{route} + R^i_{or}$. So, by adjusting the R^i_{route} and R^i_{or}, the total input traffic rate, R^i_{in} can be adjusted during congestion. In our model, we have provisioned a scheduler which schedules the interface queue between Network and MAC layer. The scheduler schedules the queue according to the Earlier Deadline First (EDF) scheduling. The scheduler rate is denoted as R^i_{sch} (the number of packets it schedules per unit time). The scheduler sends the packet to the MAC layer from which it is delivered to the node i+1.

4. Proposed Protocol

Our main motivation in designing the protocol is to perform rate control for real time traffic originated and transited through a single sensor node in such a way that it can meet the end-to-end delay requirements. To accomplish this, every node ensures that the real time traffic passes through it will not miss the deadline that is allocated to it by notifying the offspring nodes regarding the allowable incoming rate. It also adjusts its own originating rate if it functions as a source node. The details of or protocol is presented in the following subsections:

4.1 Hop by Hop Rate Adjustment:

We have modeled the queue at each sensor node as *M/G/1* system. Our protocol uses the per hop sojourn time, $D_w{}^i$ as the congestion detection metric. The sojourn time, ${D_w}^i$ is defined as the sum of the queue waiting time, ${t_w}^i$, and the average packet service time, $\overline{t_s^i}$. The queue waiting time, ${t_w}^i$ can be defined as – the time a packet experiences from the moment it enters into the queue until it reaches the head of the queue, and ready for transmission. It can be estimated using the Pollaczek-Khinchin mean value formula:

$$t_w^i = \frac{R_{in}^i \times \overline{t_s^{i^2}}}{2(1 - R_{in}^i \times \overline{t_s^i})} \qquad (1)$$

Where, R_{in}^i is the total input traffic rate at the MAC layer, $\overline{t_s^{i^2}} = \sigma^2 + \overline{t_s^i}^2$ and σ^2 is the distribution variance. The estimated sojourn time is,

$${D_w}^i = {t_w}^i + \overline{t_s^i}.$$

The packet service time is defined as the time when the packet is ready for transmission until the last bit finishes transmitting. It includes packet waiting time in the MAC layer (channel busy time, DIFS, backoff, RTS,CTS) and packet transmission time. By using EWMA (Exponential Weighted Moving Average Formula), $\overline{t_s^i}$ is updated each time a packet is forwarded as follows:

$$\overline{t_s^i} = (1 - w_s) \times \overline{t_s^i} + w_s \times inst({t_s}^i) \qquad (2)$$

Where, $inst({t_s}^i)$ is the instantaneous service time of the packet just transmitted and w_s is a constant in the range of $0 < w_s < 1$.

Initially, the scheduling rate for each of the node is set as a very small value, r_{sch}^{init}. Every node will increase their scheduling rate multiplicatively after each successful transmission as-

$$R_{sch}^i = R_{sch}^i \times \alpha; \quad \alpha > 1 \qquad (3)$$

Each node i will calculate the entailed delay, ${d_{ent}}^i$ for the real time packets. (The calculation of the entailed delay is described in the next section). When the estimated sojourn time becomes greater than the entailed delay for then node, it notifies congestion and determines the adjusted input rate, $\overline{R_{in}^i}$ from equation 1, as –

$$\overline{R_{in}^i} = \frac{2 \times d_{ent}^i}{\overline{t_s^{i^2}} + 2 \times d_{ent}^i \times \overline{t_s^i}}$$

The proposed protocol uses implicit notification of the adjusted rate to its child nodes. Each node i piggyback the adjusted input traffic rate, $\overline{R_{in}^i}$, total no of child node, C_p in its packet header. All the child node of node i overhear the information.

After obtaining the adjusted input rate from the parent node, each of its child node adjust their scheduling Rate, R_{sch}^i as follows :

$$R_{sch}^{c^i} = \frac{\overline{R_{in}^i}}{C_p} \qquad (4)$$

Where $R_{sch}^{c^i}$ is the scheduling rate of each of the child node of node i. The node i also adjusts its originating rate, R_{or}^i as-

$$R_{or}^i = \overline{R_{in}^i} - R_{route}^i.$$

4.2 Calculation of Per Hop Entailed Delay

The per hop entailed delay ${d_{ent}}^i$ is defined as- the maximum time a packet can stay in a node from the moment it arrives until the transmission ends. We compute the ${d_{ent}}^i$ –

$${d_{ent}}^i = \frac{Deadline - d_{e2e}}{h}$$

Where, Deadline is the end-to-end deadline of the packets and d_{e2e} is the end-to-end transmission delay from node source to the sink and h is the end-to-end no of hops.
The h can be found from the traditional routing protocol and d_{e2e} can be calculated as

$$d_{e2e} = d_l \times h_R$$

Here, d_l is the local estimate of delay. It can be obtained by exchanging the packet with the next hop downstream neighbors.

The entailed delay has dynamic behavior from hop to hop for the variability of the local estimate of delay.

5. Simulation

We have performed extensive simulations using ns-2 to evaluate the performance of our protocol. The simulation parameters are described as follows: 100 sensors are randomly deployed in 100x100 m^2 sensor field. The transmission range of the sensors is 30 m. The maximum communication channel bit rate is 32 kbps. We assume each packet size is 30 bytes. The weight used in the exponential weighted moving average calculation of packet service time (eq 2 in section 4.1) is set to 0.1. The maximum queue size is set as 30 packets. As a routing protocol SPEED has been used in our simulation. We have run the simulation for 60 seconds.

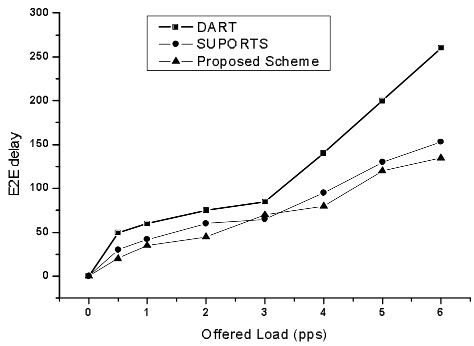


Figure 2: offered load VS E2E delay

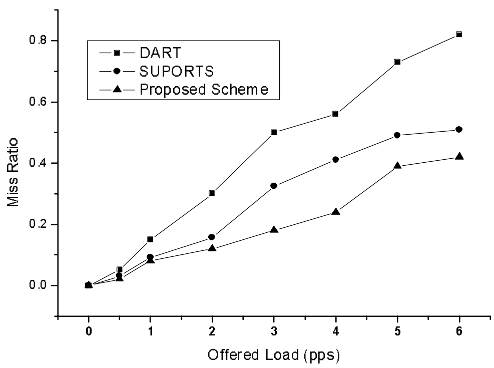


Figure 3: Offered Load VS Miss Ratio

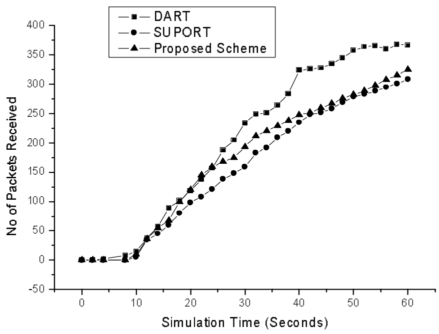


Figure 4: No of Packets Received over time

Figure 2 shows the End-to-End Delay for different offered loads (packets per second). The deadline is set as 100 ms. It shows that after a certain number of offered loads (3 pps) the end-to-end delay rises sharply. DART suffers larger end-to-end delay than SUPORTS and our Proposed scheme due to the sink initiated rate control. Our proposed scheme ensures less end-to-end delay than SUPORTS with the growth of offered load. The proposed scheme also has the least percentage of miss ratio (near 4%) with the highest offered load (6 pps) compared with other schemes as shown in figure 3. Figure 4 compares the number of received packets over time among the three schemes. For the high reliability, DART has the highest number of received packets compared with SUPORTS and Proposed scheme. Due to the similar nature, we have found almost similar number of receiv ed packets for SUPORTS and our proposed scheme.

6. Conclusion

In this paper, we have presented an efficient rate control mechanism for real time traffic in Wireless Sensor Network. We have demonstrated through the simulation that our proposed scheme achieves i) Lower end-to-end delay ii) Lower miss ratio and, iii) Moderate throughput. In future we will try to impose the reliability scheme and also we will implement in real testbed scenario.

References

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, " Wireless sensor networks: A survey," Computer Networks J., vol. 38, pp. 393-422, 2002.

[2] C. Wang et al., " Upstream Congestion Control in Wireless Sensor Networks Through Cross-Layer Optimization," IEEE Journal on Selected Areas in Communications, Vol.25, No.4, May 2007.

[3] Vehbi C. Gungor, O. B. Akan, " Delay Aware Reliable Transport in wireless sensor networks," IEEE Journal of Communication Systems, vol 20, pp 1155-1177, October 2007.

[4] Kyriakos Kareons and V. Kalogeraki, " Real Time Traffic Management in Sensor Networks," in Proc of IEEE International Real-Time Systems Symposium, 2006.

[5] Wan, C.-Y., Eisenman, S. B., and Campbell, A. T., " CODA: Congestion Detection and Avoidance in Sensor Networks," *Proceedings of ACM SenSys*, 5-7 Nov. 2003, pp. 266-279

[6] Ee, C.T. and Bajcsy, R., " Congestion Control and Fairness for Many-to-One Routing in Sensor Networks," *Proceedings of the ACM SenSys*, 3-5 November 2004, pp. 148-161

[7] Hull, B., Jamieson, K., and Balakrishnan, H., " Mitigating Congestion in Wireless Sensor Networks," *Proceedings of ACM SenSys*, 3-5 November 2004, pp. 134-147