Performance Evaluation of Required Preamble Estimation Random Access for M2M Communications

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Abstract

This paper analyzed the performance of the LTE random access (RA) protocol. We describes a RA performance analysis for LTE to support massive number of devices. Since the amount of the PDCCH resource is limited, there is a limit to the increase of the success rate when the number of preambles increases. This paper proposed the required preamble estimation RA scheme when the number of PDCCH resource increases. As a result, the performance of RA is greatly improved compared to conventional RA.

Keywords: M2M, IoT, random access, preamble, PDCCH.

1. Introduction

In the next generation networks, machine-to-machine (M2M) communication will be a very influential system due to the machine type communication (MTC) device which is rapidly increasing. It is expected that M2M devices are continuously increasing. Because of these changes of wireless communication environment, in 5G wireless communication systems, their goal is to improve the performance of the current network system over 1,000 times in terms of data rate, number of device, access delay and energy efficiency [1].

Current random access (RA) and signaling procedures in LTE system cannot support massive number of devices. In RA procedures of LTE standard system, UE transmits their information to a base station without prior resource allocation and it uses slotted aloha method using the limited number of RA preambles. Therefore, when performing conventional RA and signaling procedure in the massive number of devices environment, it will cause a problem due to a resource shortage of random access channel (RACH) and shared channel. These results can be found in the performance evaluation results of the 3GPP TR 37.868 [2]. In this paper, we evaluate RA performance when the optimum number of resource is estimated.

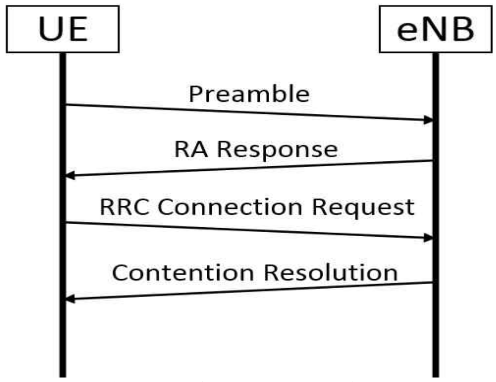

Fig. 1. Random access procedures

2. Random Access Procedures

The RA procedures consist of four message exchanges between an UE and the eNB as in Fig. 1. A RA process is completed when the four messages are successfully exchanged. In step 1, an UE randomly selects one of the available RACH preambles and transmits it to the eNB. In step 2, the eNB sends RA response (RAR) messages to UEs corresponding to the transmitted preambles. The RAR message includes UL grant information for transmission of message 3. In step 3, an UE sends a RRC connection request message to the eNB when it received the RAR message. If two or more UEs select the same preamble in step 1, a collision will occur. Then the UEs retransmit a preamble after randomly selected time within the backoff indicator. In step 4, the eNB responds with a contention resolution message to UE if message 3 was successfully received to the eNB in step 3.

3. Required preamble estimation RA

Since the number of simultaneous packet arrival in devices increase in 5G networks, the number of preambles should be increased to accommodate those devices. Since the amount of the PDCCH resource is limited in LTE, there is a limit to the increase of the success rate when the number of preambles increases. Therefore, in this paper, we estimate the number of required preambles in accordance with the total number of devices, and increases the number of PDCCH resources. The following procedures show the estimation method of the appropriate number of required preambles.

Since a traffic arrival of M2M devices is beta distribution, the expected number of arrival devices (m_i) in the i-th access opportunity is given by following equation [3]:

$$m_i = m \int_{t_{i-1}}^{t_i} p(t)\,\mathrm{d}t, \qquad (1)$$

where t_i is the time of the i-th access opportunity and m is the total number of devices. The function $p(t)$ follows Beta distribution:

$$p(t) = \frac{t^{\alpha-1}(T-t)^{\beta-1}}{T^{\alpha+\beta-1}Beta(\alpha,\beta)}, \quad \alpha > 0, \beta > 0, \qquad (2)$$

where $Beta(\alpha, \beta)$ is Beta function. The distribution of access attempts should be limited in the time T. Since LTE random access is the slotted aloha system, the success probability of preamble transmission is defined as [4]

$$P_{success} = e^{-\frac{M}{N}}. \qquad (3)$$

M is the maximum number of arrival devices (m_i). N is the required number of preamble which we estimate. The estimated N is shown in the following Table 1.

4. Performance Evaluation

To evaluate the RA performance, we used LTE RA module in the OPNET tool. We set a simulation environment same as 3GPP TR 37.868 [2] conditions shown in Table 2. To accommodate massive devices, we increase the number of PDCCH up to 10. A traffic arrival of M2M devices is set as a beta distribution over 10 seconds to apply a congestion situation. The number of devices is set to 30000, 40000 and 50000.

The success rate and collision rate is shown in Fig. 2 and 3. The success rate of proposed scheme is significantly improved compared to conventional RA. When the number of devices is 50000, a success rate is about 90%. Also, collision rate of proposed scheme is very low compared to conventional RA. The access delay is shown in Fig. 4. The access delay of proposed scheme is increased when the number of devices increase, however, it is smaller than conventional RA.

Table 1. Number of Required Preambles

Total number of devices	30000	40000	50000
Number of required preambles	88	117	146

Table 2. Simulation Environment

Parameter	Setting
PRACH Configuration Index	6
Total number of preambles	54
Maximum number of preamble transmission	10
Number of UL grants per RAR	3
Ra-Response Window Size	5 ms
mac-Contention Resolution Timer	48 ms
Backoff Indicator	20 ms

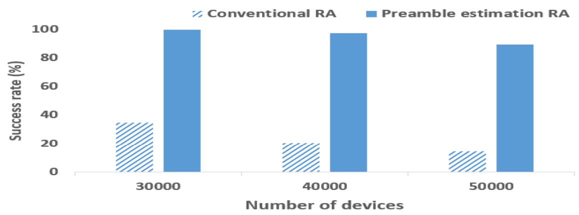

Fig. 2. Success rate of preamble esimation RA scheme.

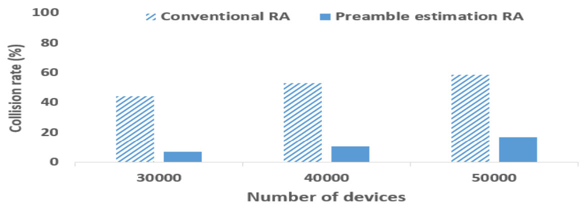

Fig. 3. Collision rate of preamble esimation RA scheme.

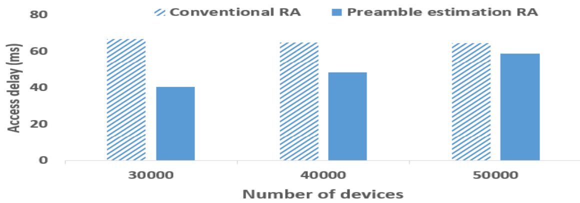

Fig. 4. Access delay of preamble esimation RA scheme.

5. Conclusion

In this paper, we analyzed the performance of required preamble estimation scheme. We estimated the appropriate number of preambles according to the total number of devices and increase the number of PDCCH resource. As the result of the simulation, the performance of RA is greatly improved compared to conventional RA in terms of success rate, collision rate and access delay. In the future, based on these performance results, we should consider how to make the most of limited PDCCH resources.

Acknowledgment

This work was supported by Institute for Information & communications. Technology Promotion (IITP) grant funded by the Korea government (MSIP). (No.R0101-16-244, Development of 5G Mobile Communication Technologies for Hyper-connected smart services)

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