Fruition beyond 2.5 G: Mobilising South Africa's Wireless Data Transition

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Abstract: This paper, written from a GSM planner perspective, presents an analysis into methodologies for South Africa's GSM/GPRS Operator's data throughput and capacity evolution. It begins by deriving the need for such a progression by considering issues like GSM's spectral inefficiency, coverage and traffic limitations on one side and provisions for multimedia services on the other.

Finally the paper addresses how South Africa can possibly evolve these technologies, in a piecemeal fashion, for seamless deployment.

Index Terms- 3G Migration, GSM/GPRS, Mobile Radio, Wireless Data.

1 INTRODUCTION

At the dawn of the twenty first century, the world is witnessing tremendous growth in the availability and functionality of a wide range of personal technologies, perhaps the most important being the convergence of the wireless devices with the data computing appliance for ubiquitous voice and data services. In order to satisfy the demand for mobile data lifestyles and the trend for dwindling telephony revenues [1], wireless operators will begin to strategize, placing emphasis on "evolution rather than revolution" [2] in leveraging their uni-service systems, incrementally enhancing them to solve data's much higher bandwidth and efficiency needs.

As incumbent operators begin to stare redundancy in the face, concerns exist around pioneering into the technology tug-of-war between WCDMA and CDMA2000. The outcome of such a decision could decide on the network's future. Also as 2G subscriber growths begin to stabilize, price erosion impacts the margins, and current network topology capabilities become depleted, network operators will lean towards differentiation through data services [1].

This paper, which endeavors to be applicable to the South African GSM/GPRS operator environment, investigates 3G's technological relevance, with the objective of seamlessly meeting SA's own market and network needs, against matched standards and predicted technology impediments, minimal incremental capex constraints and market and business case demands. Because of South Africa's contrasting coverage footprint, lower teledensity and GDP, and urban/rural composition, any solution could meander off any foreign trends. Our investigations reported in this paper were carried out to understand the possible scenarios that could be applicable to the South African GSM/GPRS operators such as vodacom and MTN.

Many roads lead to Rome, but only two roads lead to true Third Generation: WCDMA and CDMA2000 [2]. The analysis will begin with discussions around the need for progression in SA, then the limitations of GSM within the South African environment, and, after obtaining insight into the technical differences of mobile technologies, follows a discussion on how SA network's can be evolved or even face lifted. Our investigations focused on spectrum utilization, infrastructure reusability, and interoperability with the aim of recommending a narrow path and laying a foundation for further investigations. The central issue will be on ways of reducing risks by gradually adding more functionality, possibilities and value to SA's existing 2.5G (GSM/GPRS) networks through enhancement such as EDGE or 3G evolution through an overlay UMTS/CDMA2000 1x or GSM1x.

We reviewed the market needs towards operators' seamless evolution by looking at the less urgent throughput capability but more important data capacity need. To fulfilling this need, the paper then traces various standards (EDGE, GSM1x, greenfield CDMA2000 and UMTS (WCDMA), including GPRS CS-3&4, quantifying the individual benefit and their hardware requirements.

While citing the need for leveraging and depreciating existing GPRS investments and following spectral efficiency discussions, the paper concludes that fully re-utilising existing infrastructure towards DFCA, AMR and GPRS CS-3&4, then EDGE, will be one of the options for South Africa's 3G technology evolution.

2 3G SERVICES RELEVANT TO SOUTH AFRICA

South Africa's R23 Billion industry consists of 3 generally prepaid network operators, two GSM900 Operators (Vodacom (54% market share (7.5 million subscribers)), and MTN (40% market share (5.22 million subscribers))), which were launched in January and August 1994 respectively, and one GSM1800 Operator (Cell-C (6% market share (1 million subscribers)), launched in October 2001 [6]. Diversification for capacity and coverage reasons will have each operator venture into their sister bands (GSM1800 and GSM900 respectively) later this year. With network compositions varying across operators (different vendors (Ericsson, Motorola, Siemens, and Alcatel)), tailored evolution paths may slightly differ. GSM is normally predominant in urban and suburban environments, but locally, coverage extends beyond an equivalent area of Germany and France [6].

Since 3G is linked to an integrated platform for voice, data and multimedia services but with emphasis on data services, there is always the question whether South Africa in particular and Africa in general is ready for 3G given the relatively low literacy rate and spending power. The authors look at 3G as a platform for ICT enabled delivery of a wide range of services and as an encapsulation of information delivery and retrieval capabilities.

Information = **Power** (Yes)
Information = **data** (voice is a form of data)
Data = **Power**
BUT **3G** = **Data**
3G = **Power**

A large proportion of the people in South Africa are either unemployed, engage in informal sector, or operate business from home. These people require a network to reach them that has sufficient access speed to deliver information (data) at affordable tariffs. Figure 1 illustrates a typical small office application example using cdma2000 1x EV-DO. There are already a number of cdma network deployments in Africa [4] and South Africa seems to be loosing her leadership on 3G deployments in Africa.

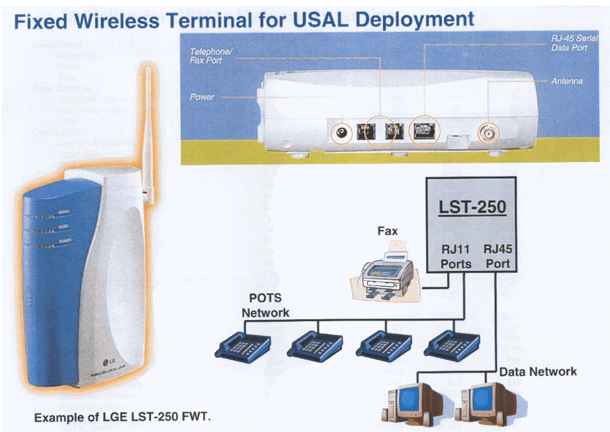

Fig. 1 Application example for Small Home Office using 3G (Derived: Qualcomm)

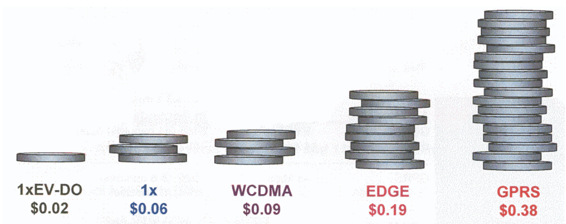

Fig. 2 The economics of Wireless Data
A reflection of spectral efficiency [3]

2.1 Impediments to Local Networks

Even in the midst of South Africa's low mobile penetration rate (25% (14.4 million subs, Feb 2003 [6])), SA's mature networks are constantly investing to keep up with the existing pure voice traffic reuse demands and the highly localized growing capacity requirements. Problems of the day are: frequent frequency planning, dimensioning for varying traffic/time-spread inflexibility, dependence on hardware size for trunking efficiencies, the inefficiencies/wastage of partially utilised hardware (idle timeslots wasted), and its hard limits to capacity and coverage.

This is in addition to the shortcomings in the effectiveness of packet data, particularly for different payloads. These, together with additional problems, such as illegal external interferers, hardware footprint space limitations, and numerous fractionally utilized (E1) transmission links and resulting trunking inefficiencies, will demand a solution for the next generation of services.

The major drawbacks of a GSM network can be summarised as follows:

- Limited data capabilities to support Internet access
- Low spectral efficiency and hence high cost of infrastructure, resulting in high tariff structure
- Coverage limitations in hilly terrain, high incidence of dropped calls
- Limited spectral efficiency resulting in congestion of the network

2.1.1 3G Services Relevant to SA

There are many services that can be offered using 3G in South Africa. These include:

1. Information (WWW, Online media, location information, reservation, and news streams)
2. Education (Virtual Schools and Libraries, Consultations, Online Training, etc)
3. Office Information (Tele-working, Mobile Office & workforce, Schedule sync, etc)
4. Public Services (Directory Services, Yellow Pages, Public Information, Remote Lottery Services)
5. Leisure (Music/Games on Demand, Virtual Sight seeing, Virtual book store, etc)
6. Special Services (Security, Hotline, emergency, Tele-medicine, Location Based Services, etc)
7. Communications (Video and Voice Telephony, Email, SMS and MMS, Announcing Services)
8. Financial Services (Point of sale Terminals, On-line banking, Home Shopping, Virtual Credit Cards)
9. Telemetric Services (Machine-Machine Services: Locations Based tracking, Navigation, Travel Info, Fleet Management, Remote Diagnostics, etc

Note that most of these services requires both capacity (erlang), reasonable speed (kbps) and efficiency of the network to offer low cost data applications that can be difficult to get from 2G and 2.5G.

2.2 3G Globally

Third Generation Mobile (3G) (UMTS/CDMA2000) is a technological (R)evolution of Second Generation (2G) digital mobile (GSM/IS-95) and their 2.5G data enhancements (GPRS/CDMAone (IS-95B)), facilitating flexible high speed low latency data packet delivery as required by demanding multimedia, and as a solution to 2G's spectral efficiency shortfalls. Its aspiration is to cost effectively bridge the advantages of mobile (ubiquity, reachability, and convenience) to that of high speed wireline data (reliability and throughput), to facilitate a host of new revenue streams (m-commerce, MMS, LBS…[7]). It is envisaged that this, together with mobile's affordable, fashionable and easy-to-use traits, will allow wireless data to make its mark faster than the internet has been able to do [1,6]. It is envisaged that CDMA, through its multiplexing efficiencies, will allow the operator to pack existing users into less spectrum, creating room for higher rate services.

CDMA2000, the first available 3G technology (September 2000- SK Telecom in Korea [8]), has stood out amongst IS-95 networks (US, Australia and most of Asia). Concurrently, most European players and large cellular groups (Vodafone (100 Million subs), Orange), have opted for the evolution to the GSM tailored capability and inter-compatible vapourware called WCDMA (Wideband CDMA)/UMTS. They (over 100 operators [4]) have since reinforced their commitment by financially entrusting extraordinary amounts into 3G licenses ($35 Billion in the UK, and an estimated $7 Billion for implementation [6]). The progress rate has also been energized by NTT Do Como's FOMA (WCDMA) 3G capable network (October 2001). Concomitantly, operators are looking towards EDGE overlays, to solve interim voice and data requirements, and their need for market demand assurance to reduce risk. UK's Hutchinson 3G, Italy's TIM, and Hong Kong's Hutchinson will be the first operators in Europe to launch EDGE in the first quarter of this year [4,5]. GSM1x, another CDMA, CDMA2000-GSM overlay option (vs. WCDMA), will commence trials (China Unicom) by the end of the second quarter this year [9], the aim of which will be to allow networks to lean towards capacity, coverage and spectrum flexibility. It is likely that, through these uncertainties, the way in which economies of scale and development play out, will draw a critical mass towards a similar technology to adapt. Success, like it did in GSM, will most likely depend on the highest adoption of the same technology.

There are currently over 154 Million cdma subscribers across the globe [4]. Figure 3 shows the global growth in cdma subscribers in the past two years.

Table 1 CDMAOne (IS-95A)/ CDMA2000 History [1,1,10,4]

Year	Technology
1993	IS-95A First standardized as another alternative for AMPS in America
1995	IS-95 Deployed (Typical, 9.6kbps, Max 14.4kbps)
1998-99	IS-95B Deployed (Max 64kbps)
2000	CDMA2000 deployed (Typical 150kbps, Max 307kbps)
2001	CDMA2000 1Xev-DO deployed (Max 2Mbps)
2003/4	CDMA2000 1xEV DV deployed (2Mbps multi-service)

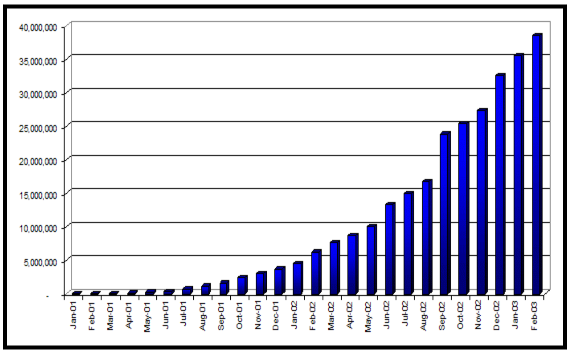

Fig. 3 cdma subs growth past two years [4]

3 3G CONVERGING TO LOCAL SA NEEDS

In 2003, a landmark year for Mobile (over 1 Billion subscribers), many still argue that GSM was chosen globally, over the 'better' CDMAOne (IS-95) standard, because of CDMA's lack of aggressive and timely deployment, and the market's lack of coverage/data demands. The fact of the matter is GSM has become the de facto standard of 509 (550 networks) operators around the world (733 Million (Aug 2002): two-thirds of cellular subscribers) [1], and the sullen mood of the financial markets is likely to keep it that way for sometime to come.

GSM/GPRS, EDGE, CDMA2000 (GSM1x) and UMTS are technologies that can be used to optimise the network, to rebuild balance sheets and retain the loyalty of customers. All these should be appraised on their system and infrastructure flexibility and complexity, within South Africa's operational concerns such as the radio environment, available frequency bands, capacity, and the data rate requirements.

The essence of how to utilise these technologies with their capabilities, is the challenge to all operators. We discuss the various possibilities that include vendor specific equipment requirements where necessary.

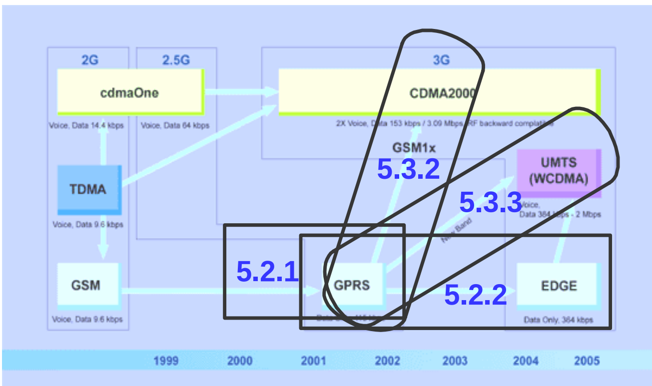

Fig. 4 Evolution Paths Techniques to 3G

The timeline is based on [5] 2001 predictions. Since then, EDGE has moved a year closer, and UMTS a year further.

4 Transition to 3G Provision Prereqisites

Before any form of provision, there are a common set of prerequisites to consider:

4.1 Optimisation Prerequisites

To maximise returns, networks have to be sure that they exhibit the correct radio atmosphere to take full advantages of offered capabilities. This is particularly so with CDMA's higher spectral loading, requiring even better than 2G cell planning [11]. Possibly tools such as Automatic Cell Planner's could be used to maximise any technology's value.

4.2 Transmission Dimensioning

Traffic demands will always increase. Consequently there are great transmission challenges in getting from 2G to 3G, predominantly that of catering for this unknown capacity growth. It is even more complex as in 2G dimensioning was based on the amount of transceivers, but in 3G, it is based on customer phone usage and traffic profiles.

4.2.1 2.5G Requirements

Transmission prerequisites for 2.5G are rather less stringent considering GPRS/ EDGE coding schemes (CS) support can be enabled on a per time-slot level, hence throughput can be controlled around transmission, hence provision can be dynamic [5]. Considering the A_{bis} interface caters for only up to 16kbps per timeslot, and CS-4 and EDGE require 22.4 and 64kbps respectively, software revisions, to make the allocation of multiple A_{bis} slots possible, will be inherent and taken as given [5]. This complexity is mostly a GPRS related modification. In GSM, a TRU typically occupies three timeslots (1 for signaling, 2 for data). For full CS-4 capability, a fully enabled GPRS/ EDGE TRU will require 1.4/4 times the data timeslots respectively (1 TRU will take up **4** (2.8+1)/ **9** (8+1) E1 timeslots respectively). Hence under heavy load, seamless upgradability will require that the transmission will have to be ad-hocly improved. EDGE will require a *factor of around three* additional capacity (only if fully utilised, which, in the short term, is unlikely).

4.2.2 3G Requirements

Within the core network, the various new interfaces (Iu, Ir, Ib, Gn, Gs), will need to be dimensioned and implemented. This complexity is what makes GSM to 3G transition a **"Revolution"** rather than an evolutionary process. In terms of the RAN/Iub transmission link, a single WCDMA TRX can deliver up to 1.5MBps (700-1000kbps plus 40% SHO overhead, protection overhead [5]) on the Iub. Therefore a *factor of approximately four* in additional capacity per ***site*** could be needed.

4.2.3 Transmission Technology

In anticipation of data, most operators, have already upgraded their cores to ATM. This is because it facilitates multi-service techniques, i.e. simultaneous voice and data, guarantees QoS through virtual connections, and supports advanced traffic engineering, encapsulating burstiness and statistical multiplexing gain. The current regulatory environment dictates that Telkom SA, the local fixed telephone network, can only provide link infrastructure (currently E1's) to sites. With 3G requiring around 4 times additional link capacity, networks should investigate the feasibility of replacing E1 (trunking inefficient), with base station supported ATM. Otherwise, as they have done or are currently doing, they could also invest in multiple remote BSC's, each situated close to site clusters, and multiplexing each link onto the ATM network. Alternatively, a flexible and manageable All-IP transport technology of the Internet, might take over from ATM [2].

5 SA Operators Building on Existing 2.5G

In fig. 4 we showed the following 3 possible transitions: GSM/GPRS to EDGE (5.2.2), GSM/GPRS to CDMA2000 (5.3.2) and GSM/GPRS to UMTS (WCDMA) (5.3.3).

GPRS, fig. 5, is widely deployed (212 Operators in 72 Countries) [5]. To overlay capabilities upon existing GPRS, there are two seamless transitions paths for fast interim provision. By protecting the existing site investment (reutilizing the GGSN, SGSN and PCU), implementation costs are rather low (approximately 7-15% of the initial GSM investment). It should pave the path towards testing data's impact and investigate the outcome of technology and handset availability, and allow more optimization flexibility in preparing the radio network C/I levels for 3G.

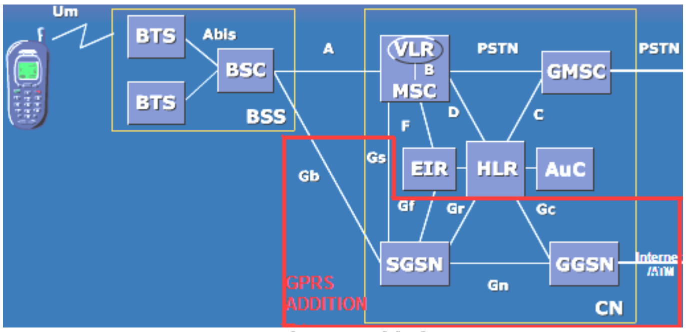

Fig. 5 Existing Packet Enabled GSM/ GPRS 2.5G Network (Derived: Siemens)

5.1 GSM/GPRS → EDGE Overlay (2.5G+)

Through modulation improvements to GSM/GPRS, an EDGE (Enhanced Data rates for Global Evolution) "add on", called EGPRS (Enhanced GPRS), can further supply rapid national "3G" coverage, increasing peak capabilities from 115 to 384kbps (avg. rates 30-130kbps), allowing networks to further squeeze value out of the investment in their existing GPRS networks. It will be available by end of the second quarter this financial year [13]. EDGE is as effective a technique for expanding data capacity as the adaptive multi-rate codec is for expanding voice capacity. The two working together result in GSM being an extremely efficient cellular technology.

5.1.1 Advantages

- ✓ By planting EDGE into an existing GPRS network, 3G coverage can grow from the current 2G spectrum, resulting in dynamic capacity/data throughput flexibility in high C/I areas.

- ✓ Furthermore, as the *data:voice* ratio increases and GPRS data cannibalizes voice capacity, this GERAN (GPRS/EDGE Radio Access Network) can also be used to free up voice capacity by reducing timeslot consumption by about 2/3rds [13].
- ✓ Investment security look promising considering that its later enhanced power control (EPC) revision (4 times faster), should improve its capabilities even further.
- ✓ It is a data only overlay upon the current network, making full use of the current network.
- ✓ Interference is measured on a per burst basis and reported (unlike GPRS where reported in idle frames).

5.1.2 Disadvantages

- As EDGE builds upon GSM data, GSM's core voice problems remain. Consequently it will also exhibit the same coverage/fade/multipath margin sensitivity, time dispersion limits, and spectrum wastage.
- Live network testing will only start the beginning of this year, and adoption will again be reliant on EDGE capable handset adoption/penetration [5].

5.1.3 Hardware Requirements

EDGE will require the EDGE capable transceiver (EDGE dTRU's and sTRU's) counterparts of that mentioned previously. There will also be some dimensioning upgrades around the core (software upgrade in BSC to enable the new Um protocol), and to the existing GGSN's, SGSN's and PCU's. The ease of this EDGE/GPRS overlay is shown [13]. Existing equipment, for example DXU's, will support up to these EDGE TRU's (some only one per cell).

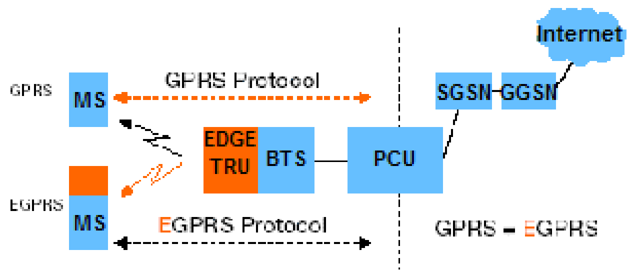

Fig. 6 EDGE overlaid upon GPRS functionality

5.2 An Overhaul through Full-3G

As mentioned previously, worldly competitors are turning to 3G, and though incompatible standards, seamless evolution is still possible, but not cheap. Need for such capabilities will probably only come with large voice/data capacity hotspot concentrations/spectral efficiency handicaps, as a complement to CS-3&4 or EDGE, but not as a complete throw away.

It will bring with it throughput advantages and multi-service capabilities for those that want to fully exploit mobile profitability beyond voice, and run their networks more efficiently with reduced capacity impediments.

5.2.1 GSM/GPRS → CDMA2000 Overlay (GSM1x)

As CDMA2000 enjoys significant cost, time-to-market and low-risk advantages (available for 2 years, 42 Commercial Networks (45 Million Subs) and over 100 low-cost handset models available [7]), predictions are that it will capture the majority of 3G subscribers, mostly from IS-95 operators, over the next 3 years to come [1]. By deploying GSM1x (GSM/ CDMA2000 1x overlay), networks can use the combined feature-rich services and roaming agreements of GSM with the spectral efficiency of CDMA2000 air interfaces, capable of offering peak data rates up to 2.4 Mbps (1xEV-DO-2001).

5.2.1.1 Advantages

CDMA2000, either as a Greenfield deployment or overlay to GSM/GPRS networks has many advantages to the operators. These include:

- ✓ An overlay will add a data evolution of up to 2.4Mbps and CDMA's improved spectral voice capacity[3,13].
- ✓ No need for new spectrum, the existing can be reused. Multiple bands also exist (450, 800, 1800, 1900, 2100)
- ✓ CDMA's better rural propagation and adaptability can be added in traffic hotspots, and rural coverage. It will be at an advantage over WCDMA because of its low spectrum consumption (1.25MHz), hence flexibly to be deployed and collocated in existing spectrum, and benefit from similar coverage footprints.
- ✓ This bandwidth flexibility combined with the low bandwidth requirement, should lower radio planning requirements because of lower than 1:1 frequency reuse .
- ✓ Because of complete IS-95 backward compatibility, handset availability is cheap and high existing IS-95 handsets can be reutilised.

5.2.1.2 Disadvantages

- Because of CDM2000's Multicarrier bandwidth, it looses the benefit of trunking efficiency compared to DS.
- The high Data Only enhancement, because of slow rate flexibility and power control being absent, can only be used for indoor application.
- Multimode handsets, required to roam between GSM and CDMA2000 aren't freely available and are likely to be expensive [4].

5.2.1.3 Hardware Requirements

CDMA2000 deployment will require completely new CDMA2000 base stations with 1x channel cards, new servers and routers (CDMA2000 BSC), a PSDN, and a connection to the GSM gateway MSC [9]. Networks will hence effectively operate in parallel, with intersystem handovers between. A synchronisation source also needs to be installed at each site.

5.3 GSM/GPRS → WCDMA/ UMTS

A UMTS overlay, designed by and for Europe, will also benefit the network through high spectral efficiency, higher user densities, and support for high bandwidth data applications (2Mbit/s indoors, up to 384kbit/s outdoors) [3].

Its unique inter GSM operability (adaptive traffic, handover, service differentiation and load control), flexible GSM/UMTS voice/data capacity management and multirate capability (8k to 2Mbps), and channel (FDD (5 MHz UL, 5MHz DL) or TDD (half duplex, 5 MHz both links)) plasticity, should maximize tailorability and the available solutions in keeping up with demand. Local implementation is qualified through the recent local spectrum reservation (SABRE (South African Band Replanning Exercise) Project- 23 January 2003) [12], but according to the UMTS forum, the lag from commitment to implementation is about 3 years due to spectrum refarming, licensing, and implementing issues.

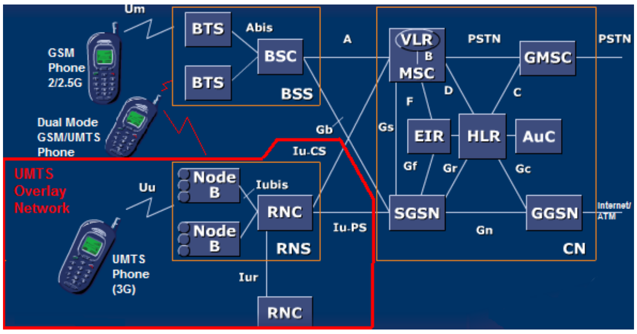

Fig. 7 GSM/GPRS UMTS Overlay Network

5.3.1 Advantages

- ✓ The 5 MHz bandwidth with high chip rate ensures that 3G's minimum throughputs of 144 and 384 Kbps are well achievable with sufficient capacity, and seamless overlay possibility, through separate spectrum, upon the existing network.
- ✓ It, together with ATM's QoS mechanisms should cater for multi-profile latency requirements, and its FDD and TDD structure benefit any macro coverage and localized highly asymmetrical throughput demands. UMTS also has HSPDA coming, to further enhance efficiencies.
- ✓ The large bandwidth can also resolve more multipaths and increase diversity
- ✓ Being asynchronous means no expensive synchronisation source is required.

5.3.2 Disadvantages

- With huge spectrum expenses (auctions result in around five times more than GSM's initial deployment costs [1]), and uncertainty around dates for additional spectrum biddings/cost and beauty contests/auctions, WCDMA local adoption feasibility, ignoring other insecurities, remain unclear. If the luck of the draw resulted in beauty contests, co-siting could give an eight times capacity increase over GSM, at a cost of 1-1.5 times the cost of original GSM equipment].
- Because of WCDMA's high bandwidth and asynchronous associated complexity, multimode handsets will also be expensive. Its TDD implementation will be limited to 3.75km range and power control will only allow 10-20km/h max].

5.3.3 Hardware Requirements

WCDMA essentially reuses most of GSM/GPRS's core network, except elements may need to be dimensioned slightly differently. The MSC and SGSN require a link and software upgrade for the Iu Interfaces (air interface (UE–Node B), Iub Interface (Node B – RNC), Iur Interface (RNC – RNC), and the Iu Core Network Interface (MSC–RNC & SGSN–RNC). A new WCDMA BTS (Node B) and BSC (RNC) also needs to be installed) [**Error! Reference source not found.**0]. Synchronization is also required for TDD base stations.

7 Conclusions

This paper has presented the evolution and 3G migration issues from a GSM operator's perspective that put premium on a leveraged solution and protection of current investments of GSM operators in South Africa. Although this approach may not be to the best interest of the general public, we believe it is the best starting point. The commercial viability of 3G in SA needs a thorough market study and investigations because of the large capital investment required setting up networks, in a largely unproven data market. The poor takeup of GPRS can not be used as a benchmark because it does not offer the kind of services and experience that 3G will offer.

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