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Delay Analysis of M2M-Applied Multi-Rate Wireless Communication System

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Abstract

Performance of M2M applications is defined as quality-of-service (QoS) requirements. For the practical implementation of M2M applications, data rate and delay constraint are considered as the most important QoS requirements. However, conventional wireless communication chip solutions have provided the limited number of data rates and delay performance, which cannot calibrate various QoS requirement of various M2M applications. As a solution to this problem, we propose a wireless communication platform equipping two wireless communication modules. In such case, the performance of the two-module-equipped platform is evaluated and compared with that of the conventional device. In our results, the two-module-equipped platform does not always outperform the conventional device in terms of the number of successful packet transmissions. Through adjusting the transmission probability of M2M devices, the two-chip device can transmit its data faster than the one-chip device.

Keywords: Cognitive Radios, Random Access, QoS-Provisioning

1 Introduction

Machine-to-machine wireless communication (M2M) is a information and telecommunication (IT) convergence technology which lets conventional devices have communication functions [1]. M2M technology can be applicable to e-Health for bio-signal measuring and reporting, smart metering for water and electricity consumption and so on [2][3]. In order to implement M2M, wireless communication technology should be tuned for the purpose of M2M applications

There are multi-purpose wireless communication chip solutions working in industrial scientific and medical (ISM) band, which are Zigbee, WiFi, Blutooth and so on [4]. Those solutions consume lower energy compared with cellular systems and support distributed multi-user access technology such as the random access. Hence, M2M applications can adopt ISM band chip solutions without pre-constructed wireless communication infrastructure. However, their data throughput and communication range are too limited to support M2M applications which require various quality-of-service at data throughput and delay [5][6].

In this paper, we analyze the delay performance of a wireless communication device using two random access-based chip solutions simultaneously. In our analytic model, a simple slotted ALOHA is adopted as a representative random access protocol. A source of data is separated and transmitted via two different wireless communication solution chips. For this case, the number of successfully transmitted data packets in a predetermined duration is evaluated. Conventionally, delay and throughput analysis of a random access protocol has been performed [7]-[9]. However, wireless transmission via combined the two chips has not been analyzed.

2 System Model

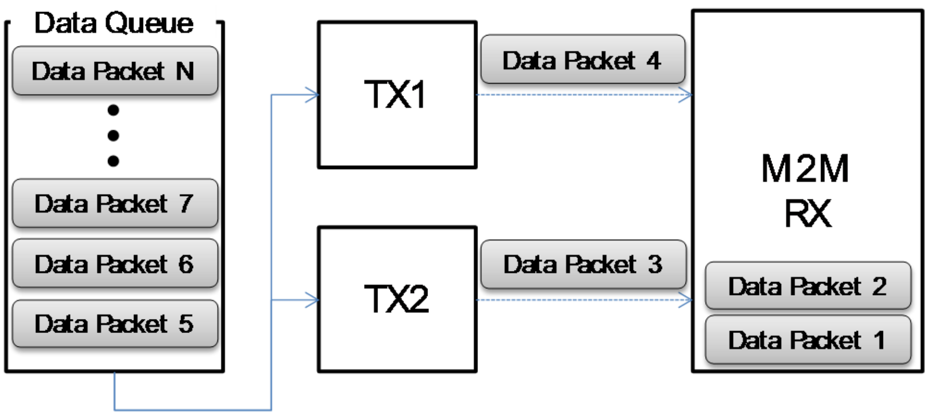

Fig. 1. M2M wireless communication platform with 2 different wireless communication solutions

System model considered in this paper is depicted in Fig. 1. There is an incoming data queue. Data packets are arrived and piled in this queue. The data queue can send a data packet to transmitter 1 (TX 1) and 2 (TX 2). If only TX1 or TX2 is available to transmit data, one data packet is delivered to the transmitter in a synchronized time slot. Two packets are sent to TX1 and TX2 simultaneously if both transmitters are available to transmit data. Using a random access protocol, a transmitted packet can be collided with other transmission in ISM band. In the collision case, there should be a retransmission. In Fig. 1, wireless transmission for data packet 1 and 2 were completed, already. TX1 and TX2 are transmitting data packet 3 and 4.

In the slotted ALOHA, packet transmission is performed in a time slot. Each user can transmit signal with a transmission probability p. In a frequency channel, there should be plural users who can access the wireless medium. Hence, collision might occur. For the fair performance comparison, the performance of a system in Fig. 1 is compared with a system with one wireless communication chip. The system in Fig. 1 occupies two frequency channels. Using this system, all users utilize both channels. However, assuming the system with one wireless communication chip, the all users are divided even into the two channels. In summary, the two chip solution users have opportunity to use two times of frequency resource although users are more crowded and collided in both frequency channels. However, the one chip solution users only have a chance to access one frequency channel. Nevertheless, users can be distributed to two frequency channels, which results in less collision.

3 Analytical Results

From [10], we further analyze the results mathematically. We define a probability p that a transmitter transmits at a time slot. Subsequently, the probability that a wireless transmission is successful can be calculated as:

$$p_s = \frac{(p \cdot (1-p)^{N-1})}{1-(1-p)^N} \tag{1}$$

where N is the number of total transmitters.

When the number of observation slots is newly defined as K, the probability that D transmitted packet is successfully transmitted is calculated as:

$$p_K(d) = \binom{2K}{d} (1-p_s)^{-d} \cdot (1-p_s)^{2K} \cdot p_s^d \tag{2}$$

If a packet is transmitted by using the one-chip solution, the successful transmission probability can be derived through substituting K for $2K$

Using (2), we can calculate the cumulative density function (cdf) as:

$$P_K(D) = \sum_{d=0}^{D} p_K(d) \tag{3}$$

Using (3), by plotting the cdf, delay performances of the two-chip and the one-chip solutions are compared. The equation in (3) is expressed as a closed form as

$$P_K(D) = 1 - \frac{p_s^{D+1} \cdot (2K)! \cdot HGF\left(1, 1+D-2K, 2+D, \frac{p_s}{-1+p_s}\right)}{(1-p_s)^{2K+D+1} \cdot (2K-D-1)!} \tag{4}$$

where HGF is the general hyper-geomeric function. The result of (4) is depicted in Fig.2.

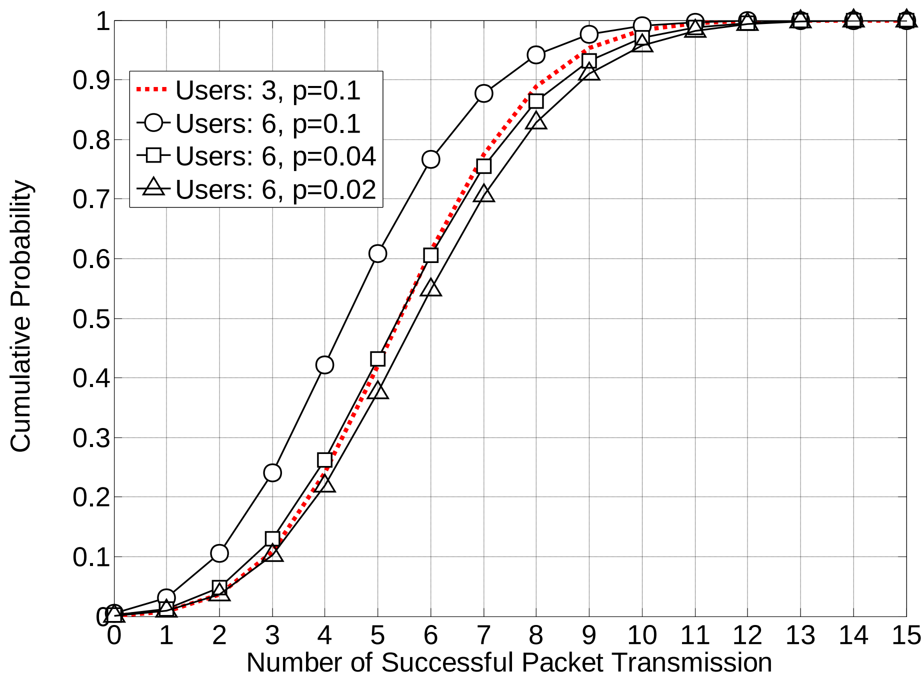

Fig. 2. Delay violation probability by using two different wireless communication modules

Fig. 2 depicts the performance comparison between one-chip and two-chip solutions. The red solid line is a reference performance. In this result, twenty time slots are observed ten thousand times. Hence, random behavior of the random access protocol is averaged out. Although an M2M application adopts the two-chip solution, two-chip device cannot outperform compared with the one-chip device if the value of the transmission probability is too high. Using the two-chip solution, more users access the frequency channels. Therefore, the transmission probability should be adjusted so as to reduce collision events. In Fig. 2, the transmission probability of the two-chip device is gradually reduced from 0.1 to 0.02. When we use the transmission probability value 0.02 with 6 users, the two-chip device finally outperforms the one-chip device with respect to the number of successful packet transmissions during a pre-determined observation time.

4 Conclusion

In this paper, a two-wireless-communication-chip solution-implemented system is proposed and evaluated. In the proposed system, we analyzed the throughput of a wireless communication device using two random access-based chip solutions simultaneously. In our analytic model, a simple slotted ALOHA was adopted as a representative random access protocol. A source of data was separated and transmitted via two different wireless communication solution chips. For this case, the number of successfully transmitted data packets in a predetermined duration was evaluated. As a result, two-chip device cannot outperform compared with the one-chip device if the value of the transmission probability is too high although an M2M application adopts the two-chip solution. Therefore, transmission probability considering the total number of users should be adjusted for the effective utilization of the two-chip equipped system. As a future work, we are going to find a optimum transmission probability with respect to the total number of users. This work could be extended to another random access protocol such as carrier sensing multiple access-collision avoidance (CSMA-CA).

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References

[1] Jaewoo Kim, Jaiyong Lee, Jaeho Kim and Jaeseok Yun, "M2M Service Platforms: Survey, Issues, and Enabling Technologies," IEEE Transactions on Communications Surveys & Tutorials, 16, 1, (2014), 61-76.

[2] M. Hasan, E. Hossain and D. Niyato, "Random access for machine-to-machine communication in LTE-advanced networks: issues and approaches," IEEE Communications Magazine, 51, 6, (2013), 86-93.

[3] Z. Fan, R. Haines, P. Kulkarni, "M2M communications for E-health and smart grid: an industry and standard perspective," IEEE Wireless Communications, 21, 1, (2014), 62-69.

[4] C. Woo and H. Wang, " Energy-Efficient Random Access for Machine-to-Machine (M2M) Communications," International Journal of Software Engineering and Its Applications, 7, 1, (2013), 189-200.

[5] S. Jung, D. Kim and S. Kim, " Cooperative Architecture for Secure M2M Communication in Distributed Sensor Networking," International Journal of Security and Its Applications, 8, 3, (2014), 175-184.

[6] L. Xu, H. Zhang and T. A. Gulliver, " Performance Analysis of the Threshold Digital Relaying M2M System," International Journal of Signal Processing, Image Processing and Pattern Recognition, 8, 3, (2015), 357-366

[7] S. Pollin, M. Ergen, S. Ergen, "Performance Analysis of Slotted Carrier Sense IEEE 802.15.4 Medium Access Layer," IEEE Transactions on Wireless Communications, 7, 9, (2008), 3359-3371.

[8] N. Tadayon, W. Honggang, D. Kasilingam, "Analytical Modeling of Medium-Access Delay for Cooperative Wireless Networks Over Rayleigh Fading Channels," IEEE Transactions on Vehicular Technology, 62, 1, (2013), 349-359.

[9] G. Bianchi, "Remarks on IEEE 802.11 DCF performance analysis," IEEE Communications Letters, 9, 8, (2005), 765-767.

[10] C. Woo and H. Wang, "Multi-Rate Wireless Communication Platform for M2M Applications," Advanced Science and Technology Letters, 94, 2, (2015), 18-21.