Performance Analysis of Capacity Improvement Using Additional Frequency Spectrum in Universal Mobile Telecommunications System (UMTS) Network

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Abstract - **Nowadays, the common method of upgrading network capacity is by upgrading the carrier by using 2100 MHz and 900 MHz spectrum. However, with increasing demand from the users, most of the macro cells are in maximum configurations and could not be upgraded further. The capacity needs are being check on a daily basis to ensure that every particular macro cells have enough capacity to cater for the data traffics. Countless research has been done on techniques to increase capacity on UMTS network. However, none of the research proposed to expand the capacity using additional frequency spectrum. This is due to allocation of spectrum already given to the mobile providers and it is costly to obtain additional frequency spectrum. Nevertheless, mobile providers can share the frequency spectrum among them. This study proposes on enhancing UMTS capacity by using additional frequency spectrum. By referring to carrier upgrade policy and triggering, two trial sites are chosen based on their high failure rate, high HS users as well as good traffic distribution. Designing process is done based on the analysis and the carrier architecture has been deployed into live network. The implementation of the additional carrier show positive improvement as the failure rate decreased to zero and the coverage of the sites becomes wider which allows it to capture additional traffic from the users.**

Keyword list – UMTS, capacity; coverage; frequency spectrum; carrier upgrade policy

I. INTRODUCTION

Universal Mobile Telecommunications System also known as UMTS is a third generation (3G) of mobile radio access technology and it could be assumed as a successor to GSM and GPRS systems. UMTS offers consistent services to users and uses wideband code division multiple access (WCDMA) radio access technology which guarantee greater bandwidth and spectral efficiency [1]. Since UMTS network has been introduced, capacity of UMTS network becomes one of the important parameter to ensure the quality of user experience. Once the system reaches its capacity, mobile providers will offer multicarrier system to extend the capacity [2]. However, with the changes of user behavior and higher demand in data services compared to voice services, the current approach such as cell splitting and cell sectoring becomes a reactive action to overcome the congestion of traffic. Furthermore, the UMTS traffic pattern also shifted from voice channel to data channel proved the importance of capacity expansion in UMTS network. The key challenge of the network planning is to achieve extended coverage with maximum users it can support together with targeted quality of services [3].

In this study, the improvement of capacity is proposed by using additional frequency spectrum in the network. The significance of the study is to measure signal strength in identified congested area which needs capacity improvement. The analysis of the failure rate is use to determine the suitable sites for additional capacity improvement.

The fast growing communication technology has witnessed huge data traffic development along the communication generation. Mobile data services are penetrating mobile markets rapidly [4]. It means, with rising of traffic demand will lead to increasing of spectrum demand in the future. By contemplating into Second Generation (2G) data traffic usage, Third Generation (3G) comes with advance features to accommodate the data traffic needs. 3G system is also known as Universal Mobile Telecommunications System (UMTS).

Each of the macro cells with 2G capability were upgraded with 3G capability in order to synchronize with the enormous data traffic usage. Since the mobile industry rely heavily on data services, it is critical for the mobile operators to maintain their network in order to compete with the data services market. Typically, each mobile provider will monitor their network based on Key Performance Indicator (KPI) as a guideline for them to plan upfront on the capacity planning.

As the capacity of the typical UMTS network is now approaching its limit using the traditional methodology such as adding sector, sectorization and introducing new macro cells for capacity expansion, new way of upgrading the capacity can be used to improve the overall network capacity [5]. The approach in this study could be helpful to mobile operators in maintaining their 3G data networks. The benefits of using additional frequency spectrum are obvious whereby it can boost the capacity, enhance the coverage and also able to improve the quality of services [6]. Usually, capacity improvement will be done at NodeB level.

This paper is organized as follows: section II provides an overview of techniques of expanding network capacity. Section III discussed on the methodology and mechanism for carrier expansion. A comparison of the result between the trial sites are discussed in section IV. Concluding remarks are given in section V.

II. LITERATURE REVIEW

Numerous studies have been done to find better ways of expanding capacity. One of the study is on implementing GSM frequency band for UMTS macro cell capacity and coverage planning by taking into consideration user demands influence and broadband intensity [7]. It is an alternative of enhancing and optimizing capacity by using 900 MHz which gives lower cost to operators and better signal propagation. The Okomura-Hata model is used to determine the type of environment for the placement of base station such as urban, suburban and rural. The effects of different types of services have been considered to determine the effectiveness of network balancing between coverage and capacity. In terms of coverage, 900 MHz provide bigger coverage compared to 2100 MHz because it can cover up to 95% of the area. For capacity, with the Noise rise of 4dB, the cells can accept more users and achieve total data throughput of 1110kbps. This study offers promising alternative to the conventional UMTS system at 2GHz range with great impact on capacity planning and provide sufficient coverage to users. However, the author did not discuss on an optimized approach for 900 MHz and 2100 MHz spectrum. Since 900 MHz provide bigger coverage, it is important to optimise the traffic distribution between these two spectrums. Otherwise, 900 MHz spectrum will capture more traffic than 2100 MHz spectrum and congestion will occur in the 900 MHz spectrum.

Many have discussed the techniques of expanding the UMTS system capacity by merging the system with WLAN that provide higher bandwidth at lower cost. Different from previous research, Alessandro Bazzi studied about the impact of integrating WLAN hot spot in real urban scenario covered by UMTS network [8]. Five WLAN hot spot are deployed and three downlink common channels (CPICH, P-CCPCH and PICH) are transmitted in all cells with spreading factors of 256 and power level of -23dB. Parameters such as call setup success rate (CSSR) and drop call rate (DCR) were considered to evaluate the quality of the end users. CSSR and DCR can be calculated in equation (1) and (2) as below [9-10]:

$$\text{CSSR} = \frac{\text{N attempt} - \text{N block}}{\text{N attempt}} \quad (1)$$

where $N_{attempt}$ is the number of call attempts and N_{block} = number of block calls.

$$\text{DCR} = \frac{\text{N drop}}{\text{N release}} \quad (2)$$

where N_{drop} is the number of drop calls and $N_{release}$ is the number of call release.

Hence, by deploying WLAN hot spot, the number of users can be increased from 18 users to 30 users with acceptable quality of coverage and capacity. It can also cover less than 3% of the total area.

Besides that, a study proposed to deploy optimized Femtocell Access Point (FAP) in order to expand the network capacity for indoor users [11]. Numerous research have been done on deploying FAP to offload macrocell traffic but others failed to prove the correct method of placing the FAP indoor with the disturbance and interference from an outdoor base station (BS). In contrast with the previous research, this study focuses on optimising the FAP indoor position with the goal of attaining highest mean capacity in the presence of co-channel interference from an outdoor BS. By considering both theoretical and simulation model, two assumptions have been made with 1 FAP and 1 outdoor BS deployed. The assumptions are the BS becomes dominant interference source to the FAP and it is fully loaded and continuously interfere with the FAP. FAP was first placed at the corner of the room. Due to severe interference face by users, the positions of the FAP have been moved towards and converge to the BS. By moving the FAP, it proves that the position of FAP varies from the center of the room and towards the interfering BS. Improvement on mean capacity is up to 20% and reduction of 8% in operational energy obtained. Hence, it is proven that optimized FAP helps to increase the network capacity and operates at lower power.

In addition, the channel and capacity quality between User Equipment (UE) and Base Station (BS) in the network system performance can be improved by using cooperative relay [12]. By referring to previous study, Hong Li et. al worked on optimizing the access path of cooperative relay to maximize the cell capacity and energy efficiency between User Equipment (UE) and Base Station (BS) [13]. By deploying relay at the edge of each cell, the edge area is separated into 12 small hexagonal cells alongside one relay node located at each relay cell. The author uses two cooperative relay (CR) schemes that is baseline and simple relay (SR) scheme as guideline. Some numerical simulations are made in order to evaluate the performance of the proposed cooperative schemes. Moreover, full buffer mode for the traffic model is assumed and UE's are equivalently distributed in each cell/sector. Both SR and CR scheme show better performance than baseline. SR gives additional 10% of average gain improvement and CR gives additional 30% of average gain improvement than baseline. From simulation result, it is proven that the cell capacity can be improved using both relay scheme compared to scenario without integrating relay. Moreover, cooperative relay scheme also provides twice energy efficiency same as baseline scheme.

III. RESEARCH METHODOLOGY

This study is mainly focused on proposing capacity improvement using additional frequency in UMTS network. The preliminary stages of the study are by doing initial investigation and background evaluation. Literature review study has been done by referring to the previous thesis, journals, articles and also working experience. Key learning from the study will be used as a reference to ensure that all aspects of alternative method for capacity upgrades has been taken into consideration.

Furthermore, the next stage is to find the main issue inside the network by referring to the actual data to get a brief idea and objectives of the study. The failure rate measurement and data collection will be done using U2000 in the identified congestion area. The accuracy of the statistics is important as this will contribute to the precise design concept. Evaluation of this data will be done based on historical and current statistic to ensure that the congestion which happens is genuine congestion and the sites require capacity upgrades.

The study will continue with designing stage and hardware assessment based on the data collection. After the designing stage is complete, it will be implemented into the network. Verifications and evaluations of results will be done after the upgrade is completed and capture the traffics. It is important to proceed with optimization between carriers because 900 MHz spectrum will capture more traffics compared to 2100 MHz due to its bigger coverage. The incoming traffic between the carriers should be balance to avoid congestion in the new layer of upgrade. Based on the results, comparison of pre and post failure rate will be done to evaluate the effectiveness of using additional frequency spectrum as solution of capacity improvement. The whole process of this research is translated in Figure 1:

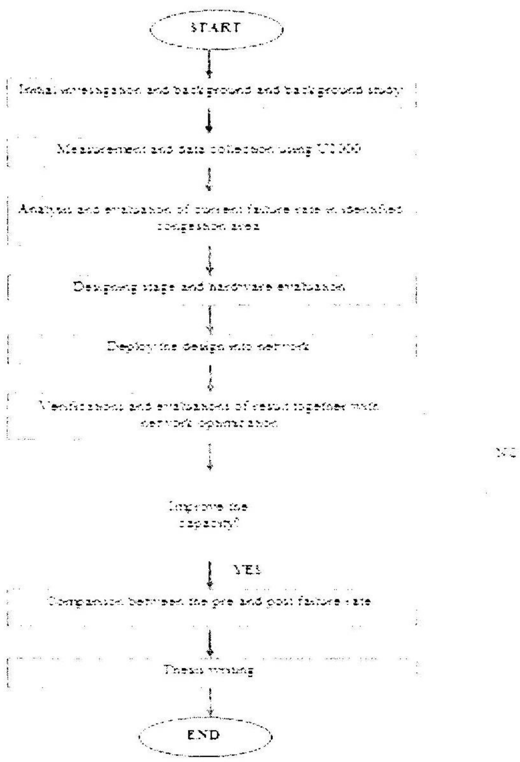

Figure 1: Flow chart of overall research

A. *Carrier Policy Upgrade and Triggering*

This policy governs the monitoring and triggering mechanism for carrier expansion on the Node B, as well as the network strategy for carrier expansions. After analysis of the data, there will be a monitoring period to ensure that the chosen sites are having genuine congestion. The monitoring period should exclude all festive or special events days to avoid triggering and capturing of hotspot due to abnormal surge/spike. Carrier Upgrade will be triggered if cell falls under one of the following conditions as shown in Figure 2:

Triggering Element	Monitoring Window
Carrier Upgrade	• Code Failure > 1% for 8 out of 14 days • Code Failure > 5% for 3 out of 14 days • Code Failure > 1% for 3 out of 4 days (weekends) • Code Utilization >60% for 8 out of 14 days
Channel Element	• CE Failure > 1% for 8 out of 14 days • CE Failure > 5% for 3 out of 14 days • CE Failure > 1% for 3 out of 4 days (weekends) • > 60% CE Utilization for 8 out of 14 days
Power	• Power Failure > 1% for 8 out of 14 days • Power Failure > 5% for 3 out of 14 days • Power Failure > 1% for 3 out of 4 days (weekends)

Figure 2: Triggering Element

When either one of the above meet the criteria, upgrade is triggered

where Code Failure is the max (RRC Failure, CS RAB Failure, PS RAB Failure), CE Failure is the max (RRC Failure, CS RAB Failure, PS RAB Failure) and Power failure refers to max (RRC Failure, CS RAB Failure, PS RAB Failure).

IV. RESULT AND ANALYSIS

Two trial sites are chosen due to cell experience Code Failure >5% for 3 out of 14 days whereby it caused traffic congestion in the particular area. It is also chosen due to high HS users attached to the sites and good traffics. Additional carrier has been implemented in both sites using the additional frequency allocated.

Optimization of the Trial Site 1 is still needed due to the additional implemented carriers are having high HS user as compare to other carrier. This is because the new carrier are having high RRC attempt and RACH utilization is high caused by better Ec/No in the new carrier. By changing parameter Qqualmin in MOD UCELLSELRESEL from -18 to -16, the HS users become balance in all carriers and sectors. Trial Site 2 also experience degradation of Drop Call Rate (DCR) and Call Setup Success Rate (CSSR) due to hardware issue. The issue is resolved by changing the hardware and changing PCPICH setting.

Table 1 shows the current configuration of carrier after implementation and optimization of new carrier in additional frequency spectrum in both trial sites. Each carrier was assigned to a different ULTRA Absolute Radio Frequency Channel Number (UARFCN).

Table 1: Carrier configuration

Frequency	Band	UARFCN
F1	W2100	10612
F2	W2100	10637
F3	W2100	10662
F4	W900	2939
F5	W2100	10686
F6 (new)	W2100	10562
F7 (new)	W2100	10587

From Figure 3 and Figure 4, it is clearly show that both of the sites are having severe failure which caused traffic congestion in the network. Existing users in the network are still allow to enter the network but the remaining users failed to enter network as there is not enough capacity allocated. High attempts to enter the network cause higher failure.

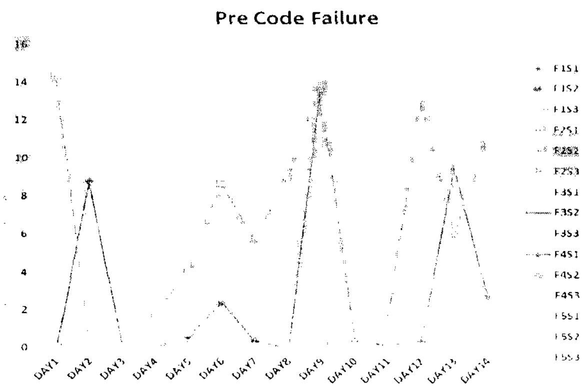

Figure 3: Pre Code Failure Trial Site 1

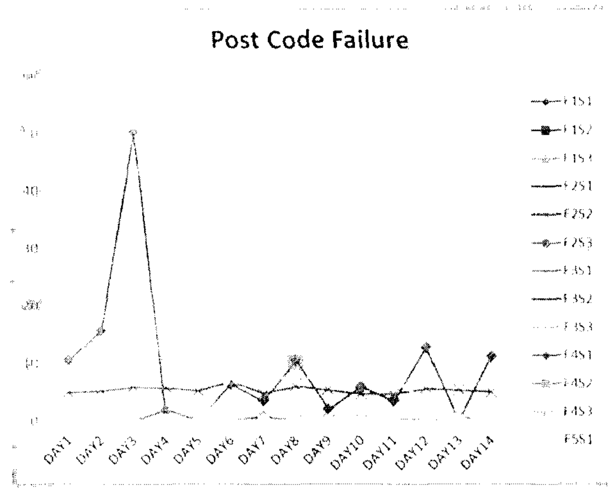

Figure 4: Pre Code Failure Trial Site 2

From the implementation of the additional carrier, it is shown in Figure 5 and Figure 6 that the new carrier has improved the performance of trial site 1 and 2. There is no failure rate after the additional carrier introduced into network.

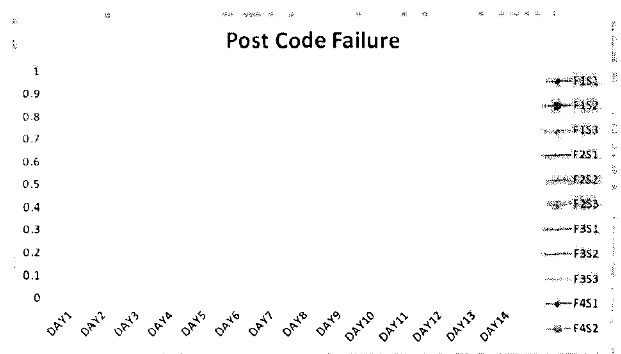

Figure 5: Post Code Failure Trial Site 1

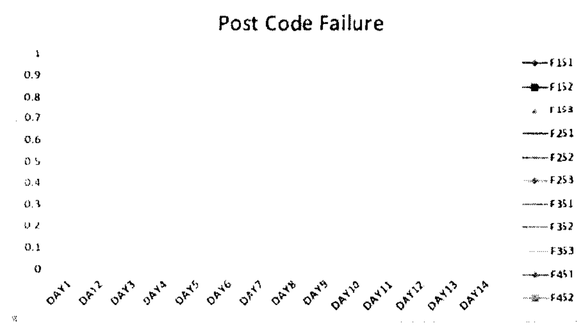

Figure 6: Post Code Failure Trial Site 2

With the improvement of failure rate in both sites, the coverage of the sites also improved. By comparing Figure 7 and Figure 8, trial site 1 is still having red coverage in sector 3 and sector 2 even though the failure rate of the sites in all carriers is zero. The red coverage might occur due to different geographical terrain factor. User will receive poor signal in red area when there is obstacle to get the signal from the trial site 1. The re-configuration of PCIPCH parameter might be needed improve the coverage in red area.

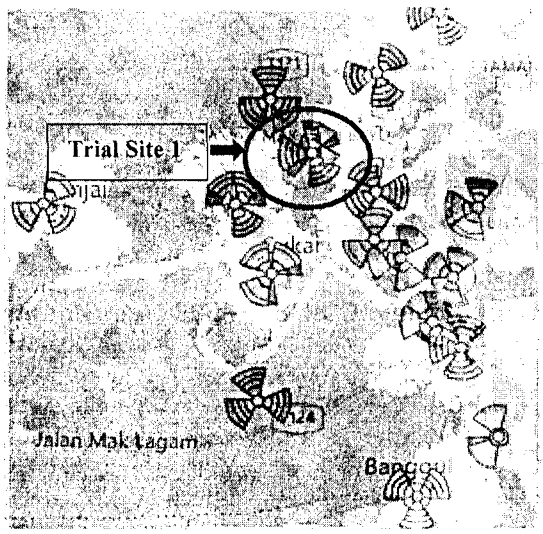

Figure 7: Post UMTS coverage of Trial Site 1

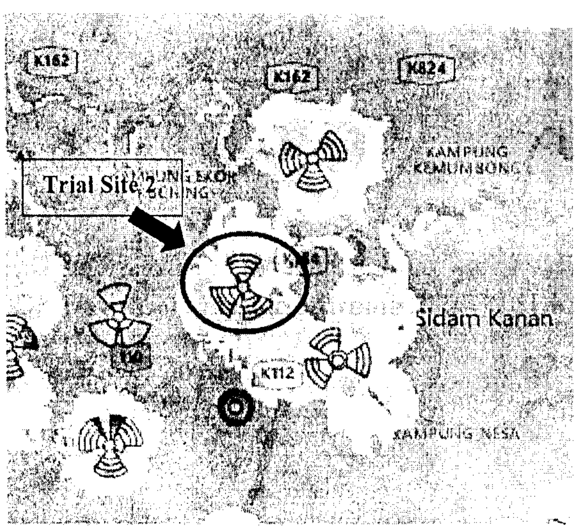

Figure 8: Post UMTS coverage of Trial Site 2

Table 2 and 3 shows the Key Performance Index (KPI) of both trial sites. In conjunctions of the improvement of code failure, the signal strength of the site becomes wide as it's manages to capture additional traffic and throughput from the users. User also experience better voice call as the drop call rate also reduced after the implementation of the new carrier.

Table 2: Key Performance Index (KPI) Trial Site 1

Key Performance Index (KPI)	Pre (4 W2100+1 W900)	Post (6 W2100 + 1 W900)	Variation	Remark
HSDPA Traffic Volume (MB)	1455417	1961312	25.79%	↑
HSUPA Traffic Volume (MB)	229631	273382	16.01%	↑
Average DL user throughput (kbps)	2126.3083	2454.960844	13.39%	↑
Average UL user throughput (kbps)	146.7254	193.2858	24.09%	↑
Call Drop Rate(%)	0.2170	0.1934	-12.71%	↑

Table 3: Key Performance Index (KPI) Trial Site 2

Key Performance Index (KPI)	Pre (4 W2100+1 W900)	Post (6 W2100 + 1 W900)	Variation	Remark
HSDPA Traffic Volume (MB)	1098604	1287059	14.64%	↑
HSUPA Traffic Volume (MB)	186712	213794	16.01%	↑
Average DL user throughput (kbps)	1437.4789	1480.0477	13.39%	↑
Average UL user throughput (kbps)	110.5644	128.8634	24.09%	↑
Call Drop Rate(%)	0.4172	0.3648	-12.71%	↑

V. CONCLUSION

In this study, the capacity improvement using additional frequency spectrum has been proposed. To evaluate the potential of the additional frequency spectrum, two sites are analyzed and being deployed with the additional carrier configurations to enhanced both capacity and coverage of the network. It shows positive results as both of the trial sites failure rate becomes zero and additional traffics are captured. The reduction of failure rate allows more users and traffics to enter the network. The performance of the site will be continuously monitored to ensure the effectiveness of the capacity improvement using additional frequency spectrum.

Moreover, the new capacity architecture also successfully applied in identified congestion area. In the future, more sites can be deployed with the new capacity architecture as a solution to maximum configurations setting of radio network to allow more capacity and coverage to the users. It is recommended for the research and development team to investigate further on method of additional carrier sectorization as this will help to enhance the capacity of the network in the future. The sectorization will need further investigation as it will require more cost and hardware involve.

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