Reduced M2M Signaling Communications in 3GPP LTE and Future 5G Cellular Networks

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***Abstract*—The increase of machine-to-machine (M2M) communications over cellular networks imposes new requirements and challenges that current networks have to handle with. Many M2M UEs (User Equipment) may send small infrequent data, which suppose a challenge for cellular networks not optimized for such traffic, where signaling load could increase significantly and cause congestion over the network. This paper evaluates current proposals to manage small transmissions over the Long Term Evolution (LTE) cellular network. We also propose a new Random Access-based Small IP packet Transmission (RASIPT) procedure for M2M UEs small data transmissions. Its main feature is data transfer without establishment of Radio Resource Control (RRC) connection to reduce signaling overhead. In our design, we assume a Software Defined Networking-based architecture for 5G system. When compared with current LTE scheme, our procedure reduces significantly the signaling load generated by M2M UEs small transmissions.**

***Index Terms*—machine to machine; small data transmission; SDT; SDN**

I. Introduction

M2M refers to the communication between machines without human intervention. Current M2M UEs communicate in the same way that human-to-human (H2H) UEs do. However, typically M2M applications only need to exchange a small amount of data [1]. Despite its minor size, it triggers redundant and costly network procedures related to resource reservations for M2M UEs, lacking the efficient support for M2M services over the network. One example is conventional 3GPP LTE, which requires performing Random Access (RA) procedure, radio bearer setup and a service request procedure before any data transmission if the UE is idle [2]. To overcome foreseen challenges, the 3GPP group has promoted enhancements within LTE to allow efficient support of M2M communications [3], which can provide low cost and long battery life M2M services with high reliability.

In this paper, we propose a new procedure, referred to as Random Access-based Small IP packet Transmission (RASIPT), based on a Software Defined Network (SDN) 5G architecture. We simulate a scenario with H2H UEs and M2M UEs to evaluate the proposed procedure. After conducted simulations, we show that conventional LTE scheme is not efficient for M2M UEs with small transmissions and new solutions as our proposed procedure can reduce significantly the signaling load generated by M2M UEs in the network.

II. Background

A. LTE

In LTE, when a UE, registered and connected at the network, becomes inactive because is not using any service, the network releases some of the allocated resources performing the S1 release procedure [2]. This procedure is used by the eNB to release the UE from connected state into idle. The inactivity timer that controls when this procedure is triggered is not standardized. It is rather defined as a vendor implementation choice. A typical value for this timer is 10ms [4]. When an idle UE wants to send a data packet, it has to perform the service request procedure to get activated and reallocated resources, see Fig. 1. Therefore, each data transmission in LTE from idle state implies a reactivation of data bearers released before, that is, it requires a new bearer setup.

B. Efficient Small Data Transmission

One of the system improvements considered for M2M communications on 3GPP networks is Small Data Transmission (SDT) procedure [3]. SDT optimizes message sequence for the transmission of one IP packet and its response when the M2M UE is idle. To do that, the procedure uses pre-established Non Access Stratum (NAS) security context to send the data as NAS signaling. After RA procedure and RRC establishment, the M2M UE transmits a NAS message with the IP data packet to the Mobility Management Entity

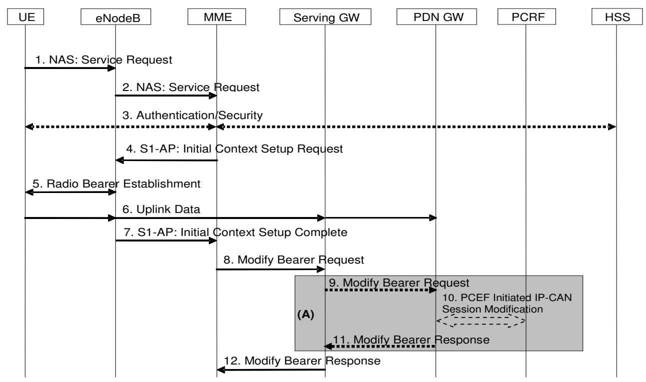

Fig. 1. UE triggered Service Request procedure [2].

(MME) (see Fig. 2). The transmission relies on RRC layer without any acknowledgments above RRC layer. For the evaluation of this procedure, we assume the situation where the MME immediately releases the RRC connection after the transmission (denoted as “alt. A” in Fig. 2).

III. Proposal

Our proposed procedure, RASIPT, is intended to reduce signaling to transfer one small IP packet to the network when a M2M UE is idle. The procedure is oriented to infrequent traffic without QoS requirements. Our solution is designed for a 5G SDN-based core architecture (e.g. [5]), where NFV and SDN controller run network functions, such as a MME. The idea itself is originated as a combination of the SDT procedure mentioned before, and the radio access enhancement proposed in the Hybrid Random Access and Data Transmission protocol [6]. The mechanism of [6] allows an idle M2M UE to send data packets after preamble transmission on the RA procedure, so, the RRC connection establishment is not needed. The solution combines an adaptive resource allocation of M2M data channels over radio resources by the eNB, and an access barring scheme to start the procedure to reduce overload over Radio Access Network (RAN) interface. We assume the same RAN design than LTE. The steps of RASIPT are as follows:

- Physical Random Access Channel (PRACH) Scheduling: The eNB configures radio resources and the access barring parameter from the estimation of active M2M UEs and broadcasts the information.
- Access Barring: Each active M2M UE participates in the access barring.
- Preamble transmission: After a successful access barring, the M2M UEs choose one preamble and send it.
- Data scheduling: The eNB schedules uplink data channels for all the preambles detected and reports the M2M UEs.
- RASIP request, Uplink data: The M2M UEs send the RASIPT request and the data packet together in the radio resources allocated before by the eNB. The eNB forwards this packet to the virtualized MME and this entity authenticates the M2M UE by decoding the packet with the UE security context stored during attach procedure [2].

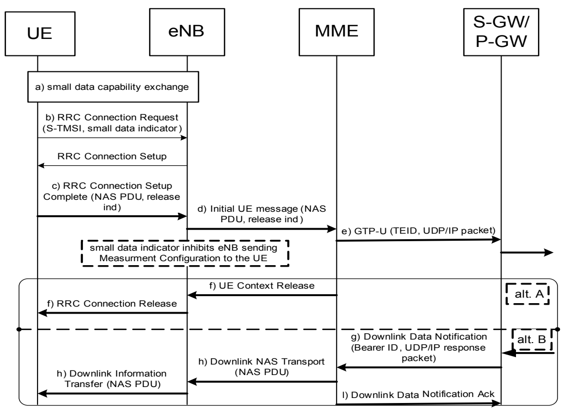

Fig. 2. SDT procedure sequence [3].

- Uplink data: The virtualized MME forwards the authenticated data packet to the gateway, as depicted at Fig. 3.

Although our proposed procedure uses a 5G SDN-based architecture, it could be implemented in LTE by adding some changes, as the increase of MME functionalities or the removal of RRC connection for small transmissions. Without bearer establishment, the network will reduce signaling messages needed for the RRC connection and reconfiguration, eNB UE’s context request, Access Stratum (AS) security establishment and later releases of resources. As in the SDT procedure, we assume no data transmission acknowledgements above RRC layer, the data transfer relies on RRC layer of the control plane, and NAS security context stored between M2M UE and SDN controller for authentication.

IV. Evaluation

A. Simulation Model

We implement our system in ns-3 simulator, where we simulated a scenario with H2H UEs and M2M UEs. H2H traffic models included are web, VoIP [7] and NRTV (Non Real Time Video) [8]. M2M traffic model simulated is based on [9], where the presented traffic model uses Coupled Markov Modulated Poisson Processes (CMMPP) to model coordinated and uncoordinated transmissions of infrequent small reports by M2M UEs. For our simulation, we use a simplified version of this model without space correlation. We assume one M2M use case of a fleet management scenario [10], with three M2M UE states (state0, state1 and alarm). The transition matrices proposed in [10] have a convergence issue due to the large number of M2M UEs that change their state to alarm and after that to state0. These M2M UEs need a long time to converge to the stationary state. To solve this, we modified the probability to change to alarm state in the coordinated traffic transition matrix. The rest of the values of the model remain as original values defined in [10]. We scheduled periodically alarms to model synchronous traffic, which generates signaling load peaks. Table I shows main M2M traffic model parameters.

In the simulation, each UE has a network state (connected/idle/detached). We consider a scenario with 800 H2H UEs and 4800 M2M UEs. We compare three schemes, which use different control procedures for M2M small data transmissions if the M2M UE is idle: for baseline LTE (LTE-Base), the M2M UE will perform a service request, for LTE-SDT, a

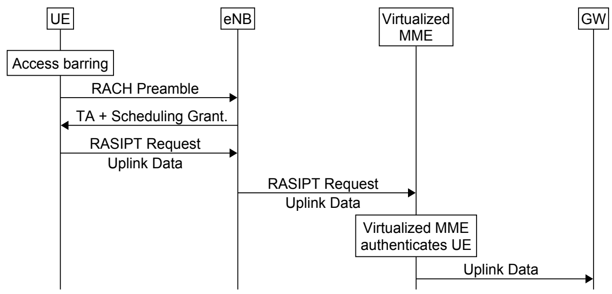

Fig. 3. RASIPT procedure sequence.

TABLE I
M2M TRAFFIC MODEL PARAMETERS

Parameter	Value
Report size	100B
Bitrates [state0, state1, alarm]	[0.15, 6.5, 24.7] B/s
Alarms frequency	1800s
Uncoordinated traffic transition matrix	$\begin{pmatrix} 0.9999325 & 0.000147 & 0.39 \\ 0.0000675 & 0.999853 & 0 \\ 0 & 0 & 0.61 \end{pmatrix}$
Coordinated traffic transition matrix	$\begin{pmatrix} 0.93 & 0 & 0 \\ 0 & 0.93 & 0 \\ 0.07 & 0.07 & 1 \end{pmatrix}$

SDT procedure, and for 5G SDN-based architecture scheme, a RASIPT procedure. To evaluate the scenario, the simulator stores statistics about each control procedure requested, and calculates the signaling messages exchanged to perform the control procedure. The simulation duration is set to 30000 s, but the first 5000 s of the simulation are removed from the results to avoid transitory behavior during H2H and M2M UE connections. The resolution is set to 1s. We assume LTE bitrate of 10 Mpbs, 5G bitrate of 300 Mbps, an inactivity timer of 10s [4], and a restart H2H session time and attach time modeled as an exponential distribution with a mean of 1200s.

B. Simulation Results

Fig. 4 presents the average signaling packets per second generated in the radio and core side of the network for H2H UEs and M2M UEs over each scheme considered. 5G SDN-base architecture scheme values are lower than the other values obtained. More interestingly, the SDT results are even slightly worse than that of the baseline LTE scheme that requires procedures not oriented to M2M small transmissions. The reason is the M2M traffic model assumed, where about half of the small transmissions made by M2M UEs are requested in an interarrival time lower than inactivity period of the network. For baseline LTE, these small transmissions not require any control procedure to send the data packet because the M2M UE still has the bearers and resources allocated, but for SDT and RASIPT, every small transmission requires the performance of the procedure to get enough resources.

The obtained results show better reduction for the core part of the network. It is due to the improvement of resource allocation reached with SDT and RASIPT solutions, where only a few network entities take part of the procedure to transmit the data packet and no data bearer establishment is needed, reducing the number of signaling packets exchanged. In alarm events, the total reduction attained is slightly higher than before due to the large amount of idle M2M UEs that change their state to alarm state and want to send a data packet.

V. CONCLUSION

In this paper, we have presented the results of an evaluation of the signaling impact of M2M communications over cellular networks. We proposed a novel procedure, RASIPT, which simplifies the transmission of a data packet using RA

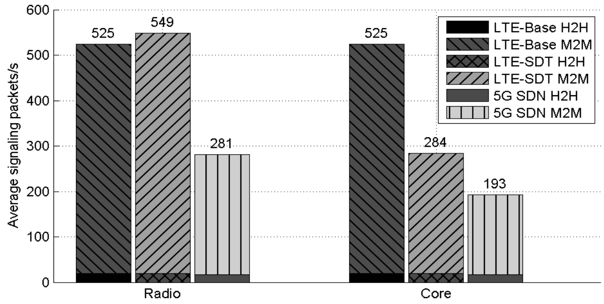

Fig. 4. Comparison of the average signaling packets/s in different parts of the network.

procedure to get enough resources to send the data packet, avoiding the need of a RRC connection and drastically reducing the signaling load generated per transmission. Our evaluation indicates that baseline LTE scheme is not efficient for supporting massive M2M communications deployments where M2M UEs use infrequent and small transmissions, the use of service request and S1 release procedures generates an excessive amount of signaling. New mechanisms oriented to M2M communications have better performance in network signaling load and, especially for our proposed RASIPT procedure, where the reduction of signaling load has reached higher values.

ACKNOWLEDGMENT

This work is partially supported by the Spanish Ministry of Economy and Competitiveness (project TIN2013-46223-P), FEDER and the Spanish Ministry of Education, Culture and Sport (FPU grant 13/04833).

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