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On alleviating MTC overload in EPS

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ABSTRACT

In this paper, we introduce novel mechanisms that anticipate system overload due to MTC signaling messages in 3GPP networks. These mechanisms proactively avoid system congestion by: (i) reducing the amount of signaling messages exchanged when triggering low mobility MTC devices and (ii) reducing the signaling message content for a group of MTC devices sharing redundant Information Element (IE) by creating a profile ID for this group. In addition, along with the second solution, we propose a dynamic grouping solution, which groups MTC device with common subscription features in orders to control the MTC signaling traffics when the network is overloaded. Numerical results show the efficiency of using the proposed solutions compared to only grouping the MTC devices, and using a bulk signaling mechanism.

1. Introduction

Machine Type Communications are about enabling automated applications (or system), which involve device (machine or robot) communication over cellular networks. MTC will facilitate the deployment of an infinite number of applications in a wide range of domains, such as transportation, health care, smart energy, supply and provisioning, city automation and manufacturing. Since MTC devices can be easily embedded in different environments (e.g., cars, cell towers, and vending machines), they may be deployed in a huge quantity, connected to the Internet; forming thus the so-called Internet of Things (IoT). Deploying MTC over cellular networks offers several advantages not only for the Mobile Network Operators (MNOs), but also for application developers or MTC application providers. Whilst for MNOs, deploying MTC applications would generate new revenue streams, for MTC providers it gives the opportunity to target a larger population of users, including mobile users.

With the intention to exploit the potential opportunities raised by a global MTC market over cellular networks, 3GPP groups are defining 3GPP network and system improvements that support MTC in the Evolved Packet System (EPS) [1]. The aim of these standardization activities is to identify 3GPP network enhancements required to support a large number of MTC devices in the 3GPP network domain and to provide necessary network enablers for MTC services. Particularly, transport services for MTC as provided by the 3GPP system and the related optimizations are being considered as well as aspects needed to ensure that MTC devices, MTC servers and/or MTC applications do not cause network congestion or system overload. Indeed, one of the main challenges associated with the deployment of MTC over 3G/LTE is the support of high load introduced by a potential number of MTC devices. System overload may occur at both the Radio Access Network (RAN) and Evolved Packet Core (EPC), due to simultaneous signaling messages from many MTC devices. This situation may have a tremendous impact on the operations of a mobile network. Signaling congestion (overload) may happen due to a malfunction in the MTC server (e.g., MTC devices rapidly trying to reconnect to the remote server which is down) or application (e.g.,

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synchronized recurrences of a particular procedure in the application) and/or due to massive attempts from a potential number of MTC devices to attach/connect to the network all at once [2]. A straightforward solution to signaling congestion can be in the form of designing MTC applications that are friendly to mobile network operators. However, mobile operators cannot risk the operations of their networks and the quality of the provided services by leaving the whole signaling congestion problem to MTC application providers.

In this paper, we propose different solutions to efficiently support MTC in 3GPP networks. We especially focus on avoiding or mitigating system overload. The main spirit of the proposed solutions is to proactively anticipate system overload by reducing the amount of MTC signaling messages exchanged in normal network operations. The first solution reduces the number of exchanged signaling messages when triggering MTC devices with low mobility. It enables direct triggering of MTC devices with low mobility by MTC-IWF (MTC InterWorking Function), without involving the MME (Mobility Management Entity). It uses accurate information on MTC device's area from HSS (Home Subscriber Server) and without storing any per-subscriber relevant state at the MME. This intuitively reduces significantly the cost of the triggering operation of MTC devices with low mobility features, that are expected to be the major type of MTC devices (e.g. utility meters, fixed alarm/monitoring sensors, etc.). Second solution defines a method for controlling and anticipating network overload in case of an event/scenario whereby a mass of messages with some common Information Elements (IEs) are to be exchanged on an interface between two nodes. The network overload control is achieved via dynamic creation of a profile characterizing the event/scenario and the common IEs. The profile creation may be triggered by an external trigger, by an event, etc. The profile along with its features/characteristics is notified to the receiving entity via a dedicated signaling message or in the first actual message relevant to the profile. Storage of the profile ID and its features/characteristics at the receiving node is based on instructions from the sending node. The profile can be deleted based on explicit trigger from the sender, after a timeout, after the reception of a number of messages, based on an event, and/or a combination of any of the above. Request for profile deletion can be also initiated at the sender based on an external trigger, based on an event, after a timeout, after the submission of a number of messages, and/or a combination of any of the above. Request for profile deletion can be via a dedicated signaling message or inserted in the last message relevant to the profile. The key features of this solution are (i) dynamic creation of a profile to characterize events/scenarios whereby a mass of messages with some common IEs are exchanged between two nodes; (ii) storage of profile is temporary to make efficient usage of available resources; (iii) actual amount of data exchanged between nodes is reduced to cope with core network overload. The same solution also enables a dynamic creation of group ID for UEs with common subscription features and/or similar behavior towards network to optimize usage of network interfaces, to reduce amount of signaling, and to reduce amount of processing at core network nodes.

The remainder of this paper is structured as follows. Section 2 highlights some research work related to MTC and 3GPP system overload. Section 3 presents the new solutions introduced for efficiently supporting MTC in 3GPP networks. Section 4 presents the system model. Section 5 evaluates the performance of the proposed solution and discusses the obtained results. Finally, the paper concludes in Section 6.

2. Related work

2.1. System architecture

Fig. 1 shows the MTC network architecture, as currently envisioned by 3GPP [1]. It consists of three main domains, namely the MTC device domain, the communication network domain, and the MTC application domain. In the network domain, most important nodes of a 3GPP EPS network are shown. The MTC application domain consists of MTC servers, under the control of the mobile network operator or a MTC provider. Table 1 provides a brief description of the most important EPS nodes, shown in Fig. 1.

Two new entities related to MTC recently emerged in the 3GPP architecture. They are namely, MTC-IWF (InterWorking Function) and SCS (Services Capability Server). A MTC-IWF may be a standalone entity or a functional entity of another network element. The MTC-IWF hides the internal PLMN (Public Land Mobile Network) topology and relays or translates signaling protocols used over the Tsp interface to invoke specific functionality in the PLMN. SCS is an entity that connects to the 3GPP network to communicate with MTC devices and the MTC-IWF entity. As depicted in Fig. 1, there are three ways of establishing connection between MTC servers and MTC devices. In the direct model, a MTC server connects directly to the 3GPP network and gathers data (through the user plane) from the MTC devices. Indirect model involves the services of SCS in order to use for example control plane device trigger. In this case, SCS is either controlled by the MTC provider or by the network operator. The final model is a hybrid model, whereby the MTC server can simultaneously use both direct and indirect models.

2.2. Related works

Whilst MTC represents an important business opportunity for mobile operators, mobile operators fear the congestion that could come with the deployment of billions/trillions of MTC devices, not to mention millions of smart mobile phones and their associated mobile traffic [25]. Some mobile operators have already experienced congestion at their networks due to the penetration of smart mobile phones. As an attempt to alleviate congestion at mobile networks, the Core Network Overload (CNO) Study item was initiated in 3GPP [13]. Most signaling congestion avoidance and overload control mechanisms proposed in

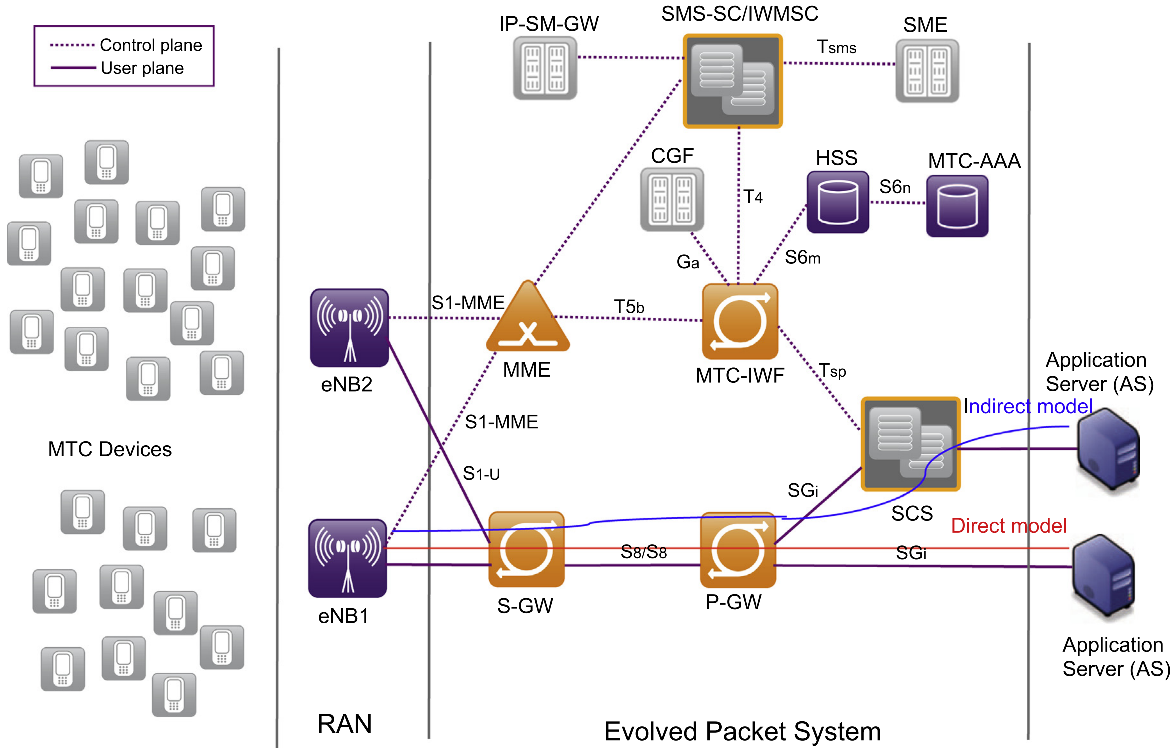

Fig. 1. Architecture for MTC in 3GPP [1].

Table 1
EPS's most important nodes.

Node	Description
eNB	Evolved Node B, the LTE's base station
MME	Mobility Management Entity, a control plane entity for all mobility related functions, paging, authentication, bearer management in EPS
MTC-IWF	MTC Interworking Function hides the internal Public Land Mobile Network (PLMN) topology and relays or translates signaling protocols used over Tsp to invoke specific functionality in the PLMN
HSS	Home Subscriber Server, main database containing subscription-related information
S-GW	Local mobility anchor for intra-3GPP handoffs
P-GW	Packet Data Network Gateway, interfaces with the Packet Data Network (e.g., Internet)
SCS	Services Capability Server is the entity that connects MTC application domain to the network domain

the context of MTC over cellular networks implement one of the following approaches: (i) segregate MTC traffic from the normal UE traffic in order to separate the network access for the two types; i.e., this helps to anticipate the congestion which may happen due to MTC traffic and (ii) when congestion occurs, apply some back-off mechanisms rejecting MTC traffic at the RAN equipment (eNB) or at the EPS nodes (e.g., MME, S-GW or even P-GW).

To differentiate MTC traffic from the classical traffic, most proposed solutions group the MTC devices into groups or clusters according to different metrics/features (e.g., low mobility, QoS requirement [22,23], belonging to macro or femtocell [21]). After grouping the MTC devices, there are two methods for separating the access to the RAN, and avoid the RACH (Radio Access CHannel) overload. The first one consists of defining "grant time periods" when MTC devices are authorized to connect to the network. The network also defines "forbidden time intervals" during which a MTC device is not allowed to connect to the network, be it the home network or a visited network. Intuitively, a grant time interval does not overlap with a forbidden time interval. Over the grant time, assigned to a MTC device, the communication window is further limited. The access time of MTC devices is also randomized over the communication window/grant time. In case of multiple MTC devices attempting to connect to the network during a specific and short communication window/grant time, to avoid signaling congestion and to cope with possible network overload during communication windows, the communication windows of the different MTC devices can be distributed over the grant time interval, via for example, randomization of the start times of the individual communication windows. This operation assists in reducing peaks in signaling and data traffic from MTC devices. Another way to define the duration of the grant interval is in the case where the network is aware of the period of time the MTC devices have to transmit. In fact, the network can dynamically increase the time grant duration dedicated to MTC devices if it is aware of the scheduling of MTC traffic. In some scenarios the network can predict when access load will surge due to MTC devices.

The second method consists in defining specific low levels parameters for separating RACH resources for MTC and non-MTC devices. The separation of RACH resources between MTC and non-MTC devices allows the limitation of the number of MTC devices capable to connect to the network, while maintaining normal network access for non-MTC traffic. To implement this separation, a simple way is to define a MTC specific backoff scheme. With this mechanism, the access attempts from MTC devices could be dispersed over a large time interval to prevent contending the RACH resources.

In addition to grouping MTC devices, there are also other solutions to anticipate the system overload by rejecting MTC device attach request if there are not sufficient network resources, or by grouping the signaling messages from a group of MTC in one common bulk signaling message. In [22,23] the authors first group the MTC devices into clusters according to their QoS characteristics and requirements, e.g., the cluster packet arrival rate and the maximum tolerable jitter by the MTC devices composing the cluster. When a MTC device attempts attaching to the network, it sends its QoS characteristics and requirements to the current eNB. If there are enough resources to satisfy the MTC requirements, the MTC device is accepted and added to an existing MTC cluster having the same constraints, or a new cluster is created. Otherwise, the attach request of the MTC device is rejected. In [20], the authors also show the potential of handling signaling messages common to a group of MTC devices in bulk. However, regrouping the MTC devices and separating their traffic from the other traffic at the RAN level is not always efficient to avoid congestion. Indeed, in some situations, there is need to reduce the MTC traffic by a specific amount implementing admission control at eNBs or even at MTC devices. Indeed, admission control can be activated at the eNB upon receiving a congestion signal from the EPS nodes (MME/HSS). Or, it can be communicated to the MTC devices level as in the 3GPP Access Class Baring (ACB) solution. ACB is a solution, which effectively reduces the collision probability of transmitting the bulk of preambles at the same RACH resource. Based on the broadcasted parameters by eNBs, a UE determines whether it is temporarily barred from accessing the cell. An access class barring factor or access probability (p) determines the probability that access is allowed. If a random number n generated by the UE is equal to or greater than p, then access is barred for a mean access barring time duration. In legacy ACB scheme, there are 16 access classes. AC 0–9 represents normal UEs, AC 10 represents an emergency call, and AC 11–15 represents specific high priority services, such as security services, public utilities (e.g., water/gas suppliers). A UE may be assigned one or more access classes depending on the particular cell access restriction scheme. In [24], the EAB (Extended Access Baring) is introduced for MTC communication, where a higher value of p and access class baring duration could be assigned to MTC devices in order to reduce the contention on RACH resources, since the MTC devices will likely be blocked by the small probability p. Similar in spirit to, the authors proposed a congestion-aware admission control solution in [18,19]. The proposed solution selectively rejects signaling messages from MTC devices at RAN following a probability that is set based on Proportional Integrative Derivative (PID) controller, and derived at a particular EPS node (e.g., MME).

3. Proposed schemes

This section introduces, in details, two solutions that aim at mitigating the system overload due to MTC by proactively reducing the MTC signaling messages. The first solution reduces the amount of MTC signaling messages in case of triggering low mobility MTC devices. The main idea is to exclude the involvement of MME in the triggering procedure, and use only MTC-IWF, which can considerably reduce the amount of signals and consequently render the triggering operation less costly. The second solution, meanwhile, decreases the size of signaling messages of a group of MTC devices by replacing the common IEs by a profile ID, similar in spirit to the concept of ROHC (Robust Header Compression). As second step of this solution, a group of MTC devices that share common subscriber features is dynamically created in order to allow the network have better control of MTC traffic when the system is operating under specific conditions.

3.1. Optimized triggering of low mobility MTC devices

In general, due to the expected large scale deployment of MTC devices, MTC device triggering shall be performed with minimal cost in terms of signaling and involving a minimal number of core network nodes. So far, a number of triggering methods have been defined and documented in current specifications [1]. Further device triggering mechanisms are expected in [2]. According to the MTC architecture as described in [1] (and shown in Fig. 1) along with the reference points, the considered device triggering variants are:

- Device triggering procedure over Tsp supported by
  - Trigger delivery using T5.
  - Trigger delivery using T4.
- Device triggering using direct model over user plane.
- Device triggering with OMA Push.

In addition to HSS, these device triggering mechanisms involve SMS-SC, MME (or SGSN), and/or PGW (or GGSN). The involvement of MME primarily serves for the mobility management of the MTC device. On the other hand, there will be a potential number (in the order of billions, if not trillions) of MTC devices that are fixed or with low mobility features. The geographical locations of such MTC devices can be known in advance to the network. It is thus important to use this information by the network, particularly by MTC-IWF, to minimize the triggering cost by minimizing the number of involved EPC nodes. It shall be noted that the focus of the proposed solution is on T5-based triggering. T4-based triggering does not apply.

In [11], a number of paging solutions are described for MTC devices with low mobility. In solution 6.3 of [11], paging is done by MME within configured areas (e.g. TAI (Tracking Area Identity), CGI (Cell Global Identity), ECGI (Evolved CGI)), pre-configured in the HSS as part of the subscription of the MTC device. The MME stores the paging area as part of the subscriber data as received from HSS. During the mobile terminated service, the MME pages the MTC Device within the specific area. The configured paging area is assumed to be smaller than typical paging areas for other UEs. Thereby paging traffic can be reduced. In solution 6.4 of [11], paging is conducted in a stepwise fashion. Indeed, for "the MTC Device with low mobility, the MME stores the RAI (Routing Area Tracking)/TAI(s) like for any other UE and in addition the last known cell (i.e. CGI /ECGI) or last known service area (i.e., SAI) as provided by RAN in S1/Iu/Gb (interfaces) signaling. For low mobility MTC devices the MME preferentially includes only one TAI for TAI list in the accept message. During the mobile terminated service, the MME may page stepwise, e.g. first in the last known cell (i.e. CGI/ECGI) or last known service area (i.e. SAI (Service Area Identifier)) and if there is no response the MME pages the MTC device in a wider area, i.e. within the RAI or TAI List allocated to the MTC device." In solution 6.5, paging is conducted within reported area. In this solution, the SGSN/MME stores the area identifier (e.g., CGI, ECGI, SAI, RAI or TAI) of a MTC device (i.e., deducible when receiving the same area identifier during a predefined period or via an explicit report from the MTC device) and pages the MTC device within the specific area.

In other approaches, a number of UE states are introduced along with a mechanism whereby tracking areas of MTC devices with low mobility are stored at MTC servers and communicated to MME upon external activation request. The MME checks the subscription information of the UE at HSS and determines the tracking area for paging. It is assumed that "the information of the TA (Tracking Area) where the MTC device resides is either stored in the subscriber profile or indicated in the activation request of the MTC server." In this paper, we also make the former assumption but have reserves about the latter. Indeed, operators tend to dynamically change the IDs of their eNBs, TAIs, RAIs, etc. to hide their network topology from a third party. Thus, mechanisms for reconfiguring TAs at MTC servers whenever the network reconfigures some cells will be required. Alternatively, geographical coordinates/postal codes can be used and mapping between the geographical coordinates and the network areas (e.g. CGI, ECGI, SAI, RAI or TAI) must be done in a dynamic way at a core network node (e.g., MTC-IWF). Making this mapping once in the lifetime of the network could be seen easy. However, frequent updates of this mapping whenever the network decides to modify the settings of its network areas could be seen as not "easy", rather costly. This is not to forget that an additional function at the node storing such mapping would become required to be able to read the geographical coordinate of the UE and convert it into the right/corresponding network area.

All MTC triggering solutions, considered so far, involve MME in the triggering of the MTC device and/or assume a state table being maintained at the MTC server storing information on the network areas of UEs (e.g. CGI, ECGI, SAI, RAI or TAI) or at the MME/MTC-IWF/HSS storing the mapping of geographical locations to the network areas. Fig. 2 shows the sequence of signaling messages for the triggering of a low mobility MTC device according to the proposed solution. Steps 1–4 are similar to the MTC device triggering procedure over Tsp [1]. In case Step 4 is optional, knowing the low mobility feature of the MTC device to be paged, SCS (or MTC application provider) may notify MTC-IWF of such low mobility feature of the device (via a flag in the device trigger request) so that MTC-IWF would request HSS for the paging area of the MTC device. Upon receiving the subscriber information request, HSS determines whether the MTC device in question is low mobility or not. In case it is, HSS sends back to MTC-IWF a subscriber information response (similar to the Tsp-based triggering procedure) with an additional information on the network area (e.g., CGI, ECGI, SAI, RAI, TAI, or a list of thereof) of the MTC device. MTC-IWF then pages the MTC device in the designated area. In Step 8, if eNBs receive paging messages from the MTC-IWF, the MTC device is paged by the eNBs, as described in detail in [7,8]. If RNC/BSS nodes receive paging messages from the MTC-IWF, the MTC device is paged by the RNSC/BSS, which is described in detail in [6]. After carrying out charging in Step 9, a device trigger report is sent to SCS in Step 10. As in [12], in response to paging, the paged MTC device initiates the attach procedure, the UE-initiated service request procedure, the tracking area update procedure, or a specific MTC application procedure. It shall be noted that the mechanism of Fig. 2 operation assumes that similar to MME, MTC-IWF has the paging capability. MTC-IWF may be also acquired with functions to control the paging based on operator policy such as paging retransmission strategies, paging prioritization and determining whether to send the Paging message to the eNBs during certain MTC-IWF high load conditions. Indeed, MTC-IWF may also supervise the paging procedure with a timer. If MTC-IWF receives no response from the MTC device to the Paging Request Message, it may repeat the paging, as per the operator's policies.

Fig. 3 shows another variant of MTC triggering for MTC devices with low mobility, and that is involving MME/SGSN, making a maximal reuse of existing procedures. This variant can be used in case MTC-IWF does not acquire paging capability and that is based on T5a/b interface [1]. Steps 1–6 of Fig. 3 are similar to those of Fig. 2. However, in the T5a/b-based triggering procedure, MTC-IWF indicates explicitly the network area of the MTC device. MME uses this information to page the MTC device in well-determined areas. It shall be noted that this optimized T5a/b-based MTC triggering procedure does not require the maintaining of any state table at MME nor at MTC-IWF.

It shall be noted that one of the key features of the proposed solution is that MTC-IWF gets accurate information on the network area of a UE from a reliable source, namely HSS, and optionally based on a flag from MTC server (which conditions interaction between MTC-IWF and HSS). Another important feature of the proposed solution

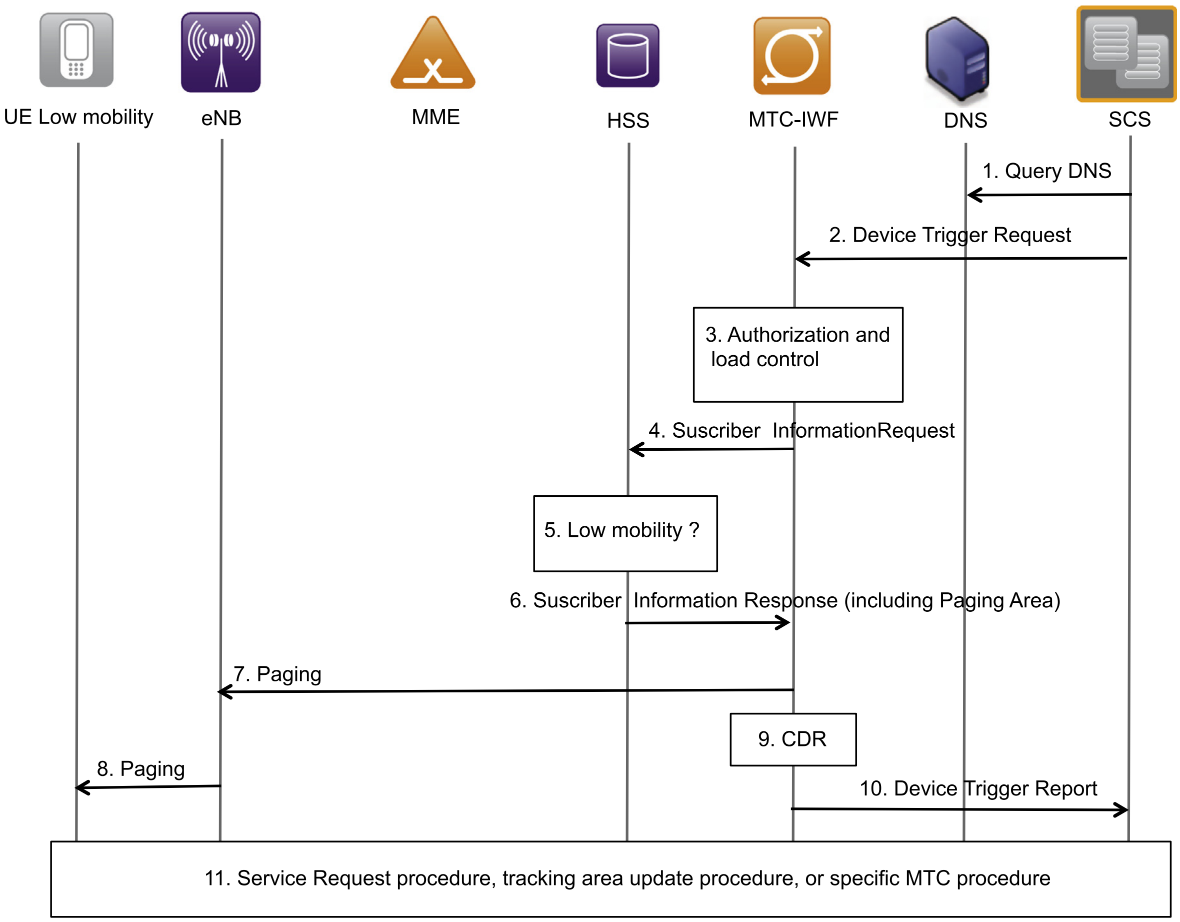

Fig. 2. Direct triggering of MTC devices with low mobility by MTC-IWF (without involving MME).

is that triggering can be done without involving MME, thus reducing triggering cost. Intuitively this requires additional MME-like paging functions at MTC-IWF which is still a new 3GPP node, and that is with no impact on RAN nodes. In the proposed solution, there is no requirement for holding any geographical information or whatsoever at MTC server, which could be otherwise costly in case of millions of MTC devices deployed by the MTC application owner. If we want to have the exact geographical coordinates, MTC devices need to be equipped with a GPS or this information needs to be input manually, etc. This intuitively rules out any requirement for mapping and updates of geographical locations/coordinates to network areas at any network node.

3.2. Group-ID based dynamic profile creation/management for optimizing MTC and alleviating relevant congestion

In [13], a number of solutions have been proposed to deal with congestion at the control plane of the core network. Most of the solutions deal with congestion at the nodal level and one solution, namely Solution 1, proposed optimizing the subscription data download from HHS by introducing the concept of Subscription Profile IDs (for static subscription data such as Access Point Name – APN – subscriptions) on HSS interfaces. Indeed, there are many scenarios where a network node needs to deal with sending a mass of messages with some fields in common to the same target node at nearly the same time. Some of these scenarios are listed below:

- *Node failure restoration*: A network node fails and the network attempts to recover from the node failure by migrating affected UEs to another node (more on restoration procedures at [3], node failure at [4]).
- *MTC*: A large number of MTC devices attempting to attach to the network, or to perform TAU (Tracking Area Update) procedure all at nearly the same time [11].
- *Energy efficiency*: The network decides to turn off a node for the sake of energy saving. Contextual information regarding UEs that were served by that node need to be transferred to another node that remains on [5].
- *Core network overload*: different scenarios are available at [13].

Stemming from this observation that there could be many scenarios whereby a mobile network node (e.g., eNB, MME, P-GW, MTC-IWF, etc.) needs to deal with

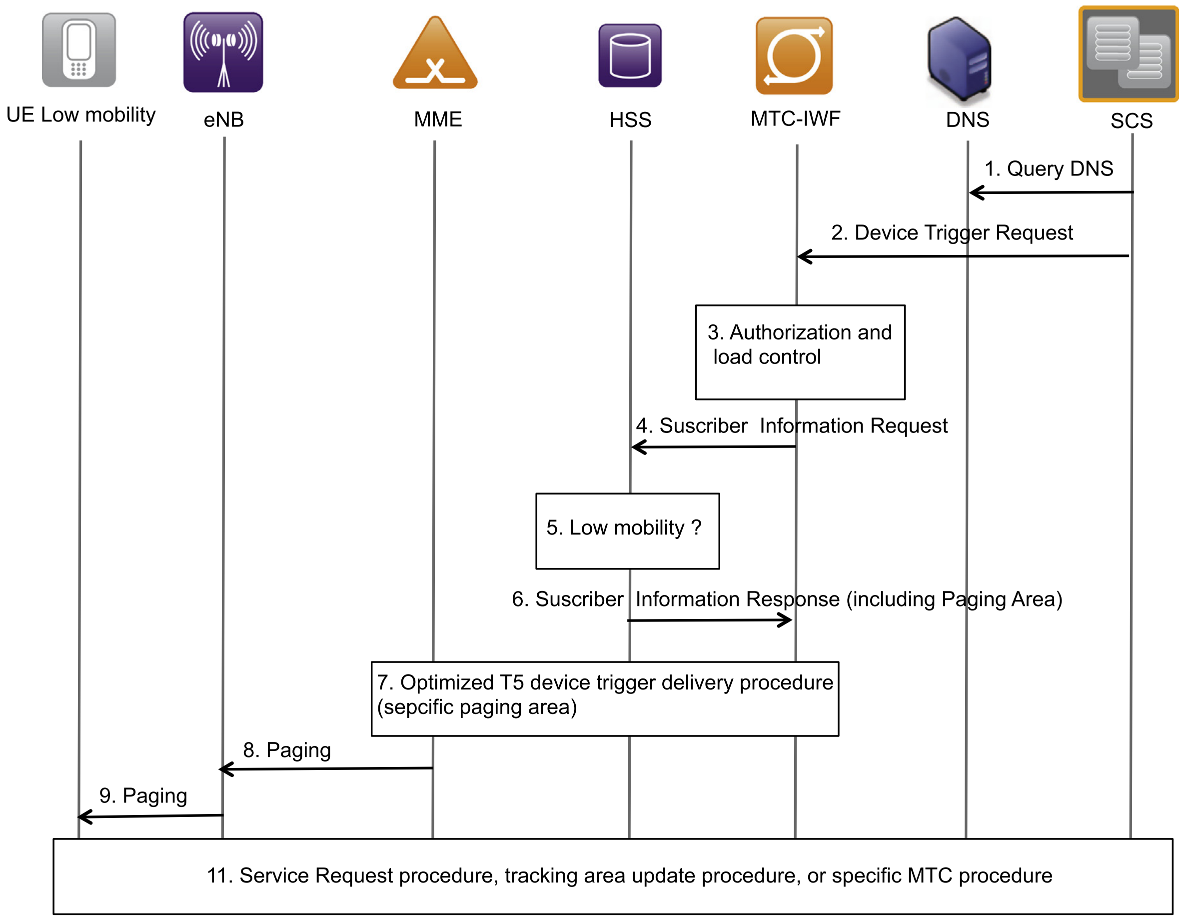

Fig. 3. Optimized T5a/b-based MTC triggering for MTC devices with low mobility (involving MME).

sending a mass of messages (i.e., at both user plane and control plane) from a group of UEs (e.g., MTC devices) with some IEs in common to the same target node at nearly the same time, in [14], the authors proposed holding such messages at a node for a specific time or till a number of messages is received, aggregating their content while avoiding duplicate IEs, and handling them in bulk to the receiving node. In this way, the message contents can be compacted considerably. Moreover, the effort of parsing the parameters of many messages is also reduced to a minimum, which shall reduce by a large factor the time spent for processing the messages at the receiving node. With this regard, it shall be noted that IETF has initiated some activities on handling diameters messages in bulk [15,16] and they have a work charter dedicated for diameter maintenance and extensions [17].

Whilst handling messages with common IEs in bulk have advantages, its main drawback is the delay it adds in processing the messages. The purpose of the solution proposed herein is to achieve the goal of the "bulk message handling solution" in reducing the amount of traffic sent on EPS interfaces, but without compromising the delay in handling messages. The proposed solution defines methods for creating and managing, in a dynamic way, profile identifiers referring to a set of IEs that are common in messages relevant to a group of UEs or MTC devices, identifiable by a unique group ID, and replacing the common IEs with the created profile ID. Before describing the core idea of the proposed solution, it shall be noted that there are many messages that can be subject to the idea of the solution. Considering messages on interfaces using Diameter and just to name a few, we can consider Update Location Request and Cancel Location Request as in [9], and CC-Request (CCR) Command as in [10]. From the format of these messages, it can be said that for UEs belonging to the same group, it is likely to have many common IEs regarding these UEs and/or their bearers. Creating a profile ID to refer to these common IEs and sending it instead of all common IEs would definitely reduce the amount of traffic exchanged on the respective interfaces. The importance of replacing common IEs in messages by a profile ID, similar in spirit to Robust Header Compression (ROCH), becomes more significant knowing that the size of messages is increasing with every release of the specifications. Fig. 4 depicts the case of creating profile ID for a TAU message. In the current 3GPP specification, a TAU message consists of mandatory fields, worth 15 bytes, and a set of optimal fields. If we focus only on MTC devices that are associated with the same MME, the only parameter that is device specific is the M-TMSI (MME Temporary Mobile Subscriber

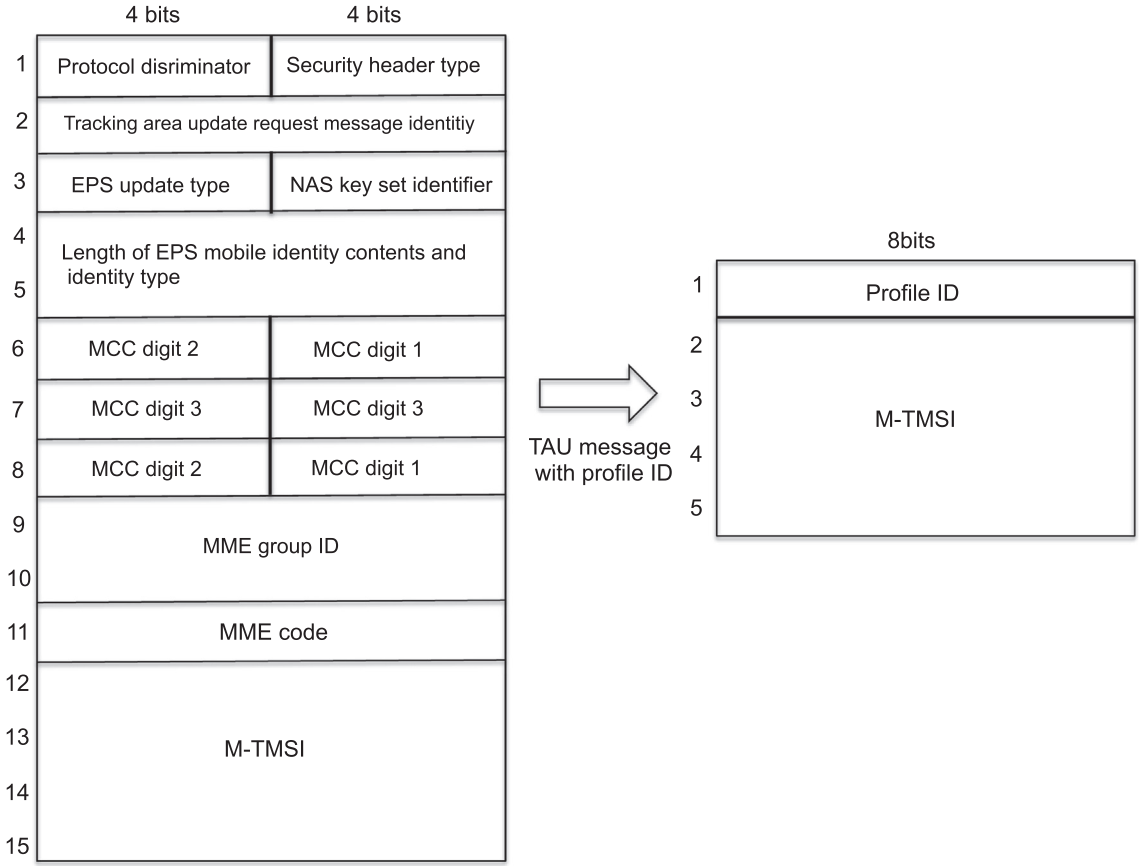

Fig. 4. Example of profile ID creation: TAU message.

Identity). Therefore the other IEs are common and can be grouped and replaced by a profile ID. The idea of signaling message compression can be applied between any two entities that exchange messages between them over a particular interface, as shown in Fig. 5.

In Fig. 5, based on a particular trigger or event, such as (1) scheduled communication from MTC devices (or certain applications of smart phones known by the network a priori) or (2) reception of a number of messages of the same procedure with common IEs and regarding a number of UEs belonging to the same group identified by a specific group ID and that is within a period of time; the sender creates a profile identified by a unique ID referring to a set of attributes (e.g., common IEs). The profile ID can be a random value or a function of the group ID of relevant UEs and other metrics. The group ID can be explicitly indicated in the messages, inferred from the identifiers (and/or other information elements) of relevant UEs, inferred from subscription data of UEs downloaded on demand or a priori from HSS or another relevant node, or inferred from a mapping between the relevant procedure and the locations (e.g., cells, tracking areas, service areas, etc.) of the relevant UEs.

As second step, the sender communicates the profile ID and its features to the receiver, optionally along with instructions on when to delete the profile at the receiver, event type, etc. This notification can be either in the form of a dedicated signaling message or it can be inserted in the first relevant message sent after the profile creation. The profile notification message can be optionally acknowledged by the receiver. In response, the receiver stores the profile ID and its attributes. For the subsequent messages relevant to the profile, the sender does not insert common IEs; instead it inserts only the profile ID. In this way, the amount of communication on the interface between the two entities can be reduced. Storage of the profile and relevant information at the receiver and/or sender can be deleted either via a dedicated signaling message or a trigger can be sent in the last message relevant to the profile sent from the sender to the receiver. Alternatively, the receiver/sender can delete information on the profile after a timeout during which no relevant message is received, after a specific timeout initially indicated by the sender or a third party, or after receiving a total number of messages, or based on an event detected by the receiver/sender.

Using the same logic used in creating profile IDs, a node such as MME, SGSN, MSC/VLR can create unique group IDs, in a dynamic way, for UEs based on the frequency at which their relevant messages of a particular procedure (e.g., mobility management procedure such as attach request, RAU (Routing Area Update), LAU (Location Area Update), TAU requests; session management procedure such as

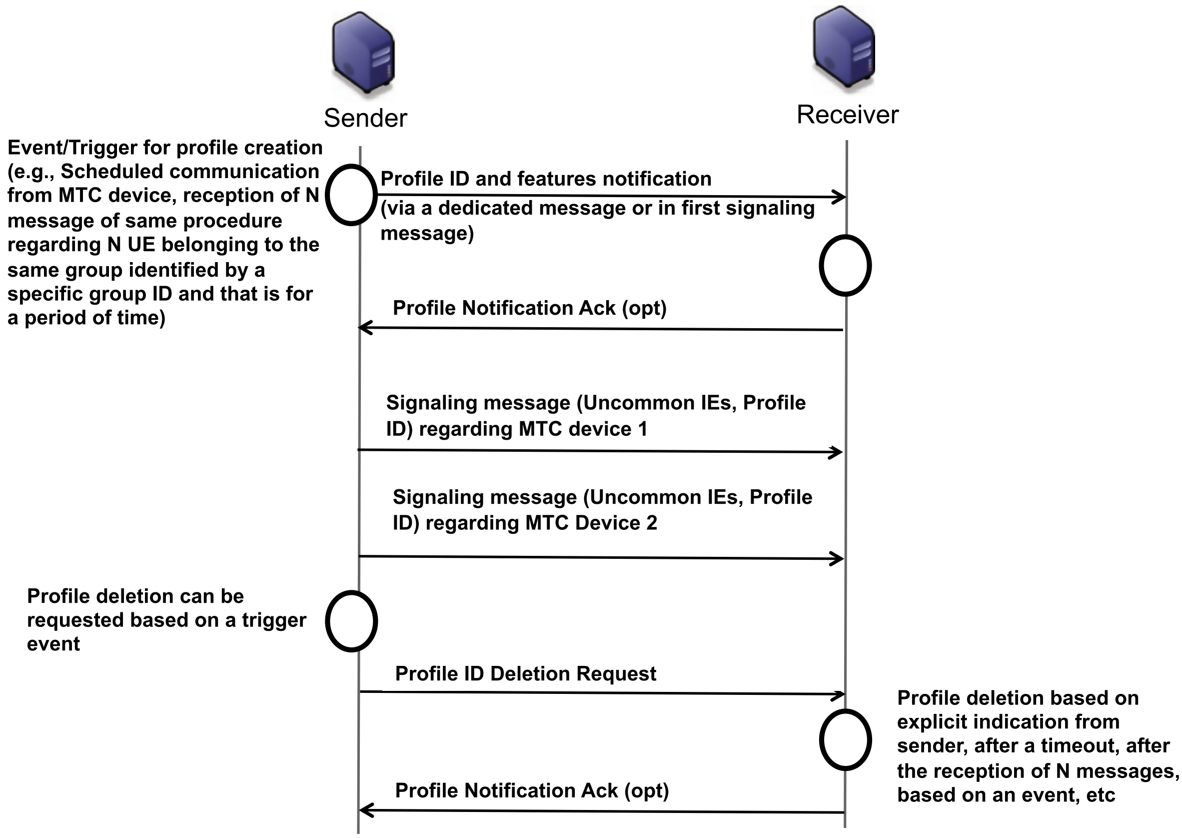

Fig. 5. Compressing messages with common IEs using a unique profile ID created and managed following a specific logic using the group ID of relevant UEs.

PDN (Packet Data Network) connectivity request and activate PDP context request) are transmitted. For instance, when a MME receives a number N of RAU request messages from N different UEs with a certain priority level during a specific period of time, the MME may create a group ID that will refer to this set of UEs and the ones that have similar subscription features and will be sending RAU request messages over another specific period of time. The MME may use this group ID to e.g., enforce any NAS level mobility management or session management congestion control handling, such as (extended) access class barring at RAN addressing UEs that are identified as belonging to the group ID. This operation can be carried out for example when the MME gets congested or when the MME becomes aware of the congestion of HSS based on long delay in responses from HSS, based on explicit notification from HSS, O&M or another mobile network node. The group ID can be managed in the same way as profile ID. Indeed, its storage and relevant information can be deleted or updated either via a dedicated signaling message, based on a trigger, after a timeout during which no message relevant to the group ID and the procedure is received, after a specific timeout initially set up, after receiving a total number of messages relevant to the group ID, or based on an event detected by the node storing the group ID. As mentioned earlier, the group ID can facilitate for an operator to carry out a specific task by addressing all MTC devices belonging to the identified group, rather than addressing each individual MTC device. Indeed, as an example, if the mobile network experiences a nodal overload situation (e.g., at HSS, MME, etc.) and needs to reject mobility management requests from the MTC devices, it can now use the grouping ID for applying Extended Access Class Barring at eNBs to address multiple UEs belonging to a specific group at the same time. If a UE of that special group sends a request, it will be identified by the eNB by looking at the group ID indicated in the request message from UE or by referring to the binding between the group ID and the UE's identifier (if the group ID is not available in the request message from UE), and the request message will be rejected at the eNB and a backoff timer will start in the UE and the UE can repeat the request when the backoff timer expires, according to the extended access class barring mechanism [18,19]. The group ID can be also used by S-GW, P-GW, PCEF (Policy and Charging Enforcement Function), and/or PCRF (Policy and Charging Rules Function) for session management, policy and charging control. Indeed, messages from UEs belonging to the same group identified by a unique group ID can be handled in bulk as proposed in [14] or using a unique profile ID as explained herein.

As a summary, in this proposed solution, based on subscriber profile received from HSS, MME or relevant core network node creates in a dynamic way a group ID to refer to UEs with particular subscription features and particular behavior towards network. MME or relevant core network node shares the group ID with other network nodes such as

S-GW, P-GW, PCRF, and eNB. These nodes make a local binding between the group ID and one or multiple UE's IDs. The group ID is used by eNBs for enforcing (extended) access class barring e.g., to deal with mobility management messages, by S-GW, P-GW, PCRF for e.g., handling session management messages and/or policy and charging control messages in bulk to optimize the usage of network interfaces.

4. System model

In this section, we study the RAN and EPC load. Our aim is to show the ability of the proposed solutions to reduce the system load and avoid congestion. Let consider that a set of MTC devices are grouped and granted with a time interval. The grouping procedures may be based on Solution 2. In the studied model we assume that all preambles access are common to the MTC group, and we focus only on the time interval dedicated to each MTC group. Fig. 6 shows the 3GPP radio frame structure and the cycle time of MTC groups in the macrocell. We assume that part of the available frames will be dedicated to the MTC groups. Each group is affected one frame noted T_f with a duration of 10 ms. Here, we focus particularly on the overload introduced by the MTC signaling through using the same concepts as those introduced in [21]. Indeed, the granted time interval is cyclic and repeated each T_{cycle}. The T_{cycle} duration depends on the number of groups and the number of frames dedicated to other UE traffic types.

MTC devices wait for the granted time to send a network attach message or other controlling messages. The transmission may fail, if either RAN or an EPC node (such as MME) is overloaded. If there is a transmission failure, the MTC device waits for the next granted time to transmit the failed message. We assume that there is no restriction on the maximum transmission attempts, so the MTC device sends the same signaling message until the transmission is successful. It is important to note that our aim is to study the general behavior of the system, so we did not model in details the contention resolutions at the RACH access for each granted interval.

4.1. Probability of RAN and EPC node overload

System overload, at the RAN (eNB) or EPC (MME) level, may occur due to significant signaling messages from MTC devices to the remote MTC server. The first metric we want to derive is the probability of the system overload at the RAN and the EPC levels. We consider the architecture of Fig. 1, whereby an MME handles (N_{mtc_tot}) MTC devices deployed over (N_{macro}) macrocells. Each macrocell handles the same number of MTC group, noted (N_{gmtc}). Each group contains (G_{mtc}) MTC devices. We assume that: (i) each macrocell (eNB) has the capacity to handle (C_{macro}) MTC messages in each cycle and (ii) MME can handle (C_{MME}) MTC messages in each cycle. Here, the macrocells are assumed to be well synchronized.

As in [11], we consider that the message generation rate is following a Poisson distribution, and hence the inter-arrival time follows an exponential distribution with mean $1/\lambda$. The probability p_{tran} that an MTC device has a signaling message to transmit during T_{cycle} is expressed as follows:

$$p_{tran} = 1 - e^{-\lambda T_{cycle}}$$

Thus, the probability that k MTC devices are connecting to the macrocell in one group is derived as:

$$p_g(k) = \binom{G_{mtc}}{k} p_{tran}^k (1 - p_{tran})^{Gmtc-k}$$

For each MTC in a macrocell, the probability set that there are k MTC devices connecting to the eNB is expressed as follows:

$$P_{G,i} = [p_g(0), \ldots, p_g(G_{mtc})]$$

where $i = 1, \ldots, N_{gmtc}$.

Since at the RAN level there are at most $N_{gmtc} \times G_{mtc}$ signaling messages from MTC devices, the probability that there are 1 to $N_{gmtc} \times G_{mtc}$ MTC devices connecting to the eNB is derived as:

$$P_{eNBj-G} = P_{G,1} * \cdots * P_{G,N_{gmtc}}$$

where $*$ denotes the convolution operator and $j = 1, \ldots, N_{macro}$.

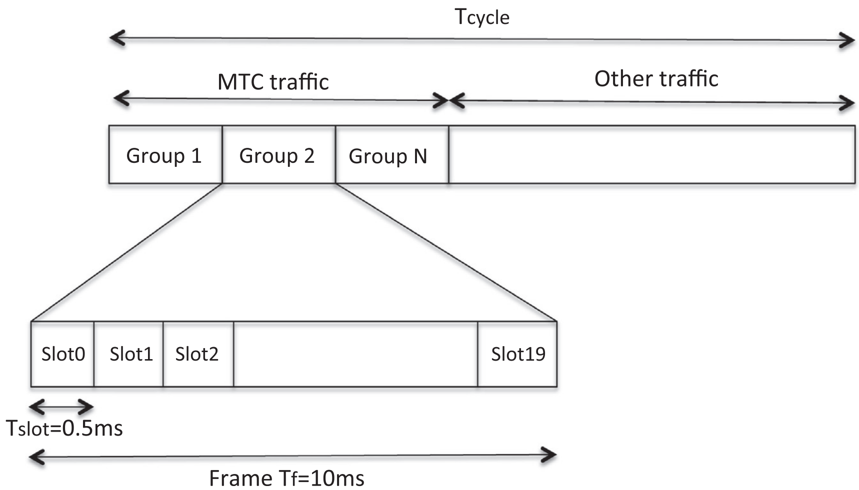

Fig. 6. Radio frame structure.

We follow the same reasoning concerning the probability set that j MTC devices connect to EPC. In EPC, at most $(N_{macro} \times C_{macro})$ MTC signaling messages may occur during each cycle. By consequence, the probability that there are (1 to $N_{macro} \times C_{macro}$) MTC devices connecting to MME is expressed as:

$$P_{EPS} = P_{eNB1-G} * \cdots * P_{eNBNmacro-G}$$

Definition 1. RAN overload occurs if the number of signaling messages sent by the MTC devices exceeds the capacity of an eNB (C_{eNB}).

Definition 2. EPC overload occurs if the number of signaling messages received from the eNBs exceeds the capacity of the MME (C_{MME}) to handle these messages.

Based on these definitions, the overload probability of RAN and MME are derived as follows:

$$p_{RAN} = 1 - \sum_{k=0}^{C_{macro}} p_g(k)$$

$$p_{MME} = 1 - \sum_{k=0}^{C_{MME}} p_{EPS}(k)$$

4.2. Transmission failure probability

As in [11], the MTC signaling message transmission fails if either RAN or MME overload occurs. In this case, the MTC device waits for the next group's granted interval (cycle) before making a new transmission attempt. To compute the connection failure probability on the condition of RAN overload (PF_{RAN}), and the connection failure probability on the condition of MME overload (PF_{MME}), we introduce two new variables:

- The average number of connection failures at the macrocell due to RAN overload (AVG_{RAN}).
- The average number of connection failures in EPC due to MME overload (AVG_{MME}).

Based on this definition, we introduce the following equations, which give the way to evaluate the AVG_{RAN} as well as AVG_{MME}.

$$AVG_{RAN}(t) = \max\left\{0, \left(G_{mtc} - \frac{AVG_{RAN}(t-1)}{G_{mtc}} - \frac{AVG_{MME}(t-1)}{G_{mtc} * N_{macro}}\right) * p_{tran} * G_{mtc} + \frac{AVG_{RAN}(t-1)}{G_{mtc}} + \frac{AVG_{MME}(t-1)}{G_{mtc} * N_{macro}} - C_{macro}\right\}$$

$$AVG_{MME}(t) = \max\left\{0, \left(\left(G_{mtc} - \frac{AVG_{RAN}(t-1)}{G_{mtc}} - \frac{AVG_{MME}(t-1)}{G_{mtc} * N_{macro}}\right) * p_{tran} * G_{mtc} + + \frac{AVG_{RAN}(t-1)}{G_{mtc}} + \frac{AVG_{MME}(t-1)}{G_{mtc} * N_{macro}}\right) * N_{macro} - AVG_{RAN(t)} - C_{MME} bigg\}$$

where $AVG_{RAN}(0) = 0$ and $AVG_{MME}(0) = 0$.

These equations are then solved by iteration. At the final stage we obtain the values of AVG_{MME} and AVG_{RAN}. The first equation expresses the fact that message failure at RAN occurs when there are no enough resources. Indeed, for each cycle we have MTC devices that connect with probability p_{tran}, in addition to the MTC devices that experienced transmission failure in the precedent cycle. Here, we assume that these devices will try to transmit again with a probability of one. For both equations we assume that: (i) for each group, the number of transmission failures at the RAN level and the EPC level is the same and (ii) for each macrocell, the number of transmission failure at the EPC level is identical. On the other hand, the second equation expresses the average transmission failure at the EPC level. In this case, a transmission failure occurs if the number of signaling messages coming from all the macro-cells exceeds the MME capacity. It is important to note that in this case, the number of MTC device messages coming from the macrocells does not exceed C_{macro}. Therefore, the maximum number of MTC devices received at MME is equal to $(C_{macro} * N_{macro})$. By using the average transmission failure for each level (RAN and EPC), we derive the probabilities of failure as follows:

$$PF_{RAN} = \frac{AVG_{RAN}}{AVG_{RAN} + C_{macro}}$$

$$PF_{MME} = \frac{AVG_{MME}}{AVG_{MME} + C_{MME}}$$

4.3. Delay

According to the proposed system model we can derive only the average minimum access delay, as the maximum delay could be infinite: we assumed that the same message is sent until successful reception. The minimum access delay is defined from the generation of the message until the reception of this message by the MTC application server. Here, we consider only one transmission attempt. This delay includes the average waiting time for the granted time interval and the access delay. The average waiting time is $T_{cycle}/2$, while the average access time in the time grant interval is $T_f/2$. Consequently, the average minimum delay is expressed as follows:

$$D_{min} = \left(\frac{T_f + T_{cycle}}{2}\right) * (1 - P_f) + \left(\frac{T_f + 3T_{cycle}}{2}\right) * P_f$$

where P_f is the total probability of failure, and is obtained as follows:

$$P_f = PF_{RAN} + PF_{MME} - RF_{RAN} * RF_{MME}$$

5. Performance evaluation

5.1. System parameters

In this section, we evaluate the performance of one of the proposed solutions, namely Solution 2, named as profile ID-based mechanism. We compare the proposed solution with the case of only grouping MTC devices, referred to as simple grouping mechanism, and the case of bulk signaling, referred to as bulk signaling method, as proposed in [20]. Table 2 shows the system parameters used in the numerical analysis. As an example, we use TAU message

Table 2
Parameter settings.

Parameter	Value
Number of macrocell (N_{macro})	40
Number of MTC devices per group (G_{mtc})	2000
Number of groups in each macrocell (N_{gmtc})	2
Capacity of MME in grouping mechanism	35,000
Capacity of RAN in grouping mechanism	1000
Capacity of MME in profile ID mechanism	42,700
Capacity of RAN in profile ID mechanism	2000
Waiting time in bulk mechanism	1 s

as the signaling message considered for profile creation. As stated before, we can create a profile and reduce the initial message size of 15 bytes to 5 bytes. Therefore, in case of using profile ID, the capacities, of handling TAU messages from MTC devices, of both RAN and EPC nodes increase by at least a factor of 2 and 1.5, respectively. This is attributable to the fact that at the RAN level, the message processing capacity during the granted time interval depends on the number of messages as well as the message size. Therefore, by decreasing the message size automatically the capacity increases with the same proportion. For MME, the message handling capacity depends on the queue length and the service rate. The smaller the messages size is, the lower the service rate becomes (i.e., a few fields to treat in the message). Accordingly, in the profile ID-based mechanism, the capacities (C_{MME}) and (C_{RAN}) are intuitively higher.

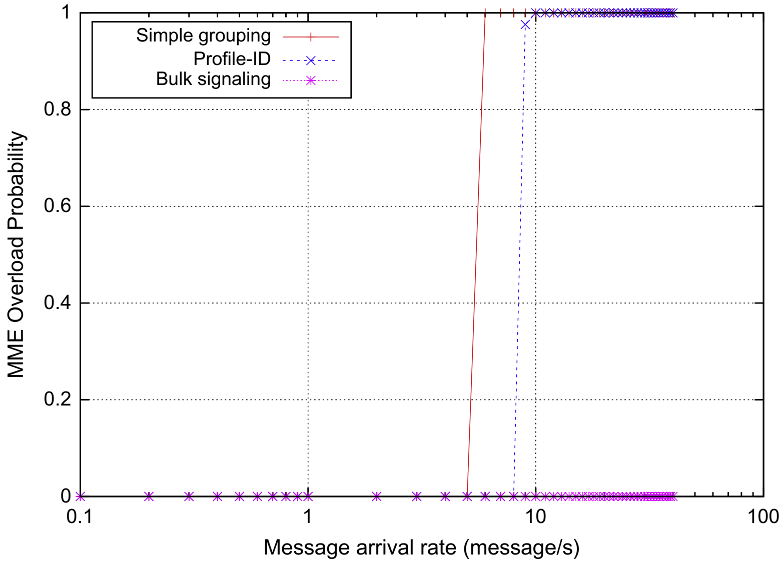

Fig. 7. MME (EPC) overload probability.

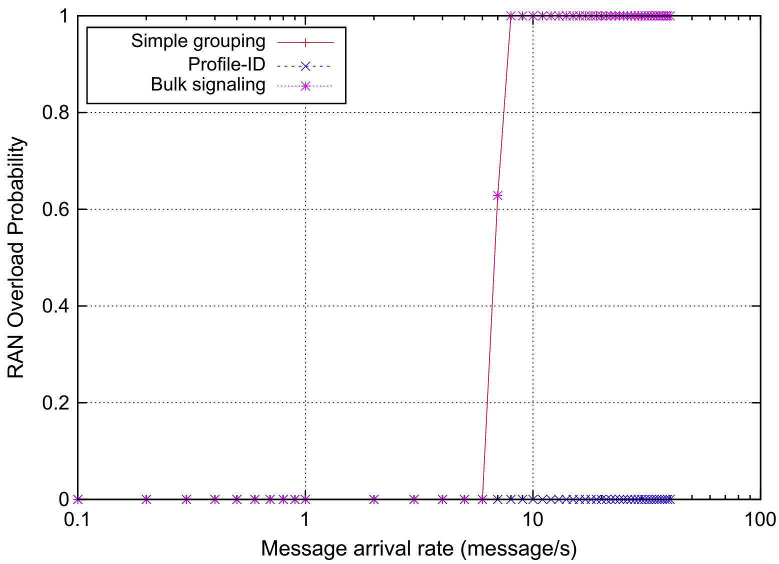

Fig. 8. RAN overload probability.

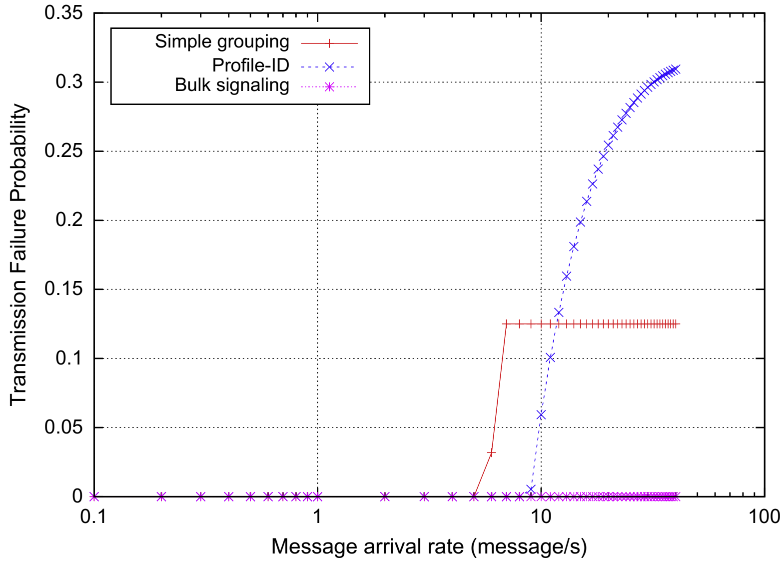

Fig. 9. Average probability of transmission failures due to MME overload.

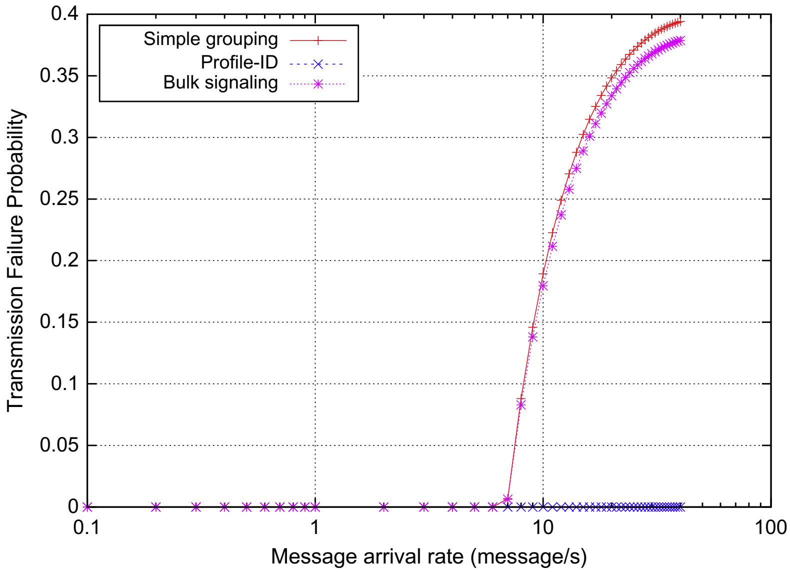

Fig. 10. Average probability of transmission failures due to RAN overlaod.

5.2. Numerical results

Figs. 7 and 8 plot the overload probabilities of MME and RAN in case of the three mechanisms. We clearly observe that the bulk signaling can efficiently avoid EPS overload as it groups a number of signaling messages into a bulk (one message). However, similar to the simple grouping mechanism, it overloads RAN as MTC messages are grouped only when they are successfully received by RAN eNBs. On the other hand, profile ID-based mechanism reduces the overload at both RAN and EPC. At MME, it permits handling more MTC messages before overloading the system, compared to the simple grouping mechanism. It thus ensures better utilization of the network resources and improves system reliability compared to the classical grouping mechanism. Furthermore, the profile ID-based solution ensures that RAN runs without being overloaded, and hence succeeds in anticipating the system overload, thanks to the message size reduction. The impact of the overload probability can be noticed from Figs. 9 and 10, which plots the probabilities of transmission failures due to MME and RAN overload for the three mechanisms, respectively. As in Fig. 7, the bulk signaling mechanism achieves zero failure at MME. In case of the simple grouping mechanism, this probability of failures arises when the message arrival rate is around four messages per seconds.

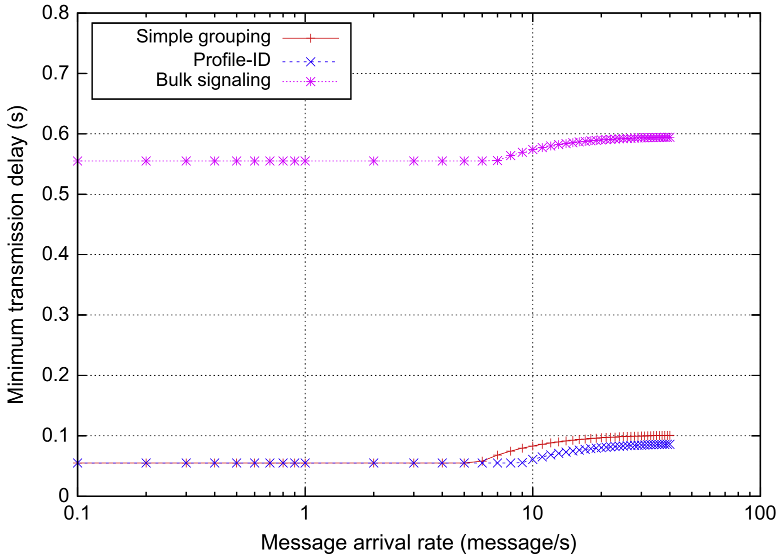

Fig. 11. Minimum transmission delay.

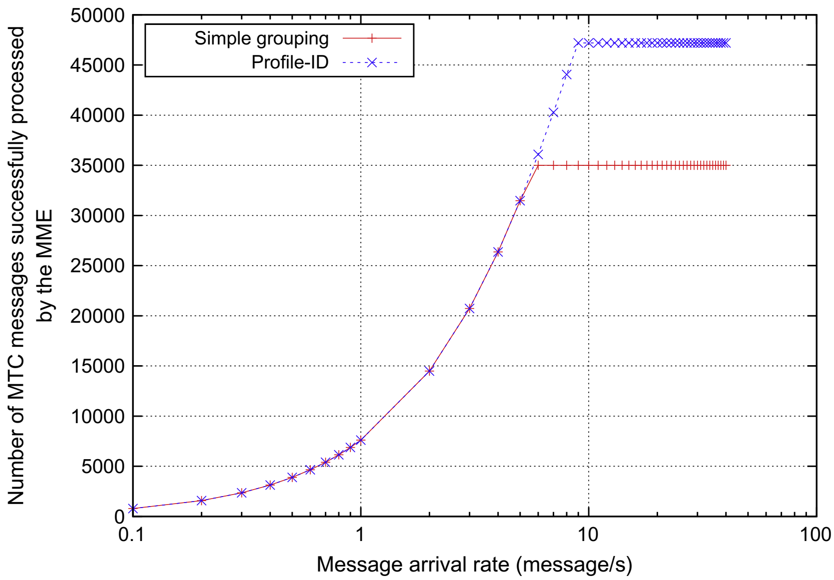

Fig. 12. Number of MTC messages successfully proceeded by MME during a T_{cycle}.

This probability reaches 0.12 and remains constant from a rate of seven messages per seconds. This is attributable to the fact that from a rate of seven messages per seconds the overall system (RAN and MME) gets overloaded and the number of MTC messages coming from the macrocells are constant and equal to ($C_{macro\text{-}grouping} * N_{macro}$). In contrast, as the profile ID-based mechanism reduces the TAU size (allowing to handle more MTC messages), this probability grows (from nine messages per second) until reaching the maximum value ($C_{macro\text{-}profilid} * N_{macro}$) when the message arrival rate reaches 40 messages per second.

Regarding the probability of transmission failures due to RAN overload, we notice that creating a profile ID ensures message transmission without failure. In case of the simple grouping and bulk signaling mechanisms, this probability grows from eight messages per second until reaching 0.37 and 0.4, respectively. The slightly better performance of the bulk signaling method is principally due to the fact that bulk signaling mechanism achieves almost no failure due to MME overload, which reduces the otherwise message retransmissions and consequently failures at RAN.

Fig. 11 shows the average minimum delay achieved in case of the three mechanisms. The same trend as for the precedent results is seen in this figure. Indeed, the best results are achieved by the profile ID-based mechanism, as the probabilities of transmission failure due to RAN and

MME overload are lower than in case of the simple grouping mechanism. However, the bulk signaling method exhibits higher delays as the MTC signaling messages are kept for an average of 0.5 s before being processed by RAN in bulk and sent to EPC. Fig. 12 illustrates the average message successfully processed by MME during a T_{cycle}. As seen in Fig. 8, the simple grouping mechanism reaches its maximum capacity when the message arrival rate is equal to four messages per second, while in case of profile ID-based mechanism, the maximum capacity is reached at nine messages per second.

6. Conclusion

MTC deployments over 3GPP networks present promising business opportunities for network operators to increase their revenues and cope with the stagnant average revenue per user (ARPU). However, there is still a gap between deploying MTC and coping with the network overload they may incur. In this paper, we introduced different solutions to mitigate the issue of network overload due to MTC signaling. The first solution renders the triggering operation less costly in case of triggering low mobility MTC devices, by limiting the triggering operation to a specific network area and also by reducing the number of involved network nodes, mainly MME. The second solution compacts the size of signaling messages sharing common information elements in order to reduce the communication and processing loads at the system interfaces and nodes, respectively. As a further improvement to the second solution, we proposed a dynamic grouping procedure for MTC devices having common subscriber features. Through numerical results we demonstrated the viability of the second solution in achieving its design goals, namely alleviating congestion and reducing the system overload that may be caused by MTC signaling. Admittedly, the exact gain in terms improving the EPS performance, shortening the overall procedure processing time/load, and reducing the system overload depends on the traffic behavior and the underlying equipment. Unfortunately, vendors as well as operators do not publicize relevant specifications and details. The gain cannot be thus accurately quantified. The presented results shall therefore serve for only a high level qualitative comparison between the proposed solutions and the considered comparison terms.

References

[1] 3GPP TS 23.682, Architecture Enhancements to Facilitate Communications with Packet Data Networks and Applications, Version 11.0.0, 2012-03-12.

[2] 3GPP TS 23.368, Service Requirements for Machine-Type Communications (MTC).

[3] 3GPP TS 23.007, Restoration Procedures, 11.0.0, 2012-12-2.

[4] 3GPP TS 23.857, Study of Evolved Packet Core (EPC) Nodes Restoration, 11.0.0, 2012-06-22.

[5] 3GPP TS 23.866, Study on System Improvements for Energy Efficiency, 12.0.0, 2012-06-22.

[6] 3GPP TS, General Packets Radio Service (GPRS) Service Description, 11.4.0, 2012-12-18.

[7] 3GPP TS 36.300, E-UTRA and E-UTRAN Overall Description, 11.4.0, 2013-01-03.

[8] 3GPP TS 36.304, User Equipment (UE) Procedures in Idle Mode, 11.2.0, 2013-01-03.

[9] 3GPP TS 29.272, MME and SGSN related interfaces based on Diameter protocol, 11.5.0, 2012-12-21.

[10] 3GPP TS 29.212, Policy and Charging Control (PCC) Reference Points, 11.7.0, 2012-12-20.

[11] 3GPP TR 23.888, System improvements for Machine-Type Communications (MTC), Version 1.6.1, 2012-03-08.

[12] 3GPP TS 23.401, General Packet Radio Service (GPRS) Enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Access, Version 11.1.0, 2012-03-12.

[13] Study on Core Network Overload Solutions; TR 23.843 V0.4.0 (2011-04).

[14] T. Taleb, K. Samdanis, Ensuring service resilience in the EPS: MME failure restoration case, in: Proc. IEEE Globecom 2011, Houston, Texas, USA, November 2011.

[15] Mark Jones, Diameter Group Signaling, IETF draft-jones-diameter-group-signaling-00, November 2011.

[16] M. Liebsch, Diameter Group Signaling – Progress Towards a Suitable Solution, IETF82, November 2011.

[17] Diameter Maintenance and Extensions (DIME) WG. <http://datatracker.ietf.org/wg/dime/charter/>.

[18] A. Ahmed, A. Ksentini, Y. Hadjadj-Aoul, T. Taleb, Congestion control for machine type communications, in: Proc. IEEE ICC 2012, Ottawa, Canada, June 2012.

[19] A. Ksentini, Y. Hadjadj-Aoul, T. Taleb, Cellular-based machine-to-machine: overload control, IEEE Network Magazine 26 (6) (2012) 54–60.

[20] T. Taleb, A. Kunz, Machine type communications in 3GPP networks: potential, challenges, and solutions, IEEE Communications Magazine 50 (3) (2012).

[21] A.-H. Tsai, L.-C. Wang, J.-H. Huang, T.-M. Lin, Overload control for machine type communications with femtocells, in: Proc. Of IEEE VTC Fall 2012, Quebec, Canada, 2012.

[22] S.-Y. Lien, K.-C. Chen, Massive access management for QoS gaurantees in 3GPP machine-to-machine communications, IEEE Communications Letter 15 (3) (2011).

[23] S.-Y. Lien, K.-C. Chen, Y. Lin, Toward ubiquitous massive accesses in 3GPP machine-to-machine communications, IEEE Communication Magazine 49 (4) (2011).

[24] KPN TSG SA, Problem of overload control with machine type communications, in: 3GPP Meeting 10ΓÇô14 May, 2010, Kyoto, Japan.

[25] T. Taleb, A. Ksentini, Impact of emerging social media applications on mobile networks, IEEE ICC 2013, Budapest, Hungary, June 2013, accepted for publication.

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