無線網路多媒體系統
Wireless Multimedia System

Dr. Eric Hsiaokuang Wu
WiMAX & 802.16

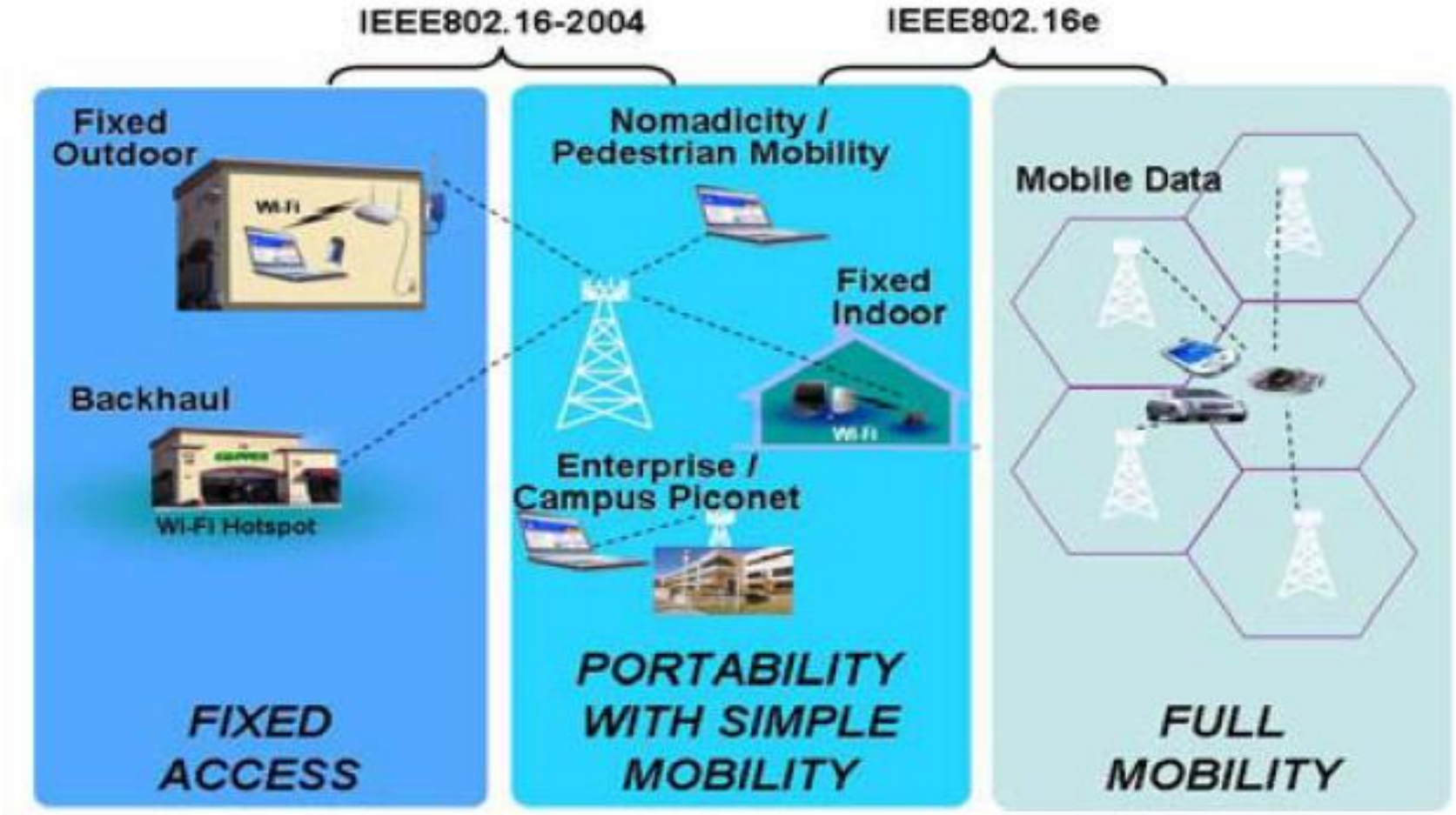
Outline

- Introduction
- OFDM/OFDMA
- Fixed WiMAX
- Mobile WiMAX
- New Generation WiMAX

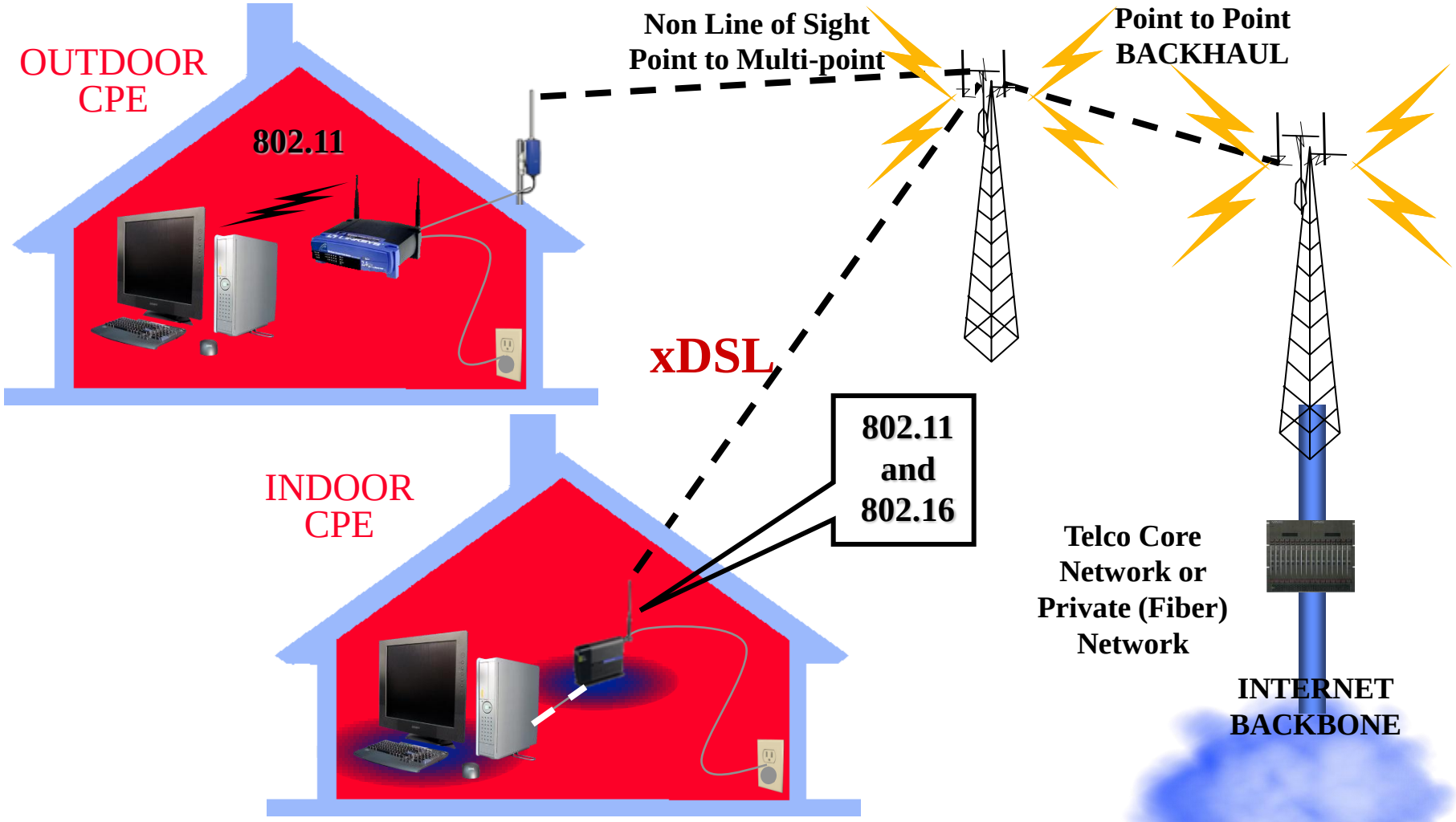
Categories of Wireless Networks

	Personal Area Network (PAN)	Local Area Network (LAN)	Metropolitan Area Network (MAN)	Wide Area Network (WAN)
Technology	Bluetooth Ultra-wideband (UWB)	802.11b 802.11a 802.11g a.k.a. Wi-Fi	802.16 802.16a 802.16e a.k.a. WiMAX	GSM GPRS CDMA 2.5G 3.5G
Data rates	Medium data rates 1Mbps to 2Mbps	High data rates 11Mbps to 54Mbps	Very high data rates Quality of service up to 268Mbps	Low to medium data rates 10Kbps to 2.4Mbps
Range	Very short range 3m (~10 feet)	Short range 100m (~300 feet)	Medium range 50km (~31 miles)	Long range Global
Connectivity	Notebook to PC to peripherals Devices to systems	Computer to computer and the Internet	LAN or computer to high-speed wire line Internet	Smart phones and PDAs to WANs and the Internet

Applications of 802.16 Standards



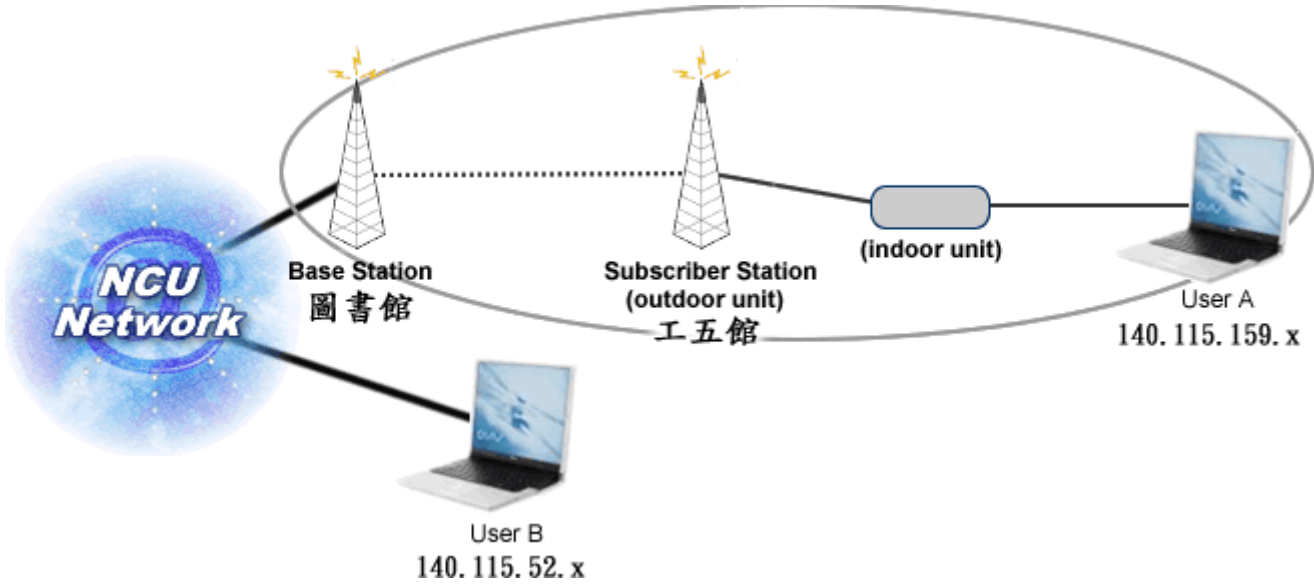
WiMAX Consumer Last Mile

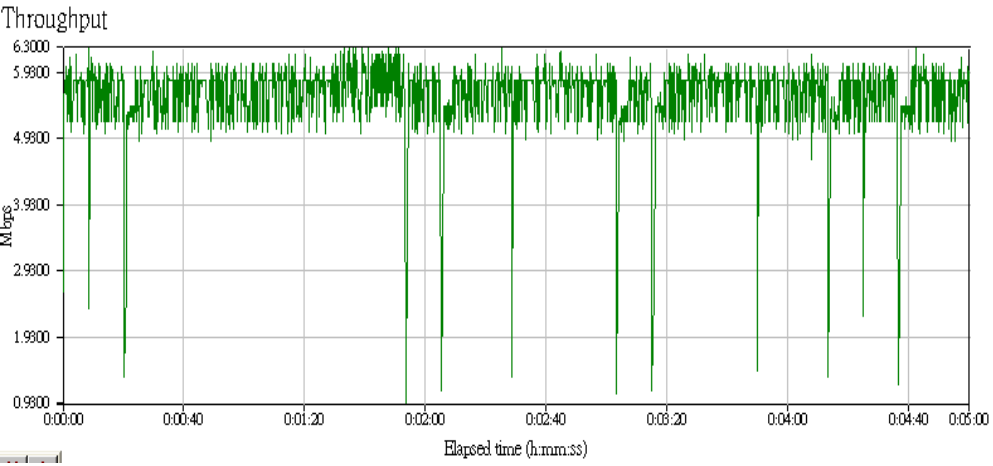


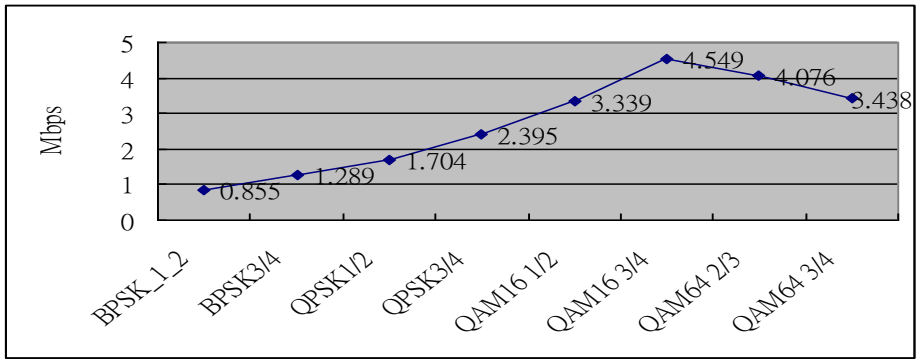
Ref: Margaret LaBrecque , "Enabling Deployments through Standards and Certification," WiMax, 2003

WiMAX 802.16


alvarion
We're on your wavelength.


NCU Network
Base Station
圖書館
Subscriber Station
(outdoor unit)
工五館
(indoor unit)
User A
140. 115. 159. x
User B
140. 115. 52. x


Throughput
6.3000
5.9800
4.9800
3.9800
2.9800
1.9800
0.9800
Mbps
0:00:00
0:00:40
0:01:20
0:02:00
0:02:40
0:03:20
0:04:00
0:04:40
0:05:00
Elapsed time (h:mm:ss)


Mbps
5
4
3
2
1
0
0.855
1.289
1.704
2.395
3.339
4.549
4.076
3.438
BPSK_1_2
BPSK3/4
QPSK1/2
QPSK3/4
QAM16 1/2
QAM16 3/4
QAM64 2/3
QAM64 3/4

WiMAX Nomadic and Portable

Non Line of Sight
Point to Multi-point

802.16

Line of Sight
BACKHAUL

802.16

802.16e PC
Card

Laptop Connected
Through 802.16

SEEKS BEST
CONNECTION

2 to 3 Kilometers Away

Telco Core
Network or
Private (Fiber)
Network

INTERNET
BACKBONE

Ref: Margaret LaBrecque , "Enabling Deployments through Standards and Certification," WiMax, 2003

WiMAX Usage

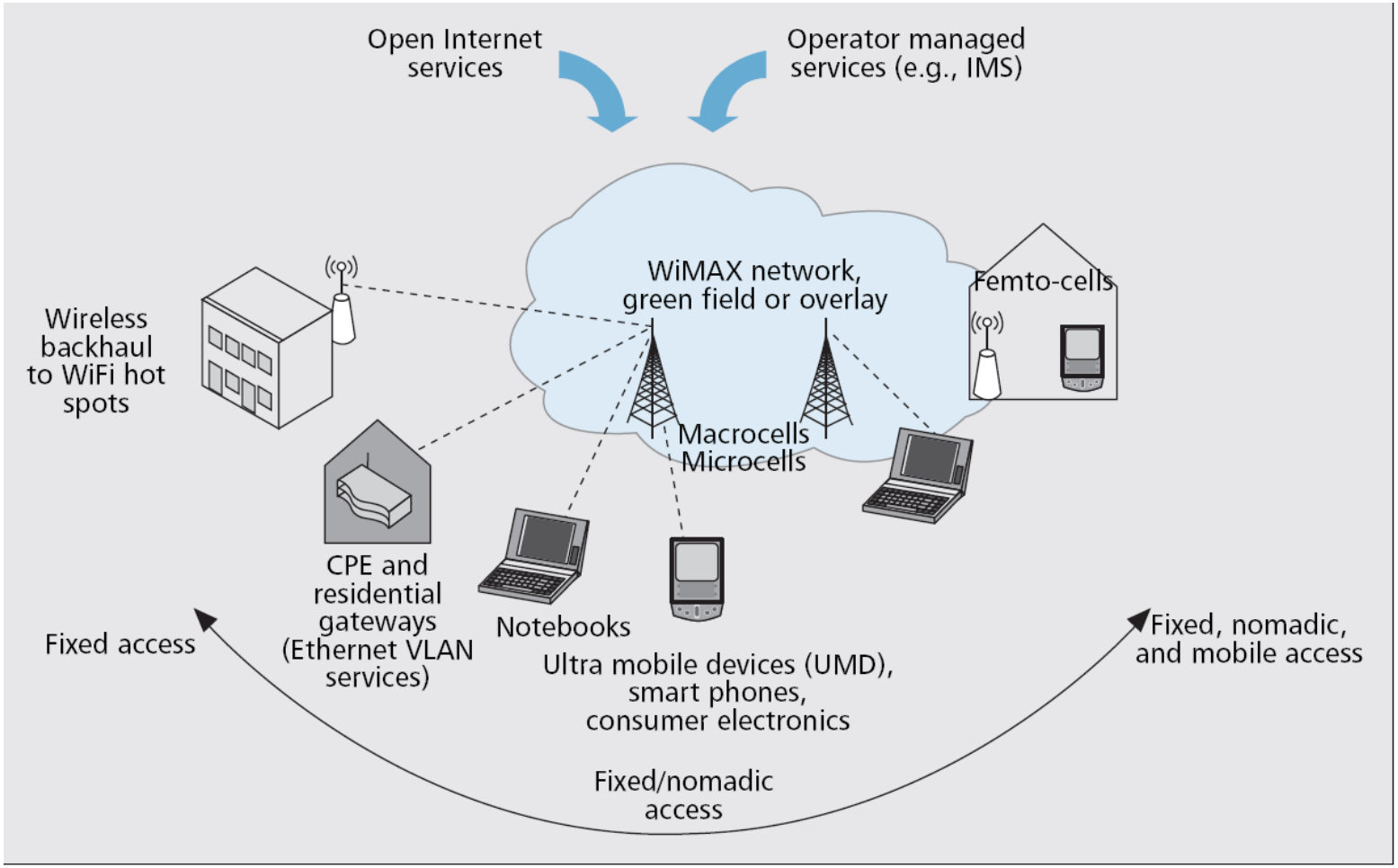


Figure 1. *Mobile WiMAX enabling a variety of usage models in the same network.*

Mobile WiMAX Roadmap

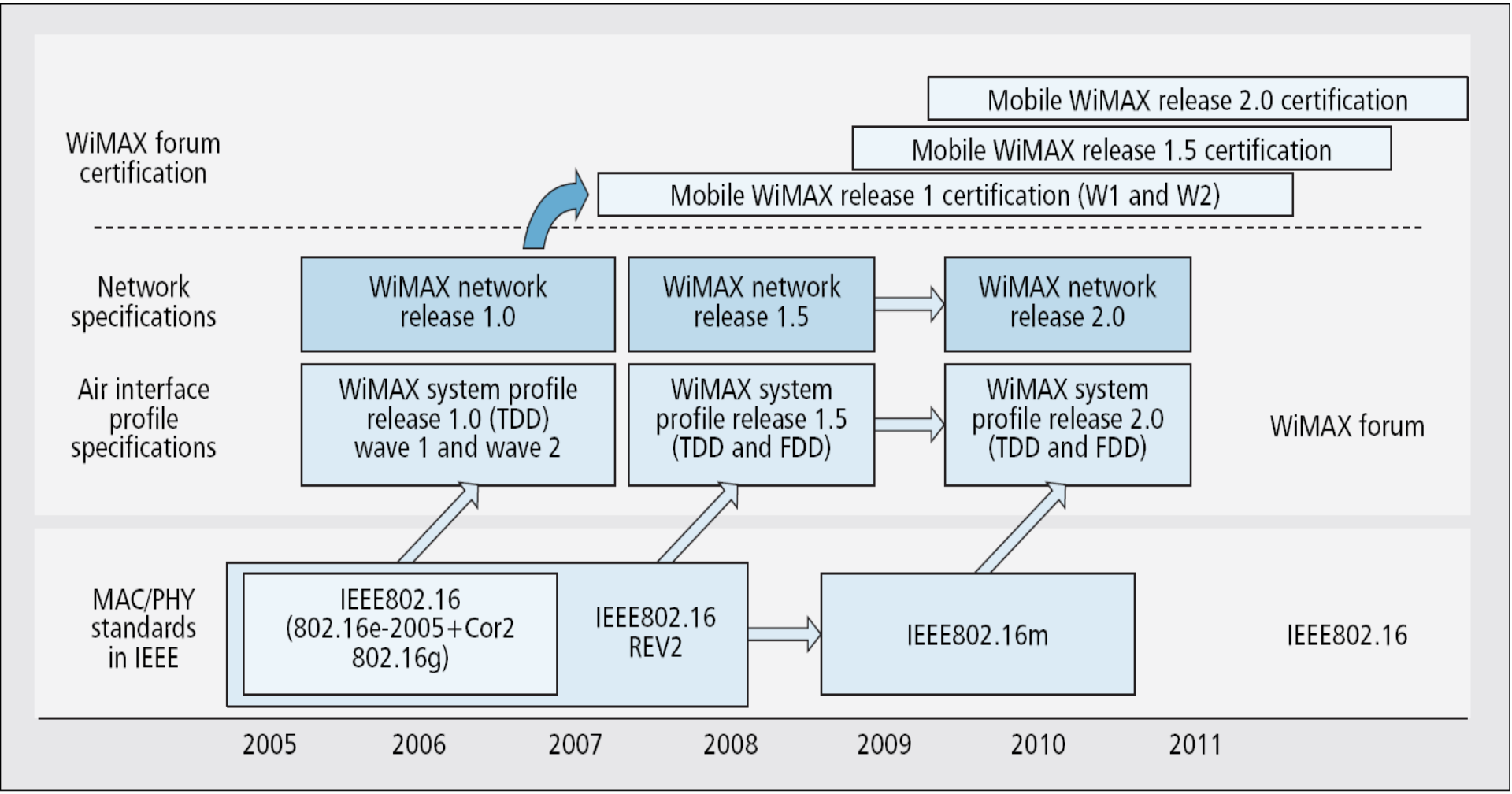


Figure 2. *Mobile WiMAX technology and network evolution roadmap.*

Why WiMAX?

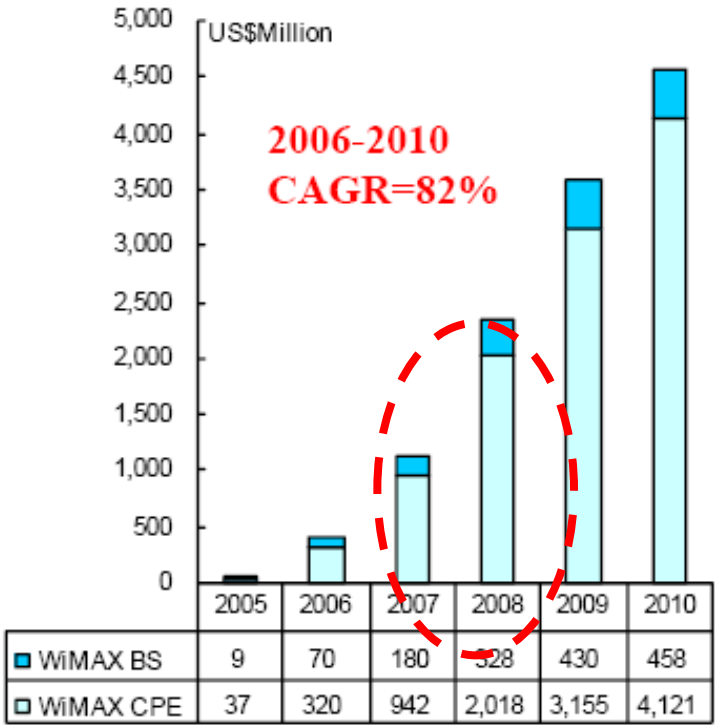
Even having Sprint win, WiMAX is still a mid-term to long-term technology

- 美國Sprint NextTel的WiMAX Trial
  - 使用技術：802.16e
  - Trial起始時間：2005年7月(持續18個月
  - 使用頻段：2.5GHz
  - 投資金額：已累計$14 million
  - 服務對象：家庭用户與企業用户
  - 服務速度：最快可達5Mbps
  - 設備提供商：Motorola, Samsung

Sprint已推出CDMA2000及CDMA 1xEV-DO網路。除了WiMAX以外，並同時測試UMTS TDD 及Flash-OFDM技術，爲未來4G網路做準備。

Source：Sprint Nextel、BellSouth，MIC整理，2006年6月

- 全球WiMAX設備市場規模預測

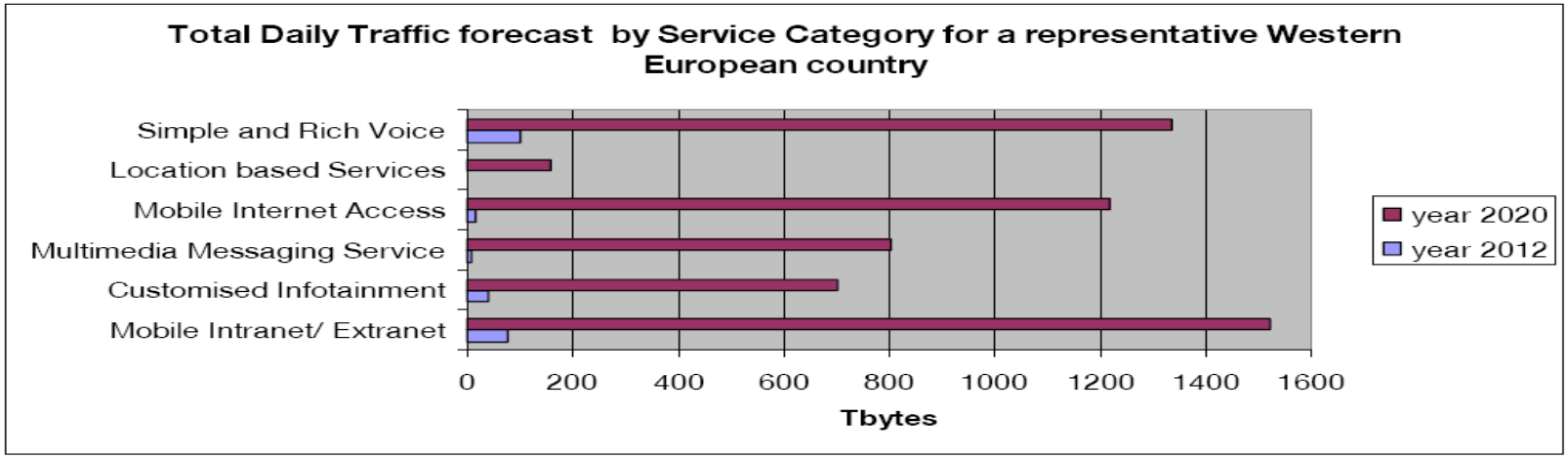


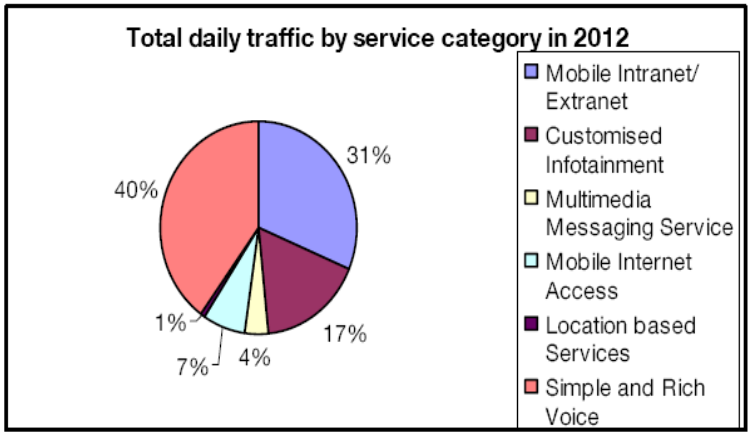
	2005	2006	2007	2008	2009	2010
WiMAX BS	9	70	180	328	430	458
WiMAX CPE	37	320	942	2,018	3,155	4,121

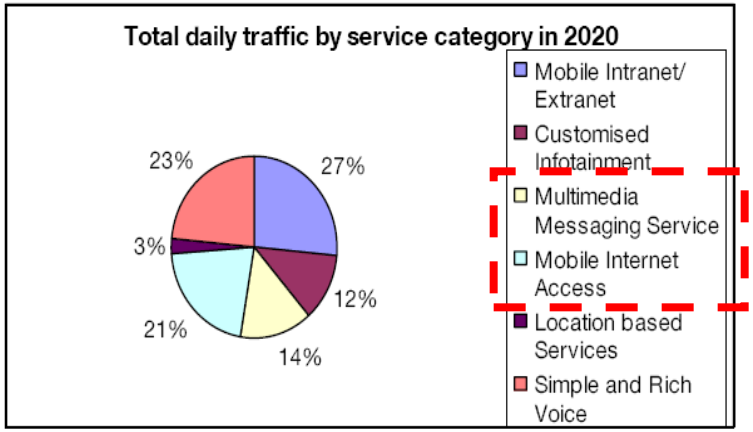
Source：MIC，2006年6月

Driving Force of 4G

- Total daily traffic in 2012 will be double up to 250 TB, and will be 5750 TB in 2020 (i.e. Total traffic/subscriber/day of 495 Mbytes) in Western Europe

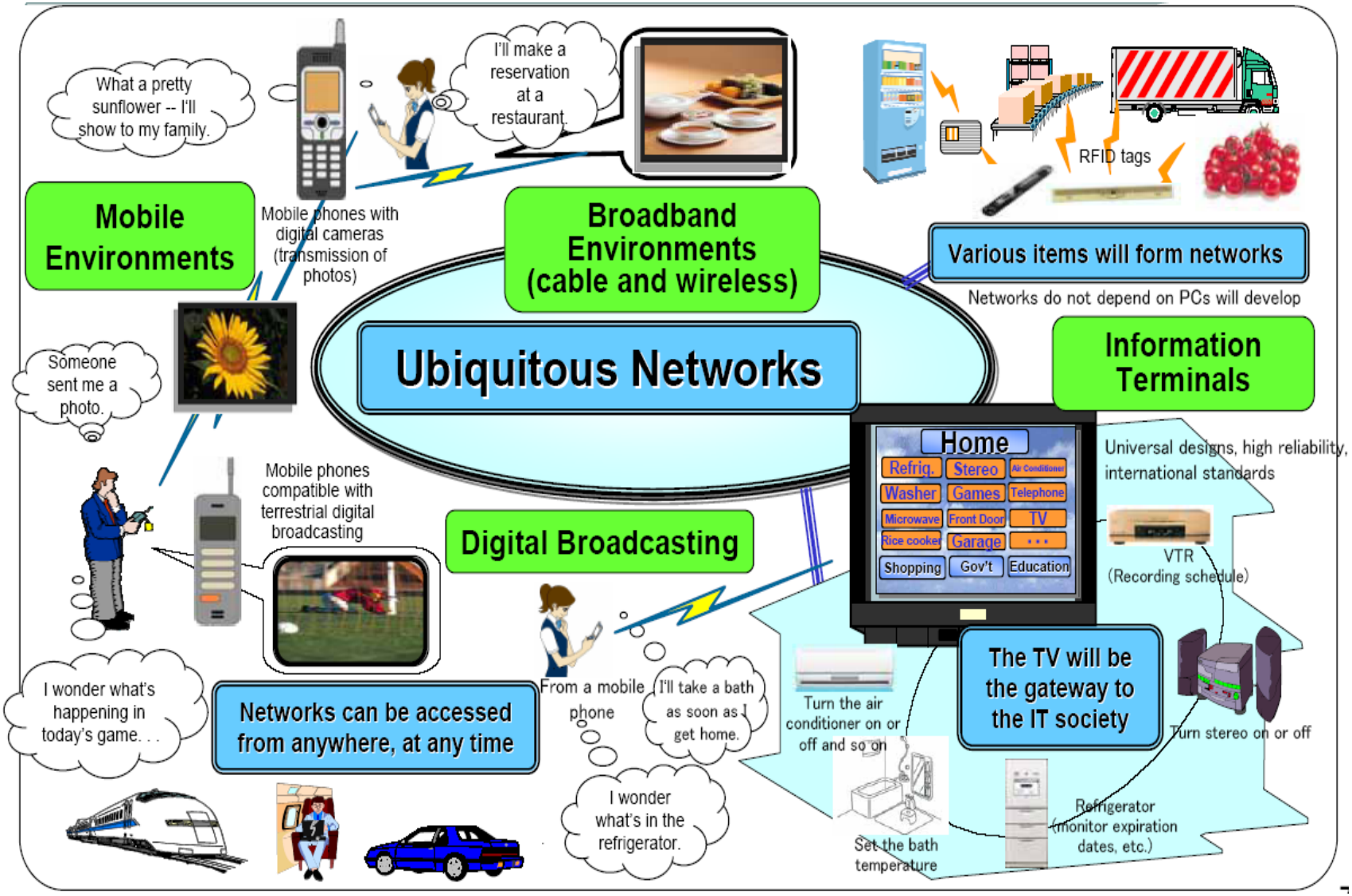






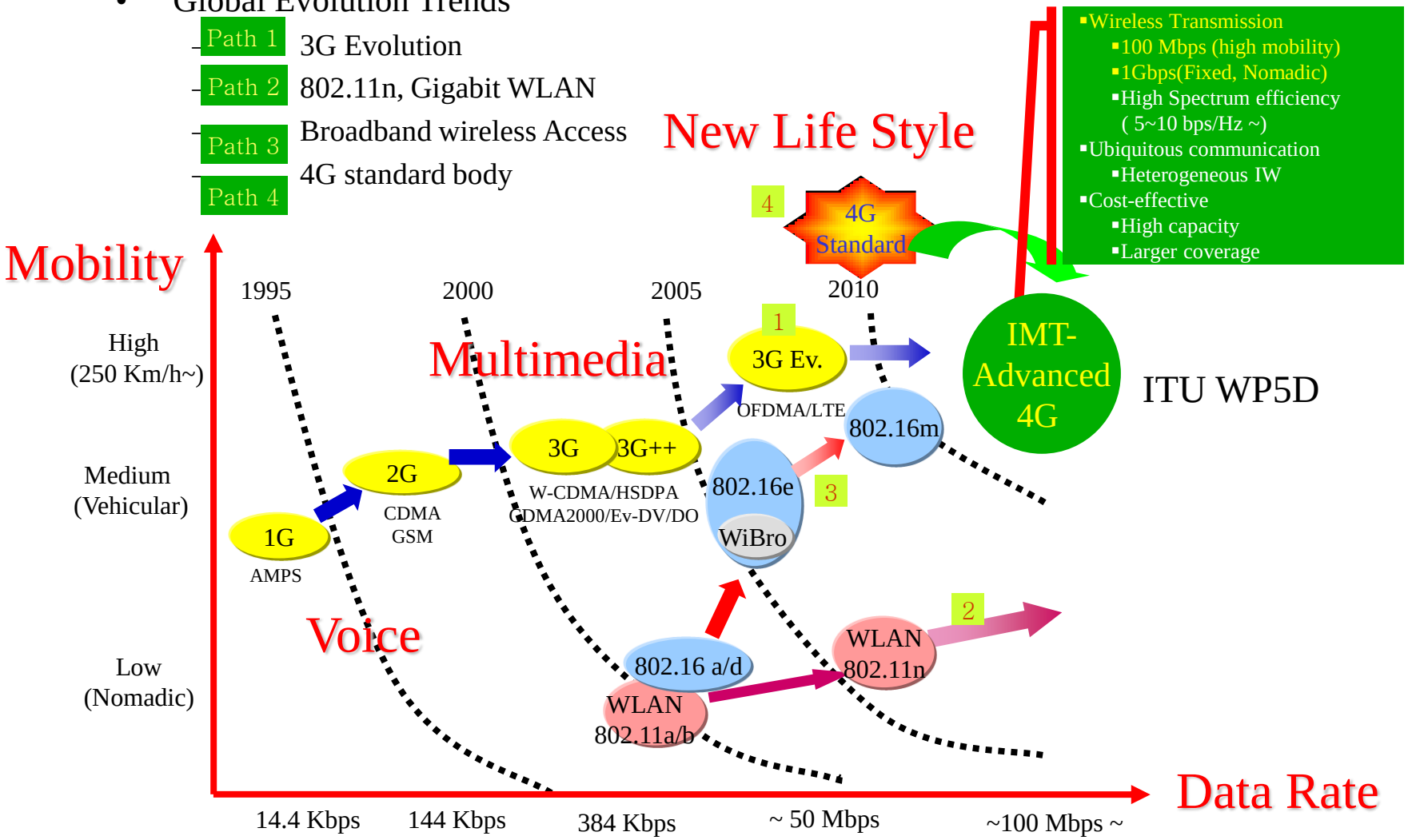
Source: MAGIC MOBILE FUTURE 2010-2020, UMTS Forum, 2005

Vision of 4G


What a pretty sunflower -- I'll show to my family.
I'll make a reservation at a restaurant.
Mobile Environments
Mobile phones with digital cameras (transmission of photos)
Broadband Environments (cable and wireless)
RFID tags
Various items will form networks
Networks do not depend on PCs will develop
Someone sent me a photo.
Ubiquitous Networks
Information Terminals
Home
Refrig.
Stereo
Air Conditioner
Washer
Games
Telephone
Microwave
Front Door
TV
Rice cooker
Garage
Shopping
Gov't
Education
Universal designs, high reliability, international standards
Mobile phones compatible with terrestrial digital broadcasting
Digital Broadcasting
VTR (Recording schedule)
I wonder what's happening in today's game. . .
Networks can be accessed from anywhere, at any time
From a mobile phone
I'll take a bath as soon as I get home.
Turn the air conditioner on or off and so on
The TV will be the gateway to the IT society
Turn stereo on or off
I wonder what's in the refrigerator.
Set the bath temperature
Refrigerator (monitor expiration dates, etc.)

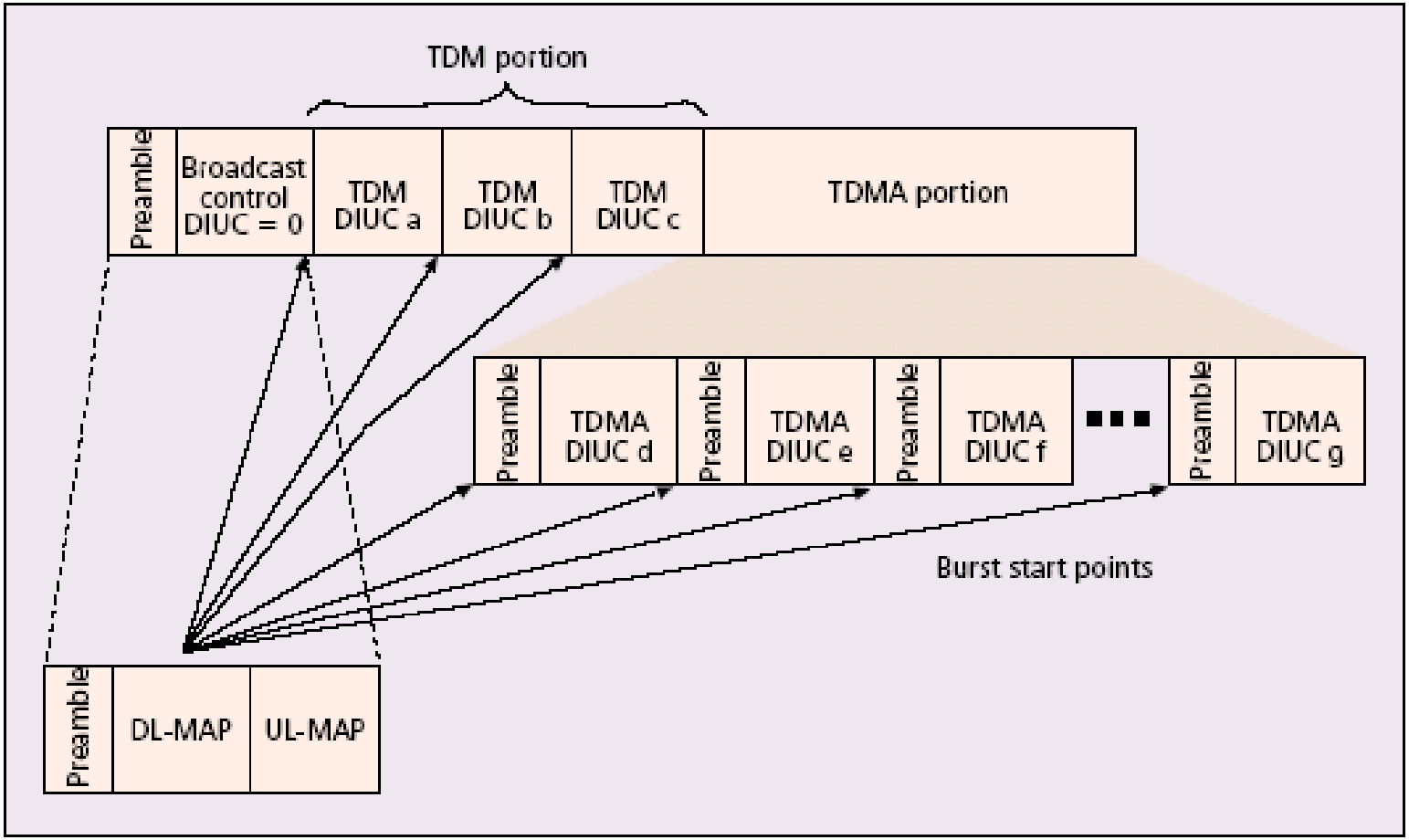
Migration Paths Toward 4G

- Global Evolution Trends
  - Path 1 3G Evolution
  - Path 2 802.11n, Gigabit WLAN
  - Path 3 Broadband wireless Access
  - Path 4 4G standard body



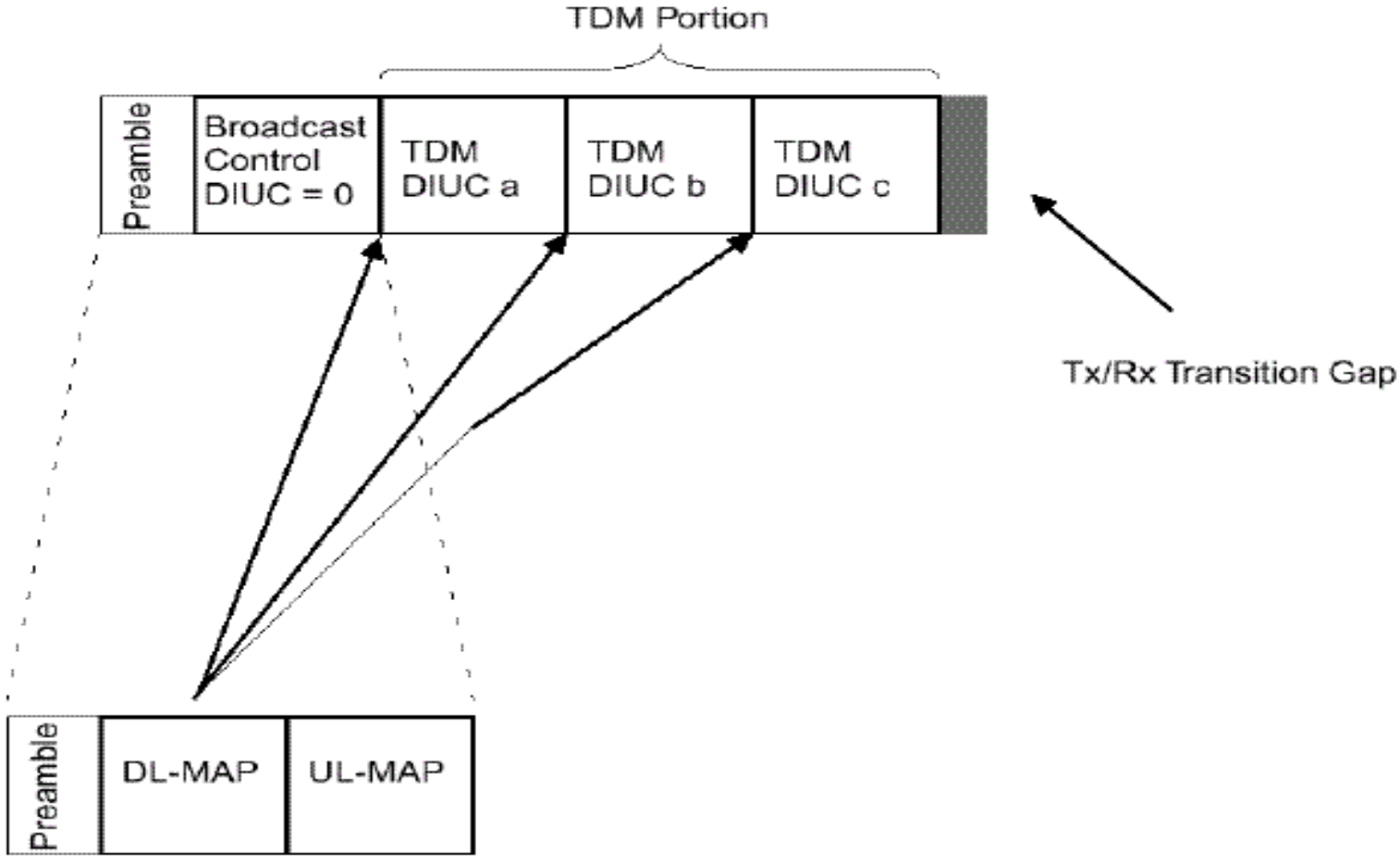
Source: "Korea 4G R&D and Standardization", LGE, 2006

General Downlink Frame Structure

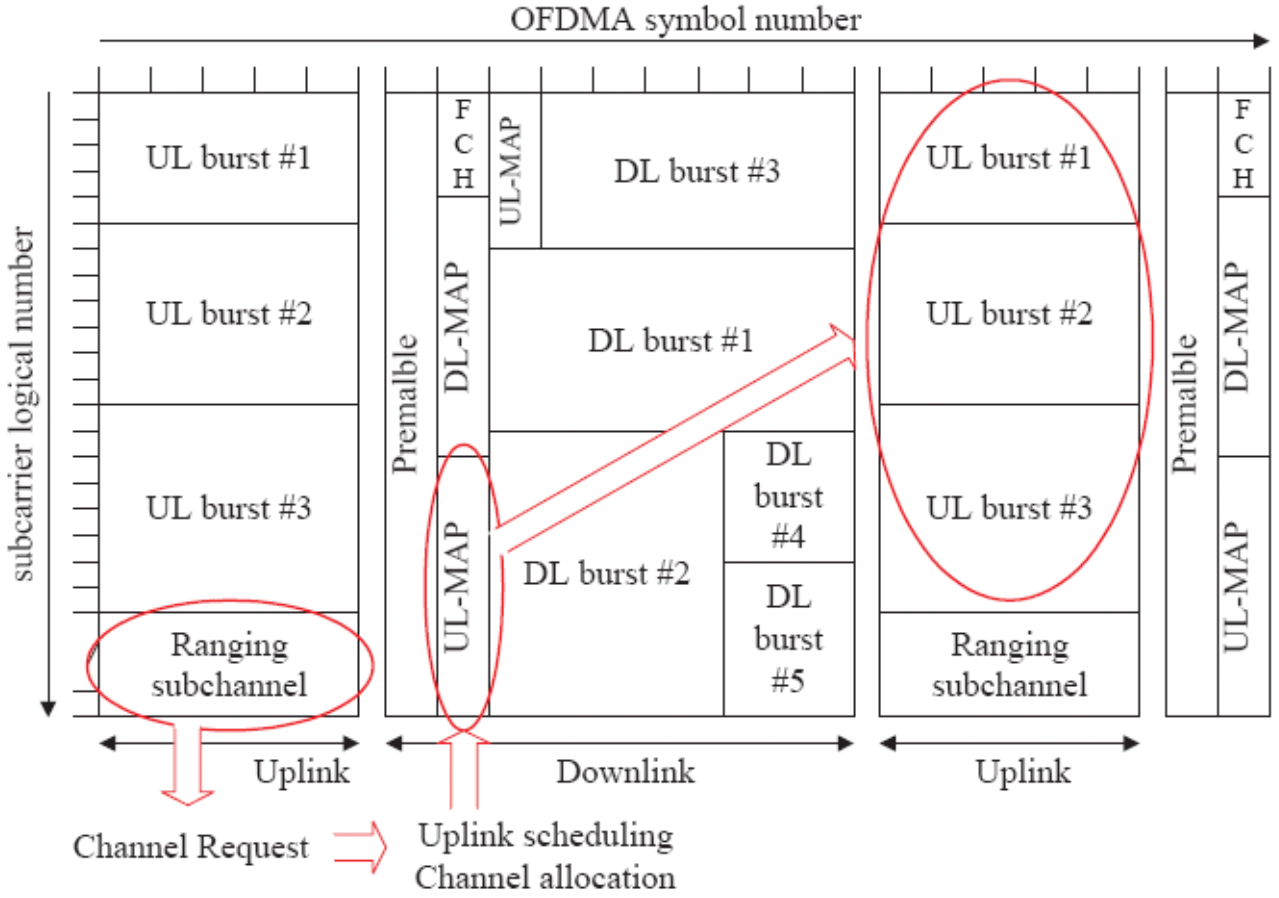


- Downlink Interval Usage Code (DIUC) indicates burst profile

TDD Downlink subframe



OFDMA TDD Frame Structure



- DL-MAP and UL-MAP indicate the current frame structure
- BS periodically broadcasts Downlink Channel Descriptor (DCD) and Uplink Channel Descriptor (UCD) messages to indicate burst profiles (modulation and FEC schemes)

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OFDMA

- **OFDMA stands for Orthogonal Frequency Division Multiple Access.** Which is a technique used in wireless network communication.
- OFDM is a combination of modulation and multiplexing.
- Multiplexing generally refers to independent signals, those produced by different sources.
- In OFDM the signal itself is first split into independent channels, modulated by data and then re-multiplexed to create the OFDM carrier.

OFDMA – part2

- OFDM is a special case of Frequency Division Multiplex (FDM).
- As an analogy, a FDM channel is like water flow out of a faucet, in contrast the OFDM signal is like a shower.

Fig. 1 – (a) A Regular-FDM single carrier – A whole bunch of water coming all in one stream. (b) Orthogonal-FDM – Same amount of water coming from a lot of small streams.

Introduction – part3

- In a faucet all water comes in one big stream and cannot be sub-divided. (typical case of FDM)
- OFDM shower is made up of a lot of little streams.

  (more strength against interference)
- Which is why several modern wireless network solutions applied OFDMA to ensure better quality of service. (ie. WiMax and 802.11a)

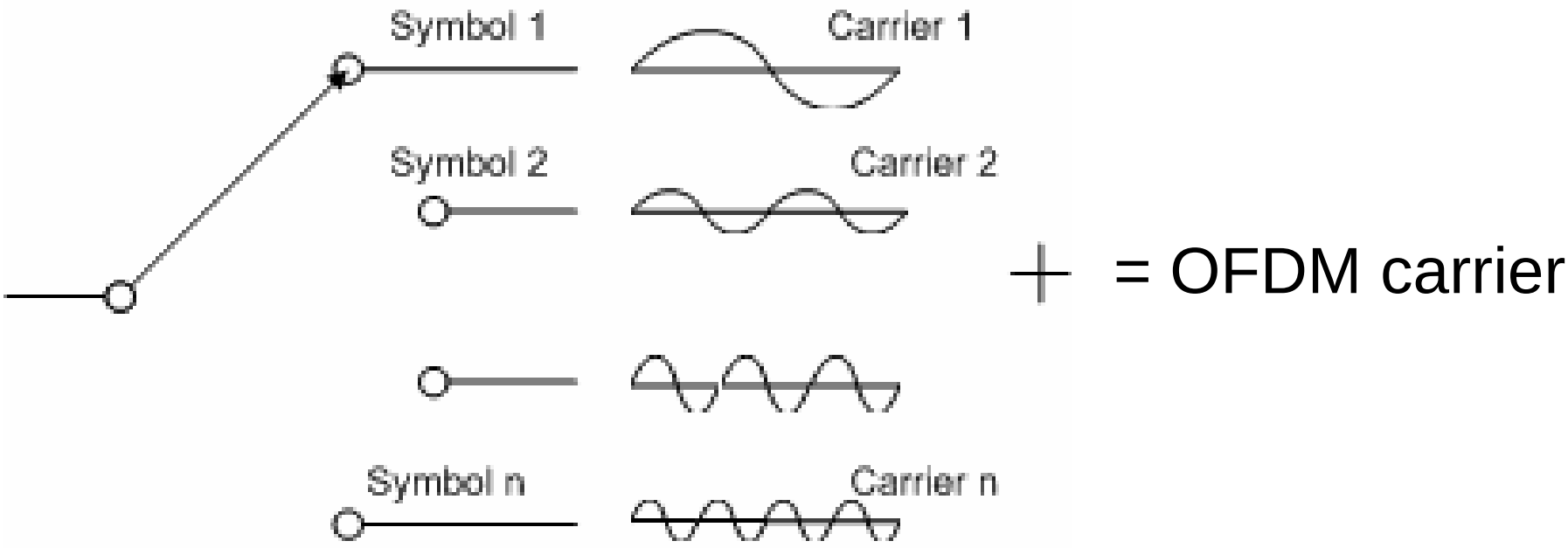
Benefits of using OFDMA

- More efficient and safe.
- Within the limited frequency allocated, OFDMA allows more data can be transmit concurrently.
- Possibility to remove the interference caused by delay and multi-path signals.
- It is like moving shipments(data) with several individual trucks.(instead of just one truck)

Fig. 2 – All cargo on one truck vs. splitting the shipment into more than one.

How to produce an OFDM carrier

- Typically we just divided the original signal into n symbol bit stream and carried by individual carriers. Then combine them into an OFDM carrier.



OFDMA

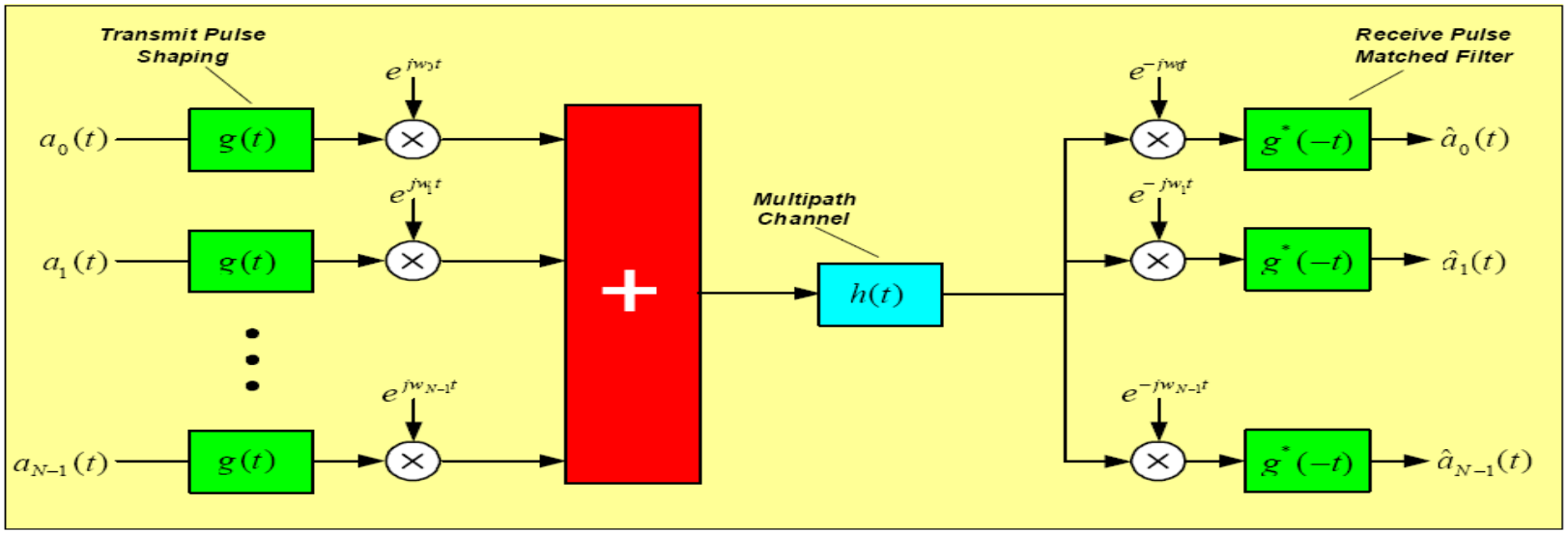


Figure 2: Basic Architecture of an OFDM System

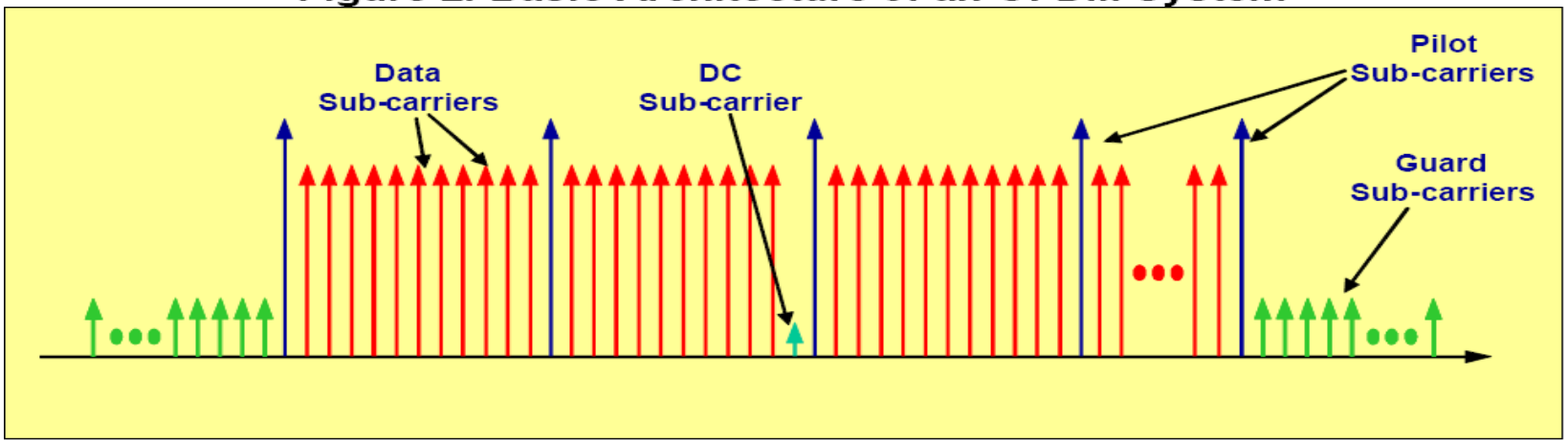


Figure 4: OFDMA Sub-Carrier Structure

Fading effect

- Sometimes a symbol going through multi-path will arrive the target at different time.

- **Solution:**
- **Delay spread and the use of cyclic prefix to mitigate it.** Will be a good solution for fading effect.

Creating the prefix

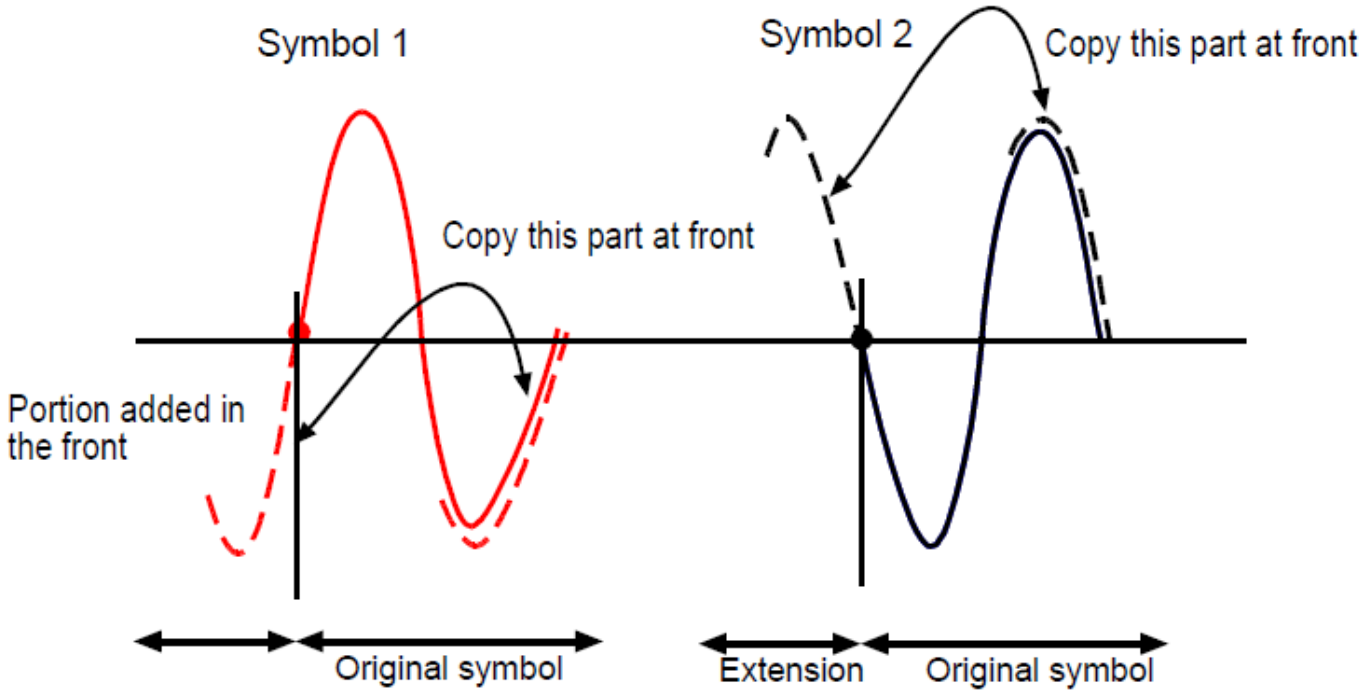


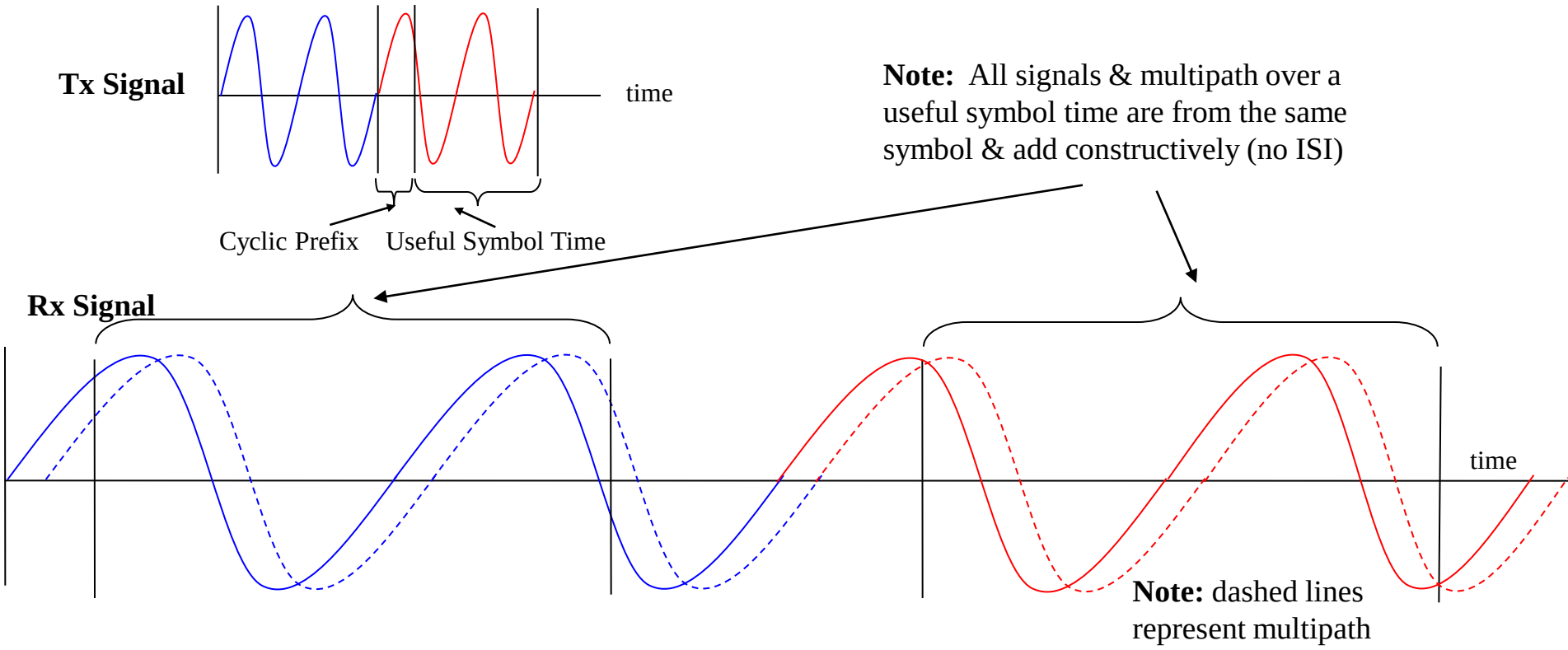
Fig. 25 – Cyclic prefix is this superfluous bit of signal we add to the front of our precious cargo, the symbol.

To avoid fading effect - part2

- The prefix of each symbol are copy-pasted from a part of original signals.
- Hence even the delayed symbol interfered the first few cycle of our received signal. We do not care. Because the prefix part is needless.

Equalizers are avoided in OFDM

Narrow bandwidth → long symbol times → all significant multipaths arrive within a symbol time minimizing ISI → no equalization → low complexity



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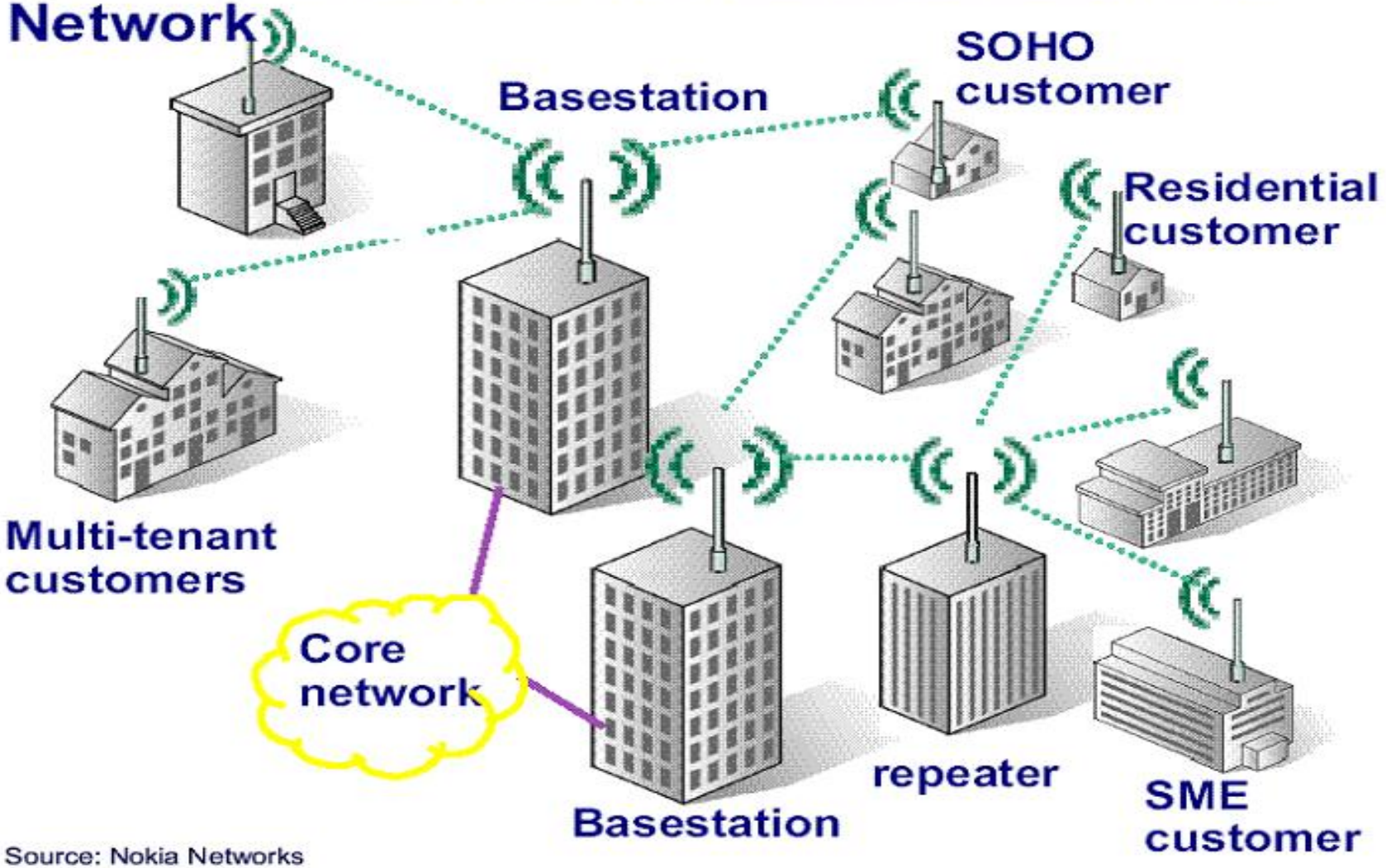
Broadband Access to Buildings

- The “Last Mile”
  - Fast local connection to network
- Business and residential customers demand it
  - Data,voice,video distrisbution,real-time video conferencing
- Network operator demand it
- High capacity cable/fiber to every user is expensive

Introduction

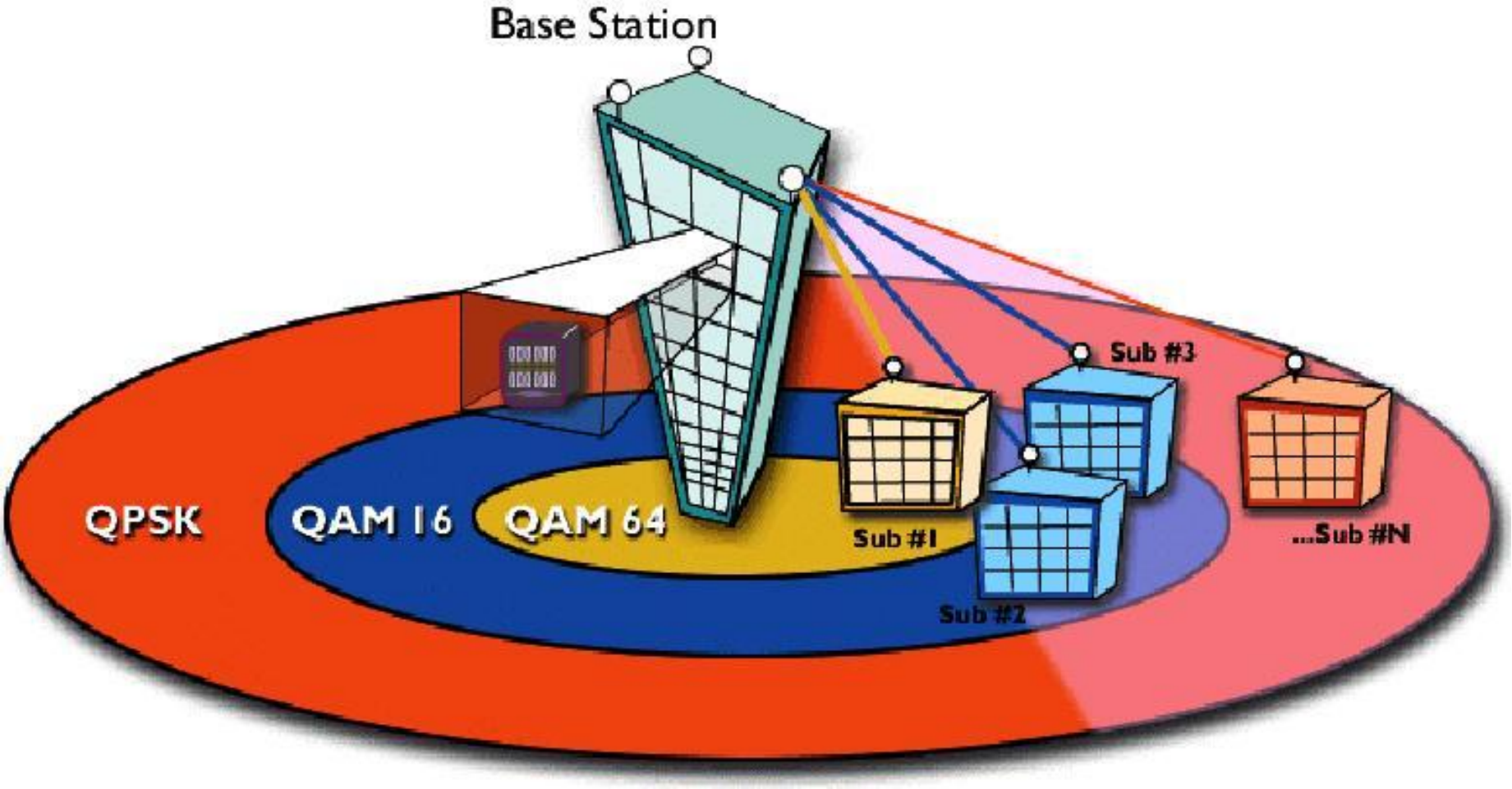
- Goal: Provide high-speed Internett access to home and business subscribers, without wires.
- Base stations (BS) can handle thousands of subscriber stations (SS)
- Access control prevents collisions.
- Supports
  - Legacy voice systems
  - Voice over IP
  - TCP/IP
  - Applications with different QoS requirements

WirelessMAN: Wireless Metropolitan Area Network

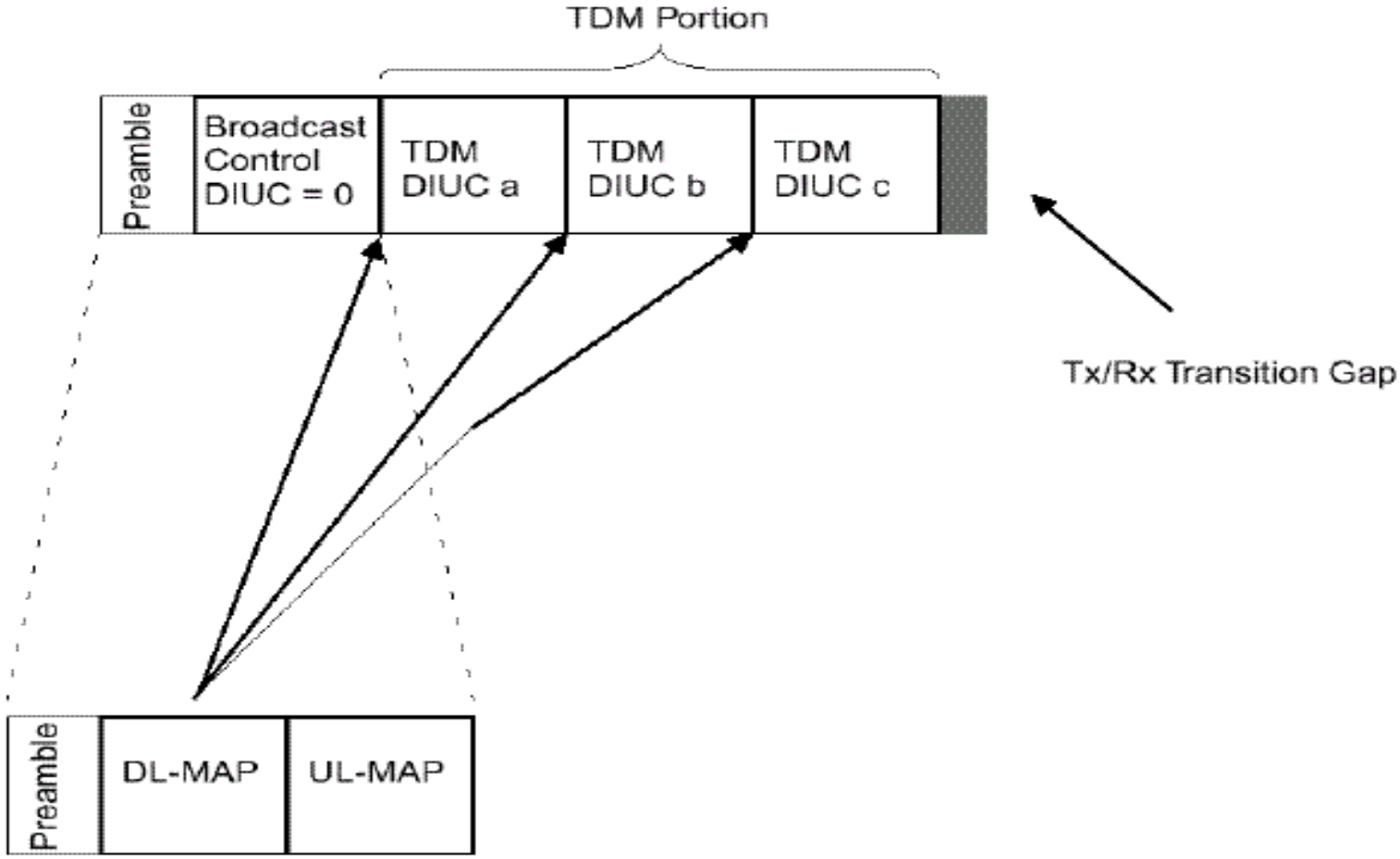


Source: Nokia Networks

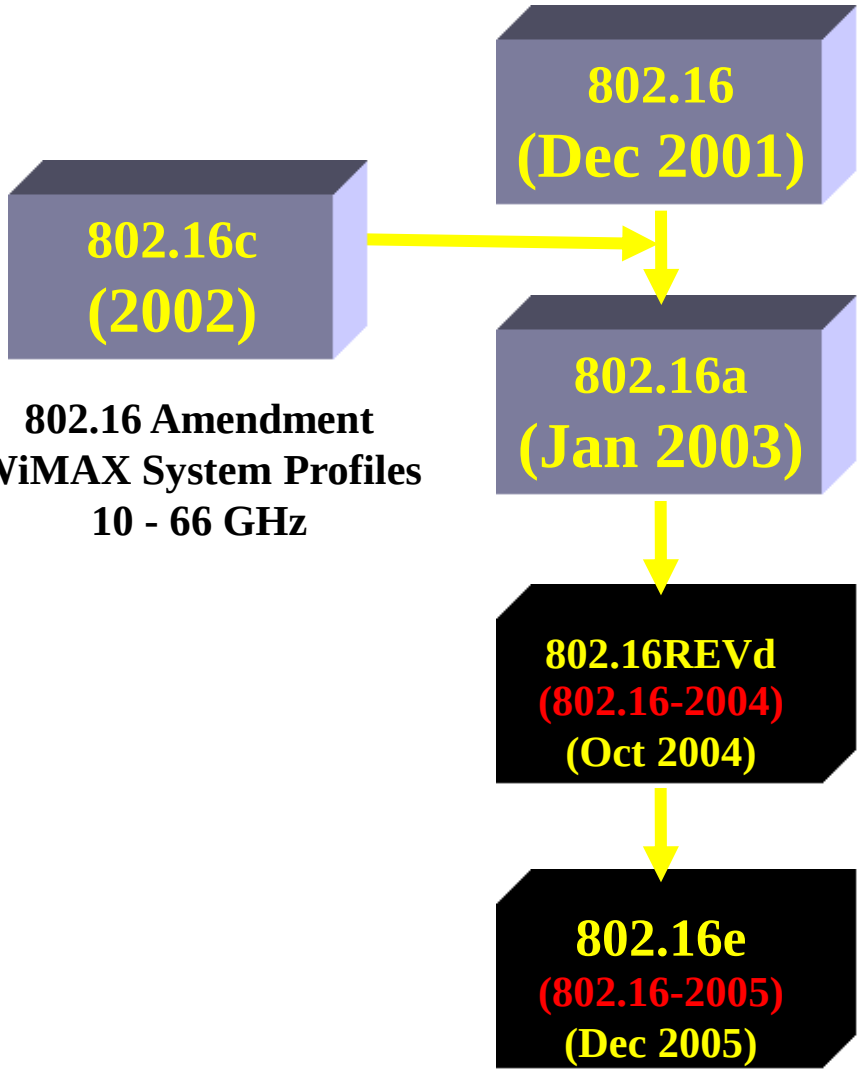
Modulation Types



TDD Downlink subframe



802.16 Standards History



802.16 Amendment
WiMAX System Profiles
10 - 66 GHz

- Original fixed wireless broadband air Interface for 10 – 66 GHz: Line-of-sight only, Point-to-Multi-Point applications
- Extension for 2-11 GHz: Targeted for non-line-of-sight, Point-to-Multi-Point applications like “last mile” broadband access
- Adds WiMAX System Profiles and Errata for 2-11 GHz
- MAC/PHY Enhancements to support subscribers moving at vehicular speeds

Introduction

- 802.16 standards: (MAC & PHY), 1999
  - 802.16.1 (10-66 GHz, line-of-sight, up to 134Mbit/s)
  - 802.16.2 (minimizing interference between coexisting WMANs.)
  - 802.16a (2-11 Ghz, Mesh, non-line-of-sigth)
  - 802.16b (5-6 Ghz)
  - 802.16c (detailed system profiles)
  - 802.16e (Mobile Wireless MAN, 802.16e 2005))
  - 802.16m
- WiMAX Forum (end to end solution), 2003
  - WiMAX Network and Profile 1.0

Point to Multipoint

- BS connected to public networks
- BS serves Subscriber Station (SSs)
  - SS typically serves a building(business or residence)
  - Provide SS with first-mile access to public networks
- Compared to a Wireless LAN
  - Multimedia QoS,not only contention-based
  - Many more users
  - Much higher data rates
  - Much longer distances

MAC Layer

- MAC is comprised of 3 sublayers
  - Service Specific Convergence Sublayer
  - MAC Common Part Sublayer
  - Privacy Sublayer

Service Specific Convergence Sublayer

- Classing SDUs and associate them to the proper MAC service flow and CID
- Support various protocols
- Internal format of CS payload is unique to the CS

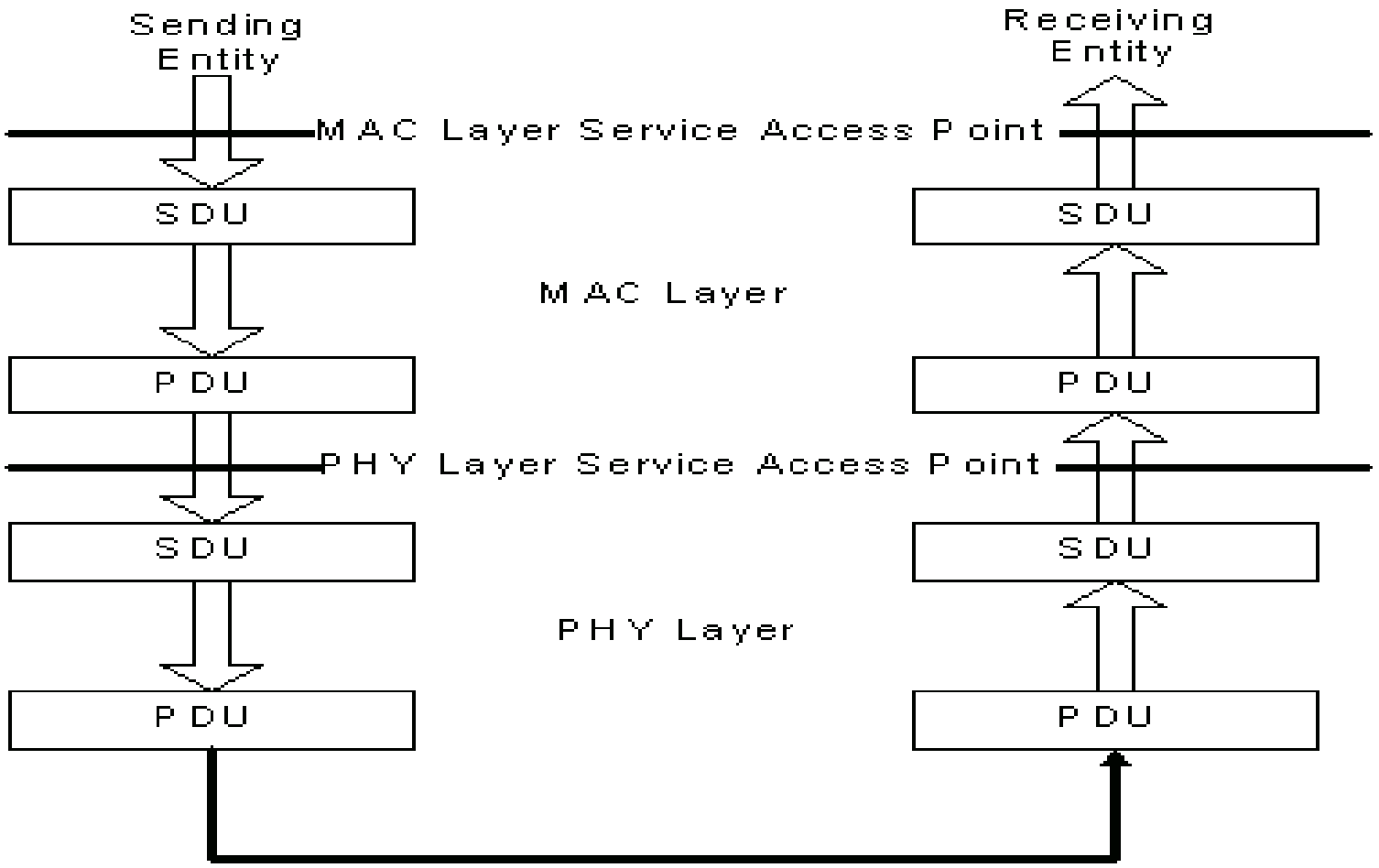
MAC Common Part Sublayer

- Provides the core MAC functionality
  - Bandwidth allocation
  - Connection establishment
  - Connection maintenance
- During initialization of an SS, 3 particular connections are established in both direction
  - Basic connection: short time critical
  - Primary management connection: longer more delay
  - Second management connection: higher layer management and SS configuration data

MAC PDU Formats

- Two header formats are defined
  - Generic header
  - Bandwidth request header
- Three types of MAC subheader
  - The grant management: used by an SS to convey bandwidth management
  - The fragmentation: indicate the presence and orientation in the payload of any fragmentation of SDUs
  - The packing: indicate the packing of multiple SDUs into a single PDU

Transmission of MAC PDUs



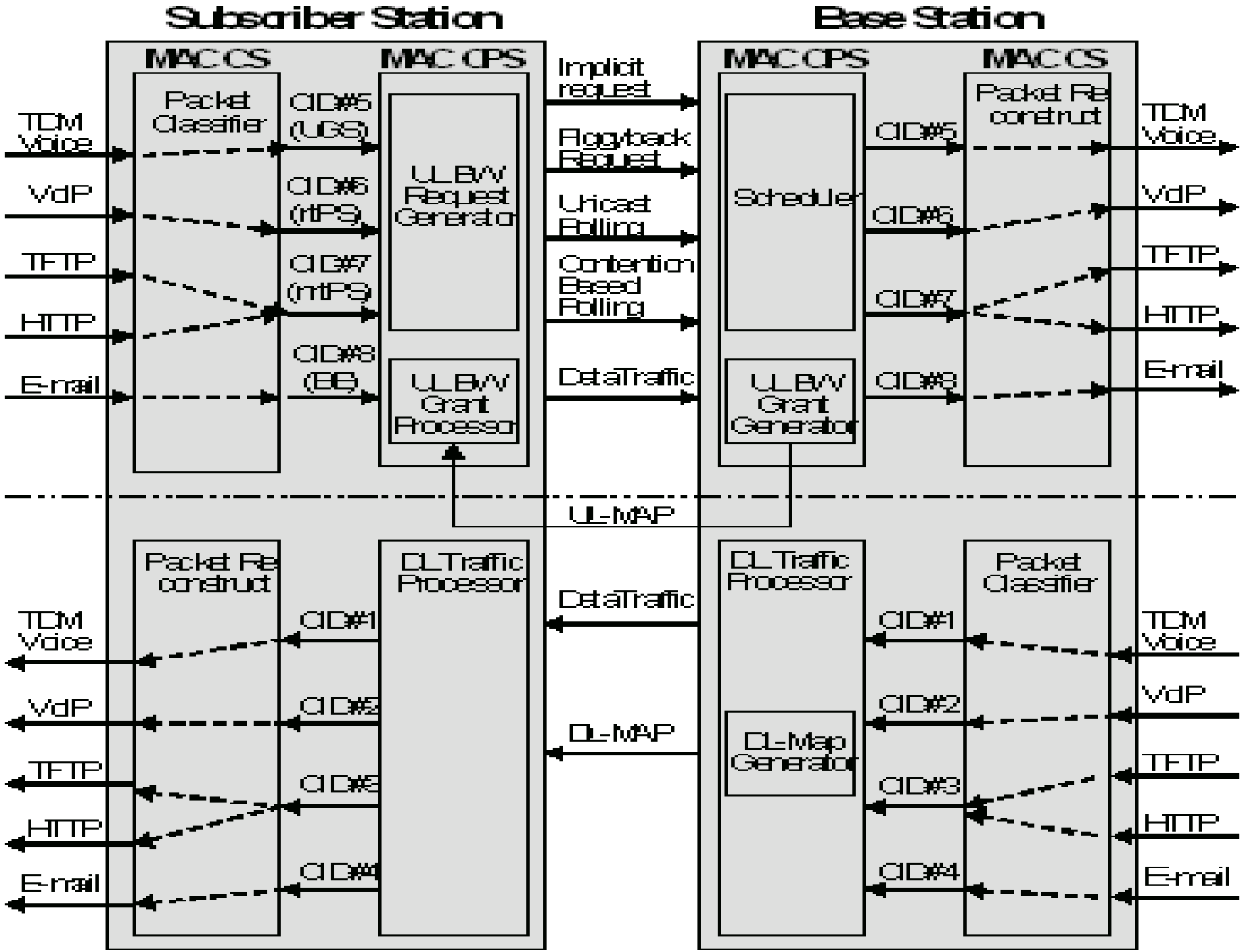
4 types of Scheduling Service

- Unsolicited Grant Service (UGS)
  - Real-time, periodic fixed size packets (e.g. T1 or VoIP)
  - Restrictions on bw requests (Poll-Me bit)
  - Slip Indicator (SI)
- Real-Time Polling Service (rtPS)
  - Real-time, periodic variable sizes packets (e.g MPEG)
  - BS issues periodic unicast polls.
  - Cannot use contention requests, but piggybacking is ok.
- Non-Real-Time Polling Service (nrtPS)
  - Variable sized packets with loose delay requirements (e.g. FTP)
  - BS issues unicast polls regularly (not necessarily periodic).
  - Can also use contention requests and piggybacking.
- Best Effort Service
  - Never polled individually
  - Can use contention requests and piggybacking

Quality of Service

QoS Category	Applications	QoS Specifications
UGS Unsolicited Grant Service	VoIP	• Maximum Sustained Rate • Maximum Latency Tolerance • Jitter Tolerance
rtPS Real-Time Packet Service	Streaming Audio or Video	• Minimum Reserved Rate • Maximum Sustained Rate • Maximum Latency Tolerance • Traffic Priority
ErtPS Extended Real-Time Packet Service	Voice with Activity Detection (VoIP)	• Minimum Reserved Rate • Maximum Sustained Rate • Maximum Latency Tolerance • Jitter Tolerance • Traffic Priority
nrtPS Non-Real-Time Packet Service	File Transfer Protocol (FTP)	• Minimum Reserved Rate • Maximum Sustained Rate • Traffic Priority
BE Best-Effort Service	Data Transfer, Web Browsing, etc.	• Maximum Sustained Rate • Traffic Priority

Table 4: Mobile WiMAX Applications and Quality of Service


Subscriber Station
Base Station
MAC CS
MAC CPS
MAC CPS
MAC CS
Packet Classifier
UL B/W Request Generator
UL B/W Grant Processor
Schedule
UL B/W Grant Generator
Packet Reconstruct
TDM Voice
VoIP
TFTP
HTTP
E-mail
CID#5 (UGS)
CID#6 (rtPS)
CID#7 (nrtPS)
CID#8 (BE)
Implicit request
Piggyback Request
Unicast Polling
Contention Based Polling
DataTraffic
UL-MAP
DL Traffic Processor
DL-Map Generator
DL-MAP
CID#1
CID#2
CID#3
CID#4

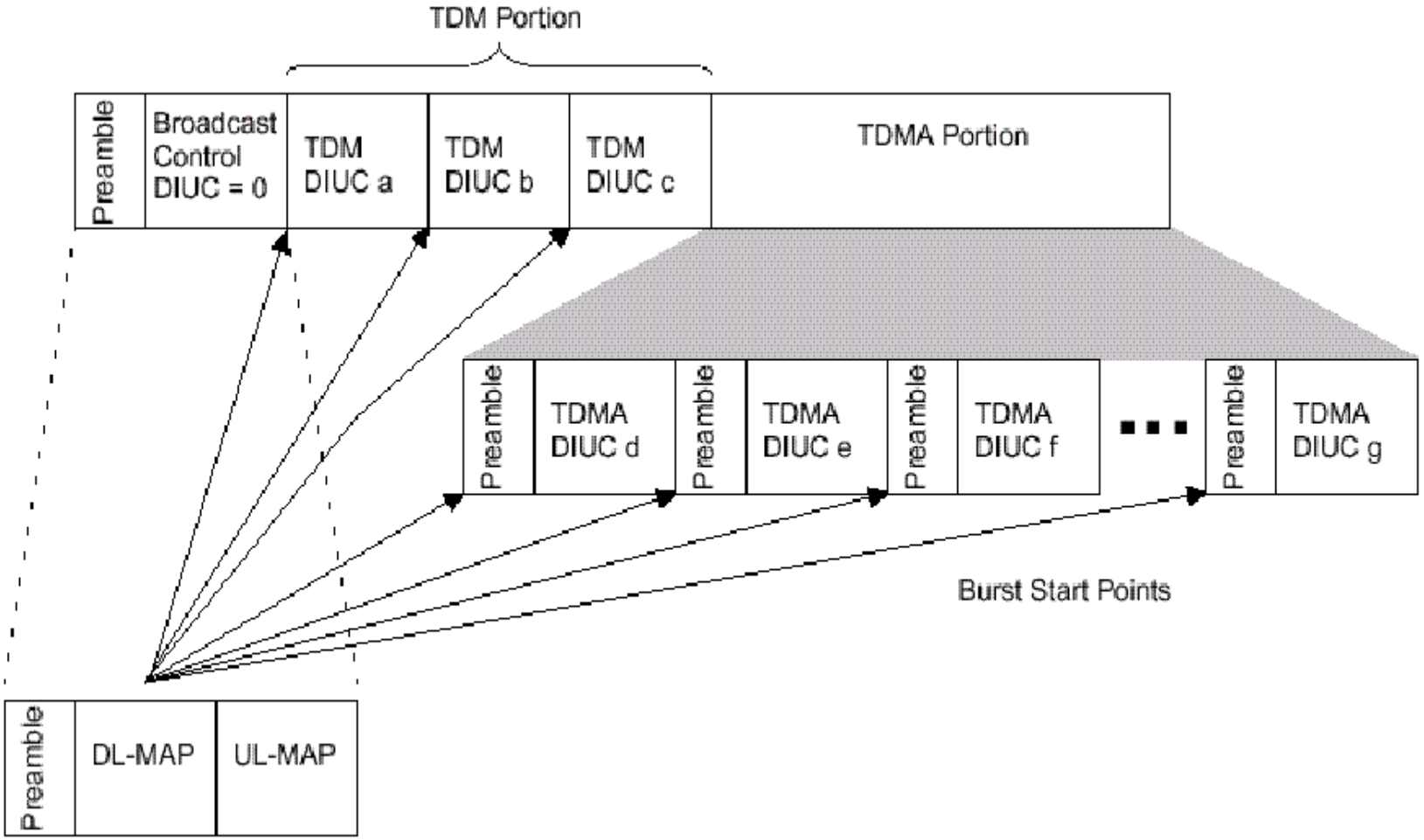
Physical Layer

- ”Burst single-carrier” modulation
- Allows use of directional antennas
- Allows use of two different duplexing schemes:
  - Frequency Division Duplexing (FDD)
  - Time Division Duplexing (TDD)
- Support for both full and half duplex stations

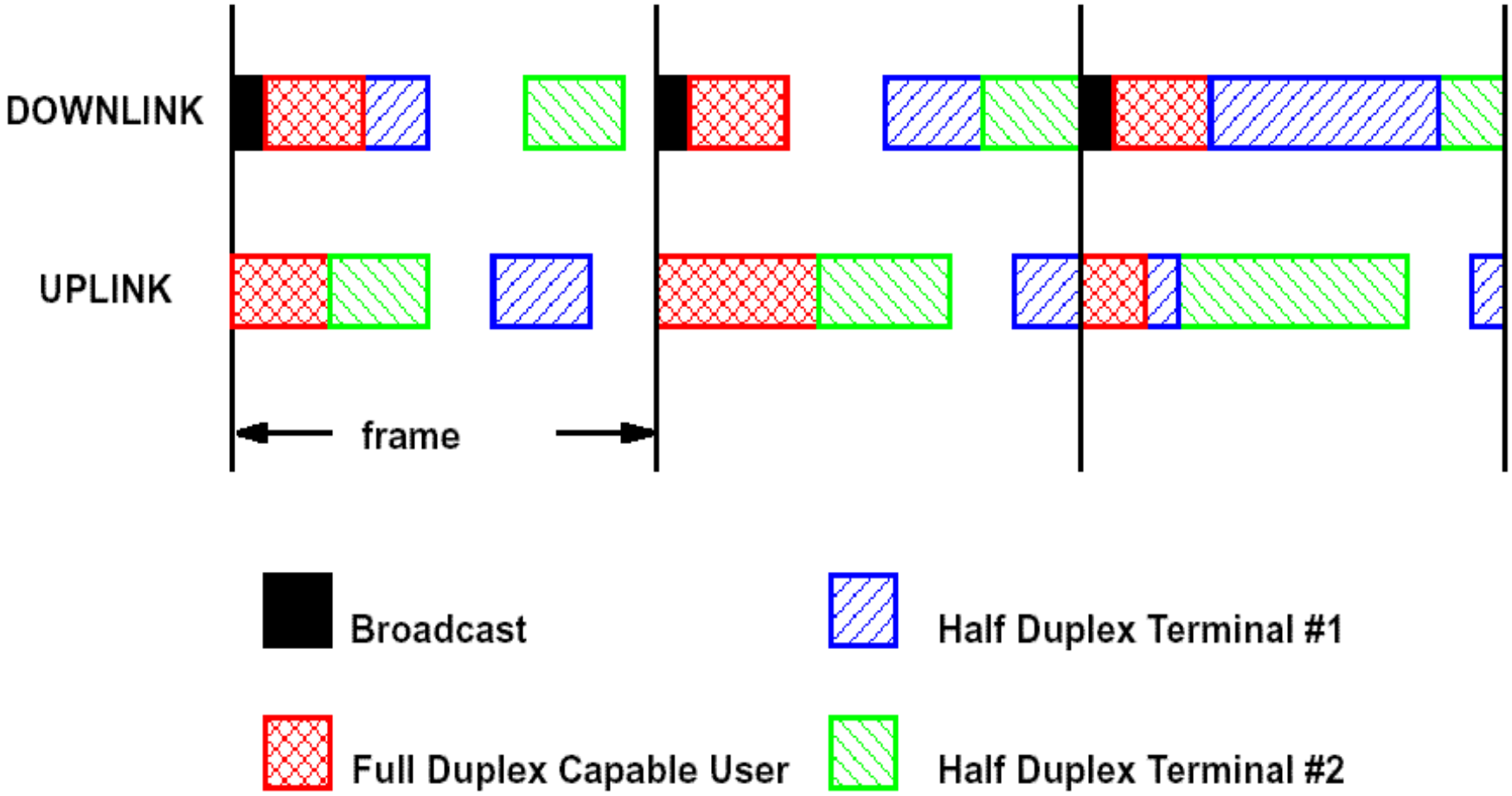
- Adaptive Data Burst Profiles
  - Transmission parameters (e.g. modulation and FEC settings) can be modified on a frame-by-frame basis for each SS.
  - Profiles are identified by ”Interval Usage Code” (DIUC and UIUC)

- Connection orienteded
  - Connection ID (CID), Service Flows(SF)
- Channel access
  - UL-MAP
    - Defines uplink channel access
    - Defines uplink data burst profiles
  - DL-MAP
    - Defines downlink data burst profiles
  - UL-MAP and DL-MAP are both transmitted in the beginning of each downlink subframe (FDD and TDD).

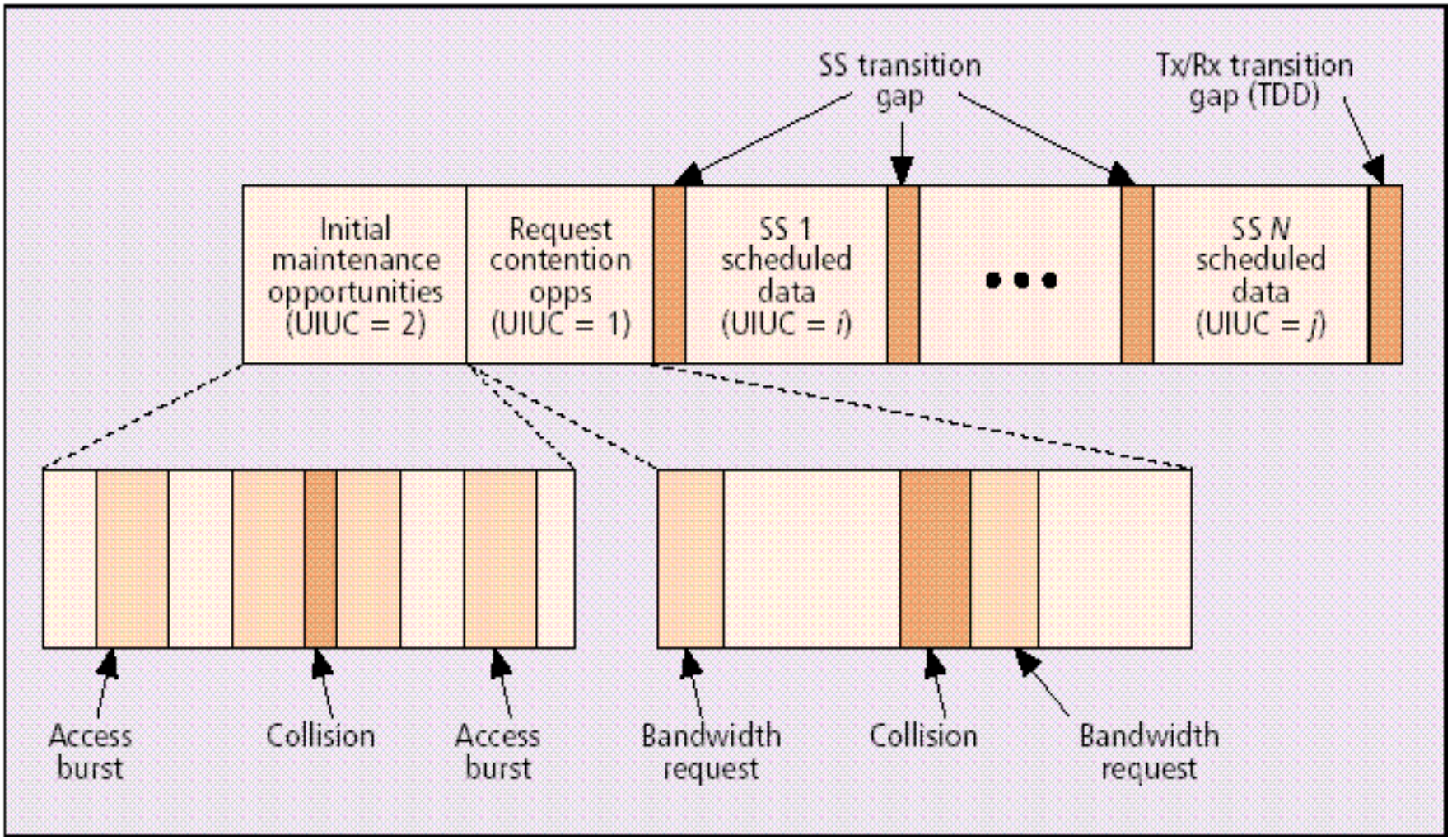
FDD Downlink subframe



FDD burst framing

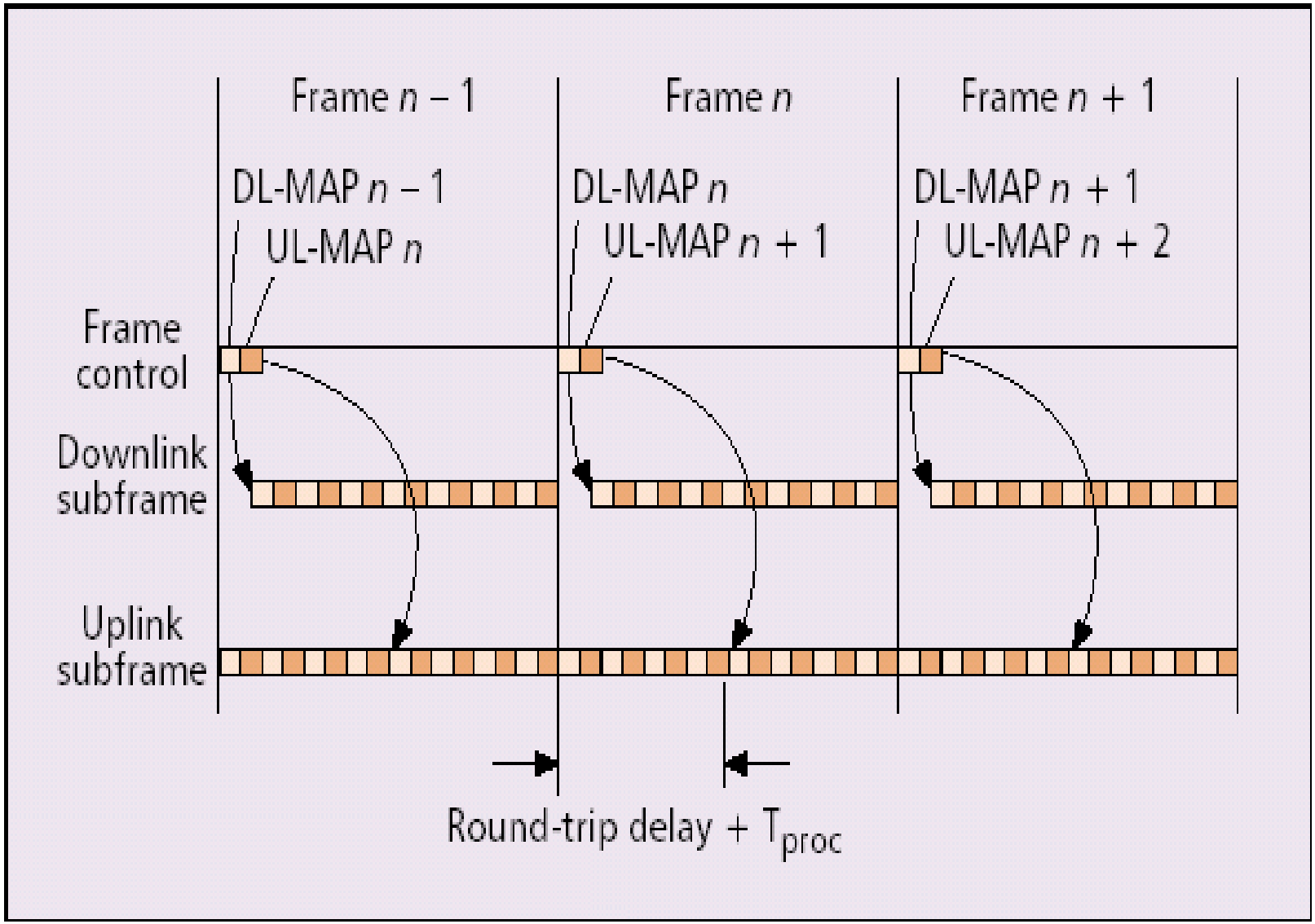


Uplink subframe(TDD or FDD)



Uplink periods

- Initial Maintenance opportunities
  - Ranging
  - To determine network delay and to request power or profile changes.
  - Collisions may occur in this interval
- Request opportunities
  - SSs request bandwith in response to polling from BS.
  - Collisions may occur in this interval aswell.
- Data grants period
  - SSs transmit data bursts in the intervals granted by the BS.
  - Transition gaps between data intervals for synchronization purposes.


Frame n – 1
Frame n
Frame n + 1
DL-MAP n – 1
UL-MAP n
DL-MAP n
UL-MAP n + 1
DL-MAP n + 1
UL-MAP n + 2
Frame control
Downlink subframe
Uplink subframe
Round-trip delay + T proc

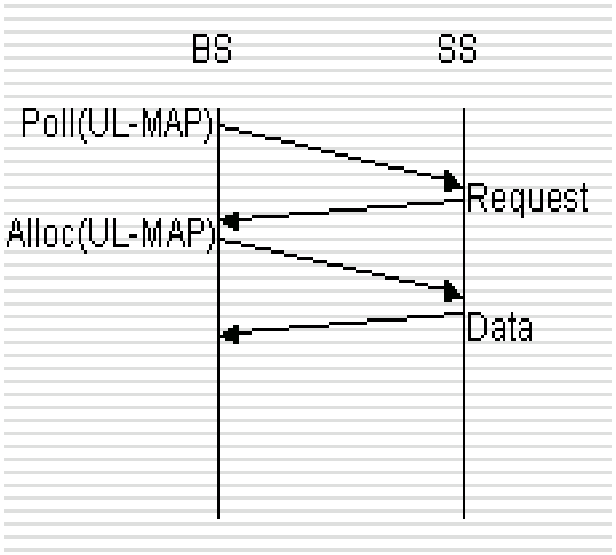
Bandwidth request and allocation

- SSs may request bw in 3 ways:
  - Use the ”contention request opportunities” interval upon being polled by the BS (multicast or broadcast poll).
  - Send a standalone MAC message called ”BW request” in an allready granted slot.
  - Piggyback a BW request message on a data packet.

Bandwidth request and allocation

- BS grants/allocates bandwidth in one of two modes:
  - Grant Per Subscriber Station (GPSS)
  - Grant Per Connection (GPC)
- Decision based on requested bw and QoS requirements vs available resources.
- Grants are realized through the UL-MAP.

Unicast Polling



1. BS allocates space for the SS in the uplink subframe.
2. SS uses the allocated space to send a bw request.
3. BS allocates the requested space for the SS (if available).
4. SS uses allocated space to send data.

Outline

- Introduction
- OFDM/OFDMA
- Fixed WiMAX
- Mobile WiMAX
- Future WiMAX

Mobile WiMAX system Profile

Figure 1: Mobile WiMAX System Profile

Key Technical Concepts and Objectives

- Orthogonal Frequency Division Multiple Access (OFDMA)-based multiple access with scalable bandwidth in downlink and uplink
- Advanced antenna technologies allowing beamforming and diversity through space time coding and spatial multiplexing (SM).
- Adaptive Physical layer (PHY) design using fast link adaptation combined with fast time and frequency scheduling
- All-IP flat network architecture supporting different deployment models and enabling both traditional operator-managed as well as new open Internet service
- Open Standard interfaces enabling over the air as well as network interoperability in multivendor deployments.

Frame Structure

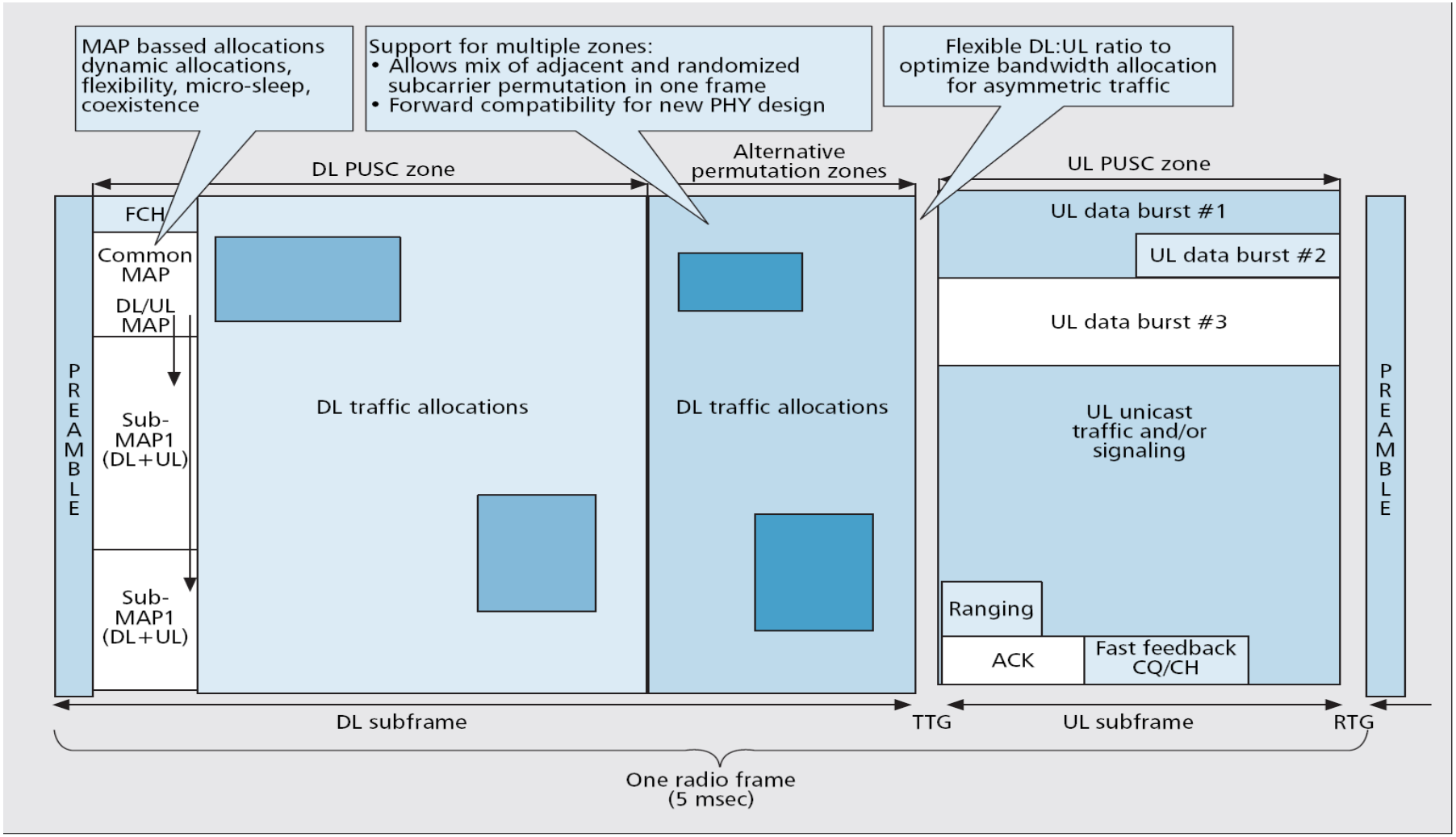


Figure 6. *Frame structure and channelization for TDD system in release 1.0.*

WiMAX Network Reference Model

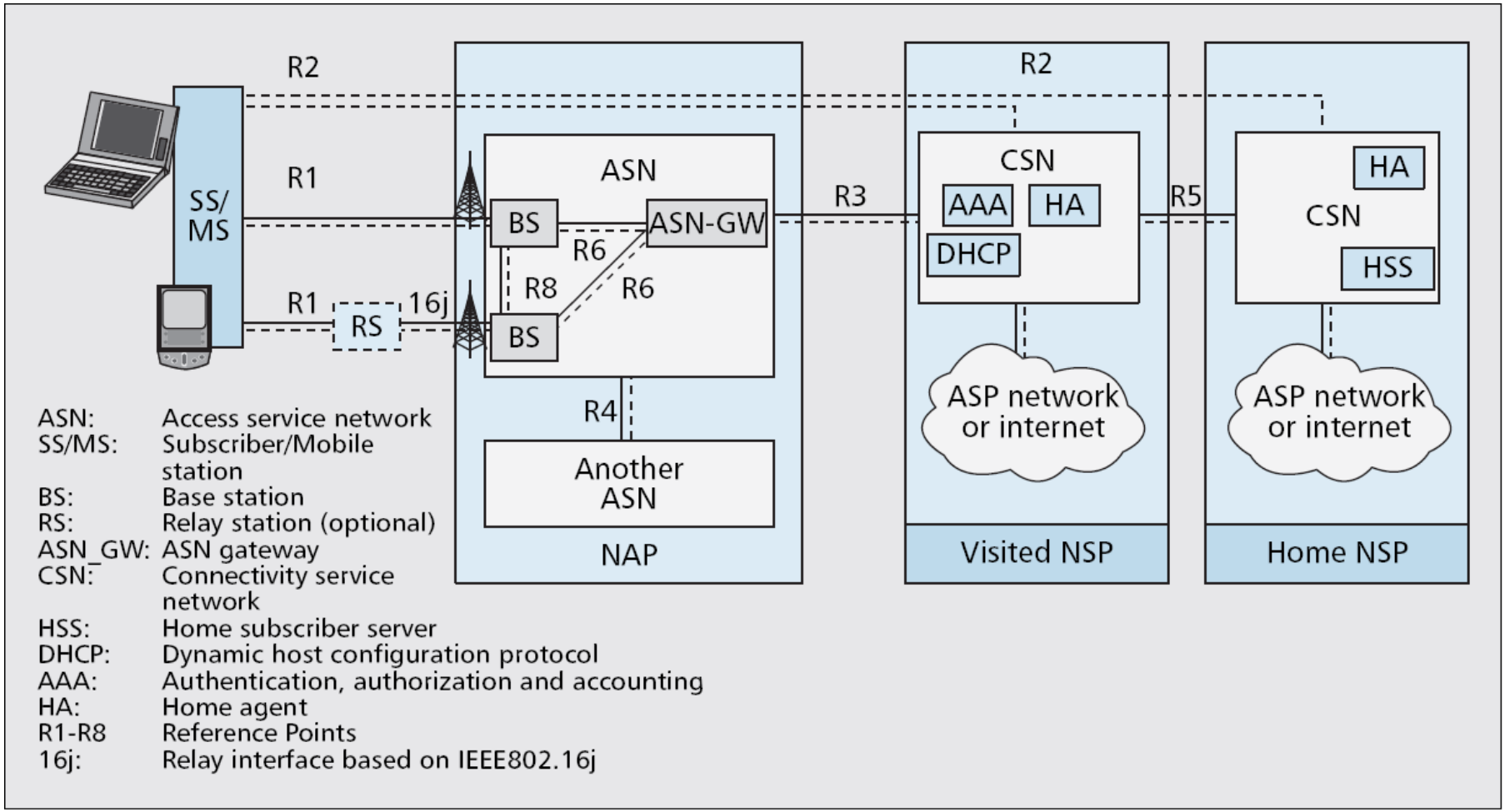


Figure 3. *WiMAX network reference model.*

MAC/PHY Structure

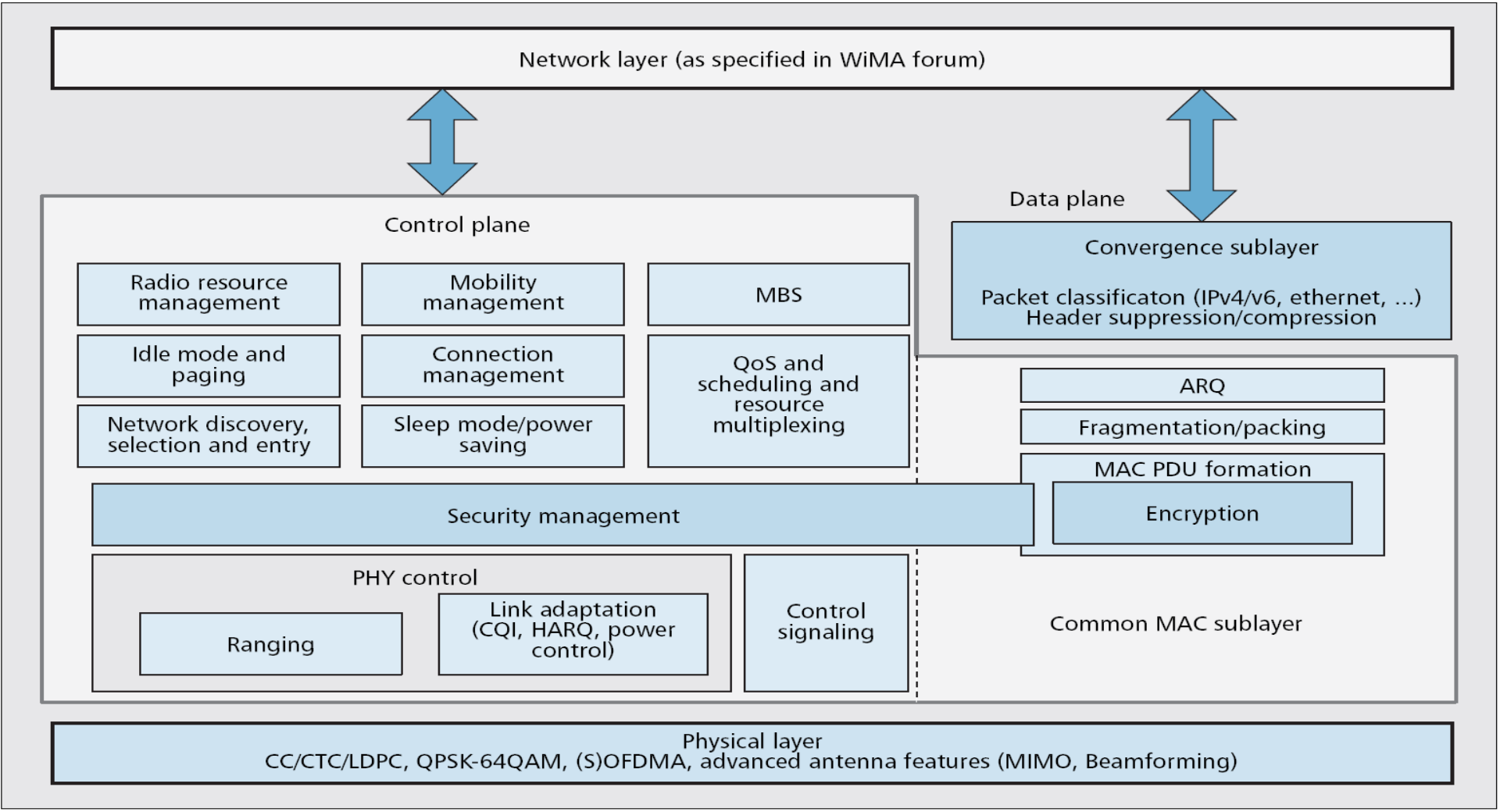
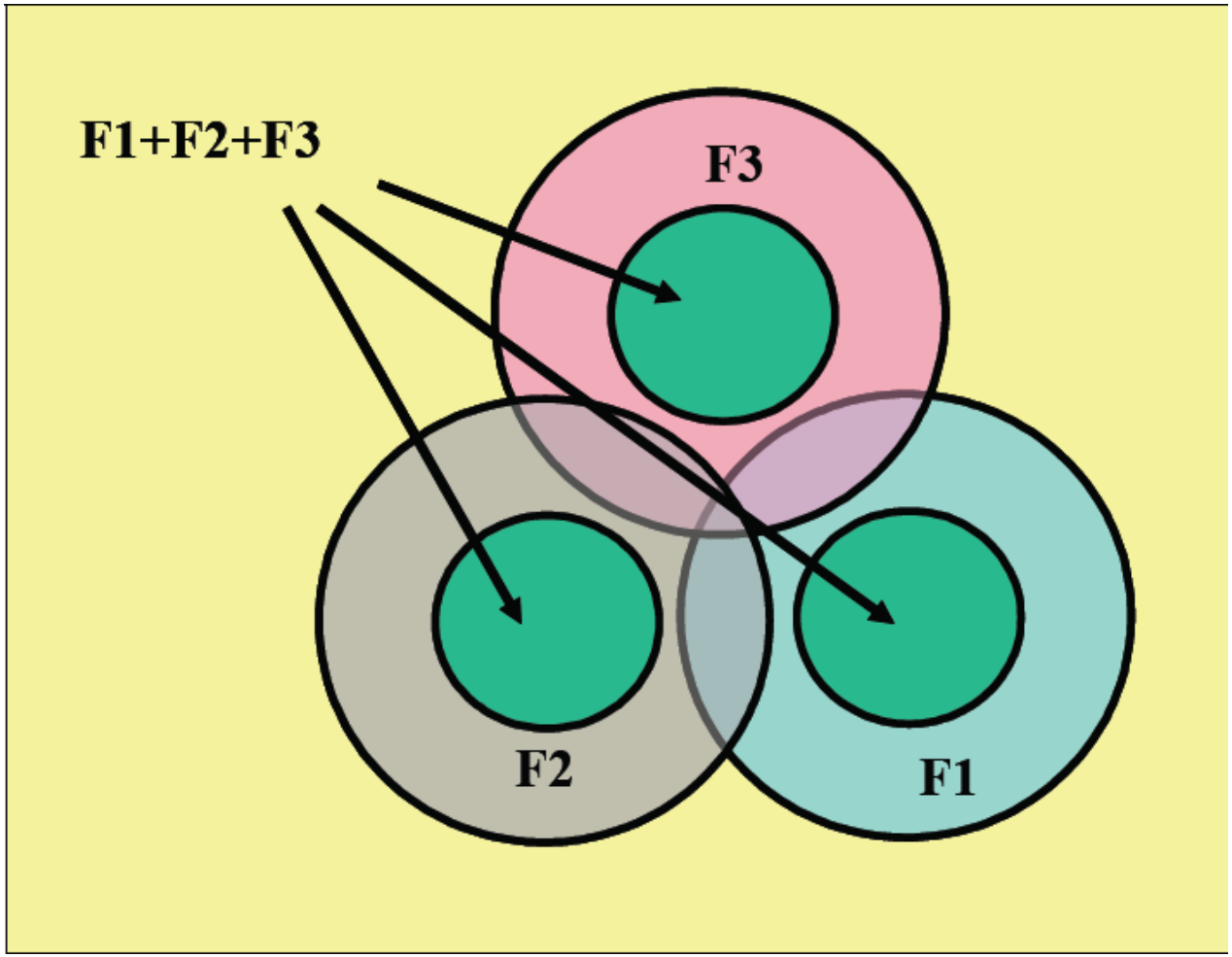


Figure 5. *MAC/PHY protocol structure in mobile WiMAX release 1.0.*

Fractional Frequency Reuse



Outline

- Introduction
- OFDM/OFDMA
- Fixed WiMAX
- Mobile WiMAX
- New Generation WiMAX

IEEE 802.16 Standards

Air Interface

802.16 MAC + 10-66GHz PHY

802.16a 2-11GHz PHY

802.16c Conformance

802.16-2004 Revision

802.16e Mobility

802.16/Cor1 Maintenance

802.16e-2005 Revision

802.16h-2009 License Exempt

802.16Rev2 Consolidate

802.16j Multi-hop Relay

802.16m Next Generation WiMAX2

: *finalized and published*

: *under development*

Management

802.16f MIB (fixed)

802.16g Management

802.16i MIB (mobile)

802.16k Bridging

Coexistence

802.16.2-2001 Coexistence

802.16.2-2004 Revision

Conformance

802.16/Conf01 >10GHz PICS

802.16/Conf02 >10GHz TSS & TP

802.16/Conf03 >10GHz RCT

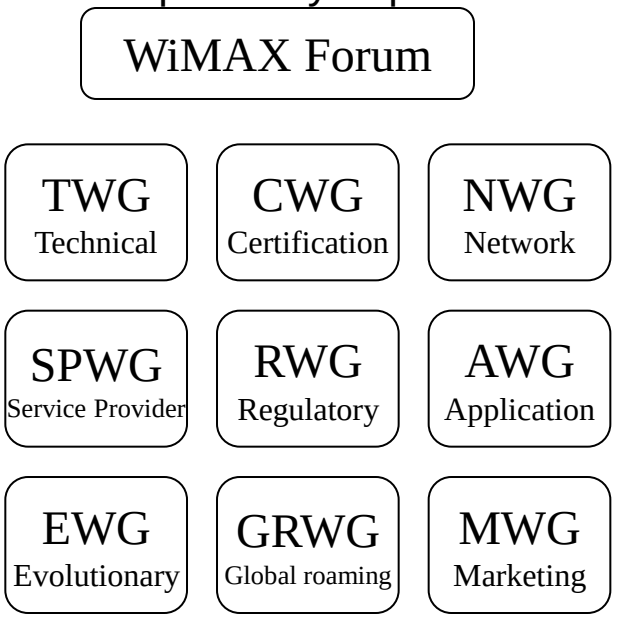
802.16/Conf04 <11Ghz PICS

WiMAX Forum

http://www.wimaxforum.org/

- **WiMAX Forum**
  - **WiMAX: Worldwide Interoperability for Microwave Access**
  - Formed in Apr 2001, by Intel, Proxim, Airspan, Fujitsu, etc.
  - 500+ members including Intel, R&S, Alvarion, Wavesat, PicoChip, Sony, Samsung, Nokia, TI, ADI, III, ITRI, etc.
- **Major Missions**
  - To promote deployment of BWA by using a global standard and certifying interoperability of products and technologies.
  - Develop baseline test specs, to facilitate the global interoperability of products and technologies
  - Support IEEE 802.16 standards

- WiMAX Product Certification
  - 802.16-2004 CPE: Wavesat, Airspan, Siemens, …
  - 802.16-2004 BS: Aperto, Redline, Sequans, Airspan, Siemens, …
  - Preparing for 802.16e compliance



802.16m

- Since January 2007, the IEEE 802.16 working group has embarked on the development of the new amendment of IEEE 802.16 (i.e. 802.16) for the 4 generation system.
- Depending on the available bandwidth and multiple antenna mode, 802.16m will be capable of over-the-air-date-transfer rate in excess of 1Gb/s and support wide range of high quality and high capacity of IP-based services and application while maintaining full backward compatibility with existing mobile WiMAX systems.

Overview of IEEE 802.16m Program

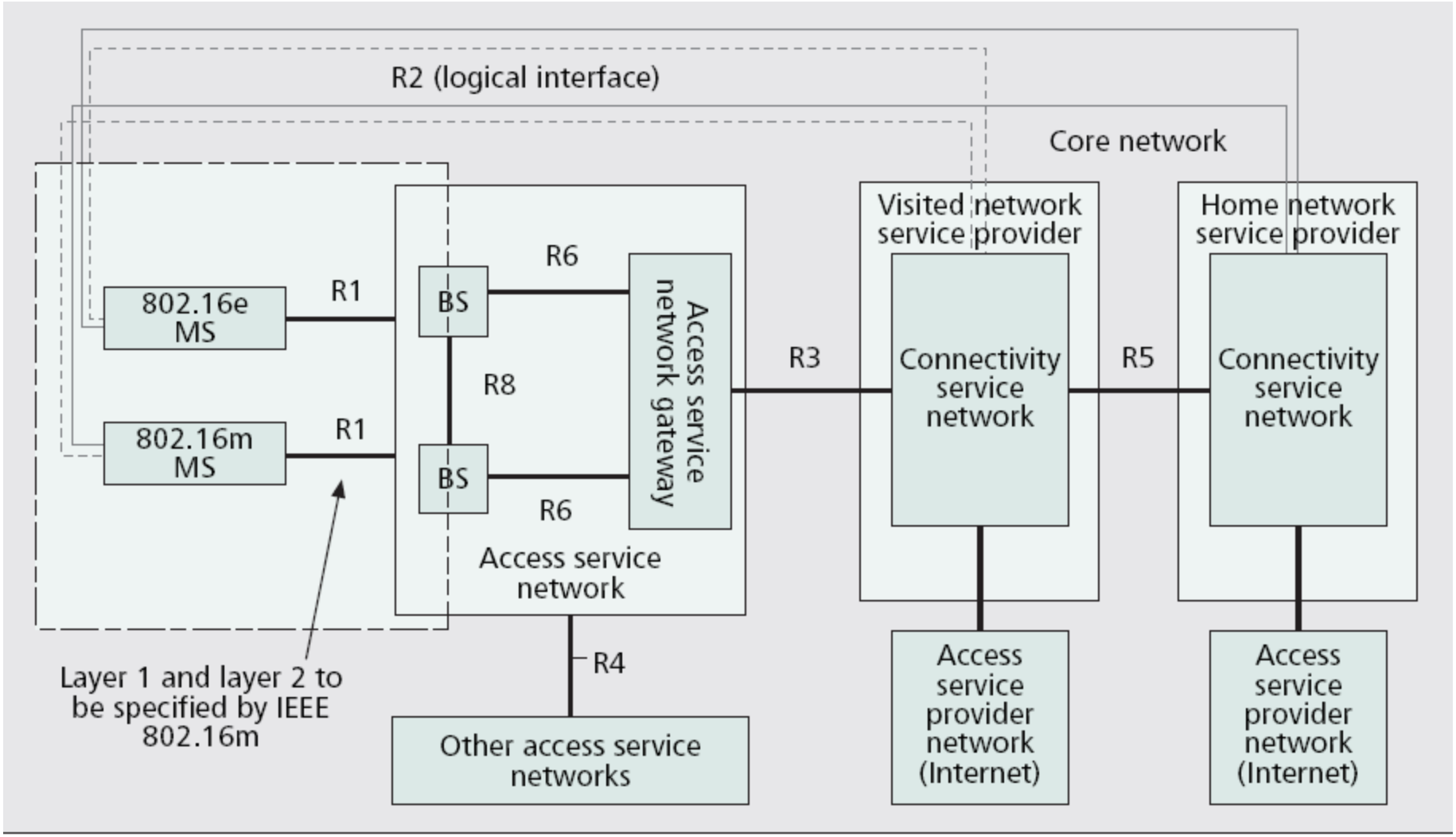


Figure 1. *Mobile WiMAX network reference model [9].*

802.16m

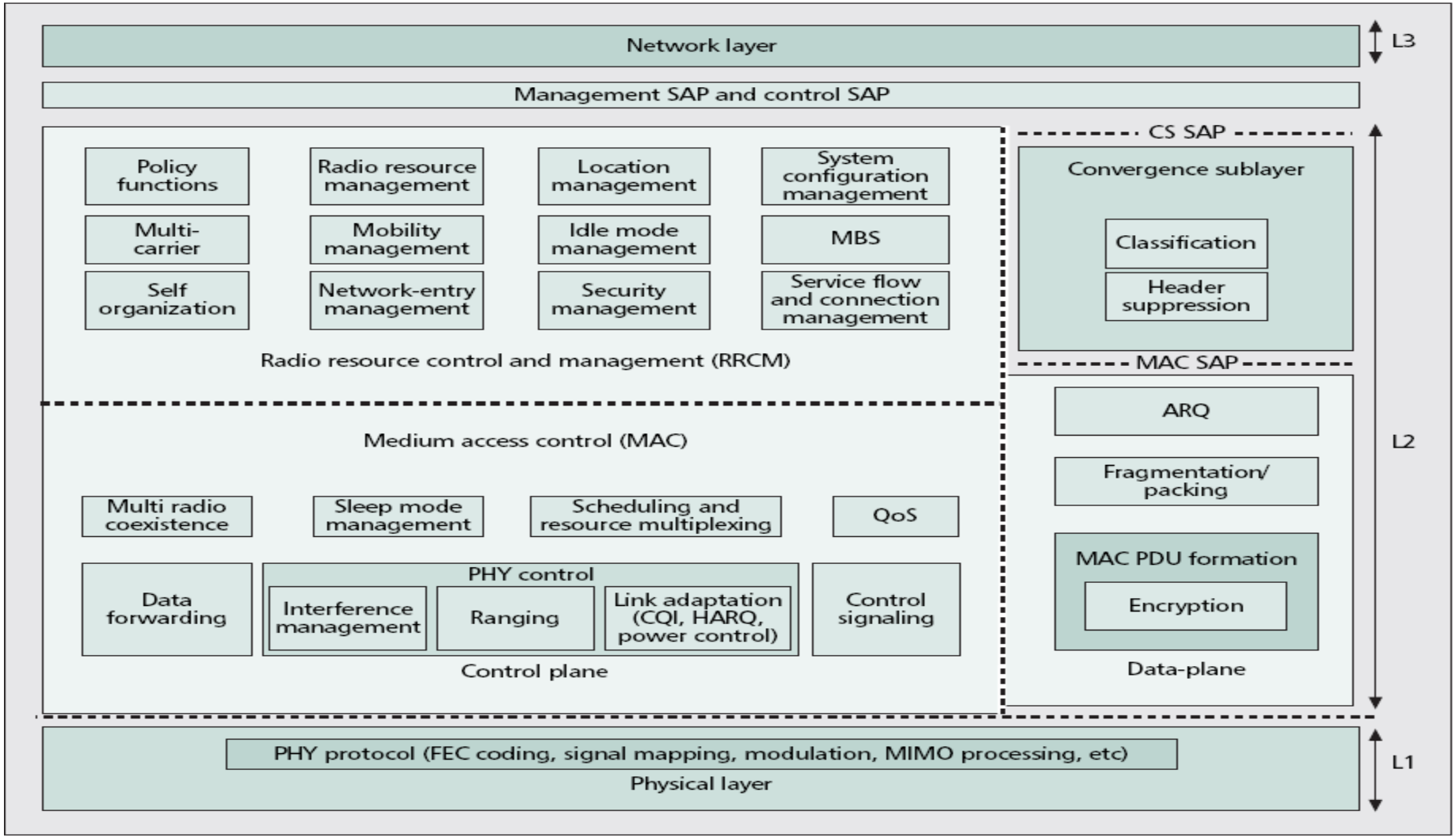


Figure 2. *IEEE 802.16m protocol stack [10].*

Advanced Features & Challenges of 802.16m

- Unified single-user/multi-user MIMO Architecture
  - support various advanced multi-antenna processing techniques including open-loop and closed single-user/multi-user MIMO schemes (single stream and multi-stream)
  - Support multi-cell MIMO techniques
- Multi-carrier support
  - The RF carriers may be of different bandwidths and can be non-contiguous or belong to different frequency bands
  - The channels may be of different duplexing modes, e.g. FDD, TDD
  - Support wider band (up to 100MHz) by BW aggregation across contiguous or non-contiguous channels

Advanced Features & Challenges of 802.16m

- Multi-hop relay-enabled architecture
  - Improve the SINR in the cell for coverage extension and throughput enhancement
- Support of femto-cells and self-organization
  - Femto-cells are low power BS at homes achieving FMC
  - Self-configuration by allowing real plug and play installation of network nodes and cells
  - Self-optimization by allowing automated or autonomous optimization of network performance with respect to service availability, QoS, network efficiency and throughput

Advanced Features & Challenges of 802.16m

- Enhanced multicast and broadcast service
  - Multi-carriers with dedicated broadcast only carriers
  - Single/multi-BS MBS
- Multi-RAT operation and handover
  - Support interworking with IEEE 802.11, GSM/EDGE, 3GPP, 3GPP2, CDMA2000etc.
- Multi-radio coexistence
  - MS reports its co-located radio activities to BS
  - Accordingly, BS can operates properly via scheduling to support multi-radio coexistence

Advanced Features & Challenges of 801.16m

- Advanced interference mitigation
  - Interference-aware BS coordination to minimize inter-cell interference
  - Fractional frequency reuse and Tx beamforming to improve cell edge capacity
  - Interference-aware scheduling via CQI metrics
  - Power control for per subframe and per subscriber