Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Harmonized Contribution on 802.16j (Mobile Multihop Relay) Usage Models**
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Re:	Submitted in response to motion passed in 802.16j TG meeting in Tel Aviv to from Ad Hoc Group tasked with producing a harmonized contribution on 802.16j Usage Models.
Abstract	This contribution describes Usage models for 802.16j.
Purpose	This contribution is the output of the Ad Hoc Group on 802.16j Usage Models. It contains harmonized text on 802.16j usage models agreed to by the Ad Hoc Group. This document is provided as input for the 802.16j TG and is proposed as the baseline for the 802.16j Usage Models document.
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802.16j (Mobile Multihop Relay) Usage Models

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2 Table of Contents

3 Introduction

This document captures the usage models for the 802.16j project. This document is intended to be used as a guideline for drafting the amendments to the standard. The purpose of usage models is to define different deployment scenarios (e.g., fixed, nomadic, mobile) to characterize requirements for the network elements (e.g., RSs) and functional entities to improve system performance (e.g., extending coverage, increasing throughput).

4 Usage Models

In this section we describe the major usage models that are envisaged for 802.16j systems. The usage models are categorized from the perspective of the infrastructure, specifically according to where coverage is being provided. The usage models differ in terms of the manner in which RSs are deployed and the types of services or performance goals that are trying to be achieved. From the perspective of an MS, the coverage provided within the different usage models is the same. As an MS moves within a network, it may encounter different usage models and may move from one usage model to another. For example, an MS can move from coverage provided inside a building by an RS deployed to provide coverage in that building, to the outdoors where it is covered by a fixed RS deployed at a nearby cell site, to a train, where coverage is provided by an RS mounted on the train to provide coverage to users riding on that train.

Although the usage models described in this document are primarily based on commercial deployments, we have also captured some of the potential military usage scenarios in order to identify the areas in which military can benefit from commercial standardization. It is recognized that military usage will place specialized requirements on aspects of the system such as security and ability to tolerate jamming. The inclusion of military usage models in this document is not intended to imply that the 802.16j standard should support these specialized military requirements.

4.1 Fixed Infrastructure Usage Model

In this usage model a service provider deploys RSs and MMR-BSs within their network to improve coverage, capacity or per user throughput in areas which are not sufficiently covered in the MMR-BS cell or to extend coverage to areas that are beyond the boundaries of the MMR-BS coverage area. Fixed relay stations that are owned by the infrastructure provider are utilized in this model. RSs can range from simple to complex. They can be mounted on towers, poles, tops or sides of buildings, lamp posts, or in other locations. The provider can plan the locations of RS antennas to obtain LOS channels between the MMR-BS and RSs, but this will not always be practical, so NLOS channel conditions on links between MMR-BS and RSs can be expected. Another potential deployment strategy is to collocate small, simple RSs with stationary client devices mounted on rooftops or within buildings. Stationary client system examples include not just private and business stationary systems, but also hot-spots owned by utilities, municipalities, and others. In general, RSs will enter the network when they are deployed and remain in the network under the management of the infrastructure provider. In the case of RSs collocated with stationary client devices, RSs may enter and leave the network unexpectedly based on the actions of the clients that own them. Topologies can include communication paths that range from 2 hops to multiple hops. Redundant routes are possible and can be utilized to provide fault tolerance and to balance the traffic load.

In some environments such as those encountered within military use case scenarios, the RS site may be pre-planned and carefully designed to provide enhanced connectivity and capacity to MS/SS users. Antenna heights may be significantly less than commercial deployments, such as cell towers or high rises due to operational safety concerns, area of operation, and amount of infrastructure available. Redundant routes are often used to provide fault tolerance and to balance the traffic load.

Figure 1 illustrates some of the use cases that appear in this usage model. These include deployment of RSs to provide coverage extension at the edge of the cell, to provide coverage for indoor locations, to provide coverage for users in coverage holes that exist due to shadowing and in valleys between buildings, and to provide access for clusters of users outside the coverage area of the BS.

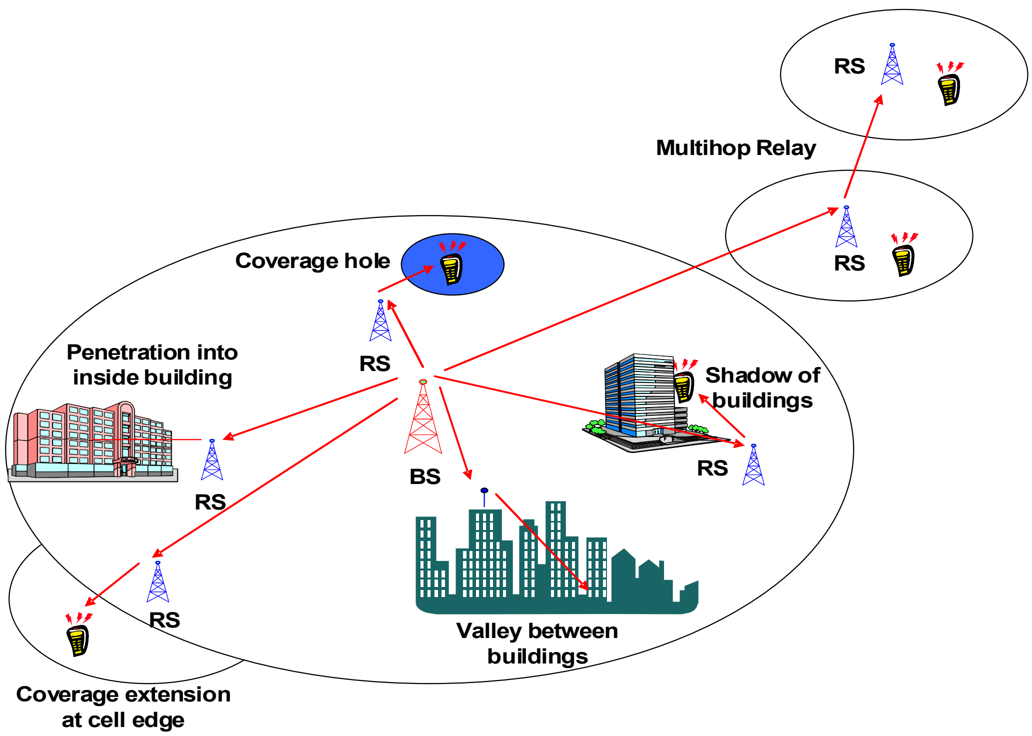

Figure 1 Example Use Cases from the Fixed Infrastructure Usage Model

4.2 In-Building Coverage Usage Model

In this usage model RSs are deployed to provide better coverage and higher throughput in a building, tunnel or underground such as on a subway platform. There can be one RS that services a small building, tunnel or underground location, or multiple RSs that service a larger building, tunnel or underground location. The RSs can be owned by the infrastructure provider or by the customer and will generally need to be simple and low cost. They can be fixed or nomadic. Channel conditions between the MMR-BS and RSs will generally be NLOS, but it is possible that the RS has one or more antennas mounted to the exterior of the building to provide the link between it and the upstream RS or MMR-BS and one or more antennas mounted inside the building to provide coverage to downstream RSs and MSs.. In this usage model RSs owned by the infrastructure provider will enter the network when they are deployed and remain in the network under the management of the infrastructure provider, while client owned RSs may enter and exit the network unexpectedly based on the actions of the clients that own them. Topologies can include communication paths that range from 2 hops to multiple hops. Redundant routes are possible and can be utilized to provide fault tolerance and to balance the traffic load. The RS may be deployed inside the building, or outside. RSs will generally be connected to a power source, but may need to operate under battery power.

Figure 2 illustrates some examples of in-building coverage. In the upper half of the figure is an example of a nomadic RS that is placed in a location in which it receives a sufficient signal to the MMR-BS or to another RS. The nomadic RS then provides access to subscribers within the room or building. In the lower half of the figure is pictured the case where a number of RSs are deployed within a larger building such as a multi-tenant dwelling or office building. Data is relayed among the RSs in the building and out to an RS or MMR-BS outside the building.

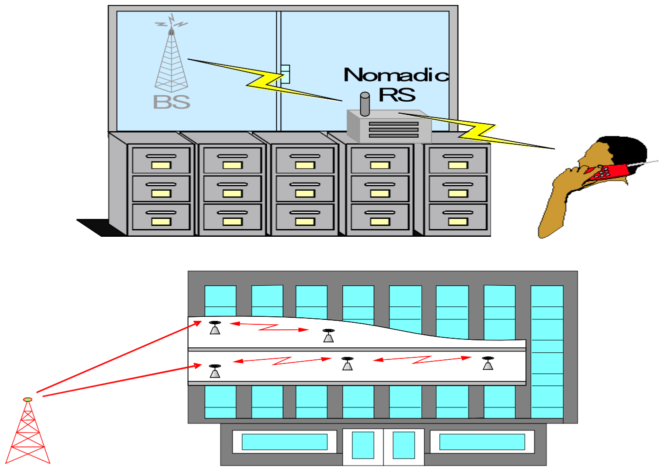

Figure 2 Examples of In-building Coverage Usage Model

4.3 Temporary Coverage Usage Model

In this usage model nomadic RSs are deployed temporarily to provide additional coverage or capacity in an area where the MMR-BS and fixed RSs do not provide sufficient coverage or capacity. RSs deployed in this usage model can range from small and simple to large and complex. In this usage model RSs will enter the network when they are deployed and will exit the network when the temporary situation for which they were deployed has ended. Topologies can include communication paths that range from 2 hops to multiple hops. LOS or NLOS channel conditions can be expected between MMR-BS and RSs. RSs will generally be connected to a power source, but may need to operate under battery power.

Some examples of the situations in which temporary coverage is required are:

Emergency / Disaster Recovery – In this case parts of the fixed infrastructure may have been destroyed or coverage is required in areas that are not serviced by fixed infrastructure deployments.

Temporary Coverage for Event – In this case an event such as a sporting event or fair requires that coverage be provided for the duration of the event.

In some environments such as those encountered within military scenarios, RS sites can be pre-planned to some extent, but may have to be placed in an arbitrary manner due to unanticipated environmental anomalies or deployment dynamics. Typically, antenna heights are relatively low, such as vehicle-mounted masts; one purpose being quick deployment and fast tear-down. RS in this configuration may have some limitations in size, weight, and power to minimize the amount of support equipment and infrastructure necessary to allow proper functionality of RS.

The detailed usage scenarios in this model are similar to those of the fixed infrastructure usage model in that RSs are deployed to provide coverage, range extension, and/or capacity. Some examples of this usage model are illustrated in Figure 3.

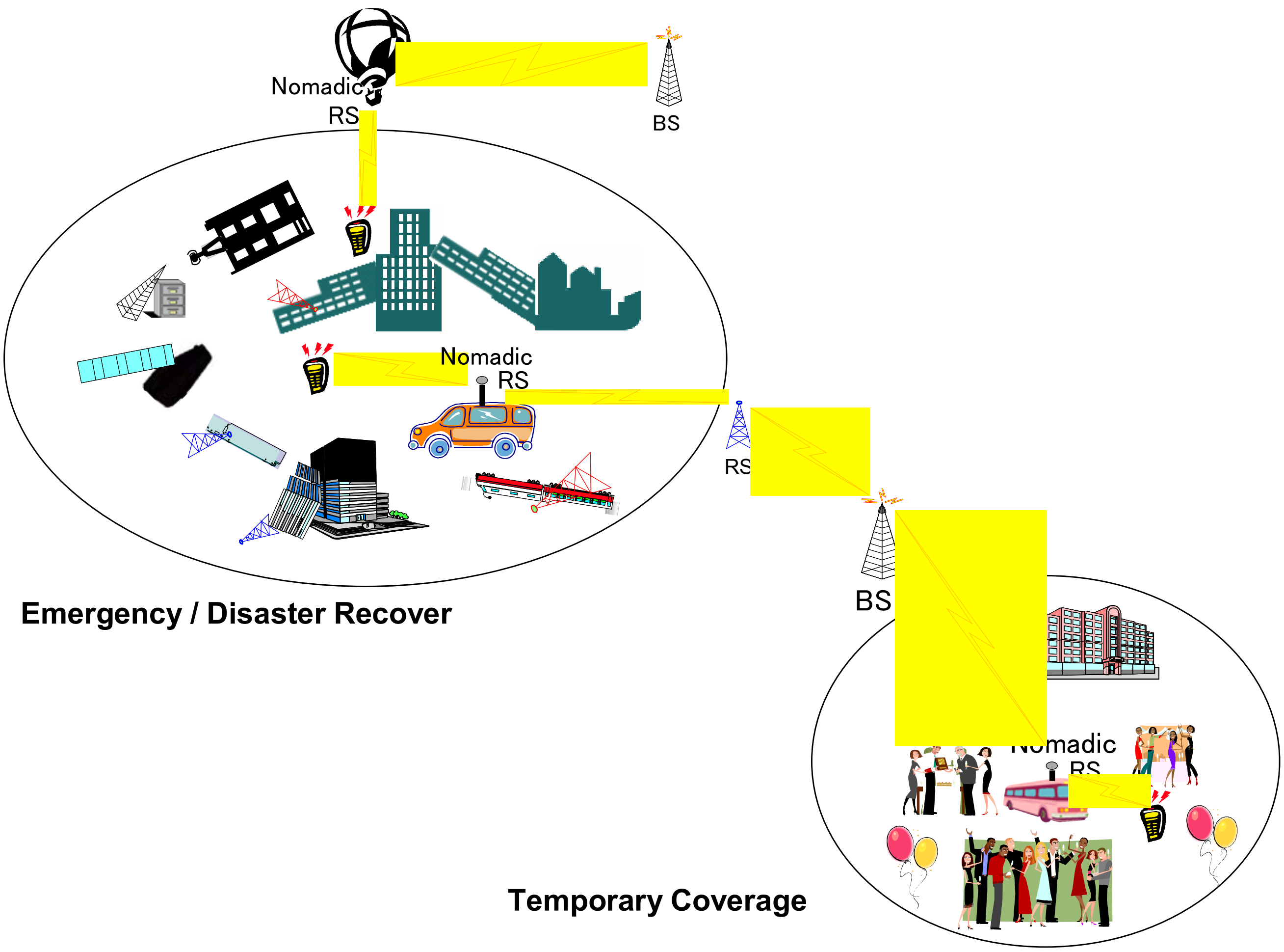

Figure 3 Examples of Temporary Coverage

4.4 Coverage On Mobile Vehicle Usage Model

In this usage model coverage is provided for MS/SS devices which are traveling together on a mobile vehicle, such as a bus or a train. A mobile RS is mounted on the vehicle and it connects to an MMR-BS or RS via a mobile link. The RS provides a fixed access link to MS/SS devices riding on the platform. RSs deployed in this usage model are expected to be complex. In this usage model RSs may enter and exit the network when the vehicle enters or exits the coverage area of the network. They may also enter the network when the vehicle is put into service (for example for the first train in the morning) and exit the network when the vehicle is taken out of service (for example after the last train in the evening). In this model, topologies may include communication paths that traverse 2 or more hops. An example of a multihop topology is the case where the train travels through a tunnel and the mobile RS onboard the train connects to RSs that are deployed along the tunnel. Examples of mobile vehicles are:

Trains
Buses
Ferries (local commuter boats/ships)

In this usage model it is expected that a mobile RS can provide service directly to a number of MSs that are riding on the vehicle, or via one or more additional RSs that are also located on the vehicle (as in the case of a long train). In this case the other RSs are mobile in the sense that they are moving on the vehicle, but they are fixed relative to each other.

In some environments such as those encountered within military scenarios, RS topology will be dynamic to support mobile force utilizing MSs. Antenna heights would be significantly lower compared to Fixed and Nomadic deployments due to vehicular restrictions, visual signature, and operational safety concerns. Mobile deployment of RS's in this configuration may have severe size, weight, and power limitations. Under the On-The-Move (OTM) operation, RSs are used to extend the range of a BS and move along with the MSs. However, MSs and RS do not need to be on the same platform. In this case the relative speed of the stations does not exceed the maximum speed supported in the 802.16e-2005 standard. In these scenarios, RS may need to coordinate with other RSs to provide better service to the MSs. Mobile RSs may need to communicate while in motion. Mobile nodes comprise of similar platforms (i.e. vehicles) used within commercial applications with the addition of low-flying air vehicles and backpack mounted nodes. In these scenarios a station may be able to operate as either a BS or RS and may need to switch roles in response to conditions in the field such as an RS losing connectivity to its upstream RS or MMR-BS.

Figure 4 illustrates some examples of coverage on a mobile vehicle. In the upper part of the figure is illustrated the case where a mobile RS is mounted in a bus and provides coverage for MSs riding on the bus. The RS on the bus may connect to the MMR-BS or may connect to an RS, as is shown on the right, where the bus is traveling along an urban street in the valley created by tall buildings. In the middle part of the figure is illustrated the case where the RS is mounted on a train. In this case as well, the RS may connect to the MMR-BS directly or may connect via one or more RSs as in the case where the train is traveling through a tunnel in which coverage is provided by a series of RSs. The lower part of the figure illustrates coverage on a ferry.

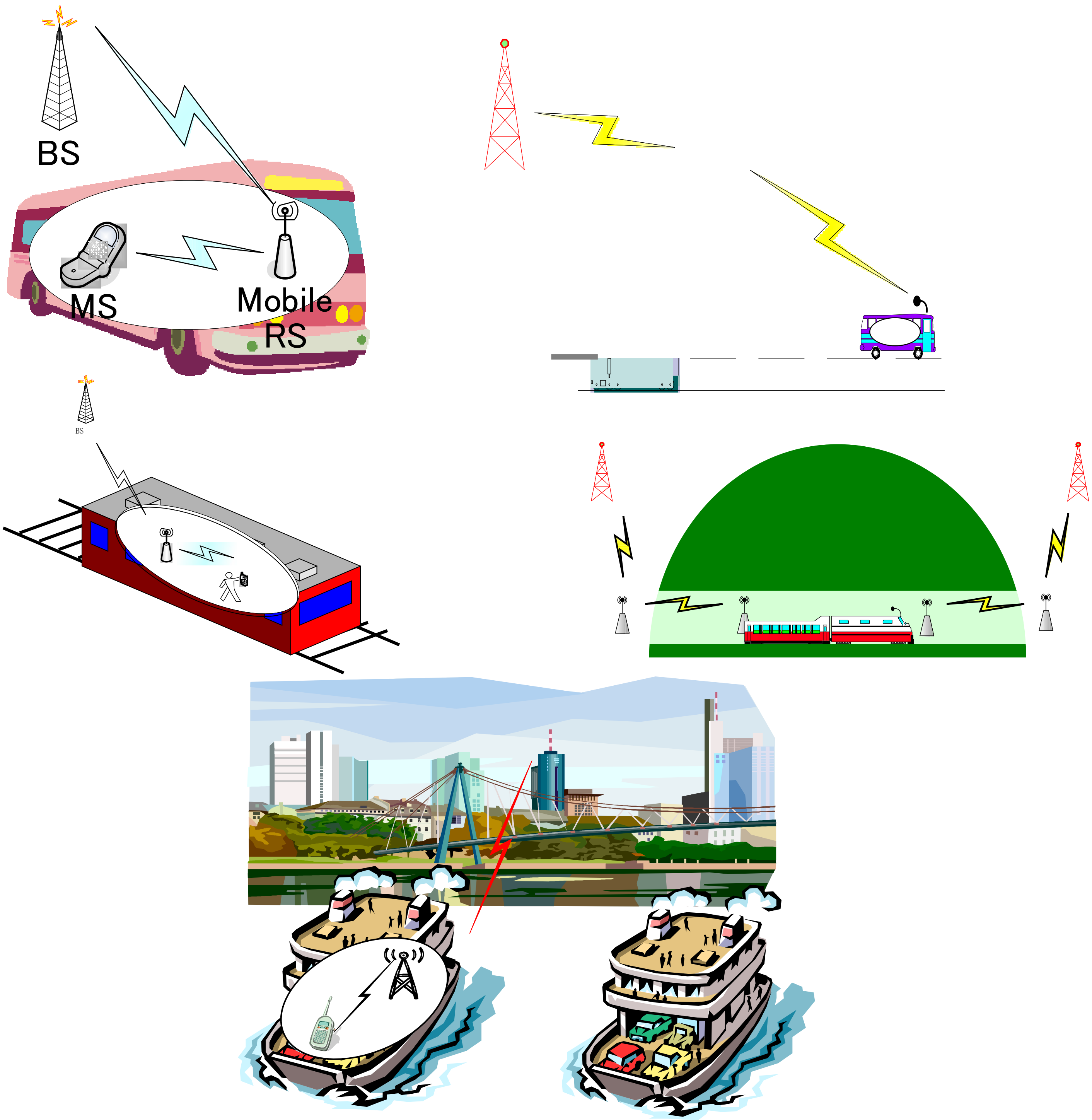

Figure 4 Examples of Coverage on Mobile Vehicle

5 Performance Objectives

The performance objectives of all 802.16j networks are a superset of those for 802.16e networks. A given deployment is provisioned to provide a given level of service to a give number of users over a given coverage area. This goal applies to all of the usage models described in section 3. In the Fixed Infrastructure Usage Model, MMR-BSs and RSs are deployed to provide coverage at a given level of service within the service area of the network operator. The specific coverage goals, service levels, and capacity needs will vary from deployment to deployment. In the In-Building Coverage Usage Model RSs are deployed to provide coverage and the required amount of capacity within a building. In the Temporary Coverage Usage Model, RSs are deployed to provide a given amount of capacity or coverage in an area where there is a temporary need for service. Finally, in the Coverage on Mobile Vehicle Usage Model, RSs provide coverage onboard the mobile vehicle at some desired capacity. RS may also be used to increase the reliability of a network for example by increasing the typical SINR for a link, or providing different forms of antenna or routing diversity.

The following subsections describe some of the ways in which RSs can be used to achieve these performance objectives.

5.1 Per-User Throughput and/or Capacity and/or Reliability Enhancement

There are two major ways in which 802.16j deployments can increase per-user throughput, system capacity, and reliability. First, RSs can be deployed in order to provide higher SINR to users at the edge of the cell. A single low SINR link is replaced with multiple higher SINR links over which higher order modulation and code rates can be supported. The resulting increase in spectral efficiency produces a capacity increase (part of which is used to transmit data over multiple hops). This additional capacity can be used to provide higher throughput to individual MSs or to support more users within the coverage area of the RS. In addition the increased SINR may be used to improve link reliability.

Second, RSs and MMR-BSs can be deployed in a dense topology (small cells) to improve the capacity within areas covered by the RSs. The density of RS nodes may also permit increased routing diversity. For example, traffic from a given MS can be routed so as to avoid a congested RS to RS link or conserve power at a particular node. These may be of particular use in military versions of the usage models.

5.2 Coverage and/or Range Extension

There are several different situations in which MMR-BS and RSs can be used to expand the coverage area of the network. First, RSs can be deployed to provide coverage to users in a coverage hole. RSs are deployed to provide coverage and enhanced throughput to MSs in areas that are in the shadow of a building of other obstruction. The RSs may be deployed in specific locations in a dense urban environment to provide coverage in the valleys between tall buildings.

The second example of coverage extension is provision of coverage in isolated areas that are outside the reach of any BS. In this case RSs are deployed to provide coverage to clusters of MSs that are beyond the perimeter of the MMR-BS coverage area.

The third example of coverage extension is extending coverage to MS riding on mobile vehicles (e.g buses and trains) operating between buildings in a dense urban environment or in tunnels.

A fourth example is the deployment of mobile RSs to provide coverage in an area not directly served by a BS. Mobile RSs are used in this case because the coverage area is adapted based on the movements of the MSs for which coverage is provided. This example may appear in military usage scenarios.

6 Topology

The following figure illustrates the types of topological constructs that are possible in the usage models described in section 4. In the figure RS refers to either a fixed, nomadic, or mobile RS.

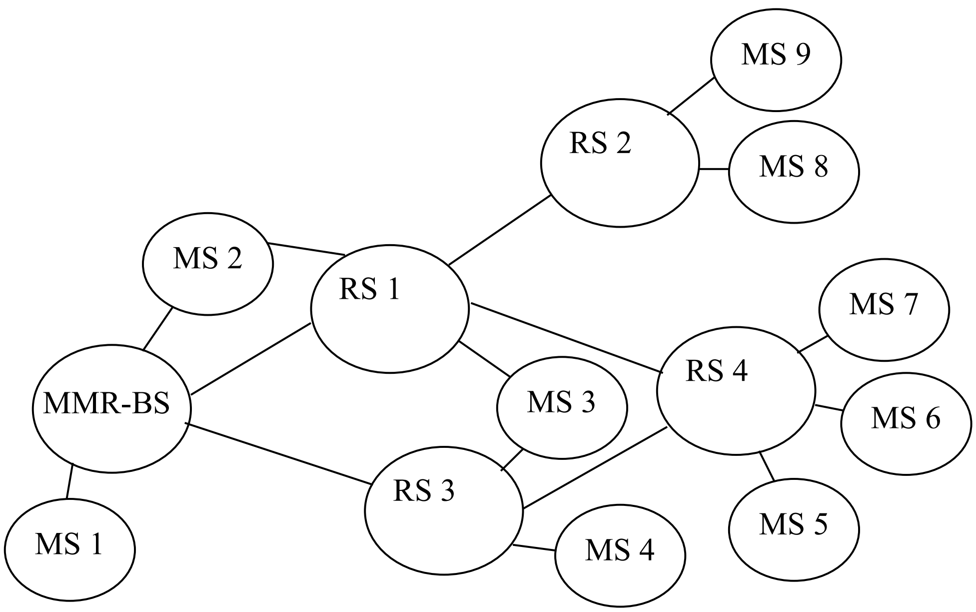

Figure 5 Topological Constructs

6.1 Supported Link Types

The topologies associated with the usage models described in section 4 include the following types of links as illustrated in Figure 5:

MMR-BS to MS – The MMR-BS can associate with multiple MSs
RS to MS – RSs can associate with multiple MSs
MMR-BS to RS – The MMR-BS can associate with multiple RSs.
RS to RS– RSs can associate with multiple RSs.

6.2 Number of Hops

It is expected that in most deployments the majority of routes will be 1 or 2 hops in length. However, routes that are greater than 2 hops in length will exist in all usage models. Some examples are multihop routes to provide coverage to a remote cluster of users, multihop routes to provide access to users in a tunnel, and multihop routes to provide coverage to an area in the shadow of a large building or other obstruction.

6.3 Types of Routes

[Editor's note: The Ad Hoc group was not able to reach consensus on the first sentence in this section (shown in red). Some of the arguments made for removal of this sentence were:

> *The sentence unnecessarily restricts the scope of the project beyond what is stated in the PAR scope. We should not narrow the scope in the usage model document.*
> *There are usage models which call for communication from MS to RS to MS. This usage appears in the military usage scenarios and also can provide more efficient communications in commercial scenarios when MSs connected to the same RS wish to communicate.*

Some of the arguments made for inclusion of the sentence were

> *Allowing MS->RS->MS communications violates the project scope as it makes this a mesh*
> *Allowing MS->RS->MS communications violates the project scope because it requires changes to the MS (is not backwards compatible) because it requires connections (CIDs) between the MS and another MS or between the MS and an RS.*
> *There is only one usage case in which this type of communication is identified (the military usage case).*

TG members are encouraged to comment on this sentence and the Ad Hoc recommends that the TG take up the resolution of this issue.]

In all of the usage models described in section 4, all data communications occur between the MMR-BS and MSs through zero or more RSs.

Downlink and uplink communications between the MMR-BS and MS can occur via either symmetric routes (the same route for DL and UL communications) or via asymmetric routes (different routes for the DL and UL). Some reasons to utilize asymmetric routes are to provide enhanced DL service such as broadcast TV, or to enhance the UL service to reduce transmission power requirements of subscriber station devices.

In most of the usage models described in section 4 the topology will allow multiple RSs and the MMR-BS to be within communication range and therefore potentially communicate with one another. In these topologies multiple routes between the MMR-BS and an MS will be possible. An example of multiple routes is shown in Figure 5 where there are two routes between the MMR-BS and MSs 5, 6, and 7, served by RS4 (one through RS 1 and one through RS3). Another example of multiple routes between the MMR-BS and MS is show in Figure 5 where MS2 can be accessed directly from the MMR-BS and also from RS1.

7 RS Characteristics

7.1 Mobility

The usage models described in section 4 identify three levels of RS mobility: fixed, nomadic, and mobile. Fixed RSs are mounted in a fixed location and are not moved.

Nomadic RSs are portable. They can be moved to a location, positioned for operation and turned on. In most usage models, nomadic RSs will have access to a power source such as a power grid or power provided by a generator, but in some cases battery operated nomadic RSs can be used.

Mobile RSs operate while they are in motion. When a mobile RS is mounted on a train the RS moves along a known trajectory. When mounted on a bus or ferry, the mobile RS follows a constrained trajectory, but one that is not always precisely the same. Finally, in the general case, mobile RSs do not move along a predetermined trajectory. In some usage scenarios, mobile RSs have access to a power source such as a generator mounted on the vehicle on which the RS is deployed. In other environments such as those encountered in the military, mobile RSs can be battery operated.

7.2 Ownership

Infrastructure Provider owned
Customer Owned

- Operated by customer to provide coverage for their use (e.g., within their building)
- Used by provider to provide coverage for other customers (e.g., when RS is deployed with a stationary client device).

7.3 Antenna usage

The usage models described in section 4 do not call for the use of specific types of antennas and thus do not limit the types of antennas that can be deployed by relay stations. Some examples of antennas that might be deployed on RSs are: omni-directional, sectorized, and directional. Antenna arrays might also be deployed. This list of antenna types is not intended to be exhaustive. It is provided for the sake of example and is not intended to limit the types of antennas that might be used in RSs.

For military usage scenario, antenna height may be significantly less than commercial deployments due to security concern, area of operation and amount of infrastructure available.

8 Summary

The following table summarizes the key characteristics of the usage models relative to performance objectives, topology and RS characteristics. Different use case examples are provided to reflect the differences that exist in modeling and identifying other requirements for those cases.

Model	Use Case Examples	Performance Objectives	Topology (see note 1) RS Characteristics (see note 2) Mobility
Fixed Infrastructure	(1) Cell Edge, (2) Coverage Holes (shadowing from trees, buildings, valleys), and; (3) Outside cell area	Coverage, capacity, range	Fixed
In Building Coverage	(1) Inside building (2) Inside tunnels (3) Under ground	Coverage, capacity	Fixed, Nomadic
Temporary Coverage	(1) Emergency/disaster recovery (2) Special events	Coverage, capacity, range	Nomadic
Coverage on Mobile Vehicle	(1) Inside buses and taxis (2) Inside Ferries (3) Inside Trains	Coverage, capacity, range	Mobile

Note 1: For all cases, 2 or more hops, all link types, and all the route types are allowed.
Note 2: All the antenna types are allowed. Ownership can be provider or client in all models and complexity ranges from simple to complex in all models.