Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Inter-Base Station Coordination for Interference Management**
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Re:	IEEE 802.16m-08/016, "Call for Contributions on Project 802.16m System Description Document (SDD)."
Abstract	This contribution focuses on the MAC/PHY protocol architecture needed for inter-base station coordination in 802.16m in order to effectively mitigate interference thereby helping to achieve the spectral efficiency and cell-edge performance goals of 802.16m. In addition to the control and data plane information exchange needed across different base stations, air interface signaling support needed for different interference mitigation techniques is also discussed. The contribution concludes with specific recommendations to amend Section 8 of IEEE 802.16m-08_003r1.
Purpose	To clarify MAC/PHY protocol support for inter-base station coordination in TGm and adopt the input to the TGm SDD.
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Inter-Base Station Coordination for Interference Mitigation

1 Introduction

IEEE 802.16e incorporates several well-known advances such as adaptive modulation/coding, power control, Hybrid Automatic Repeat request (HARQ) based error recovery, multiple antenna techniques etc. that have greatly improved the link level performance achieved under prevailing channel conditions. Despite these advances, systems are still limited by signal fading and interference from other neighboring sectors (or cells) which reduces the received Signal-to-Interference Plus Noise Ratio. These conditions are especially severe for cell-edge mobile terminals that suffer the most from inter-base station (or inter-cell/sector) interference.

In this contribution, we focus on air interface methods and control/data plane information exchange needed across different MAC/PHY instances in order to effectively mitigate interference thereby helping to achieve the spectral efficiency and cell-edge performance goals of 802.16m.

2 Enhanced Interference Management Through Inter-Base Station Coordination

Traditional interference management methods (e.g. power control, macro-diversity, channel quality aware scheduling etc. [5]) that are specified in 802.16e do not rely on inter-base station coordination and mainly use *local information* that can be gathered within a sector, e.g. received signal strength, path loss, interference measurements, signal-to-interference-plus-noise-ratios etc. While these techniques do allow interference mitigation to a certain degree, they are inherently limited in their ability to gather information from neighboring sectors. As a result, they fall short of effectively suppressing interference and providing enough system throughput improvements to achieve 802.16m spectral efficiency targets.

Inter-base station coordination may be exploited to build a greater awareness of the magnitude and waveform structure of interfering signals thus improving the interference mitigation capability of the aforementioned techniques. For example, a rudimentary exchange of the rise of Interference-over-Thermal Noise (IoT) levels from neighboring sectors may help improve the ability of power control algorithms in keeping out-of-cell interference at a desirable level [1]. Other more advanced techniques such as Collaborative MIMO and Network MIMO have recently been proposed for consideration in 802.16m [3][4]. For example, Network MIMO can successfully suppress inter-cell interference through cooperative transmit and receive beam-forming across multiple sectors in the downlink and uplink directions, respectively.

2.1 MAC/PHY Protocol Architecture for Inter-Base Station Coordination

Figures 1 and 2 illustrate a proposed logical/functional MAC/PHY architecture for Access Service Networks employing *inter-base station coordination*. Figure 1 applies to inter-base station coordination for interference mitigation on the downlink while Figure 2 applies to the uplink.

2.1.1 Inter-Base Station Coordination for Downlink Interference Mitigation

Figure 1 illustrates the inter-base station coordination architecture for interference mitigation on the downlink. In the figure, the "Multi-Base Station MAC/PHY coordination" entity is responsible for managing all control plane information exchange (obtained from "Inter-BS coordination" within each MAC Common Part Sublayer instance) and processing of control plane information, as applicable to specific inter-base station coordination techniques. In particular, it may include a set of "Inter-Base Station Interference Management" entities that are responsible for managing control signaling exchanges among coordinating base stations.

Examples of downlink interference management related control exchanges between the Inter-Base Station Control entity and the Inter-Base Station Interference Management Entity are summarized in the Appendix (see Table 1).

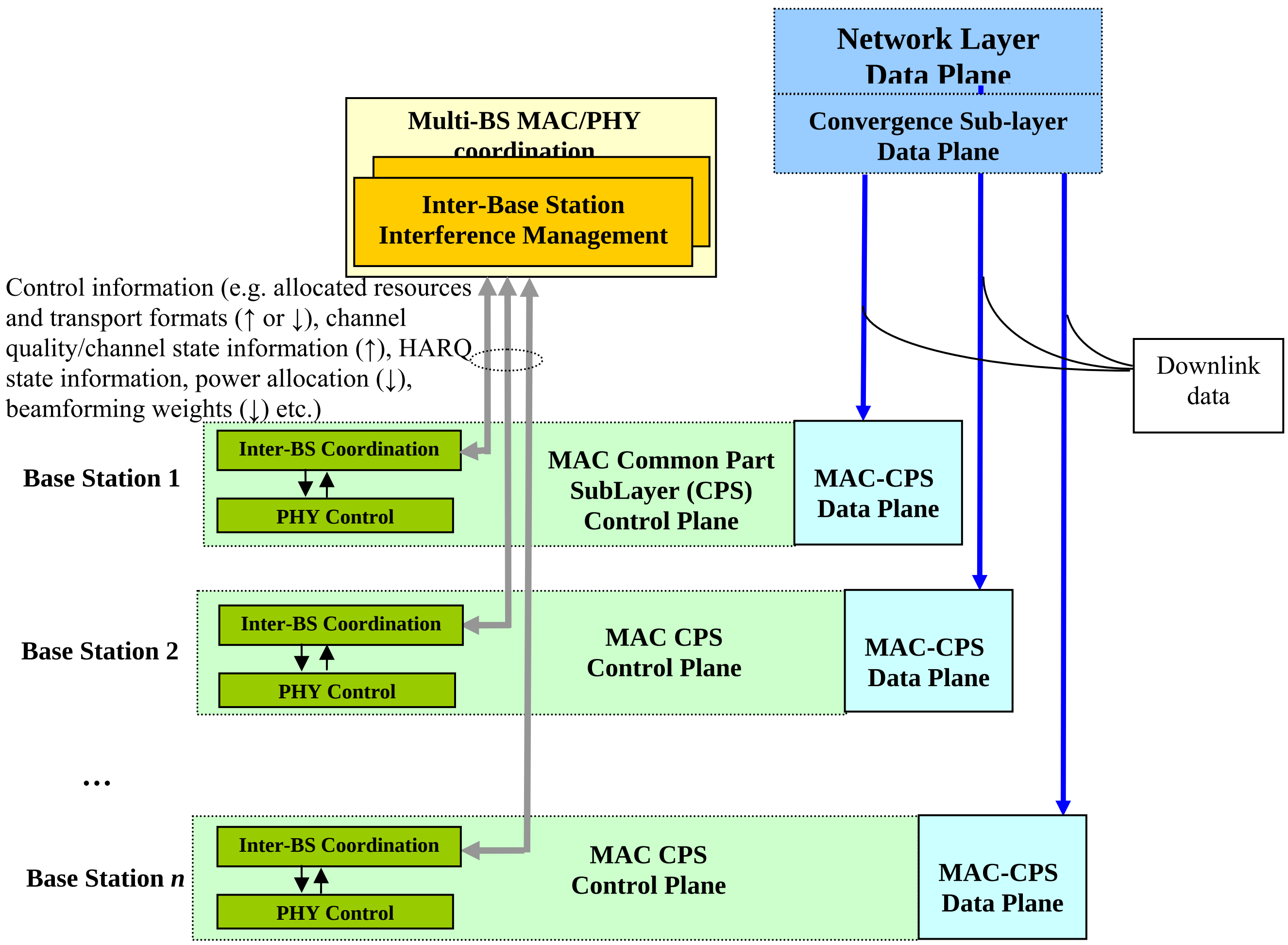

Figure 1: Logical MAC/PHY coordination architecture for inter-base station interference mitigation on the downlink.

In terms of data plane functions, the downlink architecture is as it is today; MAC Service Data Units are received by the MAC Common Part Sublayer instances of individual base stations (same user's data can be sent to multiple base stations as well, e.g. for techniques such as Collaborative and Network MIMO).

2.1.2 Inter-Base Station Coordination for Uplink Interference Mitigation

Figure 2 applies to inter-base station coordination for interference mitigation on the uplink. In the figure, the "Multi-Base Station MAC/PHY coordination" entity which includes the "Inter-Base Station Interference Management" entity and the "Joint Signal Processing" entity is responsible for managing all inter-base station information exchange and joint processing of control and data plane information, as applicable to specific inter-base station coordination techniques.

Examples of uplink interference management related control exchanges between the Inter-Base Station Control entity and the Inter-Base Station Interference Management Entity are summarized in the Appendix (see Table 1).

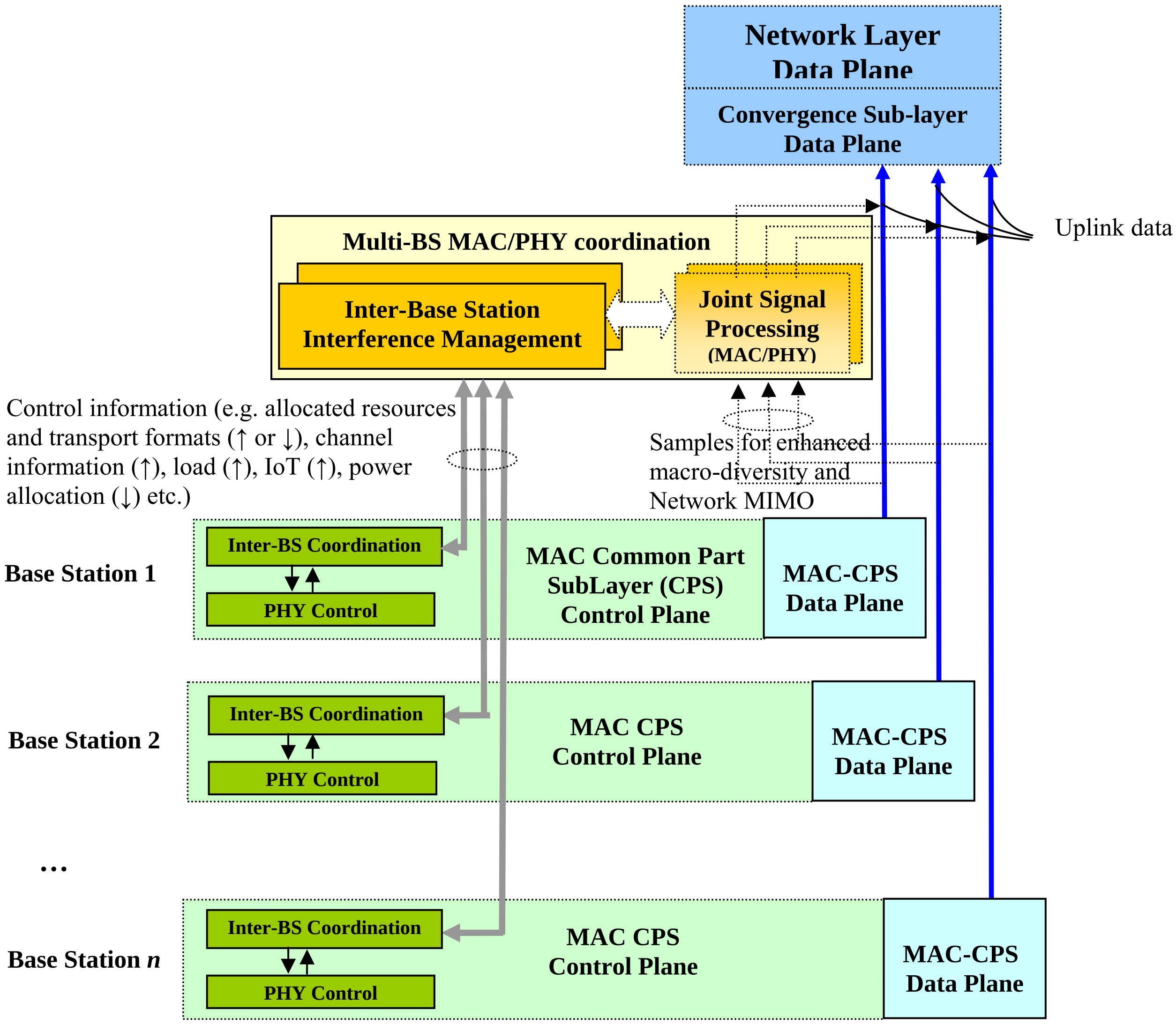

Figure 2: Logical MAC/PHY coordination architecture for inter-base station interference mitigation on the uplink.

For the uplink data plane, receiver signal processing may be carried out either at individual MAC/PHY instances (e.g. at each base station without inter-base station data plane information exchange as is done currently), or may be jointly carried out at the Joint Signal Processing unit(s) as required by specific coordination techniques. For instance, Network MIMO requires joint processing of uplink signals received by individual MAC/PHY instances over the air interface in order to mitigate interference. For coordination techniques such as IoT-based power control that do not require joint processing, receiver signal processing is performed at individual MAC/PHY instances (at each base station) and decoded data is forwarded to upper layers directly.

Note that all of the MAC/PHY coordination related functions shown in both Figures 1 and 2 may be realized in a centralized or distributed manner. Generally speaking, there may be *multiple* Inter-Base Station Interference Management and/or Joint Signal processing instances that fulfill the desired inter-base station coordination role. The location and number of coordinating instances employed in an Access Service Network are driven by performance, complexity and backhaul overhead considerations.

3 Recommended Additions to SDD

[*Rationale: Figures 4 through 6 of the current SDD draft IEEE802.16m-08/003r1 do not currently incorporate the Inter-BS coordination block even though it is mentioned in Section 8.1. The following three figures therefore add the Inter-BS coordination block to the respective figures 4-6 in the SDD. In addition, the real-time constraints of the information exchanged by the Inter-BS coordination block require its separation from other control traffic. This is realized with the new rtC-SAP (real-time control SAP) included in the figures.*

Mere mention of an "Inter-BS coordination" block in the control plane is not sufficient to illustrate how information exchange (control plane and data plane), multi-BS control and data plane information processing may be accomplished. The new Section 8.1.4 with accompanying text and Figures 8-9 introduces a multi-BS Coordination block that provides further clarity to Figures 4-6 in the SDD. The text and figures also explain operation related to inter-BS coordination for interference mitigation.]

[***Use the following figure to replace Figure 4 in IEEE 802.16m-08_003r1***]

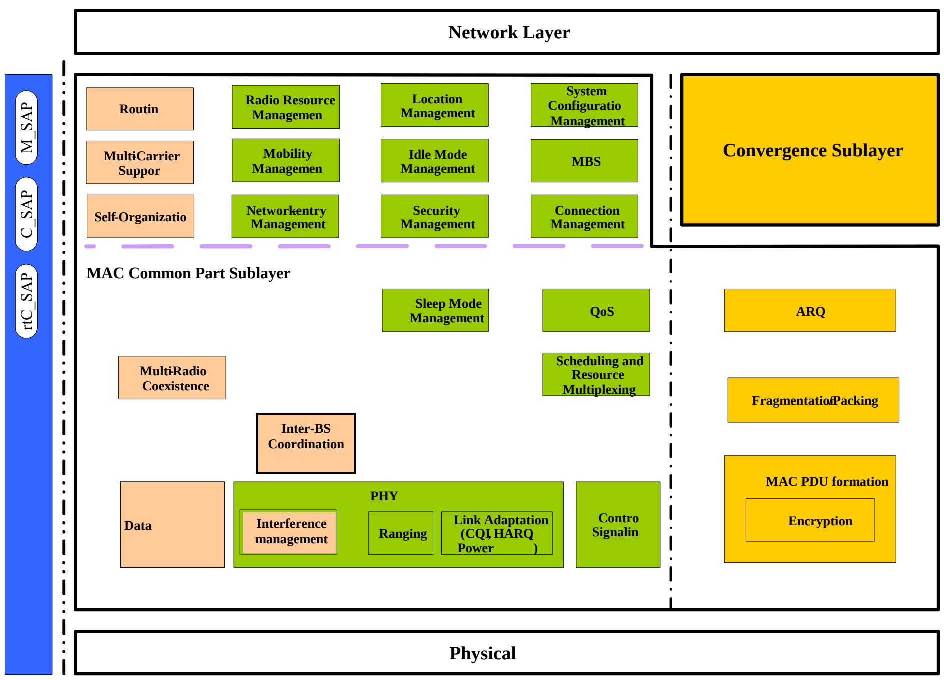

Figure 4 The IEEE 802.16m Protocol Structure

[***Use the following figure to replace Figure 5 in IEEE 802.16m-08_003r1***]

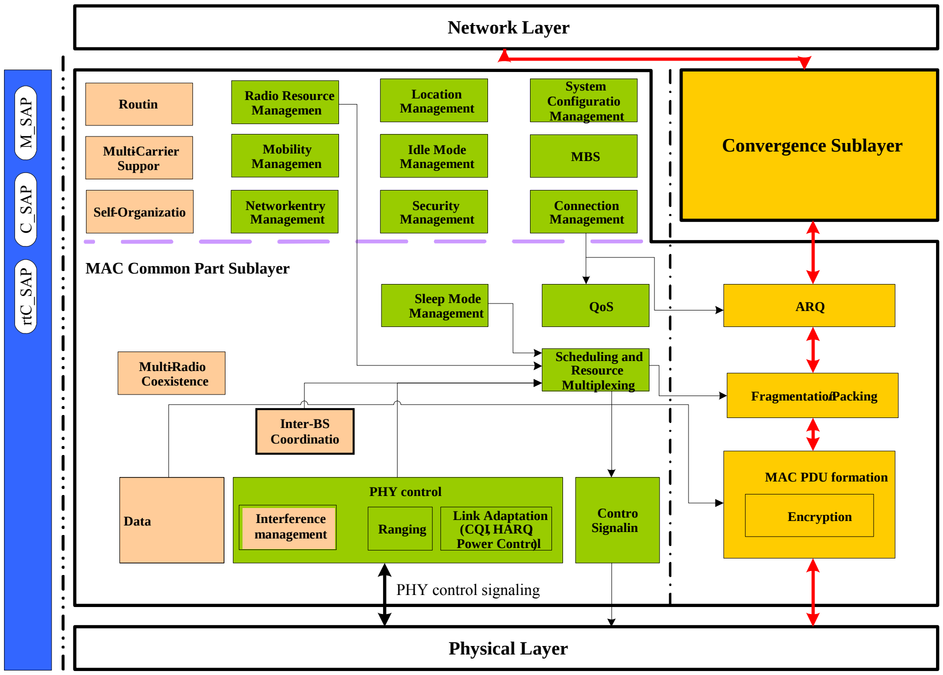

Figure 5 The IEEE 802.16m MS/BS Data Plane Processing Flow

[*Use the following figure to replace Figure 6 in IEEE 802.16m-08_003r1*]

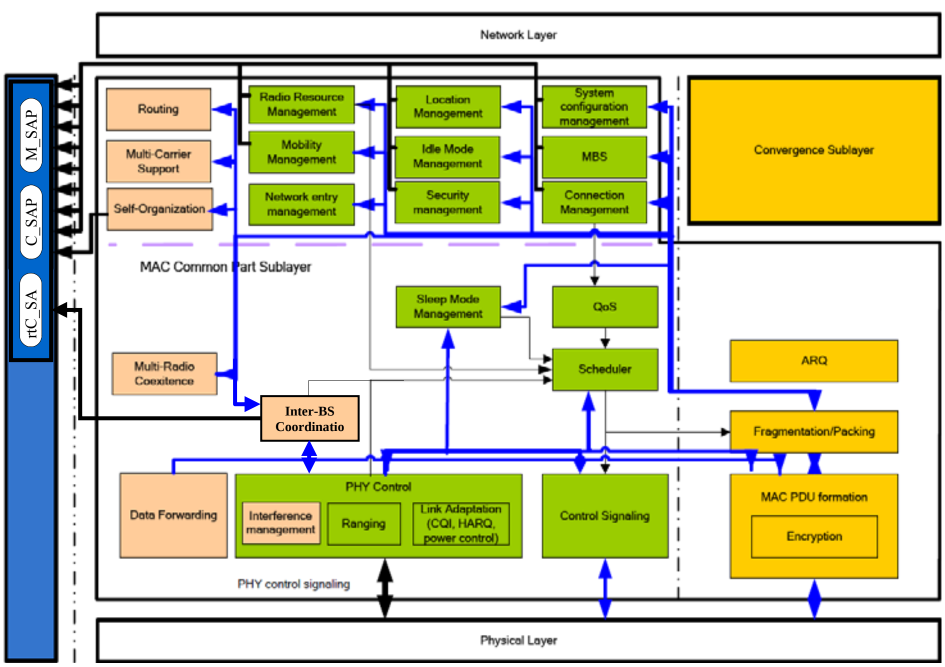

Figure 6 The IEEE 802.16m MS/BS Control Plane Processing Flow

[***Include the following text and figures in IEEE 802.16m-08_003r1***]

8.1.4 Basic Protocol Architecture for Inter-Base Station Coordination

The generic protocol architecture to support inter-base station coordination for the downlink and uplink are illustrated in Figures 8 and 9, respectively.

In Figure 8, the "Multi-Base Station MAC/PHY coordination" entity is responsible for managing all control plane information exchange (obtained from "Inter-BS Coordination" within each MAC Common Part Sublayer instance) and processing of control plane information, as applicable to specific downlink inter-base station coordination techniques. In particular, it may include a set of "Inter-Base Station Interference Management" entities that are responsible for managing control signaling exchanges among coordinating base stations.

In Figure 9, the "Multi-Base Station MAC/PHY coordination" entity which includes the "Inter-Base Station Interference Management" entity and the "Joint Signal Processing" entity is responsible for managing all inter-base station information exchange and joint processing of control and data plane information, as applicable to specific uplink inter-base station coordination techniques.

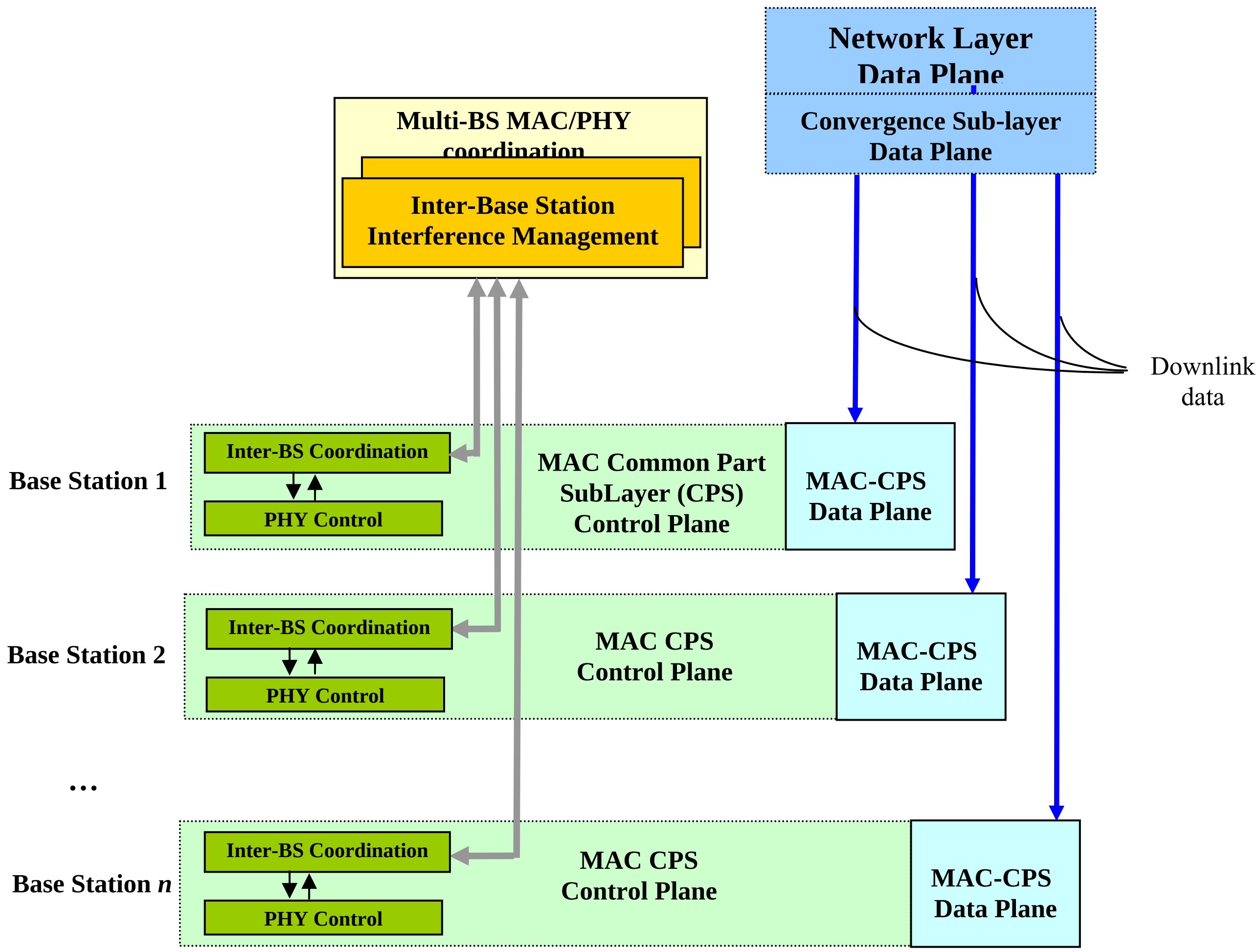

Figure 8 The IEEE 802.16m inter-base station coordination architecture for downlink operation

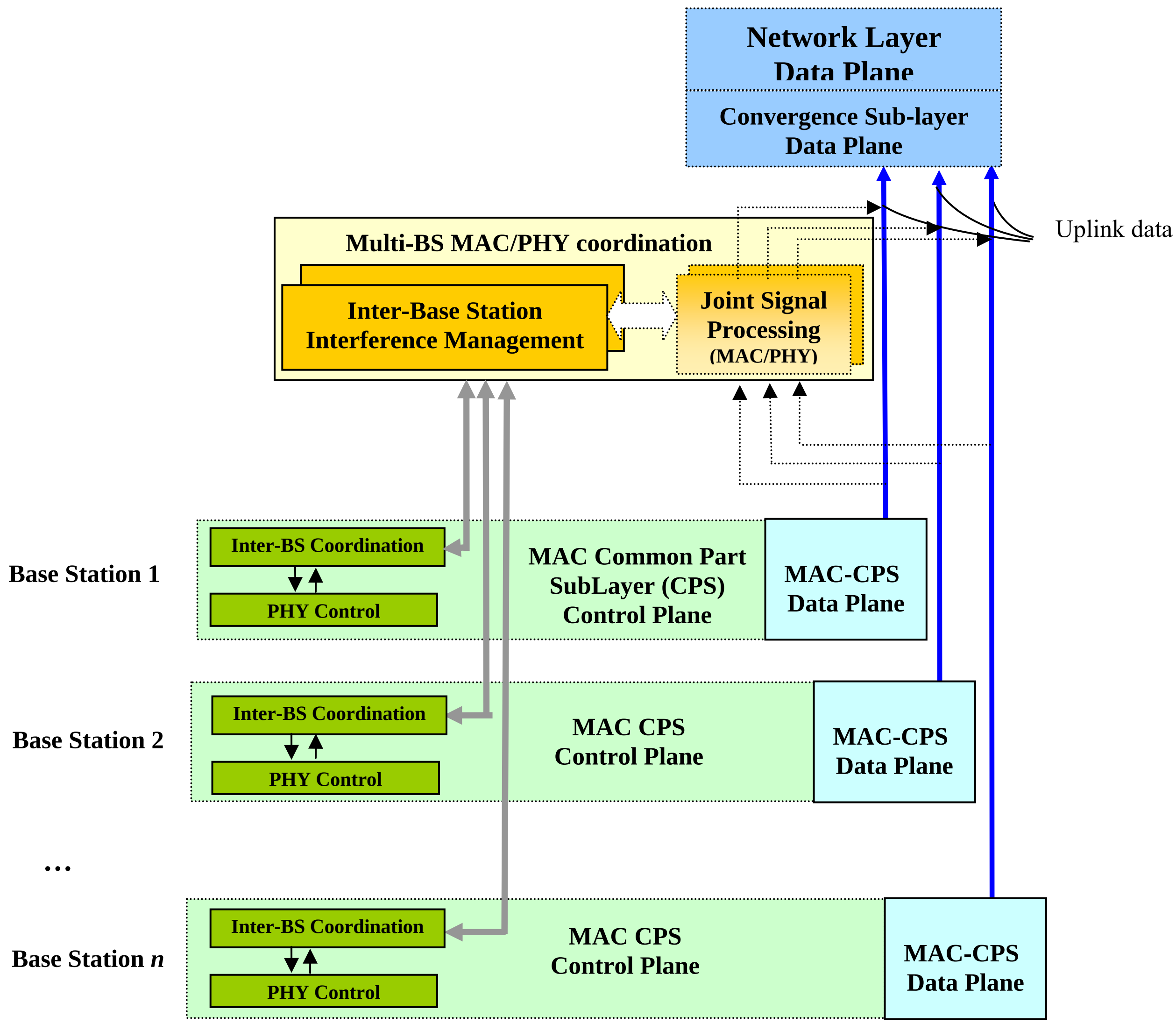

Figure 9 The IEEE 802.16m inter-base station coordination architecture for uplink operation

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References

[1] "Open Loop vs. Closed Loop Inter-cell Power Control Performance Comparison for the E-UTRA Uplink".R1-063479, 3GPP TSG-RAN WG1 #47, Lucent Technologies.

[2] LTE- IMT advanced - Candidate Technologies, 3GPP TSG RAN IMT Advanced Workshop, REV-080045, Shenzhen, China, April 7-8, 2008, Alcatel-Lucent.

[3] "Collaborative MIMO", IEEE C802.16m-07/244r1, Alcatel-Lucent.

[4] "Network MIMO for Inter-cell Interference Mitigation", IEEE C802.16m-08/044r1, Alcatel-Lucent.

[5] “Classification on Interference Management Proposals in TGm”, IEEE C802.16m-08/142r6.

Appendix

The following table provides an overview of MAC/PHY signaling requirements and potential protocol architecture changes that are needed to enable different coordination techniques.

TECHNIQUE	BRIEF DESCRIPTION	MAC/PHY ENABLING TECHNIQUES AND SIGNALING[1]
Uplink Power Control with inter-base station coordination	Enhance uplink power control through exchange of metrics that help predict interference that will be caused to neighboring sectors. Average sector throughput improvement of about 30% reported for the same cell-edge rate in [1].	**Air Interface Signaling**: ▪ Power adaptation parameters **Inter-BS signaling**: ▪ Metrics that predict interference (e.g. IoT measurements)
Fractional Frequency Reuse and Interference-aware scheduling	Interference avoidance/mitigation through adaptive frequency reuse and/or scheduling based on load and interference characterization	▪ **Inter-BS signaling** - Resources/transmission formats allocated, channel state information, interference information
Collaborative MIMO (Downlink)	Improve cell-edge user performance through coordinated multi-base station transmissions and enhance cell throughput via multi-user MIMO technique Results reported in [3] show that collaborative MIMO can improve the cell-edge throughput by up to 70% compared to open-loop SU-MIMO with 4Tx antennas per sector, 2Rx antennas per mobile terminal.	▪ **Air Interface**: - Long-term channel measurements for determining sector-mobile associations (i.e., active set determination) - Pilot/sounding channel signaling for collaborating sector measurements (for SDMA or pre-coding) ▪ **Data Plane**: - Data forwarded to every coordinating sector ▪ **Inter-BS Signaling**: - Long-term channel quality information - Timing synchronization among collaborating sectors - HARQ Management - Resource Allocation - Management of Inter-base station coordination with handover
Network MIMO (Downlink & Uplink)	Joint cooperative multiple sector transmissions or reception (in the case of the uplink) exploiting short-	▪ **Air Interface**: - Pilot/sounding signaling for short-term estimation of channel state

[1] Examples of information that may be signaled over the air interface and/or between base stations in order to enable better interference mitigation than current uncoordinated approaches.

	term channel state information (CSI). Results reported in [4] show that both cell-edge and average sector throughput improve by more than a factor of 2.	information to be used for joint transmit or receive beam-forming ▪ **Data Plane**: - (Uplink) Sampled signals from BSs to a centralized Network MIMO processors - (Downlink) Data forwarded to every coordinating sector ▪ **Inter-BS Signaling**: - (Downlink coordination) Channel state information, resources allocated and transmission formats, power allocation, beamforming weight etc. - Timing and phase synchronization among coordinating sectors - HARQ Management - Management of inter-base station coordination with handover

Table 1: Summary of Inter-Base Station Coordination Enhancements for Improved Interference Management in 802.16m.