

In this session, we will cover the following topics.

- Understanding the migration path from UMTS to 3G LTE
 - Release '99
 - HSPA and HSPA Plus
 - 3G LTE
- Understanding the migration path from CDMA2000 to EV-DO Rev C
 - CDMA2000
 - EV-DO Release 0
 - EV-DO Rev A
 - EV-DO Rev B
 - EV-DO Rev C
- A quick tutorial and market update on TD-SCDMA
- Revealing how these technologies perform in a real-world network
 - Separating the marketing hype from reality (plus why)
- Questions and Answers

A quick introduction to Signals Research Group, LLC.

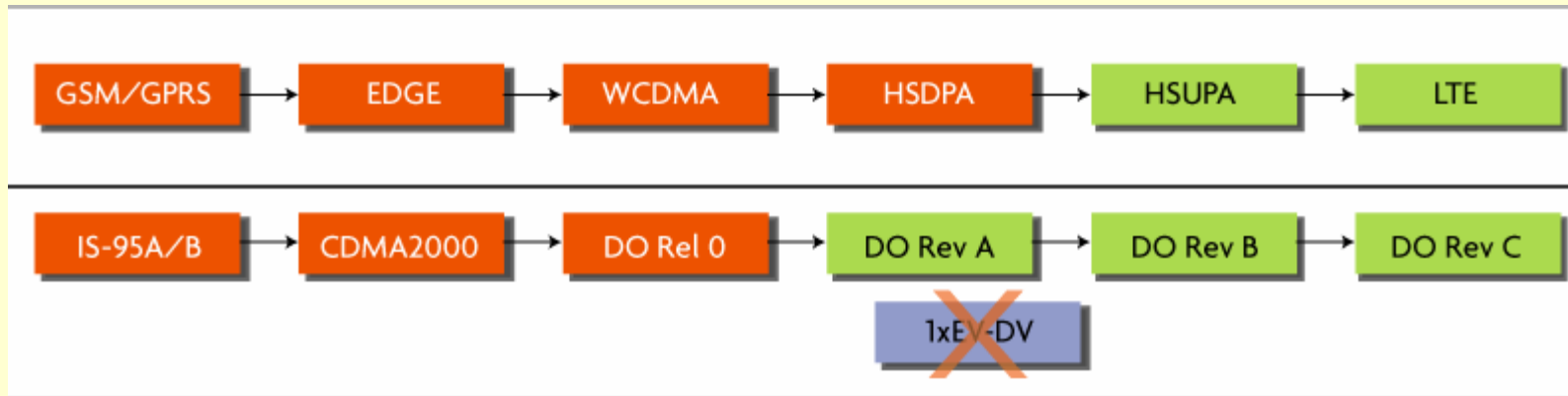
- Signals Research Group, LLC offers thought-leading field research and proprietary consulting services on the wireless telecommunications industry.
- Our flagship research product, a bi-weekly newsletter entitled “Signals Ahead,” includes more than 70 corporate subscribers on five continents across the entire wireless ecosystem, as well as trade organizations, government regulatory bodies, and organizations within the financial community.



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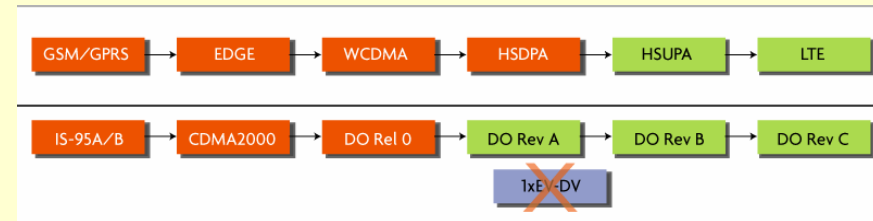
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The migration from 2G to 3G technologies results in an acronym soup.



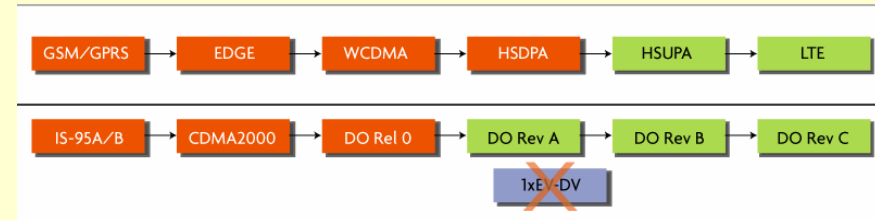
- Cellular technologies fall into two camps.
 - 3GPP (top row), or Third Generation Partnership Project, is “European centric” and is the dominant grouping of technologies
 - 3GPP2 (bottom row) represents the 3G migration path for CDMA operators
 - Technologies are and will likely remain incompatible (at least in the radio network)

UMTS – Universal Mobile Telecommunications System



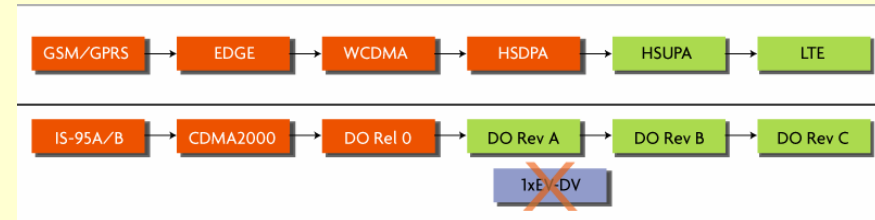
- UMTS (Universal Mobile Telecommunications System) is a so-called 3G technology.
 - First launched by NTT DoCoMo in 2001
 - Currently there are 105 UMTS networks around the world and ~80 million subscribers
 - GSM operators will deploy UMTS, it is merely a matter of timing
- Commonly deployed at 2100MHz although Cingular Wireless and Telstra are leading with respect to deploying “in-band” solutions.
 - Some economies of scale are lost when these new bands are introduced
 - Multi-bands also drive chipset prices higher
 - “in-band” solutions have greater RF propagation which helps to minimize CapEx

UMTS – Universal Mobile Telecommunications System



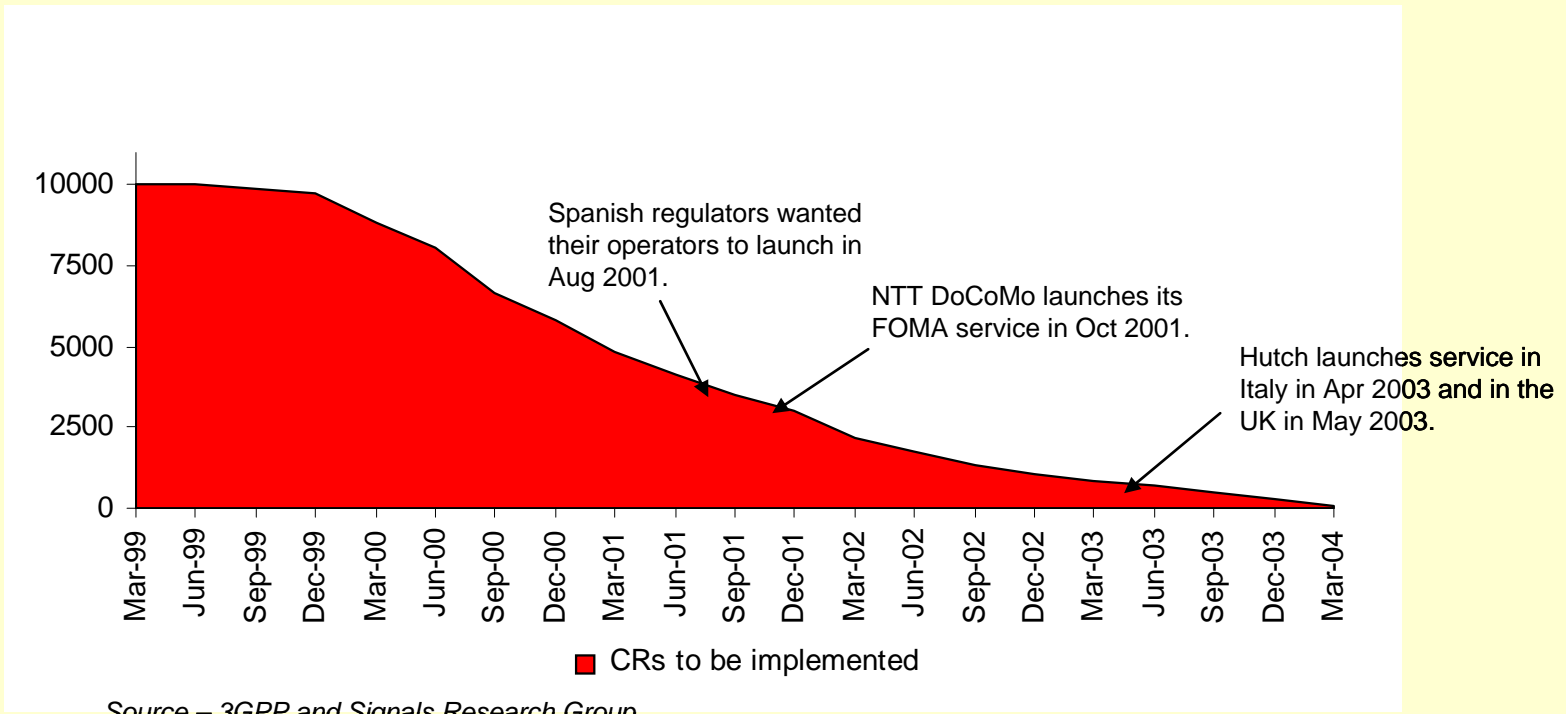
- UMTS requires a new Radio Access Network (RAN), Core Network (CN) and chipsets/devices.
 - To date, very few (if any) GSM/GPRS operators have not deployed a new core network (CN) despite the ability to reuse the legacy CN.
 - Concern over crashing the network with the new technology

UMTS – Universal Mobile Telecommunications System



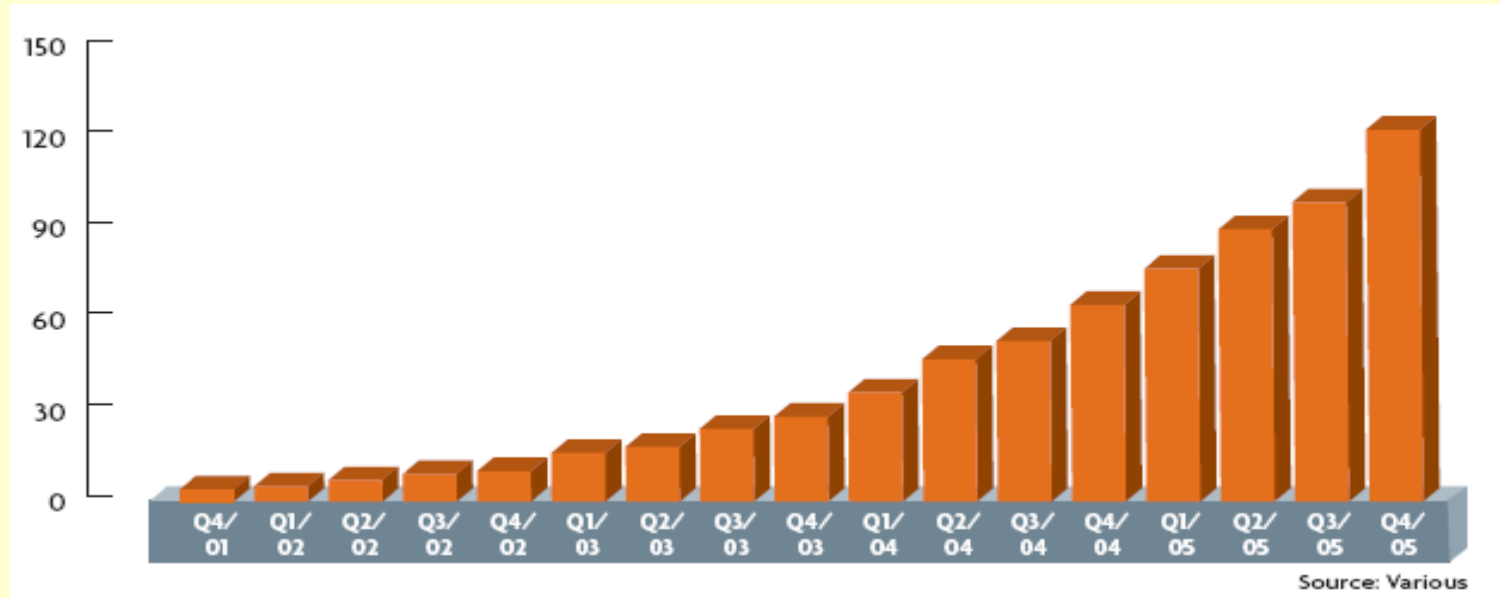
- UMTS uses a 5MHz radio channels based on CDMA versus 200kHz radio channels which use TDMA.
 - The “C” indicates that multiple users are separated by codes while the “T” indicates that they are separated by time.
 - Upside is that the technology reportedly offers ~3x increase in voice capacity over GSM, as well as higher data throughput
- UMTS supports new data applications, like video telephony.
 - EV-DO Release 0 does not support this feature

The initial success of UMTS was impacted by several factors.



- Initial launches were marred by technology glitches.
 - DoCoMo relied on a proprietary implementation
 - Change Requests (CRs) were rampant when 3 UK/Italy launched
 - RRM (radio resource management) represented a bulk of the CRs
- Poor 3G coverage and a rush-to-market mentality exacerbated the problem.

At launch there were very few commercial handsets available.



- Without an array of handsets, consumers had little choice when picking a 3G handset.
 - Only four [FOMA] handsets at the launch of the DoCoMo network
 - 10 WCDMA handsets by the end of 2002
 - 28 WCDMA (UMTS + FOMA) handsets by the end of 2003
- UMTS handsets are now relatively common place (even in India where 3G doesn't exist)

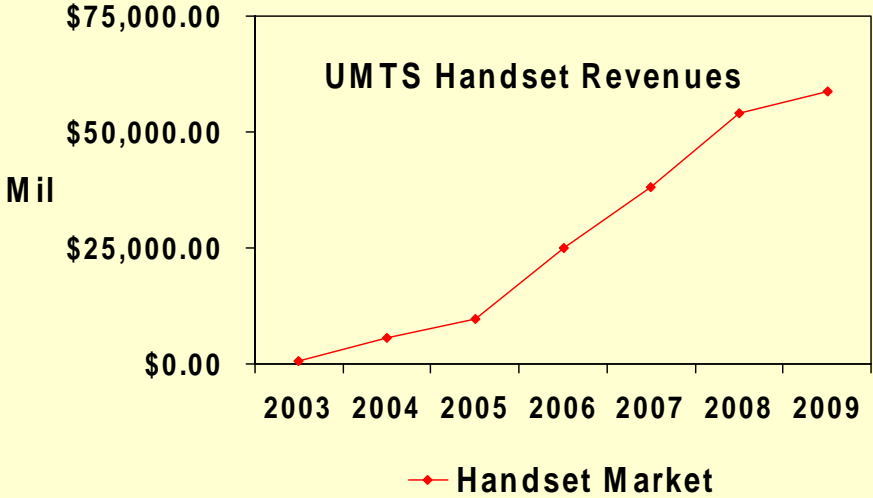
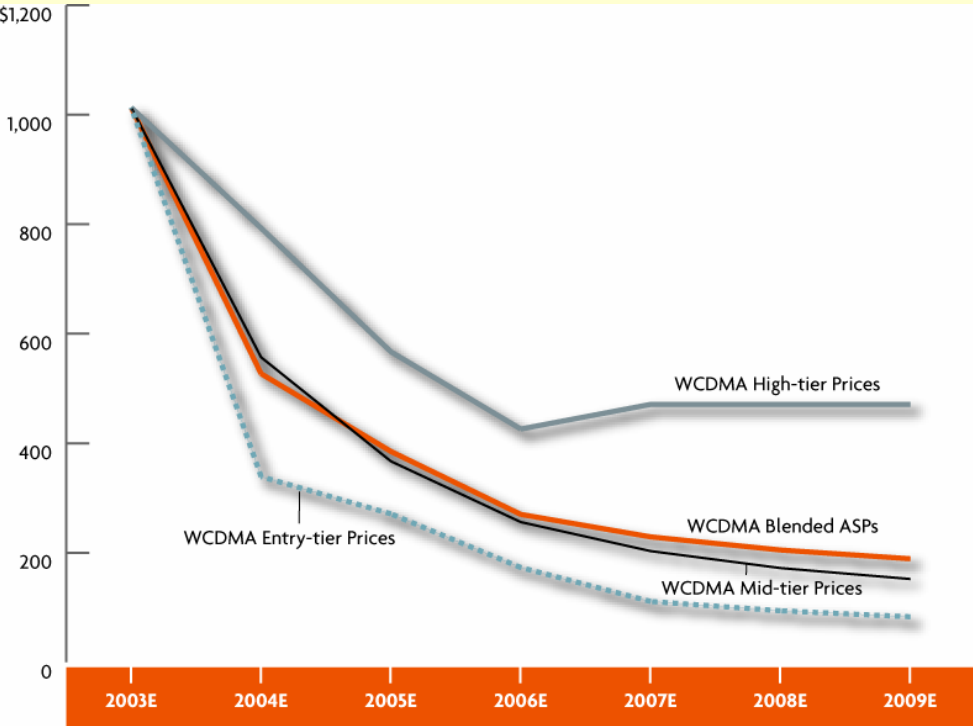
The feature set of UMTS handsets has increased.

Then And Now			
				
Motorola A830	Motorola vx3	Siemens-BenQ	Sony-Ericsson M600	Samsung SGH-z510
Avail: 2003 Dim: 117x59x27 mm Weight: 210 g Talk Time: 1.5 h Standby Time: 70 h Features: <ul style="list-style-type: none"> • 4K color screen • 32MB external • 2MB internal • Bluetooth • MP-player 	Avail: Q4 2005 Dim: 99x55x20 mm Weight: 125 g Talk Time: 5 h Standby Time: 250 h Features: 256K color screen <ul style="list-style-type: none"> • Up to 512MB ext • 64MB internal • Video telephony • 2 mega pixel camera • 8x zoom • Bluetooth • USB 	Avail: Soon Dim: 94x5x15.9 mm Weight: 110 g Talk Time: 4.5 h Standby Time: 300 h Selected Features: <ul style="list-style-type: none"> • Up to 1GB external • 64MB internal • Video telephony • 2 megapixel camera • Bluetooth • MP-3 player 	Avail: Soon Dim: 107x57x15 mm Weight: 112 g Talk Time: 7 h Standby Time: 340 h Selected Features: <ul style="list-style-type: none"> • 256K TFT screen • 64MB card • 80MB shared memory • Bluetooth • MP-3 player • USB 	Avail: Q1 2006 Dim: 99x52x14.9 mm Weight: 97 g Talk Time: 3.5 h Standby Time: 200 h Selected Features: <ul style="list-style-type: none"> • 256K TFT screen • 64MB shared memory • 1.3 megapixel camera • Video telephony • Bluetooth • MP-3 player • USB

Source: various websites, company information, and Signals Research Group, LLC

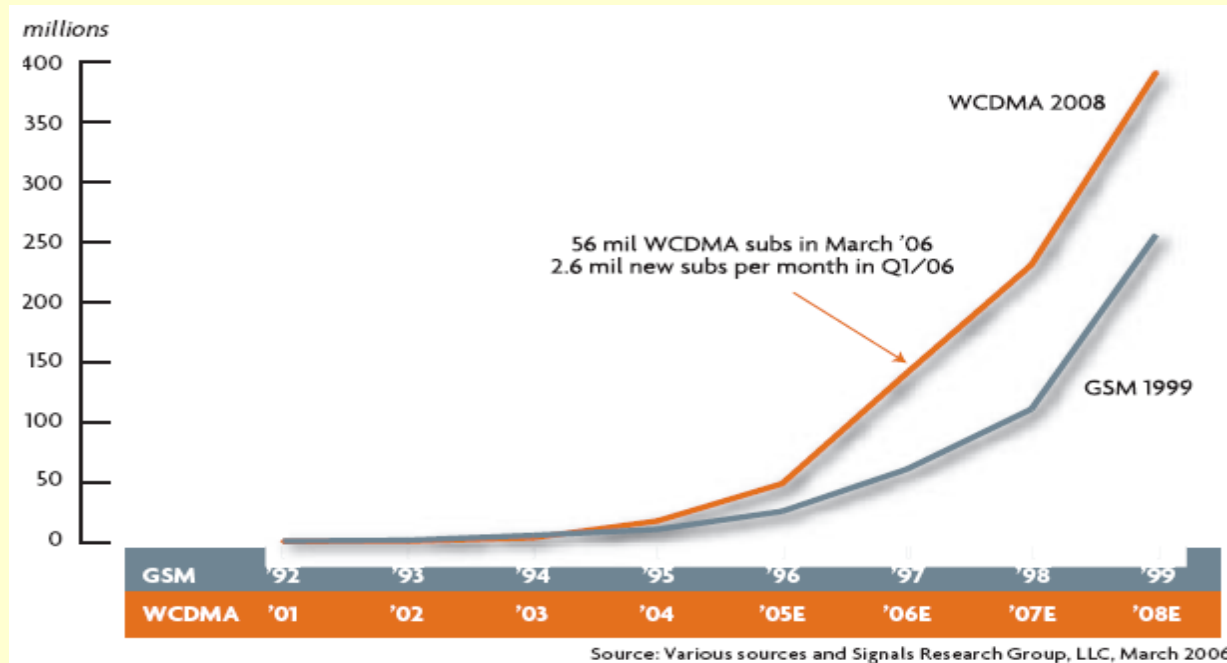
- Moore's Law is alive and well.
- Talk time and standby time have increased by up to 5x.
- UMTS handsets are 50% thinner and 50% lighter than initial UMTS handsets.
 - 130nm going to 90nm and eventually 65nm

UMTS handsets have come down in price while the feature set has increased.



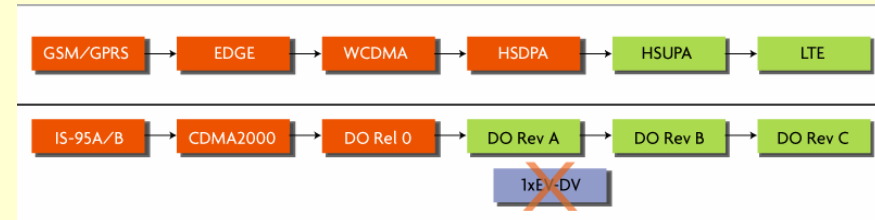
- Multi-mode UMTS handsets will drop to well below \$100 in the coming years.
- GSMA initiatives and single-mode/band devices could drive prices even lower.
 - But will these handsets have any appeal?

UMTS subscriber growth is very strong in the markets where it is deployed.



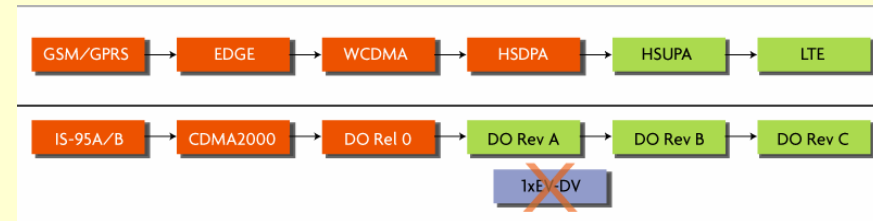
- Despite the slow uptake, UMTS subscriber growth is now on pace to exceed GSM subscriber growth during its infancy.
 - 3G licenses in China and India will help
 - Handset ASPs continue to fall rapidly
 - The success of more third-party silicon suppliers will add increased competition

HSDPA – High Speed Downlink Packet Access



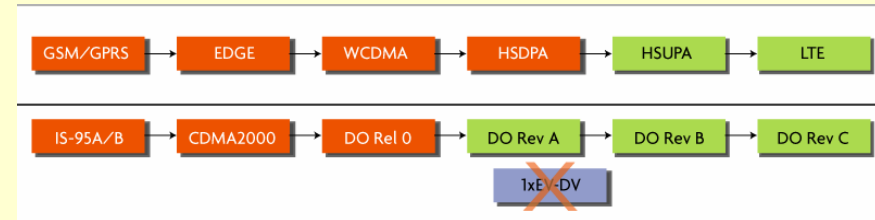
- HSDPA (High Speed Downlink Packet Access) is an enhancement to UMTS.
 - Cingular launched the first network in December 2005
 - At least 21 HSDPA networks have been deployed
- HSDPA supports peak data rates of 14.4Mbps in the downlink.
- HSDPA makes up for the shortcomings associated with UMTS (Release '99).
 - Designed to support high-bandwidth asymmetric data traffic (between the base station and user)
 - ~3x more spectral efficient than UMTS – lowers the delivery cost of mobile data content
 - Latency is also greatly improved, thus further enhancing the user experience

HSDPA – High Speed Downlink Packet Access



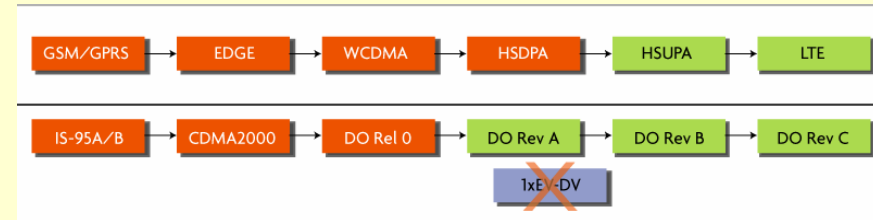
- HSDPA requires new hardware and/or software upgrades to the UMTS infrastructure.
 - Additional backhaul is required as well (can be added over time)
 - Most operators will now move directly to HSDPA versus starting with UMTS
 - Operators who were first to market with UMTS face higher “pain” in completing the upgrade
 - New handsets and baseband chipsets are required
 - Handsets are just coming to market – early devices were PC data cards

HSDPA – High Speed Downlink Packet Access



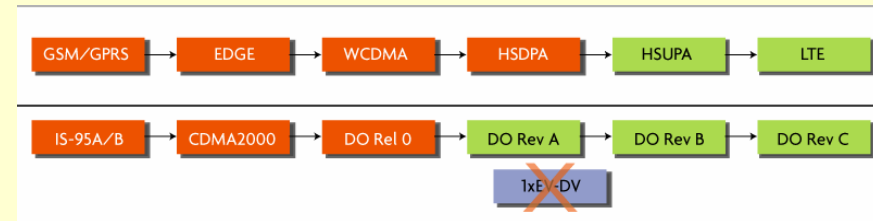
- HSDPA can be deployed within the UMTS carrier or in a standalone carrier.
 - To date, most (if not all) operators are deploying HSDPA in the same carrier as UMTS
 - Due to economics versus demand for mobile data
- HSDPA comes in several different flavors (or categories).
 - Initially, all HSDPA devices are Category 12 (1.8Mbps)
 - Category 5/6 devices (3.6Mbps) are now being introduced
 - Requires new receiver architecture (harder to implement)
 - The industry will likely converge around 3.6Mbps or 7.2Mbps

HSUPA – High Speed Uplink Packet Access



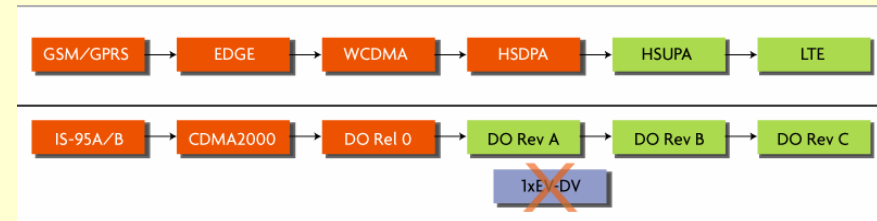
- HSUPA (High Speed Uplink Packet Access) is an enhancement to UMTS.
 - Only lab-based solutions have been demonstrated (launches possible in late 2007 or early 2008)
 - Provides the same basic capabilities of HSDPA, albeit in the uplink (between the subscriber and the network)
- HSUPA supports peak data rates of 5.7Mbps in the uplink.
 - Greatly improved latency and QoS mechanisms are additional features
- HSUPA requires new hardware and/or software upgrades to the UMTS/HSDPA infrastructure
 - New baseband chipsets and communications software are required

HSUPA – High Speed Uplink Packet Access



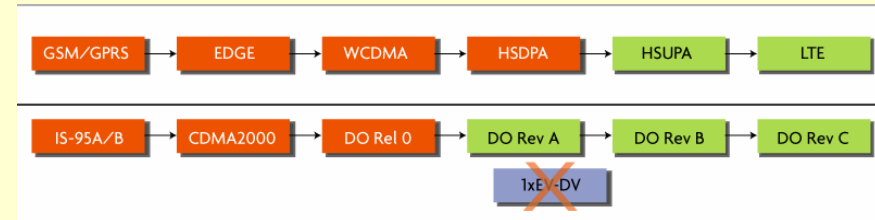
- HSPA+ is an interim 3G step that uses smart antenna technologies like MIMO (Multiple Input, Multiple Output) to offer an even higher level of performance.
 - Requires upgrades to chipsets
 - Includes support for VoIP
- HSPA+ is still going through the standardization process.
- With MIMO, the theoretical peak data rate doubles while coverage can also be enhanced.
 - Preliminary analysis suggests up to 30% improvement in throughput if all devices support the capability
 - Deploying six-sector cells may offer higher throughput (80% improvement) without impacting the devices

3G LTE – Long Term Evolution



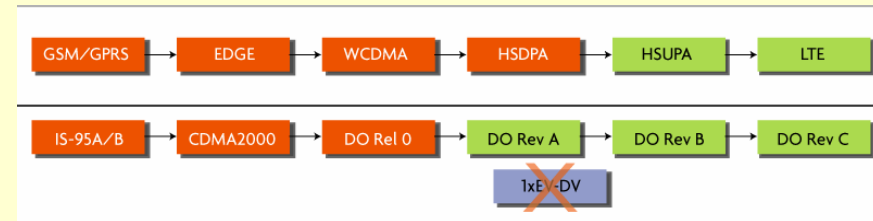
- 3G LTE (Long Term Evolution) bridges the gap between today's 3G technology and whatever comes next.
 - A runner-up technology for Sprint Nextel
- 3G LTE is still a work in progress within the 3GPP – standard should be finished in mid-2007
 - Considered part of Release 8
 - Vendors could demonstrate prototype solutions next year, but commercial rollouts are not likely until 2009+ (much depends on operator pull)

3G LTE – Long Term Evolution



- 3G LTE uses OFDMA (Orthogonal Frequency Division Multiple Access) in the radio access portion of the network
 - Unlike WiMAX, 3G LTE does not use OFDMA in the uplink
 - Requires new infrastructure
 - New baseband chipsets are required
 - Operates in TDD and/or FDD modes with scalable bandwidth (1.25MHz to 20MHz channels)
 - Supports MIMO for higher throughput and performance
- 3G LTE will generally require new frequencies – limits deployments
 - Support for wide channel allocations can only be done in new spectrum like 2.5GHz or AWS

3G LTE – Long Term Evolution

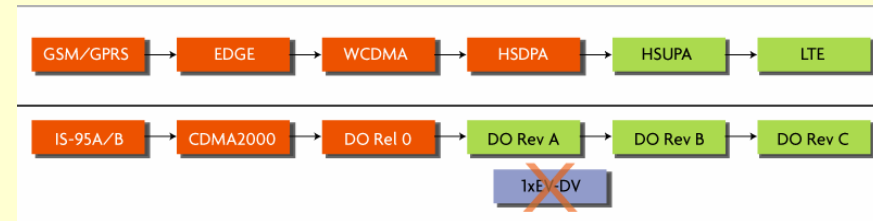


- 3G LTE supports a marked performance improvement relative to previous technologies
 - up to 100Mbps in the downlink and 50Mbps in the uplink (20MHz channels)
 - Support at least 200 active users in a cell (5MHz)
 - 3-4x improvement in downlink capacity over HSDPA
 - 2-3x improvement in uplink capacity over HSUPA
 - Mobility up to 120km/h with extended mobility features up to 350km/h
- The work of the NGMN initiative is related to 3G LTE
 - Similar goals, but includes a focus on FRAND

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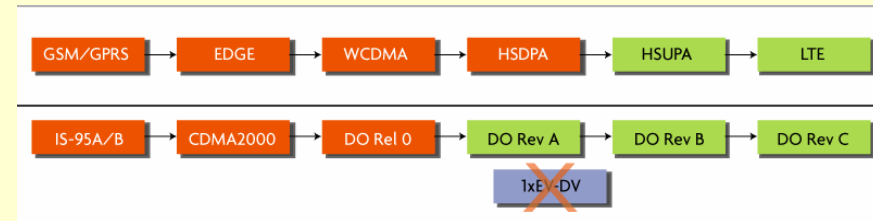
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CDMA2000 – CDMA2000



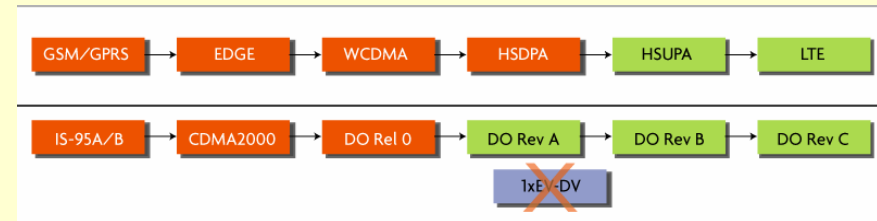
- CDMA2000 is the first 3G technology in the 3GPP2 migration path.
 - Technology was first deployed in South Korea in 2001 (SK Telecom and KT Freetel)
 - Also called 1X, which is an abbreviation of 1xRTT
 - Most, if not all IS-95 networks have since been upgraded to CDMA2000
- Upgrades are required to move from 2G (IS-95) to CDMA2000.
 - Technology requires new hardware in the base station and new hardware in the core network
 - New chipsets are required
- Technology is backwards compatible with IS-95A
 - Allows operators to seed their network with 3G devices

CDMA2000 – CDMA2000



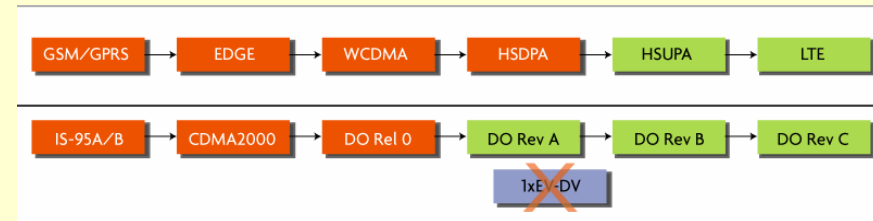
- Technology supports modest data rates with the focus is really on increased voice capacity.
 - ~2x that of IS-95A
- One reason for incompatibility with WCDMA is that CDMA2000 uses a narrow radio channel (1.25MHz)
 - UMTS must also be backward compatible with GSM (why it will be difficult to ever have 3GPP/3GPP2 convergence)

CDMA2000 EV-DO Release 0



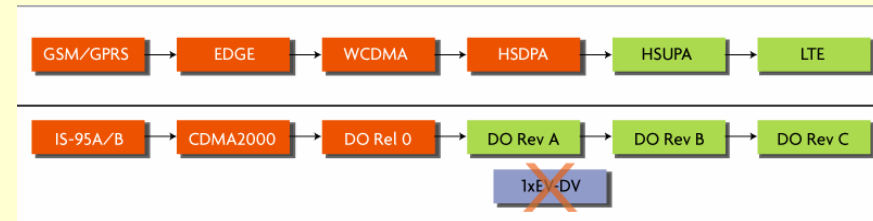
- Technology requires a hardware upgrade and new handsets/chipsets.
 - Unlike HSDPA, EV-DO requires a dedicated (1.25MHz) carrier
 - EV-DO is not backwards compatible with CDMA2000
 - Much like UMTS is not backwards compatible with GSM
- EV-DO replaced the need for EV-DV.
 - Sprint Nextel was pushing for this technology but reverted back to EV-DO due to competitive pressure from Verizon Wireless and lack of support within the 3GPP vendor community

CDMA2000 EV-DO Revision A



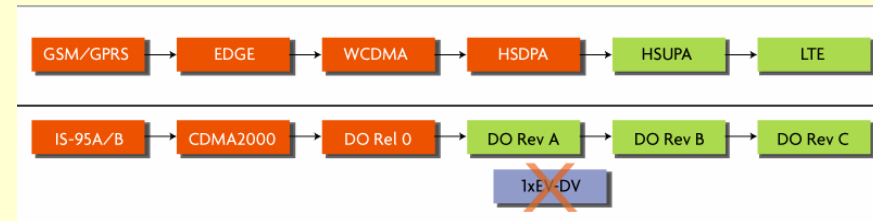
- EV-DO Revision A is very comparable to HSUPA.
 - Technology just became commercial in North America with Sprint Nextel
 - Nationwide rollout by the end of Q3/06
- Operators who have yet to deploy EV-DO will (should) start with Rev A.
- Rev A provides higher data rates and throughput in the uplink, plus quality of service capabilities.
 - Supports VoIP although vendors are backing off on capacity claims
 - Downlink data rate increases to 3.1Mbps

CDMA2000 EV-DO Revision B



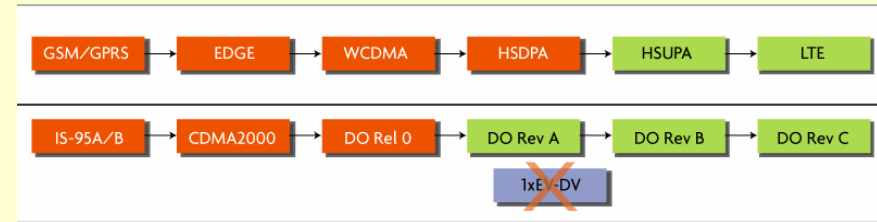
- Technology requires a hardware upgrade and new handsets/chipsets.
 - HSUPA infrastructure upgrade is largely software
- EV-DO Revision B is a multi-carrier version of Revision A.
 - Rev B logically combines multiple carriers together to boost data rates to individual users
 - Doesn't have to be contiguous spectrum
 - Peak data rates could theoretically hit 46Mbps in the downlink.
 - Technical issues and spectrum limitations will keep this from being a reality

CDMA2000 EV-DO Revision B



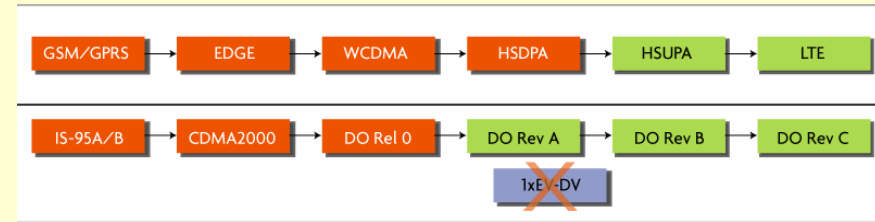
- Operators who are deploying a second Rev A carrier should strongly consider moving to Rev B.
 - Two Rev B carriers are more efficient than two Rev A carriers (also backwards compatible)
 - Improved latency is another feature
- Rev B development has accelerated over the last several months, likely due to Verizon Wireless.
 - Trials starting in mid-2007
 - Technology will likely be available in late 2007 or early 2008

CDMA2000 EV-DO Revision C



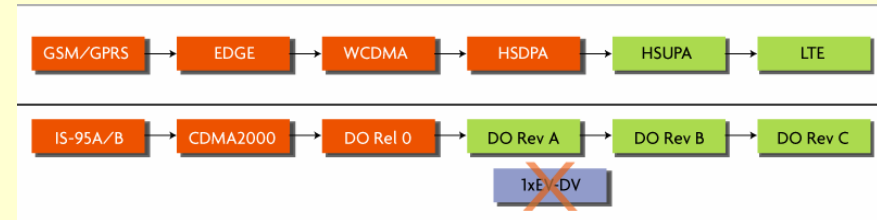
- EV-DO Revision C is very comparable to 3G LTE.
 - A runner-up technology for Sprint Nextel
 - Now referred to as UMB (Ultra Mobile Broadband)
- Technology is currently being defined in the 3GPP2 standards body.
 - Rev C combines the best of Qualcomm's IEEE 802.20 proposal and FLASH-OFDM, the technology that Flarion Technologies developed
 - Qualcomm acquired Flarion Technologies in August 2005 for its technology and intellectual property

CDMA2000 EV-DO Revision C



- Rev C uses OFDMA and smart antenna technologies, etc., to achieve a dramatic improvement in performance
 - 140Mbps in the downlink (10MHz of FDD spectrum)
 - 34Mbps in the uplink
 - Latency of 17ms
- Rev C has a greater dependence on OFDMA than 3G LTE, but also uses CDMA for a [claimed] improvement in performance.
- Rev C requires a new radio access network and handsets/chipsets.
 - Backwards compatibility is not possible

CDMA2000 EV-DO Revision C



- Timing of technology is TBD, but trials are scheduled for next year.
 - Infrastructure suppliers believe that UMB will precede 3G LTE
- Like 3G LTE, lack of available spectrum will be an issue.
- Bigger issue is who will deploy UMB.
 - VZW appears to be on board – likely use for its AWS spectrum
 - Some AWS spectrum holders are possible
 - Other major 3GPP2 operators have other commitments
- 3GPP/3GPP2 convergence is not likely due to politics and backwards compatibility issues.
 - 3G LTE and Rev C share much in common from a hardware perspective

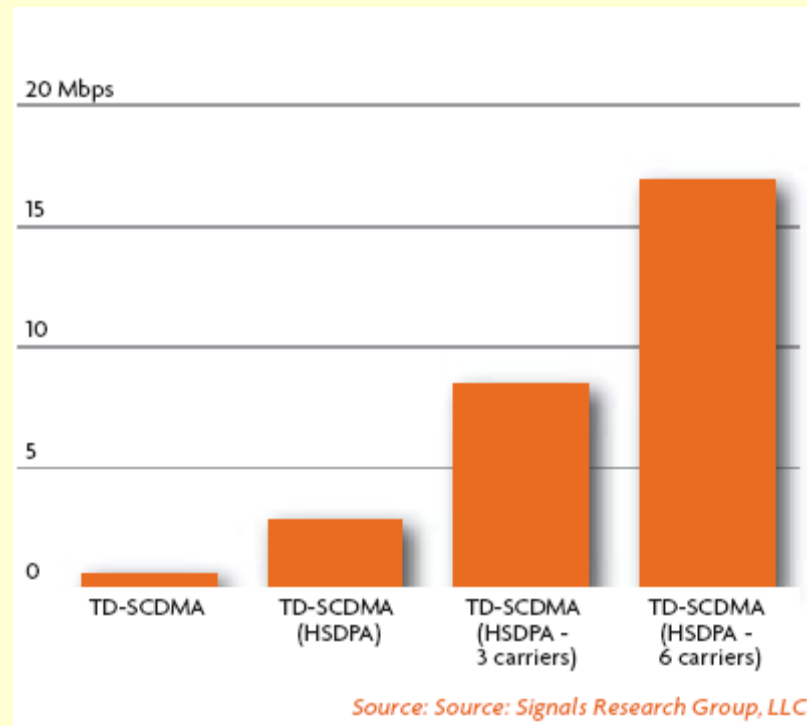
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TD-SCDMA – Time Division Synchronous Code Division Multiple Access

- TD-SCDMA is a home grown technology largely developed by the Chinese.
 - Technology is going through a series of government trials to determine the stability and performance of the standard
 - There are currently 3 trials taking place involving the infrastructure suppliers, operators and the Chinese government.
 - Network rollouts will take place once the licenses are awarded in China
 - Major infrastructure suppliers include Datang (China's version of Qualcomm), other Chinese companies and government agencies, TD-Tech (Siemens + Huawei) and ASB (Alcatel Shanghai Bell)
 - Siemens was one of the early developers of the technology

TD-SCDMA – Time Division Synchronous Code Division Multiple Access



- TD-SCDMA is not a natural evolution of any existing cellular technology.
 - Included within the 3GPP family since the core network is the same as what is used with UMTS
- TD-SCDMA has its own evolutionary path, including support for “HSDPA”

TD-SCDMA – Time Division Synchronous Code Division Multiple Access

- There are four consortiums that are pursuing the TD-SCDMA market.
 - Datang is involved in all of the consortiums (necessary)
 - Qualcomm isn't likely to enter
 - Presence of Samsung and Motorola in the T3G consortium is good for its members
 - Datang/ADI supposedly have the “best solution” but no solutions are really commercially viable at the moment
 - Like other markets, a supplier's success is largely tied to its customer base

The TD-SCDMA Device Landscape

Consortium	Participants/Investors	Customers
T3G	Datang	Samsung
	Philips	Motorola (?)
	Samsung	
	Motorola Ventures	
Commit	Datang	LG
	Nokia	Bird
	Texas Instruments	Lenovo
	LG	Nokia (?)
	Putian	DBTEL
Datang/ADI	Hyper Market International Ltd.	
	Datang	Datang
	Analog Devices	Holley Group
Spreadtrum		Alcatel-TCL
	Spreadtrum	Amoi
		Inventech
		Lenovo
		DBTEL
		Hisense
	OK	

TD-SCDMA – Time Division Synchronous Code Division Multiple Access

Participants/Investors	Comments
TD Tech Ltd.: Siemens (51%) and Huawei (49%)	>\$100M invested <i>commercially ready solution</i>
Alcatel and Datang	Datang provides Node B Alcatel provides manufacturing ALA providing expertise to reduce Node B costs <i>commercially ready solution</i> formed Nov 2004
Nokia: (49% and Putian (51%)	>\$111M invested
Ericsson and ZTE	Ericsson provides core network ZTE provides the RAN, but ERICY is the OEM
Lucent (Core Network)	Lucent involved in >50% of IOT
Nortel (Core Network)	

Source: Source: Signals Research Group, LLC

- Western companies that have partnered with Chinese companies stand the best chance of benefiting from any TD-SCDMA deployments.
 - Siemens (TD-Tech) and Alcatel are the most likely to benefit
 - Companies, like Ericsson, Lucent and Nortel are providing CN infrastructure (compatible with UMTS CN infrastructure)

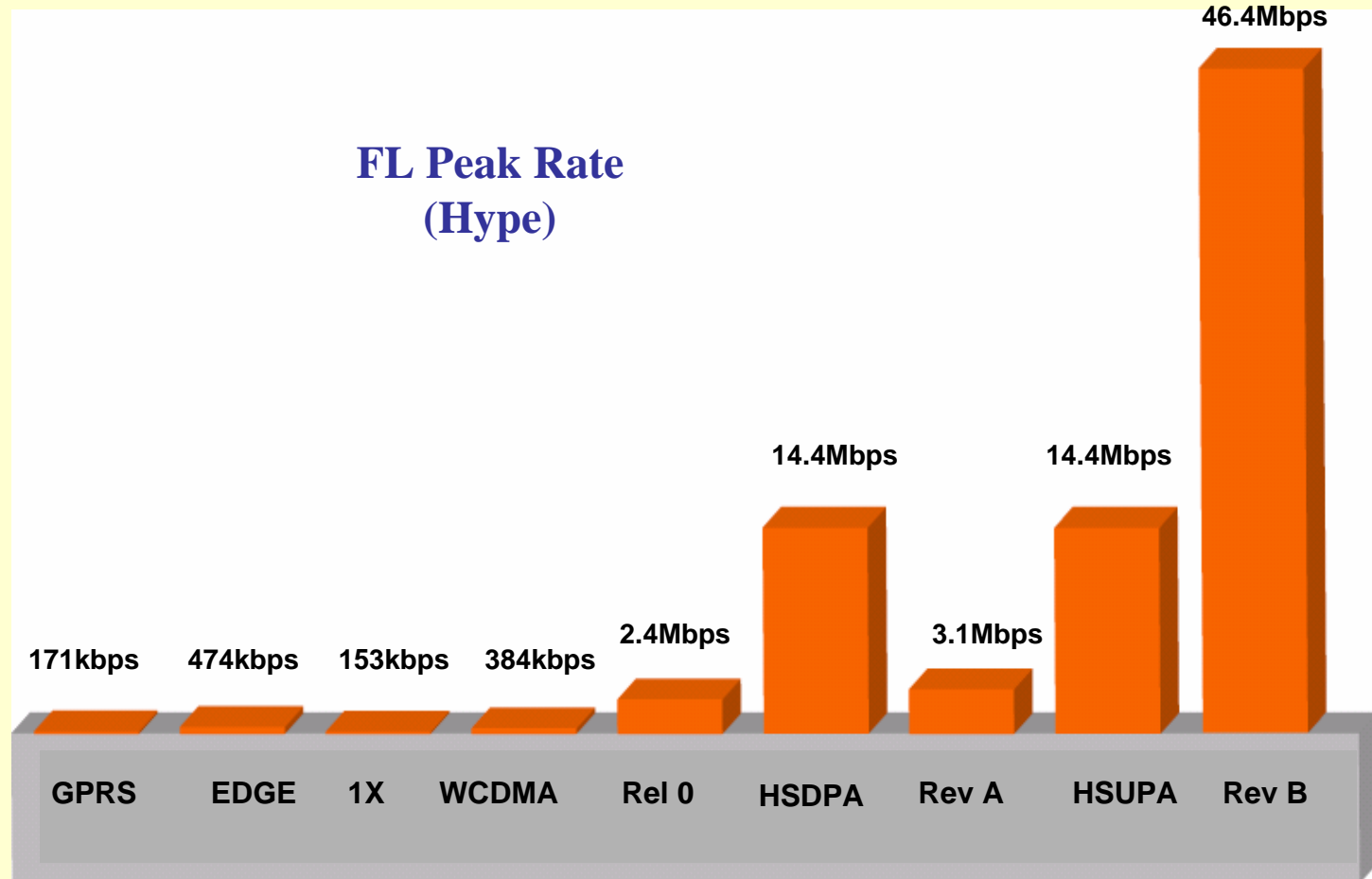
TD-SCDMA – Time Division Synchronous Code Division Multiple Access

- TBD on Market Update

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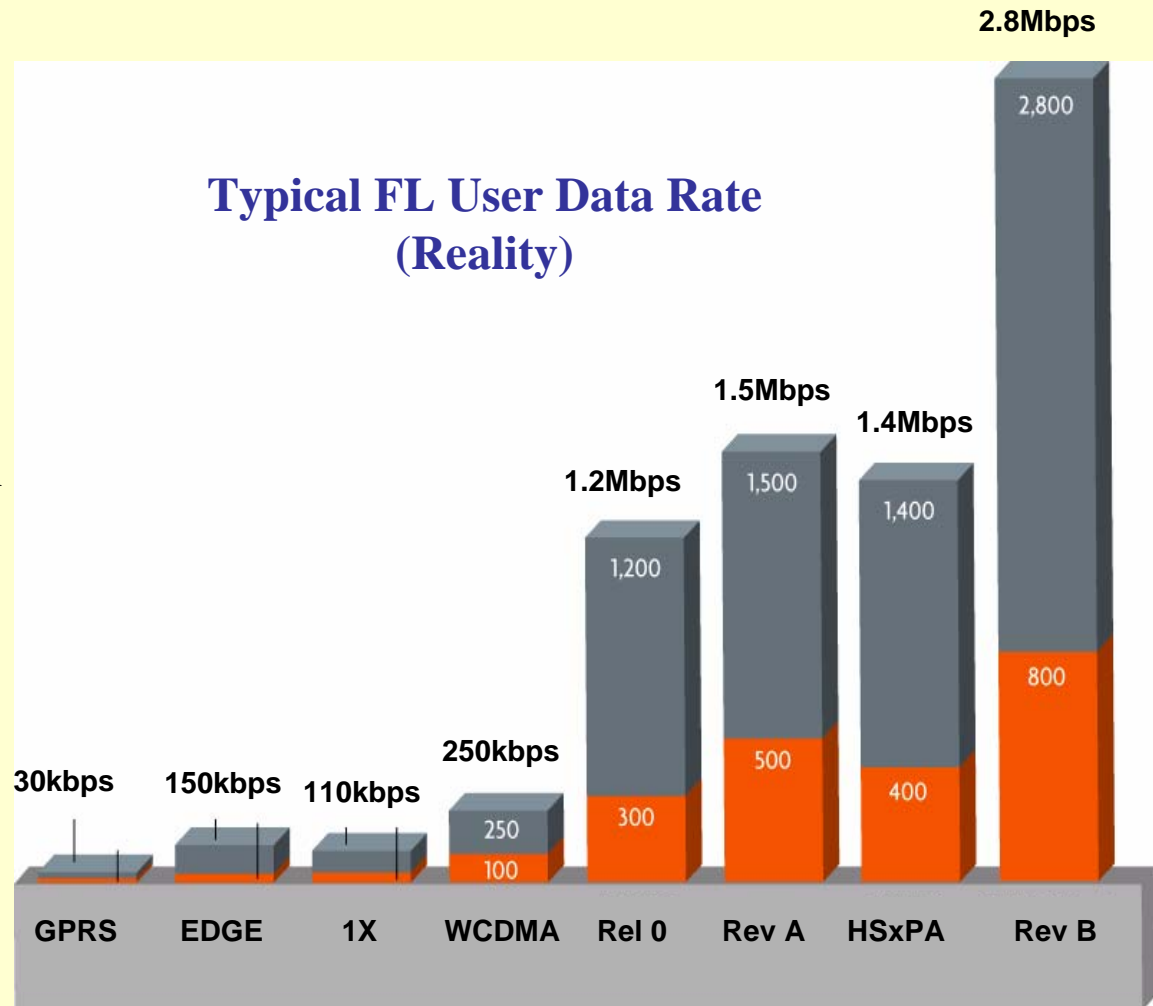
Despite the marketing hype, the 3GPP and 3GPP2 technologies have very similar performance characteristics.



- Advertised rates depict the best that a technology can deliver and are based on the requirements defined in the respective standard.

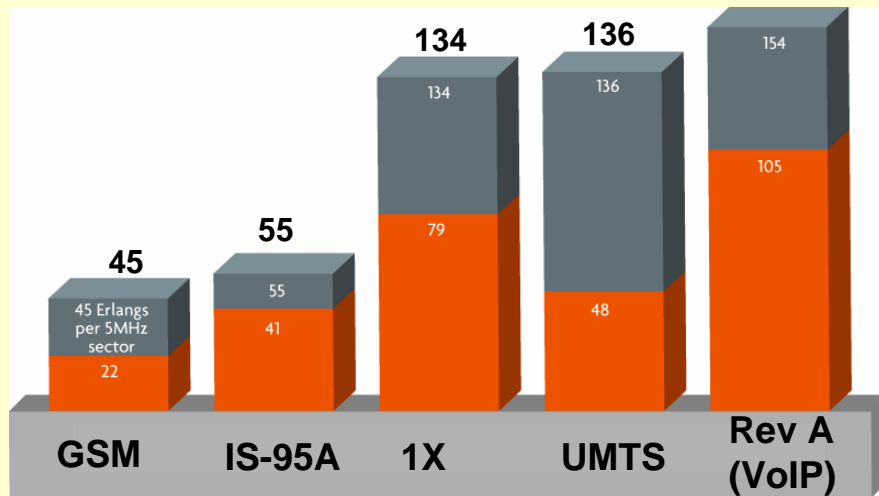
Despite the marketing hype, the 3GPP and 3GPP2 technologies have very similar performance characteristics.

- Theoretical peak rates are not measured at the application layer.
- Chipsets and infrastructure can represent bottlenecks.
- Peak rates assume pristine network conditions.
- Networks are shared between multiple users or technologies.
- Backhaul can be a chokepoint.

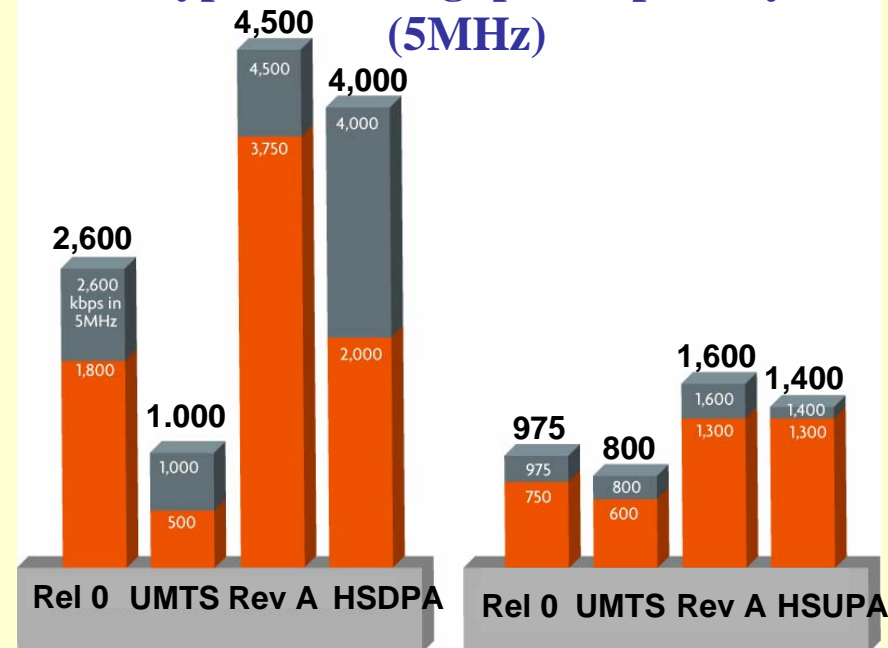


Despite the marketing hype, the 3GPP and 3GPP2 technologies have very similar performance characteristics – cont'd.

**Typical Voice Capacity
(5MHz)**

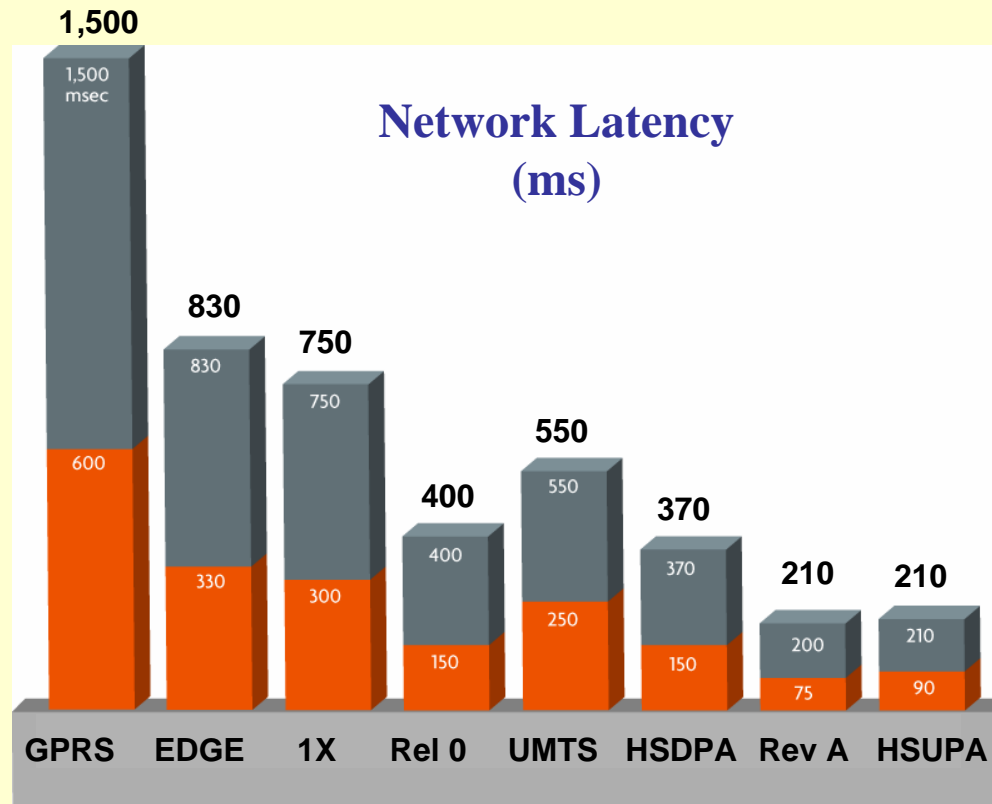


**Typical Throughput Capability
(5MHz)**



- All 3G technologies have much higher voice capacity than their 2G counterparts.
- CDMA2000 (1X) today has far greater voice capacity than UMTS but it falls short for data.
 - UMTS voice capacity assumes receive diversity (~35% improvement over today)
- Despite vastly differences in theoretical peak data rates, HSxPA and EV-DO have roughly similar throughput capabilities in the forward link and in the reverse link.

Despite the marketing hype, the 3GPP and 3GPP2 technologies have very similar performance characteristics – cont'd.



- Numbers are based on vendor input and our usage.
- Network latency between the respective technologies are roughly comparable.
- Only Rev A and HSUPA have low enough latencies to support real-time services like VoIP.

Signals Research Group, LLC recently completed an independent test of HSDPA (1.8Mbps), EV-DO Release 0 and EV-DO Revision A.

- Tests were conducted during the week of October 23rd using commercially-available devices and on commercial networks.
- Sprint Nextel's network was used for EV-DO Release 0 and Revision A.
 - At the time one carrier was supporting both technologies
- Cingular Wireless's network was used for HSDPA (1.8Mbps).
 - At the time, HSDPA (3.6Mbps) was not commercially available.
- Sierra Wireless PC cards were used for Rev A and HSDPA while a Novatel Wireless PC card was used for Release 0.
- Due to the limited availability of Rev A, San Diego was the chosen test site.
 - HSDPA was also tested in the Oakland, California area

Signals Research Group, LLC recently completed an independent test of HSDPA (1.8Mbps), EV-DO Release 0 and EV-DO Revision A – cont'd.

- All tests were repeated numerous times to arrive at an “average user experience.”
- Downlink and uplink data rates were measured by using FTP to a West Coast server.
 - The file size was >1MB
- Latency was measured by “pinging” a local server with a 32byte file.
 - Ideally, latency should be measured within the operator’s network.

Test results of a commercial EV-DO Release 0 network indicate that the technology performs as promised, but below that of HSDPA.

- Average downlink data rates can exceed 600kbps.
 - Rates ranged from 432kbps to 1.0Mbps
- Uplink data rates can average more than 130kbps.
 - The lowest recorded average data rate was 95kbps
 - The Release 0 uplink is limited to 153kbps
- Biggest disadvantage is the uplink relative to HSDPA.

Downlink

```
Command Prompt - ftp
226 Transfer complete.
ftp: 1099399 bytes received in 13.50Seconds 81.44Kbytes/sec.
ftp> get sa_0524.pdf
200 PORT command successful.
150 Opening ASCII mode data connection for sa_0524.pdf(1099399 bytes).
226 Transfer complete.
ftp: 1099399 bytes received in 14.56Seconds 75.50Kbytes/sec.
ftp> get sa_0524.pdf
200 PORT command successful.
150 Opening ASCII mode data connection for sa_0524.pdf(1099399 bytes).
```

AVG = 78.5KB/sec = 627.8kb/s

Uplink

```
Command Prompt - ftp
ftp: 1099399 bytes received in 8.68Seconds 126.63Kbytes/sec.
ftp> put sa_0524.pdf
200 PORT command successful.
150 Opening ASCII mode data connection for sa_0524.pdf.
226 Transfer complete.
ftp: 1099399 bytes sent in 63.73Seconds 17.25Kbytes/sec.
ftp>
```

17.25KB/sec = 138kb/s

The “user experience” test combines average data rates and latency to determine which network provides the most compelling experience.

- Revision A latency is more than 55% lower than competing technologies.
 - Latency includes some “Internet delay”
- For the “User Experience” test the Internet browser cache was cleared each time.
- Revision A offers the best experience, followed by HSDPA and Release 0.
 - HSDPA (3.6) won’t have much impact, but HSUPA will have considerable impact.
- HSUPA could have a slight advantage over Revision A (depends on implementation)

Latency Test by technology (msec)

	HSDPA	EV-DO Rev A	EV-DO Rel 0
Average Latency	244	106	279

Source: Signals Research Group LLC

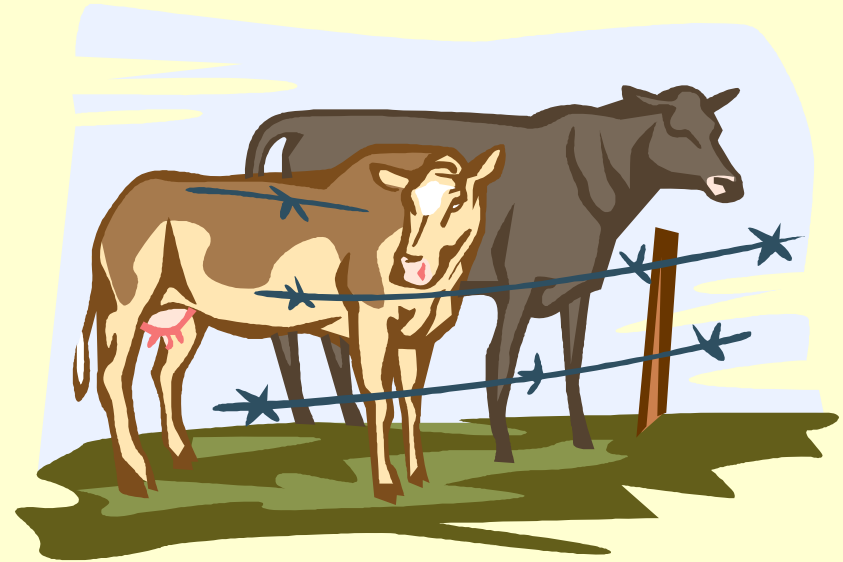
The User Experience (by technology)

Website	Time to Load (seconds)		
	HSDPA (1.8Mbps) (-75dbm)	EV-DO Rev A (-87dbm)	EV-DO Rel 0 (-87dbm)
CNN.com			
Ducati.com	5	6	11
SignalsResearch.com	14	4	8
USAToday.com	12	8	21
WSJ.com	17	15	24
NYTimes.com	12	11	15
BMW.com	6	4	9
Sony.com	35	8	64
TOTAL TIME	101	56	152

Source: Signals Research Group, LLC

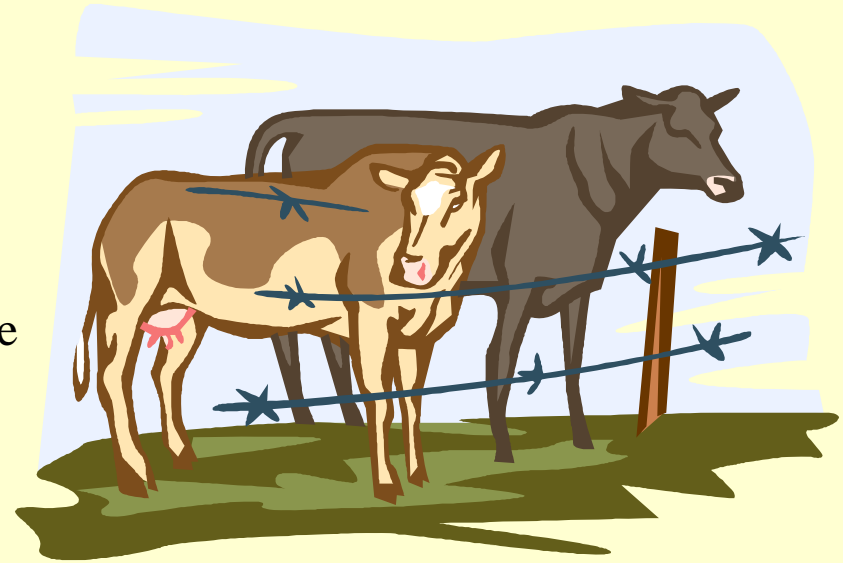
The overall conclusion is that despite claims to the contrary no technology has a distinct advantage from a performance perspective.

- The grass isn't always greener on the other side of the fence.
- Technology leapfrogging is a critical factor that must be taken into consideration.
 - Rev A outperforms HSDPA.
 - What will happen with Rev A versus HSUPA?
 - Rev C versus 3G LTE?



The overall conclusion is that despite claims to the contrary no technology has a distinct advantage from a performance perspective.

- Technology limitations (versus the standard) and operator implementations are also key factors.
 - Are other subscribers accessing the network?
 - Have the vendors fully implemented the respective standard?
 - How much of the RAN capacity is dedicated to the data technology?
 - How much backhaul capacity is provided?
 - Has the operator optimized its network?
 - Are interference mitigation solutions or other enhancements being used?



Thank you for listening!