

On the Horizon: 4G Wireless and Beyond

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A Little About Me...

- Principal, Farpoint Group
 - Since 1991
 - Advisory service for wireless networking and mobile computing
- Program Chair, MBX (and advisory board member of a few other events)
- Columnist, computerworld.com and searchmobilecomputing.com
- Blog: networkworld.com/community/mathias
- Engineer (OK, applied math/computer science)
- Analyst - in the business of predicting the future
 - Conclusions aren't important, but the reasoning behind them *is*



Core Objectives for Contemporary Wireless

- *Minimize*, if not *eliminate*, the behavioral and performance differences that exist between wireline and wireless
 - Throughput
 - Reliability
 - Management and RAS
- Anything wire can do, wireless can do, and without the need to find a place to plug in
 - Location-independence
 - *Any* application (remember WAP?)
- Augmentation, not replacement, of wire
 - If you *can* use wire, you *should* use wire



Will Wireless Replace Wire?



- Convenience
- Cost-effectiveness
- Guest access
- Location and tracking
- Mobility – all applications
 - *Voice and data*
- Limited spectrum
- Possible interference (unlicensed bands)



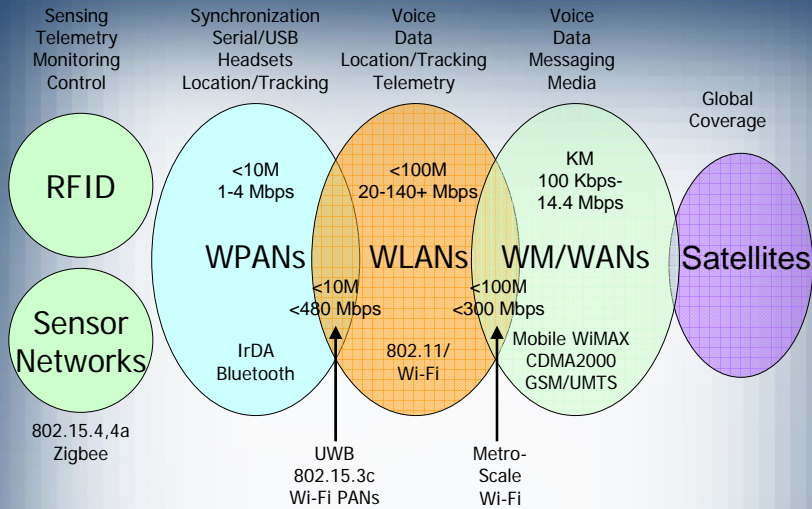
- Bandwidth multiplication
- Interconnect
- Backhaul
- Servers
- Highest possible performance (Gig-E)
- Stationary users
 - Accounting, Call Centers, ...
- Stationary equipment (printers, scanners, storage, etc.)

Commonality in higher-level services

Source: Farpoint Group



The Big Picture...



Source: Farpoint Group

Cellular G's

Generation	Characteristics	Throughput
1	Analog	<2.4 – 22 Kbps (circuit)
2	Digital	9.6 – 14.4 Kbps (GSM, CDMA circuit data)
2.5	Packet data in voice slots	20 – 40 Kbps (GPRS)
3	Digital, improved modulation	60 – 80 Kbps (1XRTT), 200 – 300 Kbps (UMTS), 500 – 800 Kbps (EV-DO)
3.5	3G, but >2 Mbps	HSPA (to 14.4 Mbps peak), Mobile WiMAX (2 Mbps (?), no voice)
4	All-IP with time-bounded services	> 2 Mbps - LTE, 802.20 (?), Mobile WiMAX, Wi-Fi, ...

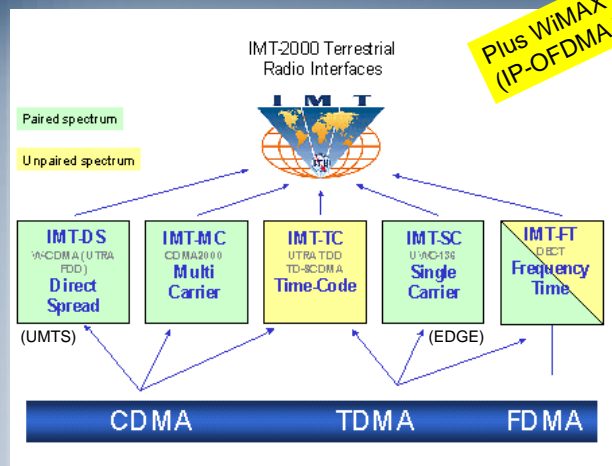
Source: Farpoint Group

What is 3G?

- Origin: ITU IMT-2000; now defined by 3GPP
- Technically: data throughput of...
 - 144 Kbps vehicular, 384 Kbps slow movement, 2 Mbps peak
- Spectrum doesn't define 3G
 - "Narrowband" 1.25-MHz. CDMA2000; EV-DO
 - "Broadband" 5 MHz. IMT-2000/UMTS/WCDMA; HSPA (3.5G)
- Improved voice services, management, OSS, spectral efficiency
 - Includes all 2G voice functions
- Progress was initially slow
 - Technical issues
 - The recession of 2000+
 - The need for a cellular industry consolidation
 - The fundamental conflict between voice and data
- But 3G services now available from all nationwide carriers (T-Mobile now deploying)



3G Technologies



Source: ITU/
Farpoint Group



“4G” Wireless

- An imprecise term - two schools of thought:
 - Ever higher throughput
 - >3.5G performance (40+ Mbps; 100 Mbps)
 - But: peak-vs.-actual remains a technical and marketing problem
 - The throughput/distance tradeoff, propagation issues, loading, etc.
 - All-IP (wireless) networks
 - Full support for time-bounded IP-based communications – not separate voice/data
 - Increased ability to manage capacity (supply and demand)
 - Essentially, what we'd like the Internet to be...
- The key is support for native IP transport with mobility and megabit+ throughput
 - Wireless, mobile, broadband, all-IP
- Deployments begin in 2010 (Bell Mobility, Verizon, etc.) but critical mass is 2013-2015
 - More dependent upon economics than technology
 - And the economics are unfavorable at present
 - Carrier spending depends upon the *consumer*...

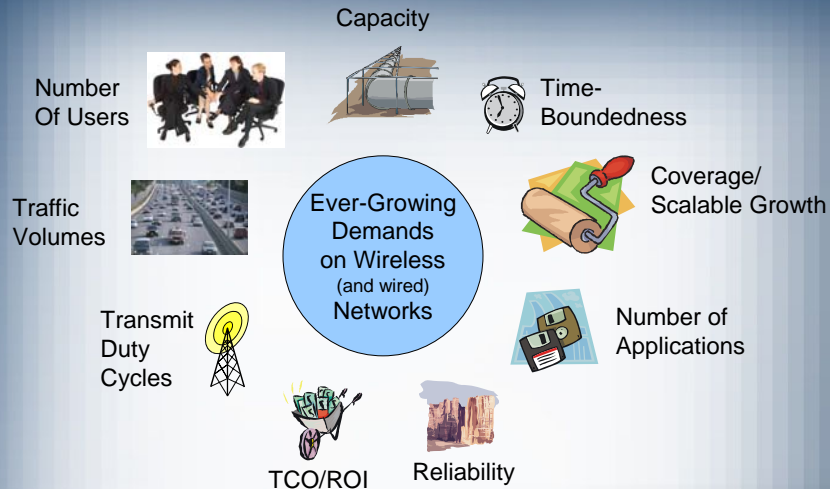


4G: Motivations and Market Drivers

- More spectrum becoming available
 - Although it's expensive...
- Transition from CDMA to OFDM/OFDMA
- All-IP works on wire; why not wireless?
- Need for improved spectral efficiency
 - And improved basic and protocol technologies offer it
- Need for carriers to move to data as a source of growth as voice market saturates
 - Currently practicing the economics of scarcity...
- Improved, more cost-effective implementation technologies
- Caution: will overlap with 3G for a long time due to large installed base
 - E.g., the Sprint/Nextel cutover problem



Scalability: Networks (of any form) Only Grow...



Source: Farpoint Group

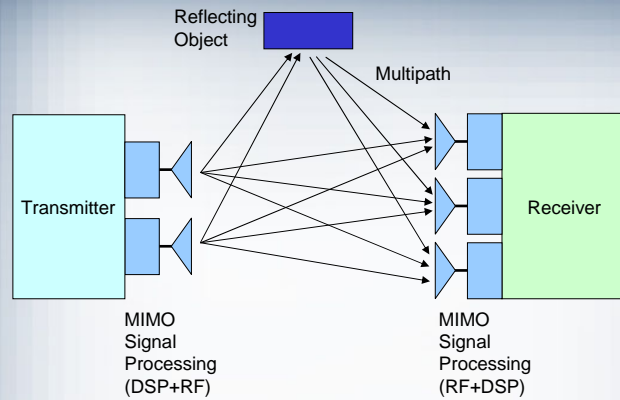


The Most Important Wireless Technology of All: *MIMO*

- **M**ultiple-**I**nput, **M**ultiple-**O**utput
 - What's being "inputted" and "outputted" is the radio channel itself
- More than a multiple-antenna technology – significant signal processing
 - More than simple antenna diversity and maximal-ratio combining
 - *Spatial multiplexing* and *beamforming/beamsteering*
- *Depends* upon multipath!
- Initial application in WLANs – 802.11n
- Eventual application in metro Wi-Fi and cellular (e.g. WiMAX Wave 2 and LTE)
- *MISO* and *SIMO* also possible
- Not related to ultra-wideband (UWB)
- Works well with OFDM/OFDMA



MIMO Example – 2T, 3R (2x3)



Source: Farpoint Group



Alternative 1 (3G): EV-DO

- Part of CDMA2000
 - Evolution of 1XRTT (153 – 307 Kbps peak; 60 – 80 Kbps typical)
- “Data Optimized” or “Data Only”
 - A single 1.25-MHz. CDMA channel
- To 2.4 Mbps (3.09 Mbps Rev A) on downlink
 - Actual throughput to 500-800+ Kbps
 - Remember: *availability (coverage)* and *latency*
- Standards work continues under the direction of the 3GPP2
- Available from Verizon Wireless (*BroadbandAccess*) and Sprint
 - Broad geographic coverage today
- Will Rev B (5 MHz. channel/multicarrier) be deployed?
 - My guess: no. And no Rev C/UMB, either
 - CDMA at end of useful life due to IP issues, not technology



Alternative 2 (3/4G): WiMAX

- Worldwide Interoperability for Microwave Access
- Fixed WiMAX
 - Standardization of the roots of microwave communications
 - Based on a subset of IEEE 802.16-2004
 - Point-to-multipoint
 - Largely viewed as obsolete
 - Mobile systems can emulate fixed systems
- Mobile WiMAX
 - Based on a subset of IEEE 802.16e-2005
 - Licensed (vast majority) and unlicensed
- Big investment in VLSI by Intel and others
 - Build it in and they will come?
- Clearwire deploying in US
 - Alternative to cellular? (my guess - *no* - no voice; 3G, not 4G)
- Major emphasis on emerging markets (e.g., Cisco/Navini)
- Specific performance and features depend upon *implementation*, not the standard



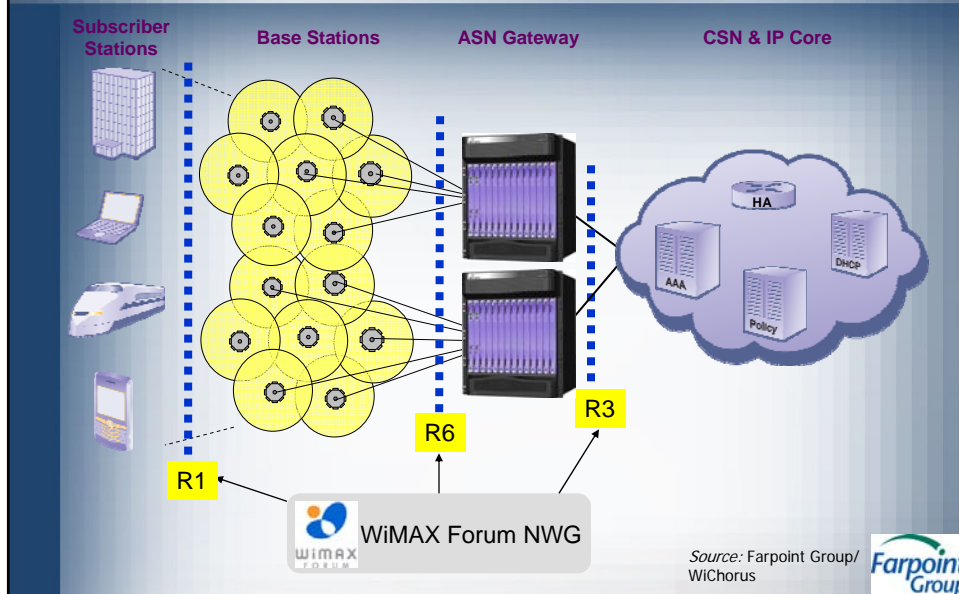
Mobile WiMAX Technology



- Based on OFDM/OFDMA
- Supports channel bandwidths from 1.25 - 20 MHz.
- 1.06-31.6 Mbps/channel downlink; .78-23.52 Mbps uplink (10 MHz. channel)
- Support for QoS; handoff latency of <50 ms.
- Multicast and broadcast support
- Security – AES, 802.1X/EAP
- Power management
- TDD only (initially, anyway)
- Support (in Wave-2) for beamforming, space/time coding, spatial multiplexing/MIMO (63.36 Mbps DL), etc.
- Fractional (sub-channel) frequency reuse
- Exact performance in any given case will depend upon specific implementation, prevailing radio conditions, etc.



Mobile WiMAX Networks



Alternative 3 (3.5G): High-Speed Packet Access (HSPA)

- Formerly, HSDPA/HSUPA
- To 14.4 Mbps (downlink), 5.8 Mbps (uplink)
 - 3.6/7.2 Mbps deployments will remain most common
- Reduce latency and cost per bit
 - 16 QAM
 - Advanced scheduling algorithms (TDMA/link budget)
- In 3GPP Release 5
 - Enhanced uplink in Release 6
 - Based on time-domain sharing of a 5 MHz. WCDMA channel
- Broad availability
 - Apple iPhone 3G and others
- Next: Evolved HSPA/HSPA+/I-HSPA
 - To 42 Mbps downlink (64QAM/2x2 MIMO), 11.5 Mbps uplink (and perhaps to 160/80 and 40/20)
 - Could have a very long life...

HSDPA Channel Assignment - Example



12 Terminal Categories defined
Category 10 = 14.4 Mbps

Source: Rysavy Research



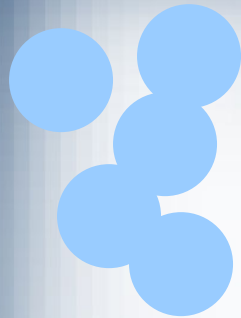
Alternative 4 (4G): UTRA LTE (Long Term Evolution)

- 3GPP Long Term Evolution (new name needed soon...)
- Evolved UMTS Terrestrial radio Access Network (E-UTRAN)
 - Downlink 100+ Mbps; uplink 50+ Mbps; MIMO
 - OFDMA (downlink), SC-FDMA (uplink)
 - 1.25 - 20 MHz. channels, any frequency bands
 - Up to 4X improvement in spectral efficiency, 10X user load/cell
- To 500 KM/h (in theory; optimized for lower speeds)
- VoIP
- MIMO
- End-to-end QoS
- Evolved packet core (EPC) – all IP
- IMS for application mobility
- Legacy GSM/UMTS support (very important)
- Content: voice, data, streaming video, gaming, Web 2.0 (social networking)
- Deployments begin 2010-2012



Large and Small Cells – Complementary Strategies

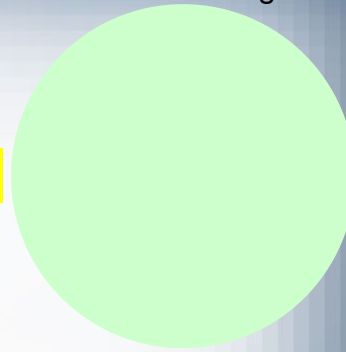
Small Cells



Capacity
Potential gaps in footprint
Lower cost per cell

$$P(D_{SC}) < P(D_{LC})$$

Big Cells

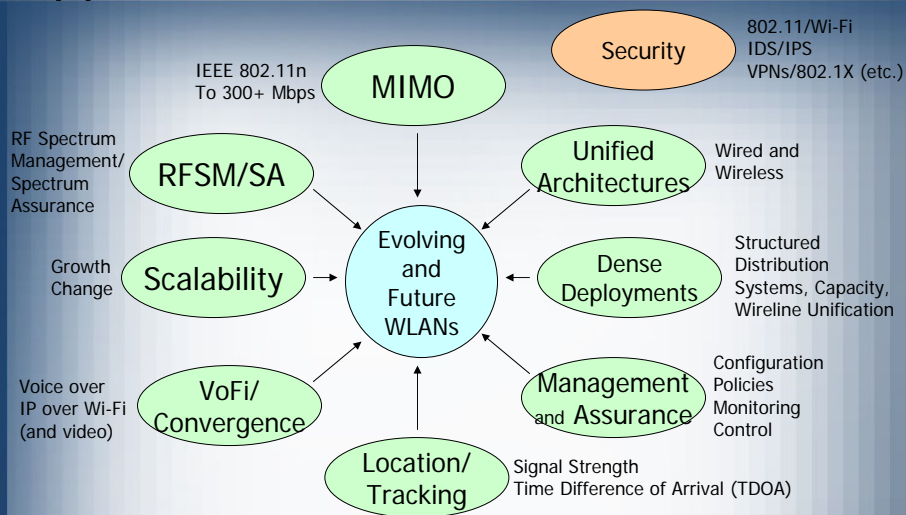


Coverage

Source: Farpoint Group



WLANs – Key Trends and Opportunities



Source: Farpoint Group



The Promise of 802.11n: Features and Benefits

Standard

- Warm, fuzzy feeling
- Lower costs/prices
- Interoperability
- Backwards compatibility

Capacity

- Ability to handle larger traffic mix
- More wire-like experience
- Improved spectral efficiency

Reliability

- More robust radio signal
- Improved rate-vs.-range

Coverage

- Improved range
- Residential
- Enterprise
- Public Space/Metro

Time-Bounded Performance

- VoFi
- Video

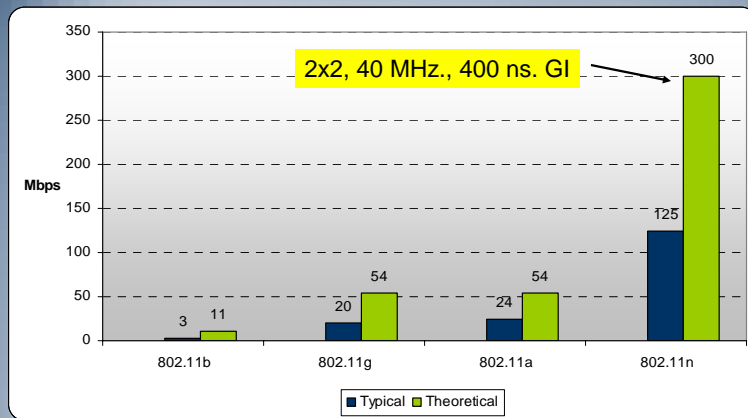
Throughput

- 4-6x .11a/g

Source: Farpoint Group



802.11n: Throughput Comparison



Source: Farpoint Group



Wireless WAN Evolution

1G – Analog (RIP)		2G – Digital, Narrowband, Circuit-Switched (2.5G Packet)		3G – Digital, Broadband, Packet; Separate Voice and Data		4G – Digital, Broadband, Mobile, All-IP	
System	Throughput	System	Throughput	System	Throughput	System	Throughput
AMPS	9.6 – 14.4 Kbps	GSM	9.6 – 14.4 Kbps	EDGE	60-80+ kbps	EV-DO (Rev B)	<75 Mbps
		TDMA (IS-136)	9.6 – 14.4 Kbps	1XRTT (IS-2000)	40-60+ Kbps	EV-DO (Rev C) UMB	<280 Mbps
		GPRS (2.5G)	20-40 Kbps	1XeV-DO (Rev 0)	300-500 Kbps	UTRA LTE	<100-300 Mbps
		CDMA (IS-95)	9.6 – 14.4 Kbps	1XeV-DO (Rev A)	500-700 Kbps	Mobile WiMAX	<75-150 Mbps
				UMTS	300-500 Kbps	Flash-OFDM (802.20?)	3 Mbps (current)
				HSPA (3.5G)	1-3 Mbps	Wi-Fi	20-150+ Mbps

→ CDMA
→ UMTS

Source: Farpoint Group



The Era of Infocentricity – The Increasing Value of *Information*

1960s/70s
Compu-Centric



- *Computers matter*
- *Custom applications*

1980s/90s
Application-Centric



- *Applications matter*
- *Standard applications*

2000+
Info-Centric



- *Information matters*
- *Browsers are it – thin clients?*
- *Anytime/anywhere access*
- *Smart-card based*
- *Continuous Connectivity*

Source: Farpoint Group



Is There Going to be a 5G?

- Well, yes, but...
- Leading candidates
 - IMT-Advanced
 - 802.16m
- General definition: >100 Mbps, up to 1 Gbps
 - <100 ms session setup
 - 10 ms roundtrip delay
- Problems
 - 3G just maturing, 3.5G/4G just rolling out
 - Costs to upgrade once again
 - And consequential impact on pricing
 - Carrier conservatism (perhaps justified in this case)
 - Risk, expense, cutover, timing, ROI, ...
 - Spectrum issues
 - Need for 40-100 MHz. chunks, even with improved spectral efficiency
 - Confusion - on the part of almost everyone involved
- Forecast - maybe by 2015...

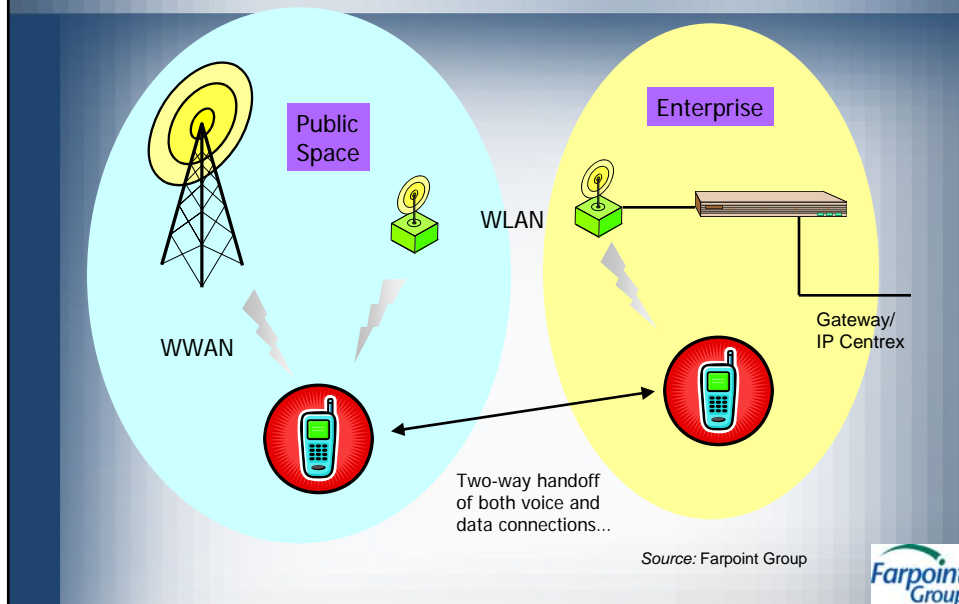


The Answer: Mobile/Mobile Convergence

- No single radio/wireless technology can do it all
 - Yet?
 - Licensed vs. unlicensed, mission (range/throughput) requirements
- Fixed/Mobile Substitution (FMS)
 - Now available: unlimited cell plans
- Convergence
 - *Fixed/Mobile (FMC)* – making the cell phone an extension on the PBX
 - *Mobile/Mobile (MMC)* – using multiple radios in the service of a single use or application (best tool for the job at a given moment)
 - Can be provisioned by carrier (IMS/VCC; GAN/UMA), or enterprise directly
 - Evolving to an element of *unified communications*
- Makes the best use of a scarce resource - the radio spectrum
- Software defined radio (SDR) may play a role here



Convergence in Action



Conclusions (for the moment, anyway...)

- Analysts are in the business of predicting the future...
- Given #1: Demand for broadband wireless will continue to grow globally
 - Data becomes as important as voice - if not more
 - Wireless replaces wire for access (network edge) and some backhaul
- Given #2: VLSI (and maybe software) will keep up with the demand
 - No reason to believe we slow down here...
- Assumption #1: Competition will allow prices for devices and service to fall, building a mass market
 - And motivating an industry shakeout/consolidation in both devices and services
- Assumption #2: 4G is a given, but will take longer than most are forecasting to achieve critical mass
 - Initial deployments: 2010?
 - Volume deployments: 2013-2015+
- 3/3.5G will fill the bill just fine until then, and, for many, well beyond (GSM - 2G - also never goes away entirely...)
- 5G isn't really required, and there are many unanswered questions, primarily related to business and economics



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