ESG

Engineering Services Group

WCDMA Network Planning and Optimization

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Revision B

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QUALCOMM®

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1 Introduction

The Engineering Service Group at QUALCOMM is working with operators throughout the world to find solutions to the same four challenges that are faced repeatedly: 1) sub-optimal RF optimization, 2) difficulty to tune all the parameters, 3) increasing the reliability of inter-system transition, and 4) providing better in-building coverage.

These are complex issues, but solving them can be simplified if a proper deployment process is followed as illustrated in Figure 1, [1], [5]. This process follows a "divide and conquer" approach, focusing on a selected variable at each step.

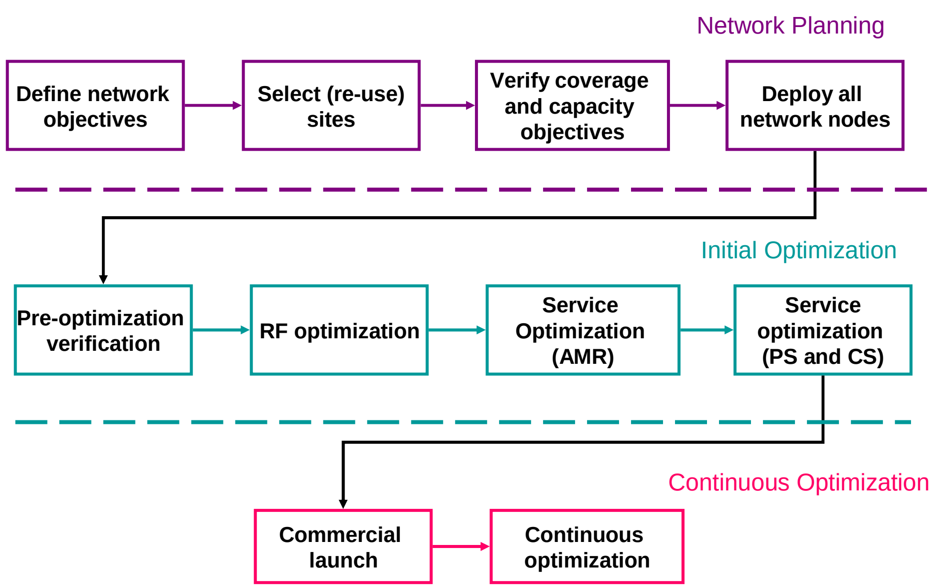

Figure 1: Summary of Network Deployment Steps

From the different phases of network deployment, Radio (RF) network planning and RF optimization are seen as critical as having long term impacts on both performance and capacity [6]. Proper RF configuration is so important that it even impact the coverage continuity (i.e., inter-system change to GSM [7]) and network evolution, notably with the introduction of High Speed Downlink Packet Access (HSDPA) [4].

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2 WCDMA Network Planning

Ensuring that the RF coverage is sufficient within the network should start naturally with a good RF network plan [2]. Network planning is, may be even more for existing operator, an area that is too often overseen. Greenfield operator have the advantage of starting from a clean plate while incumbent operator already have a set of site that they are compelled to use even if these sites were originally acquire to fit in a network with different coverage and capacity limitation.

So what is a good RF network plan?

A good network plan should address the coverage and capacity requirement of the area considered, but also be sufficiently flexible to allow network expansion without major change of the existing sites.

In WCDMA, the coverage and capacity requirement cannot be considered independently, but should be planned at the same time with proper guidelines. This relation between coverage and capacity is often referred to as the "breathing effect" of WCDMA. Comparing with TDMA/FDMA technologies, such as GSM, the coverage of a WCDMA network cannot be planned independently of the load on the network. The load on the network will impact the coverage in mainly two different ways, depending on which link (Uplink or Downlink) is considered. On the uplink, as more users are added to the network, higher noise would be detected at the node Bs. This increase in noise, called rise over thermal, requires each of the phones or data cards (UE) to increase its transmit power to overcome this noise increase: effectively the uplink coverage is reduced by this required increase in transmit power. This effect has been documented and can be summarized by the rise-over-thermal versus load curve illustrated in Figure 2: as an example, when the load is 50% of the pole capacity, the coverage is reduced by a factor of 3 dB.

On the downlink, the breathing effect cannot be quantified so easily as coverage is impacted by the maximum transmit power assigned to traffic channels and the current load on the network rather than by a quantifiable formula.

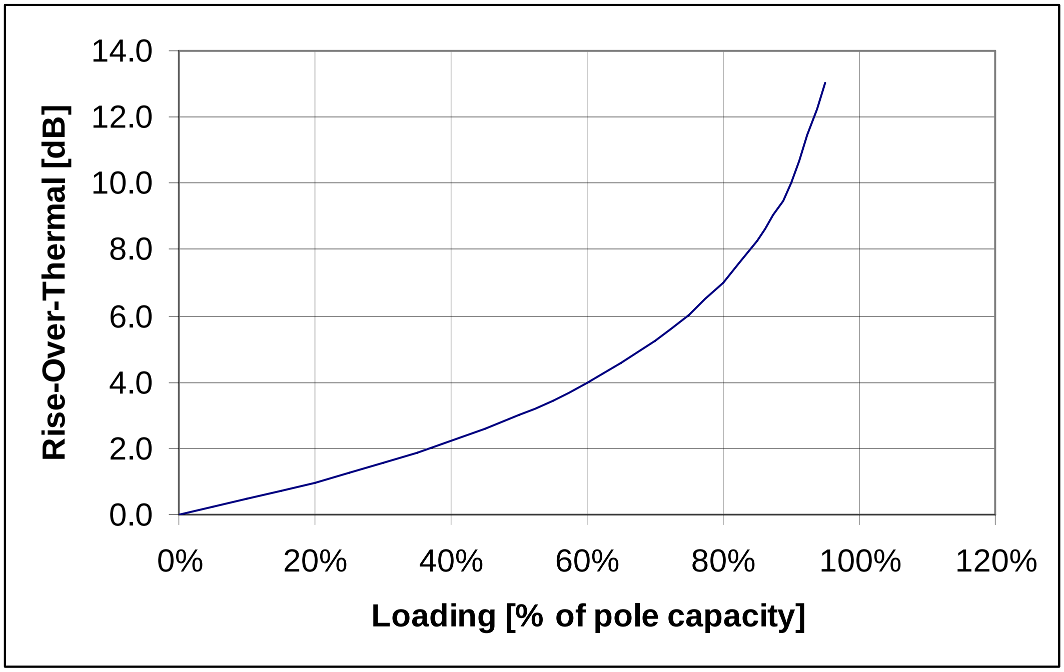

Figure 2: Impact of uplink loading on coverage express by the Rise-Over-Thermal, a.k.a. Interference Margin.

In any case, predicting coverage is easier, in the early stage of network planning by considering only the pilot channel (CPICH). Once that necessary step is completed, the coverage should be further verified for both links (downlink from Node B to UE and Uplink from UE to Node B) and for all services.

For the downlink, CPICH coverage should be verified by considering not only if the received signal code power (RSCP) of the pilot channel (CPICH) is sufficient once all the margins are included, but also by estimating the level of interference generated by the other cells. Such interference is typically quantified by the energy per chip to total received power (Ec/No) of the CPICH. Such quantity effectively estimated how much of the received signal can be used at a given location, or put it in other word, how clean is the signal received.

The relation between RSPC and Ec/No is mainly impacted by the loading of the system and the quality of the network plan. This is illustrated in Figure 3 showing the high range of Ec/No for a given RSCP value. It should be noted that the quality of the network plan would be reflected by the number of cells detected at a given location, or to word it differently, the cell overlap: a high quality network plan would be one where a single cell is detected over the majority of the cell area and transition between cells are done over clear boundaries.

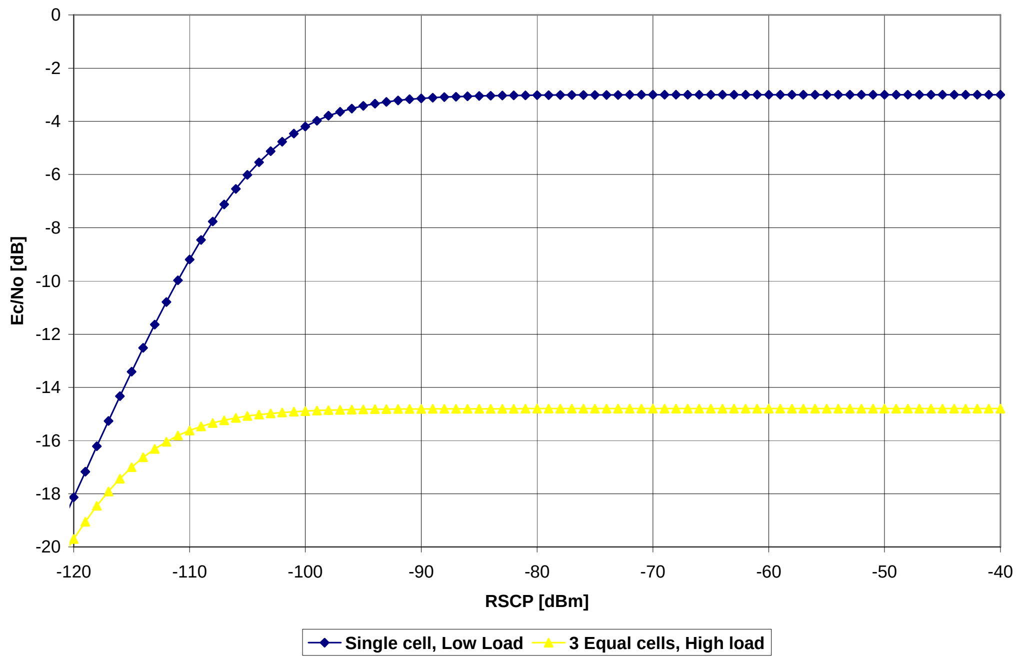

Figure 3: Relation between Ec/No and RSCP for different cell loading and different network plan quality

When the loading of the system increases the Ec/No degrades but the RSCP stays constant. Degrading Ec/No is an indication of increased other cell interference which will also increase the need for downlink traffic power (DPCH Ec/Ior, when expressed in relative terms). Power being a limited resource, the higher required transmit power may not be available, thus the coverage not being met in loaded condition: this represent the coverage and capacity trade-off for the downlink in a WCDMA systems.

In a similar way, adding sites to provide deeper coverage indoor without controlling the footprint of each of them will increase other cells interference and impact service quality and capacity of the system.

It should be noted that the total received signal power (Received Signal Strength Indicator – RSSI) is never considered in a WCDMA system as an indication of coverage. It is mainly due to the inability to estimate the quality by this value: 10 weak cells would result in a strong RSSI, but the lack of any dominant server would yield poor system performance. This concept is sometime called pilot pollution, where multiple servers contribute to a high RSSI, but where the signal cannot be used due to lack of strong dominant server.

To ensure that these issues will be minimized, several simple steps can be taken as illustrated and detailed below.

- Defining the network requirements (coverage area, coverage depth, expected traffic, traffic models …) is necessary to dimension the network both for coverage and capacity.
- Defining the number of site required for a given coverage depth: the site configuration, antenna height and downtilt notably, should be selected as a function of this number of site. Without selecting the site configuration relative to the site-to-site distance, the risk is to have either insufficient coverage or excessive downlink interference. Unlike in GSM network planning where sub-optimal site configuration can be compensate with frequency planning, the 1/1 frequency re-use of WCDMA does not allow such flexibility.
- Defining up front the number of sites required for capacity over the next few years: this number should be compare to the number of site for coverage to ensure that coverage, short term, and long term capacity needs are met. For capacity limited design, the site configuration should match the higher site count. For capacity limited design, the decision between adding sites and adding carrier should consider the possible site configurations. In particular, adding sites with limited flexibility on the antenna configuration may not always add capacity: if the added sites increase the downlink interference, the capacity of each of the sites will decrease.

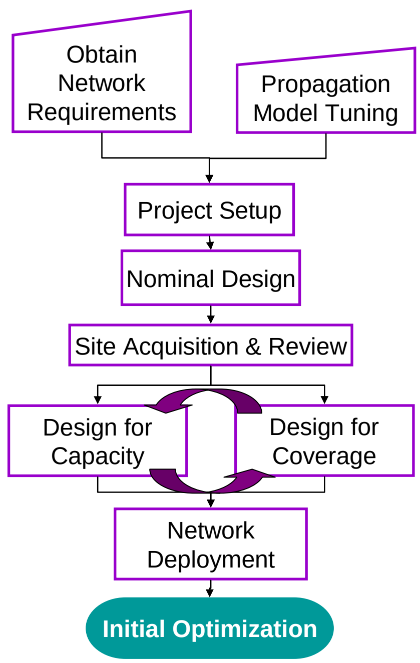

Figure 4 Simplified Network planning process

- Setting design threshold for coverage (RSCP) and interference (Ec/No) ensures that the signal has sufficient quality. If RSCP is used only for coverage estimation, Ec/No is used both for coverage and capacity estimation. For coverage, low Ec/No will ensure that the signal can not only be detected but is of sufficient quality to be used. For capacity, assuming correct Power Control setting, low Ec/No will ultimately translate into low required dedicated transmit power (DPCH_Ec/Ior) thus maximizing the capacity. Designing for capacity can simply be done by ensuring the lowest possible Ec/No is achieved in unloaded conditions. When the load increase, the degradation of performance can be easily forecasted, as increased load will result in degraded Ec/No, as illustrate in Figure 5. It should be noted that soft handover can alleviate downlink interference caused by multiple overlapping site, but at the expense of efficiency of the resource usage.

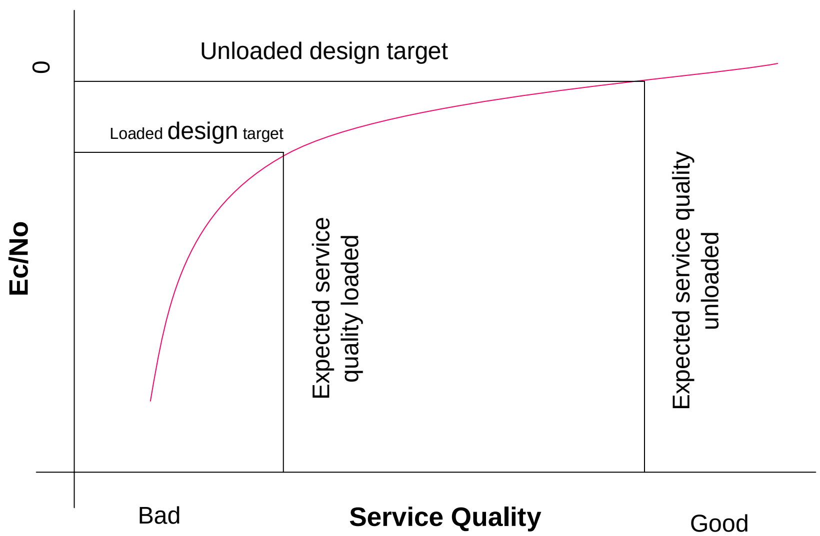

Figure 5: Impact of RF performance on service quality. On the downlink Ec/No and service quality can be correlated allowing to forecast the service quality based on measured or predicted RF performances.

- The capacity design should also include Monte Carlo simulation of the traffic growth to identify where additional sites will be required: by understanding where the capacity growth will be the best site configurations can be selected. It should be noted that this traffic forecasting in not only done to estimate the impact on Ec/No and related performance, but also to determine all the resource usage (channel element, code channels, downlink power …) to ultimately determine the cost of the network.

- Setting a clear strategy for micro-cell usage: when micro-cells are deployed to address coverage limitation then the same carrier can be used; on the other hand, when micro-cells are deployed to improve the capacity they should be deployed on a separate carrier, unless spatial isolation can be achieved, as it is the case indoor.

Similarly some simple precaution can be taken to reduce the risks:

- Existing sites are not always the best: re-using sites from other technology is not always safe, as different technologies have different coverage and capacity characteristics. Only the sites that fit in the overall network plan should be used.
- When site re-use is a necessity, typically due to site acquisition constraint, separate antenna, or at least antenna with separate variable electrical tilt setting should be use to facilitate as much as possible the future network optimization.

Ultimately the quality of a network plan will be judge on more than only a set of statistics, such are the set presented in Table 1 and [11]. This table also lists a set of subjective, or qualitative, criteria that are equally important. In particular these criteria will ensure that the network will perform well not only for Release '99 deployment but also for High Speed Downlink Packet Access (HSDPA). Since HSDPA does not make use of soft-handover, it is of the utmost importance that a single dominant server be available in the majority of the network.

Indicator	KPI	KPI target example
Coverage	Measured RSCP	> -88 dBm over 97 % of area (value should be adapted based on required margins)
Interference	Measured E_c/N_o	> -9 dB over 95 % of area
Cell overlap	Cell overlay	< 3 cells within r1a over 95 % of area
Qualitative	Cell Overshoot	No cell detected above -111 dBm (CPICH RSCP) past the 1st tier
	Integrity of cell coverage	No cell fragmentation detected
	Best server plot	Clean boundary without un-necessary change of best server

Table 1: Network planning KPIs, including quantitative and qualitative criteria

Last, part of the network design process need to focus as much on where the coverage ends that it needs to focus on where the coverage is. The end of coverage will typically includes deep indoor and the outer boundary of

WCDMA network where service continuity is assume by underlying GSM network [2]. Where the coverage ends indoor, at lower floor, mainly depends of the building penetration margin used during the design. Alternatively, at higher stories, the service availability is limited by interference from farther away servers. In either case, deploying indoor solution from repeater to dedicated indoor cell feeding distributed antenna systems can extend the service availability as far as needed. The added cost of such indoor system can be avoided, or at least differed when only a limited number of buildings need to be covered. In such case, assuming the buildings are identified early in the design process, the anchor sites for the macro-network can be chosen such as these strategic buildings can be covered, either by selecting them as site location, or by selecting the macro-site close to these strategic buildings in order to focus one sector toward them. For the continuity past the outer edge of WCDMA network, increasing voice and data service availability relies upon inter-system reselection and handover. For these processes to work optimally, it is critical to plan the boundary in low traffic area where a single dominant WCDMA server transitioned to a single dominant GSM server.

By ensuring that appropriate planning processes are followed, the deployed network will rapidly be brought to commercial operation with limited optimization effort.

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3 WCDMA/UMTS Optimization Methodology

Network optimization can initially be seen as a very involving task as a large number of variable are available for tuning impacting different aspect of the network performance. To simplify this process a step by step approach is proposed in Figure 6 [3]. This approach divides the optimization in simpler steps, each step focusing on a limited set of parameters:

- RF optimization will focus mainly on RF configuration and in a lesser extend on reselection parameters.
- Voice optimization [9] will focus on improving the call setup (Mobile Originated and Mobile Terminated) and call reliability thus focusing mainly on access and handover parameters.
- Advance services optimization will rely extensively on the effort conducted for voice. The initial part of the call setup are similar for all type of services and vendor have not at this point defined different set of handover parameters for different services. Consequently, optimizing these services will focus on a limited set of parameters, typically power assignment, quality target, and Radio Link Control (RLC) parameters.
- Inter-system (also known as inter-RAT) change (both reselection and handover) optimization is considered once the WCDMA layer is fully optimized. This approach will ensure that inter-system parameters are set corresponding to finalize boundaries rather than set to alleviate temporary issues due to sub-optimal optimization.

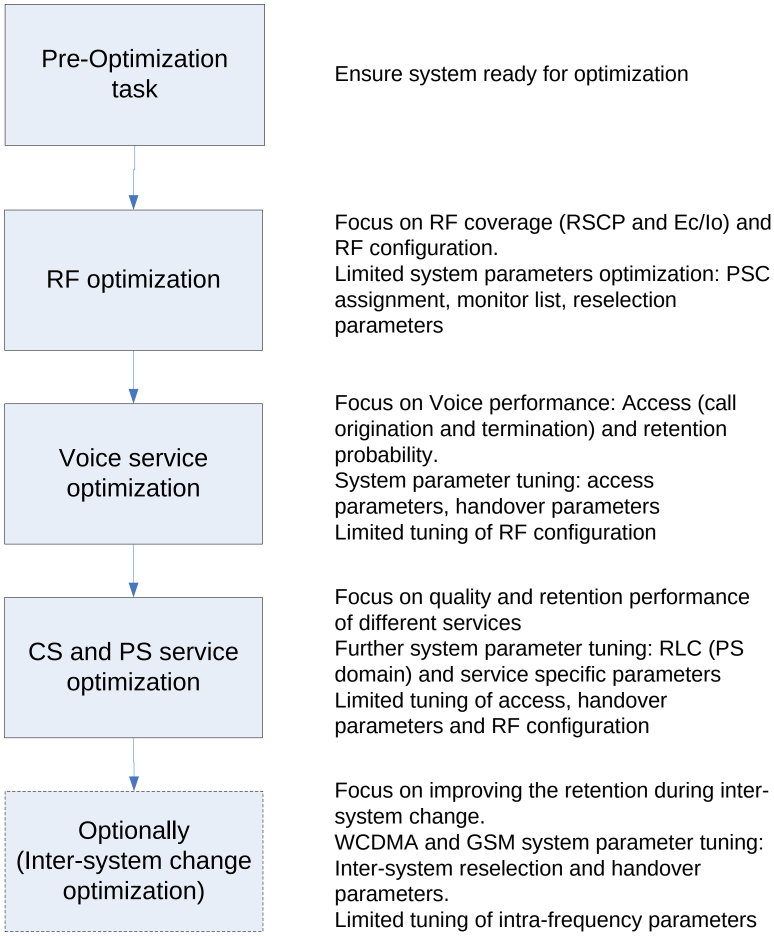

Figure 6: Optimization process is simplified by isolating basics steps. Only a limited set of variable is considered at each step.

Even after careful RF planning, the first step of optimization should concentrate on RF. This is necessary as RF propagation is affected by so many factors (e.g., buildings, terrain, vegetation…) that propagation models are never fully accurate. RF optimization thus takes into account any difference between predicted and actual coverage, both in terms of received signal (RSCP) and quality of the received signal (Ec/No). In addition, the same qualitative metrics defined for planning should be considered: cell overlap, cell transition, and coverage containment of each cell. At the same time, assuming that a UE is used to measure the RF condition in parallel with a pilot scanner, reselection parameters can be estimated considering the dynamics introduced by the mobility testing: during network planning dynamics cannot be considered, as network planning tools are static by nature, only simulating at one given location at a time, irrespectively of the surrounding. In addition, once the RF conditions are known, dynamic simulation can be used to estimate the handover parameters, even before placing any calls on the network.

Service optimization is needed to refine the parameter settings (reselection, access, and handover). Because the same basic processes are used for all types of services, it is best to set the parameters while performing the simpler and best understood of all services: voice. This is fully justified when the call flow difference for the different services are considered, as illustrate in Figure 7 and Figure 8. Either for access or for handover, the main difference between voice and other service is the resource availability. Testing with voice service greatly simplifies the testing procedure and during analysis limits the number of parameters, or variable, to tune. During this effort, parameter setting will be the main effort. Different set of parameters are likely to be tried to achieve the best possible trade-offs: coverage vs. capacity, call access (Mobile Originated and Mobile Terminated) reliability vs. call setup latency, call retention vs. Active Set size... to name only a few. The selection of the set of parameter to leave on the network will directly depend on the achieved performance and the operator priority (coverage, capacity, access performance, call retention performance…)

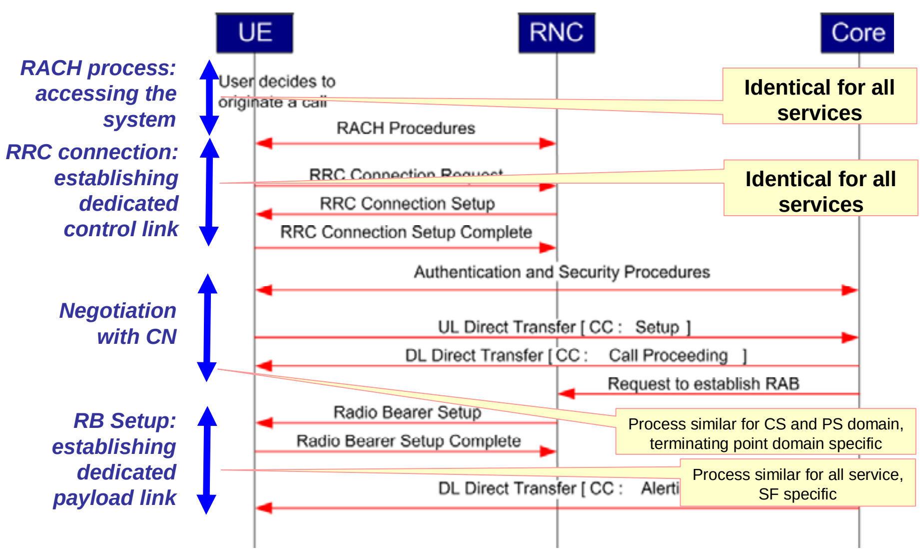

Figure 7: Difference and similarities between voice and other service, during call access.

Once the performance targets are reached for voice, optimizing advanced services such as video-telephony and packet switched (PS) data service will concentrate on a limited set of parameters: power assignment, quality target (BLER target), and any bearer specific parameters (RLC or channel switching parameters for example). During the optimization of PS data service the importance of good RF optimization will be apparent when channel switching is considered. Channel switching is a generic terms referring to the capability of the network to change the PS data bearer to a different data rate (rate switching) or a different state (type switching). Channel switching is intended to adapt the bearer to the user needs and to limit the resource utilization. Saving resource will be achieved by reducing the data rate when the RF conditions degrade. By reducing the data rate, the spreading gain increases, resulting in lower required power to sustain the link.

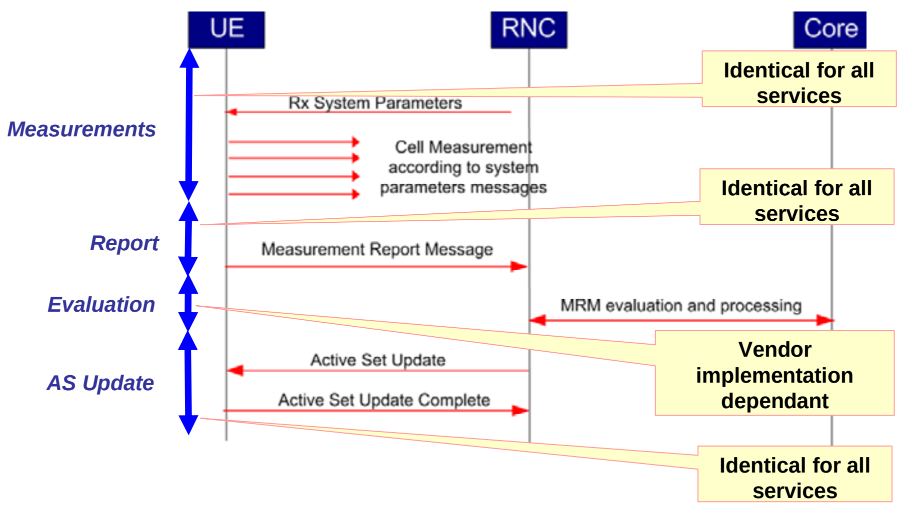

Figure 8: Difference and similarities between voice and other service, during handover.

Last once the basic services are optimized, i.e., the call delivery and call retention performance targets are met, the optimization can focus on service continuity, through inter-system changes, and application specific optimization. Inter-system changes, either reselection or handover, should be optimized only once the basic WCDMA optimization is completed to ensure that the WCDMA coverage boundary is stable.

Application optimization can be seen as a final touch of service optimization and is typically limited to the PS domain. In this last effort, the system parameters are optimized not to get the highest throughput or the lowest delay, but to increase the subscriber experience while using a given application. A typical example would be the image quality for video-streaming. The main issue for this application base optimization might be that different applications may have conflicting requirements. In such case, the different applications and their impacts on the network should be prioritized. Irrespective of the application considered, the main controls available to the optimization engineer are the RLC parameters, target quality and channel switching parameters. The art in this process is to improve the end user perceived quality, while improving the cell or system capacity.

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4 Conclusion

WCDMA network deployment can be simplified by following a simple methodology that focuses on one set of variable at a time. By following this simple process, the main issues that have been observed in previous WCDMA deployment could be alleviated. Namely:

- RF planning and optimization: by focusing on both qualitative and quantitative metrics, the main RF issues (cell overshoot, lack of dominant server, frequent change of best server) are minimized.
- Parameter setting: by isolated parameters in groups (reselection, access, handover …) that can be isolated, the tuning process is simplified. This start by considering proven recommendations [10] and dividing the optimization into simple steps, relying as much as possible on voice services.
- Inter-system performance: planning boundaries will be the first key to prevent inter-RAT issues. Once the boundaries are set to handover or reselect from a single dominant WCDMA server to, and from, a single dominant GSM server, solving inter-system issues can be achieved by just an other parameter setting.
- In-building service: Providing indoor coverage is a simple, even expansive, addition to the network. To minimize the cost, the key is to identify the building that have the greater need for coverage, then to apply a solution that meet the coverage and capacity requirement, but that can also be easily upgraded when the traffic grows.

As a result, the network performance of deployed WCDMA network would be, right from the start, meeting the subscriber expectations.

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5 References

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