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Dynamic Resource Scheduling Algorithm For Public Safety Network

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***Abstract*— The public safety network adopted the long term evolution(LTE) to overcome bandwidth limitations and service quality. In disaster, the mission critical push to talk(MCPTT) service may become slow due to LTE traffic capacity limitations. There is a need to change the service priority in real time according to the MCPTT priority. We propose that the dynamic resource scheduling algorithms according to service priority. LTE radio resources could be allocated by MCPTT user service priority. The result of algorithms is increased 75% download speed than previous method.**

Keywords- LTE, MCPTT, Public safety network, Radio resource scheduling, MCPTT priority

I. INTRODUCTION

Public safety networks have been utilized by government responder in emergency situations, such as police officer, firefighters, and officer including environment. Mission critical communications network has been used in various sectors, such as construction, transportation, utilities, factories, and mining operations.

Technologies used in public safety networks and mission critical communication networks today are at a transition with next generation solutions and applications. The existing technologies such as Terrestrial Trunked Radio and Trunked Radio System have been is use for about 25 years now. They are mature, reliable, and cost effective in supporting mission-critical voice applications. However, they are not designed to support higher bandwidth applications [1].

Long term evolution (LTE), and LTE-Advanced which is developed by the 3rd Generation Partnership Project (3GPP). The standards organizations have indicated that their future strategy is to evolve into LTE based solution for public safety systems. LTE supports scalable bandwidths of up to 20MHz and LTE-Advanced shall support wider bandwidths than LTE (e.g., up to 100MHz) and drives an exponential rise in data usage. Mobile data traffic expects to increase 1000 fold from 2010 to 2020 [2].

In public safety network, the mission critical push to talk (MCPTT) service is defined several call type, such as private call, group call and emergency call caused by on or off network. Also, MCPTT user has service priority by user level and user service. For example, Command center has super user level and dispatcher has the right to intercept, so it can intercept anytime during the call.

The 3GPP defined service level priority control. However, it is need to define the evolved packet core network priority. For example, mobile traffic is quickly higher in emergency situation. Multiple user access to network and they will be used download and upload traffic in same time. So, the MCPTT user service traffic speed is worse because of radio resource capacity limitation. The MCPTT user such as policeman and firefighter needs to send their video about this situation. So it is need to protect MCPTT user network quality.

In this paper, we propose MCPTT user scheduling algorithms. This algorithm allocates radio resource by MCPTT priority policy. If the accident is occurred, this algorithm has two cases by MCPTT user and command center.

Also, we purpose a MCPTT user radio resource control guideline for late runner in public safety network. We demonstrate improvement point about dynamic resource scheduling algorithms through a field test.

The rest of this paper organized as follows: section 2 introduces public safety network and mission critical push to talk service, Section 3 explains radio resource allocation in LTE and propose dynamic resource scheduling algorithms, section 4 presents the results of algorithms in field. Section 5 provides conclusion of this paper

II. PUBLIC SAFETY NETWORK

The 3GPP has recognized the importance of supporting public safety network since Release 12, and defined a set of architectural requirements and technical specifications [3].

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Figure 1. Public safety network concept

The figure 1 shows that public safety network concept. Environmental changes are taking place as the industry becomes more complex and population density increases. It is changed global trend to quickly more complicate and unexpected. Disasters occur more frequently and damage becomes serious. So disaster detection and rapid disaster response are needed.

It is to evolve into LTE based solution for public safety systems. Multiple user such as policeman, firefighter and government officer use public safety network for disaster.

Figure 2. Mission critical Push to talk service concept

The figure 2 show that mission critical push to talk (MCPTT) service concept. The standard of 3GPP defined release 13 about MCPTT. The MCPTT call type is divided private call, group call and emergency call.

The MCPTT service provides specialized functions like intercept and listens to ambient sound. The MCPTT user has service priority by user level and user service. For example, Command center has super user level and dispatcher has the right to intercept, so it can intercept anytime during the call. The MCPTT also defines a special function that allows the user to listen to ambient sounds and images at the command center, regardless of the user.

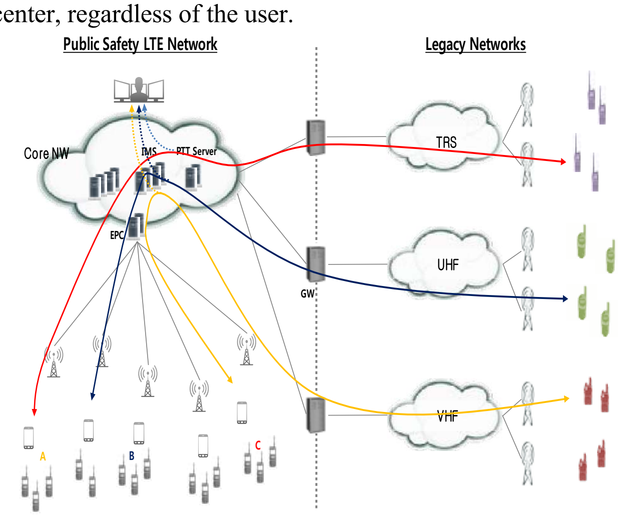

Figure 3. Public safety network diagram

The figure 3 shows that public safety network diagram. The MCPTT user can use the MCPTT service through the evolved packet core (EPC) and LTE network. It is also possible to communicate LTE with legacy network for TRS user who is an existing legacy network. The public safety network uses the LTE network defined 3GPP and interworks the legacy network like VHF, TRS and UHF.

QCI	Resource Type	Priority Level	Packet Delay Budget	Packet Error Loss	Service
1	GBR	2	100ms	10^{-2}	Conversational Voice
2		4	150ms	10^{-3}	Conversational Video (Live Streaming)
3		3	50ms	10^{-3}	Real Time Gaming
4		5	300ms	10^{-6}	Non-Conversational Video (Buffered Streaming)
65		0.7	75ms	10^{-2}	Mission Critical user plane Push To Talk voice
66		2	100ms	10^{-2}	Non-Mission-Critical user plane Push To Talk voice
5	Non-GBR	1	100ms	10^{-6}	IMS Signaling
6		6	300ms	10^{-6}	Video (Buffered Streaming) TCP-based
7		7	100ms	10^{-3}	Voice, Video (Live Streaming) Interactive Gaming
8		8	300ms	10^{-6}	Video (Buffered Streaming) TCP-based
9		9	300ms	10^{-6}	
69		0.5	60ms	10^{-6}	Mission Critical delay sensitive signaling
70		5.5	200ms	10^{-6}	Mission Critical Data

Figure 4. Standardized QCI and QoS parameter

It is very important to provide seamless PTT service to MCPTT users. The 3GPP priority system using quality of service(QoS) class idendifier(QCI) is expected to be used for relative priority treatment among communications at the transport level. The figure 4 show that QoS and QCI. The MCPTT service is defined QCI 65 and 66 for voice service and QCI 69 and 70 for data service [4].

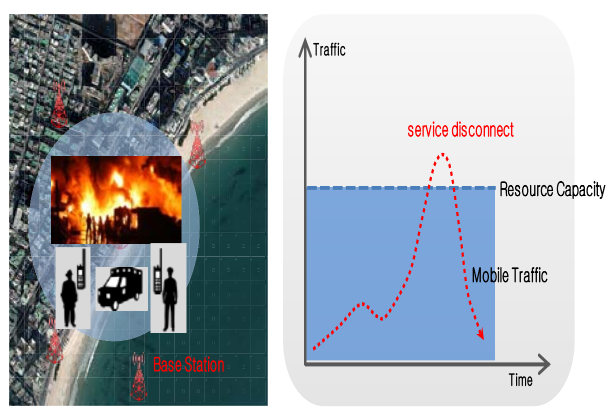

Figure 5. LTE traffic jam by disaster

If disaster occurs, a lot of people will come to the disaster area. Mobile traffic also increases when MCPTT users are concentrated in dense areas. If the capacity to handle traffic is exceeded, the MCPTT service is disconnected due to system capacity. At this time, the MCPTT user who needs to recover from the disaster can't communicate. The figure 5 shows that LTE traffic jam by disaster.

The MCPTT user such as policeman and firefighter needs to send their video for command center about this situation. So it is need to protect MCPTT user service for first.

III. MCPTT USER SCHEDLING ALGORITHMS

We purpose the MCPTT user scheduling algorithms. First, we explain MCPTT priority control as following 3GPP. Second, the method of radio resource is following. Finally, we purpose MCPTT resource scheduling algorithms by equations and floor chart. MCPTT priority changes can be accessed in two cases. The first is when the user requests and the second is when the command center requests.

A. MCPTT prioirity control

MCPTT Priority and QoS is situational. The MCPTT Service is intended to provide a real-time priority and QoS experience for MCPTT calls, as public safety users have significant dynamic operational conditions that determine their priority. For example, the type of incident a responder is serving or the responder's overall shift role needs to strongly influence a user's ability to obtain resources from the LTE system [5].

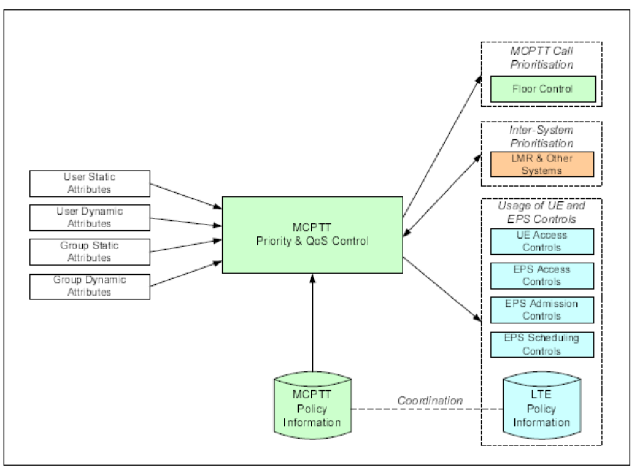

Figure 6. A conceptual on-network MCPTT priority model

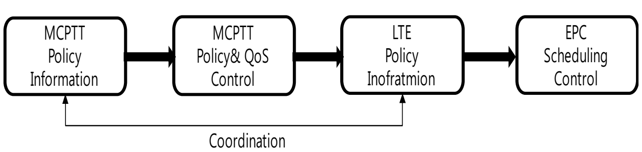

Figure 7. A conceptual MCPTT policy control model

The figure 6 and 7 show that MCPTT policy control model. MCPTT user policy information coordinates LTE policy information. EPC scheduling control uses MCPTT policy information by LTE policy information.

B. Resource scheduling algorithms

A scheduling algorithm has to determine the allocation of bandwidth among the users and their transmission order. One of the most important objectives of a scheduling scheme is to satisfy the Quality of Service requirements of its users while efficiently utilizing the available bandwidth.

There are various kinds of resource scheduling algorithms and they can be selected according to the network operator. A typical algorithm is as follows.

- Weighted Fair Queuing(WFQ): It is a generalization of Fair Queuing(FQ). WFQ is a data packet scheduling technique that is used for various size packets, where packets are grouped in flows and each flow has its own weight.
- Frist In Frist Out(FIFO): FIFO is the simplest scheduling algorithm. Packets coming from all the input links were en-queued into a FIFO memory stack, and then they were de-queued one by one on to the output link [6].
- Round Robin (RR): The scheduler assigns resources cyclically to the users without taking channel conditions into account. This is a simple procedure giving the best fairness. But it would offer poor performance in terms of cell throughput.
- Proportional Fair (PF): The scheduler can exercise PF scheduling allocating more resources to a user with relatively better channel quality. This offers high cell throughput as well as fairness satisfactorily. Thus, Proportional Fair scheduling may be the best option [7].

C. Dynamic resource scheduling algorithms

We purpose dynamic resource scheduling algorithms based on MCPTT policy information. When allocating resource, we should take into account user channel quality, packet delay and logical channel prioritization. For MCPTT services, we set the priority calculation formula as follows [8].

$$F_U = W_i \ x \ E_U / H^i_U \qquad (1)$$

Where, W_i is the weight factor of channel i. E_U is spectrum efficiency of user U. H^i_U is the history throughput of channel i. $W_{i\,MCPTT}$ is the weight factor of MCPTT priority policy information received from server.

$$W_i = W_{i\,MCPTT} \qquad (2)$$

The weight factor is changed by MCPTT policy information. The MCPTT policy information coordinate LTE policy information.

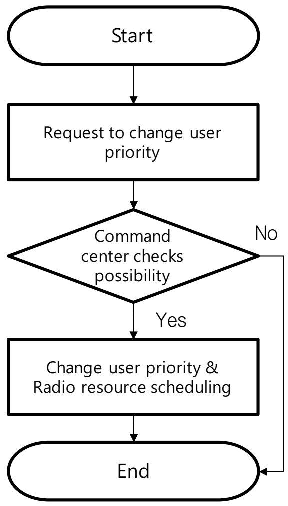

Figure 8. Dynamic resource scheduling algorithms

The figure 8 shows that dynamic resource scheduling algorithms. First, it happens request to change user priority by user or command center. Second, the command center checks possibility. For example, the command center determines whether the user is eligible to change the authority. If it is possible, user can obtain MCPTT priority and radio resource. If it is impossible, user can't achieve priority.

MCPTT priority changes can be accessed in two cases. The first is when the user requests and the second is when the command center requests.

- MCPTT user request to change priority
- Command center request to change user priority

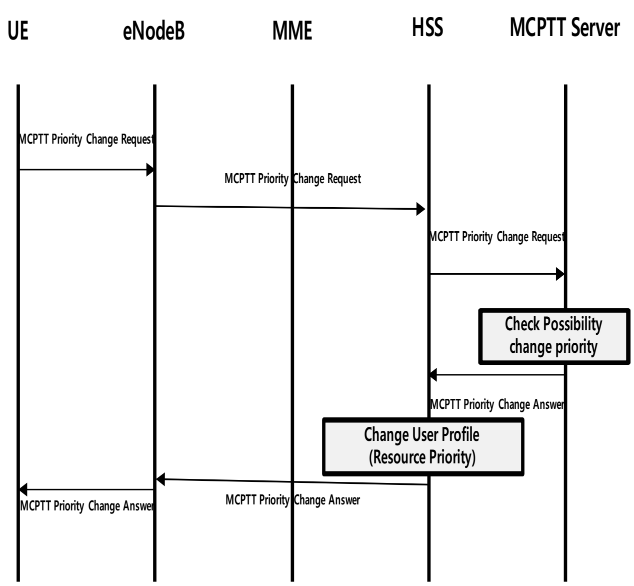

Figure 9. MCPTT user request to change priority procedure

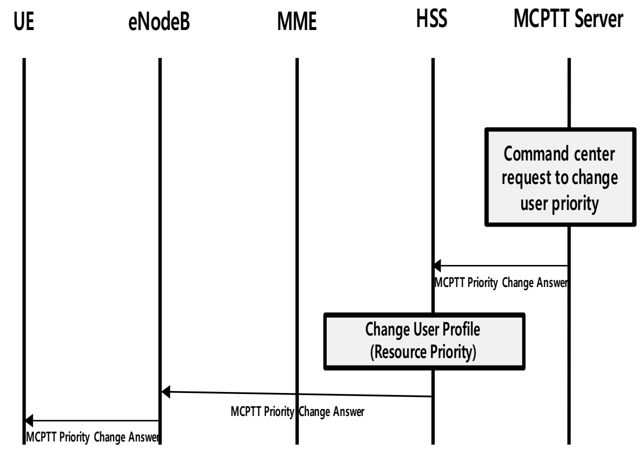

Figure 10. Command center request to change priority procedure

The figure 9 shows that MCPTT user request to change priority procedure. Also, the figure 10 show that command center request to change user priority. LTE home subscriber server (HSS) has user profile and EPC policy information. If user priority is changed, user profile also changes real time. So it can use radio resource scheduling as following e.q. 1 and 2.

IV. FIELD TEST AND PERFORMANCE EVALUATION

We use LTE simulator result and test ideal environment in shield room. In addition, we performed a field test in a public safety network real environment using dynamic resource scheduling algorithms.

TABLE I. SYSTEM PARAMETER

Parameter	***Value***
Channel Bandwidth	10MHz
Carrier Frequency	Band 28
Transmit Power	40W(46 dBm)
Reference signal power	21 dBm
Antenna gain	15 dBi
Antenna Height	50M
MIMO	2 x 2 MIMO
UE count	3
MCPTT priority	High/ Mid / Low
Resource scheduling	Proportional Fair

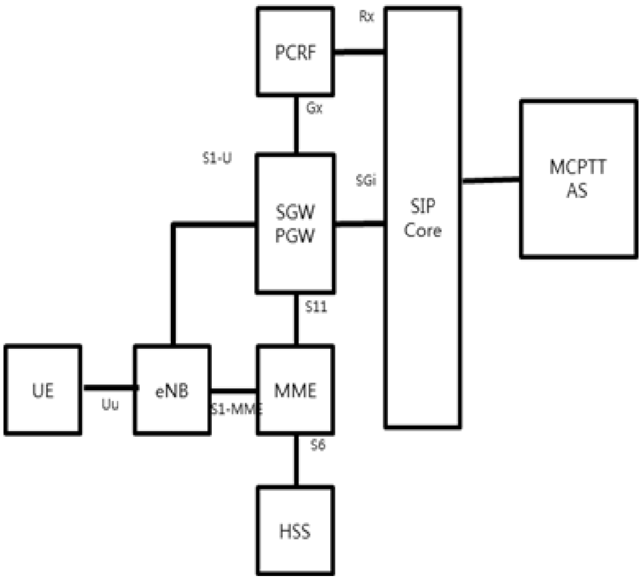

Figure 11. Network diagram

We test several cases in public safety network. First, we tested in an ideal environment in shield room. Second, we environment dynamic resource scheduling algorithms parameter in field to verify.

The Table 1 and Figure 11 is system parameter and network diagram to test. In test, 3 users have MCPTT Priority. High priority is MCPTT super user and middle priority is MCPTT normal user and low priority is non-MCPTT user. Also, radio resource scheduling use proportional fair method. If user priority is changed, HSS(Home Subscriber Server) updated LTE subscriber profile and base station will be scheduled radio resource by priority.

TABLE II. USER DOWNLOAD THROUGHPUT

User	*Original method (Mbps)*	*proposed method (Mbps)*
MCPTT super user	10.8	18.9
MCPTT normal user	10.8	8.9
non MCPTT user	10.8	4.5

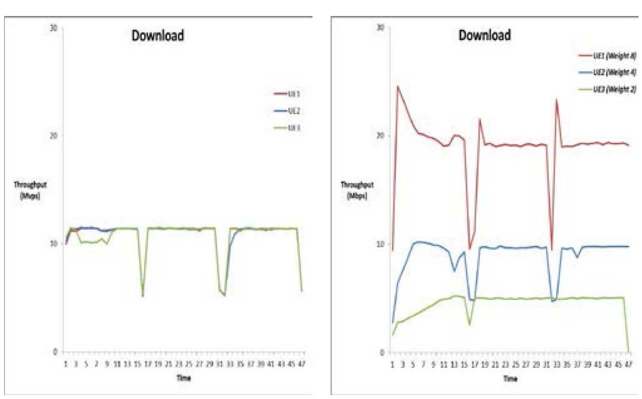

Figure 12. User download throughput

The table 2 and figure 12 show that user download throughput. MCPTT super user priority is high. So it is possible to use stable service than non MCPTT user. The MCPTT super user improved the download speed by about 75% using the proposed method.

TABLE III. USER UPLOAD THROUGHPUT

User	*Original method (Mbps)*	*proposed method (Mbps)*
MCPTT super user	7.5	11.5
MCPTT normal user	7.5	6.3
non MCPTT user	7.5	3.3

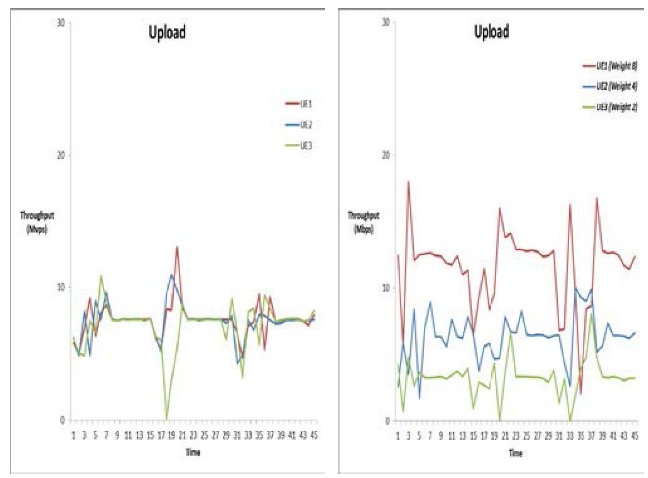

Figure 13. User upload throughput

The table 3 and figure 13 shows that user upload throughput. The MCPTT super user improved the upload speed by about 54% using the proposed method.

V. CONCLUSION

In MCPTT, there is traffic jam that causes excessive traffic due to disaster. According to MCPTT policy information, a user with high priority should make MCPTT service the top priority.

We proposed a dynamic resource scheduling algorithm that changes the user priority dynamically by directly requesting the user or by changing the user authority on the command center. In order to verify this algorithm, the ideal test and the field test were performed. As a result, the MCPTT highest priority user show that the download speed is improved by about 75% and the upload speed is improved by about 54%.

This result shows that MCPTT service can be provided from a person with high MCPTT priority in case of disruption and service cannot be provided due to traffic jam.

Further research is needed to determine the disaster situation and automatically grant authority to the user or the command center.

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