Synchronous Ethernet

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For Public Distribution

Provided for Discussion Purposes Only

This Version is Not Intended as a Proposal for Standardization

Table of Contents

1. Overview

This document defines a method of maintaining synchronous communication over Ethernet. A simple control protocol is defined to accomplish necessary negotiation of resources and roles on the network. This specification is intended to maintain full compatibility with existing Ethernet standards.

2. License

This specification is provided to the public with no restrictions or obligations of any kind.

3. Definitions

The following definitions are provided for this specification:

Cycle	A unit of transmitted data, size of cycle depends upon transmission speed
STM	System Timing Master, manages cycle synchronization across network
TSC	Time Sensitive Control, control messages which require very low latency
Slot	A segment of synchronous data, there are 192 slots per synchronous frame
SRT	Slot Routing Table, contains routing information for slot data between ports
Sync-E Link	Synchronous link
Sync-E Port	Ethernet port engaged in an synchronous link
Sync Port	Ethernet port which serves as the source of synchronization for the device
Sync-E Frame	Synchronous Ethernet frame
Async Frame	Asynchronous Ethernet frame
SDMP	Synchronous Data Management Protocol
MDCP	Media Device Control Protocol

4. Power
All devices which support Synchronous Ethernet must support 802.3af (Power over Ethernet) on all Synchronous Ethernet capable ports.

5. Full Duplex

All devices which support Synchronous Ethernet must support full duplex transmission on all Synchronous Ethernet capable ports.

Note: A full duplex link must be established before a Sync-E Link may be established.

6. Cycle

All devices which support Synchronous Ethernet must transmit and receive data in a fixed size, fixed duration 'cycle'. The data size of each cycle depends upon the Ethernet speed. Rate of transmission is always 8,000 cycles per second (8 kHz) with absolute precision of 10^{-5} and cycle-to-cycle jitter not exceeding 800 ns.

7. System Timing Master

An Synchronous Ethernet network must establish one System Timing Master (STM) using a set of defined rules. Every Synchronous device should be capable of operating as an STM. Every Synchronous Ethernet device with more than one port must be capable of operating as STM. The signaling rate of the physical layer is asynchronous with the frame transmission rate. STM is the source of sync for the Synchronous Ethernet network.

8. Sync Path

Every device must track from which port the sync is received (the 'sync port'). All Sync-E Frames coming from the sync port are the source of sync for all other ports on the device. A sync bit is defined in the synchronous frame header to identify the frame a source of sync for the device. If a device receives a Sync-E Frame with sync bit enabled, it will sync to that frame. Handling loss of sync and sync conflicts is described in the Sync-E Link Detection section of this document.

9. Sync-E Link Detection

New Link:

If a device detects that a link has been established on a previously unused synchronous port, then the device attempts to establish full duplex connectivity at the highest speed (100 or 1000 Mbps, depending on the port), then if full duplex 100 Mbps or higher is established, it does the following:

1) It listens for Sync-E Frames on the new port, but Sync-E Link is not yet established

2) If the device **is an STM** or receives sync on another port, then it sends Sync-E Frames with sync, and the following cases are considered to establish Sync-E Link:

a) If it gets Sync-E Frames from the new port but the frames do not have the sync bit enabled, then the device assumes it will remain the source of sync for the other side, and the new port has established a Sync-E Link.

b) If it does get Sync-E Frames with sync, then it performs STM resolution as follows: it examines the source MAC address of the inbound Sync-E Frame and compares it to the MAC address of the local port. If the local MAC is higher, then the device remains the source of sync for the other side, otherwise it will stop sending sync to that port and begin synching on the new port.

3) If the device **is not an STM** and does not have a Sync-E Link on another port, then it sends Sync-E Frames without sync, and the following cases are considered to establish Sync-E Link:

a) If it gets Sync-E Frames from the new port but the frames do not have the sync bit enabled, then the device waits 100 cycles to get a Sync-E Frame with sync. If after 100 cycles, it does not see a Sync-E Frame with sync, then the device will become an STM (if it is capable of being an STM) and send Sync-E Frames with sync on the new port, and Sync-E Link is established. (if the other side does the same, then STM resolution will occur next)

b) If it does get Sync-E Frames with sync, then it syncs on the new port, and Sync-E Link is established on that port

4) If the device does not receive any Sync-E Frames after 100 cycles, then it stops sending Sync-E Frames on that port, and the Sync-E Link fails.

Bad Cycle:

If a device detects that a cycle coming in from the sync port is poorly formed (ie. the device on the other end has crashed, but the link is maintained), then the device immediately sets the valid bit to 0 on all slots coming from that port. If a well-formed cycle cannot be obtained from the port by 100 cycles, then the Sync-E Link is dropped and falls back to standard asynchronous Ethernet (at the same speed) on that port, and the device attempts to recover the Sync-E Link every 1 second. When the Sync-E Link is dropped, then the device elects to be the new STM (if it is capable of being an STM).

If the device detects that a cycle coming in from a non-sync port is poorly formed, then the device immediately sets the valid bit to 0 on all slots coming from that port. If a well-formed cycle cannot be obtained from the port by 100 cycles, then the Sync-E Link is dropped and falls back to standard asynchronous Ethernet (at the same speed) on that port, and the device attempts to recover the Sync-E Link every 1 second.

Lost Physical Link:

If a device detects that the physical link on the sync port has been dropped (ie. the device on the other end has crashed, lost power, or become disconnected), then the device immediately elects to become the STM for its network (if it is capable of being an STM). The device also immediately sets the valid bit to 0 on all slots coming from that port.

If the device detects that the link on a non-sync port has been dropped, then the device immediately sets the valid bit to 0 on all slots coming from that port.

10. Synchronous Data

The Synchronous data frame has the following sections:

Ethernet Header (22 octets)
Synchronous Header (32 octets)
Header CheckSum (4 octets)
192 32-bit Synchronous Data Slots (768 octets)
Frame CheckSum (4 octets)
TOTAL = 830 octets

Ethernet header consists of the following standard sections:

Preamble (8 octets)
Destination Address (6 octets)

Source Address (6 octets)
Length/Type (2 octets)

Note: A new Ethertype value must be defined for Synchronous data frames.

In the Synchronous header the following sections are defined:

Iso Version (4 bits)
Sync (1 bit)
Reserved (19 bits)
Frame Counter in the Cycle (1 octet)
Cycle Counter (4 octets)
Data Slot Validity (24 octets)
Total = 32 octets

Frame CheckSum (FCS) is a standard 32-bit CRC value that is computed according to chapter 3.2.8 of IEEE802.3 standard.

Header CheckSum (HCS) is calculated similar to FCS but is computed as a function of the contents of only the Source and Destination Addresses, length/type and the Synchronous Header.

To maintain compatibility with Ethernet switches which do not support synchronous links, but which do support 802.1q prioritization, the 3-bit priority field for synchronous data frames must be set to 110.

11. Synchronous Data Management Protocol

In order to facilitate the negotiation of synchronous traffic, an Synchronous Data Management Protocol (SDMP) is defined. This protocol includes methods for the following:

1) Modifying SRTs
2) Slot Reservation

Note: A new protocol number must be defined for SDMP.

[Editorial Note: It may be desirable to move the SDMP specification to a separate document.]

12. SDMP Frame

SDMP messages are included in each cycle as asynchronous frames. SDMP messages have the following sections:

Ethernet Header (22 octets)
SDMP Header (2 octets)
1-5 SDMP Messages (20-100 octets)
FCS (4 octets)
Total = 48-140 octets

The SDMP header has the following sections:

Version (4 bits)
Reserved (12 bits)
Total = 2 octets

The SDMP data section of the frame may contain up to 8 12-octet messages in the following format:

Session ID (7 bits)
Response (1 bit)
Command (1 octet)
Parameters (18 octets)
Total = 20 octets

Session ID 0 signifies that there is no session defined for that message.

13. Slot Routing

A slot routing table (SRT) must be maintained on any device which can support more than one Sync-E Port. The SRT contains one entry for each active slot (active is defined as have valid data). Each route contains: source mac+slot and destination mac+slot and data type+format (and frame number in the cycle for 1000 Mbps). A default route to all outbound ports must be included, and is overridden by other routes. (some products may ship with other static routes in the default configuration, for example to disable certain audio outputs)

An example device has 4 Iso Ethernet ports active with the following MAC addresses:

00.03.93.4A.D3.37
00.03.93.4A.D3.38
00.03.93.4A.D3.39
00.03.93.4A.D3.40

Here is an example SRT for that device (assuming 100 Mbps on all ports):

Source		*Destination*		*Data Info*	
MAC	**Slot**	**MAC**	**Slot**	**Type**	**Format**
Any	any	all	any	000	000
00.03.93.4A.D3.38	003	00.03.93.4A.D3.39	002	001	001
00.03.93.4A.D3.39	any	00.03.93.4A.D3.39	001	001	001
00.03.93.4A.D3.40	012	00.03.93.4A.D3.40	002	001	001

Here is an example SRT for that device (assuming 1000 Mbps on all ports):

Source			*Destination*			*Data Info*	
MAC	**Frame**	**Slot**	**MAC**	**Frame**	**Slot**	**Type**	**Format**
Any	001	any	all	001	any	000	000
00.03.93.4A.D3.38	001	003	00.03.93.4A.D3.39	001	002	001	001
00.03.93.4A.D3.39	001	any	00.03.93.4A.D3.39	001	001	001	001
00.03.93.4A.D3.40	001	012	00.03.93.4A.D3.40	001	002	001	001

In this table the first route represents the default route which sends data from any port/slot to all ports/any available slot. In this example all populated slots from 00.03.93.4A.D3.37 would forward to the same slots on all other ports. Slot 003 from 00.03.93.4A.D3.38 would forward only to slot 002 on 00.03.93.4A.D3.39. All populated slots from 00.03.93.4A.D3.39 would forward only to the same slots on itself (outbound). Slot 012 from 00.03.93.4A.D3.40 would forward only to the same slot on itself (outbound). Therefore Iso data coming from 00.03.93.4A.D3.39 and 00.03.93.4A.D3.40 would not forward to other ports. The last 3 routes override the default route.

If a source has a newly filled slot which wants to go to a destination port which is already filled for that slot, the device cannot overwrite the destination slot. Instead the slot data can be forwarded to a different slot number on the destination port. Or, if the reservation request method is used, the data source may setup routes from each slot number on the source port to a different slot number on the destination port.

14. Slot Reservation

Using SDMP, a slot reservation request may be sent from a data originating device to a data end point device (or broadcast). This request is an SDMP message having a destination MAC address of the endpoint, or all 0s for broadcast. Each device which receives the request, including devices along the delivery path of the request such as a switch, would respond to the originator with a positive or negative answer. The request would contain the number of slots needed to transmit data and include the data type and format. If a device along the path of the SDMP request has the necessary slots open, then it will reserve them for the originator, with a TTL of 1 second. When the originator device receives a positive response from the final destination device, then it will consider the necessary bandwidth to be reserved along the path.

Any route, except the default route, should be destroyed if not used (no valid data) for more than 1 second. This allows for dead (or unplugged) devices to have their routes freed up.

Note: A device may not insert any data into any slot in a Sync-E Frame unless the data valid bit for that slot is set to 0.

15. Data Types

In the SRT a data type identifier (1 octet) and data format identifier (1 octet) is defined for each active Iso data slot. All 0s in the data type identifier would signify no data set. All 1s in the data type identifier would signify a vendor specific data type is used. The data format identifier defines the configuration of the data type (for example: sample rate, number of channels, channel order). The data format ID does not contain any descriptive data other than the format ID number. All 0s in the data format identifier would signify that only one format is possible for the data type.

For example, PCM audio may have 16 commonly used configurations, each with different sample rates, and number of channels. These format identifiers would be assigned a number 0-15.

When a vendor specific data type is used, the data format ID must represent the data type as well as the data format.

Standard data types and their formats are defined in Annexes to this specification. Vendor specific data types may be defined as well.

16. Media Device Control Protocol

In order to facilitate the simple media device control, a Media Device Control Protocol (MDCP) is defined. This protocol may include methods for the following:

1) Device type discovery

2) Device component addressing
3) Media transport controls
4) Analog-style controls
5) Data format negotiation

MDCP messages are defined in Annexes to this specification. Vendor specific MDCP messages may also be defined elsewhere.

Note: A new protocol number must be defined for MDCP.

[Editorial Note: It may be desirable to move the MDCP specification to a separate document.]

17. MDCP Frame

MDCP frames are included in each cycle as asynchronous frames. MDCP frames have the following sections:

Ethernet header (22 octets)
MDCP header (2 octets)
1-8 MDCP messages (12-96 octets)
FCS (4 octets)
total = 40-136 octets

The MDCP header has the following sections:

version (4 bits)
TSC (1 bit)
reserved (11 bits)
total = 2 octets

Note: A new protocol number must be defined for MDCP.

The MDCP data section of the frame may contain no less than 1 and up to 8 12-octet messages. An MDCP message contains the following fields:

Field Name	**Size**	**Description**
Destination Component Addr.	2 octets	
Source Component Addr.	2 octets	
SID	3 bits	Session ID
RI	1 bit	Identifies that the message is a response
Command Type	12 bits	Category of command
Command	1 octet	Command Name
Command Modifier	4 bits	Sets the context of the command
DR	1 bit	Identifies that a response must be returned
PN	1 bit	Parameter field is 1x32bit or 1x24bit + 1x8bit
Parameter Type	2 bits	Signed Int, Unsigned Int, Bit Mask, Reserved
Parameters	4 octets	Command Parameters

Total = 12 octets

A source or destination component address of all 0s signifies that the source or destination device has no components.

A command type of 111111111111 signifies a vendor specific command.

To maintain compatibility with Ethernet switches which do not support synchronous links, but which do support 802.1q prioritization, the 3-bit priority field for asynchronous MDCP frames must be set to 100.

18. Time Sensitive MDCP

To allow for low latency controls, MDCP defines a Time Sensitive Control (TSC) bit in the MDCP header. An MDCP frame having the time sensitive control bit (TSC bit) in the MDCP header is set to 1 is considered a TSC frame. A TSC frame must be included in the cycle immediately after the synchronous frame(s) and before any asynchronous frames.

[Editorial Note: It may also be desirable to have a TSC routing table, and reservation method defined.]

To maintain compatibility with Ethernet switches which do not support synchronous links, but which do support 802.1q prioritization, the 3-bit priority field for TSC frames must be set to 101. In an Synchronous Ethernet capable device with more than one port (such as an Synchronous Ethernet switch), TSC frames are forwarded before any asynchronous frames, regardless of 802.1q priority settings.

19. 10 and 100 Mbps Profiles

Currently there are no profiles defined for 10 and 100 Mbps speeds, thus synchronous links are not supported at 10 or 100 Mbps, only at 1000 Mbps and higher.

20. 1000 Mbps Profile

For 1000 Mbps, a cycle may contain from 1 to 16 synchronous frames. A default value is 10 synchronous frames per cycle. If a link is configured to send 16 synchronous frames per cycle then it still provides 2141 octets for asynchronous frames.
A cycle may also contain up to 136 TSC frames.

21. Forwarding

Asynchronous frames:

A device having more than one Ethernet port, one having a Sync-E Link and one having a standard Ethernet link, would forward asynchronous frames from the non-Sync-E Link ports to the Sync-E Link port by simply placing the frames in the asynchronous section of each cycle.

22. Annex A: Topology Examples

TBD

23. Annex B: SDMP Messages

TBD

24. Annex C: MDCP Standard Messages

MDCP Data Section Format

The MDCP data section of the frame may contain up to 8 12-octet messages in the following format:

<table>
<tr><th>Octets</th><th colspan="5">Bits 0-7</th></tr>
<tr><td>1, 2</td><td colspan="5">Destination Component Address</td></tr>
<tr><td>3, 4</td><td colspan="5">Source Component Address</td></tr>
<tr><td>5</td><td colspan="3">Command Type
(high 4 bits)</td><td>RI</td><td>SID</td></tr>
<tr><td>6</td><td colspan="5">Command Type (low 8 bits)</td></tr>
<tr><td>7</td><td colspan="5">Command (1 octet)</td></tr>
<tr><td>8</td><td>Parameter Type
(2 bits)</td><td>PN</td><td>DR</td><td colspan="2">Command Modifier
(4 bits)</td></tr>
<tr><td>9-12</td><td colspan="5">Parameter(s)</td></tr>
</table>

Table 24-1: ***MDCP Data Section Format***

The MDCP data section consists of the following fields:

- Destination Component Addresses (octets 1 and 2)
- Source Component Address (octets 3 and 4)
- Session ID (bits 5, 6, and 7 of the octet 5)
- Response Indication (bit 4 of the octet 5)
- Command Type (bits 0-3 of the octet 5 and all 8 bits of the frame octet 6)
- Command (octet 7)
- Command Modifier (bits 4-7 of the octet 8)
- Data Request (bit 3 of the octet 8)
- Parameters Number (bit 2 of the octet 8)
- Parameter Type (bits 0-1 of the octet 8)
- One or two parameters (octets 9-12)

Destination and Source Component Addresses

These fields identify sending and recipient components.

Session ID

This field is reserved for future use. It must be transmitted zero and ignored by the recipient.

Response Indicator

This bit should be set to 0 when sending a command, and 1 when sending a response.

Command Type

This 12-bit field defines the command set. The interpretation of Command, Command Modifier, Parameter Type, and Parameter fields depends on the value of the Command Type field.

Chapter 1.2 contains the list of defined Command Types.

Command

The 8-bit Command value defines the action requested of the recipient by the sender. The interpretation of this field depends on the Command Type value.

Command Modifier

This 4-bit field ranges from 0 to 15. It affects command execution based on values in the Command and Command Type fields.

Typically, Command Modifier value defines command "strength". For example, a command "Volume Up" should use larger control steps for larger Command Modifier values. The maximum value 15 requires the recipient to immediately apply the control value supplied in the command Parameters field. Zero implies the controlled parameter must not be affected. This value is usually used to request the status of a device.

Intermediate values (1 to 14) normally require a recipient to generate a number of interpolating steps to "smooth out" the change in the control parameter. Larger values result in steeper regulating curves thereby affecting faster command execution.

Data Request

If set to 1 this bit requires the recipient to respond with a control message. The response message must be sent immediately following command execution. In most cases, the response should return the new value of the regulated parameter.
If the Command Modifier is zero the requested value should remain unaffected and returned immediately.

The recipient should not respond if the Data Request bit is 0.

Parameters Number

This field defines the format of the 4-octet Parameters field. If zero, it indicates the Parameters field contains one 32-bit value whose format is determined by the Parameter Type field.

If set to 1, it indicates the Parameters field carries two values:

1. 24-bit value in octets 90-11, whose format is specified in the Parameter Type field
2. 8-bit unsigned integer value in octet 12

Parameter Type

The Parameter Type defines the format of the command parameter according to the following table:

Parameter Type Value	Name	Description
0	Scale	Parameter is a signed value
1	Select	Parameter is an unsigned value
2	Toggle	Parameter is a set of logical values (bits)
3	-	Reserved

Table 24-2: ***Defined Parameter Types***

If the Parameter Number bit is 1, the Parameter Type specifies the format of the 24-bit parameter in octets 9-11.

Parameters

There are only two parameters. The number is specified by the Parameter Number bit.

The first is 32 bits, when only one parameter is present, and 24 bits otherwise. This value can be signed, unsigned numeric, or a set of logical bits--as defined by the Parameter Type field.

If available, the second parameter is always an 8-bit unsigned numeric value. It must always specify a subcomponent to which the first parameter is applied.
Devices that do not require the highest possible resolution for their control values must use high significant bits of parameter fields and zero all unused bits. This allows compatibility between devices with different resolutions.

For example, a device generating an 8-bit control value must send it in octet 9 and zero octets 10-12 allowing a recipient to use octets 9-12 as a true 32-bit value.

Defined Command Types

Command Type Value	Name	Description
0x000	Undefined	Must not be used
0x001	Uniform	A universal set of simple control primitives
0x002	Analog-type Audio Controls for MI/Pro	An audio path control command set for use in professional equipment and musical instruments
0x003	MIDI Encapsulation	A control command set for sending MIDI messages over MaGIC network
0x004-0xEFF	-	Reserved for future definition
0xF00-0xFFF	Vendor Specific	Can be freely used by vendors for proprietary control command sets

Table 24-3: ***MDCP Command Types***

Command Type 1
Uniform Command Set

The Uniform Command Set contains universal control primitives. It may be used whenever a special command set (defined by the Command Type) is not available. The actual function is defined by the recipient Component.

The Command Type value for the Uniform Command Set is 1. The commands for this set are defined in the following table:

Command Value	Name	Description
0	Undefined	Must not be used
1	Set	Set the control value
2	Increase	Increase the control value
3	Decrease	Decrease the control value
4-255	-	Reserved

Table 24-4: ***Uniform Commands***

An implementation of this command set must use the Command Modifier field value in applications that require “smoothing” of control values. Recall that larger values of the Command Modifier field correspond to faster or “steeper” changes of these values.

Command Type 2
Audio Control Commands for Professional Musical Equipment and Musical Instruments

The Command Type value for the Professional Musical Equipment and Musical Instruments Command Set is 2. The commands for this set are defined in the following table:

Command Value	Name	Parameters	Description
0	Undefined	-	Must not be used
1	Set Volume	32-bit signed	Output Volume Control
2	Set Gain	32-bit signed	Module Gain Control
3	-	-	Reserved
4	-	-	Reserved
5	Set Tone (low)	32-bit signed	Output Tone Control
6	Set Tone (middle)	32-bit signed	Output Tone Control
7	Set Tone (high)	32-bit signed	Output Tone Control
8	Set Input Sensitivity	24-bit signed, 8-bit channel selector	Audio Input Sensitivity Control
9-14	-	-	Reserved
15	Set Equalizer	24-bit signed, 8-bit sub-band selector	Equalizer Control (Up to 256 sub-bands)
16	Mute	1 bit enable/disable	Mute Output
17	Inc. Volume	32-bit signed	Output Volume Control
18	Inc. Gain	32-bit signed	Module Gain Control
19	-	-	Reserved
20	-	-	Reserved
21	Inc. Tone (low)	32-bit signed	Output Tone Control
22	Inc. Tone (middle)	32-bit signed	Output Tone Control
23	Inc. Tone (high)	32-bit signed	Output Tone Control
24	Inc. Input Sensitivity	24-bit signed, 8-bit channel selector	Audio Input Sensitivity Control
25-30	-	-	Reserved
31	Inc Equalizer	24-bit signed, 8-bit sub-band selector	Equalizer Control (Up to 256 sub-bands)
32	Input Select	1 bits enable/disable, 8-bit channel selector	Enable/disable audio input (Up to 256 inputs)
33	Dec. Volume	32-bit signed	Output Volume Control
34	Dec. Gain	32-bit signed	Module Gain Control
35	-	-	Reserved
36	-	-	Reserved
37	Dec. Tone (low)	32-bit signed	Output Tone Control
38	Dec. Tone (middle)	32-bit signed	Output Tone Control
39	Dec. Tone (high)	32-bit signed	Output Tone Control
40	Dec. Input Sensitivity	24-bit signed, 8-bit channel selector	Audio Input Sensitivity Control

41-46	-	-	Reserved
47	Dec. Equalizer	24-bit signed, 8-bit sub-band selector	Equalizer Control (Up to 256 sub-bands)
48-63	-	-	Reserved
64	Sampling Rate	TBD	Set Digital Audio Sampling Rate
65-127	-	-	Reserved
128	E0 Gain	TBD	Effect0 Gain Control
129	E0 Attack	TBD	Effect0 Attack Control
130	E0 Decay	TBD	Effect0 Decay Control
131	E0 Sustain	TBD	Effect0 Sustain Control
132	E0 Release	TBD	Effect0 Release Control
133	E0 Q	TBD	Effect0 Q Control
134	E0 Frequency	TBD	Effect0 Frequency Control
135-255	-	-	Reserved

Table 24-5: *Command Set #2: Professional Audio*

[TBD]

25. Annex D: PCM Data

For PCM audio data the data type identifier is 1. The allowed data format IDs are the following:

Format ID	Sample Rate	Bits/Sample	No. Channels	Channel Order
0	-	-	-	-
1	44.1	16	2	LR
2	48	16	2	LR
3	96	24	2	LR

26. Annex E: MPEG Data

[TBD]

27. Future Work

1) Define SDMP Messages
2) Define MDCP Standard Messages
3) Create Topology Examples
4) Define MPEG Data Type/Format

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