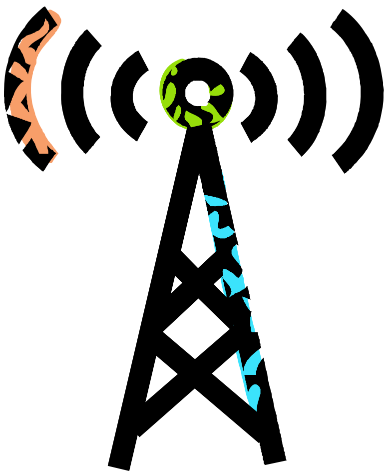

The wireless landscape...

...an industry analyst’s perspective

Michael W. Thelander
Signals Research Group, LLC
January 2007

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SIGNALS Research Group

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.

In this presentation, we will cover four distinct areas.

- 3G Economics – the 900MHz versus 2100MHz tradeoff
  - Network Modeling Assumptions
  - Results of Analysis
- TD-SCDMA Update from China
  - Key players
  - Release 5 features
  - Trial results from Baoding and outlook for 2007
- WiMAX – the hype from the reality
  - Where is it going
  - Issues and Challenges
- IMT-Advanced
  - Looking at 2015 and beyond
- Questions and Answers

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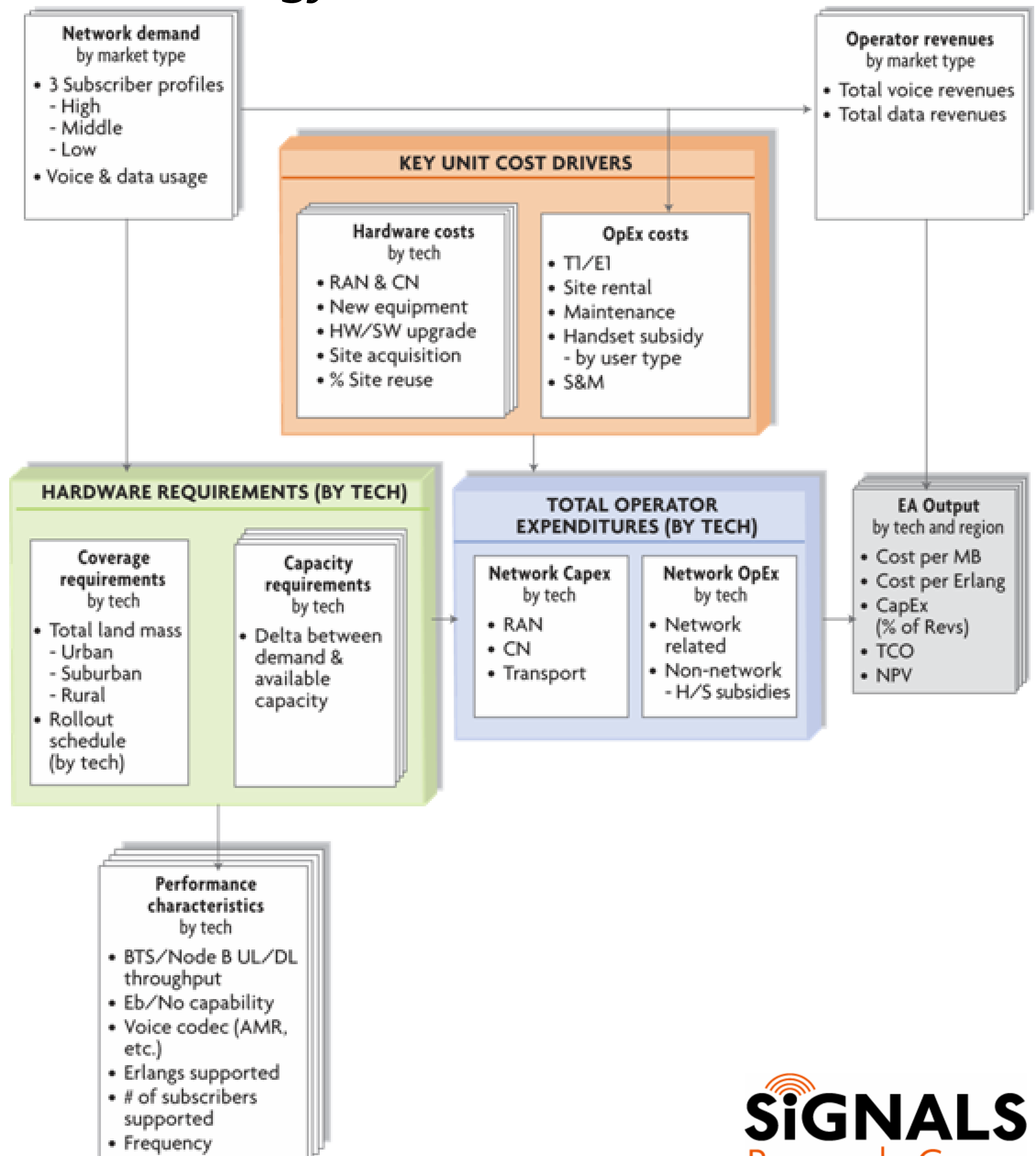
Our Methodology

- Economic modeling focused on the key network CapEx and OpEx requirements.
  - RAN
  - CN
  - TRAN
- Major hardware elements for each portion of the network were considered.
  - BTS/Node B, RNC
  - Site preparation
  - MSC's, SGSN's, etc
- OpEx includes:
  - Maintenance (10%)
  - Transmission (backhaul)



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Our model contains detailed engineering and pricing assumptions.

	Configuration (sector, TRX/carrier)	Capacity (Erlangs)	w/AMR
GSM			
Small BTS	(1,4)	19.3	38.6
Medium BTS	(3,4)	55.1	110.2
Large BTS	(3,8)	140.4	280.8
CDMA2000			
Small BTS	(3,1)	67.63	
Medium BTS	(3,5)	314.26	
Large BTS	(3,8)	499.24	
UMTS			
Node B	(3,1)	2.5Mbps	
Node B (for capacity)	(3,2)	5.0Mbps	

	Cell Radius (km)		Cell Radius (km)
GSM 900MHz		**CDMA2000 850MHz**	
Dense urban	1.75	Dense urban	1.74
Urban	1.75	Urban	2.11
Suburban	3.36	Suburban	4.37
Rural	8.15	Rural	10.53
UMTS 2100MHz		**UMTS 900MHz**	
Dense urban	1.34	Dense urban	2.47
Urban	1.63	Urban	3.00
Suburban	4.05	Suburban	6.45
Rural	8.99	Rural	12.86

BTS/Node B Data Capacity (by technology)	Configuration (sector, TRX/carrier)	Capacity (Mbps)
EV-DO Rel 0 - DL	(3,1) 1.25MHz	2.25
EV-DO Rel A - DL	(3,1) 1.25MHz	3.00
EV-DO Rel A - UL	(3,1) 1.25MHz	1.50
EV-DO Rel 0 - DL	(3,5) 1.25MHz	11.25
EV-DO Rel A - DL	(3,5) 1.25MHz	15.00
HSDPA upgrade - DL	(3,1) 5MHz	2.00
HSUPA upgrade - DL	(3,1) 5MHz	2.00
HSUPA upgrade - UL	(3,1) 5MHz	1.30
HSDPA Node B - DL	(3,2) 10MHz	6.00
HSUPA Node B - DL	(3,2) 10MHz	6.00

Source: Signals Research Group, LLC

For 3G vs. 3G study the UMTS radii assumptions were used
Used for initial upgrade of CDMA2000 BTS
Configuration used for additional capacity
For initial coverage, HSxPA capacity is shared with UMTS in the 5MHz carrier
Configuration used for additional capacity

- We used three GSM and CDMA2000 base stations configurations.
  - Small, Medium and Large
- Performance capabilities based on operator/vendor input.
- UMTS Node B's started with one carrier for coverage purposes.
- Additional capacity was provided through large configuration base stations/Node B's.
  - AMR for GSM
- Engineering assumptions used to determine cell radii.
  - Largely a function of frequency
- HSDPA deployed within UMTS carrier.

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Our model contains detailed engineering and pricing assumptions.

RAN Hardware	Configuration (sector, TRX/carrier)	Unit Price (Year 1)
GSM		
Small BTS	(1,4)	$22,000
Medium BTS	(3,4)	$57,200
Large BTS	(3,8)	$98,500
BSC	3,920 Erlangs	$1,000,000
UMTS		
Node B	(3, 1)	$50,000
Extra carrier (capacity)	(3, 1)	$35,000
RNC	460Mbps throughput	$3,100,000
HSDPA upgrade	(3, 128 elements)	$15,000
HSUPA upgrade	(3, 128 elements)	$17,000
HSxPA Node B	(3,1)	$60,000
CDMA2000 BTS		
Small BTS	(3,1)	$45,000
Medium BTS	(3,5)	$190,000
Large BTS	(3,8)	$295,000
BSC	3,700 Erlangs	$950,000
EV-DO Rel 0 upgrade	(3,1)	$35,000
EV-DO Rev A upgrade	(3,1)	$37,000
EV-DO BTS 0/A		
Large BTS	(3,8)	$311,000
Medium BTS	(3,5)	$200,000
Small BTS	(3,1)	$55,000
RNC	500Mbps throughput	$1,400,000
RAN Other		
Site preparation		$150,000
Site preparation (2G/3G shared site)		$75,000
Site lease (annual)		$13,500
HW price erosion (annual)		8%
EDGE upgrade premium		10%
Maintenance (annual)		10%

- Unit prices include provisioning and are considered to be "fully priced."
  - The key is to have relative pricing
  - Operator and vendor input
- EDGE upgrade is 10% of BTS.
- Site preparation and leasing activities can represent the dominant cost.
  - New site preparation is $150,000
  - Shared (UMTS) site preparation is $75,000
- Annual Maintenance cost (OpEx) is 10% of the deployed hardware.
- RAN CapEx also includes RNC's and BSC's.

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Our model contains detailed engineering and pricing assumptions.

CN CapEx and OpEx Assumptions

CN Hardware	Performance	Unit Price (Year 1 - $000)
GSM		
MSC	16,000 Erlangs	$2,800
SGSN	120Mbps throughput	$2,200
GGSN	350Mbps throughput	$353
HLR	528,000 subscribers	$1,400
STP	16,000 Erlangs	$2,800
UMTS/HSxPA		
MGW	6,000 Erlangs	$880
MSC Server	167,800 BHCA	$2,600
SGSN	120Mbps throughput	$2,500
GGSN	100Mbps throughput	$800
HLR	2.2 million subscribers	$1,400
CDMA2000		
MSC	16,000 Erlangs	$2,800
PDSN	500Mbps throughput	$1,000
HLR	450,000 subscribers	$660
AAA	800,000 subscribers	$150
STP	400,000 BHCA	$4,600
EV-DO Rev A		
MMD platform	2 million subscribers	$7,000
PDSN	1,000Mbps throughput	$1,000
VoIP server	500,000 subscribers	$750
CN Other		
Maintenance (annual)		10%
HW price erosion (annual)		8%

Source: Signals Research Group, LLC

- The Core Network includes the major hardware elements.
  - MSC's,
  - GGSN's, SGSN's and PDSN's
  - HLR, STP and AAA
- OpEx is 10% of deployed hardware.
- Price and performance information based on operator and vendor inputs.
- IMS-like architecture is used for VoIP (Rev A).
- Release 4 architecture is used for UMTS.

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Our model contains detailed engineering and pricing assumptions.

Trans CapEx and OpEx Assumptions

CapEx	Unit Price (Year 1)
E1/T1 (Initial)	$6,000
E1/T1 (Incremental)	$1,200
STM-1 Installation	$27,000
SDH ADM	$50,000
	# E1/T1 Lines per site
3GPP	
GSM Small BTS	0.19
GSM Medium BTS	1
GSM Large BTS	2
UMTS Node B	2
HSDPA (upgrade)	2
HSUPA (upgrade)	1
3GPP2	
CDMA 2000 Small BTS	1
CDMA 2000 Medium BTS	3
CDMA 2000 Large BTS	4
EV-DO Rel 0 (upgrade)	2
EV-DO Rev A (upgrade)	1
OpEx	
E1/T1 lease costs (annual)	$7,500
E1/T1 lease costs (annual–incremental)	$2,500
STM-1 lease costs (annual)	$90,000

Source: Signals Research Group, LLC

- Transmission CapEx is required for each newly installed site.
- Incremental E1/T1 lines are priced at a lower rate.
- IP transport (Rev A VoIP) is assumed to be 50% of E1/T1 cost.
- Transmission OpEx is largely E1/T1 lease costs.
- The number of E1/T1 lines is a function of the site capacity.

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The scenario that we present looks at the economics of deploying UMTS at 900MHz versus 2100MHz.

- The lower frequency translates into greater RF propagation, larger cells, and [hopefully] lower CapEx and OpEx.
  - A much bigger issue when deploying UMTS outside of urban areas
  - We assume 3G coverage is equivalent to 2G coverage
- No spectrum clearing costs were factored into the analysis.
  - Potentially a big cost driver
- All other assumptions, other than spectrum are held constant.

UMTS Deployment Assumptions

	Square km	Percentage
Total country size	329,000	100%
Dense Urban	9,870	3%
Urban	29,610	9%
Suburban	26,320	8%
Rural	263,200	80%

	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9		
Target rollout schedule										
Dense urban	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Urban	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Suburban	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Rural	0%	0%	5%	5%	5%	0%	0%	0%	0%	0%
Network coverage (sq km)										
Dense urban	9,870	9,870	9,870	9,870	9,870	9,870	9,870	9,870	9,870	9,870
Urban	29,610	29,610	29,610	29,610	29,610	29,610	29,610	29,610	29,610	29,610
Suburban	13,160	26,320	26,320	26,320	26,320	26,320	26,320	26,320	26,320	26,320
Rural	0	0	13,160	26,320	39,480	39,480	39,480	39,480	39,480	39,480
Effective AMR codec rate : 10.2kbps										

Source: Signals Research Group, LLC

- The GGE operator begins to deploy UMTS in Year 2.
  - Rural regions are covered in Year 4 through Year 6
- Network coverage is consistent with the GSM network.

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UMTS CapEx Requirements for Coverage

- Based on our engineering analysis when UMTS is deployed at 900MHz the cell radius is 1.4-1.8x larger than that of 2100MHz.
  - This translates into an effective cell radius that is 4.5-7.4x larger at the lower frequency.
- Larger cell areas translates into fewer Node B's.
  - More importantly, this means fewer cell sites have to be prepared and maintained, plus lower transmission CapEx – a duplicative savings
- When deployed at 2100MHz, the operator needs 7,225 Node B's (sites).
  - We assume 90% reuse of GSM sites
- When deployed at 900MHz, the operator only needs 2,228 Node B's (sites).

UMTS/GGE Network Traffic Assumptions

UMTS CapEx requirements for coverage – 2.1GHz

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
UMTS										
CapEx										
RAN	$0	$0	$609,452	$27,693	$6,963	$7,668	$8,878	$0	$0	$0
CN	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Trans	$0	$0	$20,795	$879	$259	$282	$339	$0	$0	$0
OpEx										
RAN	$0	$0	$107,797	$112,728	$113,901	$115,172	$116,613	$116,613	$116,613	$116,613
CN	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Trans	$0	$0	$22,257	$23,267	$23,541	$23,851	$24,228	$24,228	$24,228	$24,228
TCO (UMTS)	$0	$0	$760,301	$794,813	$803,482	$813,013	$824,047	$824,047	$824,047	$824,047

Source: Signals Research Group, LLC

UMTS CapEx for Network Coverage – 900MHz

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
UMTS										
CapEx										
RAN	$0	$0	$182,363	$10,952	$3,443	$3,740	$4,346	$0	$0	$0
CN	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Trans	$0	$0	$6,223	$347	$127	$139	$167	$0	$0	$0
OpEx										
RAN	$0	$0	$32,256	$34,205	$34,784	$35,406	$36,112	$36,112	$36,112	$36,112
CN	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Trans	$0	$0	$6,660	$7,059	$7,195	$7,346	$7,530	$7,530	$7,530	$7,530
TCO (UMTS)	$0	$0	$227,501	$241,149	$245,433	$250,084	$255,487	$255,487	$255,487	$255,487

Source: Signals Research Group, LLC

- Thanks to the lower frequency, the initial RAN CapEx for coverage purposes is reduced by 70%.
  - $255.5M versus $824.0M
- The higher number of cell sites also impacts TRAN CapEx.
  - $7.5M versus $24.2M
- In our model, CN CapEx is a function of network traffic, hence it is artificially held at $0 when modeling the coverage requirements.

UMTS/GGE Network Traffic Assumptions

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
GGE Base	5,400,000	6,311,766	8,456,573	11,016,742	13,290,715	14,572,215	15,142,071	15,279,389	15,298,921	15,299,992
UMTS subscribers	0	0	423,378	924,616	2,323,950	4,487,874	6,933,793	9,098,430	10,326,816	10,690,102
UMTS data usage (monthly/sub)										
Heavy			100	102	104	106	108	110	113	115
Medium			0	0	0	0	0	0	0	0
Light			0	0	0	0	0	0	0	0
Voice Usage (monthly/sub)										
Heavy	1,200	1,224	1,248	1,273	1,299	1,325	1,351	1,378	1,406	1,434
Medium	500	510	520	531	541	552	563	574	586	598
Light	250	255	260	265	271	276	282	287	293	299

Source: Signals Research Group, LLC

- In Year 1 the GGE operator has 5.4M subscribers, reaching 15.3M in Year 10
- UMTS subscriber growth is a function of the GGE installed base.
  - Reaches 10.7M in Year 10
- Voice traffic on the two technologies is equivalent on a per user basis but data traffic only occurs on the UMTS (3G network).

UMTS Incremental CapEx Requirements

UMTS 2100MHz

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
UMTS										
Addt'l carriers					233	2,326	2,756	2,553	1,592	653
Addt'l RNC's						19	17	11	4	2

Source: Signals Research Group, LLC

UMTS 900MHz

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
UMTS										
Addt'l carriers						318	2,553	1,592	653	270
Addt'l RNC's						19	17	11	4	2

Source: Signals Research Group, LLC

- Since more RAN capacity is inherently deployed when 2100MHz is used, fewer incremental Node B's are required for capacity purposes.
  - 5,386 versus 10,113
- With UMTS traffic the operator must deploy sufficient Core Network equipment.
  - Given our assumptions, the CN CapEx and OpEx are largely equivalent between 2100MHz and 900MHz; hence these numbers are not being presented

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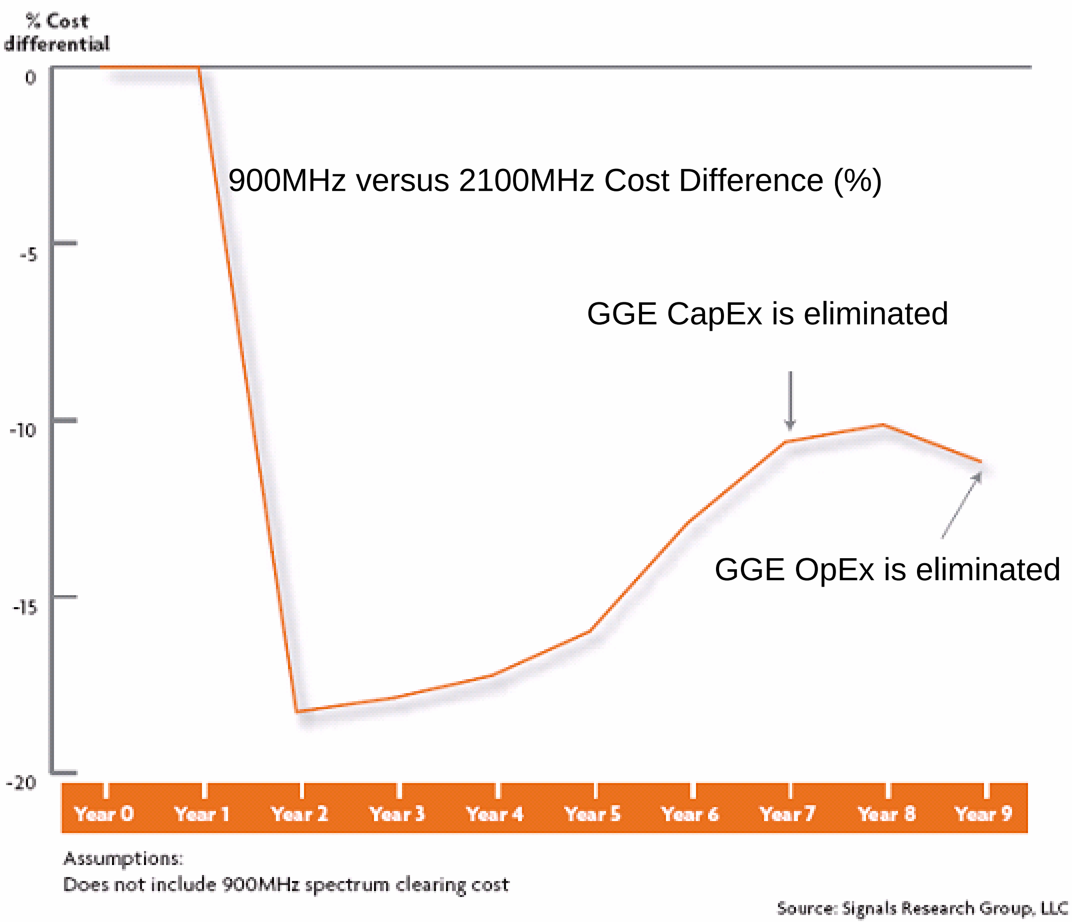
Deploying UMTS 900 reduces the initial RAN CapEx by 70% and the overall TCO by a double-digit percentage.



- Chart plots the difference in the TCO for a GGE operator migrating to UMTS.
  - 900MHz versus 2100MHz
  - Results include the GGE TCO
- Model ignores spectrum clearing and assumes price parity between spectrum bands.
- 900MHz strategy results in less upfront network capacity but more favorable economics.

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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

- There are four consortiums that are pursuing the TD-SCDMA market.
  - Datang is involved in all of the consortiums (necessary)
  - Qualcomm will likely 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*
	Hyper Market International Ltd.	
Datang/ADI	Datang	*Datang*
	Analog Devices	*Holley Group*
		Alcatel-TCL
Spreadtrum	Spreadtrum	*Amoi*
		Inventech
		Lenovo
		DBTEL
		Hisense
		OK

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TD-SCDMA – Time Division Synchronous Code Division Multiple Access

Participants/Investors	Comments
TD Tech Ltd.: Siemens (51%) and Huawei (49%)	*>$100M invested*
	commercially ready solution
Alcatel and Datang	*Datang provides Node B*
	Alcatel provides manufacturing
	ALA providing expertise to reduce Node B costs
	commercially ready solution
	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)

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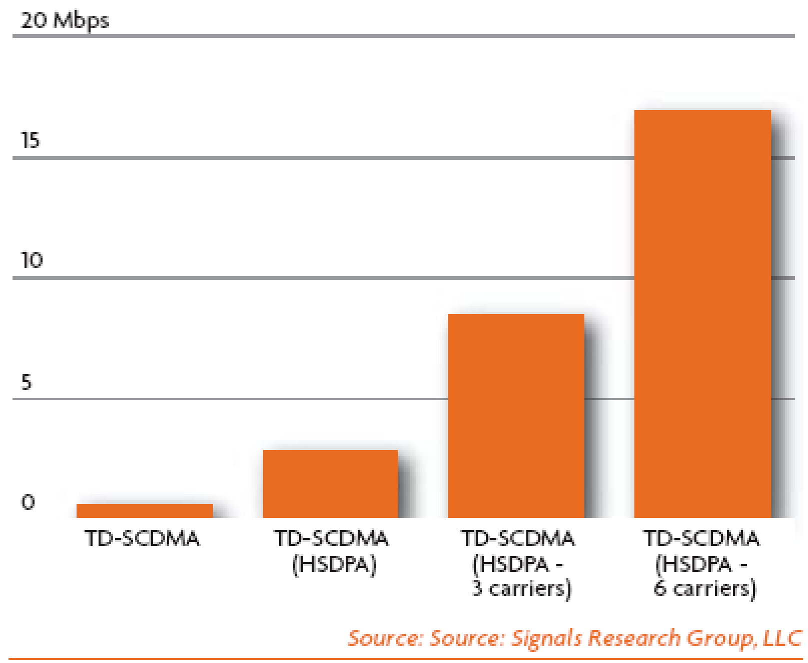
TD-SCDMA – Time Division Synchronous Code Division Multiple Access



- 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

- Major changes were implemented to the standard following Phase II trials.
- All chipset suppliers have passed the government tests while several handset manufacturers have passed the tests.
  - ADI/Datang probably the best from a silicon perspective while Samsung has the best UE's
  - Most solutions do not support TD-SCDMA to GSM handovers (Samsung is exception)

TD-SCDMA Trials

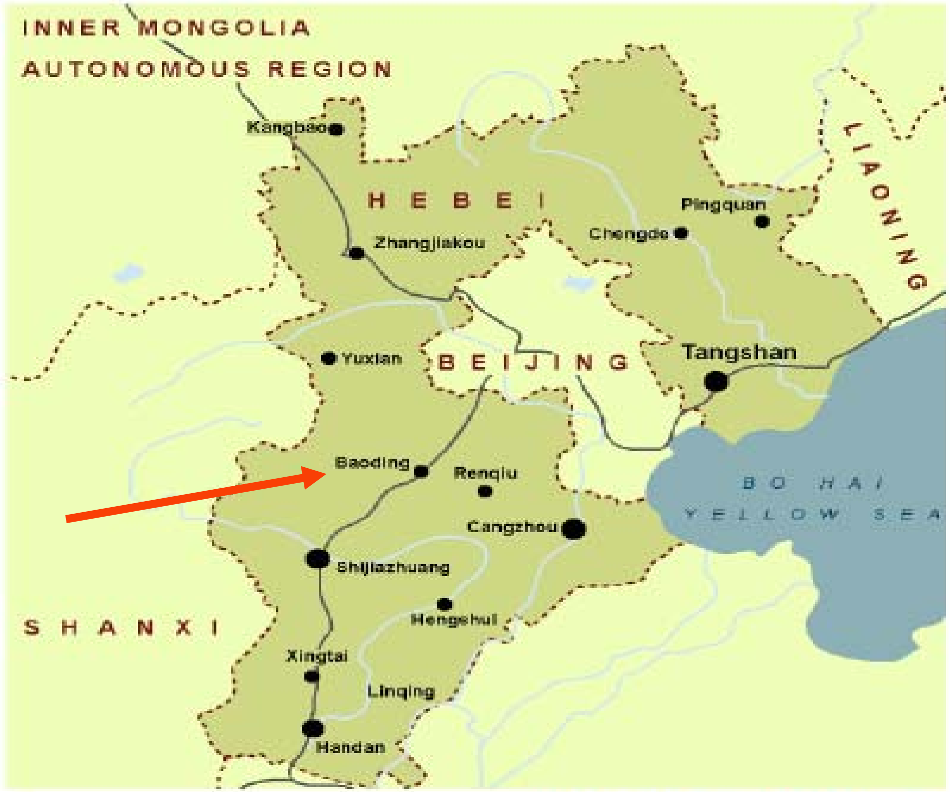
	Qingdao	Xiamen	Bao Ding
China Netcom	ASB + Datang		
	ZTE		
China Telecom			TD-Tech
			ASB + Datang
China Mobile		TD-Tech	
		ZTE	

Source: Signals Research Group, LLC

- Early this month the three trials began supporting "friendly users."
  - Largely government officials and executives from the operators
  - Around 200 users per site.
  - Moving to 2,000 friendly users at the moment, and eventually 5,000 friendly users

TD-SCDMA – The User Trial

- Baoding is ~120km Southwest of Beijing
  - Couple hundred thousand population
  - ~120 Node B's from TD-Tech and ASB-Datang
  - China Mobile is the sponsoring operator
  - Trial took place in early December, just prior to the friendly user trial kicking off
  - Handsets were largely Datang-enabled



Source: www.maps-of-china.com

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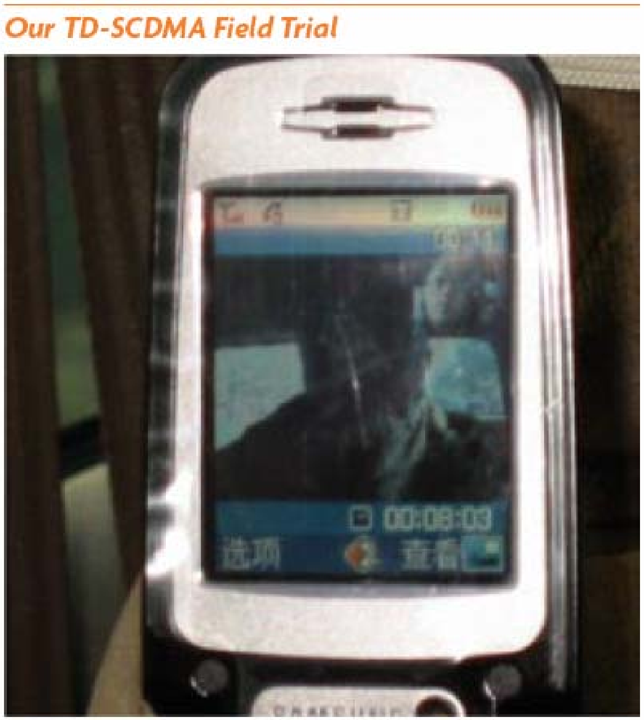
TD-SCDMA – The [Samsung] handsets



- Left-hand picture shows a video telephony call 8:03 into the call
  - Quality on par with UMTS (e.g., not that impressive but passable)
- Right-hand picture shows video streaming
  - Quality was fairly decent

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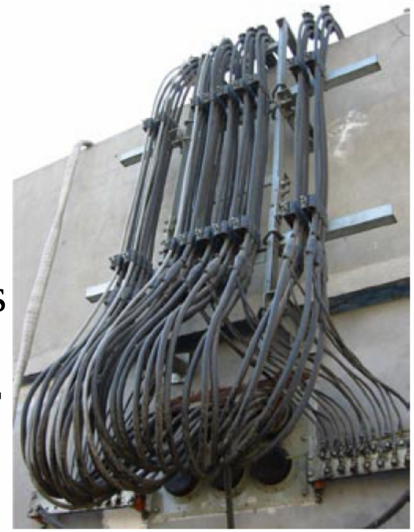
TD-SCDMA – The first-generation infrastructure

- 27 cables are currently required to support a three sector cell.
  - Smart antenna technology versus high power MCPAs
- Analog RRU is coming later this year.
  - Reduces the number of cables to 3 per sector
- Digital interface planned for the end of the year.
- Similar advancements planned for the digital baseband.

First Generation TD-SCDMA Infrastructure



Source: Signals Research Group, LLC

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TD-SCDMA – Time Division Synchronous Code Division Multiple Access

- Based on a drive text in Baoding, the technology performs admirably.
  - One dropped video call during the drive
  - No dropped voice calls
  - Issue is battery life
- Friendly user trial will likely last for the next several months.
- TD-SCDMA license(s) possible with the Chinese New Year.
  - China Mobile is a likely candidate for a nationwide license
  - China Telecom for Northern China
- More network rollouts possible in early 2007.
  - Olympic cities (Beijing, Shanghai and Hong Kong)
- HSDPA coming, but likely early 2008 due to UE limitations

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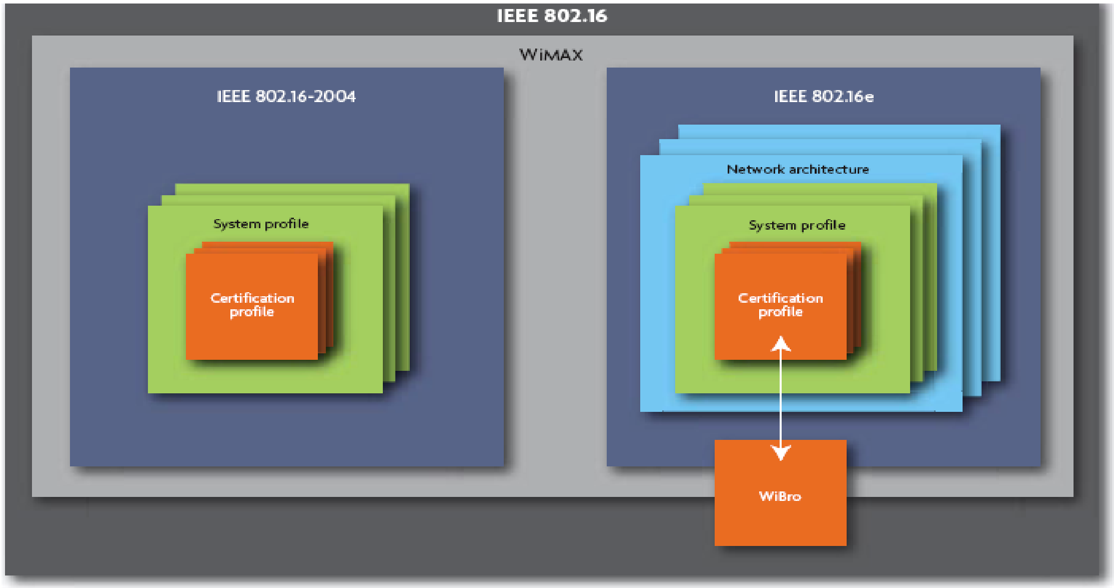
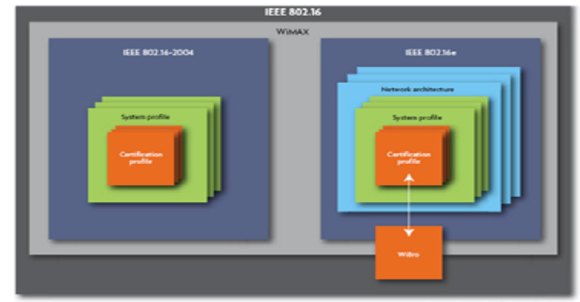
The relationship between the two IEEE standards and WiMAX can best explained via an illustration.



Source: Source: Signals Research Group, LLC

- In addition to being limited to the PHY and MAC, the IEEE standard contains a litany of options – some options are incompatible with each other.
  - Standard address a wide range of frequency bands, channel allocations and TDD/FDD
  - A "system profile" defines a set of optional features
  - A "certification profile" allows interoperability testing
  - A "network architecture" is only relevant for a mobile solution

WiBro will evolve to become a Mobile WiMAX profile, but it isn't there yet.



Source: Source: Signals Research Group, LLC

- In February 2002 the South Korean government assigned 100MHz of 2.3GHz for the deployment of a mobile broadband wireless technology.
  - Operators began trialing several proprietary solutions
- While IEEE 802.16 work was beginning, the South Korea MIC, ETRI and TTA were developing a "home-grown" standard for South Korea.
  - At its inception it was referred to as HPi (High-speed Portable Internet)
  - HPi was specific to the needs of the local market versus being designed for a global solution
- Politics and external pressure led to a convergence with IEEE 802.16e
  - HPi was re-branded WiBro (Wireless Broadband) in April 2004

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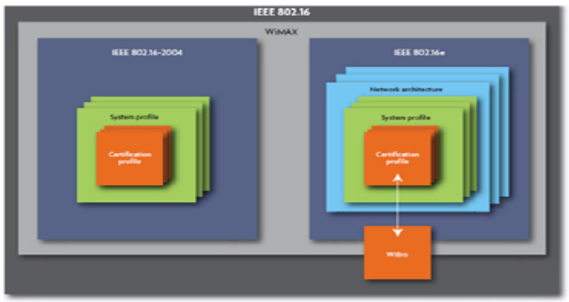
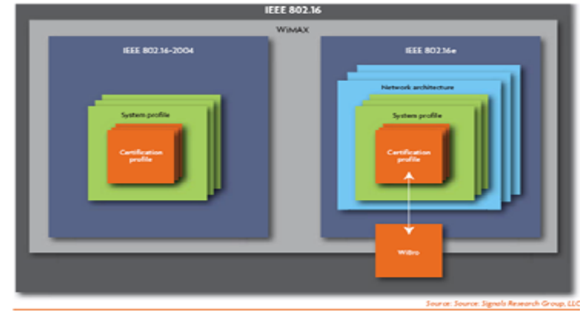
WiBro will evolve to become a Mobile WiMAX profile, but it isn't there yet.



Source: Source: Signals Research Group, LLC

- Important to remember that IEEE 802.16e and WiMAX are not synonymous.
- Like Mobile WiMAX, WiBro is comprised of Phase 1 and Phase II.
  - Phase I retains the "proprietary" elements of HPi and reflects what is deployed today
  - Phase II, which was largely completed in late 2005 (<u>before 802.16e was approved</u>), more closely aligns with the PHY and MAC requirements of 802.16-2005.
  - South Korean documentation suggests alignment with WiMAX in 2008
- There are several key technical differences between WiBro and WiMAX.
  - Akin to FOMA versus UMTS
  - Number of assigned tones for data and signaling are not consistent
  - Handoff mechanism (WiBro uses FBSS; WiMAX uses HHO)

WiBro will evolve to become a Mobile WiMAX profile, but it isn't there yet.



- WiBro performance today is at best on par with HSDPA or EV-DO Rev 0
- Lack of compelling features, handsets, and coverage is limiting the technology's adoption.
  - Deployment limited to certain regions of the country – largely within Seoul
  - At launch there were only a few handsets and a data card
  - PDA devices are not popular in South Korea
- The next phase of the network rollout will likely kick off in 2007.
- Korea Telecom is the most supportive while SK Telecom is just playing it safe.
- KTF and SKT are focused on 3G (HSPA) for future growth.

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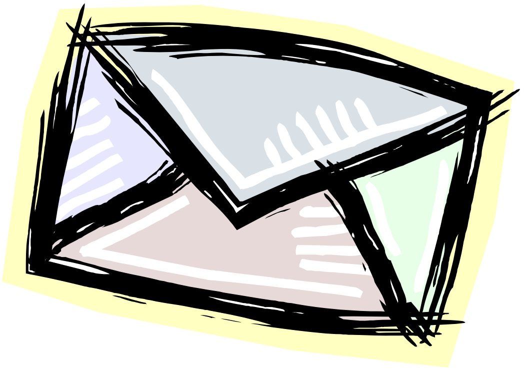
The Mobile WiMAX reality check is not yet in the mail.



- Mobile WiMAX, as defined by the performance of WiBro, is not very compelling.
  - Average data rates are on par with EV-DO Release 0 from a fixed location
  - Sector throughput is no better than HSDPA
- Some leading Mobile WiMAX infrastructure suppliers do not yet support mobility.
- Despite all the hype surrounding MIMO, MIMO has never been proven in a WWAN.
  - Infrastructure and chipsets do not currently support the feature
  - MIMO is far more important than OFDMA

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There are several similarities between Mobile WiMAX and the future evolution of 3G (both migration paths).

	Mobile WiMAX	3G LTE	Rev C
OFDMA	X	X	X
All-IP Architecture	X	X	X
MIMO and AAS, etc	X	X	X
Scalable Bandwidth	X	X	X
Multiple Duplex Schemes (FDD, TDD, etc)	X	X	X
Large Ecosystem of Suppliers	X	X	
Uncertain IPR future	X	X	X

- The real question is one of legacy, timing, strategy and choice of frequency bands.
  - Why 2.5GHz is such a hotly contested spectrum band

There are also a few key differences between Mobile WiMAX and the future evolution of 3G (both migration paths).

- The uplink between the three technologies follow different strategies.
  - WiMAX uses OFDMA
  - 3G LTE uses SC-FDMA
  - Rev C uses OFDMA and CDMA
- 3GPP dismissed OFDMA due to concerns about PAPR (Peak to Average Power Ratio).
  - Traded a potential performance hit for mobility
- Some concerns over how well Mobile WiMAX deals with interference.
  - Interference is one Achilles heel of OFDMA (another is PAPR)

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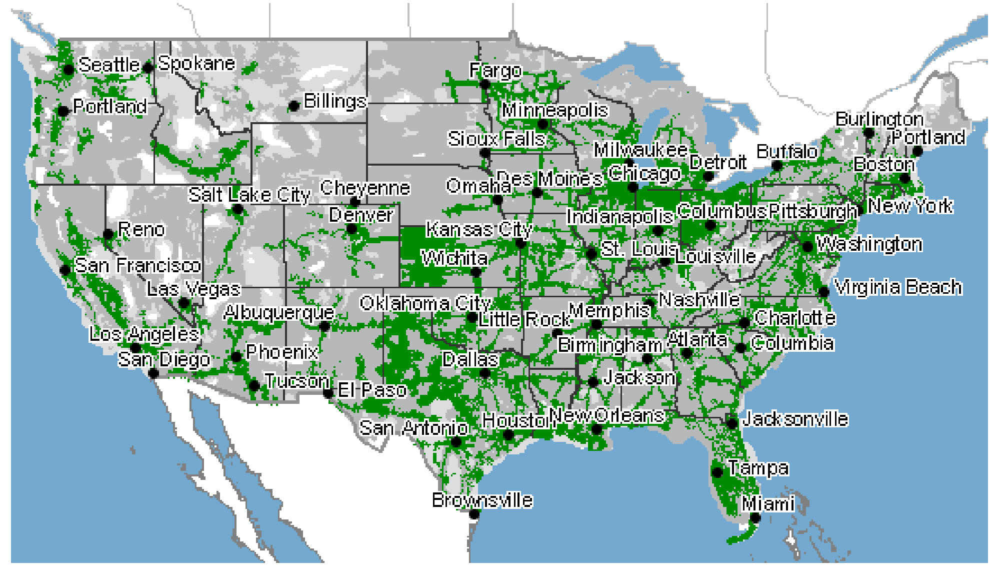
Mobile WiMAX got a huge endorsement when Sprint Nextel announced its 2.5GHz strategy last August.

- Sprint Nextel announced a $3B commitment to deploy a “nationwide” Mobile WiMAX network.
  - 100 million pops covered by the end of 2008
  - additional rollouts subject to the economics
- Announcement marks the first important operator commitment to the technology.
  - SK Telecom and Korea Telecom didn’t have a real choice of technologies
  - Clearwire’s investment from Intel and Motorola came with restrictions
  - Other operators are not significant or have not made firm commitments

Mobile WiMAX may or may not be 1/10th the cost of 3G – the devil is in the details.



Source: Sprint Nextel website

- The US population is highly concentrated in non-rural areas (~230 million).
  - 57.2% of population live in a dense urban or urban area (6.7% of the landmass)
  - 19.1% of the population live in a suburban area (12.1% of the landmass)
  - Therefore, ~76% of the population live within 18% of the US landmass
- The Sprint Nextel 3G network reportedly covers 275 million pops
  - Data suggests that the 3G network covers at least 20-25% of the US landmass
  - This network will support Rev A by the end of October 2007

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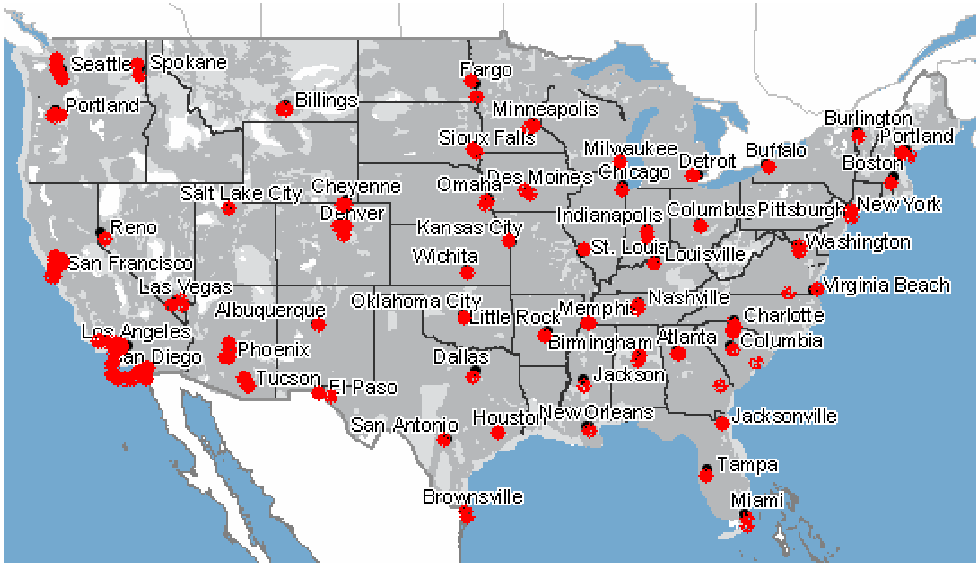
Mobile WiMAX may or may not be 1/10th the cost of 3G – the devil is in the details – (cont'd).



Source: SRG estimates

- The Sprint Nextel Mobile WiMAX network will cover 100 million pops.
- With 57.2% of the US population living on 6.7% of the landmass, this implies that the Mobile WiMAX network will cover less than 5% of US landmass.
  - Conservatively 1/4th to 1/5th the size of the 3G network
- In order to compare technologies, the same level of coverage and services must be assumed.
  - Comparing apples and bananas

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When deployed for coverage purposes, higher frequencies significantly increase the cell count.

Frequency	Cell Radius (km)	Cell Area (km^2)	Relative Cell Count
450MHz	48.9	7,521	1
850MHz	29.4	2,712	2.8
1900MHz	13.3	553	13.6
2500MHz	10	312	24.1

Source: ITU filing

- Relative to its 1900MHz network, the operator would need 1.7x more base stations.
  - All things being equal
- Technologies, like beamforming or higher power amplifiers can be used to make up some of the difference.
  - These solutions come with a cost
  - Spectrum in some markets comes with severe power limitations

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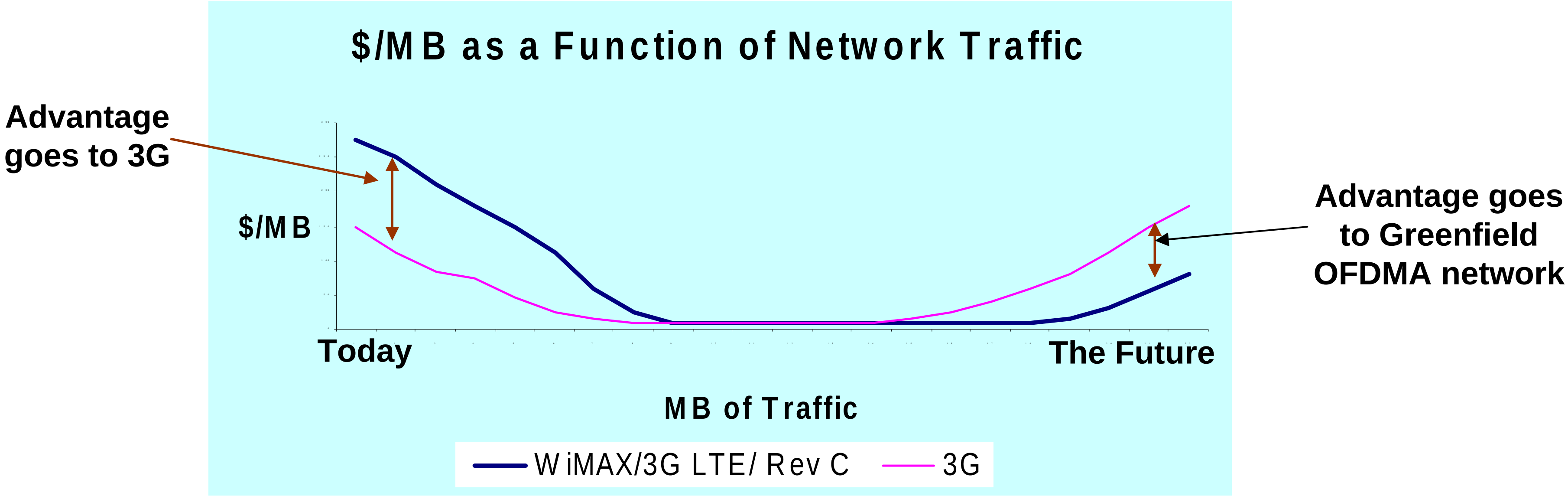
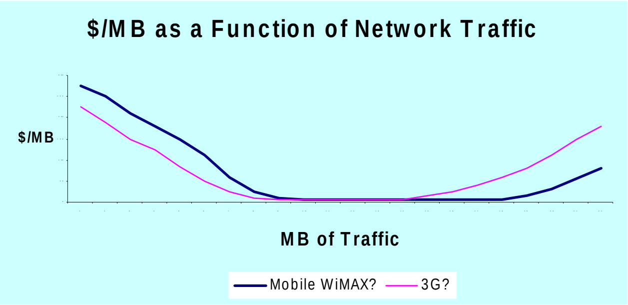
Mobile WiMAX may or may not be 1/10th the cost of 3G – the devil is in the details – (cont'd).



- The cost to deliver the first byte of data is infinitely expensive.
- Once the network is more heavily utilized the $/MB becomes attractive.
- $3B Greenfield networks with an abundance of capacity face a far greater challenge with respect to the economics.
- At some point the advantage will shift to favor a Greenfield OFDMA network.
  - But when?

Mobile WiMAX may or may not be 1/10th the cost of 3G – the devil is in the details – (cont'd).



- Multi-mode WiMAX/3G handsets cannot be less expensive than single-mode 3G handsets.
  - Extra baseband silicon, RF and PA requirements
- Without compelling features like video encoders/decoders, high-quality displays, 3D graphics, etc, Mobile WiMAX handsets would not be compelling.
  - Suggests that Mobile WiMAX devices will have to be mid-tier or high-end devices
- Single-mode WiMAX (or any 2.5GHz technology) devices could conceivably be less expensive but with limited coverage they would not be appealing to most consumers.
  - Lower cost is best achieved through economies of scale

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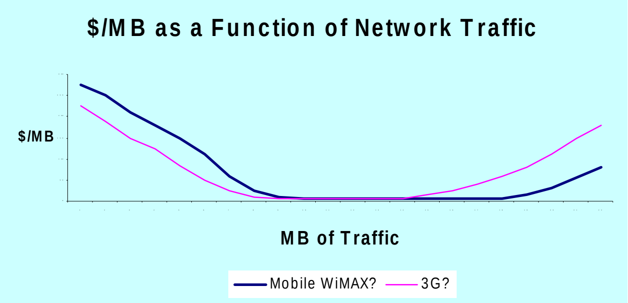
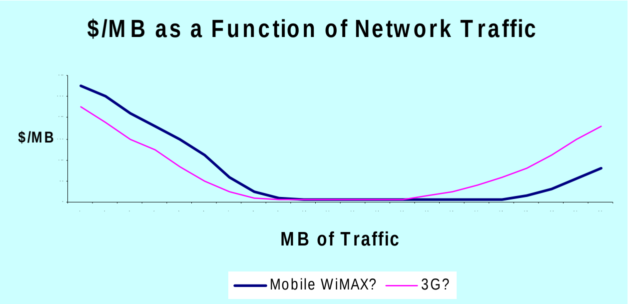
Mobile WiMAX may or may not be 1/10th the cost of 3G – the devil is in the details – (cont'd).



- Mobile WiMAX base stations can't be (aren't) less expensive than 3G base stations.
  - Again, economies of scale is a critical issue
  - Hundreds of thousands of 3G base stations versus a couple hundred WiBro base stations
- The digital portion of the base station is perhaps 25% of the total cost of the base station.
  - The cabinet doesn't care what technology is inside
  - The antenna cabling, multi-carrier amplifiers, etc don't care either
- PAPR constraints could actually drive up the cost of the analog portion (amplifiers must support higher power and be more linear to support the demands of OFDMA).

Yet there are valid reasons why Mobile WiMAX (LTE or Rev C) could be less expensive then today's 3G technologies.



- "3G spectrum" is a limited resource – once its gone, its gone.
- Adding a few extra 3G carriers (HSPA or EV-DO) is arguably less expensive then deploying a network, but only to a certain limit.
  - Base stations only support so many channel cards
  - A 10MHz carrier can be less expensive than deploying multiple 1.25MHz/5MHz carriers
    - Savings comes from both digital and analog (RF, cabling and PA's)
- Technologies that facilitate more throughput per site should lead to lower costs even if the technology itself is more expensive.

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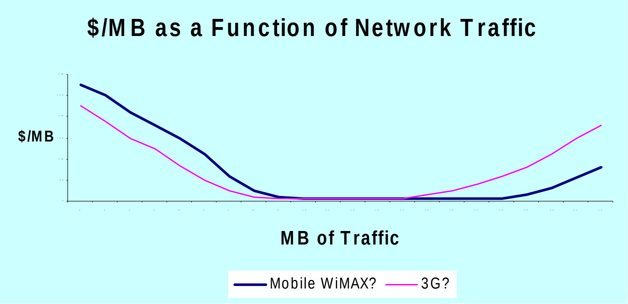
But will there be enough demand to justify the new network?



- Taking vendor claims at face value Mobile WiMAX can support 14Mbps of sustained throughput in a 10MHz radio carrier.
  - This equates to 42Mbps per cell site (~2.3km^2)
  - Arguably this impacts the backhaul, but we'll ignore this issue for the moment
- If a subscriber consumes 1GB per month it would equate to 2.7MB during a typical Busy Hour.
  - Equates to 15 users in a cell during BH
- At the moment Sprint Nextel has deployed at most 2 EV-DO carriers (2.5MHz of FDD spectrum) at any given point in its network.
  - Mobile WiMAX would at least double this amount while Rev A would remain (3x total)

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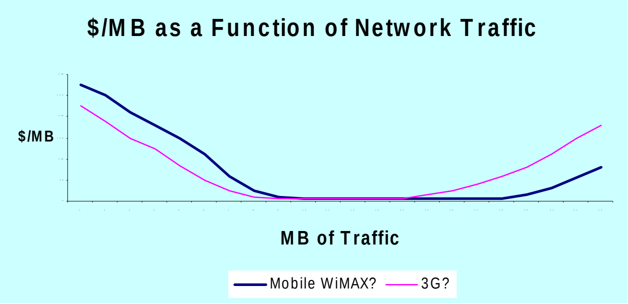
But will there be enough demand to justify the new network (cont'd)?



- Wireless DSL services could consume a lot of bandwidth.
  - Wireless cannot compete when competitively-priced wireline services are available
  - DSL/cable modem extension is valid, but it isn't needed in urban areas
  - Mobile PC market isn't big relative to mobile devices yet mobile devices generally don't consume a lot of data
    - A Catch 22 situation
- Mobile TV is a viable application.
- Self-generated content for the youth market.
  - Again, devices would have to be affordable for the mass market

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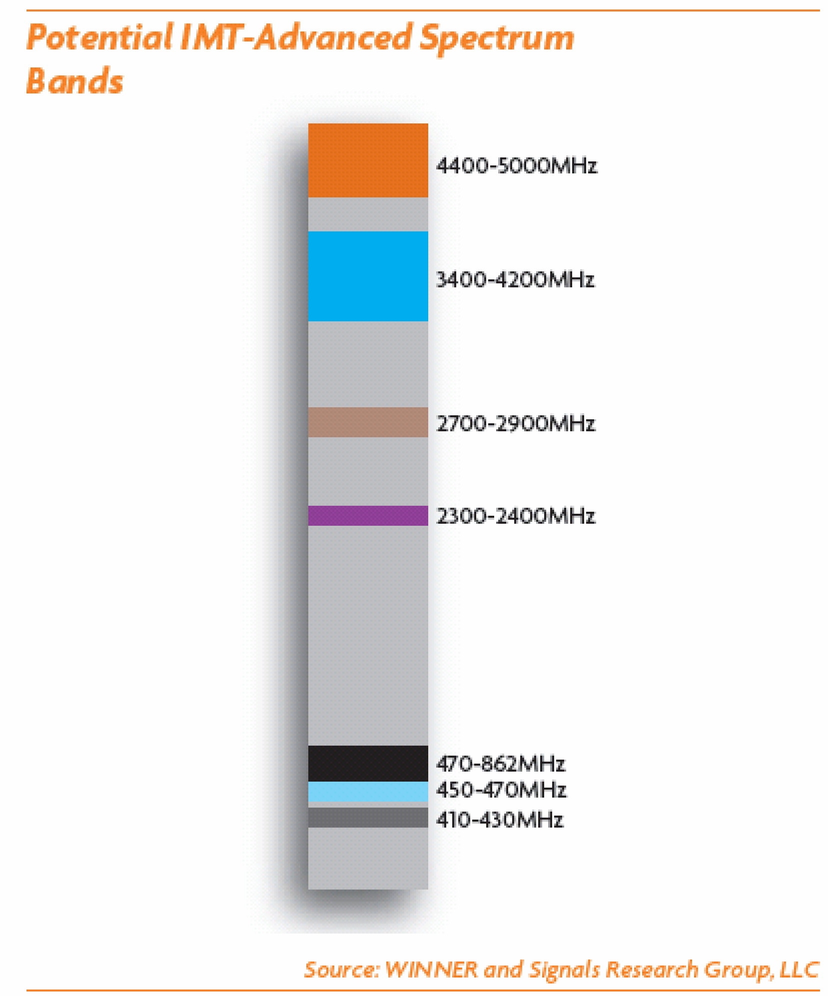
In this presentation, we will cover four distinct areas.

- 3G Economics – the 900MHz versus 2100MHz tradeoff
  - Network Modeling Assumptions
  - Results of Analysis
- TD-SCDMA Update from China
  - Key players
  - Release 5 features
  - Trial results from Baoding and outlook for 2007
- WiMAX – the hype from the reality
  - Where is it going
  - Issues and Challenges
- IMT-Advanced
  - Looking at 2015 and beyond
- Questions and Answers

Some operators and vendors are already looking ahead to IMT-Advanced.

- In 2007 the World Radio Conference (WRC-07) will meet to determine new spectrum for IMT-Advanced services.
  - In 1992 the WARC met with the outcome being the identification of the 2.1GHz band for IMT-2000 services.
  - In 2000, the WRC met with the outcome being the identification of the “3G extension band,” or 2.5GHz to 2.69GHz.
- While it may seem a bit premature to be discussing the next great wireless technology there are a few data points that are worth considering.
  - There is generally an 8-10 year gap between spectrum being identified and new technologies making use of the spectrum
  - Without new spectrum and without a more spectrally efficient technology the industry could face a shortfall of well more than 500MHz by the year 2015
  - For comparison purposes European operators have 220MHz for GSM, 140MHz for UMTS with an additional 190MHz becoming available shortly.

Various consortiums of suppliers and operators have begun to identify bands that could be used.



- In all probability the new spectrum will be located above 3GHz.
- Presents economic and technical challenges.
  - Higher spectrum means shorter RF propagation (more infrastructure)
  - NLOS communications becomes more difficult (in-building penetration)
  - Battery life (PAPR)
- Spectrum below 2GHz is also possible for wide area coverage.
  - Wide channels wouldn't be possible

In addition to identifying new spectrum bands, these consortiums are working to define the actual technologies that will be used.

- A "Catch-22" situation exists when neither the spectrum nor the technology are known.
- Initial work will help justify specific spectrum requirements and lead to the selection of the pertinent technology as an IMT-Advanced technology.
- The European consortium is called the Wireless World Initiative (WWI).
  - WINNER (Wireless World Initiative New Radio) is defining the RAN
  - E2R (End-to-End Reconfigurability) deals with software defined radios
  - SPICE (Service Platform for Innovative Communication Environment) advances the IMS framework
- FuTURE is a Chinese-influenced consortium.
- mITF (Mobile IT Forum) is a Japanese-influenced consortium.
- IEEE 802.16m is an extension of IEEE 802.16e (Mobile WiMAX)

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The ITU has defined requirements for IMT-Advanced technologies.

The vision of the WWRF is that in 2017 there will be 7 trillion devices serving 7 billion subscribers.

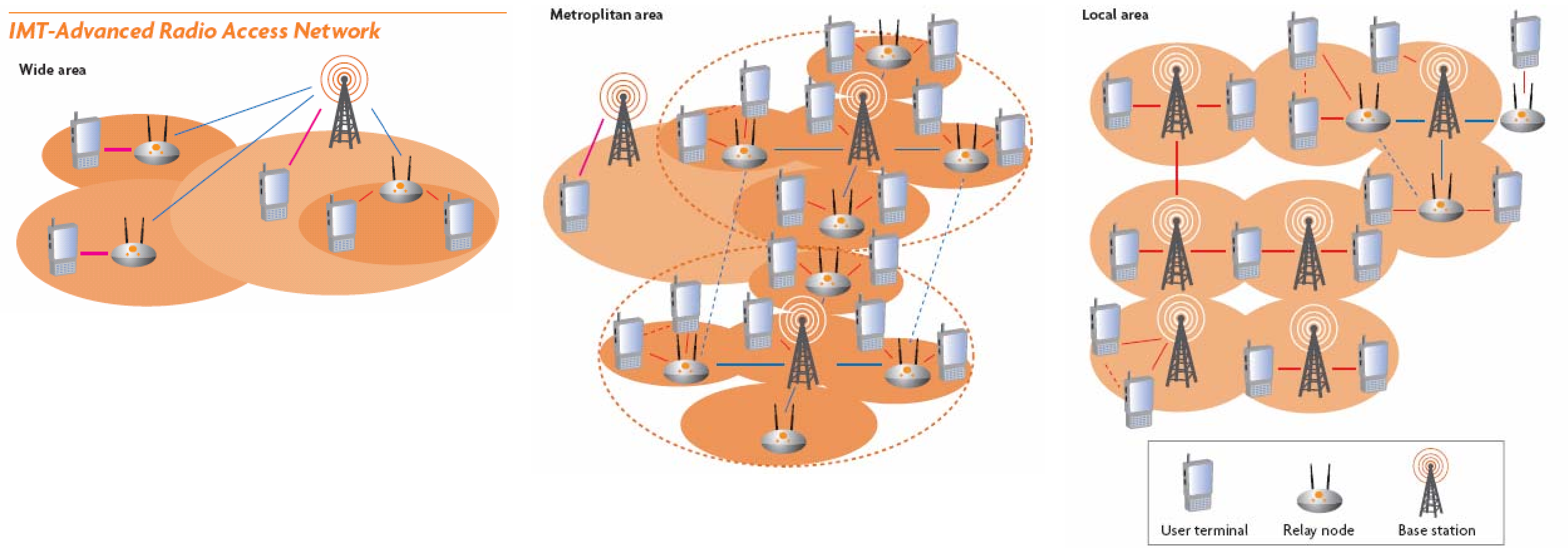
Sample IMT-Advanced Applications and Requirements

Application	Data Rate	Delay
Real-time gaming	1-20Mbps	‹20ms
Real-time video streaming	2-5Mbps	‹20ms
Simple telephony and messaging	8-64kbps	100-200ms
Large file exchanges	Up to 50mbps	›200ms
Lightweight browsing	64-512kbps	›200ms
High-quality video streaming	30Mbps	›200ms

Source: WINNER

- Peak spectral efficiency of 10bits/Hz/site in wide-area deployments for high load
- Peak spectral efficiency in isolated sites of 25 bits/Hz/site
- A sustained average “high-end” data rate per link of 50Mbps above Layer 2
- A consistent and ubiquitous data rate per link of 5Mbps above Layer 2
- User speeds ranging from 0-500km/h should be supported
- A maximum delay over the radio interface (latency) of 1ms at Layer 2
- A maximum bandwidth per radio link of 100MHz

The WINNER initiative has defined its RAN technologies and network architecture.



- WINNER proposes Relay Nodes and Peer-to-Peer communications as part of its network topology.
- TDD (100MHz channels) will be used to meet the high bandwidth requirements with FDD (20MHz channels or higher) for wide area coverage.
- Heavy dependence on OFDM for the PHY layer, MIMO and multiple access technologies, based on the specific requirements.

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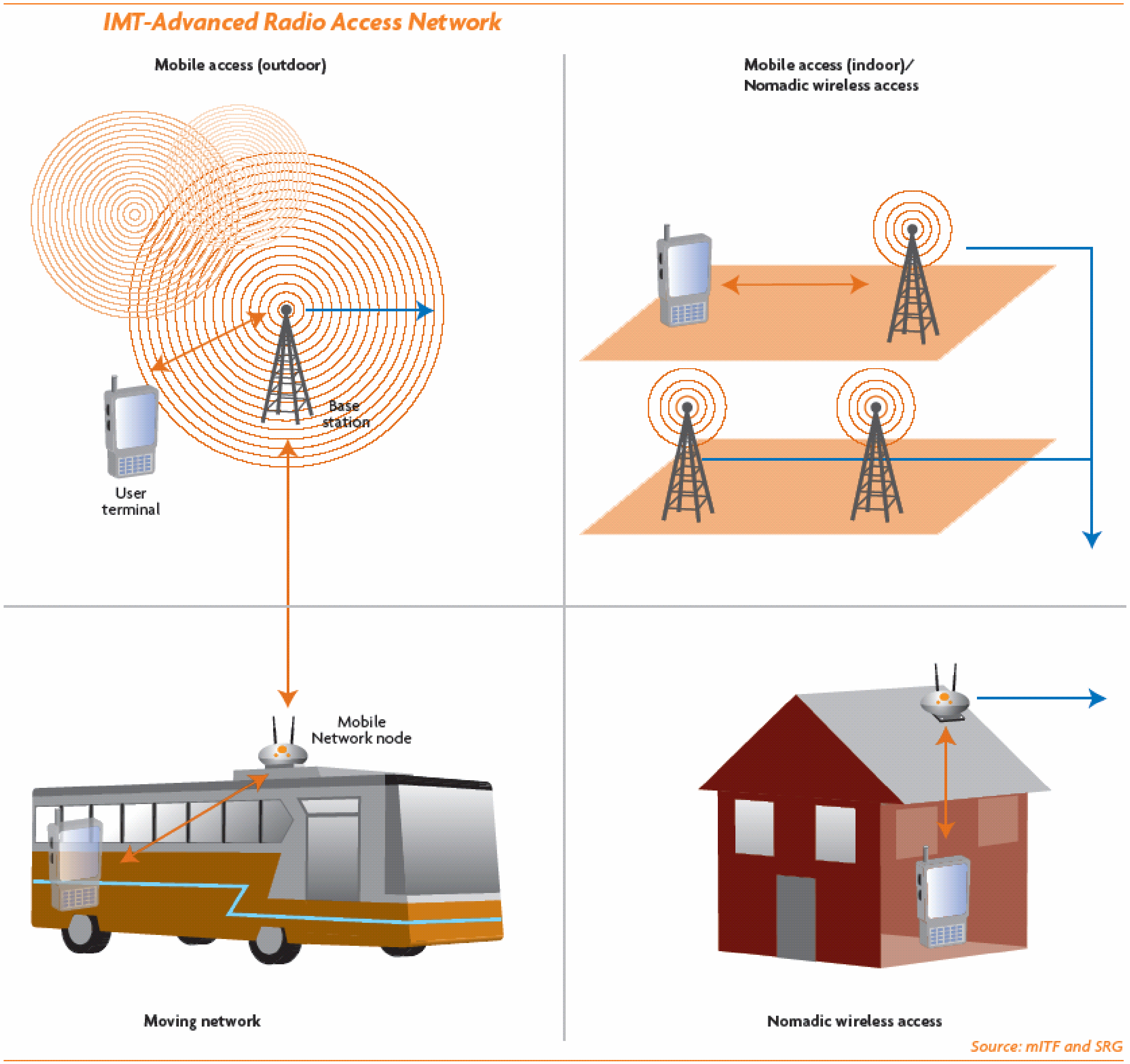
The work of the Mobile IT Forum may or may not lead to the universally accepted version of "4G."

- The Mobile IT Forum has published several documents that describe its vision of "4G."
- Could use the concept of an "Ad Hoc" network to fill in dead spots.
  - Mobile devices serve as relay points
- The system architecture includes a mini residential base station (BS) and a Moving Network Node (MNN).
  - Serves as relay points in the network
  - BS is deployed at home
  - MNN is deployed in moving vehicles, like buses or trains
  - Mobile devices communicate with the BS/MNN via a different technology
  - Solves PAPR concerns

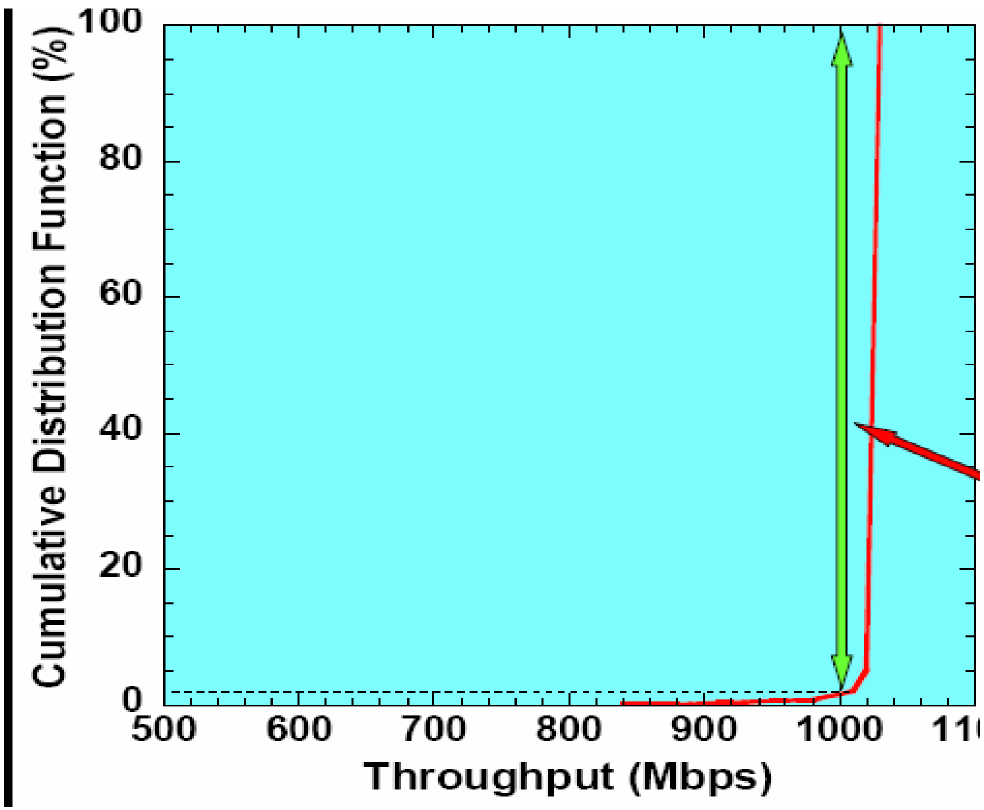
The Mobile IT Forum's vision of an IMT-Advanced system architecture.



Several "new" technologies are being considered for the Radio Access Network – variations on an OFDM/CDMA theme with MIMO.

- GMC (Generalized Multi-carrier) – proposed by WINNER, this concept provides great flexibility to the choice of access technology.
- VSF-OFCDM (Variable Spreading Factor – Orthogonal Frequency Code Division Multiplexing) is being considered and was used by NTT DoCoMo in its 4G technology demonstration.
- VSCRF-CDMA (Variable Spreading and Chip Repetition Factor CDMA) was used by NTT DoCoMo for uplink – wasn't mentioned in the Mobile IT Forum documentation.
- OFDMA (Orthogonal Frequency Division Multiple Access) is being considered, but there are concerns over PAPR.
- SCS-MC-CDMA (Sub-carrier selecting-multi carrier-CDMA) is being considered and is somewhat similar to MC-CDMA.
- IFDMA (Interleaving Frequency Division Multiple Access) is being considered and is somewhat similar to SC-FDMA (the 3G LTE uplink technology).

"4G-like" performance requirements can be achieved today as demonstrated by NTT DoCoMo.



- 1Gbps achieved over 95% of the course.
  - 4 by 4 MIMO with 100MHz radio channel (40MHz in the uplink)
  - ~300m distance to BTS with NLOS conditions and 30km/h vehicular speeds

Radio Resource Management (RRM) is a key part of IMT-Advanced.

- Using traditional spectrum allocation methods each IMT-Advanced operator would need at least 140MHz of spectrum.
  - Even more with N <> 1 frequency reuse
  - Spectrum needed for relay hops
  - Plus the need for additional capacity
- There simply isn't enough "non-nosebleed" spectrum available.
- Most consortiums and leading infrastructure suppliers recommend flexible spectrum allocations.
  - Spectrum is dynamically assigned between operators based on network loading, usage patterns, etc.
  - This means that operators will have to share spectrum with their competitors

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The "what" isn't as important as the "why" and the "when."

- "4G-like" performance requirements can be achieved today as demonstrated by NTT DoCoMo.
- The most important question is whether or not there is a sound business case for deploying a "4G" network.
  - Bandwidth over the air will always be limited to its wireline counterparts
  - Do operators really want another forklift upgrade to their networks?
  - If there is uncertainty regarding the need for OFDMA performance capabilities, 4G is stretching things even further
  - What applications and services will drive this level of usage?
- All of this leads to a question of when will 4G arrive?
  - Anything more than 12-18 months away will always be another year away from happening.

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With IMT-Advanced 8-10 years away, there are still several takeaways that the industry must now consider.

- More spectrum will be required at some point.
  - Without a more spectrally-efficient technology the demand for more spectrum increases
- Higher spectrum has technical and economic issues
  - Opportunity for smart antenna and higher efficient PA solutions
- Spectrum sharing will have regulatory impacts that must be addressed.
  - Policies for licensing and taxing the spectrum will need to be changed
- A more spectral efficient technology won’t be possible without MIMO.
- If consortiums or companies want to influence IMT-Advanced and command meaningful market share they need to plan now.
- Reconfigurable multi-band/mode solutions will increase device complexity and create opportunities for some companies.

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Thank you for listening!