The Road to 4G Wireless

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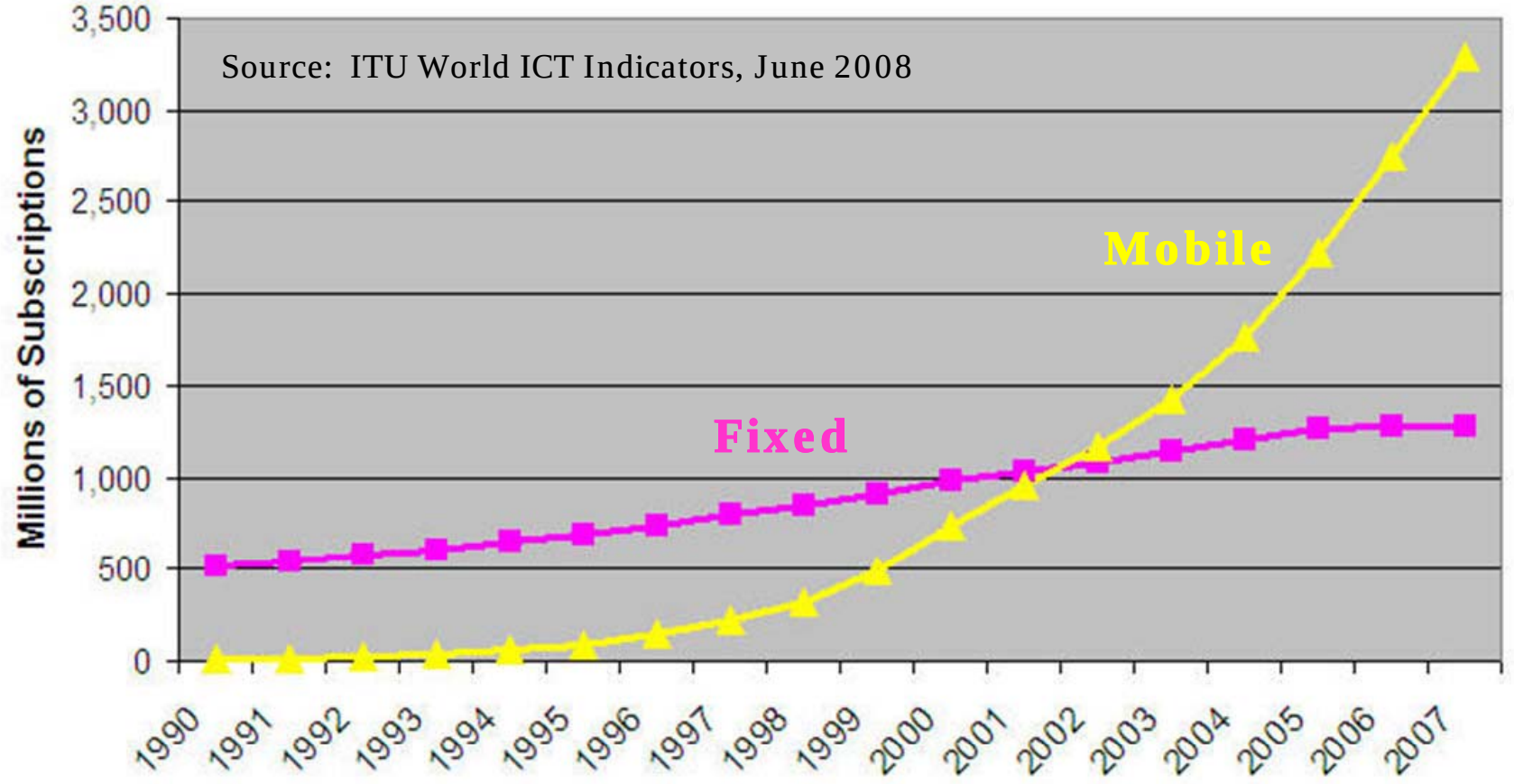
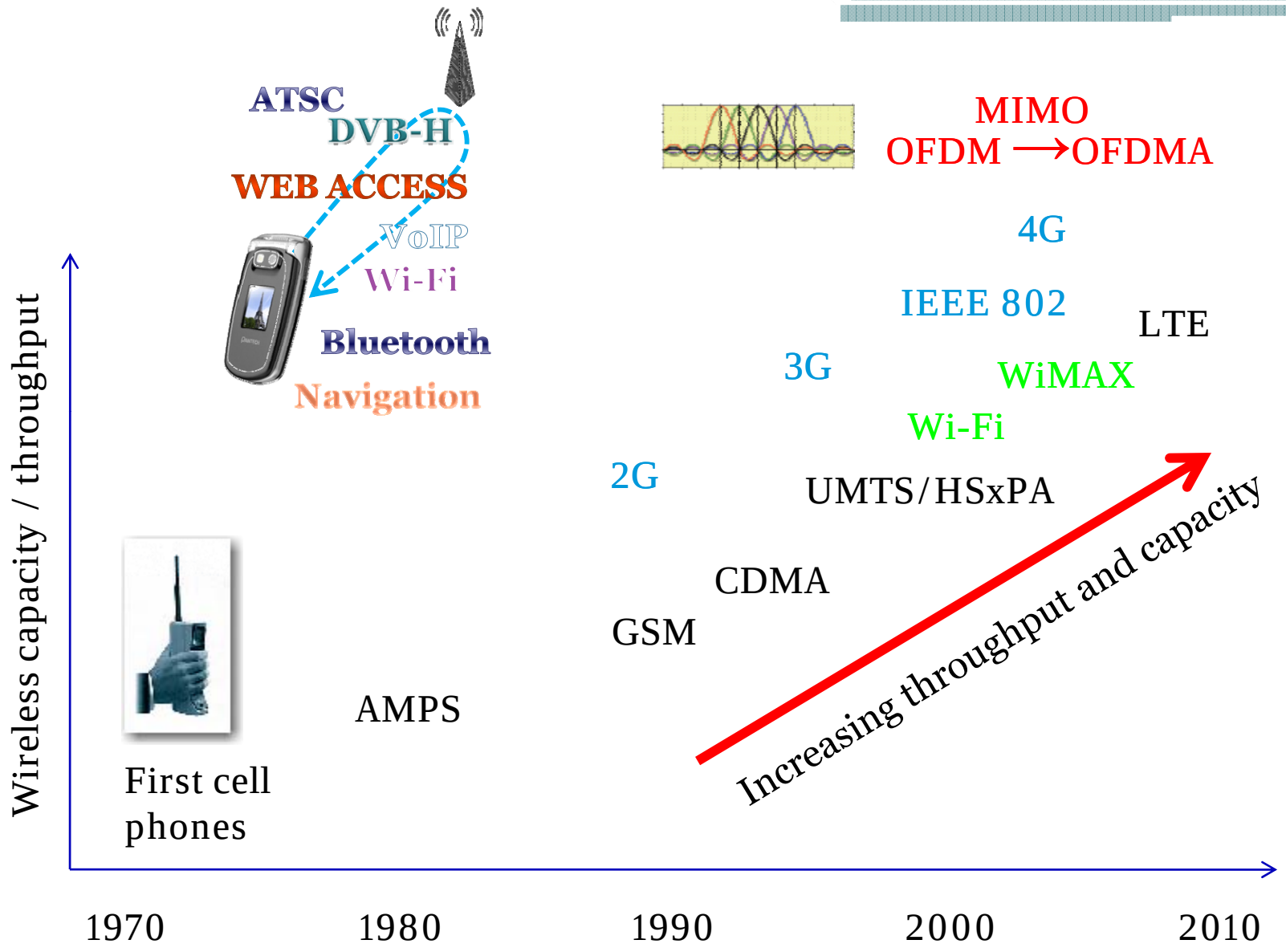
Interop/Vegas
May 2009

Agenda

- Fanny Mlinarsky, octoScope
  - History and overview of wireless broadband
- Mike Seymour, Alcatel-Lucent
  - Vice President Wireless Solutions & Marketing
  - Market segmentation for LTE and WiMAX
- Prakash Sangam, Qualcomm
  - Sr. Manager Technical Marketing
  - LTE and 3G evolution

It's a Mobile World




ATSC
DVB-H
WEB ACCESS
VoIP
Wi-Fi
Bluetooth
Navigation
MIMO
OFDM → OFDMA
4G
IEEE 802
LTE
3G
WiMAX
Wi-Fi
2G
UMTS/HSxPA
CDMA
GSM
AMPS
First cell phones
Increasing throughput and capacity
Wireless capacity / throughput
1970
1980
1990
2000
2010

The ‘G’s

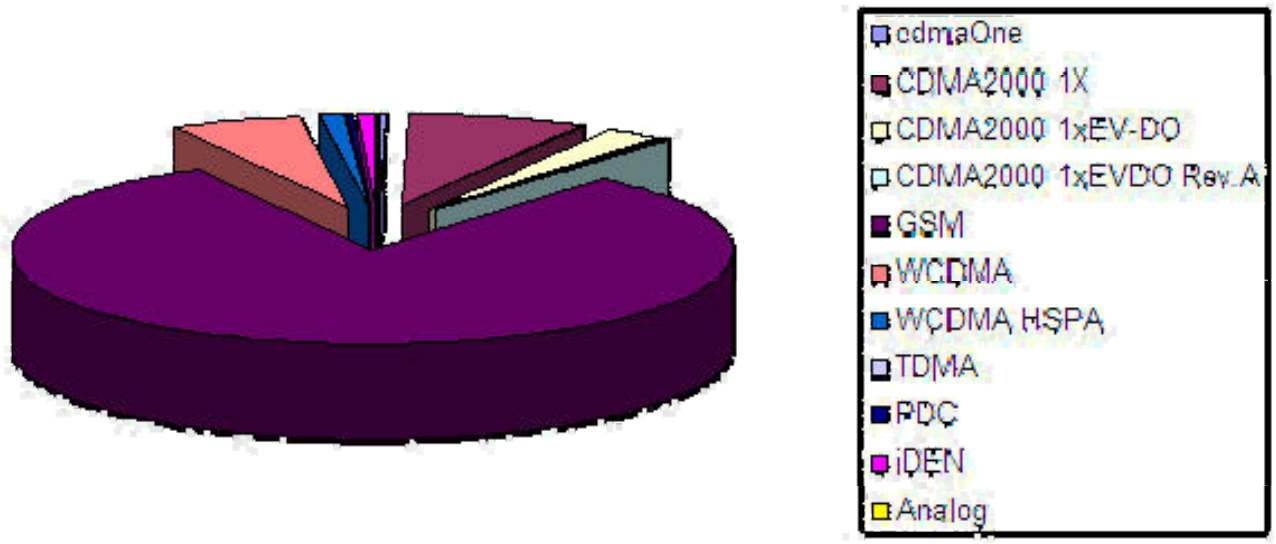
G	Summary	Data Rates
1	Analog – AMPS, NMT, TACS	Typical 2.4 Kbps; max 22 Kbps
2	Digital – TDMA, CDMA	9.6 - 14.4 Kbps (circuit data)
2.5	GPRS – mux packets in voice timeslots	15 - 40 Kbps
3	Improved modulation, using CDMA variants	50 – 144 Kbps (1xRTT); 200 – 384 Kbps (UMTS); 500 Kbps – 2.4 Mbps (EVDO)
3.5	More modulation tweaks	2–14 Mbps (HSPA)
4	New modulation (OFDMA); Multi-path (MIMO); All IP	LTE: >10 Mbps; eventual potential >100 Mbps

Source: Brough Turner

GSM is Dominant Today

- GSM used by 81% of subscribers worldwide
  - AT&T and T-Mobile use GSM in the US today
- Asia leads with 42% of all mobile subscriptions

Mobile subscriptions, 2Q-08



Source: Wireless Intelligence / GSM Association

IEEE 802.11

- **1989**: FCC authorizes ISM bands (Industrial, Scientific and Medical)
  - 900 MHz, 2.4 GHz, 5 GHz
- **1990**: IEEE begins work on 802.11
- **1994**: 2.4 GHz products begin shipping
- **1997**: 802.11 standard approved
- **1998**: FCC authorizes the UNII (Unlicensed National Information Infrastructure) Band - 5 GHz
- **1999**: 802.11a, b ratified
- **2003:** 802.11g ratified
- **2006:** 802.11n draft 2 certification by the Wi-Fi Alliance begins
- **2009:** 802.11n draft 10 released in May

20??: 802.11 ac/ad: 1 Gbps Wi-Fi

802.11 has pioneered commercial deployment of OFDM and MIMO – key wireless signaling technologies today

IEEE 802.16

- **1998**: IEEE formed 802.16 WG
  - Started with 10–66 GHz band; later modified to work in 2–11GHz to enable NLOS (non-line of site)
- **2004:** IEEE 802.16-2004d
  - Fixed operation standard ratified
- **2005:** 802.16-2005e
  - Mobility and scalability in 2–6 GHz
- **2009:** P802.16Rev2/D9
  - Approved by IEEE on 13 May 2009
- **Future:** 802.16m – next generation
  - SDD (system definition document)
  - SRD (system requirements document)

From OFDM to OFDMA

orthogonal frequency division multiplexing
orthogonal frequency division multiple access

3GPP (3rd Generation Partnership Project)

- Partnership of 6 regional standards groups, which translate 3GPP specifications to regional standards
- ITU references the regional standards

ITU – International Mobile Telecommunications

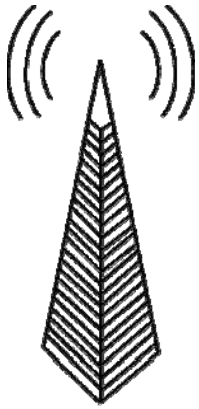
- **IMT-2000**
  - Global standard for third generation (3G) wireless communications
  - Provides a framework for worldwide wireless access by linking the diverse systems of terrestrial and satellite based networks.
  - Data rate limit is approximately 30 Mbps
  - Detailed specifications contributed by 3GPP, 3GPP2, ETSI and others
- **IMT-Advanced**
  - New generation framework for mobile communication systems beyond IMT-2000 with deployment around 2010 to 2015
  - Data rates to reach around 100 Mbps for high mobility and 1 Gbps for nomadic networks (i.e. WLANs)
  - IEEE 802.16m working to define the high mobility interface
  - IEEE 802.11ac and 802.11ad VHT (very high throughput) working to define the nomadic interface

ITU Frequency Bands for IMT Advanced

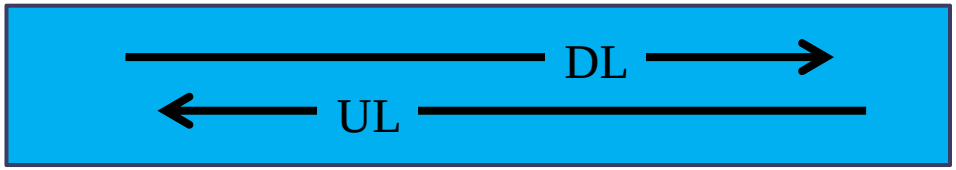
- 450-470 MHz, 698-960 MHz, 1710-2025 MHz, 2110-2200 MHz, 2300-2400 MHz, 2500-2690 MHz, 3400-3600 MHz

TDD Time division duplex

FDD Frequency division duplex (full and half duplex)



TDD: single frequency channel for uplink and downlink



FDD
Paired channels

White Spaces
Sharing of the TV Spectrum

- 6 MHz TV channels 2-69
  - VHF: 54-72, 76-88, 174-216 MHz
  - UHF: 470-806 MHz
- 2009 transition from analog to digital TV frees up channels 52-69 due to higher spectral efficiency of digital TV
- White Spaces legislature advocated the WIA (www.wirelessinnovationalliance.org)
- The new regulations (FCC Dockets 04-186, 02-380) require the use of cognitive radios to determine whether a channel is available prior to transmitting.
- IEEE 802.19 and IEEE 1900 working on the standards

3GPP Releases

Release		
99	Mar. 2000	UMTS/WCDMA
5	Mar. 2002	HSDPA
6	Mar. 2005	HSUPA
7	2007	DL MIMO, IMS, services (VoIP, gaming, push-to-talk)

- Long Term Evolution (LTE)
  - 3GPP work on LTE started in November 2004
  - Standardized in Rel-8
  - Spec finalized and approved in January 2008
  - Target deployment in 2010
  - LTE-Advanced study phase in progress

WiMAX and LTE Scalability

	WiMAX						
Channel bandwidth (MHz)	1.25	5	10	20	3.5	7	8.75
Sample time (ns)	714.3	178.6	89.3	44.6	250	125	100
FFT size	128	512	1024	2048	512	1024	1024
Sampling factor (ch bw/sampling freq)	28/25				8/7		
Subcarrier spacing (kHz)	10.9375				7.8125		9.766
Symbol time (usec)	91.4				128		102.4

	LTE					
Channel bandwidth (MHz)	1.4	3	5	10	15	20
FFT size	128	258	512	1024	1536	2048

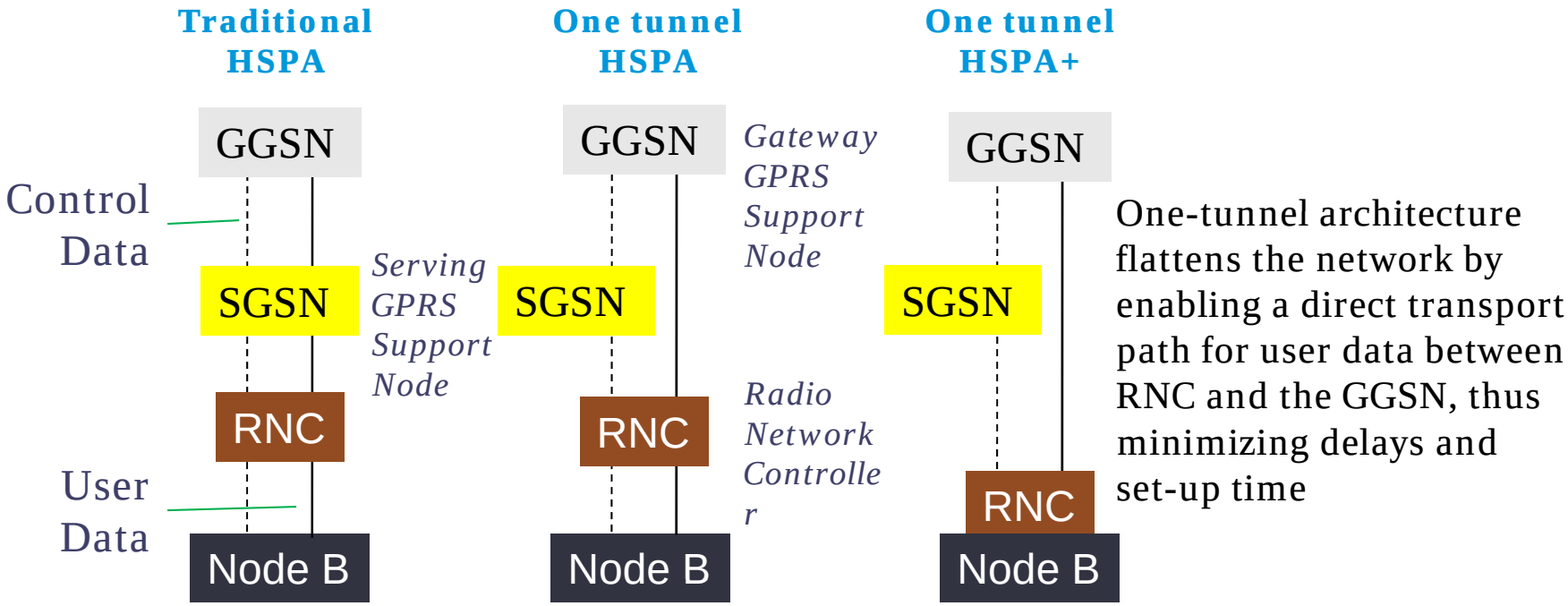
3G/4G Comparison

	Peak Data Rate (Mbps)		Access time (msec)
	Downlink	Uplink	
HSPA (today)	14 Mbps	2 Mbps	50-250 msec
HSPA (Release 7) MIMO 2x2	28 Mbps	11.6 Mbps	50-250 msec
HSPA + (MIMO, 64QAM Downlink)	42 Mbps	11.6 Mbps	50-250 msec
WiMAX Release 1.0 TDD (2:1 UL/DL ratio), 10 MHz channel	40 Mbps	10 Mbps	40 msec
LTE (Release 8), 5+5 MHz channel	43.2 Mbps	21.6 Mbps	30 msec

Release 8 – LTE
Release 9 – enhancements to LTE, 2009
Release 10 - LTE Advanced (1Gbps DL and 500 Mbps UL, 100 MHz bw), 2010

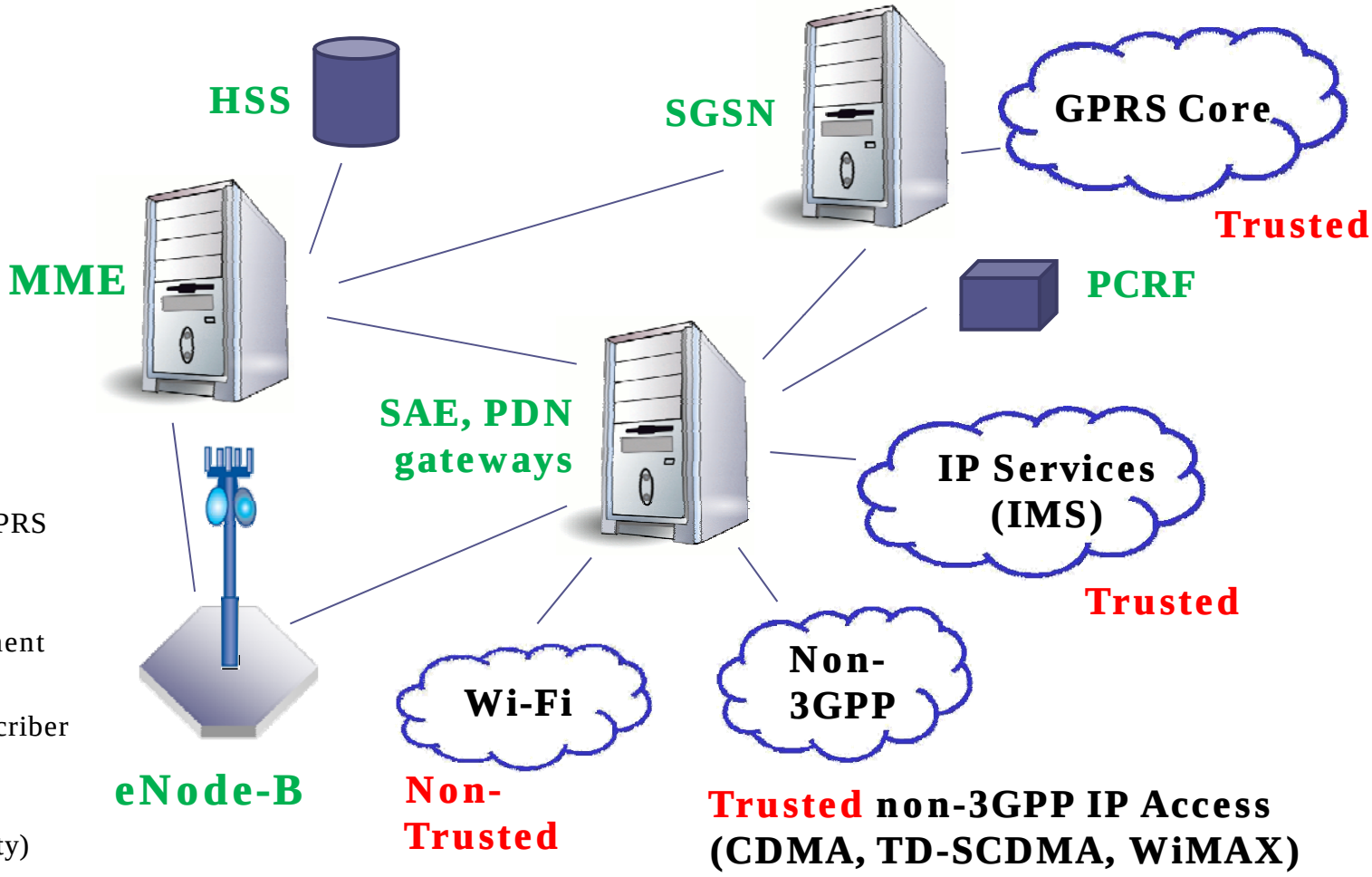
HSPA and HSPA+

- HSPA+ is aimed at extending operators' investment in HSPA
  - 2x2 MIMO, 64 QAM in the downlink, 16 QAM in the uplink
  - Data rates up to 42 MB in the downlink and 11.5 MB in the uplink.
- HSPA+ is CDMA-based and lacks the efficiency of OFDM



One-tunnel architecture flattens the network by enabling a direct transport path for user data between RNC and the GGSN, thus minimizing delays and set-up time

LTE SAE (System Architecture Evolution)



SGSN (Serving GPRS Support Node)

PCRF (policy and charging enforcement function)

HSS (Home Subscriber Server)

MME (Mobility Management Entity)

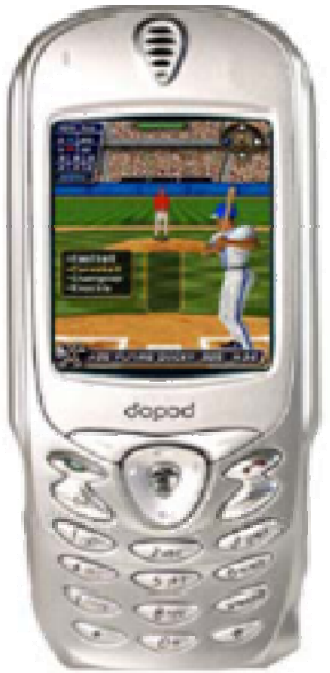
SAE (System Architecture Evolution)

PDN (Public Data Network)

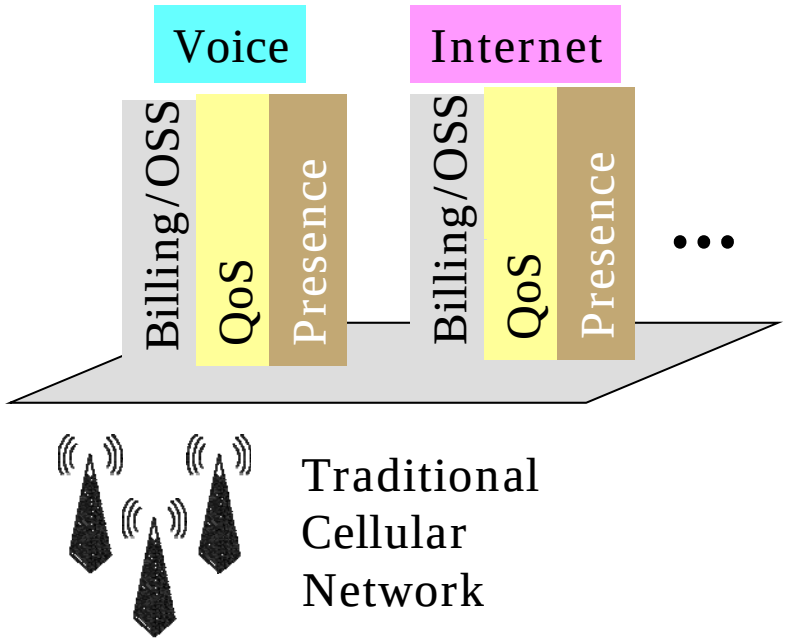
SAE includes RAN and EPS

LTE Architecture – IMS Based

- LTE specifies IP multimedia subsystem (IMS), optimizing the architecture for services .
- IMS is being used in wired infrastructure to enable VoIP and other applications; LTE expands on this capability to deliver seamless services.
- Hotspot-like initial deployments, primarily in urban areas will leverage HSPA for full coverage
- Most LTE devices will be multi-mode, supporting HSPA and other interfaces
- LTE femtocells will be integrated in the architecture from the onset to increase capacity and indoor coverage.

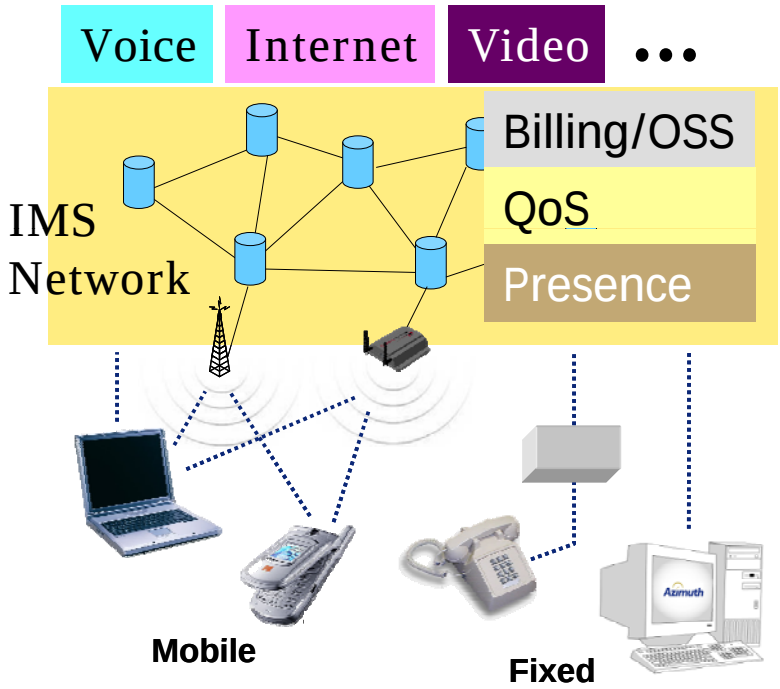


Traditional "Stovepipe"



Stovepipe model – replicates functionality

IMS



IMS – common layers facilitate adding services

Operator Influence on LTE

- LTE was built around the features and capabilities defined by Next Generation Mobile Networks (NGMN) Alliance (www.ngmn.org)
  - Operator buy-in from ground-up
- LTE/SAE (Service Architecture Evolution) Trial Initiative (LSTI) formed through the cooperation of vendors and operators to begin testing LTE early in the development process (www.lstiforum.org)
- NGMN defines the requirements
- LSTI conducts testing to ensure conformance.

ngmn
the engine of broadband wireless innovation

formed 9/2006 by major operators:

- Sprint Nextel
- China Mobile
- Vodafone
- Orange
- T-Mobile
- KPN Mobile
- NTT DoCoMo

LSTi
LTE/SAE Trial Initiative

On the Road to 4G

- WiMAX appears to have 3-4 lead over LTE, but...
  - Most deployments are fixed WiMAX in the developing world
  - All eyes are on Clearwire to see if mobile WiMAX can compete here in the US
- When will LTE see significant deployments?
  - Ink is not yet dry on the 3GPP standard
  - History shows a few years lag between standard ready and initial deployments
- Will 3G delay LTE?
- How will HSPA, WiMAX and LTE coexist and what will the market segmentation be?
- What role will open spectrum (white spaces) play?

Q & A

- Fanny Mlinarsky, octoScope
- Mike Seymour, Alcatel-Lucent
- Prakash Sangam, Qualcomm

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Additional Material

First Generation

- Advanced Mobile Phone Service (AMPS)
  - US trials 1978; deployed in Japan (’79) & US (’83)
  - 800 MHz; two 20 MHz bands; TIA-553
- Nordic Mobile Telephony (NMT)
  - Sweden, Norway, Demark & Finland
  - Launched 1981
  - 450 MHz; later at 900 MHz (NMT900)

- Total Access Communications System (TACS)
  - British design; similar to AMPS; deployed 1985

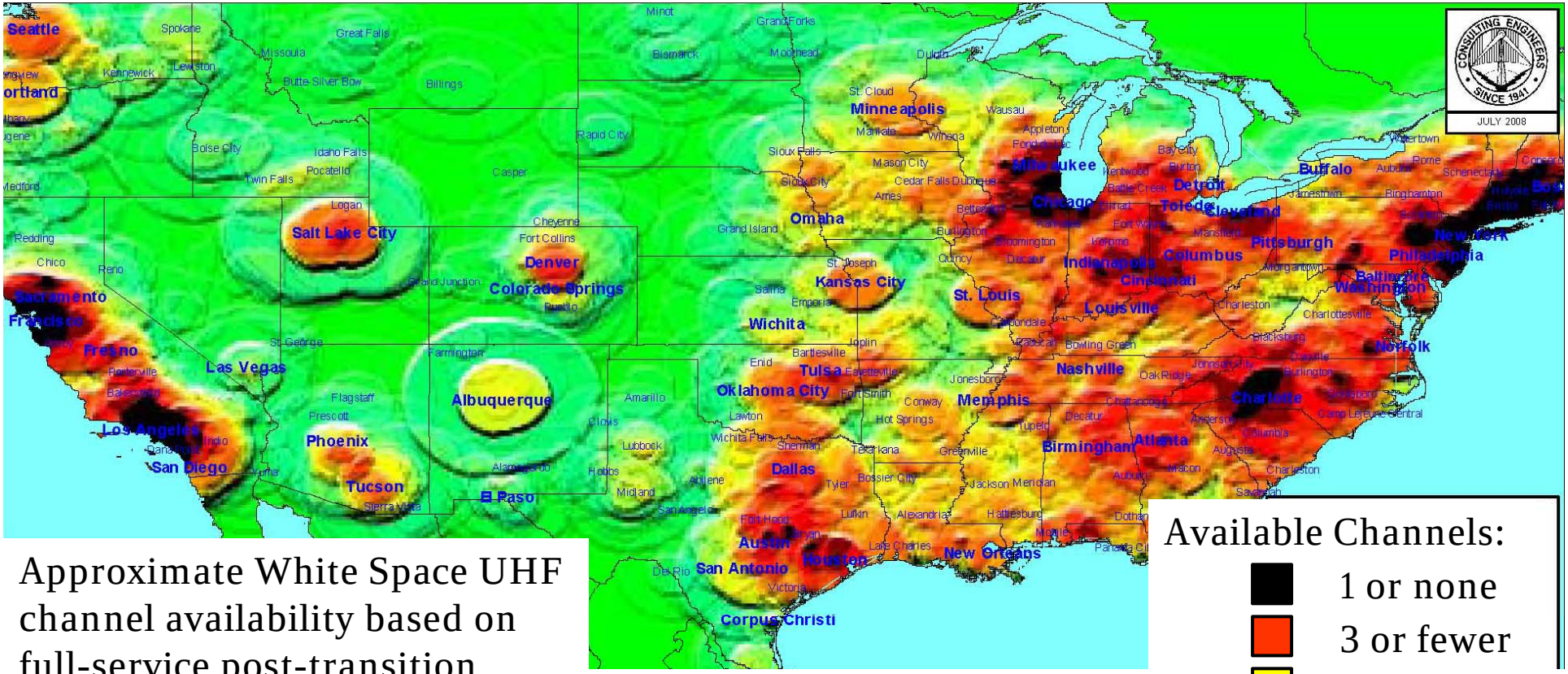
2G - CDMA

- Code Division Multiple Access
  - All users share same frequency band
- Qualcomm demo in 1989
  - Claimed improved capacity & simplified planning
- First deployment in Hong Kong late 1994
- Major success in Korea (1M subs by 1996)
- Adopted by Verizon and Sprint in US
- Easy migration to 3G (same modulation)

2G - GSM

- Originally “Groupe Spécial Mobile ”
  - Joint European effort beginning in 1982 focused on seamless roaming across Europe
- Services launched 1991
  - Time division multiple access (8 users per 200KHz)
  - 900 MHz band; later extended to 1800 MHz; then 1900 MHz
  - Quad-band “world phones” support 850/900/1800/1900 MHz
- GSM – dominant world standard today
  - Well defined interfaces; many competitors; lowest cost to deploy

White Space Channel Availability



Approximate White Space UHF channel availability based on full-service post-transition broadcast station allocation

Source: duTreil, Lundin & Rackley, Inc. Sarasota, Florida