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OPTIMIZATION IN QUALITY OF SERVICE FOR LTE NETWORK USING BANDWIDTH EXPANSION

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Abstract -- *QoS (Quality of Service) of LTE networks can bring the providers to provide broadband services with high performance to end user. Furthermore, the expected data rate transfer is up to 300 Mbit/s per user while the range of bandwidth varies from 1.4 MHz to 20 MHz. The network worked in 1800 MHz bands, 64 QAM modulation technique and used 10 MHz and 15 MHz channel bandwidth. There is a congestion problem for LTE network with 10 MHz channel bandwidth due to high utilization. The paper tries to analyze the QoS parameters, named Key Performance Indicators (KPI) for LTE Networks to solve the problem using bandwidth expansion. The KPIs parameter that is measured by drive test is accessibility, retainability, PRB downlink utilization, and user number. Based on the KPIs measurements results, it is showed that the proposed method to expand the bandwidth from 10 MHz to 15 MHz can avoid congestion problem and impact on improving the performance of LTE network.*

Keywords: *LTE; MIMO; QoS; Congestion; Utilization; Peak Data Rate*

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INTRODUCTION

Recently, there is a considerable increase in internet traffic owing to the growing number of smart devices and mobile data services. However, since the wireless network capacity is limited resources, the data flooding and signaling problems transform into inconvenience for mobile operators, particularly at the time when demand for the network resources is more significant than network capacity. This situation generates congestion problems in the network. Here is the effect of congestion to the wireless networks, from the application operating more slowly to application failing.

Quality of Service (QoS) defines the network quality in terms of quantitative network performance parameters named Key Performance Indicators (KPI). The service experienced by end users is measured using some performance indicators (PIs) that are aggregated to form a KPI. According to the 3rd generation partnership project (3GPP) standard, there are six main KPIs that directly influence network performance and end-user experience: accessibility, retainability, integrity, availability, and mobility (Rohde & Schwarz, 2018). The expansion of network capacity became the standard part of the network operators' strategic decisions, considering the constant rise of the Internet traffic volumes caused by the rapid development of the digital market Mitrovic et al., (2018). There is a correlation between the growth of substantial consuming internet services and the growth of internet traffic volumes, confirmed by many global reports, such as Ericsson (2019). This fact creates the need for capacity management to ensure the wireless network is appropriately sized to meet the demand of network resources, which leads to the significant cost savings for network operators. Forconi & Vizzari (2013) and Vaser & Forconi, (2015) compared the QoS aspects of the LTE and WiMAX in the first part. In the second part, they focused on QoS aspects in E-UTRAN (Evolved Universal Terrestrial Radio Access Network) section of LTE networks. Finally, in the third part, they analyzed the QoS aspects of the end-to-end LTE network with the E-UTRAN section and EPC (Evolved Packet Core) section. Mahfoudi et al. (2014) investigated the congestion avoidance capacity for LTE Network by using LTE-SIM network simulator. The research shows that the LTE Network is capable of avoiding Network Congestion phenomena by choosing for each traffic type the suitable scheduling algorithm and by configuring in corresponding Base Station exact parameters.

Hu et al. (2014) developed a novel model to evaluate LTE network performance based on traffic measurements and service growth trends. A relational algorithm is designed to obtain the relationship between LTE network resources and LTE KPIs, and a forecasting algorithm is developed to trend network resource consumptions based on traffic and service growth. Sirait et al. (2016) described that to reach suitably higher capacity backhaul in LTE network. It is urgent to emerge new transmission technology as an attempt to enhance the backhaul capacity. Kim & Park (2017) investigated the stochastic behavior of the number of allocated Resource Blocks (RB) in the downlink (DL) of OFDMA system where a base station (BS) manage multiple devices with QoS requirements based on the specifications for LTE-A system. Al-Dulaimi et al. (2016) investigated the balancing model of RB allocation in LTE downlink. The novelty of the model is that it can be used to describe the process of resource blocks allocation in LTE downlink concerning user equipment request priority. Kotagi et al. (2016) studied the downlink energy efficiency aspect by proposed a power control and RB allocation scheme called Breathing for LTE-A in IoT networks. Wu et al. (2015) suggested a low complexity joint user grouping and resource allocation algorithm due to solve the problem of resource allocation for multi-user dual layer beam-forming. This paper describes the performance of LTE network in 10 MHz in terms of utilization to demonstrate the number of capacities that are used, and it found that above 90% utilization of the system is used. This situation is influencing to Key Performance Index (KPI) of LTE Network. The paper proposed to overcome the problem of usage in the LTE network and to upgrade the use of channel bandwidth to 15 MHz, and then it will be comparing the performance of these network for each channel bandwidth. The primary purpose of this approach is to ensure the best capacity expansion based on future traffic demand.

The remaining of the paper is organized as follows. Section 2 explains about LTE Network Architecture and research method. Then, Section 3 is described as the measurement of LTE Network. Finally, the conclusions are given in Section 4.

MATERIAL AND METHOD

LTE Key Performance Indicator (KPI)

LTE Network is a set of measurable events, parameters, and measurements that are used to gauge or compare performance in terms of meeting mobile network's strategic and operational goals (Andini et al. 2018; Rahayu & Pohan, 2018); Cox, 2014). For a wireless system like the LTE, a set of Key Performance Indicators (KPIs) are defined for the evaluation of system performance, in particular, the performance of the evolved Radio Access Network (eRAN). Network performance KPIs are categorized into the following: accessibility, retainability, mobility, integrity, utilization, availability, and traffic KPIs. Monitoring and maintaining key performance indicators of LTE networks is essential for achieving the high quality of experience for end-users, and also meet to network performance from an operator perspective. For mobile networks, the ITU Telecommunication Standardization Sector (ITU-T) has worked with ETSI to describe a general model for QoS from the user perspective (Ericsson, 2012). Fig. 1 illustrates a cost-efficient KPI methodology that includes just a few QoS-aligned KPIs based on measurements for subscriber experience and network quality (Ericsson, 2012).

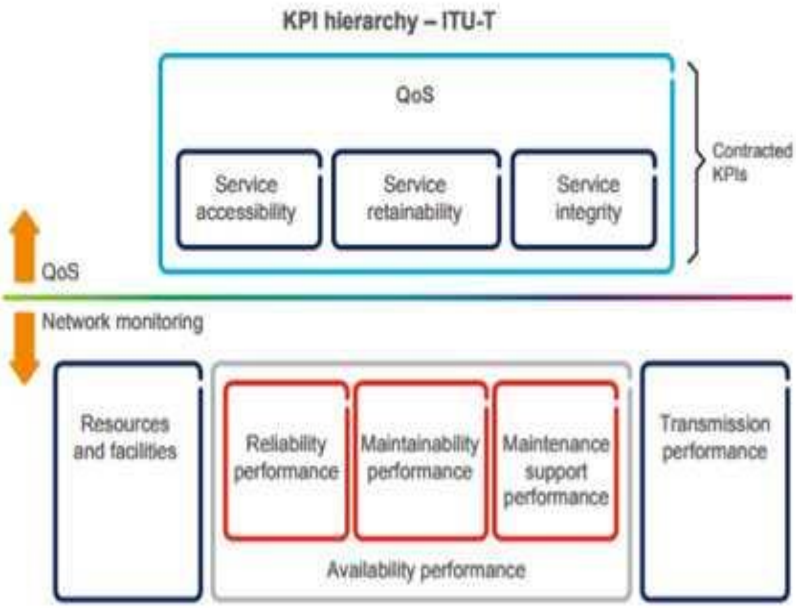

Figure 1. The QoS Component of the ITU-T KPI Hierarchy

LTE Frame Structure

There are two types the LTE frame structure based on topology either FDD or TDD. Total frame is about 10ms, with a total of 10 sub-frame in a frame. Each sub-frame composed of 2-time slots. An LTE FDD frame is made of total 20 slots, each of 0.5ms as depicted in Fig. 2. Two consecutive time slots form into one sub-frame. There are ten such sub-frames build into one radio frame. The duration of one sub-frame is about 1ms. Furthermore, the period of LTE radio frame is about 10ms. Each radio frame will have 307200 Ts. Where in one Ts equals 1/(15000 × 2048) seconds.

An FDD frame is composed of two half frames that each of 5ms duration resulting in total frame duration of about 10ms. Each radio frame will have a total of 10 sub-frames, each sub-frame will have 2-time slots. Sub-frame configuration is based on uplink-downlink configuration (0 to 6). Generally, in all the case, sub-frame #0 and sub-frame #5 is frequently used by downlink. The particular sub-frame brings DwPTS (Downlink Pilot Time Slot), GP (Guard Period) and UpPTS (Uplink Pilot Time Slot). For the 5ms DL to UL switch point periodicity case, SS (Special sub-frame) exist in both the half frames. For the 10ms DL to UL switch point periodicity case. SS lives only in the first half frame. Fig. 3 shows an LTE Frame Structure in TDD.

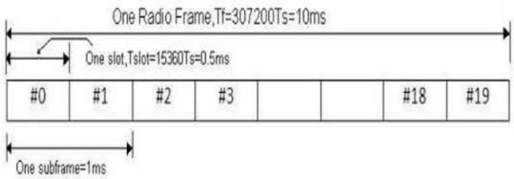

Figure 2. LTE-Frame Structure, FDD

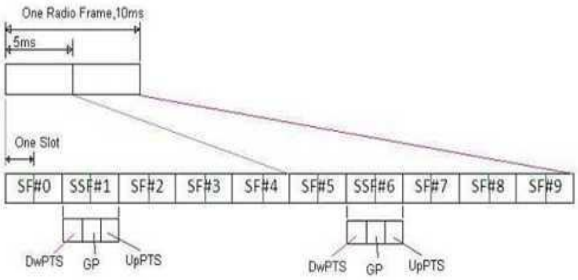

Figure 3. LTE Frame Structure, TDD

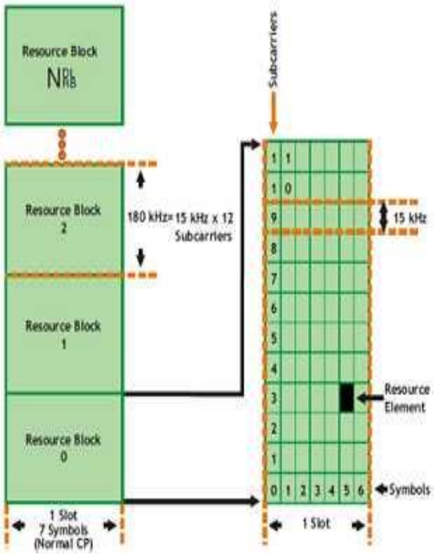

Figure 4. LTE DL PRB allocation over the time and frequency domain

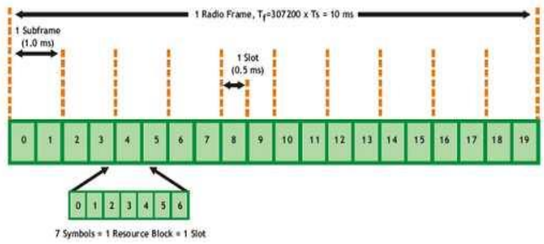

Figure 5. LTE Sub-frame with 20 MHz Bandwidth

A PRB consists of 12 consecutive subcarriers and 14 OFDM symbols in the time domain. A PRB also the smallest part of resource allocation assigned by LTE DL scheduler. The transmitting signal of LTE DL consisting of multiple subcarriers for a duration of OFDM symbols and is depicted in Fig. 4. In addition, Fig. 5 show LTE frame structure in term of sub-frame with 20 MHz bandwidth.

LTE Peak Data Rate

The LTE design objective is to achieve a peak data rate up to 100 Mbps above by using the following parameters: Bandwidth 20 MHz, Modulation 64 QAM, antenna MIMO 2 × 2. Table 1 shows the relationship between channel bandwidth and the number of the resource block.

Table 1. Channel Bandwidth and Number of Resource Block

Channel bandwidth (Mhz)	Maximum Number of RBs	Maximum Occupied Bandwidth (Mhz)
1.4	5	1.08
3	15	2.7
5	25	4.5
10	50	9.0
15	75	13.5
20	100	18.0

Source: (LTE Resource, Anritsu. 2009)

The smallest part of Resource Block (RB) is Resource Element (RE). There is 84 RE during 0.5 ms period in one RB. In 1 ms period of TTI (Time Transmission Interval) there is 168 RE 168 or 168 OFDM symbols or 168 bit/ms. LTE peak data rate could be count as Equ. 1.

$$\begin{aligned} Peak\ Data\ rate = {} & PRB\ Numbers\ \times 12\ Sub \\ & - carrier \times 2\ Slot \\ & \times 7\ Modulation\ \times 64\ QAM \\ & \times MIMO\ (2\ \times 2) \times 1000ms/ \end{aligned} \quad (1)$$

Theoretically, in 15 MHz Bandwidth, the reached peak data rate is 151.2 Mbps and 100.8 Mbps in 10 MHz Bandwidth. From the calculation of data rate, it concludes that bandwidth is the prominent factor in term of the Resource Block numbers. Table 2 shows resume the peak data rate with various bandwidth.

Table 2. LTE Peak Data Rate with MIMO 2X2

Channel Bandwidth (Mhz)	Resource Block	*Peak Data Rate (Mbps)*
1.4	6	12.09
3	15	30.24
5	25	50.4
10	50	100.8
15	75	151.2
20	100	201.6

Method

This paper proposed a conducted network performance by monitoring the performance of the key parameters and assessment of the performance concerning capacity and coverage (Ajay, 2018). Furthermore, it used drive tests method to collect the KPIs parameters from the field of measurements. The selection of those KPIs parameters should be made in such a way that they measure both the end-user-experienced performance and the resource utilization, that is, how much of the resources for signaling to maximize (Reunnanen, 2015).

On the other hand, the method used the drive test activity to measure the state of the air interface to identify RSRP level, SINR level, KPI CSSR, and CCSR in both of 10 MHz channel bandwidth and 15 MHz channel bandwidth respectively.

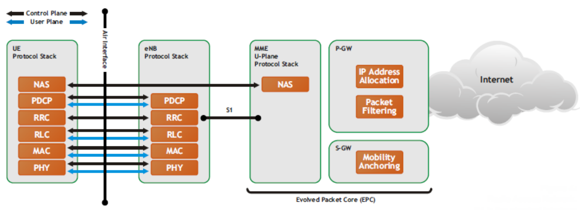

Figure 6. Air Interface in 4G-LTE Network

Fig. 6 shows the protocol used in the air interface from a 4G-LTE network point of view.

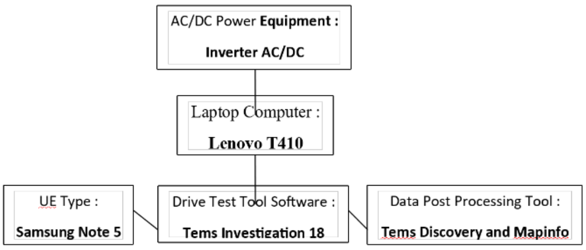

Figure 7. Drive Test Kits in Measurement Process

Fig. 7 showed the drive test kits that we used in the measurement process, include AC/DC power equipment, mobile equipment, TEMS Investigation as a drive testing software (in a laptop), and a Data post-processing tool. Results of the measurement presented in the following section:

RESULTS AND DISCUSSION

In this section, it provides the measurements results to verify the performance of network quality for 10MHz channel bandwidth and 15MHz channel bandwidth respectively.

PRB Downlink Utilization

PRB downlink is one of the KPI parameters which demonstrates the LTE network capacity. This parameter is developed using Equ. 2.

$$\frac{The\ Number\ of\ PRB\ DL\ Capacity\ Average}{The\ Available\ Number\ of\ PRB\ DL} \times 100 \qquad (2)$$

Fig. 8 demonstrate the performance of PRB downlink and maximum user in 10 MHz bandwidth. In Fig. 8, it showed that in day three we found the highest value of PRB downlink 97%. Table 3 demonstrates the three highest value of PRB downlink at 10 MHz Bandwidth.

Table 3. PRB Downlink in 10 Mhz Bandwidth

Day	Time	PRB DL Used the average	PRB DL Available	PRB DL (%)
3	03:00 PM	48.54	50	97.00
1	03:00 PM	47.265	50	94.53
4	02:00 PM	46.507	50	93.01

The number of users in 10 MHz Bandwidth is showed in Table 4, where the highest number of users is 248 and 246 respectively in day 4 and day 3.

Table 4. User Number in 10 MHz Bandwidth

Day	Time	L.Traffic.User .Max
4	09:00 AM	248
3	02:00 PM	246
4	02:00 PM	239
4	10:00 AM	236
3	03:00 PM	226

The next we demonstrate the measurement results in 15 MHz bandwidth.

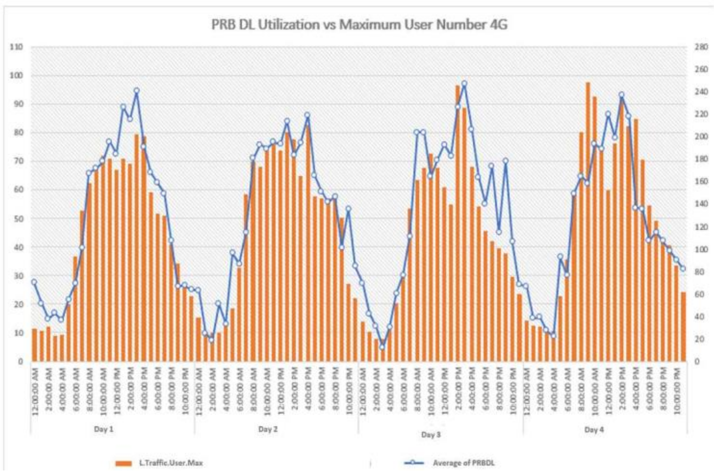

Figure 8. PRB Downlink and Number of User in 10 MHz

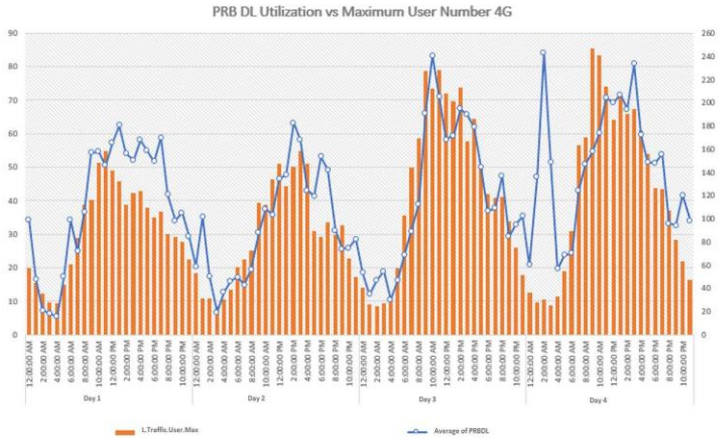

Figure 9. PRB Downlink and Number of User in 15 MHz

Fig. 9 demonstrate the performance of PRB downlink and a maximum user at 15 MHz bandwidth. In Fig. 9 showed that the highest PRB Utilization is 86% in day 4 and the next value is 83% in day 3. Table 5 demonstrates the three highest value of PRB downlink at 15 MHz bandwidth.

Table 5. PRB Downlink in 15 MHz Bandwidth

Day	Time	PRB DL Used the average	PRB DL Available	PRB DL (%)
4	02:00 AM	63.077	75	84.00
3	10:00 AM	62.396	75	83.19
4	03:00 PM	60.618	75	80.82

The number of users in 15 MHz Bandwidth is showed in Table 6, where the highest number of users is 241 and 247 respectively in day 4.

Table 6. User Number in 15 MHz Bandwidth

Day	Time	L.Traffic.User .Max
4	10:00 AM	241
4	09:00 AM	247
3	11:00 AM	228
3	10:00 AM	212
4	11:00 AM	214

From Fig. 8 and Fig. 9, also from Table 3 and Table 5, we conclude that there is a reduction in the percentage of PRB downlink between 10 MHz and 15 MHz Bandwidth. In term of PRB downlink used average, there is an increase between 10 MHz and 15 MHz bandwidth. By Table 2 there is an increase in the value of PRB downlink available between 10 MHz and 15 MHz bandwidth. Based on these figures and data, it can be stated that there is an increase in term of the number user between 10 MHz and 15 MHz bandwidth.

Based on the formula of the peak data rate in Equ. 1, it found that there is an increase in the data rate between 10 MHz bandwidth and 15 MHz bandwidth. In Table 3 the highest value of percentage PRB downlink is 97.00%, it means that the remaining of PRB downlink is 3%. From the calculation of the peak data rate, we found that the value of the peak data rate is 3.024 Mbps. In Table 5 the highest value of percentage PRB downlink is 84.00%, it means that the remaining of PRB downlink is 16%. From the calculation of the peak data rate, we found that the value of the peak data rate is 24.19 Mbps.

Accessibility of LTE Network

Accessibility KPIs are used to measure the probability of whether services requested by a user can be accessed within specified tolerances in the given operating conditions. Accessibility in the LTE network could be observed from the Call Setup Success Rate (CSSR). Fig. 10 demonstrate the value of CSSR at 10 MHz Bandwidth.

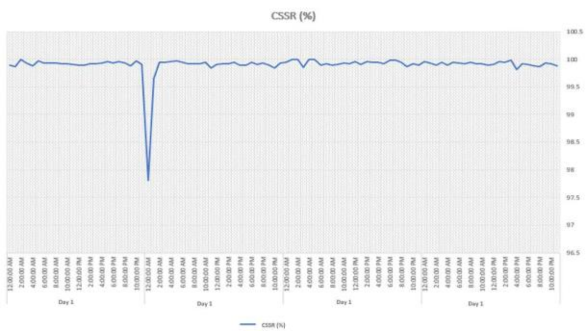

Figure 10. CSSR in 10 MHz Bandwidth

Fig. 10 shows that the value of CSSR is mostly above 99.5%, only the second day we found that the value of CSSR drop into below 98%. It means that the percentage of CSSR is nearly 100%. Fig. 11 demonstrates the value of CSSR in 15 MHz bandwidth.

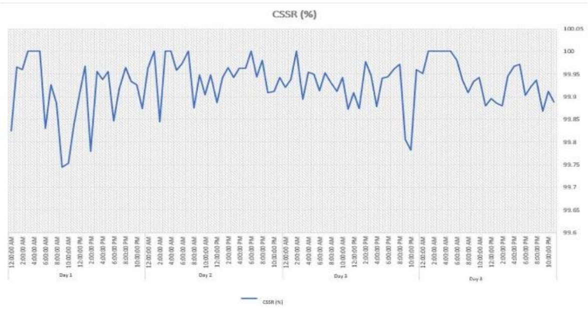

Figure 11. CSSR in 15 MHz Bandwidth.

Fig. 11 showed that all the value of CSSR is above 99.7%. It means that the percentage of CSSR is nearly 100%.

From Fig. 10 and Fig. 11 we conclude that there is an improvement in CSSR value in 15 MHz bandwidth compare the value of CSSR in 10 MHz bandwidth.

Retainability of LTE Network

Retainability KPIs are used to evaluate the network capability to retain services requested by a user for the desired duration once the user is connected to the services. Retainability in LTE network could be observed from service drop rate. Fig. 12 demonstrate the value of service drop in 10 MHz Bandwidth.

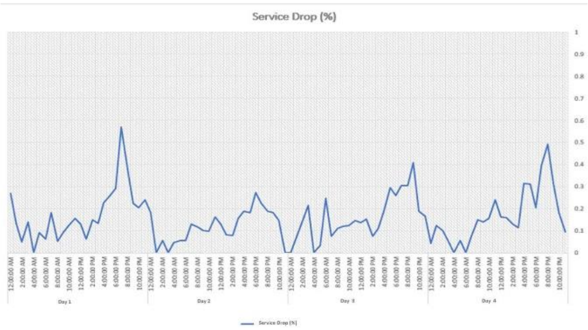

Figure 12. Service Drop in 10 MHz Bandwidth

Fig. 12 showed that the value of retainability in 10 MHz bandwidth is below 0.6%.

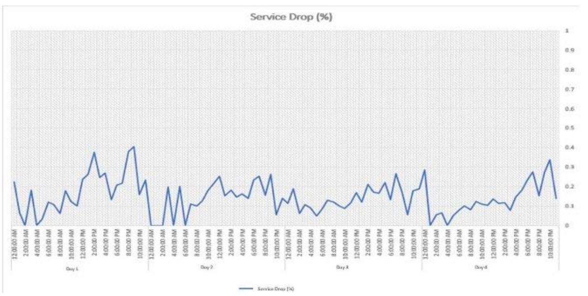

Figure 13. Service Drop in 15 MHz Bandwidth

Fig. 13 demonstrate the value of service drop in 15 MHz bandwidth. Fig. 13 showed that the value of retainability is below 0.5%. From Fig. 12 and Fig. 13 we conclude that there is an improvement for the value of retainability in 15 MHz bandwidth compare with the value of retainability in 10 MHz bandwidth.

CONCLUSION

The conclusion from the above results, we found that there is an increase in term of PRB downlink utilization with the highest value in 10 MHz bandwidth is 97% decrease to 84% in 15 MHz bandwidth. From PRB downlink utilization we conclude that there is an increase in term of peak data rate from 10.08 Mbps in 10 MHz Bandwidth to 24.19 Mbps in 15 MHz bandwidth. There is an increase in total user number in 10 MHz bandwidth with the highest total user number is 248 decrease to 247 in 15 MHz bandwidth. Accessibility of LTE network following the value of CSSR, in this term, we found that an increase in CSSR value from above 99.5% in 10 MHz bandwidth increase to 99.7% in 15 MHz bandwidth. Retainability of LTE network by service drop of the network, in this term we found that there is an improvement in CSSR value from below 0.6% in 10 MHz bandwidth decrease to below 0.5% in 15 MHz bandwidth. Overall, in terms of QoS KPIs in LTE network, we found that bandwidth expansion from 10 MHz to 15 MHz can improve the performance of the LTE network.

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