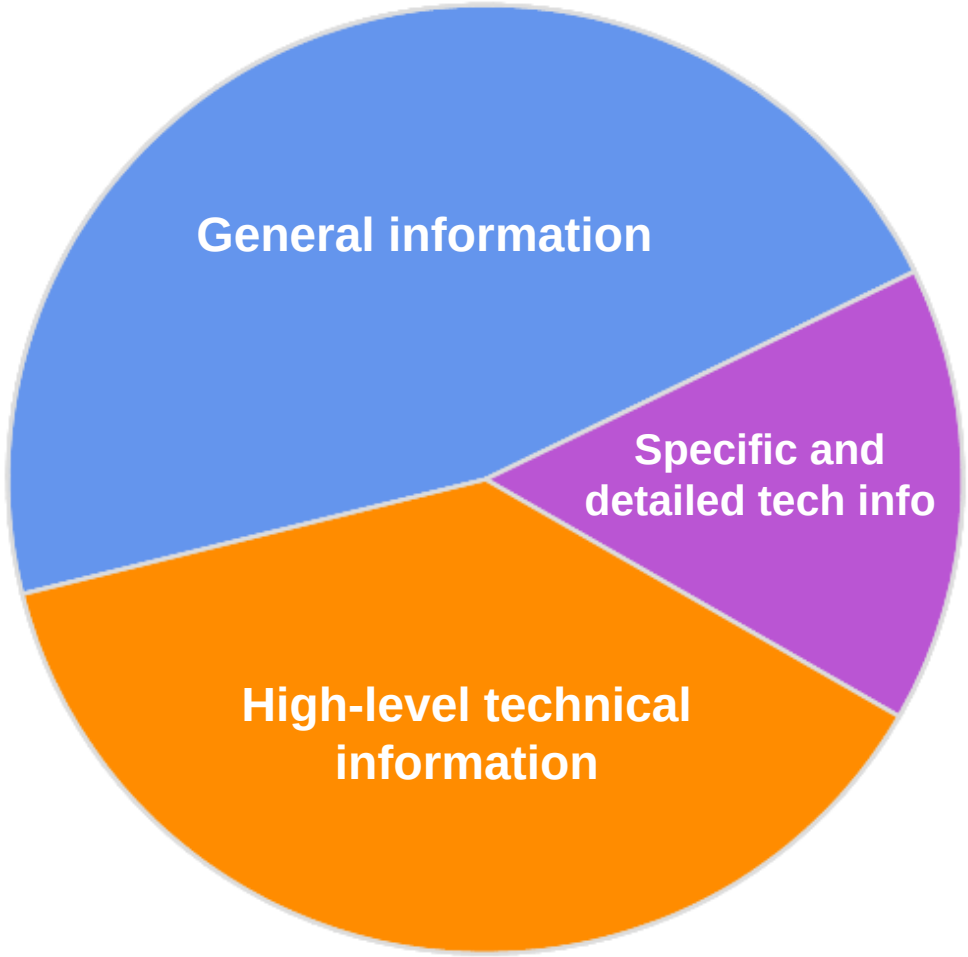
IEEE Seattle ComSoc (COM19) technical event Sept. 30, 2010

- About Neocific
  - A wireless technology company
    - Consulting
    - Prototyping and product development
    - Reference designs on HW/SW platforms
  - Current focus
    - Broadband wireless technologies : WiMAX, LTE, WiFi and others
    - Software defined radios
    - Cognitive radio

Previous LTE Talks

- November 13, 2008, 3GPP Evolved Packet Core (SAE) by Dr. Farooq Bari
- May 19, 2009, LTE - A technical overview
- Oct. 30, 2009, IEEE Pacific Northwest Wireless Workshop 2009, “Key Technologies in 3.5G and 4G”
- May 20, 2010, LTE Analysis: A Vendor's Perspective by Dr. Iyappan Ramachandran

Member Survey



Sept. 30, 2010

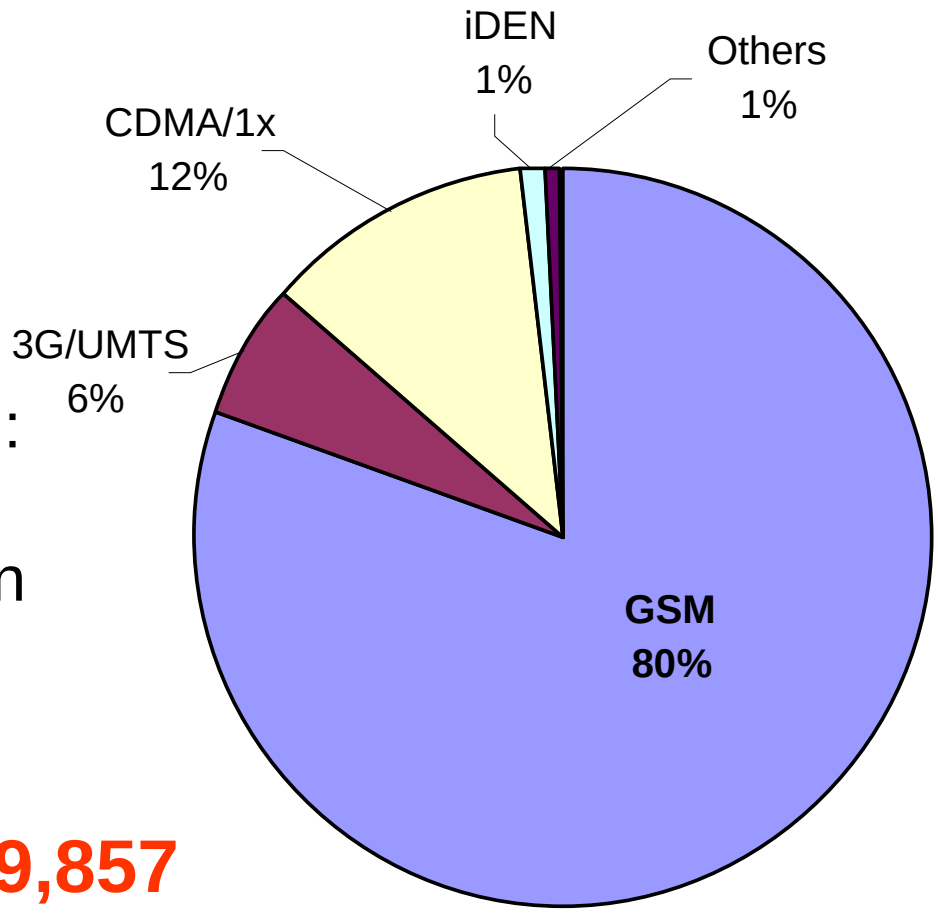
Titus Lo, Ph.D.

Outline

- **Wireless Landscape**
  - **Utilization**
  - **Top operators**
  - **Market forces**
- Wireless technology evolution
- Market outlook
- High-level technical

Wild Wireless World

- Currently there are about 3.4 billion wireless subscribers in the World
  - GSM: 2.7 billion
  - 3G/UMTS (WCDMA): 200 million
  - CDMA/1x: 400 million
  - iDEN 28 million



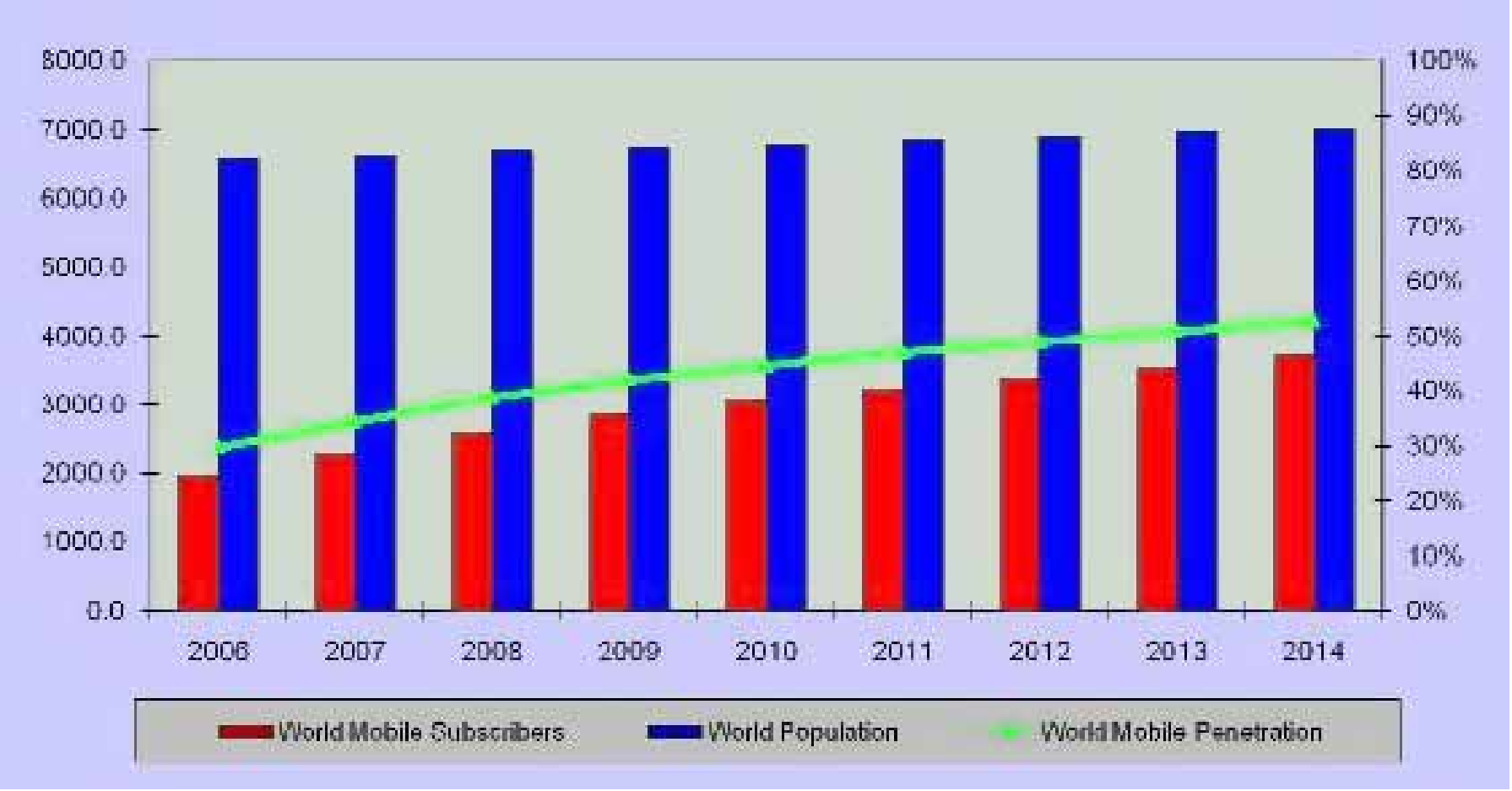
As of Sep 29, 2010

US population: 310,369,857

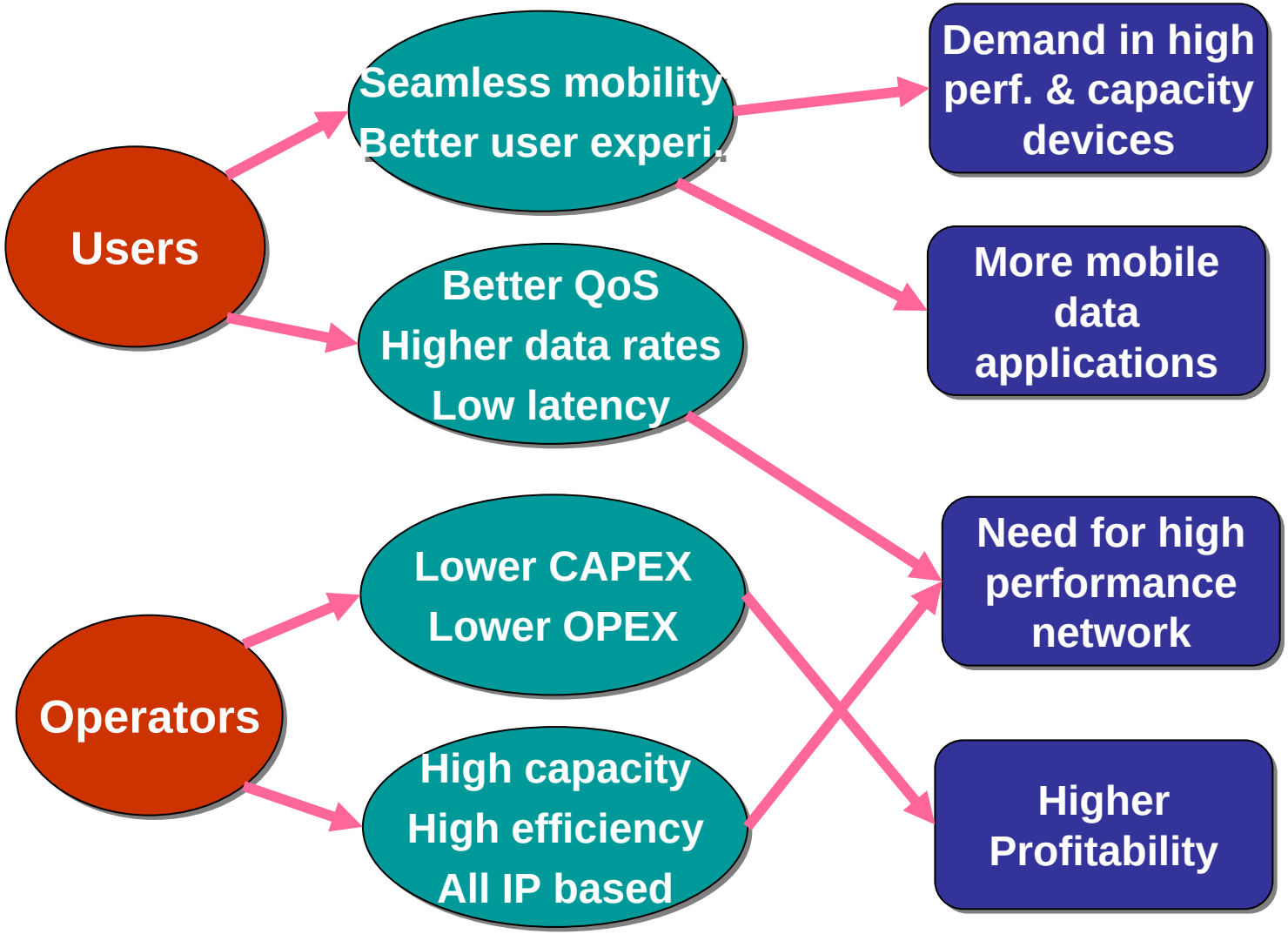
World population: 6,871,973,544

Top 10 Service Providers

Worldwide Growth



Forces behind Evolution



What End-Users Want

- Continuing growth in worldwide demand for mobile data services, fueled by rapidly improving quality and availability
- Consumers' demands more from mobile broadband
  - expanded services
  - richer multimedia experiences
  - easier access
  - greater personalization
  - Lower charges
  - Simple network connectivity
  - Ubiquity: Anywhere, Anytime, Any device
  - Enhanced & varied services: more speed & reduced latency
  - Better experience

More Mobile Data Applications

- VoIP
- Social networking
- Mobile ad
- Video telephony
- Multimedia broadcast/multicast
- Internet apps (e.g., search, browsing)
- Interactive apps (e.g., games, learning)
- Push services (e.g., location based services)
- Business services

What Operators Want

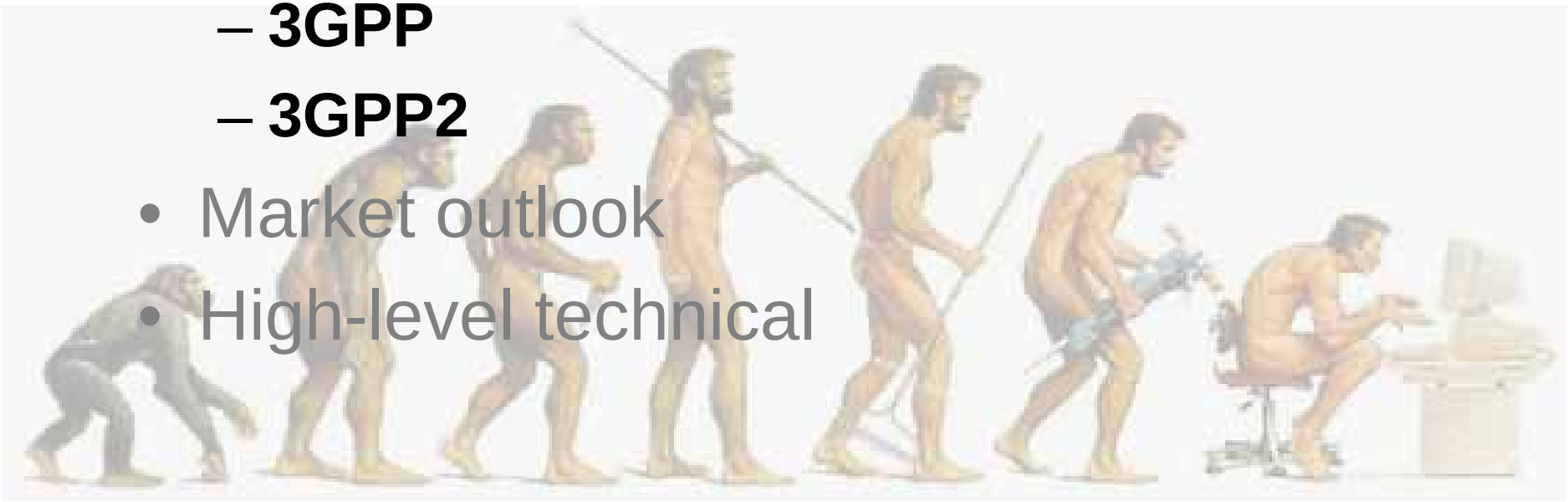
- A network capable of delivering these applications with QoS
  - High-speed
  - Broadband access
  - Delivered anywhere and at any time
- Lower Cost of Ownership:
  - Reduced migration, CAPEX/OPEX, and protecting investments by reusing existing assets
- Data rate and latency
  - Higher data rate and capacity / Reduced latency for multimedia rich applications
- Architecture
  - Greater simplicity, less protocol complexity
- Mobility
  - Seamless handover ensuring service continuity with legacy systems
- Spectrum
  - Greater efficiency and flexibility

3G Was Good Enough

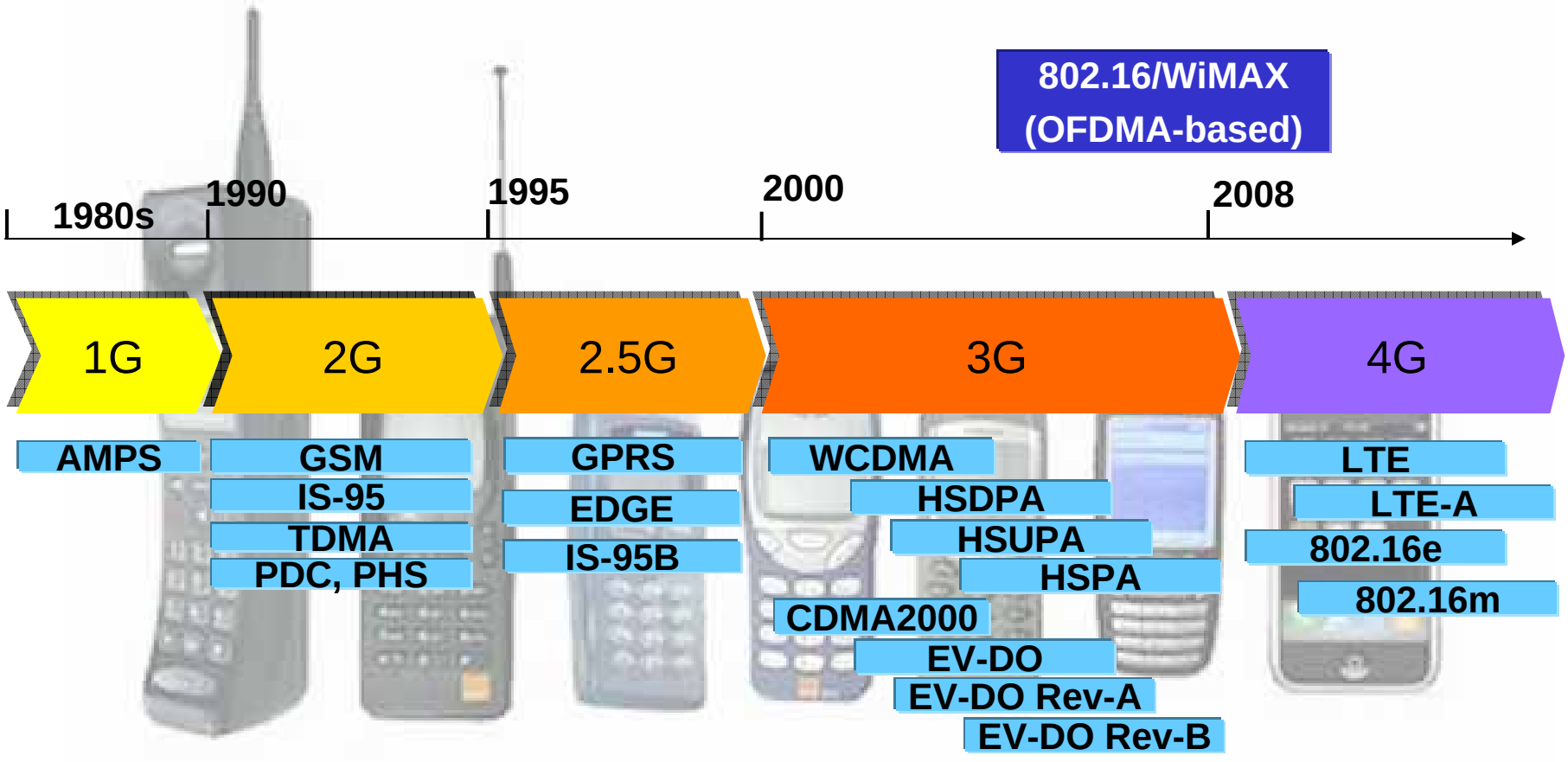
- 3G technology
  - 3GPP: WCDMA, HSDPA, HSUPA, HSPA
  - 3GPP2:CDMA2000, EV-DO, EV-DO Rev-A/B
- 3G capable of delivering services
  - VoIP
  - Social networking
  - Video telephony
  - Multimedia broadcast/multicast
  - Apps

Outline

- Wireless landscape
- **Wireless technology evolution**
  - **Standards**
  - **3GPP**
  - **3GPP2**
- Market outlook
- High-level technical



Wireless Standard Evolution



3GPP Evolution

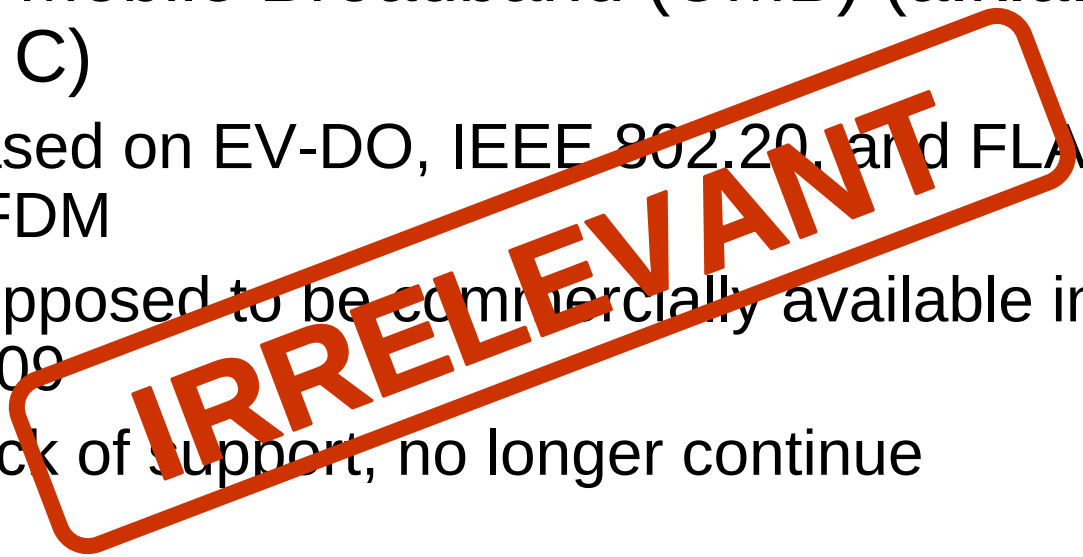
- Release 99 (Mar. 2000): UTRA in FDD and TDD (3.84 Mcps) modes
- Rel-4 (Mar. 2001): TD-SCDMA
- Rel-5 (Mar. 2002): HSDPA, IMS (IP Multimedia Services)
- Rel-6 (Mar. 2005): HSUPA, MBMS
- Rel-7 (2007): DL MIMO, optimized real-time services (VoIP, gaming, push-to-talk)
- Rel-8 (2008): Long Term Evolution (LTE)
  - Standardization effort started in late 2004
    - With HSPA (downlink and uplink), 3G would remain highly competitive for several years; however,they needed to respond to IEEE802.16/WiMAX, which they saw as a threat for loosing competitive edge
  - LTE focus:
    - Enhancement of the UTRA (3G air interfaces)
    - Optimisation of the UTRAN architecture
    - To ensure the continued competitiveness of the 3GPP technologies for the future

3GPP Technology

	WCDMA	HSPA	HSPA+	LTE
Max DL speed (bps)	384K	14M	28M	100M
Max UL speed (bps)	128K	5.7M	11M	50M
Latency	150 ms	100 ms	50 ms	10 ms
Access Technology	CDMA	CDMA	CDMA	OFDMA/SC-FDMA
Release	Rel. 99/4	Rel. 5/6	Rel. 7	Rel. 8
Initial roll-out time	2003	2005 DPA 2007 UPA	2008/09	2009/10

3GPP2 Evolution

- CDMA2000 1X (1999)
- CDMA2000 1xEV-DO (2000)
- EV-DO Rev. A (2004): VoIP
- EV-DO Rev. B (2006): Multi-carrier
- Ultra Mobile Broadband (UMB) (a.k.a. EV-DO Rev. C)
  - Based on EV-DO, IEEE 802.20, and FLASH-OFDM
  - Supposed to be commercially available in early 2009
  - Lack of support, no longer continue



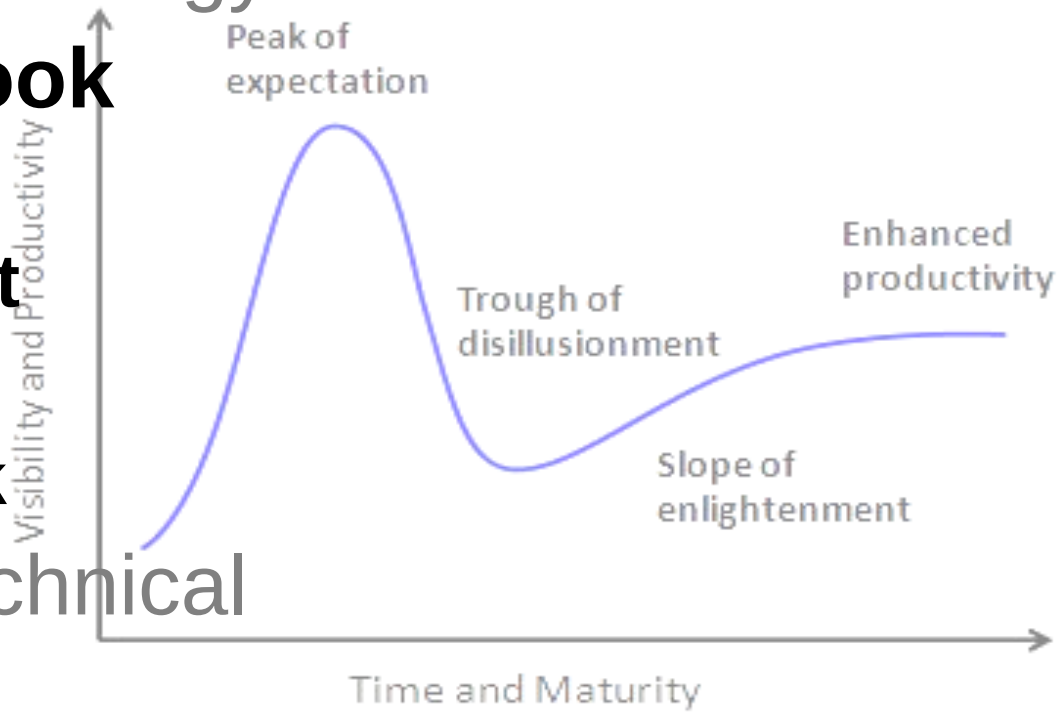
WiMAX vs. LTE

- Technology
  - Worldwide technology standards
    - efficient radio technology
    - simplified all-IP network architecture with greater flexibility and scalability
  - High speed and performance to deliver a new generation of multimedia services
    - Lower costs for end users and operators alike
    - compelling and profitable services
  - Designed to meet the demands for mobile data services
  - Designed to deliver what consumers and service providers want
- Spectrum/policy
  - Supports from regulators
- Operators/service providers

Market chose LTE

Outline

- Driving forces behind wireless technology evolution
- Wireless technology evolution
- **Market outlook**
  - **Benefits**
  - **Deployment**
  - **Forecast**
  - **IPR outlook**
- High-level technical



Benefits for Operators

- **Investment protection**
  - Reuse of some existing assets
  - Smooth migration and installation for existing and new customers
- **Increase in revenues**
  - Deploy services at lower cost with better user experience
  - Deliver richer multimedia services based on higher throughput and minimum latency
  - Enhanced support for end-to-end QoS
- **CAPEX & OPEX reduction**
  - Reduced cost-per-bit
  - More flexible usage of existing and new frequency bands
  - Simplified architecture; all-IP based
  - Seamless inter-operation with 3GPP and non-3GPP networks

Benefits for Users

- **Better experience, better services**
  - End-users enjoy stress-free mobile broadband that rivals fixed broadband services
  - More advanced services suit end-user needs, expectations and lifestyle

Deployment Landscape

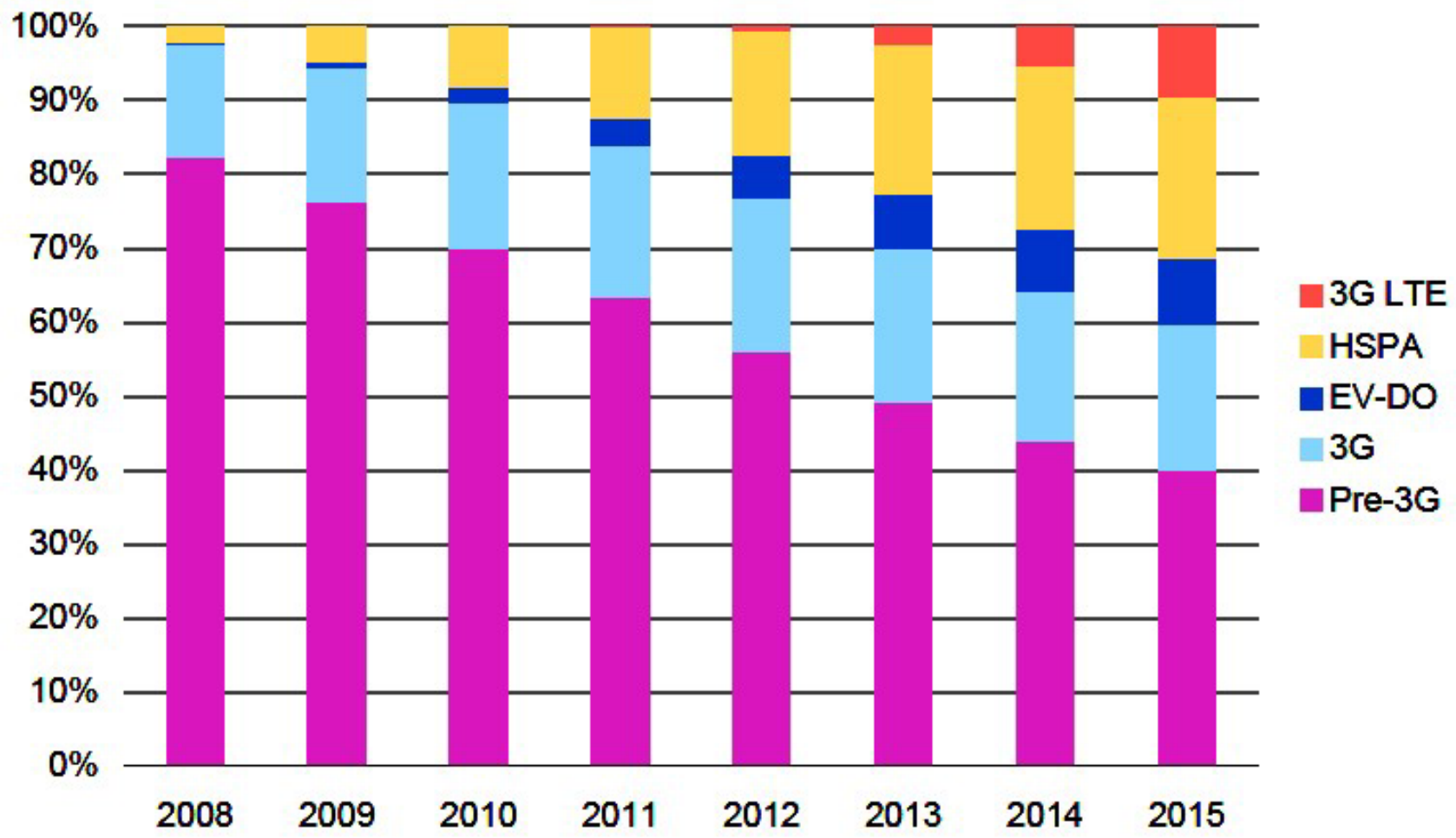
- According to the GSA
  - There are now 64 operators committed to deploying LTE networks in 31 countries worldwide
  - 22 LTE networks will be in commercial service by end 2010
  - 39 or more LTE networks commercially launched by end 2012.
- TeliaSonera launched the world's first commercial LTE network last December in Norway and Sweden
- Verizon’s LTE network will cover the U.S., giving its 93 million subscribers access to LTE data cards and handsets

Deployment Schedule

Operator	Markets	Launch date	Vendor
AT&T	Unnamed US markets	2011	Ericsson, AlcaLu
CenturyLink /Qwest	select US rural markets	2010	
China Mobile	China	2011	
eMobile	Japan	2010	
MetroPCS	Major US markets	2010	Ericsson
MTS	Uzbekistan	2010	Huawei
KDDI	Japan	2012	Motorola, NEC
KT Freetel	South Korea	2010	

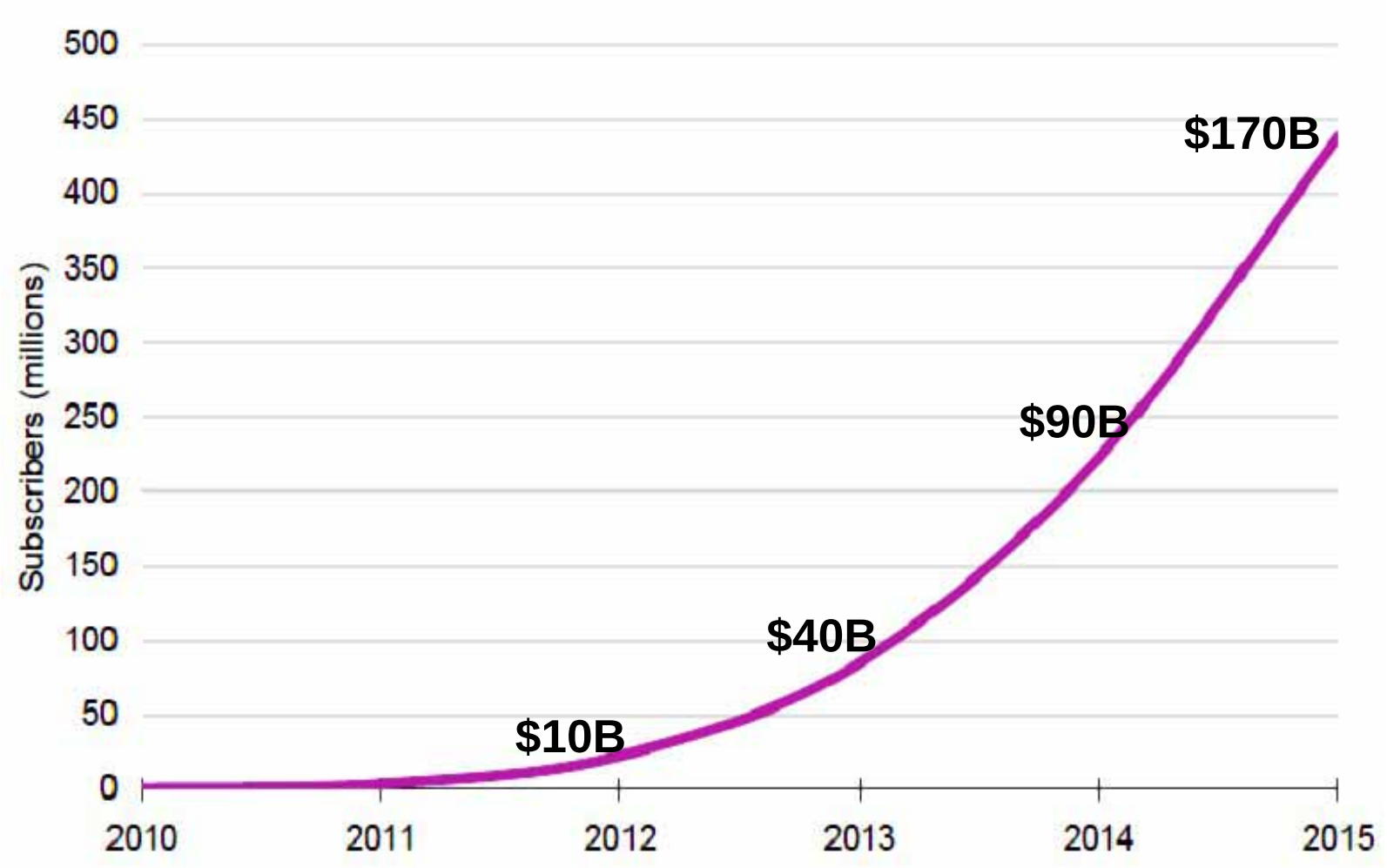
Operator	Markets	Launch date	Vendor
NTT DoCoMo	Japan	2010	NSN, Fujitsu, Panasonic
Rogers Wireless	Vancouver, B.C.	2010	
SK Telecom	South Korea	2010	
TeliaSonera	Stockholm	2009	Ericsson
TeliaSonera	Oslo, Norway	2010	Huawei
Tele2/Telenor Sweden	Sweden	2010	
Verizon Wireless	25-30 US markets	2010	Ericsson, AlcaLu
Zain	Bahrain	2010	NSN

Technology Usage Forecast



Source: Analysys Research Limited

Subscriber/Revenue Forecast



Source: Analysys Research Limited

Top Infrastructure Vendors

Ericsson	Commercial contracts: AT&T, Verizon Wireless, MetroPCS, NTT DoCoMo, TeliaSonera
Alcatel-Lucent	Commercial contracts: AT&T, Verizon ***45 LTE trials*** around the globe
Huawei	Nine commercial LTE contracts: TeliaSonera, MTS 50 LTE Trials
Motorola	***20 LTE trials*** or engagements with customers around the world
NSN	***30 LTE trials*** globally talks with 15 top-tier operators to build commercial networks
ZTE	***LTE trial*** networks for leading telecom operators in Europe, North America, Asia-Pacific and MEA
Fujitsu	Commercial contracts: NTT DoCoMo

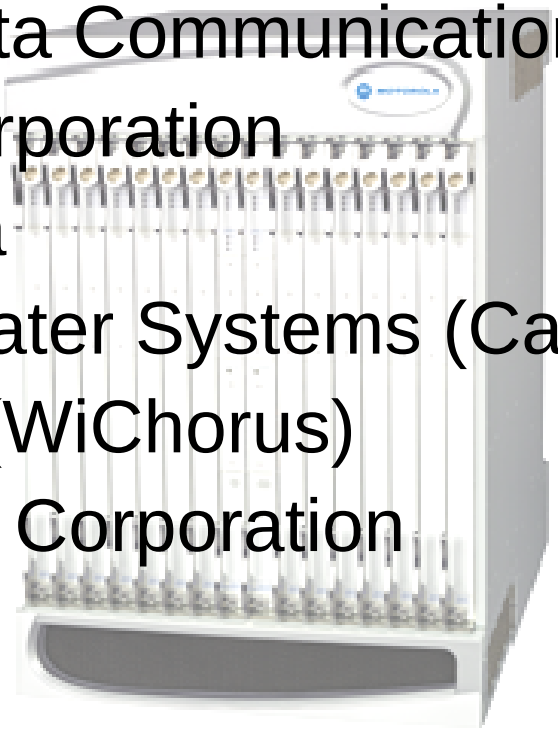
LTE infrastructure market to hit $5B in 2013

Backhaul Solution Vendors

- Alcatel-Lucent
- RAD Data Communication
- Ceragon Networks (formerly Giganet), part of RAD Group
- Dragon Wave (Canada)
- Tellabs/ SwissCom Collaboration
- Harris Stratex Networks (Aviat Networks)
- Proxim Wireless
- Axerra Networks
- Accedian Networks (Canada)
- Conterra Telecom Services

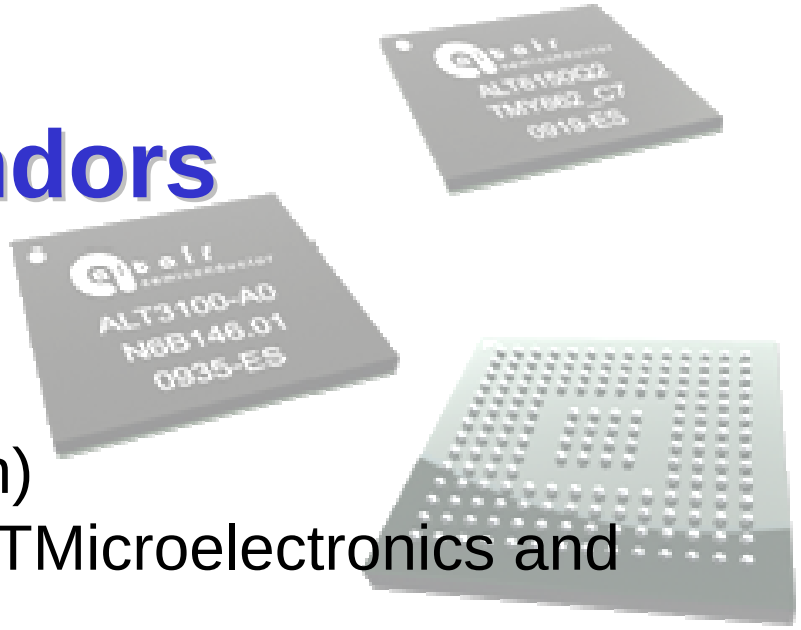
EPC Solution Providers

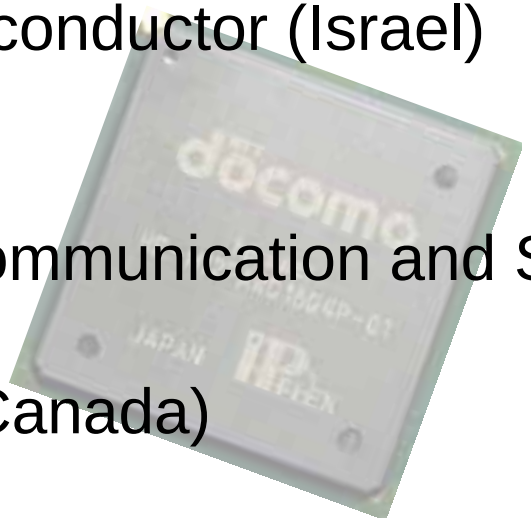
- CISCO (Starent Networks)
- NSN
- RAD Data Communications
- NEC Corporation
- Motorola
- Bridgewater Systems (Canada)
- Tellabs (WiChorus)
- RadiSys Corporation
- Aricent
- Hitachi

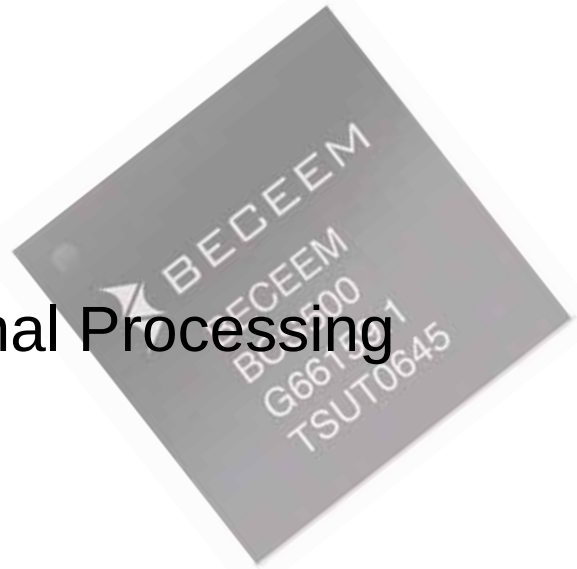


Chipset Vendors

- QUALCOMM
- Broadcom
- Intel (Infineon Wireless Solution)
- ST-Ericsson (joint venture by STMicroelectronics and Ericsson)
- Samsung
- DoCoMo
- Altair Semiconductor (Israel)
- Beceem
- BitWave
- Comsys Communication and Signal Processing
- Sequans
- Wavesat (Canada)







Handset Vendors

- Nokia
- LG
- Samsung
- Sony Ericsson
- ZTE
- Apple
- Kyocera
- Blue Wonders Communication (Germany)
- RIM

Test/Measurement Equipment Vendors

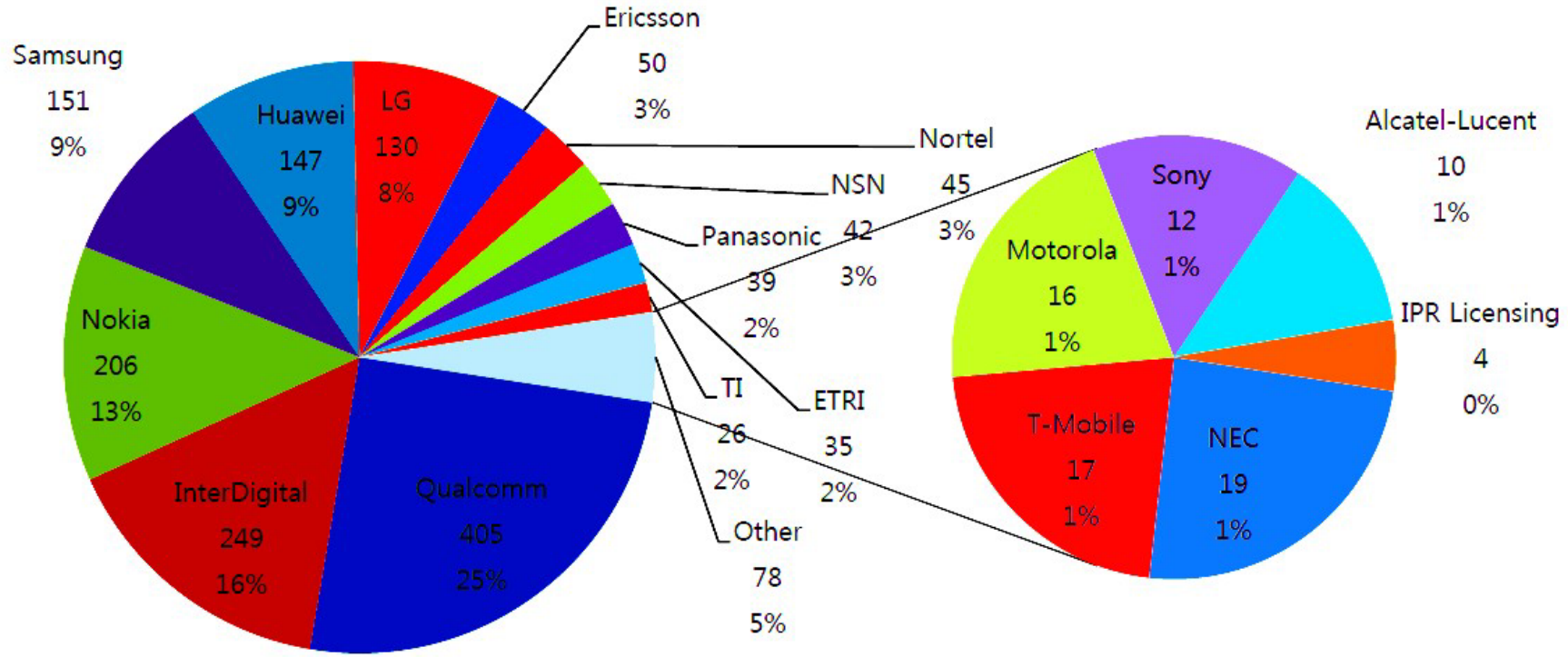
- Agilent
- Rohde-Schwarz (Germany)
- Tektronix
- Aeroflex
- Couie (Japan)
- Signalion (Germany)
- Sanjole

LTE IPR Outlook

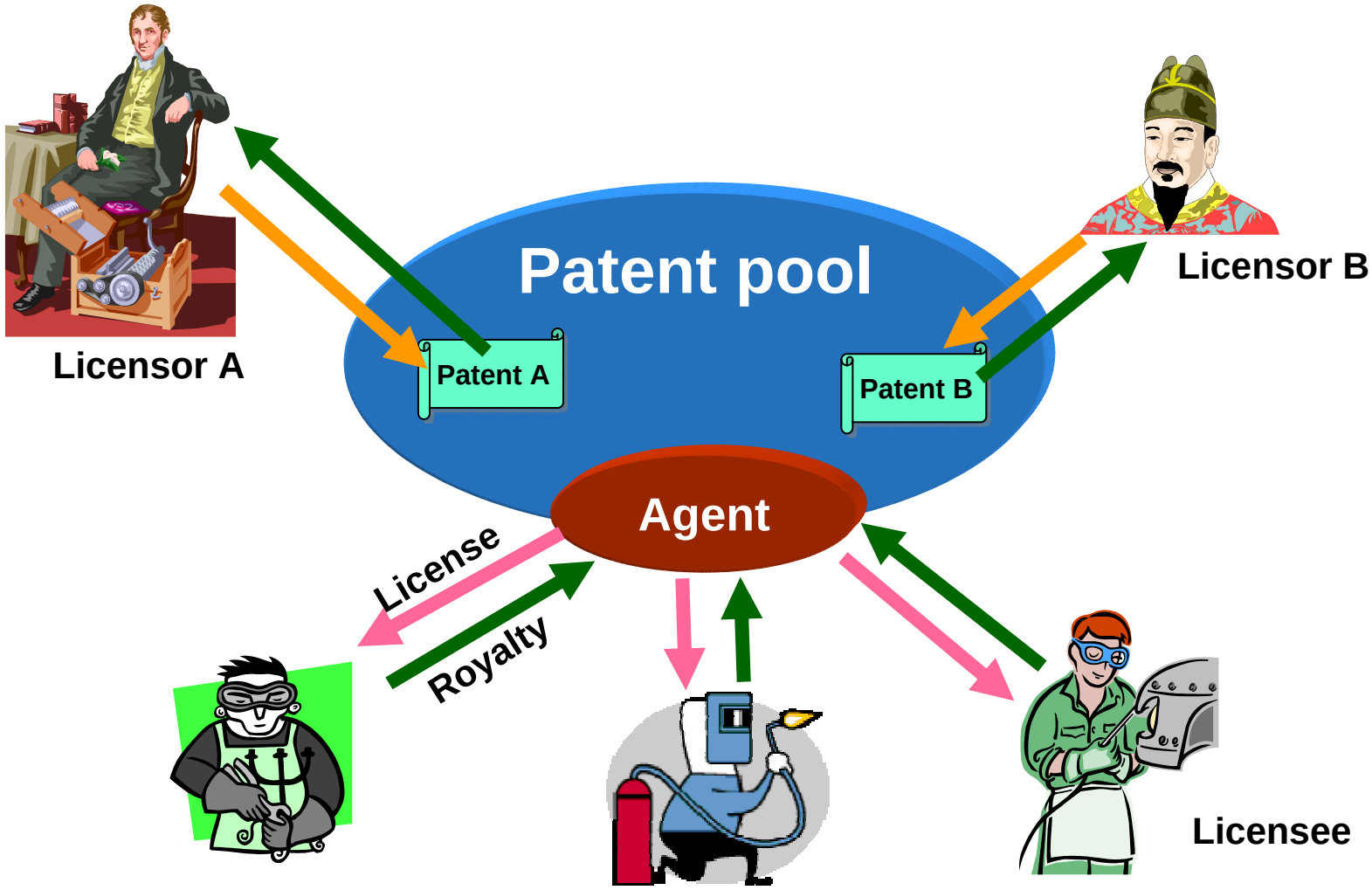
- LTE IPR landscape
- Patent pool
- Mutual agreement
- NPE to be reckoned with

LTE IPR Landscape

- As of September 30 2009, there are total of 1607 declarations for LTE essential patent candidates



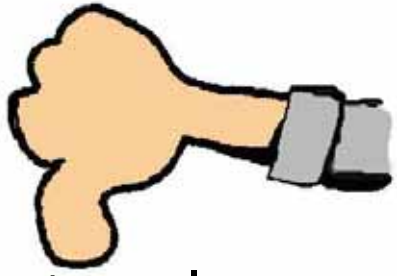
Patent Pool Model



Patent Pool Pros

- Greatly simplify the licensing process by providing a one-stop shop for the essential IPR
- May solve the royalty stacking coordination problems
  - Licensors agree to a price cap that guarantees licensees a fixed price by diluting royalties proportionately for each new IPR claim added to the pool
  - In exchange, licensors would get their patent strengthened if the pool charges fixed royalties for use of any pool patents that reduce the incentive to invent around or legally challenge any one patent.
- May reduce the transaction costs associated with implementing a standard, as with the successful DVD and MPEG-4 patent pools

Patent Pool Cons



- Despite these theoretical advantages of patent pools in standardization, empirical evidence as to their benefits remains to be seen
- When there is competing interests between a firms' product and IPR positions, it will be difficult for patent pools to attract broad enough participation necessary to make a significant patent pool
- Patent pools have been shown to fail when the primary motivation is to cap royalties
  - The largest patent holders are outside the 3GPP pool
  - Its particular pool has failed to make a significant impact on the market

LTE Patent Pools

- Via Licensing
  - Wholly owned subsidiary of Dolby Laboratories, Inc.
  - Based at San Francisco
  - Built the framework for the patent pool with 14 LTE patent owners from eight countries (China, France, Finland, Germany, Japan, Korea, the Netherlands, and USA)
- Sisvel
  - An Italian company that also operates a patent pool for MPEG audio technology
  - The largest number of any of the three patent-pool companies
  - Brought together 32 significant LTE patent holders from China, Japan, Korea, Europe, and North America
- MPEG LA
  - A Denver-based company
  - Formed the pool with 12 patent owners

Mutual Agreement

- Some essential patent holders prefer only bilateral license deals (e.g., Ericsson, Qualcomm, Nortel)
- Qualcomm and Nortel expressly opposite patent pools
- Most major essential patent holders have not expressed their positions
- Expected royalty in low single digit percentage

  - Nortel's LTE portfolio may worth $400M~ $2.7B
    - Nortel retains > 3,000 patents, many relating to OFDMA, MIMO, and other key attributes of LTE
    - RIM, WiLAN, and Mosaid Technologies

NPE to be reckoned with

- Who are NPE
  - By definition: a patent owner who does not manufacture or use the patented invention, but seeks to enforce its right through the negotiation of licenses and litigation.
  - Inventors
    - "failed entrant“: individuals and companies who have tried to bring their innovations to market but failed
    - R&D organizations (e.g., universities)
  - Patent investors
    - Individuals or companies that purchase patent property without performing research or even commercializing any product
- NPE Impacts
  - ~$7B poured into NPEs past 10 yrs
  - Litigations initiated by NPEs increased by 300%
  - 16% of all patent litigations by NPEs

NPE – Patent Troll

- Using purchased patents to reap profits from those who commercialize innovation, raising costs to consumers, and retarding innovation
- Damaging invention and commercialization by exploiting their unfair advantage in the market
  - Increase entry barriers for new companies that might otherwise lower prices through competition
  - Increase the cost to consumers for the use of the patents that NPEs purchase from others for the primary purpose of pursuing profit
- Heavily litigation-focus
  - The losers are businesses, consumers, and an overburdened court syste

NPEs shouldn't ask for money if they're not producing anything

NPE – Servicing the Patent Market

- A market agent in the patent market
  - Providing liquidity, market clearing, and increased efficiency to the patent markets
- Patent owners are able to enforce their constitutionally given monopoly rights to practice inventions they have created or purchased
- Classic arbitrageur practice
  - Balancing out an unbalanced market
- Valuable services to individual inventors
  - Most inventors barely have enough money to file for a patent application
  - Patent litigation is exorbitantly costly for individual inventors
  - Without another company to finance the litigation or at least to license or buy the patent, inventors may never see any benefit from their inventions

NPE to be reckoned with

- Offensive Play
  - Licensing fees
  - Debatable tactics
  - Usual suspects: InterDigital. Wi-Lan, NTP, Mosaid, Lemelson, Intellectual Venture, CSIRO, …
  - First shot fired at 4G by Adaptix, suing Sprint/Clearwire
- Defensive play
  - Protection fees
  - Gaining popularity
  - Provide protection to its members by acquiring patents that may be, or are currently, enforced against their "members"
  - RPX, Allied Security Trust, …

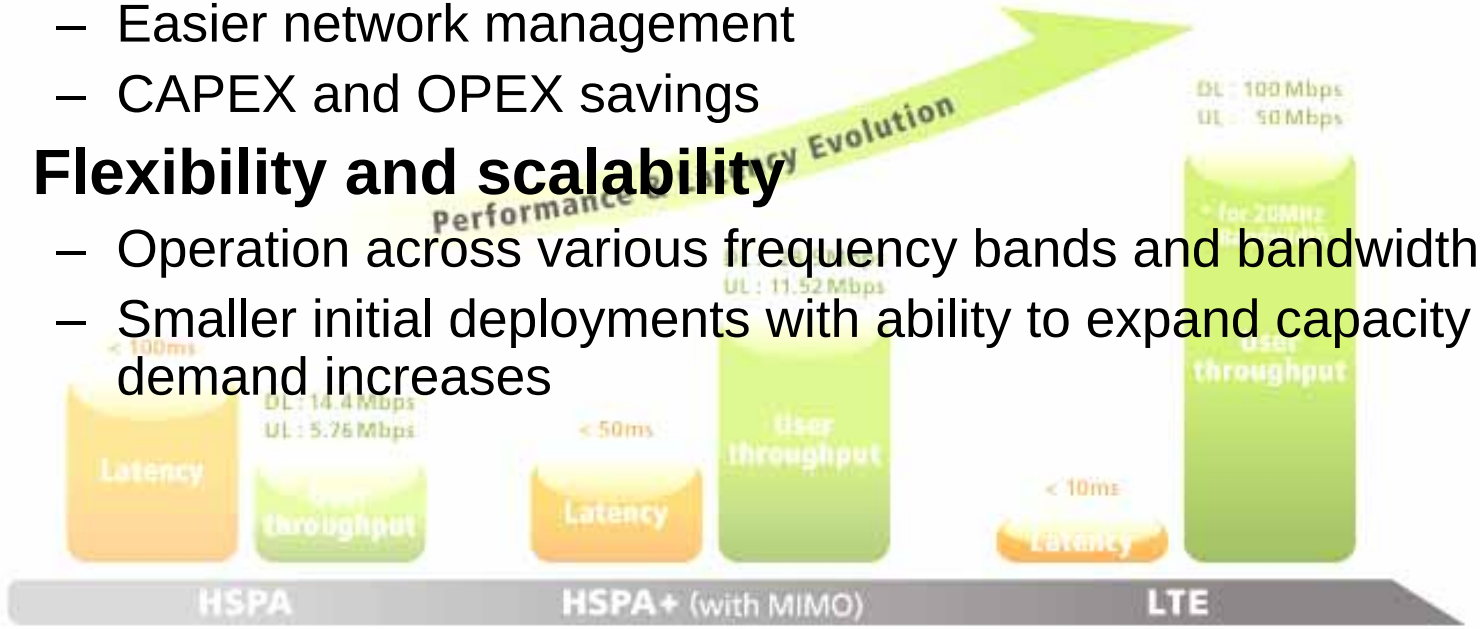
"Let's get this straight-who's paying who protection money?"

Outline

- Driving forces behind wireless technology evolution
- Wireless technology evolution
- Market outlook
- **High-level technical**
  - **Capabilities**
  - **Key features**
  - **LTE-Advanced**

Capabilities

- **Highly efficient radio technology**
  - Increased spectral efficiency and greater capacity
  - Lower cost-per-bit and greater profit margins
- **Simplified all-IP network architecture**
  - Reduced service delay and improved end-user experience
  - Easier network management
  - CAPEX and OPEX savings
- **Flexibility and scalability**
  - Operation across various frequency bands and bandwidths
  - Smaller initial deployments with ability to expand capacity as demand increases



Key Technologies/Features

- Multiple access
- Bandwidth scalability
- Advanced antenna technology
- MBMS/SFN
- Link adaptation
- Interference mitigation strategies and methods
- ARQ/HARQ
- Resource scheduling
- Power management

LTE -Advanced

- Advanced version of LTE (3GPP Rel. 10) designed to meet IMT-Advanced requirements
- Evolution of current OFDMA approaches
- High-order MIMO (e.g., 4X4)
- Wider radio channels
- Multi-channel operation in either same or different frequency bands
- Ability to share bands with other services.

LTE and LTE-A

	LTE	LTE-A
Max DL speed (bps)	100M	1G
Max UL speed (bps)	50M	500M
Tx bandwidth	20	70 for DL 40 for UL
Latency	10 ms	<5 ms
Spectral efficiency	15 bps/Hz for DL 3.75 bps/Hz for UL	30 bps/Hz for DL 15 bps/Hz for UL
Access Technology	OFDMA/SC-FDMA	OFDMA
C-plane capacity	>200 active users with 5MHz BW	>300 active users without DRX with 5MHz BW
Mobility	Up to 350Km/h	Up to 350Km/h


Thank You