WiMAX Standardization

FUJITSU LABORATORIES LTD

Michiharu Nakamura

Introduction

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- ■ **Mobile WiMAX is a system that provide**
  - ■ Broadband wireless access in Metropolitan area
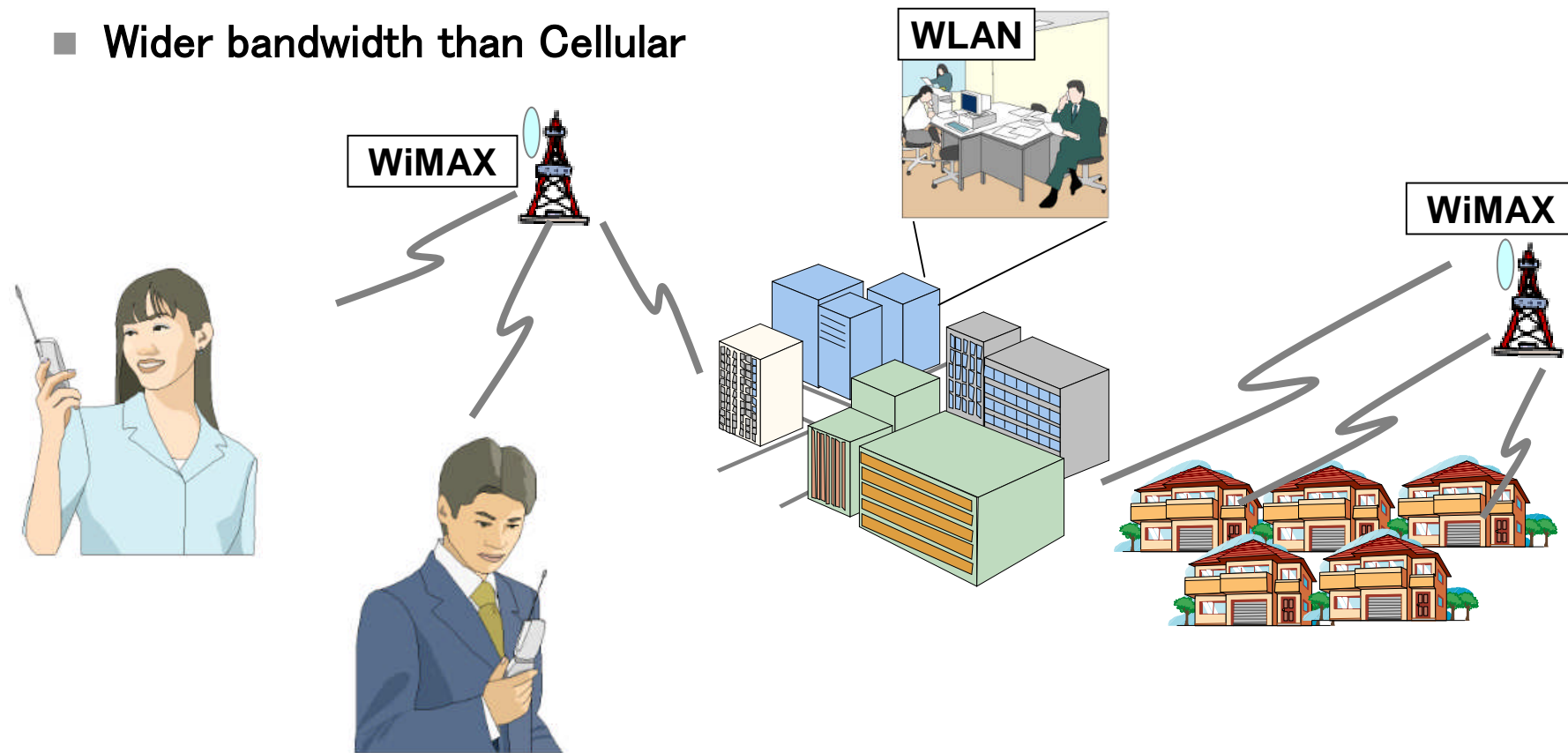
- ■ **Standardization of Mobile WiMAX takes place in two places**
  - ■ WiMAX Forum
  - ■ IEEE802.16WG

- ■ **They have different objectives and different standardization process**
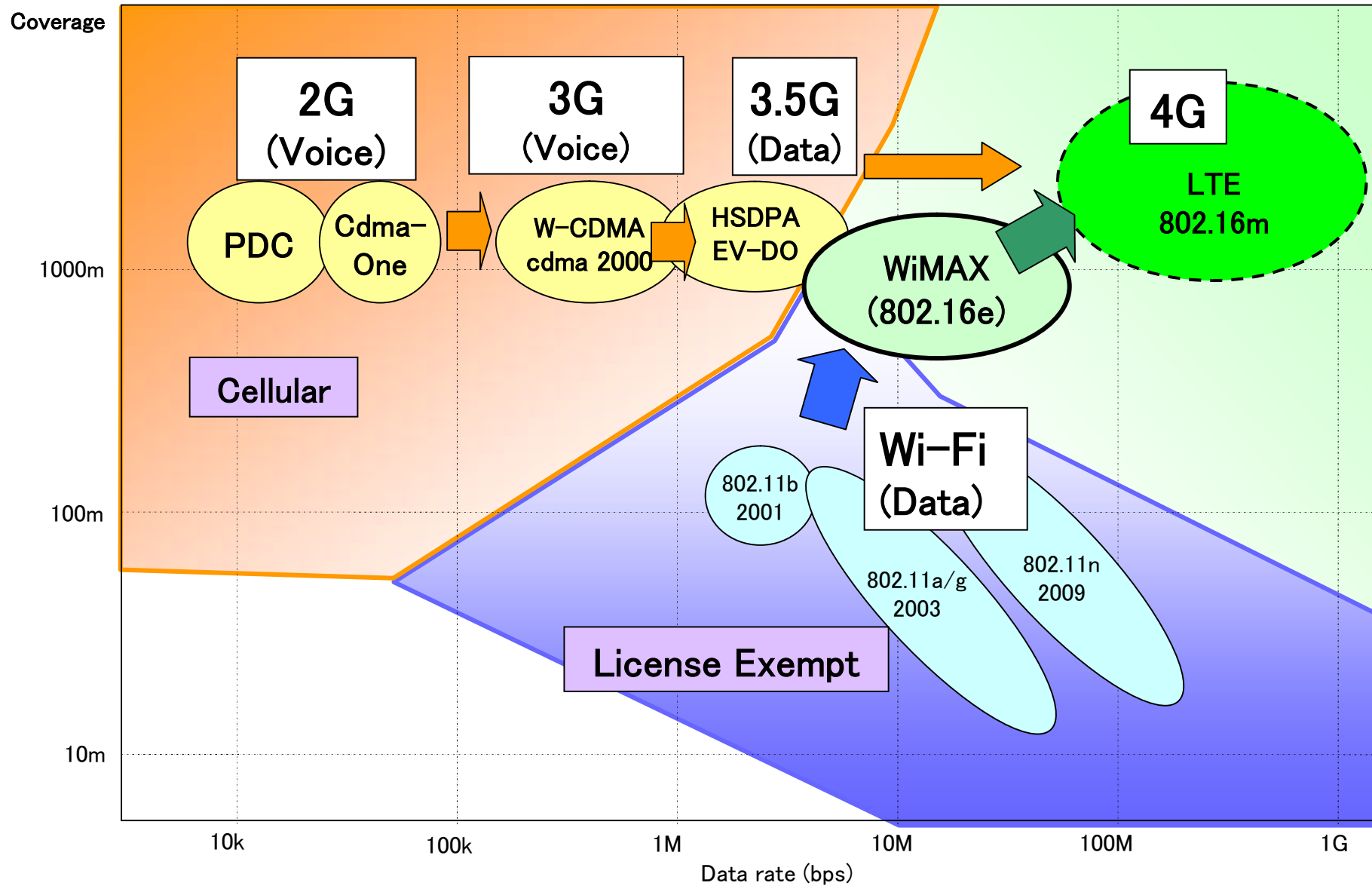
- ■ **This presentation introduces standardization activities of the two organizations**
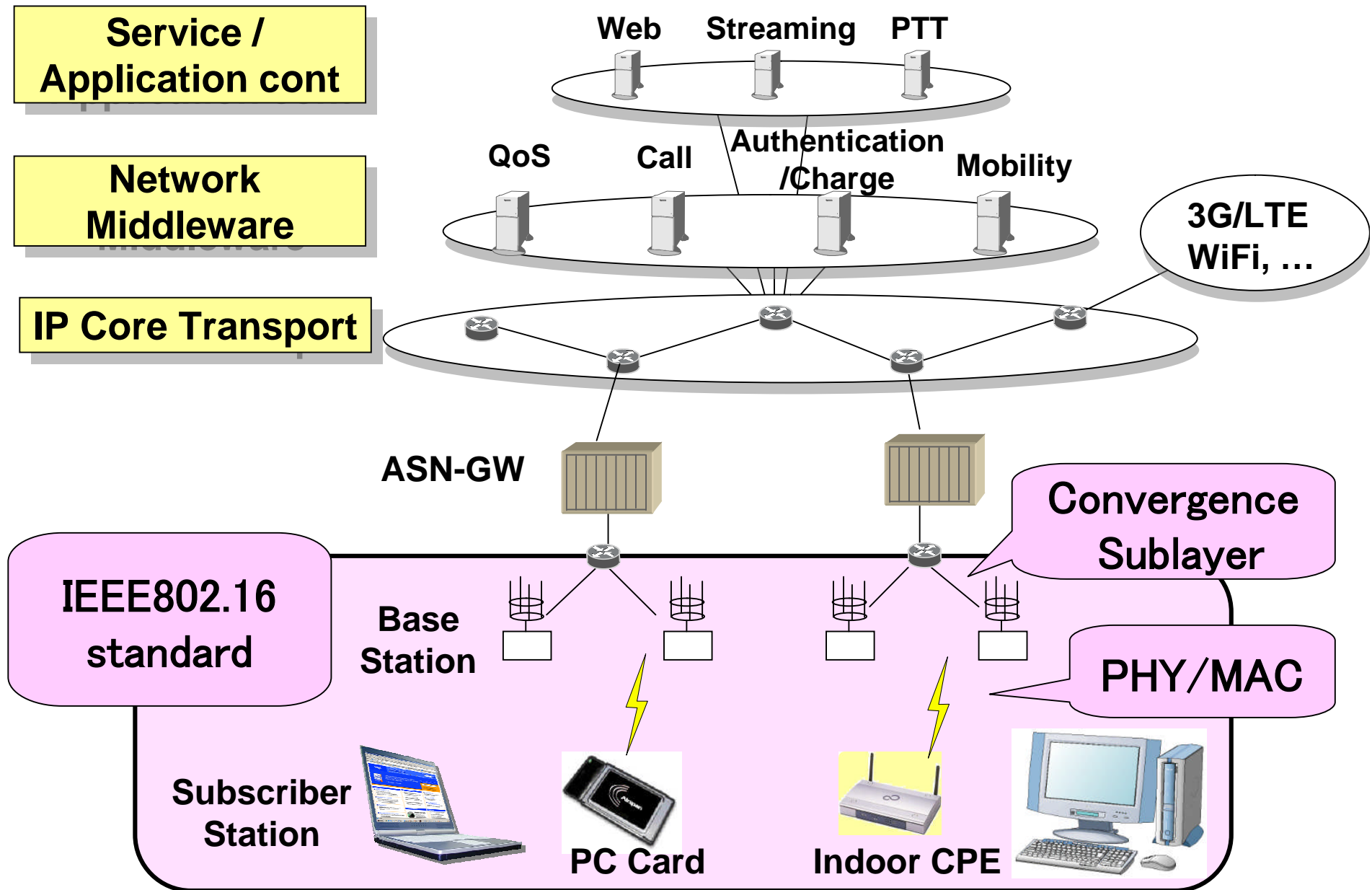
What is WiMAX

■ Broadband wireless access system defined by **WiMAX Forum**

  ■ WiMAX: Worldwide Interoperability for Microwave Access

  ■ **Wider coverage area than WLAN**

  ■ **Wider bandwidth than Cellular**

WiMAX System Structure

Service / Application cont

Network Middleware

IP Core Transport

Web   Streaming   PTT

QoS   Call   Authentication /Charge   Mobility

3G/LTE WiFi, …

ASN-GW

Convergence Sublayer

IEEE802.16 standard

Base Station

PHY/MAC

Subscriber Station

PC Card

Indoor CPE

**802.15:
BAN·PAN**

**802.11:
WLAN**

**802.16: MAN
(Metropolitan
Area Network)**

**802.20:
MBWA**

1m　　10m　　100m　　1km　　10km

Coverage

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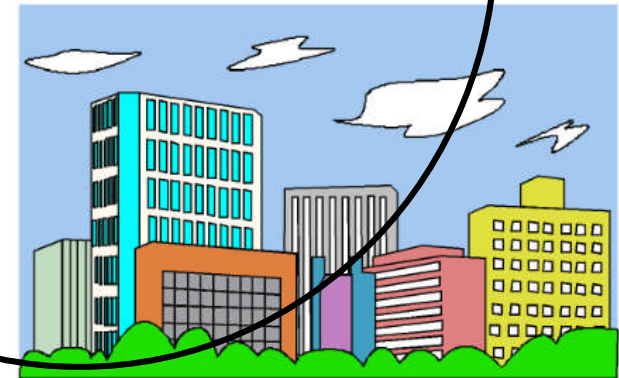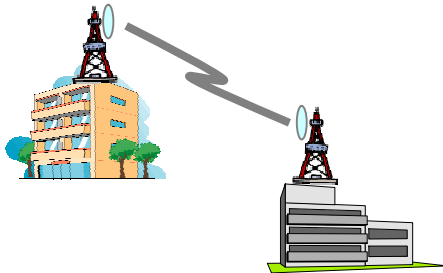
802.16-2001

10-66GHz
FWA, LOS

802.16a-2003

802.16-2004

＜11GHz
FWA, NLOS

802.16-2009?

802.16e-2005

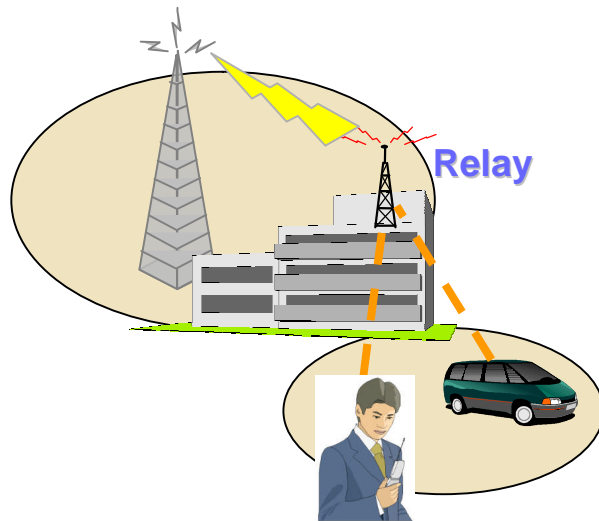Cor2 P802.16-REV2
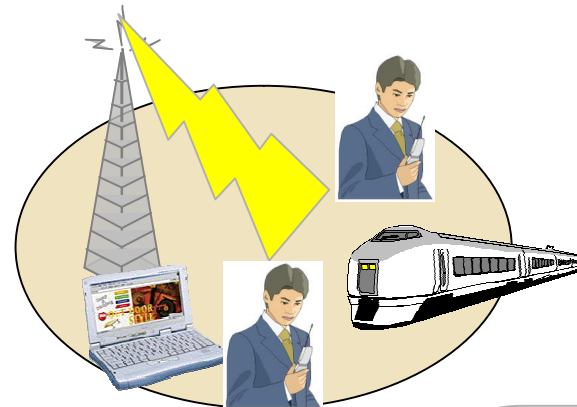
＜11GHz
Mobile, NLOS

IEEE802.16 Standards(2)

FUJITSU
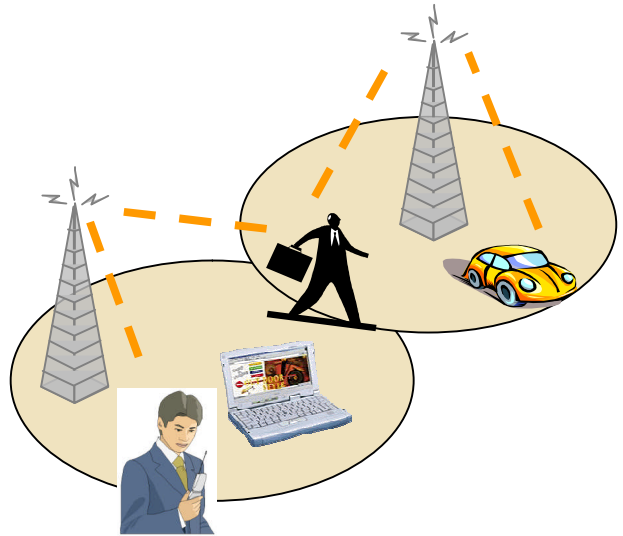
P802.16j

Relay

P802.16m

Relay Station and
MR-BS for
802.16e based MS

For IMT-advanced:

2x user throughput
2x sector throughput
350km/h support

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- ✓ **Provide low-cost solution (networking, mobile performance)**
- ✓ **Fit to IP Communication**
- ✓ **Flexible frequency assignment**
- ✓ <u>**Various operational parameters and functions are defined**</u>

For optimal operation under various usage scenarios

- ✓ **Only MAC/PHY layers are specified (i.e. Core network is out of scope in the 802.16)**

	IEEE802.16WG	WiMAX Forum
Objective	Development of <u>Technical</u> Standard	Promotion of WiMAX <u>industry</u>
Participation	Individual expert	Company base
Meetings	3 IEEE802 plenary 3 WG Interim	3 Forum Plenary WG meetings / Audio conferences
Main Activities	■ PHY/MAC specifications 　　■ Fixed System 　　■ Mobile System (IMT-2000) 　　■ IMT-Advanced 　　■ Relay	■ System Requirements ■ System Profile ■ Network specification ■ Certification test spec ■ Certification ■ Marketing activities

IEEE802.16 WG

WiMAX Forum
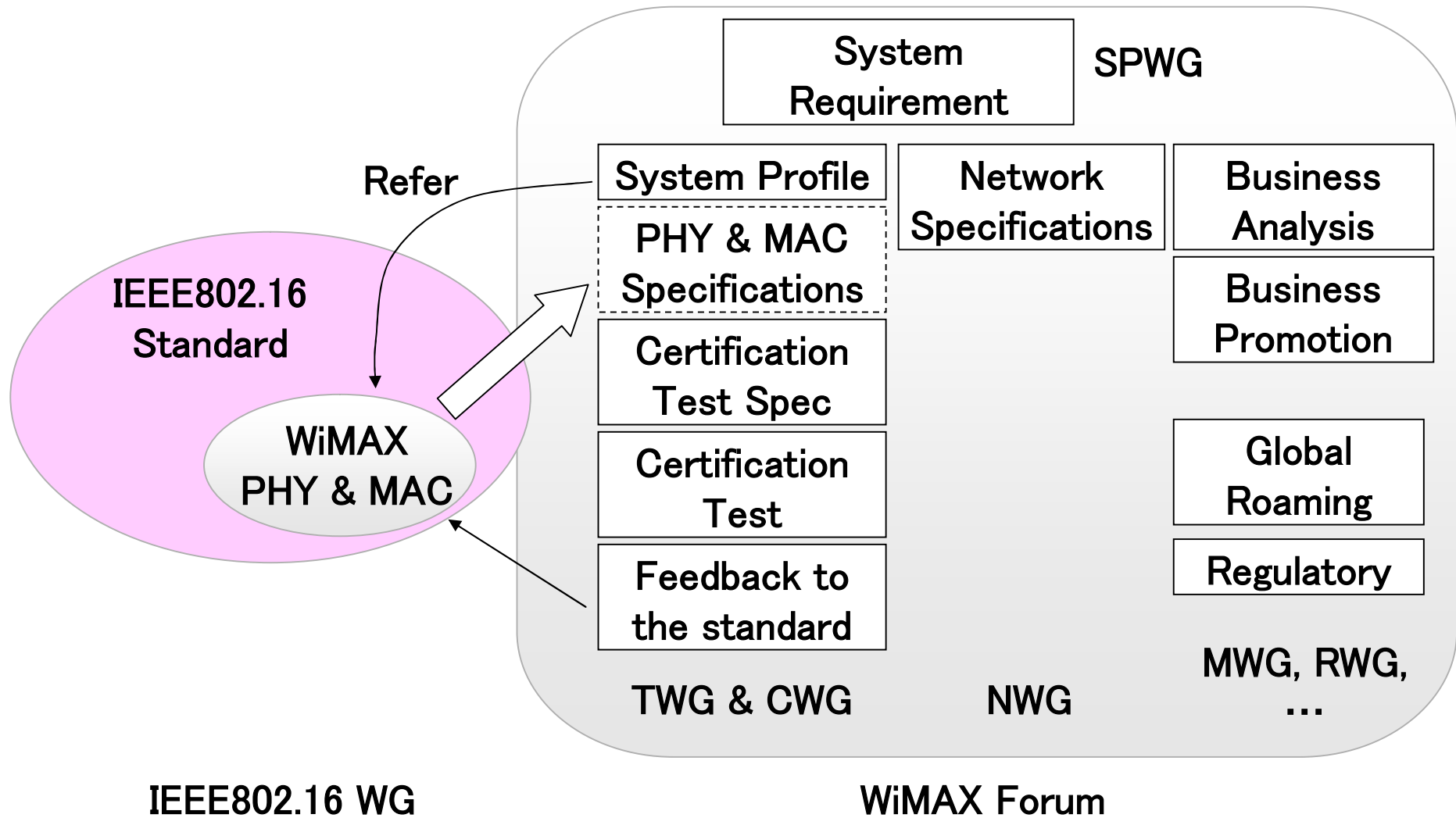
Proprietary vs WiMAX Certified

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	Proprietary (incl. Pre-WiMAX)	WiMAX Certified
Time of availability	✔	
Functionality and Performance	Various	Common
Multi vendor		✔
Interoperability		✔
Cost		Cost down by mass produce in world wide
Market size	Small	Large

WiMAX Forum

- **NPO based in US**
  - Established in 2001 as private association
  - Formal launch in 2003
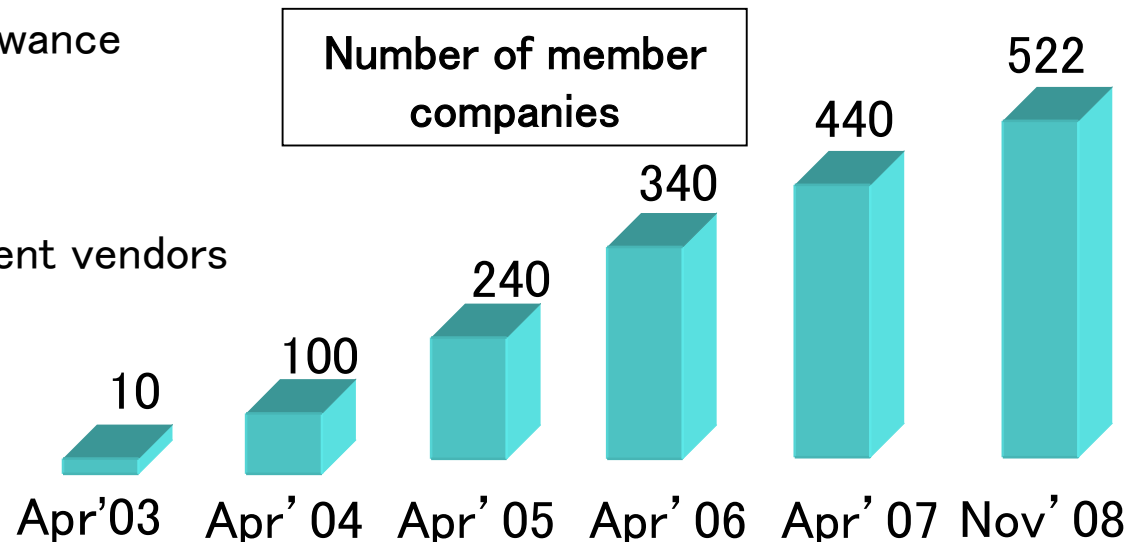   - Airspan, Alvarion, Aperto, Fujitsu, Intel, Proxim, Wi-LAN, OFDM Forum

- **Objectives:**
  - Promotion of IEEE802.16 based products
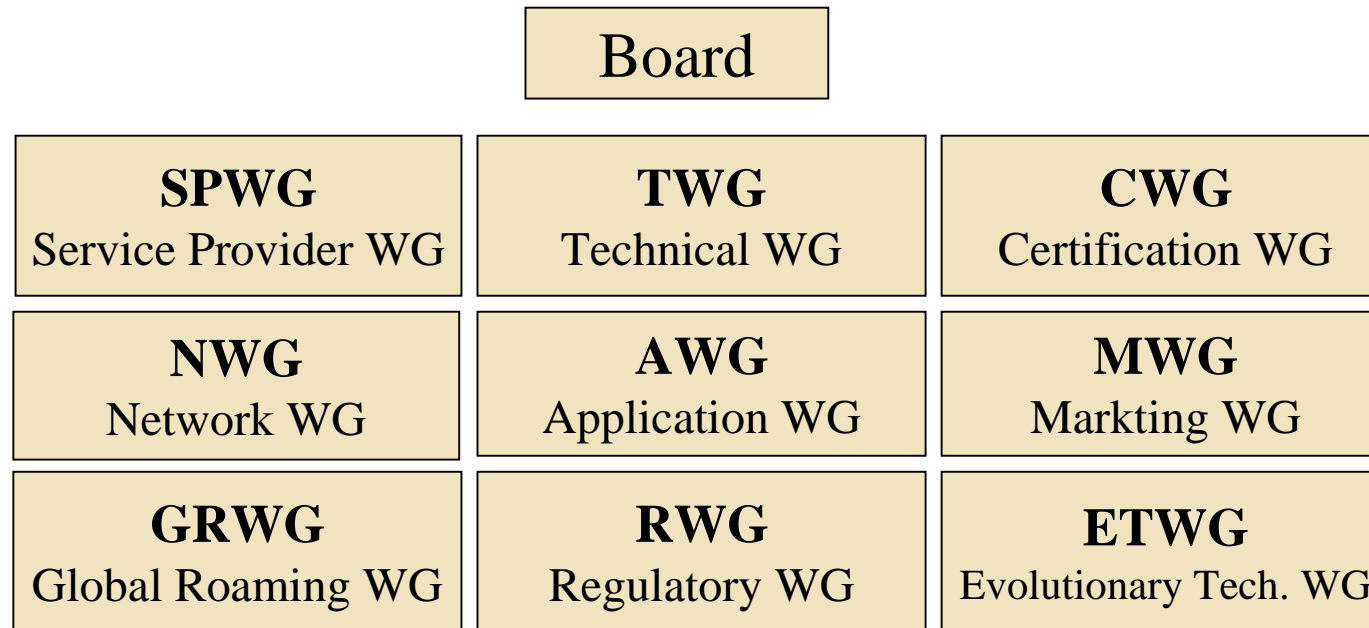 - Define system profiles
  - Create end to end network specification
  - Conduct interoperability test
  - Give the certificate logo allowance
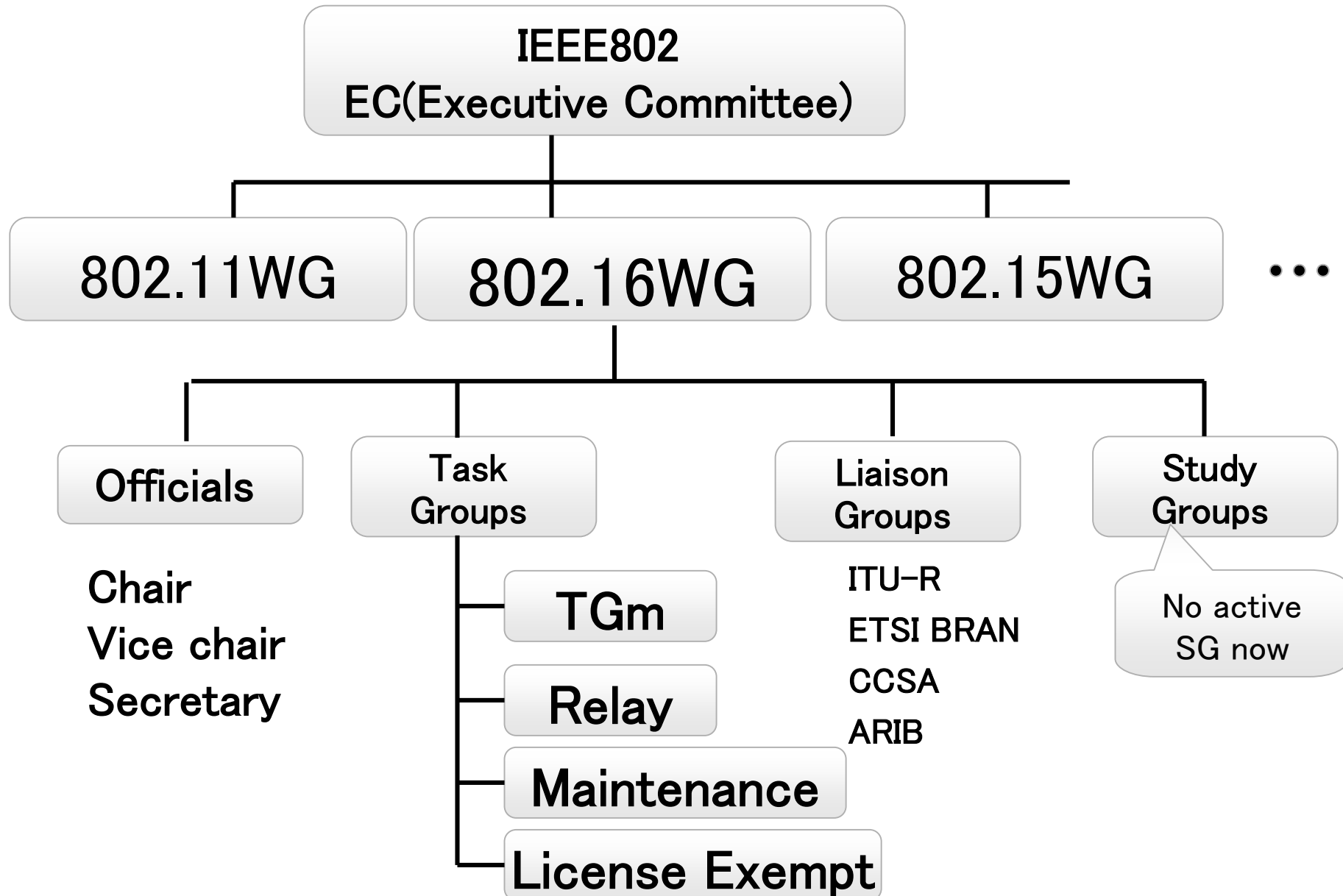
- **Member companies**
  - Wireless Operators
  - Equipment vendors, component vendors
  - Test equipment vendors

Board Companies

Number of member companies

522
440
340
240
100
10

Apr'03 Apr'04 Apr'05 Apr'06 Apr'07 Nov'08

WiMAX Forum Organization

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```
                    ┌─────────────┐
                    │    Board    │
                    └─────────────┘
```

SPWG Service Provider WG	**TWG** Technical WG	**CWG** Certification WG
NWG Network WG	**AWG** Application WG	**MWG** Markting WG
GRWG Global Roaming WG	**RWG** Regulatory WG	**ETWG** Evolutionary Tech. WG

■ **40 companies have voting right (TWG/CWG at Nov'08)**

Principal member companies that attended 2 out of 3 last meetings

- 35 Equipment Vendors
- 5 Operators

802.16WG Organization

```
                    ┌─────────────────────────┐
                    │        IEEE802           │
                    │ EC(Executive Committee)  │
                    └─────────────────────────┘
                                │
        ┌───────────────────────┼───────────────────────┐
   ┌──────────┐          ┌──────────────┐         ┌──────────────┐
   │ 802.11WG │          │  802.16WG    │         │  802.15WG    │   ...
   └──────────┘          └──────────────┘         └──────────────┘
                                │
        ┌───────────────┬───────┴────────────┬──────────────────┐
  ┌───────────┐   ┌──────────┐         ┌──────────┐       ┌──────────┐
  │ Officials │   │  Task    │         │ Liaison  │       │  Study   │
  └───────────┘   │ Groups   │         │ Groups   │       │ Groups   │
                  └──────────┘         └──────────┘       └──────────┘
```

Officials

Chair
Vice chair
Secretary

Task Groups

- TGm
- Relay
- Maintenance
- License Exempt

Liaison Groups

ITU-R
ETSI BRAN
CCSA
ARIB

Study Groups

No active SG now

IEEE802.16WG meeting

- IEEE802 Plenary meeting: March, July, November

- 802.16WG Interim meeting: January, May, September

- Voting right:

  - Given to <u>individual participants</u> at plenary meetings who attended more than 2 out of 4 meetings

  - Lose if not attending meetings more than 1 year or not participating ballots
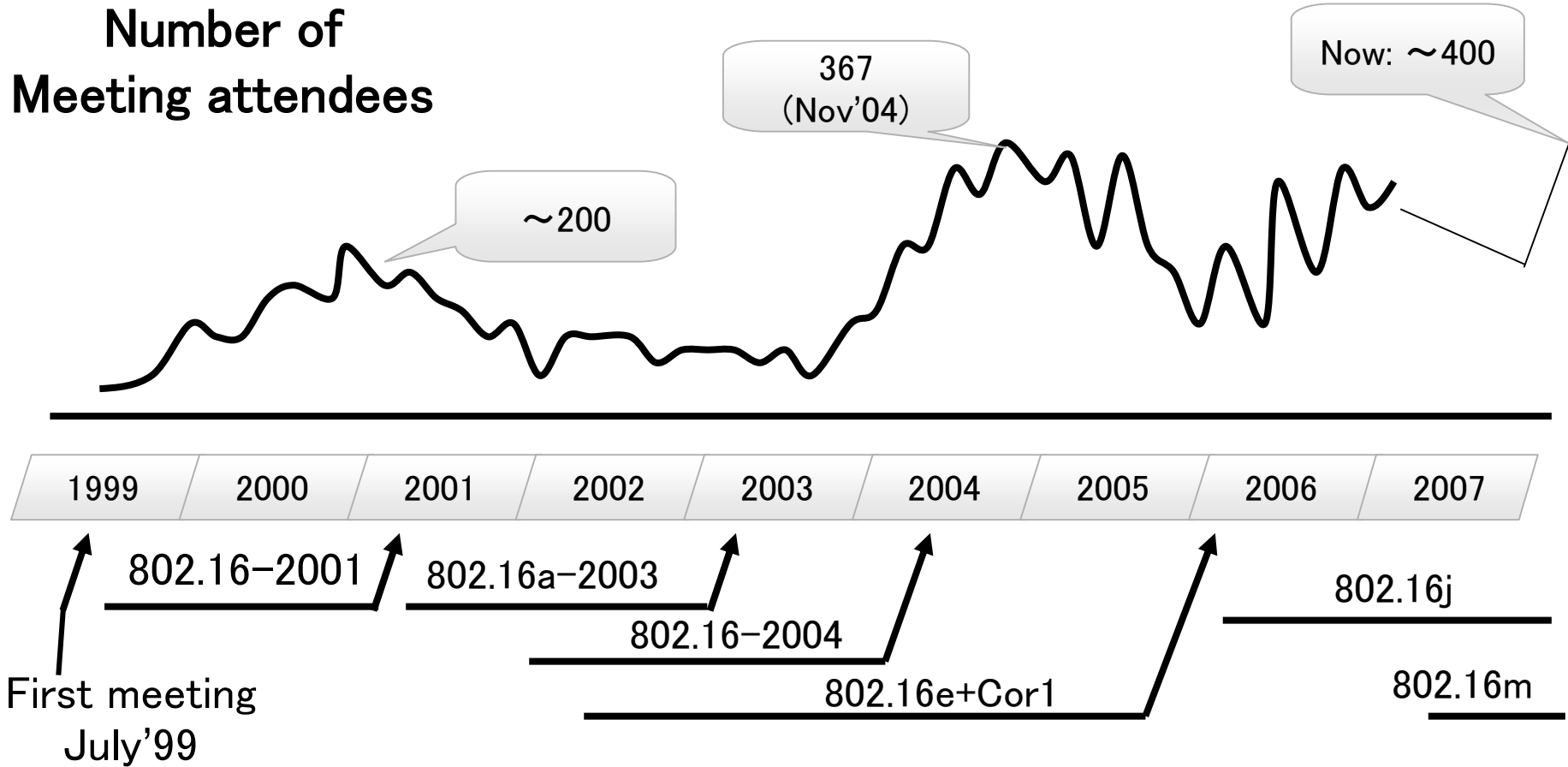
- Decisions

  - 50% for general matters

  - 75% to accept specification text

- IEEE802 EC (Executive Committee) checks whether WG not be dominated by one company.

IEEE 802.16WG participants

802.16 WG member

- 267 Voting members at Apr'07

90% from Vendors

Operators(16)：Sprint, FT, BT, KDDI, DoCoMo

Univs, etc.(7)

Isreal(11)：Rancom, Alvarion

Japan(22)：Fujitsu, Mitsubishi

China/Taiwan(28)：Huwawei, ZTE

EU(30)：Nokia-Siemens, Ericsson, Alcatel-Lucent

NA(91)：Motorola, Intel, Nortel + Many small companies

Korea (55)：Samsung, ETRI, LG, Posdata
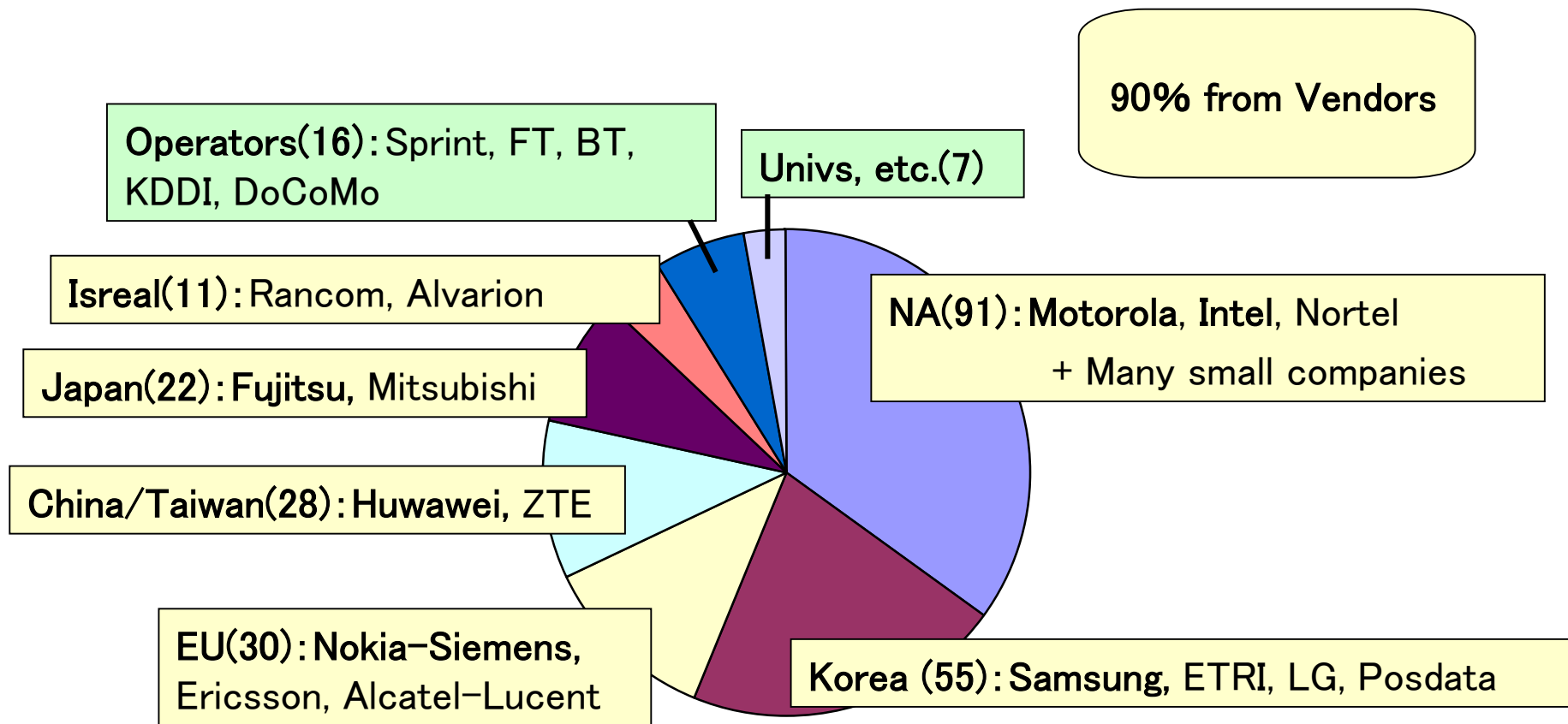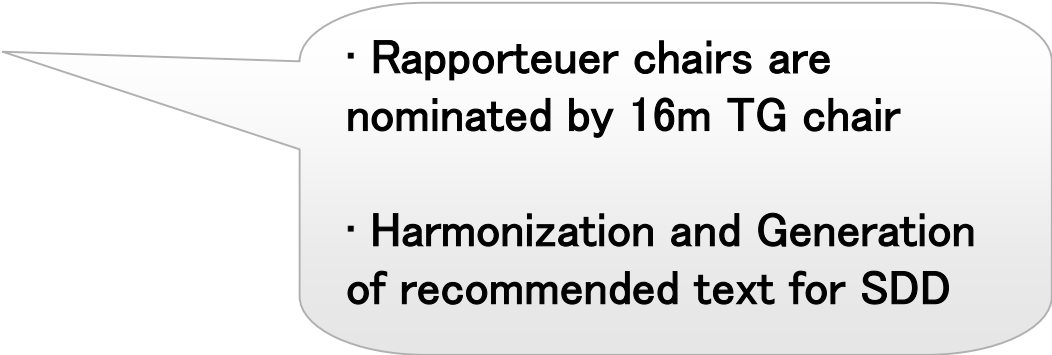
IEEE802 standardization process

Study Group

Feasibility study

Task Group

Requirements,
Usage scenarios

Call for Contribution

Text adoption

Draft

Contribution

Technical
Explanation

Specific text
for the Draft

WG letter ballot

Comment resolution

Revised Draft

Sponsor ballot

Comment

IEEE SA approval

Comment
（Problem statement）

Suggested Remedy
（Text to Draft）

Publication
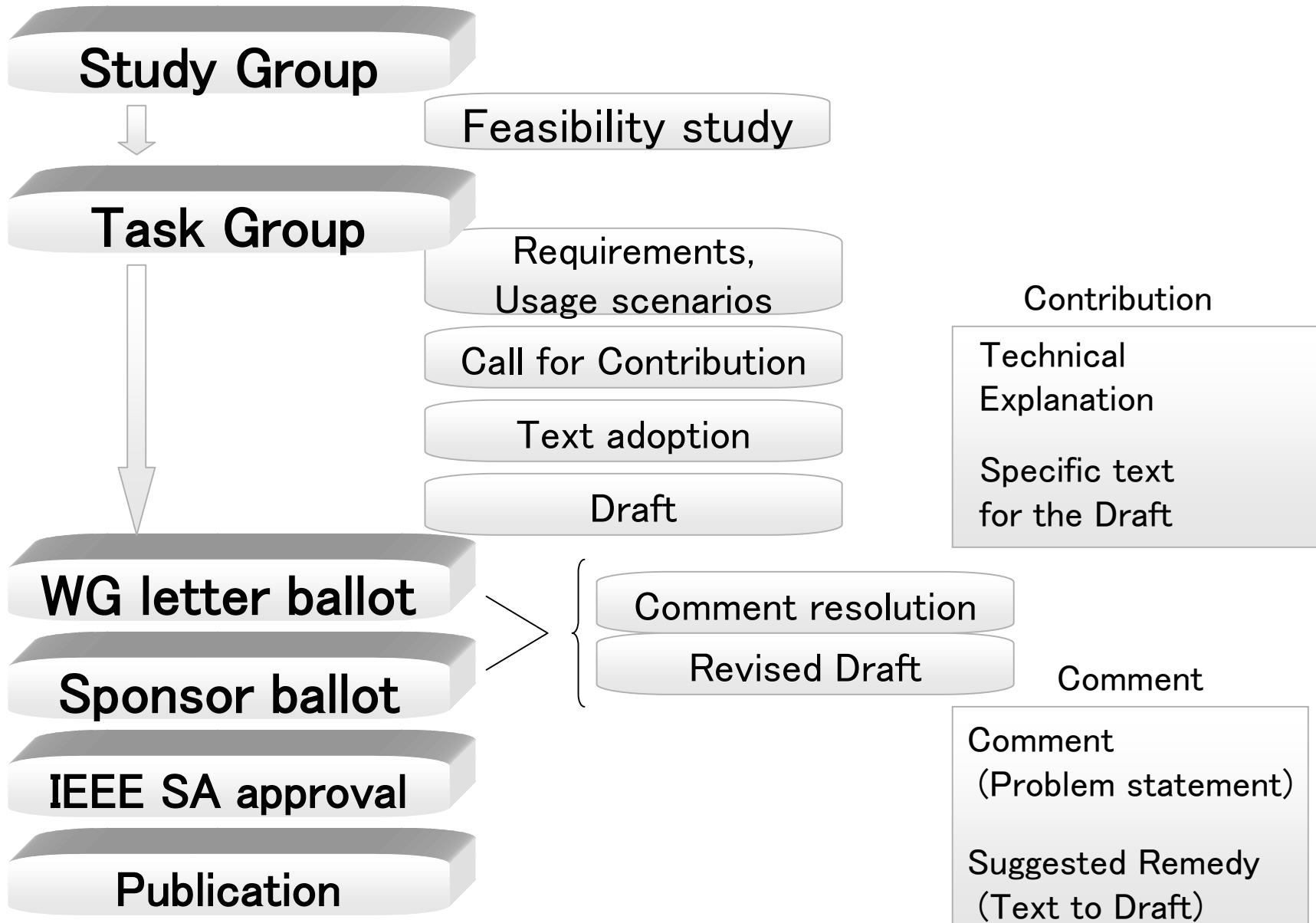
802.16m standardization

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- Evaluation Methodology (EVM): Completed and maintained
- System Requirements Document (SRD): Completed and maintained
- System Description Documents (SDD): Being developed
  - Describes high level architecture
  - Will be a baseline document for IMT-advanced submission to ITU-R
  - Call for contributions
  - Rapporteur Group discussion
    - PHY
    - Preamble
    - MIMO
    - Link Adaptation
    - HARQ
    - UMAC(HO, ARQ, Other)
    - UL_PHY Control
    - Security
    - LBS
    - e-MBS
    - Multi Carrier

> ・Rapporteuer chairs are nominated by 16m TG chair
>
> ・Harmonization and Generation of recommended text for SDD

- 802.16 Text:
  - Main standard text
  - Started to describe "frame structure"

802.16m development schedule

2007	2008	2009	2010

EVM, SRD

SDD

Frame Structure, Multiple Access →

Pilot, Resorce Allocation, Control channel →

MIMO, HARQ, Synchronization →

Ranging, Link Adaptation UMAC →

MBS, LBS, Security, Coexistence →

Relay, SON, Femto →

802.16 text

Draft v1.0 →

WG letter ballot →

Sponsor ballot →

ITU-R Proposal Submission

ITU-R Proposal Evaluation
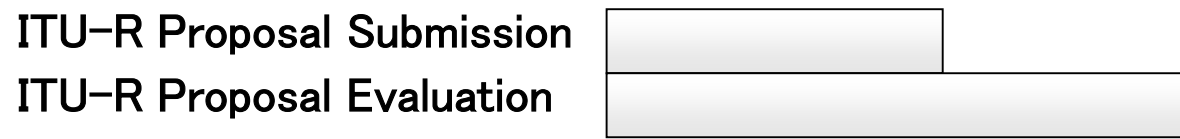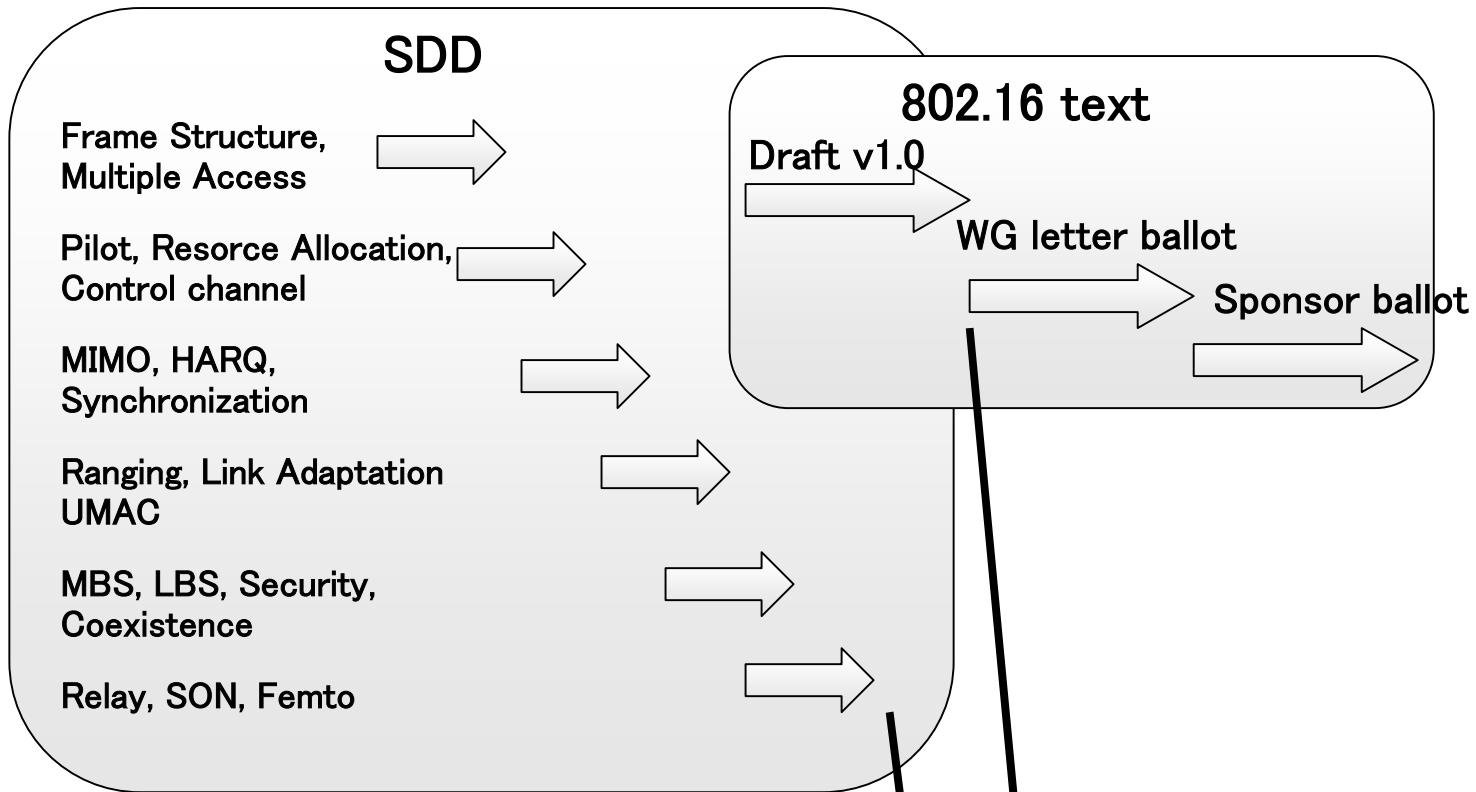
Mobile WiMAX System Profiles

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- Defined by WiMAX Forum
- List of parameters and functions to be supported
- WiMAX certification examines the listed parameters and functions

（Fixed WiMAX）

Mobile WiMAX

802.16-2004	802.16e-2005	Cor2	802.16-REV2	P802.16m

Chap.12 of 802.16-2004	Mobile WiMAX Rel1.0	Mobile WiMAX Rel1.5	Mobile WiMAX Rel2.0

Rel1.5 System Profile development in WiMAX Forum

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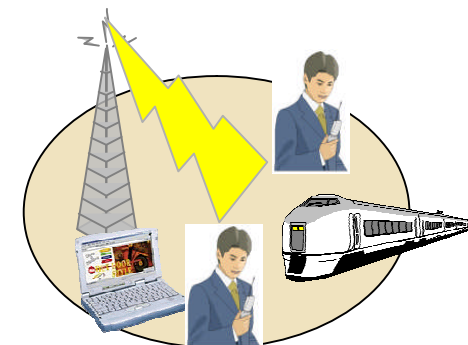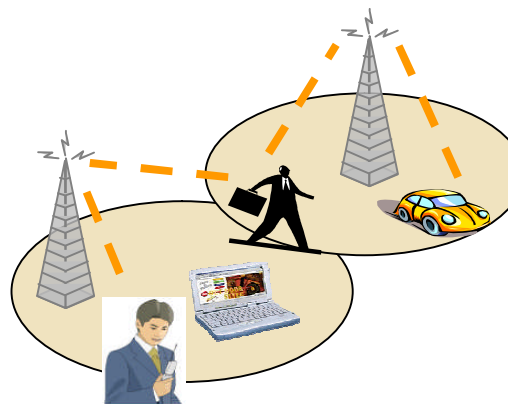
- **Discussion in 6 adhocs**
    - Certification Profile (band plan)
    - FDD
    - MIMO/BF
    - MAC enhancement
    - Network support
    - Coexistence

- **Profile ToC**
    - Call for comments on ToC
        - Add new item or remarks
    - Call for recommendation (y/n/option) to each items

- **Discussion and Decision**
    - 60% in favor in "one company one vote"

Summary

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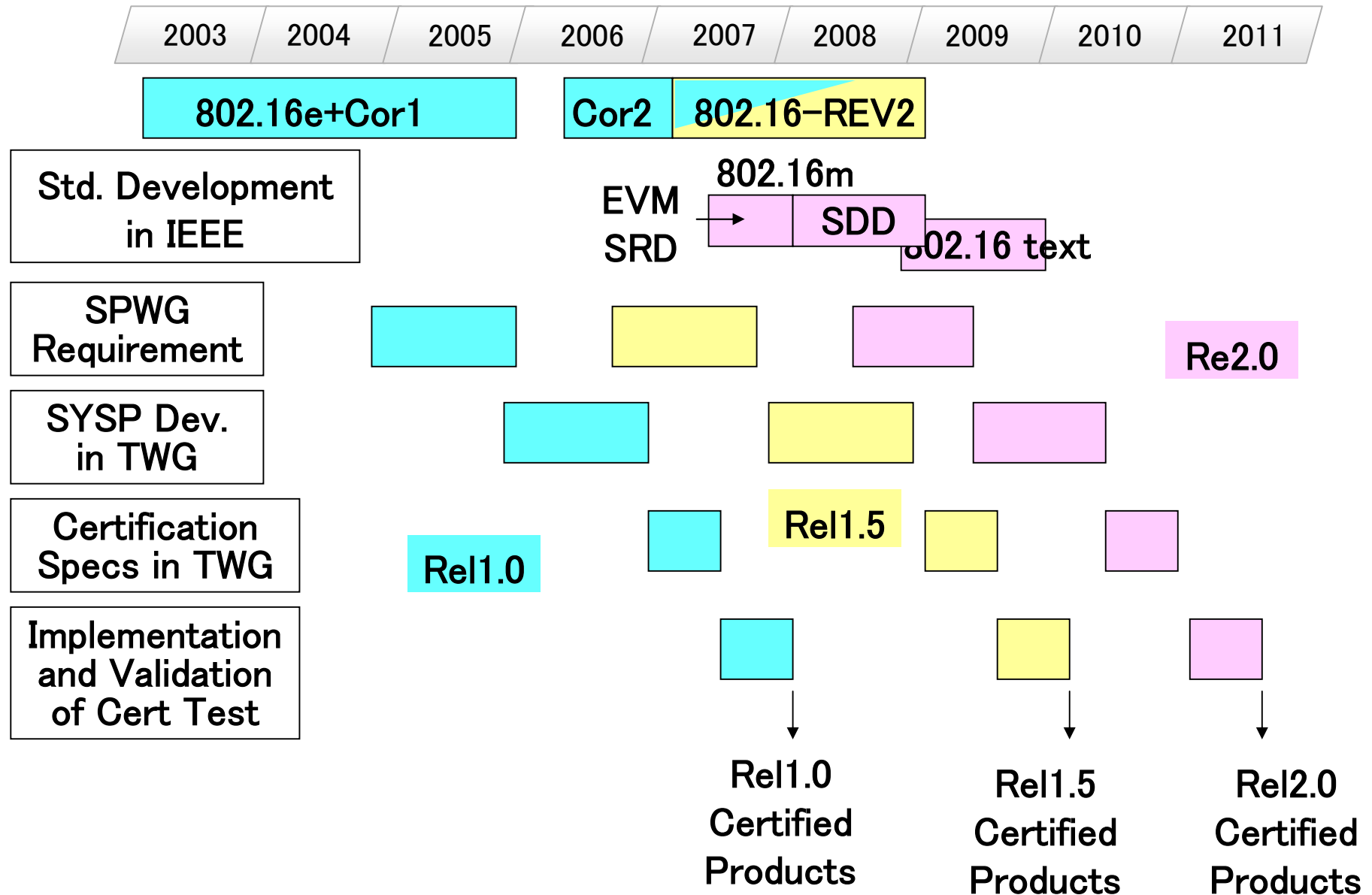
- ■ WiMAX is a Broadband wireless access system
  - ■ Promoted by **WiMAX Forum**
  - ■ Detail wireless specification is developed by **IEEE 802.16 WG**

- ■ Mobile WiMAX System Profile refer to IEEE 802.16 standards

- ■ Organization and standardization process are introduced
  - ■ IEEE802.16 WG develops wireless MAN air interface specification
  - ■ WiMAX Forum targets business promotion of wireless system based on IEEE802.16 standard.

- ■ Mobile WiMAX
  - ■ Rel1.0: Certification started
  - ■ Rel1.5: System Profile almost complete
  - ■ Rel2.0: IEEE standard is now being developd

PHY specification in 802.16-2004

- **802.16-2004 had 4 PHY schemes**

  - SC (Single Carrier)
    - Added in 802.16-2001

  - SCa (Single Carrier)
    - added in 802.16a, but deleted in 802.16REV2

  - OFDM (Orthogonal Frequency division multiplex)
    - Fixed WiMAX System use this PHY mode

  - OFDMA (Orthogonal Frequency division multi-access)
    - 2-dimensional (frequency and time) resource allocation
    - <u>Later extensions (i.e. 802.16e, 802.16j, 802.16m) base on this mode</u>.

SC, SCa
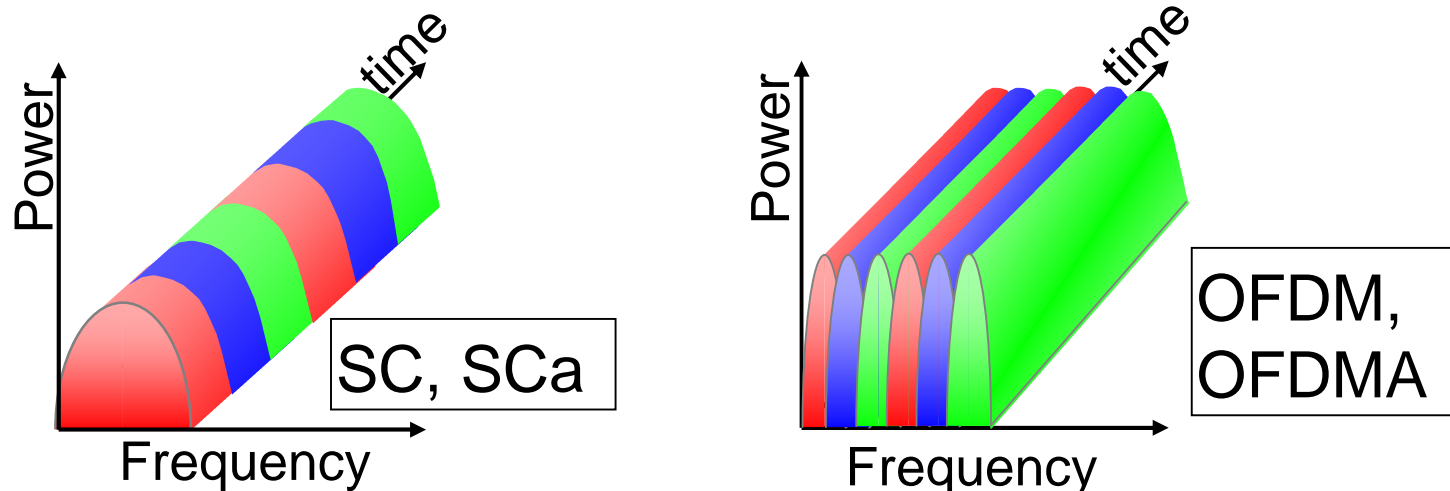
OFDM, OFDMA

Transmission by OFDM
(Orthogonal Frequency Division Multiplexing)

Signal Amplitude

Time

Down Link Burst #n

Sub-Carrier
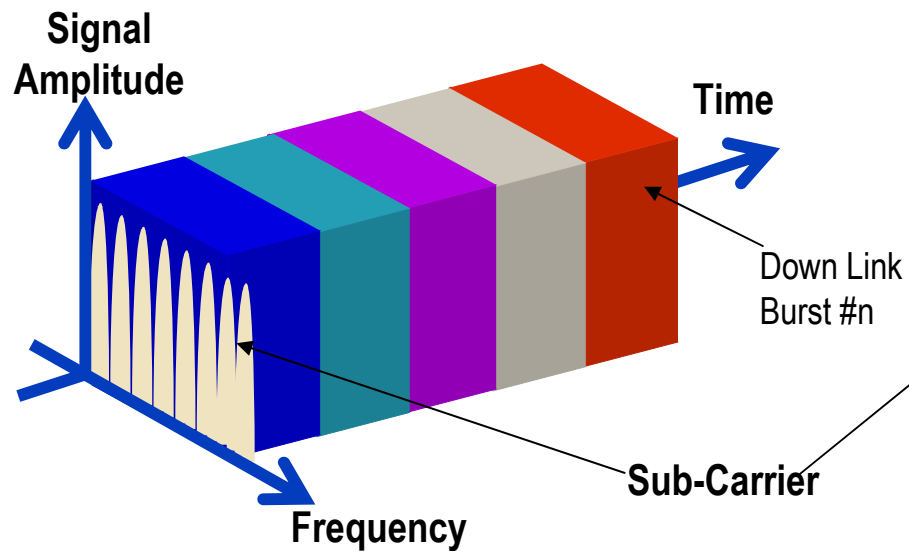
Frequency

- All sub carriers are allocated to one user.

Transmission by OFDMA
(Orthogonal Frequency Division Multiple Access)

Signal Amplitude

Time
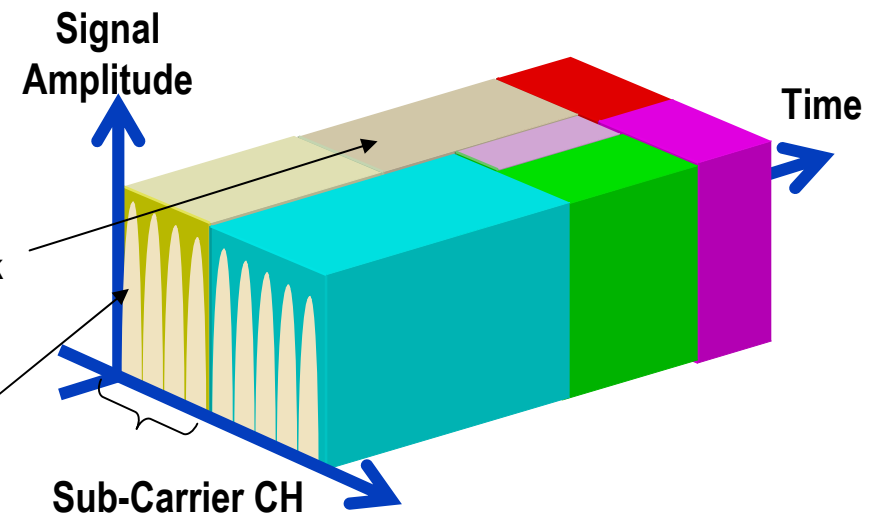
Sub-Carrier CH

- Sub carriers are flexibly allocated to one or more users depending to their radio condition.

Scalable OFDMA (S-OFDMA)

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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
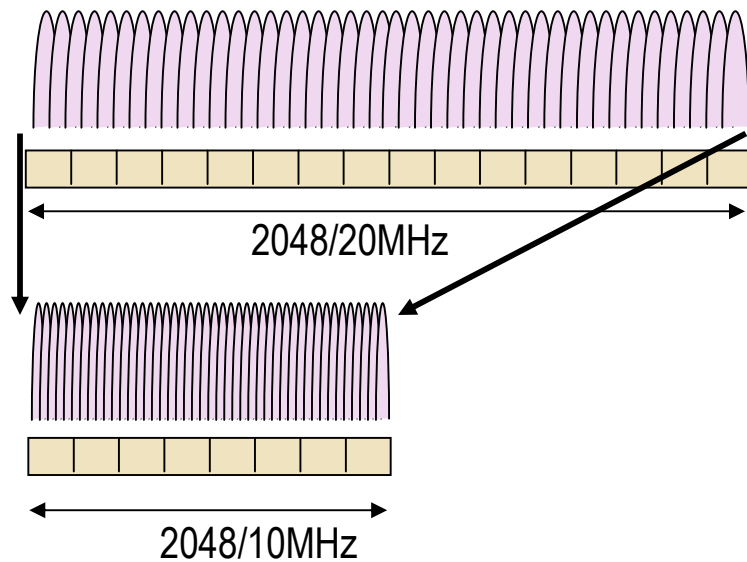
SOFDMA:802.16e-2005

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

2048/20MHz

2048/10MHz

2048/20MHz

1024/10MHz

512/5MHz

128/1.25MHz

Subcarrier allocation
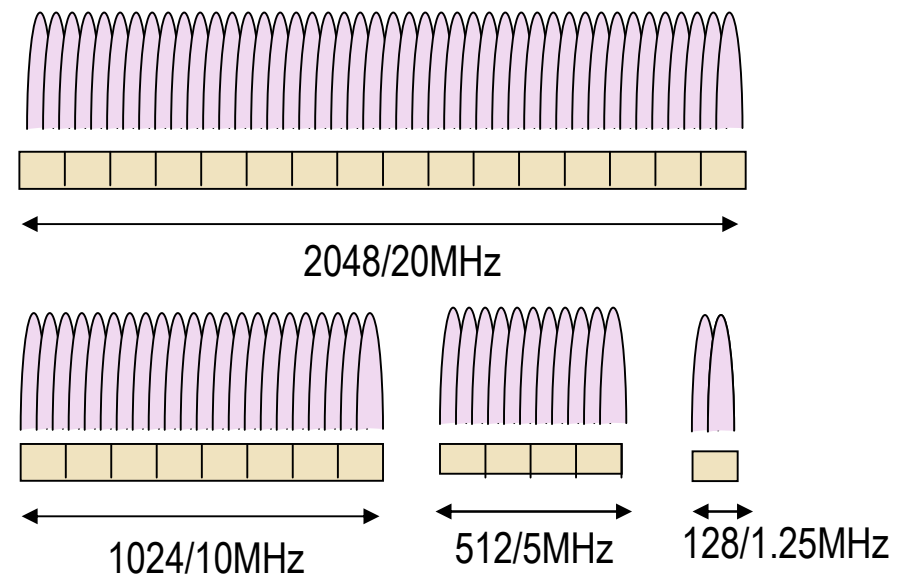
- **Distributed subcarrier allocation**
  - One subchannel use physically distributed subcarriers
  - Frequency diversity effect

Frequency
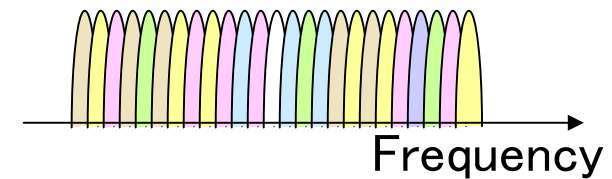
- **Adjacent subcarrier allocation**
  - One subchannel use physically adjacent subcarriers
  - Multi-user diversity

Frequency

Multi-Antennas for Higher Capacity
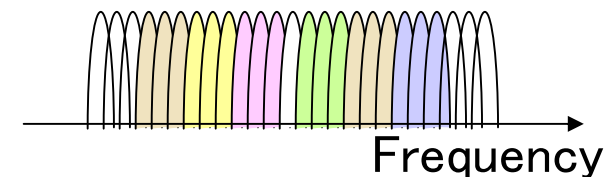
➢ AAS (Adaptive Antenna System)

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

Desired signal

Desired user

Interference

Interferer

Interferer
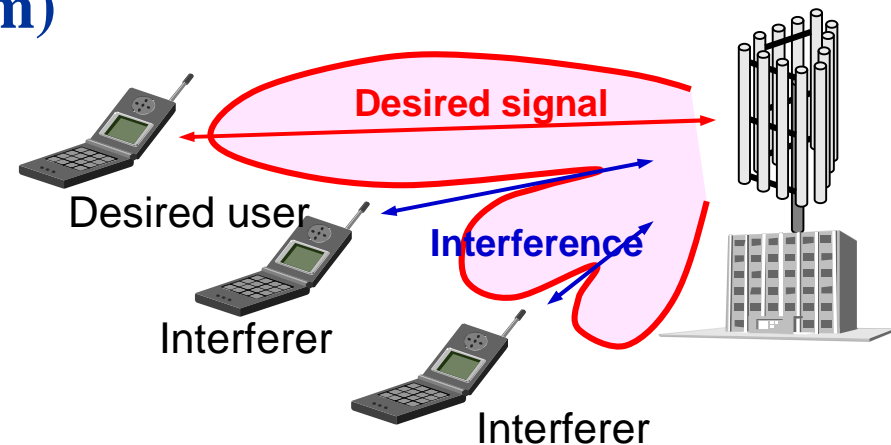
➢ MIMO (Multi Input Multi Output)

- 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

Four-times channel capacity using the same frequency band

STC (Space Time Coding)

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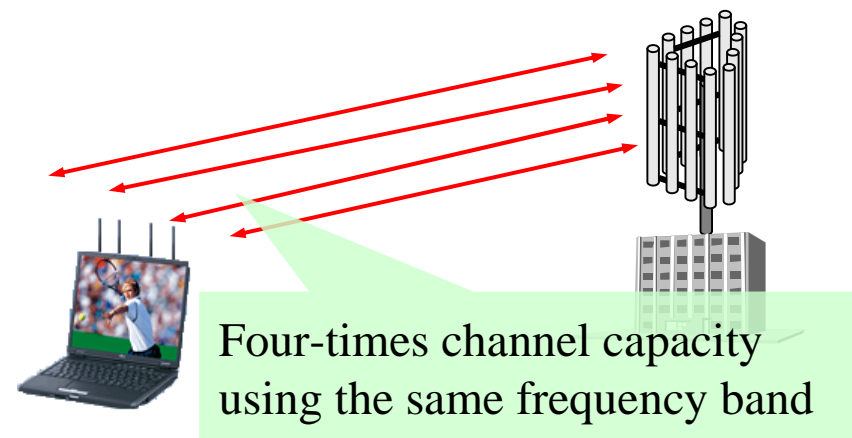
- **Tx diversity**
    - No additional antenna at MS
    - Don't increase maximum throughput
    - Increase link budget, coverage area

2 Tx antennas

2x1 STC

1Rx antenna

$$r_1 = h_{11} s_1 + h_{21} s_2 + n_1$$

h_{11}

h_{21}

h_{12}

h_{22}

s_1

s_2

r_1

r_2

s_1

s_2

$$H = \begin{pmatrix} h_{11} & h_{21} \\ h_{12} & h_{22} \end{pmatrix}$$

MIMO Signal Processing

$$r_2 = h_{12} s_1 + h_{22} s_2 + n_2$$
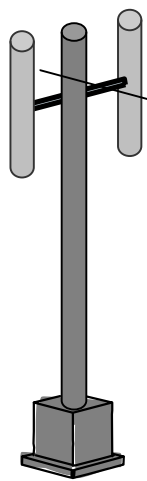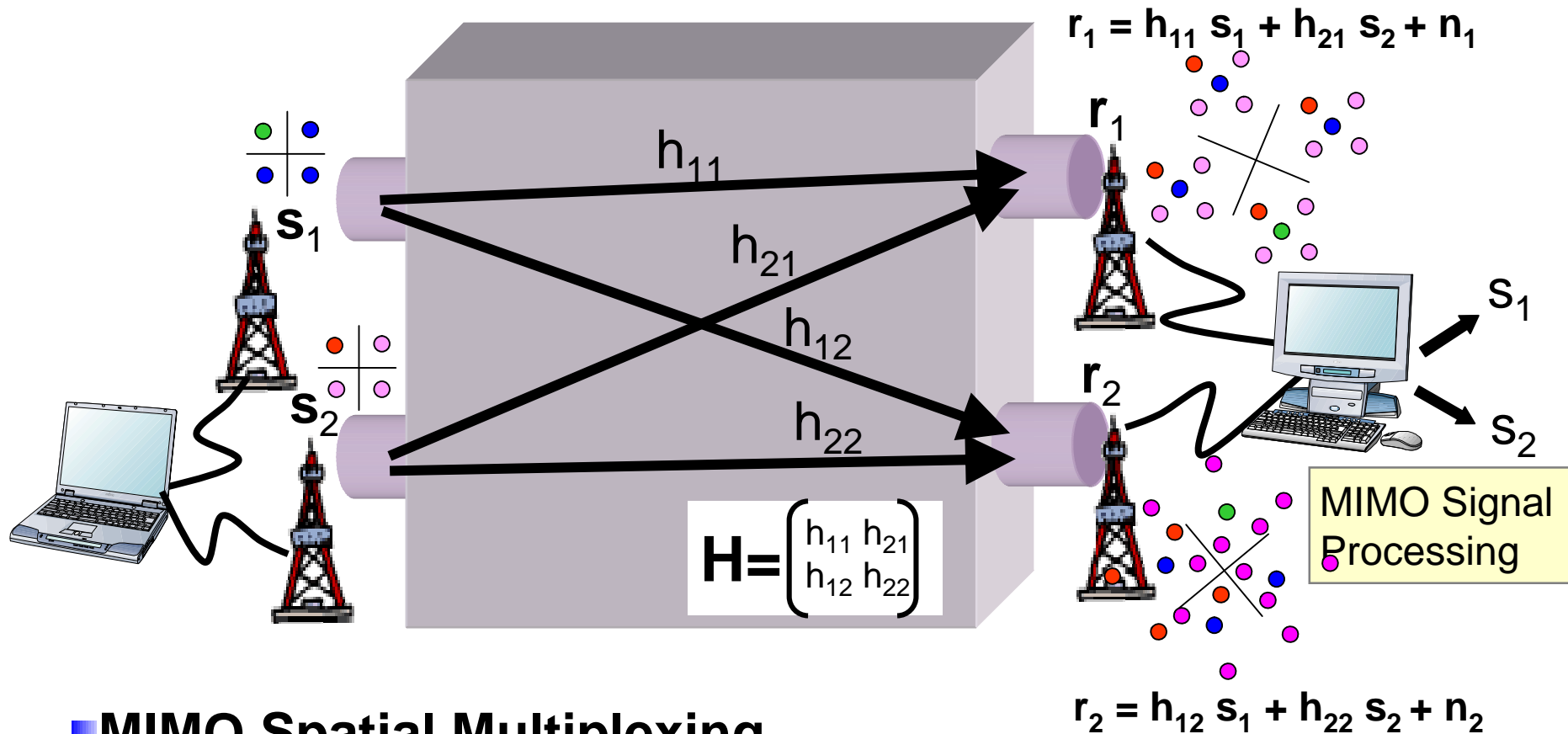
■ MIMO Spatial Multiplexing

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 precoding**

$$\begin{bmatrix} s'_1 \\ s'_2 \end{bmatrix} = \begin{bmatrix} w_{11} & w_{12} \\ w_{21} & w_{22} \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$$

MIMO Channel Information
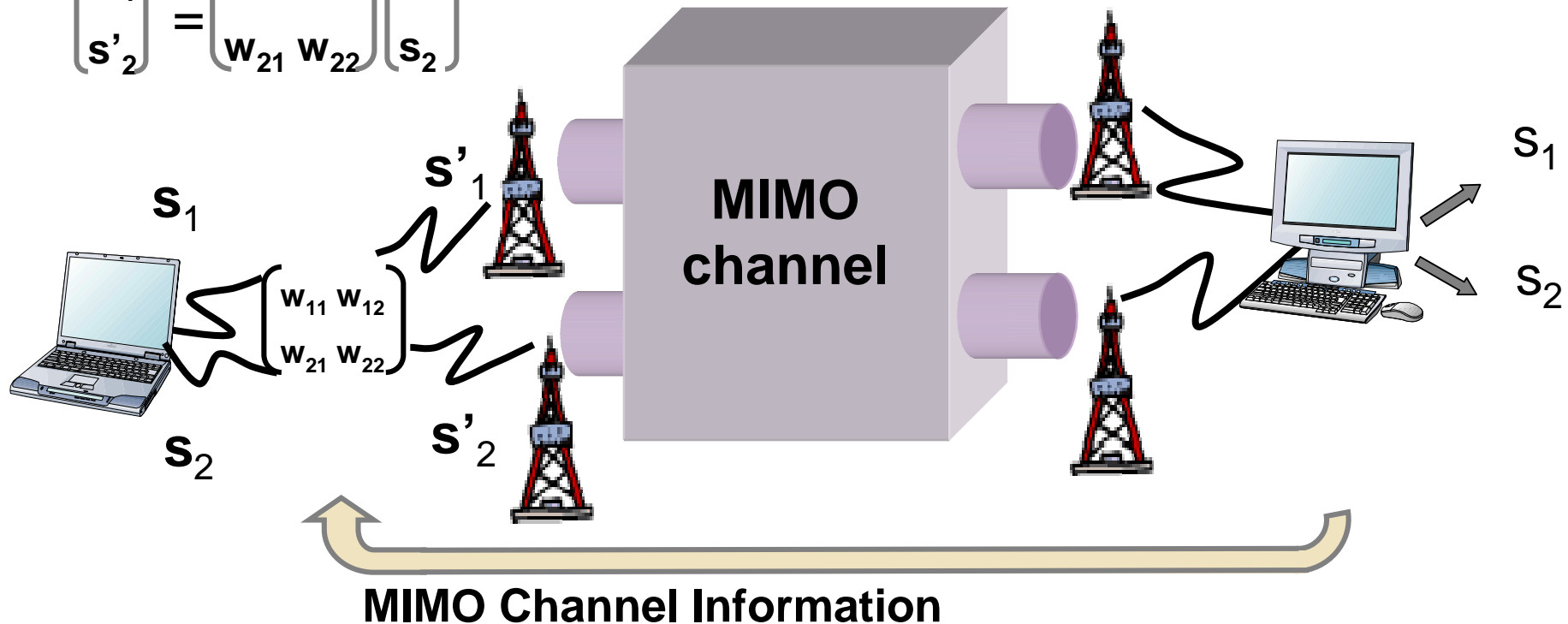
Code book:
- ・Several precoding matrixes are prepared as codebook
- ・Use index of the precoding matrix in feedback

# Collaborative SM (Spatial Multiplexing)

Quadrature Amplitude Modulation
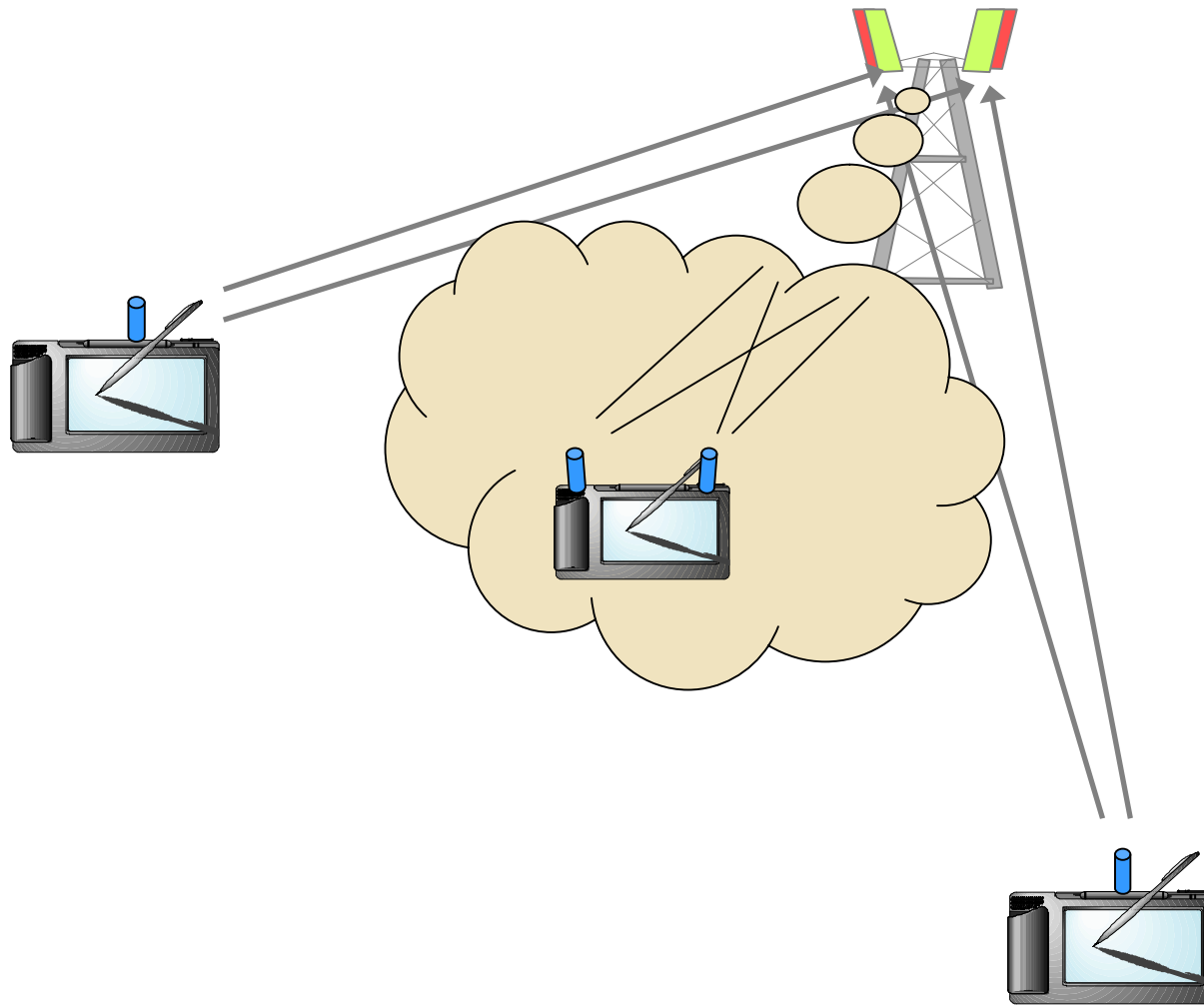
■ Modulation Phase and Amplitude

QPSK

16QAM

QPSK constellation:

10   00

11 | 10

16QAM constellation:

i_1

i_2 i_2

q_2 1011   1001   0001   0011

1010   1000   0000   0010

1110   1100   0100   0110

q_1

q_2 1111   1101   0101   0111
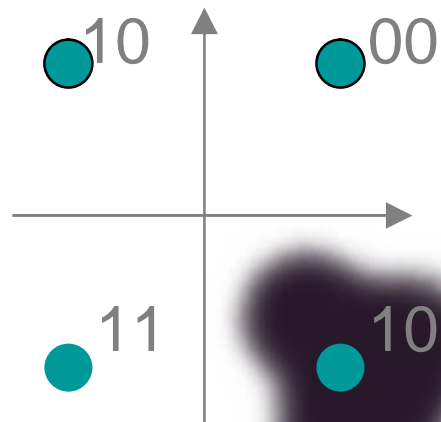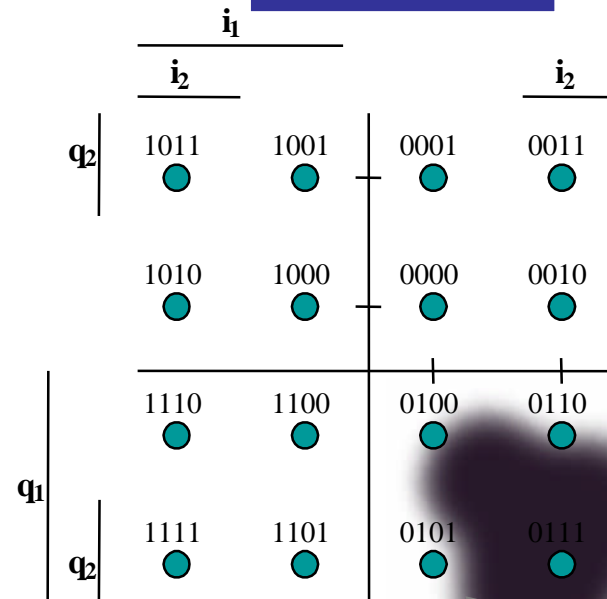
Same amount of noise

2 bits per symbol
Robust

4 bits per symbol
Requires high S/N

Adaptive Modulation and Coding（AMC）

Channel Quality Indicator (CQI)
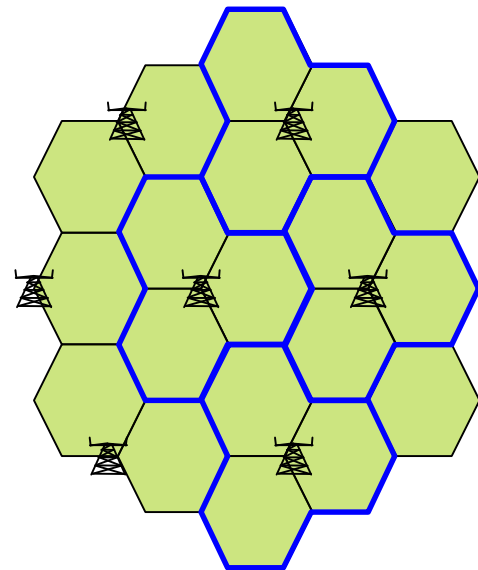
16 QAM

QPSK

Radio Channel Quality

time (mS)
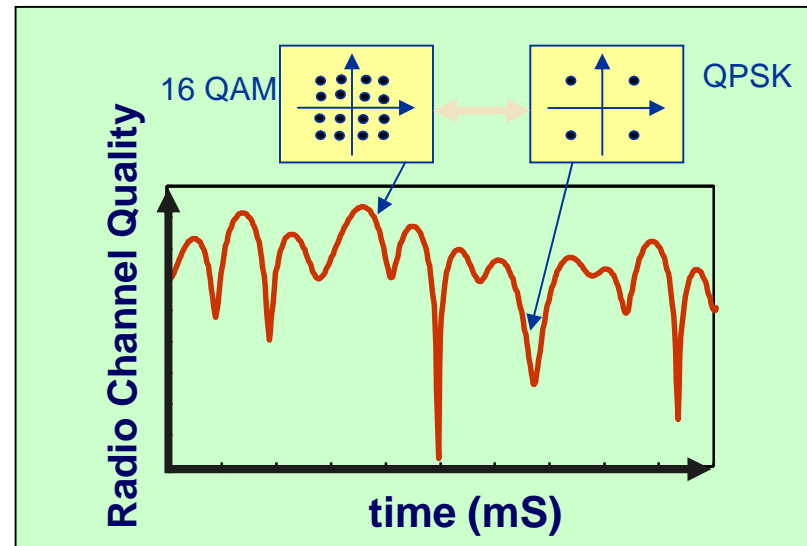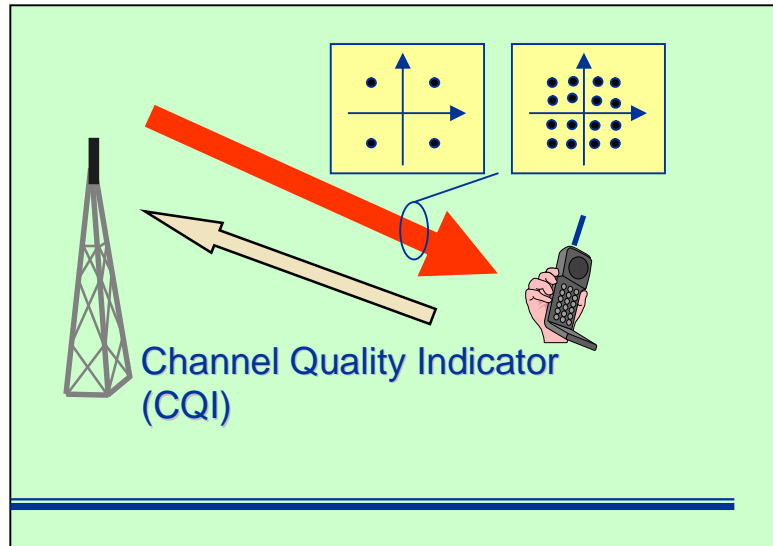
■Use high level modulation and coding rate when channel condition is good
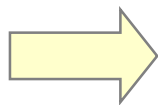
Data Throughput can be increased

Fractional Frequency Reuse (FFR)
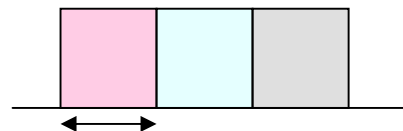
FUJITSU
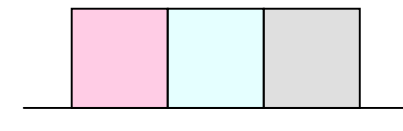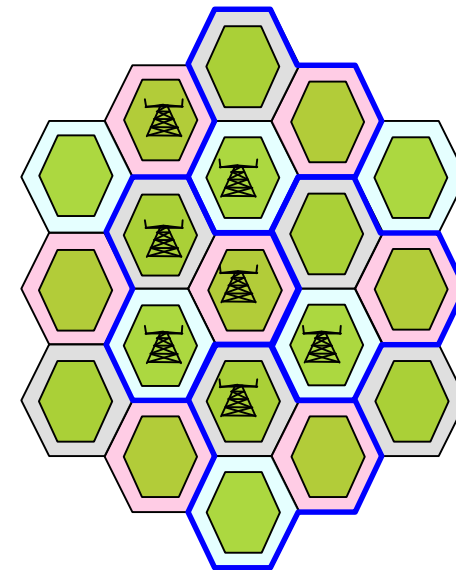
BS

BW

(Ex. 10MHz)

BW/3
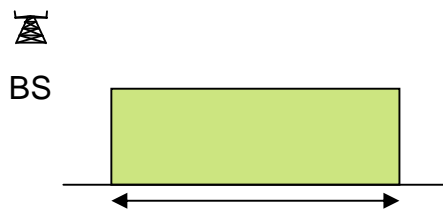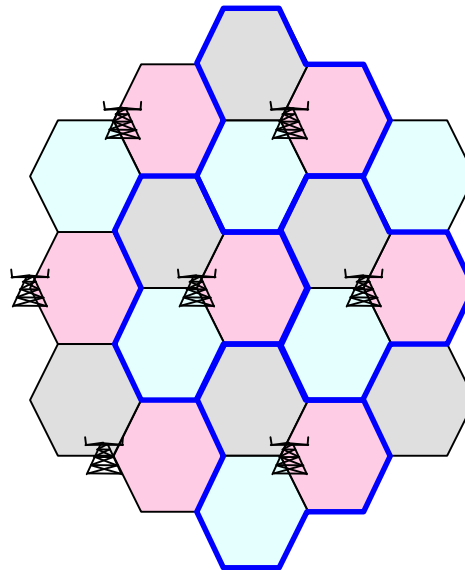
(Ex. 3.3MHz)

FRF =3
Zone

FRF =1
Zone

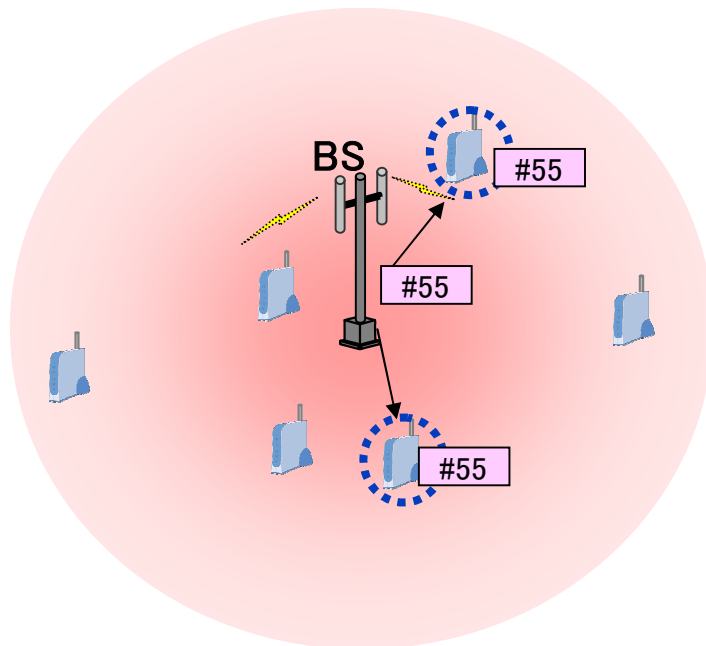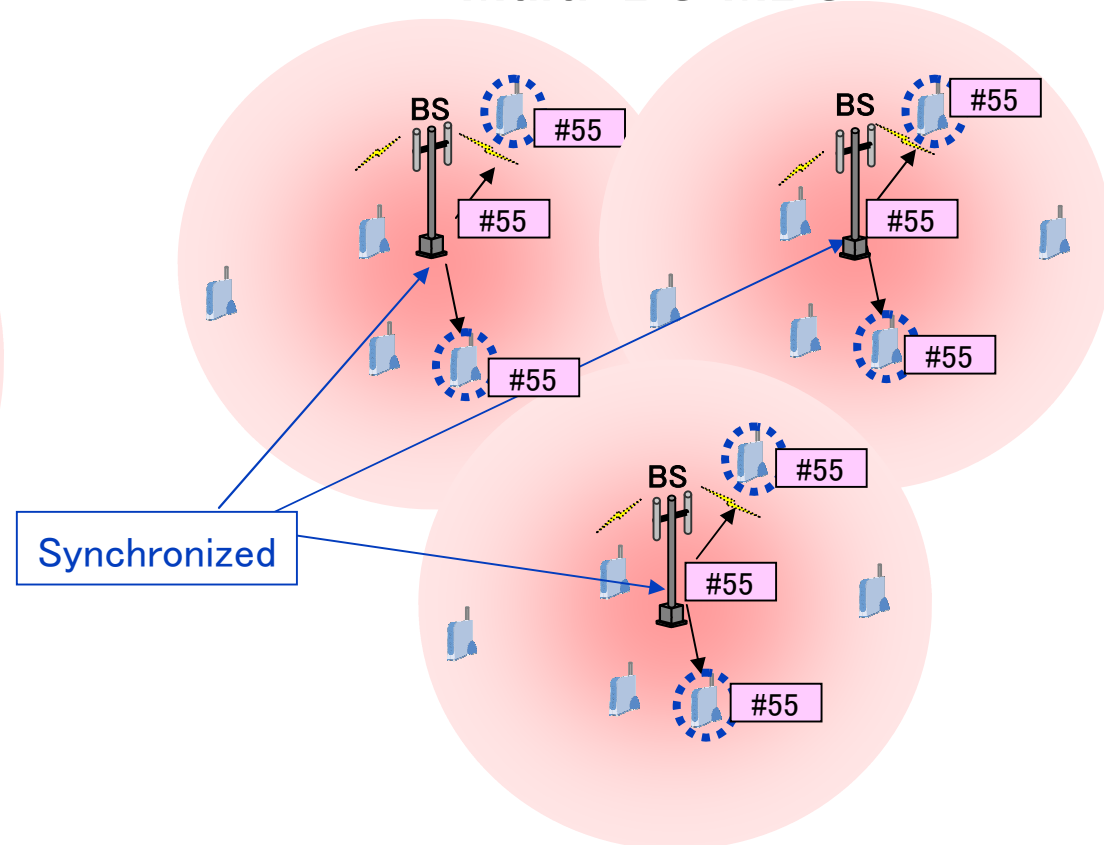| FRF = 1	FRF = 3	$1 \leqq FRF \leqq 3$

FRF: Frequency Reuse Factor

Multicast and Broadcast Service (MBS)

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- Multicasting
- Same CID is allocated to multiple MSs
- Common QoS、Burst Profile (Modulation info)

Single BS MBS

Multi-BS MBS

Synchronized

Half Duplex FDD

- Base Station: Tx and Rx all the time

- Mobile Station: Tx or Rx at one time

BS

DL	to MS(g1)	to MS(g2)
UL	from MS(g2)	from MS(g1)

MS (g1)

DL Rx	UL Tx

MS (g2)

UL Tx	DL Rx

802.16j

- **Latest Draft: P802.16j/D7 (November 2008)**
    - Expected to finish and publish in early 2009
    - WiMAX Forum SPWG completed "Relay Requirement"
- **Add Relay functionality to 802.16e**
   - Low cost Coverage extension
    - Based on OFDMA-PHY TDD

MR-BS:BS which has RS support

RS: fixed/mobile RS

MS: no additional requirement (Backward compatible)

Rel1.5 functions
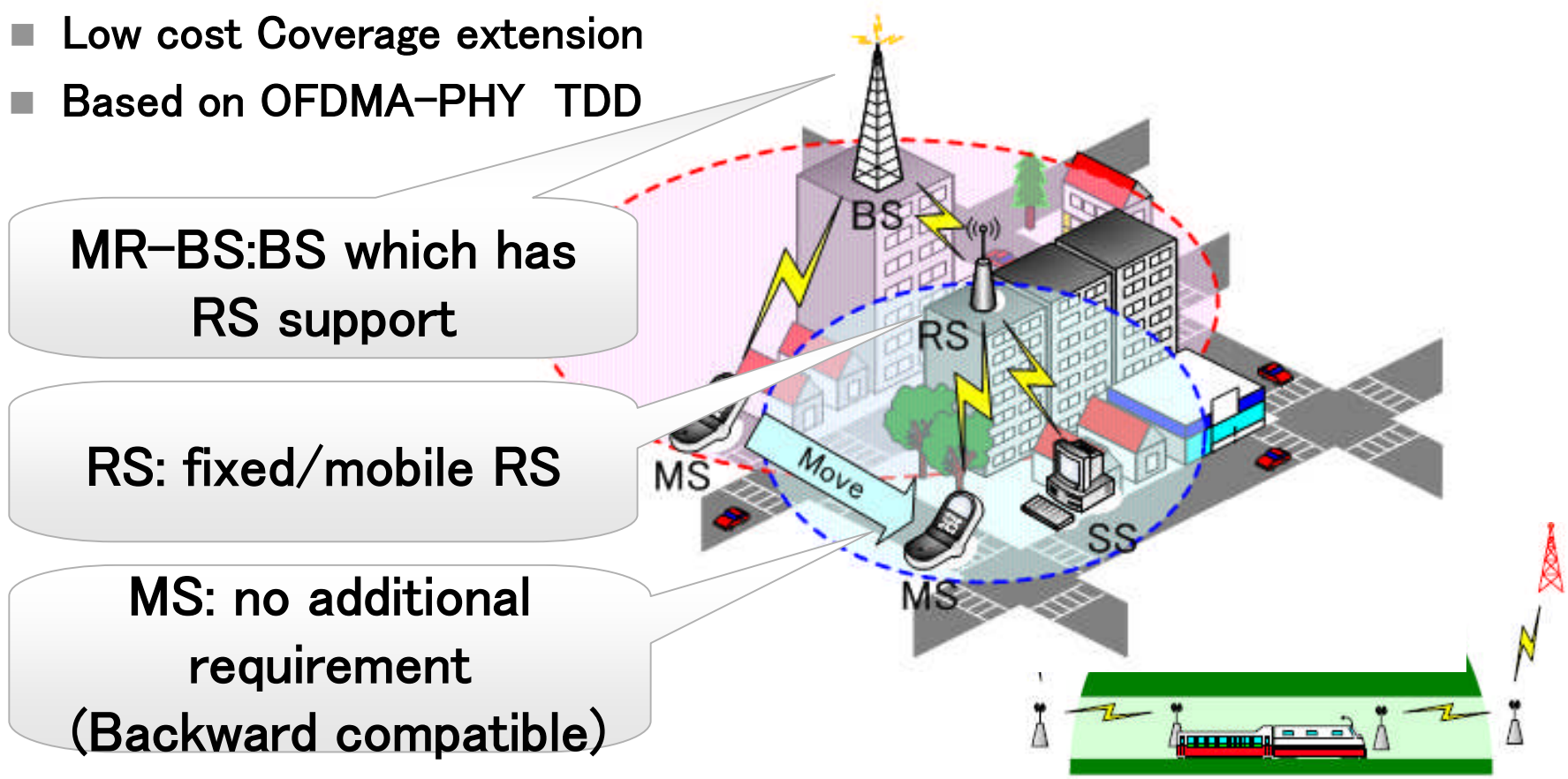
- **Based on 802.16Rev2**
  - To be completed in early 2009
  - Certification starts end of 2009

- **Key features**
  - New Certification Profiles
    - 700MHz, AWS(DL:2.1GHz, UL:1.7GHz), other IMT bands
  - HFDD support
  - MIMO and 64QAM support in UL
  - CL-MIMO
    - Codebook based CL-MIMO
  - MAC enhancement
    - Persistent allocation（for VOIP traffic）
    - HO time improvement
  - NWG1.5 support
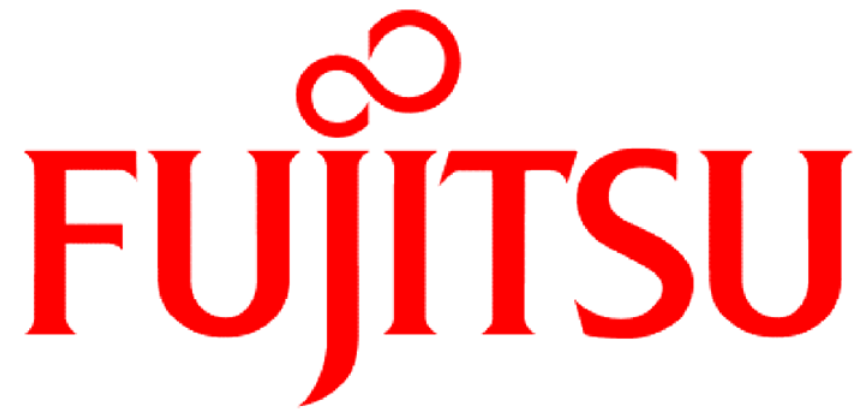   - LBS functionality
  - Coexistence
    - vs. Bruetooth /WLAN

5 ms

DL

UL
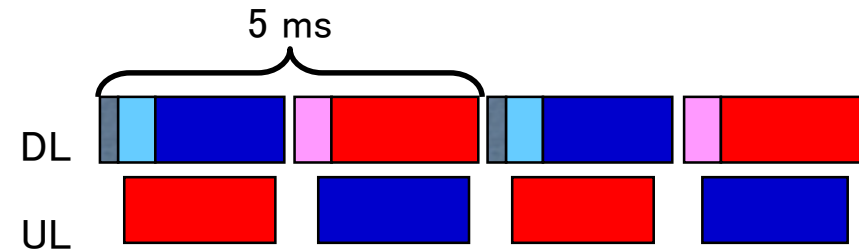
Technologies of WiMAX systems

		Fixed WiMAX (802.16-2004)	Mobile WiMAX Rel1.0/1.5 (802.16e/80.16REV2)	Mobile WiMAX Rel2.0 (802.16m)
Freq.	Frequency band	< 11GHz	< 6GHz	< 6GHz
	Bandwidth	1.25～20MHz	1.25～20MHz	1.25～40MHz
Duplex		TDD	TDD(rel1.0) TDD/FDD (rel1.5)	TDD/FDD
Peak Data Rate		75Mbps (DL+UL)	75Mbps (DL+UL)	＞160Mbps(DL) ＞ 56Mbps(UL)
Cell Radius		2-10km（max. 50km）	2-3km	5km（Max 100km）
Modulation	Primary (AMC)	BPSK/QPSK/16QAM/64QAM	QPSK/16QAM（DL and UL） 64QAM (DL for Rel1.0) 64QAM (DL&UL for Rel1.5)	QPSK/16QAM/ 64QAM
	Secondary	OFDM	SOFDMA	SOFDMA
Technology for higher data speed		AAS, STC, MIMO	AAS, STC, MIMO CL-MIMO (Rel1.5)	AAS, STC, MIMO
Mobility		Fix、Nomadic	Max. 120km/h	Max. 350km/h

AMC: Adaptive Modulation and Coding
AAS: Adaptive Antenna System, STC: Space Time Coding
MIMO: Multiple Input Multiple Output

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THE POSSIBILITIES ARE INFINITE