Mobile WiMax: Description and Deployment

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Outline

- The big picture
- 802.16 Specifications family
- OFDM and OFDMA fundamentals
- Profiles
- System architecture, handoff, QoS
- Summary

The Big Picture

Personal
Unlicensed
Device Connectivity

Fixed
Licensed and Unlicensed
Networking

Portable
Licensed and Unlicensed
Wireless Services

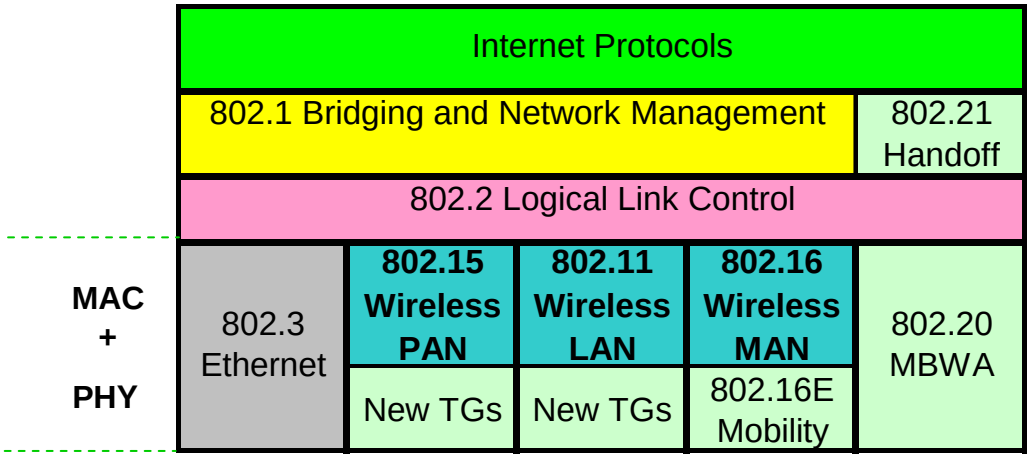
Mobile
Licensed Broadband
and Wideband
Services

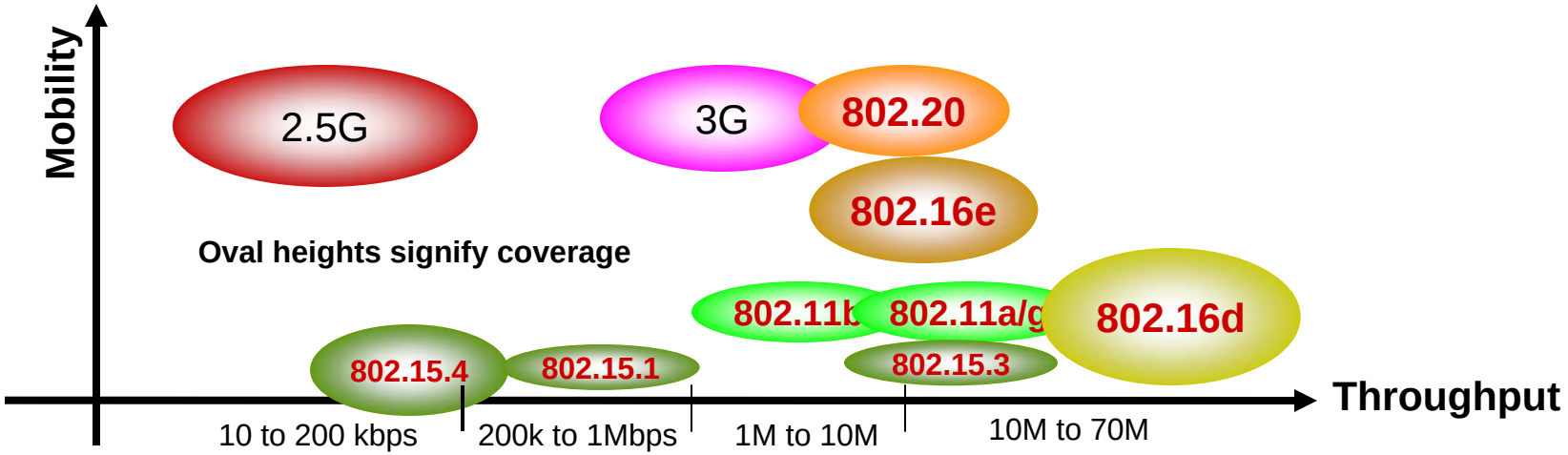
Device to Device	Device to Peripherals	Campus Networking	Access & Backhaul	Zonal	Nomadic	Low Mobility	Cellular WAN
WPAN 802.15	WPAN 802.15.x	WiFi 802.11	WiMAX 802.16d	WiFi 802.11	WiMAX 802.16e	WiMAX 802.16e	2.5G, 3G→ 802.20

$$\text{Coverage}_{WPAN} < \text{Coverage}_{WLAN} < \text{Coverage}_{WMAN} < \text{Coverage}_{WWAN}$$

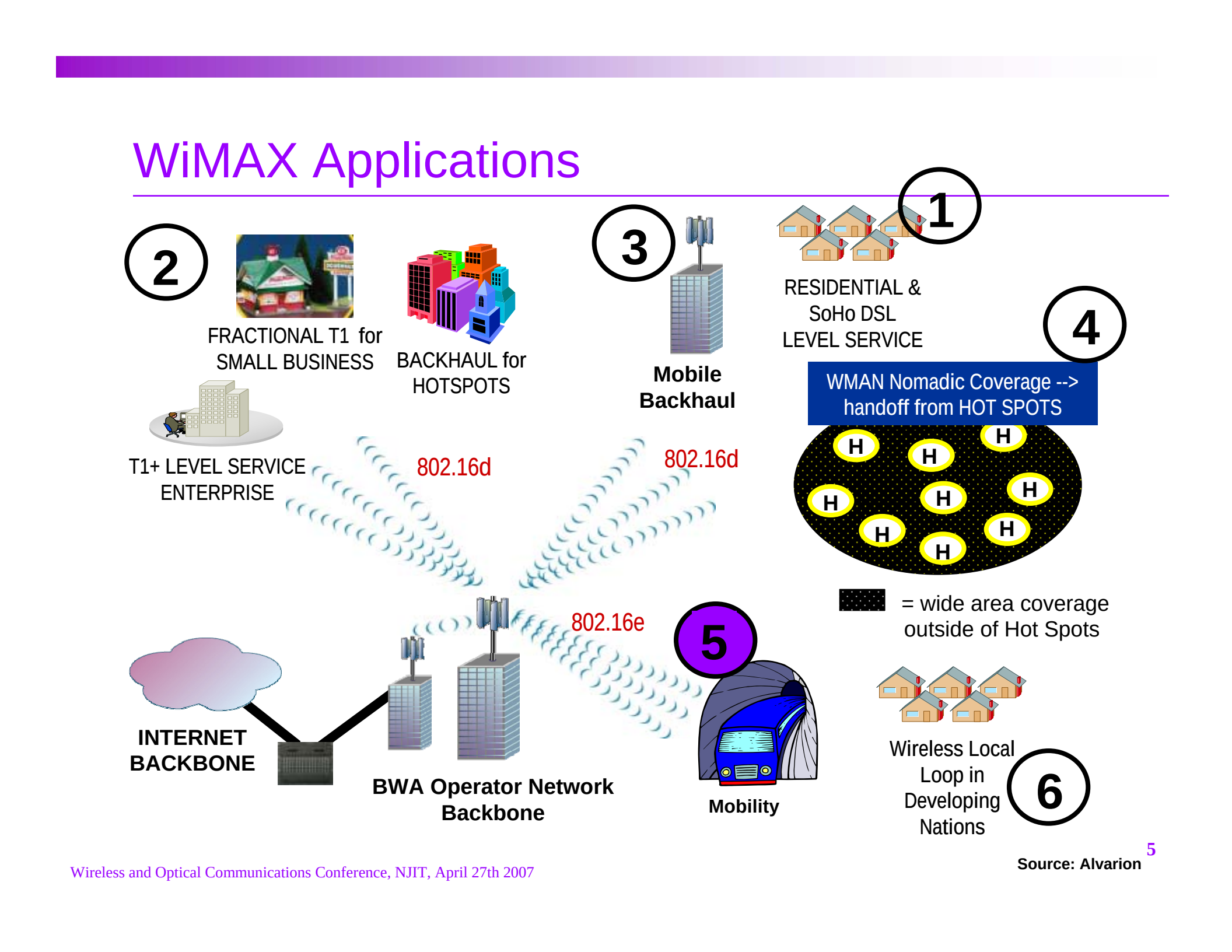
Source: Intel Corp/ Modified

Zones of Interest of the IEEE





WiMAX Applications

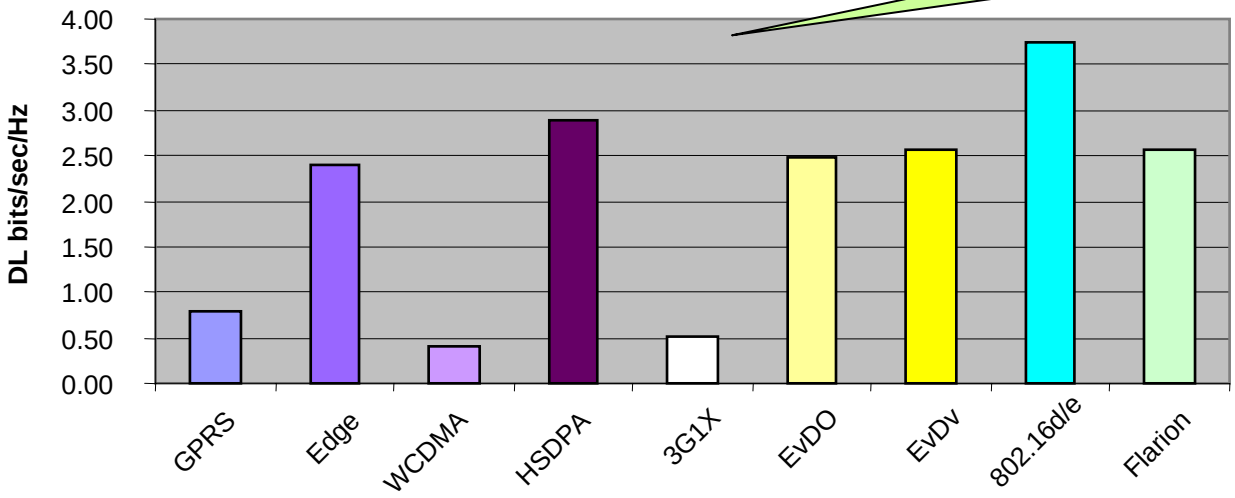


Source: Alvarion

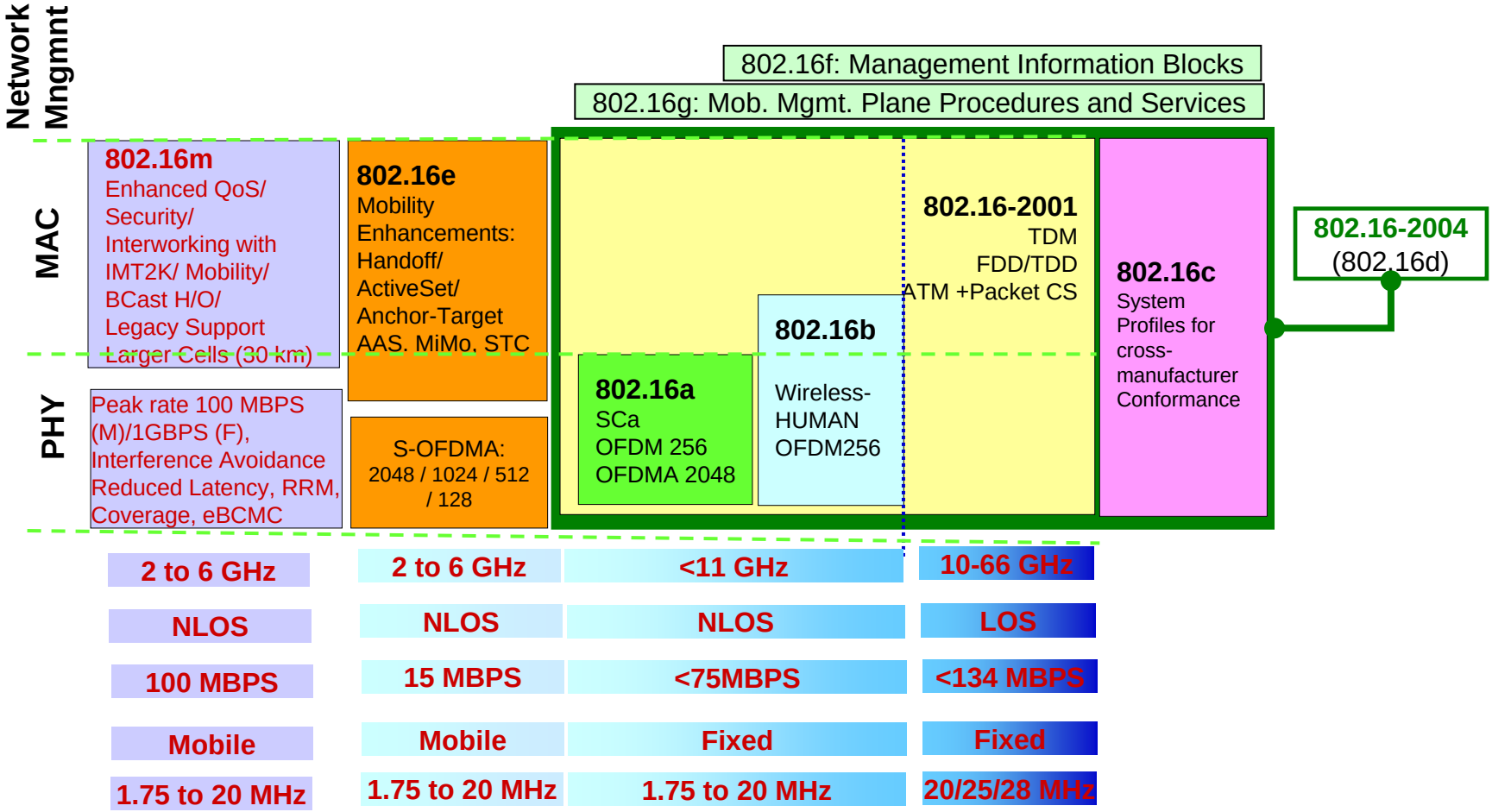
Comparing 802.16d/e with Others

	Channel Bandwidth	FDD/TDD	DL Peak	UL Peak	Standard Body	bits/sec/hz
GPRS	200 KHz	FDD	160 kbps	160 kbps	3GPP2	0.80
Edge			480 kbps	480 kbps		2.40
WCDMA	5 MHz	FDD/TDD	2 Mbps	2 Mbps		0.40
HSDPA		FDD	14.4 Mbps	7 Mbps		2.88
3G1X	1.25 MHz	FDD	640 kbps	450 kbps	3GPP	0.51
EvDO			3.1 Mbps	1.8 Mbps		2.48
EvDv			3.1 Mbps	1.8 Mbps		2.56
802.16d/e	upto 20 MHz	FDD/TDD	upto 75 Mbps	upto 75 Mbps	IEEE	3.75
Flarion	1.25 MHz	FDD	3.2 Mbps	900 kbps	-	2.56

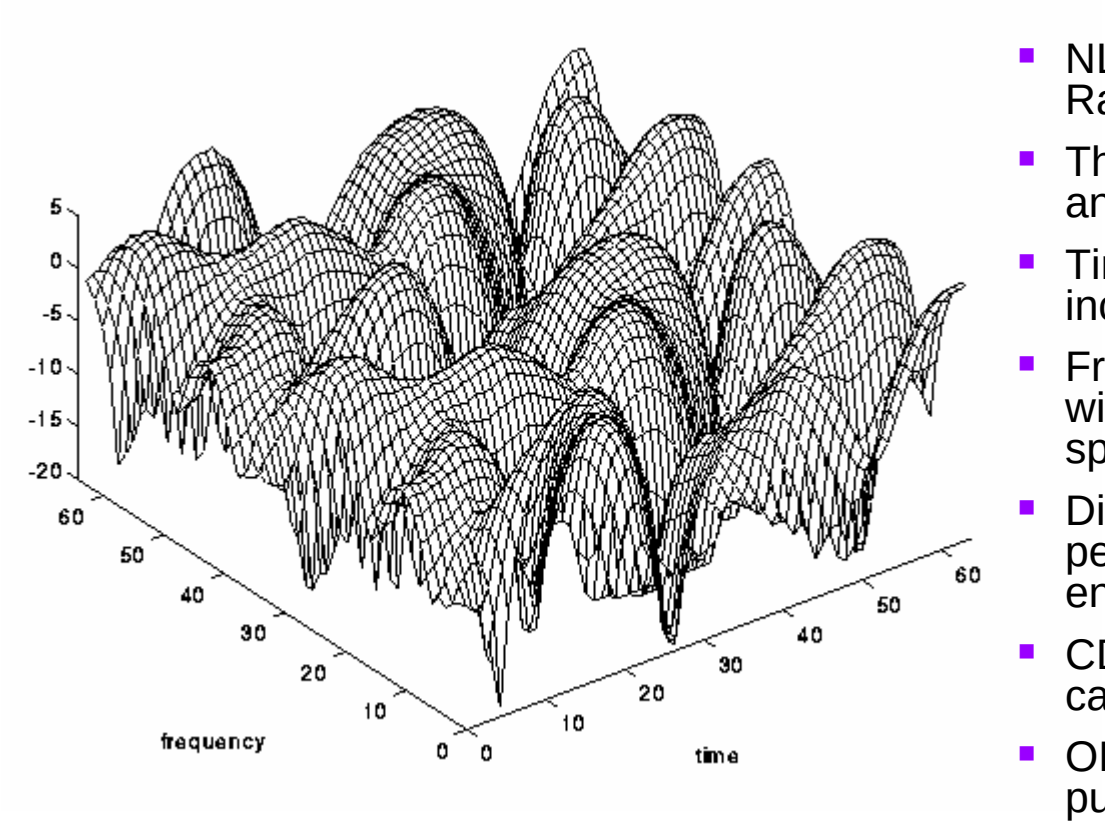
Normalized Throughput Comparison (Peak Bursts)



802.16 Specifications



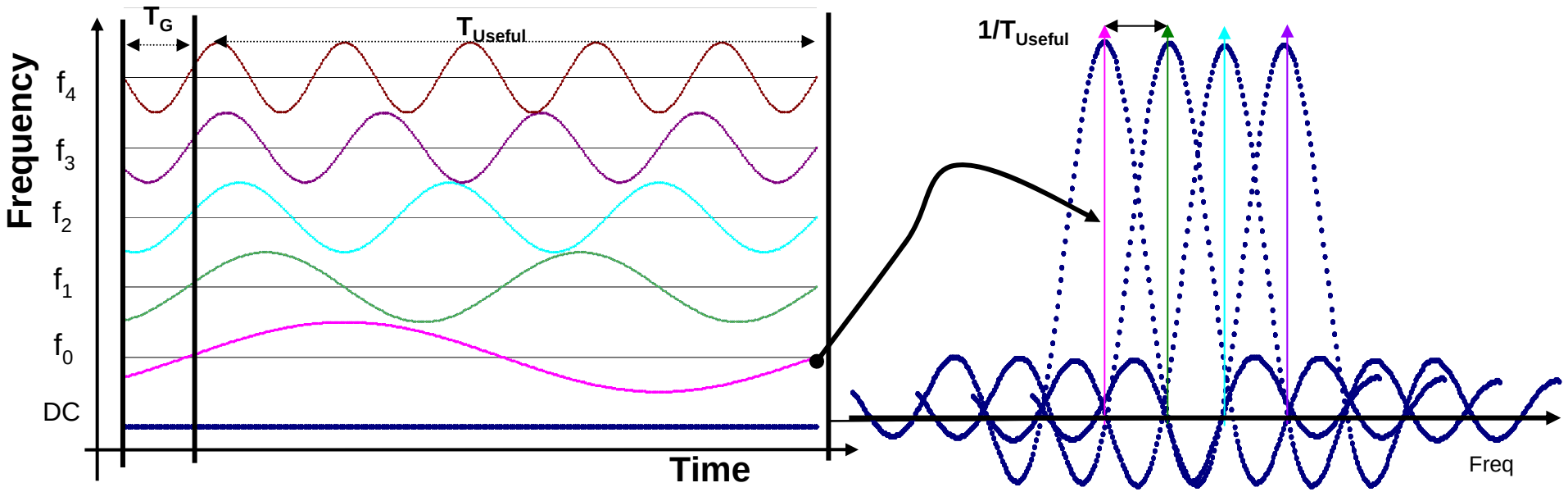
Why OFDM



Rayleigh Envelope Variation is time and frequency

- NLOS signal envelopes are Rayleigh distributed
- The signal fades both with time and frequency separation
- Time correlation decreases with increasing velocity (Doppler)
- Frequency correlation decreases with increased multipath delay spread
- Diversity is *the* key to enhance performance in fading environments
- CDMA uses multiple rake fingers to capture frequency diversity
- OFDM uses parallel long duration pulses to capture time diversity
- Frequency diversity is captured by coding across time and frequency

OFDM Basics



- Signal is accessible in time and frequency➔ Time variations and frequency variations can be coded/interleaved across ➔ Advanced Space-Time-Frequency Coding
- Guard Interval absorbs the designed multipath effects ➔ Single tap multiplicative equalizer➔ NLOS operation
- **OFDMA**: Single Frequency Network operation with reuse factor of 1 ➔ Planning benefit + Spectrum Utilization
- Invented at Bell Labs : Chang and Gibby, 1960s ➔ DVB-T, SDARs, WiFi, WiMax, HiperLAN/MAN, DAB, DSL and coming in EvDO, UMTS!

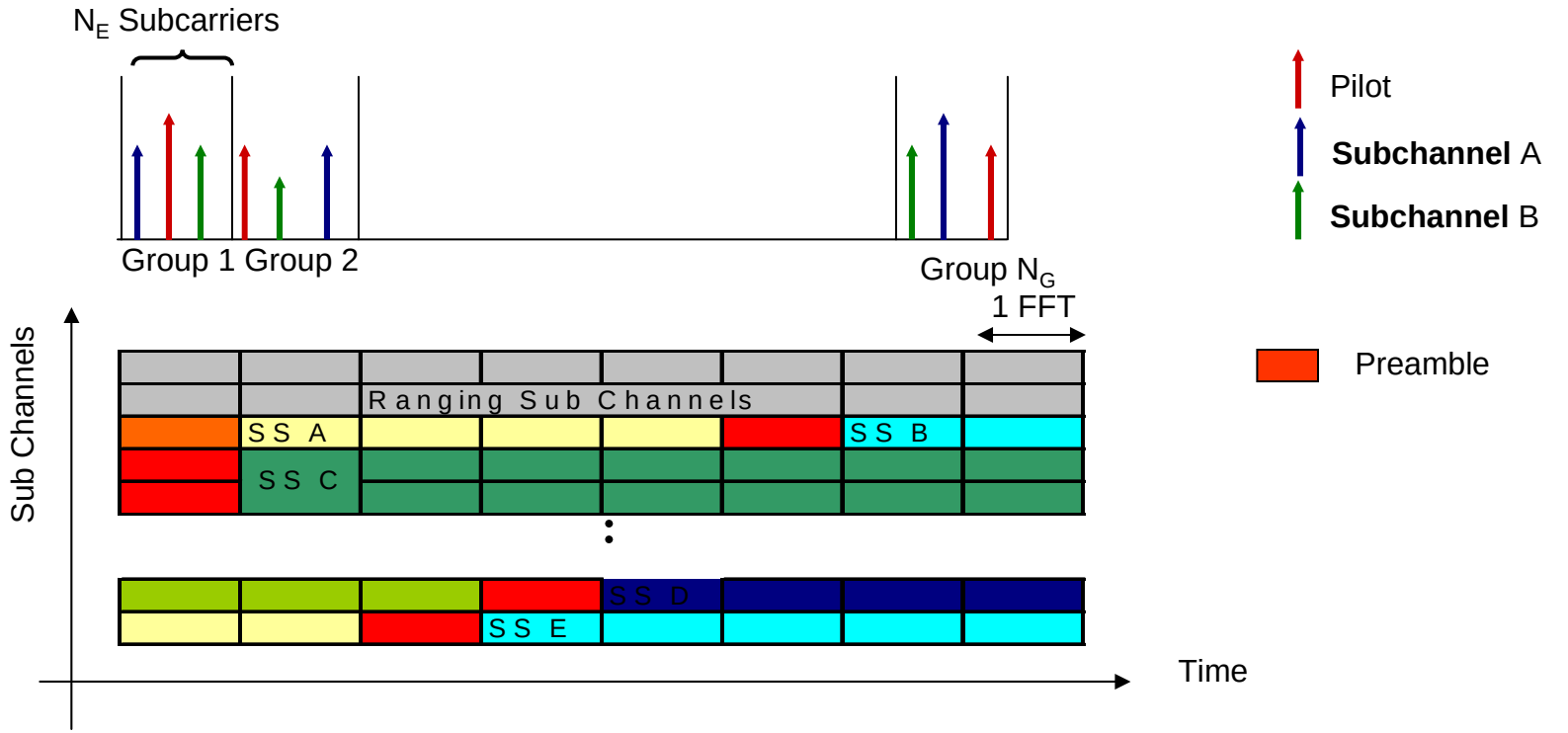
✓ R.W. Chang [1966], "Synthesis of Band-Limited Orthogonal Signals for Multichannel Data Transmission," Bell System Technical Journal, 45, pp. 1775-1796.

✓ B. R. Salzberg [1967], "Performance of an Efficient Parallel Data Transmission System," IEEE Transactions on Communication Technology, 15, 6, pp 805-811

✓ R.W. Chang, and R.A. Gibby [1968], "Theoretical Study of Performance of an Orthogonal Multiplexing Data Transmission Scheme," IEEE Transactions on Communication Technology, 16, 4, pp. 529-540.

✓ S.B. Weinstein, and P.M. Ebert [1971], "Data Transmission by Frequency-Division Multiplexing Using the Discrete Fourier Transform," IEEE Transactions on Communication Technology, 19, 5, pp. 628-634

OFDMA Operations



- Different modulation/coding in each sub channel
- Media Access Protocol (MAP) messages are used to assign SSs to Sub channels
- FFT Size = 2048; DL: N_G = 48 / N_E = 32; UL: N_G = 53 / N_E = 32; 1 Schannel ≈ 1/32nd of total BW
- Sub-carriers are assigned in a pseudorandom fashion to the SSs
- High throughput SSs are assigned more that one SC
- SSs need only modulate a few of the 2048 SCs/ BS modulates all ➔ Commensurate with low power CPEs and building penetration loss
- Throughput per Sub channel (6 MHz) = 178.1 (QPSK) / 428.1 (16 QAM) / 668.7 (64 QAM) (kbps)
- Total Throughput (6 MHz) = 4.8 / 11.6 / 18.2 MBPS

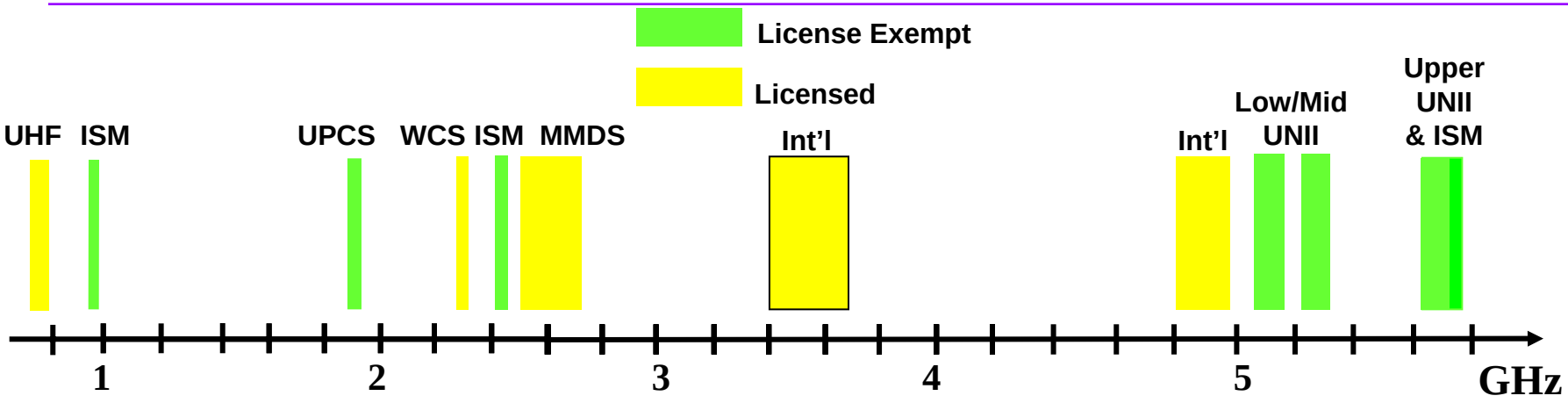
Reference: Koffman, Roman, "Broadband Wireless Access Solutions Based on OFDM Access in IEEE 802.16", IEEE Comm. Magazine,April 2002, pp 94-103

802.16e and WiMax Profiles

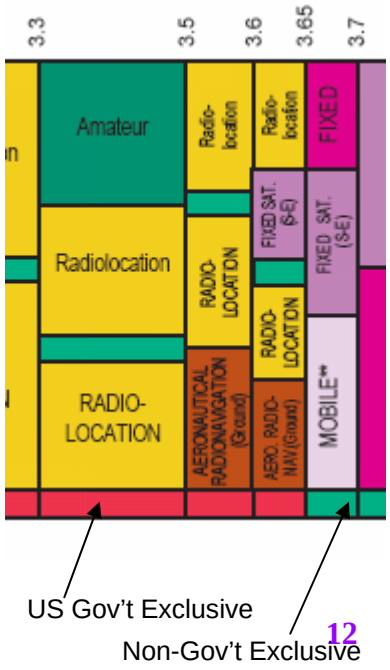
PhyProfiles	Bandwidth	Duplexing (OFDMA_R1 to OFDMA_R30 RF profiles)
ofdma_profP1	1.25 MHz	TDD
ofdma_profP2	3.5 MHz	TDD/FDD
ofdma_profP3	7.0 MHz	TDD/FDD
ofdma_profP4	8.75 MHz	TDD
ofdma_profP5	14 MHz	TDD/FDD
ofdma_profP6	17.5 MHz	TDD
ofdma_profP7	28 MHz	TDD/FDD
ofdma_profP8	10 MHz	TDD
ofdma_profP9	20 Mhz	TDD
Modulation		4/16/64.
Symbol Rate		(BWMHz-0.88)/1.25
FFTSize: D: 2048 / E: 2048/1024/512/128 (SOFDMA)		

		Frequency band (GHz)					
Channelization (MHz)	**FFT Size**	**2.3 - 2.4**	**2.305-2.32**	**2.345-2.36**	**2.496-2.69**	**3.3 - 3.4**	**3.4-3.8**
5	512	TDD	TDD	TDD	TDD	TDD	TDD
7	1024					TDD	TDD
8.75	1024	TDD					
10	1024	TDD	TDD	TDD	TDD	TDD	TDD

Spectrum Availability

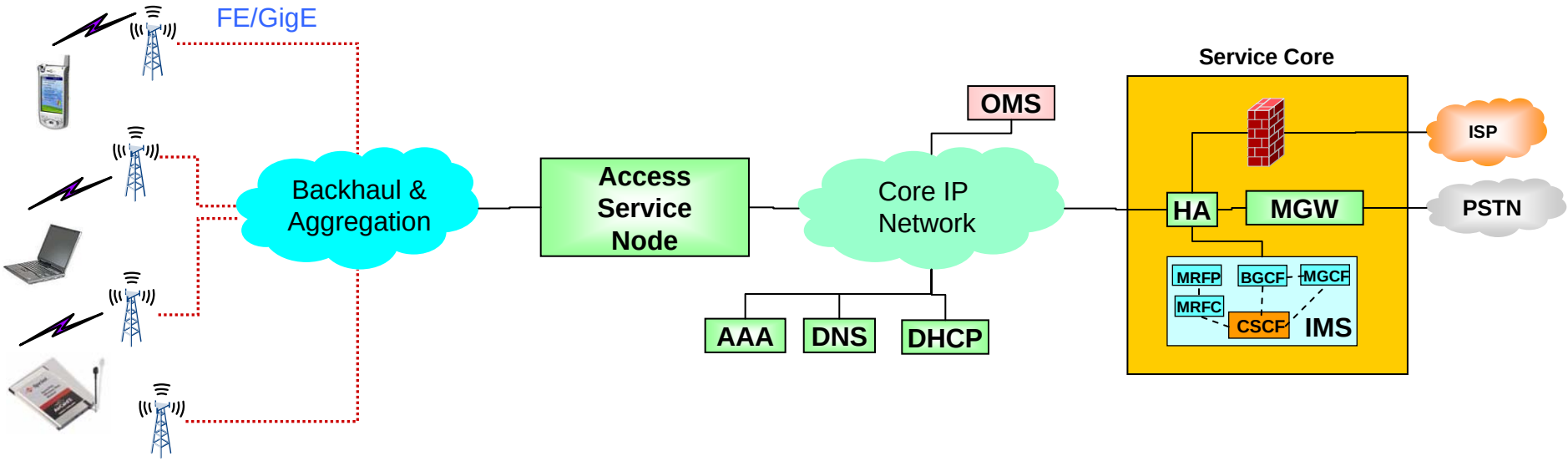


UHF	0.75 - 0.8	Channels 60-69, called the upper 700Mhz, are by congressional statute to be reclaimed for new services (broadband wireless).
ISM	0.9 - 0.93	Industrial, Scientific & Medical Band – License exempt band
UPCS	1.91 - 1.93	License exempt Personal Communications Services
WCS	2.3	Wireless Communications Service. Licensed by Verizon, Bellsouth & AT&T
ISM	2.4 - 2.48	Industrial, Scientific & Medical Band – License exempt band
MMDS	2.5 - 2.7	Multi-channel Multipoint Distribution Service. Licensed in U.S. by Sprint, Worldcom & Nextel, Nucentrix.
Int'l	3.4 - 3.7 4.8 - 5	Licensed Bands- Europe, Latin America, Asia Licensed Bands-Japan
UNII	5.15 - 5.35 5.73 - 7.83	License exempt National Information Infrastructure band



Source: Intel Corporation

Mobile WiMax System Architecture

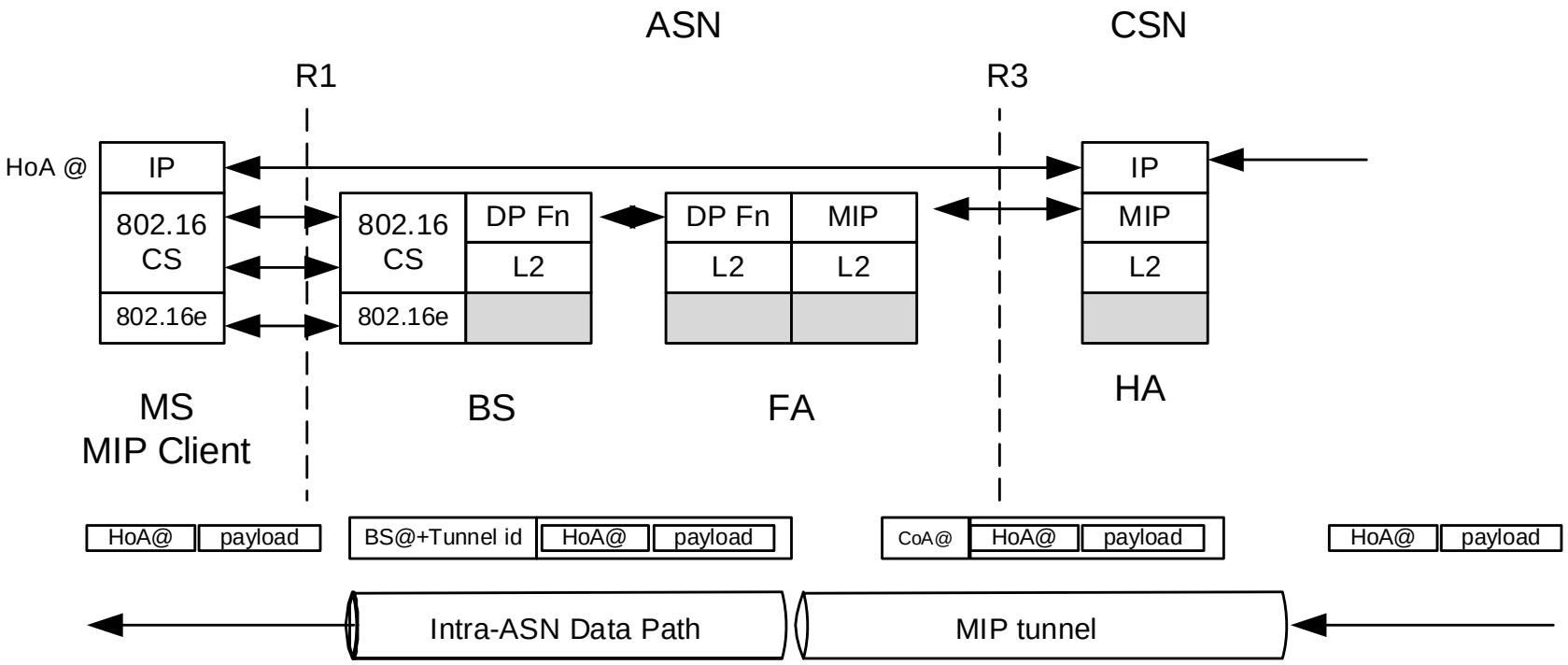


- Ranging
- Basic Capability Setup
- Registration
- Establish IP Connectivity
- Mobility (MIP, P-MIP, SIP)
- QoS

- Subscriber Access Management
- Authenticate, Authorize, Account
- SLA enforcement
- Handover Management
- Allocate IP addresses (SIP)
- Proxy Mobile IP or FA

- Call Control
- Gateway Functionalities
- IP address allocation (MIP)

Mobile IP in Mobile WiMax



CS: Convergence Sublayer

DP: Data path function

Source: WiMax Forum NWG

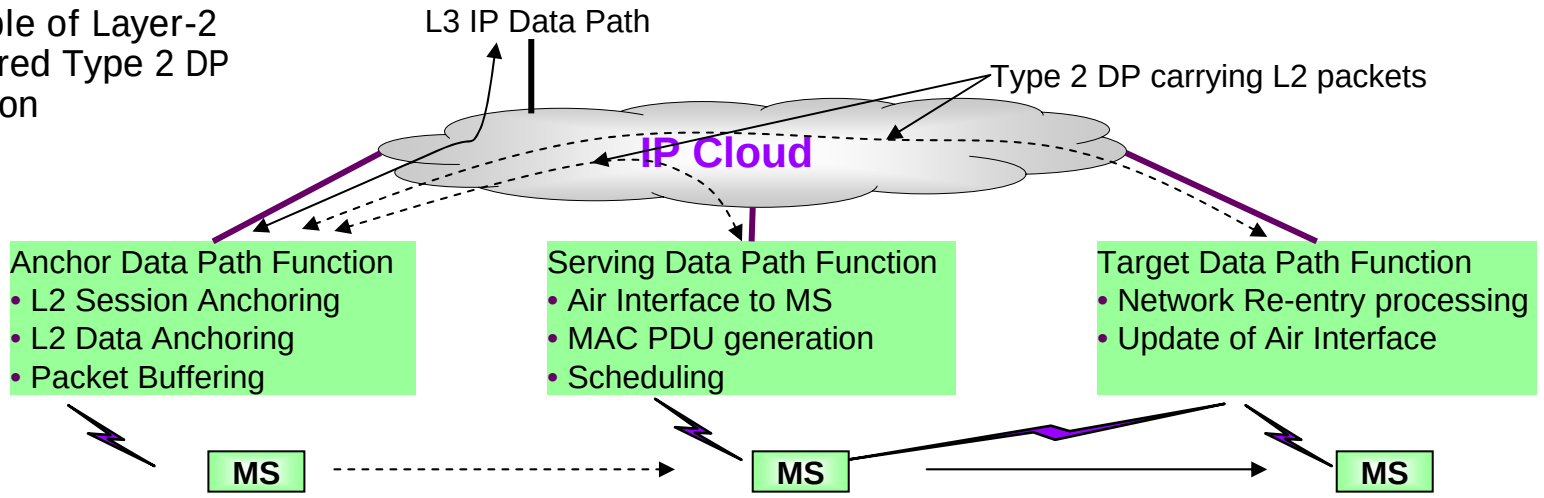
WiMAX Handoffs (1)

ASN Anchored Mobility (Micro Mobility)

– Mobility of an MS *not* involving a CoA update (i.e. a MIP re-registration) with the following functions defined

- ✓ Data Path (Bearer) Function: Manages the data path setup and includes procedures for data packet transmission between two functional entities (usually b/w BSs)
  - Type 1: IP or Eth forwarding over IETF L2 (Eth or MPLS) or L3 IP-in-IP or GRE...) transport
  - Type 2: *802.16E* MAC forwarding over IETF L2 (Eth or MPLS) or L3 IP-in-IP or GRE...) transport
- ✓ Handoff Function: Controls overall HO decision operation and signaling procedures related to HO
- ✓ Context Function: Addresses the exchanges required in order to setup any state or retrieve any state in network elements.

Example of Layer-2 Anchored Type 2 DP Function

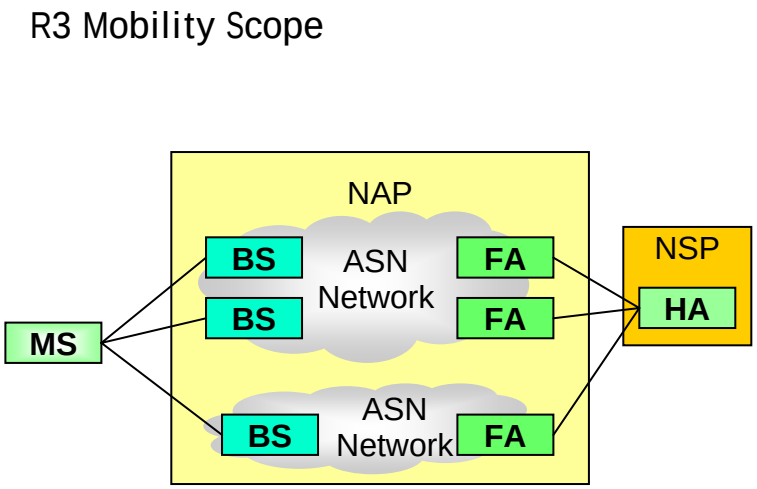


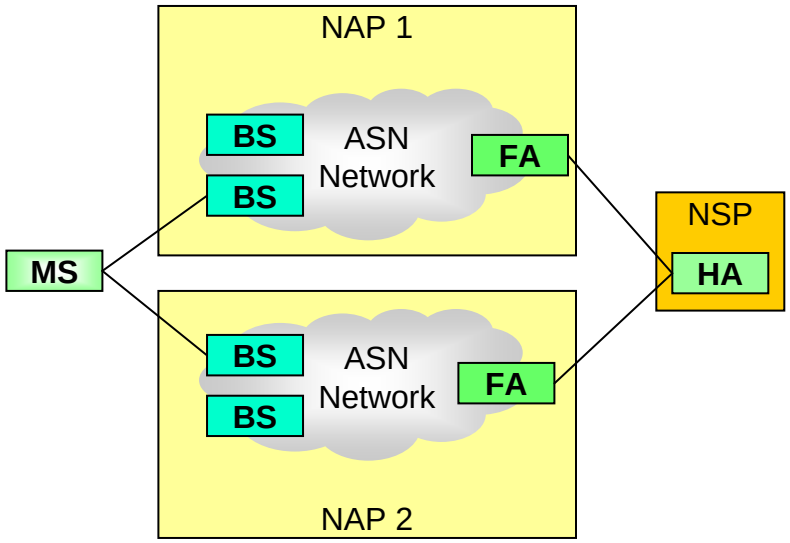
WiMAX Handoffs (2)

CSN Anchored Mobility (Macro Mobility)

- Mobile IP based macro mobility between the ASN and CSN across R3 reference point
- In case of IPv4 implies re-anchoring of FAs
- If FA serves multiple BSs then CSN anchored mobility umbrellas ASN anchored mobility (within the FA)
- Reverse Tunneling b/w ASN and CSN shall be supported
- For non-roaming HA must be in CSN, Roaming: HA either in V-NSP or H-NSP
- User subscription profile in H-CSN
- MIP client shall always operate as if in a foreign network
- P-MIP shall be supported in which case MS is unaware of CSN anchored mobility

R3 Mobility Scope





NAP: Network Access Provider
NSP: Network Service Provider

802.16e QoS Offerings

QoS Class	Type of traffic	Scheduling	Parameters
Unsolicited Grant Service (UGS)	Reatlime data services with fixed size data and period transmissions. E.g: T1/E1/VoIP w/o silence suppression	BS grants service periodically. SS contention and piggyback requests prohibited.	Unsloicited grant size, Grants per interval, Nominal grant interval, Tolerated grant jitter
Realtime Polling Services (rtPS)	Real time data with variable sized packets and with periodic transmission. E.g: MPEG	Periodic unicast request opportunities granted to SS. Contention/piggyback requests prohibited	Nominal polling interval, tolerated poll jitter, minimum reserved traffic rate
Enhanced RTPS (ertPS)	Real-time services with variable size data packets on a periodic basis, such as Voice over IP services with silence suppression.	Efficiency of both UGS and rtPS. Unicast grants in an unsolicited manner like in UGS, UGS allocations are fixed in size, ertPS allocations are dynamic. Piggyback.	Maximum Sustained Traffic Rate, the Minimum Reserved Traffic Rate, the Maximum Latency, and the Request/Transmission Policy.
Non-realtime polling services (nrtPS)	Delay tolerant with variable packet size and aperiodic transmission. E.g.: FTP	Periodic unicast request opportunities granted to SS but farther apart. Contention/piggyback requests allowed	Nominal polling interval, minimum reserved traffic rate, traffic **priority**
Best Effort (BE)	Handled on a space available basis	Contention/piggyback requests from SS to BS	Minimum reserved traffic rate, traffic **priority**

Parameters for QoS Provisioning

Service Flow Identifier	Minimum Reserved Traffic Rate
Connection ID	Minimum Tolerable Traffic Rate
Service Class Name	Service Flow Scheduling Type
QoS Parameter Set Type	Request/Transmission Policy
Traffic Priority	Tolerated Jitter
Maximum Sustained Traffic Rate	Maximum Latency
Maximum Traffic Burst	Fixed-length versus Variable-length SDU Indicator

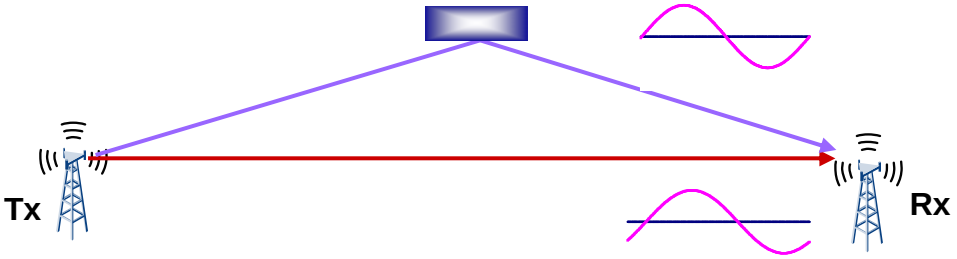
QoS parameters are of 3 types: {Provisioned, admitted and active} == QoS Parameter Set

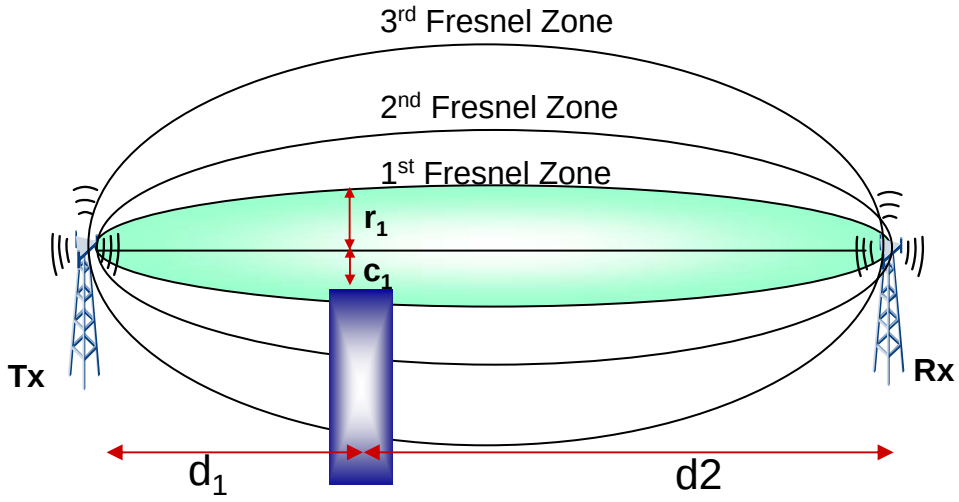
Summary

- Mobile WiMax is a forerunner to the 4G evolution and architecturally is well ahead of LTE and EvDO Rev C
- OFDM and the all IP architecture is what 4G systems are heading towards and WiMax is already there (and will converge with 16m)
- Mobile WiMax offers a scalable solution that accommodates users with varying capacity demands
- Mobile WiMax has superior QoS mechanisms built into the standards
- Mobile WiMax offers a a mobility evolution plan (SIP, P-MIP, MIP; IPv4, IPv6)
- Drawbacks:
  - WiMax has defined only TDD operations (government sector...)
  - Large bandwidths require large spectrum to tessellate (MiMo, AAS will alleviate)
  - Higher band of operation will shorten coverage (need to work on lower carriers...)

Appendix

So What is LoS?





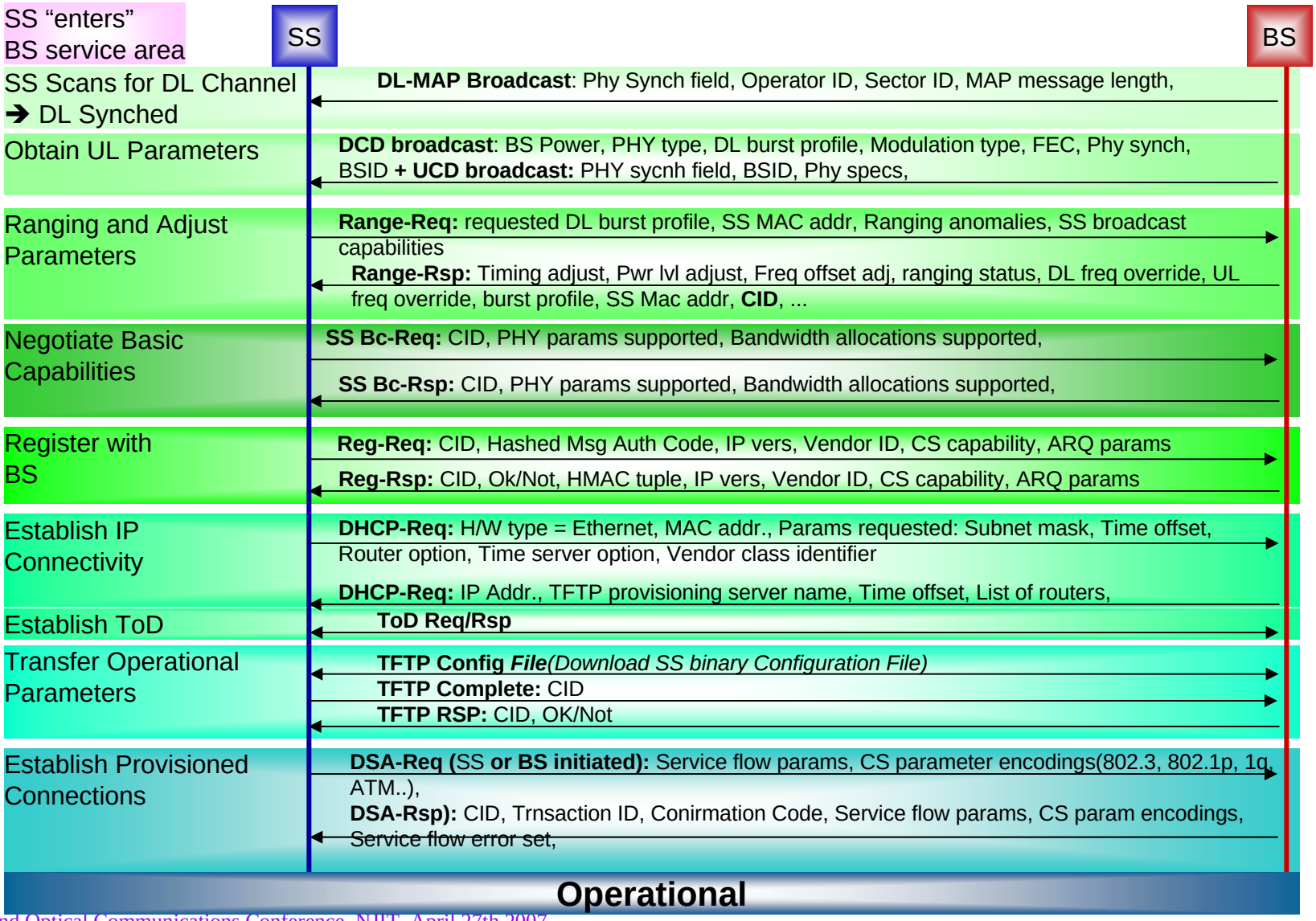
$$F_N = \sqrt{\frac{N \lambda d_1 d_2}{d_1 + d_2}}$$

Set N = 1, d_1, d_2 ➔ r_1

$c_1 \geq 0.6\ r_1$: LOS

$c_1 < 0.6\ r_1$: NLOS

System Operation



DSA: Dynamic Service Allocation

WiBro: *2.3 GHz* Portable Internet

Standardization and Commercialization:

- Korean standardization effort → TTA
- Named in April 2004: Wireless Broadband → WiBro
- Urban, High data rate >1 MBPS @ <60 km/hr
- Draft Completion/802.16e Harmonization: Q205, Field testing : 4Q05, Commercialization: 1Q06
- Korea Information Strategy Development Institute: ">10.5M users by 2010"

Source: ITU-APT Regional Seminar 2004

System Profile

- Standard activities: Radio (PHY, MAC, RRC), Services & Network, IPR Processing, I'natl coordination
- System Definition:
  - Frequency Reuse: 1
  - 2.3 GHz only
  - TDD-only with 5 m-sec framing
  - Service Coverage: 1 km
  - Mobility < 60 km/hr,
  - Spectral Efficiency: DL/UL = 6/2 (max) 2/1 (avg)
  - Throughput/user: DL/UL = 3/1 Mbps (max); 512/128 kbps (avg)
  - Throughput/sector: DL/UL = 18/6 MBPS
  - QPSK/16/64 QAM
  - Handoff time: 150 ms
  - 10 MHz B/W OFDMA
- Network elements: PSS (Personal SS), RAS (Radio Access Station), ACR (Access Control Router)
- ACR: Packet classification, header suppression, service flow management, traffic switching and integration, H/O management...