

Congestion Control Optimization of M2M in LTE Networks

Jiann-Liang Chen, Han-Chuan Hsieh and Yanuarius Teofilus Larosa

Department of Electrical Engineering

National Taiwan University of Science and Technology, Taipei, Taiwan

Lchen@mail.ntust.edu.tw, D10007501@mail.ntust.edu.tw and larosa@ee.ntust.edu.tw

Abstract—This paper introduces optimization methods of M2M communication based on 3GPP standard. The optimization techniques are specified on M2M bearer within the mobile communication network. Its presentation intends to present an insight and approach to develop high quality communication frameworks for IoT data test-bed, based on Long Term Evolution (LTE) communications systems. The test-bed framework is achieved by featuring an emulation of Evolve Packet Core (EPC) construction using NetFPGA and OpenFlow platforms. The test-bed model will be expected to offer the sensitiveness control over IoT communication data type. In addition the emulation scheme provided by this test-bed will allow an extensive achievement toward M2M over LTE compliance for IoT integrated architecture in the near future.

Index Terms—Internet of Things (IoT), Machine-to-Machine (M2M), Human-to-Human (H2H), Long Term Evolution (LTE), NetFPGA, OpenFlow.

I. INTRODUCTION

Internet of Things (IoT) is entered its second decades of its research and development. Its milestone can be traced since Kevin Ashton and David L. Brock from MIT were pioneering the term of Internet of Things itself. Their vision is spreading out AutoID Lab research throughout the world. Now one has foreseen the current advancement of IoT technology in AutoID Lab. In MIT AutoID Lab two domain issues are addressed in IoT region. Started from 2009, MIT AutoID Lab works to develop Geolocation API to define a high-level interface that inferred from wireless network signals. Scientifically the Geolocation problem can be leveraged from the perspective of sensor node placement. It is related to a recent research from MIT researcher that found these issues interestingly by proposing a model of trigonometric polynomial scheme to decrease the error sampling data. Enabling global collaboration in tackling IoT research issues, AutoID Lab originated by MIT, ETH Zurich and St. Gallen University were initiating global IoT conference for every two years. The last conference took place in Tokyo addressed the issue of green technology. Sensor networks and mobile communications network are integrated and have become an inevitable trend. However, the design objective of mobile communication systems (LTE/WiMAX, 3G/2G, and WiFi) is Human-to-Human (H2H) communication, otherwise from the characteristics of Machine-to-Machine (M2M) communication. Diversification of M2M applications are developed and

implemented through enlightened communication networks, so the optimization methods to mobile communications network for M2M business development are essential to overcome the large scale signals.

Regarding the rapid development of mobile communications technologies and variety of enterpriser applications, the Network Heterogeneity issue is becoming more prominent. In this context, the Internet of Things as a new type of network architecture related to a telecom application services. Obviously, IoT is a mixed network, including sensor networks, wireless network, mobile communication network and Internet. How to improve the transmission performance in existing IoT network is considering and the heterogeneity of enterpriser devices for telecommunication information QoS control have more stringent on requirements, so, it would be the bottleneck of IoT development about the data rate smoothness in heterogeneous network.

The Internet has unexpected characteristics of the transmission of data and process a large number of destabilizing factors, and therefore prone to a large number of pending packets [1]. The IoT as an emerging and complex network, so, the unexpected data rate is inevitable. To overcome the data burst of IoT, a suitable algorithm is essential for root cause finding; it must be able to handle the burst of a large number of data rate from the network applications. In traditional network, the root causes of congestion: the network resources can not meet the demand of users, so the performance will drop and produce network congestion in more complex network and various device interfaces are inconsistent. If there is no any useful appropriate control measurement, it will definitely lead to network congestion. The root cause analysis of congestion in heterogeneous IoT network and a variety of existing network control algorithm is analyzed and summarized.

II. FUNDAMENTAL CONSIDERATIONS

A. M2M network Architecture

The 3G and LTE mobile communication networks are designed to server H2H communication services, but it is difficult to supply all services characteristics of M2M communication and adapt to the multimedia of M2M business show in Figure 1. It is a new topic to research the capability of a large scale of M2M applications. M2M network can be constructed in the mobile communication system to support all sizes

of M2M network. M2M nodes with a limited hierarchical aggregation to constitute a M2M network then connect to the mobile communication system with M2M gateway. The mobile base station directly connected the sensors with mobility, the sensors either nodes or gateway of M2M. No M2M nodes are essential for ad hoc networks, the minimize transmission delay to support the high real-time requirements of monitoring applications. The Mobile devices (such as mobile phones, notebook and tablet) with sensor function could be used as nodes and gateway of M2M [2].

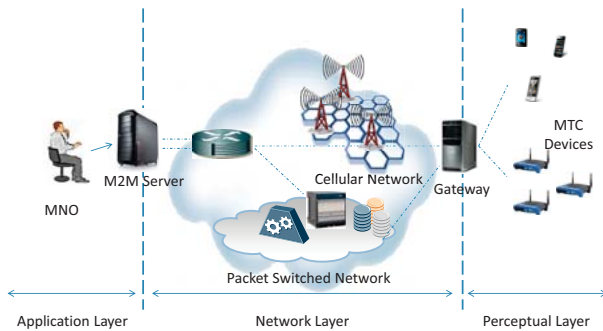


Fig. 1. 3GPP M2M Architecture.

B. LTE Network Architecture

Long Term Evolution (LTE) for the current emphasis by wireless network operators that a standard of 3GPP and will be implement for the future 4G networks, the goal of the System Architecture Evolution (SAE) effort in 3GPP is to develop a framework for the evolution and migration of current systems to a system which supports high data rates, low latency, all IP network packet-optimized and provides service continuity across heterogeneous access networks. LTE wireless broadband in addition to data for the design of optimized performance characteristics can be with another GSM service provider's network compatible, so no matter service providers are already deploying UMTS technology may apply to the architecture of LTE deployment, which can allow service providers to provide better through the application of LTE services. The 3GPP on LTE in January 2008 had been included in the official 3GPP R8 standard, released in December LTE R8 version of FDD-LTE standard that defines Standardized by 3GPP LTE architecture also known as Evolved UTRAN architecture (E-UTRAN) where the system using the Node B (eNB) and the receiving network gateway (eGW) composed of two functional modules shown in Figure 2 and interface points of LTE architecture in Table 1. Functional modules using WCDMA Node B network transport protocol, which can effectively reduce network complexity and cost of the delay time to reach the requirements, and has a radio resource management (RRM), User Equipment and Network QoS agreement between the location search, mobility management, and conversion between different receiver technology, security, encryption, file compression, request retransmission (ARQ),

IP address assignment, multimedia broadcast and multicast (MBMS) and other functions. Strategies used between Node B transmissions grid (Mesh) way links, as defined by 3GPP next generation network architecture [3].

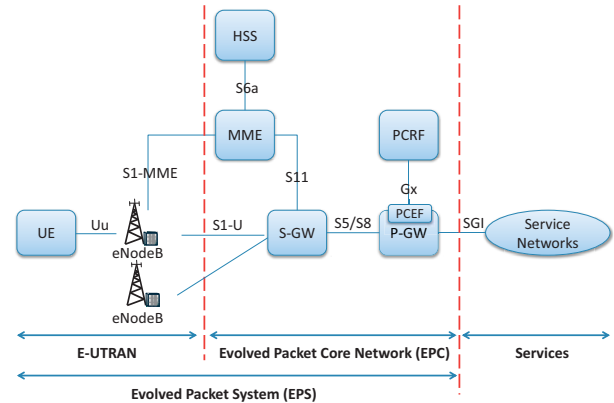


Fig. 2. Overview of the LTE network architecture.

TABLE I
LTE/EPS STANDARD REFERENCE POINTS.

LTE/EPS Standard Reference Points	
S1-MME	Reference point for the control plane protocol between E-UTRAN and MME.
S1-U	Reference point between E-UTRAN and Serving GW for the per bearer user plane tunneling and inter eNodeB path switching during handover.
S5-S-MIP	It provides user plane tunneling and tunnel management between Serving GW and PDN GW. It is used for Serving GW relocation due to UE mobility and in case the Serving GW needs to connect to a non-collocated PDN GW for the required PDN connectivity.
S6a	This interface is defined between MME and HSS for authentication and authorization.
Gx	It provides transfer of QoS policy and charging rules from PCRF to PCEF in the PDN GW.
S8	It is the roaming interface in case of roaming with home routed traffic. It provides the user plane with related control between Gateways in the VPLMN and HPLMN.
S11	This interface is reference point between MME and Serving GW.
S-Gi	Reference point between the PDN-GW and the packet data network. The packet data network can be a private or public data (IP) network or an intra-operator packet data network, e.g. for provision of IMS services.

C. NetFPGA Platform

The Net Field Programmable Gate Array (NetFPGA) is a low-cost open platform which is proposed by Stanford University. Shows on Figure.3, NetFPGA contains an FPGA [4], four 1 Gigabit Ethernet ports, some buffer memory (SRAM and DRAM), and a PCI interface. In originally, NetFPGA was only a platform which is design for a router implementation class in Stanford University [5], and then the school cooperated with some company such as Cisco [6], Google [7], Xilinx [8], and Juniper [9] to make it a product for research and experimentation. The Nowadays, more than 1,000 NetFPGA systems have been deployed at over 150 institutions in over 15 countries around the world because of its advantage includes line-rate, flexible, open platform, and enable fast networking hardware prototyping (e.g. modified Ethernet switches and IP routers) for research, and classroom experimentation.



Fig. 3. NetFPGA Platform Board.

D. OpenFlow-Capsulator Platform

The OpenFlow [10] is an open standard which is based on an Ethernet switch, with an internal flow-table, and a standardized interface to add and remove flow entries in the network environment [11]. Imagine that if every developer wants to build their own network in laboratory for experiments, much resource they would spend? As a result, campus network seems to be the best solution. However, if the experiment affects the original campus network, that may destroy the campus network. Network virtualization is the way to solve this problem which not only can control the packets routing but also can approach the load balance by sharing the load to other unused wire, Figure 4 shows the OpenFlow implementation.

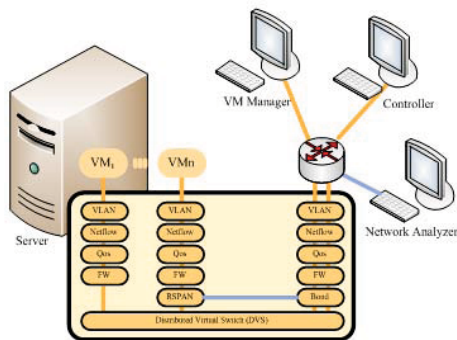


Fig. 4. OpenFlow network topology.

III. PERFORMANCE ANALYSIS

A. Challenging Problems Discussion

When core network congestion shown in Figure 5, the E-UTRAN should be identified and promptly reject low priority MTC devices access in order to ensure high-priority devices including higher priority MTC devices. For this reason, Delay Tolerant indicator is issued by 3GPP for network congestion to endure long delays. The application for earthquake early warning system when network congestion must be overcome as soon as possible to let the pick in and update data, so not all of the MTC application can tolerate the time delay. When core network in congestion status, the eNB will reject or release the connection with higher delay tolerance, and feedback a backoff value. MTC applications no longer initiate the RRC connection, when the devices receive the message, then issue a timer to wait.

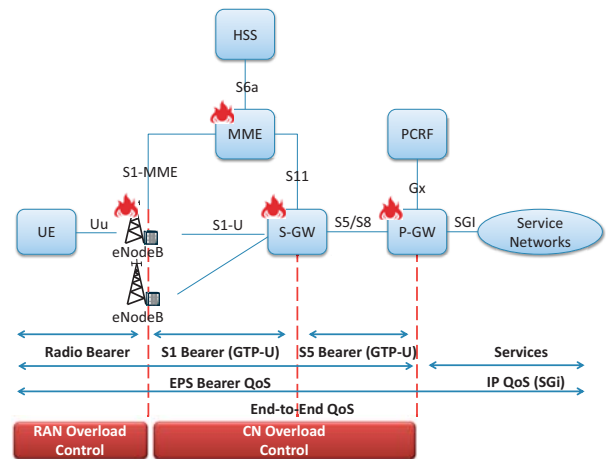


Fig. 5. Core Part of LTE Network.

E-UTRAN access control is implemented by the Access Class Barring function to inhibit excessive traffic and avoid congestion shown in Figure 6. When the devices to establish a connection, the devices should be the first implementation of the Access Class Barring check. If the check is successful, the devices will send the RACH preamble, start for RRC connection process.

A large scale MTC device access network simultaneously will issue huge capacity of RACH messages and RACH preamble collision probability, so the collision probability of devices will also increase. Dynamic allocation of RACH resources to solve MTC device network access issue: some of the RACH resources used for MTC, the other for communication network devices, in the other words, the collision probability of MTC devices will not impact on communication network devices and the RACH resource allocation based on radio status to dynamic adjustment in the communication network.

The purpose of time and frequency domain scenarios will increase RACH resources. In Time domain scenario, when the eNodeB detected the peak of the random access is coming (such as Preambles utilization exceeds a predefined threshold), PRACH resources Paging or SIB can temporarily increase one or more sub-frame. In Frequency domain scenario, there are 6 RB for RACH access resources occupied as follow LTE specific. When the eNB detected the peak of the random access is coming, Paging or SIB to temporary increase 6 RB RACH resources.

The backoff time of initial access is zero as LTE network setting, when access is not successful, the eNB will inform the devices to a specific rollback time, devices will issue a random value between zero and backoff time, the device will trigger an access behavior until backoff time is up. Dedicated RACH. This method is a definition of the MTC device access period / time slot such as paging cycle / slot, each MTC device can only access specific slot and the slot dedicated by ID (IMSI).

The MTC applications in smartmeter scope for Mobile Originating call are not allowed. The MTC Server to trigger MME

corresponding to paging MTC devices, and only paged devices could access network and upload data. The Paging message must contain each paging ID, and only the devices with ID will respond to paging messages. The method introduces the concept of the group ID assignment in MTC devices, you can send paging messages, all belong to the group ID of the MTC device will respond the message. By using the group ID, greatly reduce the paging overhead. In addition, the size modification of the group could control the number of MTC devices to access the wireless network.

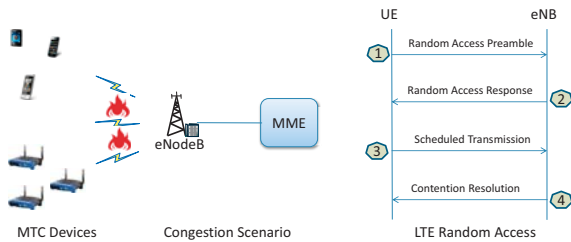


Fig. 6. Radio Part of LTE Network.

B. Performance Analysis

Once the network connection is established by signaling actions follow the action A and B preferences, the flow maintenance is needed to assure the quality regarding to connection setup signaling. Different from network setup action, in this part the assignment of actions are not taken into account anymore. Instead the entire transit nodes are having the equal impact on the traffic quality as well as its contribution to enhance the total link. It is necessary to be reminded that EA LTE always considered as the highest determination for the traffic flow. In Figure 7 the identification of events are separately distinguish among nodes. Denote the sub-event as E_{esn} where four sub-events and two external events forming end to end event denotes by E_{end} . During the application traffic flow is expected that no events occur to interrupt the current flows, that global denotation for $E_{end} = \phi$. $E_{end} = \phi$ occurs when either E_{esn} are emerged in random occasion. Set of E_{esn} will accumulatively determine the EA actions in giving the budget for traffic flow.

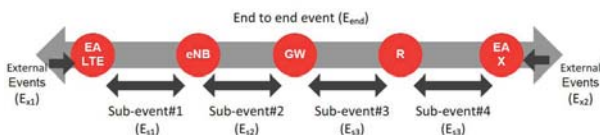


Fig. 7. Test flow event identification.

In Figure 7 the identification of events are separately distinguish among nodes. Denote the sub-event as where four sub-events and two external events forming end to end event. During the application traffic flow is expected that no events occur to interrupt the current flows, that global denotation

occurs when either the are emerged in random occasion. Set event identification will accumulatively determine the EA actions in giving the budget for traffic flow.

- Sub-event#1 acts as the control configuration toward eNB, at least there are six functions are possibly applied: radio resource control (RRC), packet data convergence protocol (PDCP), radio link control (RLC), MAC, and PHY. Those control modules are possibly to be invoked during traffic flow.
- Sub-event#2 addresses the event in accordance with EPS bearer control. Here also need to remind that EPS is consisted by S-GW and P-GW, where the EPS bearer is in relation with P-GW. The S-GW itself is defined as the local event between eNB and GW.
- Sub-event#3 appears as the random occasion on IP network/Internet domain where the scale this event source is very extensive. Therefore the identification of link event here is function as the congestion and flow control parameters control. The emerging of the events is considers that the specific QoS parameter such as delay and throughput has accordance with R and GW queuing discipline model.
- Sub-event#4 gives the link event as the traffic flows on the edge router. The same function of sub-events 1 will be applied on the Sub-event 4 if in case that X of $EA = LTE$.

IV. CONCLUSION

Analysis of congestion control strategy for MTC network, the following several cases are considering: wireless network consisting; a mixed of wired and wireless network congestion. Congestion control of MTC network requires the congestion caused by the co-ordination of the above three reasons, the manifestation of network congestion is the excessive number of TCP connections in the network, the forwarding capacity is limited, the decline in network transmission capacity and reliability drop, then known as network congestion. When congestion is severe, the throughput may be a serious decline, it was said that network crashes.

Part of MTC network was constituted of wireless network, so its congestion causes are following:

- 1) Bit error rate (BER) on the transmission performance: a wired network has a good error control mechanism (Error Correction Mechanism), but wireless network dues to its uncertainties, resulting in a variety of unpredictable error, no effective mechanism for error handling, and can not be effective recovery.
- 2) Frequently switch impacts on network quality: the network switching as wired to the wireless switch, wireless to wired switch, and location update of mobile devices lead to network data traffic switching will affect the network performance.
- 3) No effective mechanisms of error monitoring: it is usually that a wireless network can only monitor the discarded packet not be effectively discarded because of an error was detected, and it can not be correct according to the specific cause of the error recovery.

The remaining task need to be accomplished by this framework is how to show the accuracy of the test-bed in running some types of IoT application. With giving the trial over various applications, the system will become more mature, moreover for future expectation, one can see how communication entity will contribute its role upon QoS assessment for IoT framework. In addition this future approach will give knowledge on how to pursue the balance between prominent entities of IoT.

ACKNOWLEDGMENT

This work is a partial result of project No. 101-2219-E-011-002 conducted by National Taiwan University of Science and Technology (NTUST) under the sponsorship of the National Science Council, ROC. The authors also thank for the support from project 101MG07-1 and 100H451602 conducted by NTUST.

REFERENCES

- [1] B. David, E. Omar, H. Olivier, "M2M Communications: A Systems Approach," *John Wiley and Sons Ltd.*, pp.172-224, March 2012.
- [2] H. Olivier, B. David, E. Omar, "The Internet of Things: Key Applications and Protocols," *John Wiley and Sons Ltd.*, pp.223-246, Jan. 2012.
- [3] Hyung G. Myung, "Technical Overview of 3GPP LTE," May 2008.
- [4] Neda Beheshti, Yashar Ganjali, Monia Ghobadi, Nick McKeown and Geoff Salmon, "Experimental Study of Router Buffer Sizing," *Proceedings of the 8th ACM SIGCOMM conference on Internet measurement (IMC '08)*, pp.197-210, Oct. 2008.
- [5] NetFPGA, www.netfpga.org
- [6] Stanford University Class CS344: Building an Internet Router, <http://yuba.stanford.edu/cs344/>
- [7] Cisco, <http://www.cisco.com>
- [8] Google, <http://www.google.com>
- [9] Xilinx, <http://www.xilinx.com>
- [10] Juniper, <http://juniper.net>
- [11] OpenFlow website, <http://www.OpenFlowSwitch.org>