WiMax

ICTP-ITU School on Wireless Networking for Scientific Applications in Developing Countries

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Worldwide Interoperability for Microwave Access

The Worldwide Interoperability for Microwave Access Forum (WiMAX) was formed with the following objective:

Promote the wide-scale deployments of fixed broadband wireless access networks operating above 2 GHz by using a global standard and certifying the interoperability of products and technologies.

Designed from the Ground Up for Metropolitan Area Networks

In January 2003, the IEEE approved the 802.16a standard which covers frequency bands between 2 GHz and 11 GHz. This standard is an extension of the IEEE 802.16 standard for 10 – 66 GHz published in April 2002. These sub 11 GHz frequency ranges enable non line-of-sight performance, making the IEEE 802.16a standard the appropriate technology for last-mile applications where obstacles like trees and buildings are often present and where base stations may need to be unobtrusively mounted on the roofs of homes or buildings rather than towers on mountains.

Throughput, Scalability, QoS and Security

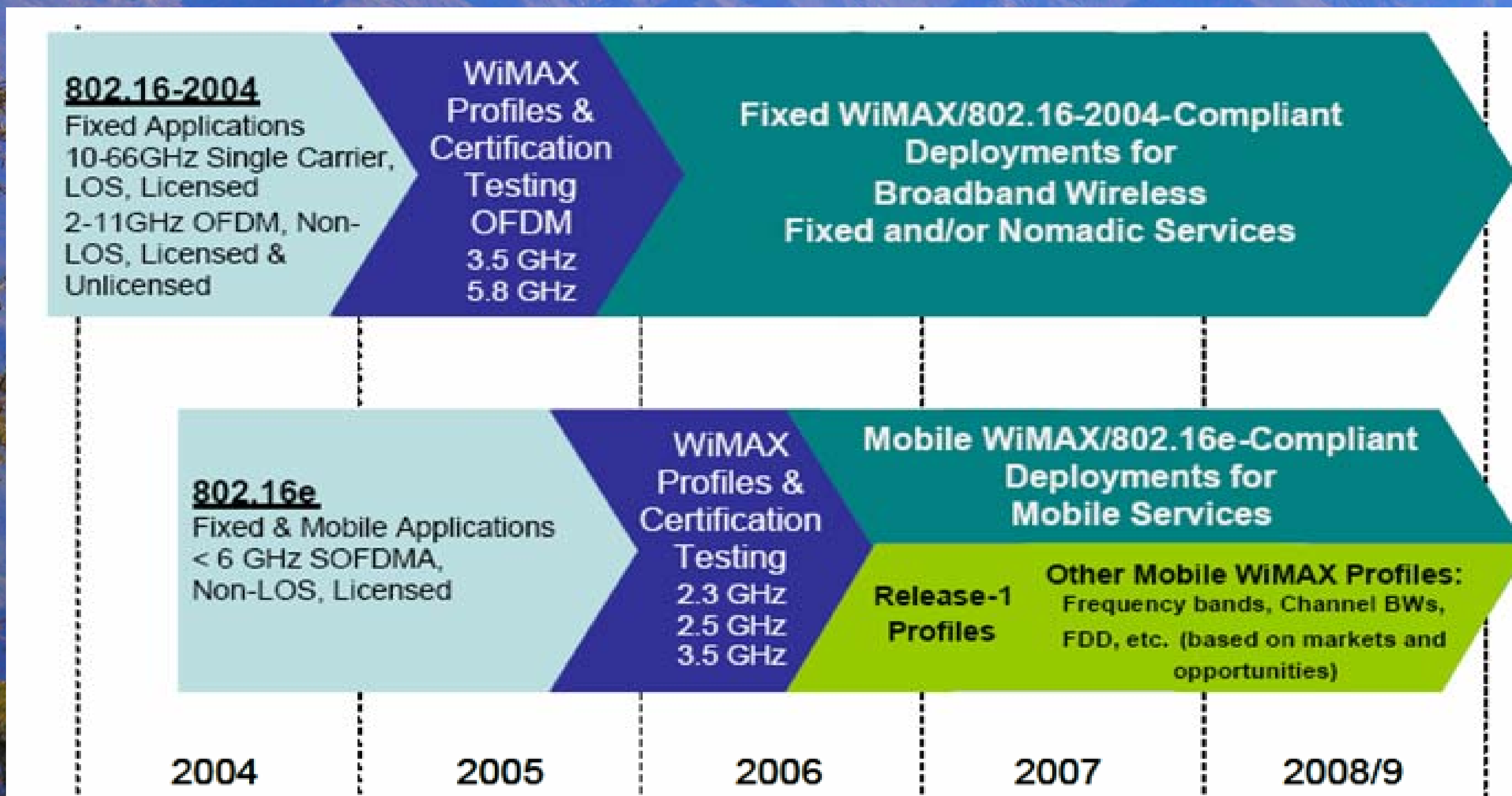
By using a robust modulation scheme, IEEE 802.16 delivers high throughput at long ranges with a high level of spectral efficiency that is also tolerant of signal reflections. Dynamic adaptive modulation allows the base station to tradeoff throughput for range. For example, if the base station cannot establish a robust link to a distant subscriber using the highest order modulation scheme, 64 QAM, the modulation order is reduced to 16 QAM or QPSK, which reduces throughput and increases effective range.

Evolution of Broadband Wireless

From Wireless LAN to Access, from Proprietary to Standard Solutions

'00 01	'02 '03	'04 '05
Proprietary Solutions ➡	**Proprietary** ➡	**Standard-based 802.16a Solutions**
▪ **Data rate**: 2-11 Mbps peak ▪ **Chip sets**: use 802.11 RF and PHY or proprietary ▪ **Based on** 802.11, 802.11b	▪ **Data rate**: 6-54 Mbps peak ▪ **Chip sets**: OEMs forced to develop their own Silicon - Some use 802.11a RF & PHY ▪ **Air interface**: OFDM & S-CDMA approached ▪ **Based on 802.11a**	▪ **Data rate**: up to 72 Mbps peak ▪ **Chip sets**: Volume Silicon supplier ▪ **Standards**: Interoperable, carrier-class ▪ **Based on 802.16**

WiMAX Roadmap



MAC design

- MAC protocol is connection oriented
  - Flows uniquely distinguished by the connection identifier
  - Allows for leaner headers
- MAC layer is 'protocol agnostic'
- Data is transmitted in variable length PDUs
- Network protocol are interfaced via 'Network convergence layers'
- Convergence layer operations include
  - Assigning packet flows to connections
  - Mapping of network protocol parameters to MAC parameters
  - Payload header suppresession etc.

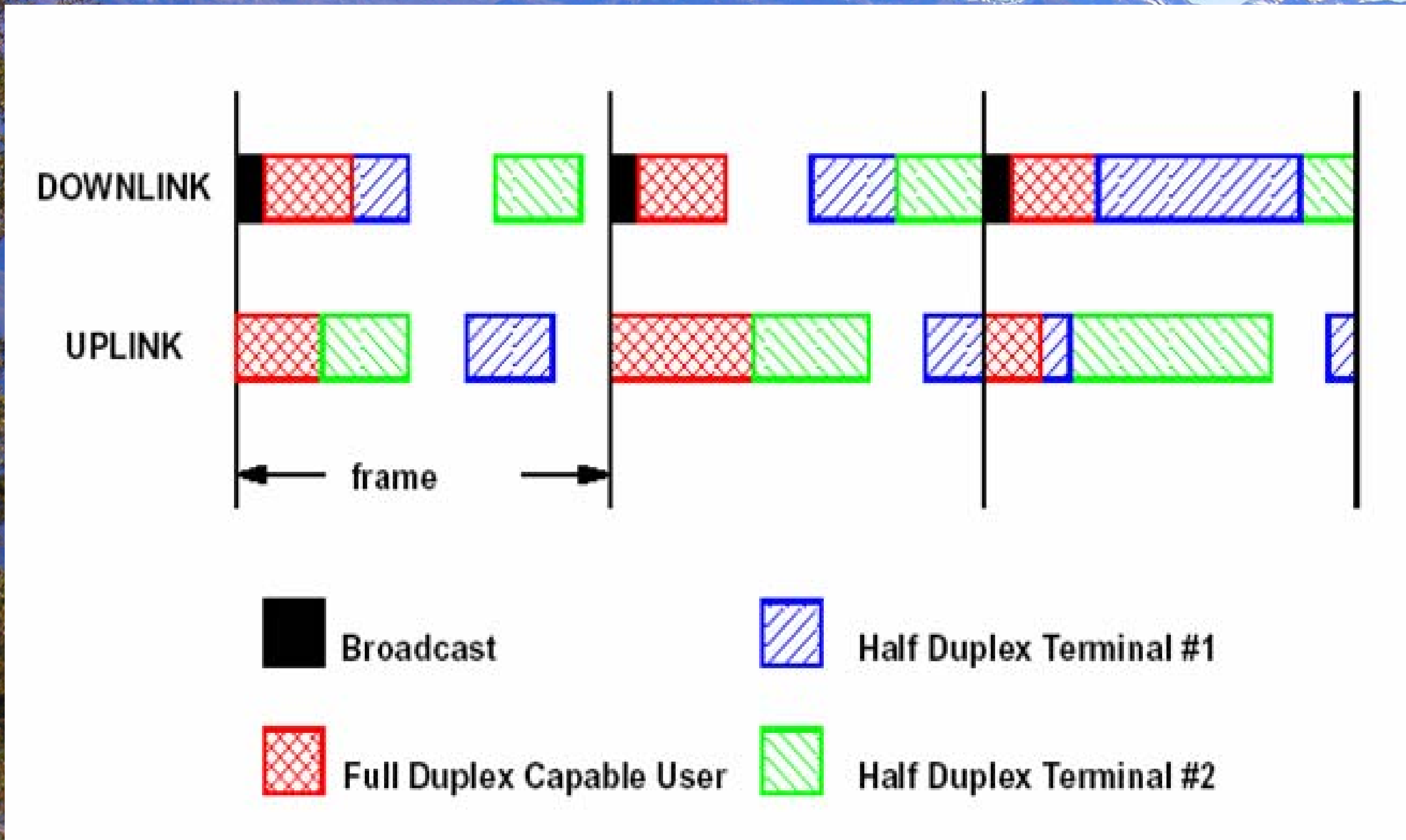
802.11 and 802.16

Other than the coverage and mobility, a key difference between the 802.11
and the 802.16 is the MAC. Unlike the 802.11, which supports 10’s of users, the
802.16 MAC is designed to support thousands of users using a grant-request
mechanism. The QoS support for voice and video is designed from ground up,
and differentiated service levels are also introduced

features

- scalable OFDMA
- variable channel configurations for multiuser diversity exploitation
- multiple-input multiple-output (MIMO) and advanced antenna systems
- advanced channel coding and hybrid-ARQ
- *0* QoS and service classes.

FDDD Frames


DOWNLINK
UPLINK
frame
Broadcast
Half Duplex Terminal #1
Full Duplex Capable User
Half Duplex Terminal #2

Frame structure

The scalable OFDMA supports both TDD and FDD frame structures, with the frame size ranging from 2 ms to 20 ms. Each frame is divided into four regions:

DL (downlink transmission),
TTG (transmit transition gap),
UL (uplink transmission),
RTG (receive transition gap).

The TTG and RTG provide guard periods against round trip delay in TDD operation as well **as** a ramping down period of the power amplifiers.

802.16 Standard: MAN Pt-Mp

- Base Station connected to the public Network
- Feeds Subscriber stations (SS)
  - Both Types of BS
  - SS Serves a building
- Multiple services with QoS

General Features

- Wideband Channels (20~28 MHz)
- Múltiple Access, TDM/TDMA
- Adaptive both Upstream and Downstream
- TDD, FDD o Half Duplex

Burst Adaptive Profile

- (Burst Profile)
  - Modulation and FEC
- Dynamically assigned according to the condtions of the link : Capacity and robustness interchange
- SS features are known at the time of the link

Duplexing Techniques

- Downlink a burst is provided at every SS
- Uplink every SS is provided with a variable length time slot

Polling

Polling is the mechanism by which the BS allocates the bandwidth to an individual SS or a group of SSs specifically for the purpose of making bandwidth requests. Two types of polling are defined: unicast polling and multicast/broadcast polling.

802.16: Specifically Designed for the Outdoor MAN

	802.11	802.16	Technical
Range	Sub ~ 50 m indoor . (add access points for greater coverage)	Up to 40 km Average cell size 7 – 12 km	802.16 PHY tolerates greater multi-path delay spread (reflections)
Coverage	Optimized for indoor, short range	NLOS performance Standard support for advanced antenna techniques	802.16: 256 OFDM (vs. 64 OFDM); adaptive modulation
Scalability	Channel bandwidth is wide (20 MHz) and fixed -> Cell planning is constrained	Channel b/w is flexible to accommodate both licensed and license exempt bands -> easier cell planning	Only 3 non-overlapping 802.11b channels; 5 for 802.11a 802.16: limited by available spectrum
Bit rate	2.7 bps/Hz peak Up to 54 Mbps in 20 MHz channel	3.6 bps/Hz peak Up to 50 Mbps in a 14 MHz channel	802.16: MAC efficiency constant with PHY rate increase
QoS	No QoS support -> 802.11e working to standardize	QoS built into MAC -> voice/ video, differentiated services possible	802.11: contention-based MAC (CSMA) 802.16: scheduled MAC

Quality of Service

The grant/request characteristics of the 802.16 Media Access Controller (MAC) enables an operator to simultaneously provide premium guaranteed levels of service to businesses such as T1-level service, and high-volume “best-effort” service to homes, similar to cable-level service, all within the same

base station service area cell.

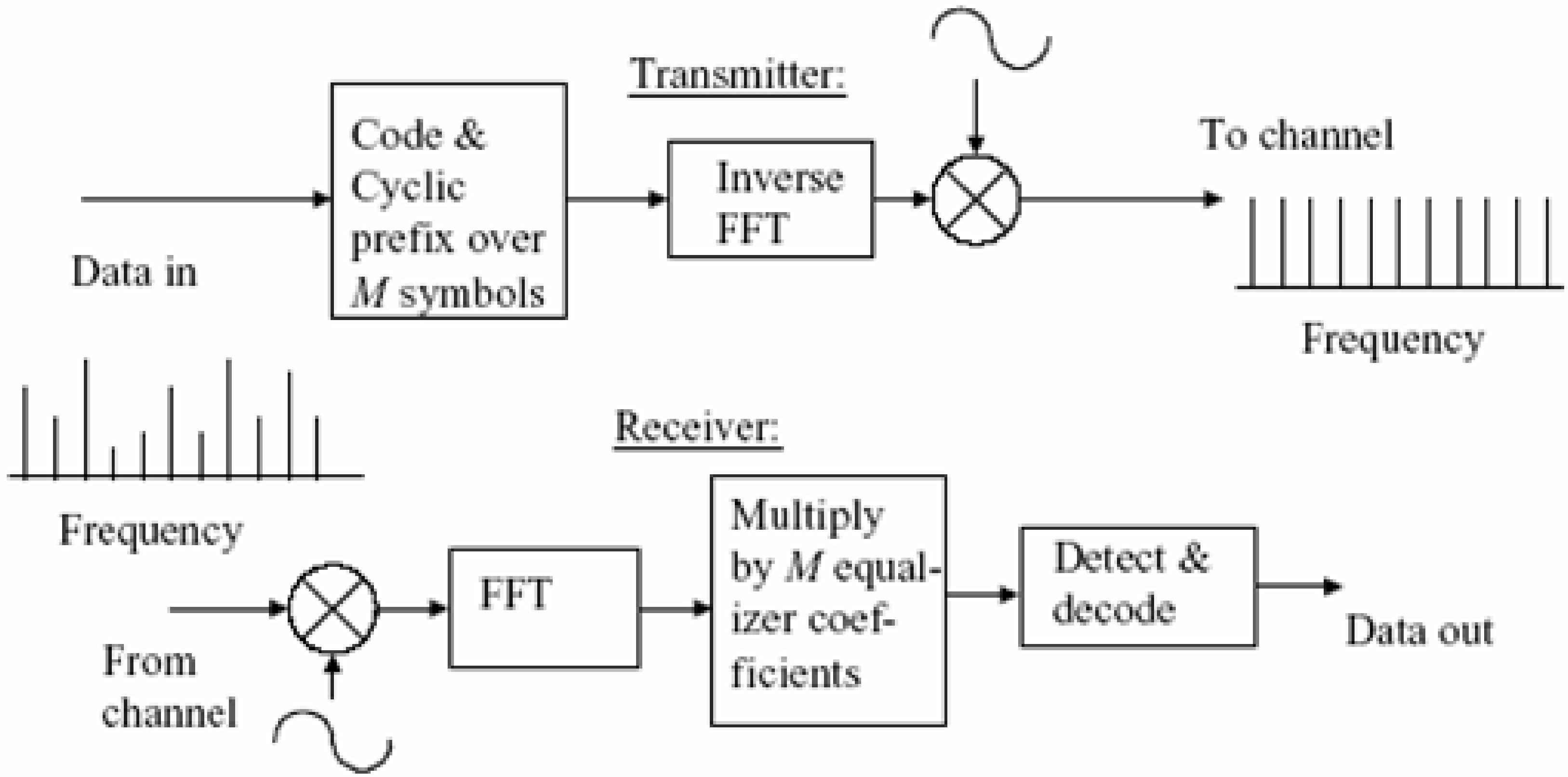
Coverage.

In addition to supporting a robust and dynamic modulation scheme, the IEEE 802.16 standard also supports technologies that increase coverage, including mesh topology and “smart antenna” techniques. As radio technology improves and costs drop, the ability to increase coverage and throughput by using multiple antennas to create “transmit” and/or “receive diversity” will greatly enhance coverage in extreme environments.

OFDM

he IEEE 802.16-2004 standard-specified OFDM as the transmission method for NLOS connections. The OFDM signal is made up of many orthogonal characters, and each individual carrier is digitally modulated with a relatively slow symbol rate. This method has distinct advantages in multipath propagation because, in comparison with the single carrier method at the same transmission rate, more time is needed to transmit a symbol. The BPSK, QPSK, 16QAM, and 64QAM modulation modes are used, and the modulation is adapted to the specific transmission requirements. Transmission rates of up to 75 Mbit/s are possible.

OFDM



- Process *M*-symbol blocks, with complexity ~ _ $M \log_2 M$ at both transmitter and receiver (*M* typically about 5 to 10 times the max. expected delay spread).
- Nonadaptive OFDM has same bit rate on each subcarrier.
- Coding over all subchannels is essential to overcome frequency-selective fades.

OFDM Flavors

In IEEE 802.16-2004, a distinction is made between two methods: OFDM and OFDMA. In the normal OFDM mode, 200 characters are available for data transmission and both TDD and FDD methods are used. In the OFDMA mode, various subscribers can be served simultaneously by assigning each subscriber a specific carrier group (subchannelization) that carries the data intended for that subscriber. The number of carriers can vary over a wide range depending on permutation zones and FFT base (128, 512, 1024, 2048).

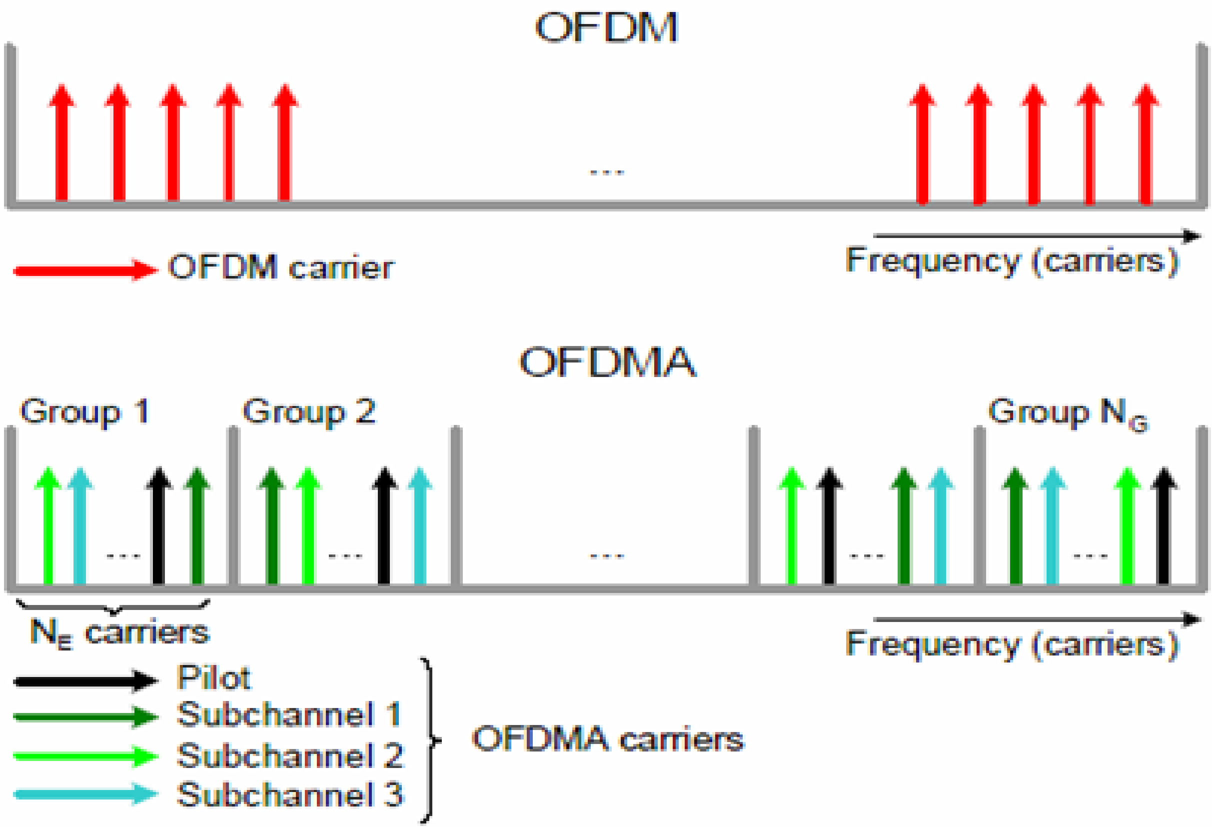
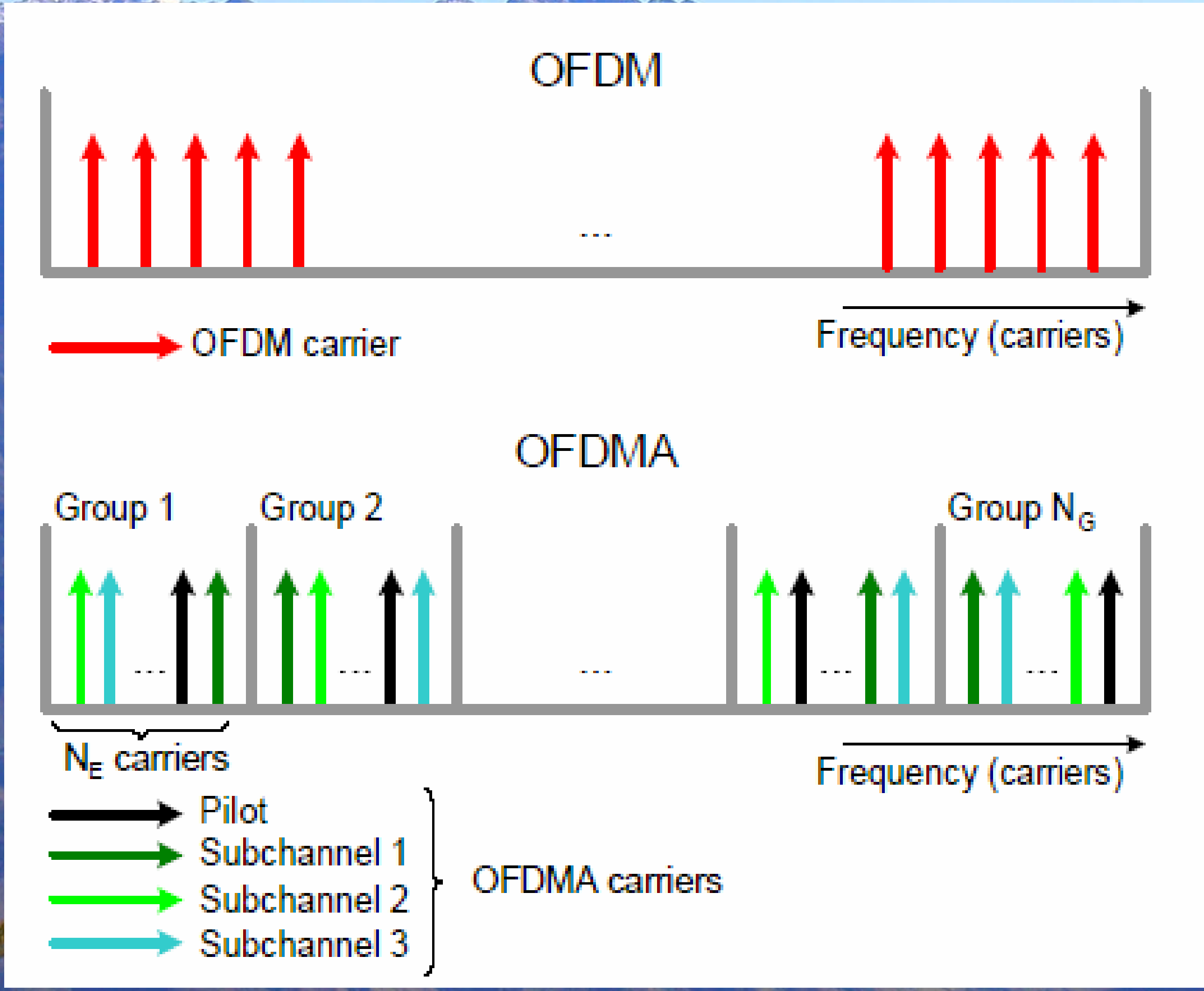


Figure 2. OFDM and OFDMA

In OFDM, all carriers are transmitted in parallel with the same amplitude. OFDMA divides the carrier space into N_G groups, each of which has N_E carriers, and into N_E sub-channels, each with one carrier per group. In OFDMA with 2048 carriers, for instance, this translates in N_E=32 and N_G= 48 in the downlink, and N_E=32 and N_G= 53 in the uplink, with the remaining carriers used for guard bands and pilots. Coding, modulation and amplitude are set separately for each sub-channel based on channel conditions to optimize the use of network resources.

OFDM Flavors



OFDMA Advantages

OFDMA supports multiple access, which allows user devices to transmit only through the sub-channel(s) allocated to them. In OFDMA with 2048 carriers and 32 sub-channels, if only one sub-channel is allocated to a device, all the transmit power will be concentrated in 1/32 of the spectrum available and may bring a 15 dB gain over OFDM

OFDMA Advantages

SOFDMA brings an additional advantage over OFDMA. It scales the size of the Fast

Fourier Transform (FFT) to the channel bandwidth in order to keep the carrier spacing

constant across different channel bandwidths

Constant carrier spacing results in a higher

spectrum efficiency in wide channels, and a cost reduction in narrow channels.

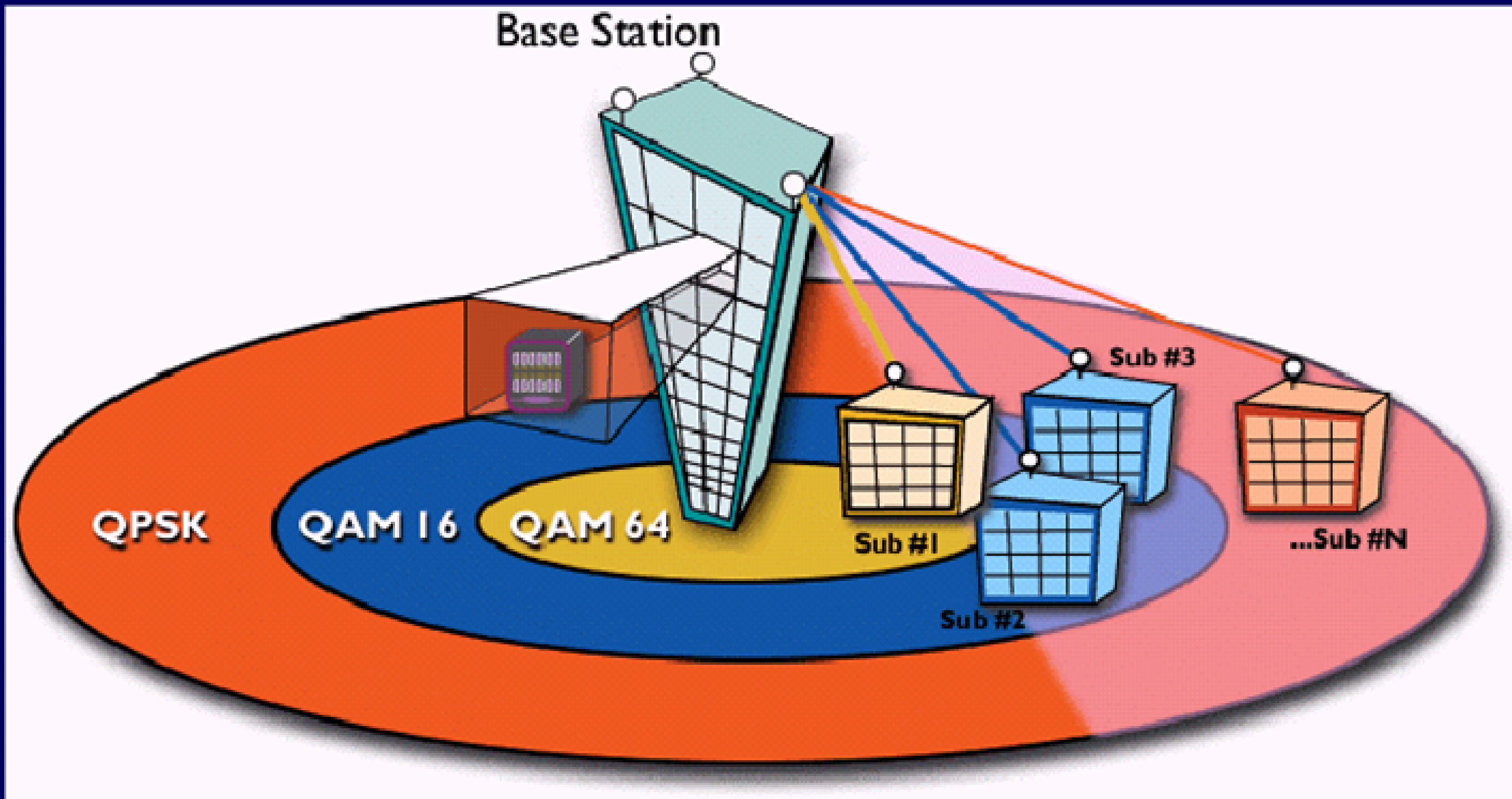
WiMAX OFDMA-TDD

OFDMA is the air interface adopted by the worldwide WiMAX and Korean WiBro standards **as** the technology for mobile broadband connectivity. OFDMA uses the multi-channel OFDM approach and provides subscriber access in the time domain (TDMA) and in the frequency domain (FDMA) and duplexes in time (TDD). Decisions as to which timeslot, subchannel, and power level to communicate over are determined by the intelligent **MAC** which seeks to maximize the SINR for every subscriber. This allows subscribers to operate at the maximum modulation rates obtainable given the radio frequency conditions at the subscriber location

RF propagation loss difference between ISM and UNII bands

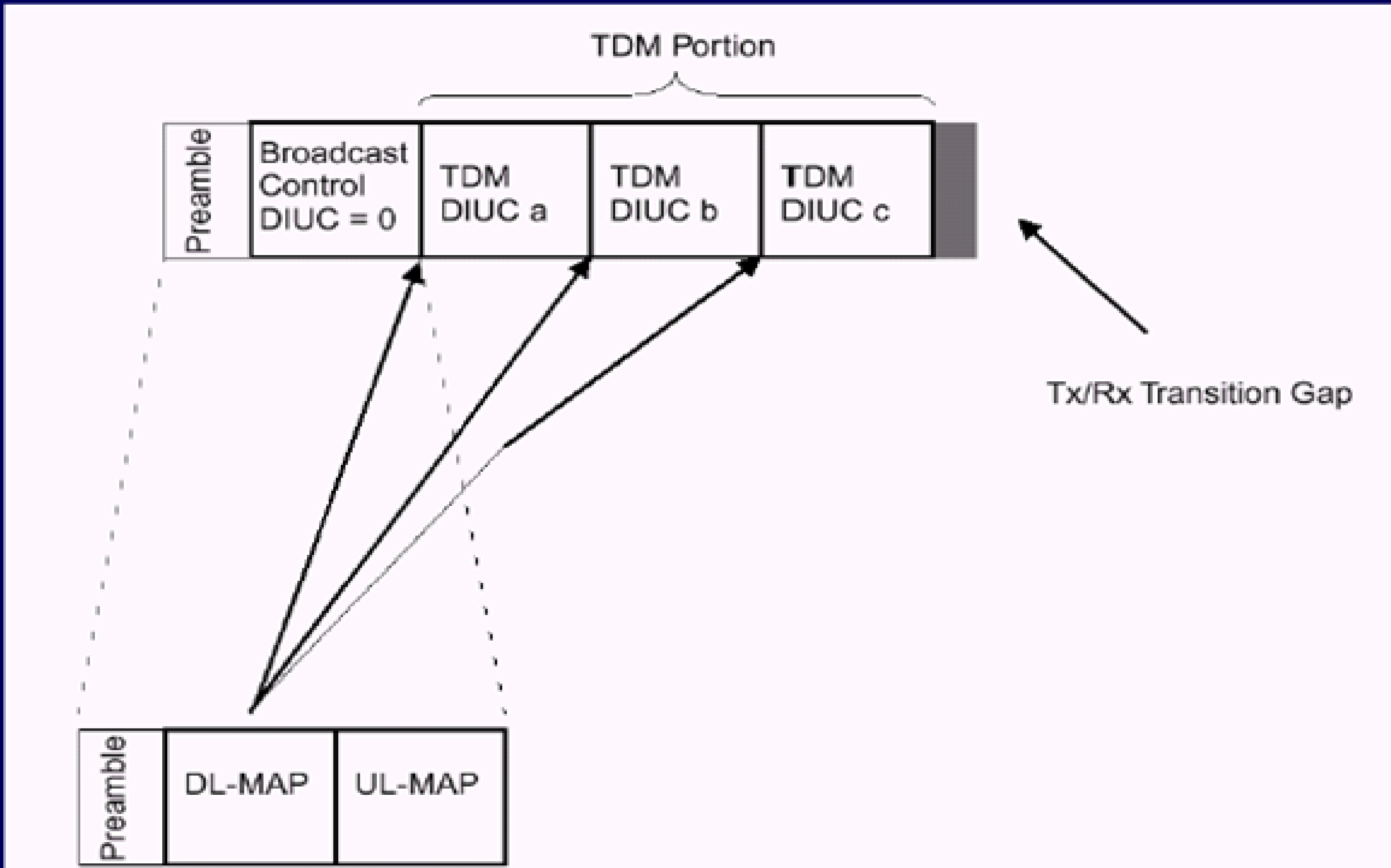
The essentially equivalent free space path loss exponents for the ISM and UNII bands indicate that the difference in loss will theoretically be about 7 dB in favor of the ISM band for all distances. measurements reveal that for a LOS link this difference is about 3~4 dB instead

Physical Layer Adaptivity



(burst-by-burst adaptivity not shown)

TDD



DIUC: Downlink Interval Usage Code

Transmission Rates

Channel Width (MHz)	Symbol Rate (Msym/s)	QPSK Bit Rate (Mbit/s)	16-QAM Bit Rate (Mbit/s)	64-QAM Bit Rate (Mbit/s)
20	16	32	64	96
25	20	40	80	120
28	22.4	44.8	89.6	134.4

QoS

Each connection in 802.16 is associated with a data service and each data service is associated with a set of QoS parameters that reflect the service requirement. The 802.16 standard defines four types of services: Unsolicited Grant Service (UGS), Real-time Polling Service (rtPS), Non-realtime Polling Service (nrtPS) and Best Effort (BE).

QoS

QoS Class	Data Type	Application
unsolicited grant service	periodic interval, fixed-sized packet; real time	T1/E1; VoIP with silience suppression
unsolicited grant service	periodic interval; variable-sized packet; real time data stream	video telephony; interactive video game; VoD/AoD
real time polling service	variable-sized packet; delay-tolerant data stream; minimum data rate	high speed file transfer; MMS; Web browsing
best effort service	no minimum service level	FTP, WWW, E-mail

Extensions for < 11 GHz

- OFDM Support
- ARQ
- 802.16b Mesh Mode
  - Optional Topology
  - Subscriber to Subscriber Communication

BWA Standards Evolution

Prestandard

2003

AN-50: 2002
Most Promising Network Transport Technology

802.16a

2004

AN-100: 2004
Backbone/Edge Networking Equipment

802.16d

2005

802.16e

2006

AN100U: 2005
Runner-Up" for the "Most Promising New Technologies in 2005/Backbone, Edge Networking Equipment"

Market development and emerging needs will drive transitions and application of standards.

BWA Services Evolution

Fixed Outdoor
2004/05

Fixed Indoor
2005/06

Portability
2005/06

Mobility
2007/08

Each transition has effect on the network, client equipment, and airlink technology

Some WiMAX CHANNEL PLANS

Profile	Band	Channel BW*	Duplex	License
700*	Upper 700 MHz Band	5 MHz	TDD	Yes
2.3T1*	WCS Band	5 MHz	TDD	Yes
2.5T1	MDS (BRS-EBS Band)	5 MHz	TDD	Yes
3.5T1	3.5 GHz Band	7 MHz	TDD	Yes
3.5F1	3.5 GHz Band	3.5 MHz	FDD	Yes
5.8T1	5.8 GHz ISM/UNII	10 MHz	TDD	No

* **future potential WiMAX bands & channels**

Example: Redline

Redline’s 802.16 Systems are Designed for High Performance in Real World Environments

RANGE

Range: beyond 30 mi/50 km (QPSK)

256OFDM for Non-Line-of -Sight operation: reflective, refractive & diffractive

High Spectral Efficiency –

5 bps/Hz Air Rate, 2.7 – 3.3 bps/Hz Ethernet Data Rate

CAPACITY

High data rate – Ethernet

37.5 - 45.5 Mbps

Over air rate –

~70 Mbps

Can be configured for one-way latency of <4 msec

RELIABILITY

CIR/PIR support

Standards based interface (802.1p/Q)

Dynamic Adaptive Modulation (DAM)

Forward error correction, Time Division Duplex (TDD)

Encryption for enhanced security (DES/AES)

256 OFDM for robust NLOS

VERSATILITY

Supports TDM transport (T1 & E1)

Operates on Licensed and Unlicensed Bands

PTP and PMP modes

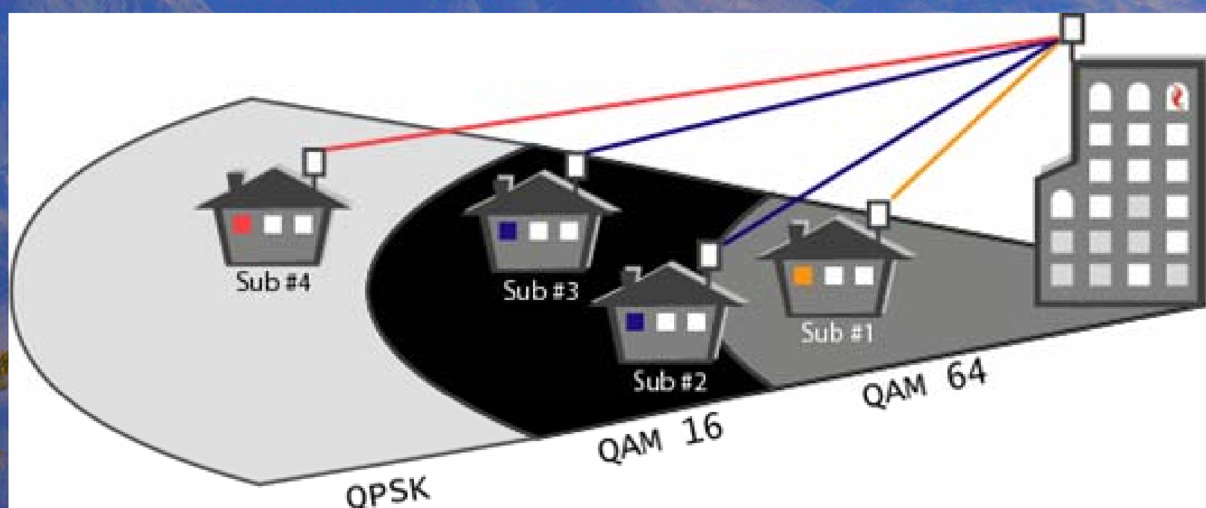
Easy deployment – minutes vs. hours or days

Redline's AN-100

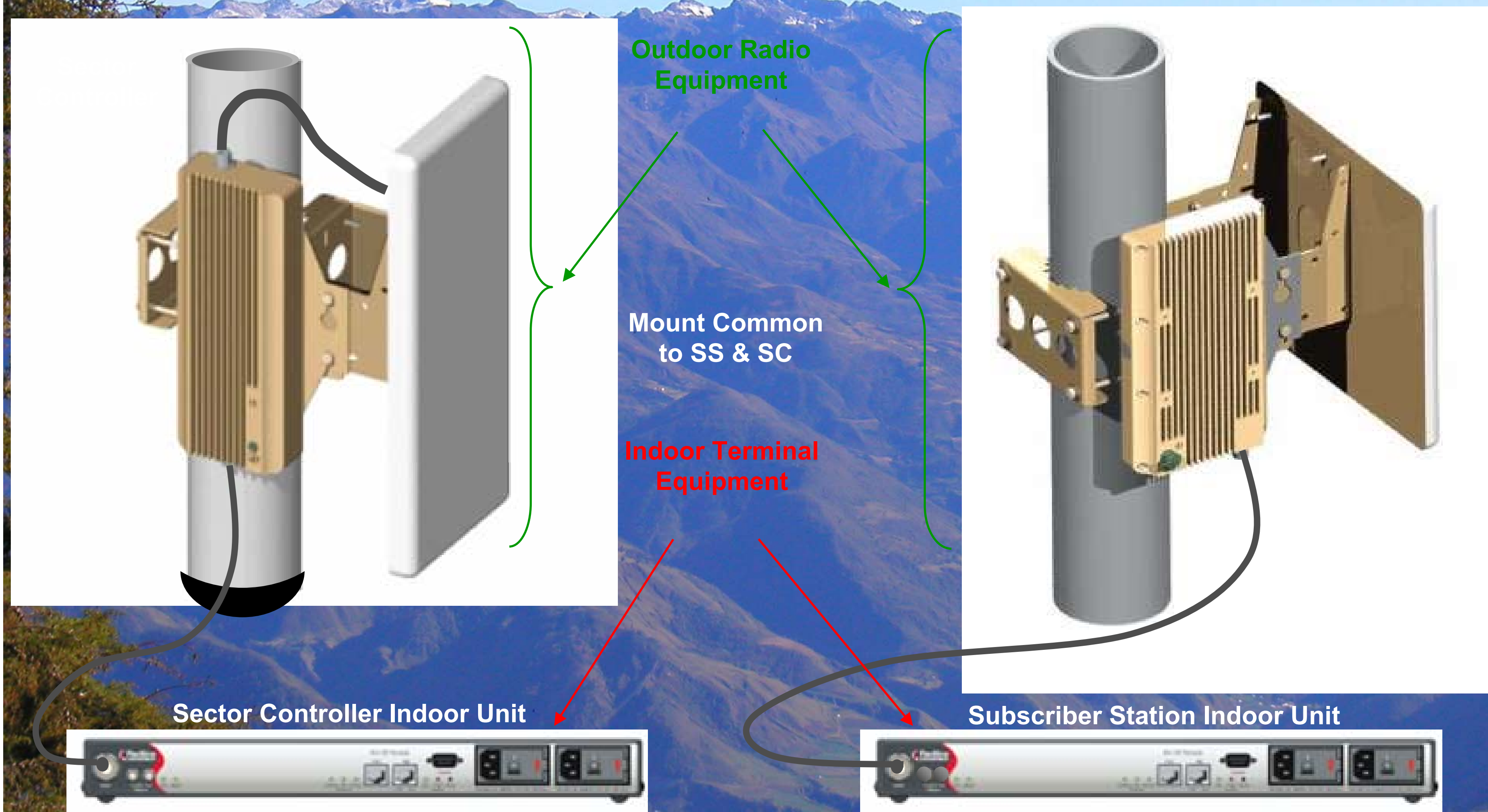
- Worlds First Standards Compliant <u>Complete</u> WirelessMAN Solution
  - First Shipping IEEE 802.16a Product (Feb 2004)
  - Mature Product - Over 1yr in Operation
- Winner of 2004 SUPER*Quest* Award
  - "Backbone/Edge Networking Equipment" category
- Delivers…
  - Ability to Guarantee Multiple QoS Levels
  - Low Latency, High Capacity (14MHz Channel)

Modulation schemes
(Reach & Rate Data – Field Proven)

7 MHz Channel Estimate	PMP Link Budget	PTP Link Budget
64 QAM/ -75 dBm 18.7 Mbps 22.5 Mbps	.6 mile NLOS 3 miles OLOS 5 miles LOS	1 mile NLOS 8 miles OLOS 12 miles LOS
16QAM/ -82 dBm 12.4 Mbps 15 Mbps	.8 mile NLOS 5 miles OLOS 8.5 miles LOS	1.5 mile NLOS 12 miles OLOS 17 miles LOS
QPSK/ -89 dBm 6.2 Mbps 7.5 Mbps	1.1 mile NLOS 9 miles OLOS 14 miles LOS	2.4 mile NLOS 18 miles OLOS 24.5 miles LOS



AN-100 SC And SS System Components



AN-100C

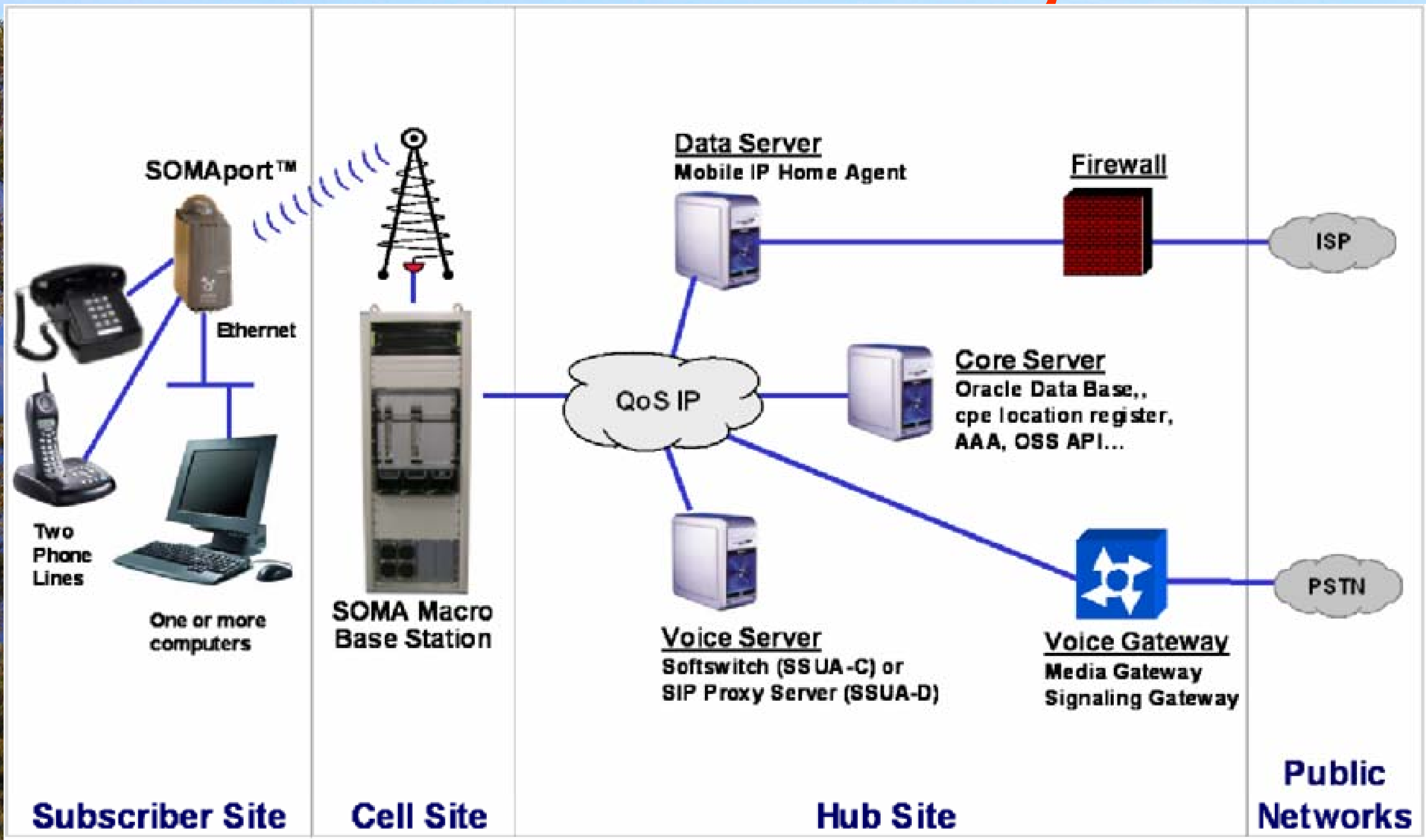
AN-100S

Split IF Design (Radio ODU, Terminal IDU)

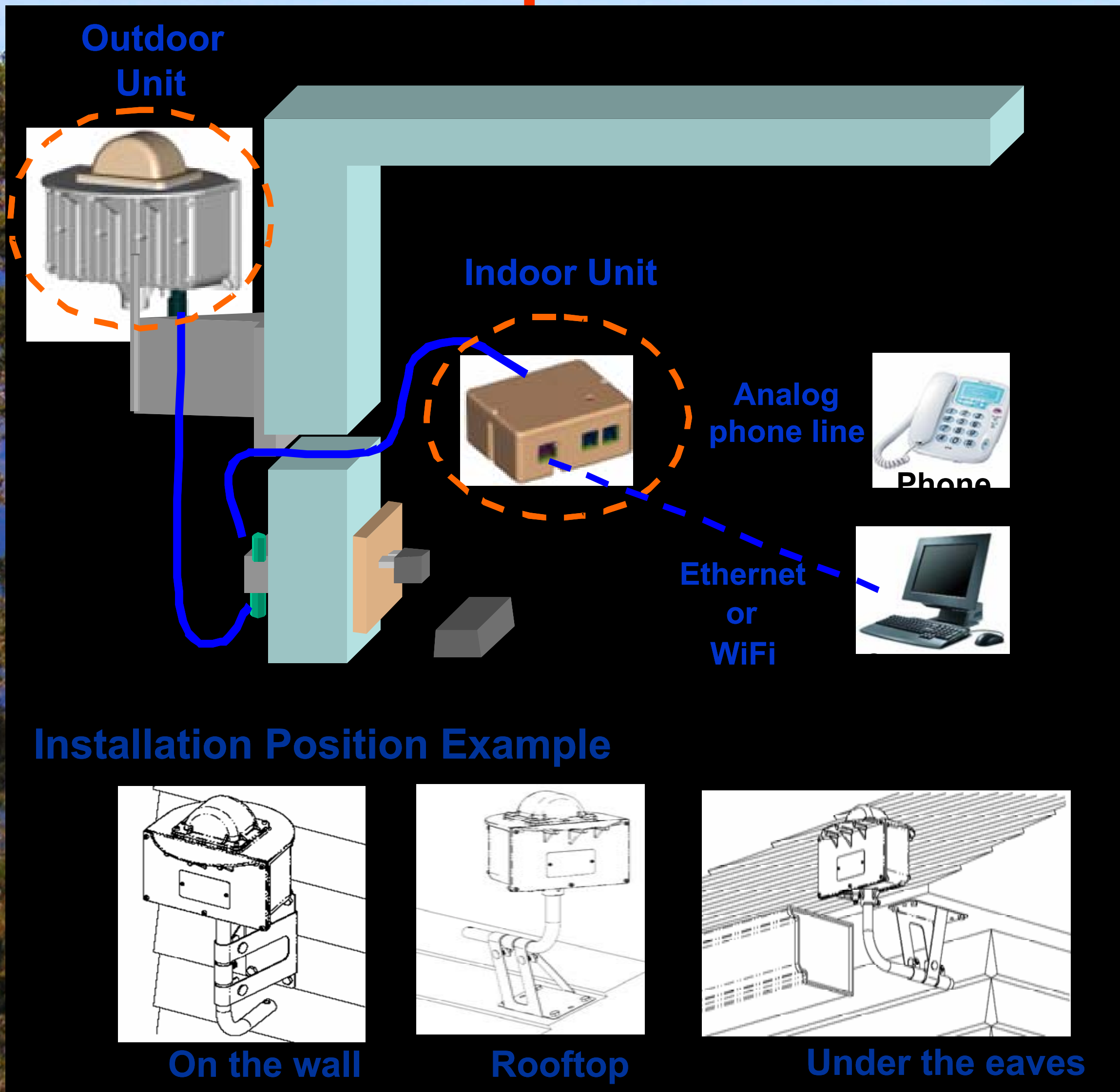
NLOS

Example of NLOS capability

SOMA Broadband Wireless Access and Services System



SOMAport 310 Outdoor Subscriber Unit



- Sanyo design
- Outdoor CPE
  - Waterproof
  - Heat/Cold protection
  - RAN specification is same as an indoor type CPE (SOMAport 300)
- Purpose
  - Range extension for subscribers outside normal indoor coverage radius (~doubles radius)
  - Remediation for poor performance when indoor subscriber unit is in a coverage shadow

Security

The security sublayer provides authentication, security key exchange and encryption. Currently, 802.16 the provides two component protocols:

- an encapsulation protocol which encrypts the packet data during communication. The protocol defines the pairing of data encryption and authentication algorithms and the rules for applying these algorithms to MAC PDUs.
- a key management protocol which provides the secure keying data distribution from BS to SS. Through this protocol, the BS and SS synchronize the keying data. The BS can also use this protocol to enforce conditional access to network services.