FEMTOCELL E2E PERFORMANCE ANALYSIS AND STABILITY IN THE UMTS NETWORK

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Abstract **- The femtocells cover a small area same as Wi-Fi where they are competing with each other. The femto unit, low-cost type of cellular base stations, where optimized for home used and enterprise (small business). The purpose of this paper is to study the femto implemantion and analyze the End-to-end (E2E) performance of the femto. We are focusing on the End-to-end (E2E) femto analysis, the performance is measured based on the best parameter sets in femto with the acceptable value in the real networks. The circuit switch (CS) and packet switch (PS) performance is talking part to determine the best quality performance of the femto. The deployment of the femtocell in the network can improve the network quality, support coverage especially in the building area and reduce the budget of implementing the macrocell.**

Index term – Femtocell, 3G, UMTS, E2E, CS, PS

I. INTRODUCTION

Some studies, more than 50% voice calls and more than 70% data traffics are originated indoor [1]. In order to improve network and users satisfaction, higher data rate and reliability for subscribers (User) is needed and reduce amount of traffics on expensive macrocell network (Operator). Therefore small cell is implemented.

There are several types of cell which are macrocells, microcells, picocells and femtocells. Every cell types have their own ability and in this paper focusing on the femtocells [2]. Figure 1 shows the short brief on the differences on the cells.

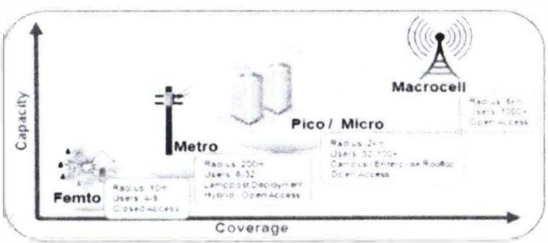

Figure 1 : Cells type

Femtocells are the miniature cellular base stations which connect via broadband (plug and play) infrastructure, to provide improvement 3G signal within the home area or enterprise. The femtocells represent the most exciting development in home networking since the arrival of Wi-Fi.

The solution of existence the femtocells are to provide high user experience at home, enterprise and public places. The behavior of the UEs are unpredictable, they are sometime statics and sometime mobility. Therefore, the coverage has to improve, so the femtocells bring opportunity to cover deep indoor and the coverage holes. The implementation of macrocells are not perfect enough to cover all the area, there may have holes of coverage.

As compare with macrocell microcells and picocells, in UMTS technology all the base stations are connected to RNC. Different with femtocells, they bring possibility of auto configuration function in femto access point.

The solution of femtocell may give benefit to the network :
i - Higher end user throughputs
ii - Extended coverage of the network
iii - Improved network performance
iv - Simple in maintain

Even though the femtocell can improve the quality of network, when there are many femtocells implemented will caused interference problem. When there are thousands of femtocells are up, neighbour list creation is need to pre-handover to success. For better improvement and experience of handover, some modifications setting required for the existing network [9]

The reported performance indicators show various properties from end-user perspective. They are relevant to operators for Femto system performance characterization. The tests were performed in Femto SyVe lab.

The wireless communications have to major limitation, there are range and capacity. The deployment of macrocell consuming high power, provide high data rates. The appearance of the femtocell will be an effective solution to satisfy the coverage and data rate required by the operators. The reason implementing of femtocell are for coverage, capacity and power [13]

For the section II, will be describe more on the femto network architecture which is the elements of the femtocell network. Section III is on methodology, explain on the test network configuration, network parameters, equipments and analysis strategies.

II. NETWORK ARCHITECTURE OVERVIEW

A. Femtocell Network Architecture (UMTS)

Femto technology is widely used in worldwide and because of their capability to improve the performance of the network, it is highly demand. Since femtocells can be representing several of network technology, here we only focusing specified network. Figure 2 shows the femtocells network architecture implemented in UMTS.

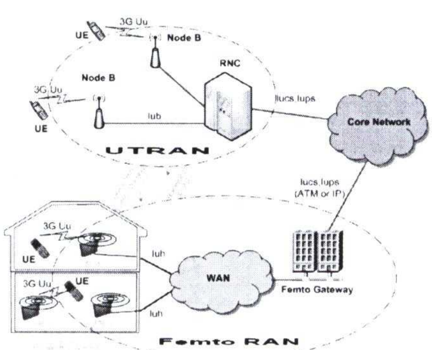

Figure 2 : Femtocells architecture

Femtocells network element descriptions :

I - Home NodeB (HNB)
The purpose of HNB practically is to improve the indoor coverage inside the home/apartments, public places (hotspots) or inside the offices (enterprise). The device is combined with NodeB and RNC functions. The residential HNB, which is located in end-user premises, communicate with the FGW using the IuH protocol via broadband connection line (xDSL). The xDSL must be available in the end-user's location. Enterprise HNBs are usually connected to dedicated local networks

II - Femto Gateway (FGW)
FGW is a door of all femtocells connected and capable to manage thousand of femtocells. All femtocells are configured link to FGW, the traffics flow to FGW and will to the radio resource management for example RNC in UMTS.

III. METHODOLOGY

A. Test network configuration

The test system consists of 2 FGWs and 7 FAPs as depicted in the Figure 3 below. One frequency was used. In addition voice handovers were executed to another frequency *i.e WCDMA (macro)*. The only mobility related test case was related Voice handover to WCDMA (macro), all other tests were executed in a stationary environment.

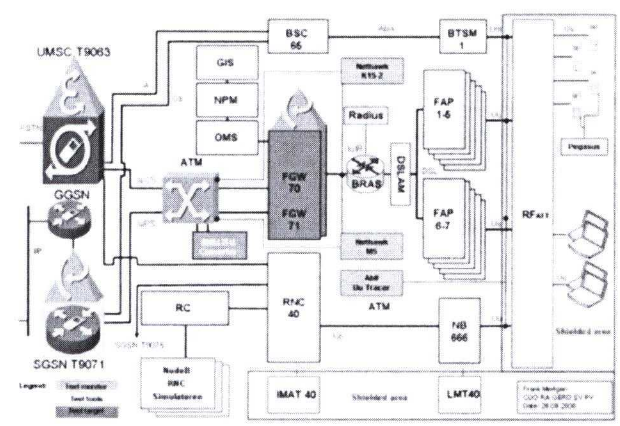

Figure 3: Overview Femto Testbed setup

The radio conditions during the stationary tests were typically:

- CPICH Ec/N0= -3…-4 dB
- CPICH RSCP= -60 dBm.

Common ADSL 2+ with 24 mbit/s in DL and 1 mbit/s in UL was used in the DSLAM – FAP interface. For HSUPA tests the ADSL 2 + line were not used, instead the FAP was directly connected to the FGW.

B. Network parameters

The following list is based on the recommended parameters set and shows the most important network parameters used in these tests. Any deviations from the described configurations are described below in the relevant test description.

3G CS core parameters:

- Authentication is used (Milenage).
- Ciphering is used (UEA1).
- IMEI checking is used.
- Integrity protection UIA1 is used.
- TMSI re-allocation is used (only with location update).

3G PS core parameters:

- Authentication is used (Milenage).
- Ciphering is not used (UEA1).
- Dynamic IP address allocation is used.
- IMEI checking is not used.
- Integrity protection UIA1 is used.
- IPv4 is used.
- Network Mode of Operation I is used.
- P-TMSI re-allocation is used.

3G RAN parameters:

Table 1 : RAN parameters

SRB rate	13.6 kbit/s
CPICH	- 10dBm
Limit of maximum DL Transmission Power	10 dBm
Used DPC_MODE	0
Power ramp step on PRACH preamble value	3 dB
Preamble retrans maximum number	32
Maximum number of preamble cycles	32
Periodical location update (T3212) is not used	0

C. Equipments

The test User Equipment (UE) used was Nokia Slide, Nokia N95, Nokia N80, Nokia 6680, Novatel Wireless Merlin X950D card and Motorola Razr V3xx.The test UEs were connected to automatic call generators or test laptop with USB cable.

D. Measurement setup and test traffics

All measurements except the Handover performance related are referenced were performed with stationary mobiles in the Femto SyVe lab. The system background load was kept low enough to not cause performance degradation due to DL transmit power or UL noise rise. The load was generated with automatic call generators for the success and drop rate tests.

The typical routine consisted of KPI testing periods and fault finding periods. During the KPI testing period the configuration was kept stable and network load at moderate level. Single UE stability test was done with 500 calls and 72 hour endurance test was performed with 4 UEs per FAP. Number of generated calls with HO was 169.

The traffic was generated with automatic call generators. The phones used were Nokia (N95, N80, 6680) and Mototola (Razr V3xx). In addition Novatel datacard was used for HSDPA/HSUPA Traffic generation. Call duration varied randomly (even distribution) between 10 and 30 seconds for stationary AMR users. Rel99 NRT traffic consisted of 1 megabyte (stationary users) file FTP uploads and downloads.

HSPA traffic consisted typically of stationary 16QAM capable users performing 30 megabyte FTP downloads and 10 megabyte uploads. HSPA calls consisted of a sequence of PDP context activation, FTP download and PDP context deactivation. The traffic distribution might not reflect actual customer network conditions but was selected to give best results for troubleshooting purposes.

E. Analysis

The reported setup times were measured from UE internal message log traces. The success rate measurement data was collected with the Pegasus (= call generator) tool. FTP throughput is measured with DOS FTP client. In parallel a tool NetMeeter is started to monitor the traffic.

IV. ANALYSIS AND RESULTS

The outcome of the E2E performance result is based on the parameter setting at the Femto SyVe Lab.

A. Call Setup Times

Table 2 shows the test result for call setup times. The call setup times is measured in five aspects. There are mobile originating voice call (MOC), mobile terminating voice call (MTC), mobile to mobile voice call, GPRS attach time and PDP context session activation time – GPRS. Target value is set based on theory case study. For successful call setup times, there have to meet all the target value.

All the given values were measured under ideal lab conditions without mobility. The voice call setup time was tested with UE to PSTN, PSTN to UE and UE to UE calls. The overall values are 450 ms higher than in RU due to different CN used in tests (SAG CN). Call Setup Times were tested with 6680. The SwissQual tool was used to generate the test calls. The performance numbers are based on timestamps in the UE logs.

Mobile originating voice call (MOC) - The call setup time was measured between *RRC Connection Request* and *ALERT* messages for A-subscriber.

Mobile terminating voice call (MTC) - The call setup time was measured between *Paging* and *ALERT* messages.

Mobile to mobile voice call - The call setup time was measured between *RRC Connection Request* and *ALERT* messages for A-subscriber.

GPRS attach time - GPRS attach time was measured between messages *RRC Connection Request* and *ATTACH_ACCEPT*.

PDP Context session activation time – GPRS attached

Before the test execution the UE was registered in the HLR and IMSI attached. In the test the PDP context session was activated by connecting to the network with the laptop Windows "dial up connection". The activation time was measured between messages *RRC Connection Request* and *PDP_CONTEXT_ACTIVATION_ACCEPT*.

Table 2: Call Setup Time performance results

Call Setup Times		
	target	result
Mobile originating voice call	< 3.45 s	3.18 s
Mobile terminating voice call	< 3.85 s	3.84 s
Mobile to mobile voice call	< 7.3 s	7.05 s
GPRS attach time	< 1.7 s	1.25 s
PDP context session activation time – GPRS attached	< 4.0 s	3.16 s

B. Handover procedure

The mobile was connected via RF combiner to a Femto cell and an inter-frequency macro cell. The hand over is triggered by decreasing the RF signal of the Femto cell with an attenuator, so that an ongoing cs call performs a hand-over to the macro cell. After the call the mobile moves back to the Femto cell with cell re-selection by increasing the RF level of the Femto cell.

In case of the audio break measurement the attenuator is handled manually. For handover success rate an automatic (programmable) attenuator is used. Number of generated calls with HO was 169. Handover performance was tested with N95. The used tool was Pegasus with programmable RF attenuator.

Table 3 shows the handover performance results and measured by two aspects which are femto to macro handover audio break UL/DL and femto- marco voice handover success rate.

Femto to macro Handover audio break UL/DL –
The audio break is measured with an N95 connected using the headset interface of the mobile. It is determined in uplink and downlink direction separately. The voice gap is determined by analyzing the recorded wave files. The gap includes the time with no audio signal or noise instead of original signal during the hand over.

Femto to Macro cell voice handover success rate - The results were provided by the Pegasus tool based on "AT commands" issued to the UE to check if the call is still running.

Table 3 : Handover performance results

Handover Performance		
	target	result

Femto to macro Handover audio break UL/DL	< 300 ms / 250 ms	226 ms / 208 ms
Femto – Macro cell voice handover success rate	> 99.5 %	100 %

C. Round trips times

The UEs were connected to the test laptop via USB cable. The indicated value is the average of at least 500 procedures for each ping payload. The tests were performed only with 16QAM modulation in use. Used UEs were Nokia 6260 slide for full HSPA and Celcom Datacard for other cases.

The desired bit rate of the RAB in both directions was set by restricting the possible RABs at the FAP and activating/de-activating HSDPA/HSUPA. An ICMP client (ping) with configurable parameters (payload size, repeat amount) was used with varying payload size.

Table 4 shows the round trip time performance. The test is taken by 1B packet, 32 B packet and 1382 B packet. The higher the B packet, the longer time is taken ICMP.

Table 4 : Round trip time performance result

Round Trip Time Performance		
1 B Packet	target	result
64 / 64	160 ms	126 ms
384 / 384	160 ms	97 ms
64 / HS-DSCH	115 ms	106 ms
384 / HS-DSCH	95 ms	95 ms
E-DCH / HS-DSCH	64 ms	63 ms
32 B Packet	target	result
64 / 64	170 ms	139 ms
384 / 384	160 ms	104 ms
64 / HS-DSCH	115 ms	113 ms
384 / HS-DSCH	95 ms	95 ms
E-DCH / HS-DSCH	64 ms	63 ms
1382 B Packet	target	result
64 / 64	540 ms	510 ms
384 / 384	390 ms	182 ms
64 / HS-DSCH	360 ms	317 ms
384 / HS-DSCH	185 ms	141 ms
E-DCH / HS-DSCH	*126 ms*	*105 ms*

D. Key performance Indicator (FEMTO)

The femto performace is analyzed for a week (7 Days). The specific KPI is selected to ensure the stability of the Femto performance in the real network. Due to femto functionality is to improve the network coverage, major KPI for CS and PS is selected to take count the real performance of the femto.

The purpose of a Radio Access Bearer (RAB) is to provide a connection segment using the WCDMA Radio Access Network (WCDMA RAN) for support of a UMTS bearer service. The WCDMA RAN can provide Radio Access Bearer connections with different characteristics in order to match requirement for different UMTS bearers. CS RAB is related to voice performance while PS RAB is related to data browsing experiences.

To meet the acceptance, each performance has set the target. Table 5 shows summaries KPI and target value.

Table 5 : Counter and KPI target value

Counters and KPI	**Traget**
CS RAB attempts	
CS RAB success rate (%)	99
CS RAB failure rate (%)	2
CS RAB drop failure rate (%)	1
PS RAB attempts	
PS RAB success rate (%)	99

PS RAB failure rate (%)	2
PS RAB drop failure rate (%)	1

Refer to CS RAB attempts as shown in Figure 4, a long period of 7 days the attempts keep increasing. CS RAB success rate meet the criteria which is above 99%. The CS RAB failure rate is below 2% which is the highest is at day 7 (0.36%). The user experiences on CS RAB drop failure rate all are below 1%. Overall achievement on the CS RAB is acceptable and can conclude the femto cell performs tremendously.

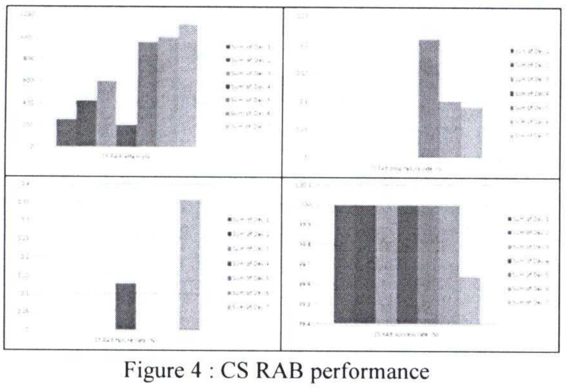

Figure 4 : CS RAB performance

On the data browsing experiences as shown in Figure 5, PS RAB is taking part. PS RAB attempts keep increasing a long 7 days. Mostly 0% PS RAB drop failure rate except for day 5 (0.83%) and day 6 (0.16%). But there are still meet the criteria which are below 1%. All days PS RAB success rate are above 99%. And the PS RAB failure rate all are below 2%. Overall performances of the data browsing are good.

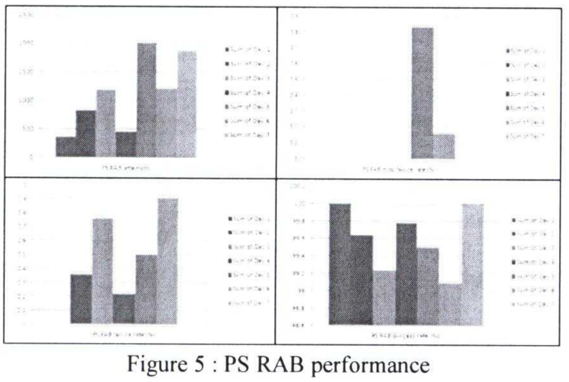

Figure 5 : PS RAB performance

PS traffics for DL is increasing everyday shows the users is increased and demanding for data browse. Higher traffics contribute the higher throughput and shows the femtocell is well performed as illustrated in Figure 6.

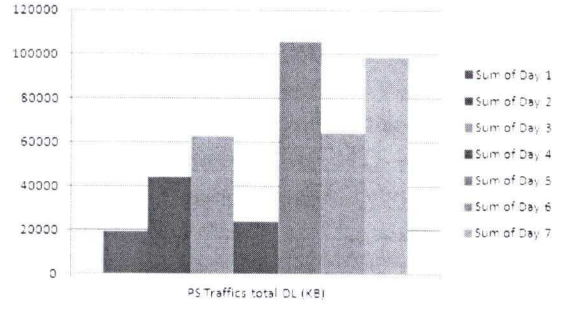

Figure 6 : PS traffics for total DL (Kbit/s)

V. CONCLUSION

The macro layer is usually assumed to be unaffected by femto RAN, which is the case when dedicated carriers are used. However, when a macro carrier is shared with femto, there is no guarantee that macro UEs, macro layer KPIs, coverage, and capacity on the shared carrier are not affected by the femto layer.

The idea of femtocell requirement and the engineers come out the femto because it gives big influences in the network. The femtocell impact a huge benefits for cellular users such as better coverage, higher capacity, lower transmit power, prolong handset battery life and higher signal-to-interference-plus-noise ratio (SINR). A the same time, the femtocell support benefits for cellular providers for example improved Macrocell BSs reliability, offload data traffic from the Macrocell BSs , increasing the area spectral efficiency (total number of active users per Hertz per unit area) and last but not lease operating Cost benefits.

The function of femtocells fulfills the blind spot with zero coverage, just support a small area. When there are more blind spot plan to reduce, thus more femtocells are install and implemented to support the existing marcocells, may caused some unnecessary handover between macrocell and femtocell. the unnecessary handover is need to reduce for better user experiences using data browsing. For futher investigation proposal what is the main cause of femtocell handover failure, how bad it impact to the UE, how to improve the performances for better handover experience between femtocell and macrocell, what is best parameter and setting in the heterogeneous network.

The implementing of the femtocell can improve the network quality in term of user experience and network businesses. However, there are a few challenges need to overcome in order to improve for better femtocell experiences.

In technically challenges, need to deep study on the cell association and biasing, interference analysis and also mobility and soft handover. For the study on the interference analysis, can look on the interference cancellation technique, using of sectorial antennas at FAP and interference avoidance (power and subchannel management) as a proposal method to overcome interference.

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