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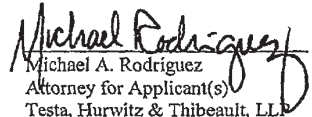
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☐ A check or money order is enclosed to cover the filing fees ☐ The Commissioner is hereby authorized to charge the required fees to Deposit Account No. 20-0531. Enclosed is a copy of this sheet. ☐ The Commissioner is hereby authorized to charge any additional filing fees or credit any overpayment to Deposit Account Number: 20-0531		
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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government. ☐ No. ☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____		
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Home Network Method and Apparatus - 1394

Introduction

This addendum is related to the transmission of IEEE-1394 signals over "no new wires" home networks.

By "no new wires" we mean any home networking media that exists in the house, and does not require high quality wires, such as Category-5 twisted pair, plastic optical fiber etc... that cannot be found often in existing homes. Power lines, telephone lines, existing coax cables and wireless are examples for "no new wires" media.

Since high quality wires are not frequently found in existing homes, a service provider that wishes to install a home network for his customers must rewire their houses. This is prohibitive due to high cost and much time consuming. Therefore, although high quality wires are ideal to carry high-speed multimedia signals in the home, they only represent a niche market. Today, major work is done by home networking technology providers to develop "no new wires" home network technologies.

The IEEE-1394 standard (also known as Firewire) specifies a high-speed serial bus that is ideal to connect high-speed multimedia (data audio and video) devices. The IEEE-1394 is emerging as a standard home network protocol. It has the following features that make him ideal for local are networks in the house:

- High-speed network (at least 100 Mbps, but reaches 1600 Mbps over high quality fibers)
- Inherent quality of service support.
- Plug and play and hot plug-in
- Peer to peer
- Support for copy protection protocol ("5C")

IEEE 1394 defines two types of connections between 1394 devices: Short haul connections (specially designed shielded 4.5 m cable) for local buses, and Long haul connections (either unshielded Category 5 or optical fibers) for network backbones. The CAT-5 standard supports data rates of about 100 Mbps with a distance of upto 100 m. However, as mentioned above CAT-5 wires are not often found in existing and new built houses, and requires rewiring.

IEEE-1394.1 is another standard that is under development. It defines a 1394 bridge between two IEEE-1394 buses. It is, therefore, desire to find solutions that will be able to connect between 1394 devices over "no new wire" networks.

Beside the need to use media that does not usually exist in the house, some other features of the IEEE-1394 protocol make it not applicable with current "no new wires" transmission technologies. Among those are:

1. The wide frequency band that is required (about 125 MHz for both short haul and long haul).
2. Transmission is defined over two-pairs of wires (two different signals are transmitted on each one of the pairs)

3. A Bus architecture that is defined in a way where each one of the 1394 transceivers is connected to only one transceiver. Such architecture protects from collisions on a wire, which might occur if two transmitters start to transmit a signal simultaneously. An example of a 1394 bus is depicted in figure1. It can be seen that there are no more than two transceivers connected to each other. Figure 2 depicts a simple embodiment of coax wires, where three transceivers are connected through a power splitter. The power splitter connects TXVR2 and TXVR3 to TXVR1. In such an embodiment collision might occur if TXVR2 and TXVR3 start transmitting simultaneously. Such an embodiment is not supported by IEEE-1394, but is often found in home networks. Similar embodiments are found with the other no new wires technologies as well.

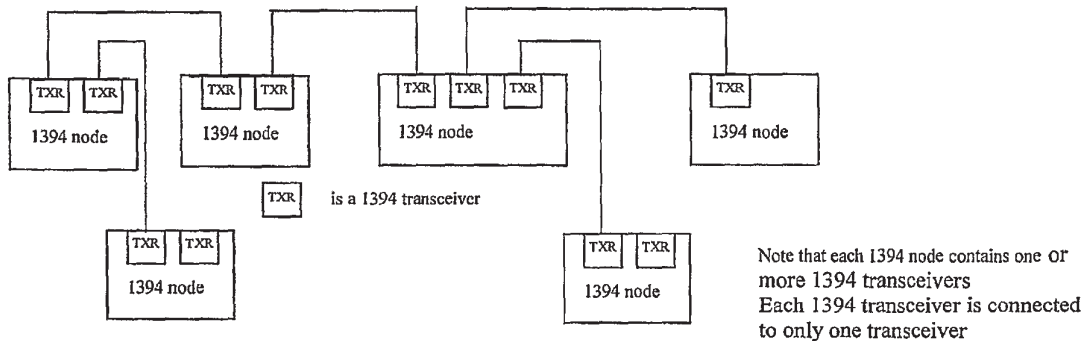


Figure 1

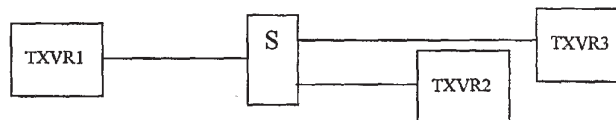


Figure 2

4. Another limitation is the requirement that 1394 devices should reply to a message they receive via the 1394 network in less than 10uSec. This time is prohibitive for most home network transmissions that use coding in order to improve performance in the presence of noise, or use large buffers at their transmitters or receivers. Current technologies that transmit signals over phone lines. Power lines and wireless cannot support this requirement. Also, hi-performing, spectrally efficient coax networks might not support such low latencies.

These limitations make existing no-new-wire technologies not suitable for the transmission of 1394. Power lines as well as phone lines are limited in bandwidth and cannot extend to about 100 MHz as required. Wireless bandwidth is also limited, to upto 20 MHz at 5 GHz, as is defined in the 802.11a and the HiperLan standards. Coax wires has much more available bandwidth and can support 100 MHz of bandwidth. However, if

Some network uses frequencies above CaTV frequencies and supports already installed low cost splitters than frequency band is also limited.

1394 bus architecture is also prohibitive since in most cases existing wirings and wireless architectures do not support it.

A method to connect 1394 devices over a wireless home network has been suggested by the European Telecommunications Standard Institute (ETSI) in its HiperLAN standard, by employing 1394 bridge architecture, according to the 1394.1 standard. However, higher level applications of the 1394 protocol, such as Audio Video Commands (AV/C) protocol, that allows the control of Audio Video devices, or Internet Protocol (IP) over 1394, that allows transport of IP over the 1394, do not support this standard. Since the 1394.1 standard is still under development and devices that support it are expected to become available only in a few years from now, this method is problematic, and cannot be used effectively today.

Proposed method

The following text refers to a home network over existing coax wires and low cost splitters, but the same methods and embodiments can be used in conjunction with any other home networking architectures, as power lines, home phonedlines and wireless.

This patent addendum discloses an embodiment and a method for a home network that is based on no-new-wires technology with limited bandwidth, high latency and no 1394-like bus architecture. It is suggested to make relatively simple modifications in the standard 1394a Phy and Link layers. The modifications enable the appearance of all 1394 devices in the network as if they reside on the same 1394 short haul bus. In this way legacy 1394 devices (not necessarily bridge-aware devices) can be connected over the network while supporting any 1394 application, that supports 1394 bus architecture.

A more detailed description of the invention and of the modifications required is given below. At principle the modifications are as follows:

1. Phy Layer –
 - A modified reset, initialization and identification process that allows for global network node discovery.
2. Link Layer –
 - A Routing table is added to the Link layer. The Link layer uses the Routing table in order to determine whether the destination_ID of an asynchronous message is on another bus. If it does it acts according to the 1394.1 bridge standard. It sends an ACK_pending message to the source node and forward the message to the backbone. If it doesn't it handle the message as a standard Link layer.
 - Isochronous channels and Asynchronous streams are forwarded to the backbone network. In other embodiment, isochronous channels and Asynchronous streams are forwarded to the backbone according to an Isochronous Routing table.

A logical diagram of a home network embodiment consisting of several local buses and a backbone network is depicted in Figure 3. Each local bus is connected to the network via a Universal Module (UM). One of the UMs in such an embodiment is defined as the Prime UM. It has some unique functionality, as described below. The local bus that includes the Prime UM is the Prime Bus.

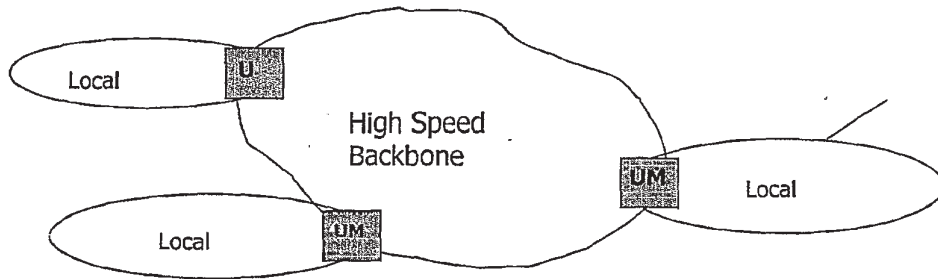


Figure 3

In the disclosed embodiment, 1394 devices are connected through a backbone medium, like the existing coax wires in the house. The backbone connects between several 1394 buses. The devices that are connected to each one of the buses are 1394 devices. Devices on different buses can still see each other and speak to each other according to the short haul 1394 protocol.

A possible implementation of a UM is depicted in Figure 4. The UM functions as a 1394 to the coax backbone bridge portal.

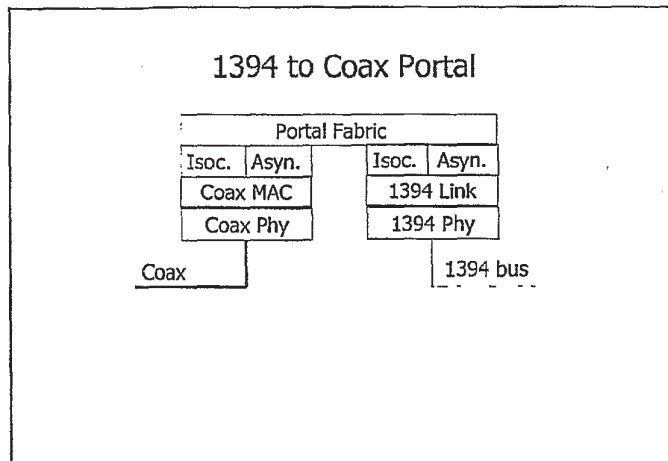


Figure 4

A UM that is connected to the 1394 bus is always the Root node of its bus.

The local 1394 bus in this embodiment has features of a regular 1394a bus as well as of 1394.1-bridged networks, as follows:

- Each node receives a unique Phy Identification number (Phy_ID) (0-62).
- For each local bus, the bus identification number (Bus_ID) is equal to 0x3ff.
- There exists only one Isochronous Resource Manager (IRM) in the network. Each channel and each stream that is generated in the network receives its channel number and bandwidth allocation from the single IRM. The IRM has to be one of the UMs. Usually it is the Prime UM.
- Each bus has its own Cycle Master (CM). The CM in each bus has to be the UM of that bus.
- Each bus has its own Bus Manager (BM).
- Arbitration, signaling and data transfers are local to each bus.
- Asynchronous messages between devices on the same bus stays local and are not forwarded to the network backbone.
- Asynchronous packets destined to a remote device (a device in another bus) are routed and responded (by an ACK_pending message) according a routing table that resides in each one of the UMs. The routing table defines remote UMs according to the Phy_ID in the asynchronous message destination field.
- Isochronous channel packets and Asynchronous Streams are forwarded through the backbone to all the other buses, or forwarded to other buses according to a Routing Table.
- One clock reference exists for the whole network the common clock is generated at the prime bus, and is recovered by the UMs at the other buses.

Figure 5 depicts a logical diagram of the Home Network with four 1394 buses. Any number of buses can be supported by the proposed embodiment.

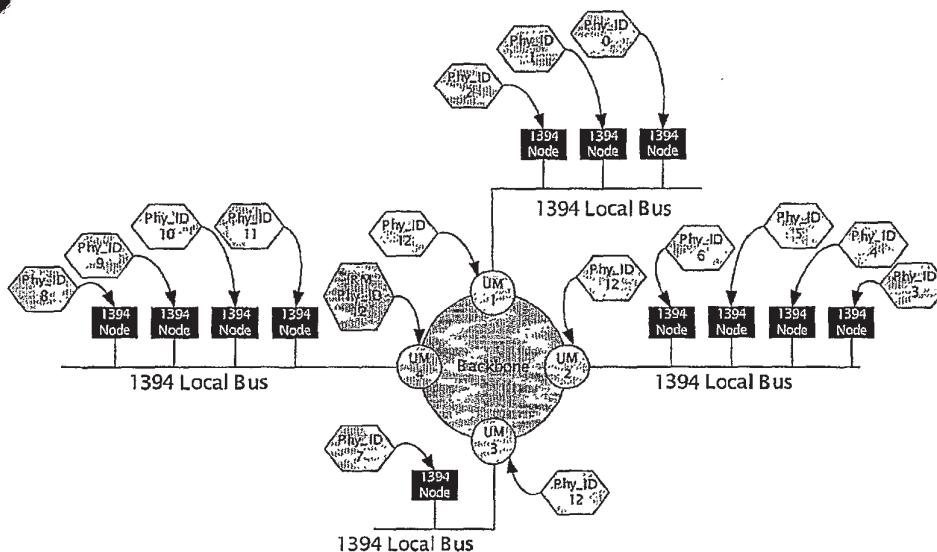


Figure 5

Each UM reflects the other buses into its local bus by means of:

- Sending Self Identification (Self_ID) packets according to a special reset procedure that is needed for 1394 node discovery mechanisms.
- Forwarding streams through the backbone, with updating timestamp of 61883 isochronous packets. The 61883 is a standard that specifies transport of MPEG signals over the 1394, and allows the video transfers from one 1394 device to another.
- Sending Acknowledge pending (ACK_pending) messages for Asynchronous Packets that are delivered to other buses, according to Routing Table that resides in each UM. By responding by ACK_pending message to any asymmetric message that targets devices on other buses, the 10 uSec limitation mentioned above is not prohibitive any more, and a very large latency over the backbone is allowed.
- Forwarding Asynchronous Packets that are delivered to other buses through the backbone, according to the Routing Tables.
- Receiving packets from other buses that are destined to a device on the local bus of the UM through the backbone.
- Reset in one bus is spread to the other busses, and is done as is described below.

During a global reset procedure that is described below, an initialization and identification process of the 1394 network is carried out. An emulated bus structure is created where all 1394 devices in the network see each other, and each device has a unique Phy_ID. Figure 6 depicts the logical 1394 network structure after the end of initialization and identification process of the network that is depicted in Figure 5. In the emulated bus topology each UM appears as the root 1394 node with three phy ports. Port

(P1 in the figure) of each UM is connected to bus. Phy port 0 and phy port 2 appear to all 1394 devices on the local bus either as not connected or as a branch of the bus. The branch appears to contain other 1394 devices that are physically located in other buses but logically appear to the local bus devices as if they reside on the same bus. In this method all existing 1394 devices in the network seemingly reside on the same bus. Therefore, this method supports any application that work with 1394 buses over the entire network.

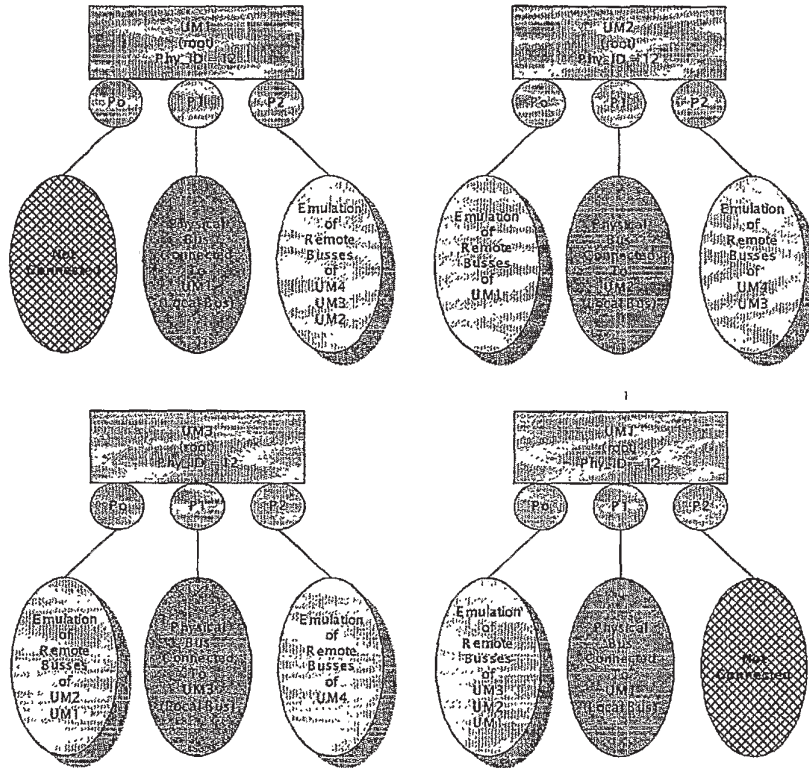


Figure 6

Appendix - Detailed Description

The following text gives a detailed description of the solution –

1. 1394 over Coax - details

Processes

Initialization

Definition

Initialization is a procedure performed after the backbone has been initialized:

- Number of UMs (N) is known.
- Each UM has its own number (1-N).
- A prime UM is selected – UM#1. (so it will always be the same one if we want one UM to have more capabilities then others.)

When the Initialization procedure is ended, the network is functioning.

Procedure

1st Global Reset of all the buses – receiving bus state

The prime UM sends through the backbone 1st Global Reset message to all the UMs. The reset is performed in each bus with the root enforcing of the UM (generated by the UM).

After the reset:

- Each UM sends an updating bus message to the prime UM with:
 - (1) Its own Phy_ID (the number of nodes on the bus –1).
 - (2) For every Node on the local bus LINK state – Active/Not Active.
 - (3) For every Node on the local bus whether it is Bridge Capable.
- The bus functions only locally.

The updating bus message has the following structure: (*),

phy_id[68:63]															
LINK Active[62:0]															
Physical id of root	Phy62													phy1	phy0
Bridge Capability															
	Phy31														Phy0
		62													Phy32

(*) The LINK filed is one bit, The Bridge capabilities is two bit long.

(**) All other fields in the Phy_ID packet in the emulated packets aren't important for this solution so they all get the same predefined value.

Updating Network table

The prime portal generates the network table:

1	2	3	...	N
---	---	---	-----	---

M1	M2	M3	...	MN
Link[M1:0]	Link[M2:0]	Link[M3:0]		Link[MN:0]
BC[M1:0]	BC[M2:0]	BC[M3:0]		BC[MN:0]

Mi = Number of nodes in the local bus of UMi.

Link[Mi:0] = LINK Active/Not Active for every Node in the local bus of UMi.

BC = Bridge Capabilities for every Node in the local bus of UMi. (will be used if the system will operate in a bridge environment).

Afterwards it transmits the table to all the UMs with an update_network_table message.

All the UMs shall update their network table accordingly.

The update_network_table message includes the time of generating the next bus reset.

2nd Global Reset of all the buses – emulating the network in each bus

Each UM generates a bus reset at the time specified in the update_network_table message with root enforcing (of the UM).

During the Self_ID period each of the UMs (each UM is the root in the local bus) manages the process according to the following:

```

node_counter = 0. /* Node # counter, (counts from 0 till the number of all Nods in the
                  /*System.)
for (i = 1; i++; i<=N) { /* N is the number of UMs in the system.
    If (i == UM#) {
        signal GRANT to its child ;
        /* Allowing Self_ID of the real nodes on the bus.
        While (not RX_IDENT_DONE)
        /* local Self_ID process isn't finished yet.
        Increment node_counter for every Self_ID packet
        sent on the bus;
    }
    Else {
        for ( J = 1; j++; j<=network_table [i])
        Send emulated Self_ID packet (node_counter++);
        /* Phy_ID in a packet sent is the node_counter value,
        /* node_counter is incremented for every packet sent.
    }
}
Send UM Self_ID packet (node_counter); /* node_counter is equal to total
                                      /* number of nodes in the system.
Release the bus;
                                     /* idle – end of reset.

```


UM Self_ID

Bit#h	Field Code	Field Name	Value sent	Comments
1F:1E	Packet identifier		10b	Self_ID packet
1D:18	Phy_ID	Physical ID	Sum of all Nodes on the local busses. (counter+1 from pseudo code)	All UM portals have the same Physical ID.
16	L	Link active	1:link active	
15:10	gap_cnt	Gap Count	?	?
F:E	sp	PHY speed	00 – 100Mb/s	backbone
D:C	brg	Bridge-capability	00 – not a bridge	
B	c	Contender	1 - Contender for the role of ISO	in our case we win in all cases.
A:8	pwr	Power Class	011: node provides 45W	Good for both 1394 and 1394a, If this is too much power we can reduce it to 15/30W.
7:6	P0	Port#0	UM#1 – 01: no connection to other node. All other UMs – 11: port connected to child node.	
5:4	P1	Port#1	All UMs – 11: port connected to child node.	
3:2	P2	Port#2	UM#N – 01: no connection to other node. All other UMs – 11: port connected to child node.	
1	i	Initiated reset	1: reset initiated by this node. 0: reset initiated by another node.	
0	m	More packet follow	0: No more ID Packets are needed.	A node with up to 3 ports sends a single ID packet.

emulated self_id

Bit#h	Field Code	Field Name	Value sent	Comments
1F:1E	Packet identifier		10b	Seld-ID packet
1D:18	Phy_ID	Physical ID	The value of 'counter' from the pseudo code.	
16	L	Link active	1:link active	? (Should be discussed)
15:10	gap_cnt	Gap Count	?	?
F:E	sp	PHY speed	00 -100Mb/s	backbone
D:C	brg	Bridge-capability	00 - not a bridge	Will be used if operating in a bridge environment.
B	c	Contender	0 - Contender for the role of ISO	In our case the UM well win in all cases.
A:8	pwr	Power Class	000: node does not require bus power nor repeat bus power.	No power influence on the local bus.
7:6	P0	Port#0	10: connected to parent node.	Remote busses are
5:4	P1	Port#1	The node with the lowest phy_id number on the local bus has this port disabled:01, all other nodes-11: port connected to child node.	
3:2	P2	Port#2	00: port not present.	
1	i	Initiated reset	0: reset not initiated by this node	

0	m	More packet follow	0: No more ID Packets are needed.	A node with up to 3 ports sends a single ID packet.
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Reset procedure- Network update

Definition

Network update is a procedure performed after the network completed an Initialization process.

NOTE: If there are no topology changes in the local bus the reset need not be propagated to other busses.

Procedure

After the local bus reset sequence is completed and the UM port got its new Phy_ID, This information is propagated by a new_phy_id message to the prime UM.

The prime UM updates the network table and sends a update_network_table message. From this point all Ums will operate as if this is an update_network_table message received in an Initialization process.

Local Reset of a specific bus – receiving bus new state

Updating Network table

2nd Global Reset of all the buses – emulating the network in each bus

Asynchronous packet handling

Definition

After Network Initialization process has ended each UM has to handle Asynchronous packets received from the bus (Inbound) and Asynchronous packets received from the backbone (outbound).

Procedure

Inbound (1394 to backbone)

The UM performs the following forwarding algorithm based on the packets physical id destination address, the portals physical ID and the Network Table(*).

In case Bus_ID = 0x3FF :

Phy_ID (**)	output	Comments
3F16	UM isn't Prime UM: Forward only.	Broadcast packet. UM that aren't Prime UM can only be accessed by the Prime UM by there own protocol.
	UM is Prime UM: Forward & Process	
Not corresponding to a node on the local bus. (*)	Forward	Packet addressed to a node not on the local bus. Generate an ACK Pending/Busy/Retry packet on the local bus.
corresponding to a node on the local bus. But not the UMs Phy_ID (*)	Discard packet	
UMs Phy_ID	UM is Prime UM: Process	The Prime UM is responsible to access other UM.
	UM isn't Prime UM: Forward.	

In case Bus_ID $\neq$ 0x3FF the packets are forwarded (ack_pending).

(*) During the Initialization process the UM maintains two registers, one with the Phy_ID of the node with the lowest ID on the local bus and one with the highest ID on the local bus. A Phy_ID between those values belongs to the local bus.

Outbound (backbone to 1394)

The UM performs the following forwarding algorithm based on the packets physical id destination address, the portals physical ID and the Network Table(*).

If A packet is addressed to the Portals address it is passed to the Portal **only** if the packets source is the Prime Portal (a flag that has to be added).

In case Bus_ID = 0x3FF :

Phy_ID	output	Comments
3F16	Forward	Broadcast packet.
Not corresponding to a node on the local bus. (*)	Discard	Packet addressed to another bus.
Corresponding to a node on the local bus. But not the UMs Phy_ID (*)	Forward	Packet addressed to a local node.
UMs Phy_ID	UM is Prime UM: Portal	The Prime UM is responsible to access and control all other UMs.
	UM isn't Prime UM: Discard	

In case Bus_ID $\neq$ 0x3FF the packets are forwarded.

(*) During the Initialization process the UM maintains two registers, one with the Phy_ID of the node with the lowest ID on the local bus and one with the highest ID on the local bus. A Phy_ID between those values belongs to the local bus.

Streams handling

Definition

ISO/Asynchronous packets require no filtering; they are forwarded as is to the Backbone and from the Backbone to the local bus.

Procedure

Inbound (1394 to backbone)

All packets are forwarded as is.

Outbound (backbone to 1394)

All packets are forwarded as is.

1394 to backbone

Facilities

Network table

Each UM in the system has its own Network table.

Link/PHY changes

The following describes the changes that have to be done to current LINK/PHY operation so that they can support this solution.

PHY changes

Self_ID Packets

Each PHY shall be changed to be able to transmit emulated Self_ID packets according to network table.

PHY Packets

All PHY packets on the bus have to be snooped by the UM portal and forwarded to other UMs if needed. Currently PHY packets are not passed to the LINK layer.

(Example: A link on packet will cause the LINK_ON signal in the LINK/PHY interface to be asserted and this will not do for our system)

The packets that have to be passed are:

Link on, Ping packet – if not used for gap count optimization, remote access/reply, remote command/confirmation, resume packet.

LINK changes

Routing

Synchronizing

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