Broadband Wireless Puzzle
Fitting the Pieces Together

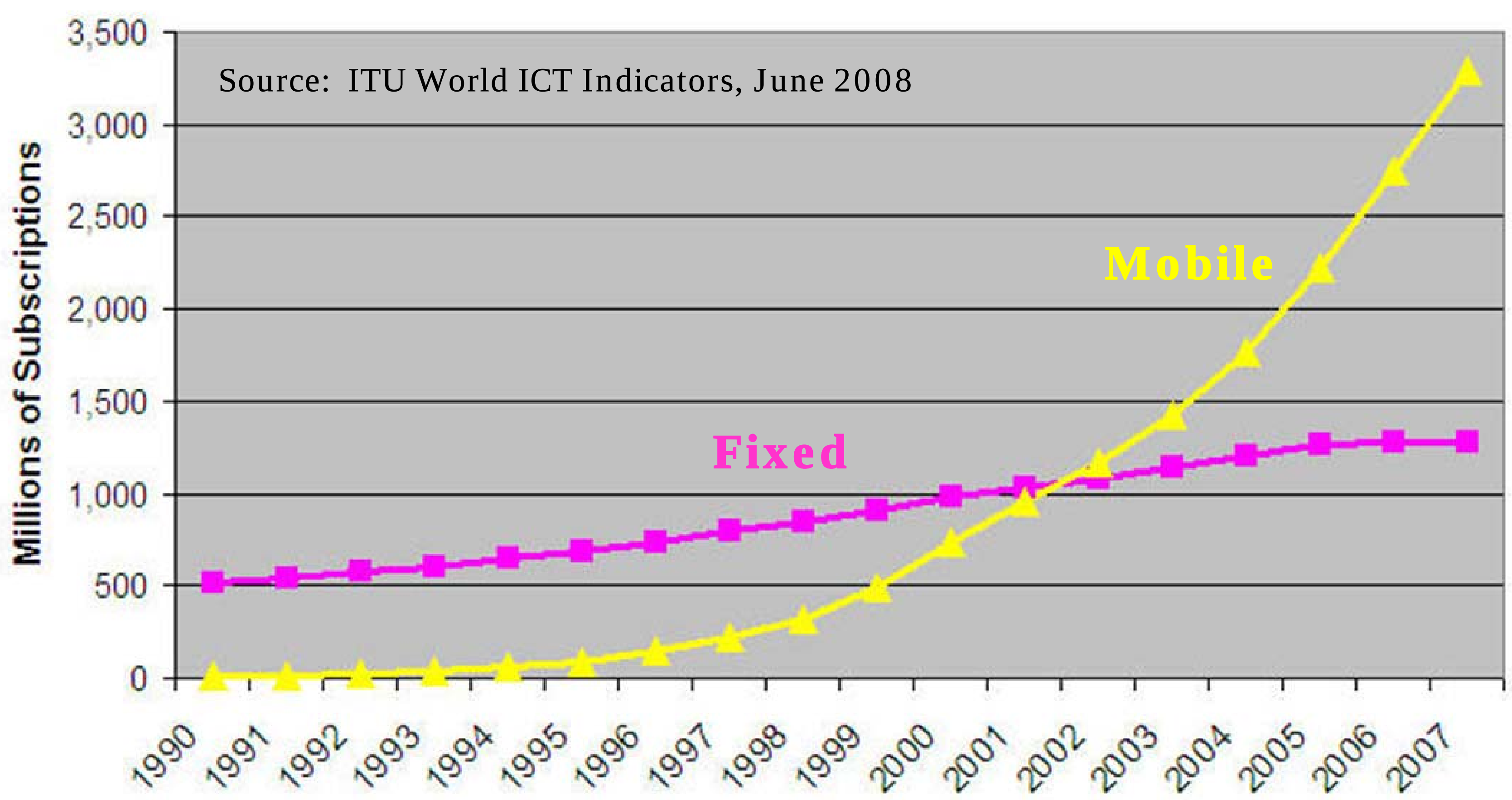
BBWF@CTIA

March 31, 2009

Agenda

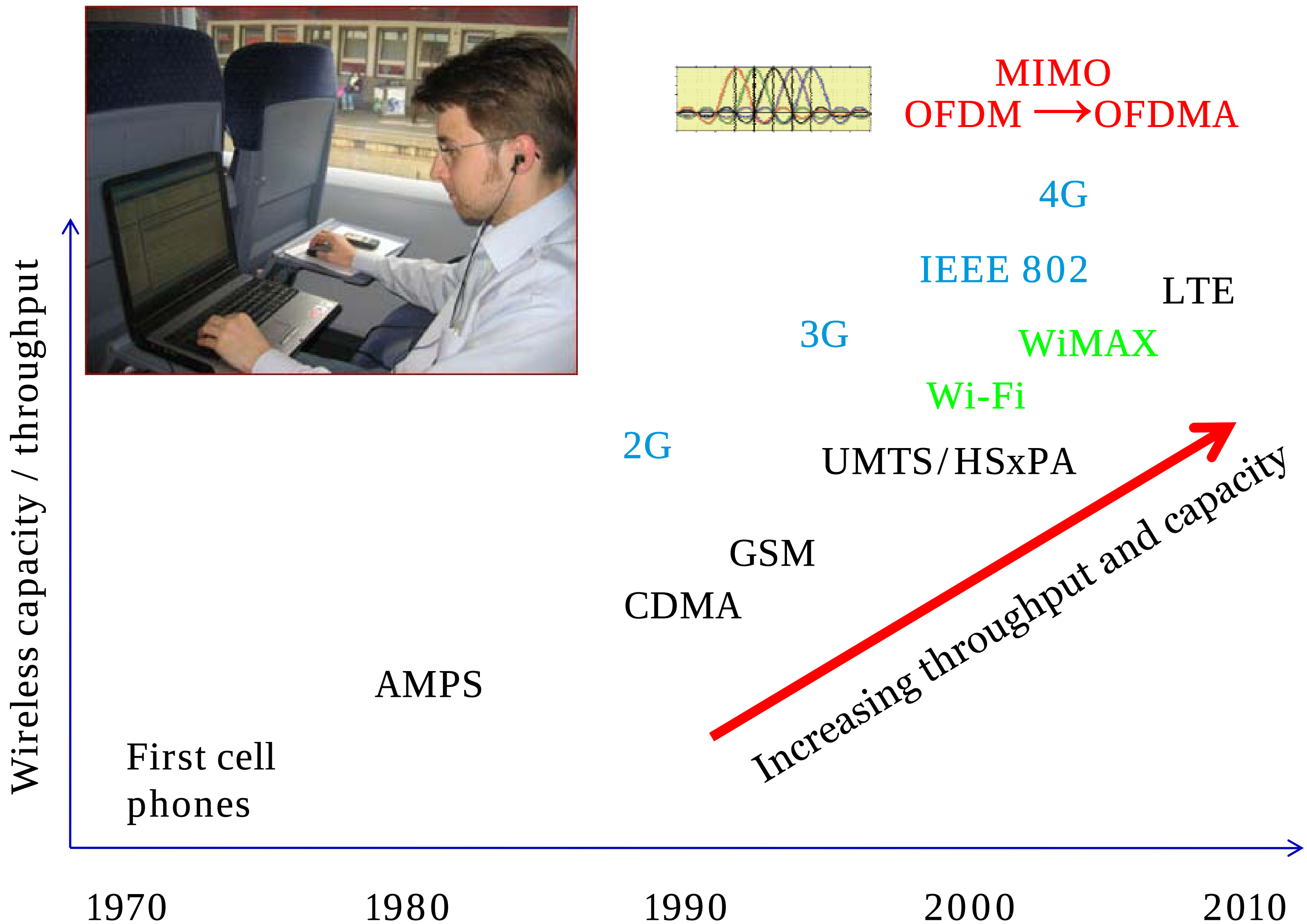
1:30 – 2:10	Fanny Mlinarsky, octoScope Review of the 'G's
2:10– 2:40	Philipp Deibert, NGMN Alliance Next Generation Mobile Broadband
2:40– 3:10	David Kelf, Sigmatix Business of Basebands
	Break
3:20– 3:50	Victor Menasce, Wavesat Multi-protocol 4G – Discovering Synergies
3:50– 4:20	Larry Fischer, ADC Microcellular 4G Architecture
	Q & A

It's a Mobile World



The author would like to acknowledge

- Brough Turner
  - Formerly with NMS Communications
- Charles Cooper
  - dLR


MIMO
OFDM → OFDMA
4G
IEEE 802
LTE
3G
WiMAX
Wi-Fi
2G
UMTS/HSxPA
GSM
CDMA
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	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

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)

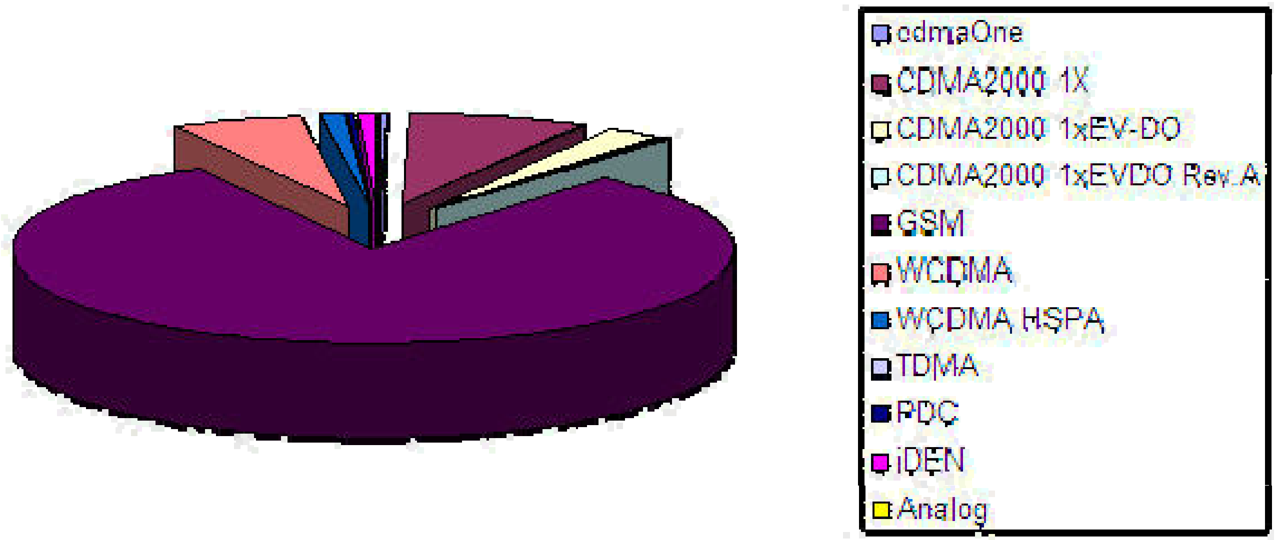
2G - GSM

- 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

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

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
- **Latest:** P802.16Rev2/D9 draft
- **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

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

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

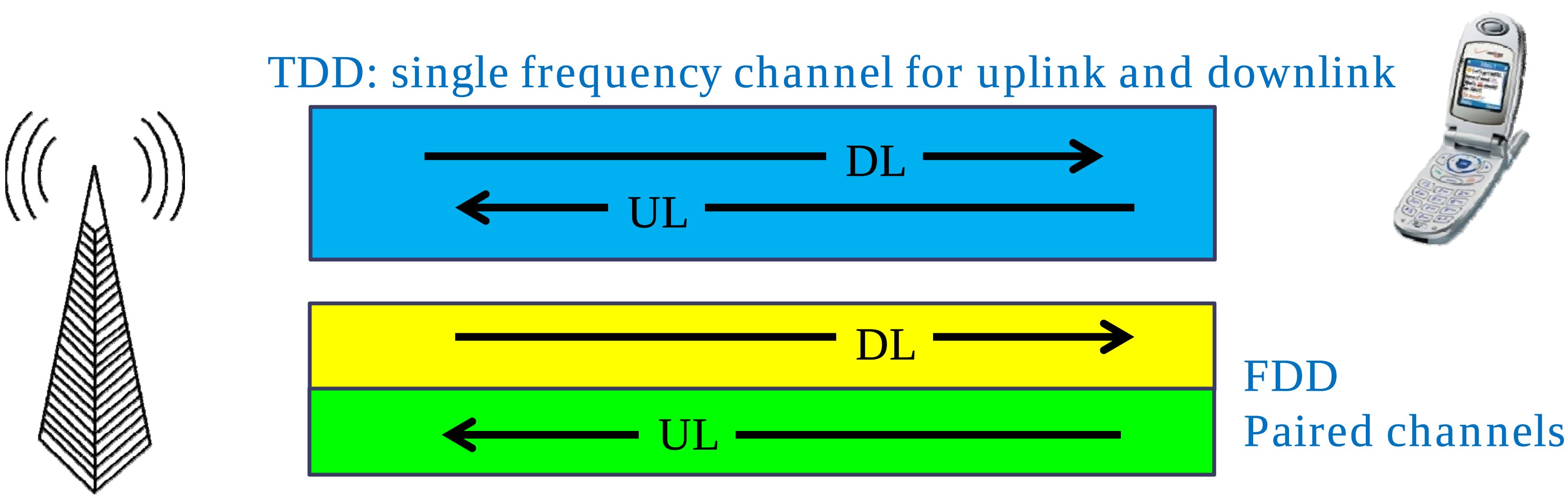
- **IMT-2000**
  - Global standard for third generation (3G) wireless communications
  - Provides a framework for worldwide wireless access by linking the diverse systems of terrestrial and satellite based networks.
  - Data rate limit is approximately 30 Mbps
  - Detailed specifications contributed 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

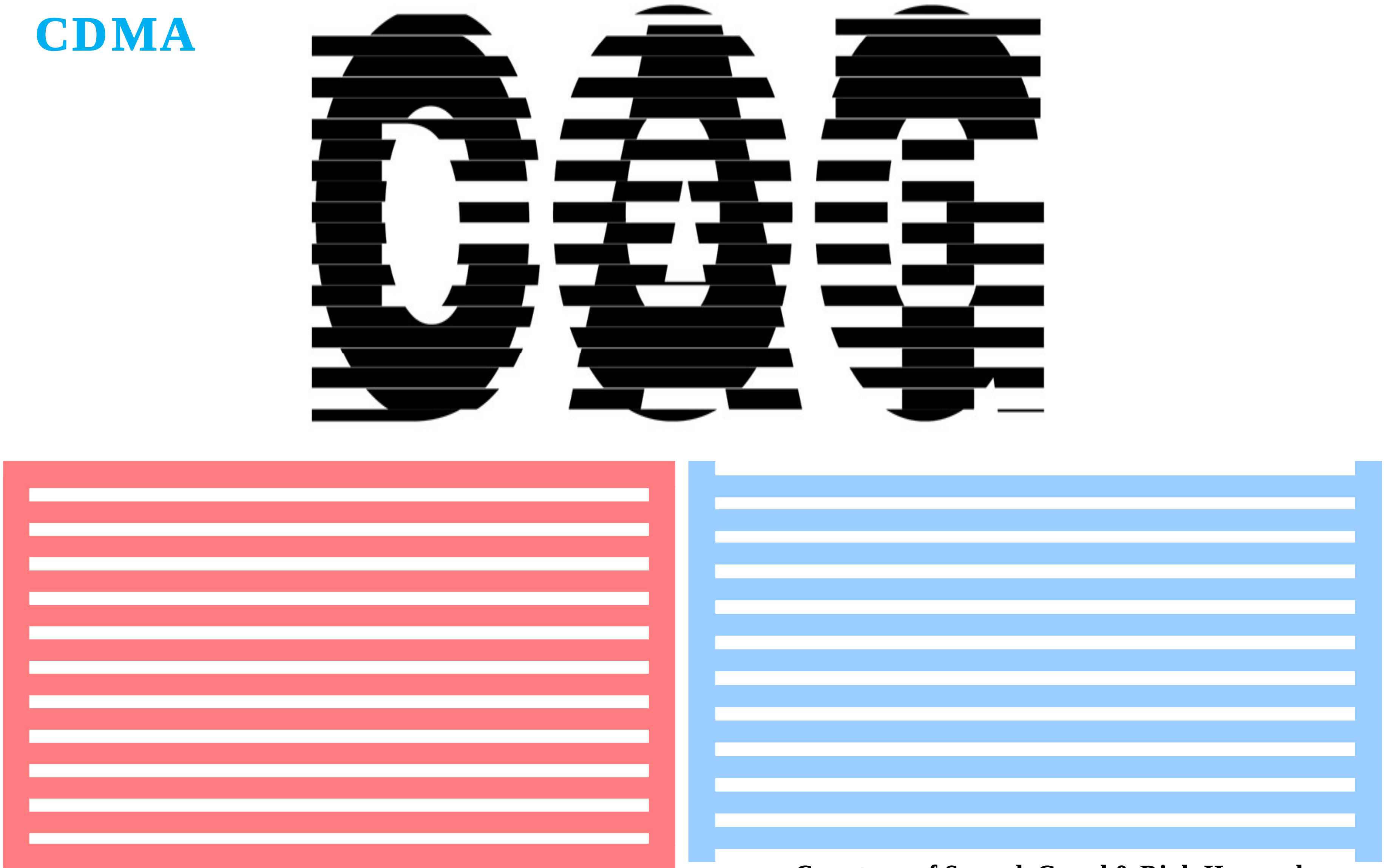
FDD Frequency division duplex (full and half duplex)



Modulation and Access Schemes

- **CDMA** (code division multiple access) is a coding and access scheme
  - CDMA, W-CDMA, CDMA-2000
- **SDMA** (space division multiple access) is an access scheme
  - MIMO, beamforming, sectorized antennas
- **TDMA** (time division multiple access) is an access scheme
  - AMPS, GSM
- **FDMA** (frequency division multiple access) is an access scheme
- **OFDM** (orthogonal frequency division multiplexing) is a modulation scheme
- **OFDMA** (orthogonal frequency division multiple access) is a modulation and access scheme

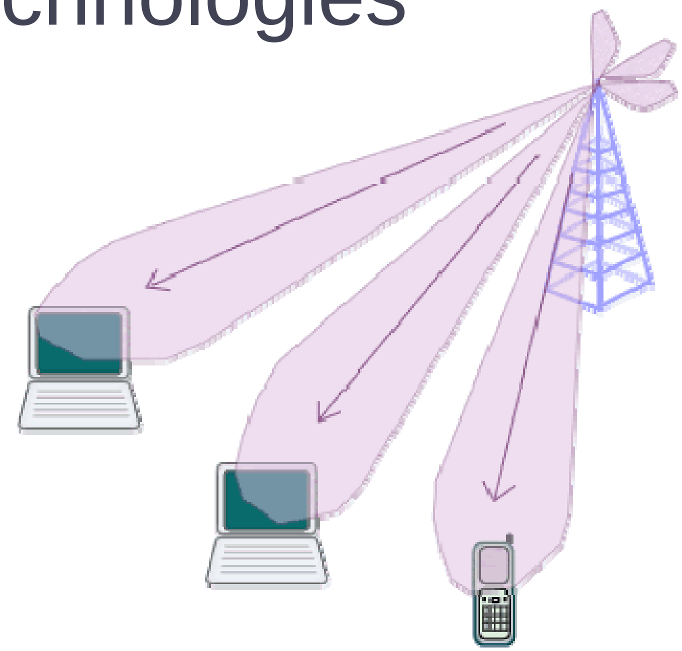
CDMA

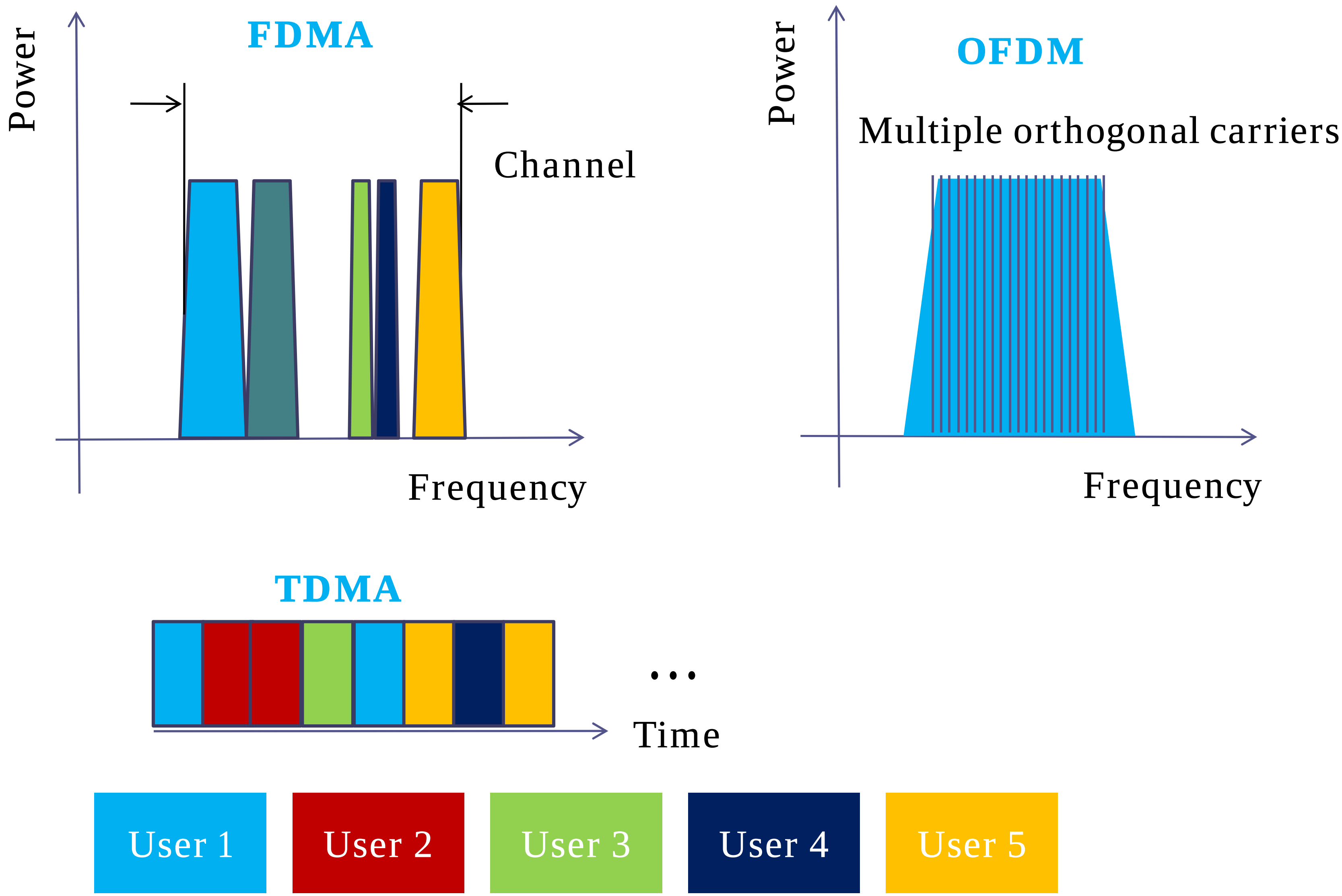


Courtesy of Suresh Goyal & Rich Howard

SDMA = Smart Antenna Technologies

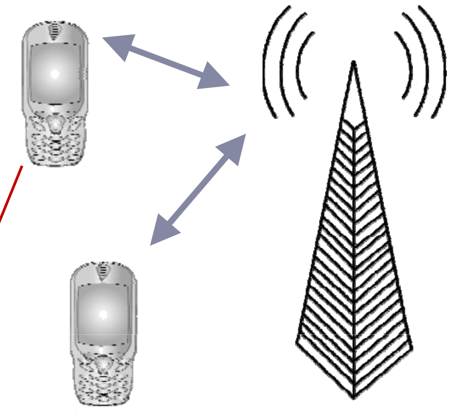
- **Beamforming**
  - Use multiple-antennas to spatially shape the beam to improve coverage and capacity
- **Spatial Multiplexing (SM) or Collaborative MIMO**
  - Multiple streams are transmitted over multiple antennas
  - Multi-antenna receivers separate the streams to achieve higher throughput
  - In uplink single-antenna stations can transmit simultaneously
- **Space-Time Code (STC)**
  - Transmit diversity such as Alamouti code reduces fading

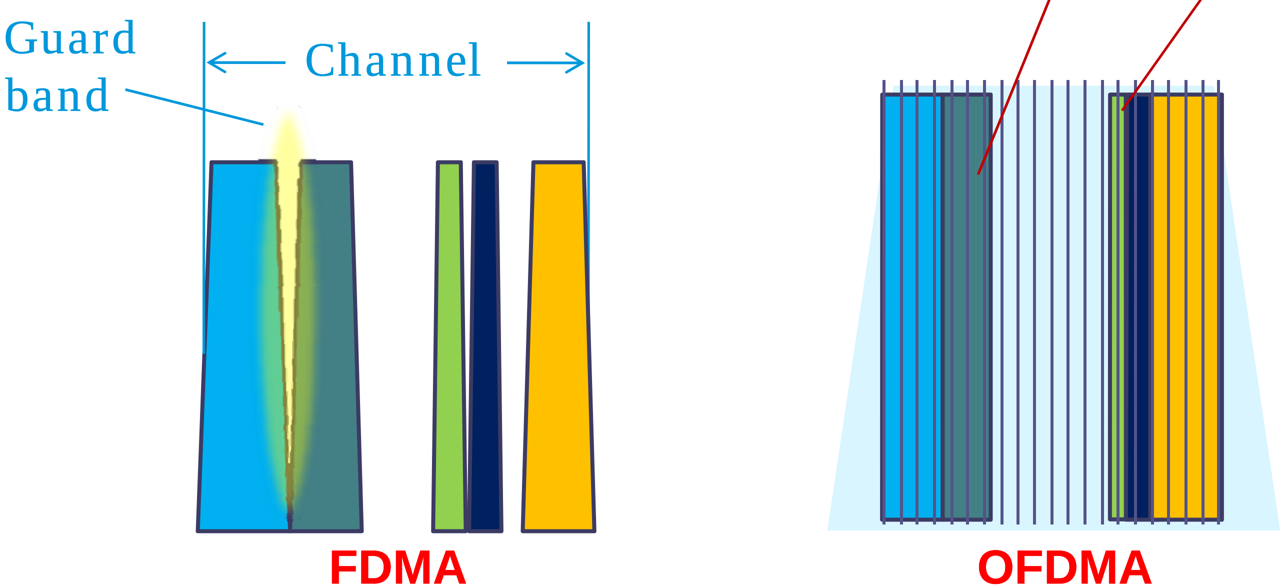


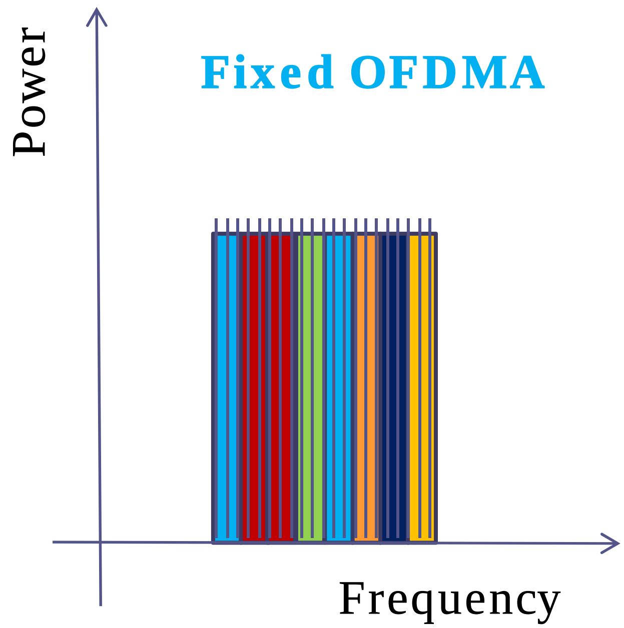

FDMA
Power
Channel
Frequency
OFDM
Power
Multiple orthogonal carriers
Frequency
TDMA
…
Time
User 1
User 2
User 3
User 4
User 5

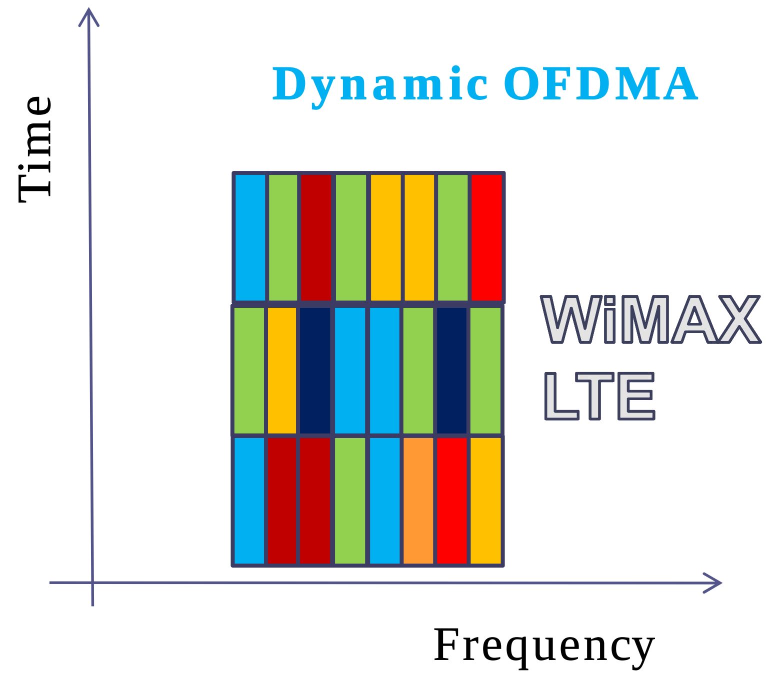
FDMA vs. OFDMA

- OFDMA is more frequency efficient than FDMA
  - Each station is assigned a set of subcarriers, eliminating frequency guard bands between users









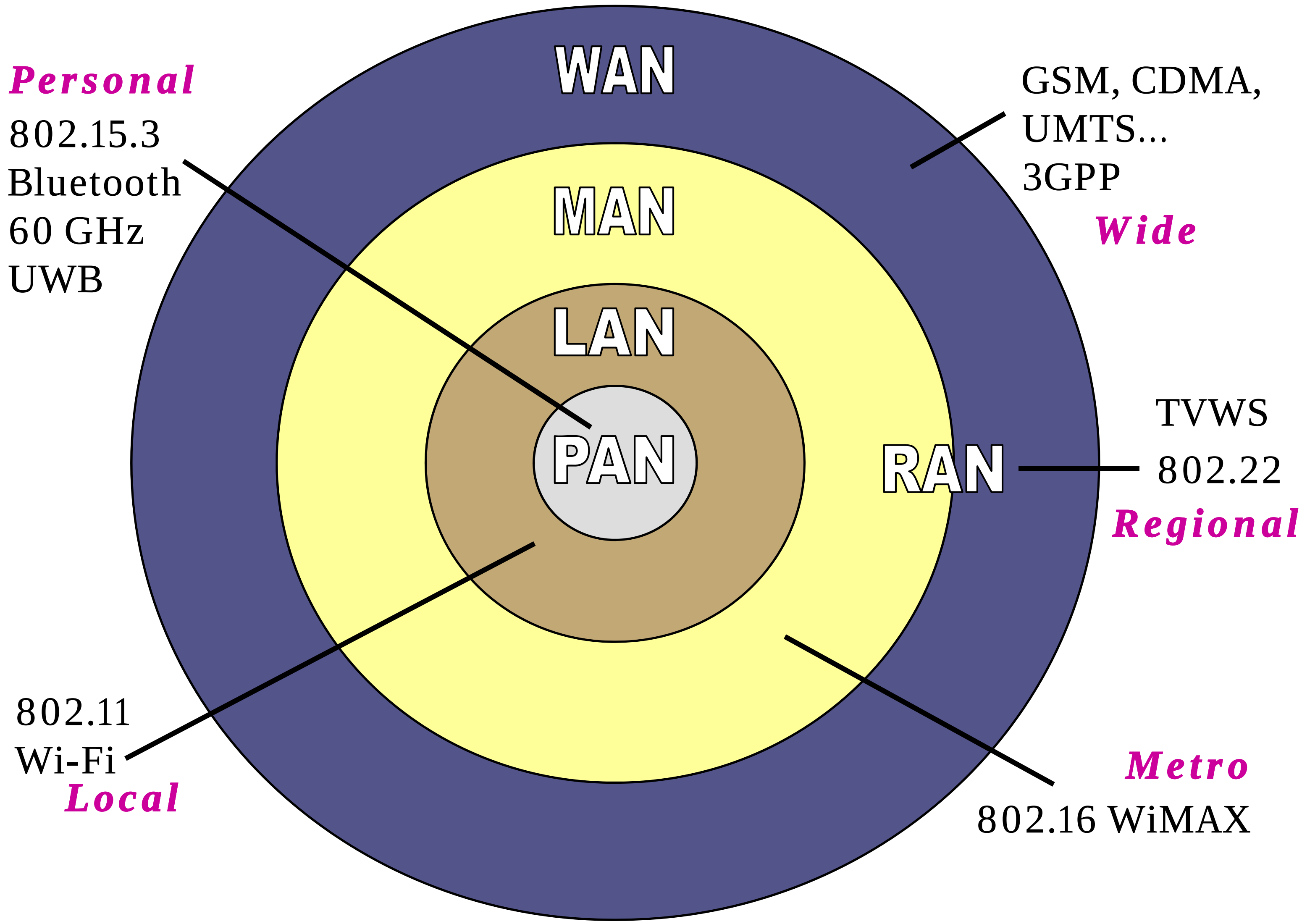
Frequency allocation per user is continuous vs. time

Frequency allocation per user is dynamically allocated vs. time slots

User 1 | User 2 | User 3 | User 4 | User 5

Key Features of WiMAX and LTE

- OFDMA (Orthogonal Frequency Division Multiple Access)
- Users are allocated a slice in time and frequency
- Flexible, dynamic per user resource allocation
- Base station scheduler for uplink and downlink resource allocation
  - Resource allocation information conveyed on a frame-by frame basis
- Support for TDD (time division duplex) and FDD (frequency division duplex)


WAN
MAN
LAN
PAN
RAN
Personal
802.15.3
Bluetooth
60 GHz
UWB
GSM, CDMA,
UMTS…
3GPP
Wide
TVWS
802.22
Regional
802.11
Wi-Fi
Local
Metro
802.16 WiMAX

IEEE 802 LAN/MAN Standards Committee (LMSC)

Wireless standards dominate the work of IEEE 802

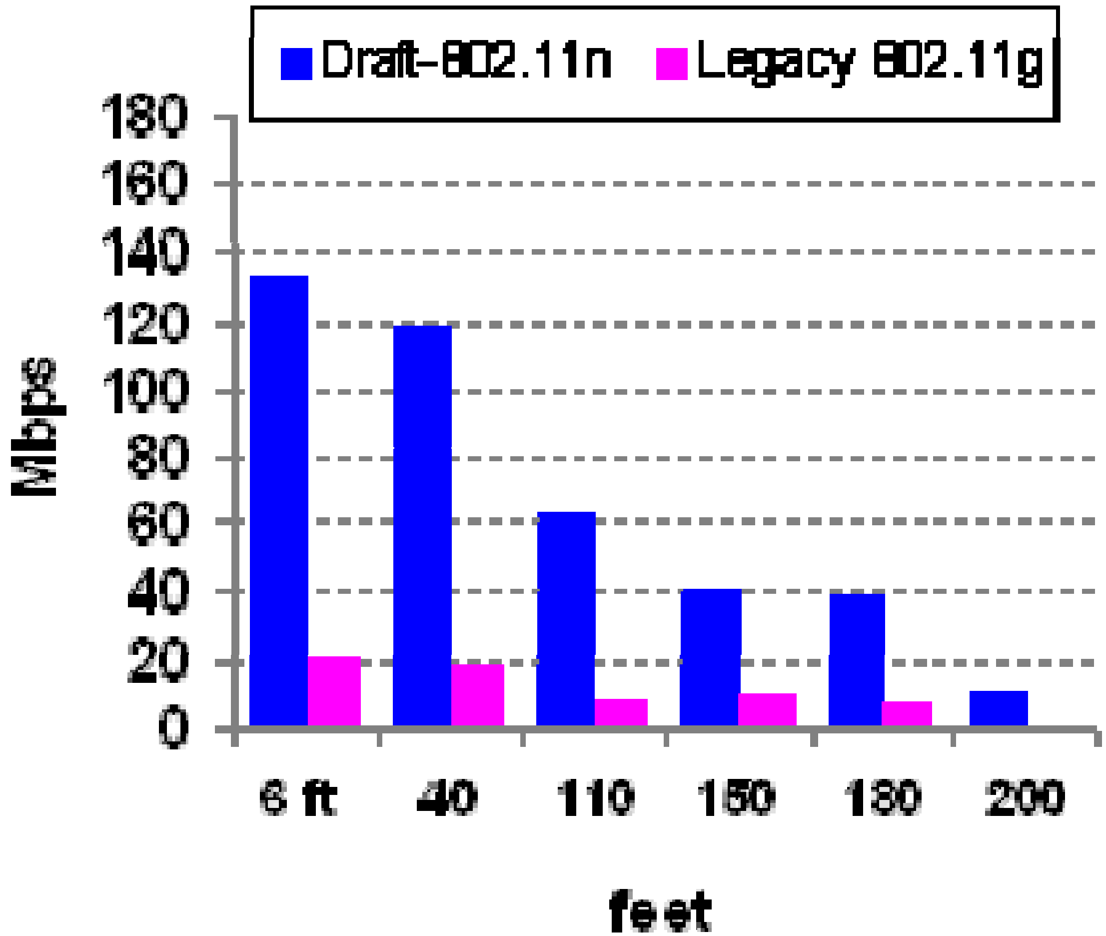
- **802.1** Higher Layer LAN Protocols
- ➡ **802.3** Ethernet
- ➡ **802.11** Wireless LAN
- ➡ **802.15** Wireless Personal Area Network
- ➡ **802.16** Broadband Wireless Access
- **802.17** Resilient Packet Ring
- ➡ **802.18** Radio Regulatory TAG (technical advisory group)
- ➡ **802.19** Coexistence TAG
- ➡ **802.21** Media Independent Handoff
- ➡ **802.22** Wireless Regional Area Networks
- ➡ **802** TV White Spaces Study Group

IEEE 802.11 Active Task Groups

- **TGn** – High Throughput
- **TGp** – Wireless Access Vehicular Environment (WAVE/DSRC)
- **TGs** – ESS Mesh Networking
- **TGT** – IEEE 802 Performance
- **TGu** – InterWorking with External Networks
- **TGv** – Wireless Network Management
- **TGw** – Protected Management Frames
- **TGy** – 3650-3700 MHz Operation in USA
- **TGz** – Direct Link Setup
- **TGaa** – Robust streaming of AV Transport Streams
- **TGac** – VHTL6 (very high throughput < 6 GHz)
- **TGad** – VHT 60 GHz

http://grouper.ieee.org/groups/802/11

Draft 802.11n vs. Legacy Throughput Performance



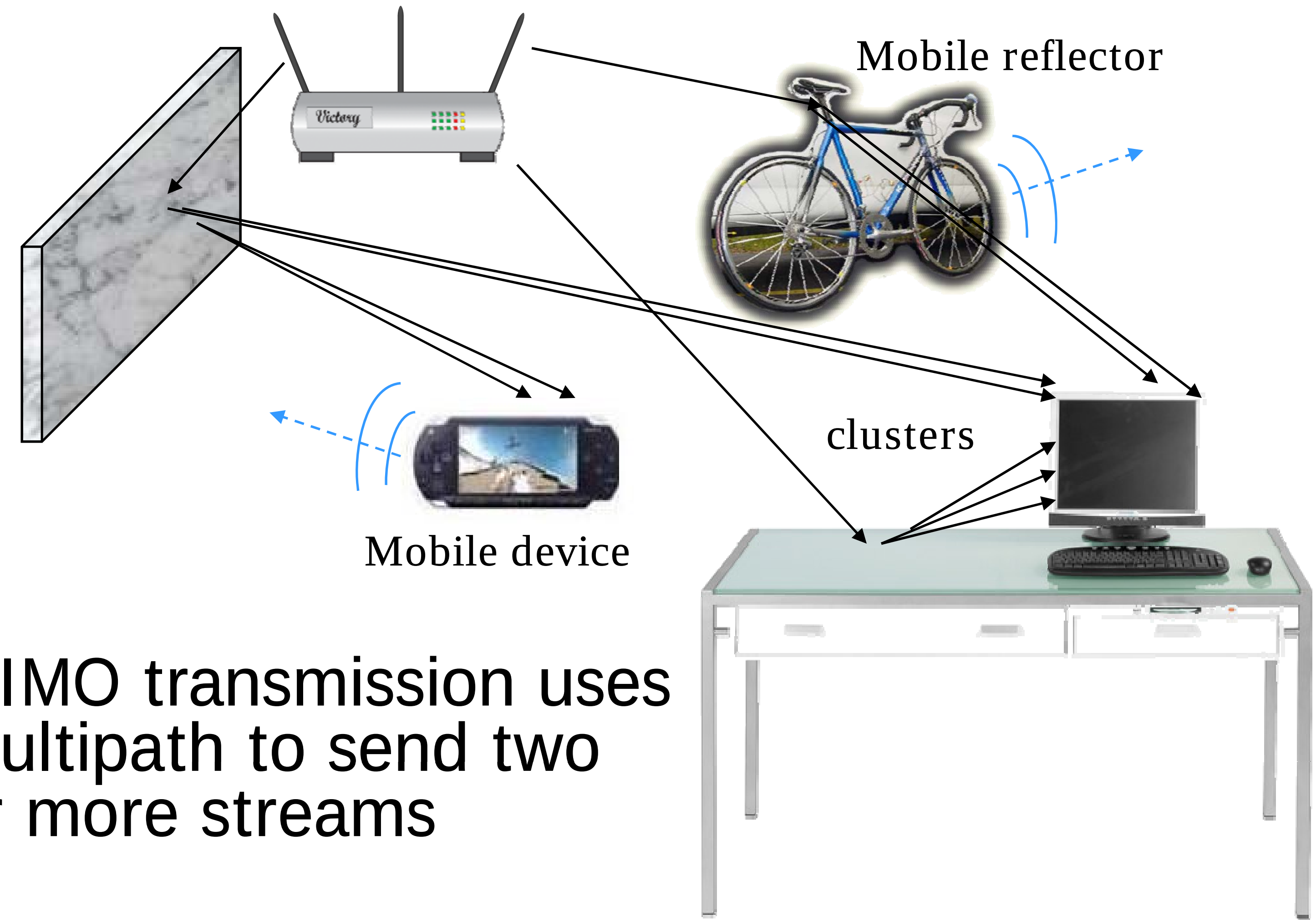
802.11n Throughput Enhancements

802.11n throughput enhancement	Description	Throughput enhancement over legacy
Spatial multiplexing	With 2 spatial streams throughput can be double that of a single stream.	100%
40 MHz channel width	Doubling the channel width over the legacy 20 MHz channel can double the throughput.	100%
More efficient OFDM	With 52 data sub-carriers vs. 48 for the legacy networks, the highest data rate per stream is 65 Mbps vs. the 802.11a/g 54 Mbps	20%
Shorter GI	The short GI of 400 ns allowed by 802.11n reduces the symbol time from 4 microseconds to 3.6 microseconds increasing the symbol rate by 10%.	10%
Frame aggregation and Block ACK	64k bytes A-MPDU; 8k bytes A-MSDU	Up to 100%

IEEE 802.11a,b,g,n

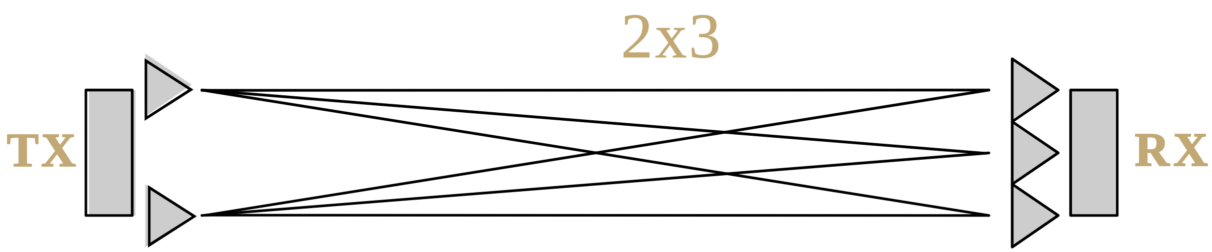
	20 MHz Channel		40 MHz Channel	
	1 stream	2 streams	1 stream	2 streams
	Data Rate, in Mbps			
802.11b 2.4 GHz	1, 2, 5.5, 11			
802.11a 5 GHz	6, 9, 12, 18, 24, 36, 48, 54			
802.11g 2.4 GHz	1, 2, 6, 9, 12, 18, 24, 36, 48, 54			
802.11n GI[1]=800ns 2.4 GHz	6.5, 13, 19.5, 26, 39, 52, 58.5, 65	13, 26, 39, 52, 78, 104, 117, 130		
802.11n GI[1]=800ns 5 GHz	6.5, 13, 19.5, 26, 39, 52, 58.5, 65	13, 26, 39, 52, 78, 104, 117, 130	13.5, 27, 40.5, 54, 81, 108, 121.5, 135	27, 54, 81, 108, 162, 216, 243, 270
802.11n, GI=400ns 2.4 and 5 GHz	7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2	14.4, 28.9, 43.3, 57.8, 86.7, 115.6, 130, 144.4	15, 30, 45, 60, 90, 120, 135, 150	30, 60, 90, 120, 180, 240, 270, **300**

[1,] GI = Guard Interval, period within an OFDM symbol allocated to letting the signal settle prior to transmitting the next symbol. Legacy 802.11a/b/g devices use 800ns GI. GI of 400ns is optional for 802.11n.



MIMO transmission uses multipath to send two or more streams

MIMO Radio Systems



- Data is organized into spatial streams that are transmitted simultaneously - This is known as *Spatial Multiplexing*
- **SISO**: Single-Input/Single-Output; **MIMO**: Multi-Input/Multi-Output; **SIMO**: Single-Input/Multi-Output; **MISO**
- There's a propagation path between each transmit and receive antenna (a "MIMO path")
- N x M MIMO (e.g. "4x4", "2x2", "2x3")
  - *N* transmit antennas
  - *M* receive antennas
  - Total of *N* x *M* paths

Lightly Regulated Band for 802.11, 802.16

- March 2005 FCC offered 50 MHz 3650 to 3700 MHz for *contention-based protocol*
- 802.11y meets FCC requirement; 802.16h is working to comply
- 21st century regulation geared for digital communications
  - multiple services to share the band in an orderly way

- **300 Million licenses one for every person or company**
- **$300 per license for 10 years**
- **Registered stations (base stations): 1 W/MHz, ~15 km**
- **Unregistered stations (handsets, laptops): 40 mW/MHz, 1-1.5 km**

IEEE 802.16 Active Task Groups

- 802.16h, License-Exempt Task Group
  - Working with 802.11 TGy and 802.19 Coexistence TAG
- 802.16j, Mobile Multihop Relay
  - Extended reach between BS (base station) and CPE (customer premises equipment)
- 802.16m, IMT Advanced Air Interface
- Maintenance
  - Developing 802.16Rev2
  - Working with the WiMAX Forum

http://grouper.ieee.org/groups/802/16

IEEE WirelessMAN 802.16

WiMAX Forum

- IEEE 802.16 contains too many options
- The WiMAX Forum defines *certification profiles* on parts of the standard selected for deployment; promotes interoperability of products through testing and certification
- The WiMAX Forum works closely with the IEEE 802.16 *Maintenance group* to refine the standard as the industry learns from certification testing

WiMAX Forum™ Mobile System Profile
Release 1.0 Approved Specification
(Revision 1.6.1: 2008-04-01)

current	Release 1.0	802.16e/TDD
Under development	Release 1.5	802.16e/TDD and FDD
Future	Release 2.0	802.16m (IMT Advanced)

4G - 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

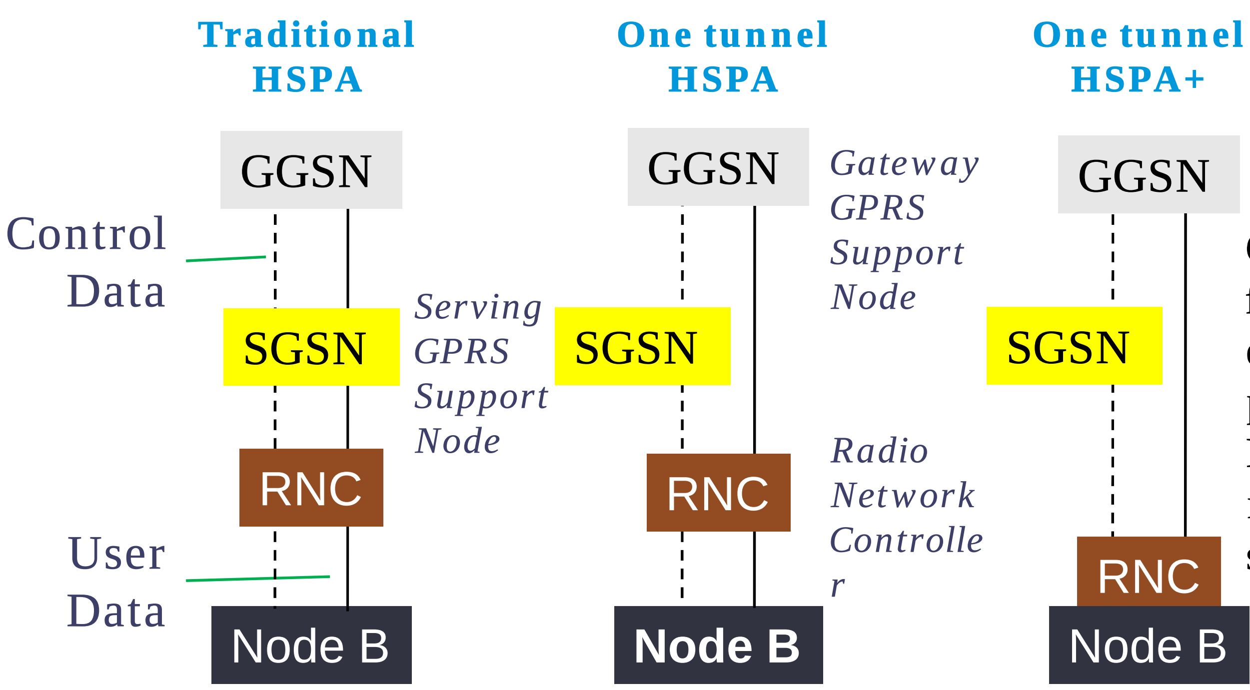
3G/4G Comparison

	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 (1 Gbps DL and 500 Mbps UL, 100 MHz bw) 2010

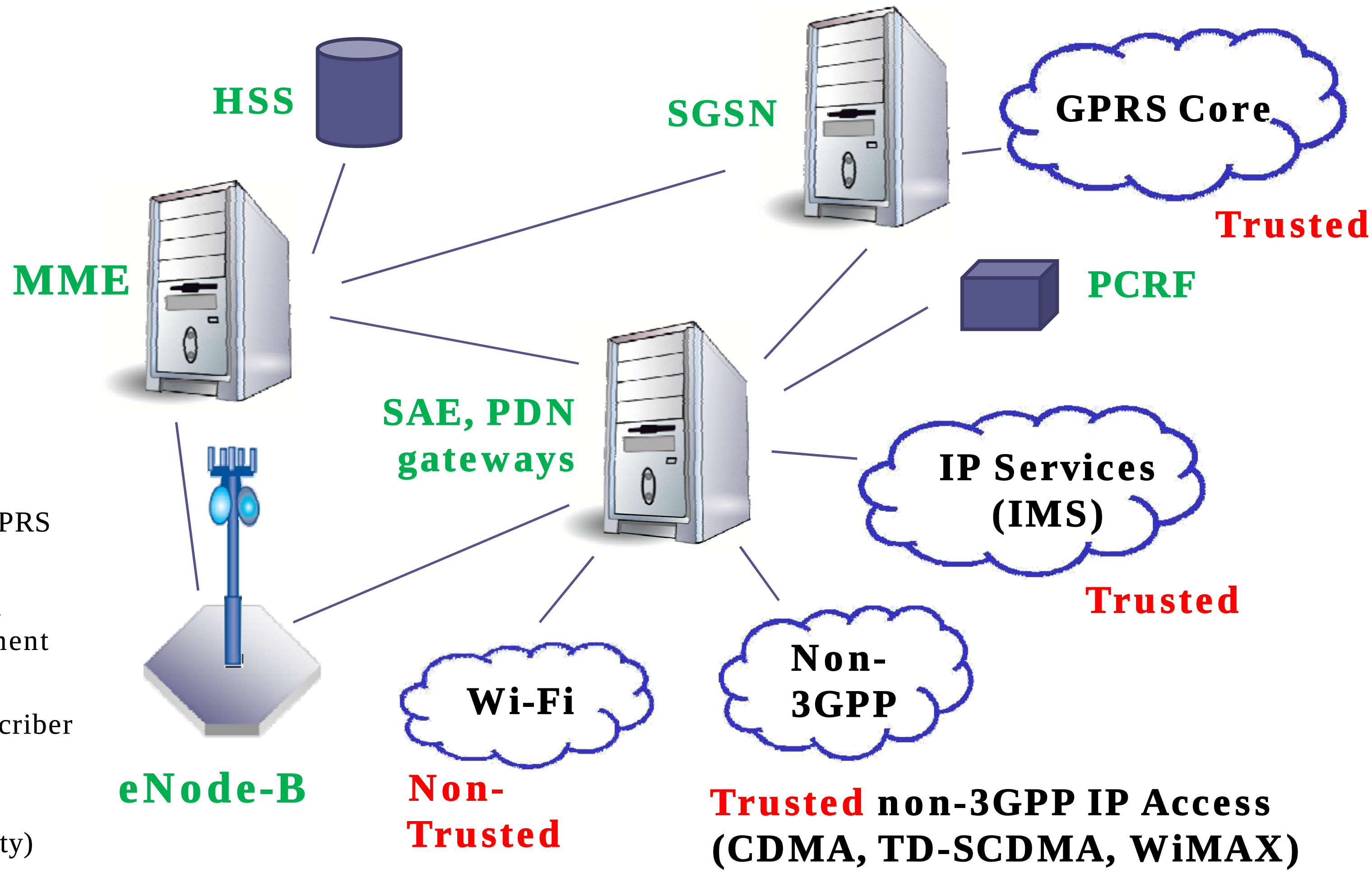
HSPA and HSPA+

- 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

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.

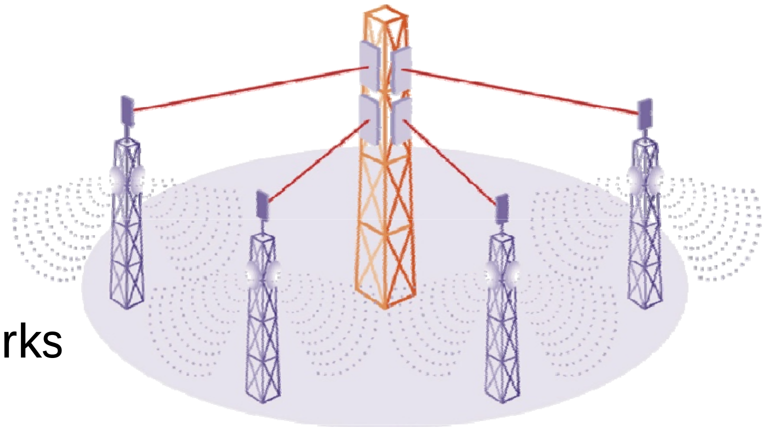
formed 9/2006 by major operators:

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

Backhaul

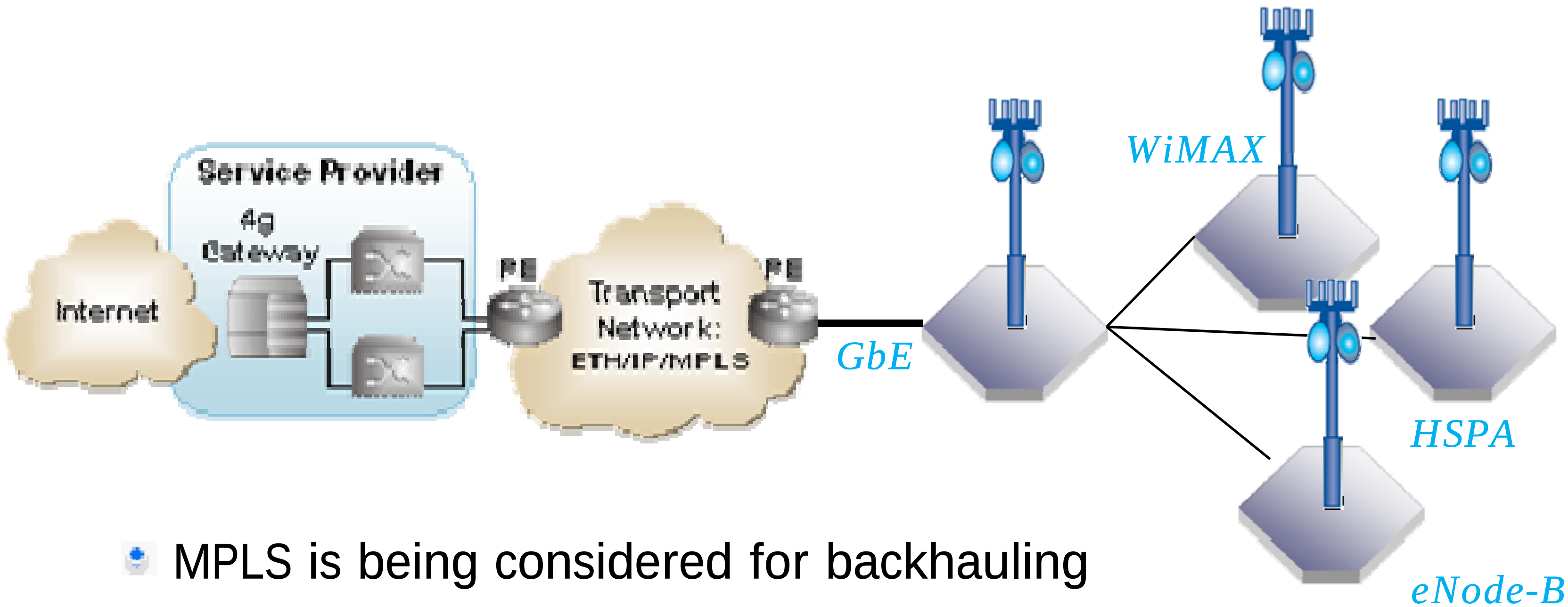
- LTE requires high-capacity links between eNodeB and the core. The options are:
  - Existing fiber deployments
  - Microwave in locations where fiber is unavailable
  - Ethernet
- Co-location of LTE with legacy networks means the backhaul has to support
  - GSM/UMTS/HSPA/LTE or LTE/CDMA
  - Time division multiplexing (TDM), asynchronous transfer mode (ATM) and Ethernet traffic
- NGMN wants to standardize backhaul in order to reduce cost while meeting stringent synchronization requirements.

Backhaul is the key to reducing TCO for operators.



Non-TDM backhaul solutions may be unable to maintain the strict timing required for cellular backhaul.

Multi-Protocol Label Switching (MPLS) Backhaul



- MPLS is being considered for backhauling
  - Supports TDM, ATM, and Ethernet simultaneously
  - Incorporates RSVP-TE (Resource Reservation Protocol-Traffic Engineering) for end-to-end QoS
  - Enables RAN sharing via the use of VPNs
- BS (base stations) could act as edge MPLS routers, facilitating migration to pure IP.

WiMAX vs. LTE

- Commonalities
  - IP-based
  - OFDMA and MIMO
  - Similar data rates and channel widths
- Differences
  - SC-FDMA (single carrier FDMA) uplink for LTE
  - LTE backhaul is designed to support legacy with a careful migration plan from current deployments
  - WiMAX is better suited to greenfield deployments

Commercial Issues

LTE

- Deployments likely slower than projected

But

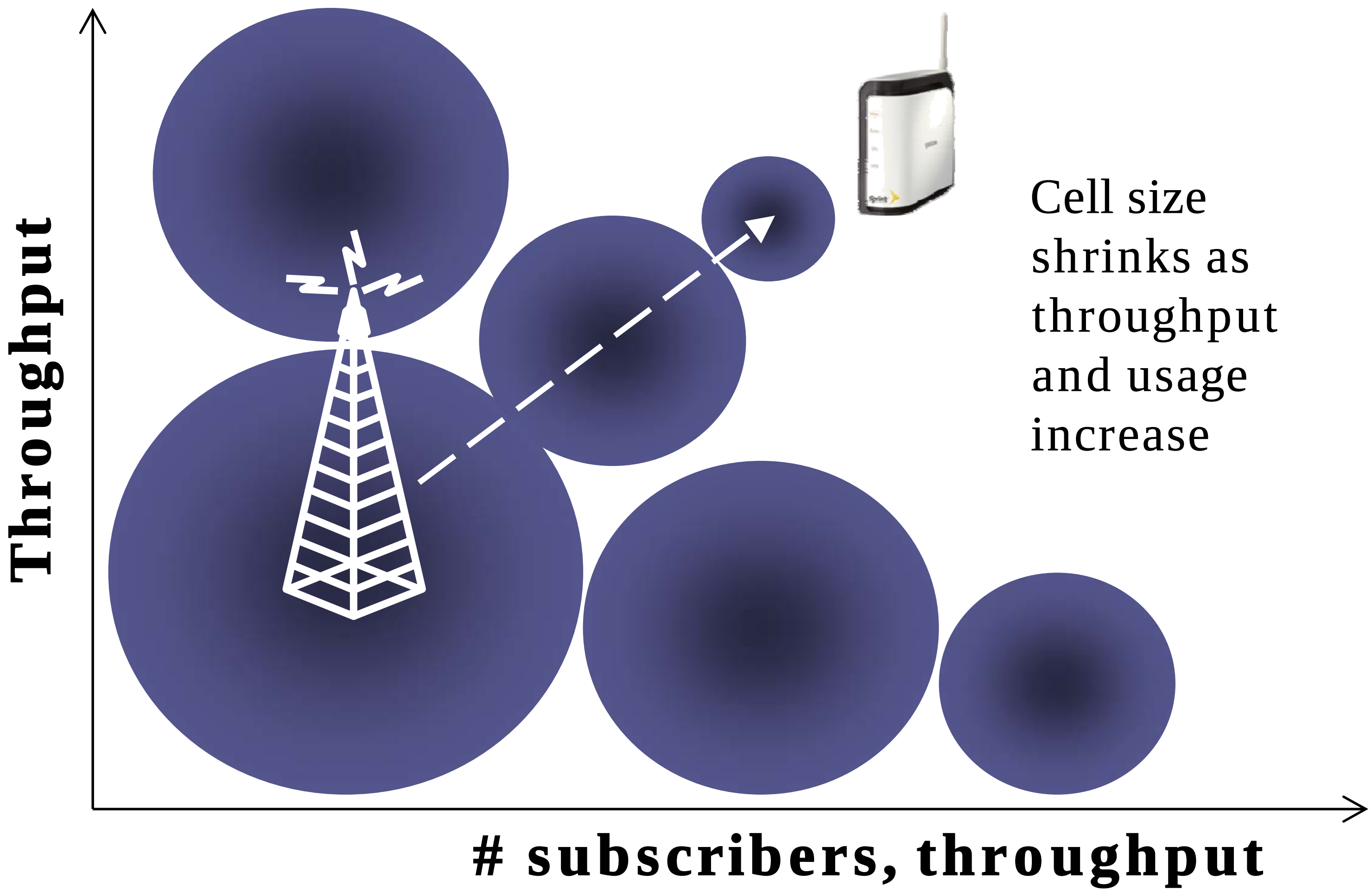
- Eventual migration path for GSM/3GSM, i.e. for > 80% share
- Will be lowest cost & dominant in 2020

WiMAX

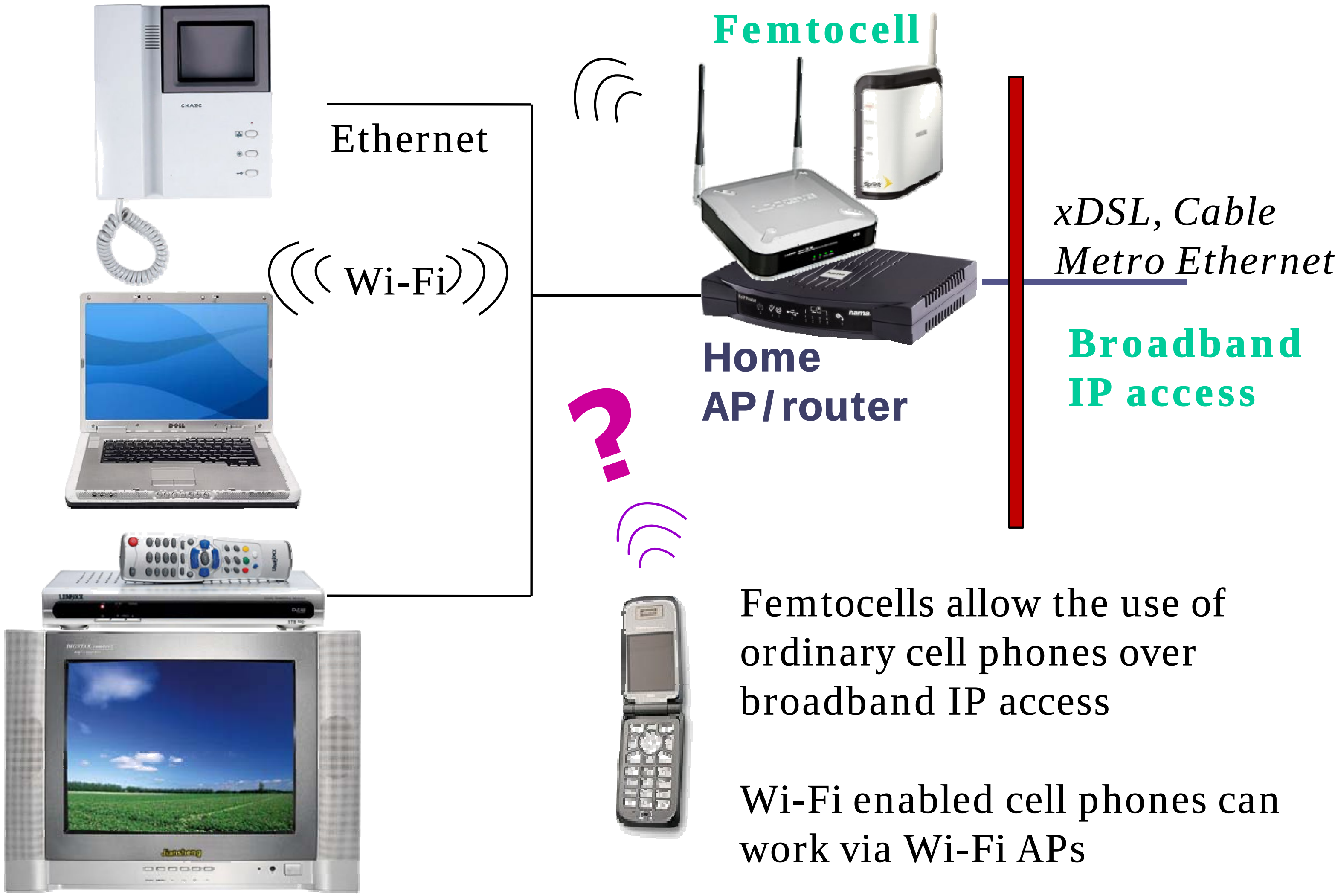
- 2-3 year lead, likely maintained for years
- Dedicated spectrum in many countries

But

- Likely < 15% share by 2020 & thus more costly

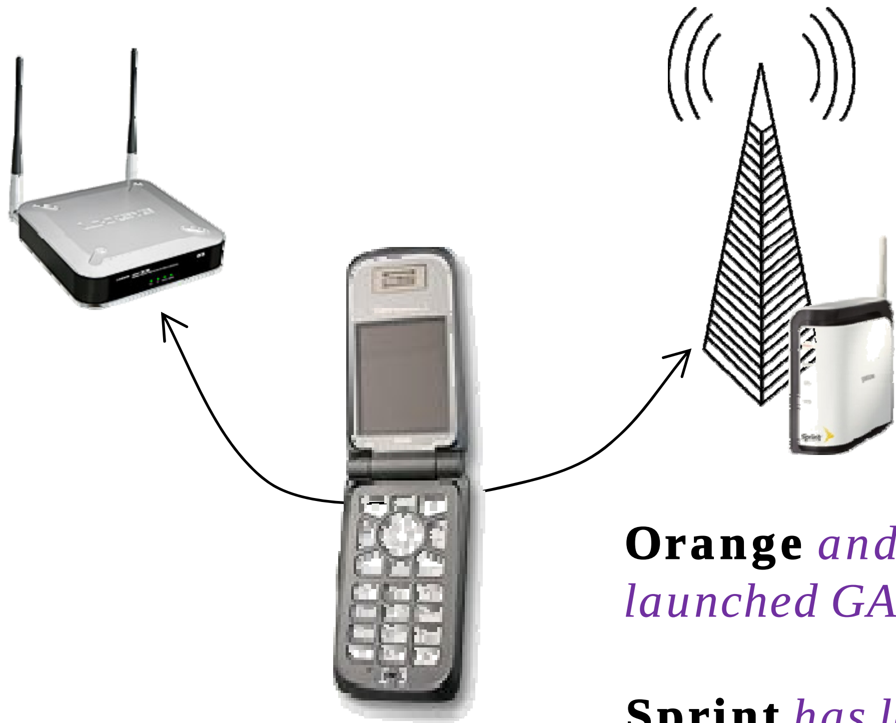


Cell size shrinks as throughput and usage increase



Femtocells allow the use of ordinary cell phones over broadband IP access

Wi-Fi enabled cell phones can work via Wi-Fi APs



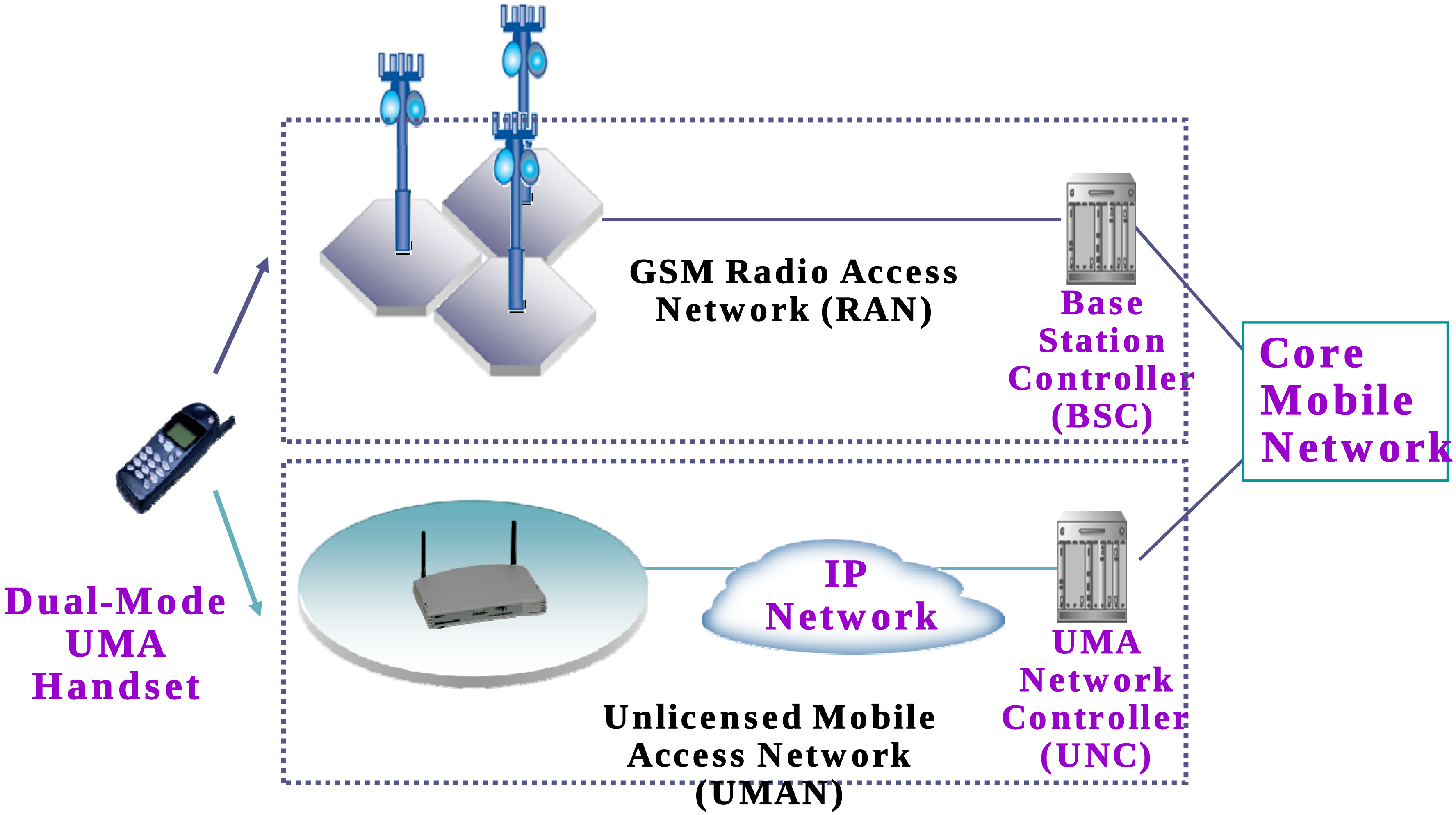
Orange *and* **T-Mobile** *have launched GAN/UMA services*

Sprint *has launched Femtocell service,* **at&t** *and* **Verizon** *have made Femtocell announcements*

Wi-Fi cell phone transitions between cellular and Wi-Fi networks (3GPP GAN, VCC or proprietary SIP)

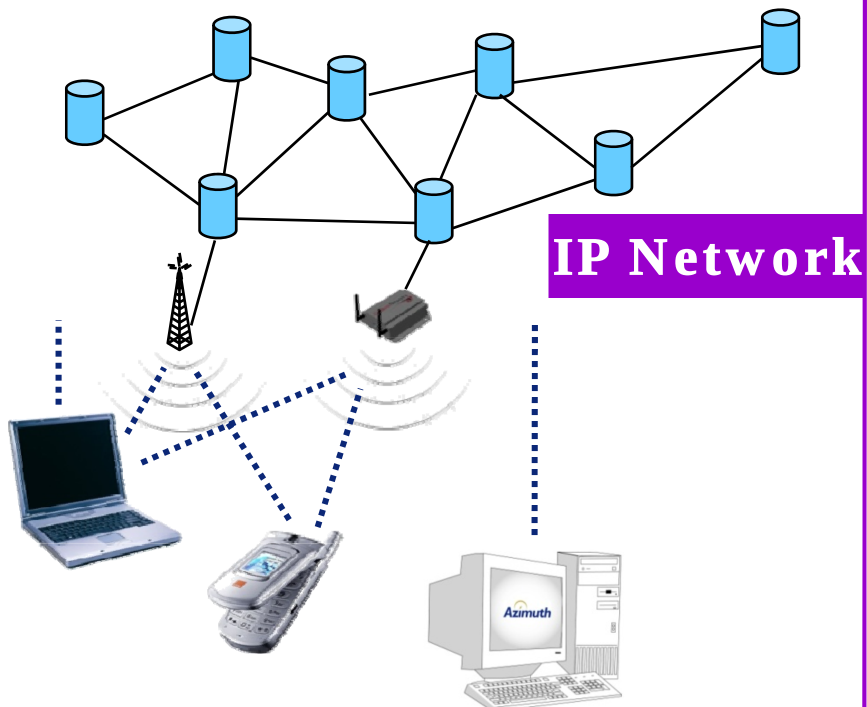
Femtocells support traditional phones

GAN (Generic Access Network) / UMA (Unlicensed Mobile Access)

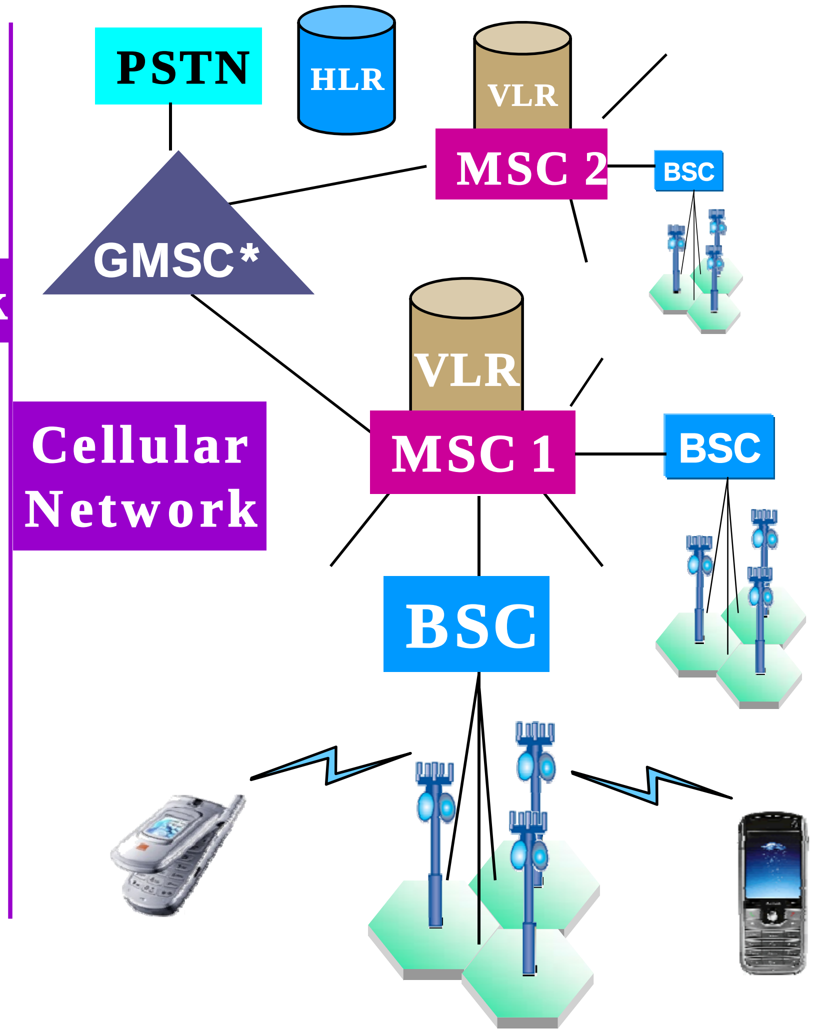


Operators and vendors agreed to develop UMA in December 2003

Data Networks vs. Traditional Cellular Networks

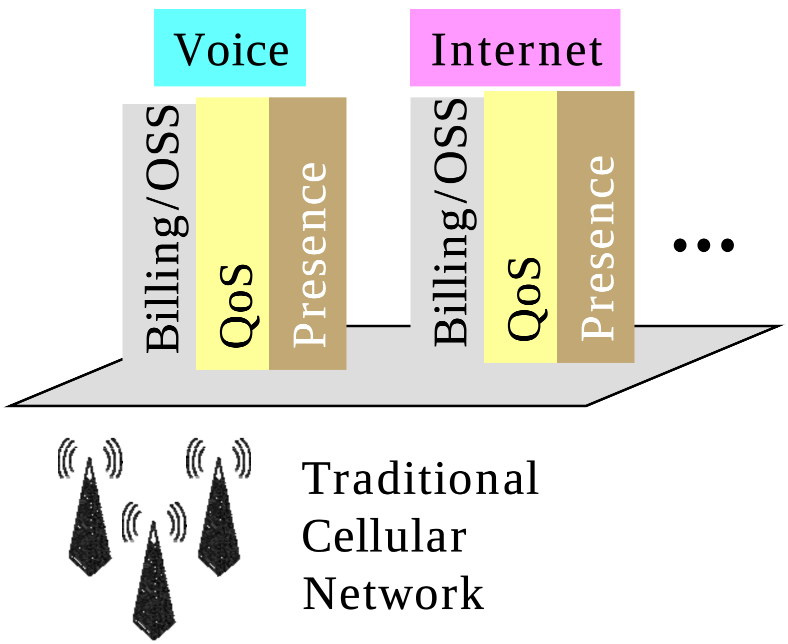


Today's cellular infrastructure is set up for ***thousands*** of BSCs, ***not millions*** of femtocells.



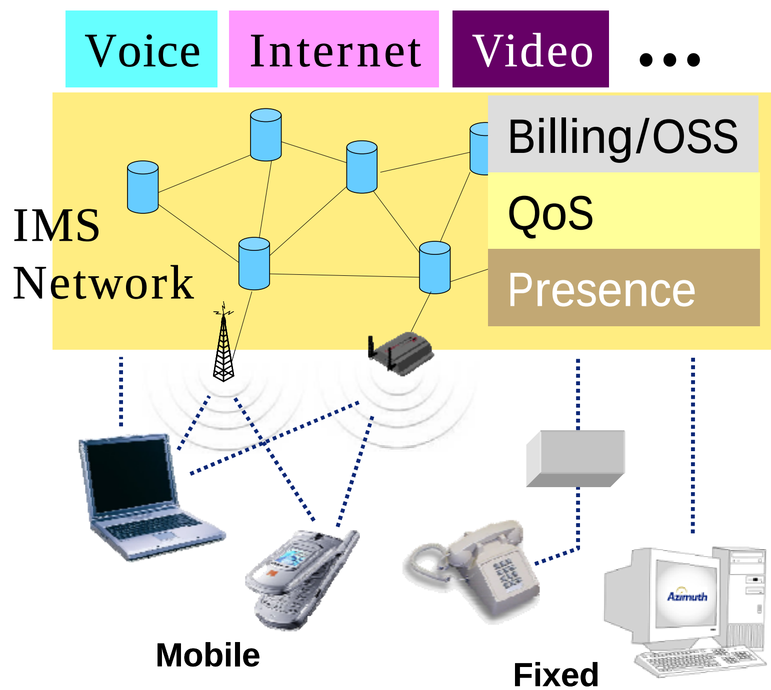
*Gateway Mobile Switching Center

Traditional "Stovepipe"



Stovepipe model – replicates functionality

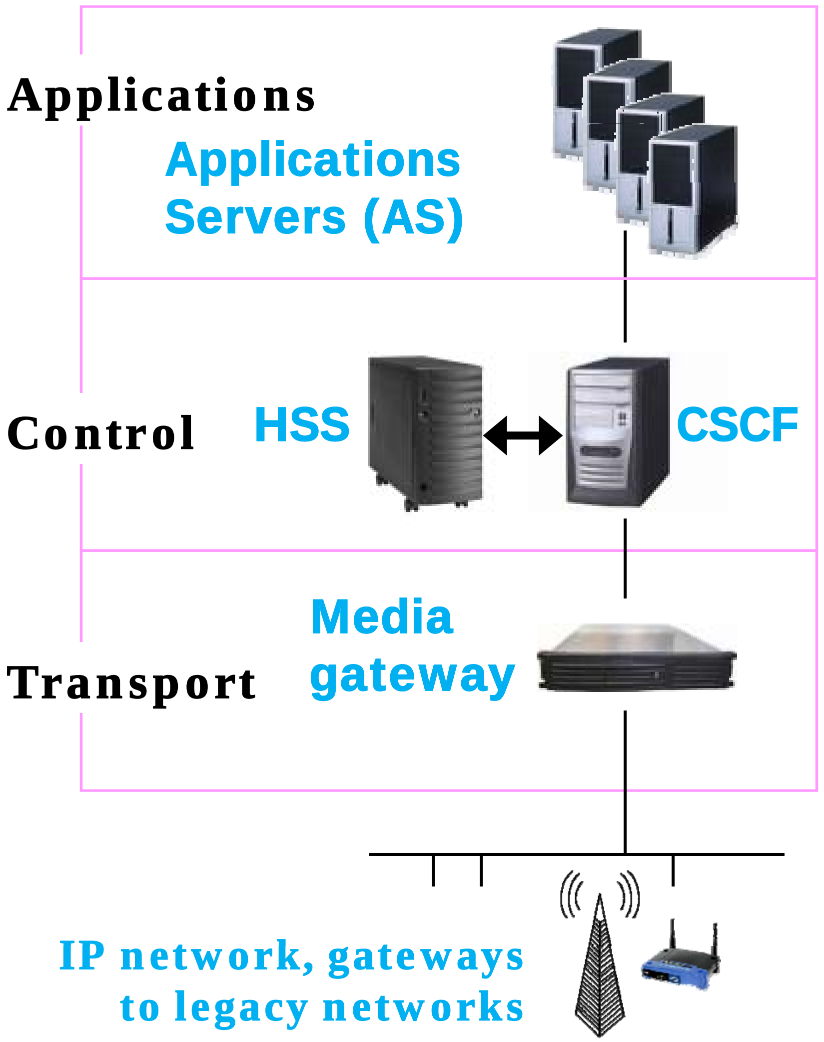
IMS



IMS – common layers facilitate adding services

Key Components of the IMS Architecture

- **CSCF (call session control function)**
  - Heart of IMS architecture
  - Handles multiple real-time IP based services (voice, IMM, streaming video, etc.)
  - Responsible for registering user devices and for ensuring QoS
- **HSS (home subscriber server)**
  - Central repository for customer data
  - Interfaces with operators HLRs (home location registers), which keep subscriber profiles
  - Enables roaming across distinct access networks
- **AS (application server)**
  - Delivers services, such as gaming, video telephony, etc.
  - Types of AS: SIP, Parlay X, customized legacy AS



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.

LTE Highlights

- DL: OFDMA
- UL: Single Carrier FDMA (SC-FDMA)
- Adaptive modulation and coding
- QPSK, 16QAM, and 64QAM
- Advanced MIMO spatial multiplexing techniques

LTE Frequency Bands - FDD

Band	Uplink (UL)	Downlink (DL)
1	1920 -1980 MHz	2110 - 2170 MHz
2	1850 -1910 MHz	1930 - 1990 MHz
3	1710 -1785 MHz	1805 -1880 MHz
4	1710 -1755 MHz	2110 - 2155 MHz
5	824-849 MHz	869 - 894 MHz
6	830 - 840 MHz	875 - 885 MHz
7	2500 - 2570 MHz	2620 - 2690 MHz
8	880 - 915 MHz	925 - 960 MHz
9	1749.9 - 1784.9 MHz	1844.9 - 1879.9 MHz
10	1710 -1770 MHz	2110 - 2170 MHz
11	1427.9 - 1452.9 MHz	1475.9 - 1500.9 MHz
12	698 - 716 MHz	728 - 746 MHz
13	777 - 787 MHz	746 - 756 MHz
14	788 - 798 MHz	758 - 768 MHz
17	704 - 716 MHz	734 - 746 MHz

Source: 3GPP TS 36.104 V8.4.0 (2008-12)

LTE Frequency Bands - TDD

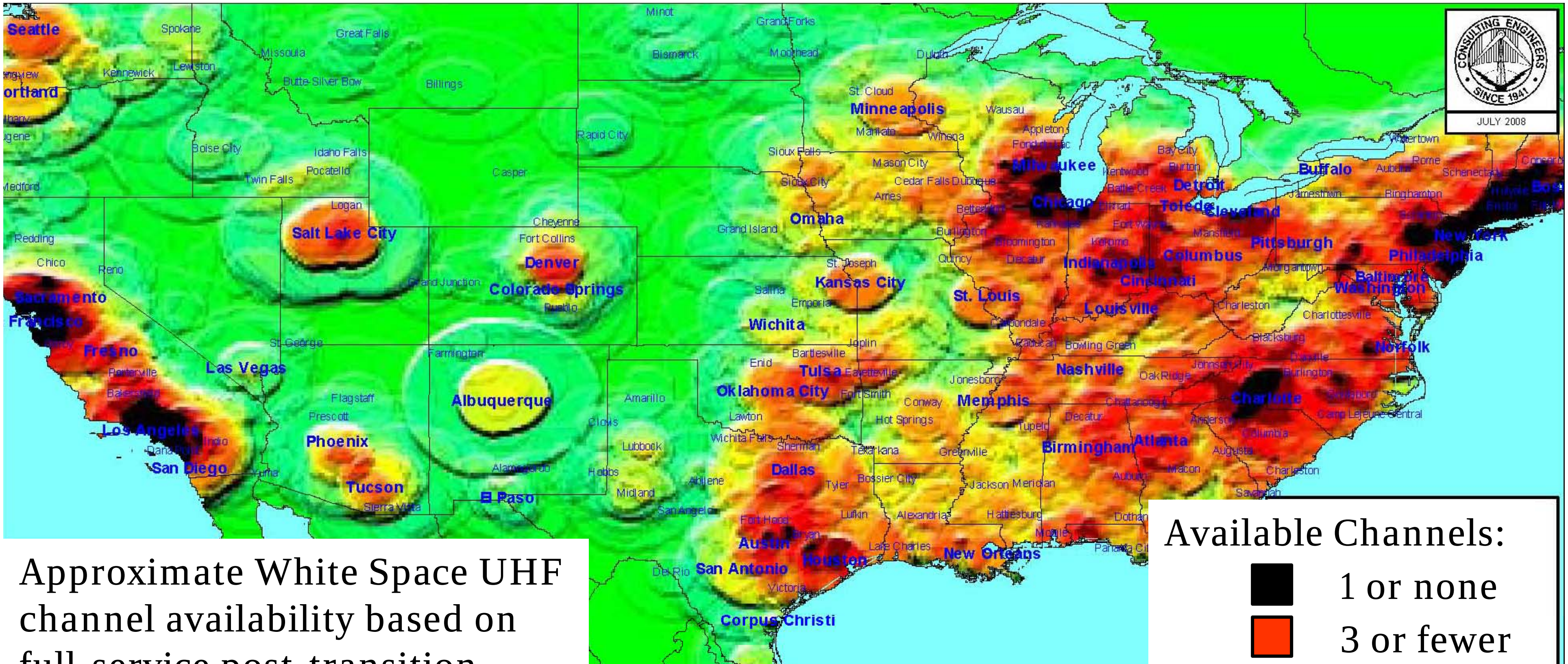
Band	Uplink (UL) /Downlink (DL)
33	1900 - 1920 MHz
34	2010 - 2025 MHz
35	1850 - 1910 MHz
36	1930 - 1990 MHz
37	1910 - 1930 MHz
38	2570 - 2620 MHz
39	1880 - 1920 MHz
40	2300 – 2400 MHz

Source: 3GPP TS 36.104 V8.4.0 (2008-12)

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
- FCC is updating its regulations and has recently allowed the use of cognitive radio for White Spaces, unused TV spectrum
- WSD = white spaces device

White Space Channel Availability



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

duTreil, Lundin & Rackley, Inc.
Sarasota, Florida

White Spaces Radio Technology

- 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.
- Two types of services are targeting TV spectrum:
  - Fixed services: WRAN (wireless rural area networks), being standardized by IEEE802.22
  - Mobile services: White Spaces, being advocated by the WIA (www.wirelessinnovationalliance.org)
  - IEEE 802 LAN/MAN committee formed new study group in November, 2008 to investigate white spaces standardization

Detailed standard needed

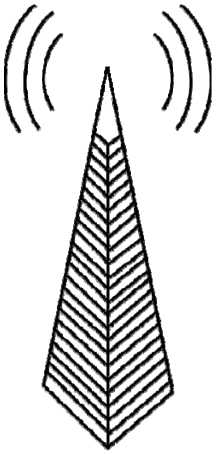
IEEE 802 taking initiative

Detecting Licensed Transmissions

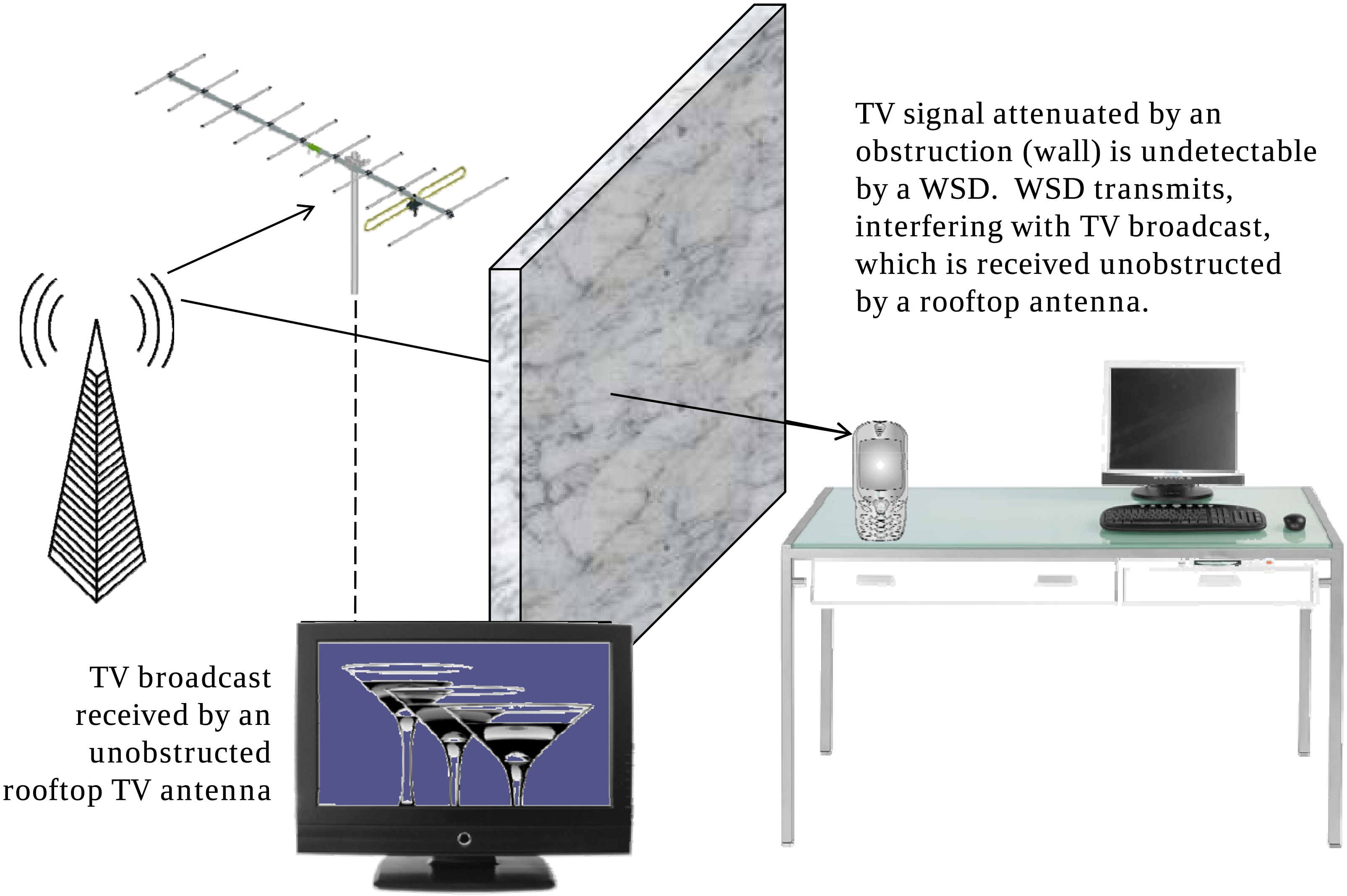
- Methods for detecting licensed transmissions:
  - An internal GPS could be used in conjunction with a database to determine whether the WSD is located far enough away from licensed stations.
  - WSD could receive information from a broadcast station indicating which channels are available.
  - WSD could incorporate sensing capabilities to detect whether licensed transmitters are in its range. If no signals are detected, the device could transmit. If signals are detected, the device would have to search for another channel.

Protected devices: TV stations, wireless microphones

- FCC sensing thresholds :
  - -116 dBm for ATSC (Advanced Television Systems Committee, digital TV)
  - -94 dBm for NTSC (National Television System Committee, analog TV)
  - -107 dBm for wireless microphones



Hidden Node Scenario



TV signal attenuated by an obstruction (wall) is undetectable by a WSD. WSD transmits, interfering with TV broadcast, which is received unobstructed by a rooftop antenna.

TV broadcast received by an unobstructed rooftop TV antenna

Gaining Access To Spectrum

- License-exempt
  - ISM (900 MHz, 2.4 GHz)
  - Extended into UNII (5 GHz) and 60 GHz
- Low power – in the noise floor of licensed services
  - Ultra Wideband in 3.1–10.6 GHz
- Shared use
  - 3650-3700 MHz; lightly licensed based on contention
- TV White Spaces
  - Multi-year battle vs. strong vested interests
  - Favorable FCC decision – Nov. 2008
  - Tight restrictions likely to be eased over time

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Agenda

1:30 – 2:10	Fanny Mlinarsky, octoScope Review of the 'G's
2:10– 2:40	Philipp Deibert, NGMN Alliance Next Generation Mobile Broadband
2:40– 3:10	David Kelf, Sigmatix Business of Basebands
	Break
3:20– 3:50	Victor Menasce, Wavesat Multi-protocol 4G – Discovering Synnergies
3:50– 4:20	Larry Fischer, ADC Microcellular 4G Architecture
	Q & A

Next Generation Mobile Broadband

- **Philipp Deibert**
  Executive Program Manager
  NGMN Alliance
- Mr. Deibert is executive program manager for the NGMN Alliance-a group of leading mobile operators and vendors. Before joining NGMN he was a senior associate with Booz Allen Hamilton in the Communication and Technology Practice and held positions at Motorola and German Television ZDF.

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Multi-protocol 4G – Discovering Synergies

3:50– 4:20 Larry Fischer, ADC
Microcellular 4G Architecture

Q & A

The Business of Basebands

- **David Kelf**
  President and CEO
  Sigmatix, Inc.
- Mr. Kelf has 25 years of industry experience. Prior to Sigmatix, he was vice president of marketing at Co-Design Automation, inventors of SystemVerilog, acquired by Synopsys. He was director of marketing at Cadence where he was responsible for their industry leading HDL simulator. Mr. Kelf also served as vice president of marketing at Novas.

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Multi-Protocol 4G: Discovering Synergies

- **Victor Menasce**
  Vice President Engineering
  Wavesat
- Mr. Menasce is a 21 year industry veteran and brings extensive experience in wireless, processing, telecom and semiconductors. Prior to joining Wavesat, he was chief technical officer with Applied Micro Circuits Corporation. He has also held senior positions with Somerset Technologies, Tundra Semiconductor and Nortel Networks. Mr. Menasce is an Electrical Engineering graduate of Dalhousie University.

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Microcellular 4G Architecture

- **Larry Fischer**
  Director of Engineering, R&D,
  Network Solutions
  ADC
- In 15 years at ADC, Mr. Fischer has directed RF development, product management and today leads R&D. His 30+ years of experience includes cell radio development at EF Johnson. Mr. Fischer holds a Mechanical Engineering BS from Iowa State and an Applied Math MS from the Illinois Institute of Technology.

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