WiMAX: A Promising Technology for the Next Generation Wireless Communications Systems

June 22, 2007

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THE POSSIBILITIES ARE INFINITE

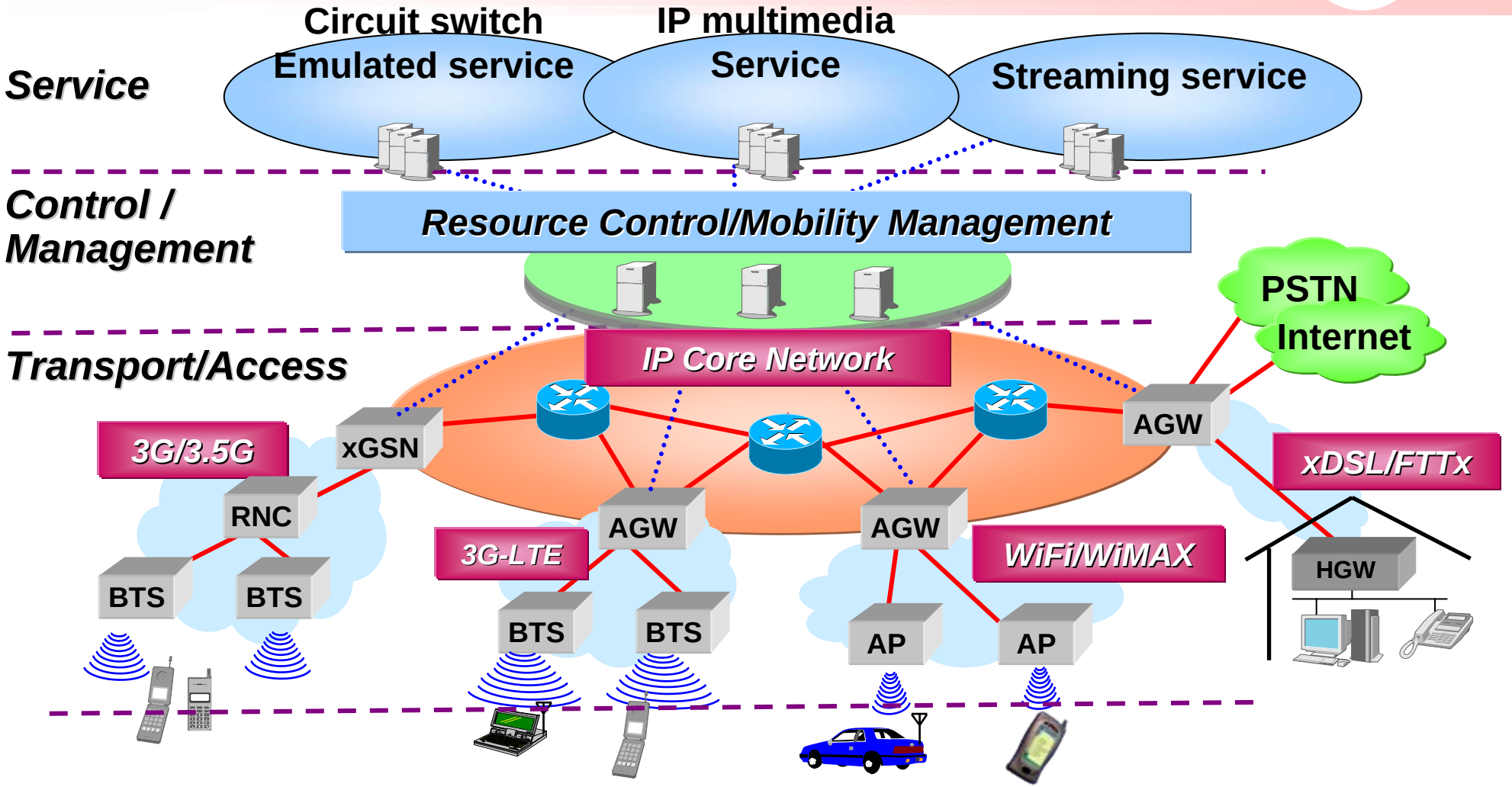
Outline

1. **Network and Wireless: What is WiMAX's role?**
2. **Advanced technologies for WiMAX systems**
3. **Application systems for digital divide**
4. **Standardization activities: IEEE and ITU-R**

Outline

1. **Network and Wireless: What is WiMAX's role?**
2. Advanced technologies for WiMAX systems
3. Application systems for digital divide
4. Standardization activities: IEEE and ITU-R

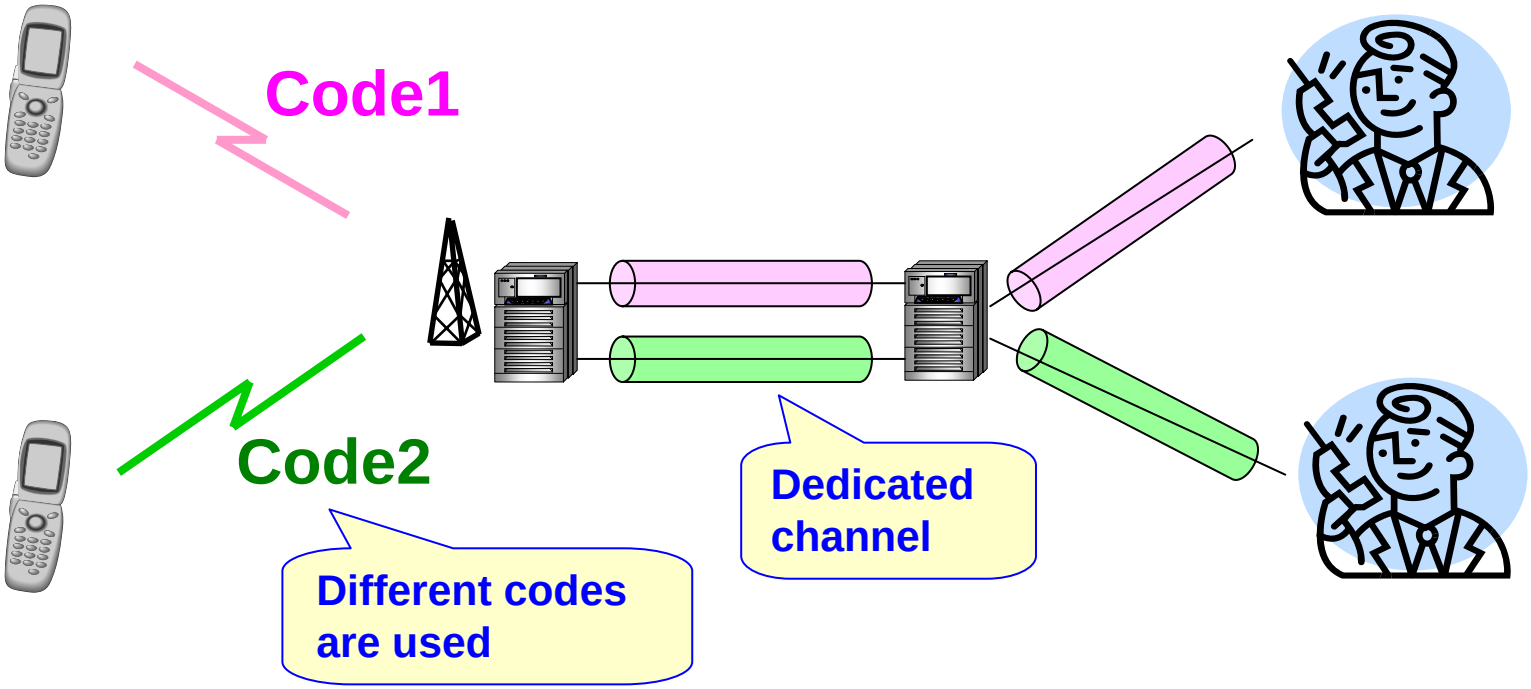
Next Generation Packet-based Network



BTS: Base station transceiver
RNC: Radio Network Controller
xGSN: Serving/ Gateway GPRS Support Node

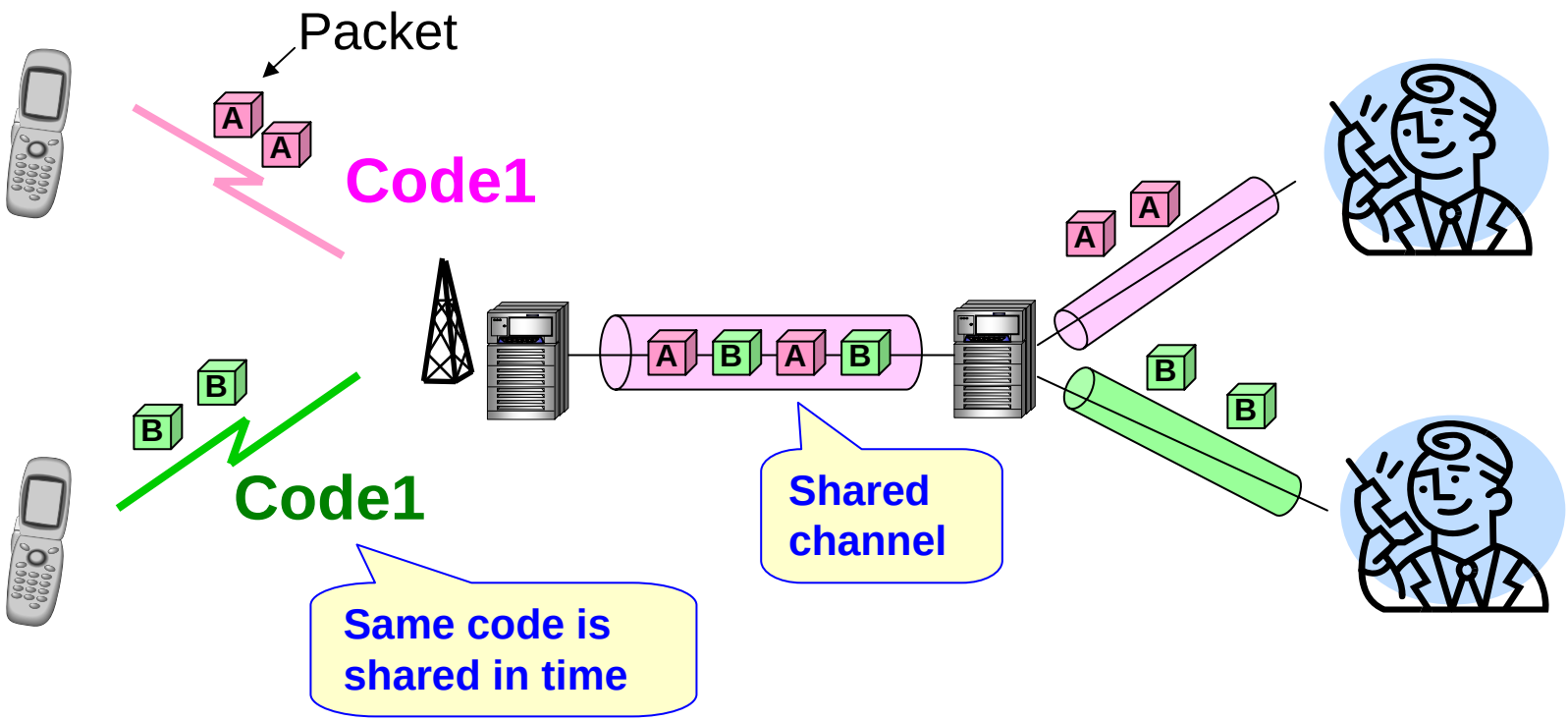
AGW: Access Gateway
AED: Access edge Device
LTE: Long Term Evolution

Circuit Switching



Keep channel resource during the call
(Code, Bandwidth, etc.)

Packet Switching

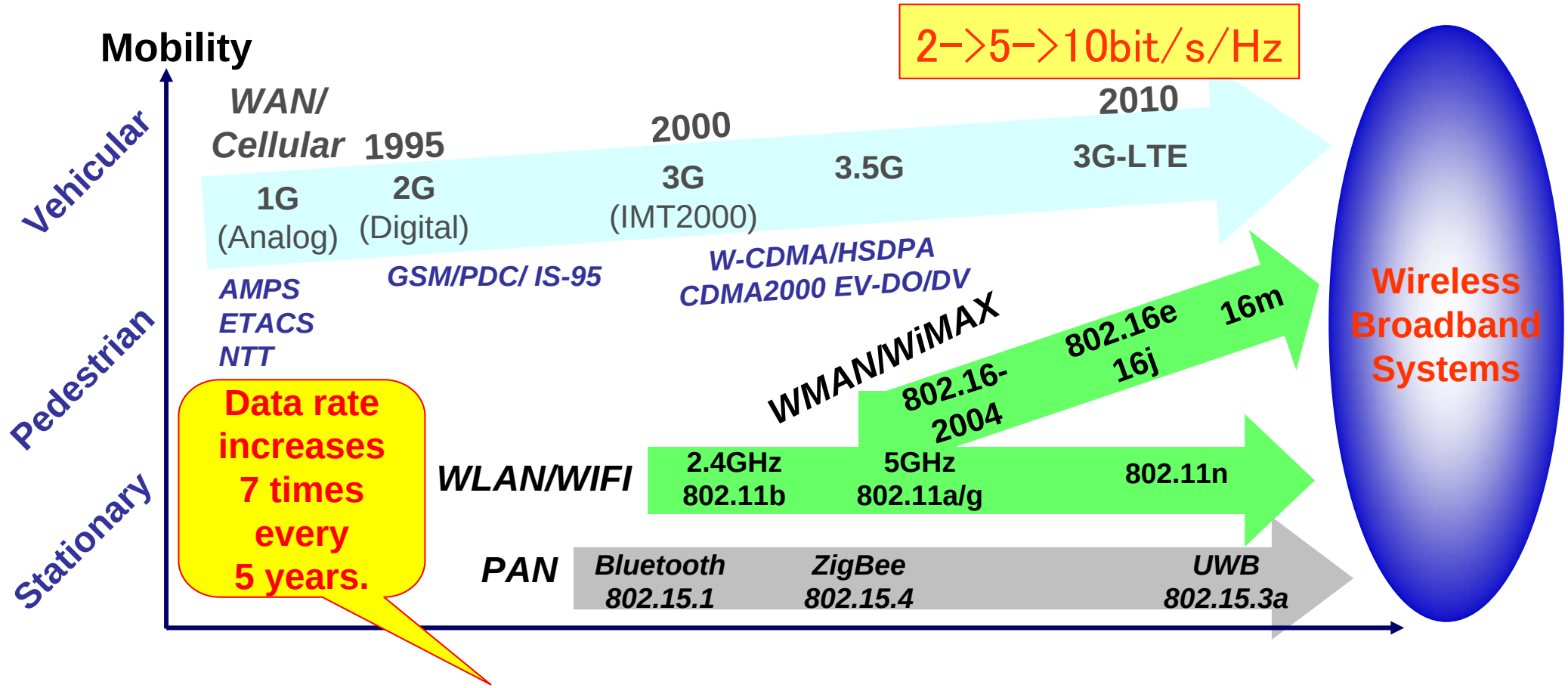


Share channel resource among users
(Code, Bandwidth, etc.)

Circuit Switch and Packet Switch

	Circuit switching	Packet switching
Feature	• Keep channel resource during the call	• Share channel resource among users
Pros.	• Constant bandwidth during the call • There is no interruption by other users after call-setup	• Efficient use of channel resource • Total capacity will be increased due to the statistical multiplexing
Cons.	• Keep channel resource even if there is no data to transmit • Capacity is limited by the number of channels	• Bandwidth may not be guaranteed • Packet may be lost when channel congestion occurred • Packet order will not guaranteed

Wireless Technology Trend



Data Rates	~40kbps	2Mbps	14Mbps	54Mbps	100Mbps	1Gbps
Spectral Efficiency (bit/s/Hz)	0.4	0.4	2.8	2.7	5	10
Radio Access	TDMA QPSK	DS-CDMA MC-CDMA	Adaptive QAM	OFDM/QAM Adaptive Coding		MIMO Adaptive Array

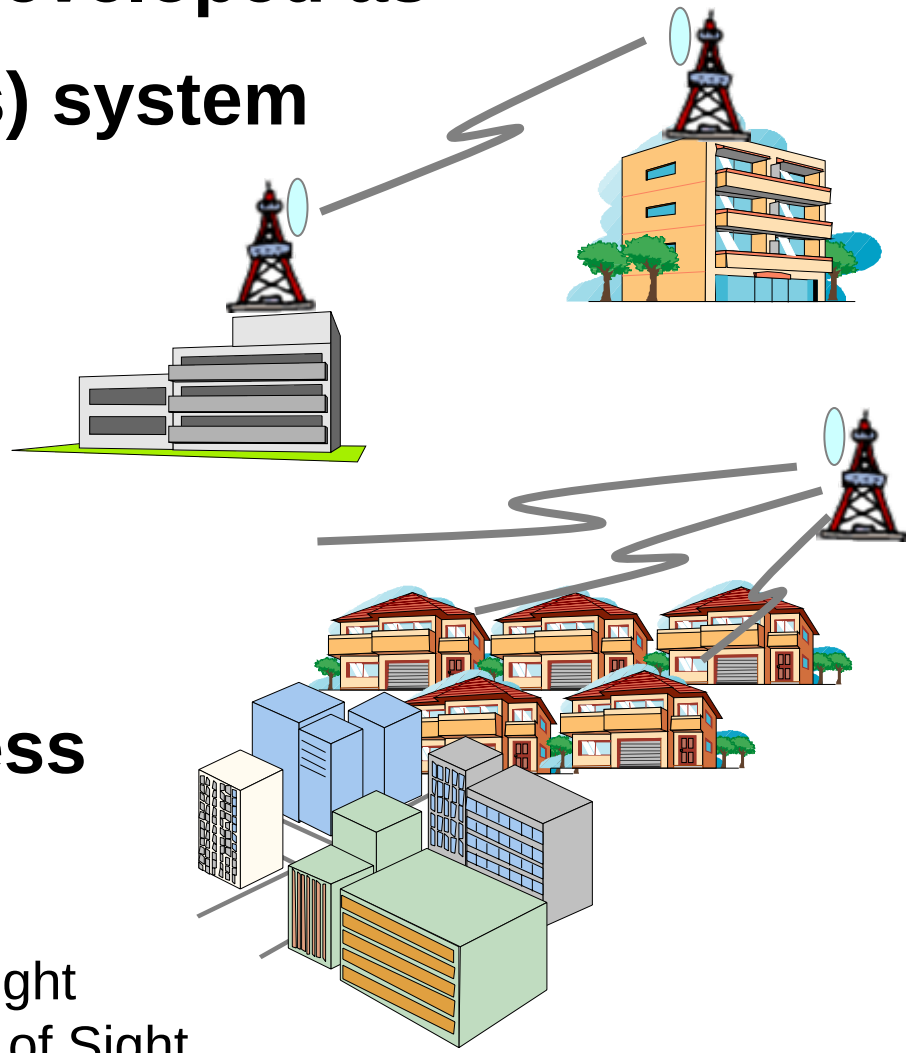
Beyond 3G Packet-based Wireless Systems

	3.5G		3G-LTE (3.9G)	IMT-Advanced (4G)	WiMAX	
	(1x-EVDO Rev.A)	(HSDPA,HSUPA)			802.16e	802.16m
Access method	DL：CDMA UL: CDMA	DL: CDMA UL: CDMA	DL: OFDMA UL: SC-FDMA	DL: OFDMA(?) UL: (?)	DL: SOFDMA UL: SOFDMA	DL: SOFDMA UL: SOFDMA
Bandwidth	1.25 MHz	5 MHz	20 MHz	>100 MHz	20 MHz	>20 MHz
Modulation	BPSK,QPSK 8PSK,16QAM	HPSK,QPSK 16QAM	QPSK,16QAM 64QAM,etc.	QPSK,16QAM 64QAM,etc.	QPSK,16QAM 64QAM,etc.	QPSK,16QAM 64QAM,etc.
Data rate (max.)	DL: 3.1Mbps UL: 1.8Mbps	DL: 14.4Mbps UL: 5.7Mbps	DL: 100Mbps UL: 50Mbps	DL: ~1Gbps UL: >50Mbps	DL+UL: 75Mbps	DL: >130Mbps UL: >56Mbps
Service-in	Year 2006	Year 2006	Expected in 2009	Expected in next decade	Expected in 2007	Expected in next decade
Features	Enhancement of data rate and QoS	Enhancement of packetised data rate	Great improvement of data rate and latency	Further improvement of data rate and mobility	Great improvement of data rate and latency	Further improvement of data rate and latency

3G-LTE: 3G Long Term Evolution

Wireless MAN History: WiMAX (Metropolitan Area Network)

- **Wireless MAN was initially developed as FWA(Fixed Wireless Access) system**
  - **first**
    - **Point to Point Access**
    - **LoS link**
  - **enhanced to support**
    - **Point to Multipoint Access**
    - **NLoS link**



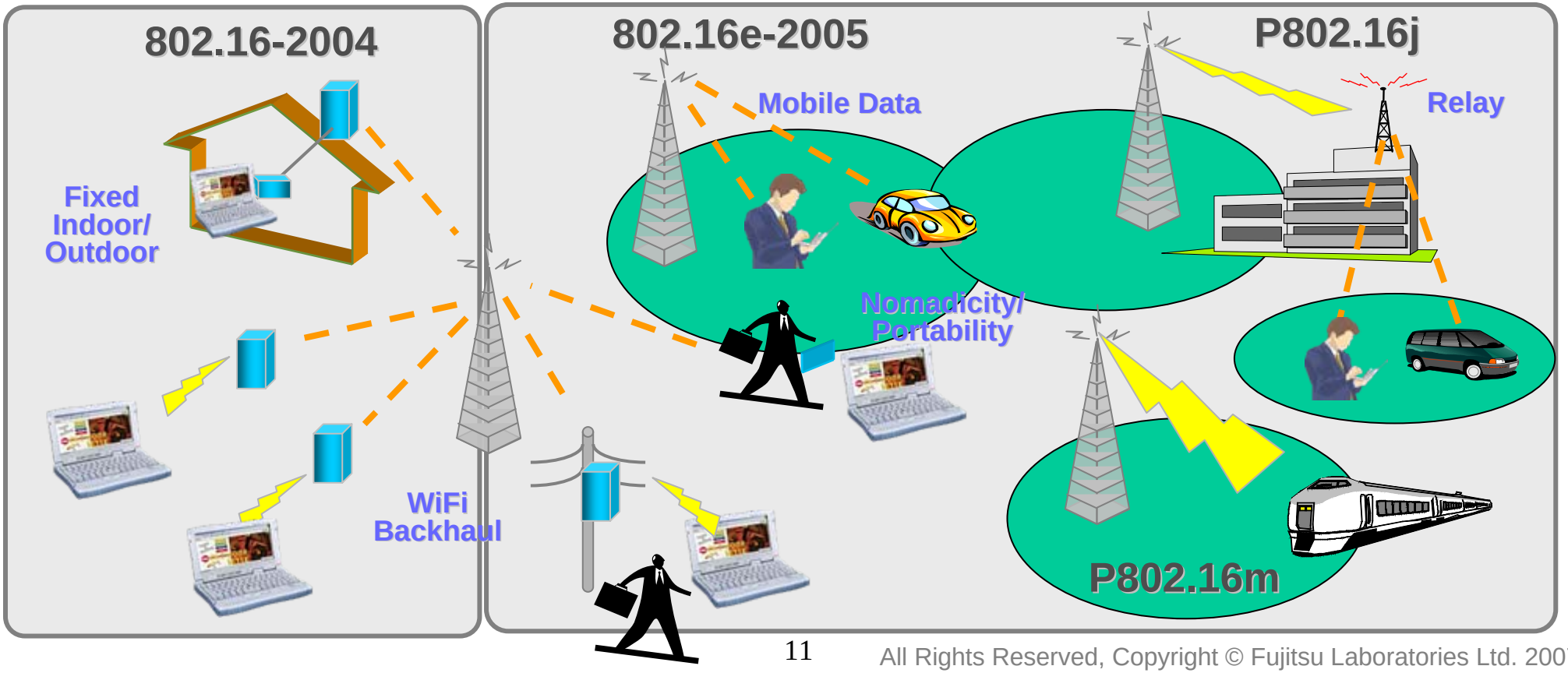
LoS :Line of Sight
NLoS :Non Line of Sight

802.16 Series Wireless MAN Specifications

Fixed → Nomadic/Portable → Simple Mobile/ Full Mobile → Relay / High speed

- Alternative to ADSL
- Business Access
- WiFi Backhaul

Complements Cellular System



Main Features of IEEE802.16

- ✓ Provide low-cost solution
  (networking, mobile performance)
- ✓ Fit to IP Communication
- ✓ Flexible depending on frequency assignment
- ✓ Various operational parameters are defined
- ✓ Only MAC/PHY layers are specified
  (i.e. Core network is out of scope in the 802.16)

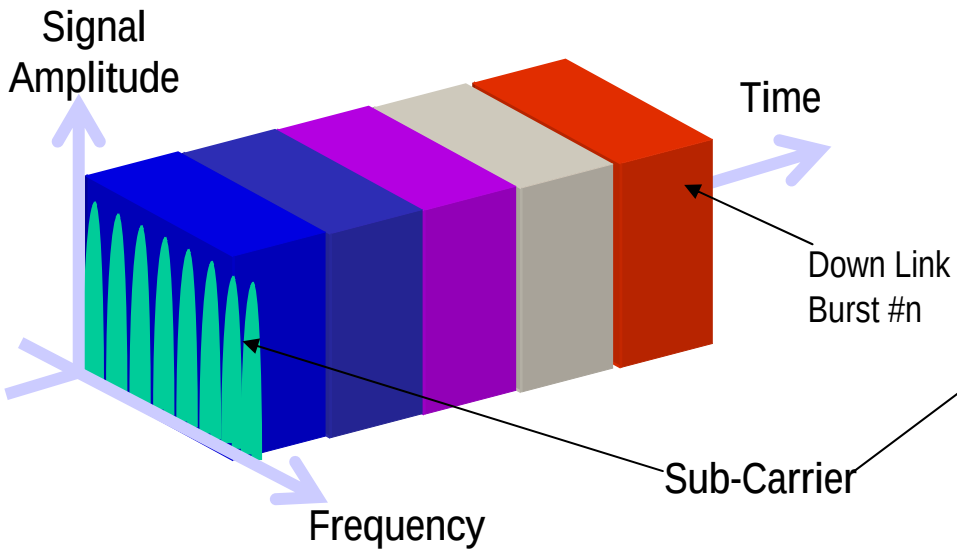
Specification of WiMAX

		Fixed (802.16-2004)	Mobile (802.16e-2005)	802.16m
Freq.	Frequency band	< 11GHz	< 6GHz	< 6GHz
	Bandwidth	1.25～20MHz	1.25～20MHz	1.25～20MHz
Peak Data Rate		75Mbps (DL+UL)	75Mbps (DL+UL)	> 130Mbps(DL) > 56Mbps(UL)
Cell Radius		2-10km（max. 50km)	2-3km	Up to 5km*
Modu-lation	Primary (AMC)	BPSK/QPSK/16QAM/64 QAM	QPSK/16QAM/ 64QAM	QPSK/16QAM/ 64QAM
	Secondary	OFDMA	SOFDMA	SOFDMA
Technology for higher data speed		AAS, STC, MIMO	AAS, STC, MIMO	AAS, STC, MIMO
Mobility		Fix、Nomadic	Max. 120km/h	Max. 350km/h

AMC: Adaptive Modulation and Coding, SC: Single Carrier,
AAS: Adaptive Antenna System, STC: Space Time Coding
MIMO: Multiple Input Multiple Output
*: some members propose “functionally up to 100km” for rural area application

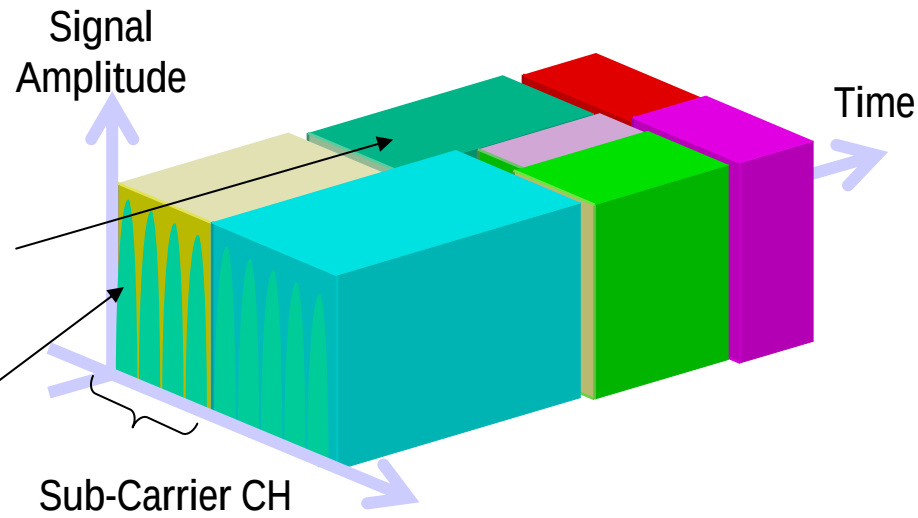
OFDM and OFDMA

Transmission by OFDM
(Orthogonal Frequency Division Multiplexing)



- All sub carriers are allocated to one user.
- Used in 802.16-2004

Transmission by OFDMA (Orthogonal Frequency Division Multiple Access)



- Sub carriers are flexibly allocated to one or more users depending to their radio condition.
- Used in 802.16e-2005 and 802.16m

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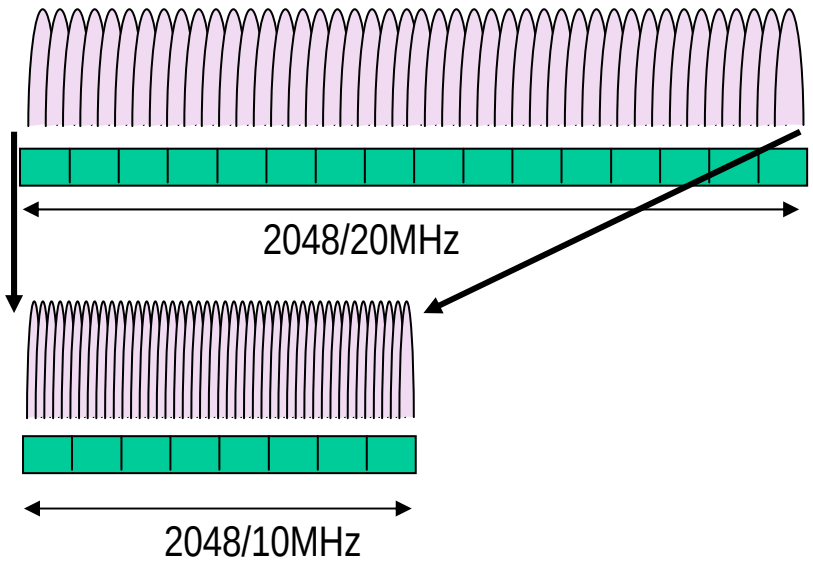
Scalable OFDMA (S-OFDMA)

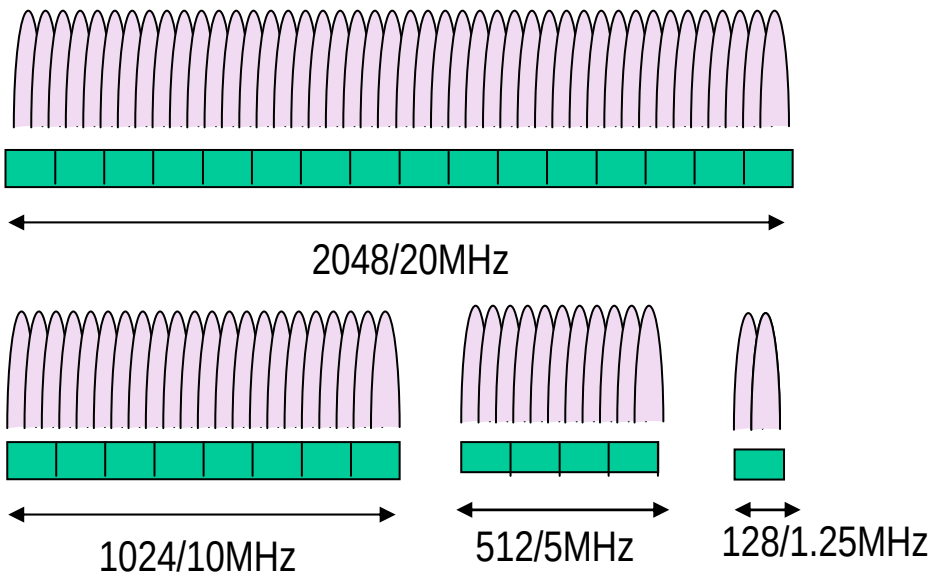
OFDMA:802.16-2004

- FFT size is fixed to 2048 for all bandwidth
- Interval of the sub-carriers becomes narrower as available bandwidth.
- More difficult to keep performance

SOFDMA:802.16e-2005

- Allocate the FFT size according to available frequency bandwidth
- Interval of sub-carriers is fixed.

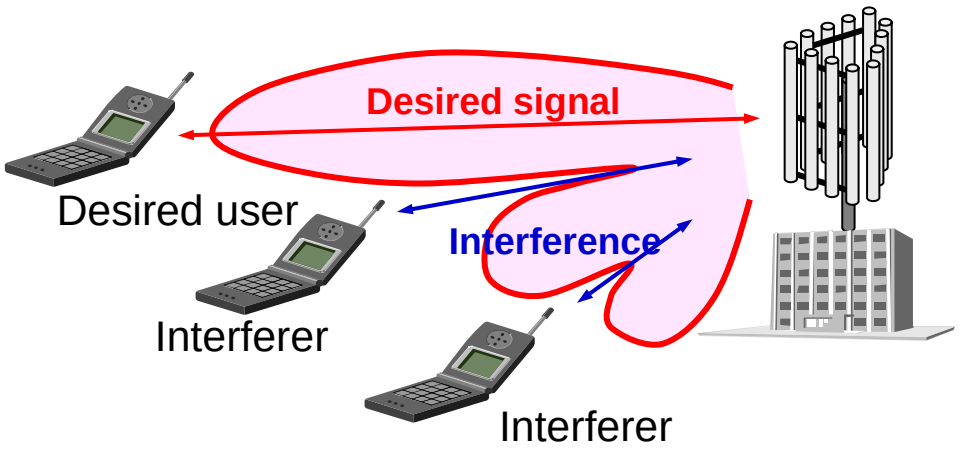




Multi-Antennas for Higher Capacity

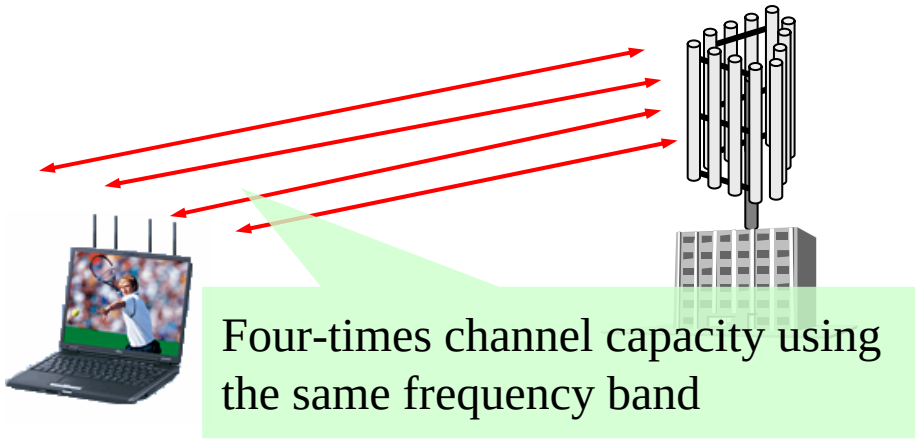
➢AAA (Adaptive Array Antennas)

- Space division to reduce interference at both terminal and base station
- Optimal antenna directivity is best calculated on real-time basis.

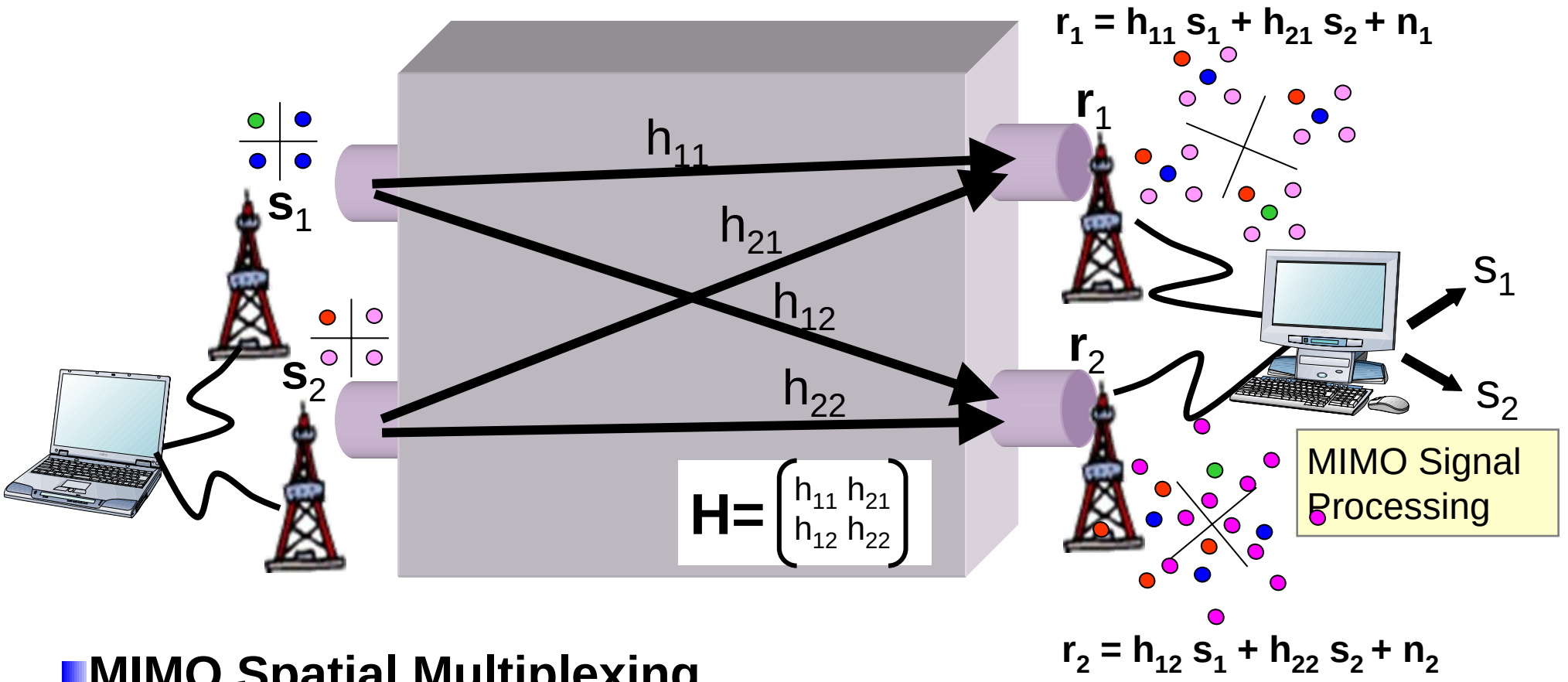


➢MIMO (Multi Input Multi Output)

- Space Division Multiplexing in the same space using the same frequency band
- Expected capacity increase of number-of-antenna-fold
- Adaptive signal processing required to establish each independent channel



MIMO: Multiple Input Multiple Output

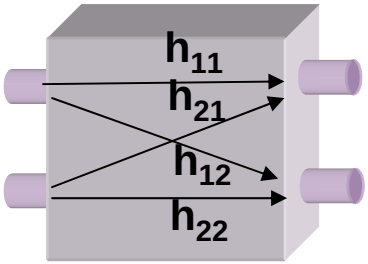


MIMO Spatial Multiplexing

Multiple data streams are transmitted through multiple antennas

⇨ Data rate can be increased proportional to the number of antennas (min. of Tx and Rx)

MIMO Signal Processing Schemes



$$\begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = H \begin{bmatrix} S_1 \\ S_2 \end{bmatrix}$$

$$r_1 = h_{11}\, s_1 + h_{21}\, s_2$$
$$r_2 = h_{12}\, s_1 + h_{22}\, s_2$$

ZF: Matrix Inverse

$$\begin{bmatrix} \hat{S}_1 \\ \hat{S}_2 \end{bmatrix} = \hat{H}^{-1} \begin{bmatrix} r_1 \\ r_2 \end{bmatrix}$$

$$h_{22} r_1 = h_{22} h_{11}\, s_1 + h_{22} h_{21}\, s_2$$
$$h_{21} r_2 = h_{21} h_{12}\, s_1 + h_{21} h_{22}\, s_2$$

$$h_{22} r_1 - h_{21} r_2 = (h_{22} h_{11} - h_{21} h_{12})\, s_1$$

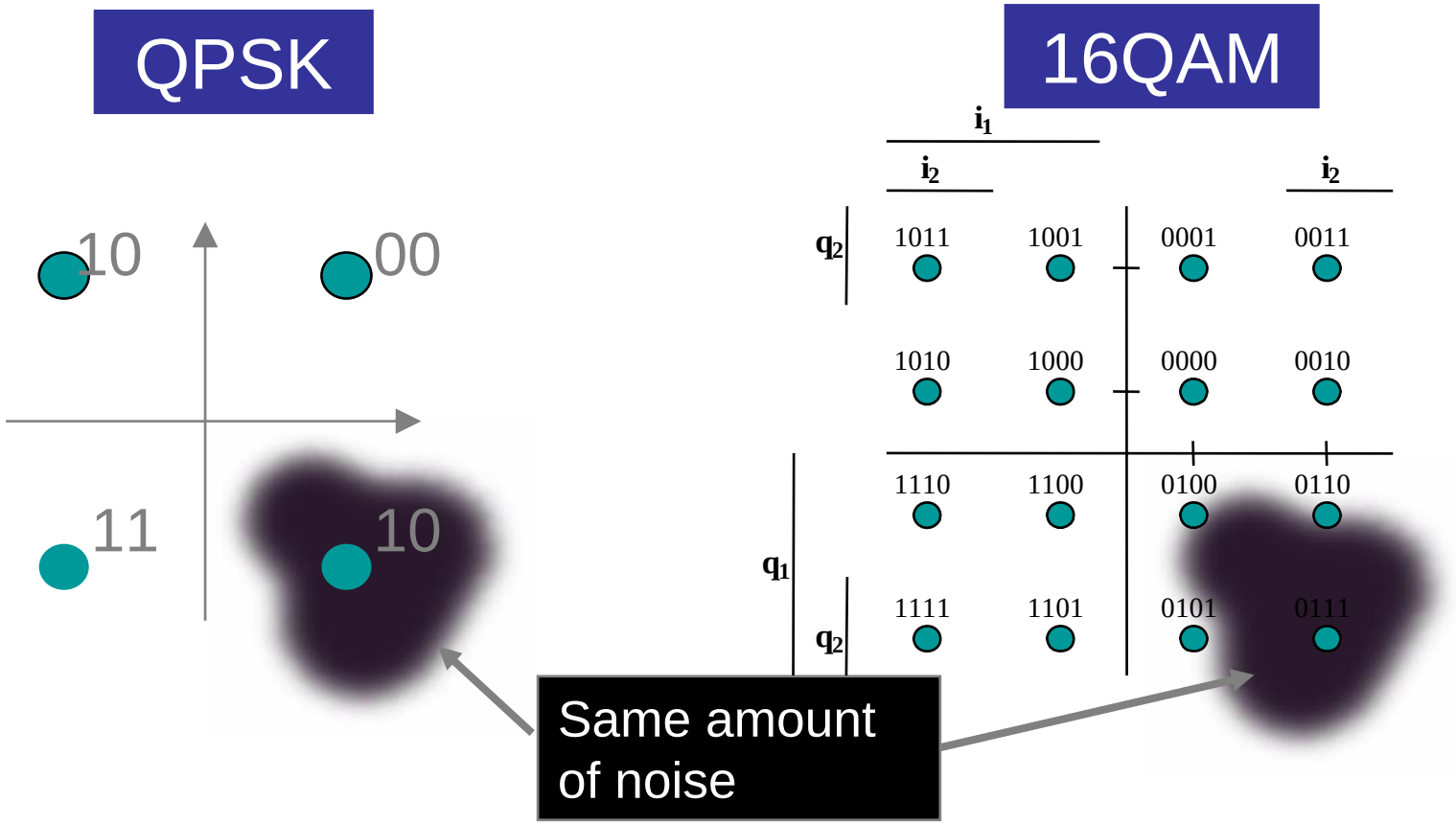
$$s_1 = \frac{h_{22} r_1 - h_{21} r_2}{h_{22} h_{11} - h_{21} h_{12}} \qquad s_2 = \frac{h_{12} r_1 - h_{11} r_2}{h_{12} h_{21} - h_{11} h_{22}}$$

Other schemes

- **MMSE:** Wiener Filter
- **BLAST:** Serial Interference Canceller
- **MLD:** Maximum Likelihood Detection
- **Eigen-mode precoding:** with feedback

Quadrature Amplitude Modulation

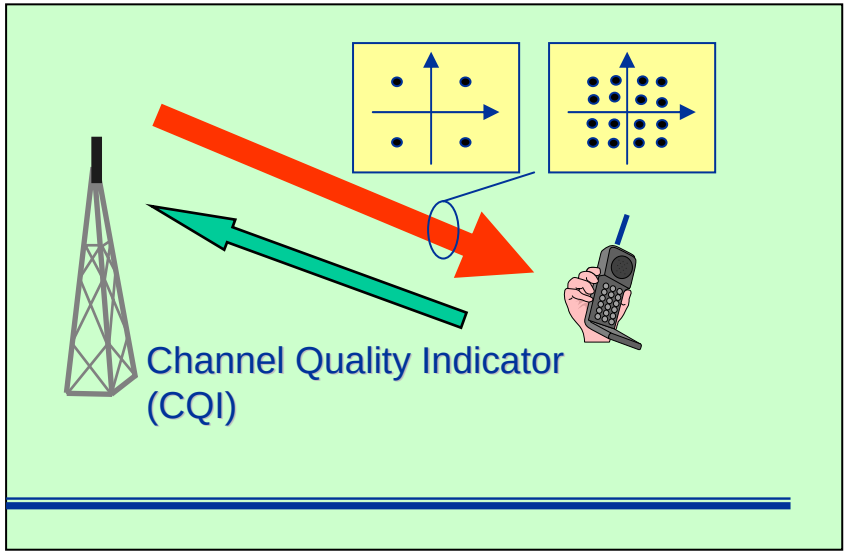
- Modulation Phase and Amplitude

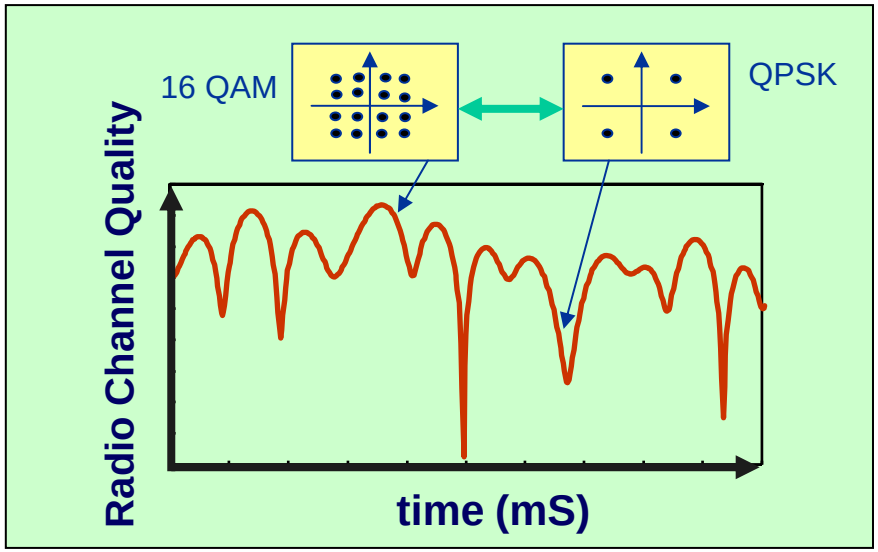


2 bits per symbol
Robust

4 bits per symbol
Requires high S/N

Adaptive Modulation and Coding (AMC)



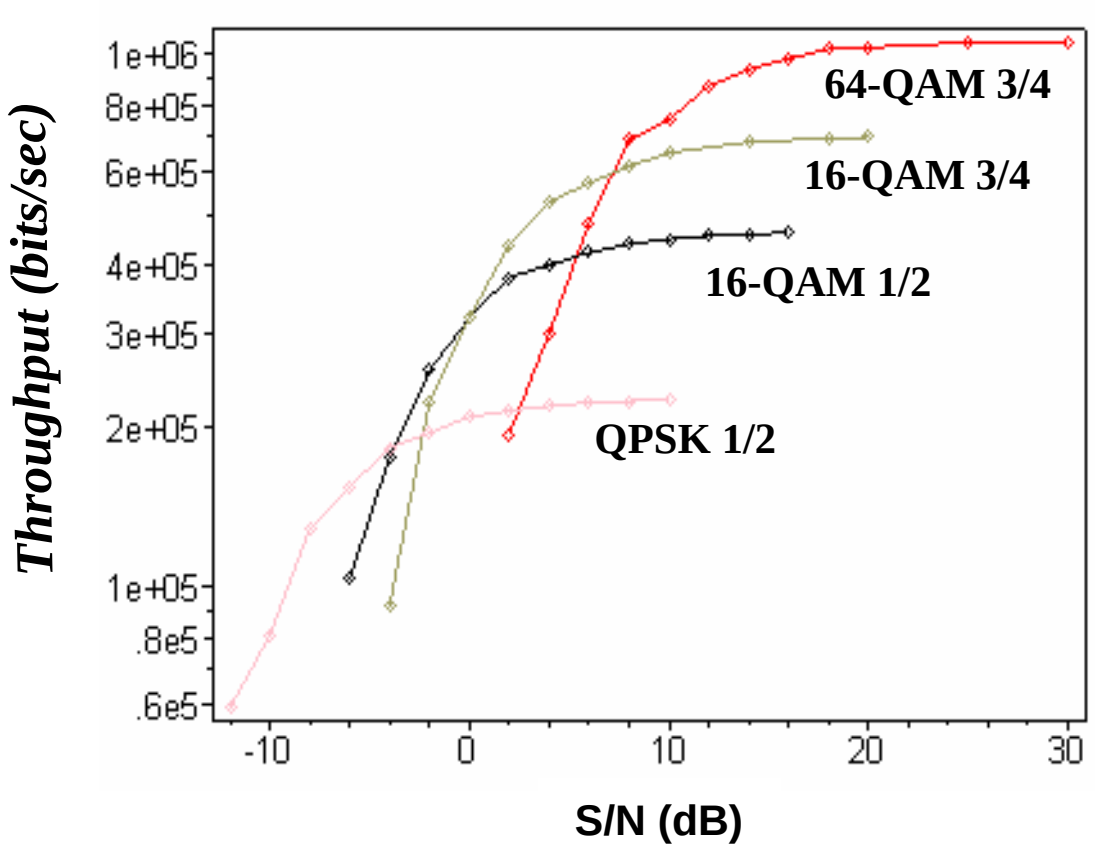


- Use high level modulation and coding rate when channel condition is good

⇒ Data Throughput can be increased

Adaptive Modulation and Coding (AMC)

- Throughput Performance

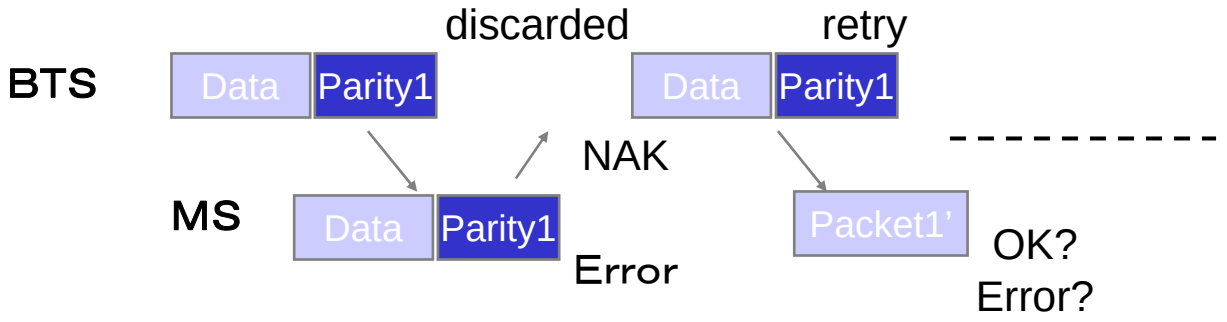


Single path
Rayleigh Fading
Fd = 5.555 Hz

Hybrid ARQ

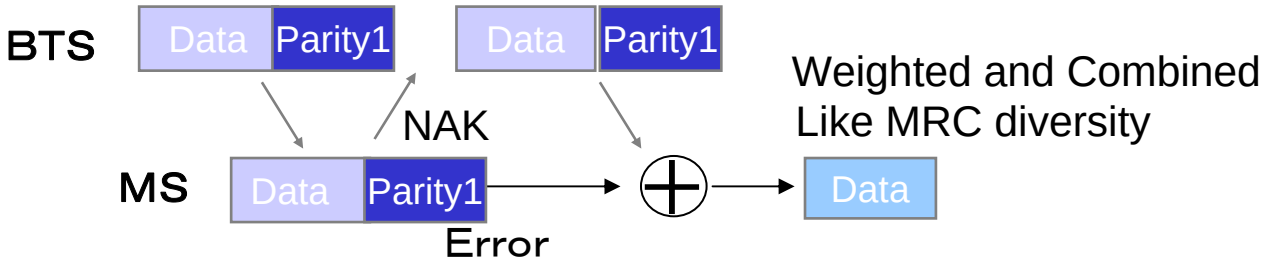
<Conventional ARQ>

- Discard error packet
- Retry

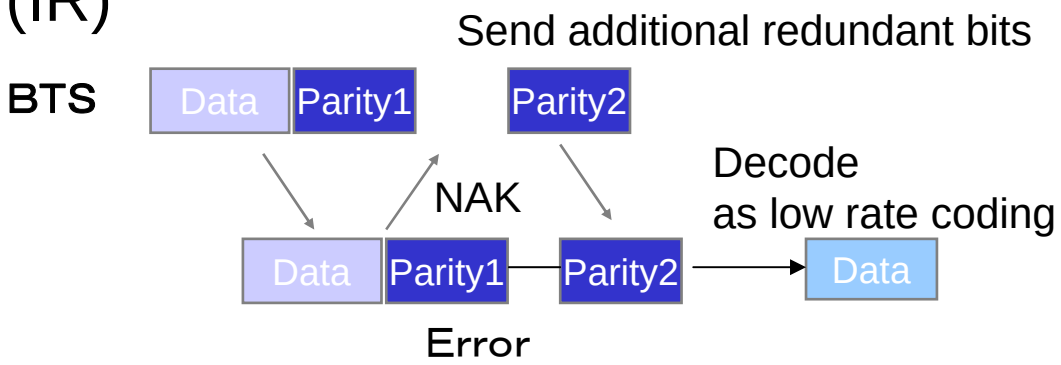


<Hybrid ARQ>

- Chase Combining (CC)
  - Store
  - Resend
  - Combine



- Incremental Redundancy (IR)
  - Store
  - Send
    Additional redundant bits

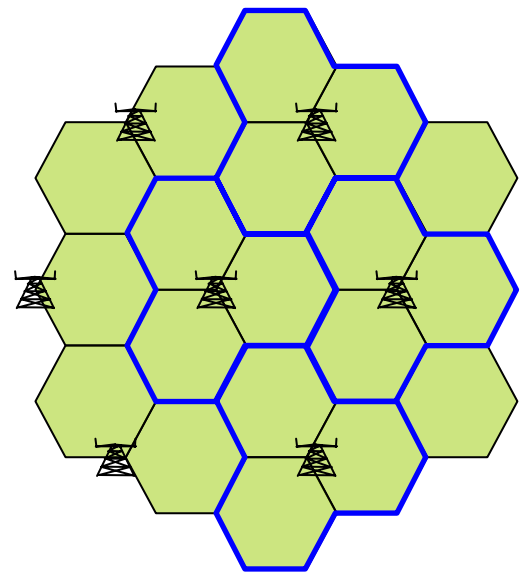


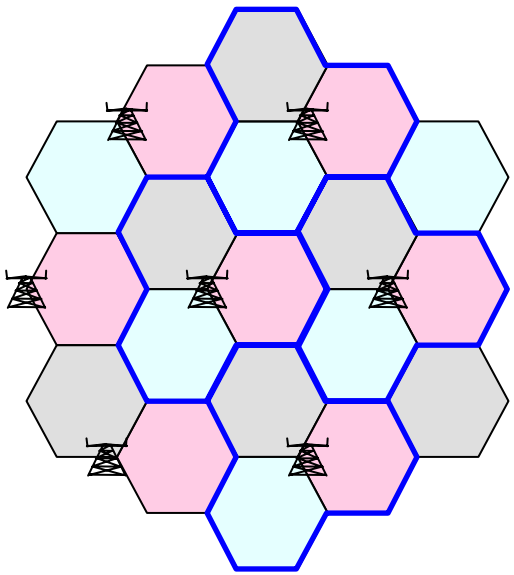
ARQ: Automatic Repeat Request
MRC: Maximum Ratio Combining

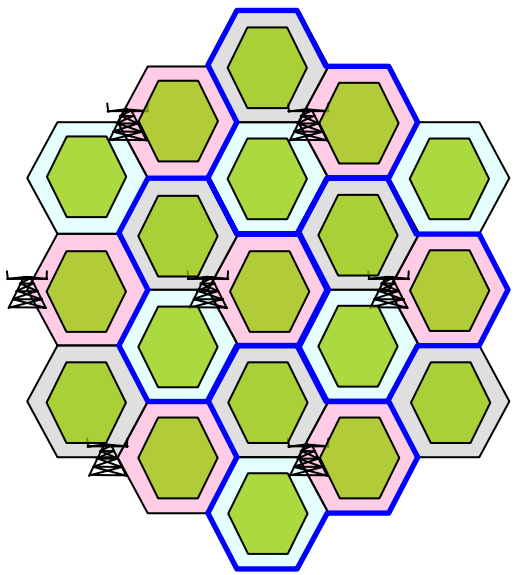
Critical Problems to Solve

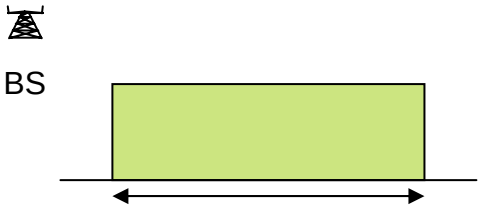
- Single Frequency Network (SFN) operation
  - Fractional Frequency Reuse (FFR)
  - Antenna diversity (STC)
  - Other-cell interference mitigation: Scheduling algorithm
- Peak-to-Average Power Ratio (PAPR) in Uplink (UL)
  - Linearization for terminal: high-linearity PA, Digital Pre-Distortion (DPD)
  - 3G-LTE employs Single-Carrier (SC) approach
- Control channel quality in Time Division Duplex (TDD): Data/C-ch mixed frame structure
  - Circular-Shifted Transmit Diversity (CSTD) for 2-Tx antennas
  - Repetition Coding

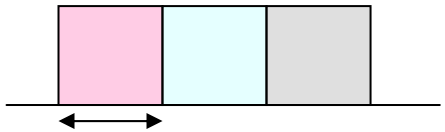
Fractional Frequency Reuse (FFR)

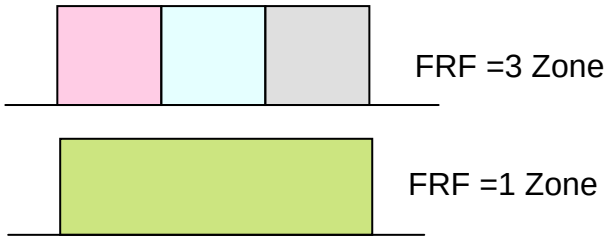








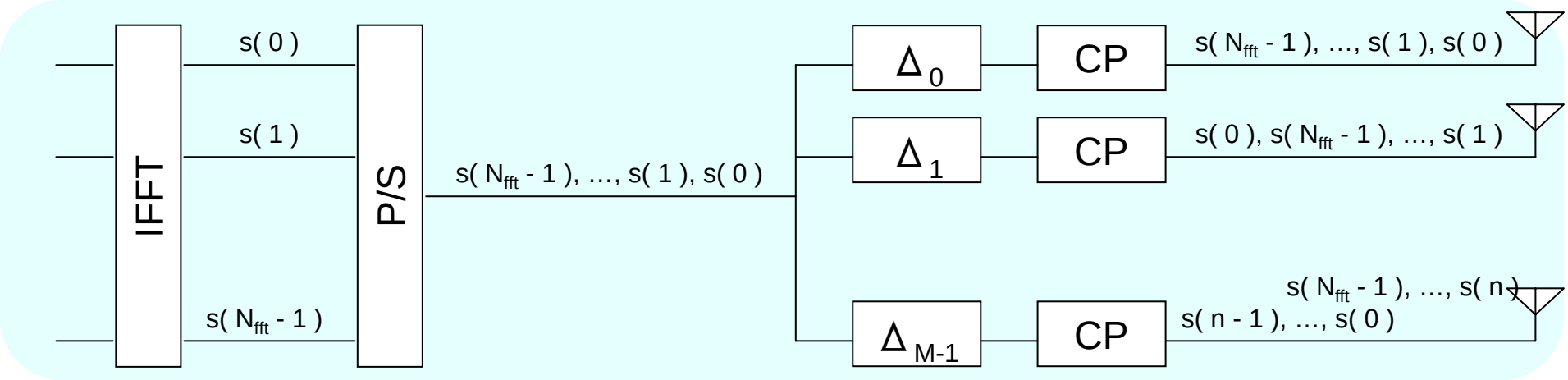




FRF = 1	FRF = 3	1 ≦ FRF ≦ 3

FRF: Frequency Reuse Factor

Circular-Shifted Transmit Diversity (CSTD)



■Transmitter

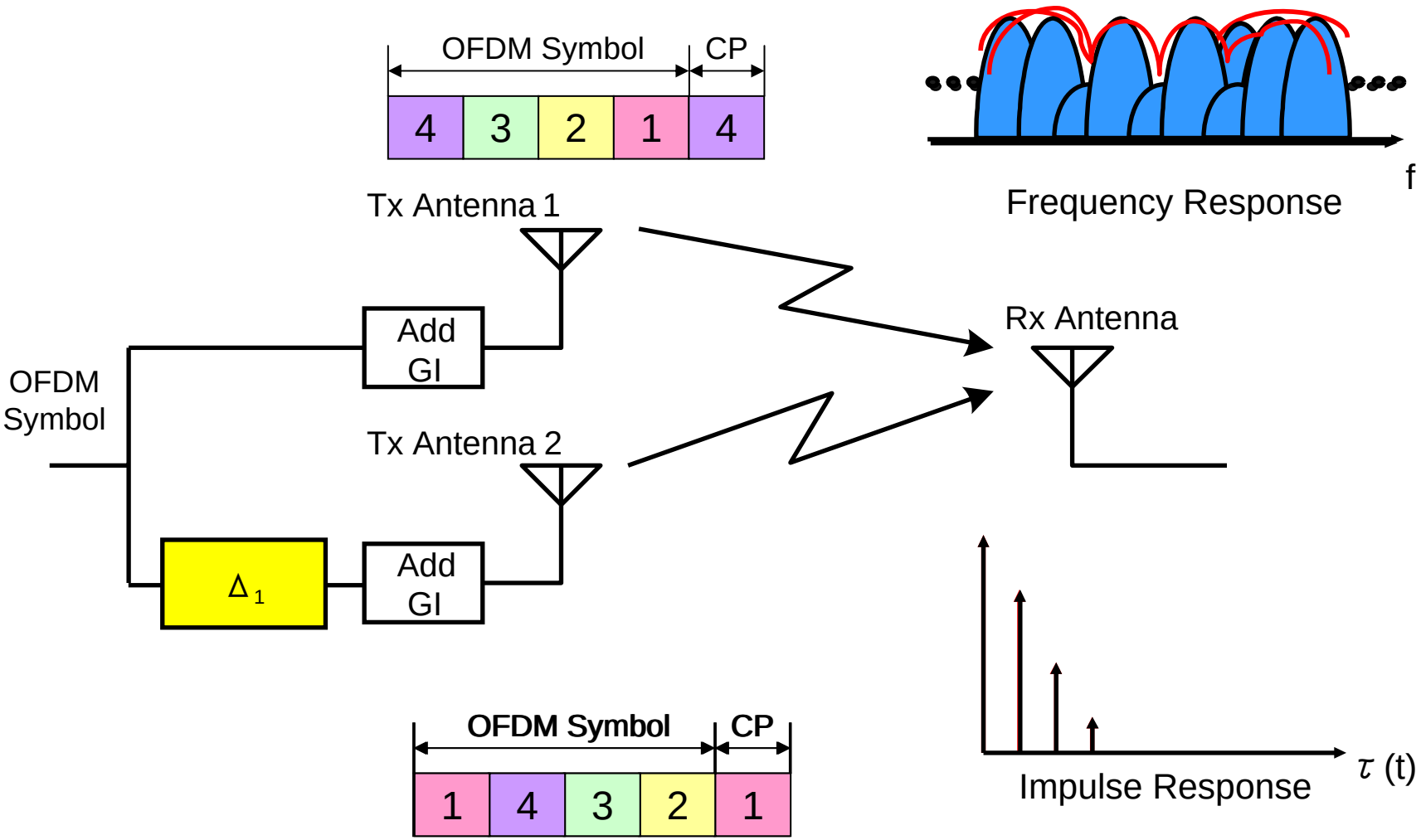
-Transmit circular-shifted OFDM symbols by Δ-circular operator at each antenna

$\Delta_0 = 0$

$\Delta_1 < \Delta_2 < \ldots < \Delta_{M-1}$

→ Available delay path more than Cyclic Prefix (CP)

Circular-Shifted Transmit Diversity (CSTD)



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Multi-hop Relay (802.16j)

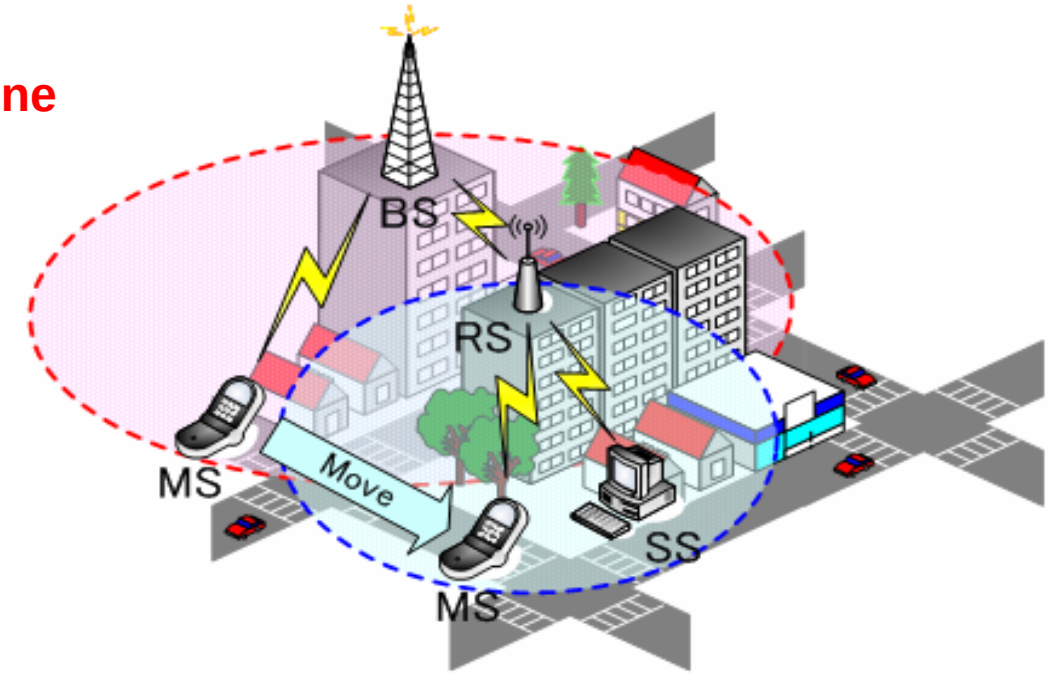
■Add the repeater function:

-Wider coverage without backhaul line

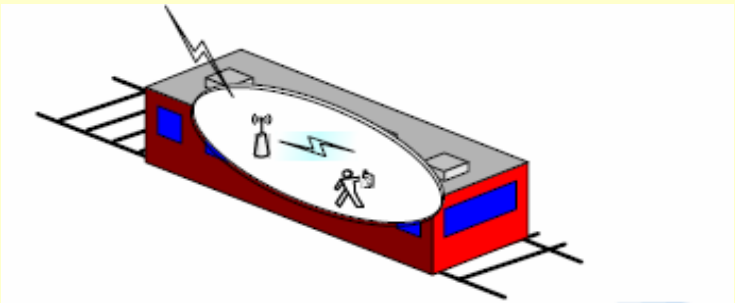
-Higher throughput

■Two Relay modes:

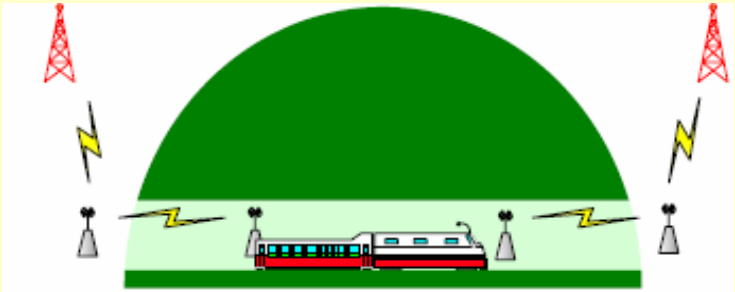
- •Transparent relay
  - •Two hop simple relay
  - •Centralized scheduling
- •Non-transparent relay
  - •Multiple Relay
  - •For expanding coverage
  - •Centralized/Distributed scheduling



Sample Application



Passengers in a train



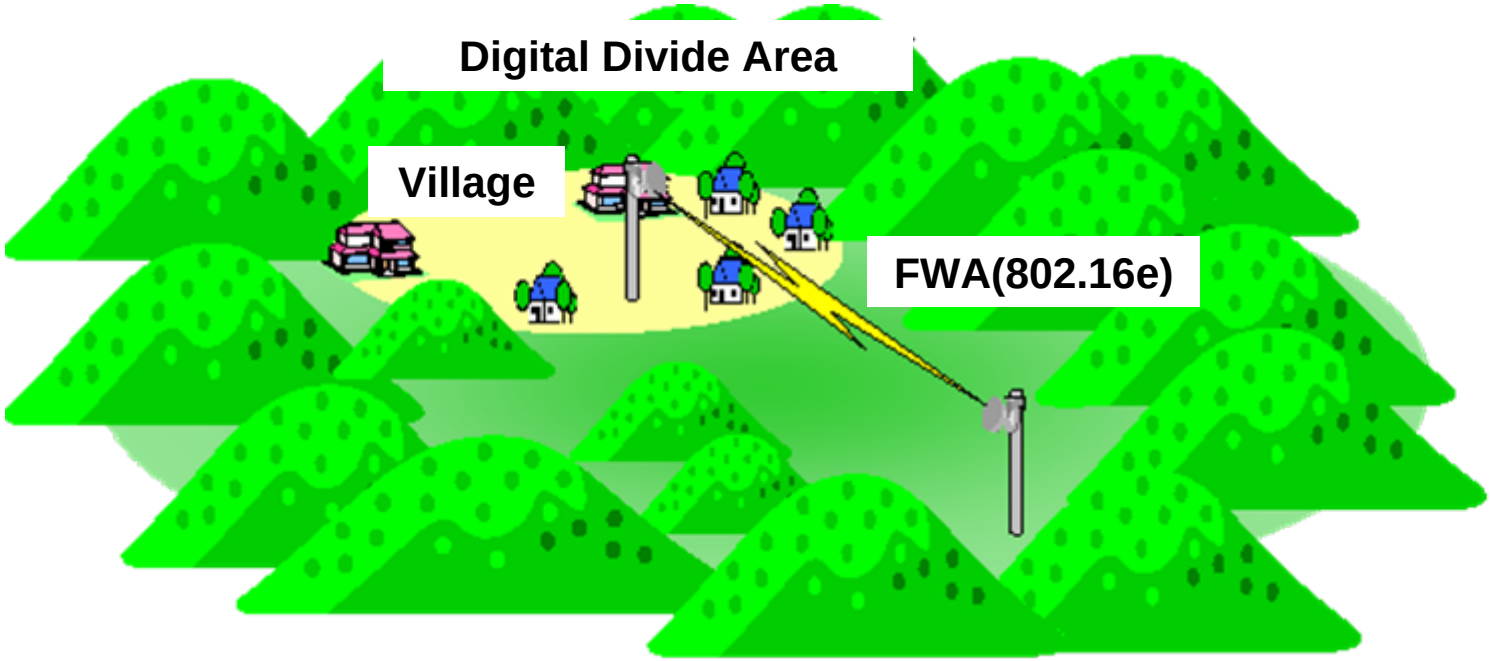
Train/vehicles in a tunnel

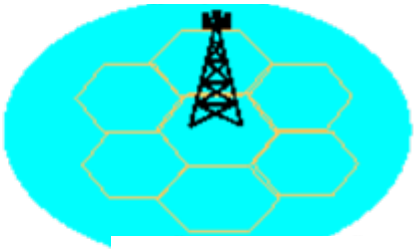
Fixed Wireless Access (FWA)

■802.16e usage according to application:

-FWA for digital divide area

-MWA for dense urban area





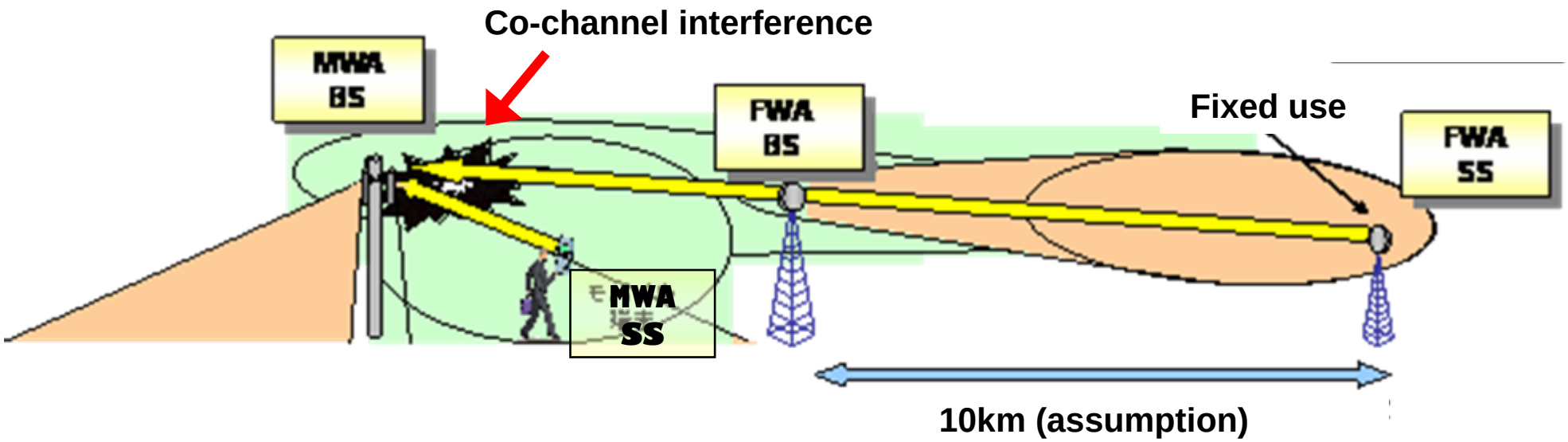
MWA: Mobile Wireless Access

Coexistence FWA and MWA

■MIC of Japan studied the possibility of coexistence FWA/MWA:

-Antenna directivity for FWA SS should be considered

-Site engineering between MWA/FWA should be considered



MIC: The Ministry of Internal Affairs and Communications

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IEEE802.16 Standard Family

802.16 Rev2

802.16-2004 (Oct 2004)

IEEE Std 802.16
•10-66 GHz PHY
Apr 2002

802.16c
Profiles
Jan 2003

802.16a
•2-11 GHz PHY
Jan 2003

802.16-REVd
• <11 GHz NLos PHY
Jun 2004

802.16e-2005 (Jan 2006)

802.16-2004/ Cor1

802.16e-2005
•Mobile Amendment

802.16-2004/ Cor2

802.16f-2005
• MIB for fixed operation
Sep 2005

Supporting Specification

802.16/Conformance 01,02,03,04

802.16.2 Coexistence

802.16h
•License Exempt Band

802.16g
•Management Plane

802.16i
• Mobile MIB

802.16k
• Media Access Control Bridge

802.16j
• Mobile Relay

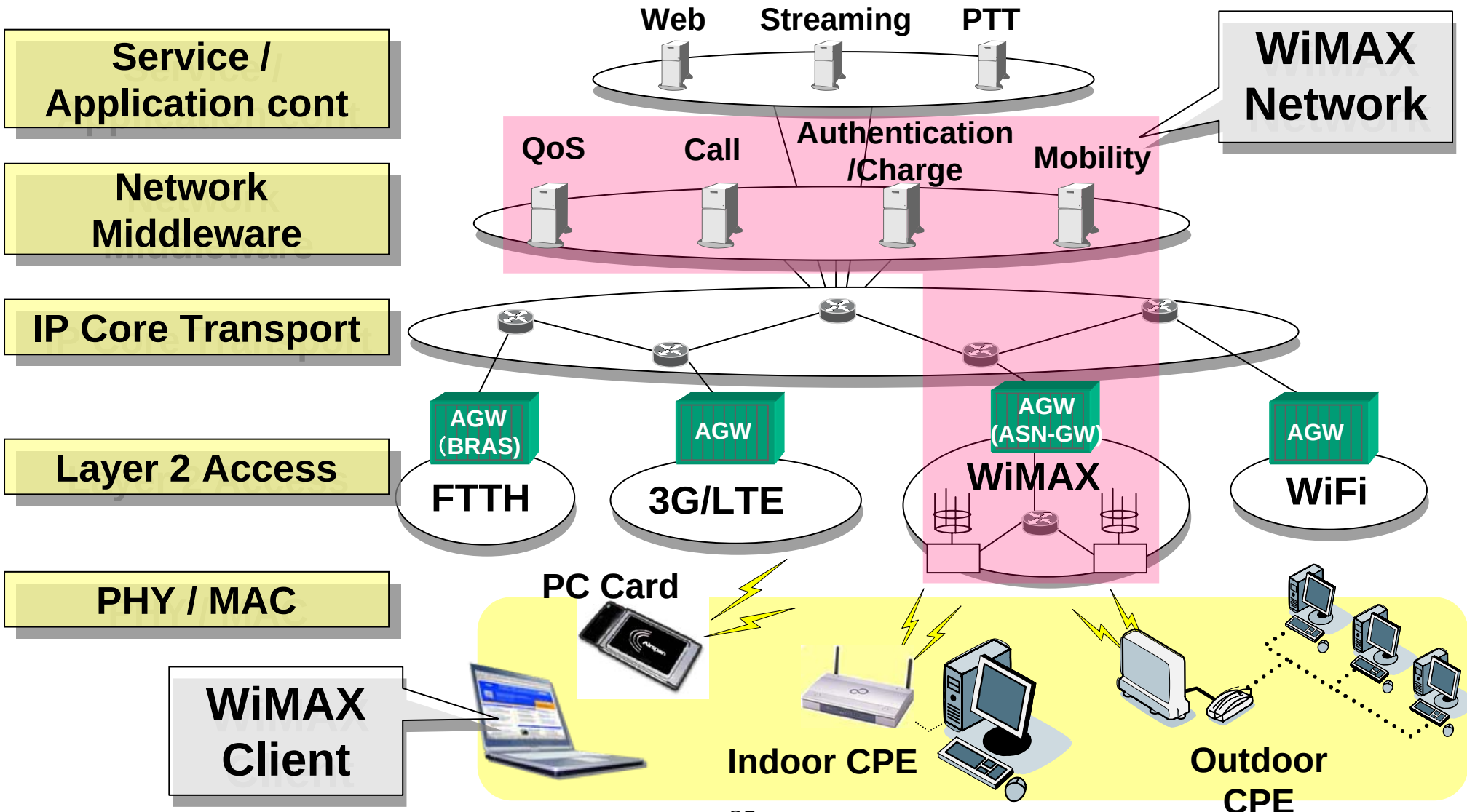
802.16m
• IMT-Advanced

:Active

WiMAX Forum

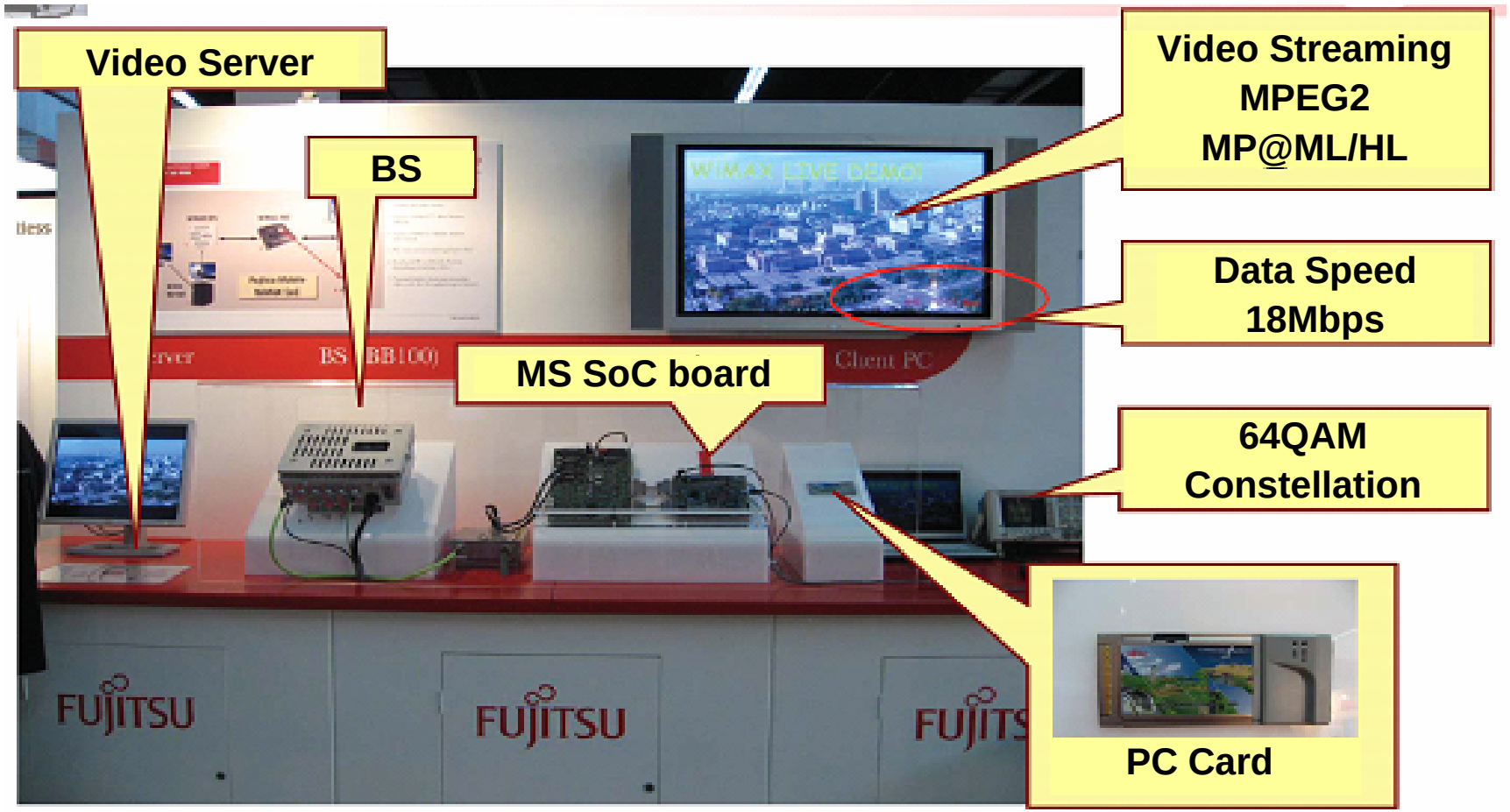
- Non profitable organization
- Established in 2001 to promote Broadband Wireless Access
- Objectives
  - Promotion of IEEE802.16 based products
  - Define system profiles
  - Create end to end network specification
  - Conduct interoperability test
  - Give the certificate logo allowance
- Members
  - Increase about 100 per year:
    about 100(June 2004), more than 420 now
  - Fujitsu is a board member from the beginning

WiMAX System Structure

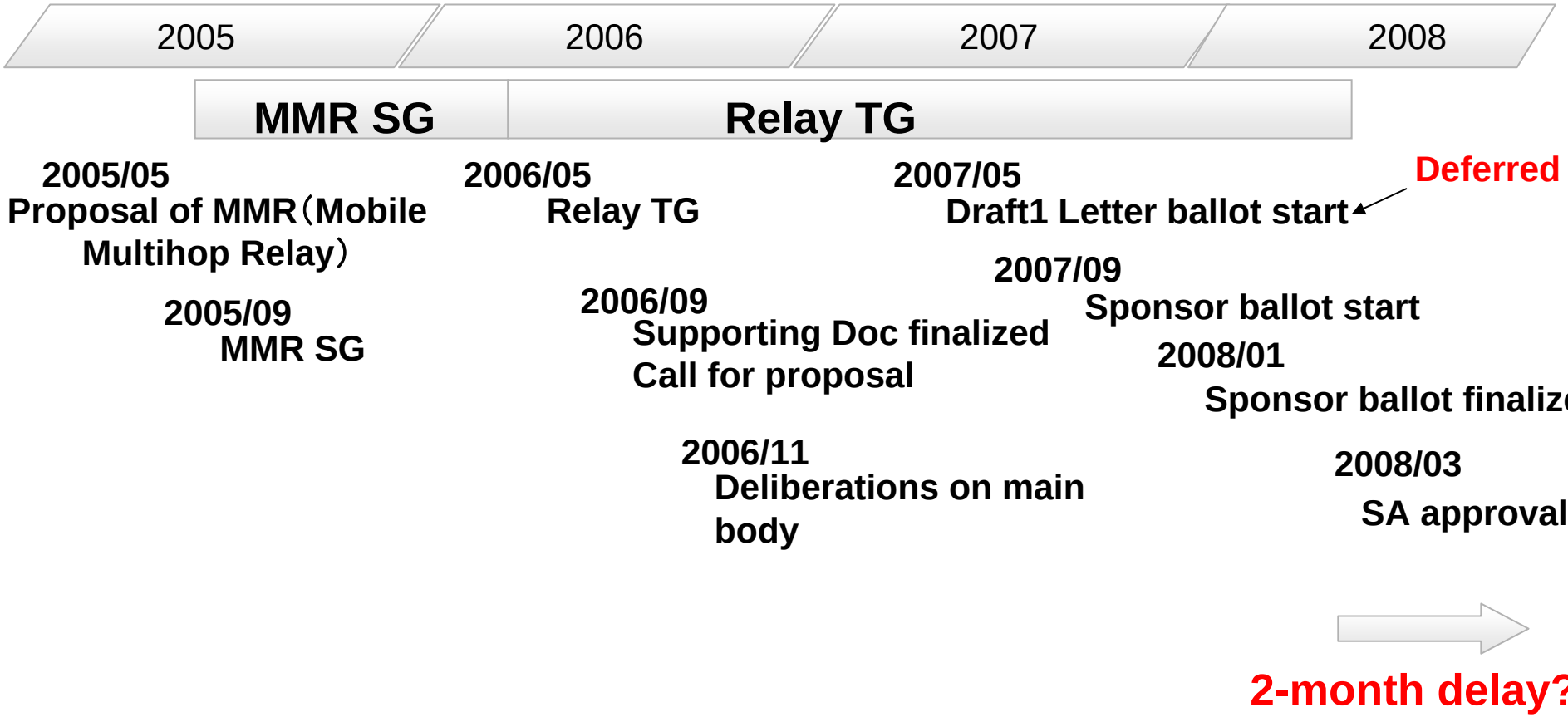


Mobile WiMAX System

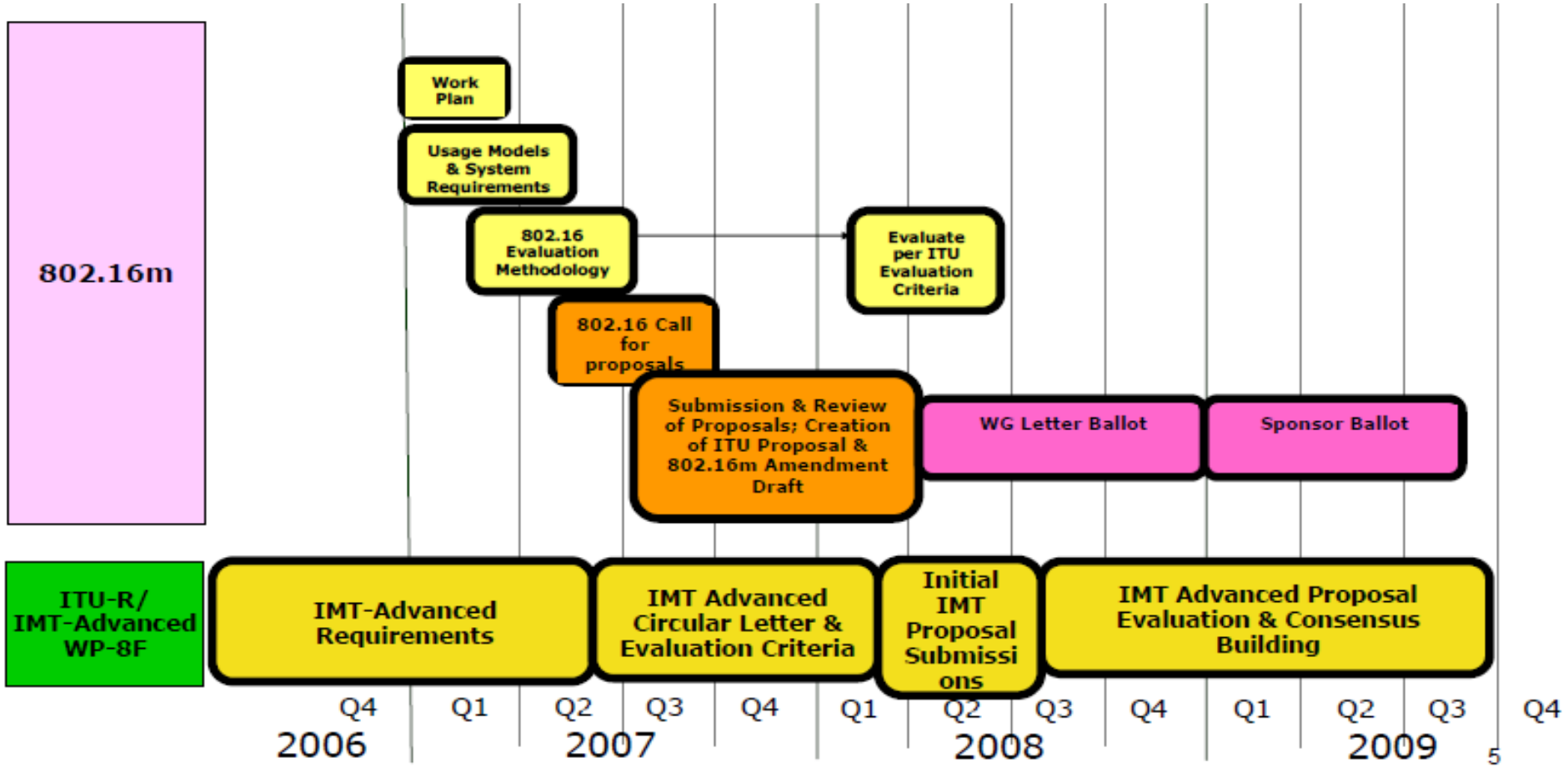
3GSM World Congress
2007/2/13 – 2/16, Barcelona, Spain



802.16j Time Line



802.16m Time Line Plan



5

ITU-R: IMT-2000

- IMT-2000
  - 3G mobile communications systems
  - Aimed at the global standard for up to 2Mbps (in stationary) in 2000
- IMT-2000 terrestrial family (2000/05) defined in ITU-R M.1457
  1. CDMA direct spread … WCDMA
  2. CDMA multicarrier ….CDMA-2000
  3. CDMA TDD … TD-SCDMA
  4. TDMA single carrier … EDGE
  5. FDMA/TDMA ….DECT
- IMT-2000 frequency band
  - 806-960 MHz
  - 1710 – 1885 MHz
  - 1885 – 2025 MHz
  - 2110 – 2220 MHz
  - 2500 – 2690 MHz

IP-OFDM for IMT-2000

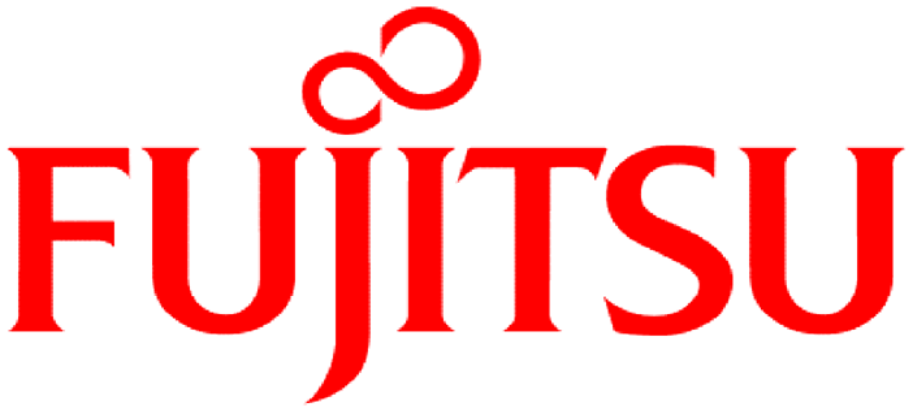
- **The 6th air interface for IMT-2000**
  - **IP-OFDMA … 802.16e OFDMA**
  - **Submit M.1457 amendment to ITU-R WP8F at the Cameroon meeting in 2006/11**
  - **9 Evaluation groups**

    TIA(USA), TTA(Korea), CEG(Canada),

    ChEG(China), ATIS(USA), IEG(Israel),

    WCA(USA), ARIB-EG(Japan), Anatel(Brazil)
  - **22nd WP8F meeting (held in Kyoto) in 2007/05**

    → Failed to reach consensus concerning the decision on IP-OFDMA as the 6th member of IMT-2000 (Forward the decision to SG8)



THE POSSIBILITIES ARE INFINITE