Bursty Traffic을 위한 IEEE 802.15.4 GTS 기법의 대기 해석

래투안남, 최선웅, 장영민 정회원

Queuing Analysis of IEEE 802.15.4 GTS Scheme for Bursty Traffic

Nam-Tuan Le, Sunwoong Choi, Yeong M.in Jang *Regular Members*

요 약

IEEE 802.15.4과 IEEE 802.15.7은 대표적인 저속 무선망 및 가시광 WPAN 표준이다. 이 표준의 MAC 프로토콜들은 비컨 모드에서 GTS를 이용하여 실시간 응용 프로그램에 대한 QoS 보장 트래픽 플로우를 지원할 수 있다. 그러나 최적으로 할당하는 방법은 아직 명확하게 해결되지 않았다. IEEE 802.15.4 MAC에 관한 현재의 분석 모델은 주로 포화 트래픽 또는 non-bursty 불포화 트래픽 상황이란 가정 하에 개발되었다. 이러한 가정은 bursty 멀티미디어 트래픽의 특성을 반영하지 못한다. 이 논문에서는 burst Markov 변조On-Off 도착 트래픽을 사용하여 GTS 할당을 위한 새로운 분석 모델을 제안한다.

Key Words : GTS, ON-OFF sources, Bursty traffic, IEEE 802.15.4, QoS, queuing theory

ABSTRACT

The IEEE 802.15.4 and IEEE 802.15.7 standard are the typical of low rate wireless and Visible Light Wireless personal area networks. Its Medium Access Control protocol can support the QoS traffic flows for real-time application through guaranteed time slots (GTS) in beacon mode. However, how to achieve a best allocation scheme is not solved clearly. The current analytical models of IEEE 802.15.4 MAC reported in the literature have been mainly developed under the assumption of saturated traffic or non-bursty unsaturated traffic conditions. These assumptions don't capture the characteristics of bursty multimedia traffic. In this paper, we propose a new analytical model for GTS allocation with burst Markov modulated ON-OFF arrival traffic.

I. Introduction

The IEEE 802.15.4 protocol has been used for various applications, especially home network and Wireless Sensor Network (WSN). Currently, with the rapid development in the field of lighting and illumination, white-light and other visible LEDs become more efficient, have a high reliability and can be incorporated into many lighting applications. These sources can also be modulated at high-speed, offering the possibility of using sources for simultaneous illumination and data communications. There are more and more applications in indoor/outdoor using visible light from lighting as a communication medium. One of the earliest researches on Visible Light Communication is originated in Japan, where the Visible Light Communication consortium has been in existence for several years[5]. IEEE 802.15.7 VLC task group is in processing for standardizing and will be standardized in next year. Most of existing 802.15.4 researches focused on performance evaluation and theoretical analysis either through simulations or through experiments. Although guaranteed time slots are the only approach for the QoS guarantee, there

국민대학교 전자공학부 무선네트워크 및 통신 연구실 (namtuanlnt@gmail.com, schoi@kookmin.ac.kr, yjang@kookmin.ac.kr)
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are only a few researches that study this in particularly. However, because of the protocol's simplicity and flexibility, it has some weaknesses about QoS even though it provides GTS. Based on IEEE standard, in order to allocate GTS in CFP, the active portion is splitted into 16 slot periods, and a GTS has to be allocated to an integer number of those slots. The optional CFP can accommodate up to seven GTSs. If a device wants to use GTS to transmit or receive its packets, it shall send out a GTS request in CAP to the PAN coordinator. After considering the whole available resources, the PAN coordinator broadcasts its GTS user list with detailed GTS description in next beacon. Depending on the superframe size, the size of one slot period varies. The application may waste a GTS if the size of each periodic message is not suitable for the slot period. Also, it is not possible to support multiple GTS requests with different cycles. Recently, as the demand for real-time features increases, the supporting QoS has become an important issue in these fields. In IEEE 802.15.4 QoS applications, two features make the standard GTS allocation scheme bandwidth-unfriendly. One is that the demand for bandwidth varies according to the sensor nodes, namely in space domain. The other is that the demand for bandwidth from a node varies from time to time, namely in time domain. Thus a static, preconfigured GTS allocation scheme is not efficient for a process with dynamical bandwidth requirements [4]. The problem we want to discuss in this article is the GTSs bandwidth underutilization problem when the available guaranteed bandwidth is higher than the required bandwidth. Most existing work of 802.15.4 MAC focus on saturated traffic conditions where all nodes have frames to transmit anytime. Since multimedia applications have become ubiquitous in wireless networks over recent years, it is critical to take the bursty characteristics of multimedia traffic into consideration for the analysis of 802.15.4 MAC in LR-WPAN. As a step towards the end, this paper evaluates the performance of the GTS allocation in 802.15.4 MAC under the bursty multimedia traffic using ON-OFF model.

The contribution of this paper is structured as follows. In section II, we provide the reader with a quick overview of the IEEE 802.15.4 standard and GTS transmission. Markov modulated ON-OFF arrival traffic is shown in section III. Section IV evaluates the performance of the proposed model and the improvement result from simulation. Finally, concluding remarks of the research results and contributions are given in section V.

Ⅱ. GTS service

According to the standard [1], a node that has allocated a GTS can transmit a message if and only if the whole transaction, including data transmission, the Intra-Frame Spacing (IFS) and the acknowledgement (if requested), can be completed before the end of the GTS. Otherwise, it must wait until the next GTS. In this paper we only pay attention on QoS transmission (acknowledgement is requested), the process can be shown in Figure 1

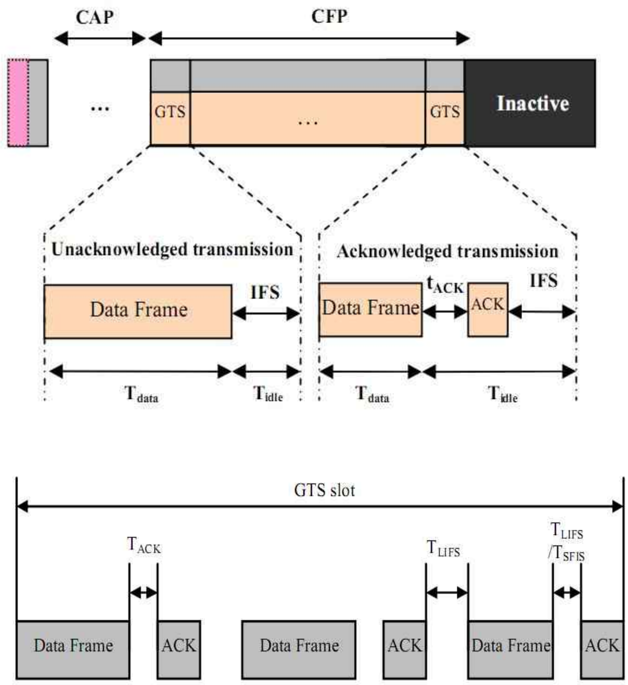

Figure 1 GTS transmission

$$R_n = n\left(\frac{T_{data}C}{BI}\right) = n\frac{(Ts - T_{idle})}{BI}C \qquad (1)$$

Where, Tdata is duration for real data in one TimeSlot (Ts) which is presented by DataFrame in Figure1, a QoS GTS data transmission. It can be shown that the duration of one GTS includes two parts: Tdata is the maximum duration used for data frame transmission inside a GTS. And Tidle is the sum of idle time spent inside a GTS due to protocol overheads (Inter-Frame Spacing and ACK frames). Consecutive data frames transmissions are separated by Inter-Frame Spacing (IFS) periods. The IFS is equal to a Short Inter-Frame Spacing (SIFS=48 bits), for frame lengths smaller than aMaxSIFSFrameSize (144bits). Otherwise, the IFS is equal to a Long Inter-Frame Spacing (LIFS=160bits), for frame lengths greater than a MaxSIFSFrameSize bits and smaller than aMaxPHYPacketSize (1016 bits). BI denotes the time duration of a beacon interval. And C is the data rate supported in physical layer. The service rate of GTS can be shown in Figure2.

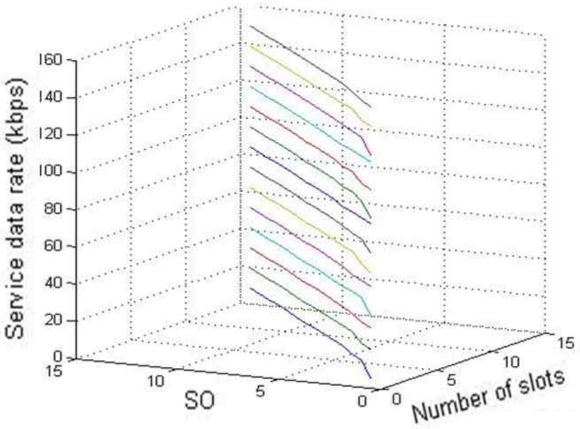

Figure 2 IEEE 802.15.4 GTS service rate

The latency of the service in n Time-Slots shown as

$$T_n=BI-n*T_S \qquad (2)$$

Ⅲ. Markov modulated ON-OFF arrival traffic

The analysis of queuing at the burst level is shown in Figure 3. A two-state discrete-time Markov chain is used to characterize the burst ON-OFF traffic source that alternates between the ON and OFF states. The parameters (α,β) denote the probabilities that the Markov chain stays in ON and OFF states, respectively. A packet arrival is generated at burst level when the Markov chain is in ON state and there is no arrival during the OFF state. Once the source has entered the OFF state, it will stay there for at least one time unit after in the OFF state the source remains in the OFF state with a probability β. Once the source has entered the ON state, it will generate at least one packet. After each one of these arrivals the source generates other packets with a probability α. The ON-OFF traffic source is thus a stream of geometrically distributed correlated bursts and silent periods. The mean traffic arrival rate, λ and the mean burst length, B, are given as follow, respectively[3].

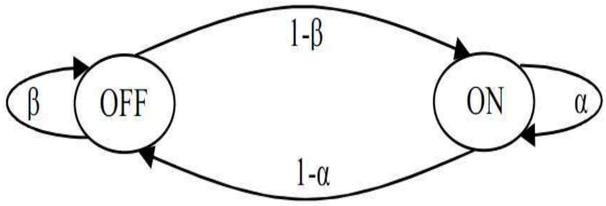

Figure 3 Markov Modulated ON/OF model

Assume that R is the actual packet arrival rate, and S is the actual transmission rate. E[ON-time] the expected on-time for the source and E[OFF-time] the expected off-time for the source. If the source is in the OFF state and the buffer is empty, then it remains empty; if the buffer is not empty, then it empties at a constant rate S .If the source is in the ON state and the buffer is not full, then it fills at a constant rate R-S; if the buffer is full, then the cells are lost at a constant rate R-S. The calculations are presented following[2]

E [number of packets arrival in an ON time]

$$=1/(1-a) \qquad (3)$$

E [number of time slots in an OFF period]

$$=1/(1-\beta) \qquad (4)$$

The number of ‘excess-rate’ arrival of system in an ON period is

$$E\ [Burst] = E\ [ON\ time]\ (R-S) \qquad (5)$$

And the real arrival rate of system is

$$R_{Real\_Traffic}=R\lambda \qquad (6)$$

Queuing analysis: Assume that the buffer capacity of every node is Q and N is the number of current packets in system. Poverflow is the probability the packet can not find cell in the queue on arrival and is lost. From [2] the calculation of overflow rate for burst model is

$$P_{overflow} = P\{N > Q\} = \frac{R-S}{R\left[1+\left(\left(\frac{\beta}{\alpha}\right)^{Q}-1\right)\left(\frac{1-\alpha}{\beta-\alpha}\right)\right]} \qquad (7)$$

Ⅳ. GTS allocation

The GTS allocation of tradition standard is a “request and response” between coordinator and nodes as following. In CAP, nodes which need resources will send requests to the coordinator. Upon receiving these requests, the coordinator will check whether there are sufficient available Time-Slots in the superframe for this request or not. If the number of available Time-Slots in the superframe is smaller than the number of requested one, the GTS allocation request will be rejected; otherwise it is accepted. If the GTS allocation request is accepted, the admitted node must keep track of beacon frames for checking which Time-Slots have been allocated in the current superframe.

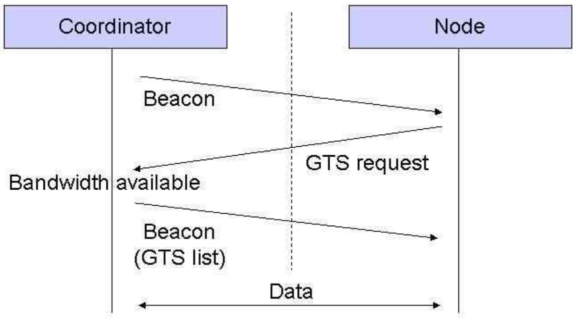

Figure 4 GTS allocation process

Our analysis model will be applied in the first step of standard process. The actual transmission rate S is service rate Rn of one GTS. The number of slots for GTS is from equation(1), (2) and (6). The result from Figure 5 is the GTS allocation comparison between approached model and standard scheme. And Figure 6 shows the effect of arrival data rate and length of queue to probability of packet loss. In this analysis, the traffic is at 60% loading with $\alpha=0.4$; $\beta=0.6$ and the service rate is at SO=4

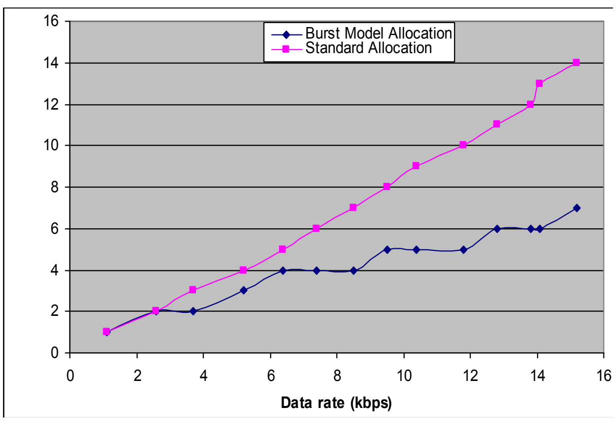

Figure 5 GTS allocation

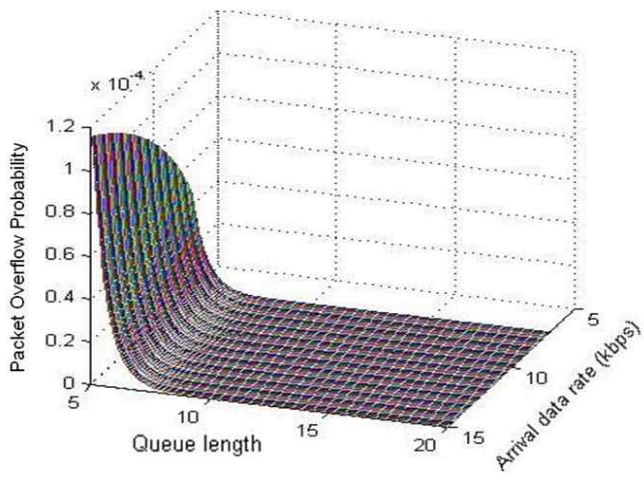

Figure 6 Overflow probability

V. Conclusion

The analysis performances of proposed model show that MMPP ON/OFF burst traffic is a suitable reference GTS allocation scheme for Multimedia QoS.

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저 자

Nam-Tuan Le 정회원

He received the diploma in Faculty of information and communication Technology from HaNoi University of Science and Technology, VietNam in 2005. He is currently Master student in Department Electronics Engineering, Kookmin University, South Korea. His research interests are sensor networks (MAC protocol), queuing model, resource management and visible light communication.

Sunwoong Choi 정회원

He received the B.S., M.S., and Ph.D. degree in Computer Engineering from Seoul National University, Korea, in 1998 and 2000, and 2005, respectively. He worked for Samsung Electronics between 2005 and 2007. Since 2007, he is with the School of Electrical Engineering, Kookmin University, South Korea. His research interests include LED-ID MAC and routing protocols for mobile wireless networks, network resource management, and future internet.

Yeong Min Jang 정회원

He received the B.E. and M.E. degree in Electronics Engineering from Kyungpook National University, Korea, in1985 and 1987, respectively. He received the doctoral degree in Computer Science from the University of Massachusetts, USA, in 1999. He worked for ETRI between 1987 and 2000. Since September 2002, he is with the School of Electrical Engineering, Kookmin University, South Korea. His research interests are IMT-Advanced, Multi-Screen Convergence, LED-ID/USN networks, and femtocell networks.