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Re:	Submitted in response to Call for Contributions IEEE 802.16j-06/001 issues on 2006-04-06 by Roger Marks to address the “Usage Model” topic.
Abstract	This contribution describes some potential RS types, Usage Models and Deployment Strategies for MMR networks.
Purpose	This contribution is provided as input for the 802.16j Usage Models document.
Notice	
Release	
Patent Policy and Procedures	

802.16j (Mobile Multihop Relay) Usage Models

1 Table of Contents

2 Executive Summary

Usage models identified in this document provide a more detailed description of the scope of IEEE 802.16j that will be developed. Moreover, the technology requirements derived from the usage models serve as part of the criteria for determining whether a draft is complete and ready for balloting.

We specify the usage of 802.16j RSs in terms of the potential RS types, typical usage models, and potential deployment strategies. RS types are defined in terms of the complexity/cost of the RS. An example RS type is a simple, low-cost RS with one transceiver. Usage models capture the reason(s) that the RS is being deployed. For example, an RS can be deployed to provide higher SINR coverage to MSs in the MMR cell. Deployment strategies capture the manner in which the carrier builds out their network. An example deployment strategy is to carefully plan the locations/cell sites of fixed RSs in order to guarantee that MMR links are LOS.

We find this approach of splitting the problem into RS types, usage models, and deployment strategies to be useful because we believe that each usage model can be achieved using more than one RS type, each RS type can be used in more than one usage model, and combinations of RS types and usage models can be deployed using a variety of strategies. Furthermore, the usage models themselves are not cleanly separable, as an MMR network can be deployed to achieve more than one goal (for example, both coverage and capacity) and the usage of an RS may need to evolve over time.

2.1 RS Types

We identify the following potential types of RSs, recognizing that these types identify points on a continuum of potential RS designs. See section 4 for details.

- Simple RS – Low cost RS with one transceiver, no control functionality, and an antenna switch to optionally support multiple antennas.
- Full Function Fixed/Portable RS – RS which operates on multiple OFDMA channels[1], optionally supports MIMO, and implements distributed control functions
- Mobile RS – Full function RS with mobility

The following table summarizes the key characteristics of the different RS types.

	Simple RS	Full Function Fixed/Nomadic RS	Mobile RS
Number of OFDMA channels	1	>1	>1
Duplexing on MMR and access links	TDD	TDD or FDD	TDD or FDD
Frequency sharing between access and MMR links	Yes	Yes or No	Yes or No
Control Functions	Centralized in MMR-BS	Centralized in MMR-BS or	Centralized in MMR-BS or distributed in RSs

[1] An OFDMA channel is a contiguous frequency band over which the 802.16 OFDMA waveform is transmitted. See section 3.3.2 for a more detailed explanation of this term.

		distributed in RSs	
Mobility	Fixed/Nomadic	Fixed/Nomadic	Mobile
Antenna support	SISO or MIMO	MIMO	MIMO

2.2 Usage Models

We have identified the following usage models in commercial deployments. Military and public safety / disaster recovery deployments are left for further study. See section 5.1 for details.

- Enhanced Data Rate Coverage– Provide higher SINR to users within the cell. This can also be thought of as providing higher throughput to individual MSs within the cell.
- Range Extension – Provide coverage to users outside the edge of the cell.
- Capacity Enhancement – increase system capacity by deploying RSs in a manner that enables more aggressive frequency reuse. Some examples are a Manhattan-type environment, or a general pico-cell deployment.

The following table summarizes the key features of the three models.

	Enhanced Data Rate Coverage Model	Range Extension Model	Capacity Enhancement Model
RS Location	Outer donut in MMR-BS cell; coverage holes within MMR-BS cell	Usage clusters outside the perimeter of the MMR-BS cell	Environment Dependant. High capacity demand locations within the MMR-BS cell
MMR Link Capacity	Low	Low	High
Frequency Reuse in MMR Cell	Not required but possible	Not required but possible	Required

2.3 Deployment Strategies

Different strategies can be used in deploying RSs within an MMR network. We describe the following strategies. See section 5.2 for details.

- LOS deployment strategy – RS locations and antenna placement are carefully planned in order to achieve LOS links between MMR-BS and RSs and between RSs.
- NLOS deployment strategy – RS locations and antenna placement are not constrained by the need to achieve LOS links between MMR-BS and RSs. Techniques such as MIMO are used to provide sufficient capacity or link budget enhancement on MMR links
- Mobile RS deployment strategy – Mobile RSs encounter varying link conditions, so we consider them a separate deployment strategy.

The following table summarized the characteristics of the three deployment strategies.

	LOS Strategy	NLOS Strategy	Mobile RS
Expected Channel Conditions	LOS, Ricean	NLOS	Varies
RS Deployment	Carefully planned	Convenient location near traffic demand	Random

RS Antenna Location[2]	Tower, building	Tower, building, light post, other	Bus, train
RS Mobility	Fixed, carefully placed portable	Fixed, portable	Mobile
MMR-BS Deployment	Carefully planned	Carefully planned	Carefully planned
MMR-BS Antenna Location	tower	tower	tower

[2] An RS may have separate antennas for the MMR link(s) and for the access link. The table refers to the placement of the antenna(s) used for the MMR link. Separate antennas used for to provide access link may be mounted in different locations.

3 Introduction

3.1 Document Overview

In this document we capture the key aspects of RS usage and deployment. The purpose of the document is to help guide the creation of detailed RS requirements and ultimately the creation of the 802.16j standard. The usage and deployment models described in this document serve to define the scope of the 802.16j project in more detail.

The document is structured as follows. We first define some representative RS types which span the spectrum of RS functionality and complexity. We then describe a number of usage models and discuss how the various RS types can be used to achieve the goals of each usage model. Finally, we discuss several deployment strategies that apply to a multitude of RS types and usage models. The document is split in this fashion because there is not a one-to-one correspondence between RS types, usage models, and deployment strategies.

3.2 Document State

The current version of this document describes RS types, usage models, and deployment strategies associated with commercial deployments. Usage models associated with public safety / disaster recovery deployments and with military deployments are left for further study. Also, the similarities between military usage models and commercial usage models have not been explored to determine if there are common RS types that can support both types of usage models.

3.3 Terminology and Concepts

In this section we define the terminology and concepts used throughout this document. Most of the terms are drawn from contribution C80216j-06_019, which is also to be presented in the Tel Aviv meeting [1]. We have copied the most relevant terms from that document here for the sake of convenience.

3.3.1 Stations and Links

Figure 1 is used to define the terminologies which are used in this document, where

- **access link:** An 802.16 radio link between an MS and a serving station (i.e., a BS, MMR-BS, or RS)
- **BS:** a base station which does not have any MMR-enabled functionality. Therefore, there is no way for RS to link to it
- **MMR-BS**: a BS which has MMR-enabled functionalities.
- **MMR link**: An 802.16j radio link between an MMR-BS and an RS or between a pair of RSs
- **serving station:** A station (i.e., a BS, MMR-BS, or RS) that is directly connected to an MS via a single radio link or hop
- **upstream**: In the direction of an MMR-BS following the MMR path originating at an MS
- **downstream:** In the direction of an MS following the MMR path originating at an MMR-BS
- **MMR-cell**: The geographic area consisting of all locations where an MS may communicate through a particular MMR-BS using either one-hop communications links with that MMR-BS or using relayed communications links

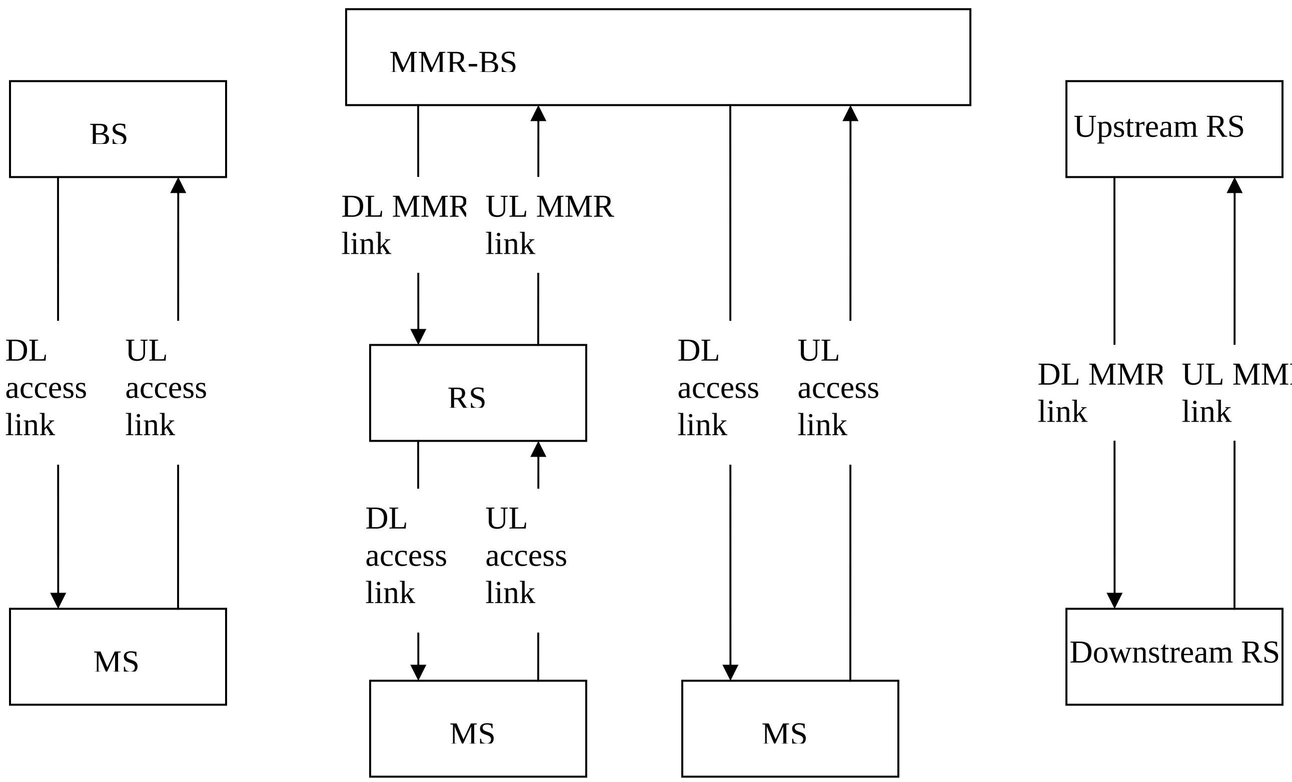


Figure 1 Stations and Links

3.3.2 Frequency Usage

In this document we use the term OFDMA channel, or simply channel, as it is defined in [1]. An OFDMA channel is a contiguous frequency band over which the 802.16 OFDMA waveform is transmitted. An OFDMA channel is divided into subcarriers, which are grouped into subchannels and slots, which are allocated for burst transmission.

Several aspects of frequency usage are considered in this document.

- Duplexing scheme: Scheme used to assign frequencies to uplink and downlink communications. In TDD scheme, a single OFDMA channel is shared between the uplink and downlink. In FDD, separate channels are assigned to the uplink and downlink.
- Sharing of frequencies between access links and MMR links: In an MMR system, there can be multiple RSs within an MMR-cell, and thus multiple MMR links and access links. It is possible for the MMR links and access links to share a channel or to be deployed on different channels
- Frequency reuse within the MMR-cell: OFDMA channels assigned to either MMR link(s) or access link(s) or shared by both, can be reused with the MMR-cell through spatial multiplexing.

From the perspective of a single RS, the frequency usage choices can be expressed in terms of the different types of links that an RS can support, as illustrated in Figure 1. An RS can support a DL MMR Link and an UL MMR link to the MMR-BS. It can support a DL Access link and UL Access link to the MSs that it serves. It can also support a DL MMR link and an UL MMR link to other RSs. All of these links can operate on separate OFDMA channels or they can share OFDMA channels. Multiple combinations are possible. Furthermore, the channels (the frequencies on which they operate) used by one RS can be the same as the frequencies used by other RS(s) within the MMR cell.

4 Relay Station Types

In this section we describe some of the potential RS configurations that should be supported by the 802.16j standard. The types that we have identified do not represent an exhaustive list of potential RS types. However, we discuss some of the features that increase cost and complexity in an RS.

The type of RS is not strictly determined by the usage model for which it is deployed. In other words, for a given usage model, the service provider may choose to deploy a variety of different RS types depending on traffic, mobility, topology, etc. within the vicinity of each RS location. Thus, in a given MMR network, there can be not only multiple usage models but also multiple RS types for each usage scenario.

4.1 RS Complexity and Cost

RS cost is determined by a number of factors including the complexity of the PHY, MAC, and upper layers, the cost of the RF components (antennas, power amps, etc.), and by the number of Tx/Rx chains. When determining the cost and complexity of an RS, we consider the following factors.

- Number of OFDMA channels on which the RS must receive and transmit
- Amount of control functionality implemented in the RS
- RS mobility support (dynamic frequency allocation[3], handover algorithms, etc.)
- Antenna technology (SISO, Beam Forming, MIMO)

4.2 Simple Relay Station

The Simple RS operates on one OFDMA channel (one frequency), which does not change dynamically, and contains no control functionality. Deployments that use this type of RS utilize the same channel for access and MMR links. The simple RS has one transceiver, and can optionally have an antenna switch to support sectorized deployments. Frequency assignments are static, with updates made on large timescales. MMR-BSs that serve these types of RSs manage all control functionality. The associated MMR-BSs provide control messaging for the RSs as well as the contents of control messages intended for the MSs. Although RSs of this type do not perform any control functions, they must be able to act on control messages issued from the MMR-BS and transmit broadcast and control messages to the MSs that they serve on behalf of the associated MMR-BS. Simple RS will also be able to make a number of simple but essential measurements, such as received signal quality measurements, and report these to the MMR-BS.

Simple RSs can be either fixed or portable/nomadic. A simple portable/nomadic RS will require some degree of functionality to enable the MMR-BS to sense the changes in operational environment and adapt their mode of operation accordingly.

Simple RSs can be used in different ways to achieve different objectives (i.e. usage models). For example, simple RSs can be deployed along the cell edge to increase subscriber SINRs or in coverage holes in the interior of the cell to provide access where there previously was none.

Simple RSs can also be deployed in order to provide high capacity. Each RS may be assigned a separate OFDMA channel, allowing frequency reuse within the MMR cell. As long as each RS is served by the MMR-

[3] Note that dynamic frequency allocation is not intended to imply the use of unlicensed band frequencies. Some amount of dynamic frequency assignment can be performed from a set of licensed band frequencies allocated for use within an MMR cell.

BS on the same channel as it serves its access links, the RSs do not require increased complexity for multiple radios or other related enhancements, although the RS will be limited to serve only one of the four links (DL/UL MMR link, DL/UL Access link) at a time. If the number of RSs within the MMR cell is kept small, the MMR-BS can perform centralized control of the RSs in the MMR cell avoiding the added complexity of distributed control.

We discuss the details of the potential usage models and deployment strategies in section 5. In that section we provide more examples of how the RS types can be used to implement each of the usage models.

4.3 Full Function Relay Station

At the opposite end of the spectrum is a full function RS which operates on multiple OFDMA channels, adapts to changes in RS location, implements distributed control functions (such as scheduling) under the coordination of the MMR-BS, and supports MIMO in order to operate in NLOS environments.

The full function RS enables the carrier to utilize a variety of different frequency usage schemes. Access and MMR links can be operated on different channels or on the same channel. MMR links can operate on multiple channels. Also the assignment of frequencies to MMR links can be dynamic to some degree. This type of support requires multiple transceivers and the ability to tune to different frequencies on a timescale of a few milliseconds. The full function RS must be able to make control decisions such as scheduling and route selection decisions.

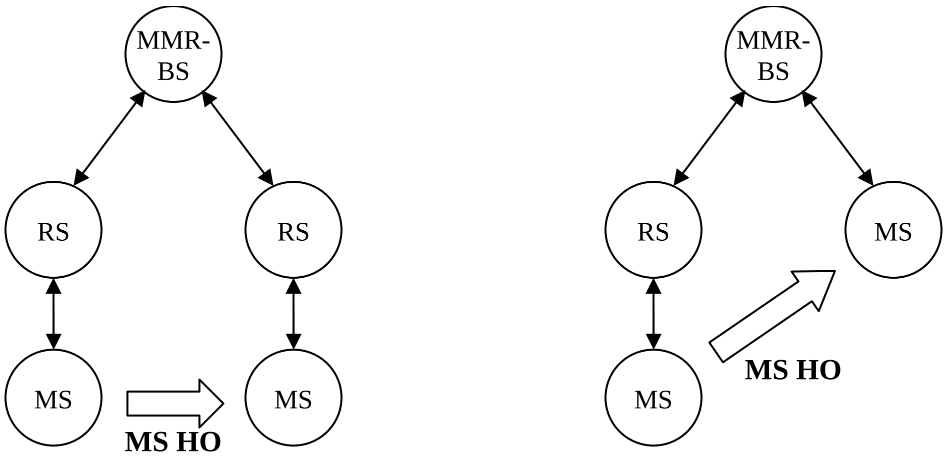
As with the Simple RS, the Full Function RS can be used in a variety of usage models. See section 5.1 for details.

There are two flavors of Full Function RSs. These are the Fixed/Portable Full Function RS and the Mobile Full Function RS. Fixed/Portable Full Function RSs have the major features described above. Mobile RSs add support for handover and the ability to deal with a varying channel due to mobility.

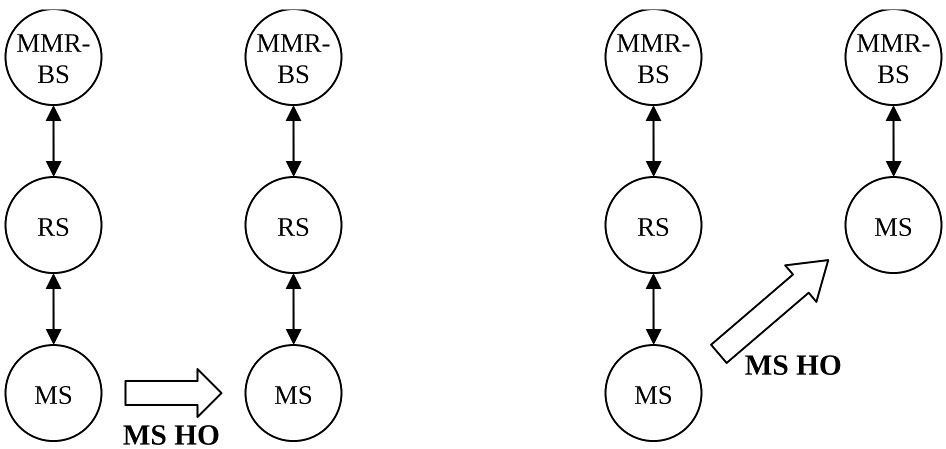
Figure 2 illustrates some of the expected handover scenarios in MMR deployments. Figure 2(a-b) demonstrate the types of handovers required to support independent MS roaming in MMR networks. In particular, Figure 2(a) presents two examples of intra-MMR-cell handover of an MS associated with a fixed/portable RS. The first is a handover of an MS between RSs within the same MMR-cell. The second is a handover of an MS between an RS and the MMR-BS of the same MMR cell. It should be noted that an MS can also be handed over from an RS to the MMR-BS, and that in general, the number of hops between the MMR-BS and MS can change (increase or decrease) as a result of handover. Similarly, Figure 2(b) illustrates two examples of inter-MMR-cell handover of an MS associated with a fixed/portable RS. The first is a handover of an MS between RSs belonging to different MMR-cells. The second is a handover of an MS between an RS and an MMR-BS of different MMR-cells. In all of these cases, the MMR-BSs and RSs must be able to support MS handovers in the context of multi-hop connections.

By comparison, Figure 2(c) demonstrates the types of handovers required to support joint RS/MS roaming (i.e. roaming of an entire RS cell). In this scenario, the MS does not engage in handover procedures since its point of attachment does not change as it moves in conjunction with its serving mobile RS. Instead, the RS manages all handover functions for itself as well as its associated MSs. As a result, the full function mobile RS must be able to initiate and execute a handover procedures while maintaining its MS connections.

(a) Examples of intra-MMR-cell handover of MS connected to fixed/portable RS



(b) Examples of inter-MMR-cell handover of MS connected to fixed/portable RS.



(c) Examples of mobile RS roaming within the MMR-cell and the inter-MMR-cell handover of the RS and its associated MS to the next MMR cell.

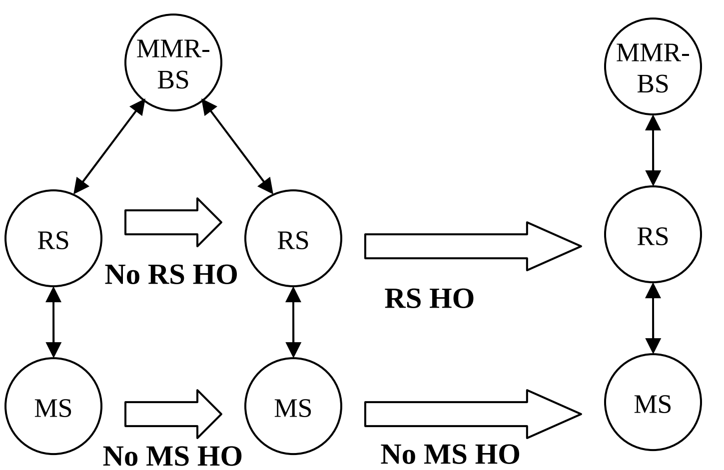


Figure 2 Handover scenarios in MMR deployments.

4.4 Military Relay Station

This section is left for further study.

5 RS Usage in Commercial Deployments

5.1 Usage Models

Usage models are used to describe the different reasons that a carrier may deploy RSs. The key reasons that a carrier might deploy RSs are:

- Enhanced Data Rate Coverage– Provide higher uniform SINR to users within the cell. This can also be thought of as providing higher throughput to individual MSs within the entire cell.
- Range Extension – Provide coverage to users outside the edge of the cell.
- Capacity Enhancement – increase system capacity by deploying RSs in a pico-cell deployment enabling more aggressive frequency reuse.

In general a carrier will not deploy RSs strictly to provide Enhanced Data Rate Coverage, Range Extension, or Capacity Enhancement alone. The three are not mutually exclusive and real life deployments will use RSs to provide some combination all of these three models. Furthermore, the capacity needs of a network are likely to increase as the network matures, so although deployments may start out providing Enhanced Data Rate Coverage and/or Range Extension without providing capacity beyond a traditional 802.16e cellular deployment, deployments will need to scale to provide Capacity Enhancement as the network evolves.

In the subsections that follow we describe three models, the Enhanced Data Rate Coverage model, the Range Extension model and the Capacity Enhancement model. The Enhanced Data Rate Coverage and Range Extension models are very similar. They represent one end of the continuum of potential deployment models, while the Capacity Enhancement model represents the other end.

5.1.1 Enhanced Data Rate Coverage Model

5.1.1.1 Overview

In this model we assume that system capacity is not an issue. Frequency reuse within the MMR cell is not required and the reason for deploying RSs is to provide more higher SINR coverage to users within the MMR cell.

Figure 3 illustrates the relative SINR level as a function of the distance from the center of the MMR cell. In this usage model RSs are deployed to:

- Provide higher SINR access to MSs at edge of MMR-BS cell (in the medium and low SINR rings in the figure).
- Provide higher SINR access to MSs in a “coverage hole” that exists due to shadowing. In the figure these holes might exist in any of the rings.

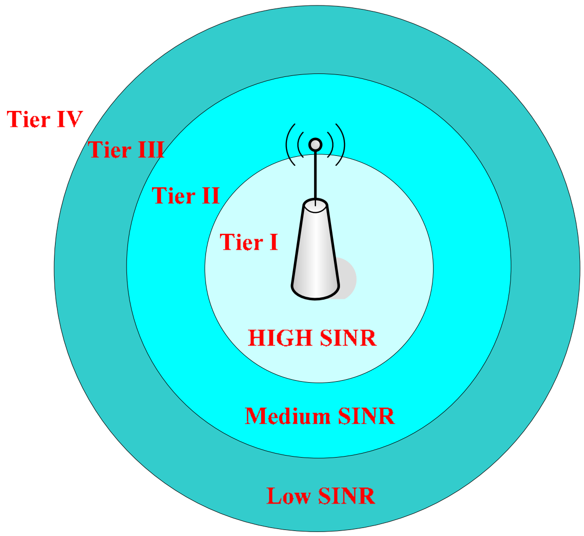


Figure 3 SINR Levels in an MMR cell

5.1.1.2 Topology

Figure 4 shows the basic topology of this usage model. An MMR-BS is deployed at the center of the MMR cell. The area in which the MMR-BS accesses MSs directly is shown in green. A number of RSs are deployed within the MMR cell. Their coverage area is shown in white. The MMR cell is the coverage area of the MMR-BS and all of its associated RSs and is represented by the combination of the green and white areas in the figure. The RSs are deployed in order to provide higher SINR at the cell edge or to provide access in coverage holes within the perimeter of the MMR-BS cell. Coverage holes can exist in the shadows of large buildings or in tunnels that run through the MMR cell.

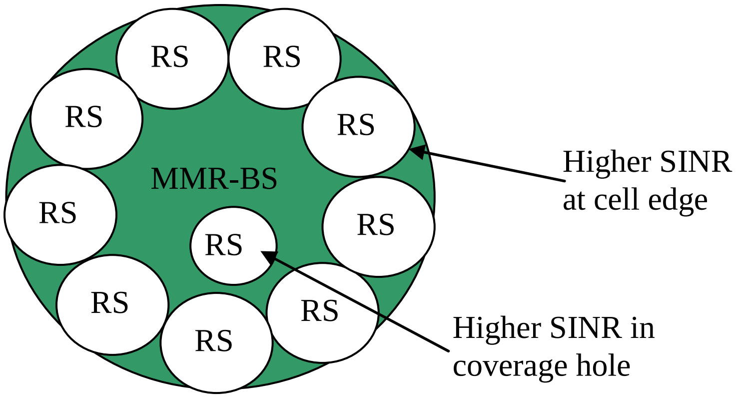


Figure 4 Enhanced Data Rate Coverage Topology

In general the maximum number of hops between the MMR-BS and an MS will be two in this usage model, but the number of hops can be larger than two in the case of shadowing in a valley between two buildings, or in a tunnel.

Fault tolerance can be provided by overlapping the coverage areas of the RS cells. Because system capacity is not an issue, the number of RSs in the cell is not limited by the capacity of the MMR links, or the ability of the MMR-BS to aggregate traffic.

5.1.1.3 Frequency Usage

Capacity is not an issue in this scenario. If SINR is limited due to low signal power, then the access links and MMR links can share an OFDMA channel, although separate channels (on different frequencies) can also be used in order to simplify the scheduling of traffic on MMR links and access links. The entire MMR cell can share a channel, the MMR cell can be sectorized and RSs within each sector can share channel, or different RSs can operate on different channels. If SINR is limited due to interference, separate channels might be required or alternatively time division strategies will be required to co-ordinate transmission and reduce interference.

Uplink and downlink channels can be either TDD or FDD.

5.1.1.4 Implementation by Different RS Types

The Enhanced Data Rate Coverage Model can be implemented using any of the RS types described above. Because capacity is not an issue, the Simple RS can be used, with multiple (or all) RSs in the MMR cell sharing an OFDMA channel. When Simple RSs are used, the MMR-BS controls the entire MMR cell. The problem of scheduling, routing, frequency assignment, interference management, and other control functions are fairly simple because the number of frequencies and hop counts are limited.

Full Function RSs can also be used to implement Enhanced Data Rate Coverage. Different channels (on different frequencies) can be deployed for the access and MMR links, making scheduling simpler. On the other hand, some degree of frequency sharing may be desirable for improved trunking efficiency, however this increases scheduler complexity.

5.1.2 Range Extension Model

5.1.2.1 Overview

In this model we also assume that system capacity is not an issue. Frequency reuse within the MMR cell is not required and the reason for deploying RSs is to provide coverage to clusters of users that are outside of the perimeter of the MMR-BS cell. In Figure 3 these are users that fall outside the “Low SINR” ring, where SINR is limited in this scenario due to low received signal power.

5.1.2.2 Topology

Figure 5 shows the basic topology in this usage model. An MMR-BS is deployed at the center of the MMR cell. The area in which the MMR-BS accesses MSs directly is shown in green. RSs are deployed outside of the green area to extend coverage beyond its perimeter. Their coverage area is shown in white. The MMR cell is the coverage area of the MMR-BS and all of its associated RSs and is represented by the combination of the green and white areas in the figure. The RSs are deployed in order to provide coverage to clusters of users that are beyond the potential coverage area of the MMR-BS. Such clusters of users can exist outside the edge of a cell in suburban environments.

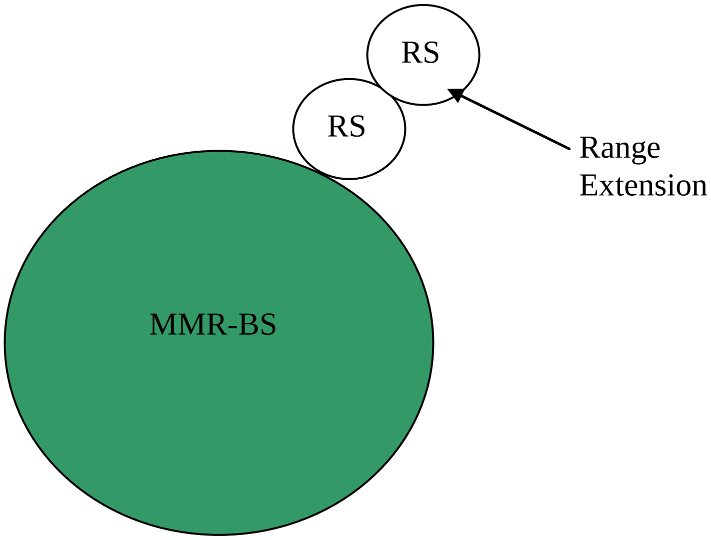


Figure 5 Range Extension Topology

The topology in this model is potentially many hops. The number of hops is limited mainly by the latency incurred by packets traversing the network.

Fault tolerance is possible when external clusters of users are served by overlapping RS cells. Because system capacity is not an issue, the number of RSs in the MMR cell is not limited by the capacity of the MMR links or the ability of the MMR-BS to aggregate traffic.

5.1.2.3 Frequency Usage

Frequency usage is the same as in the Enhanced Data Rate Coverage model.

5.1.2.4 Implementation by Different RS Types

Implementation by different RS types is the same as in the Enhanced Data Rate Coverage model.

5.1.3 Capacity Enhancement Model

5.1.3.1 Overview

The capacity enhancement model is employed in order to provide high system capacity by allowing aggressive frequency reuse within the MMR cell and improvement in SINR, where the SINR is limited due to interference and not lack of signal power.

5.1.3.2 Topology

In this usage model, RSs are deployed in order to increase capacity to high load regions within the MMR cell. RSs can be deployed individually or in clusters depending on capacity needs.Figure 6 illustrates one possible topology of a high capacity MMR cell. In this example, the load is assumed to be equal in all areas of the cell. The MMR-BS is deployed at the center of the MMR cell, and RSs are deployed around it. Each hexagon represents the area within which the MMR-BS or RS provides access to MSs. In this example, the coverage areas of the RS cells and the MMR-BS cell are the same. Even though the MMR-BS provides access to MSs only within the orange hexagon, the MMR-BS and RSs are able to communicate via MMR-links between them. The MMR cell consists of all of the coverage areas of the RSs and MMR-BS (the area of all of the hexagons in the figure).

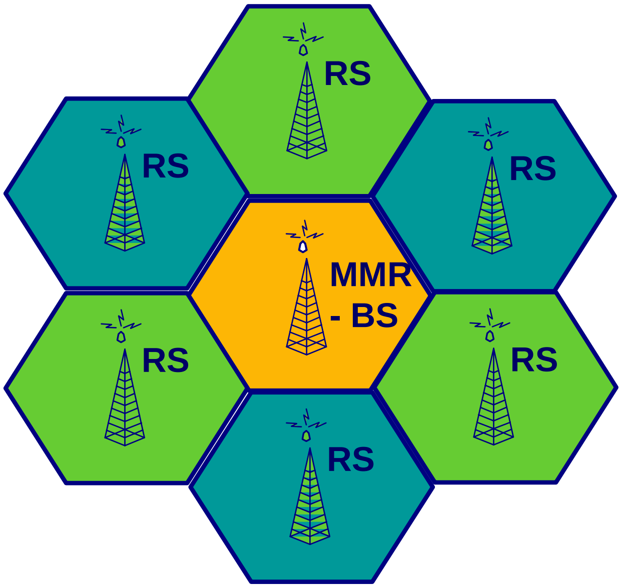


Figure 6 Pico-cell Capacity Enhancement Topology

Figure 7 illustrates another example topology deployed in a Manhattan-like environment. In this topology, the MMR-BSs and RSs are deployed on street corners with antennas mounted below the roofline of the surrounding buildings. RSs provide coverage and throughput enhancement to those users who are in heavily shadowed areas within an MMR-cell. In addition, the MMR-cell capacity can be increased by exploiting spatial multiplexing gain among non-overlapped shadowed areas.

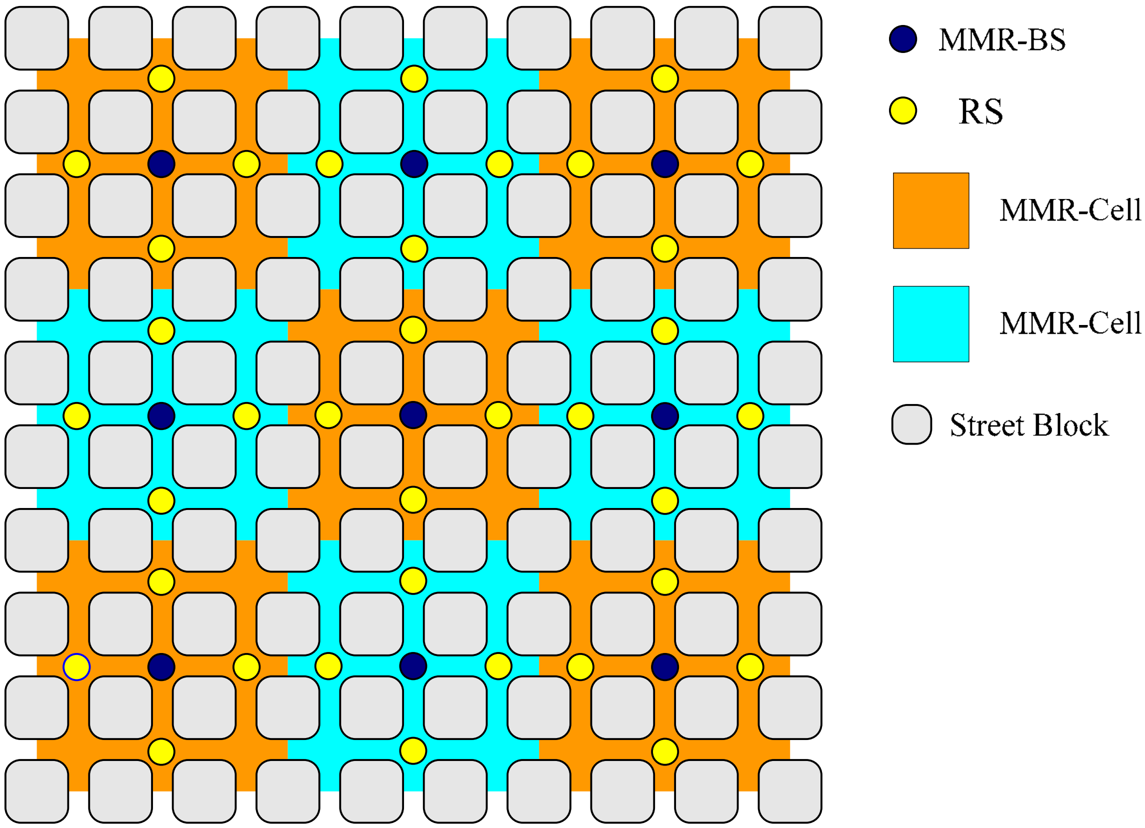


Figure 7 Manhattan-environment Capacity Enhancement Topology

The maximum number of hops in this usage model is 2 or more. The number of RSs in an MMR cell is limited by the capacity of the MMR links, the ability of the MMR-BS to aggregate traffic, and the throughput of the wired backhaul connecting the MMR-BS to the core network.

Since the range of RSs often extend into neighboring RS cells, fault tolerance can be provided by using multi-hop topologies,

5.1.3.3 Frequency Usage

In the high capacity model, frequency reuse is designed to maximize total throughput in the MMR cell. Aggressive frequency reuse increases system capacity. However, increased frequency reuse can also increase interference, which decreases throughput. To some extent the interference can be actively managed by the MMR-BS by controlling when and where transmissions on the same frequency occur within the cell. Cross-cell coordination between MMR-BSs can also take place in order to manage cell-edge interference caused by two neighbouring cell-edge RS's. These factors must be considered in order to determine the optimal frequency reuse strategy.

In Figure 6 the color within each hexagon indicates the frequency of the OFDMA channel on which the access link within that cell operates. As an example, we have used a 1x1x3 frequency reuse pattern (1 cell, 1 sector per cell, 3 frequencies), but any standard frequency pattern (e.g., 1x3x3 can be used). Multi-sector RSs and MMR-BSs can be deployed to allow sectorized deployments.

The MMR links in the MMR cell either share the access channels or operate on separate channels. Frequency reuse will be required in order to match the capacity of the access links. Techniques to achieve high spectral efficiency in the MMR links will be required in order to aggregate the traffic from each RS cell to the MMR-BS without requiring double the number of channels.

In Figure 7, the MMR-link can also share the access-link channels or operate on separate ones. In the case of both MMR and access links sharing the same channelss, a frequency reuse of factor two can be easily obtained by using different frequencies in differently colored MMR-cells as shown in Figure 7, thanks to the spatial isolation provided by buildings. By using directional antennas, frequency reuse of factor one (universal frequency reuse) is also possible.

If the access and MMR links share frequencies, they must implement the same duplexing method. Otherwise, they can be chosen independently.

5.1.3.4 Implementation by Different RS Types

The Capacity Enhancement model can be implemented using both Simple RS and Fully Functional RS types. Simple RSs can be used if the number of RSs within an MMR cell is kept small (allowing centralized control) and different frequencies are assigned to different RSs (both their access link and MMR link) in order to reuse frequencies to provide the required capacity.

Full Function RSs can be used in larger MMR cells (more RSs). In this case, the MMR-BS need not perform all control functions. More complex topologies can be deployed in order to provide greater opportunities for load balancing and fault tolerance.

5.2 Deployment Strategies

In 802.16j networks, access links are generally NLOS. However, MMR links can be either LOS / near LOS or NLOS depending on the manner in which RSs are deployed. There are two strategies that can be used to deploy 802.16j networks. RSs can be deployed in order to ensure the MMR links are LOS / near LOS. This requires careful planning of RS locations and antenna height/location. On the other hand, RSs can be deployed assuming that MMR links will be NLOS. This relaxes the restrictions on RS and RS antenna placement.

As with the usage models, these two strategies are not mutually exclusive and a network may utilize both strategies in different MMR cells or even within an MMR cell. In the following subsections we describe the two strategies in more detail.

5.2.1 Line of Sight Deployment Strategy – Fixed RSs

This deployment strategy is used to build out fixed networks. It can be used by carriers with existing cell sites (converting BSs to RSs) or by carriers building out new networks (acquiring and developing new cell sites). This strategy can also be used to place portable RSs, but it may not be possible to place a portable RS in a manner that provides an LOS link to another RS or to the MMR-BS.

5.2.1.1 RS Deployment Characteristics

- Relay station locations are carefully planned to provide LOS or near LOS links between MMR-BS and RS or between RSs.

- Antennas are mounted on towers or tall buildings
- Relay stations are mostly fixed. Portable RSs may be employed to support temporary events such as concerts or trade shows, but their location and the location of their antennas needs to be carefully planned, making them very similar to fixed RSs. Mobile RSs are not supported in this strategy.

5.2.1.2 MMR-BS Deployment Characteristics

The location of MMR-BS is carefully planned to provide LOS links between MMR-BS and RS. MMR-BS antennas are deployed on towers.

5.2.1.3 Channel Characteristics

MMR link is LOS or Ricean.

5.2.2 Non-Line of Sight Deployment Strategy – Fixed and Portable RSs

This deployment strategy can be used in building out a network or in deploying portable RSs to temporary locations to provide temporary coverage and/or capacity at an event or at a location where coverage/capacity needs to be quickly improved.

5.2.2.1 RS Deployment Characteristics

- Relay station locations may or may not be planned carefully. Links between MMR-BS and RS and between RSs are NLOS
- Antennas are mounted on towers, buildings, light poles or elsewhere
- Relay stations are fixed or portable/nomadic.

5.2.2.2 MMR-BS Characteristics

Placement requirements for the MMR-BS and its antenna may not be as strict as when using the LOS deployment strategy

5.2.2.3 Channel Characteristics

MMR link is NLOS.

5.2.3 Mobile RS Deployment Strategy

5.2.3.1 Mobile RS Deployment Characteristics

When relay stations are mobile, their locations cannot be planned. Mobile RSs will most likely exist on vehicles such as buses or trains, so antennas will be mounted on the top or side of the vehicle.

5.2.3.2 MMR-BS Characteristics

Placement requirements for the MMR-BS and its antenna may not be as strict as when using the LOS deployment strategy

5.2.3.3 Channel Characteristics

NLOS for both MMR link and access link.

5.3 Traffic Characteristics

5.3.1 Traffic Flow Model

Traffic flow can be between MSs within the MMR cell or between MSs and the network beyond the MMR cell. The percentage of each depends on subscriber behavior patterns within the deployment environment.

5.3.2 Traffic Load

The types of services relayed by a particular RS are determined by the serving MMR-BS after considering QoS policy for each service flow according to the QoS policy determined by the operator. An MS may have different paths to deliver traffic to MMR-BS and to receive traffic from MMR-BS. For example, the UGS service flow of an MS may be assigned and transmitted to/received from MMR-BS directly, and the BE service flow could be assigned and relayed by one RS. Moreover, two different BE service flows of MS may individually pass through two different RSs which are connected to the same MMR-BS.

The following types of applications are expected to generate traffic:

- Web browsing
- VoIP
- Gaming
- SMS/MMS chat
- Multi-media (e.g. video streaming, music downloads)
- Push-to-Talk/Push-to-View/etc., or in general, Push-to-X
- Video-chat
- Video conferencing
- Video on Demand
- Broadcast TV
- Picture uploading
- MP3/iTune playing
- iRadio
- Content synchronization (e.g., iTune sync)

5.4 Security Considerations

- **Authentication**
  - The authentication between MS and MMR-BS is mandatory.
  - The authentication between RS and MMR-BS is mandatory.
  - The authentication between MS and RS is optional. However, authentication of the MS by the MMR-BS is mandatory in this case.
  - The RS may play the role of authenticator between supplicant MS and the authentication server.

- **Privacy**

- There are two encryption models, namely link-based encryption model and path-based encryption model.
- With link-based encryption model, MPDUs between MMR-BS and MS are selectively encrypted and decrypted at RSs.
- With path-based encryption model, MPDUs between MMR-BS and MS are encrypted and decrypted only at MMR-BS and MS. That is, RS is transparent to the encrypted MPDUs between MMR-BS and MS.

5.5 Management Considerations

- The RS is managed by the MMR-BS with which it is associated.
- Management messages destined for an MS which is served by a Simple RS, are issued from the MMR-BS.
- Management messages destined for an MS which is served by a Full Function RS, are either issued from the MMR-BS or from the serving RS.
- Management messages are not processed by a Simple RS. They are only relayed to the MS for which they are destined.
- The Full Function RS and Mobile RS could be required to process those management messages issued from serving MMR-BS to an MS.

6 Public Safety / Disaster Recovery Deployment Usage Model

6.1.1 Overview

A network is pieced together from existing operational MMR-BSs and fixed RSs, and portable and mobile RSs (vehicle mounted). Portable RSs are driven to the required locations and are stationary while they provide access and relay services. Mobile RSs are operational while the vehicle is in motion.

This section is left for further study.

7 Military Deployment Usage Model

This section is left for further study.

8 References

[1] R. Peterson et. al. “Definition of terminology used in Mobile Multihop Relay” IEEE Contributed Documents of 802.16 Relay Task Group, IEEE C80216j-06_019, May 1, 2006.