Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Integrated Relay Architecture for IEEE 802.16m Systems**
Date Submitted	**January 16, 2008**
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Re:	Call for Contributions on IEEE 802.16m System Description Document 80216m-07/047
Abstract	Integrated relay architecture and protocol structure proposal for IEEE 802.16m systems
Purpose	For discussion and approval by IEEE 802.16 Working Group (Consideration of integrated relay for IEEE 802.16m systems)
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Integrated Relay Architecture for IEEE 802.16m Systems

Sassan Ahmadi et al,

1 Introduction

IEEE 802.16m system requirements document (IEEE 802.16m-07/002r4) has provisioned use of multi-hop relay concept in IEEE 802.16m systems (see Section 8.1 of IEEE 802.16m-07/002r4). This contribution provides a proposal for a scalable multi-hop relay architecture where mobile stations are aware of presence of relay stations and the relay functionality is an integral part of the air-interface as opposed to an add-on feature.

2 IEEE 802.16m System Architecture

The same generic architecture should be defined to support relay and non-relay operations within IEEE 802.16m systems.

2.1 Access Network Architecture

IEEE 802.16m specifies the air interface for the following nodes:

- IEEE 802.16m Base Station (BS) – A base station that implements the base station functionality of the IEEE 802.16m specification. IEEE 802.16m BSs supports communications with IEEE 802.16m RSs, IEEE 802.16m MSs, and IEEE 802.16e MSs.
- IEEE 802.16m Relay Station (RS) – A relay station that implements the relay station functionality specified in the IEEE 802.16m specification. IEEE 802.16m RSs support communication with IEEE 802.16m BSs, IEEE 802.16m MSs, IEEE 802.16m RSs, and IEEE 802.16e MSs.
- IEEE 802.16m MS – An MS which supports the mobile station functionality specified in the IEEE 802.16m specification.
- IEEE 802.16e MS – An MS which supports the mobile station functionality compliant with the WirelessMAN-OFDMA Reference System, as specified in IEEE 802.16m System Requirements (IEEE 802.16m-07/002r4).

Figure 1 illustrates the proposed access network architecture. The IEEE 802.16m BS is associated with zero or more IEEE 802.16m RSs, zero or more IEEE 802.16e MSs and zero or more IEEE 802.16m MSs. The R1 interface is specified by the IEEE 802.16e-2005 standard. The R1', R1'x, R1'y, and R1'z interfaces are specified by IEEE 802.16m standard. R1'z interface applies to the case when more than two hops is supported. The number of hops supported in the standard is for further study.

The IEEE 802.16m BS and IEEE 802.16m RS support legacy IEEE 802.16e MSs via the R1 interface. Support for IEEE 802.16m MSs is provided either directly by the IEEE 802.16m BS or by the IEEE 802.16m RS via the R1' and R1'x interfaces respectively. Communications

between the IEEE 802.16m BS and IEEE 802.16m RS and between instances of the IEEE 802.16m RS occurs over R1'y and R1'z interfaces respectively.

Communications between IEEE 802.16m MSs and IEEE 802.16j RSs will be supported via the R1 interface. This is not depicted in the diagram because this interface is not specified as part of the IEEE 802.16m standard.

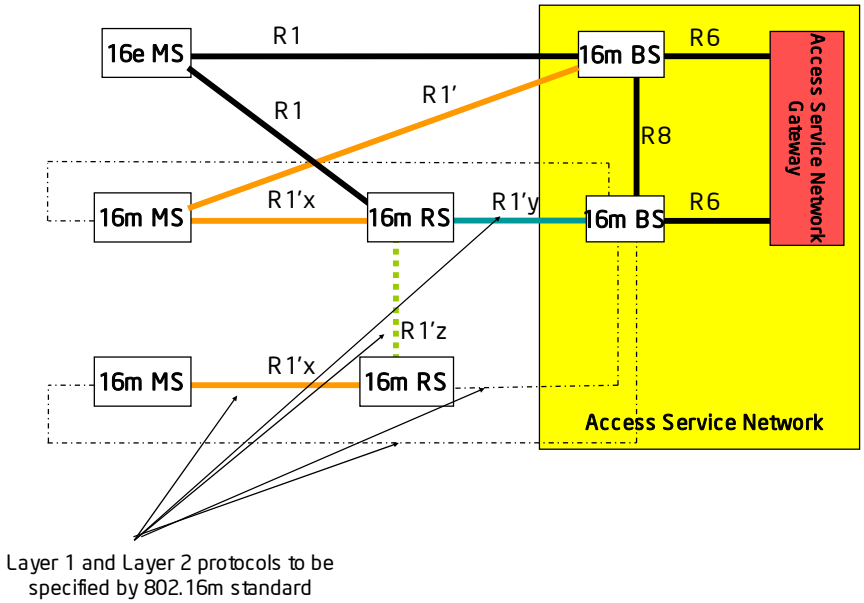


Figure 1 IEEE 802.16m Access Network Architecture

When no RSs are present within the cell, the BS operates as a single PMP link to support communications with all of the MSs in the cell.

RSs may be deployed within a sector in order to provide improved coverage in an area within or beyond the cell. The coverage area provided by RSs is not divided into sectors. When RSs are present within a sector, communications between the BS and MS can occur directly or through one or more RSs.

The topology of the nodes within a sector is a directed acyclic graph with the BS acting as the one and only source node and the MSs acting as the sink nodes in the downlink and reverse version for the uplink. Multiple paths between the BS and MSs are possible to support cooperative transmissions of data from multiple RSs or from the BS and one or more RS.

User data is transmitted between the BS and MS. User data is not permitted to flow from an MS, through an RS and to another MS. IEEE 802.16m defines an air interface between the

BS and MS and does not specify how communications occur between MSs.

2.2 Frequency Usage within a Relay-enabled Cell

When RSs are present within a sector, two frequency usage schemes are supported. Individual links in the BS-RS-MS topology can share a single frequency channel to support all communications within the sector. This is referred to as shared channel relay. In this frequency usage model the stations within the sector collaborate to share the resources of the channel that is assigned for their collective use.

Individual links in the BS-RS-MS topology can also be assigned to use separate instances of frequency channel. This is referred to as dedicated channel relay. In this frequency usage model, the allocation of resources on individual links is performed by the station (MR-BS or RS) designated to control the link. Stations that control individual links operating using the dedicated channel relay model do not collaborate in the assignment of resources even if they are operating at the same frequency.

The proposed architecture does not limit the number of different frequency channels that can be assigned to support individual access and relay links (or groups of them) within a sector.

2.3 Duplexing In the Presence of Relay

The IEEE 802.16m specification supports both TDD and FDD duplexing modes. Half duplex FDD and full duplex FDD MSs are supported in FDD mode. It is assumed that a given network is deployed using entirely TDD or FDD duplexing scheme. When RSs are used in an FDD deployment, downlink communications between all stations are assigned to the downlink channel and uplink communications between all stations are assigned to the uplink channel.

3 Relay Functional Architecture

Relay support in IEEE 802.16m is integrated into the architecture rather than added on as a second step as was unavoidable in IEEE 802.16j. In IEEE 802.16m, IEEE 802.16m MSs are aware of the presence of RSs and the multi-hop nature of the path between them and the BS.

Relay support in IEEE 802.16m is based on a common set of relay functions that are supported by all IEEE 802.16m RSs and all IEEE 802.16m BSs which support relay operation. These common relay functions form a common framework which provides basic relay support. Other more advanced relay functions are specified on top of this common framework to extend this basic relay function set. It may be the case that not all RSs implement these more advanced relay functions. This method of specification ensures that completely independent RS types are not defined to support different deployment models and that multiple distinct sets of relay features are not specified to provide similar relay functions. Instead, it promotes commonality between potentially different RS types and

discourages the creation of multiple, incompatible RS types. The base relay function set includes a common relay frame structure. Other members of the base relay function set are for further study. The more advanced relay functions are also for further study.

4 Relay-enabled Protocol Structure

In IEEE 802.16m, the protocols are designed to account for the multi-hop nature of the system. The same generic set of protocol structure and functions should be defined to support relay and non-relay operation within IEEE 802.16m. Intermediate nodes (i.e. relay stations) implement a subset of the PHY and MAC functions of the end nodes (i.e. BS and MS). Different types of relay station implement the common relay functions and potentially different subsets of advanced relay PHY/MAC functions. Different types of relay stations may be used to support different deployment scenarios.

Functions and protocols within IEEE 802.16m are explicitly classified as hop-by-hop functions/protocols, which are performed independently on each hop of a path between the BS and MS and end-to-end functions/protocols, which are performed in a coordinated manner across a path between the BS and MS. When it is possible, protocols in IEEE 802.16m are specified in a uniform way across the hops.

Figure 2 illustrates the IEEE 802.16m protocol functions, showing the separation of data plane and control plane functions and an example classification of MAC functions into end-to-end and hop-by-hop functions . The final classification depends on more detailed relay architecture choices and is for further study.

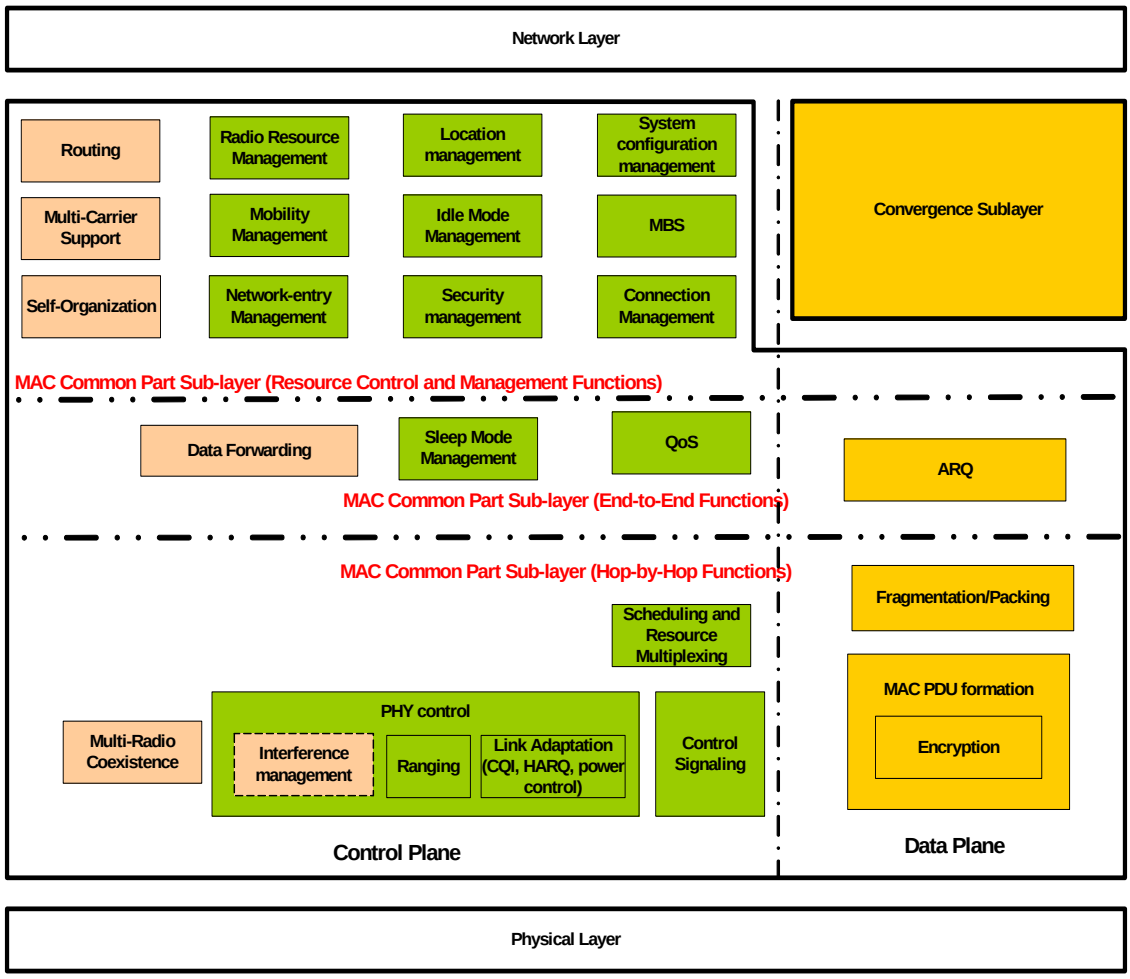


Figure 2 IEEE 802.16m Protocol Functions with example classification of hop-by-hop functions and end-to-end functions

In IEEE 802.16e most control functions are centralized in the BS. The BS controls most operations and the MS requests that decisions be made or changed, reports channel state information, and carries out the commands of the BS. In IEEE 802.16m new RS functionalities are introduced and the control model is extended in one of two following ways. In a centralized model, the BS makes control decisions and the RSs carry out the orders of the BS and relay control information between the BS and MS. The other alternative model is a distributed model in which the RS makes control decisions for MSs attached to it and optionally communicates those decisions to the BS. In both control models, the role of the MS does not change in a significant way from the role of the MS in IEEE 802.16e. Figure 3 illustrates the two control models used in IEEE 802.16m.

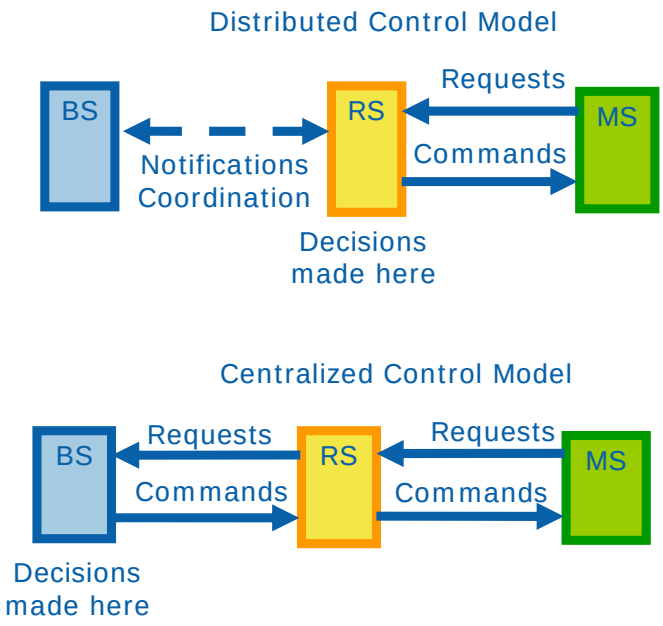
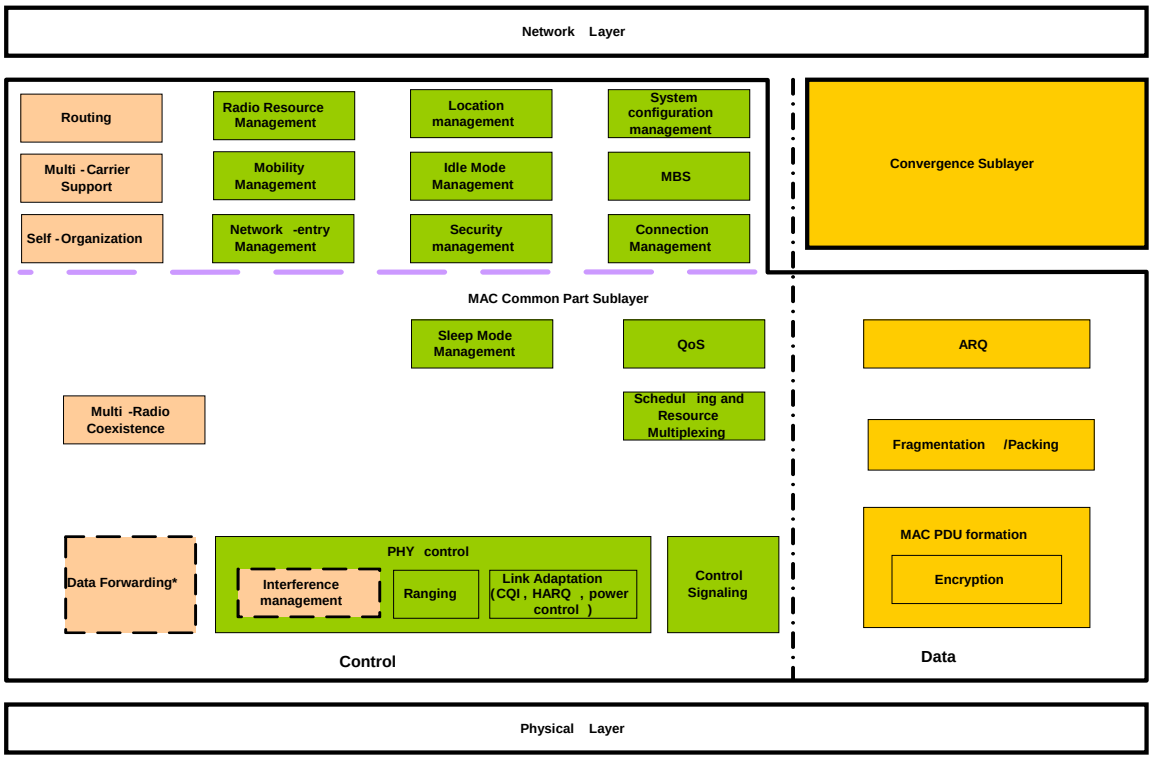


Figure 3 Various relay control models

The determination of whether a particular control function should be centralized or distributed is made independently for each control function. For example, some functions, such as the ranging process, are more naturally performed in a distributed manner, while other functions such as the rest of the network entry process are more naturally performed in a centralized manner. The classification of specific control functions as centralized or distributed is for further study.

4.1 Protocol Functions for End Nodes (BS, MS)

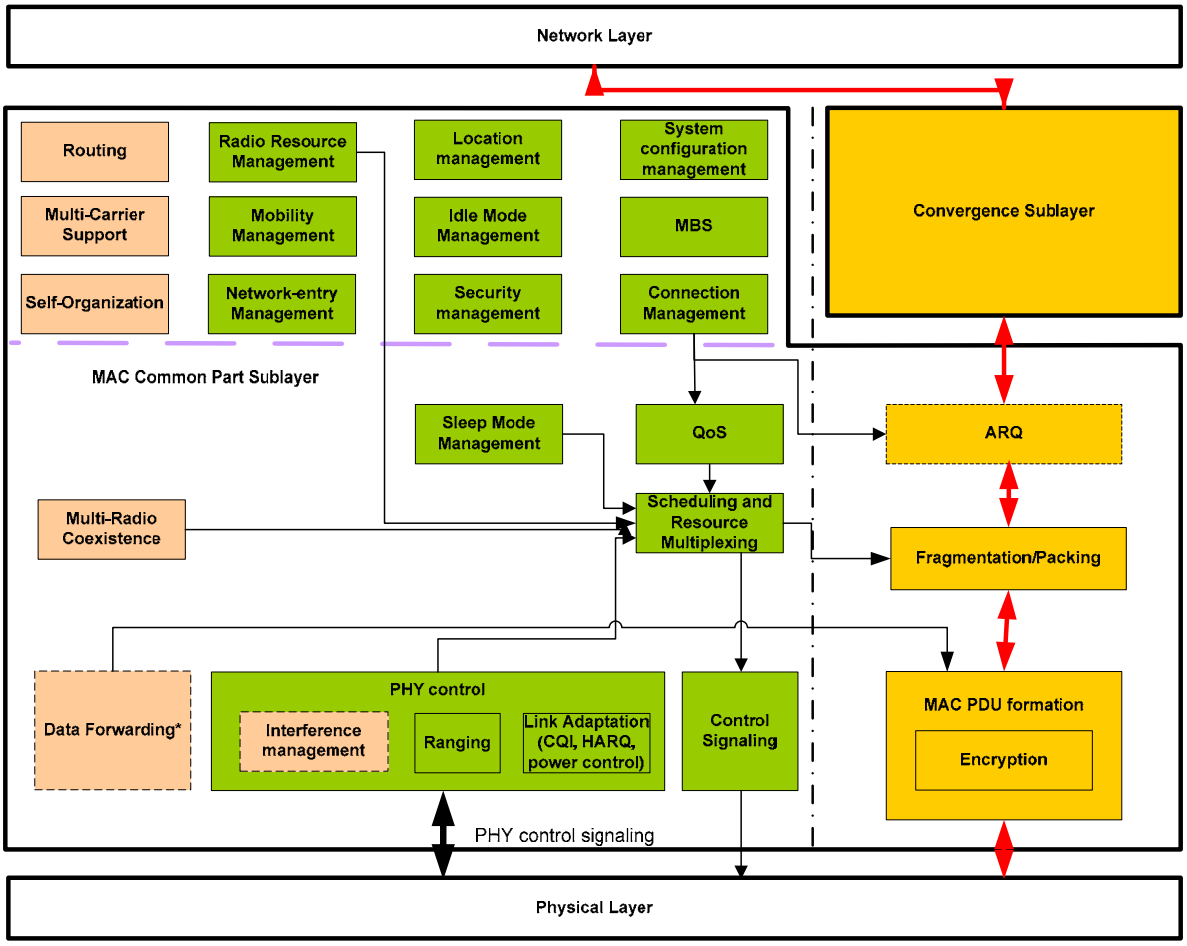
The end nodes are defined as network entity that sources and sinks packets from the network layer. In this case, end nodes are BS and MS. Figure 4 shows the proposed protocol functions for end nodes.



* Note that the Data Forwarding Function applies only to the BS

Figure 4 Protocol Functions of End Nodes (BS, MS)

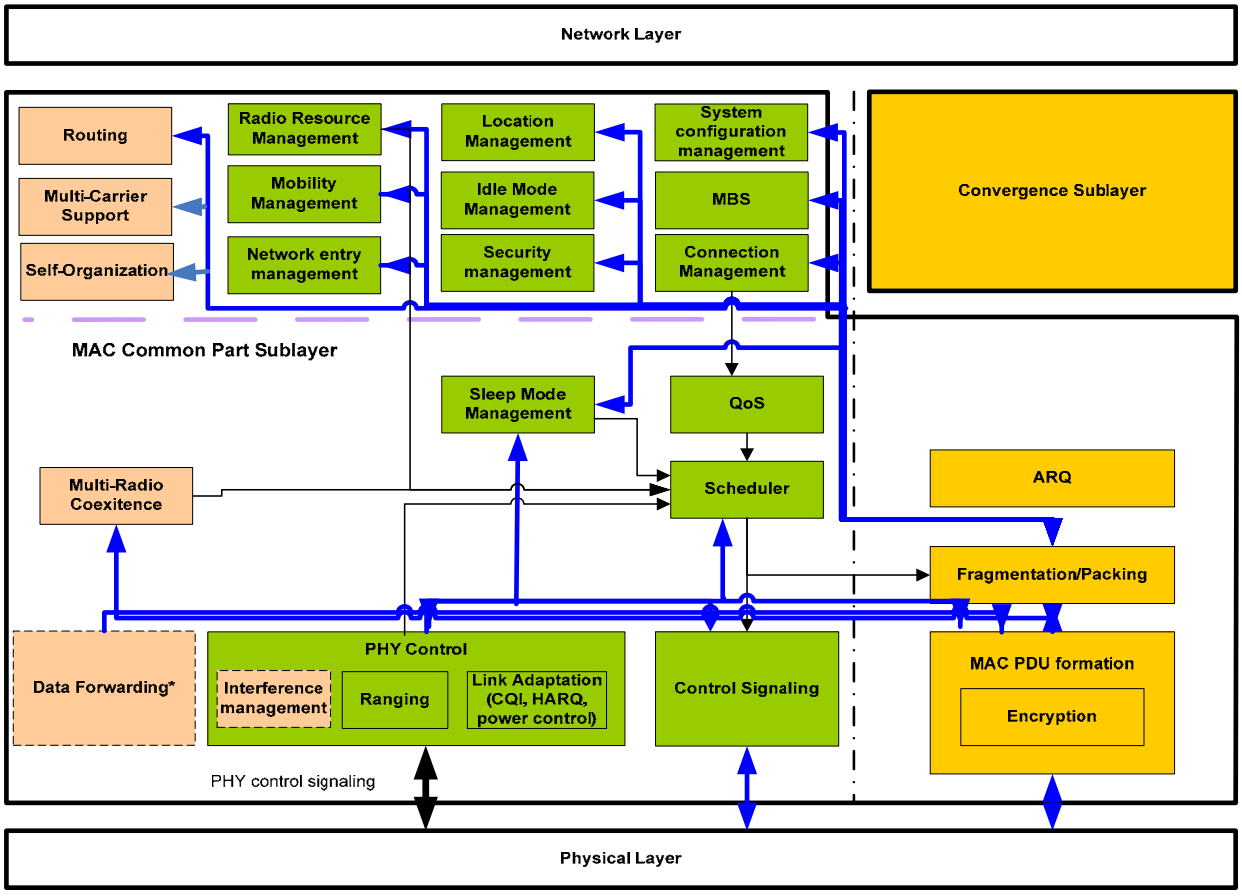
Figure 5 shows the proposed data flow across protocol functions in end nodes.



*** Note that the Data Forwarding function applies only to the BS**

Figure 5 Data Flow Across Protocol Functions in End Nodes (BS, MS)

Figure 6 shows the proposed MAC signaling flow across protocol functions in end nodes.



*** Note that the Data Forwarding function applies only to the BS**

Figure 6 MAC Signaling Flow across Protocol Functions in End Nodes (BS, MS)

4.2 Protocol Functions for Intermediate Nodes (RS)

Intermediate nodes are network entity that does not source and sink network layer packets. Intermediate nodes provide relay function for packets that traverse between end nodes.

Figure 7 shows the proposed protocol functions for intermediate nodes or relay station. An intermediate node may consist of a subset of the protocol functions shown in Figure 7. The subset of functions depends on the type or category of the RS. The IEEE 802.16m standard shall define the different RS configuration supported in the standard and the corresponding subset of protocol functions that are correspondingly supported.

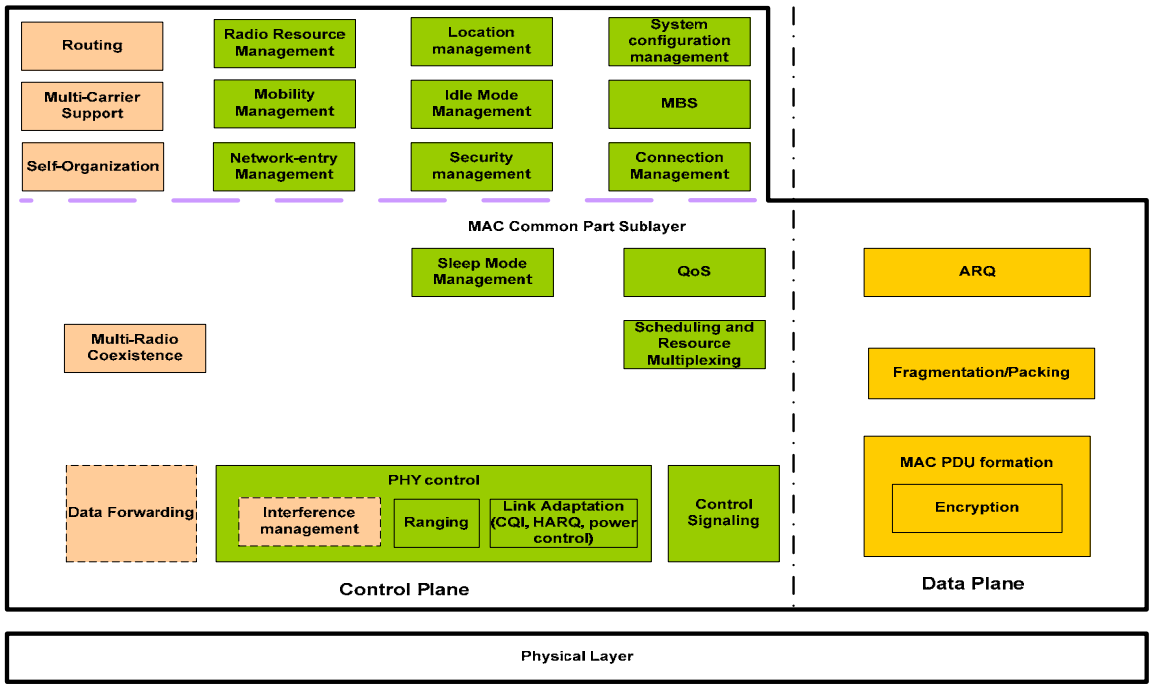


Figure 7 Protocol Functions of Intermediate Nodes (RS)

Figure 8 shows the proposed data flow across protocol functions in intermediate nodes.

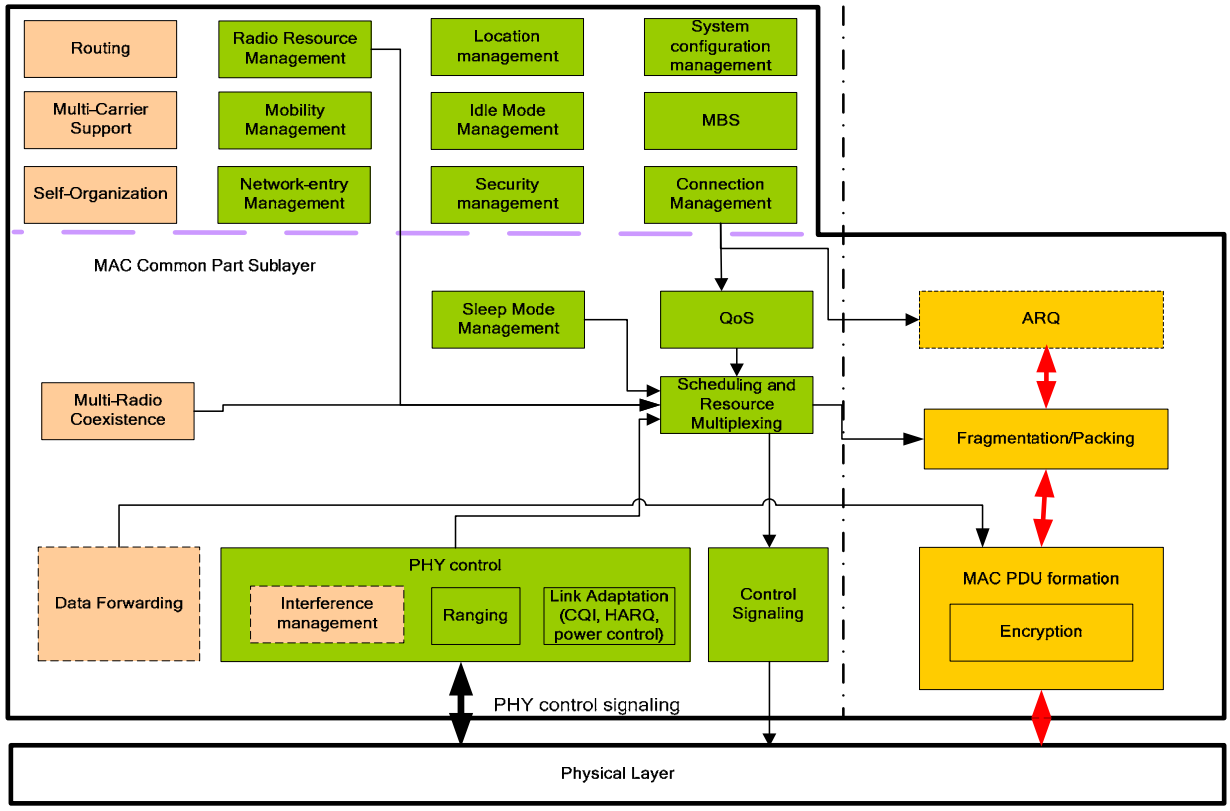


Figure 8 Data Flow Across Protocol Functions in Intermediate Nodes (RS)

Figure 9 shows the proposed MAC signaling flow across protocol functions in intermediate nodes.

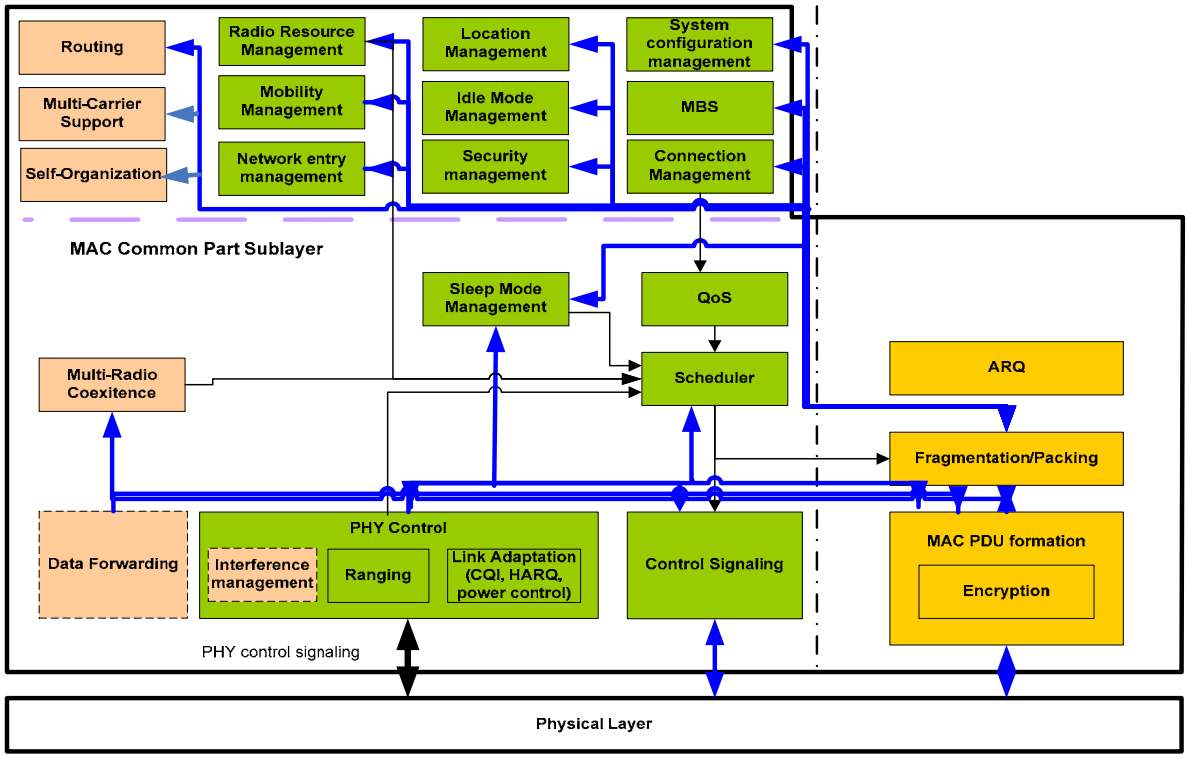


Figure 9 MAC Signaling Flow across Protocol Functions in Intermediate Nodes (RS)

5 Proposed Text for SDD

Insert the following text into **Overall Network Architecture** ***sub-clause (i.e. Chapter 4 in [1]):***

---------- Text Start ----------

4.0 Access Network Architecture

IEEE 802.16m specifies the air interface for the following nodes:

- IEEE 802.16m Base Station (BS) – A base station that implements the base station functionality of the IEEE 802.16m specification. IEEE 802.16m BSs supports communications with IEEE 802.16m RSs, IEEE 802.16m MSs, and IEEE 802.16e MSs.
- IEEE 802.16m Relay Station (RS) – A relay station that implements the relay station functionality specified in the IEEE 802.16m specification. IEEE 802.16m RSs support communication with IEEE 802.16m BSs, IEEE 802.16m MSs, IEEE 802.16m RSs, and IEEE 802.16e MSs.
- IEEE 802.16m MS – An MS which supports the mobile station functionality specified in the IEEE 802.16m specification.
- IEEE 802.16e MS – An MS which supports the mobile station functionality compliant with the WirelessMAN-OFDMA Reference System, as specified in IEEE 802.16m System Requirements Document.

Figure x-1 illustrates the access network architecture inclusive of the relay nodes. The IEEE 802.16m BS is associated with zero or more IEEE 802.16m RSs, zero or more IEEE 802.16e MSs and zero or more IEEE 802.16m MSs. The R1 interface is specified by the IEEE 802.16e-2005 standard. The R1', R1'x, R1'y, and R1'z interfaces are specified by IEEE 802.16m standard. R1'z interface applies to the case when more than two hops is supported. The number of hops supported in the standard is for further study.

The IEEE 802.16m BS and IEEE 802.16m RS support legacy IEEE 802.16e MSs via the R1 interface. Support for IEEE 802.16m MSs is provided either directly by the IEEE 802.16m BS or by the IEEE 802.16m RS via the R1' and R1'x interfaces respectively. Communications between the IEEE 802.16m BS and IEEE 802.16m RS and between instances of the IEEE 802.16m RS occurs over R1'y and R1'z interfaces, respectively.

Communications between IEEE 802.16m MSs and IEEE 802.16j RSs will be supported via the R1 interface. This is not depicted in the diagram because this interface is not specified as part of the IEEE 802.16m standard.

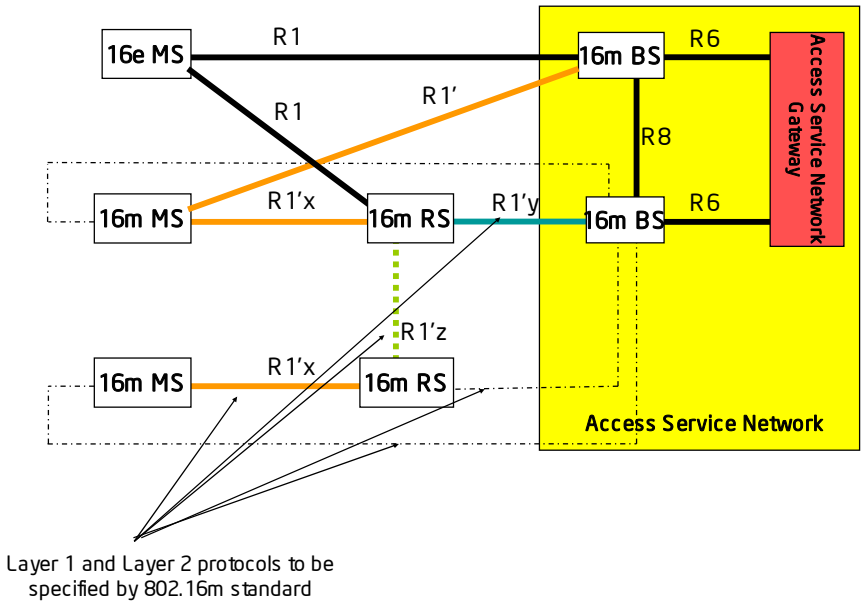


Figure x-1: IEEE 802.16m Access Network Architecture

When no RSs are present in the cell, the BS operates as a single point-to-multi-point link to support communications with all of the MSs in the cell.

RSs may be deployed within a sector in order to provide improved coverage in an area within or beyond the cell. The coverage area provided by RSs is not divided into sectors. When RSs are present within a sector, communications between the BS and MS can occur directly or through one or more RSs.

The topology of the nodes within a sector is a directed acyclic graph with the BS acting as the one and only source node and the MSs acting as the sink nodes in the downlink and reverse version for the uplink. Multiple paths between the BS and MSs are possible to support cooperative transmissions of data from multiple RSs or from the BS and one or more RS.

User data is transmitted between the BS and MS. User data is not permitted to flow from an MS, through an RS and to another MS. IEEE 802.16m defines an air interface between the BS and MS and does not specify how communications occur between MSs.

---------- Text End ----------

Insert the following text into IEEE 802.16m Air-Interface Protocol Structure *sub-clause (i.e. Chapter 8 in [1]):*

---------- Text Start ----------

8.0 Generic IEEE 802.16m Air-Interface Protocol Structure

8.1 Relay-enabled Air-Interface Protocol Structure

In IEEE 802.16m, the protocols are designed to account for the multi-hop nature of the system. The same generic set of protocol structure and functions are defined to support relay and non-relay operation within IEEE 802.16m. Intermediate nodes (i.e. relay stations) implement a subset of the PHY and MAC functions of the end nodes (i.e. BS and MS). Different types of relay station implement the common relay functions and potentially different subsets of advanced relay PHY/MAC functions. Different types of relay stations may be used to support different deployment scenarios.

Functions and protocols within IEEE 802.16m are explicitly classified as hop-by-hop functions/protocols, which are performed independently on each hop of a path between the BS and MS and end-to-end functions/protocols, which are performed in a coordinated manner across a path between the BS and MS. When it is feasible, protocols in IEEE 802.16m are specified in a uniform way across the hops.

Figure y-1 illustrates the IEEE 802.16m protocol functions, showing the separation of data plane and control plane functions and an example classification of MAC functions into end-to-end and hop-by-hop functions . The final classification depends on more detailed relay architecture choices and is for further study.

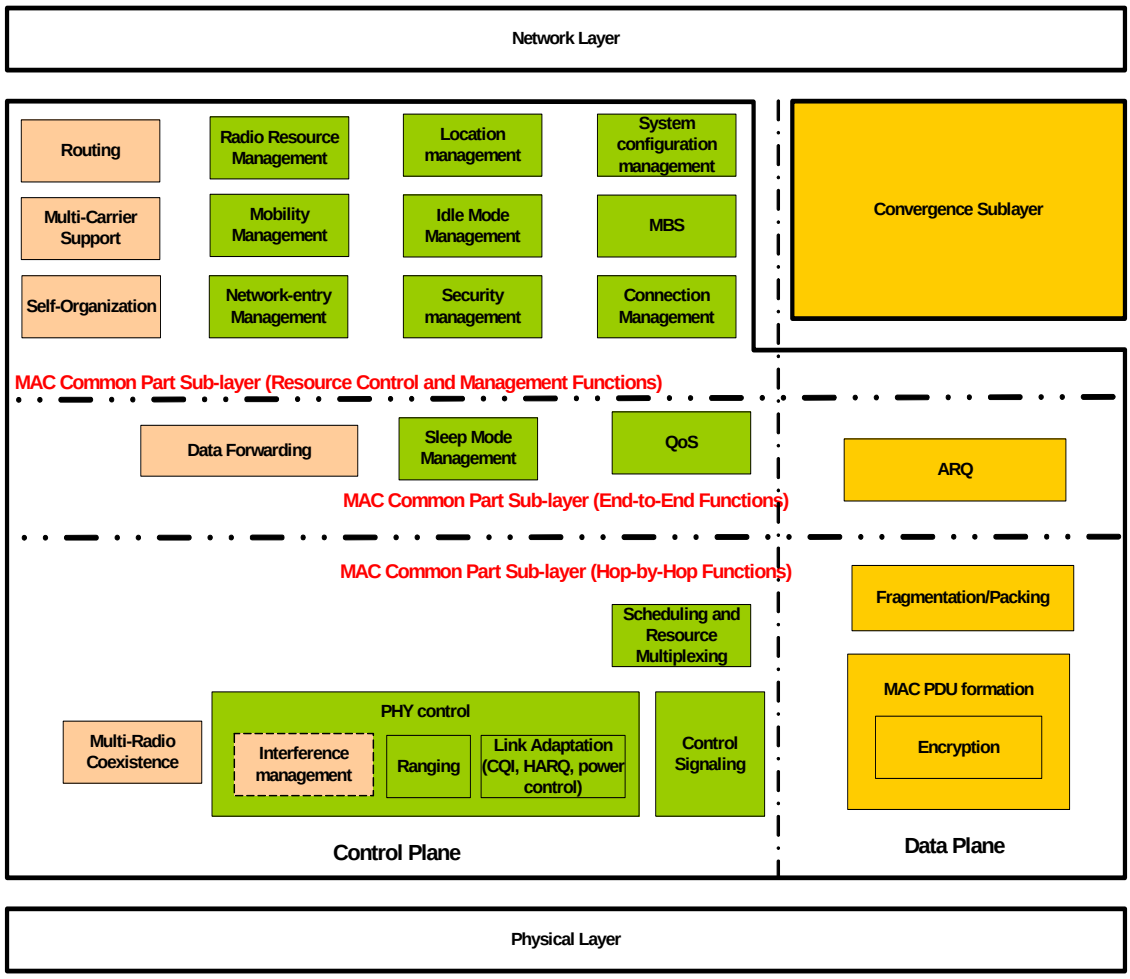


Figure y-1: IEEE 802.16m Protocol Functions with example classification of hop-by-hop functions and end-to-end functions

In IEEE 802.16m new RS functionalities are introduced and the control model of IEEE 802.16j is extended in one of two following ways. In a centralized model, the BS makes control decisions and the RSs carry out the orders of the BS and relay control information between the BS and MS. The other alternative model is a distributed model in which the RS makes control decisions for MSs attached to it and optionally communicates those decisions to the BS. In both control models, the role of the MS does not change in a significant way from the role of the MS in IEEE 802.16e. Figure y-2 illustrates the two control models used in IEEE 802.16m.

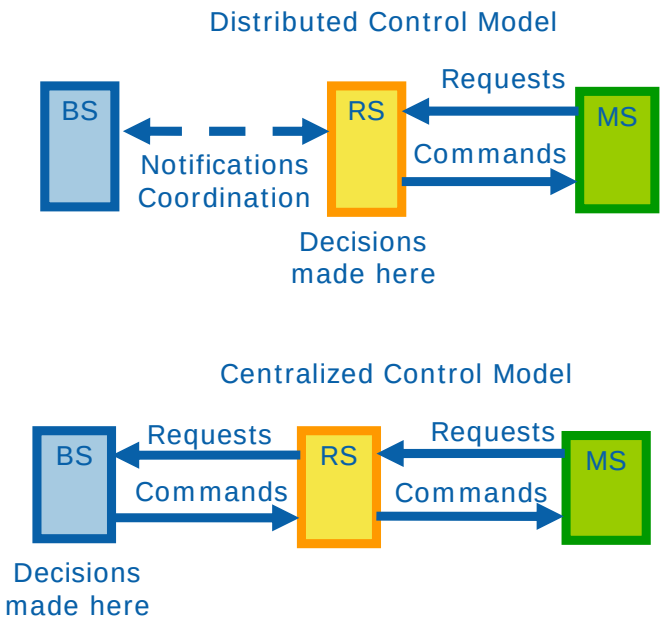
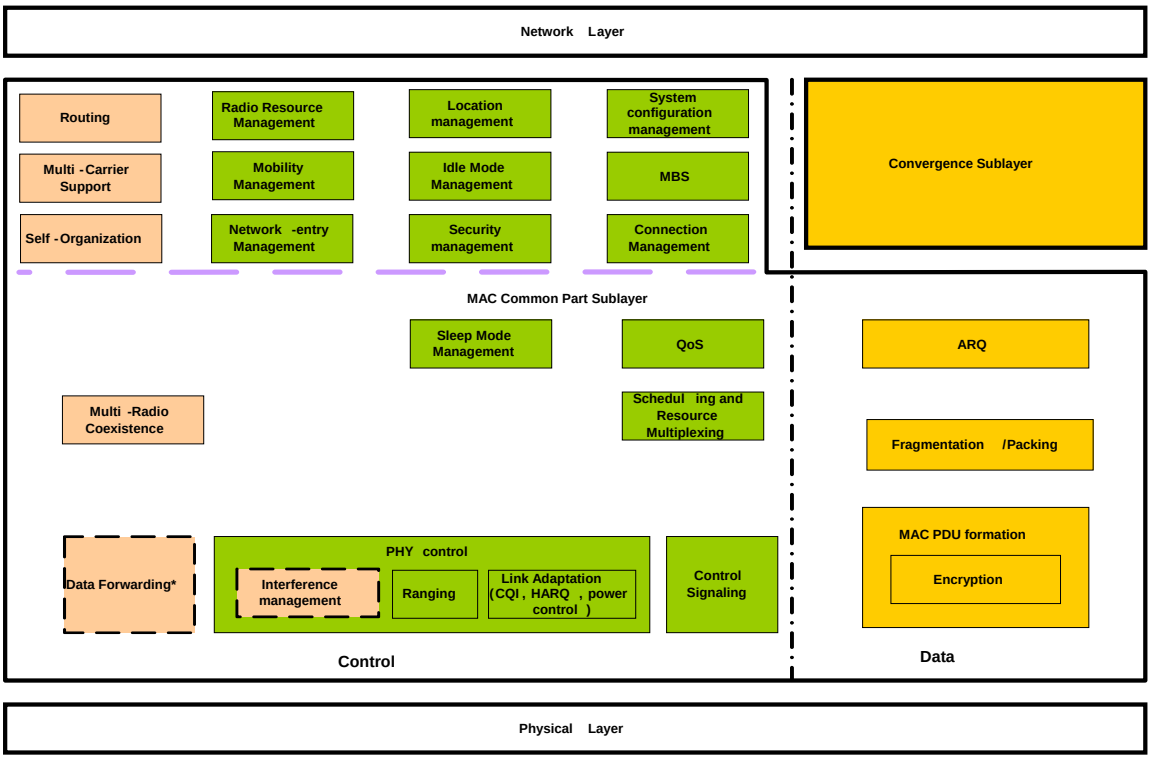


Figure y-2: Various relay control models

The determination of whether a particular control function should be centralized or distributed is made independently for each control function. For example, some functions, such as the ranging process, are more naturally performed in a distributed manner, while other functions such as the rest of the network entry process are more naturally performed in a centralized manner. The classification of specific control functions as centralized or distributed is for further study.

8.1.1 Protocol Functions for End Nodes (BS, MS)

The end nodes are defined as network entity that sources and sinks packets from the network layer. In this case, end nodes are BS and MS. Figure 4 shows the proposed protocol functions for end nodes.



*Note that the Data Forwarding function applies only to the BS

Figure 10 Protocol Functions of End Nodes (BS, MS)

8.1.2 Protocol Functions for Intermediate Nodes (RS)

Intermediate nodes are network entity that does not source and sink network layer packets. Intermediate nodes provide relay function for packets that traverse between end nodes.

Figure 7 shows the proposed protocol functions for intermediate nodes or relay station. An intermediate node may consist of a subset of the protocol functions shown in Figure 7. The subset of functions depends on the type or category of the RS. The IEEE 802.16m standard shall define the different RS configuration supported in the standard and the corresponding subset of protocol functions that are correspondingly supported.

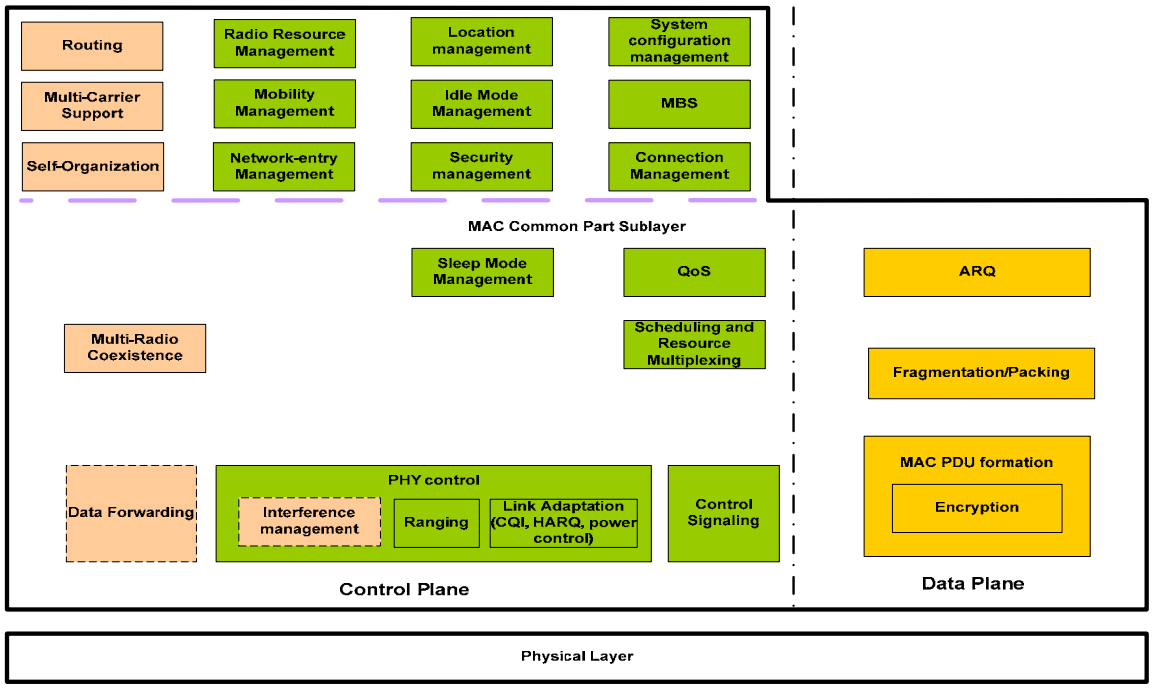


Figure 11 Protocol Functions of Intermediate Nodes (RS)

---------- Text End ----------

[Insert the following text into Clause 16 Support for multi-hop Relay]:

---------- Text Start ----------

16.1x Relay Functional Architecture

Relay support in IEEE 802.16m is integrated into the architecture rather than added on as a second step as was unavoidable in IEEE 802.16j. In IEEE 802.16m, IEEE 802.16m MSs are aware of the presence of RSs and the multi-hop nature of the path between them and the BS.

Relay support in IEEE 802.16m is based on a common set of relay functions that are supported by all IEEE 802.16m RSs and all IEEE 802.16m BSs which support relay operation. These common relay functions form a common framework which provides basic relay support. Other more advanced relay functions are specified on top of this common framework to extend this basic relay function set. It may be the case that not all RSs implement these more advanced relay functions. This method of specification ensures that

completely independent RS types are not defined to support different deployment models and that multiple distinct sets of relay features are not specified to provide similar relay functions. Instead, it promotes commonality between potentially different RS types and discourages the creation of multiple, incompatible RS types. The base relay function set includes a common relay frame structure. Other members of the base relay function set are for further study. The more advanced relay functions are also for further study.

---------- Text End ----------

References

[1] IEEE C80216m-07/320r1, "Draft Table of Content for the IEEE 802.16m System Description Document", November 2007.