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Grouping Aggregation and On-Demand Parsing Mechanism for Congestion Mitigation in 3GPP Machine-to-Machine Communications

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Abstract: Challenges associated with the deployment of Machine Type Communication (MTC) over 3GPP cellular network focus on the overload control and congestion mitigation introduced by potential numbers of 'smart devices'. Bulk processing mechanism, common to handling a group of similar control sessions, is a promising solution, however, there are still little work exploring the protocol-layer procedure optimization for the signaling sessions of group-based MTC application. This study mainly examines the in-building smart monitoring scenario and puts forward some novel schemes that efficiently aggregate and parse a bulk of Session Initial Protocol (SIP) sessions simultaneously from numerous MTC machines. By investigating the unique features of the group-based MTC applications and the media description fields of the Session Discovery Protocol (SDP), this study generates some new extension attributes which are used as the group identifier for a bulk of MTC devices with common behaviors and then illustrates the aggregate procedure for SIP bulk sessions to control overload and then, in addition, carefully presents a Group-based On-demand Parsing Mechanism (GOPM) to efficiently process concurrent SIP sessions in downlink direction. Theory analysis and performance evaluation both prove that the MTC signaling traffics can be controlled when the network is overloaded and therefore the network congestion can be reduced effectively.

Key words: Machine-to-machine, SIP session aggregation, on-demand parsing, MTC gateway, group-based call, SDP extension attribute

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INTRODUCTION

During last decade, research efforts have been investigating to the Machine Type Communications (MTC) applications where an infinite number of heterogeneous 'smart things' can be seamlessly interoperated with each other (Zhang *et al*., 2011), the new applications can be emerged in a wide range of domains and in future they are expected to increase the number of connected MTC-capable devices with at least two orders of magnitude (Gao *et al*., 2013).

With the intention to exploit the potential opportunities and advantages, 3GPP Long Term Evolution-Advanced (LTE-A) cellular network has been regarded as the attractive solution facilitating Machine-to-Machine (M2M) communications (Salih *et al*., 2012). However, there are still diverse challenges, normally the machines are small and simple, MTC is designed for machines whereas, LTE-A is designed for human in heart. Moreover, due to a large number of devices, tremendous information traffic is gathered and congestions are more likely to occur, especially when massive attempts from a huge number of MTC devices simultaneously trigger connections and attachments to 3GPP cellular network all at once, traffic congestion and system overload can be significant which may tremendously impact on the performance of 3GPP LTE-A network (Nokia, 2010; Taleb and Kunz, 2012).

In 3GPP release 10 and beyond, network system improvements are defined by 3GPP System Architecture working group 2 (SA2) to support MTC applications in LTE core networks. There are two main possible solutions to alleviate congestion and control overload, one is the soft mechanism in (3GPP, 2010a) and the other is the rigid mechanism in (3GPP, 2010b). In the former proposal, 3GPP launch some soft measures to minimize the frequency of attempts from MTC devices such as back off based scheme (ZTE, 2010) and Access Class Barring (ACB) scheme (3GPP, 2011; Larmo and Susitaival, 2012). In the later proposal, 3GPP initial solutions such as separating Random Access Channel (RACH) resources scheme (Lee *et al*., 2011) and dynamic allocation of RACH

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resources scheme (Hasan *et al*., 2013). However, back off based scheme and separating RACH resources provide performance improvement only under a light congestion level. The ACB based scheme may lead to unacceptable response time delay and the performance of dynamic allocation of RACH resources scheme is limited by the availability of additional resources. In brief, solutions from the point of 3GPP radio network are restricted by the constrained resources.

Moreover, 3GPP deliver a group-based mechanism which processes a group of similar signaling messages from MTC machines in a single shot (Ksentini *et al*., 2012). In study, Lien and Chen (2011), the authors deliver the spirit of grouping the MTC devices into cluster according to their Quality-of-Service (QoS) features. Kwang-Ryul proposes to select a group leader entity within a local communication area and creates, in a dynamic way, a group ID to refer to a bulk of MTC devices with common behavior characteristics, this proposal accumulates the received uplink traffic to the MTC server and periodically merges them into an efficient format suitable for cellular network, thus traffic can be more efficient to MTC environments (Jung *et al*., 2010). However schemes for mapping a group of MTC devices into a common bulk one are still insufficient and unclear.

In this study, regarding in-building monitoring application as example, it especially addresses on the control-plane congestion avoidance from the aspect of signaling-layer protocol implement and procedure optimization for bulk processing. The key features and innovative characters of this work are (1) Statically creation of a group identifier in SIP header to identify the machines under the same MTC gateway and (2) Present a Group-based On-demand Parsing Mechanism (GOPM) to efficiently process concurrent SIP sessions in downlink direction. By this solution, the total amount of signaling messages is reduced dramatically, the process efficiency for SIP parsing is improved effectively, especially in massive devices concurrent environment.

SYSTEM MODEL AND KEY ISSUES ANALYSIS

System model: Figure 1 shows the typical architecture of in-building monitoring MTC network based on LTE-A

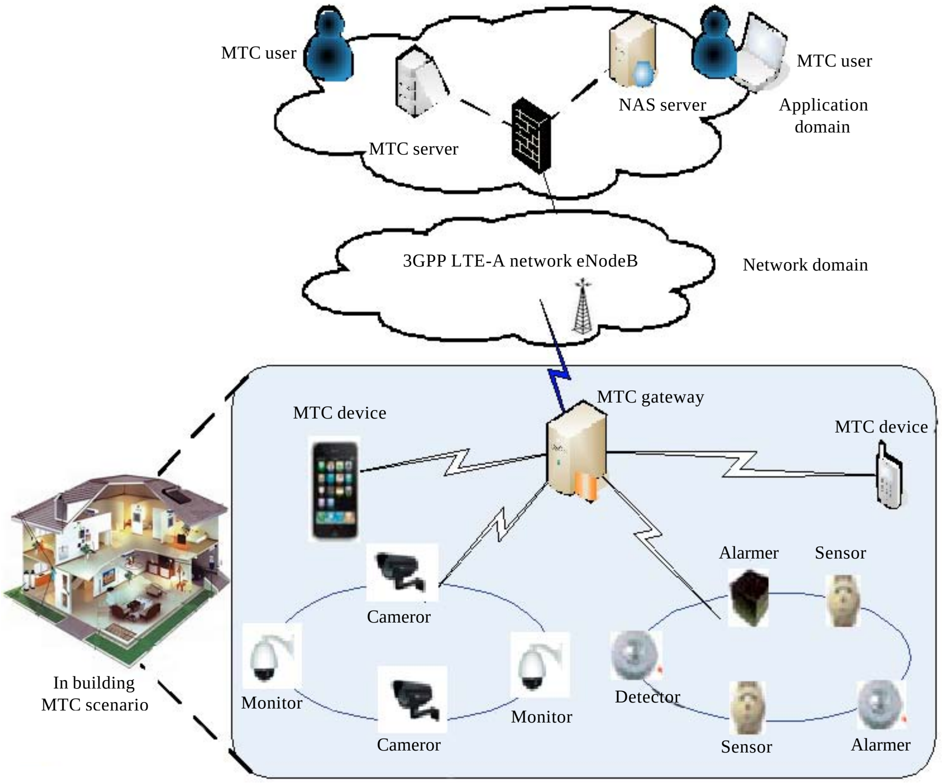

Fig. 1: Typical architecture of in-building monitoring MTC network

which has a backbone network and some multiple sub-networks. In the backbone network, there is a central MTC gateway (HGW) managing the whole network and connecting MTC network to LTE-A cellular network. The integrated voice, data, multimedia, session control, admission and QoS management functions are implemented by the HGW device so as to share external public network information and applications with the MTC devices within the building. HGW may be a variety of network equipment and consumer electronic devices such as home server, wireless router, Personal Digital Assistant (PDA) and etc. Each sub-network operates in a self-organized manner and may be designed for a specific application. As shown in Fig. 1, the remote video monitoring cameras, smoke detectors, fire sensors and infrared alarms are the typical MTC devices in building, HGW should process the SIP sessions on behave of MTC devices.

Problem description: Actually, the SIP sessions for MTC in-building monitoring application are divided into two directions: The uplink direction and the downlink direction.

In the uplink direction, HGW will process and transmit the SIP messages from MTC devices and then forward them to MTC user/server. Considering the event-driven nature and concurrent features, the messages that result from the detected events can easily cause congestion in the networks. So, the implement of SIP messages aggregation is crucial (Cheng *et al*., 2012). In other words, concurrent SIP session messages with the same characters, e.g., destination address, event type, transaction timestamp or service requirement, will be compressed or aggregated into one SIP message to reduce the signaling overhead and simplify the devices' management in terms of traffic, policing and charging.

In downlink direction, HGW will receive and parse the SIP messages from MTC server on behave of MTC device. Study of Liao *et al*. (2009), Cortes *et al*. (2004) and Zou *et al*. (2007) shows that the bottleneck is the SIP parsing capability of HGW device. For some specific functionality, HGW is not expected to know all the concrete information because some of them are redundant. It is not the entire but only parts of the SIP messages that HGW will parse in the SIP protocol stack. The parsing method optimized for a group of concurrent SIP messages will be significant to improve the processing efficiency of HGW device for congestion avoidance.

GROUP-BASED SIP AGGREGAGTION MECHANISM

Novel sdp extension attributes for group-based sessions: Thanks for the scalability of SDP protocol, the following novel extension attributes are defined: Media description domain in SDP message can be extended with new attribute 'a=' as the parsing of the Traffic Type Indication (TTI) field, Group Identification (GID) field and Global Unique Identifier (GUI) field, the definition states with multiple command lines as following:

```
Media description, if present
m = (media name and transport address)//m = <media><port><proto><fmt>
example: m= audio 49170 RTP/AVP 0
a = tti :<traffic-type>
//example a = tti : building_monitor
a =gid :<Group-Identification>
//example a =gid : building -monitor-alice (optional)
a=gui:<global-unique-identifier>
//example a=gui:<china-bupt-2039401x>(optional)
```

The GID field and the GUI field are optional. For the SIP message in grouping calling session, GID field is enabled and GUI field is disabled; On the other hand, for the general SIP message from a MTC device, the GUI field is enabled.

The GID field is allocated by a global Naming and Addressing Server (NAS), once the MTC devices in the same domain form a group, the MTC devices will register to the NAS to obtain a GID. The NAS server will record the location and domain of the MTC devices and their supported service type. In practice, the NAS server and the MTC server could locate in the same physical entity or in separated physical entities.

Procedure of request GID and group SIP URI: HGW is a SIP user agent that processes SIP messages and sessions and it triggers a MTC group registration procedure on behalf of the MTC devices. To do this, the HGW needs the group SIP URI and thus it obtains the group SIP URI by referencing the NAS server by sending a register message to the registrar in the NAS. The HGW's domain name is contained in the contact field of the register message.

Figure 2 shows the group SIP registration and grouping call session establishment procedure. MTC gateway sends initial information regarding the MTC devices to the 3GPP cellular network. The initial information may includes one or more GIDs for the MTC devices as one or more groups, respectively, number of the MTC devices in each group and/or number of MTC devices connected to the MTC gateway, a list of GUIs of the respective MTC devices, or MTC features of each MTC device.

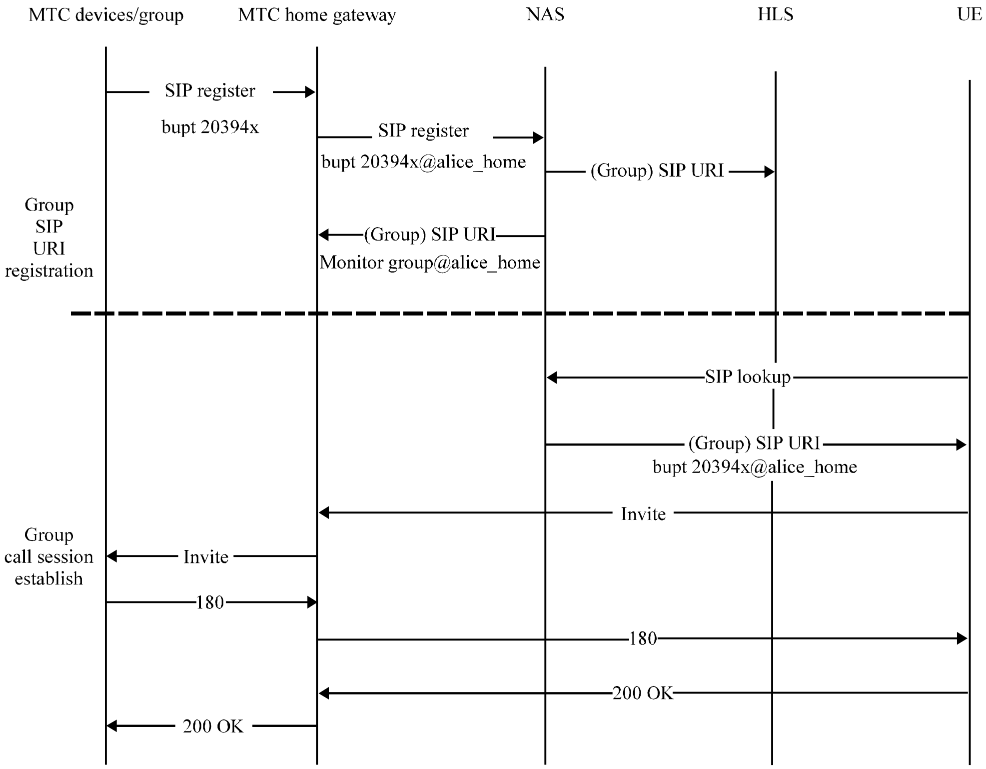

Fig. 2: Registration and establishment procedure for group sessions

The NAS is a distributed database that maintains the mapping relationship between MTC GID or GUI and their SIP URI. The NAS provides lookup or service similar to Object Naming Server (ONS) and DNS. The NAS takes MTC GID or GUI as input and returns SIP URI. The HGW or UE sends the concerned MTC device GUI or MTC devices group GID to the NAS in order to obtain their SIP URI. Then, the NAS finds out the SIP URI or SIP group URI for the received GUI or GID and returns it to the HGW or UE. If the UE wants to setup a session with the MTC devices group, the UE sends an Invite message to the corresponding HGW. Then the HGW replies with group SIP URI. In other words, if a MTC group resides under an HGW's administration, the HGW informs the UE of the MTC group's current group SIP URI by sending a 200 OK message that contains the HGW's IP address in the contact field. On receiving this 200 OK message, the UE learns the MTC group's current SIP URI by parsing the contact field. In addition, if the UE wants to monitor the MTC device group's condition, it can receive data from the HGW by exploiting the established SIP session.

Key issues analysis about grouping mechanism: The key issue in grouping mechanism is the algorithm which choose the group device member, pick up the group gateway and determine the group size dynamically, especially considering the vanish, presence and moving of MTC devices. For the grouping, simple protocol should be proposed to find each other and make a group within a local communication area. Also, the group leader selection algorithm should be designed based on communication capability, communication link quality, storage status and battery status of each node.

GROUP-BASED ON-DEMAND PARSING MECHANISM

Actually, for specific MTC devices, part of the SIP methods, headers or answer codes is enough to carry out the services, other information is redundant. Therefore, the SIP messages parsing functions should be paid attention to enhance the processing efficiency of HGW for grouping call.

The function of SIP specific parsing is described by the XML documents configured on the SIP server. When the system is initiated, these XML documents are loaded. On receiving the SIP messages, pre-defined headers of the message type defined in XML document are parsed by SIP server; whereas, the others not mentioned in the XML document are ignored directly or translated into message format that are interpreted by MTC device. As headers and their values are parsed based on specific rules, most of the SIP messages remain unparsed which enables significant savings in the processing time and the processing resource of HGW, comparing with full parsing. The parsing parts are based on application type and it can be defined according to some rules. And the new parsing method doesn't have impact on the interoperation of SIP devices.

Following codes show the general XML configuration documents:

```
<?xmlversion=”1.0”_Cencoding=”UTF-8”?>
<complexType>
<element name=”sip method” or “status code”>//On-demand parsing, such as INVITE
<element name =”tti”>//decide whether MTC device session or normal session
< complex Type>
<sequence>
<element name=“gid or gui”>//decide whether group or single device calling session
</sequence>//MTC device specific or group specific parsing
</complexType>
</element>
</complexType>
< complexType>
```

Figure 3 shows the MTC devices Group On-demand Parsing Mechanism (GOPM) which is based on the observation that a specific MTC group is primarily interested in a subset of the information contained in a SIP message. For example, for a basic call of the in-building monitoring application, the MTC group mainly concerns about the ‘From’, ‘to’, ‘CallID’ and ‘Contact’ headers of incoming SIP messages. HGW only parse the specific SIP messages for the MTC group in GOPM. The incoming SIP messages are given as following:

```
INVITE sip:alice @bupt.com SIP/2.0
Via: SIP/2.0/UDP pc33.bupt.com;
branch=z9hG4bK776asdhds
Max-Forwards: 70
To: alice <sip: alice @bupt.com>
From: Bob <sip:bob@ biloxi.com>;
tag=1928301774
Call-ID: a84b4c76e66710@pc33.biloxi.com
CSeq: 314159 INVITE
Contact: <sip:bob@pc33.biloxi.com>
Content-Type: application/sdp
Content-Length: 142
a= gui: Home-monitor-alice
```

The parsing messages of the MTC group are given as following:

```
INVITE//Message content
Bob//Source
Alice :Home-monitor-alice//Destination (Group ID/MTC Device ID)
a84b40@pc33.biloxi.com//Call-ID
sip:bob@pc33.biloxi.com//Contact
```

Furthermore, HGW translate the SIP message into format that is interpreted by MTC devices to decrease the SIP message overhead. In the design of application protocol of MTC device, parts of the SIP information may be selected as the MTC message format content. GDPS reduces the message interpret and processing delay.

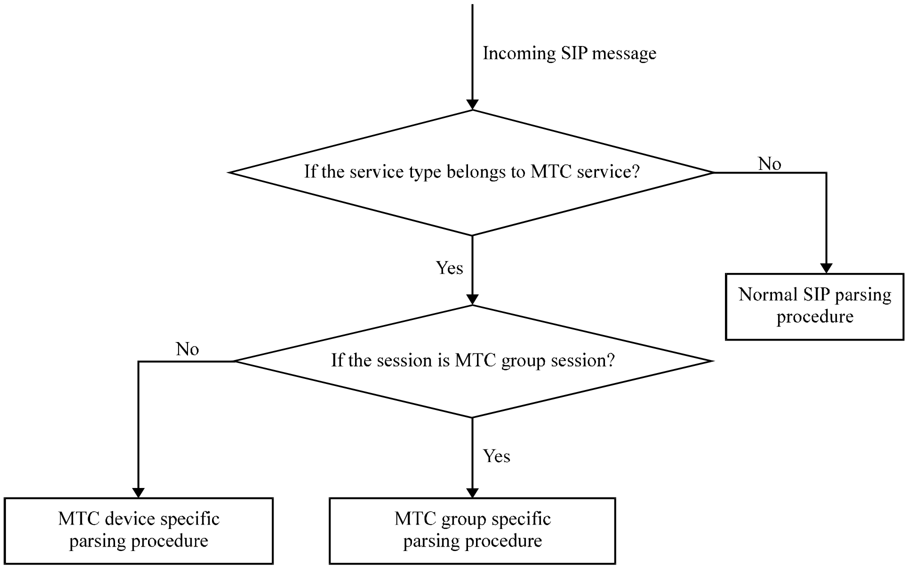

Fig. 3: Group-based SIP messages parsing

SIMULATION AND NUMERICAL RESULTS

HGW in Fig. 1 can be modeled as a tandem Jackson network entity comprising of several nodes with M/M/1 queuing. All arrived SIP messages are placed into the internal queues and served with First-In First-Out (FIFO) manner (Wanke *et al.*, 2007). The simulator is based on MATLAB 7.0. To evaluate the average queue delay of MTC session message, random seed are used in each run to generate the arrival time and departure time of MTC message based on the arrival rate and process rate. The MATLAB simulator is time-driven, in each time slot, we count the queue length and query delay of each message. Based on the statistics, reject or waiting operation is implemented to each session message. Total 200 msec is simulated in each run. Fifty random seeds (i.e., 50 runs) are tested to average the performance.

As shown in Fig. 4, there are normal MTC devices and group MTC devices in the HGW domain, denoted by N and M, respectively. The normal and grouping MTC services arrive at HGW comply with the Poisson Process with λ_n and λ_m, respectively. The service time at the first queue, called parsing queue hereafter, is exponentially distributed with μ_n and μ_m, respectively (Ohta, 2004). On leaving the first queue, SIP messages enter the next queue, called processing queue hereafter, where the service time has an exponential distribution with the parameter μ_i:

$$\sum_{i=1}^{N} \lambda_{n,i} = \lambda_n \tag{1}$$

$$\sum_{i=1}^{M} \lambda_{m,i} = \lambda_m \tag{2}$$

$$\lambda_n + \lambda_m = \lambda \tag{3}$$

According to Jackson theorem and Little's theorem, the mean delay time of a message spent in HGW is:

$$D = \frac{1}{\lambda}\left(\frac{\rho_0}{1-\rho_0} + \sum_{i=1}^{M} \frac{\rho_{m,i}}{1-\rho_{m,i}} + \sum_{j=1}^{N} \frac{\rho_{n,i}}{1-\rho_{n,i}}\right) \tag{4}$$

Thereinto:

$$\rho_0 = \frac{\lambda}{\mu_n + \mu_m}$$

$$\rho_{m,i} = \frac{\lambda_{m,i}}{\mu_{m,i}}, 1 \le i \le M$$

$$\rho_{n,j} = \frac{\lambda_{n,j}}{\mu_{n,j}}, 1 \le j \le N \tag{5}$$

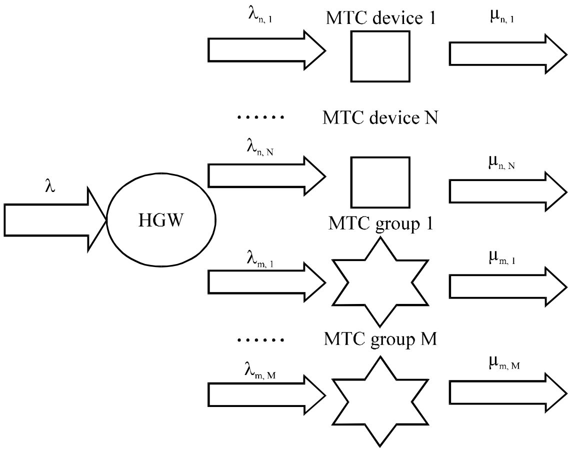

Fig. 4: SIP parsing in receiving direction

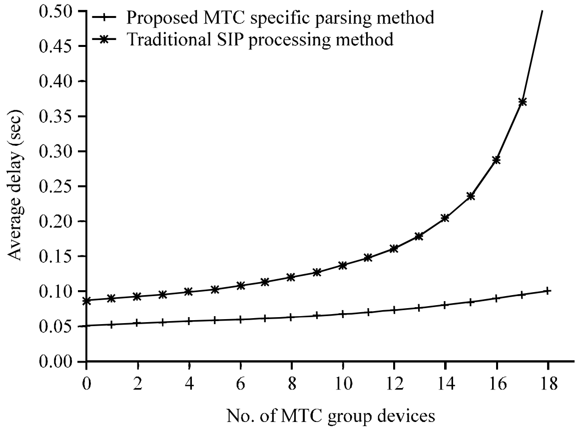

Fig. 5: Average delay of HGW SIP parsing mechanism

To illustrate the performance of MTC gateway SIP parsing mechanism, the average delay is chosen as the performance metrics (Abdulkafi *et al.*, 2012). The performance under normal SIP handling procedure is compared for reference. In normal SIP handling procedure, the process times in MTC gateway and MTC devices are relatively large.

Based on the experiment data and experience value, the process times in MTC gateway and MTC device using the parsing method $\mu_n = 30$, $\mu_m = 40$, $\mu_{n,i} = \mu_{m,i} = 60$. On the other hand, the process time using traditional method $\mu_{n,i} = \mu_{m,i} = 30$. There are 20 normal MTC devices and several MTC group devices in the MTC gateway domain. The traffic arrival rate of MTC device and MTC group device $\lambda_n = 2$, $\lambda_m = 1$.

Figure 5 shows the average delay with different MTC group devices number.

In the procedure of SIP aggregation, the total amount of exchanged SIP messages are reduced, therefore, the network overload and congestion are alleviated. This

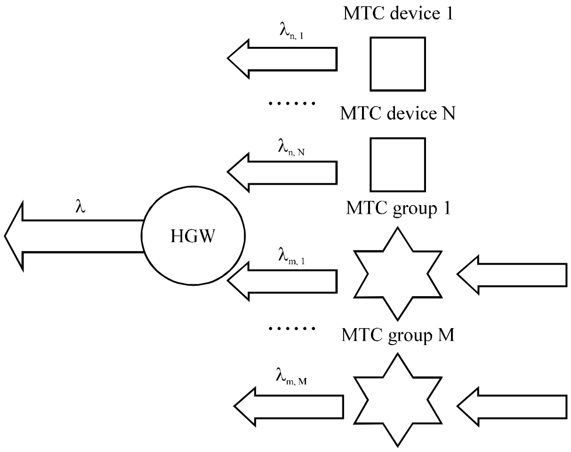

Fig. 6: SIP session aggregation in transmitting direction

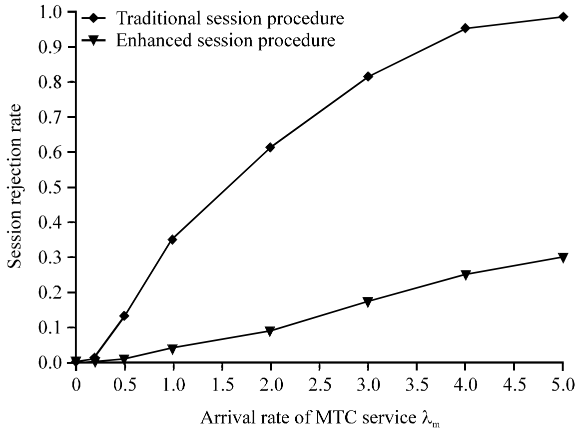

Fig. 7: Session rejection rate of HGW SIP aggregation Mechanism

study simulates the average SIP message delay by SIP aggregation mechanism and normal SIP session establishment. As shown in Fig. 6, the initiate SIP messages are modeled as FIFO Finite Delay Tolerate model. The SIP session request with larger query delay or query length than the threshold will be rejected. The reject rate represents the ability of alleviate network congestion.

The departure normal and grouping MTC services message arrival in the HGW comply with the Poisson Process with λ_n and λ_g, respectively. The service time at the queue is exponentially distributed with μ_n and μ_m, respectively.

Similarly, based on Little's theorem, the average delay in SIP message transmit procedure could be calculated as:

$$D = \frac{1}{\lambda}\left(\sum_{i=1}^{M}\frac{\rho_{m,i}}{1-\rho_{m,i}}+\sum_{j=1}^{N}\frac{\rho_{n,j}}{1-\rho_{n,j}}\right) \tag{6}$$

Thereinto:

$$\rho_{m,i} = \frac{\lambda_{m,i}}{\mu_{m,i}}, 1 \le i \le M$$

$$\rho_{n,j} = \frac{\lambda_{n,j}}{\mu_{n,j}}, 1 \le J \le N \tag{7}$$

The rejection rate of session I, denoted by R_i, could be defined as:

$$R_i = \text{Prob}\{D_i \ge D_{th} \| Q_i \ge Q_{th}\} \tag{8}$$

Thereinto: D_{th} is the maximum delay tolerate, Q_i is the query length when session i entry the query, Q_{th} is the maximum query length.

In this simulation, $D_{th} = 0.4$, $Q_{th} = 5$. The session arrival rate of MTC group device and normal MTC device $\lambda_n = 2$, $\lambda_m = 1$. The number of MTC device is fixed to 20. Figure 7 shows the average rejection rate performance with different MTC group service arrival rate. For comparison, traditional SIP session handle mechanism without SIP aggregation is evaluated.

CONCLUSION

Based on the analyses of MTC gateway SIP message process behaviors in MTC network, the SIP message specific parsing and aggregation procedures and related protocols support are discussed. Our study has demonstrated that the proposed SIP mechanisms of MTC gateway would reduce the network congestion and improve the network performance due to the introduction of massive MTC devices. This work presented here can be helpful for future research in the optimization for SIP protocols and mechanisms for MTC network based on IMS infrastructure with improved performance. Future work involves analyzing the MTC QoS feature metrics (e.g., priority access, low mobility, online/offline small data transmission, etc.) in conjunction with GID to cater for multiple applications scenario.

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REFERENCES

3GPP, 2010a. Architecture enhancements for Non-3GPP accesses. TS 23.402. http://www.3gpp.org/DynaReport/23402.htm

3GPP, 2010b. System improvements for machine-type communications. TR 23.888, V0.5.1. http://www.3gpp.org/DynaReport/23888.htm

3GPP, 2011. Study on RAN improvements for machine type communications. TR 37.868 V11.0.0, September 2011, France. http://www.qtc.jp/3GPP/Specs/37868-b00.pdf

Abdulkafi, A.A., T.S. Kiong, J. Koh, D. Chieng and A. Ting, 2012. Energy efficiency of heterogeneous cellular networks: A review. J. Applied Sci., 12: 1418-1431.

Cheng, M.Y., G.Y. Lin, H.Y. Wei and A.C.C. Hsu, 2012. Overload control for machine-type-communications in LTE-advanced system. IEEE Commun. Mag., 50: 38-45.

Cortes, M., J.R. Ensor and J.O. Esteban, 2004. On SIP performance. Bell Labs Tech. J., 9: 155-172.

Gao, Y., Y. Li, H.Y. Yu, X.F. Wang and S.H. Gao, 2013. System level performance of a novel dynamic CoMP scheduling in 3GPP LTE-advanced heterogeneous networks. Inform. Technol. J., 12: 424-428.

Hasan, M., E. Hossain and D. Niyato, 2013. Random access for machine-to-machine communication in LTE-advanced networks: Issues and approaches. IEEE Commun. Mag., 51: 86-93.

Jung, K.R., A. Park and S. Lee, 2010. Machine-Type-Communication (MTC) device grouping algorithm for congestion avoidance of MTC oriented LTE network. Proceedings of the International Conference on Security-Enriched Urban Computing and Smart Grid, September 15-17, 2010, Daejeon, Korea, pp: 167-178.

Ksentini, A., Y. Hadjadj-Aoul and T. Taleb, 2012. Cellular-based machine-to-machine: Overload control. IEEE Network, 26: 54-60.

Larmo, A. and R. Susitaival, 2012. RAN overload control for machine type communications in LTE. Proceedings of the IEEE Globecom Workshops, December 3-7, 2012, Anaheim, CA., UAS., pp: 1626-1631.

Lee, K.D., S. Kim and B. Yi, 2011. Throughput comparison of random access methods for M2M service over LTE networks. Proceedings of the IEEE GLOBECOM Workshops, December 5-9, 2011, Houston, TX., USA., pp: 373-377.

Liao, J.X., Q. Qi, T. Li, Y. Cao and X. Zhu, 2009. A demand-driven parsing method for SIP offload in home network. IEEE Trans. Consumer Electron., 55: 1308-1314.

Lien, S.Y. and K.C. Chen, 2011. Massive access management for QoS guarantees in 3GPP machine-to-machine communications. IEEE Commun. Lett., 15: 311-313.

Nokia, 2010. Discussion on MTC and RACH load. R2- 102889, Nokia Corporation, Nokia Siemens Networks.

Ohta, M., 2004. Simulation study of SIP signaling in an overload condition. Proceedings of the IASTED International Conference on Communications, Internet and Information Technology, November 22-24, 2004, St. Thomas, US Virgin Islands, pp: 321-326.

Salih, Y.K., O.H. See and S. Yussof, 2012. MIH: State of art and a proposed future direction in the heterogeneous wireless networks. J. Applied Sci., 12: 1318-1331.

Taleb, T. and A. Kunz, 2012. Machine type communications in 3GPP networks: Potential, challenges and solutions. IEEE Commun. Mag., 50: 178-184.

Wanke, S., M. Scharf, S. Kiesel and S. Wahl, 2007. Measurement of the SIP Parsing Performance in the SIP Express Router. In: Dependable and Adaptable Networks and Services, Pras, A. and M. van Sinderen (Eds.). Springer, New York, USA., ISBN: 9783540735298, pp: 103-110.

ZTE, 2010. R2-104662: MTC simulation results with specific solutions. 3GPP TSG RAN WG2 Meeting 71, August 2010.

Zhang, Y., R. Yu, S. Xie, W. Yao, Y. Xiao and M. Guizani, 2011. Home M2M networks: Architectures, standards and QoS improvement. IEEE Commun. Mag., 49: 44-52.

Zou, J., W. Xue, Z.Y. Liang, Y.X. Zhao, B. Yang and L. Shao, 2007. SIP parsing offload: Design and performance. Proceedings of the IEEE Global Telecommunication Conference, November 26-30, 2007, Washington, DC., USA., pp: 2774-2779.