Evaluation and optimization of LTE-A Random Access Channel capacity for M2M communications

[Extended Abstract]

Soukaina CHERKAOUJI
Univ Lyon, INSA Lyon, Inria, CITI
F-69621, Villeurbanne, France
soukaina.cherkaoui@insa-lyon.fr

Hervé RIVANO
Univ Lyon, INSA Lyon, Inria, CITI
F-69621, Villeurbanne, France
Herve.rivano@inria.fr

Razvan Stanica
Univ Lyon, INSA Lyon, Inria, CITI
F-69621, Villeurbanne, France
razvan.stanica@insa-lyon.fr

ABSTRACT

Random Access Channel (RACH) is designed to support human-based traffic which is commonly Poisson-distributed. Bursty arrivals generated by the continuously increasing number of Machine-to-Machine (M2M) connections result in severe contention. This paper proposes the modeling and computation of the capacity of the LTE-A Random Access Channel (RACH) in terms of simultaneous successful access. In particular, we investigate the hypothesis of piggybacking the payload of Machine Type Communications from M2M devices within the RACH, and show that M2M densities considered realistic for smart cities applications are difficult to sustain by the current LTE-A architecture. The access capacity is then maximized with a better adaptation of the identified key RA parameters to the load of the system.

Keywords

RACH, Capacity, LTE-A, MTC, M2M

1. CONTEXT

In the context of smart cities there is a strong push promoting ubiquitous connectivity for Machine Type Communications (MTC), ubiquitous coverage can be ensured by cellular networks technologies such as LTE-A. However, it has been basically designed, engineered and managed to afford access to a reasonable number of Human-to-Human (H2H) communications, with high downlink data rate. Support of small packet from a considerable amount of devices is an emerging but identified issue [2]-[3], such as in the case of background traffic of recent smartphones (e.g. application notifications, system synchronization). In this way, the network bottleneck is the access procedure.

Smart metering and reporting applications generate and transmit periodically very low amount of data. As a consequence, M2M UEs have to go through a signaling-heavy RA procedure, simply to transmit one message to the network. Therefore, the idea of piggybacking the M2M data transmission within one of the RA procedure messages is tempting and it is now considered as the best solution for this type of traffic. This means that the M2M data is transmitted on the shared resource of the RACH, which raises questions regarding the capacity of the RACH, which was not designed for these purposes.

Figure 1: LTE-A random access procedure

2. ACCESS CAPACITY

Users who are unsynchronized on the uplink need to initiate the RA procedure to get scheduled resources for sending their data. Contention-based RA procedure is then triggered consisting of four successive message exchanges between the eNB and the UE as shown in figure 1. Assuming the network serves only one user category (i.e M2M) and the M2M data is piggybacked in the message 3 of the RA procedure; Our target is three-folds: (1) Design a RA procedure model, (2) Assess the RA parameters impact on the access capacity, (3) Adjust the RA parameters to optimize the access capacity.

In a previous work [1] we have proposed a RA procedure model. It models a user as belonging to one of the following tree states:

- Idle state: waiting for traffic arrival
- Transmitting state: message3 transmission with the M2M data
- Backlogged state: transmission deferral until the decrementing backoff timer is null
The access capacity depends not only on the load of the network but also on the RA parameters settings. Namely the number of preambles or codes available to initiate a RA procedure, the backoff indicator, the frequency of RA slots, the retransmission limit. Based on the proposed model, a Python simulator is developed. Computer simulations enabled the estimation of the access capacity according to a set of fixed RA parameters. Among the studied parameters, backoff window presents a good lever for improving the access capacity for highly dense networks. Figure 2 shows the benefits of increasing the backoff window when the network is very loaded.

\[ \text{Figure 2: LTE-A random access procedure} \]

3. BACKOFF ADAPTATION

In this paper we will present a history based backoff window noted \( b_o \) adaptation. Assuming the success probability is known in a period basis, \( b_o \) is incremented by a predefined step noted \( b_o\text{step} \) when the previous success probability exceeds a specific threshold \( \epsilon \) in case the new \( b_o \) value is not higher than the backoff limit value \( b_o\text{limit} \), otherwise it takes previous values from last period \( b_o\text{pp} \) or before last period \( b_o\text{ppp} \). The backoff adaptation algorithm is detailed in Algo 1.

\begin{algorithm}
\caption{History-based strategy}
\begin{algorithmic}[1]
\Require period \( \geq 2 \) \&\& \( b_o\text{pp} = b_o = b_o\text{def} \)
\Procedure{Badapt}{b_o\text{pp}, b_o, ps\text{diff}, \epsilon, b_o\text{step}, b_o\text{limit}, on}
\If{on \( == 1 \)}
\If{ps\text{diff} \( \geq \epsilon \)}
\If{b_o + b_o\text{step} \( < b_o\text{limit} \)}
\State b_o \( \leftarrow b_o + b_o\text{step} \)
\Else
\State b_o \( \leftarrow b_o\text{pp} \)
\EndIf
\ElseIf{ps\text{diff} \( < \epsilon \)}
\State b_o \( \leftarrow b_o\text{ppp} \)
\Else
\EndIf
\EndIf
\EndProcedure
\end{algorithmic}
\end{algorithm}

\[ \text{Figure 3: Access capacity with Fixed and Dynamic backoff window value} \]

Consider 4000 users per cell with 48 preambles, Fig 3 shows the benefit of backoff adaptation along time.

4. CONCLUSION

This paper highlights the access procedure congestion problem that may face LTE-A networks by supporting thousands of devices per cell. A RA procedure model from a prior work [1] is briefly introduced to assess the access capacity. The Backoff window value is adapted through a online history-based algorithm to optimize the access capacity. We expect to implement our signaling lightweight proposal in the OpenAirInterface.

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6. REFERENCES


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