A Novel Random Access for Fixed-Location Machine-to-Machine Communications in OFDMA Based Systems

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CONTENTS

Introduction

- According to the estimation of the wireless world research forum (WWRF), up to 7 trillion wireless devices will be connected to various networks for serving 7 billion people in the future.
- This extremely large number of devices may cause an addressing problem and may cause a shortage problem in limited radio resources.
- To support machine-to-machine (M2M) communications in future OFDMA-based cellular networks, several standardization bodies have studied M2M communications and specify features and requirements of M2M communications.

Introduction

- They have low/no mobility, many devices, etc., which are quite different from those of human-to-human communications.
- Proposes a novel random-access scheme based on fixed timing alignment (TA) information at many fixed-location machine devices to reduce collision probability, lower average access delay, and achieve energy-efficiency.

RANDOM ACCESS IN OFDMA-BASED SYSTEM

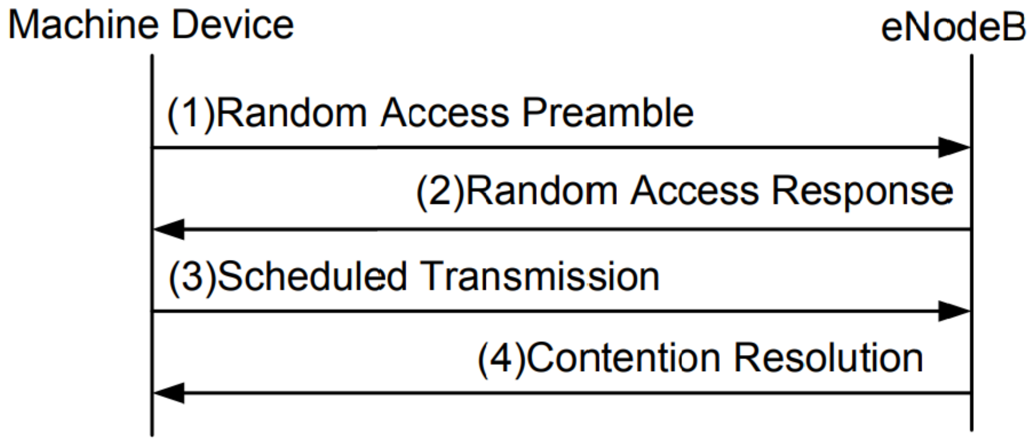


Fig. 1. Random access procedure in LTE system

TABLE I
BACKOFF PARAMETER (BP) VALUES

Index	BP value (ms)	Index	BP value (ms)	Index	BP value (ms)
0	0	6	80	12	960
1	10	7	120	13	Reserved
2	20	8	160	14	Reserved
3	30	9	240	15	Reserved
4	40	10	320		
5	60	11	480		

Collision Probability

- $Number\ of\ orthogonal\ preambles\ =\ M$
- $Assume\ we\ have\ k\ machine\ devices$
- $Probability\ (each\ device\ selects\ one\ preamble)\ =\ \frac{1}{M}$
- Probability that a given device selecting one preamble among $M\ preambles$ experiences a collision with other device(s) among $(k-1)\ device(s)\ =\ \boldsymbol{P_c^{ue}(M,k)}$
- $\boldsymbol{P_c^{ue}(M,k)} = 1 - \left(1 - \frac{1}{M}\right)^{k-1}$
- Collision probability increases as machine devices increase.

Proposed Random Access Scheme

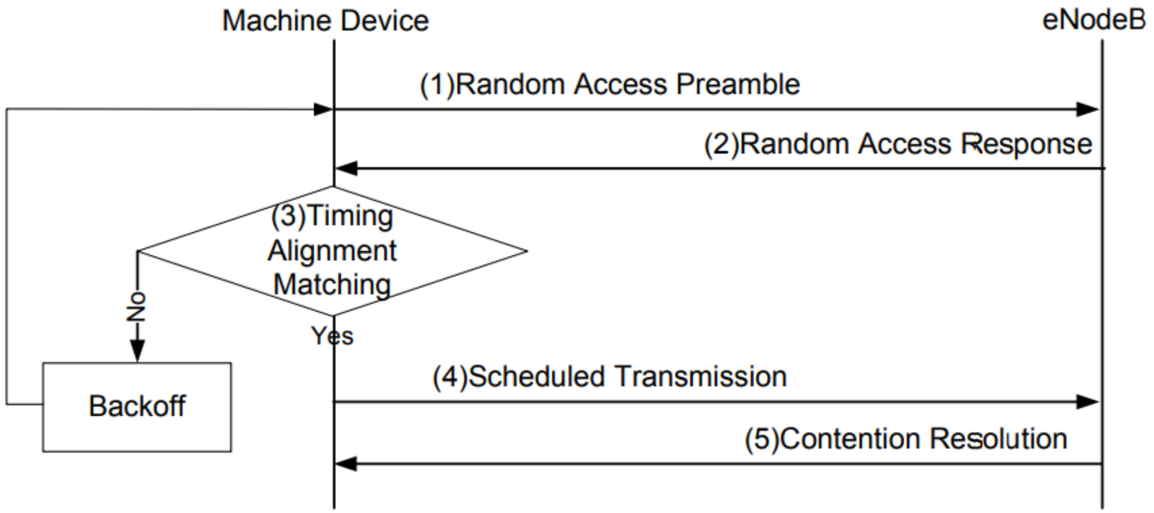


Fig. 2. Proposed random access procedure.

ASSUMPTION:

- TA value is fixed and unchanged.

Due to measurement or estimation errors at eNodeB for every RA procedure, each fixed-location machine device needs a TA matching mechanism.

$$\begin{cases} matched, & if\ T_{curr} \in [T_{stored} - \varepsilon, T_{stored} + \varepsilon,] \\ mismatched, & otherwise \end{cases}$$

As the ε value becomes larger, more machine devices are likely to belong to the acceptable TA range. However, it may result in an increase in the collision probability.

Collision Analysis, Access Delay, Energy Efficiency

- Suppose $k + 1$ machine devices including one tagged device select their own preambles and attempt random accesses on a single RA slot.
- Assume tagged fixed-location machine *o has a TA value of* $T_o = \frac{2r_o}{c}$
- $r_o \sim distance\ between\ tagged\ device\ and\ eNodeB$
- $c \sim light\ speed$
- *Let* $f(r)$ $be\ the\ pdf\ that\ there\ exists\ a\ fixed - location\ machine\ device$
- *At* $distance\ (r, r + dr) from\ eNodeB.$
- We want to calculate the probability that a tagged machine device experiences a collision with other machine device(s) among k devices.

Collision Analysis, Access Delay, Energy Efficiency

- If tagged device is located according to the $f(r)$ distribution, the collision probability of the tagged device is

  - $P_c'^{\,ue} = \int_0^R f(r)\left(1-\left(1-\frac{P(r)}{M}\right)^k\right)dr$

- where $P(r) = \int_{r-\frac{\varepsilon c}{2}}^{r+\frac{\varepsilon c}{2}} f(r)dr$ is prob. that there exits one machine device
- which attempts random access on the same RA slot within a range of
- $\left[r-\frac{\varepsilon c}{2},\ r+\frac{\varepsilon c}{2}\right]$

Collision Analysis, Access Delay, Energy Efficiency

- In a uniformly distributed case of $f(r) = \frac{2r}{R^2}$ the collision probability is

- $P_c'^{\,ue} = 1 - \frac{2}{R^2}\left\{\int_{R-\frac{\varepsilon c}{2}}^{R} r\left(1-\frac{R^2-\left(r-\frac{\varepsilon c}{2}\right)^2}{MR^2}\right)^k dr + \int_0^{\frac{\varepsilon c}{2}} r\left(1-\frac{\left(r+\frac{\varepsilon c}{2}\right)^2}{MR^2}\right)^k dr + \int_0^{\frac{\varepsilon c}{2}} r\left(1-\frac{\left(4r\frac{\varepsilon c}{2}\right)^2}{MR^2}\right)^k dr\right\} \ldots\ldots\ldots(*)$

Numerical Results

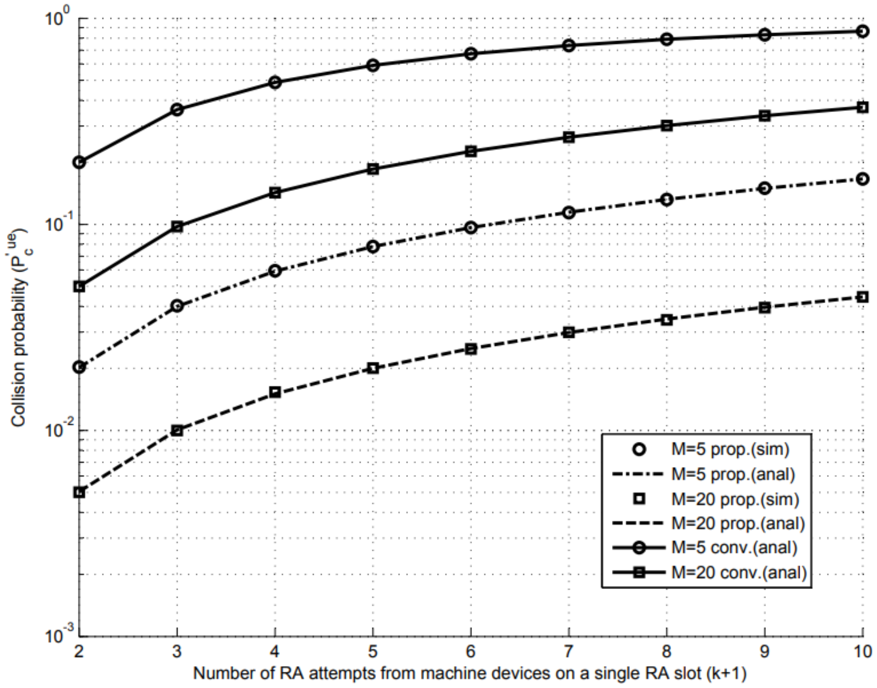


Fig. 4. Access Delay

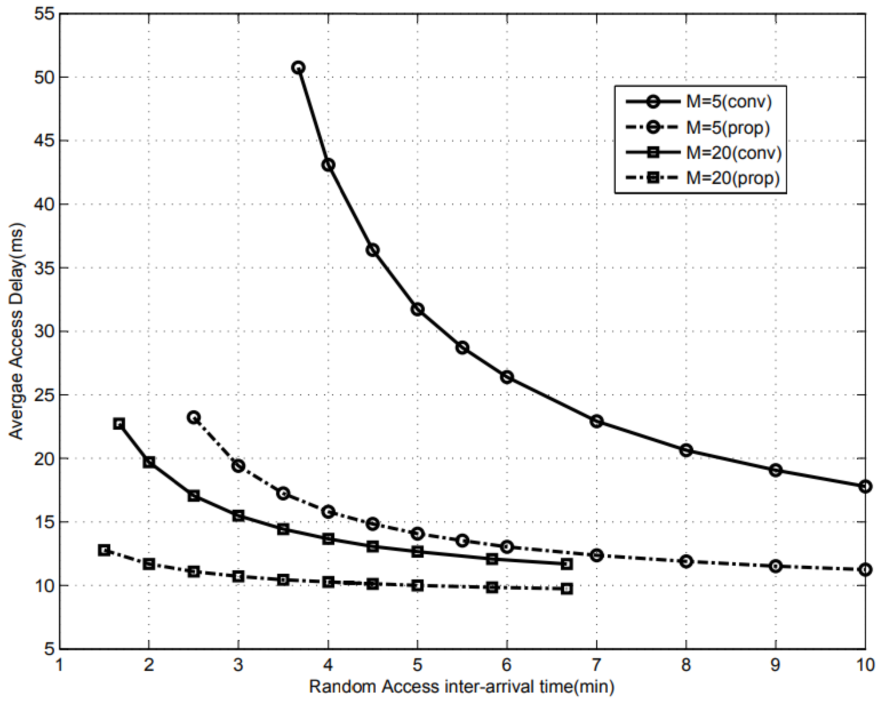


Fig. 5. Impact of the number of machine devices on the access delay of the proposed and conventional scheme.

Numerical Results

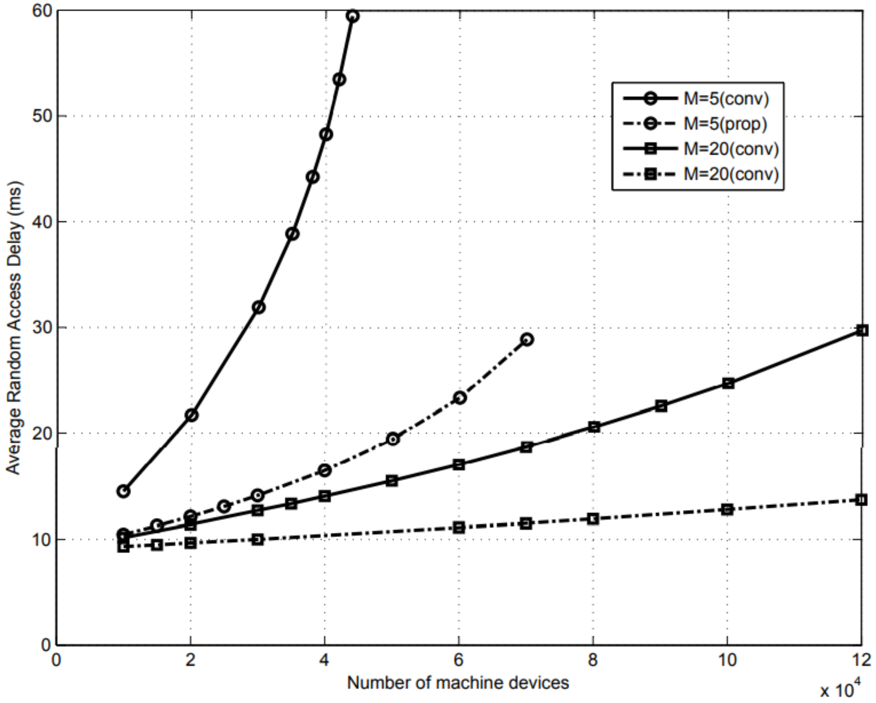


Fig. 5. Impact of the number of machine devices on the access delay of the proposed scheme and the conventional scheme.

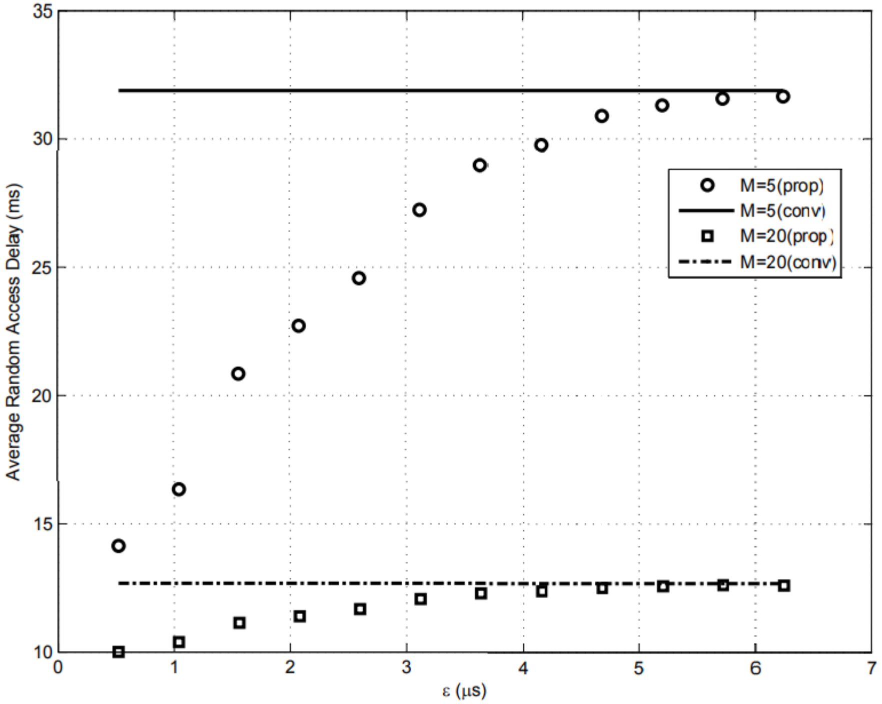
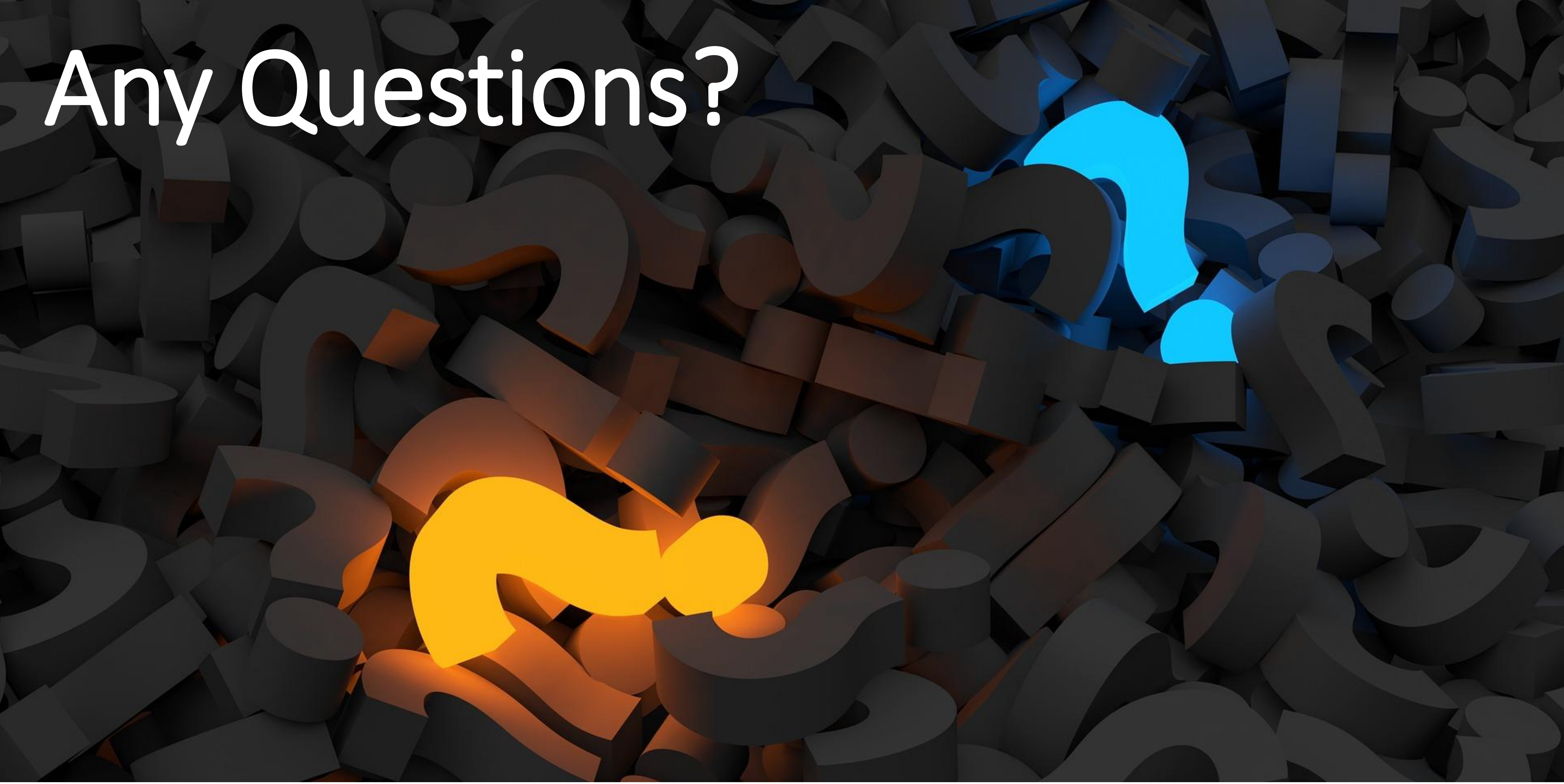


Fig. 6. Impact of ϵ on the access delay of the proposed scheme.

Conclusion

- In the proposed scheme, the collision probability is reduced due to the factor $P(r)$. In other words, a tagged machine device experiences a collision when at least one of other machine devices located in $(r - \frac{\varepsilon c}{2},\ r + \frac{\varepsilon c}{2})$ selects the same preamble as the tagged device on the same RA slot.
- In the conventional scheme, a tagged machine device may collide with any other machine devices selecting the same preamble on the same RA slot in the entire cell area.


Any Questions?