

On UMTS overlay deployment

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I. INTRODUCTION

Deploying UMTS on top of an existent GSM network (*UMTS overlay*) needs special consideration for securing all the benefits of a synergetic network. Aspects regarding UMTS network evolution, coverage, co-location, interference and noise, inter-system handover, mobility management, and traffic load sharing must be carefully investigated. The paper focuses on the constraints imposed by the overlay. Once these are fixed, the UMTS design process should follow the general criteria already presented in literature [3], [4].

Even if initially, UMTS may provide basic coverage fallback to GSM only, the goal is to create a true seamless network, where both radio access technologies (WCDMA and GSM), together with other access technologies, integrate into a single network. There are two important areas in this evolution [5].

The first relates to improving the performance of handovers between the two radio access networks. 3GPP is currently working on enhancements to the WCDMA and GSM standards (such as inter-system packet handover) that will reduce the actual interruption in user data transfer from seconds to fractions of a second during packet-switched service.

The other area relates to the ability of selecting the access technology that provides the best

quality for a given service. By changing the radio access technology based on the requested service type, it is possible to jointly optimize the quality of service and the overall capacity of the system [5].

II. UMTS STANDARD EVOLUTION

UMTS overlay deployments have to consider the complete picture of the mature network and its evolution path. From its first release in '99 (Figure 1), the UMTS standard continuously evolved, incorporating new technologies for radio access and core network.

The original release laid the foundation of a wideband CDMA (WCDMA) radio access technology for the UMTS Radio Access Network (UTRAN), capitalizing on the already available GSM/GPRS core network. Release 4 applied the layered architecture concept and introduced a QoS governed IP transport for the core network. The layered core network architecture has many benefits

- Independent evolution of control and connectivity layers
- Common seamless core network (GSM, UMTS)
- Flexibility for common transport backbone (TDM/ATM/IP)

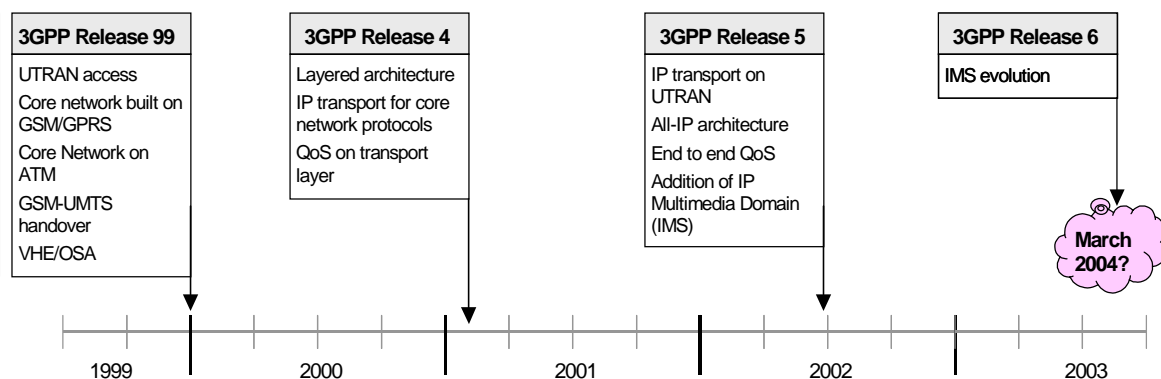


Figure 1 UMTS releases and main features

- Pooling of nodes and devices
- Client /Server architecture like in IP networking

Release 4 incorporates the latest developments in switch mechanisms, which allow service delivery and control functionality to become independent from the growth of the user traffic. Switch mechanisms are separated into *media gateways* (MGWs) (including switching, transcoding and user-plane transmission aspects) and *media gateway control functions* (MGCFs) (containing switch and service control functionality), connected via standard interfaces (e.g. H.248/Megaco). This separation enables flexible transcoder aspects such as *tandem-free operation* (TFO) and *transcoder-free operation* (TrFO) to be supported thus reducing the transmission costs to the network operator by allowing mobile coded rate (lower rate) speech to be carried across the network. The introduction of the Session Initiation Protocol (SIP) enables to deliver services (including voice and multimedia) that are neither limited nor restricted to the old 64 kbit/s fixed bandwidth and functionality.

IP transport was added to UTRAN in Release 5, paving the way towards an *'all-IP' architecture* with *end-to-end QoS*. The deployment of a true cellular QoS mechanism allowed the addition of voice and multimedia over IP enabling the convergence of the hybrid packet- and circuit-switched infrastructure into a single IP core network.

Addition of an *IP Multimedia Subsystem (IMS)* started in Release 5, the completion of it being due in Release 6.

III. UMTS LAUNCH ARCHITECTURE

Depending on how the new WCDMA radio access overlay will connect to the core network, two UMTS launch architectures are available for GSM/GPRS operators

- Integrated architecture
- Overlay architecture

A. Integrated UMTS architecture

The integrated architecture upgrades and uses the MSC and routing elements of the legacy GSM/GPRS network (Figure 2). It has the advantage of re-using the same O&M system, service delivery mechanisms, switch sites, and platforms. If not carefully deployed, the capacity and performance of the GSM/GPRS revenue-

earning network may be degraded by the new unproven WCDMA overlay.

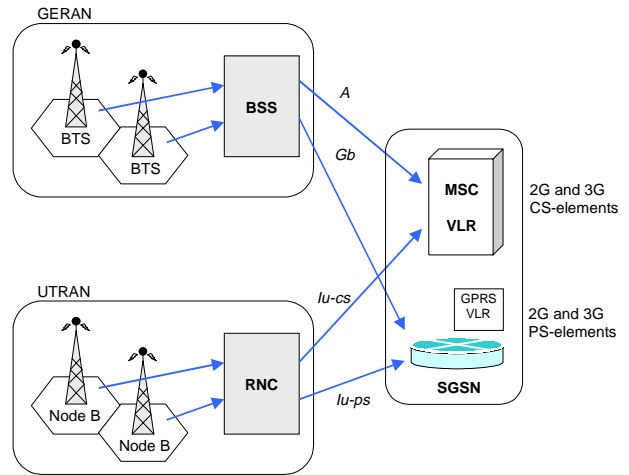


Figure 2 Integrated UMTS architecture

B. Overlay architecture

It uses a different (overlay) network of switching and routing elements to support UMTS (Figure 3).

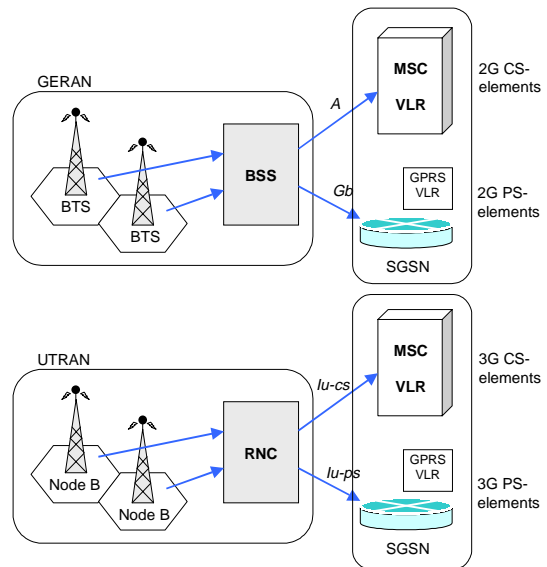


Figure 3 UMTS overlay architecture

Such an approach enables an independent development of the UMTS access without affecting the operating GSM/GPRS. On the downside, besides the financial effort for purchasing new hardware, the 3G MSC needs similar service delivery mechanisms to be developed (3G users must receive services equivalent with 2G users) as well as O&M capacity to support the new infrastructure

IV. WCDMA OVERLAY DEPLOYMENT

There are several benefits of deploying UMTS if the operator already has a GSM network:

- Reducing deployment costs through co-location/co-sitting
- Controlling the NB interference (avoiding near-far effects)
- Resource sharing; coverage extension, capacity sharing, service distribution

A general flowchart describing the UMTS overlay planning is presented in Figure 4. The actions listed in the flowchart are detailed below.

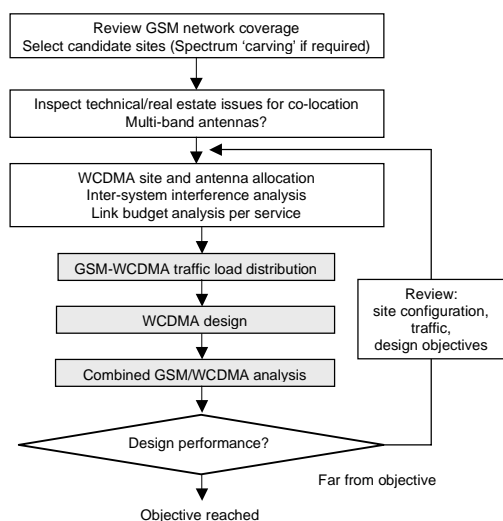


Figure 4 UMTS overlay planning

The UMTS overlay planning includes two major phases: the first one copes with the radio coverage while the second one (gray boxes in Figure 4) fixes the service availability. A GSM coverage review is required for finding out what UMTS services will benefit of full or partial cell radio coverage if re-using the GSM legacy radio access network (section IV.A). When sharing site locations¹ with GSM, real estate and technical issues have to be explored. On the technical side, co-sitting feasibility, inter-system interference and background noise are the main concerns (sections IV.B-IV.E).

After securing the UMTS radio coverage, the planning will focus on service availability. This phase starts by distributing the traffic load between the GSM and WCDMA sub-networks. A traffic simulator and a set of rules for inter-system handover are required in this process. Section V gives some notes on GSM-WCDMA handovers.

Once the traffic load to be supported by WCDMA and the site locations/configurations are known, the WCDMA radio access may be designed as an independent sub-network. A synthetic presentation of WCDMA RAN design is given in [3]. The last step requires special simulation tools for analyzing the performance of the seamless GSM-WCDMA network. If the design objectives are not satisfied, the process will loop back reconsidering site configurations, traffic load and distribution, WCDMA bearer selection, and even challenging the initial objectives.

A. Coverage analysis

WCDMA radio access may share site locations¹ with legacy 2G narrow band systems or may share site and/or infrastructure with peer WCDMA systems. The paper will focus on the first case.

Utilization of existing 2G-sites (co-location) is important in speeding up the WCDMA deployment. The feasibility of co-location depends on the quality of 2G-network coverage compared with WCDMA. Holes in the 2G-coverage (for basic services as voice) or increased intra-system interference for WCDMA should be avoided.

There are several bases for giving priority to UL analysis when assessing UMTS coverage; WCDMA down link (DL) is capacity and not coverage limited [1], streaming, interactive, and background services are strongly asymmetric, requiring low data rates in the UL direction. A complete UL coverage analysis should include dedicated channels (DCH) as well as common channels such as RACH. For the sake of simplicity, the paper will focus on dedicated channels only.

Table 1 presents a comparison between relative uplink (UL) coverage for existing GSM 900/1800 full rate speech services and WCDMA speech, 144 kbps, and 384 kbps data services [1]. Figures may change based on equipment and/or deployment characteristics. For the selected parameters, the analysis shows the 144 kbps WCDMA data services can be provided, with the same coverage probability as the GSM speech,

¹ **Co-location** will be used throughout the paper for indicating re-use of a site location only. Alternatively, **co-sitting** will be used for indicating when the new (WCDMA) system makes use of the existing antenna system. The second case is a subset of the first one.

TABLE 1 UPLINK PATH LOSS DERIVATION FOR EXISTING GSM AND WCDMA RADIO ACCESS [1]

	Unit	GSM900/ speech	GSM1800/ speech	WCDMA/ speech	WCDMA/ 144 kbps	WCDMA/ 384 kbps
Mobile Tx power	dBm	33	30	21	21	21
Receiver sensitivity ¹	dBm	-110	-110	-124	-117	-113
Interference margin ²	dB	1	0	2	2	2
Fast fading margin ³	dB	2	2	2	2	2
BS antenna gain ⁴	dBi	16	18	18	18	18
Body loss ⁵	dB	3	3	3		
MS antenna gain ⁶	dBi	0	0	0	2	2
Relative path loss gain with frequency ⁷	dB	11	1			
MAPL	dB	164	154	156	154	150

1 GSM sensitivity includes receive antenna diversity. WCDMA sensitivity is calculated based on the equation $10 \times \log_{10}(kTBF) - SF_{dB} + EbNo_{dB}$, where bandwidth B=3.84 MHz, spreading gain SF=B/(data rate), and F=4dB is the WCDMA base station noise figure.

2 An interference margin of 1 dB was used for GSM because of the small amount of spectrum in GSM 900 that does not allow large reuse factors. For a loading of $\chi=37\%$, the noise raise is $10 \times \log_{10}(1 - \chi) = 2 \text{ dB}$

3 The reduced fast fading margin comes from including the macro diversity gain

4 Three sector configuration are assumed for both GSM and WCDMA

5 Data terminals have not to stay close to the user's had

6 Antenna gain for data terminals is 2 dBi

7 Represent variations in the path loss attenuation with frequency versus the UMTS Region 1 band

when using GSM1800 sites. If GSM900 sites are used for WCDMA and 144 kbps seamless coverage is desired, a 10 dB coverage improvement is needed for WCDMA. The UL coverage for rates larger than 144 kbps is important for advanced conversational services (e.g. video-telephony) only.

B. Co-location and co-sitting

Given the limited number of sites for new base stations, and the cost of erecting new masts, site sharing between UMTS and GSM is likely to be of importance, especially for incumbent operators. Other than the mechanical issues, there should be no problem with the co-location of WCDMA and GSM900/1800 sites. It should be possible to share the same headframe between GSM and UMTS, assuming there is sufficient space for the additional antennas and feeders, and assuming that the structure is capable of withstanding the additional wind loading.

It may be possible to extend the mast/headframe vertically, although this is unlikely, as most will be as tall as possible in order to maximize coverage for GSM. This will have a significant impact on wind loading. More likely would be the availability of space beneath existing antennas. However this will lead to reduced coverage from the UMTS cells, although this will generally be acceptable on capacity cells in urban and suburban areas, where the cell spacing is determined by the traffic load rather than the propagation conditions.

Where there is no possibility to install additional antennas (due to space or load restrictions), it may be possible to use multi-band antennas in order to minimize the physical impact of sharing. However, such antennas will have reduced performance compared to single band antennas, and so the impact on the link-budget must be assessed to ensure that there is no adverse affect on the coverage of the two systems. Dual band antennas for GSM800 and GSM 1800 are currently available, and several antenna suppliers have plans for dual- and tri-band antennas for GSM900/UMTS², GSM1800/UMTS, and GSM900/ GSM1800/ UMTS. Where there is marginal impact the use of multi-band antennas would be the preferred solution, in terms of cost and environmental impact.

C. WCDMA interference

UTRA FDD is designed to operate in either of the paired frequency bands listed in Table 2 [2]. Deployment in other bands is not precluded.

TABLE 2 UTRA/FDD FREQUENCY BANDS PER REGIONS

	Unit	Region 1	Region 2
Up-link (MS transmit, base receive)	MHz	1920 - 1980	1850 - 1910
Down-link (MS receive, base transmit)	MHz	2110 - 2170	1930 - 1990

² UMTS for Region 1

In Europe (Region 1), new spectrum was allocated for UMTS, outside the PCN band (Figure 5), thus increasing the protection of GSM receivers. The spurious emission limits of WCDMA transmitters within the GSM 900 or DCS 1800 systems [2] are listed in Table 3. The figures are useful when performing isolation calculations for collocating WCDMA and GSM antennas in region 1.

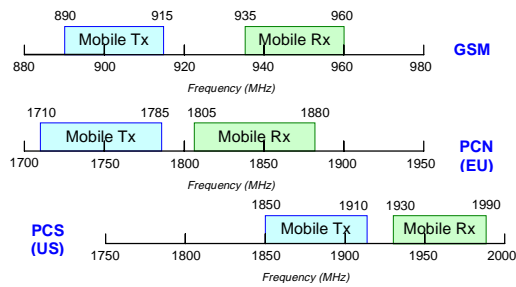


Figure 5 Spectrum allocated to cellular services

When WCDMA is deployed in the PCS band (e.g. Region 2), for frequency separation below 12.5 MHz, the spurious emission limits must be replaced by spectrum emission masks (Figure 6 and Figure 7). The level of acceptable out of band emission depends on the frequency separation and the power (P) on the WCDMA RF carrier. When the spurious emission limits changes with power, a single graph is given for a power in the specified range. For example, Figure 6 gives the graph for P=35 dBm, for the range [31, 39) dBm. For other power figures, the graph has to be shifted up or down accordingly.

D. Interference from 2G systems

When WCDMA RF channels are created by spectrum clearing, narrow band interference from legacy 2G radio access networks may degrade the coverage and capacity of WCDMA. Because UMTS is a wideband technology, such deployments leave very little room for 2G-3G guard bands. The worst-case interference takes place when WCDMA is adjacent to a non-

coordinated (see below) 2G spectrum.

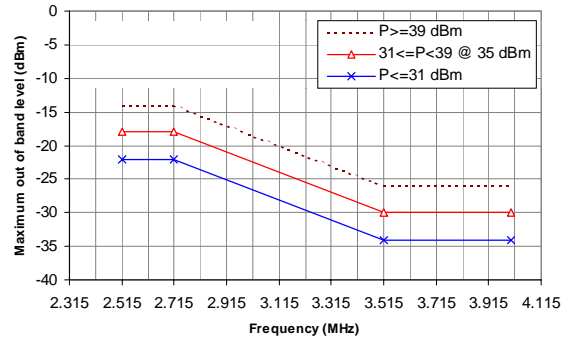


Figure 6 UMTS Node B out of band emission (measurement bandwidth 30 kHz)

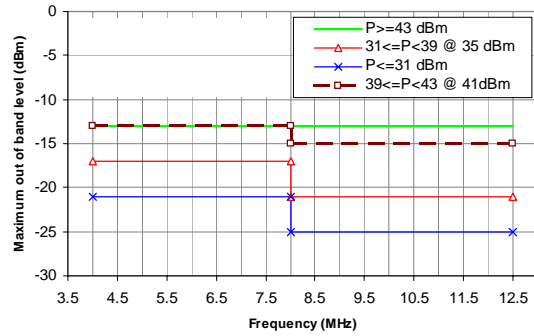


Figure 7 UMTS Node B out of band emission (measurement bandwidth 1 MHz)

The interference mechanisms from adjacent 2G bands may be classified as

- Adjacent channel interference (ACI) for up-links
- ACI, intermodulation, and wide band noise in the down-link

WCDMA-2G *coordination* takes place if, for any given location within a geographical area (market), path losses to 2G- or WCDMA-base stations are approximately identical. In such

TABLE 3 WCDMA SPURIOUS EMISSION CO-EXISTENCE LIMITS

Band (MHz)	Max Level (dBm)	Measurement Bandwidth (kHz)	Note
921 - 960	-57	100	Protection of GSM 900 MS receiver in geographic areas in which both GSM 900 and UTRA are deployed
876 - 915	-98	100	Protection of GSM 900 BTS receivers when GSM 900 BTS and UTRA BS are co-located
1805 - 1880	-47	100	Protection of DCS 1800 MS receiver in geographic areas in which both DCS 1800 and UTRA are deployed
1710 - 1785	-98	100	Protection of DCS 1800 BTS receivers when DCS 1800 BTS and UTRA BS are co-located

instances, the interference suffered by WCDMA terminals becomes less critical near 2G base stations because power control schemes may achieve the WCDMA required CIR. Stated differently, WCDMA dead zones are less likely. Thus, besides the advantage of location sharing, co-locating 2G/3G sites will enable a coordinated WCDMA deployment also, which reduces the risk of 2G-interference.

The interference problem is aggravated when there is no WCDMA-2G coordination (e.g. 2G terminals on macro-cell border and close to WCDMA base station, WCDMA macrocells overlaid on 2G microcells, etc). Different scenarios of WCDMA RF channels “carved” within a legacy 2G-spectrum are presented in Figure 8. In the first scenario (A), Operator 1 has a single WCDMA channel in the center of the legacy 2G allocated spectrum. The frequency separation between the WCDMA carrier and the uncoordinated 2G carriers of operator 2 and 3 is large enough for minimizing the 2G interference coming from these bands.

The most critical scenario in Figure 8 would be (B), because uncoordinated 2G carriers are adjacent to the WCDMA channel. If more than one WCDMA carrier are used by operator 1 (Figure 8 - C), the likelihood of inter-frequency handovers for WCDMA mobiles will increase.

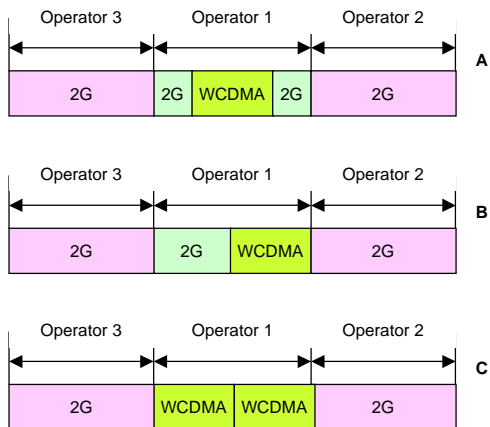


Figure 8 WCDMA deployment scenarios in the PCS band

E. Noise measurements

The previous sub-sections give the reason why to locate the WCDMA channel(s) in the center of the 2G available PCS spectrum. Once the spectrum for WCDMA is cleared, it is a good practice to measure the noise level in the cleared frequency bands before starting the actual deployment. The background noise measurement is useful for identifying co-location

issues (as imperfect spectrum clearance or leakage from adjacent bandwidth) and for estimating the sensitivity reduction due to background noise rise from heavy motor traffic (~ 1.9 dB in urban environments). A background noise measurement campaign conducted in Austria indicated an approximately normal probability distribution function for the noise power with a mean of -104.5 dBm and a standard deviation of 2.9 dB.

F. Reduction in coverage and capacity from 2G interference

WCDMA reacts to increasing interference power depending on the power allocation scheme. If a WCDMA base stations monitors individual link powers then, terminals in high interference areas would be dropped, thus creating the *WCDMA dead zones*. If the total transmitted power was monitored at the WCDMA base station, its increase over a specified threshold (from excessive power demanded by interfered terminals) would trigger the Radio Resource Management algorithms resulting in dropping terminals, which is equivalent with a capacity reduction.

Coverage and capacity reductions may be investigated through Monte Carlo simulations [3]. Some preliminary conclusions are presented below:

- A denser WCDMA network will be more resistant to 2G interference
- Guard bands of approximately 1MHz should eliminate 2G interference issues (applicable for non-coordinated 2G systems)
- If the legacy 2G-network is made of micro cells and the WCDMA cells are large (≈ 1.5 km) guard bands cannot alleviate capacity reductions.

WCDMA-2G collocation has a double advantage: it reduces deployment costs and builds coordination for minimizing 2G Interference risks

V. UMTS-GSM HANDOVER

Without mobile terminals equipped with both WCDMA and GSM technology, the UMTS and GSM networks can be considered as two independent networks with their own set of subscribers and services. Usually, the two networks are designed to cooperate, and depending on the objective of the UMTS network, designers might choose different paths for optimizing inter-system handover.

If the initial UMTS objective is to provide islands of high data rate services and seamless speech and low data rate coverage, the GSM/GPRS network would provision the 3G-coverage extension, demanding for that purpose reliable handovers from WCDMA to GSM/GPRS. Conversely, the 3G-network could be thought of as a capacity extension of the overloaded 2G-network, therefore emphasizing on the handovers from GSM/GPRS to UMTS. The last objective would be to optimize the capacity of the aggregated networks through *service-based radio access technology* selection (e.g. voice over 2G and medium/high data services over 3G). For such an approach, both types of handovers should be jointly optimized.

With the advent of mobile terminals capable of handing over between the two networks, the original GSM neighbors' list and registration area will have to be updated, and the UMTS cell coverage double-checked for slotted mode degradation.

A. Handover signaling

The concept is to encapsulate handover (HO) messages having exactly the same structure as if they had been sent on the alternate radio access technology. For example, when the network sends a WCDMA to GSM HO message, part of the message will include a GSM HO-message, with the syntax required by the GSM RAN. This part of the WCDMA message is extracted in the mobile terminal and processed as if it had been received as a regular GSM message in GSM. The same principle is used for handover from GSM to WCDMA, and when information is passed on the interfaces between network nodes [5].

B. Message size

Handover from GSM to WCDMA is still an open issue. The GSM channel limited data rate rules out the transmission of large payloads in an acceptable time frame (long handover signaling degrades the performance of services).

One proposal to overcome the challenge [5], is to replace the signaling of each handover parameter with a short reference to a pre-defined WCDMA radio channel configuration, which is either stored in the mobile terminal (default configuration) or sent to the mobile terminal in broadcast messages. The pre-defined WCDMA radio channel configuration describes bit rates, data block sizes and other radio parameters of voice or video call service.

C. Measurements

If the mobile terminal uses one access technology at a time, it needs to perform measurements on GSM while communicating in WCDMA and vice versa³. This is accomplished by the introduction of the WCDMA slotted (or compressed) mode of operation (Figure 9). Since WCDMA and GSM are different technologies, measurement results ought to be compared with technology specific thresholds.

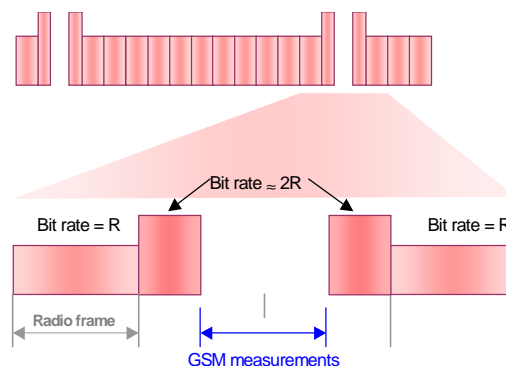


Figure 9 WCDMA slotted mode operation

D. Service based radio access technology

System capacity can be increased by selecting *service-based radio access* technology. In Figure 10), the blue (technology A) and red (technology B) triangles describe system capacity to handle voice and data traffic in two separate access technologies. Technology A can handle more data users (data centric) and less voice users in comparison with technology B.

If these technologies are combined and service-based handover between them enabled, the capacity can vary depending on how the service is allocated. To achieve maximum capacity (dashed black line), all data users should be allocated to the data centric technology (A) and all voice users to technology B. Minimum capacity will result if all users are allocated the other way around (solid red line).

³ Terminals with separate WCDMA and GSM receiver can perform measurements on the GSM network without slotted mode with the price of power consumption. For reducing the power consumption in the idle mode, when dual-mode terminals must take measurements from both networks, measurements on the other technology could be inhibited when the quality of the current access technology is adequate for the network settings.

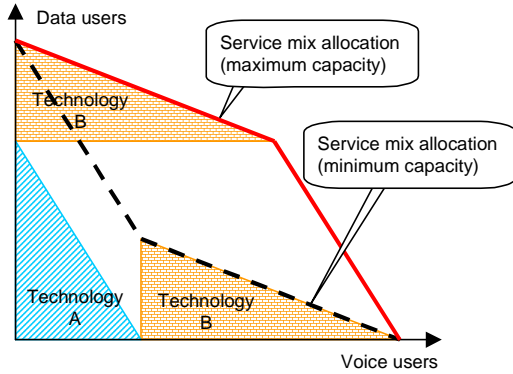


Figure 10 Capacity improvements from service based radio access technology [5]

VI. REGISTRATION AREA OVERLAY

Location Areas (LAs) in GSM cannot overlay (Figure 11). This results in frequent location update procedures on the borders between two LAs and, especially, where more than two LAs come together. The problem is particularly acute in densely populated areas, where the paging load and VLR capacity force a reduction in the size of the LA. Despite the reselection hysteresis and careful planning, this “ping-pong” effect continues to exist in reality, causing unnecessary load on the MSC, HLR and signaling network, thus notably reducing its effective capacity (overloading the processor in the core network). This problem also exists in GPRS Routing Areas with mobile stations in standby state.

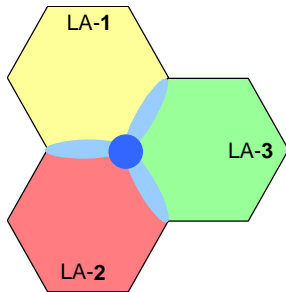


Figure 11 Density of location update procedures in GSM Location Areas

To overcome the problems, UTRAN defines URAs (UMTS Registration Areas) and the possibility of overlying them (Figure 12). The main benefit of the URA overlay is the reduction of location related signaling, triggered by the change of registration area. Currently, 3GPP is working to standardize the overlay for GPRS routing areas, so that, for instance, a new one can be centered where several others join (Figure 12).

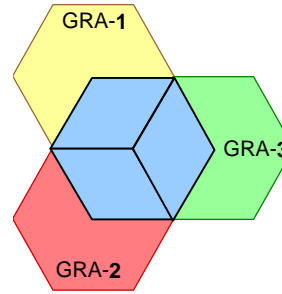


Figure 12 Optimum position for overlaid GRA (blue).

The concept of routing area overlay call for changes in the registration area management practices (Figure 13) by allowing GRAs to cross BSC boundaries

- one BSC could parent cells belonging to several GRAs and
- cells parented by different BSCs could belong to a certain GRA.

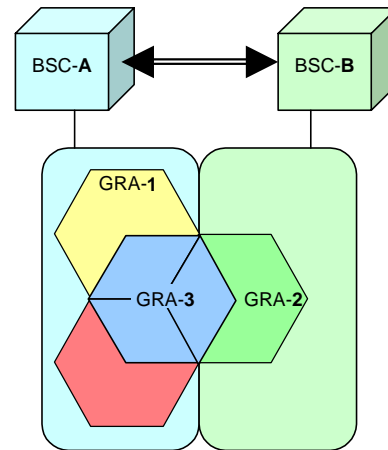


Figure 13 – GRAs crossing BSC areas.

With the new concept, a cell belonging to several GRAs would request the broadcast of several GRA IDs on the cell’s BCCH.

VII. CONCLUSIONS

The paper gives an overview of the major aspects to be studied when deploying UMTS on top of an existent GSM/GPRS network. UMTS is still evolving; 3GPP working groups standardizing new features about every year. In the same time, GSM is continuously updated with the final objective of a seamless network supporting multiple radio access techniques (GERAN and UTRAN). Thus, UMTS designs, specially the overlays, have to be made with the vision of the mature network and migration strategies in mind.

UMTS overlays have the benefits of faster and more economical deployments through co-location (IV.B), infrastructure sharing, including RAN- and core network elements (III). Enjoying the benefits calls for a lot of coordination with the legacy GSM/GPRS network starting from joint GSM/UMTS coverage analysis (IV.A), PCS spectrum carving (IV.C), interference and noise control (IV.D, IV.E), handover optimization (V), and ending with location/routeing area updating (VI).

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