3G Wireless Technology Challenges.

By William Hearmon, Chairman African 3G Forum 9 January 2007

Back to Basics.

Basic wireless propagation physics determines that free space loss is a reality in the earth's atmosphere. *The higher the frequency the greater the loss,* and therefore the shorter the range of a wireless signal. This poses a problem in Africa. With a population of 800 million people, with over 600 million surviving mostly as subsistence farmers in wide spread rural communities, the widest range possible from a base station is a pre-requisite in order to provide basic telecommunication services.

In addition, a trade-off exists between frequency and the capacity of the wireless link to carry information or data. The higher the frequency the more cycles you have and the more voice and data signals can be accommodated. This is defined by Shannon's law, and it is a function of the frequency and the signal-to-noise ratio. Should free space loss not be a problem then we would all be using the highest frequencies we could get and perhaps use technologies like WiMAX, say in the10 or 20 GHz bands. Should Shannon's capacity rules not apply then we would use HF-like frequencies down at 2 KHz or VHF at 30 or 80 MHZ.

Next, we have the real world challenge and the reality of economics. How many subscribers can we squeeze into a Megahertz of spectrum? What are the economies of scale for the Customer Premises Equipment (CPE) or the mobile handset, data card or fixed wireless terminal (FWT)? Is there a standard which will result in lower prices for CPE so that we can avoid being trapped by technologies that result in higher prices?

The bottom line is that in the real world of Africa basic mobile telephony with GSM at 900 MHz has been the most successful for the above reasons. In sub-Saharan Africa there are 48 countries with 72 GSM mobile operators and 153 million SIM cards issued[1]. This has all been achieved in the past ten years with growth being almost exponential. So given that the right frequencies were available to support coverage and capacity, scale ensured that the cost of base stations and CPE came down and the operators and their investors made excellent profits and return on investment..

1. The industry has finally acknowledged that SIM cards and subscribers in a predominately pre paid market are not the same thing. The actual number of real GSM subscribers in Africa is probably 80 million. But it is still an amazing feat.

The next question is, given the above is there any real need for 3G technologies in Africa?

Access technologies

Before we get into the need to converge voice mobile handsets and the internet using broadband technologies, one should look at the types of multiple access used by the various technologies, the challenges and benefits and again the economics. While doing so we should be aware that the GSM ARPU (Average Revenue per Subscriber) for all GSM operators is getting disastrously low. How can we justify 3G technologies, which operate at higher frequencies and therefore have reduced base station range and higher costs?

GSM uses a time division method to get many subscribers talking within the same frequency slot, called TDMA. This is not unlike couples at a cocktail party being given a time slot within which to speak. There are 8 time slots in each 200 KHz slot in the GSM world. When one looks at Erlang (the basic measure of telephone traffic) per MHz for a typical pre-paid call model in Africa, a single base station radio can service about ***200 subscribers***. This is a very rough rule of thumb based on 13 mErlang per subscriber, an average hold time of 55 seconds and a grade of service of 2% at 900 MHz.

Code Division Multiple Access CDMA uses a coding structure to get many subscribers talking within the same frequency band. These are called Walsh codes. This is not unlike the same group of couples at a cocktail party speaking in different languages to understand each other above the noise. The big difference is that when a time slot is allocated in GSM it is consumed, even if the couple say nothing. With CDMA the system sees that there is spare capacity available and just uses it. The bottom line is that with a CDMA mobile system in the identical call model as above the operator can service ***1600 subscribers*** with a single base station…….with the same resources.

But it is still not as simple as that! Why was GSM accepted and rolled out much more aggressively in Africa than CDMA, given the significant difference in carrying capacity We will have a look at the reasons here.

The GSM platform was stabilised and ready to deploy in 1989. (Remember the PC chipset standard then was the 286). The standards authorities, equipment manufacturers together with government regulators in Europe and Africa decreed that the mobile licence they were issuing to operators would not only specify the spectrum of 900 MHz but it would have to be GSM. This fact, together with the SIM card and ability to have handsets with ubiquitous roaming, brought to bear an economy of scale that was impressive. CDMA was just not ready at that time to offer the promised subscriber capacities.

IS95 was the CDMA world's 2G equivalent of GSM. It was only around 1998 that the manufacture of the IS95 CDMA chipsets, handsets and networks were in a similar position to compete with GSM. Today, CDMA 2000 1X is offering and supplying the promise of much higher capacities discussed above, coupled with excellent voice quality and coverage. It has caught up with low handset prices, roaming and economies of scale. Due to the superb spectrum efficiency of CDMA the GSM world accepted CDMA techniques as the solution for their 3G technology, which is known as WCDMA and falls under the UMTS category.

For these above reasons, the growth in 2G GSM networks has been stagnant at 72 for the past three years in Africa. The growth in CDMA 2000 1X has been astronomical. From six networks in 2003 there are now 35 operators, with new licences being granted monthly. These licences are neutral in that the new operator can choose whatever system he wants. All have gone for CDMA and mostly in 800 MHz for economic reasons.

Welcome to world of broadband and 3G

Basic mobile telephony has done a wonderful job of empowering Africa. The subsistence farmer is no longer held to ransom by the middle man if he has a simple voice mobile phone. With his larger crop he can now negotiate a price for his tomatoes before picking them and going to market. Information is power and the middle man can be kept in his place without holding the poor farmer to ransom because of his ability to make a phone call on his prepaid mobile phone**.** The Moçambique fisherman can call ahead to find out which harbour or port will offer the best price for his catch. The charcoal seller can see if there is a demand for his wheelbarrow of coal before he lugs it up the hill to the village. Even without electricity in their homes they have discovered practical and unique ways to charge their mobile phones.

Imagine if they could have 3G with internet access to surf the web and at better and lower prices for voice and data. They could grow bigger and better tomatoes, catch fish in the right place and with the best techniques and learn about controlling malaria with mosquito nets. So what is this third generation communications network?

The 3G Standard

3G stands for third-generation wireless technology and networks. 3G is based on the International Telecommunication Union (ITU) initiative for a single global wireless standard called International Mobile Telecommunications-2000 (IMT-2000). This concept of a single standard evolved into a family of five 3G wireless standards. Of those five, the most widely accepted are CDMA2000, WCDMA (UMTS) and TD-SCDMA.

According to the ITU and IMT-2000, a wireless standard must meet minimum bit-rate requirements to be considered 3G:

- 2 Mbps in fixed or in-building environments
- 384 Kbps in pedestrian or urban environments
- 144 Kbps in wide area mobile environments
- Variable data rates in large geographic area systems (satellite)

In addition to providing faster bit rates and greater capacity over previous-generation technologies, 3G standards excel by effectively:

- Delivering mobile data
- Offering greater network capacity

- Operating with existing second-generation technologies
- Enabling rich data applications such as VoIP, video telephony, mobile multimedia, interactive gaming and more

A Brief History of 3G

First generation wireless, or 1G, refers to analogue networks introduced in the mid-1980s. Examples include Advanced Mobile Phone Service (AMPS) used in North America and Total Access Communications System (TACS) used in the UK. In South Africa we had the C450 mobile system run by Telkom which was relatively expensive and took ten years to achieve ten thousand subscribers.

Most 1G technologies and systems were country or region-specific and thus offered limited coverage. As mobile communications grew in popularity, networks often became overloaded, resulting in busy signals and dropped calls. The solution was second-generation wireless, or 2G, which emerged in the early 1990s. 2G technologies were digital and offered the much-needed capacity that 1G analogue systems did not offer.[2]

Several technologies were widely used:

- GSM was and still is popular in Europe, Africa, Asia Pacific, and Latin America
- TDMA was used in the Americas and is still used in Latin America
- CDMA IS-95 or cdmaOne was used primarily in the Americas and Asia Pacific

However, these 2G technologies are incompatible with each other. Thus, mobile service subscribers were still often limited to using their phones in a single country or region. In an effort to standardise future digital wireless communications and make global roaming with a single handset possible, the ITU established a single standard for wireless networks in 1999. Called IMT-2000, which is commonly referred to today as 3G, the initiative set forth the requirements (mentioned above) for the third generation of wireless networks.[2]

Where is 3G Today in Africa?

Today, WCDMA (Wideband CDMA) and CDMA2000 are by far the dominant standards in terms of current commercial services, operator deployment plans and vendor support. In the ACF website www.3gafrica.org one may see via the selection of maps available where the deployments in various frequency bands are taking place. Nigeria has many licensed operating companies in the CDMA2000 1X-EV-DO 800 MHz band alone. Tanzania has just licensed four. MTN and UTL in Uganda have been operating CDMA2000 WiLL systems for a while now. Mauritius and South Africa have had WCDMA networks for more than a year. Movicel in Angola is the largest mobile operator in Africa using CDMA2000. Every one of the 48 countries in sub-Saharan Africa are licensing and deploying multiple CDMA systems in the next year.

Launched commercially by wireless operators in 2000, CDMA2000 1X was the world's first operational 3G technology, capable of transmitting data faster than most dial-up services. Today, more than 280 million people enjoy the benefits of CDMA2000 1X, which provides enhanced data capacity compared with all 2G technologies.

Also known as UMTS (Universal Mobile Telecommunications System), WCDMA (Wideband CDMA) is the 3G standard chosen by most GSM/GPRS wireless network operators wanting to evolve their systems to 3G network technology. WCDMA offers enhanced voice and data capacity and peak data rates faster than most dial-up services and average rates consistently greater than GSM/GPRS (Global System for Mobile communications/General Packet Radio Service) and EDGE (Enhanced Data for GSM Evolution). As of September 2006, more than 62 million subscribers were using WCDMA for their mobile voice and data needs.

What Does 3G Offer Africans and Who Benefits from It?

3G wireless services enable consumers and professionals to experience excellent voice quality as well as a wide array of compelling data services, including:

- Mobile Internet connectivity
- Mobile email

- Multimedia services, such as digital photos and movies taken by and shared via wireless handsets
- Wireless application downloading
- Video-on-demand and short-format Clipcast™ content
- Real-time multiplayer gaming
- Enhanced emergency and location-based services
- Low-latency push-to-talk and push-to-video message services

For consumers, 3G quite simply means a more rewarding wireless experience—high-quality, low-cost voice, and fun and useful data services whenever they want them, whenever they need them and wherever they have mobile phone service.

The small farmer and rural business entrepreneur in Africa can empower himself by linking into the 3G networks emanating out of his cities. CDMA 2000 systems in 850MHz have a cell area of 2712 km2 and in 450 MHz a cell area of 7521 km2. The relative range is 29.4 Km and 48.9 Km respectively. With WCDMA this is severely reduced due to the high frequency with a cell area of only 312 km2. In South Africa Vodacom and MTN have only rolled out their WCDMA coverage in very limited urban areas. For them it was an expensive "forklift migration" due to the fact that GSM air interface is totally incompatible with WCDMA. So UMTS/WCDMA needs to down band to 900 MHz to satisfy Africa's needs.

Not so for countries and operators that originally went for CDMA 2000 networks. The systems are forward and backward compatible. So for new operators in Africa the system of choice is CDMA 2000 with a frequency being selected in 850 MHz due to the combination of range and the fact that 95% of handsets are manufactured in this band and thus lend to an economy of scale low prices. Lehman Brothers estimates that the total cost of building and operating a CDMA 2000 network to serve 1 million users at 850 MHz is 31-38 percent of the cost for the same WCDMA network at 1900 MHz.
In South Africa the SNO and 5 of the 7 USAL's have selected CDMA 2000 1xEV-DO Rev.A in 850 MHz as their technology of choice. See below what the properties of such systems will have for their new users.

Enterprises can leverage 3G's advanced data capabilities to gain critical competitive advantages such as increased productivity, streamlined processes, improved customer service and enhanced communications. Workforces, farmers, transporters and entrepreneurs can essentially work from anywhere at anytime. Phones coming out of China even have barcode scanners built in to them.
3G technology also benefits the other participants in the wireless value chain. Wireless network operators are able to capitalise on increased voice capacity, greater network efficiency, lower costs per user served, increased ARPU (average revenue per user) and greater service differentiation. Device manufacturers can leverage the enhanced capabilities of 3G networks to sell premium wireless devices in volume. Finally, 3G technology's data capabilities open up an enormous world of opportunity for application developers and content providers.

What's Next?

The future of 3G is impressive—in fact, it's already here!

HSDPA/HSUPA

HSDPA (high-speed downlink packet access) is an evolution of WCDMA, optimized for packet-switched data applications. HSDPA provides impressive enhancements over WCDMA on the downlink (also referred to as the forward link)—promising 14.4 Mbps peak data rates—resulting in a better end-user experience. Subscribers with HSDPA service are able to receive emails with large attachments, surf the web or download multimedia or text files faster than ever.

For operators, HSDPA offers a three- to five-fold capacity increase over WCDMA, which translates into significantly more data users and lower cost per bit. At the conclusion of September 2006, there were more than 60 other HSDPA networks planned or in deployment and nine announced trials around the world. On 3rd April 2006, the first HSDPA network was launched in South Africa by Vodacom.
HSDPA will be followed by another evolution still in standards development. Just as EV-DO Rev. A greatly improves the uplink of 1xEV-DO, HSUPA (high-speed uplink packet access) extends the benefits of HSDPA to the uplink (also referred to as the reverse link). HSUPA will support up to 5.76 Mbps peak rates, further improving the end user experience. HSUPA will provide end users with a

DSL-like experience and enable lower latency services such as VoIP, multiplayer interactive gaming, push-to-talk and more. The first HSUPA deployments are expected in 2007.

CDMA2000 1xEV-DO

Launched in 2002, CDMA2000 1xEV-DO is a data-optimized evolution of the CDMA2000 standard, capable of delivering peak forward link data rates of 2.4 Mbps, or rates comparable to wired broadband. By dividing radio spectrum into separate voice and data channels, EV-DO, which uses a 1.25 MHz data channel, improves network efficiency and eliminates the chance that an increase in voice traffic would cause data speeds to drop.

CDMA2000 1xEV-DO Rev. A

EV-DO Rev. A is a significant evolutionary step in the CDMA2000 1xEV-DO progression. Launched in 2006, EV-DO Rev. A provides a peak forward link data rate of 3.1 Mbps and a peak reverse link rate of 1.8 Mbps.

In addition, EV-DO Rev. A incorporates comprehensive improvements to the air link that reduce call set up times, decrease transmission delays and enable greater service control. These enhancements, combined with the increased data rates, enable network operators using EV-DO Rev. A to offer richer, more interactive applications and services such as wire line-quality VoIP, low-latency push-to-talk, online gaming, video on demand and video messaging, as well as the ability to upload large data files.
EV-DO Rev. A also features Platinum Multicast. Offering three times more capacity than Gold Multicast, Platinum Multicast provides even greater network efficiency and reduces the cost of rich media content delivery to a large subscriber base when coupled with a content delivery system solution such as the MediaFLO™ Media Distribution System. Platinum Multicast's multi-tone modulation enhancement uses CDMA and OFDM waveforms on the forward link to multimedia handsets, while continuing to use CDMA for forward and reverse links on unicast services.

With its additional speed and capacity, Platinum Multicast enables operators to deliver live content such as breaking news, traffic, sports and weather. Furthermore, it offers operators greater flexibility—depending on network needs, operators can choose to deliver more channels of content or fewer channels of content in higher resolution.

EV-DO Rev. B

EV-DO Rev. B, a further development on the CDMA2000 roadmap beyond Rev. A, offers multi-channel capabilities, which allow network operators to aggregate multiple 1.25 MHz channels simultaneously and increase data rates dramatically. The first implementation of Rev. B will support up to 9.3 Mbps on the forward link and 5.4 Mbps on the reverse link (the standard, at its theoretical limit and aggregating 20 MHz of spectrum, allows up to 75 Mbps on the forward link and 27 Mbps on the reverse link) One of the chief advantages of Rev. B is that it puts the control for scaling bandwidth into the network operators' hands, allowing operators to tailor their systems to the spectrum they have available.

Rev. B's flexibility will enable significant capacity and performance improvements, while protecting CDMA2000 operators' current investments in networks and devices. Furthermore, it will allow more of operators' spectrum to be used for IP-based services, including mobile broadband data, wireline-quality VoIP and multicast traffic in a manner that results in lower operator costs through greater efficiencies.

Time Division-Synchronous Code Division Multiple Access

TD-SCDMA is a 3G mobile telecommunications standard, being pursued in the People's Republic of China by the Chinese Academy of Telecommunications Technology (CATT), Datang and Siemens AG, in an attempt to develop home-grown technology and not be "dependent on Western technology"

This is likely primarily for practical reasons, both current 3G formats may require the payment of IPR fees to Qualcomm and UMTS requires license fees from the primarily European-based 3G consortium. It is based on spread spectrum CDMA technology which makes it unlikely that TD-SCDMA will be able to completely escape payment of CDMA license fees to Qualcomm. The launch of an operational system was initially projected by 2005 but has been delayed.

On January 20, 2006, Ministry of Information Industry of the People's Republic of China formally announced that TD-SCDMA is the country's standard of 3G mobile telecommunication. On February 15th, 2006, a timeline for deployment of the network in China was announced, stating pre-commercial trials would take place starting after completion of a number of test networks in select cities. These trials are expected to run from March to June, 2006. TD-SCDMA enabled handsets are also set to start testing around the same time, and are expected to be available in Q2 or Q3 of 2006. TD-SCDMA 3G phones are expected to become available at the end of 2006 and other 3G networks will be delayed until TD-SCDMA is ready.

Once mass production is established this may be another exciting and valuable technology to empower the 600 million non communicated African people. With China's great interest and aggressive thrust into Africa it is a strong possibility.

The standard has been adopted by 3GPP since Rel-4, known as "UTRA TDD 1.28Mcps Option".

Technical highlights of TD-SCDMA

TD-SCDMA uses TDD, in contrast to the FDD scheme used by W-CDMA. By dynamically adjusting the number of timeslots used for downlink and uplink, the system can more easily accommodate asymmetric traffic with different data rate requirements on downlink and uplink than FDD schemes. Since it does not require paired spectrum for downlink and uplink, spectrum allocation flexibility is also increased. Also, using the same carrier frequency for uplink and downlink means that the channel condition is the same on both directions, and the base station can deduce the downlink channel information from uplink channel estimates, which is helpful to the application of beamforming techniques.

TD-SCDMA also uses TDMA in addition to the CDMA used in WCDMA. This reduces the number of users in each timeslot, which reduces the implementation complexity of multiuser detection and beamforming schemes, but the non-continuous transmission also reduces coverage (because of the higher peak power needed), mobility (because of lower power control frequency) and complicates radio resource management algorithms.

The "S" in TD-SCDMA stands for "synchronous", which means that uplink signals are synchronized at the base station receiver, achieved by continuous timing adjustments. This reduces the interference between users of the same timeslot using different codes by improving the orthogonality between the codes, therefore increasing system capacity, at the cost of some hardware complexity in achieving uplink synchronization

What about WiMAX?

WiMAX has been touted as 4G…..as the future. This paragraph is from a white paper in the WiMAX Forum website.

"The WiMAX technology, based on the IEEE 802.16-2004 Air Interface Standard is rapidly proving itself as a technology that will play a key role in fixed broadband wireless **metropolitan area** networks. The first certification lab, established at Cetecom Labs in Malaga, Spain is fully operational and more than 150 WiMAX trials are underway in Europe, Asia, Africa and North and South America. Unquestionably, Fixed WiMAX, based on the IEEE 802.16-2004 [1] Air Interface Standard, has proven to be a cost effective fixed wireless **alternative to cable and DSL services**. In December, 2005 the IEEE ratified the 802.16e amendment [2] to the 802.16 standard. This amendment adds the features and attributes to the standard necessary to support mobility. The WiMAX Forum is now defining system performance and certification profiles based on the IEEE 802.16e Mobile Amendment and, going beyond the air interface, the WiMAX Forum is defining the network architecture necessary for implementing an end-to-end Mobile WiMAX2 network. Release-1 system profiles will be completed in early 2006"

Firstly, it is limited to metropolitan areas due the high frequencies used. Secondly it needs homes with electric power. Lastly, there are no working systems in rural Africa showing that it is commercially viable. It is a Pico system that needs too many security risk and electric power challenged base stations. PHS failed in Dar es Salaam for this very reason. So WiMAX is not for Africa's 600 million disenfranchised subsistence farmers.

The cost to provide a carrier grade, ubiquitous WiMAX radio network, is expected to be similar to a 3G mobile radio network. Today's standard mobile radio networks will continue to expand and continue to be the dominant platform for delivery of mobile voice and data services. Depending on spectrum availability WiMAX can play a significant role in Africa's larger cities in complementing these networks.

Conclusion.

Practical, political and economic considerations will eventually determine the final outcome. The old colonial way of forcing technologies and commercial relationships with vested interests down the throats of African countries are going the way of the Dodo. "Internet access via mobile telephony will help to close the gap between rich and poor nations", says Eric Schmidt, CEO of Google. Technologies which maximise coverage, capacity and quality with low built-in IPR fees run by operators who run tight ships and supplied by vendors who know and embrace Africa are winning the day. One of the best examples of this is Kasapa in Ghana.

4G is not WiMAX as some have been heard to state. It is everything that comes after 3G. There is no definition from the ITU. What we do know is that it will be the World Wide **Wireless** Web and will use IPv6 for its address code. With IPv6 there are 128 address bits compared with the current IPv4 with only 32. As one wise person put it, "You will be able to address every grain of sand on earth".

Moving forward, both CDMA2000 and WCDMA will continue to evolve with the goal to increase network capacity, improve data rates and enhance system performance. These are impressive systems that will enhance and better the lives of all who live in Africa. For more detailed technical information on CDMA2000 and WCDMA please refer to 3GPP.org and 3GPP2.org. and the African CDMA Forum at www.3gafrica.org.

2. Editors note to page3. Only the terms 1G and 2G are officially recognised by the ITU. Terms like 2.5 G, 2.75G and 3.5 G are all just marketing terms used by vendors to promote their wares. Only when 3G was conceived did 1 and 2 come into being…… similar to World War 1.