Discussion Base for 802.16 Mobile Multi-hop Relay Tutorial draft

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Mitsuo Nohara	Voice:	+81-3-6678-3599
KDDI Corporation	Fax:	+81-3-6678-0279
10-10, Iidabashi 3-chome, Chiyoda-ku, Tokyo 102-8460, Japan	E-mail:	mi-nohara@kddi.com
Kenji Saito, Keizo Sugiyama	Voice:	+81-46-847-6350
YRP Research Center, KDDI R&D Laboratories Inc.	Fax:	+81-46-847-0947
7-1 Hikarinooka, Yokosuka, Kanagawa 239-0847, Japan	E-mail:	saito@kddilabs.jp

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None

Purpose:

Proposal of a new task group for mobile multi-hop relay networking in IEEE 802.16 systems

Discussion Base for 802.16 Mobile Multi-hop Relay Tutorial draft

Mitsuo Nohara
KDDI Corporation

Kenji Saito, Keizo Sugiyama
KDDI R&D Laboratories Inc.

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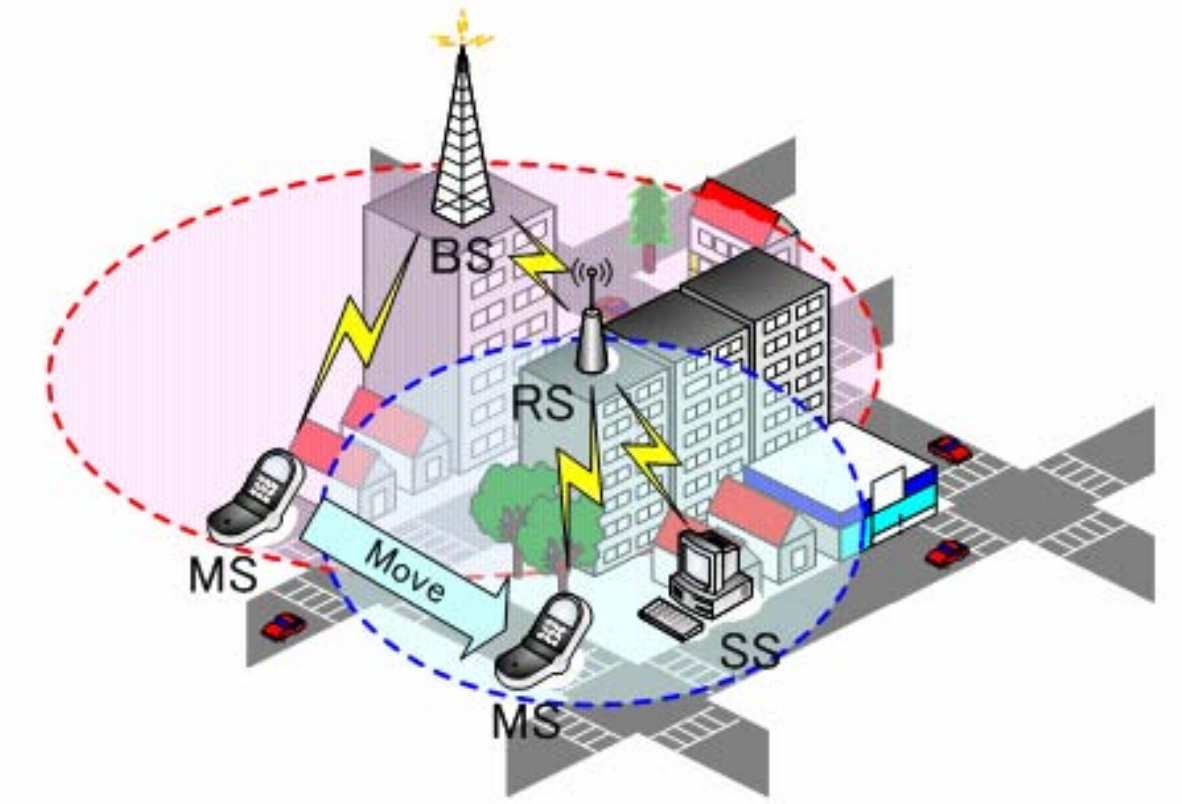
Outline

- 802.16 MMR project
- Benefits
- Background
- Network Topology in 802.16
  - Classification
  - Concept of 802.16MMR
- Study items for 802.16MMR
- Tentative schedule
- Summary

802.16 MMR project

- Develop 802.16 MMR (Mobile Multi-hop Relay) for fixed / mobile terminal
  - PHY: Enhance normal frame structure
  - MAC: Add new protocols for the Relay networking

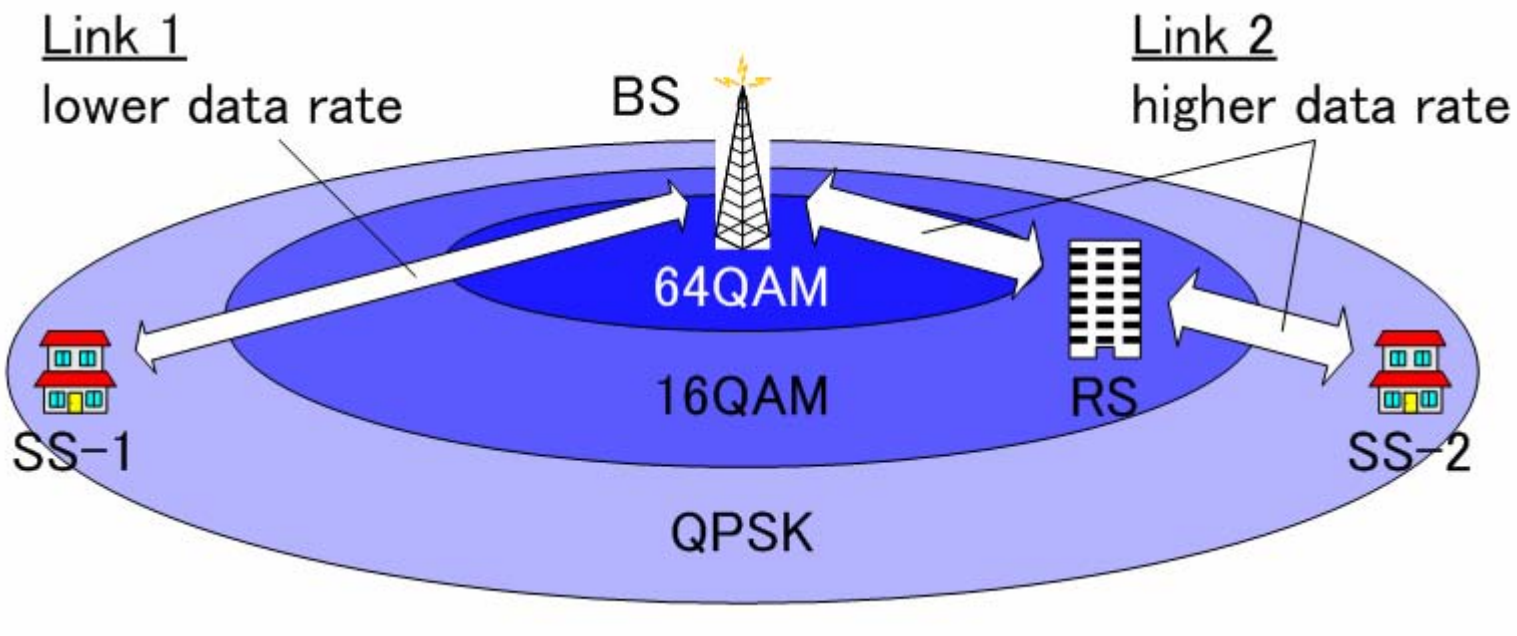


Benefits

- Two benefits from introducing RS
  - Coverage extension:

    Expansion for coverage area of existing PMP mode
  - Throughput enhancement

    Higher throughput over multi-hop paths



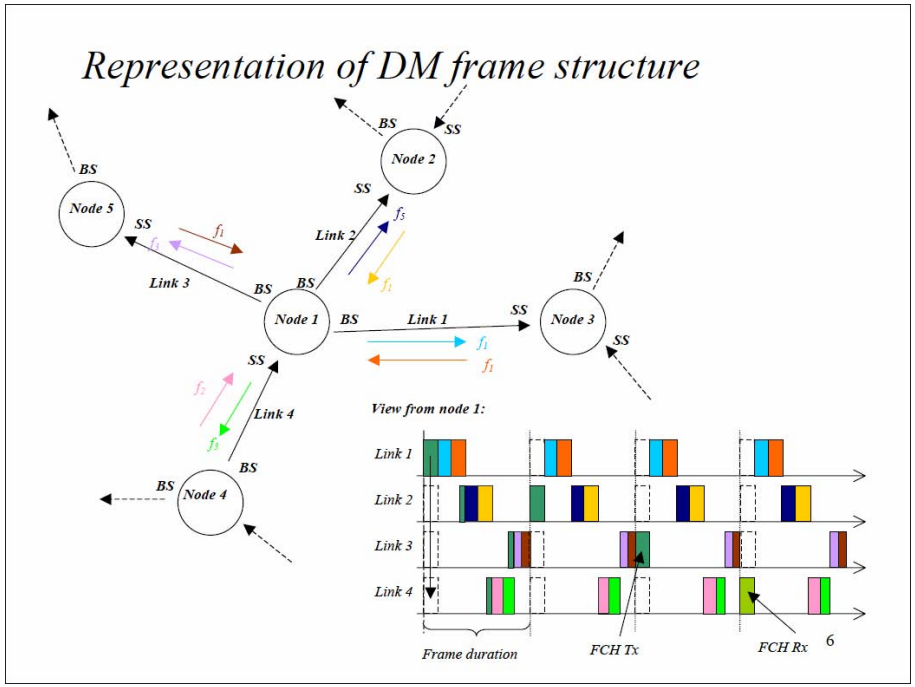
Background

- High frequency band such as 2-6 GHz has wide frequency bandwidth and enables to obtain higher throughput.
- The higher the frequency becomes, the more difficult non line-of-sight (NLOS) communication is.
- Relay Station (RS) is expected to extend coverage to the NLOS area efficiently, compared to highly functional Base Station (BS).

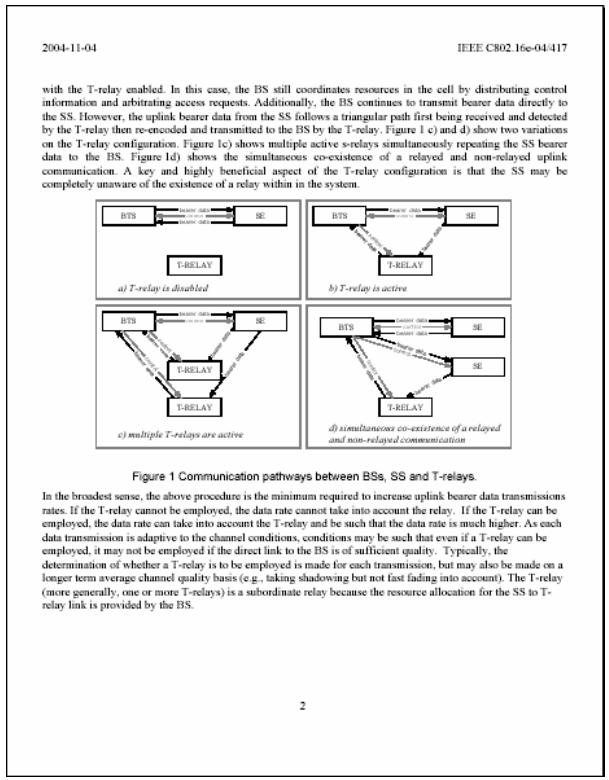
Background

- Related works for 802.16 relay and mesh

IEEE S802.16d-03/67
"Directed Mesh in 802.16"
by Radiant Network PLC



IEEE C802.16e-04/417
"Transparent Uplink Relaying for OFDMA" by Motorola


2004-11-04 IEEE C802.16e-04/417

with the T-relay enabled. In this case, the BS still coordinates resources in the cell by distributing control information and arbitrating access requests. Additionally, the BS continues to transmit bearer data directly to the SS. However, the uplink bearer data from the SS follows a triangular path first being received and detected by the T-relay then re-encoded and transmitted to the BS by the T-relay. Figure 1 c) and d) show two variations on the T-relay configuration. Figure 1c) shows multiple active s-relays simultaneously repeating the SS bearer data to the BS. Figure 1d) shows the simultaneous co-existence of a relayed and non-relayed uplink communication. A key and highly beneficial aspect of the T-relay configuration is that the SS may be completely unaware of the existence of a relay within in the system.

Figure 1 Communication pathways between BSs, SS and T-relays.

In the broadest sense, the above procedure is the minimum required to increase uplink bearer data transmissions rates. If the T-relay cannot be employed, the data rate cannot take into account the relay. If the T-relay can be employed, the data rate can take into account the T-relay and be such that the data rate is much higher. As each data transmission is adaptive to the channel conditions, conditions may be such that even if a T-relay can be employed, it may not be employed if the direct link to the BS is of sufficient quality. Typically, the determination of whether a T-relay is to be employed is made for each transmission, but may also be made on a longer term average channel quality basis (e.g., taking shadowing but not fast fading into account). The T-relay (more generally, one or more T-relays) is a subordinate relay because the resource allocation for the SS to T-relay link is provided by the BS.

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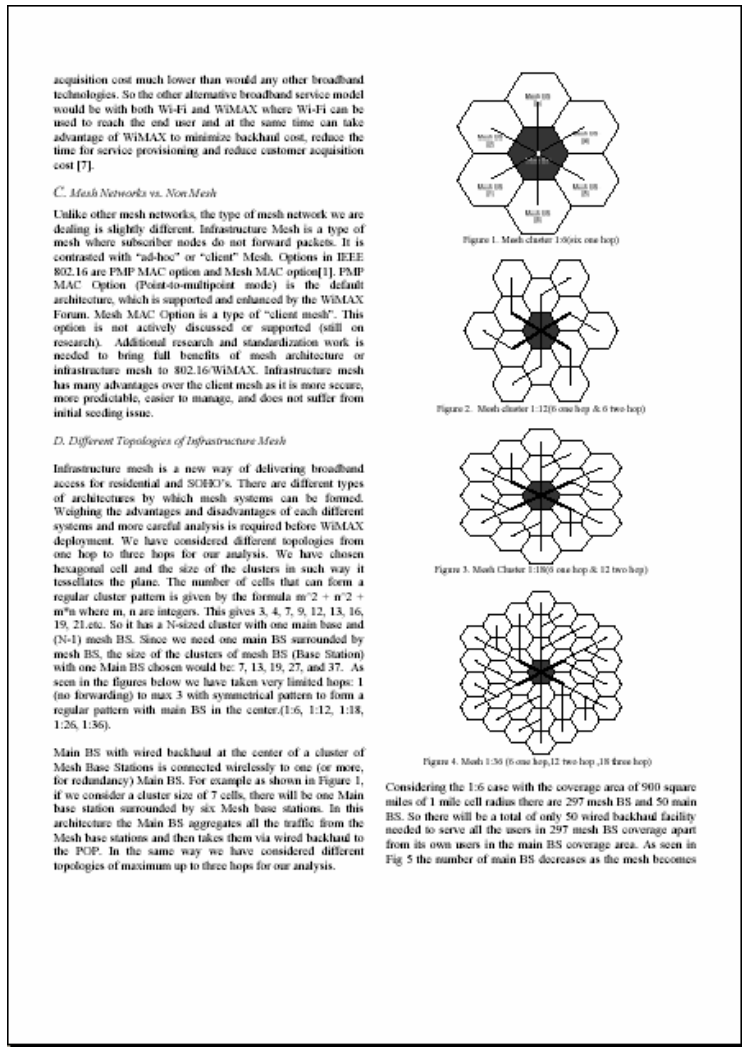
Background

- Related works for 802.16 relay and mesh (cont.)

V.Gunasekaran and F.Harmantzis
"Affordable Infrastructure for Deploying WiMAX Systems : Mesh v. Non Mesh"
Proc. IEEE VTC 2005, May 2005



acquisition cost much lower than would any other broadband technologies. So the other alternative broadband service model would be with both Wi-Fi and WiMAX where Wi-Fi can be used to reach the end user and at the same time can take advantage of WiMAX to minimize backhaul cost, reduce the time for service provisioning and reduce customer acquisition cost [7].

C. Mesh Networks vs. Non Mesh

Unlike other mesh networks, the type of mesh network we are dealing is slightly different. Infrastructure Mesh is a type of mesh where subscriber nodes do not forward packets. It is contrasted with "ad-hoc" or "client" Mesh. Options in IEEE 802.16 are PMP MAC option and Mesh MAC option[1]. PMP MAC Option (Point-to-multipoint mode) is the default architecture, which is supported and enhanced by the WiMAX Forum. Mesh MAC Option is a type of "client mesh". This option is not actively discussed or supported (still on research). Additional research and standardization work is needed to bring full benefits of mesh architecture or infrastructure mesh to 802.16/WiMAX. Infrastructure mesh has many advantages over the client mesh as it is more secure, more predictable, easier to manage, and does not suffer from initial seeding issue.

D. Different Topologies of Infrastructure Mesh

Infrastructure mesh is a new way of delivering broadband access for residential and SOHO's. There are different types of architectures by which mesh systems can be formed. Weighing the advantages and disadvantages of each different systems and more careful analysis is required before WiMAX deployment. We have considered different topologies from one hop to three hops for our analysis. We have chosen hexagonal cell and the size of the clusters in such way it tessellates the plane. The number of cells that can form a regular cluster pattern is given by the formula $m^2 + n^2 + m*n$ where m, n are integers. This gives 3, 4, 7, 9, 12, 13, 16, 19, 21.etc. So it has a N-sized cluster with one main base and (N-1) mesh BS. Since we need one main BS surrounded by mesh BS, the size of the clusters of mesh BS (Base Station) with one Main BS chosen would be: 7, 13, 19, 27, and 37. As seen in the figures below we have taken very limited hops: 1 (no forwarding) to max 3 with symmetrical pattern to form a regular pattern with main BS in the center.(1:6, 1:12, 1:18, 1:26, 1:36).

Main BS with wired backhaul at the center of a cluster of Mesh Base Stations is connected wirelessly to one (or more, for redundancy) Main BS. For example as shown in Figure 1, if we consider a cluster size of 7 cells, there will be one Main base station surrounded by six Mesh base stations. In this architecture the Main BS aggregates all the traffic from the Mesh base stations and then takes them via wired backhaul to the POP. In the same way we have considered different topologies of maximum up to three hops for our analysis.

Figure 1. Mesh cluster 1:6(six one hop)

Figure 2. Mesh cluster 1:12(6 one hop & 6 two hop)

Figure 3. Mesh Cluster 1:18(6 one hop & 12 two hop)

Figure 4. Mesh 1:36 (6 one hop,12 two hop ,18 three hop)

Considering the 1:6 case with the coverage area of 900 square miles of 1 mile cell radius there are 297 mesh BS and 50 main BS. So there will be a total of only 50 wired backhaul facility needed to serve all the users in 297 mesh BS coverage apart from its own users in the main BS coverage area. As seen in Fig 5 the number of main BS decreases as the mesh becomes

Background

- An instance of relay for cellular network
  - A Common Operator Repeater (Analog repeater) was jointly developed by four mobile operators in Japan as follows,

    (1) KDDI

    (2) NTT DoCoMo Inc.

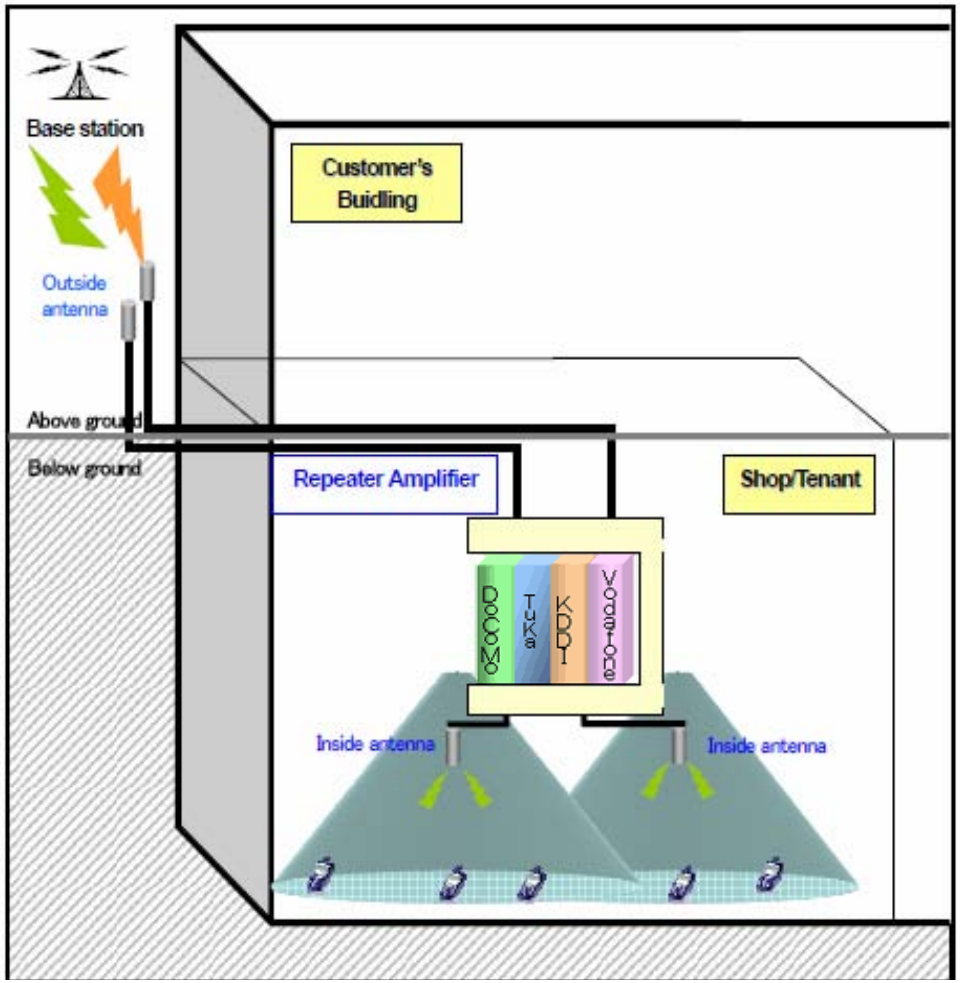
    (3) Vodafone K.K.

    (4) TU-KA Cellular Tokyo Inc.*

    *TU-KA Cellular Tokyo got merged with KDDI
  - The repeaters have been installed in optimal areas to deliver signals from outdoors to the area with communication difficulty, like stores underground and/or inside buildings.
  - Service started on June 22, 2005

Background

- An instance of relay for cellular network (cont.)



- Source http://www.vodafone.jp/english/release/2005/050622e.pdf

Network Topology in 802.16
― PMP and Mesh mode ―

- PMP mode
  - Mandatory topology in 802.16-2004 and 16e
  - “ ***traffic only occurs between BS and SS*** “
- Mesh mode
  - Optional topology in 802.16-2004 (OFDM PHY only)
  - “ ***traffic can be routed through other SSs and can occur directly between SSs*** “

Network Control Configulation of Mesh mode in 802.16-2004

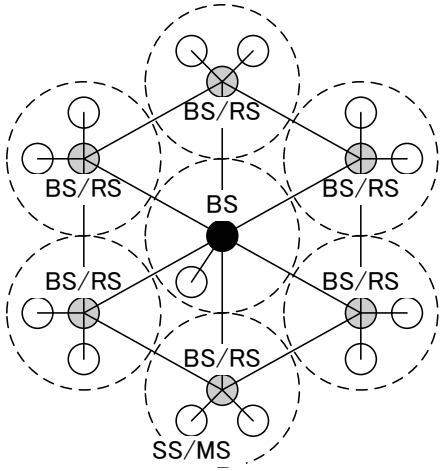
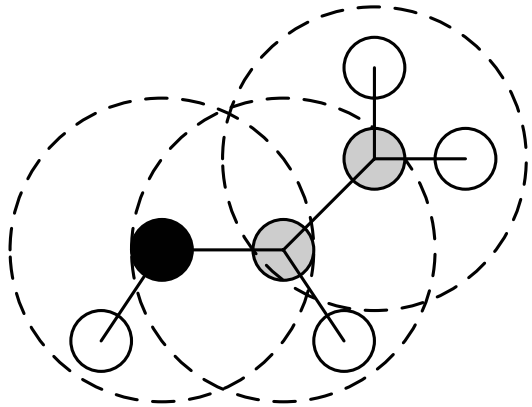
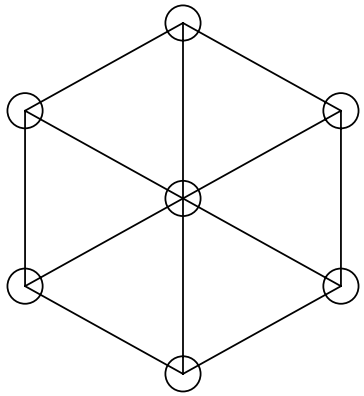
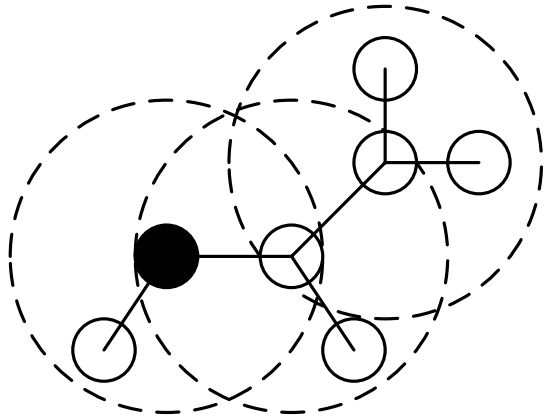
Mesh scheduling		Content
Distributed	Coordinated	Schedule coordination to all neighbor SSs
	Un-coordinated	Schedule negotiation by directed requests and grants between two SSs
Centralized		• Mesh BS Determination of flow assignments by resource requests from SSs • SS Determination of actual schedule from Mesh BS's flow assignments

Mesh Mode in 802.16-2004

- Current Mesh Mode has the following disadvantages
  - No compatibility with PMP mode
    - PHY: Different frame structure (not compatible to PMP mode), OFDM only (for both licensed and unlicensed bands)
    - MAC: Different Network Entry procedure (not compatible to PMP mode)
  - No support for TGe mobile station (MS)
    - Not support a fast route change for MS

❖ Need to develop New Relay mode in IEEE 802.16

Classification – Mesh vs. Relay –

	Mesh	Relay
Infra-structure		
Client	 **Mesh mode in 802.16-2004 may be classified into this category.**	

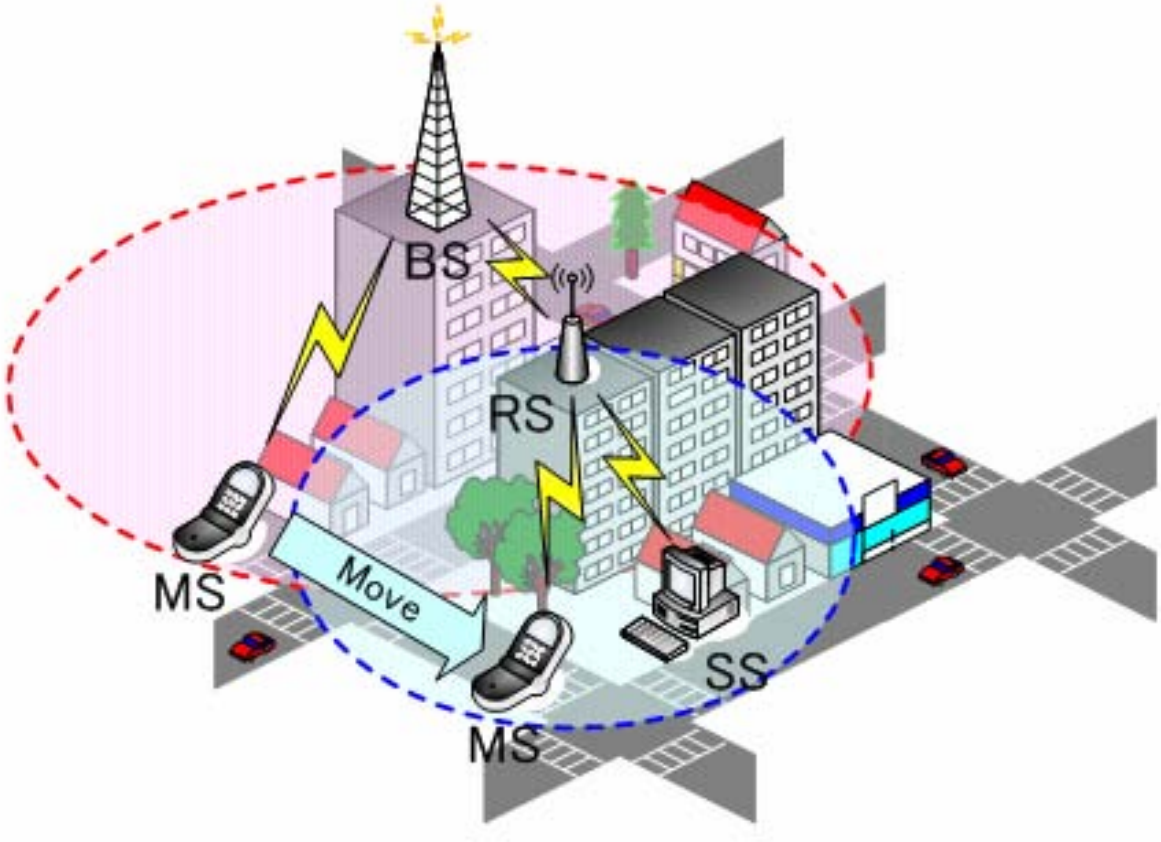
- "Infrastructure" means that a operator provides dedicated equipment that has Mesh or Relay function.
- "Client" means that a user terminal has Mesh or Relay function.

Classification – Mesh vs. Relay – (cont'd)

	Mesh		Relay	
	Infrastructure	Client	Infrastructure	Client
Network topology	Multi-connection to other nodes		Tree	
Purpose	Inter-BS communication for backhaul	Inter-SS/MS communication (such as ad-hoc mode)	• Coverage extension • Throughput enhancement	
Who is the repeater?	All of BS/RS	All of SS/MS	Fixed RS or Nomadic RS	• Nomadic RS • SS/MS that has relay function
Licensed band?	Business use: Licensed band Other one: Unlicensed band			

Concept of 802.16MMR

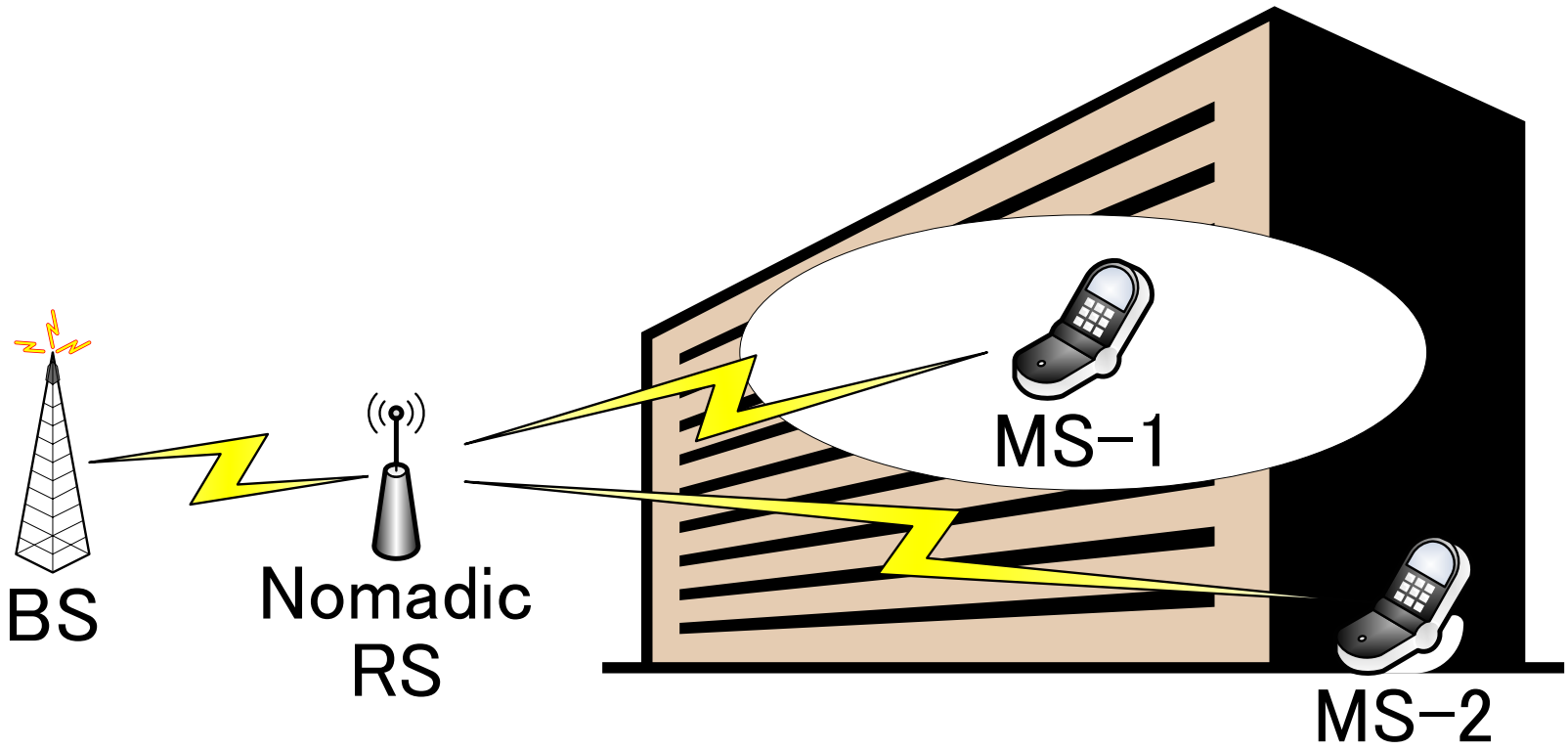
- Fixed RS for infrastructure relay



  - RS is located within BS coverage
  - RS connecting with BS shares radio resource with other SS/MS

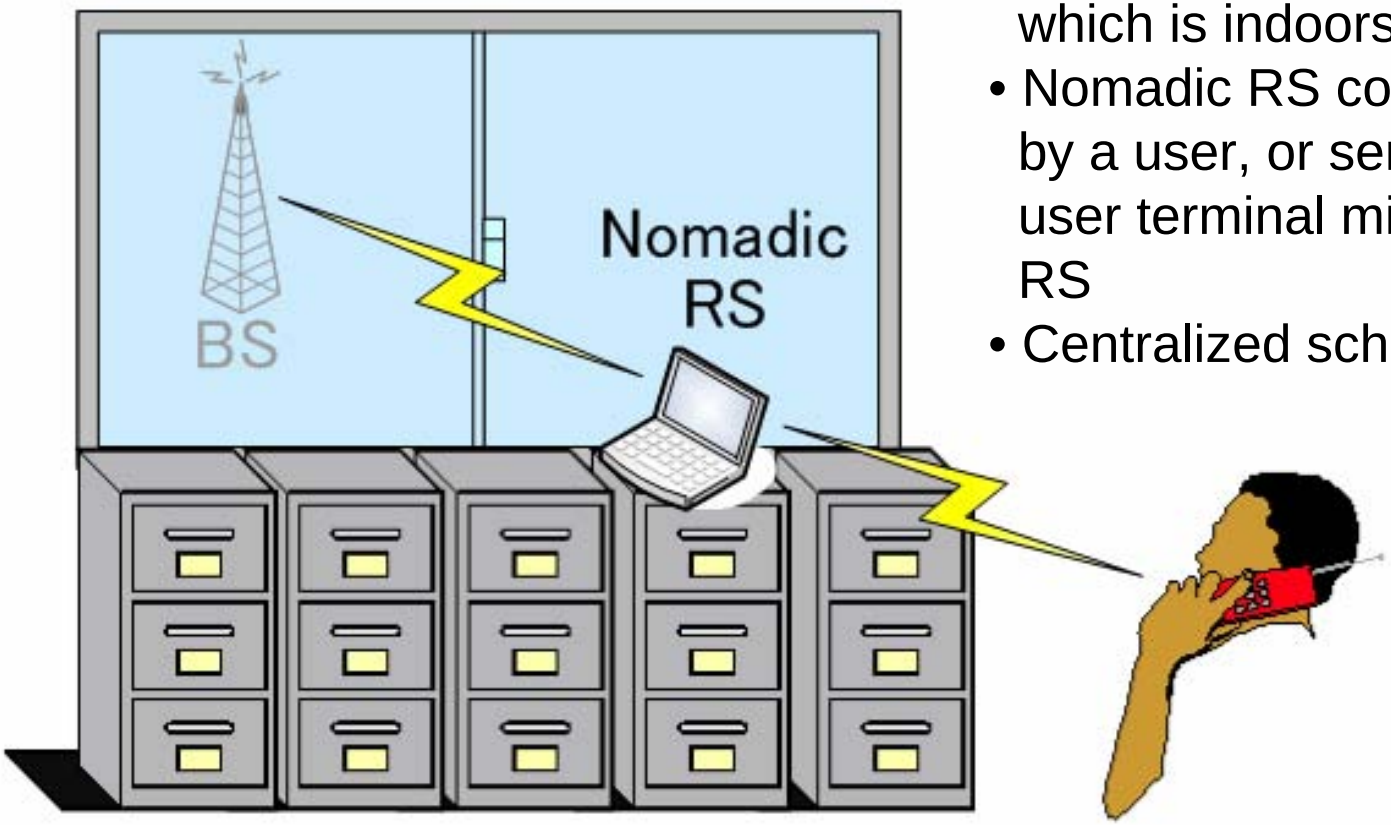
Concept of 802.16MMR
(cont'd)

- Nomadic RS for infrastructure relay
  - Providing BWA service for an event, exhibition etc.
  - Nomadic RS shall be installed by a operator



Concept of 802.16MMR
(cont'd)

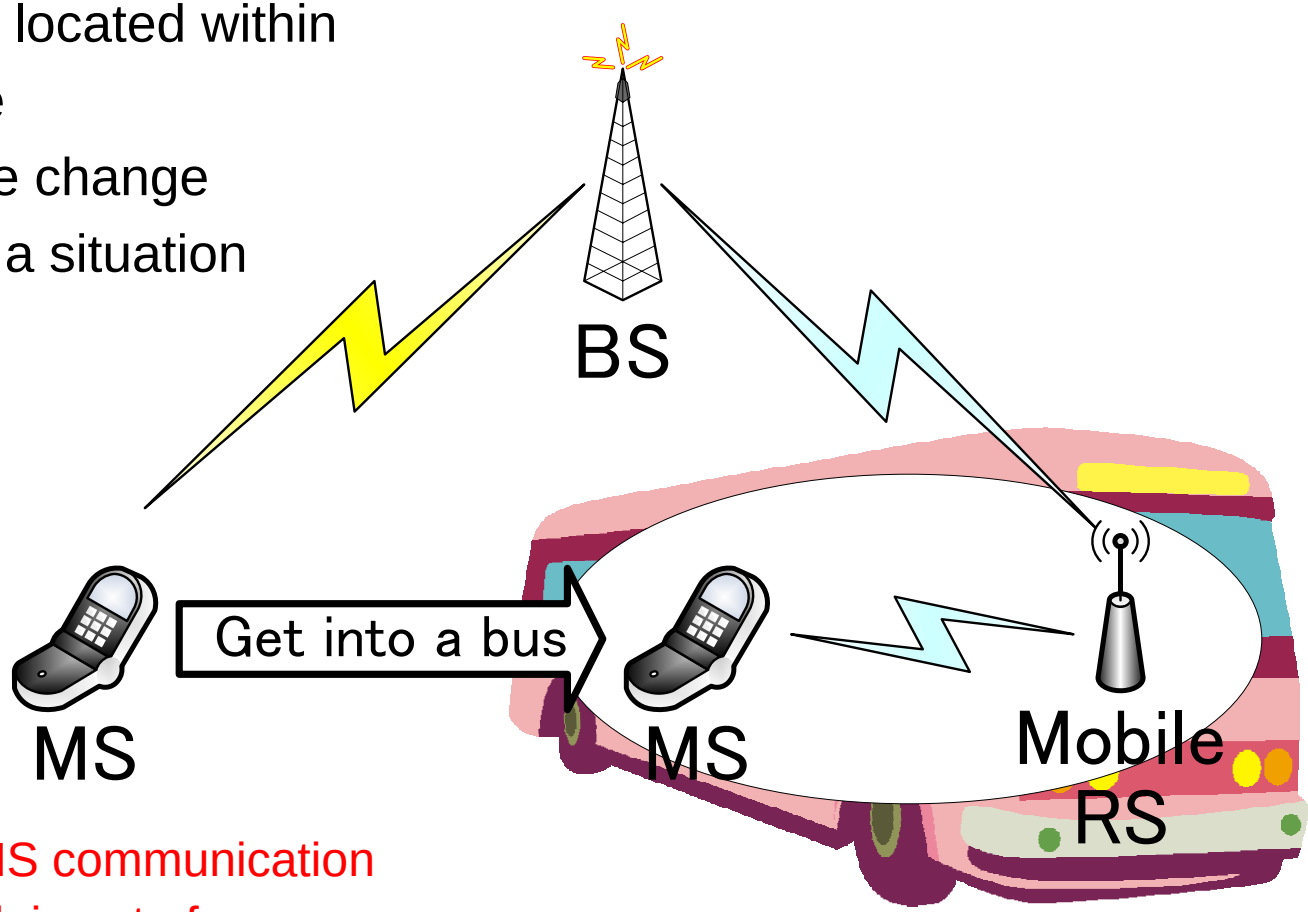
- Nomadic RS for client relay



- Coverage extension to SS/MS which is indoors
- Nomadic RS could be installed by a user, or semi-stationary user terminal might be a nomadic RS
- Centralized scheduling by BS

Concept of 802.16MMR
(cont'd)

- Mobile RS for infrastructure relay
  - Mobile RS is located within BS coverage
  - Optimal route change according to a situation



NOTE : Inter-SS/MS communication like ad-hoc network is out of scope.

Classification – Fixed / Nomadic / Mobile RS –

		Relay Station		
		Fixed RS	Nomadic RS	Mobile RS
Scenario	Infrastructure	• Permanent installation • Coverage extension for non-service area	Temporal / portable installation	Installation to public vehicle, such as train and bus
	Client	Coverage extension by SS that has relay function	• Allow user to enable/ disable relay function • Coverage extension for indoor	Inter-MS communication
Higher Layer		• Out of scope of IEEE 802		
MAC	Infrastructure	• Optimal route selection (L2 Routing) • Control of relayed SS by BS or RS		
	Client	• Substitute route selection *Avoidance of service interruption by SS power off	Control of relayed SS by BS	• Dynamic / optimal route selection • Centralized control by BS
PHY	To fixed terminal	(802.16-2004) OFDM : 256, OFDMA : 2048		
	To mobile terminal	(TGe) OFDM : 256, OFDMA : 128, 512, 1024, 2048		
RF Band	Infrastructure	Relay mode and PMP mode share a same frequency band or use different but adjacent frequency bands		
	Client	Relay mode and PMP mode share a same frequency band		

- The considered scope in 802.16MMR is filled with cyan color

Definitions – Infrastructure / Client mode –

Item	Infrastructure mode	Client mode
Ownership	Each RS is owned by the service provider.	Each RS is owned by a client.
RS Location	Defined by the provider thus the RS coverage can be optimized.	Defined by each client, thus best-fit for it, meantime, the system optimization can be difficult.
Authentication	The BS can assume the RS is reliable.	Some measure must be required to find out if the RS is reliable, in the beginning of the RS installation, session initiation and during the communication.
Notes	The ownership by one provider may restrict a quick service introduction and service enhancement.	Some network level requirements shall be applied to each RS such as 24-hours operation, when it works as an network element. Any RS having MSs of the same owner can be regarded just as a gateway to “SS/MS.”

Study items for 802.16MMR

		Relay	
		Fixed / Nomadic	Mobile
Frame structure based on PMP		Common subject	
Network entry procedure		Common subject	
Mobility	L2 routing	For MS	For both RS and MS
	HO sequence		
	Optimal route selection		
Radio Resource Management	Frequency reuse strategy	Coordination between BS and RS	More complex than Fixed / Nomadic
	Spectrum efficiency		
	Interference		
Synchronization		Common but more complicated for mobile	
Security		Common subject※	

※There may be more security issues for the client RS compared with Infra-ones.

Backward Compatibility

- Definition
  - BS supporting the New Relay mode is able to accommodate 3 types of SSs
    - 802.16-2004 PMP mode SS
    - TGe PMP mode MS
    - New Relay mode SS/MS
- Such backward compatibility provides a smooth migration
  - TGe system can gradually support the New Relay mode in the future

Tentative schedule

Year	Month	802.16 session	Actions
2006	Jan.	#41 Interim	SG: the 3rd meeting – PAR Completion
	Mar.	#42 Plenary	802 EC endorses PAR approval PAR Submission & Approval
	May	#43 Interim	1st TG meeting
	July	#44 Plenary	2nd TG meeting Require Document & Procedure for proposal Selection & merging
	Call for Contribution		
	Sept.	#45 Interim	3rd TG meeting Presentation & Selection
	Drafting standard		
	Nov.	#46 Plenary	1st WG letter ballot
2007	Jan.	#47 Interim	2nd WG letter ballot
	Mar.	#48 Plenary	1st sponsor ballot
	May.	#49 Interim	Sponsor Recirculation
	July.	#50 Plenary	Submission to Rev. Com
	Sep.	#51 Interim	SA Approval

Summary

- Propose a new TG of Relay mode for fixed / mobile terminal
- Working scope
  - PHY: Enhance normal frame structure
  - MAC: Add new protocols for the Relay networking
- Main features
  - Tree structure: one of the end of relayed data path should be at BS
  - Efficiently provide Relay connection to SS/MS (with small number of hops)
  - Support OFDMA as well as OFDM PHY mode
  - Backward compatible to PMP mode
  - PMP & Relay modes : share a same band, or use different but adjacent bands
- Considered RS types

		Ownership	
		Infrastructure	Client
Mesh		No	No
Relay	Fixed	Yes	Yes
	Nomadic	Yes	Yes
	Mobile	Yes	No