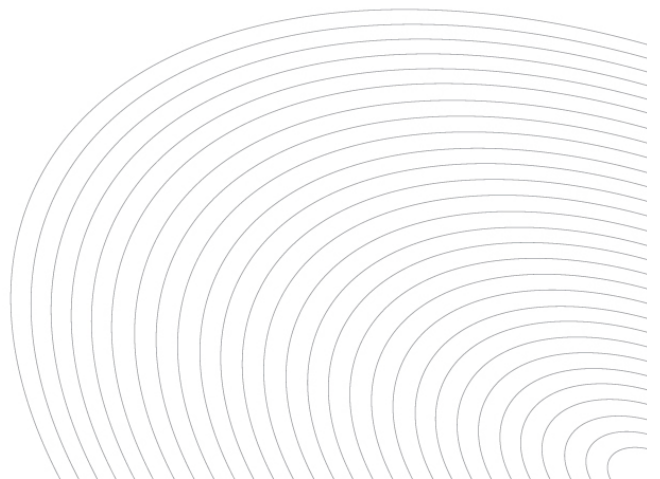




## **WirelessHD Specification Version 1.1 Overview**

**May 2010**



## Preface

### Notice

THIS DOCUMENT IS PROVIDED "AS IS" WITH NO WARRANTIES WHATSOEVER, INCLUDING ANY WARRANTY OF MERCHANTABILITY, NONINFRINGEMENT, FITNESS FOR ANY PARTICULAR PURPOSE, OR ANY WARRANTY OTHERWISE ARISING OUT OF ANY PROPOSAL, SPECIFICATION OR SAMPLE.

Broadcom Corporation, Intel Corporation, LG Electronics Inc., NEC Corporation, Panasonic Corporation, Royal Philips Electronics N.V., SAMSUNG ELECTRONICS, CO., LTD, SiBEAM, Inc., Sony Corporation and Toshiba Corporation and WirelessHD, LLC disclaim all liability, including liability for infringement of any proprietary rights, relating to use of information in this Document. No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted herein.

Copyright © Broadcom Corporation, Intel Corporation, LG Electronics Inc., NEC Corporation, Panasonic Corporation, Royal Philips Electronics N.V., SAMSUNG ELECTRONICS, CO., LTD, SiBEAM, Inc., Sony Corporation and Toshiba Corporation, 2007-2009. All rights reserved. Unauthorized use or duplication prohibited. Third-party brands and names are property of their respective owners.

### Contact Information

Feedback on this document should be addressed to [info@wirelesshd.org](mailto:info@wirelesshd.org)

The URL for the WirelessHD web site is: <http://www.wirelesshd.org/>

# WirelessHD Specification Overview

**May 2010**

## 1 Introduction

The WirelessHD specification defines a wireless protocol that enables consumer devices to create a wireless video area network (WVAN) with the following characteristics:

- Stream uncompressed audio and video up to Quad Full HD (QFHD) resolution, 48 bit color and 240 Hz refresh rates
- Support for 3D video formats
- Efficient data networking using IP
- Flexible wireless connectivity using USB bridging
- Simple, fast file transfer with OBEX.
- Low rate PHY (2.5-40 Mb/s) for omni-directional control and discovery
- Medium-rate PHY (0.5-2 Gb/s) for low power, mobile applications and low-complexity universal bi-directional data support
- High-rate PHY (1-7 Gb/s) for high quality, full resolution video
- Improved coverage and higher data rates (in excess of 28 Gb/s) through the use of the spatial multiplexing high rate PHY (SM-HRP) option
- Video coding to improve link robustness
- HDCP 2.0 in addition to DTCP content protection support
- Advanced A/V and device control protocol
- Unlicensed operation at 60 GHz with a typical range of at least 10 m for highest resolution HD A/V
- Smart antenna technology to enable non line of sight (NLOS) operation
- Data privacy for user generated content

The requirement for high data throughput at distances of 10 m necessitates a large allocated frequency spectrum. A large amount of spectrum is available on an unlicensed basis in many regulatory domains in the 60 GHz band. In North America, South Korea and Japan, a total of 7 GHz is allocated for use, while in the European Union, 9 GHz has been allocated of which 5 GHz of which is overlapping in all of the regions. The band 57-64 GHz is allocated in North America and South Korea, 59-66 GHz is allocated in Japan and 57-66 GHz is allocated in the European Union. The regulations allow very high effective transmit power (the combination of transmitter power and antenna gain), greater

than 10 W of effective isotropic radiated power (EIRP). High EIRP and wide allocated bandwidth will allow high throughput connections that, however, are very directional.

The WirelessHD specification defines a novel wireless protocol that enables directional connections that adapt very rapidly to changes in the environment. This is accomplished by dynamically steering the antenna beam at the transmitter while at the same time focusing the receiver antenna in the direction of the incoming power from the transmitter. This dynamic beam forming and beam steering not only optimizes the line-of-sight link, it allows the use of reflections and other indirect paths when the line-of-sight connection is lost.

This summary document generally follows the order of the WirelessHD specification, revision 1.1. The section headings are the same, i.e., section 5 of this document and the WirelessHD specification both discuss the low rate physical layer (LRP). Subsection numbering, however, is not necessarily the same but does follow the same general order as in the WirelessHD specification.

## **1.1 *New in WirelessHD 1.1***

The following features are new for WirelessHD 1.1

- Support for 3D frame sequential video modes
- Support for 2D 4K (Quad HD), 2D 4K (Quad Full HD), and 2D 4K (Digital Cinema)
- Support for refresh rates up to 240 Hz
- Coded video with scalable coding to preserve picture quality
- Additional HRP modes that extend the data rate from 4 Gb/s to 7.1 Gb/s
- Spatial multiplexing for HRP (SM-HRP) that allows up to 4 concurrent HRP streams (MIMO) for data rates up to 28.5 Gb/s
- Efficient, low-power medium-rate PHY (MRP) with data rates from 0.5-2 Gb/s to support mobile applications
- Two additional LRP channels (5 total) for higher aggregate throughput in a service area and improved coexistence with other WirelessHD WVANs.
- Enhanced robustness for LRP mode 3 (10 Mb/s) by selecting the best TX beam patterns
- Efficient beam forming for SM-HRP and MRP based on the successful HRP and LRP beam forming protocol.

- Support for efficient data transfer with bidirectional CTBs (to reduce higher layer ACK latency)
- USB pass through mode
- Simple file transfer using OBEX running on a link manager (LM) service in the MAC sublayer
- MAC enhancements: Station controlled channel time extension, searching for Station on other channels

## 1.2 Abbreviations

The following abbreviations are used in the specification and this summary

ACK	acknowledgement
ACL	access control list
ATP	association time out period
A/V	audio/video
AWV	antenna weight vector
BER	bit error rate/ratio
BPSK	binary phase-shift keying
CE	consumer electronic
CRC	cyclic redundancy check
CrdID	coordinator identifier
CTB	channel time block
DA	domain authorization
DSC	digital still camera
DM	domain manager
DVC	digital video camera
EEP	equal error protection
FEC	forward error correction
HR	high rate
HRP	high rate physical layer
HMRP	high or medium rate physical layer
HRPDU	high rate protocol data unit
IP	internet protocol
LR	low rate
LRP	low rate physical layer
LRPDU	low rate protocol data unit
MAC	medium access control
MIMO	multiple input, multiple output
MLME	medium access control layer management entity
MR	medium rate
MRP	medium rate physical layer
MRPDU	medium rate protocol data unit
MSC	message sequence chart
NLOS	non line of sight

OBEX	object exchange <sup>1</sup>
OFDM	orthogonal frequency domain multiplexing
PER	packet error rate/ratio
PHY	physical layer
PMP	personal media player
PSMA/CA	preamble sense medium access with collision avoidance
PVR	personal video recorder
QAM	quadrature amplitude modulation
QFHD	quad full high definition
QHD	quad high definition
QoS	quality of service
QPSK	quadrature phase-shift keying
RATB	random access time block
SIFS	short inter-frame spacing
SM	security manager
SMBF	spatial multiplexed beam forming
SM-HRP	spatial multiplexing high-rate physical layer
STB	set top box
STID	station identifier
TDD	time division duplex
UEP	unequal error protection
USB	universal serial bus <sup>2</sup>
WVAN	wireless video area network
WVNID	wireless video area network identifier

## 2 Use cases

### 2.1 Applications

The WirelessHD WVAN supports a variety of applications, but is focused foremost on the delivery of high quality, uncompressed A/V content. The applications supported by the WirelessHD specification are listed in Table 1. The data rates in the table are only approximate, exact values are available in EIA/CEA-861D

**Table 1: Applications supported by WirelessHD**

Application	Data rate	Target latency
Uncompressed QHD (2560x1440p, 59.954/60 Hz, 36 bit color)	8.0 Gb/s	2 ms

<sup>1</sup> The OBEX specification is available from the Infrared Data Association (IrDA) at <http://www.irda.org>

<sup>2</sup> The USB specification is available from the USB Implementers Forum at <http://www.usb.org>

Application	Data rate	Target latency
Uncompressed 720p frame sequential 3D A/V (1280x1440p, 59.94/60 Hz, 36 bit color)	4.0 Gb/s	2 ms
Uncompressed 1080p, 120 Hz (1920x1080p, 119.88/120 Hz, 30 bit color)	7.5 Gb/s	2 ms
Uncompressed 1080p A/V	3.0 Gb/s <sup>3</sup>	2 ms
Uncompressed 1080i A/V	1.5 Gb/s	2 ms
Uncompressed 720p A/V	1.4 Gb/s	2 ms
Uncompressed 480p A/V	0.5 Gb/s	2 ms
Uncompressed 7.1 surround sound audio	40 Mb/s	2 ms
Compressed 1080p A/V <sup>4</sup>	20-40 Mb/s	2 ms
Uncompressed 5.1 surround sound audio	20 Mb/s	2 ms
Compressed 5.1 surround sound audio	1.5 Mb/s	2 ms
File transfer	> 1.0 Gb/s	N/A

The A/V applications are supported with a pixel error ratio of less than  $10^{-9}$  for 24-bit color. This corresponds to an application level bit error rate (BER) of less than  $4 \times 10^{-11}$ .

## 2.2 Typical devices

Both stationary and mobile devices are supported by the specification. Advanced power management methods are available to enable mobile devices.

In addition, while the WirelessHD radios will typically be embedded, the specification supports the creation of external adapters to enable legacy devices.

## 2.3 Specific use cases

Using the applications previously defined, a variety of use cases can be defined. To simplify the number of unique use cases, the potential sources and sinks are grouped as follows:

- HD A/V source: set top box (STB), Blu-ray disc (BD) player, BD recorder<sup>5</sup>, personal video recorder (PVR), broadcast HD receiver, etc.

<sup>3</sup> Some applications require deep color (> 8 bits/pixel)

<sup>4</sup> This specification does not preclude the use of other codecs for compressing A/V data. At a minimum compressed A/V data can be transported as regular data packet.

- Audio source/server: Any of the HD video sources, stereo tuner, broadcast radio receiver.
- HD A/V sink: flat panel display (including LCD, plasma and projection), BD recorder, PVR, etc.
- HD video sink: Same as HD A/V sink, except in the uses case, the audio is delivered to a different location.
- Compressed A/V sink: PVR, BD recorder.
- Compressed A/V source: Personal media players (PMPs), digital video cameras (DVCs), digital audio players, etc.
- Audio sink: Speakers, audio receiver/amplifier
- Data source/sink: PMP, DVCs, digital still cameras (DSCs), digital audio players

A summary of the uses cases is listed in Table 2. In the use cases listed, the destination of the audio or video is not necessarily the display or the Coordinator of the WVAN. Many of the use cases involve multiple destinations of the isochronous data.

**Table 2: Use cases for WirelessHD**

UseCase #	Source(s)	Sink(s)	Data rate(s)	Number of streams
1	HD A/V	HD A/V	3.0 Gb/s	1
2	HD A/V	HD video Audio	3.0 Gb/s 40 Mb/s	2
3	HD A/V Compressed A/V	HD A/V Compressed A/V	3.0 Gb/s 24 Mb/s	2
4	HD A/V HD A/V	HD A/V HD A/V	1.5 Gb/s 1.5 Gb/s	2
5	HD A/V Compressed A/V	HD video Compressed A/V Audio	1.5 Gb/s 24 Mb/s 40 Mb/s	3
6	Audio	Audio	30 Mb/s	1
7	HD A/V	HD A/V HD A/V	1.5 Gb/s 1.5 Gb/s	2
8	Data source	Data sink	1.0 Gb/s	1
9	HD A/V HD A/V	HD A/V HD A/V Audio	0.5 Gb/s 0.5 Gb/s 40 Mb/s	3
10	HD A/V HD A/V	HD A/V Audio Audio	1.5 Gb/s 40 Mb/s 40 Mb/s	3

<sup>5</sup> Any device capable of recording HD content will also be capable of sourcing HD content as well.



UseCase #	Source(s)	Sink(s)	Data rate(s)	Number of streams
11	HD A/V Audio	HD A/V Audio	3.0 Gb/s 40 Mb/s	2

For all of the use cases listed in Table 2, with the exception of use case #6, the high or medium rate physical layer (HMRP) is used for data transfer because it is capable of a throughput well in excess of 7 Gb/s. While the low rate physical layer (LRP) is capable of carrying data, its throughput is less than 40 Mb/s. If no other data transfer is taking place in the network, as in use case #6, the LRP mode may be used for low-rate data streaming of audio. This allows a Station like an flat panel display that does not have a HMRP transmitter to stream audio it receives from over-the air broadcast to remote speakers. Use cases 9 through 11 are not as important as use cases 1 through 8 as they represent usage that are not as likely to occur.

## 2.4 Mobile use cases

Some of the devices listed in 2.3 are mobile and portable devices that have different requirements than stationary devices. The following devices are considered for these use cases:

- Mobile devices: mobile phone, PDA, PMP, DSC, DVC
- Portable devices: laptop PC
- Stationary devices: TV display, TV audio, projector, STB, stereo speakers

The requirements and assumptions are different for mobile and portable devices, as listed in Table 3.

**Table 3: Target requirements for mobile and portable devices**

Device	Power	Antennas	Range
Mobile	< 300 mW	1-4	3-5 m, LOS/NLOS
Portable	< 1 W	~16	10 m, NLOS

The use cases considered as being representative of the wide variety of use cases possible with mobile devices are summarized in Table 4.

**Table 4: Mobile device use case summary**

Use case	#	Data rate	Sender	Receiver	Comments
Mobile display	1.1	1 Gb/s	Mobile phone, PDA, PMP, DSC, DVC	TV, projector, monitor	Source processing enables 1080p at 1 Gb/s, HDMI interface
	1.2	1 Gb/s	Laptop PC	TV, projector, monitor	
Mobile IP	2.1	40 Mb/s	Mobile phone, PDA, PMP, DSC, DVC, laptop PC	PMP, TV, projector or monitor	Compressed 1080p video in IP packets, IP over USB interface (DLNA)
	2.2	50 Mb/s	Mobile phone, PDA, PMP, DSC, DVC or STB/TV with internet connectivity	STB/TV with internet connectivity or Mobile phone, PDA, PMP, DSC, DVC	IP packet exchange, IP over USB interface
	2.3	1 Gb/s	Laptop PC or STB/TV with internet connectivity	STB/TV with internet connectivity or laptop PC	High speed IP packet exchange, IP over USB interface
Audio streaming	3.1	40 Mb/s	Mobile phone, PDA, PMP, DVC, laptop PC	TV audio, stereo speakers	PCM or compressed audio over I2S or S/PDIF interface
Sync&Go	4.1	> 480 Mb/s	Mobile phone, PDA, PMP, DSC, DVC, TV, laptop PC	Mobile phone, PDA, PMP, DSC, DVC, TV, laptop PC	File transfer over native USB, IP over USB or OBEX

## 3 WirelessHD Architecture

### 3.1 Overview

The WVAN consists of one Coordinator and zero or more Stations. The Coordinator is normally, but not always, a device that is a sink for audio or video data, e.g., a display, but also potentially a media storage device like a PVR. A Station, on the other hand, is a device that has media that it can source and/or sink or has data to exchange, potentially at the same time. The device that is the Coordinator also acts as a Station in the WVAN. An example of a WVAN is illustrated in Figure 1.

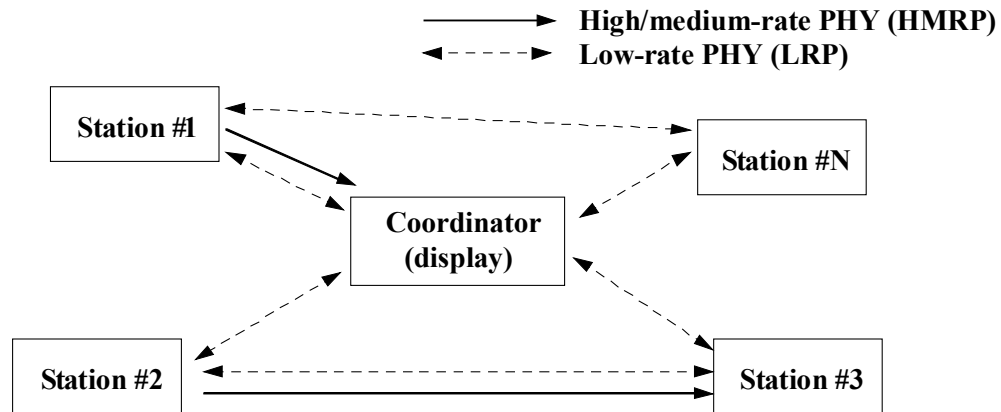


Figure 1: Example of a WVAN

The high-rate PHY (HRP) and medium-rate PHY (MRP) support multi-Gb/s throughput at distance of 10 m through adaptive antenna technology. Because of this, the high-rate or medium-rate PHY (HMRP) is highly directional and can only be used for unicast connections. The HMRP is optimized for the delivery of uncompressed high definition video, other data can be communicated using the HMRP. To support multiple video resolutions, the HMRP has more than one data rate defined. The HMRP carries:

- isochronous data such as audio and video,
- asynchronous data,
- MAC commands,
- antenna steering information, and
- higher layer control data for A/V devices.

The low-rate PHY (LRP) is a multi-Mb/s bidirectional link that also provides a range of 10 m. Multiple data rates are defined for the LRP, with the lower data rates having near omni-directional coverage while the highest data rates are directional. Because the LRP has near omni-directional modes, it can be used for both unicast and broadcast connections. Furthermore, because all Stations support the LRP, it can be used for Station-to-Station links. The LRP supports multiple data rates, including directional modes, and is used to carry:

- low-rate isochronous data such as audio,
- low-rate asynchronous data,
- MAC commands including the beacon,

- acknowledgements for HMRP packets,
- antenna beam forming information,
- capabilities information, and
- higher layer control data for A/V devices.

The HMRP and LRP operate in overlapping frequency bands and so they are coordinated in a TDMA manner by the MAC.

### **3.2 Device capabilities**

There are two types of devices, based on MAC capabilities, in WirelessHD specification; Coordinator and Station.

The Coordinator:

- controls the timing in the WVAN,
- keeps track of the members of the WVAN,
- is able to transmit and receive using the LRP,
- may be able to transmit data using the MRP,
- may be able to receive data using the MRP,
- may be able to transmit data using the HRP, and
- may be able to receive data using the HRP.

A Station:

- is able to transmit and receive using the LRP,
- may initiate stream connections,
- may be able to transmit data using the MRP,
- may be able to receive data using the MRP,
- may be able to transmit data using the HRP, and
- may be able to receive data using the HRP.

In addition to the two MAC personalities of Coordinator and Station, each device in the WVAN has different PHY capabilities. For HRP, the capabilities are:

- HR0 - a device that is not able to either receive or transmit using the HRP,

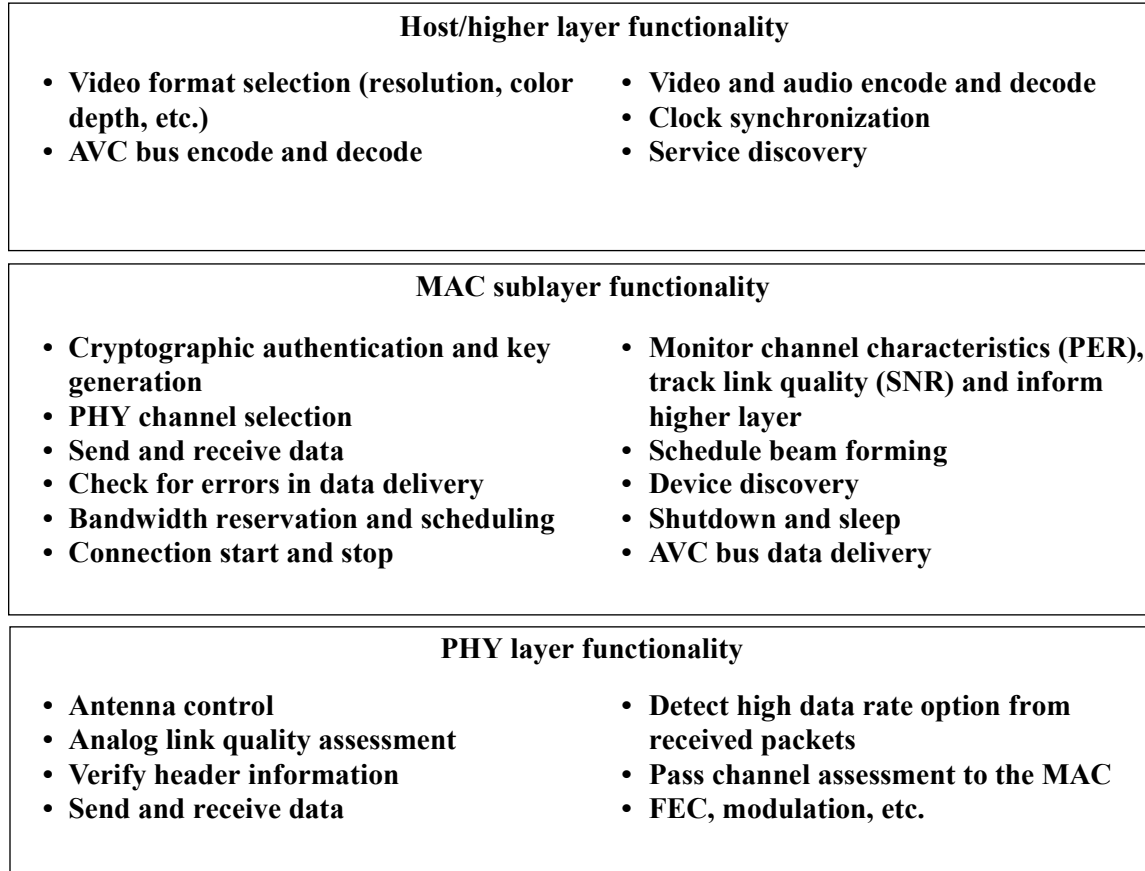
- HRRX - a device that is able to receive in the HRP, but is not able to transmit using the HRP,
- HRTX - a device that is able to transmit in the HRP, but is not able to receive using the HRP, and
- HRTR - a device that is able to both transmit and receive using the HRP.

For MRP, the capabilities are:

- MR0 - a device that is not able to either receive or transmit using the MRP,
- MRRX - a device that is able to receive in the MRP, but is not able to transmit using the MRP,
- MRTX - a device that is able to transmit in the MRP, but is not able to receive using the MRP, and
- MRTR - a device that is able to both transmit and receive using the MRP.

All compliant WirelessHD devices are able to transmit and receive using the LRP.

The major functions supported by the host/higher layer, MAC and PHY are illustrated in Figure 2.



**Figure 2: Functional breakdown of the characteristics of a WirelessHD device.**

The division of functionality between the layers is used only to properly define the functionality of this specification. Only those items in the MAC and PHY are defined in this document. Furthermore, the division of logical functionality does place any requirements on the organization or division of a particular implementation as long as it adheres to the requirements in this specification.

### **3.3 Layering model**

There are four functional divisions in the WirelessHD layering model; the PHY layer, the MAC sublayer, the Adaptation sublayer and the Station Management Entity (SME). The relationships of the various parts is illustrated in Figure 3. There are two protocols in the adaptation sublayer; the AVC protocol and the A/V packetizer. The AVC protocol

performs the device control, the connection control, the device capability and so on. The role of A/V packetizer is to make the formatted A/V data for the HMRP data service.

The four entities provide three types of service: high rate data service, low rate data service, and the management service. The high data rate service supports video, audio and data delivery. The low data rate service supports audio data, MAC commands, and small amounts of asynchronous data. The layering model is defined in the specification only to describe the functionality of the WirelessHD system. It does not describe a required architecture for compliant implementation.

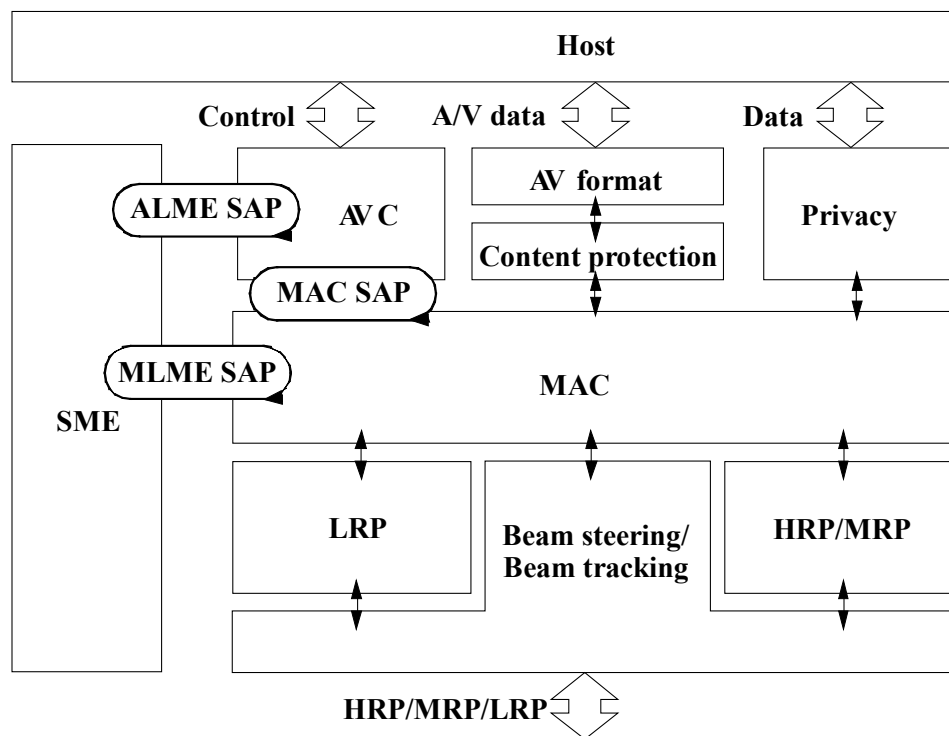


Figure 3: Reference model for WirelessHD specification

## 4 High rate PHY (HRP)

### 4.1 Overview

The HRP is designed to provide greater than 7 Gb/s data rates while delivering a single stream using OFDM modulation and beam steered transmit and receive antennas. Multiple data rates are supported by the HRP with various modulations and coding.

In addition, the HRP may provide greater than 28 Gb/s data rate using spatial multiplexing.

### 4.2 General requirements of the HRP

The general parameters for the HRP are given in Table 5. Unless otherwise specified, the terms sampling rate or sample are in terms of the reference sampling rate. If spatial multiplexing, as defined in 4.6, is used, each data stream has the parameters given in Table 5.

**Table 5: General parameters of the HRP**

Parameter	Value	Symbol
Occupied bandwidth	1.76 GHz	N/A
Reference sampling rate	2.538 Gsamples/s	$f_{s(HR)}$
Number of subcarriers	512	$N_{sc(HR)}$
FFT period	$N_{sc(HR)} / f_{s(HR)} \sim 201.73$ ns	$T_{FFT(HR)}$
Subcarrier spacing	$1 / T_{FFT(HR)} \sim 4.957$ MHz	$\Delta f_{sc(HR)}$
Guard interval	$64 / f_{sc(HR)} \sim 25.22$ ns	$T_{GI(HR)}$
Symbol duration	$T_{FFT(HR)} + T_{GI(HR)} \sim 226.95$ ns	$T_{S(HR)}$
Number of data subcarriers	336	$N_{dsc(HR)}$
Number of DC subcarriers	3	N/A
Number of pilots	16	N/A
Number of null subcarriers	157	N/A
Modulation	QPSK, 16-QAM, 64-QAM	N/A
Outer block code	RS(224,216)	N/A
Inner code	1/3, 1/2, 2/3, 5/6 (EEP), 2/5, 1/2, 4/7, 2/3, 4/5 (UEP)	N/A



A total of four channels in the frequency range of 57-66 GHz are defined for the HMRP.

Due to regulatory restrictions, not all of these channels are available in all geographic regions. The HMRP frequency channels are listed in Table 6. Support of two channels, channel index 2 and channel index 3 is required for all devices.

**Table 6: HMRP frequency plan**

Channel index	Start frequency	Center frequency	Stop frequency
1	57.240 GHz	58.320 GHz	59.400 GHz
2	59.400 GHz	60.480 GHz	61.560 GHz
3	62.560 GHz	62.640 GHz	63.720 GHz
4	63.720 GHz	64.800 GHz	65.880 GHz

### 4.3 HR protocol data unit (HRPDU) format

The HRPDU is formatted as illustrated in Figure 4.

HRP preamble	HRP header	MAC header	HCS	Packet body	Beam tracking
--------------	------------	------------	-----	-------------	---------------

**Figure 4: HRPDU packet format**

The HRP Header, MAC Header and Header Check Sequence (HCS) fields are sent with at the lowest HRP data rate (still about 1 Gb/s). The Packet Body field is made up of up to seven sub-packets to improve the efficiency and the may be sent using any HRP mode that is supported by the source and destination.

The HRP header contains the following information

- Indication if the beam tracking field is present
- Indication if the UEP mode uses coding or mapping
- Initialization for the scrambler
- Number of spatial streams used for the packet
- For each of the seven possible sub-packets
  - The HRP mode index used for the sub-packet
  - The length of the sub-packet

An example of an HRPDU using seven sub-packets is illustrated in Figure 5.

	HRP	HRP	HRP	HRP
--	-----	-----	-----	-----

	<b>mode 0</b>			<b>mode 1</b>			<b>mode 5</b>	<b>mode 3</b>		
Preamble	PHY header	MAC header	HCS	SP <sub>1</sub>	SP <sub>2</sub>	SP <sub>3</sub>	SP <sub>4</sub>	SP <sub>5</sub>	SP <sub>6</sub>	SP <sub>7</sub>

Figure 5: Example packet that utilizes multiple HRP modes for sub-packets

In the example, the first three sub-packets are carrying control, data and audio, respectively, and so the HRP mode uses EEP. The fourth sub-packet is contains a retry of video data, using UEP- MSB to improve the delivery probability. The last three sub-packets contain new video data using a UEP HRP mode.

#### 4.4 HRP RF characteristics

The HRP transmit mask is illustrated in Figure 6.

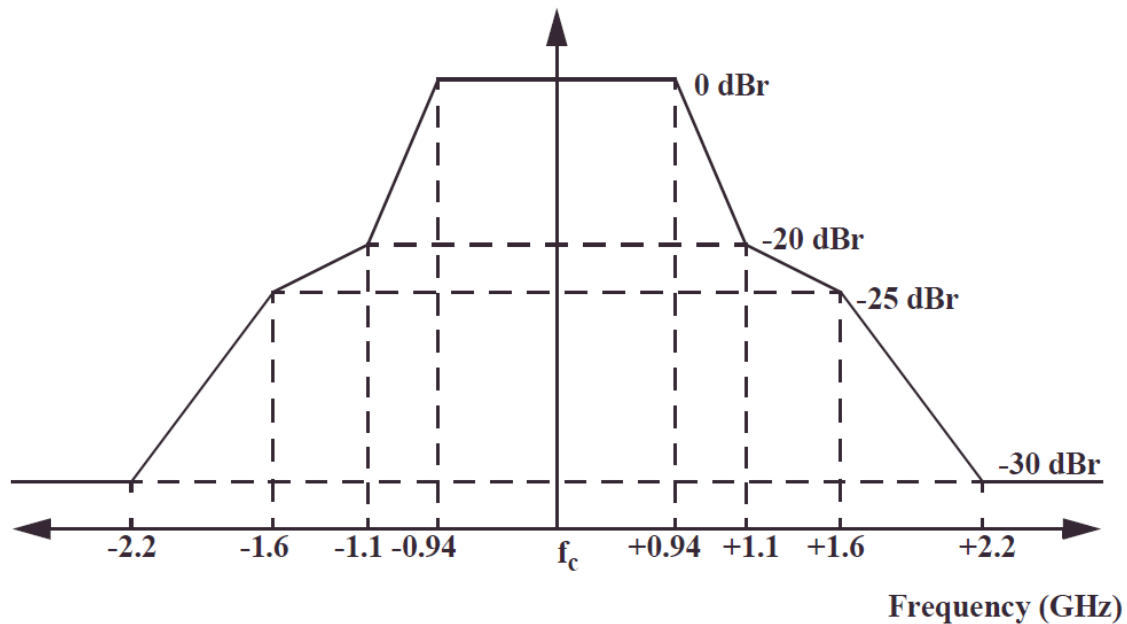
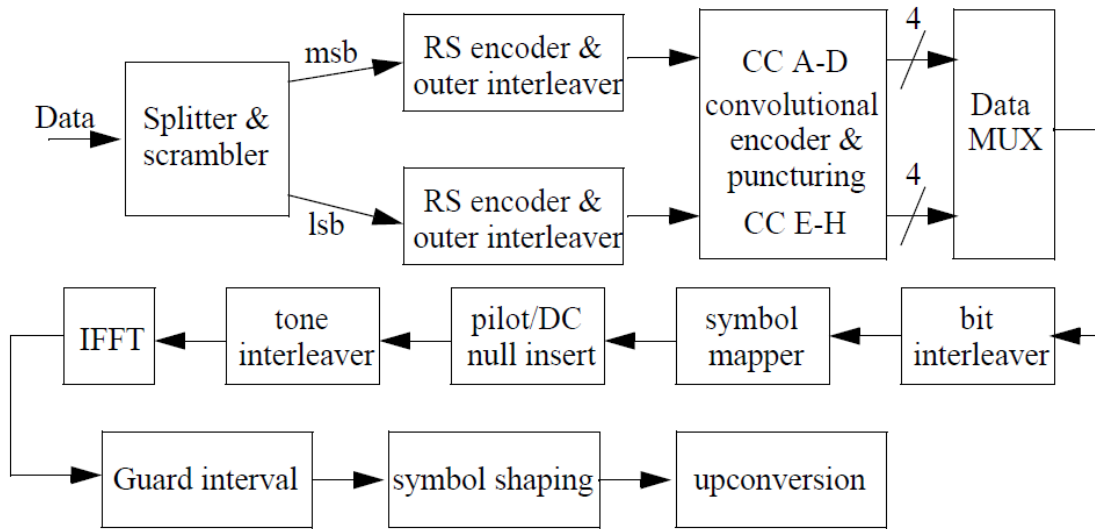


Figure 6: HRP transmit mask

#### 4.5 HRP baseband

The HRP baseband is conceptually composed of the blocks shown in Figure 7.



**Figure 7: HRP reference implementation block diagram**

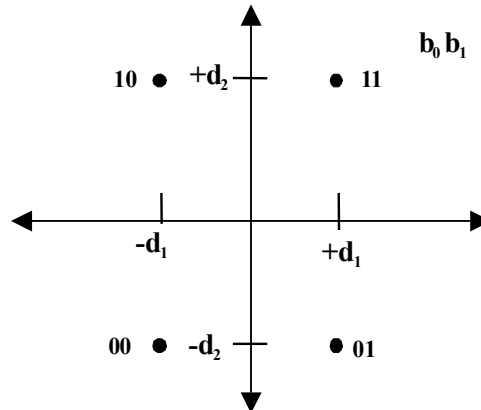
The key characteristics each of the HRP mode indices are listed in Table 7. If a stationary Station supports the use of the MRP or HRP, it shall support the use of HRP mode index 0, HRP mode index 1 and HRP mode index 7. That is, if a stationary Station supports MRP, it shall also support HRP in the same direction, i.e., TX, RX or both TX and RX. If a Station supports an EEP HRP mode index, it shall support all EEP HRP mode indices with raw data rate less than the data rate of that mode. If Station supports an UEP HRP mode index, it shall support all UEP HRP mode indices with raw data rate less than the data rate of that mode.

**Table 7: HRP data rates and coding**

HRP mode index	Coding mode	Modulation	Code rate				Raw data rate (Gb/s)
			MSB		LSB		
			[7] [6] [5] [4]	[3] [2] [1] [0]			
0	EEP	QPSK	1/3				0.952
1		QPSK	2/3				1.904
2		16-QAM	2/3				3.807
3	UEP (coding)	QPSK	4/7		4/5		1.904
4		16-QAM	4/7		4/5		3.807
3	UEP (mapping)	QPSK	2/3				1.904
4		16-QAM	2/3				3.807
5		QPSK	1/3		N/A		0.952

6	MSB-only retransmission	QPSK	2/3	N/A	1.904
7	EEP	QPSK	1/2		1.428
8		QPSK	5/6		2.379
9		16-QAM	1/2		2.855
10		16-QAM	5/6		4.759
11		64-QAM	2/3		5.711
12		64-QAM	5/6		7.138
13	UEP (coding)	QPSK	2/5	2/3	1.428
14		16-QAM	2/5	2/3	2.855
15		64-QAM	4/7	4/5	5.711
13	UEP (mapping)	QPSK	1/2		1.428
14		16-QAM	1/2		2.855
15		64-QAM	2/3		5.711

The QPSK constellation is illustrated in Figure 8.



**Figure 8: QPSK constellation mapping**

The 16-QAM constellation is illustrated in Figure 9.

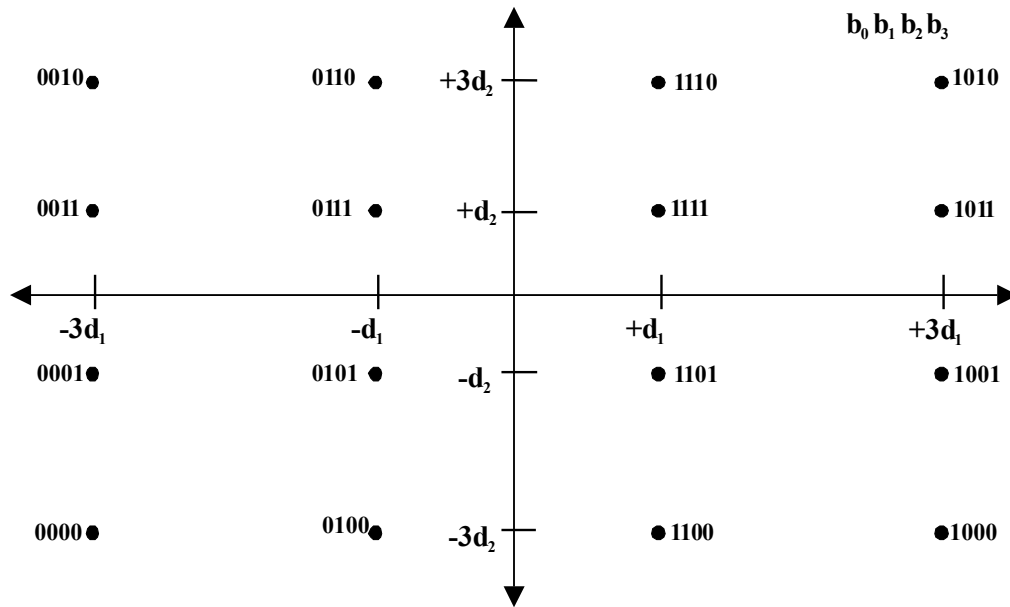


Figure 9: 16-QAM constellation mapping

The 64-QAM constellation is illustrated in Figure 10.

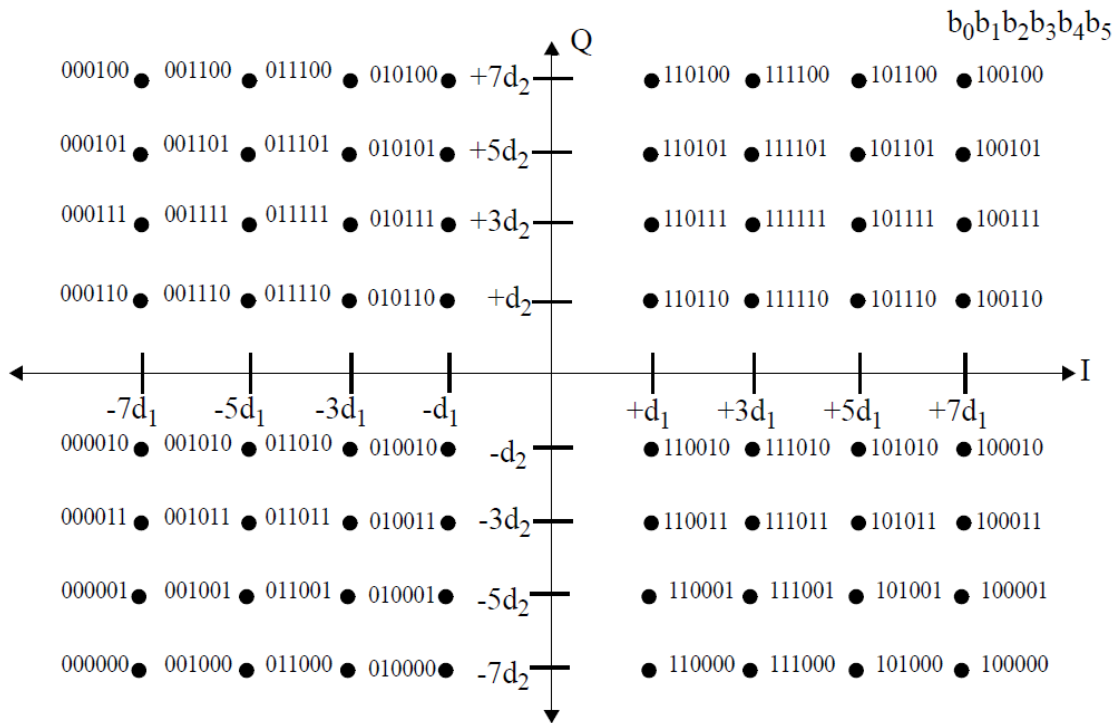


Figure 10: 64-QAM constellation mapping

## 4.6 Spatial multiplexing HRP

The spatial multiplexing HRP (SM-HRP) mode is an optional mode. If a Station supports the SM-HRP, it supports a minimum of two data streams.

A reference implementation of the baseband of spatial multiplexing is illustrated in Figure 26.

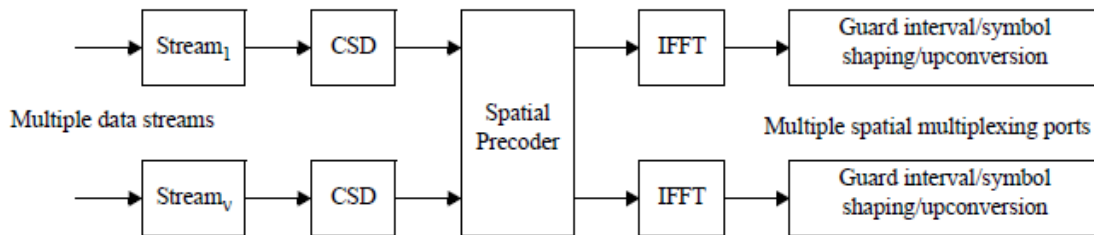


Figure 11: Reference implementation for SM-HRP baseband

The SM-HRP is based on the HRP, using different scrambler seeds, pilot insertion, and beam direction to differentiate spatial streams. In addition, spatial precoding is used to improve performance.

## 5 Low-rate PHY (LRP)

### 5.1 Overview

The LRP uses OFDM and offers omni-directional, directional and beam formed modes. A summary of the LRP modes is given in Table 8.

Table 8: Summary of the LRP modes

LRP mode index	Modulation	FEC	PHY rate (Mb/s)		Repetition	
			omni	beam formed	omni	beam formed
0	BPSK	1/3	2.542	20.337	8x	1x
1		1/2	3.813	30.505	8x	1x
2		2/3	5.084	40.673	8x	1x
3		2/3	10.168	N/A	4x	N/A

A Station shall support omni-directional LRP mode indexes 0, 1 and 2. All other LRP mode indexes are optional.

## 5.2 General requirements of the LRP

The general parameters of the LRP are given in Table 9. Unless otherwise specified, the terms sampling rate or sample are in terms of the reference sampling rate.

**Table 9: General parameters of the LRP**

Parameter	Value	Symbol
Occupied bandwidth	92 MHz	N/A
Reference sampling rate	317.25 Msamples/s	$f_{s(LR)}$
Number of subcarriers	128	$N_{sc(LR)}$
FFT period	$N_{sc(LR)} / f_{s(LR)} \sim 403.47$ ns	$T_{FFT(LR)}$
Subcarrier spacing	$1 / T_{FFT(LR)} \sim 2.4785$ MHz	$\Delta f_{sc(LR)}$
Guard interval	$64 / f_{sc(LR)} \sim 88.26$ ns	$T_{GI(LR)}$
Symbol duration	$T_{FFT(LR)} + T_{GI(LR)} \sim 491.73$ ns	$T_{S(LR)}$
Number of data subcarriers	30	$N_{dsc(LR)}$
Number of DC subcarriers	3	N/A
Number of pilots	4	N/A
Modulation	BPSK	N/A
Header convolutional code	1/3, 1/2	N/A
Data convolutional code	1/3, 1/2, 2/3	N/A

The LRP uses the same frequency bands as the HMRP. In addition, within each of the four HMRP channels, five LRP channels are defined. Only one LRP channel is used by a WVAN at a time. This allows multiple WVANs to use the same HMRP frequency channel in close proximity while minimizing the interference. Each LRP channel is defined relative to the center frequency of the current HMRP channel,  $f_{c(HMRP)}$ . The LRP frequency channels are defined in Table 10. Devices are required to support of all LRP frequency channels in a supported HMRP channels.

**Table 10: LRP frequency plan**

LRP channel index	Start frequency (MHz)	Center frequency (MHz)	Stop frequency (MHz)
0	$f_{c(\text{HMRP})}-366.25$	$f_{c(\text{HMRP})}-317.25$	$f_{c(\text{HMRP})}-268.25$
1	$f_{c(\text{HMRP})}-207.625$	$f_{c(\text{HMRP})}-158.625$	$f_{c(\text{HMRP})}-109.625$
2	$f_{c(\text{HMRP})}-49$	$f_{c(\text{HMRP})}$	$f_{c(\text{HMRP})}+49$
3	$f_{c(\text{HMRP})}+109.625$	$f_{c(\text{HMRP})}+158.625$	$f_{c(\text{HMRP})}+207.625$
4	$f_{c(\text{HMRP})}+268.25$	$f_{c(\text{HMRP})}+317.25$	$f_{c(\text{HMRP})}+366.25$

### 5.3 LR protocol data unit (LRPDU) format

Various LRPDU formats are defined. The omni LRPDU is illustrated in Figure 12. The omni LRPDU is used for broadcast packets, such as the beacon, and for packets for which the timing or direction is not known a-priori.

Omni LRP preamble	Omni LRP header	MAC header	HCS	Packet body
-------------------	-----------------	------------	-----	-------------

**Figure 12: Omini LRPDU packet format**

The beam formed LRPDU uses a shorter preamble because the beam forming process allows faster acquisition of the packet. Beam formed LRPDU's provide higher data rates but require that the link between the stations uses the beam forming process. The beam formed LRPDU format is illustrated in Figure 13.

Beam formed LRP preamble	Beam formed LRP header	MAC header	HCS	Packet body
-----------------------------	---------------------------	------------	-----	-------------

**Figure 13: Beam formed LRPDU packet format**

The Omni LRP header and the Beam Formed LRP header contain the LRP mode, the Packet Body length and the scrambler initialization.

The directional LRPDU is used for acknowledging HMRP packets and for small amounts of data. The format of this packet is illustrated in Figure 14.

Directional LRP preamble	Directional LRP header	Directional LRP payload
--------------------------	------------------------	-------------------------

**Figure 14: Directional LRPDU packet format**



## 5.4 LRP RF characteristics

### 5.4.1 LRP transmitter requirements

The LRP transmitter spectral mask is shown in Figure 15.

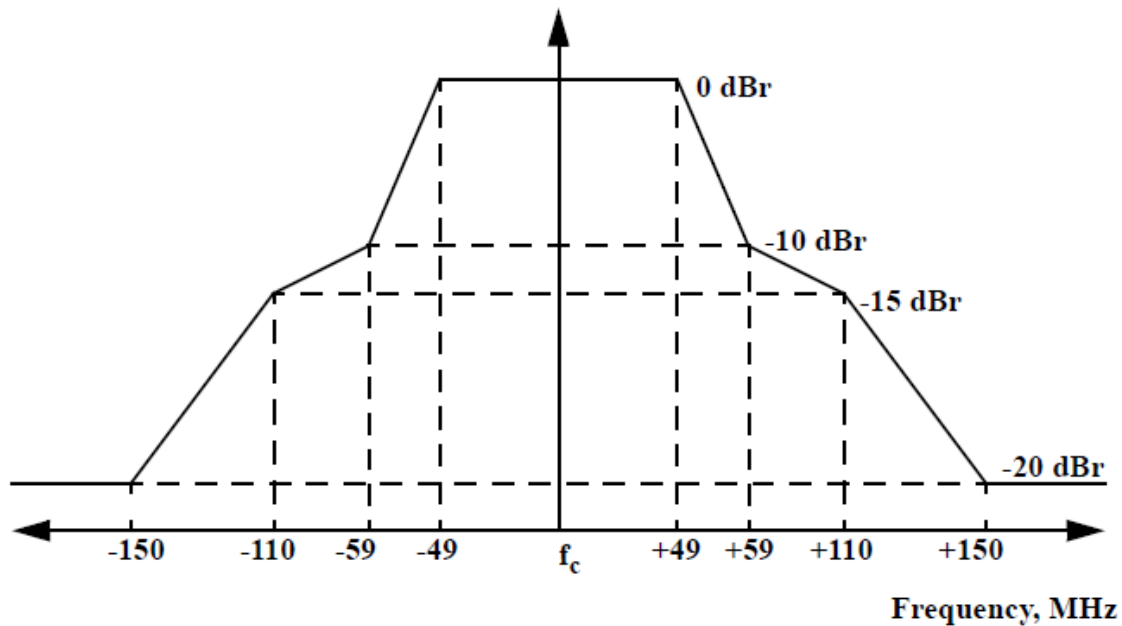


Figure 15: LRP TX mask

## 5.5 LRP baseband

The LRP baseband reference architecture is illustrated in Figure 16.

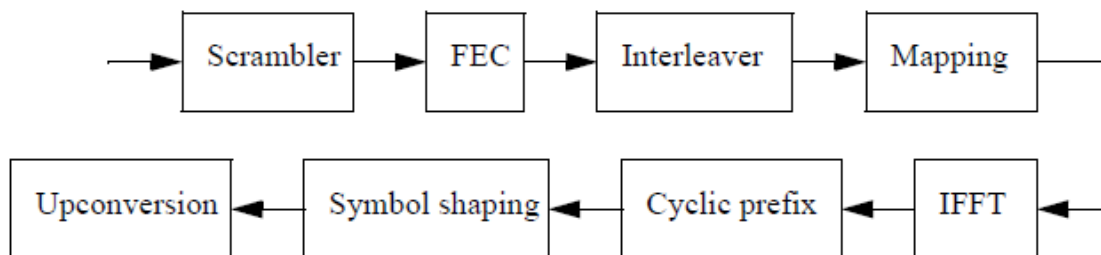


Figure 16: LRP baseband reference architecture

## 6 Beam forming

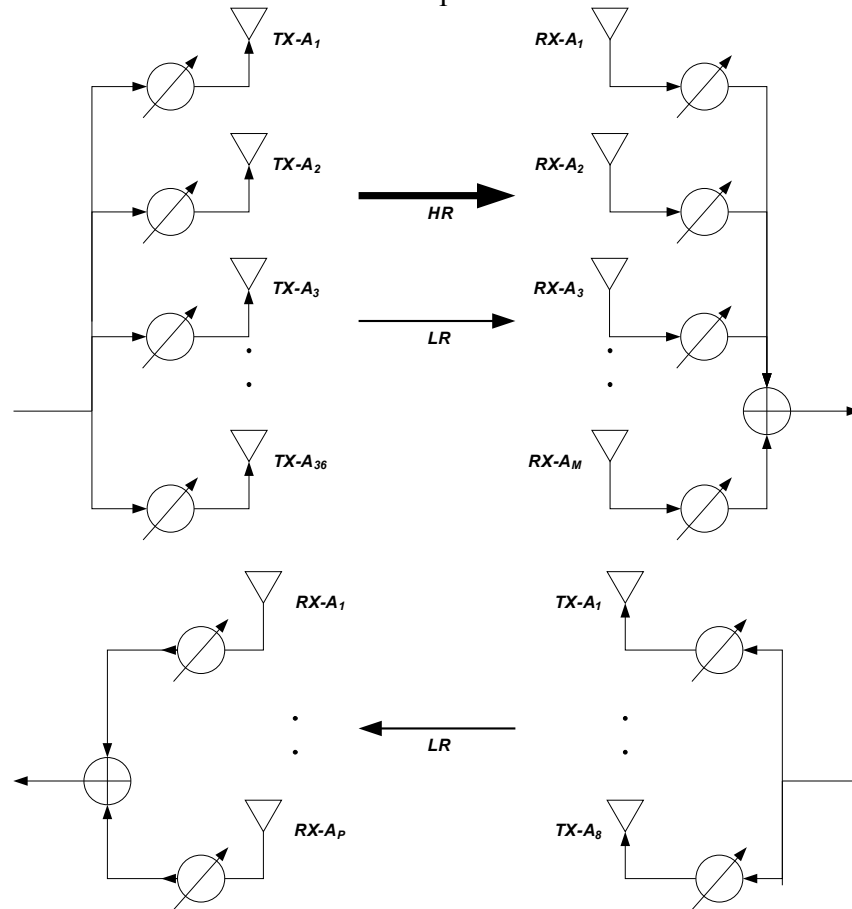
Two different methods for beam forming are defined in the specification. The first, explicit feedback beam forming, is a method that supports all types of WirelessHD devices, HRRX, HRTX and HRTR. There is no requirement that the transmitter and receiver for a station are the same and no calibration is required. The second, implicit feedback beam forming, can only be used when both the source and destination are HRTR capable.

The beam forming requirements for Stations are:

- All Stations that support HRP for TX, RX or both TX and RX support the HRP explicit beam forming protocol and packet formats.
- All Stations that support MRP for TX, RX or both TX and RX shall support the MRP explicit beam forming protocol and packet formats.
- Stations may also support the LRP explicit beam forming protocol and/or the extended HRP beam forming protocol and their associated packet formats.
- All Stations that support SM-HRP for TX, RX or both TX and RX shall support the SM-HRP beam forming protocol and packet formats.

### 6.1 *Explicit feedback beam forming*

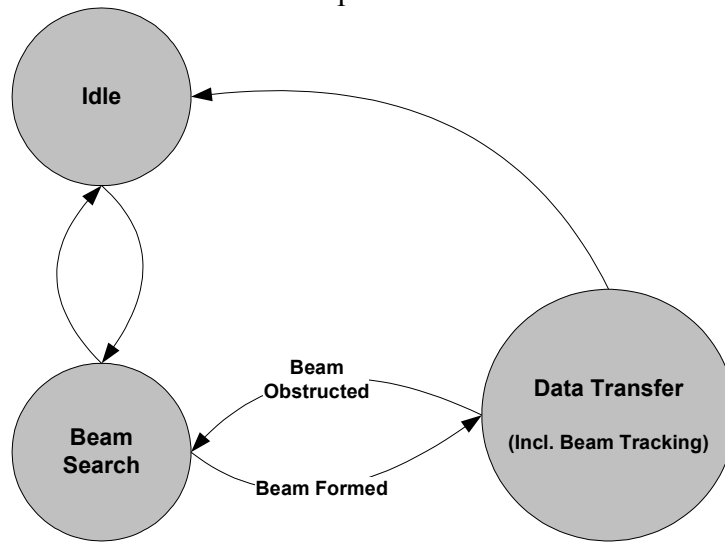
In order to provide Gb/s data rates at 10 m, high gain antenna networks are required in the 60 GHz band. While these arrays are small, it is important that the beam that is created can be steered around obstacles to find the best path from transmitter to receiver. Figure 17 shows the arrangement of a typical phased array system.



**Figure 17: General WirelessHD antenna array configuration**

This process consists of beam search and beam tracking. Beam search is the process of estimating the transmitter and receiver antenna-array weight vectors (AWVs) that result in the optimum (highest gain or highest SNR) beam over the channel between the beam-forming transmitter and receiver. Beam tracking is the process of tracking transmitter and receiver AWVs that correspond to the existing beam over time due to small perturbations of the channel. While beam search is a stand-alone process using a dedicated time-interval, beam tracking takes place during the data transfer and is appended to existing HMRP, or beam-formed LRP, packets and corresponding ACK packets.

The state transitions for adaptive beam forming are illustrated in Figure 18.



**Figure 18: Overall adaptive beam-forming state transition**

The explicit beam forming method is defined for use with HRP, MRP and LRP.

## **6.2 Spatial multiplexing (SM) HRP beam forming**

Explicit-feedback SM-HRP beam-forming is carried out in conjunction with transmission of SM-HRP packets. The number of spatial streams that are formed depends on the condition of the corresponding multi-input multi-output (MIMO) channel and may be up to the maximum number of spatial multiplexing ports on the TX and RX side, i.e. number of TX and RX digital processing ports.

SM-HRP beam-forming uses a general framework similar to that of explicit beam forming.

The spatial multiplexing system architecture may be either a split-antenna architecture as illustrated in Figure 19, or a shared-antenna, as illustrated in Figure 20.

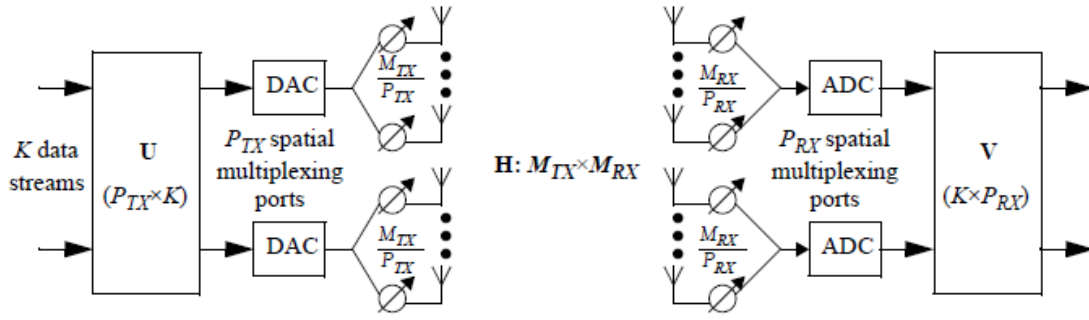


Figure 19: Split antenna spatial multiplexing system architecture

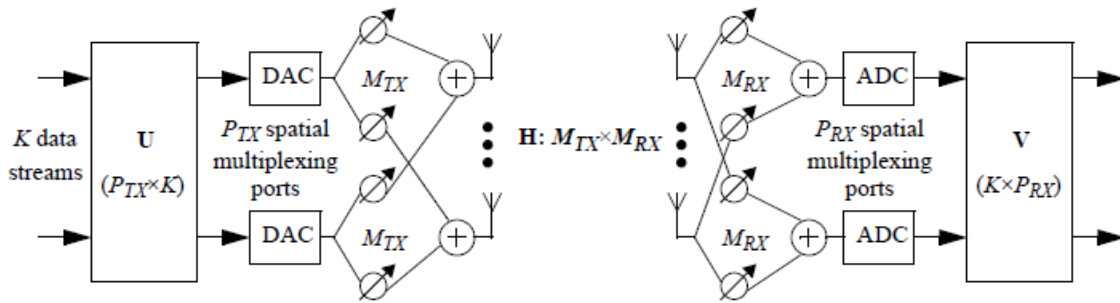


Figure 20: Shared antenna spatial multiplexing system architecture

### 6.3 Implicit feedback beam forming

The implicit feedback approach to beam forming requires that a pool of candidate beam vectors, called a beam book, for the transmitter and receiver. This beam book is maintained at both the transmitter and receiver. A possible architecture for an implicit feedback beam forming system is illustrated in Figure 21.

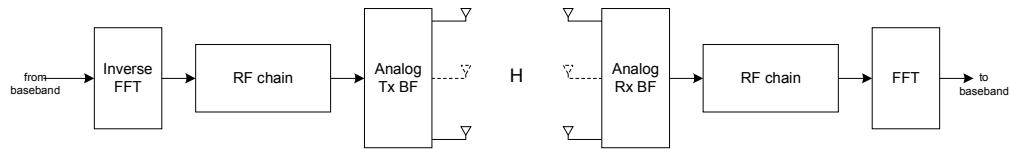


Figure 21: Example architecture for beam book beam forming system.

The state transitions for the implicit feedback beam forming method are illustrated in Figure 22.

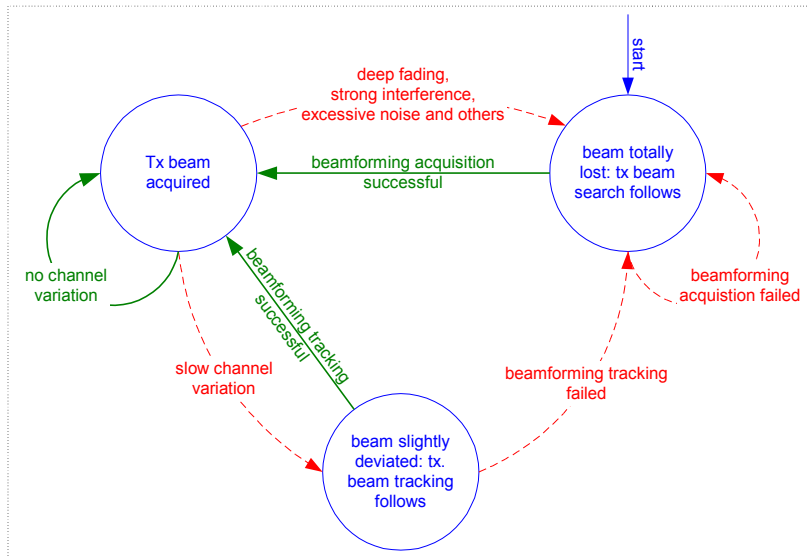


Figure 22: Illustration of the beam book beam forming state transition

## 7 MAC specification

### 7.1 MAC overview

The basic timing of the WVAN is based on a superframe, the duration of which is set by the coordinator. Note that the superframe is not necessarily associated with a video frame. Each superframe begins with a beacon sent by the Coordinator. The start of the superframe and all subsequent timing is measured from the first symbol of the PHY preamble of the beacon.

The superframe may have zero or more contention periods, called random access time blocks (RATBs) that are used by Stations to send packets if they do not have time allocated to communicate with the desired destination.

The superframe may contain zero or more channel time blocks (CTBs) that are assigned to a specific source identifier (SrcID) and destination identifier (DestID). CTBs are used to send data, both asynchronous and isochronous, between two or more Stations and/or the Coordinator. Either the HMRP or LRP can be used in a CTB, however in most cases

the HMRP is used to send data to avoid taking up too much of the time resources in the network.

The number, length and position of the CTBs and any contention periods are determined by the Coordinator based on requests from the Stations and is communicated in the beacon.

## **7.2 *Start, maintain and shutdown WVANs***

### **7.2.1 Beacon announcements**

The Coordinator may place some information elements (IEs) in the beacons to inform the Stations in the WVAN. Some IEs are typically sent in every beacon, such as the Schedule IE or the RATB Allocation IE, while others are only sent if certain operations are in use, such as PS mode. Other IEs are only sent to indicate a change in the condition of the WVAN. IEs that are announced are placed in consecutive beacons at least the number of times required, unless the Coordinator has run out of room in the beacon.

### **7.2.2 Channel scanning and selection**

Before starting a WVAN, the Station shall scan a specified set of LRP channels and corresponding HMRP channels before starting a new WVAN. The Coordinator will pick the HMRP channel and an LRP channel within that HMRP channel that has the lowest level of interference based on a passive scan of the channels. The method for selecting the channel is implementation dependent.

Once the WVAN is operating, the Coordinator is able to use the current channel assessment procedure to estimate the current channel status by collecting information from other Stations in the WVAN. The Coordinator is also able to request that the Stations in the WVAN search other HMRP channels to see if they are available using the new channel searching procedure.

### 7.2.3 Starting a WVAN

A WVAN begins when a Station takes on the responsibility of being the Coordinator. The Station will start the new WVAN in the ‘best’ LRP and HMRP channel pair that was found during the scanning process. Once the Station has selected a channel, it listens to the selected LRP channel to see if it is still clear. If at the end of this listening period the channel is clear, the Station, now the Coordinator, begins broadcasting its beacon once every superframe. When the WVAN begins, the Coordinator allocates an additional Station ID (STID) to itself for the purposes of exchanging data with other Stations that become members of the WVAN.

### 7.2.4 Changing WVAN configuration

The Coordinator may change some of the key characteristics of the WVAN. In particular, the Coordinator may change the following characteristics:

- WVAN identifier (WVNID)
- Beacon position
- Superframe duration
- Channel index

When one of the parameters needs to be changed, the Coordinator announces the change in the beacon and the number of the beacon for which the change will take effect.

### 7.2.5 Coordinator handover

The first coordinator capable station that turns on will become the Coordinator of the WVAN. However, the current Coordinator may need to handover Coordinator responsibility to another Station in the WVAN. In addition, in the case that the Coordinator suddenly ceases operation, it is important that another Station takes over Coordinator responsibilities as fast as possible. There are three entities involved in the Coordinator handover process:

- Current Coordinator – The Station currently acting as Coordinator
- New Coordinator – The Station that has been selected to take over as Coordinator in an active handover process.



- Next Coordinator – The Station that has been selected by the Current Coordinator to take over in the event that the Current Coordinator ceases operation without handing over.

Three types of Coordinator handover processes are defined in this specification:

- Regular handover – The Coordinator will transfer the required information to the New Coordinator prior to handing over control of the WVAN.
- Fast handover – The Coordinator has previously passed the required information to the New Coordinator via the Preliminary Handover process, as defined in , and so the handover proceeds without sending any additional information.
- Implicit handover – The Next Coordinator loses contact with the Coordinator and takes over as the Coordinator of the WVAN.

The information required by either the Next Coordinator or New Coordinator to take over as Coordinator of the WVAN is called the Coordinator relevant information and includes the following information:

- Information about the Stations that are currently associated in the WVAN (i.e., MAC address, MAC capabilities, PHY capabilities, STID, etc.).
- The current requests from stations for CTBs.
- The power save status of Stations in the WVAN.

Regular handover begins when the Current Coordinator notifies a Station in the WVAN that it has been selected to be the New Coordinator. After all of the current Coordinator relevant information has been sent to the New Coordinator, the Current Coordinator begins a countdown of the superframes until the superframe in which the New Coordinator will take over as the Coordinator of the WVAN.

When a new Station joins the WVAN, the current Coordinator will compare the Order ID of the new Station with its own Order ID. The priority order, type of device and Order ID are listed in Table 11. If the Order ID of the new Station is higher than the priority order of the Coordinator, the Coordinator will handover to the new Station. On the other hand, if the Order ID of the new Station is the same as that of the Current Coordinator, then the Current Coordinator may handover control to the new Station.

Priority order	Devices	Order ID
Top	DTV	0
Primary	STB	1
	DVD/BD player	2
	DVD/BD recorder	3
	A/V receiver	4
	Personal computer	5
	Video projector	6
Non-primary	Game console	7
	Digital video camera	8
	Digital still camera	9
	PDA	10
	PMP	11
	MP3 player	12
	Cell phones	13
	Others	14

To enable fast handover and implicit handover, the Coordinator will transfer the Coordinator relevant information to the Next Coordinator as that information changes. If none of this information has changed when the Current Coordinator begins handover, then the fast handover method can be used.

Implicit handover is used to handle the case when the Coordinator suddenly goes away, e.g., the Coordinator is powered off in such a way that handover is not performed or when the Coordinator moves out of range of the rest of the Stations in the WVAN, or vice versa.

If the Next Coordinator fails to receive a specified number of beacons from the Coordinator, it will send a Probe Request command to the Current Coordinator to attempt to determine if the Current Coordinator is still operating. If the Next Coordinator fails to receive an acknowledgement to this packet, it will assume that the Current Coordinator has ceased operation. The Next Coordinator will then take over as the Coordinator of the WVAN by sending a beacon at the next scheduled superframe start.

### **7.2.6 WVAN shutdown**

The Coordinator shuts down the WVAN by notifying the Stations in the WVAN via the beacon of the beacon number of the last beacon that it will send.

## **7.3 *Device and service discovery***

A Station requests that the Coordinator sends information about either a single Station or a group of Stations or all Stations in the WVAN by sending a WVAN Information Request command to the Coordinator. The coordinator responds with the WVAN Information response command with the requested information if the Station is a member of the WVAN.

Using the Probe Request command, the Station can request information elements (IEs) from a target Station. The target Station upon receiving the Probe Request command responds to the originator Station with the requested IEs using the Probe Response command.

Using the Announce command, a Station sends unrequested IEs to a target Station. This command will have one or more IEs that the originator Station is sending to the target Station.

Remote Station search is used to find Stations that do not support the WVANs current HMRP/LRP channels. The Coordinator sends a request to the Stations in the WVAN to begin searching for other Stations. Stations that accept the request, change to other channels, start temporary WVANs and report back to the Coordinator with the information of the Stations that were found on those channels.

## **7.4 *Association and disassociation with a WVAN***

### **7.4.1 Association**

An unassociated Station initiates the association process by sending an Association Request command to the coordinator. Upon receiving the Association Request command, the coordinator sends an Association Response command indicating either that

- The Station has been associated and the STID has been assigned, or
- The request has been rejected with the reason for the rejection

If Coordinator lacks the resources to support adding a new Station, it will send an Association Response command with the reason code set to indicating the reason why it cannot support the requesting Station. If the coordinator finds that the Station was previously associated on its WVAN, the Coordinator updates the information for the Station. If sufficient resources are available, the coordinator sends an Association Response command with the reason code set to Success.

After the Station associates with the WVAN, the Coordinator announces the new Station in the beacon to enable other Stations in the WVAN to initiate connections, if desired, with the new Station.

The coordinator ensures that one STID is associated with one device at any given time within the WVAN. The only exception to this is the Coordinator itself. The Station serving as the Coordinator has two values of STID associated with it, one for the coordinator function and the other for all of the non-coordinator traffic. Hence the coordinator is seen as two logical operational entities within the same Station.

### **7.4.2 Disassociation**

Either the Coordinator or the Station initiates the disassociation process. The coordinator removes a Station from the WVAN by sending a Disassociation Request command with an appropriate reason code to the Station. Similarly a Station may disassociate from the WVAN by sending a Disassociation Request command to the coordinator with an appropriate reason code.

All Disassociation Request commands, when received correctly, are acknowledged by the intended recipient. Even if the Coordinator does not receive the acknowledgement, the Coordinator will consider the Station disassociated. Similarly, after sending the Disassociation Request command, the Station will consider itself disassociated, even if the acknowledgement is not received from the coordinator.

For each Station in the WVAN, the coordinator maintains timer, called the association timeout period (ATP) timer. If the coordinator does not receive any packet originating from an associated Station within the ATP duration, it will disassociate the Station from the WVAN.

If the Station does not receive the beacons from the Coordinator longer than the ATP, the Station will consider itself disassociated from the WVAN and may try to associate again.

When a Station is disassociated for any reason, the Coordinator announces this via the beacon to other Stations in the WVAN.

## **7.5 *Multiple WVAN management***

### **7.5.1 Drone WVAN**

A Drone WVAN (D-WVAN) is a WVAN temporarily formed under an established WVAN but in the different frequency channel (HMRP, LRP or both) to accommodate more connections. The original WVAN then becomes the “home” WVAN (H-WVAN). The D-WVAN functionality is useful for accommodate more AV connections when there is no more time available in the H-WVAN.

The D-WVAN acts as an autonomous WVAN except it uses a distinct D-WVAN ID that indicates its hierarchical position (i.e. it is not H-WVAN). All new Stations associate first with the H-WVAN before attempting to associate with the D-WVAN.

The Drone Coordinator (D-Coordinator) also acts as autonomously as the original Home coordinator in the D-WVAN. The Stations in the D-WVAN are also members of the H-WVAN and the membership is always maintained even though they are temporarily staying in the D-WVAN. However, PS mode is not supported in the D-WVAN and the D-Coordinator will reject all requests to change to PS mode.

Stations will typically start a D-WVAN when no more bandwidth reservation is possible because the network resources are completely occupied by other connections. The Station that was to be the source of the stream, the originator, will begin the process by sending

the D-WVAN IE in an Announce Request command to the Station that was to be the destination of the stream, the target. If the target Station does not accept the request or does not support D-WVAN operation, it will respond with an Announce Response command with the Reason Code set to request refused or unsupported IE, respectively.

If the target Station accepts the request, it shall request to enter PS mode and then begin to search for an appropriate channel on which to become the D-WVAN coordinator. When the target Station finishes the channel search process, sends a response to the originator Station with the result of the search. If the search was successful, then the response contains the new channel information and the DWVNID that will be used in the D-WVAN. If the search failed or the target Station wants to cancel the process, the Reason Code shall be set to indicate the reason for failure.

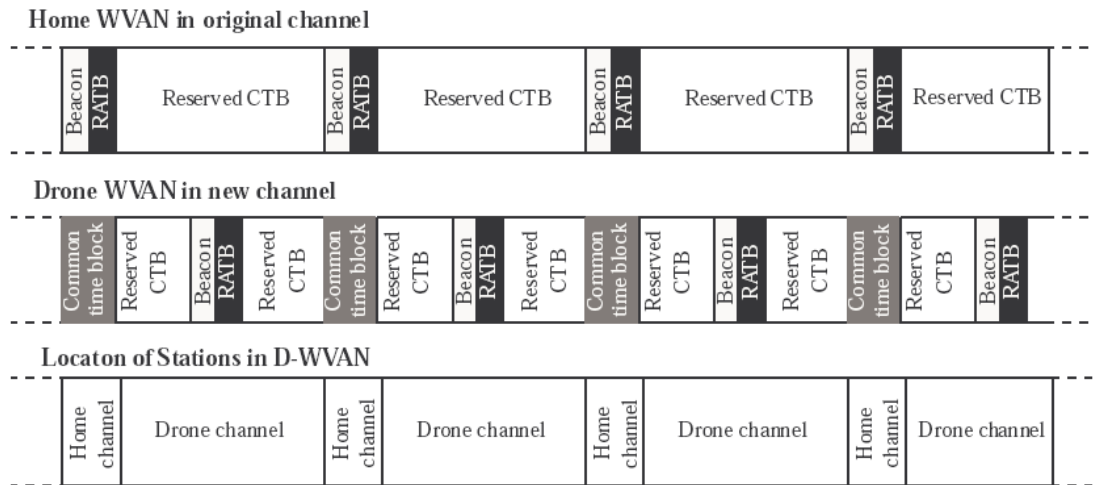
The target Station will then request to enter DRONE mode and if successful, will change to the selected channel and begin sending beacons as the D-Coordinator of the D-WVAN. When the originator Station sees that the target Station has entered DRONE mode, it may change to the new channel and attempt to associate with the D-WVAN, using the regular association protocol. The H-Coordinator may refuse the request to allow a Station to enter DRONE mode.

A Station leaves a D-WVAN and returns to the H-WVAN by first disassociating with the DWVAN and then changing back to the H-WVAN channel.

D-WVAN message link may be used by Stations that need the link time between H-WVAN and D-WVAN to maintain AVC control message link or to update their ATP and is optional for all other Stations. To maintain the control message link, any stations in D-WVAN may stay in the H-WVAN for a certain duration in a superframe periodically.

The Stations that use this feature keep the timing of the H-WVAN's beacon when the station leaves the H-WVAN to decide when to switch to the H-WVAN, which is called dropping in to the H-WVAN. The frequency with which a Station returns to the H-WVAN to listen to the beacon and RATB is related to the control latency and other implementation concerns. Stations dropping in to the H-WVAN stay in the H-WVAN at

least as long as the H-WVAN's beacon duration plus the RATB following the beacon, if present. The Station may also decide stay in the H-WVAN as long as necessary. The arrangement of dropping in time with respect to the H-WVAN timing is illustrated in Figure 23.



**Figure 23: Common time block allocation in D-WVAN**

### 7.5.2 Concurrent association

On power-up a device may be able to receive beacon frames from multiple Coordinators, with each Coordinator running their own WVAN network. A Station is allowed to establish an association for each WVAN it detects. No special coordination of the WVAN's is required to support concurrent association.

After successful association with each WVAN, the device sets itself into PS mode operation. The duration of sleep state has to be such that, the device is able to operate in the unsynchronized WVANs.

If the application layer on the device initiates or is the target of an isochronous stream connection, the MAC layer changes its power management mode and disassociates with each of the other WVANs with which it is associated.

## 7.6 Channel access

### 7.6.1 Superframe structure

Time division, multiple access (TDMA) is used to coordinate all transmissions in the WVAN, including HMRP and LRP. At any one time one of the two PHYs is used for transmission. The beacon packet is transmitted periodically to identify the start of the superframe and to communicate management information for the WirelessHD WVAN.

CTBs are allocated in groups called a schedule. In each superframe, a schedule has one or more CTBs associated with it. For a given schedule, the CTBs are all the same size.

Multiple schedules may be allocated for one stream or an asynchronous allocation.

Multiple streams belonging to the same Station may also be transmitted during the CTBs of a single schedule. One or more packets may be sent in each CTB.

The Schedule IEs and RATB Allocation IEs in the beacon apply to the following superframe. That is, the timing information in beacon number N applies to the superframe that begins with beacon number N+1. This allows sufficient time for the Stations to process the timing information in the beacon before they are required to use the information for channel access.

RATBs are used to allow Stations to transmit without the need to request channel time. A superframe may contain one or more RATBs. RATBs may be allocated in one of the following manner by the coordinator:

- as a contention period (SrcID = BcstID, DestID = BcstID),
- for Coordinator Receive (SrcID = STIDn, DestID = CrdId),
- for Coordinator Transmit (SrcID = CrdId, DestID = STIDn), or
- for a Station pair (SrcID = STIDx, DestID = STIDy).

The Coordinator may allocate RATBs in the superframe for specific purposes, such as bandwidth reservation.



### 7.6.2 Contention periods

A contention period is defined to be a RATB with the SrcID field set to BcstID. Stations use PSMA/CA to access the medium during a contention period using the LRP.

Each contention period has N backoff slots which translates to N+1 transmit opportunities. N is currently set to 4. A backoff slot is composed of the time to detect the channel as clear and the receive to transmit turnaround time, called the short inter-frame spacing (SIFS). The backoff procedure uses the truncated binary exponential backoff mechanism.

### 7.6.3 Bidirectional CTB usage

Regular CTBs are unidirectional, i.e., data is only allowed to be carried in one direction, from the source of the CTB to the destination of the CTB. Stations that support data protocols such as IPv4, IPv6 or USB need to be capable of high-speed communication using an HMRP mode in both transmit and receive and also need to be allowed to send data in both directions within a CTB. In addition, the balance of traffic from source to destination and destination to source needs to be able to be adjusted quickly based on the traffic arriving from the upper layers. Stations that support HMRP TX and HMRP RX support bidirectional CTB usage.

A bidirectional data exchange is initiated by originator Station by setting HMRP ACK requested bit and Poll bit both to one in the MAC header. If the target Station has no data to send, then it shall set the Time Change field to “No channel time requested” in the Packet Control Extension field in the packet that it sends in response. If, however, the target Station has data to send, then it sets HMRP ACK requested bit in the Packet Control Extension field to one and Time Change field to one of “Channel time increase requested”, “Channel time decrease requested” or “No change requested.” The originator Station may then reduce its channel time usage so that the target is able to use the channel time released by the originator Station. An example of channel time adjustment in a bidirectional CTB is illustrated in Figure 24.

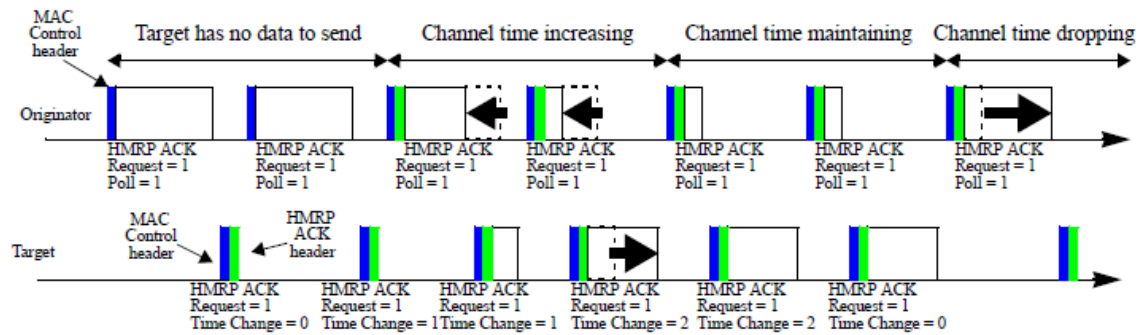


Figure 24: Example of bidirectional data exchange

#### 7.6.4 Station controlled channel time extension

In addition to the Dynamic CTB extension method, a Station may extend transmissions past the current assigned CTB into following unreserved channel time without any intervention of the Coordinator so that the Station may use that extra time for retransmission, beam searching, bidirectional data transfer, etc.

If the Station needs to extend transmissions past the current CTB, it sets the channel time extension (CTE) bit in the packets it sends before the end of that channel time block. The receiving Station continues to listen for packets or beam searching during the following unreserved channel time block. If the transmitter does not require a further extension, it signals this via the CTE bit and the destination is no longer required to listen and may switch to sleep state.

An example of station controlled channel time extension is illustrated in Figure 25.

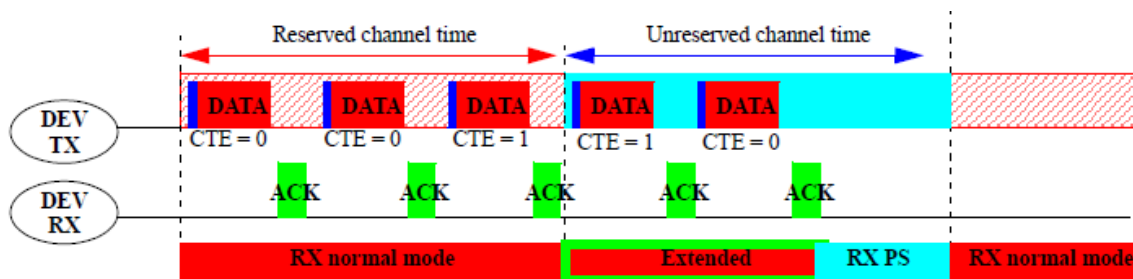


Figure 25: Example of station controlled channel time extension

### **7.6.5 Dynamic CTB extension**

Dynamic CTB extension is an optional feature to provide flexible channel time allocation. During one reserved CTB, if more channel time is required immediately after the current CTB the unallocated channel time following the current reserved CTB can be used as extension of current reserved CTB. This extension is communicated to the Stations in the WVAN with a broadcast CTB Extension Announcement command from the Coordinator. A Station uses the CTB Extension request command to ask the Coordinator to send the CTB Extension Announcement command.

### **7.6.6 Dynamic CTB Truncation**

Dynamic CTB truncation is an optional feature that allows a Station that does not have any more data to send during a CTB to release the unused channel time. The Coordinator releases its time by broadcasting a CTB truncation announcement command with the LRP. A Station first sends a CTB truncation request command to the Coordinator, who will then broadcast a CTB truncation announcement. Other Stations that receive this announcement may then contend for the remaining time in the CTB using the LRP.

## **7.7 *Bandwidth reservation***

Bandwidth reservation enables Stations to reserve time in the superframe to communicate with another Station.

When Coordinator allocates bandwidth to a Station, different type of schedules, static or dynamic, can be given depending on the request. A static schedule has the same allocation in the following superframes, i.e., the Coordinator will not change it from superframe to superframe. On the other hand, a dynamic schedule may be different from superframe to superframe.

A Station shall not transmit during a dynamic schedule unless it has correctly received the beacon for that superframe. A Station may continue to transmit during a static schedule for up to mMax-LostBeacons superframes since the last beacon that was correctly received with the Stations static schedule.

To change a static schedule the Coordinator places an IE in the beacon that indicates a change in the beacon position with, no offset to the beacon start time. Stations that receive this IE will be informed that the Coordinator will be changing the some or all of the static schedules to new locations beginning with the indicated superframe.

A normal schedule allows only one Station to initiate transmission during the schedule. A paired allocation, however, alternately allows two Stations to initiate transmission during CTBs in a schedule. The first CTB in a superframe for the stream has the Station that is the SrcID as the source of the packets, continuing for every other CTB assigned to that stream in the superframe. The second CTB in the superframe for the stream has the Station that is the DestID as the source of the packets, also continuing for every other CTB assigned to that stream in the superframe.

For isochronous streams, the Coordinator ensures CTBs are allocated in every superframe, and tries to satisfy the additional requirements such as the minimum required number of CTBs per superframe, and the minimum interval between CTBs. For asynchronous streams, the Coordinator allocate CTBs in each superframe according to resource availability, and may even allocate zero CTBs for the stream in a superframe .

For isochronous streams, the originating Station may request either a fixed number of time block or a range of time blocks, from minimum to maximum. If the Coordinator accepts the request, it allocates at least the minimum number of time blocks in every superframe. The Coordinator may also allocate up to the maximum number, if the time is available. Any additional time blocks beyond the minimum are be allocated as a dynamic schedule.

### **7.7.1 Isochronous traffic stream addition**

A Station requests the allocation of channel time by sending the Bandwidth Request command to the Coordinator. The Coordinator responds with a Bandwidth Response command indicating either that the time has been allocated or that the request has been refused and the reason why it the request was refused.

### **7.7.2 Isochronous traffic stream change**

The stream owner, that is, the originating Station or the Coordinator may change an established reservation for isochronous stream. The originating Station requests a change to the time allocation by sending a Bandwidth Request command to the Coordinator with the new parameters. The Coordinator responds with Bandwidth Response command indicating either that the time has been allocated or that the request has been refused and the reason why it the request was refused.

### **7.7.3 Isochronous traffic stream deletion**

The Coordinator, the source Station or the destination Station may delete a stream. If the source or destination Station initiates stream deletion, it sends a Bandwidth Request command to the Coordinator indicate that the stream should be deleted. The Coordinator responds to the request with a Bandwidth Response command. If the Coordinator deletes the stream, it will inform the source Station why the stream was deleted by sending a Bandwidth Response command with the reason why the stream was deleted. In all cases, the Coordinator informs all other devices of the deletion of the stream by placing a null CTB in the beacon for a specified period of time.

### **7.7.4 Asynchronous traffic reservation**

Asynchronous stream reservation uses the same process as for isochronous stream creation. However, an asynchronous request is not for an allocation that repeats in every superframe until canceled. Instead it is a request for a finite amount of time on the medium. Once the Coordinator has allocated all of the requested time, it will not allocate channel time for that request again. A request for an asynchronous stream replaces the previous request for that target Station and unallocated time from the previous request is replaced by the current request.

The Coordinator may place the CTBs for an asynchronous allocation anywhere in the superframe or spread them over multiple, non-contiguous superframes.

### **7.7.5 Asynchronous traffic termination**

The asynchronous termination process is essentially the same as for isochronous stream termination, except that:

- Only the Coordinator or the originating Station are allowed to terminate the allocation.
- The termination is not announced in the beacon.

### **7.8 *Link assessment and adaptation***

The transmitter may request that the receiver provides detailed information such as the channel status, received signal quality, etc.

Link Adaptation uses three steps;

- Link assessment – determining the link quality
- Link recommendation – the destination communicates its recommendation to the source
- Link adjustment – the source may adjust the transmit mode to improve the link quality.

Link assessment is the method that the Stations use to evaluate the quality of the channel and the signals. Both the source and destination can perform link assessment.

There are two types of messages that can be used to communicate the link recommendation. One, referred to as normal link recommendation, uses two MAC command packets, Link Recommendation Request command and Link Recommendation Response commands. The second, referred to as fast link recommendation, uses additional fields in the MAC header of a data packet and the Imm-ACK packet to send the request and response data.

Regardless of the message format used, there are also two modes for link recommendation, an active mode and a passive mode are available. In the active mode the transmitter requests the information whereas in the passive mode the receiver sends the information without prompting by the transmitter.

Based on the source Station's assessment of the link and the information from the destination Station, the source Station may choose to adjust the link parameters to improve the link quality. Options for adjusting the link include:

- Beam Steering
- HMRP mode and LRP mode adjustment
- UEP (unequal error protection)
- Transmit power control

## **7.9 Data delivery**

The data delivery specification has a close relationship with the MAC schedule, A/V composite packet format and Beam-Search operation. The beacon specifies the MAC schedule at the CTB level, but there may be multiple packets within one CTB.

All CTBs allocated for beam-formed PHY modes use inter-packet period (IPP) timing for sending packets. CTBs used for omni LRP packets may use IPP timing for sending packets. IPP timing, if used, is determined by the source Station which then sends the Stream Characteristics IE to the destination in an Announce Request command.

The IPP includes the time for the transmission of the longest packet for the stream, two SIFS durations and time for ACK packet. In a typical case, the CTB may be sized to be multiple IPPs. When IPP timing is used, the end of the ACK packet always occurs one SIFS before the end of the IPP duration. The start of any data packet from the source will be aligned to the beginning of an IPP.

When beam-tracking information needs to be transmitted, the ACK packets will be longer to transmit this data and the data packets will have additional information to be transmitted as well. In this case, the source needs to shorten the data portion of the packet to allow time for the transmission of the additional beam tracking data.

If the source has nothing to send, there are two options:

- not send anything for the particular packet time, or
- send just a packet header in which zero packet length is noted.

If the source sends a zero length packet, it will expect to receive the ACK packet, if requested, at the same time as if the packet was the size of the longest packet.

### 7.9.1 Data delivery in bidirectional CTBs

Stations using bidirectional capability in a CTB exchange the Reorder Buffer Allocation IE to determine the size of the buffers at the receiver. This allows the transmitting Station to perform flow control on the data stream so that it will not overflow the receiver's buffers, causing lost packets. The Reorder Buffer Allocation IE applies to a pair of Stations and can be used to change the buffer allocation when the situation at the receiver changes. The transmitting Station also uses Reorder Buffer Allocation IE to request a buffer size or to deallocate it completely.

### 7.9.2 Link manager (LM) operation

The WirelessHD MAC provides some of the functions that are associated with the logical link controller (LLC) in other specifications, i.e.

- Segmentation and reassembly (SAR): Large packets may be fragmented.
- Flow control: The transmitter restricts its transmissions based on knowledge of the buffer size at the receiver.
- In order delivery of packets: The transmitter MAC sends packets in order and retries them in order. At the receiver, the MAC sends packets up in order and discards out of order packets.
- Protocol multiplexing: Higher level protocols, e.g., IPv4, IPv6, USB, OBEX, are identified in the data sub-packet format.

The LM entity within the MAC provides the following additional capabilities:

- Multiplexing connections within a specific protocol
- Explicit flow control
- Reliable delivery

The LM entity multiplexes connection by allowing the Stations to assign port numbers to a connection. Each Station assigns the port number it will use to receive data for the connection and associates it with the port assigned by the other Station to the connection.



Explicit flow control and reliable delivery are enabled by providing a numbering for LM packets and an acknowledgment the LM packets sent in a connection. The acknowledgment packet not only indicates the packets successfully received at the destination LM entity, it also indicates the last packet that was successfully transferred to the higher layer. This tells the transmitter which packets have been cleared from the receiver's buffer and therefore, the space remaining in the receiver's buffer.

## **7.10 *Retry and recovery***

### **7.10.1 ACK policies**

The WirelessHD specification supports two types of ACK policies, immediate acknowledgement (Imm-ACK) and no acknowledgement (no-ACK). The Imm-ACK policy allows the acknowledgement of parts of the packet in a fashion similar to block acknowledgement policies in other standards and specifications. The Imm-ACK packet indicates which of the sub-packets were received correctly by the destination. When the no-ACK policy is used, the destination does not send an Imm-ACK in response, regardless of whether it received the packet or sub-packets correctly.

In all cases, the source of the packet determines the ACK policy that will be used for the packet by setting the appropriate value of the ACK Policy field in the Packet Control field. The ACK policy may be changed by the source on a packet-by-packet basis.

### **7.10.2 Reliable broadcast or multicast (ReBoM)**

ReBoM is used only by the Coordinator to allow multiple destinations to ACK a broadcast or multicast packet. The ReBoM process takes place within a single CTB. The packet from the Coordinator includes a bitmap of Stations indicating that these Stations will send an ACK to the Coordinator in a scheduled manner. The Stations wait for  $N \cdot \text{SIFS} + (N-1) \cdot \text{AckDuration}$  time units from the end of the packet transmission before transmitting the ACK, where,  $N$  represents the total number of 1's starting from the LSB till the bit position corresponding to the Station's STID in the bitmap.

### **7.10.3 Packet retry**

If there are errors when a sub-packet is received, the transmitter has the option of retransmitting the sub-packet. (In this context, the term sub-packet includes the case where a packet contains only one sub-packet.) The source device determines if a sub-packet is retried and the number of times that it is retried. The source device maintains the order of data sub-packets as they are retried. The delivery of audio and video sub-packets may be out of order if it is supported by the destination..

## **7.11 Power management**

A Station that is a member of the WVAN is in one of two power management (PM) modes at all times. The possible modes are:

- NORMAL - The Station is participating in every superframe.
- PS - The Station is only listening to the beacons and not necessarily to every beacon.

When a Station is in either of the PM modes, it will be in one of two states, either wake or sleep. When a station is in the wake state it is transmitting, receiving or preparing to transmit or receive. In sleep state, the Station will have portions of its radio turned off to save power.

In the NORMAL mode, a Station is in the wake state during the following time periods:

- Every expected beacon arrival time
- The entire duration of the RATB
- Any CTB for which the Station is either the source or destination, including those where the source or destination is the BestID.

At all other times, the Station may be in sleep state to save power.

### **7.11.1 Power save modes**

To save additional power, a Station may request to enter PS mode. To enter PS mode, the Station sends the PM Request command to the Coordinator with the PM Mode field set to

“PS.” The Coordinator responds to a correctly received PM Request command with the PM Response command. If the Coordinator allows the Station to enter PS mode, the Coordinator may terminate all allocations for which the Station is either the source or destination. The Station enters PS mode when it receives a beacon from the Coordinator with the bit for its STID set in the PM Mode IE.

A Station in PS mode returns to NORMAL mode by sending the PM Request command to the Coordinator with the PM Mode field set to “NORMAL.” The Station will consider itself in NORMAL mode as soon as it attempts to send the command.

If any Station in the WVAN is in PS mode, the Coordinator includes the PM Mode IE in the beacon so that all other Stations in the WVAN will know the mode of all Stations in the WVAN.

While the Station is in PS mode, it is not required to be in wake state for every beacon. Instead, the Station may skip beacons to save power. The number of beacons that the Station skips is based on its application requirements for latency.

### **7.11.2 Communicating with Stations in PS mode**

In order for another Station, the originator, to communicate with a Station in PS mode, the target, the Station in PS mode needs to change to NORMAL mode. There are two methods that may be used to have a Station in PS mode switch to NORMAL mode

- Sending the PM Mode Request command to the Coordinator with the TargetID set to the STID of the Station in PS mode
- Requesting an allocation with the Station in PS mode with the Bandwidth Request command.

In either case, the Coordinator will then place the PM Wake IE in the beacon with the STID of the target Station. When a Station in PS mode sees its STID in a PM Wake IE will switch to NORMAL mode.

A Station may also request that the Station in PS mode switch to NORMAL mode for communications during the RATB only by using the appropriate settings in the

Bandwidth Request command. In this instance, the Coordinator will indicate that the Station is being requested to switch to NORMAL mode for communication during the RATB.

### 7.11.3 Transmit power control

The devices in WirelessHD are able to control the transmit power to reduce power consumption and still ensure reliable transmissions. The transmitter requests a transmit power control (TPC) report from the receiver using the Probe Request command. The receiver sends back the TPC report in the Probe Response command after it receives the request. The receiver uses the Transmit Power Change command to ask the transmitter to increase or decrease its transmit power as appropriate. The transmitter may adjust its transmit power accordingly after receives the Transmit Power Change command.

## 8 MAC packet formats

### 8.1 *Packet conventions*

Unless otherwise specified, the figures illustrating the packet, sub-packet and field formats are all displayed with the least significant bit (lsb) and least significant octet on the left and the most significant bit (msb) and most significant octet on the right.

The transmission order shall be the lsb of the least significant octet first over the air with the most significant bit of the most significant octet last. The only exceptions to this are any CRCs, such as the HCS and PCS, which are sent msb first over the air, lsb last.

The Station ID (STID) is a 6 bit number. Unless otherwise specified, when the STID is placed in a 1 octet field, the STID is placed in the 6 lsbs and the 2 msbs are set to 0b00.

### 8.2 *General packet format*

The general packet format is illustrated in Figure 26.

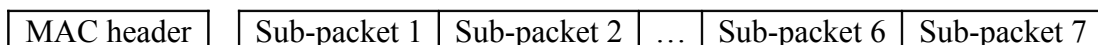


Figure 26: General packet format

The gap between the MAC header and the first sub-packet is filled with the HCS that is calculated and inserted by the PHY. A MAC packet may have one to seven sub-packets of varying sizes.

### 8.2.1 MAC header format

The HMRP MAC header is formatted as illustrated in Figure 27.

MAC control header	MAC extension header	Security header	Video header	CP header	HMRP ACK header	Reserved
--------------------	----------------------	-----------------	--------------	-----------	-----------------	----------

**Figure 27: HMRP MAC header format**

The LRP MAC header is formatted as illustrated in Figure 28.

MAC control header	MAC extension header	Security header	ReBoM header	CP header
--------------------	----------------------	-----------------	--------------	-----------

**Figure 28: LRP MAC header format**

The MAC control header contains:

- Protocol version
- Packet class (normal, composite, omni ACK or beacon)
- ACK policy
- Indications for which of the other headers are present
- Retry indication
- Beam tracking request information
- Packet type (control, data, audio, RTT)
- Source and destination ID
- WVNID
- Stream index
- Either the best TX pattern indication, for LRP packets, or HMRP ACK header present, HMRP request, Poll, CTE and Time Change fields.

The MAC extension header contains:

- Fast link mode, recommended HMRP and LRP modes
- Transmit power control recommendation
- Sub-packet types for each of the sub-packets
- LRP antenna feedback
- Identify the sub-packets that are a part of each ACK group

- Indicate if the lsb CRC is to be used in determining if an ACK is sent. (this applies only to sub-packets using UEP HMRP mode).
- Pixel clock, audio clock and 27 MHz clock fields containing the respective clock information for synchronizing playback.

The Security header contains information for user data security. The information included is:

- Key identifier (SECID)
- Cipher type
- Indication of the security applied (no security, integrity code only, or encryption and integrity code) for each sub-packet
- Secure packet counter for key freshness

The Video header contains control information for up to 4 video sub-packets and the playback time, relative to the pixel clock, of the indicated video sub-packet. The control information for each sub-packet of uncoded video includes:

- Partition index
- Interlace field indication (i.e., if it is the top or bottom field)
- Video frame number
- H-position of the first pixel
- V-position of the first pixel
- Frame start adjust

. The control information for each sub-packet of coded video includes:

- Playback time for next frame
- Interlace field indication
- Video frame number of the reference line and sub-slice
- V-position of the reference line and sub-slice

The ReBoM header contains a bitmap of the Stations that are being requested to participate in the ReBoM process.

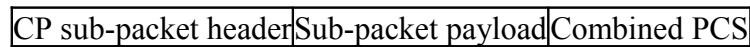
The CP header contains content protection information for the packet and is defined by the content protection method that is being used for the data.

The HMRP ACK header contains

- A bitmap of the subpackets being ACKed
- Request for the receiver to begin beam searching
- Request for time for the sender to beam searching

### 8.2.2 Sub-packet format

Audio and video sub-packets in an HMRP are formatted as illustrated in Figure 29.

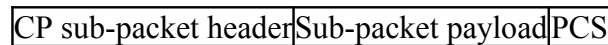


**Figure 29: Sub-packet format**

The CP sub-packet header contains information for content protection of that sub-packet.

The combined PCS field contains the msb PCS in the msbs and lsb PCS in lsbs.

All other sub-packets are formatted as illustrated in Figure 30.



**Figure 30: LRP data sub-packet format**

The sub-packet payload field for packets with user data privacy applied contains a message integrity code at the end of the payload.

In addition, data sub-packets with packet type data support the aggregation of MSDUs or the fragmentation of MSDUs in their payloads.

Sub-packets containing coded video are further subdivided into multiple sub-slices, each sub-slice having a header that contains the slice number offset relative to the V-position, the sub-slice data start offset the length of the sub-slice data.

## 8.3 Packet formats

Various packet formats are defined to support the different types of messages in the WVAN.

The beacon is a broadcast packet used to synchronize the WVAN and announce changes.

The beacon contains:

- Various control bits
- Superframe duration
- Superframe number
- IEs containing the schedule of CTBs in the superframe
- Other IEs that contain information relevant to the WVAN

The composite packet contains up to seven sub-packets, each of which may contain data, commands, audio and/or video.

The Normal packet is used to send a single sub-packet of information.

The directional ACK packet is used to acknowledge HMRP packets and beam formed LRP packets.

The omni ACK packet is used to acknowledge omni LRP packets.

The HMRP ACK packet is used to acknowledge HMRP packets during bidirectional data exchange.

## 8.4 Information elements

Information elements (IEs) are used in packets and MAC commands to transfer information. The IEs, are formatted as illustrated in Figure 31.

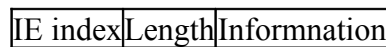


Figure 31: General format of information elements

The IE index field is used to identify the type of IE.

## 8.5 MAC commands

Each MAC command sub-packet contains one or more MAC commands, as illustrated in Figure 32.

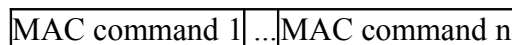


Figure 32: General format of MAC command sub-packet

The format of a MAC command is illustrated in Figure 33.



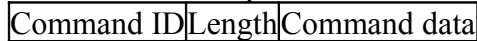


Figure 33: General format of MAC commands

## 8.6 USB message encapsulation

The format the data portion of a sub-packet marked for USB pass through is illustrated in



Figure 34: Data field when protocol type indicates USB pass through

Formats for USB 2.0 pass through data, acknowledgments, port status and USB 3.0 pass through data are defined in the specification.

## 8.7 Link management protocol data unit (LMPDU) formats

The LM command format is illustrated in Figure 35.

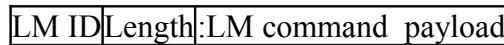


Figure 35: LM Command format

# 9 MAC interface

## 9.1 MAC interface overview

A summary of the MLME primitives that are defined is given in Table 12. The number in the column indicates the sub-section of the WirelessHD specification that defines the primitive.

Table 12: List of interface primitives

Name	Request	Indication	Response	Confirm
MLME-SCAN	9.2.1.1	–	–	9.2.1.2
MLME-START	9.2.2.1	–	–	9.2.2.2
MLME-STOP	9.2.3.1	9.2.3.2	–	9.2.3.3
MLME-HANDOVER	–	9.2.4.1	9.2.4.2	–
MLME-NEW-COORDINATOR	–	9.2.4.3	–	–
MLME-WVAN-PARM-CHANGE	–	9.2.4.4	–	–
MLME-ASSOCIATE	9.3.1.1.	9.3.1.2	–	9.3.1.3
MLME-DISASSOCIATE	9.3.2.1	9.3.2.2	–	9.3.2.3
MLME-INFO	9.3.3.1	–	–	9.3.3.2

Name	Request	Indication	Response	Confirm
MLME-PARAMETER-GET	9.3.4.1	–	–	9.3.4.2
MLME-LINK-QUALITY	9.4.1.1	–	–	9.4.1.3
MLME-LINK-QUALITY-CHANGE	–	9.4.1.2	–	–
MLME-ADD-STREAM	9.4.2.1	–	–	9.4.2.2
MLME-NEW-STREAM	–	9.4.2.3	–	–
MLME-CHANGE-STREAM	9.4.2.4	–	–	9.4.2.5
MLME-END-STREAM	9.4.2.6	9.4.2.7	–	9.4.2.8
MLME-PM-MODE	9.5.1.1	9.5.1.2	–	9.5.1.3
MLME-MEASURE-RTT	9.6.1.1	–	–	9.6.1.2
MLME-SET-RTT-REPL	9.6.2.1	–	–	9.6.2.2
MAC-ISOCH-DATA	9.7.1.1	9.7.1.2	–	9.7.1.3
MAC-ASYNC-DATA	9.7.2.1	9.7.2.2	–	9.7.2.3

A request primitive is used to initiate an action, e.g., MLME-ASSOCIATE.request starts the association process for a Station.

An indication primitive is used to report the reception of an unsolicited information, e.g., the MLME-WVAN-PARM-CHANGE.indication reports that the Coordinator is in the process of changing one of the WVAN parameters.

A response primitive asks the MAC to send a reply to a previously received request, e.g., the MLME-HANDOVER.response is sent in response to the MLME-HANDOVER.indication.

A confirm primitive reports the result of a request to the upper layer. Thus, the MLME-CHANGE-STREAM.confirm reports the result of the request via the MLME-CHANGE-STREAM.request primitive to modify the characteristics of an existing stream.

## 9.2 *WVAN management*

### 9.2.1 Scanning for WVANs

#### 9.2.1.1 MLME-SCAN.request

This primitive is used to request that the MAC sublayer perform a passive scan of one or more HMRP channels for WVANs.

Upon receipt of this primitive, the MAC scans all of the LRP channels in the specified HMRP channels for beacons from WVANs and reports the result in MLME-SCAN.confirm.

#### **9.2.1.2 MLME-SCAN.confirm**

This primitive is used to report the result of a MAC sublayer scan for WVANs.

If the request succeeds, then zero or more sets of information for the WVANs that were found will be returned in the confirmation. If the request fails, the confirmation will be indicate the reason for the failure.

### **9.2.2 Starting a WVAN**

#### **9.2.2.1 MLME-START.request**

This primitive is used to request that the MAC sublayer start a new WVAN.

Upon receipt of this primitive, the MAC will attempt to start a new WVAN as the coordinator and report the result in MLME-START.confirm.

#### **9.2.2.2 MLME-START.confirm**

This primitive is used to report the result of the MAC sublayer attempting to start a new WVAN.

If the attempt to start the WVAN was successful, then the confirmation will contain the identifier for the WVAN that was started. If the attempt to start the WVAN failed, then confirmation will indicate the reason for the failure.

### **9.2.3 Stopping a WVAN**

These primitives support the process of stopping operations as a Coordinator. The process may result in the shutdown of WVAN operations or the handover of Coordinator operations to another Station in the WVAN.

**9.2.3.1 MLME-STOP.request**

This primitive initiates the WVAN shutdown procedure or the WVAN handover procedure.

In response to this primitive, the MAC will either begin the handover process or shutdown the WVAN, as indicated in the request. If the request is for shutdown, the MAC will initiate the WVAN shutdown process. If the request is for handover the Coordinator will attempt to handover control to another Station in the WVAN.

**9.2.3.2 MLME-STOP.indication**

This primitive reports that the Coordinator is shutting down the WVAN.

**9.2.3.3 MLME-STOP.confirm**

This primitive reports the results of the request to stop operations as a Coordinator.

The confirmation will indicate if the request was successful or the reason why it failed.

**9.2.4 Coordinator handover and configuration change**

These primitives are used as part of the handover process where the current Coordinator's responsibilities are transferred to another Station in the WVAN as well as to inform the SME of changes to the WVAN.

**9.2.4.1 MLME-HANDOVER.indication**

This primitive indicates the reception by the MAC of a Handover Request command.

**9.2.4.2 MLME-HANDOVER.response**

This primitive indicates that SME of the Station targeted for Coordinator handover is ready to act as Coordinator.

In response to this primitive, the MAC will send the Handover Response command to the Coordinator.

#### **9.2.4.3 MLME-NEW-COORDINATOR.indication**

This primitive indicates that the role of the Coordinator has been assumed by a different Station in the WVAN.

#### **9.2.4.4 MLME-WVAN-PARAM-CHANGE.indication**

This primitive indicates that either the channel or WVNID has changed in the WVAN.

### **9.3 Station configuration**

#### **9.3.1 Association**

These primitives deal with Stations associating with a WVAN.

##### **9.3.1.1 MLME-ASSOCIATE.request**

This primitive is used to request that the Station attempt to associate with a specific WVAN.

Upon receipt of this primitive, the MAC attempts to associate with the WVAN that is most closely described by the request and reports the result of the attempt with an MLME-ASSOCIATE.confirm.

##### **9.3.1.2 MLME-ASSOCIATE.indication**

This primitive is used to inform the SME that a Station has associated with the WVAN.

##### **9.3.1.3 MLME-ASSOCIATE.confirm**

This primitive is used to report the result of the Station attempting to associate with a specific WVAN.

If the attempt to associate succeeds, the confirmation will contain the information regarding the WVAN that was joined and the STID parameter will contain the ID assigned by the Coordinator.

If attempt fails, confirmation will indicate the reason for the failure.

### **9.3.2 Disassociation**

These primitives deal with Stations disassociating with a WVAN.

#### **9.3.2.1 MLME-DISASSOCIATE.request**

This primitive is used to request that the Station disassociate from a specific WVAN.

Upon receipt of this primitive, the MAC will disassociate from the WVAN.

#### **9.3.2.2 MLME-DISASSOCIATE.indication**

This primitive is used to inform the SME either that a Station has disassociated from the WVAN or that the Station has been disassociated from the WVAN.

If the Station has been disassociated by the Coordinator, then the indication contains Station address and STID for the Station that was disassociated. The indication will also contain the reason why the Station was disassociated, it was given by the Coordinator.

#### **9.3.2.3 MLME-DISASSOCIATE.confirm**

This primitive is used to report the result of the Station disassociating from the WVAN.

The request to disassociate is always successful.

### **9.3.3 WVAN information**

These primitives are used request information about a single Station or all of the Stations in the WVAN.

#### **9.3.3.1 MLME-INFO.request**

This primitive is used by the AVC layer to request the device list from the MAC sublayer.

When the MAC sublayer receives this primitive, it first checks to see if it has the requested information. If not, the MAC will attempt to retrieve the requested information from the Coordinator. In all cases, the MAC responds with an MLME-INFO.confirm.

### **9.3.3.2 MLME-INFO.confirm**

This primitive is used to notify the AVC layer of a result of an MLME-INFO.request message.

If the request is successful, the confirmation will include the information about the requested Stations. If the request fails, then the confirmation will include the reason for the failure.

### **9.3.4 MAC information**

These primitives are used to get information about the current MAC sublayer status.

#### **9.3.4.1 MLME-PARAMETER-GET.request**

This primitive is used by the AVC layer to get parameters from the MAC sublayer.

When the MAC sublayer receives this primitive, it retrieves the current value of the parameter and responds with an MLME-PARAMETER-GET.confirm.

#### **9.3.4.2 MLME-PARAMETER-GET.confirm**

This primitive is used by the MAC sublayer to report the value of parameter requested by an MLME-PARAMETER-GET.request.

## **9.4 Data connections**

### **9.4.1 Link quality**

These primitives are used to find and monitor the link quality of a connection.

#### **9.4.1.1 MLME-LINK-QUALITY.request**

This primitive is used by the AVC layer to request the MAC sublayer to report the current link quality.

When the MAC sublayer receives this primitive it estimates the link quality with the Station specified in the DestID.

**9.4.1.2 MLME-LINK-QUALITY-CHANGE.indication**

This primitive is used by the MAC sublayer to inform the AVC layer that the link quality has changed.

**9.4.1.3 MLME-LINK-QUALITY.confirm**

This primitive is used to notify the AVC layer of a result of an MLME-LINK-QUALITY.request primitive.

If the request is successful, the confirmation contains the PER and RSSI parameters measured for the link. If the request fails, the confirmation will contain the reason for the failure.

**9.4.2 Stream management**

These primitives are used to add, change and end stream connections.

**9.4.2.1 MLME-ADD-STREAM.request**

This primitive is used by the AVC layer to request the MAC sublayer to reserve channel time.

When the MAC sublayer receives this primitive it performs the stream reservation process.

**9.4.2.2 MLME-ADD-STREAM.confirm**

This primitive is used to notify the AVC layer of a result of an MLME-ADD-STREAM.request.

**9.4.2.3 MLME-NEW-STREAM.indication**

This primitive is used to inform the AVC layer that another Station has created a stream to the Station.

**9.4.2.4 MLME-CHANGE-STREAM.request**

This primitive is used by the AVC layer to request that MAC sublayer change the reserved channel time.



When the MAC sublayer receives this primitive it performs the stream modification process.

#### **9.4.2.5 MLME-CHANGE-STREAM.confirm**

This primitive is used by the MAC sublayer to inform the AVC layer of the result of an attempt to change the channel time.

#### **9.4.2.6 MLME-END-STREAM.request**

This primitive is used by the AVC layer to request that the MAC sublayer releases previously allocated channel time.

The MAC sublayer performs stream termination process when it receives this primitive.

#### **9.4.2.7 MLME-END-STREAM.indication**

This primitive notifies the AVC layer that a previously allocated stream has ended.

#### **9.4.2.8 MLME-END-STREAM.confirm**

This primitive is used to notify the AVC layer of the result of an MLME-END-STREAM.request.

### **9.5 *Power management***

#### **9.5.1 PM mode change**

These primitives support the process of changing the power management mode of a Station.

##### **9.5.1.1 MLME-PM-MODE.request**

This primitive initiates a request to change the current PM mode.

When the MAC receives this primitive, it initiates the PM Mode change process. If the Station is already in the requested PM mode, the MAC will respond with the MLME-PM-MODE.confirm primitive indicating success without taking any further action.

### **9.5.1.2 MLME-PM-MODE.indication**

This primitive indicates that the Station changed its current PM mode that was not in response to a request by the higher layers.

The MAC will change its PM Mode in response to requests from other Stations, particularly from PS to NORMAL.

### **9.5.1.3 MLME-PM-MODE.confirm**

This primitive reports the results of the request to change the Station's PM mode.

## **9.6 Round trip time measurements**

These primitives are used to measure round trip time (RTT) between the MAC sublayer of the RTT initiator and the RTT acceptor.

### **9.6.1 RTT initiator side**

These primitives are used by RTT initiator to measure RTT with the RTT acceptor.

#### **9.6.1.1 MLME-MEASURE-RTT.request**

This primitive is used to initiate the measurement of RTT by the MAC of RTT initiator.

When the MAC of RTT initiator receives this primitive, the MAC initiates reservation of a CTB (bi-directional reservation) for RTT test and its response, and then sends the RTT test request command using the reserved CTB allocated for the RTT initiator.

#### **9.6.1.2 MLME-MEASURE-RTT.confirm**

This primitives is used by the MAC sublayer to inform the AVC layer of the result of an attempt to measure RTT.

### **9.6.2 RTT acceptor side**

These primitives are used by an RTT acceptor to respond the RTT request sent by an RTT initiator within the MAC of an RTT acceptor.

**9.6.2.1 MLME-SET-RTT-REPLY.request**

This primitive is used to set the MAC sublayer of RTT acceptor to be able to respond a request from an RTT initiator.

When the MAC of RTT acceptor receives this primitive, and when the MAC receives RTT test request command from the RTT initiator, the MAC sends RTT test response command using the reserved CTB allocated for the RTT acceptor.

**9.6.2.2 MLME-SET-RTT-REPLY.confirm**

This primitives is used by the MAC sublayer to inform the AVC layer of the result of an attempt to respond RTT request from RTT initiator.

**9.7 Data interface**

These primitives are used to transfer MAC service data units (MSDUs) to other MAC entities.

**9.7.1 Isochronous data**

These primitives are used to transfer isochronous data.

**9.7.1.1 MAC-ISOCH-DATA.request**

This primitive is used to initiate the transfer of an isochronous MSDU to another MAC entity.

**9.7.1.2 MAC-ISOCH-DATA.indication**

This primitive indicates the reception of an isochronous MSDU.

**9.7.1.3 MAC-ISOCH-DATA.confirm**

This primitive reports the results of the attempt to deliver the MSDU.

**9.7.2 Asynchronous data**

These primitives are used to transfer asynchronous data.

**9.7.2.1 MAC-ASYNC-DATA.request**

This primitive is used to initiate the transfer of an asynchronous MSDU to another MAC entity.

**9.7.2.2 MAC-ASYNC-DATA.indication**

This primitive indicates the reception of an asynchronous MSDU.

**9.7.2.3 MAC-ASYNC-DATA.confirm**

This primitive reports the results of the attempt to deliver the MSDU.

**10 Audio video control (AV/C) specification****10.1 Overview**

The AV/C includes the following functions;

- Device capability exchange – In this function, a device discovers other devices and exchanges device information (e.g. device category, device name) with other devices.
- Connection control – In this function, a device establishes or releases the AV stream connection between a Source and a Sink by using AVC messages.
- Device control – In this function, a device controls other device by using AVC messages (e.g. power on/off, play/stop etc.).

**10.2 Device model**

Figure 36 shows the device model used in this specification. A device has multiple logical input and output ports, SinkPort[0-63] and SrcPort[0-63], respectively, for video and audio data.

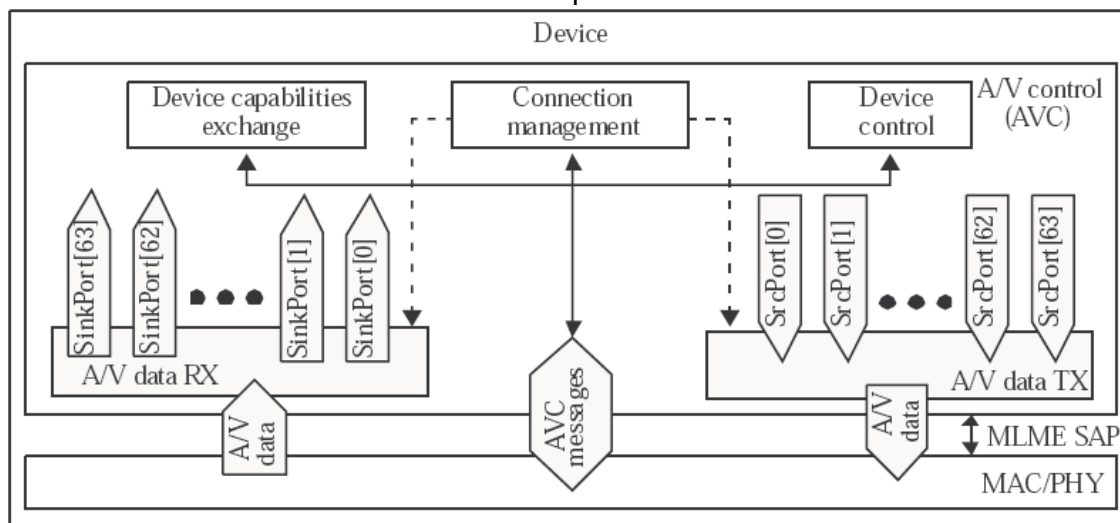


Figure 36: Device model used for AV/C specification

### 10.3 AV/C messages

The AV/C messages are used for connection establishment and control of other devices (e.g. power on/off, play/stop etc). The AVC message packet format is illustrated in Figure 37.

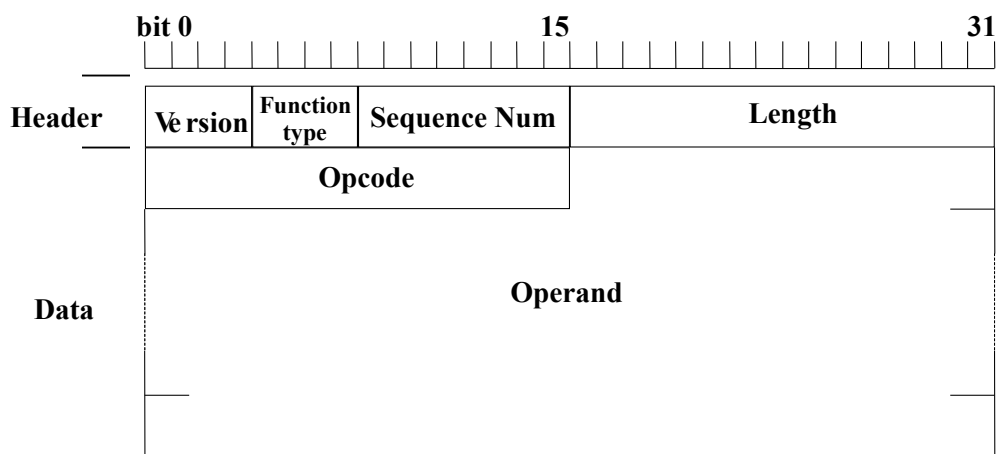


Figure 37: AVC message packet format

The function types in the AVC message are listed in Table 13.

**Table 13: Function type**

Function type
Connection management
Device control
A/V clock regeneration
Content protection
HDMI pass through
Reserved

The messages used for AV/C are listed in Table 14.

**Table 14: Connection control opcodes**

Operation code type
DEVICE CAPABILITY REQUEST
DEVICE CAPABILITY RESPONSE
CONNECT REQUEST
CONNECT RESPONSE
DISCONNECT NOTIFY
STREAM START NOTIFY
OUTPUT FORMAT NOTIFY
FAST FORMAT ADAPATATION REQUEST
FAST FORMAT ADAPTATION RESPONSE
Reserved

## **10.4 AV stream control sequence**

### **10.4.1 Overview**

Figure 38 shows a basic sequence between a Station (Source) and a Coordinator (Sink) after the Station is associated in a WVAN until it starts transmission of AV data in case that a Station (Sink) initiates connection process.

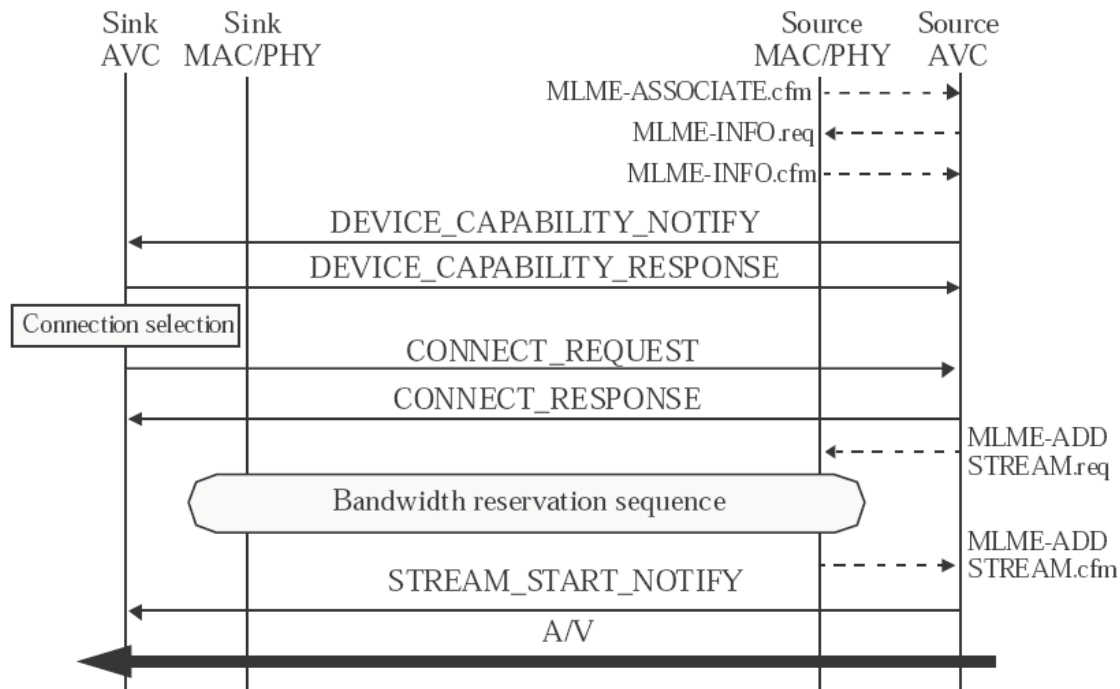


Figure 38: Connection control basic sequence

### 10.4.2 Device capability definition

The device capabilities contain the following information:

- MRP type – one of MRRX, MRTX, MRTR, or MR0
- HRP type – one of HRRX, HRTX, HRTR or HR0
- Device category – for example, DTV, DVD player, STB, etc.
- Manufacturer name
- Device name – used to identify devices for the user in the WVAN
- Version of the specification
- Video source and/or sink capabilities
- Audio source and/or sink capabilities
- AVC capabilities – fast connect, HDMI pass through, fast video format adaptation, and fast audio format adaptation
- Supported video and/or audio formats

### 10.4.3 Device capability request procedure

A Device in the WVAN may request that other Devices notify of it of their capabilities.

All Devices have device capabilities such as wireless type (HRRX, HRTX, HRTR, HR0).

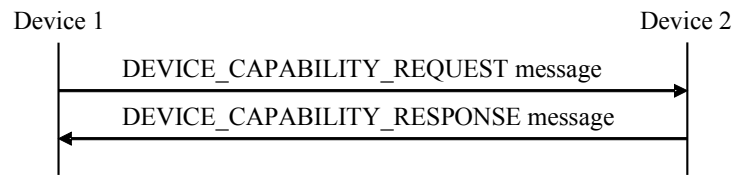
The types of capabilities that can be requested are:

- Device info
- Device name
- MAC address
- Supported format
- Vendor dependent information

The supported format information may contain one or more of the following types of format information:

- Video format information
- Audio format information
- Speaker allocation, i.e., the positions of the speakers in a multi-channel system
- Detailed timing information – specific information for video formats
- Maximum video buffer
- Maximum audio buffer
- Coded video information
- Extended video information
- Content protection support

This message exchange for device capabilities is illustrated in Figure 39.



**Figure 39: Message sequence for device capability request procedure**

#### 10.4.4 Connection procedure

Before starting the transmission of A/V data between a Source and a Sink, the Source reserves the bandwidth required for A/V data transmission and reserves ports between the Source and the Sink for A/V data transmission.

If the source initiates the connection procedure, it sends the `CONNECT_REQUEST` message to the Sink to confirm whether send A/V data to the Sink. When the Sink receives the `CONNECT_REQUEST` message, the Sink sends a `CONNECT_RESPONSE`



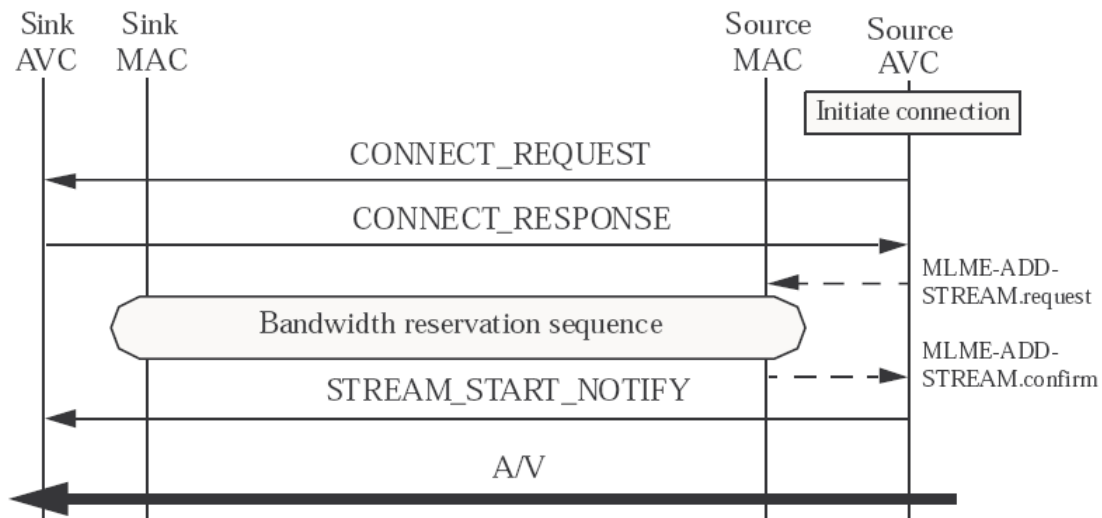
message which includes the result of the request. The Sink may also respond with its supported formats in the response message.

If the Sink initiates the connection, it sends the `CONNECT_REQUEST` message to the Source with the SinkPort and to reserve the SrcPort. If supported, the Sink may also include its supported formats in the request message. After the Source receives the `CONNECT_REQUEST` message, the Source reserves the SrcPort for A/V data transmission with the SinkPort. After the Source completes the SrcPort reservation, the Source sends a `CONNECT_RESPONSE` message and performs the bandwidth reservation process.

The Source may also request the supported format of the Sink. In that case, the Sink will respond with a `DEVICE_CAPABILITY_RESPONSE` message.

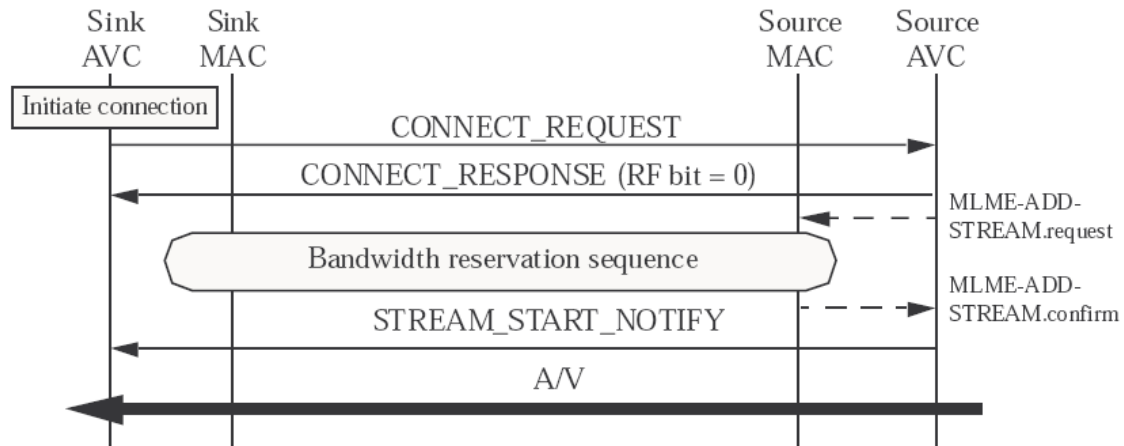
Both the Source and the Sink may disconnect a stream. In either case, the Source will be responsible for ending the stream allocation using the stream termination procedure.

Figure 40 illustrates a source initiated connection sequence.



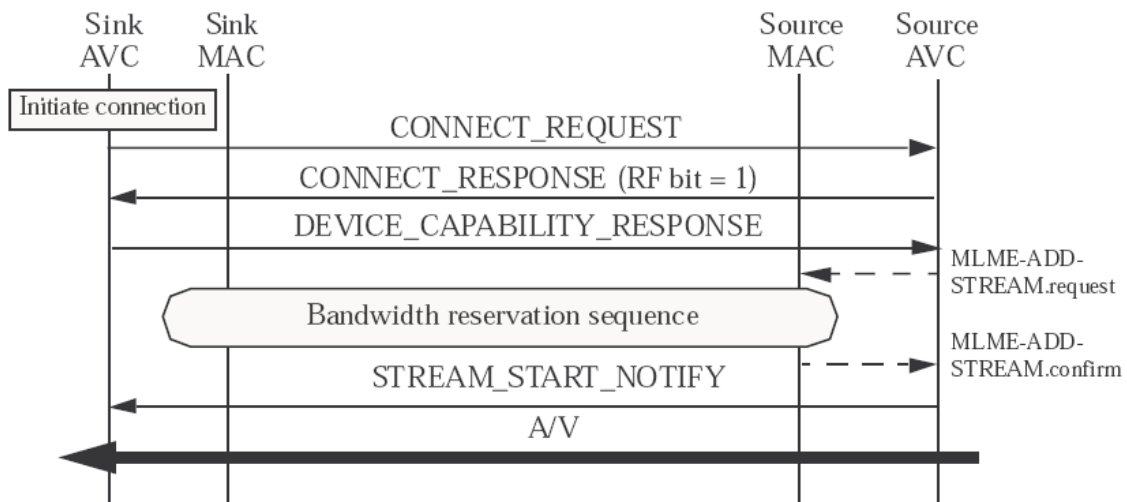
**Figure 40: Message sequence for source initiated connection**

Figure 41 shows the sequence of messages for a source initiated connection when the source is not requesting format information from the sink.



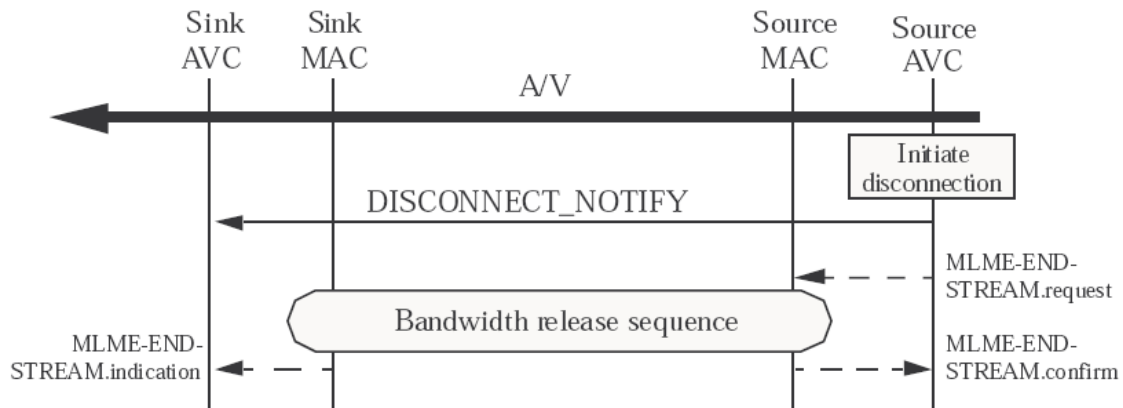
**Figure 41: Message sequence for sink initiated connection with the source not requesting format information from the sink**

Figure 42 shows the sequence of messages for a source initiated connection when the source is requesting format information from the sink.



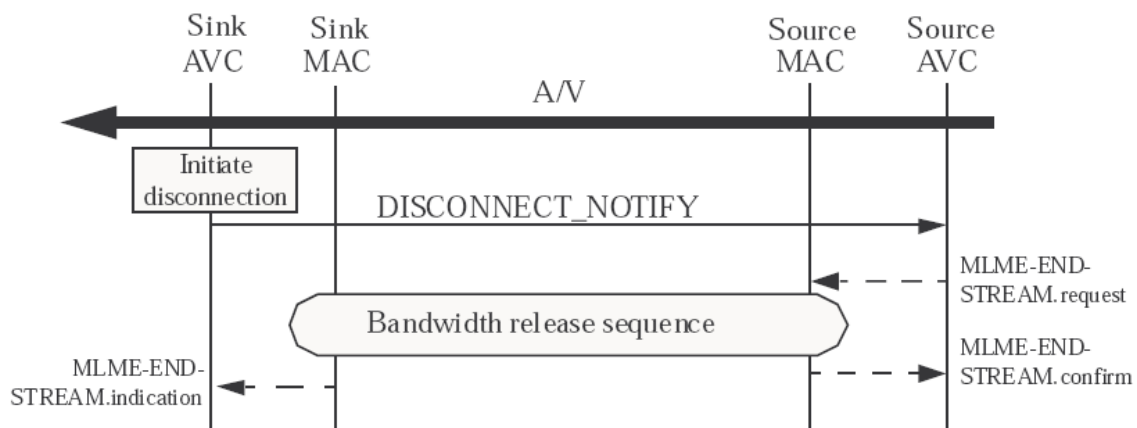
**Figure 42: Message sequence for sink initiated connection with the source requesting format information from the sink**

Figure 43 illustrates the message sequence for a Source initiated disconnection procedure



**Figure 43: Message sequence for a Source initiated disconnection procedure**

Figure 44 illustrates the message sequence for a Sink initiated disconnection procedure.



**Figure 44: Message sequence for Sink initiated disconnection**

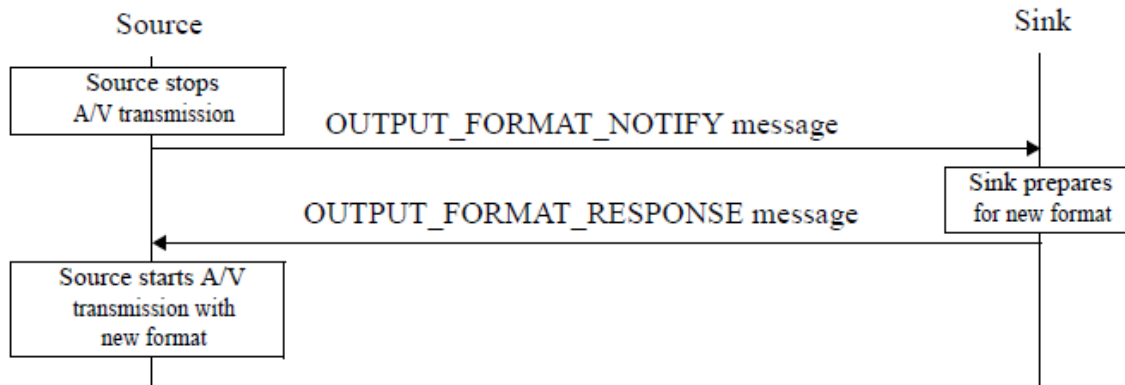
#### 10.4.5 Output format data transmission procedure

Before a Source starts the transmission of A/V data, the Source may send output format data which includes the video format and audio format to the Sink. This process is illustrated in Figure 45.



**Figure 45: Message sequence for output format data transmission procedure**

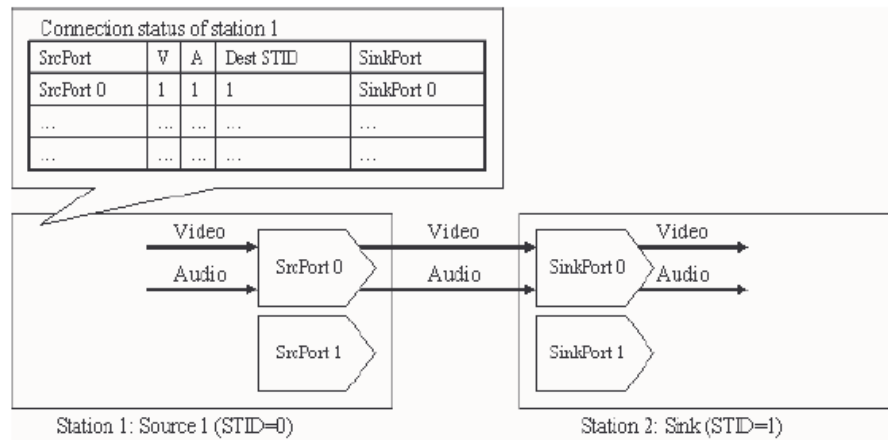
If the Sink indicates that it supports the use of OUTPUT\_FORMAT\_NOTIFY as a part of its device capabilities, then the process illustrated in is used.



**Figure 46: Format change when both devices support OUTPUT\_FORMAT\_NOTIFY**

#### 10.4.6 A/V stream transmission procedure

In the connection procedures, a SrcPort of a Source is linked to a SinkPort of a Sink. The Source sends the A/V stream data input through its SrcPort to the SinkPort of the Sink device which is linked to the SrcPort. Figure 47 shows an example of A/V transmission procedure. In this example, when audio and video data in input to SrcPort 0, destination STID of audio and video data is set to one and destination port of audio and video data is set to SinkPort 0.



**Figure 47: Example of A/V transmission procedure**

#### 10.4.7 Output format switching procedure

Figure 48 shows a sample sequence of the output format switching procedure. For A/V transmission, if link quality degraded, the MAC layer informs the AVC of the degradation of link quality by MLME-LINK-QUALITY-CHANGE.indication. If needed, the AVC stops the video streaming. The AVC determines the change of transmission video format requiring lower data rate. Then AVC sends MLME-CHANGE-STREAM.request to request the MAC layer to change the parameters of the lower layer. Before the Source restarts video data transmission, it sends the OUTPUT\_FORMAT\_NOTIFY message which includes AVI InfoFrame to the Sink.

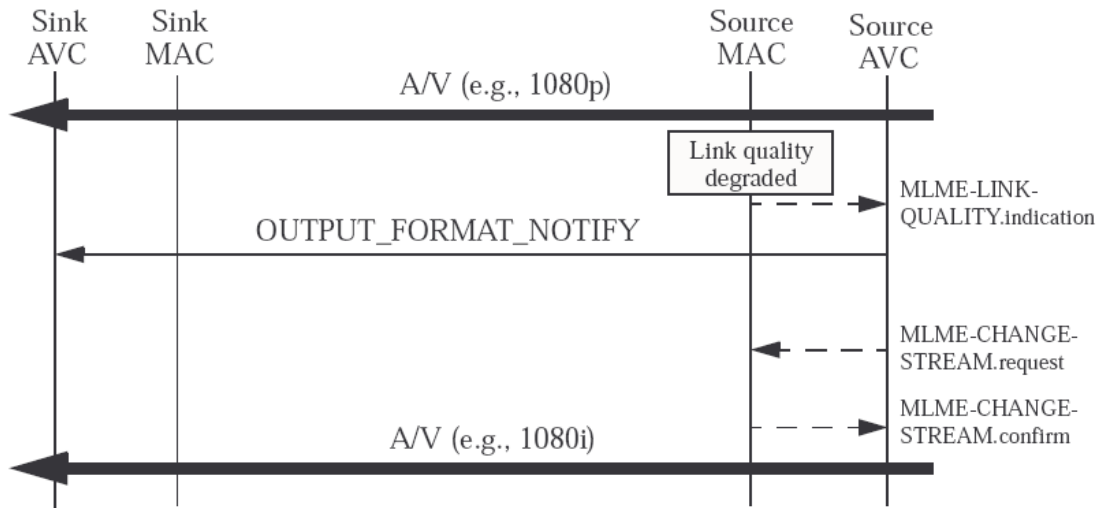


Figure 48: Example output format switching procedure

## 10.5 Device control (DEVCTL)

### 10.5.1 Overview

DEVCTL is a protocol that provides high-level control functions between all of the various audiovisual products in a user's environment. End user features include:

- **One Touch Play** – Allows a device to be played and become the active source with a single button press.
- **Device Power Control** – The user can control the power of all devices (e.g., power on, standby) and a device can discover the current power status of another device.
- **One Touch Record** – Offers a What You See Is What You Record (WYSIWYR) facility, meaning that whatever is shown on the display is recorded on a selected recording device.
- **Timer Programming** – Allows the user to program the timers in a Recording Device from an EPG running on a TV or STB.
- **Deck Control** – Enables a device to control (e.g. play, fast forward etc.) and interrogate a playback device (a deck).
- **Tuner Control** – Allows a device to control the tuner of another device.
- **Remote Control Pass Through** – Enables remote control commands to be passed through to other devices within the system.
- **Audio Amplifier Control** – Enables a device to control the audio configuration of another device.

- **Device OSD Name Transfer** – Enables devices to upload their preferred OSD name to the display. The display can then use this name in any menus associated with that device.
- **OSD Display** – Enables a device to use the on-screen display of the display to display text strings.
- **System Information** – Queries the system to determine device addresses and language.
- **Vendor Specific Commands** – Allows a set of vendor-defined commands to be used between devices of that vendor.
- **System Audio control** – An audio amplifier can be used with the TV and its volume can be controlled by the TV.
- **Formatted Strings Transfer** – This feature allows a device to recognize the capability of the remote display and to transfer text strings fit to the display to be displayed to the user.

## 10.6 Content protection message communication function

In general, content protection specifications include the authentication, key exchange for encryption, and other messages exchange. Two messages are provided to provide a means of message transaction between DTCP content protection entities of devices, CP\_CONTROL\_COMMAND and CP\_CONTROL\_RESPONSE. A third message, HDCP\_2P0\_CONTROL is provided to support HDCP 2.0 mapping to WirelessHD.

## 10.7 HDMI pass through mode

HDMI pass through mode is an optional feature that allows a WirelessHD device, referred to as a pass through (PT) WirelessHD device, to send HDMI messages to another PT WirelessHD device. The messages and opcodes used for HDMI pass through mode are listed in Table 15.

**Table 15: HDMI pass through opcodes**

Operation code type
PASS THROUGH REQUEST
PASS THROUGH RESPONSE
EDID REQUEST
EDID RESPONSE
DATA ISLAND NOTIFY
CEC NOTIFY
CEC NACK

Operation code type
LOG_ADDR_TABLE_NOTIFY
HPD_NOTIFY
Reserved

The message formats for the HDMI pass through mode are defined as optional features, while the use of these messages is described in the informative appendix.

## 11 Audio and video formats

### 11.1 Video format requirements

All WirelessHD systems support a common set of video modes to ensure a basic level of interoperability. The requirements are:

- A WirelessHD Source that accepts 60Hz video formats supports the 720x480p @ 59.94/60Hz video format.
- A WirelessHD Source that accepts 50Hz video formats supports the 720x576p @ 50Hz video format.
- A WirelessHD Source that accepts 60 Hz video formats, and that supports stereoscopic (3D) video formats, supports 1280x720p @ 59.94/60 Hz or 1920x1080p @ 23.97/24 Hz Stereoscopic (3D) video format.
- A WirelessHD Source that accepts 50 Hz video formats, and that supports stereoscopic (3D) video formats, supports 1280x720p @ 50 Hz or 1920x1080p @ 24 Hz Stereoscopic (3D) video format.
- A WirelessHD Sink that accepts 60Hz video formats supports the 720x480p @ 59.94/60Hz video format.
- A WirelessHD Sink that accepts 50Hz video formats supports the 720x576p @ 50Hz video format.
- A WirelessHD Sink that accepts 60Hz video formats, and that supports HDTV capability, supports 1280x720p @ 59.94/60Hz or 1920x1080i @ 59.94/60Hz video format.
- A WirelessHD Sink that accepts 50Hz video formats, and that supports HDTV capability, supports 1280x720p @ 50Hz or 1920x1080i @ 50Hz video format.
- A WirelessHD Sink that accepts 60 Hz video formats, and that supports stereoscopic (3D) capability, shall support 1280x720p @ 59.94/60Hz or 1920x1080p @ 23.97/24 Hz stereoscopic (3D) video format.
- A WirelessHD Sink that accepts 50 Hz video formats, and that supports stereoscopic (3D) capability, shall support 1280x720p @ 50Hz or 1920x1080p @ 24 Hz stereoscopic (3D) video format



- A compliant WirelessHD implementation that supports a video mode on any of its outputs supports that video mode across the WirelessHD interface.
- A compliant WirelessHD device supports RGB 4:4:4, YCbCr 4:2:2 and YCbCr 4:4:4 color spaces in all of the resolutions that it supports. Compliant WirelessHD devices may support color depths of 24, 30, 36 and/or 48 bits per pixel. All WirelessHD devices support 24 bits per pixel.

## 11.2 Audio format requirements

A compliant WirelessHD implementation that supports audio source or sink functionality at a minimum supports linear PCM format with 16 bits per sample at sampling frequencies of 32 kHz, 44.1 kHz, and 48 kHz.

Each audio sub-packet contains the playback time for the samples to enable synchronized playback. Audio sub-packet formats are defined for IEC 60958-1, One Bit Audio and DST Audio.

## 11.3 Source processor subsystem

The source processor subsystem formats the A/V data prior to transferring it to the MAC in order to enhance the quality of the A/V data that is transmitted. The reference model of the A/V packetizer is illustrate in Figure 49

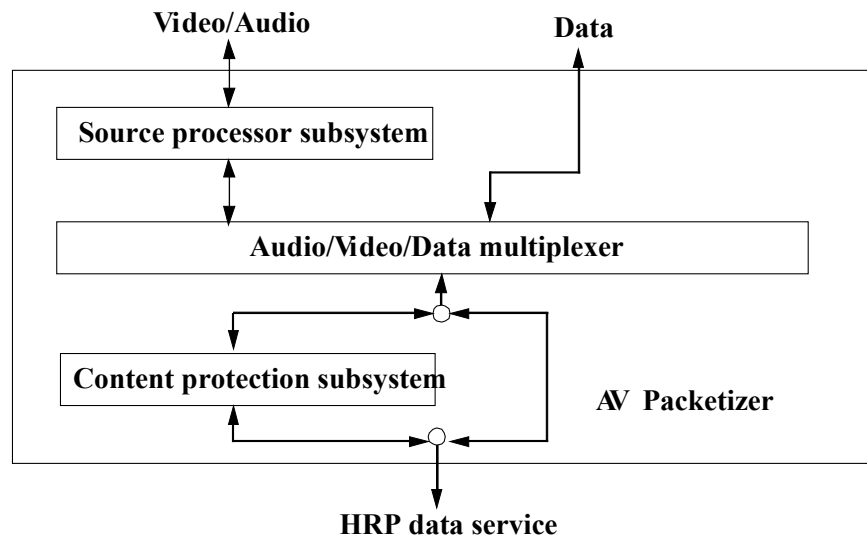


Figure 49: Reference model of A/V packetizer

## **11.4 Clock synchronization**

The purpose of the clock synchronization is to synchronize video clock and audio clock between devices in WVAN are described. The media can be regenerated by precisely maintaining the relation of A/V clock timing between the source device and the sink device. Clock synchronization provides the following capabilities:

- Pixel clock regeneration
- Audio clock regeneration
- AV synchronization (lip sync)

### **11.4.1 Pixel clock regeneration**

The pixel clock regeneration is provided by inserting a time stamp into the each packet.

### **11.4.2 Audio clock regeneration**

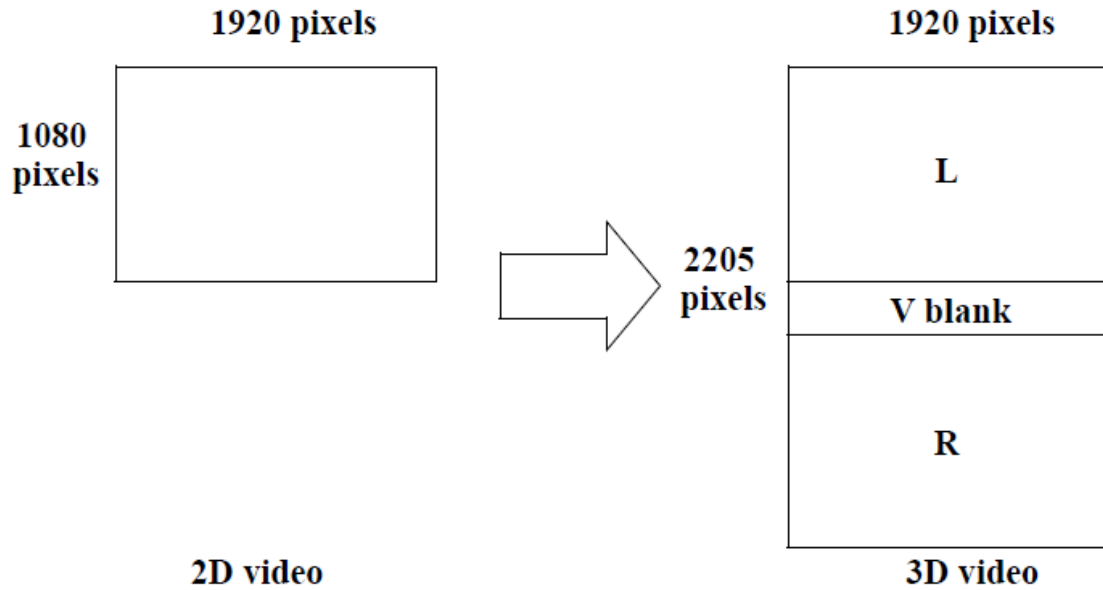
In many video source devices, the audio clock and pixel clock are generated from a common clock, for example 27 MHz. In this case, because these two clocks have synchronized, the audio clock is generable from the pixel clock. However, if the audio clock and the video clock are asynchronous, it is possible to regenerate it by using the time stamp that works with the audio clock.

### **11.4.3 AV synchronization (lipsync)**

Some common home theater device configurations will render the audio in a device other than the TV. In these configurations, the video processing latency of the TV may cause perceptible lip sync issues to the user. These issues can be corrected by delaying the audio to compensate for the video processing latency.

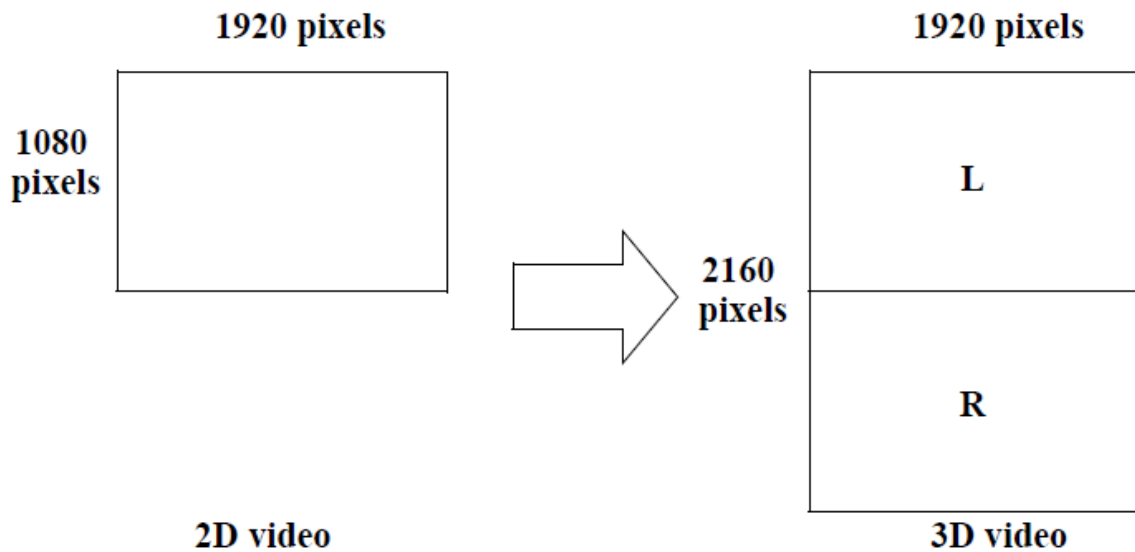
## **11.5 3D frame sequential format**

The use of the 3D frame sequential format using for an uncoded video stream is illustrated in Figure 50 for 1920x1080p.



**Figure 50: 3D frame sequential usage for an uncoded video stream**

The use of the 3D frame sequential format using for a coded video stream is illustrated in Figure 51 for 1920x1080p.



**Figure 51: 3D frame sequential usage for an coded video stream**

## 11.6 Coded video streams

For coded video, the incoming stream is split into slices, which contains a row of blocks of pixel data. A scalable, lossless coding transformation is then applied to each of these blocks using one of three possible coding modes:

- natural mode,
- graphics mode, and
- skip mode

The video codec framework is illustrated in Figure 52. The video codec subsystem is a part of the source processor subsystem. The video codec subsystem in the transmitter consists of slice based video compressor, pixel partitioning and format adaptation functionalities. The video codec subsystem in the receiver consists of slice based video de-compressor, pixel combination and format adaptation functionalities.

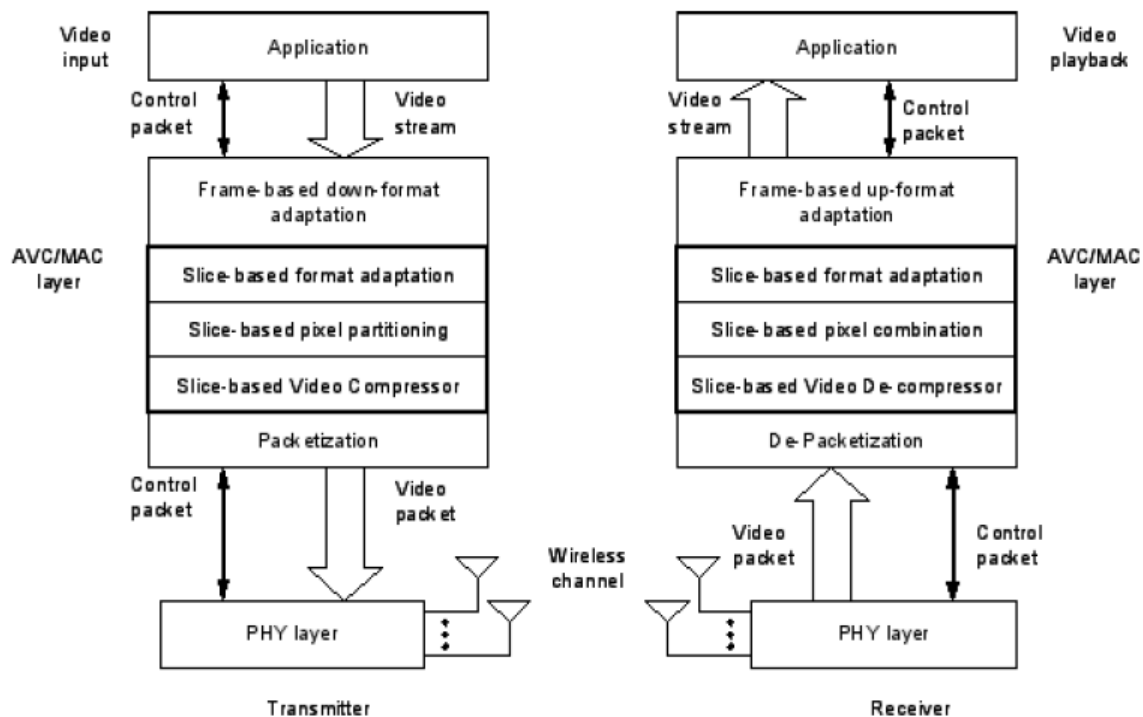


Figure 52: Video codec framework

## 12 Security

### 12.1 *User data privacy (informative)*

In order to ensure the privacy of data owned by users of WirelessHD implementations, a security suite is defined in this specification that provides the following security services:

- Authentication and key establishment – The identity of both Stations is mutually assured using public-key cryptography and a secret key is established between the Stations.
- Beacon protection – The beacon contents are cryptographically authenticated.
- Command protection – Each command is encrypted and its contents are cryptographically authenticated (except for the association commands).
- Key distribution – A secure method for updating the data keys between devices.
- Freshness protection – A strictly increasing secure frame counter is used to prevent the replay of old messages.
- Data privacy – Data is encrypted to prevent unauthorized users from viewing the data
- Data integrity – The integrity of the data is cryptographically authenticated for both the source and content.

These privacy methods are achieved using three main functions:

- A four-pass public key exchange
- An encryption algorithm
- A cryptographic integrity calculation

The public key, encryption and integrity calculations are specified by the security suite.

This specification supports the use of one or more security suites, but only one is defined for this revision of the specification.

There are two roles in the security process, security manager (SM) and Station. In a secure WVAN, the security manager role is provided by the Coordinator.

For authorization, there are two methods defined, peer authorization and the optional domain manager (DM) authorization. For peer authorization, any trusted Station may take on the role of authorization responder (AR). For DM authorization, the role of DM is selected by the user to authorize all Stations in the secure WVAN.

A secure WVAN is one in which the Coordinator requires that all Stations that join the WVAN successfully authenticate with the Coordinator. In addition, all Stations in the WVAN have a common symmetric group key that is used for encryption and data integrity.

## 12.2 Content protection

Content Protection capability is recommended for all WirelessHD compliant devices, and its implementations using Digital Transmission Content Protection (DTCP) are authorized by WirelessHD in the form specified by the Digital Transmission License Administrator, LLC (DTLA). The version of the application of DTCP to WirelessHD is “Supplement G”, and related volume 1.

In addition, Digital Content Protection, LLC (DCP) has provided a mapping document for HDCP 2.0 to WirelessHD titled “HDCP on WirelessHD Specification Rev2.0.pdf”

## 13 Medium rate PHY(MRP)

### 13.1 Overview

The MRP is designed to provide about 0.5 to 2 Gb/s data rates using OFDM modulation and beam formed transmit and receive antennas. The data rates, modulations and codings are described Table 16. If a Station supports the use of the MRP or HRP, it supports the use of MRP mode index 0, MRP mode index 1 and MRP mode index 7. That is, if a Station supports HRP, it also supports MRP in the same direction, i.e., TX, RX or both TX and RX. If a Station supports an EEP MRP mode index, it supports all EEP MRP mode indices with raw data rate less than the data rate of that mode. If Station supports a UEP MRP mode index, it supports all UEP MRP mode indices with raw data rate less than the data rate of that mode.

**Table 16: MRP data rates and coding**

MRP mode index	Coding mode	Modulation	Code rate		Raw data rate (Gb/s)
			MSB	LSB	

			[7] [6] [5] [4]	[3] [2] [1] [0]	
0	EEP	QPSK	1/3		0.476
1		QPSK	2/3		0.952
2		16-QAM	2/3		1.904
3	UEP (coding)	QPSK	4/7	4/5	0.952
4		16-QAM	4/7	4/5	1.904
3	UEP (mapping)	QPSK	2/3		0.952
4		16-QAM	2/3		1.904
5	MSB-only retransmission	QPSK	1/3	N/A	0.476
6		QPSK	2/3	N/A	0.952
7	EEP	QPSK	1/2		0.714
8		QPSK	5/6		1.190
9		16-QAM	1/2		1.428
10	UEP (coding)	QPSK	2/5	2/3	0.714
11		16-QAM	2/5	2/3	1.428
10	UEP (mapping)	QPSK	1/2		0.714
11		16-QAM	1/2		1.428

### 13.2 General requirements of the MRP

The general parameters for the HRP are given in Table 5. Unless otherwise specified, the terms sampling rate or sample are in terms of the reference sampling rate. If spatial multiplexing, as defined in 4.6, is used, each data stream has the parameters given in Table 5.

Table 17: General parameters of the HRP

Parameter	Value	Symbol
Occupied bandwidth	890 MHz	N/A
Reference sampling rate	1.269 Gsamples/s	$f_{s(MR)}$
Number of subcarriers	256	$N_{sc(MR)}$
FFT period	$N_{sc(MR)} / f_{s(MR)} \sim 201.73$ ns	$T_{FFT(MR)}$
Subcarrier spacing	$1 / T_{FFT(MR)} \sim 4.957$ MHz	$\Delta f_{sc(MR)}$
Guard interval	$32 / f_{sc(MR)} \sim 25.22$ ns	$T_{GI(MR)}$
Symbol duration	$T_{FFT(MR)} + T_{GI(MR)} \sim 226.95$ ns	$T_{S(MR)}$
Number of data subcarriers	168	$N_{dsc(MR)}$
Number of DC subcarriers	3	N/A
Number of pilots	8	N/A
Number of null subcarriers	77	N/A

Modulation	QPSK, 16-QAM	N/A
Outer block code	RS(224,216)	N/A
Inner code	1/3, 1/2, 2/3, 5/6 (EEP), 2/5, 1/2, 4/7, 2/3, 4/5 (UEP)	N/A

The MRP uses the same channels as the HRP.

### **13.3 MR protocol data unit (MRPDU) format**

The MRPDU is formatted as illustrated in Figure 4.

MRP preamble	MRP header	MAC header	HCS	Packet body	Beam tracking
-----------------	---------------	------------	-----	----------------	---------------

**Figure 53: MRPDU packet format**

The MRP Header, MAC Header and Header Check Sequence (HCS) fields are sent at the lowest MRP data rate. The MRP Header field is the same format as the HRP Header field. The MAC Header, HCS and Packet Body field are the same for both HRP and MRP.

The MRP preamble is similar to the HRP preamble, but consists of 12 symbols instead of 8 symbols. Note that the symbols for the HRP and the MRP have the same time duration.

### **13.4 MRP RF characteristics**

The MRP transmit mask is the same as the HRP.

### **13.5 MRP baseband**

A reference implementation of the MRP baseband for the EEP mode is illustrated in Figure 54 and for the UEP mode is illustrated in Figure 55.



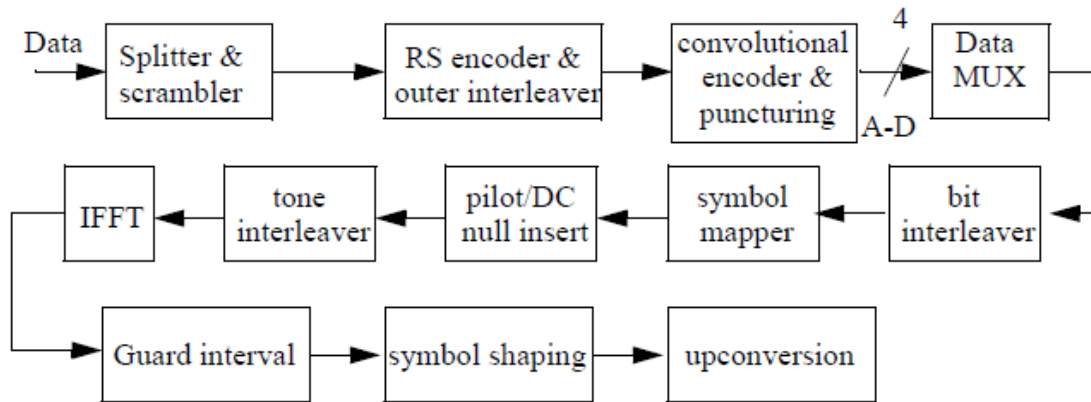


Figure 54: MRP baseband reference implementation for EEP mode

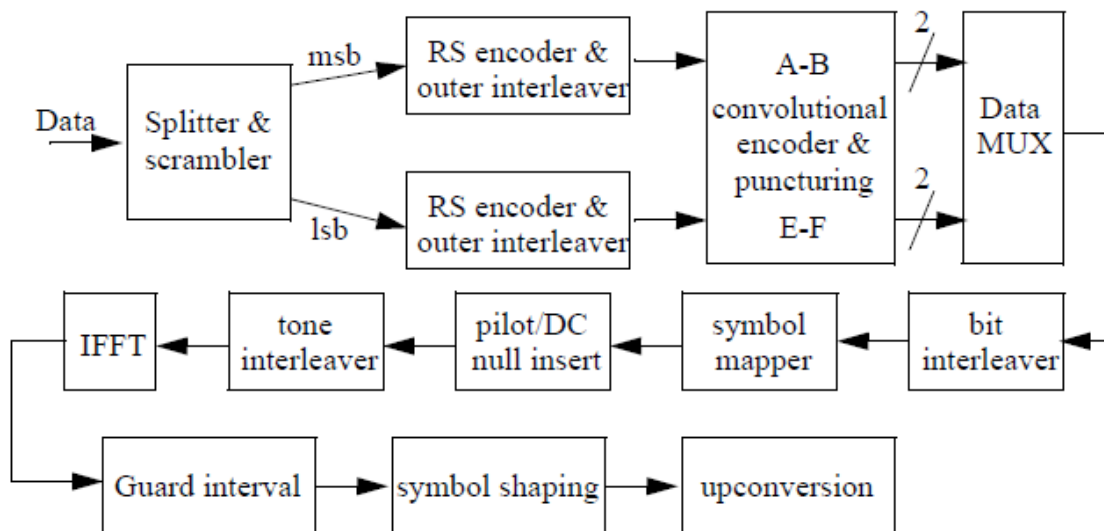


Figure 55: MRP baseband reference implementation for UEP mode

The baseband blocks for the MRP are the same as for the HRP, except for the outer interleaver and multiplexers, because only four convolutional encoders are used. Stuff bits are added to complete the inner encoder and pad octets are added to complete the outer encoder and ensure an integer number of symbols.

## 14 Data protocol support

### 14.1 USB pass through mode

This section provides a mapping of USB to WirelessHD. The architecture of the mapping for is shown in Figure 56.

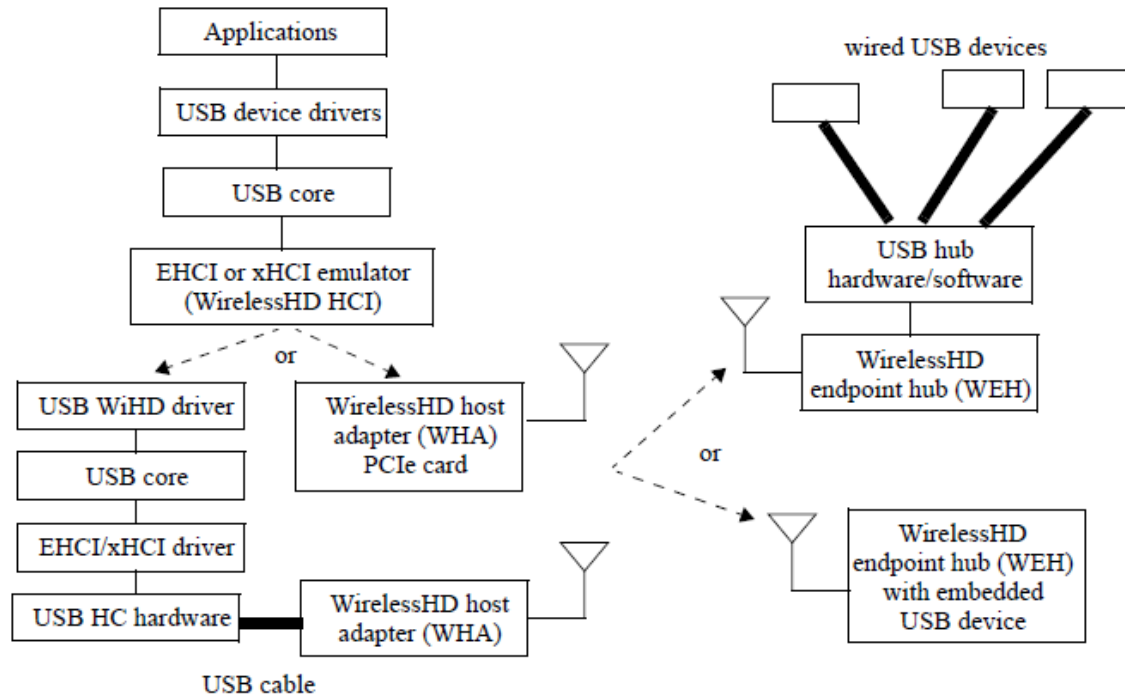


Figure 56: USB to WirelessHD mapping architecture

In Figure 56, the WirelessHD HCI acts either as a USB 2.0 host controller conforming to the EHCI interface or as a USB 3.0 host controller conforming to the xHCI interface. The software/hardware implementing the WirelessHD HCI, the WirelessHD host controller (WHC), contains the functionality required to support bridging the USB link over the WirelessHD WVAN. In the case where the WHC is operating as a USB 2.0 HC, then it implements one EHCI and zero companion host controllers.

There are two possible architectures on the host side. If the WirelessHD adapter (WHA) is attached via an internal bus, then the WHCI driver communicates directly with the adapter over the internal bus.

If, on the other hand, the WHA is attached via a USB cable, then adapter appears as a WirelessHD host adapter to the USB core. Devices that are connected wirelessly to this adapter appear only at the WHCI to USB core interface, not at the EHCI/xHCI interface. The WHCI driver encapsulates message to be sent out over the USB link and removes the encapsulation of USB messages received over the link. In addition, it monitors the state of the WVAN to emulate plug and un-plug events.

The WirelessHD endpoint hub (WEH) appears as USB compliant hub (either 2.0 or 3.0) to the USB core software on the host. This includes supporting low-speed and full-speed devices with split transactions. The WEH may provide one or more USB physical connections that allow standard USB devices to be plugged in and to be connected wirelessly to the host.

This specification only provides for a single WirelessHD connection to bridge USB, in essence becoming a cable replacement. Multiple USB devices are supported by using a hub at the remote wireless end.

USB 2.0 and USB 3.0 transactions are mapped in a different manner to WirelessHD packets. This is in keeping with the USB 3.0 architecture which uses parallel paths for 2.0 and 3.0 data, as described in 14.2.

## **14.2 OBEX support**

The OBEX protocol requires a transport layer that provides reliable, flow-controlled connections. Normal data services in WirelessHD are unreliable and require an upper layer, e.g., TCP, to enforce reliable delivery. For OBEX, this capability is provided by the LM protocol in the WirelessHD MAC.

OBEX transfers are setup using the LM Operation command whereas the transfer of the object uses the LM Object Body command. The LM Object Body command is used to enable an implementation to efficiently handle high throughput data without loading down the host system. The steps to perform an OBEX transfer are:

- Open a port to the destination using LM Connect Request command.

- Setup the transfer (OBEX connect, exchange capabilities, change directory if needed, etc.).
- Issue OBEX PUT or GET, as needed.
- The Station with the object sends it in one or more LM Object Body commands.

If no further transactions are required, the port is closed.

## A Bibliography

- [1] Enhanced Host Controller Interface Specification for Universal Serial Bus, revision 1.0, March 12, 2002,  
<http://www.intel.com/technology/usb/download/ehci-r10.pdf>.
- [2] Universal Serial Bus Specification, revision 2.0, April 27, 2000,  
<http://www.usb.org/developers/docs/>.
- [3] Universal Serial Bus 3.0 Specification, revision 1.0, November 12, 2008,  
<http://www.usb.org/developers/docs/>.

## B Appendix

### ***B.1 HDMI pass through mode (informative)***

The HDMI pass through mode is available in an HDMI pass through WirelessHD (PT WirelessHD) device. In HDMI pass through mode, EDID, some Data Island Packets and CEC messages are passed through the WirelessHD link.

In HDMI pass through mode, a single PT WirelessHD device is connected to another single PT WirelessHD device with a proprietary connection. HDMI pass through mode does not connect with normal mode.

Figure 401 shows an example of communication between HDMI devices via WirelessHD.



Figure 57: Example of communication between HDMI devices via WirelessHD

### B.1.1 Pass through connection establishment/cancellation

When a PT WirelessHD Device, the originator, requests that another PT WirelessHD Device, the target, establish or cancel a pass through connection, the originator sends a `PASS_THROUGH_REQUEST` message to the target. When the target receives the `PASS_THROUGH_REQUEST` message, the target sends the `PASS_THROUGH_RESPONSE` message which includes the result of the request. If the target accepts the request, the target sets the Result Code field to "success". Otherwise, the target sets the Result Code field to "failure".

If PT WirelessHD Device has disassociated from WVAN, the pass through connection is cancelled.

### B.1.2 Address assignment

PT WirelessHD devices and HDMI devices communicate with each other using logical addresses. Logical addresses are updated with the `LOG_ADDR_TABLE_NOTIFY` message. Figure 58 shows an example of logical address (LA) assignment.

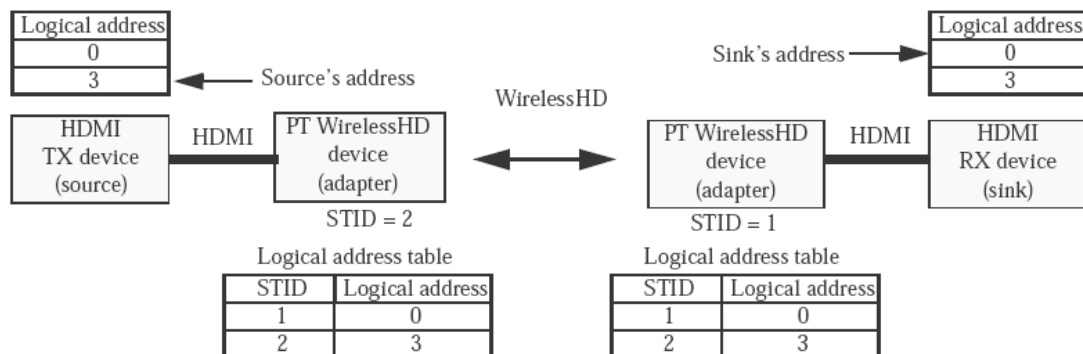


Figure 58: Example of logical address assignment

### **B.1.3 EDID transmission**

When a PT WirelessHD Device, the originator, has read the EDID, the originator sends the HPD\_NOTIFY message to the other PT WirelessHD Device, the target, to indicate that a pass through connection has established. When the target receives the HPD\_NOTIFY message, the target sends the EDID\_REQUEST message to the originator. When the originator receives the EDID\_REQUEST message, the originator sends the EDID\_RESPONSE message. When the target receives the EDID\_RESPONSE message and its EDID is available for reading, the target asserts high voltage level on its Hot Plug Detect pin.

When a PT WirelessHD Device, the originator, detects HPD deassertion, the originator sends the HPD\_NOTIFY message to the other PT WirelessHD Device, the target, with which it has established a pass through connection. When the target receives the HPD\_NOTIFY message the originator deasserts low voltage level on its Hot Plug Detect pin.

### **B.1.4 TMDS Data Island packet transmission**

When an PT WirelessHD Device receives the TMDS signal from the Source, it retrieves the Data Island Packets from the Data Island. If the information included in AVI InfoFrame or Audio InfoFrame is different from the previous one, the PT WirelessHD Device sends the DATA\_ISLAND\_NOTIFY message including the AVI InfoFrame and the Audio InfoFrame to the PT WirelessHD Device with which the pass through connection was established.

When the PT WirelessHD Device receives other Data Island Packet, it sends the DATA\_ISLAND\_NOTIFY message including the received Data Island Packet.

### **B.1.5 Command pass through**

All PT WirelessHD devices have the following functions:

- Message fragment – A PT WirelessHD device fragments a CEC message on the CEC bus into CEC\_NOTIFY messages. It also defragments CEC\_NOTIFY messages that it receives into a CEC message on the CEC bus.
- Proxy ACK – A PT WirelessHD device acknowledges to the CEC message instead of destination device.
- CEC Routing – A PT WirelessHD device delivers a CEC unicast message to a destination device by unicast transmission.

### **B.1.6 CEC message transmission**

When an PT WirelessHD device receives the CEC message whose length is greater than 7 octets on CEC bus, the PT WirelessHD device fragments the received CEC message to several CEC\_NOTIFY messages.

### **B.1.7 Proxy ACK**

When an PT WirelessHD device receives a CEC message from a device which exists in same HDMI cluster, the PT WirelessHD device checks whether the destination address of the CEC message exists in same HDMI cluster (i.e., that the wired flag is set to one) and whether the destination address of the CEC message exists in the logical address table. If the destination address of the CEC message does not exist in same HDMI cluster (i.e., the wired flag is zero) and it exists in the logical address table, the PT WirelessHD device acknowledges the CEC message instead of the destination device. Otherwise the PT WirelessHD device does not acknowledge the CEC message.

### **B.1.8 CEC Routing**

When the destination device is connected to same HDMI cluster, the PT WirelessHD device does not send the CEC message from a device which is connected to same HDMI cluster to the wireless interface. When the PT WirelessHD device receives a CEC message from wireless interface and destination device does not exist in the same HDMI cluster and the destination address is not broadcast, it will output the CEC message to HDMI cluster.