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Networking IEEE 1394 Clusters *via* UWB over Coaxial Cable— Part 4: AV/C Relay Agents

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Abstract

This technical specification standardizes the model, definition, and behaviors of AV/C relay agents, IEEE 1394 devices that enable network connectivity across L3 IP bridges for "legacy" AV/C devices. Legacy devices comprise all deployed (or planned for deployment) AV/C equipment that does not implement FCP and CMP over IPv4 and is therefore unable to interoperate with other AV/C equipment across L3 IP bridges. AV/C relay agents surmount this obstacle by acting as a surrogate for an AV/C device in a remote IEEE 1394 cluster.

Keywords

AV/C, IEEE 1394, relay agent, Serial Bus, surrogate

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Foreword (This foreword is not a normative part of 1394 Trade Association Specification 2007004)

During June, July and August of 2005, a 1394 Trade Association delegation visited a number of multiple system operators (MSOs). The purpose was straightforward: to determine MSO requirements for IEEE 1394 that, if satisfied, could speed the deployment of IEEE 1394 in the residential environment. Broadly speaking, the MSOs require a network capable of distributing multiple program streams from a set-top box (STB) equipped with multiple tuners to different televisions throughout the residence. In-depth discussion with the MSOs yielded the detailed requirements below:

- The network has to operate over existing coaxial cable infrastructure without disturbance to incumbent CATV services or services whose deployment is imminent. The MSOs postulated that a “typical” existing installation might have a diameter (*i.e.*, the maximum cable distance between any two wall plates) of 100 m and that the path between any two wall plates might pass through a 4-way signal splitter and up to two 2-way signal splitters. The network should be able to provide equal quality of service between all possible wall plate pairings—although remediation, *i.e.*, installation of higher-quality coaxial cable and higher-quality signal splitters, is tolerable in a small number of cases;
- The network requires sufficient bandwidth to transport up to four HDTV or SDTV program streams concurrently. Allowing for the increased bandwidth requirements of “trick” play, *e.g.*, fast-forward, single frame advance, *etc.*, the MSOs estimate a minimum requirement of 300 Mb/s of isochronous data;
- The network protocols should support transmission of the program guide from the STB to a television;
- The network has to interconnect clusters of Ethernet devices and permit them to communicate as if they were connected to the same local-area network; and
- The network has to support communications between IEEE 1394 AV disk drives, STBs, personal video recorders (PVRs) and televisions—but the MSOs are indifferent with respect to support for other IEEE 1394 devices.

Separate from the MSO requirements, FCC rules mandate that the network protocols support the transport of commands specified by CEA 775, “DTV 1394 Interface Specification” and CEA 931, “Remote Control Command Pass-through Standard for Home Networking”.

December of that same year saw the launch of the High-Definition Audio-Video Network Alliance (HANA). The alliance intends to satisfy all of the MSO requirements enumerated above and, in addition, provide network support for legacy IEEE 1394 AV/C devices—although not necessarily for HANA's initial deployment. HANA is also the key proponent for CEA 2027-B, “A User Interface for Home Networks Using Web-based Protocols”.

Through the development of a comprehensive family of technical specifications (of which this document is a part), the 1394 Trade Association plans to satisfy both MSO and HANA requirements. Because association member companies have a large infrastructure investment in contemporary, deployed IEEE 1394 AV/C devices that are not network-enabled, the newly designed network functionality must be at least as rich as the functionality available today, within a local cluster, to “legacy” devices. In particular:

- Network-enabled AV/C devices must a) be able to discover and operate with both network-enabled and legacy AV/C devices within the local cluster and b) additionally be able to discover and operate with network-enabled AV/C devices connected to the network but not to the local cluster;
- The functionality described above for network-enabled AV/C devices should be made available to legacy AV/C devices. This may require network-enabled “helper” devices that communicate across bridges on behalf of legacy AV/C devices;
- Mindful of the latency introduced by bridges, the network must be designed to connect IEEE 1394 clusters across a maximum of two intervening bridges connected by coaxial cable. If the accumulated latencies are

small enough, it might be possible for remote devices to operate across more than two bridges—but this is neither guaranteed nor required; and

– The network and network-enabled AV/C devices must together provide digital content protection at least as robust as that available within a local IEEE 1394 cluster.

Because of the importance of the residential network to future growth in the deployment of IEEE 1394 devices, the 1394 Trade Association Wireless working group commenced development in 2006 of the following technical specifications organized under the family title " Networking IEEE 1394 Clusters *via* UWB over Coaxial Cable ":

– Part 1: Continuous Pulsed Ultra-wideband (C-UWB) PHY

– Part 2: L3 IP Bridges

– Part 3: FCP and CMP over IPv4

– Part 4: AV/C Relay Agents

Part 1 specifies a physical layer (PHY), which is, in combination with the Medium Access Control (MAC) sublayer specified by IEEE Std 802.15.3b-2006, suitable for the coaxial cable portion of the residential network.

Part 2 specifies layer 3 (L3) bridges capable of connecting isolated IEEE 1394 clusters into a residential network *via* Internet protocol (IP) and subsequently accepting messages to configure the flow of additional isochronous data from one cluster to another.

Part 3 (this document) specifies methods to transport commands (and receive status in return) within the residential network by use of IPv4 rather than by IEEE 1394-specific methods. It also provides methods to program plug control registers *via* IP messages rather than by IEEE 1394-specific methods. These facilities enable AV/C to be used outside of the local cluster—even to be controlled from locations outside the residence.

Part 4 specifies how third-party devices acting as relay agents for legacy AV/C devices render them capable of interoperation with AV/C devices in remote clusters.

The Board of Directors of the 1394 Trade Association accepted this technical specification on July 27, 2008. Board of Directors acceptance of this technical specification does not necessarily imply that all board members voted for acceptance. At the time the 1394 Trade Association Board of Directors accepted this technical specification, it had the following members:

The Wireless Working Group, which developed and reviewed this technical specification, had the following participants:

Hans van der Ven, Chair
Michael Scholles, Vice-chair
Allen Heberling, Secretary

Eric Anderson
Yasaman Bahreini
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Les Baxter
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Networking IEEE 1394 Clusters *via* UWB over Coaxial Cable— Part 4: AV/C Relay Agents

1 Scope and purpose

1.1 Scope

This is a technical specification whose scope encompasses the use of IEEE 1394 devices, called AV/C relay agents, to enable network connectivity between "legacy" AV/C devices. Legacy AV/C devices are those whose functionality is limited to the local IEEE 1394 cluster because they lack FCP and CMP over IPv4 capabilities and are unaware of L3 IP bridge protocols for communications with remote devices. AV/C relay agents remedy this deficiency because a) they implement FCP and CMP over IPv4 b) they are aware of L3 IP bridge protocols and c) they act as surrogates for remote AV/C devices. A legacy AV/C device issues a request to a target surrogate or returns a response to a controller surrogate; the surrogate in turn transmits the request or response to the remote AV/C device. An AV/C relay agent connected to the same IEEE 1394 cluster as a legacy AV/C device enables complete network connectivity for the legacy device. This technical specification standardizes the model, definition, and behaviors of AV/C relay agents and devices that use them.

NOTE – This specification defines the interfaces, functions, and operations necessary to ensure interoperability between conforming implementations. However, the designer should bear in mind that this specification is a functional description: an implementation may employ any design whose observable behavior conforms to this specification and any standards included by reference.

1.2 Purpose

IEEE 1394 is a cost-effective interconnect for two important groups of devices: desktop and notebook computers and their associated peripherals on the one hand and consumer electronic devices on the other. IEEE 1394 is increasingly a convergent interconnect between the two groups. However, the use of IEEE 1394 in other environments, *e.g.*, the transfer of high-speed digital video data between rooms of a house, is hampered by the lack of commercially viable, standard architectural and protocol solutions for high quality of service residential networks. Other parts of the specification family to which this document belongs base themselves upon existing protocols and physical infrastructure to a significant extent—but they are inherently new and therefore not supported by deployed ("legacy") AV/C devices. This raises a serious obstacle to deployment of the residential network: if legacy devices are stranded with only their existing local cluster functionality, there may be insufficient motivation for consumers to upgrade to the residential network. This technical specification surmounts this obstacle and, using AV/C relay agents, confers full network operability upon legacy devices. The overall goal has been to produce a technically solid solution that is also pragmatic and readily deployable in order to enable a larger market for IEEE 1394 products.

1.3 Context

This technical specification is part of a larger collection of technical specifications grouped under the title, "Networking IEEE 1394 Clusters *via* UWB over Coaxial Cable". The documents that form the group are listed below:

Part 1: Continuous Pulsed Ultra-wideband (C-UWB) PHY

Part 2: L3 IP Bridges

Part 3: FCP and CMP over IPv4

Part 4: AV/C Relay Agents

Implemented in their entirety, the technical specifications provide a comprehensive solution for networking AV devices in separate rooms of a house. The use of Internet protocol for command-and-control functions offers the possibility of extending control functionality outside the IEEE 1394 cluster to handheld or desktop Ethernet or WiFi devices. The isochronous MPLS capabilities of the L3 IP bridges, in combination with the C-UWB PHY throughput and the IEEE 802.15.3 MAC deterministic quality of service, extend IEEE 1394's high quality of service across the network. In addition, the provision for "relay agents" guarantees that deployed AV/C devices will not be stranded with little or no network connectivity.

2 Normative references

2.1 Reference scope

The specifications and standards named in this section contain provisions, which, through reference in this text, constitute provisions of this 1394 Trade Association Technical Specification. At the time of publication, the editions indicated were valid. All specifications and standards are subject to revision; parties to agreements based on this 1394 Trade Association Technical Specification are encouraged to investigate the possibility of applying the most recent editions of the specifications and standards indicated below.

2.2 Approved references

The following approved specifications and standards may be obtained from the organizations that control them.

[R1] 1394 Trade Association, Document 2004006,
AV/C Digital Interface Command Set General Specification 4.2

[R2] 1394 Trade Association, Document 200XNNN,
Networking IEEE 1394 Clusters *via* UWB over Coaxial Cable—Part 2: L3 IP Bridges

[R3] 1394 Trade Association, Document 200XNNN,
Networking IEEE 1394 Clusters *via* UWB over Coaxial Cable—Part 3: FCP and CMP over IPv4

[R4] IEC 61883-1 (2008-02), Edition 3.0, Consumer audio/video equipment—Digital interface—Part 1: General

[R5] IEEE Std 1212-2001, Standard for a Control and Status Register (CSR) Architecture for Microcomputer Buses

[R6] IEEE Std 1394-1995, Standard for a High Performance Serial Bus

[R7] IEEE Std 1394a-2000, Standard for a High Performance Serial Bus—Amendment 1

[R8] IEEE Std 1394b-2002, Standard for a High Performance Serial Bus—Amendment 2

[R9] IEEE Std 1394c-2006, Standard for a High Performance Serial Bus—Amendment 3

[R10] IETF Draft-Cheshire-DNSExt-DNS-SD-04, DNS-Based Service Discovery, August 10, 2006

[R11] IETF Draft-Cheshire-DNSExt-MulticastDNS-06, Multicast DNS, August 10, 2006

[R12] IETF RFC 1035, Domain Names – Implementation and Specification, November 1987

[R13] IETF RFC 2131, Dynamic Host Configuration Protocol, March 1997

[R14] IETF RFC 2734, IPv4 over IEEE 1394, December 1999

[R15] IETF RFC 2855, DHCP for IEEE 1394, June 2000

[R16] IEEE RFC 3927, Dynamic Configuration of IPv4 Link-Local Addresses, May 2005

Throughout this document, the term "IEEE 1394" shall be understood to refer to IEEE Std 1394-1995 as amended by IEEE Std 1394a-2000, IEEE Std 1394b-2002 and IEEE Std 1394c-2006.

2.3 Reference acquisition

The references cited may be obtained from the organizations that control them:

1394 Trade Association, 315 Lincoln, Suite E, Mukilteo, Wash 98275 USA; (817) 410-5750 / (817) 410-5752 (FAX); http://www.1394ta.org/

Institute of Electrical and Electronic Engineers (IEEE), 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331, USA; (732) 981-0060 / (732) 981-1721 (FAX); http://www.ieee.org/

International Electrotechnical Commission (IEC), Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse; http://www.iec.ch/

Internet Engineering Task Force (IETF) Secretariat, c/o NeuStar, Inc., 46000 Center Oak Plaza, Sterling, VA 20166, USA; (571) 434-3500 / (571) 434-3535 (FAX); http://www.ietf.org/rfc.html

3 Definitions and notation

3.1 Definitions

3.1.1 Conformance

Several keywords are used to differentiate levels of requirements and optionality, as follows:

expected: A keyword used to describe the behavior of the hardware or software in the design models assumed by this technical specification. Other hardware and software design models may also be implemented.

ignored: A keyword that describes bits, bytes, quadlets, octlets or fields whose values are not checked by the recipient.

may: A keyword that indicates flexibility of choice with no implied preference.

reserved: A keyword used to describe objects (bits, bytes, quadlets, octlets and fields) or the code values assigned to these objects in cases where either the object or the code value is set aside for future standardization. Usage and interpretation may be specified by future extensions to this or other specifications and technical bulletins. A reserved object shall be zeroed or, upon development of a future specification or technical bulletin, set to a value specified by such a specification or technical bulletin. The recipient of a reserved object shall ignore its value. The recipient of an object defined by this technical specification as other than reserved shall inspect its value and reject reserved code values.

shall: A keyword that indicates a mandatory requirement. Designers are required to implement all such mandatory requirements to assure interoperability with other products conforming to this technical specification.

should: A keyword that denotes flexibility of choice with a strongly preferred alternative. Equivalent to the phrase “is recommended.”

3.1.2 Glossary

The following terms are used in this technical specification:

channel: A relationship that defines a group of local IEEE 1394 devices: zero or one source permitted to transmit stream packets for the channel and zero or more sinks configured to receive stream packets for the channel. A number between zero and 63, inclusive, identifies the group. Channel numbers are allocated cooperatively through isochronous resource management facilities.

controller: In the context of AV/C, a device that transmits commands and optional data to a target and expects to receive status and optional data in return.

controller surrogate: One of two functional roles of an AV/C relay agent. The controller surrogate receives FCP command frames from a remote controller *via* FCP/IP and writes the command frames to a designated legacy AV/C device's FCP command register. The controller surrogate also receives FCP response frames written to its response register by the legacy AV/C device and transmits them to the remote controller via FCP/IP. See also target surrogate.

local: An IEEE 1394 device is local with respect to another IEEE 1394 device if they are part of the same cluster (arbitration domain), *i.e.*, share the same root.

octet: Eight bits of data (synonymous with byte).

octlet: Eight bytes (64 bits) of data.

quadlet: Four bytes (32 bits) of data.

remote: An IEEE 1394 device is remote with respect to another IEEE 1394 device if one or more L3 IP bridges are on the route between the two devices.

sink: A device, or an application within a device, that receives isochronous stream data.

source: A device, or an application within a device, that transmits isochronous stream data.

stream: Either asynchronous or isochronous data originated by a source and received by zero or more sinks. An isochronous stream is uniquely identified by the source's EUI-64 and an index locally unique at the source. An isochronous stream's parameters include the payload, arbitration overhead and speed.

target: In the context of AV/C, a device that receives commands and optional data from a controller, executes the command and returns status and optional data to the controller.

target surrogate: One of two functional roles of an AV/C relay agent. The target surrogate receives FCP command frames written to its FCP command register by a legacy controller and transmits them to the remote target *via* FCP/IP. The target surrogate also receives FCP response frames from the remote target via FCP/IP and writes the response frames to the FCP response register of the legacy AV/C controller that initiated the transaction. See also controller surrogate.

3.1.3 Abbreviations

The following abbreviations are used in this technical specification:

DHCP	Distributed host control protocol
CMP	Connection management procedures
CMP/IP	CMP over IPv4
DNS	Domain name service
EUI 64	Extended Unique Identifier, 64 bits
FCP	Function control protocol
FCP/IP	FCP over IPv4
FC PDU	Function control protocol data unit
HDTV	High-definition TV
mDNS	Multicast DNS
OUI	Organizationally unique identifier
PCR	Plug control register
PHY	Physical layer
PVR	Personal video recorder
ROM	Read-only memory
RR	Resource record
STB	Set top box
UDP	User datagram protocol

3.2 Notation

3.2.1 Numeric values

Decimal and hexadecimal numbers are used within this specification. By editorial convention, decimal numbers are most frequently used to represent quantities or counts. Addresses are uniformly represented by hexadecimal numbers. Hexadecimal numbers are also used when the value represented has an underlying structure that is more apparent in a hexadecimal format than in a decimal format.

Decimal numbers are represented by Arabic numerals without subscripts or by their English names. Hexadecimal numbers are represented by digits from the character set 0 – 9 and A – F followed by the subscript 16. When the subscript is unnecessary to disambiguate the base of the number, it may be omitted. For the sake of legibility, hexadecimal numbers are separated into groups of four digits separated by spaces.

As an example, 42 and $2A_{16}$ both represent the same numeric value.

3.2.2 Bit, byte and quadlet ordering

In order to promote interoperability with other transports or memory buses that may have different ordering conventions, this specification defines the order and significance of bits within bytes, bytes within quadlets and quadlets within octlets in terms of their relative position and not their physically addressed position.

Within a byte, the most significant bit, *msb*, is that which is transmitted first and the least significant bit, *lsb*, is that which is transmitted last on IEEE 1394, as illustrated below. The significance of the interior bits uniformly decreases in progression from *msb* to *lsb*.

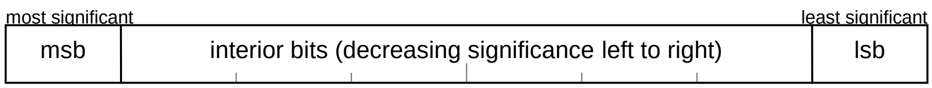

Figure 1 – IEEE 1394 bit order within a byte

Within a quadlet, the most significant byte is that which is transmitted first and the least significant byte is that which is transmitted last on IEEE 1394, as shown below.

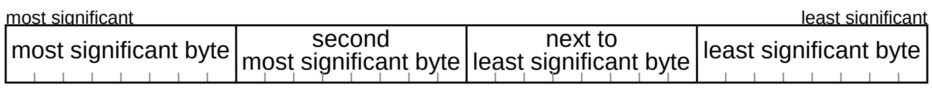

Figure 2 – IEEE 1394 byte order within a quadlet

Within an octlet, which is frequently used to contain 64-bit IEEE 1394 addresses, the most significant quadlet is that which is transmitted first and the least significant quadlet is that which is transmitted last on IEEE 1394, as the figure below indicates.

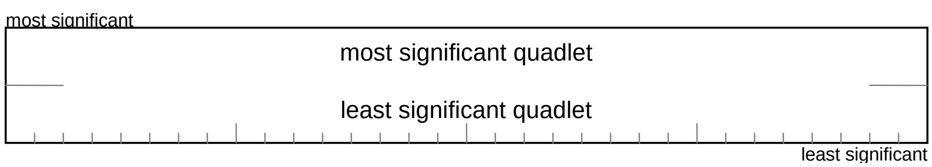

Figure 3 – IEEE 1394 quadlet order within an octlet

Without knowledge (outside of the scope of this specification) of the ordering conventions of the other bus, no assumptions can be made about the ordering (significance within a quadlet) of bytes at the unaligned beginning or fractional quadlet end of a block transfer that is not quadlet aligned or is not an integral number of quadlets.

4 Overview (informative)

[R2] explains the details as to why contemporary AV/C devices that conform to [R1] but not to [R2] itself (henceforth "legacy" AV/C devices) are unable to communicate across L3 IP bridges. [R2] also specifies two new protocols to be used in a network environment:

– an alternate transport for AV/C command and response frames, called Function Control Protocol over IPv4 (FCP/IP); and

– alternate methods to manage isochronous connections between AV/C devices, called Connection Management Procedures over IPv4 (CMP/IP).

Both FCP/IP and CMP/IP are, as their acronyms suggest, based upon Internet protocol.

Newer AV/C devices should be manufactured with FCP/IP and CMP/IP capabilities, since this will render them "out-of-the-box" network-capable. However, the deployed base of AV/C devices lacks these capabilities and risks being stranded as non-network-capable. Consider the network technology illustrated by Figure 4 (legacy AV/C devices are shown shaded in gray).

NOTE – Because they are not pertinent to the discussion of legacy AV/C devices, the pictured topology omits analog devices that might be connected to the coaxial cable backbone and omits the network interface unit (NIU) through which the MSO provides programming and other services. Although not illustrated, the NIU is assumed to be incorporated within the set-top box.

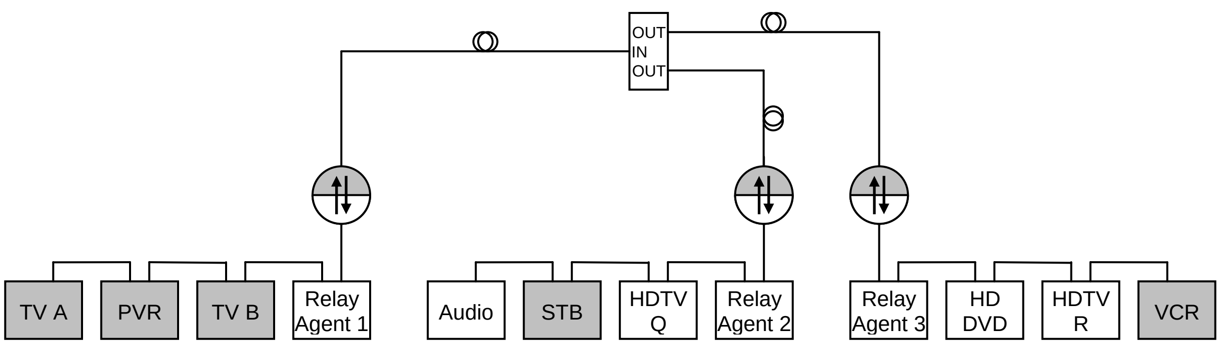

Figure 4 – Network topology with legacy and FCP/IP-capable devices

Without assistance, the legacy devices can interoperate only with other legacy devices within the same IEEE 1394 cluster. The newer, FCP/IP-capable devices can interoperate with each other regardless of where they are within the network; they can also use legacy methods to interoperate with legacy devices in their own cluster. What is lacking is the ability of a legacy AV/C controller to transmit a command frame to a remote target and the complementary ability of a legacy AV/C target to transmit a response frame to the remote controller.

The solution is to add a device with which the legacy AV/C device can interact. A legacy AV/C target can receive commands from and transmit responses to only a local controller, while a legacy AV/C controller can transmit commands to and receive responses from only a local target. An AV/C relay agent, when connected to the same IEEE 1394 cluster as the legacy AV/C device, impersonates a remote AV/C device. In order to support legacy targets, the relay agent acts as if it is a controller. Contrariwise, to support legacy controllers, the relay agent acts as if it is a target. These roles, which may be active concurrently within the same relay agent, are referred to as controller surrogate and target surrogate, respectively.

Once AV/C relay agents have been added to the topology, as shown by Figure 4, methods must be provided for the legacy AV/C devices to be discovered by other devices in remote IEEE 1394 clusters. Legacy AV/C target discovery is straightforward: relay agents read the configuration ROM of all devices within each one's local IEEE 1394 cluster in order to discover legacy AV/C targets and then use mDNS services to broadcast a list of the legacy target EUI-64s.

FCP/IP-capable AV/C controllers elsewhere within the network listen for these announcements and store the information for future use.

The establishment of the relationship between a relay agent, a remote target and a legacy AV/C controller is more complex. First, an AV/C relay agent must search for and find legacy AV/C controllers within its local IEEE 1394 cluster. Because there is no requirement that controllers exhibit a unit directory in configuration ROM, they are not necessarily discoverable. Controllers may be easily discoverable if they implement an AV/C subunit type that, by convention, signifies the presence of the otherwise undetectable controller.[1] FCP/IP-capable controllers with a display and user interface, *e.g.*, a television, listen for the list of legacy target EUI-64s broadcast *via* mDNS by relay agents. Using AV/C commands, it then categorizes each EUI-64 as belonging to either a legacy AV/C target or a legacy AV/C controller. In order to render a particular legacy AV/C target accessible to a particular legacy AV/C controller, all the user need do is to select the two devices. Although the design of a graphical user interface that permits the user to associate legacy AV/C controller and target pairs is beyond the scope of this specification, the mechanisms to create the desired association are defined in this specification. Once the desired association has been established (and heralded by a bus reset), the legacy AV/C controller should discover, by its normal brute-force search of local devices' configuration ROM, the existence of the relay agent impersonating the desired remote AV/C target.

Figure 5 illustrates the command and response pathways used when a relay agent acts as a controller surrogate to enable a remote AV/C controller to communicate with a legacy AV/C target within the relay agent's IEEE 1394 cluster. As part of its function to enable communications between the two devices, a relay agent translates between FCP (indicated by dashed red lines and arrowheads) and FCP/IP (indicated by dotted green lines and arrowheads)[2]. HDTV P originates a command and transmits it *via* a UDP datagram to Relay Agent 1, which writes the FCP command frame to the PVR's command register. When the PVR generates a response frame, it writes it to Relay Agent 1's response register. Because the relay agent has retained transaction state information, it knows that a response frame originated by the PVR should be returned to HDTV P. Relay Agent 1 encapsulates the response frame within a UDP datagram addressed to HDTV P.

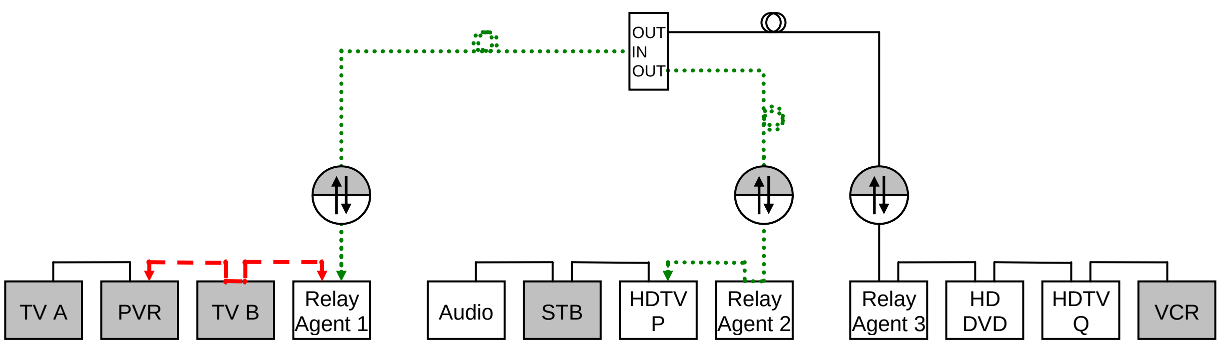

Figure 5 – Legacy AV/C target command/response pathways

Figure 6 illustrates the command and response pathways used when a relay agent acts as a target surrogate to enable a legacy AV/C controller within the relay agent's IEEE 1394 cluster to communicate with a remote target. Relay Agent 1, within the same IEEE 1394 cluster as TV B, has been configured to impersonate the remote HD DVD and is aware that the HD DVD is an FCP/IP-capable target and not a relay agent. TV B originates a command and writes the FCP command frame to Relay Agent 1's command register. Because the relay agent is configured to impersonate

[1] Alternatively, an AV/C relay agent can provoke legacy AV/C controllers into identifying themselves by exhibiting an AV/C unit directory and implementing a vendor-specific AV/C unit that has no subunits. Consult 7.3.1 for a more thorough discussion of this strategy.

[2] Figure 4 through Figure 7, inclusive, faithfully reproduce actual IEEE 1394 topology insofar as they represent individual PHY ports on the devices shown. However, unless an arrowhead terminates at a particular device, the data transfer represented by the dotted line is only repeated by the PHY and not received by the device. In Figure 5, for example, the red dotted line that connects the PVR and Relay Agent 1 represents UDP datagrams transmitted from one device to the other; these datagrams are not received by TV B.

the HD DVD, it transmits the command frame *via* a UDP datagram to the HD DVD. When the HD DVD generates a response frame, it encapsulates the response frame within a UDP datagram for transmission to Relay Agent 1. Because the relay agent has state information for its relationship with both the controller and target, it knows that a response frame originated by the HD DVD should be written to TV B's response register.

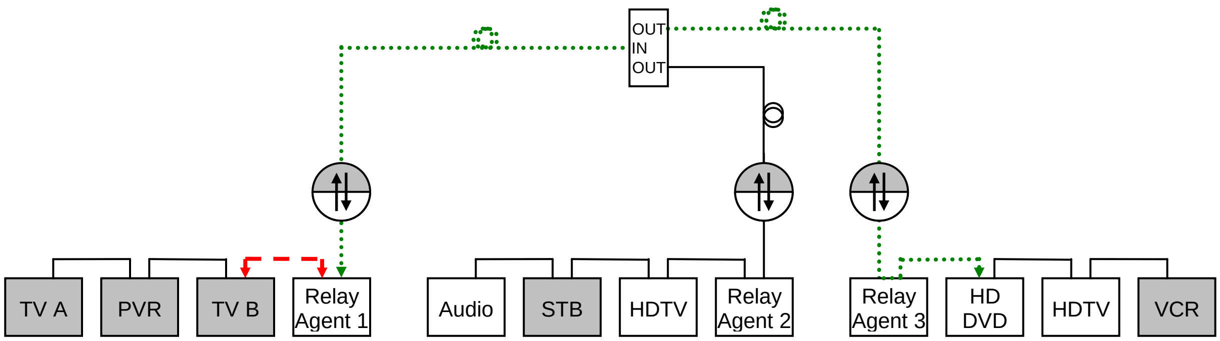

Figure 6 – Legacy AV/C controller command/response pathways

Figure 7 illustrates the command and response pathways used when both controller and target are legacy AV/C devices and each is supported by a relay agent connected to the same IEEE 1394 cluster. TV B originates a command and writes the command frame to Relay Agent 1's command register (the relay agent is impersonating the STB). Because of the previously established relationship between the target surrogate and the STB, the relay agent encapsulates the command frame and transmits it *via* a UDP datagram to Relay Agent 2. Relay Agent 2, acting as a controller surrogate, writes the command frame to the STB's command register. When the STB generates a response, it writes the response frame to Relay Agent 2's response register. Based upon state information retained for the FCP transaction, the relay agent determines that the response frame should be transferred to Relay Agent 1. The response frame is transmitted encapsulated within a UDP datagram. Upon receipt of the datagram, Relay Agent 1 extracts the response frame and writes it to TV B's response register.

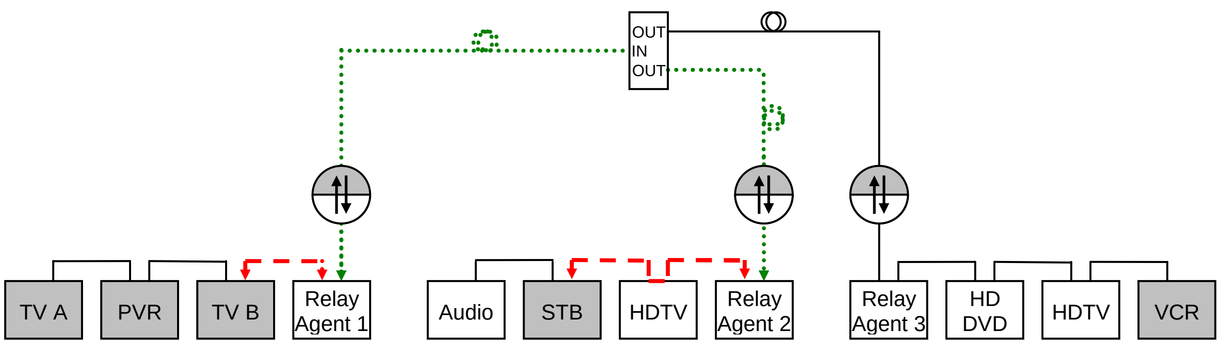

Figure 7 – Controller and target surrogates command/response pathways

5 Data structure formats

5.1 DNS messages and resource records

DNS is normatively specified by [R12], which should be consulted for more detailed information than either the brief overview of DNS message and resource record formats found in [R3] or the AV/C relay agent-specific information that is presented in the clauses that follow. .

5.1.1 Host address (A) resource record

The NAME field of an A record shall contain the AV/C relay agent's host name. The RDATA field shall contain the relay agent's 32-bit IPv4 address.

5.1.2 Pointer (PTR) resource record

The NAME field of a PTR record shall contain the service name `_1394ta-relay._udp.local`.

The RDATA field of a PTR record shall contain a service instance name. There shall be a SRV record for the specified service instance name.

5.1.3 Server (SRV) resource record

The NAME field of an SRV record shall contain the service name `_1394ta-relay._udp.local` prepended by an instance name. The combined service instance name identifies an AV/C target instantiation of the FCP/IP service specified by this document. For example, `bridge_.1394ta-relay._udp.local` could describe an L3 IP bridge's instantiation of the service.

The RDATA field of an SRV record shall contain the variable-length character string subfields designated Priority, Weight, Port and Target.

The Priority and Weight subfields shall be equal to zero. SRV records, as used by AV/C relay agents, shall not determine the selection of an AV/C relay agent when more than one is present within an IEEE 1394 cluster. That choice is beyond the scope of this specification. Nonzero values for these subfields would preempt independent selection criteria, *e.g.*, load balancing among multiple relay agents.

The Port subfield shall specify the AV/C relay agent port number, encoded as a 16-bit unsigned integer in network byte order, to which UDP/IP datagrams containing FC PDUs should be addressed.

The Target subfield shall specify the AV/C relay agent's host name. There shall be at least one address record for the specified host name. When responding to an mDNS query, the relay agent should return its address record in the additional data section.

5.1.4 Text (TXT) resource record

The NAME field of a TXT record shall contain, explicitly or by inheritance from the preceding RR, the service instance name of the SRV record to which it pertains.

The RDATA field of a TXT record shall contain the parameters enumerated in the table below. The parameters shall be encoded as length-delimited character strings consisting of the parameter name separated from the parameter value by an equal sign.

Parameter	Value
txtvers	The txtvers parameter shall be equal to UTF-8 "1" and shall be the first character string in the RDATA field. This indicates that the format of the TXT record conforms to [R10], *i.e.*, the RDATA contains only length-delimited character strings.
eui64 [a]	The eui64 parameter shall be equal to the value of the EUI-64 of the AV/C relay agent identified by the Target subfield in the SRV record to which this TXT record pertains.
relay_version	The relay_version parameter shall be equal to UTF-8 "1" to indicate that the AV/C relay agent conforms to this specification.

[a] The parameter's value shall be encoded as a sequence of UTF-8 characters, each of which represents a hexadecimal digit that corresponds to four bits of the parameter's numeric value.

5.2 Function control protocol data unit (FC PDU)

As specified by [R3], individual FCP command and response frames shall be encapsulated within a protocol data unit whose format conforms to Figure 8. This document specifies additional values for the *type* field and formats for the *data* field associated with those types.

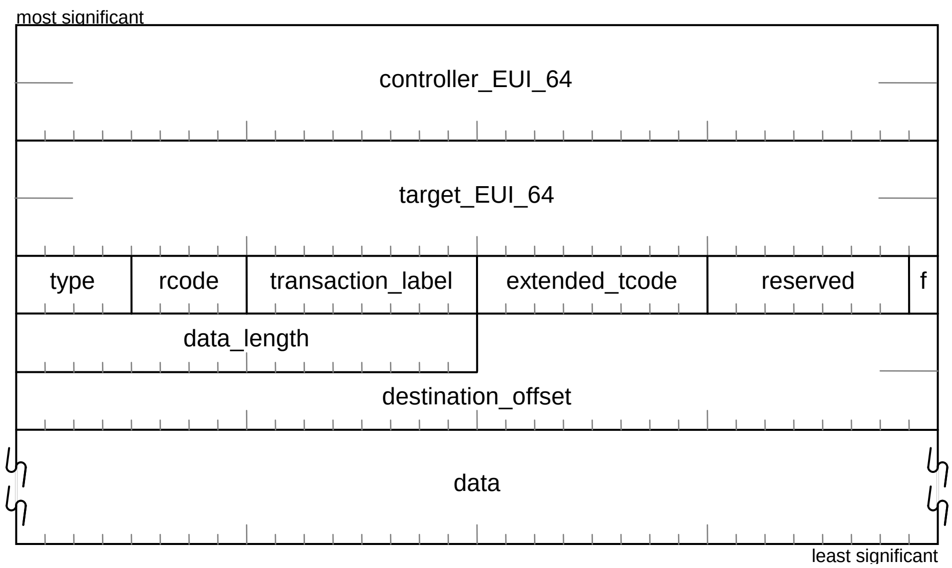

Figure 8 – FCP/IP protocol data unit format

Except as specified by this document, the meaning and usage of all FC PDU fields are defined by [R3].

The value of the *controller_EUI_64* field shall be equal to the EUI-64 of the actual controller, as reported by its configuration ROM bus information block. For FCP command frames initiated by a legacy AV/C controller, the AV/C target surrogate initializes this field. Otherwise, an FCP/IP-capable controller initializes the field with the value of its own EUI-64. In no case does it ever contain the value of an AV/C relay agent's EUI-64.

The value of the *target_EUI_64* field shall be equal to the EUI-64 of the actual target, as reported by its configuration ROM bus information block. For FCP command frames initiated by a legacy AV/C controller, the AV/C target surrogate initializes this field. Otherwise, an FCP/IP-capable controller initializes the field with the value of the target's EUI-64. In no case does it ever contain the value of an AV/C relay agent's EUI-64.

The *type* field shall specify the type of PDU, as specified by the table below:

Type	Description
0 – 1	See [R3]
2	Read local or remote device memory and return the information in the *data* field of a Transport Status response (see 7.6).
3	Write the information in the *data* field to local or remote device memory and return a Transport Status response (see 7.6).
4	Use the arguments in the *data* field and local or remote device memory to perform the lock operation specified by *extended_tcode* and return the results in the *data* field of a Transport Status response (see 7.6).
5	See [R3]
6	The *data* field contains a list of EUI-64s of legacy AV/C devices within the relay agent's IEEE 1394 cluster (see 5.2.1).
7	The *data* field contains a list of EUI-64 pairs, each of which represents the AV/C relay agent's target surrogate persona for a particular legacy AV/C controller (see 5.2.2)..
8	The *data* field contains an EUI 64 pair, which establishes one or more target surrogate personae, each for a singular legacy AV/C controller (see 5.2.3)
9 – F_{16}	Reserved for future standardization.

The value of the *rcode* field is meaningful only when the *type* field is equal to five, in which case it shall indicate the transport status of the most recent FCP command frame or request transmitted by the controller, as encoded by the table below.

<table>
<tr><th>rcode</th><th>Name</th><th>Description</th></tr>
<tr><td>0</td><td>Complete</td><td>See [R3]</td></tr>
<tr><td>1</td><td>Timeout</td><td>No response was received from the legacy AV/C target after it transmitted ack_pending to the relay agent.</td></tr>
<tr><td>2</td><td>Nonexistent</td><td>The target identified by target_EUI_64 is not in the relay agent's legacy target list or is nonresponsive, i.e., its link layer is inoperative.</td></tr>
<tr><td>3</td><td>Busy</td><td>The retry limit for ack_busy_X, ack_busy_A or ack_busy_B was exceeded.</td></tr>
<tr><td>4</td><td>Conflict error</td><td rowspan="3">See [R3]</td></tr>
<tr><td>5</td><td>Data error</td></tr>
<tr><td>6</td><td>Type error</td></tr>
<tr><td>7</td><td>Address error</td><td>Some or all of the address range specified by the block write request referenced unimplemented CSRs</td></tr>
<tr><td>8 – E_{16}</td><td></td><td>Reserved for future standardization</td></tr>
<tr><td>F_{16}</td><td>FCP attention</td><td>An IEEE 1394 bus reset has caused a legacy AV/C device to discard its FCP transaction context.</td></tr>
</table>

The *FCP_reset* bit (designated as *f* in Figure 8) resets an FCP attention condition maintained by an AV/C controller surrogate on behalf of the legacy AV/C target identified by *target_EUI_64*.

The contents of the *data* field are *type*-dependent and are discussed in 5.2.1 through 5.2.3, inclusive.

5.2.1 Legacy AV/C target list

When the value of the *type* field is equal to six, the *data* field contains an unordered list of legacy AV/C targets connected to the same IEEE 1394 cluster as the AV/C relay agent that transmitted the FC PDU. The list consists of up to 62 EUI-64s, each one of which identifies a legacy AV/C target. The maximum size of the *data* field is 496 bytes.

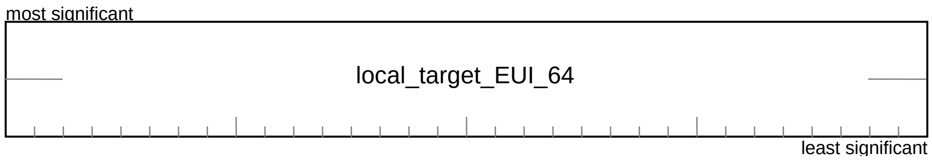

Figure 9 – Legacy AV/C target EUI-64 format

The *local_target_EUI_64* field shall contain the EUI-64 of a legacy AV/C target connected to the AV/C relay agent's IEEE 1394 cluster. The relay agent is capable of functioning as a controller surrogate for this device.

5.2.2 Target surrogate personae

When the value of the *type* field is equal to seven, the *data* field contains a list of target surrogate personae active for the AV/C relay agent that transmitted the FC PDU. The list contains up to 62 target surrogate personae; each persona is a 16-byte structure whose format conforms to Figure 10. The maximum size of the *data* field is 992 bytes. A target surrogate persona identifies the remote AV/C target impersonated by the relay agent to a particular legacy AV/C controller within the same cluster as the relay agent. There may be a default persona that identifies the remote AV/C target impersonated to legacy controllers that lack an individually configured persona.

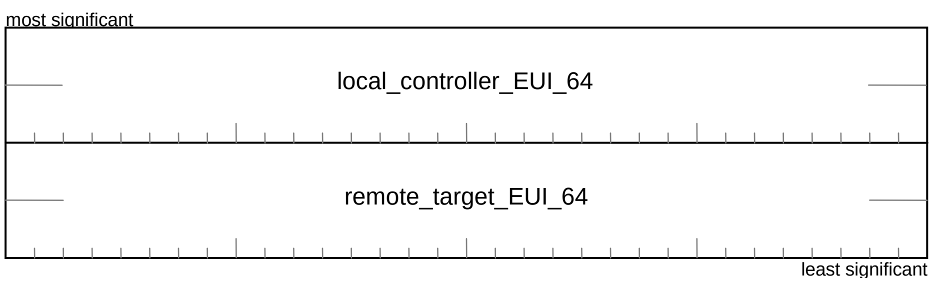

Figure 10 – Target surrogate persona format

If the *local_controller_EUI_64* field has a value of FFFF FFFF FFFF $FFFF_{16}$, the persona is the default persona for the AV/C relay agent that transmitted the FC PDU. Otherwise, the *local_controller_EUI_64* field shall contain the EUI-64 of the legacy AV/C controller to which the persona pertains. There shall be at most one persona for a particular legacy AV/C controller, *i.e.*, the value of *local_controller_EUI_64* shall not be repeated in other personae.

The *remote_target_EUI_64* field shall contain the EUI-64 of the legacy AV/C target impersonated by the AV/C relay agent in target surrogate mode. Different personae may impersonate the same remote AV/C target to different legacy AV/C controllers.

5.2.3 Set target surrogate personae

When the value of the *type* field is equal to eight, the *data* field contains up to 62 target surrogate personae in the format specified by Figure 10. The maximum size of the *data* field is 992 bytes. Each persona in the *data* field either creates a new persona or updates an existing persona in the AV/C relay agent's active personae; other, unreferenced personae are not altered. A controller’s active persona may be deleted by zeroing *remote_target_EUI_64*.

6 Configuration ROM

6.1 Configuration ROM hierarchy

All nodes that implement AV/C relay agents shall implement general format configuration ROM in accordance with [R5], [R6] *et seq*. and this specification. General format configuration ROM is a self-descriptive structure as illustrated below. The bus information block and root directory are at fixed locations; all other directories and leaves are addressed by entries in their parent directory.

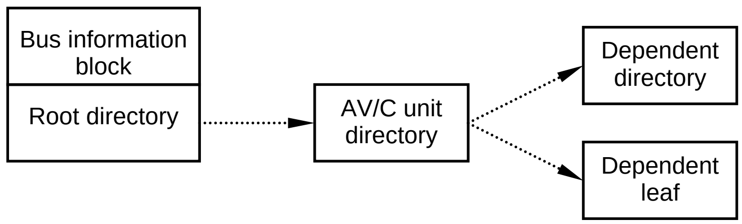

Figure 11 – AV/C configuration ROM hierarchy

6.2 Power reset initialization

During the initialization process that follows a power reset an AV/C relay agent might not be able to respond to Serial Bus request subactions addressed to parts of configuration ROM. When the relay agent has insufficient information to make more than the first quadlet of configuration ROM accessible, it shall return a data value of zero in the response to any read request addressed to FFFF F000 0400_{16} or acknowledge the request subaction with *ack_tardy*, as specified by [R6] *et seq*. Until the initialization process completes, responses to requests addressed to other parts of configuration ROM are unspecified.

AV/C relay agents shall complete initialization within five seconds of a power reset. Once power reset initialization completes, the relay agent shall make all mandatory configuration ROM entries available. The relay agent should not initiate a Serial Bus reset solely because of the completion of power reset initialization.

6.3 Bus information block

All AV/C relay agents shall implement a bus information block at a base address of FFFF F000 0404_{16}. For convenience of reference, the format of the bus information block defined by [R6] *et seq*. is reproduced below.

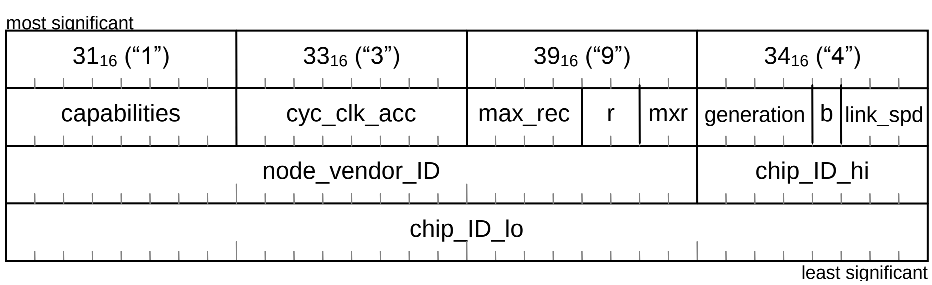

Figure 12 – Bus information block format

The first quadlet contains the string “1394” in ASCII characters.

The *capabilities* field is a collection of bits, illustrated by Figure 13.

most significant

irmc	cmc	isc	bmc	pmc	adjustable	reserved

least significant

Figure 13 – Bus information block *capabilities* field

The *irmc* bit shall be one if the node is isochronous resource manager-capable; otherwise, this bit shall be zero.

The *cmc* bit shall be one if the node is cycle master-capable; otherwise, this bit shall be zero.

The *isc* bit shall be one if the node supports isochronous operations; otherwise, this bit shall be zero.

The *bmc* bit shall be one if the node is bus manager-capable; otherwise, this bit shall be zero.

The *pmc* bit shall be one if the node is power manager-capable; otherwise, this bit shall be zero. A node that reports a value of one for *pmc* shall also set *bmc* to one.

The *adjustable* bit shall be one if the node's cycle offset is adjustable, as specified by [R6] *et seq*.; otherwise, this bit shall be zero.

The *cyc_clk_acc* field specifies the node's cycle master clock accuracy in parts per million. If the *cmc* bit is one, the value in this field shall be between zero and 100. If the *cmc* bit is zero, this field shall be all ones.

The *max_rec* field defines the maximum data payload that the AV/C relay agent supports. The data payload applies to block write requests addressed to the relay agent, asynchronous stream packets received by the relay agent and block read responses transmitted by the relay agent. The maximum data payload is equal to $2^{max\_rec + 1}$ bytes. If *max_ROM* is nonzero, *max_rec* shall be greater than or equal to $2^{max\_ROM + 1} + 1$.

The *max_ROM* field (abbreviated as *mxr* in the figure above) shall specify the size and alignment of read requests supported by configuration ROM, whether within the address range FFFF F000 0400_{16} through FFFF F000 $07FF_{16}$ inclusive or another portion of the AV/C relay agent's address space, as specified by [R6] *et seq*.

The *generation* field indicates changes in configuration ROM; see [R6] *et seq.* for details.

The *bridge_aware* bit (abbreviated as *b* in the figure above), shall be one.

The *lnk_spd* field shall report the maximum speed capability of the AV/C relay agent's link layer, encoded as specified below:

Value	Speed
0	S100
1	S200
2	S400
3	S800
4	S1600
5	S3200
6 – 7	Reserved for future standardization

The *node_vendor_ID* field shall contain an organizationally unique ID (OUI) obtained from the IEEE RA, as specified by [R5]. Unique identifiers for a company or organization may be obtained from the IEEE at the address given below:

Institute of Electrical and Electronic Engineers, Inc.
Registration Authority
445 Hoes Lane
Piscataway, NJ 08855-1331

Application for an OUI (also known as a *company_ID*) may be made *via* the Internet:

http://standards.ieee.org/regauth/oui/forms/

The *chip_ID_hi* and *chip_ID_lo* fields are concatenated to form a 40-bit chip ID value. The vendor or organization specified by *node_vendor_ID* shall administer the chip ID values. When appended to the *node_vendor_ID* value, these form a unique 64-bit value called the EUI-64 (Extended Unique Identifier, 64 bits).

6.4 Root directory

6.4.1 Root directory (general)

Configuration ROM for AV/C relay agents shall contain a root directory. The root directory immediately follows the bus information block and has a base address of FFFF F000 0414_{16}. The root directory shall contain one each of the Vendor_ID and Node_Capabilities entries and at least one Unit_Directory entry that specifies the location of a unit directory whose format conforms to [R2].

6.4.2 Vendor_ID entry

The Vendor_ID entry is an immediate entry in the root directory that provides the company ID of the vendor that manufactured the module. Figure 14 shows the format of this entry.

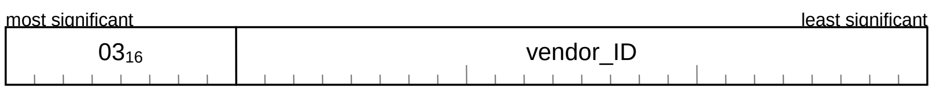

Figure 14 – Vendor_ID entry format

03_{16} is the concatenation of *key_type* and *key_value* for the Vendor_ID entry.

The *vendor_ID* field shall contain an OUI obtained from the IEEE-RA. There is no requirement that the values of *vendor_ID* and *node_vendor_ID* be equal.

NOTE – A recommended convention to provide vendor identification in displayable form is to follow immediately the Vendor_ID entry with a textual descriptor leaf entry. This associates an ASCII string with the module vendor. See [R5] for the specification of textual descriptor leaves.

6.4.3 Node_Capabilities entry

The Node_Capabilities entry is an immediate entry in the root directory that describes node capabilities. Figure 15 shows the format of this entry.

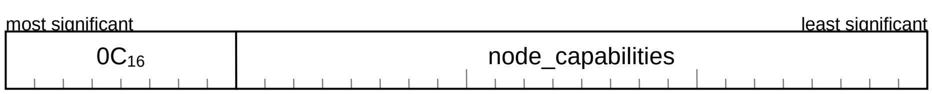

Figure 15 – Node_Capabilities entry format

$0C_{16}$ is the concatenation of *key_type* and *key_value* for the Node_Capabilities entry.

The *node_capabilities* field contains subfields, specified by [R6] *et seq*. AV/C relay agents shall implement the SPLIT_TIMEOUT register, the 64-bit fixed addressing scheme, the STATE_CLEAR.*lost* bit and the STATE_CLEAR.*dreq* bit and indicate this by setting the *spt*, *64*, *fix*, *lst* and *drq* bits to one. If no other *node_capabilities* bits are one this results in a value of 00 $83C0_{16}$.

6.4.4 Unit_Directory entry

The Unit_Directory entry is a directory entry in the root directory that describes the location of a unit directory within configuration ROM. AV/C relay agents should implement only one unit directory, an AV/C unit directory conformant to [R2]. However many unit directories are implemented by the relay agent, each shall be located by a separate Unit_Directory entry. Figure 16 shows the format of this entry.

most significant	least significant
$D1_{16}$	indirect_offset

Figure 16 – Unit_Directory entry format

$D1_{16}$ is the concatenation of *key_type* and *key_value* for the Unit_Directory entry.

The *indirect_offset* field specifies the number of quadlets from the address of the Unit_Directory entry to the address of the unit directory within configuration ROM.

6.5 AV/C unit directory

Configuration ROM for AV/C relay agents shall contain exactly one unit directory in the format specified by [R2]. The unit directory shall contain Specifier_ID and Version entries (see [R5]).

6.6 AV/C directory entries

6.6.1 Specifier_ID entry

The Specifier_ID entry is an immediate entry in the AV/C unit directory that specifies the organization responsible for the architectural definition of AV/C devices. Figure 17 shows the format of this entry.

most significant	least significant
12_{16}	00 $A02D_{16}$

Figure 17 – Specifier_ID entry format

12_{16} is the concatenation of *key_type* and *key_value* for the Specifier_ID entry.

00 $A02D_{16}$ is the OUI obtained by the 1394 Trade Association from the IEEE RA. The value indicates that the 1394 Trade Association was originally responsible to define the meaning of the Version entry; the trade association has since transferred this responsibility to the IEC.

6.6.2 Version entry

The Version entry is an immediate entry in a unit directory that, in combination with the OUI obtained from the Specifier_ID entry, specifies the unit's software interface. Figure 18 shows the format of this entry.

most significant	least significant
13_{16}	01 0001_{16}

Figure 18 – Version entry format

13_{16} is the concatenation of *key_type* and *key_value* for the Version entry.

01 0001_{16} indicates that the unit conforms to [R2] and uses the AV/C command/transaction set defined by pertinent 1394 Trade Association specifications.

7 Operations

7.1 Service announcement and discovery

AV/C relay agents shall conform to [R2] and **Error! Reference source not found.**[R3] with respect to link-local address assignment, host name assignment, service announcement and service discovery.

An AV/C relay agent's preferred host name should have a low probability of collision with another device's host name. Because of the likelihood that multiple relay agents from the same vendor will be present in a single residential network, each should construct its preferred host name from its manufacturer’s name, its model designation and 16 contiguous bits sampled from the least significant 40 bits of the relay agent's EUI-64. For example, “SkunkWorks-Relay-Rooter-FE-CE” might be the host name for a particular model relay agent manufactured by SkunkWorks Network Appliances.

AV/C controllers can discover AV/C relay agents by broadcasting a DNS message whose QNAME field is initialized to `_1394ta-avc-relay._udp.local` and whose QTYPE field is initialized to PTR. This causes all AV/C relay agents to return, either by multicast or unicast, a DNS response record whose Answer section contains the PTR record that satisfies the query and whose Additional Data section contains the associated A, SRV and TXT records that describe the service instance’s IP address and port number. The controller may connect to the relay agent, which then automatically transmits FC PDUs that contain its legacy AV/C target list and active target surrogate personae.

7.2 Controller surrogate operations

When an FCP/IP-capable AV/C controller interacts with a remote legacy AV/C target, it requires the assistance of an AV/C relay agent acting as a controller surrogate (see Figure 19). From the perspective of the target, the AV/C relay agent is the controller: it writes FCP command frames to the target's command register at FFFF F000 $0B00_{16}$ and receives FCP response frames written to its response register at FFFF F000 $0D00_{16}$.

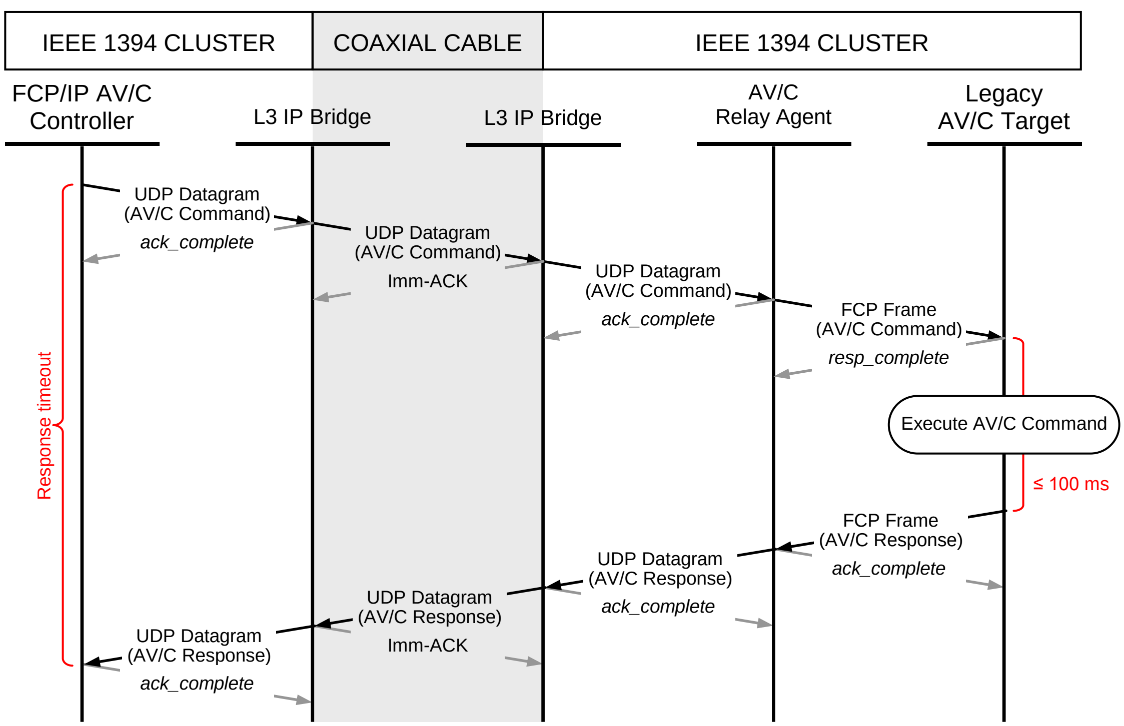

Figure 19 – Command/response sequence with AV/C controller surrogate

An FCP/IP-capable controller initiates a remote FCP operation by transmitting a command frame FC PDU to an AV/C relay agent connected to the same IEEE 1394 cluster as the legacy AV/C target. The *data* field shall contain the FCP command frame, the *controller_EUI_64* field shall be set to the value of the AV/C controller's EUI-64 and the *target_EUI_64* shall be set to the value of the target's EUI-64 as obtained from a legacy AV/C target list (see 5.2.1) published by the relay agent.

NOTE – If a target's EUI-64 is published by more than one AV/C relay agent, the controller may transmit the UDP datagram that contains the FC PDU to any one of the relay agents, as they do not preserve any context information from one FCP transaction to the next.

When an AV/C relay agent receives an FCP command frame, it first checks to see if the FC PDU's *target_EUI_64* field matches an EUI-64 present in its legacy AV/C target list. If there is no match, the relay agent shall return a Transport Status message to the AV/C controller with the *rcode* set to two. Otherwise, the relay agent shall use an IEEE 1394 block write request addressed to the target's command register at FFFF F000 $0B00_{16}$ to transfer the FCP command frame to the legacy target. This initiates an FCP transaction with the legacy target. So long as the transaction is pending, the relay agent shall maintain state information that consists of the EUI-64 and the source IP address of the FC/IP-capable controller and the EUI-64 of the target. An AV/C relay agent should support multiple, concurrent FCP transactions for the same or for different targets.

The next action taken by the AV/C relay agent depends upon the request status returned for the block write request, and, if the request status is COMPLETE or DATA ERROR, additionally depends on the response code, as summarized by Table 1. Under the circumstances indicated, the AV/C relay agent may elect to retry the block write request. If the relay agent abandons the retry attempt or if retry is not permitted, it shall transmit a Transport Status message to the AV/C controller with the *rcode* indicated.

Table 1 – Relay agent actions after legacy AV/C target response to command frame

Request status	Response code	Retry permitted	*rcode*	Comment
COMPLETE	*resp_complete*	—	0	The FCP command frame has been successfully delivered to the legacy AV/C target; Transport Status message optional.
	resp_conflict_error	No	4	The legacy AV/C target is busy executing a previously received command; retry must be initiated by the AV/C controller.
	resp_type_error	No	6	Packet header of the block write request does not conform to [R6] *et seq*.
	resp_address_error	No	7	Some or all of the address range specified by the block write request referenced unimplemented CSRs
TIMEOUT	—	No	1	After receipt of *ack_pending*, no response was received from the legacy AV/C target; retry must be initiated by the AV/C controller.
ACKNOWLEDGE MISSING		Yes	2	The legacy AV/C target did not acknowledge the block write request, and might be disconnected from the cluster or in a suspended state with its link inoperative.
RETRY LIMIT		No	3	The legacy AV/C target is busy (perhaps executing a previously received command); retry must be initiated by the AV/C controller.
DATA ERROR	*resp_data_error*	Yes	5	The legacy AV/C target detected a CRC error for the block write request's data payload.

When the request status is COMPLETE and the response code is *resp_complete*, the AV/C relay agent shall commence a 200 ms FCP request timeout. If no FCP response frame is written to the relay agent's response register at FFFF F000 $0D00_{16}$, the AV/C relay agent shall discard the state information associated with the transaction. Otherwise, the relay agent shall transmit the response frame to the FCP/IP-capable controller that initiated the transaction. The source IP address for the UDP datagram shall be the relay agent's IP address and the destination address shall be the controller's IP address; the *controller_EUI_64* and *target_EUI_64* fields shall be set to their values as retained in the transaction state information. If the response frame indicates INTERIM STATUS, the transaction state information shall be maintained until receipt of a FINAL STATUS response frame from the target.

When a FINAL STATUS response frame is received from the target, the AV/C relay agent shall discard all state information for the now-complete FCP transaction.

7.3 Target surrogate operations

7.3.1 Legacy AV/C controller discovery

Since legacy AV/C controllers do not necessarily contain an AV/C unit directory in their configuration ROM, they are not directly discoverable and must be provoked into revealing their whereabouts. An AV/C relay agent accomplishes this by exhibiting an AV/C unit directory in its configuration ROM. A controller enumerates its local IEEE 1394 cluster after a power reset or a bus reset, at which time it will discover the relay agent's AV/C unit directory (see [R1]). Because the unit directory advertises the presence of an AV/C unit but does not advertise its type, the controller is expected to query the unit and subunit types *via* UNIT INFO and SUBUNIT INFO status commands.

In response to the UNIT INFO status command, the relay agent shall return status data whose *unit_type* field is equal to $1C_{16}$ (vendor-dependent), *unit* field is zero and *company_ID* field is equal to 00 $A02D_{16}$. The use of the 1394 Trade Association's OUI departs from the recommendation of [R1] that *company_ID* be equal to the value of the Vendor ID entry in the root directory, but is necessary to cause the legacy AV/C controller to abandon its efforts to identify—and subsequently control—the AV/C relay agent’s dummy subunit.

Relay agent response to a SUBUNIT INFO status command depends upon the value of the *page* and *extension_code* fields. The only permissible value specified by [R1] for the *extension_code* field is seven; when this field has any other value, the relay agent shall return a NOT IMPLEMENTED response. Otherwise, if the value of the *page* field is zero, the relay agent shall return an ACCEPTED response with one *page_data* entry that describes a vendor-dependent *subunit_type* ($1C_{16}$) with a *max_subunit_ID* of zero; the remaining three *page_data* entries shall be set to all ones. For nonzero values of the *page* field, the relay agent shall return an ACCEPTED response whose *page_data* field is set to all ones.

Receipt of any AV/C command other than those whose implementation is mandated by [R1] (at the time of writing, only UNIT INFO and SUBUNIT INFO) shall cause the relay agent to return a NOT IMPLEMENTED response.

Upon receipt of a UNIT INFO status command from a legacy AV/C controller, the AV/C relay agent shall update its database of legacy AV/C controllers with this controller's EUI-64. Subsequent to a bus reset, the relay agent shall update the same database by deleting EUI-64 entries for disconnected legacy controllers.

7.3.2 Target surrogate personae

In its role as a target surrogate, an AV/C relay agent impersonates a remote AV/C target for the benefit of a local, legacy AV/C controller. It accomplishes this by three behaviors:

– When accessed by a particular legacy controller, a subset of the remote target's configuration ROM completely replaces the relay agent's own configuration ROM (for that controller, only). That is, read requests addressed to the relay agent are completed with responses that contain data obtained from remote target's configuration ROM. Whether the relay agent's "native" configuration ROM is visible to particular legacy controller is determined by the *source_node_ID* in the read request addressed to the relay agent. The replacement configuration ROM consists of only those parts of the remote target's configuration ROM required for an IEEE 1394 node or pertinent to the target's AV/C capabilities: a) the bus information block, b) the root directory Vendor_ID and Node_Capabilities entries, any textual descriptor entries that immediately follow the Vendor_ID entry, one and only one Unit_Directory entry that references an AV/C unit directory, c) the AV/C unit directory itself and d) all leaves and directories dependent upon the AV/C unit directory. The impersonated configuration ROM permits legacy controllers to “discover” the remote target's EUI-64[3] and its AV/C unit directory;

– The AV/C relay agent forwards FCP command frames received at FFFF F000 $0B00_{16}$ to the appropriate remote AV/C target, *i.e.*, the one currently paired with the originator of the FCP command frame; and

– The AV/C relay agent filters access to the remote AV/C target's plug control registers (PCRs). Read requests addressed to the relay agent's PCRs are completed with responses that contain a mixture of data from the remote AV/C target's PCRs and state information maintained by the target surrogate. Changes to the relay agent’s PCRs initiated by lock requests directly alter the local PCRs and trigger CMP/IP requests that effect analogous changes to the remote AV/C target's PCRs.

The interactions above, between a particular AV/C controller and a particular remote AV/C target, form a target surrogate persona, *i.e.*, the “face” the relay agent presents to that controller.

Most devices that read an AV/C relay agent's configuration ROM do not detect an AV/C target, since the relay agent's "true" identity does not contain an AV/C unit directory. Only when a relay agent has been configured to impersonate a particular remote AV/C device for a particular local device (presumed to be a legacy AV/C controller) does an AV/C unit directory appear in the relay agent's configuration ROM. Although a relay agent can impersonate any remote AV/C target—either legacy or FCP/IP-capable—it can only do so for one remote AV/C target at a time.[4] Within this constraint, a relay agent can impersonate the same remote AV/C target to different legacy AV/C controllers or, more commonly, impersonate different remote AV/C targets to different legacy AV/C controllers.

Target surrogate personae may be established autonomously by an AV/C relay agent or externally by a set target surrogate personae FC PDU transmitted by some other device. The criteria used to select those remote AV/C targets to be impersonated by an AV/C relay agent are beyond the scope of this specification. Annex D discusses possible heuristics for the autonomous establishment of target surrogate personae by AV/C relay agents as well as a scenario that permits the user to establish target surrogate personae.

7.3.3 Target surrogate FCP/IP operations

In its role as a target surrogate, an AV/C relay agent accepts command frames written to its command register at FFFF F000 $0B00_{16}$ by a legacy AV/C controller connected to the same IEEE 1394 cluster as the relay agent. The command frames are intended for a remote AV/C target, which is impersonated locally by the relay agent. After the remote, FCP/IP-capable AV/C target processes the command frame, it returns a response frame to the target surrogate relay agent *via* an IPv4 UDP datagram, which the relay agent writes to the legacy AV/C controller’s response register at FFFF F000 $0D00_{16}$ to complete the transaction. Figure 20 describes the message exchanges necessary to complete the transaction.

[3] Some curious effects are engendered by shadowing the remote AV/C target's EUI-64. As far as they are presented with different target surrogate personae, legacy AV/C controllers would report different EUI-64s for the same local node, while devices other than legacy AV/C controllers would report the node's “true” EUI-64. An AV/C relay agent should not implement an AV/C device, as this device would be inaccessible to legacy AV/C controllers yet available to FCP/IP-capable controllers.

[4] For example, to control two remote AV/C devices concurrently (such as to coordinate a recording session between an STB and a DVR, both located in different clusters than legacy AV/C controller), two relay agents must be connected to the same cluster as the legacy AV/C controller. Each of the relay agents will act as a target surrogate for one of the remote devices.

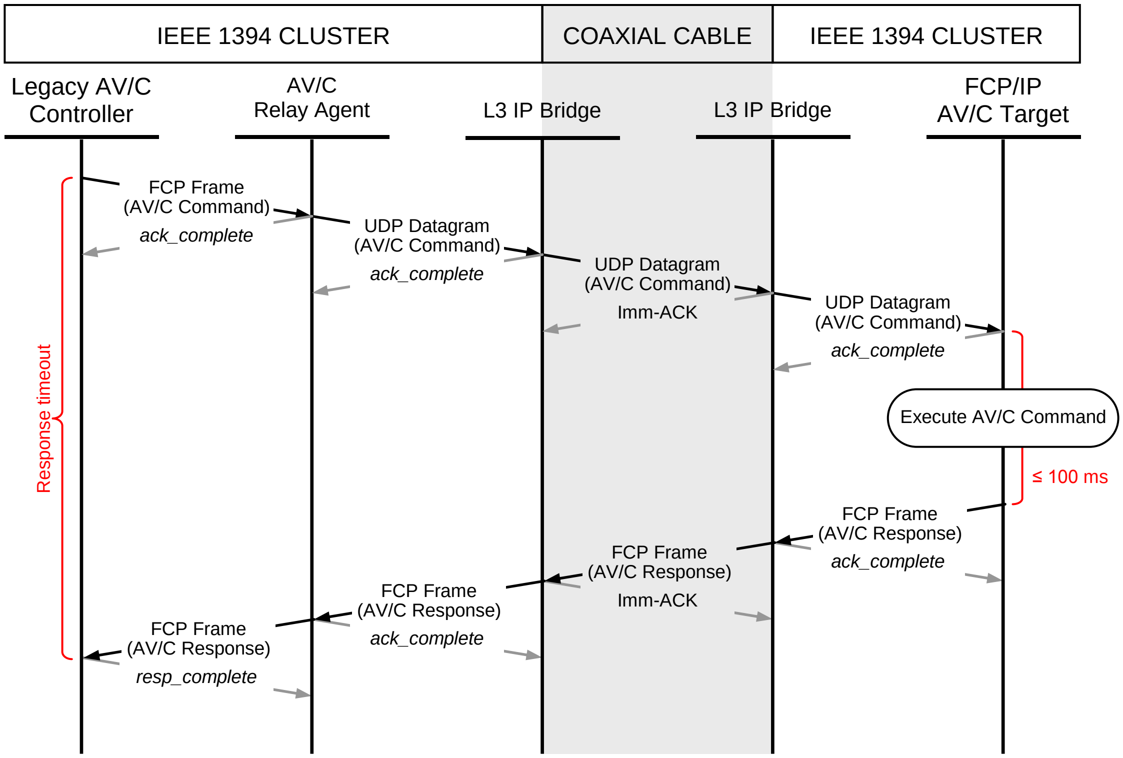

Figure 20 – Command/response sequence with AV/C target surrogate

A legacy AV/C controller initiates an FCP transaction with a remote AV/C target by writing an FCP command frame to the target surrogate's command register at FFFF F000 $0B00_{16}$. The AV/C relay agent, upon receipt of the FCP command frame, encapsulates it in an FC PDU; the *controller_EUI_64* field shall be set to the value of the legacy AV/C controller's EUI-64 and the *target_EUI_64* field shall be set to the value of the remote AV/C target associated with the target surrogate persona currently active for the legacy AV/C controller.

In order to route the UDP datagram that contains the FC PDU, the AV/C relay agent must differentiate between remote legacy AV/C targets and remote FCP/IP-capable AV/C targets. If the remote target is legacy AV/C, the datagram shall be addressed to an AV/C relay agent within the remote IEEE 1394 cluster. Otherwise, when the remote target is FCP/IP-capable, the datagram shall be addressed directly to the target.

When a response frame FC PDU is received by an AV/C relay agent, the value of the PDU's *controller_EUI_64* field identifies the legacy AV/C controller for which the response is intended. Before transferring the response frame to the controller, the relay agent shall determine whether there is an active persona whose *remote_target_EUI_64* parameter value equals the value of the PDU’s *target_EUI_64* field. If such a persona exists, the relay agent shall compare the value of the PDU's *controller_EUI_64* field to the value of the persona's *local_controller_EUI_64* parameter. The relay agent shall write the FCP response frame to the controller's response register at FFFF F000 $0D00_{16}$ if the two fields match and shall silently discard the response frame otherwise. In the absence of an individual persona that matches *target_EUI_64*, the relay agent shall compare the value of the PDU's *target_EUI_64* field to the value of the default target surrogate persona's *remote_target_EUI_64* parameter. If the two values are equal, the relay agent shall write the FCP response frame to the controller. Otherwise, the response frame FC PDU shall be silently discarded.

7.3.4 Target surrogate CMP/IP operations

Since legacy AV/C controllers use CMP as specified by [R2] and are ignorant of CMP/IP, AV/C target surrogates perform CMP/IP-based connection management on behalf of legacy controllers. The necessary information is gathered from lock requests addressed to a source target surrogate's oPCR and lock requests addressed to a sink target surrogate's iPCRs. A target surrogate's PCRs are proxies for the remote target's PCRs; the information they contain is not identical to that of the remote PCRs but is functionally equivalent. PCRs contain a mixture of information that represents device state and information associated with isochronous resource allocation. The former cannot be changed by a lock request whereas the latter can, as is best illustrated for each type of PCR, output and input, shown below in Figure 21 and Figure 22, respectively.

most significant — least significant

o	b	point_to_point	xspd	channel	spd	overhead	payload

Figure 21 – Output plug control register (oPCR) format

The *online* bit (designated by *o* in the figure above) and the *payload* field are shown shaded in gray to signify that they cannot be modified by a lock request; their values are set internally by the device. The *broadcast* bit (designated by *b* in the figure above) and the *point_to_point*, *xspd*, *channel*, *spd* and *overhead* fields can be modified by a lock request.

most significant — least significant

o	b	point_to_point	r	channel	reserved

Figure 22 – Input plug control register (iPCR) format

The *online* bit is shown shaded in gray to signify that it cannot be modified by a lock request; its value is set internally by the device. The *broadcast* bit and the *point_to_point* and *channel* fields can be modified by a lock request.

NOTE – Output and input plug control registers are specified by [R2].

In addition to their susceptibility to modification by a lock request, the unshaded fields in the figures above represent information that is valid only within the context of the local cluster. For example, the channel number used by the remote source device to output a particular stream need not be the same as the channel number allocated by the legacy AV/C controller for the same stream. Consequently, a target surrogate cannot simply "shadow" the remote target's PCRs. Instead, a target surrogate shall implement proxy oPCRs and iPCRs in one-to-one correspondence with those implemented by the remote target. Within each proxy PCR, the unshaded fields shall be directly modifiable by lock requests originated by the legacy AV/C controller. The *payload* field shall be set to the value of the same field within the remote target's corresponding oPCR. The value of the *online* bit is conditioned by the existence of a path that includes the remote target's PCR as an endpoint. Until such a path is created by the target surrogate, the corresponding proxy PCR show reported value of zero for the *online* bit. Once the path is established, the *online* bit shall be set to the value of the same field within the remote target's corresponding PCR.

Upon receipt of a lock compare-and-swap request (henceforth, a "lock request") originated by a legacy AV/C controller and addressed to one of the target surrogate's proxy PCRs, the target surrogate shall perform the following steps:

a) Before performing the lock request, the target surrogate shall synchronize the values of the *online* bit and, if applicable, the *payload* field in the proxy PCR with the values of the corresponding fields in the remote PCR. Once this is complete, the target surrogate shall perform the lock operation and shall return the results in a response packet;

b) If the proxy PCR's *point_to_point* connection count has been incremented, a new connection has been (or is about to be) established by the legacy AV/C controller. When the *point_to_point* connection counter transitions from zero to nonzero, the target surrogate shall multicast a PATH ENDPOINT message to identify itself to the nearest L3 IP bridge on the route to the source device (see [R2]) and to notify the bridge that isochronous resources, bandwidth and channel number, have already been allocated for the specified stream within the cluster. Subsequently, CMP/IP procedures shall be used to create a corresponding path for the new connection.

The target surrogate shall search within its IEEE 1394 cluster for a PCR that is the complementary endpoint to the just-updated proxy PCR. Two PCRs are complementary endpoints with respect to each other if one is an iPCR and the other an oPCR and both PCRs reference the same IEEE 1394 channel number. The connection represented by complementary PCRs is active if both PCRs have nonzero *point_to_point* connection counts; otherwise, the connection is inactive. For each pair of active complementary endpoints that includes one of the target surrogate's PCRs and for which no path exists, a target surrogate shall transmit a PATH REQUEST message to create a path between the source and sink devices; the *legacy_CMP* bit shall be set to one to indicate that isochronous resources have already been allocated.

NOTE – Neither broadcast out nor broadcast in connections are supported by CMP/IP. Target surrogates ignore any changes in the value of the broadcast connection bit in a proxy PCR.

c) If the proxy PCR's *point_to_point* connection counters been decremented, a connection has been deleted by the legacy AV/C controller; CMP/IP procedures shall be used to tear down the corresponding path for the deleted connection. The target surrogate shall search within its IEEE 1394 cluster for PCRs that are complementary to the just-updated proxy PCR. A comparison of the newly developed list of active connections against the prior list of active connections reveals the just-deleted connection, for which the target surrogate shall transmit a PATH TEARDOWN message to tear down the path between the source and sink devices. Path teardown operations automatically delete target surrogate endpoints created by an earlier PATH ENDPOINT when they are no Longer needed.

When searching its local IEEE 1394 cluster for one or more PCRs that represent endpoints complementary to its own proxy PCRs[5], a target surrogate shall restrict its search to AV/C devices (either legacy or FCP/IP-capable) and to AV/C relay agents. AV/C devices are probed by an ordinary IEEE 1394 read requests addressed to the device's PCRs. AV/C relay agents are probed *via* a remote read FC PDU whose *controller_EUI_64* field has been set to the value of the EUI-64 of the legacy AV/C controller. If a target surrogate persona for the specified legacy controller is active at the relay agent, the current values of the proxy PCRs for the controller will be returned. Otherwise, the relay agent shall return a Transport Status message whose *rcode* is set to ACKNOWLEDGE MISSING to indicate that no target surrogate persona is active for the specified legacy controller.

The table below summarizes the source of the information used by an AV/C relay agent target surrogate to construct a PATH ENDPOINT, PATH REQUEST or PATH TEARDOWN message:

[5] If the AV/C relay agent's proxy PCR is an iPCR, there can be only one complementary endpoint within the IEEE 1394 cluster, an oPCR, and the search may stop as soon as it is found. However, if the proxy PCR is an oPCR, there could be more than one complementary endpoint and the search must examine all devices within the cluster.

Field name	Source	Comment
controller_address	Target surrogate	The IPv4 address of either the sink target surrogate or the source target surrogate within the legacy AV/C controller's IEEE 1394 cluster. If both target surrogates are present, the source target surrogate takes precedence.
lifetime	Target surrogate	CMP does not manage connection lifetime; the target surrogate shall select an appropriate lifetime.
max_payload	oPCR	Converted to bytes from the pertinent proxy oPCR *payload* field, which is expressed in quadlets.
relay_agent_EUI_64	Target surrogate	The EUI-64 of the AV/C relay agent originating the request.
sink_address	Controller surrogate	If the sink device is not FCP/IP-capable, use the IPv4 address of the AV/C relay agent connected to the same IEEE 1394 cluster as the sink device.
	Sink device	Use the IPv4 address of the sink device if it is FCP/IP-capable.
sink_EUI_64	Sink device	The EUI-64 of the actual sink device, without regard to whether it is legacy AV/C or FCP/IP-capable.
sink_plug	iPCR	The index of the sink's iPCR (this is the same as the index of the proxy iPCR in the target surrogate's address space).
source_address	Controller surrogate	If the source device is not FCP/IP-capable, use the IPv4 address of the AV/C relay agent connected to the same IEEE 1394 cluster as the source device.
	Source device	Use the IPv4 address of the source device if it is FCP/IP-capable.
source_EUI_64	Source device	The EUI-64 of the actual source device, without regard to whether it is legacy AV/C or FCP/IP-capable.
source_plug	oPCR	The index of the source's oPCR (this is the same as the index of the proxy oPCR in the target surrogate's address space).

Fields not enumerated in the table above are either constant, have a value explicitly specified by [R2] or are optional.

7.4 Bus reset and FCP attention

A bus reset aborts all pending FCP transactions for legacy AV/C devices. From a legacy AV/C controller's perspective, an FCP transaction is pending from the time it writes an FCP command frame to the target's command register at FFFF F000 $0B00_{16}$ until it receives an FCP response frame written by the target to the controller's response register at FFFF F000 $0D00_{16}$. From a legacy AV/C target's perspective, and FCP transaction is pending from the receipt of an FCP command frame at its command register until the target writes an FCP response frame to the controller's response register. Target operations initiated by the pending FCP request, *e.g.*, a rewind command for a VCR, continue unaffected by bus reset, but targets do not transmit a response frame nor do controllers expect its receipt. AV/C relay agents accommodate this behavior as follows.

An AV/C relay agent reacts to bus reset as a controller surrogate differently than as a target surrogate. In the first case, as a controller surrogate, the relay agent shall search its legacy AV/C target list for local targets whose pending FCP transactions have been aborted by bus reset. For these targets (and these targets only), the relay agent shall establish an FCP attention condition and shall transmit an FCP attention message to the AV/C controller that initiated the aborted FCP transaction (or, in the case of a legacy AV/C controller, its associated target surrogate). So long as the FCP attention condition persists for a controller/target pair, the AV/C relay agent shall silently discard any command frame FC PDUs from the controller addressed to the target until one is received whose *fcp_reset* bit is one. Receipt of such a PDU shall clear the FCP attention condition for the target, which permits the AV/C relay agent to transmit the current and subsequent FCP command frames to the target.

NOTE – A target FCP attention condition is created only for the controller that originated the now-aborted FCP transaction and can be cleared only by the same controller.

As noted above, an AV/C target surrogate reacts differently to bus reset. The relay agent shall search its active target surrogate personae for all those that have pending FCP transactions with remote targets. For these personae (and these personae only), the relay agent shall establish an FCP attention condition and shall transmit an FCP attention message to the remote target (or, in the case of a legacy target, its associated controller surrogate). So long as the FCP attention condition persists for a persona, the AV/C relay agent shall silently discard any response frame FC PDUs addressed to the controller associated with the persona. Upon the first write to the target surrogate's FCP command register at FFFF F000 $0B00_{16}$ by the controller associated with the persona, the relay agent shall clear the FCP attention condition for the target surrogate persona and forward the FCP command frame to the remote target encapsulated in an FC PDU whose *fcp_reset* bit is one.

In both its roles, controller or target surrogate, an AV/C relay agent transmits an FCP attention message to inform a remote device that bus reset has occurred within the relay agent's IEEE 1394 cluster. Dependent upon context, the message recipient is an FCP/IP-capable controller or target, a target surrogate associated with a legacy AV/C controller or a controller surrogate within the same IEEE 1394 cluster as the affected legacy AV/C target. The actions taken in response to receipt of an FCP attention message are summarized below:

– An FCP/IP-capable controller that receives an FCP attention message shall discard all information for pending FCP transactions with remote target identified by *target_EUI_64*. Once this is accomplished, the controller may resume communications with the remote target by setting the *fcp_reset* bit to one in an FC PDU addressed to the remote target or its associated AV/C relay agent.

– An FCP/IP-capable target that receives an FCP attention message shall establish an FCP attention condition for the remote controller identified by *controller_EUI_64* and shall discard all information for pending FCP transactions initiated by that controller. The FCP attention condition shall persist until the target receives, from the same controller, a command frame FC PDU whose *fcp_reset* bit is one.

– An AV/C target surrogate that receives an FCP attention message shall discard all information for pending FCP transactions with the remote target identified by *target_EUI_64*. Next, the relay agent shall generate bus reset; this causes legacy AV/C controllers to abort pending FCP transactions. For those personae associated with the remote target, the relay agent shall establish an FCP attention condition. While the FCP attention condition persists for a persona, the AV/C target surrogate shall silently discard any response frame FC PDUs addressed to the persona's legacy AV/C controller. Upon the first write to the target surrogate's FCP command register at FFFF F000 $0B00_{16}$, the relay agent shall clear the FCP attention condition for the target surrogate persona and forward the FCP command frame to the remote target encapsulated in an FC PDU whose *fcp_reset* bit is one.

– An AV/C controller surrogate that receives an FCP attention message shall establish an FCP attention condition for the local target identified by *target_EUI_64* and shall discard all information for pending FCP transactions with that target. Next, the relay agent shall generate bus reset, which causes the legacy AV/C target to abort pending FCP transactions. Until the FCP attention condition is cleared, the controller surrogate shall silently discard any command frame FC PDUs addressed to the legacy AV/C target—unless the *fcp_reset* bit is one, in which case the relay agent shall clear the FCP attention condition and write the FCP command frame to the legacy AV/C target's command register.

NOTE – An unwelcome side effect of bus reset, whether initiated by a controller surrogate or target surrogate, is the possible disruption of FCP transactions pending for AV/C controllers or targets other than the controller or target identified by the FCP attention message.

Care shall be exercised by an AV/C relay agent in response to a bus reset generated by the agent itself because of receipt of an FCP attention message. The relay agent shall suppress transmission of an FCP attention message for devices that have already established an FCP attention condition. In order that all of the FCP attention conditions are established before a relay agent generates bus reset, FCP attention messages addressed to the same AV/C relay agent should be transmitted within the same datagram and the relay agent should defer the bus reset until it has processed all the FCP attention messages contained within the datagram.

7.5 Combined controller surrogate and target surrogate operations

A legacy AV/C controller can interoperate with a remote, legacy AV/C target (see Figure 23) if there are AV/C relay agents in both IEEE 1394 clusters, one acting as a target surrogate and the other acting as a controller surrogate.

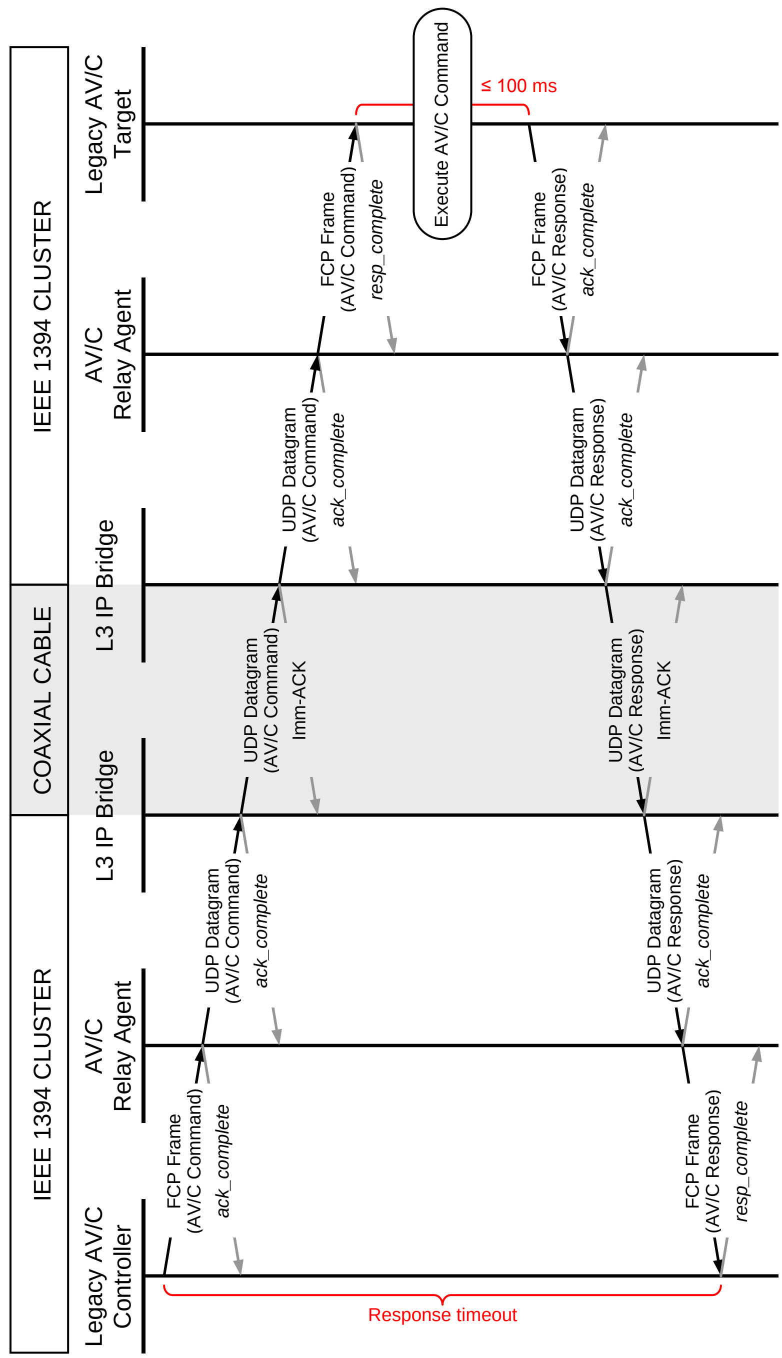

Figure 23 – Command/response sequence with AV/C relay agent controller and target surrogates

7.6 Remote memory access

The FC PDU defines three *type* values for read, write or lock access to another node's memory space. Their principal utility is to read configuration ROM or PCRs—although implementers may find other uses. The interpretation of a particular read, write or lock request is context-dependent and is determined by the type of device to which the request is transmitted and the value of the *controller_EUI_64* and *target_EUI_64* fields in the PDU, as specified by the table below:

Recipient	*controller_EUI_64*	*target_EUI_64*	Action
FCP/IP-capable AV/C target	(don't care)	Recipient's EUI-64	The AV/C target applies the requested operation to its own memory space and reports the result, with optional *data*, in a Transport Status message returned to the originator.
AV/C relay agent	Legacy AV/C controller	0 [a]	If *controller_EUI_64* matches a target surrogate persona, the relay agent transmits an analogous request to the remote target identified by the persona. When the remote target's response is received, the relay agent reports the result, with optional *data*, in a Transport Status message returned to the originator.
	Not a legacy AV/C controller	Local device EUI-64	If *target_EUI_64* identifies a local device, the relay agent issues the request to the device and reports the result, with optional *data*, in a Transport Status message returned to the originator.
		Unknown EUI-64	If *target_EUI_64* does not identify a local device, the relay agent reports the error in a Transport Status message returned to the originator.

[a] Xerox Corporation owns organizationally unique identifier (OUI) 00-00-00, from which an EUI-64 of all zeros is derived. In correspondence with the IEEE Registration Authority Committee, Xerox has agreed not to assign an EUI-64 of all zeros to any product.

Annex A
(normative)

Service announcement and discovery with SSDP

In addition to the service announcement and discovery methods mandated by [R3], an AV/C relay agent might implement support for Simple Service Discovery Protocol (SSDP). Although such implementation is optional, if implemented it shall conform to this annex.

A.1 Service announcement

Subsequent to power reset or when newly connected to an IEEE 1394 cluster, an AV/C relay agent shall announce its presence by transmitting a multicast HTTP message to 239.255.255.250:1900; the method shall be `NOTIFY` and the notification subtype shall be `ssdp:alive`. The text below in italics indicates values to be provided by the relay agent's manufacturer.

```
NOTIFY * HTTP/1.1
HOST: 239.255.255.250:1900
CACHE-CONTROL: max-age = advertisement lifespan, in seconds
LOCATION: URL of XML file that describes this instance of an AV/C relay agent
NT: urn:1394ta-org:service:avcRelay:1
NTS: ssdp:alive
SERVER: firmware/version UPnP/1.0 product/version
USN: uuid:eui64::urn:1394ta-org:service:avcRelay:1
```

The value of `max-age` should be 1800 (30 minutes).

Since AV/C relay agents are not obligated to implement mDNS, the host component of the `LOCATION`: URL should not require DNS resolution—it should be a numeric IPv4 address.

The `SERVER`: parameters `firmware`, `product` and their respective `version` are all vendor-dependent and should be descriptive.

The `uuid` parameter shall represent the value of the device's EUI-64 and shall be encoded as a 16-character string of hexadecimal digits 0 – 9 and A – F, inclusive, each of which represents, in network nibble order, four bits of the 64-bit number.

A.2 Planned disconnection or shutdown

When the disconnection or shutdown of an AV/C relay agent and its associated service are planned, the service should multicast an `ssdp:byebye` to alert potential users of the relay agent. Receipt of this message cancels all the outstanding service announcements from the relay agent. The format of the message is as follows:

```
NOTIFY * HTTP/1.1
HOST: 239.255.255.250:1900
NT: urn:1394ta-org:service:avcRelay:1
NTS: ssdp:byebye
USN: uuid:eui64::urn:1394ta-org:service:avcRelay:1
```

The `uuid` parameter shall be encoded as described in A.1.

A.3 Service discovery with M-SEARCH

When an AV/C relay agent experiences power reset or is newly connected to an IEEE 1394 cluster, it should transmit a multicast HTTP message to 239.255.255.250:1900; the method shall be `M-SEARCH`.

```
M-SEARCH * HTTP/1.1
HOST: 239.255.255.250:1900
MAN: “ssdp:discover”
MX: 1
ST: urn:1394ta-org:service:avcRelay:1
```

A.4 Service discovery response

An AV/C relay agent should respond to an M-SEARCH discovery request with a unicast HTTP message transmitted to the source IPv4 address and source port number. The structure of the service discovery response, shown below, is essentially similar to that of the announcement.

```
HTTP/1.1 200 OK
CACHE-CONTROL: max-age = advertisement lifespan, in seconds
DATE: datestamp response generation
EXT:
LOCATION: URL of XML file that describe this instance of an AV/C relay agent
SERVER: firmware/version UPnP/1.0 product/version
ST: urn:1394ta-org:service:avcRelay:1
USN: uuid:eui64::urn:1394ta-org:service:avcRelay:1
```

The comments made in A.1 continue to apply to the `max-age` parameter, the host component of the `LOCATION: URL`, the `SERVER`: parameters `firmware`, `product` and their respective `version` and the `uuid` parameter.

The `DATE:` header, if present, shall record the full time (as specified by [B5] [B3]) the response was generated.

The presence of the `EXT:` header confirms that the `MAN:` header was understood by the target device.

A.5 AV/C relay agent XML file

For an AV/C relay agent, the LOCATION: URL shall point to an XML file with the following contents:

```
<?xml version="1.0"?>
<scpd xmlns="urn:schemas-upnp-org:service-1-0">
  <specVersion>
    <major>1</major>
    <minor>0</minor>
  </specVersion>
  <service>
    <name> avcRelay </name>
    <descriptorList>
      <descriptor>
        <name> relayPort </name>
        <dataType> ui2 </dataType>
        <value> N </value>
      </descriptor>
    </descriptorList>
  </service>
</scpd>
```

The `relayPort` variable shall specify the port number, 1024 through 65 535, inclusive, to which UDP/IP datagrams intended for the AV/C relay service shall be addressed. There is no expectation that different instantiations of the AV/C relay service by different devices would use the same port number. However, devices that implement more than one instance of the AV/C relay service (*e.g.*, multiple relay agents within a single IEEE 1394 node) shall use a different port number for each instance of the service.

Annex B
(normative)

Minimum IEEE 1394 node capabilities

AV/C relay agents shall conform to the requirements of this annex, which are in addition to the minimum capabilities defined by [R6] *et seq*.

The device shall be able to receive and transmit primary packets whose data payload is less than or equal to 1024 bytes; the *max_rec* field in the device's bus information block shall be greater than or equal to nine. This ability applies to requests and responses addressed to or originated by the device.

The device shall be able to initiate write requests and shall report this by setting the *drq* bit in the Node_Capabilities entry in configuration ROM to one. Consequently, AV/C relay agents shall implement the *dreq* bit in the STATE_CLEAR and STATE_SET registers. The value of STATE_CLEAR.*dreq* shall be unaffected by a bus reset. AV/C relay agents may autonomously set *dreq* to zero (request initiation enabled) upon a power reset or a command reset.

During initialization subsequent to a power reset and if its link layer is active, an AV/C relay agent shall either respond to quadlet read requests addressed to FFFF F000 0400_{16} with a response data value of zero or acknowledge the request subaction with *ack_tardy*. This indicates that the remainder of configuration ROM, as well as other AV/C relay agent CSRs, is not accessible.

Annex C
(normative)

Conformance requirements

This annex is intended to assist designers, implementers and conformance test developers; it provides a concise summary of mandatory and optional features and, for each feature, reference to the governing normative clauses or external documents.

The conformance requirements for AV/C relay agents are specified by the tables below. Related features are grouped together in separate tables; each feature is identified by an item designator. References within brackets are normative or bibliographic citations while numeric references without brackets denote sections or clauses within this document. Subsidiary clauses inherit the implementation requirements of their parent clause. Entries in the implementation column are decipherable according to the following table.

Entry	Interpretation
Mandatory	The device shall implement the feature.
Optional	The device may implement the feature.
Not applicable	The feature is outside the scope of this document.
Optional [*label*]	The device shall implement at least one of the options belonging to the option group designated by *label*.
Item: *status*	The implementation *status* (mandatory, optional or not applicable) of the feature is conditional upon the implementation of another feature identified by *item*.

AV/C relay agents may implement any IP-capable network interface.

Table C-1 – Network interface implementation requirements

Item	Feature	Reference	Implementation
N1	IEEE 802		Optional [N]
N2	IEEE 1394	[R5] *et seq.*	Optional [N]
N3	Minimum node capabilities	Annex B	N2: Mandatory

All AV/C relay agents shall implement Internet protocol on all of their network interfaces. Different interface technologies may have different normative references for their implementation, as is noted.

Table C-2 – Internet protocol implementation requirements

Item	Feature	Reference	Implementation
IP1	Internet Protocol version 4 (IPv4)	N1: [B1] N2: [R14]	Mandatory
IP2	Address resolution protocol (ARP)	N1: [B2] N2: [R14]	Mandatory
IP3	Distributed host control protocol (DHCP)	N1: [B4] N2: [R15]	Mandatory

Item	Feature	Reference	Implementation
IP4	Link-local address assignment	[R16]	Mandatory
IP5	Multicast DNS (mDNS)	[R11]	Mandatory
IP6	DNS-based service discovery (DNS-SD)	[R10]	Mandatory

In addition to conformance to [R3], all FCP/IP data structure extensions and relay agent operations defined within this—are mandated for all interfaces of all devices conformant to this specification.

Table C-3 – Data structure format implementation requirements

Item	Feature	Reference	Implementation
D1	FCP/IP	[R3]	Mandatory
D2	MDNS messages and resource records	5.1	Mandatory
D3	FCP data unit (FC PDU)	5.2	Mandatory

Table C-4 – AV/C relay agent operations implementation requirements

Item	Feature	Reference	Implementation
R1	FCP/IP	[R3]	Mandatory
R2	Service announcement and discovery	7.1	Mandatory
R3	Controller surrogate operations	7.2	Mandatory
R4	Target surrogate operations	7.3	Mandatory
R5	Bus reset and FCP attention	0	Mandatory

Annex D
(informative)

Target surrogate personae

An AV/C relay agent, acting as a target surrogate, can impersonate only one remote AV/C target at a time to a particular local legacy AV/C controller. This is an inherent consequence of the AV/C protocol, which permits only one AV/C unit directory in the device's configuration ROM. This annex discusses how to make the best use of target surrogate personae, a scarce and valuable resource.

To recapitulate 5.2.2, a target surrogate persona is a one-to-one relationship between a particular legacy AV/C controller in the relay agent's IEEE 1394 cluster and a particular AV/C target in a remote cluster. The target persona controls what a legacy AV/C controller "sees" when it reads an AV/C relay agent's configuration ROM. Similarly, when the controller writes an FCP command frame to FFFF F000 $0B00_{16}$ in the relay agent's address space, it is a target surrogate persona that determines to which remote AV/C target the command frame will be forwarded. A relay agent may impersonate the same remote target to more than one local legacy controller; it may also, over time, impersonate different remote targets to the same legacy controller.

The problem of target surrogate personae assignment is obviously simple in its degenerate case: if, from the perspective of any particular IEEE 1394 cluster within the residential network there is only one remote target, then the cluster's AV/C relay agent presents the same target surrogate persona—that of the solitary remote target— to all the legacy AV/C controllers within the cluster.

When, from the viewpoint of a particular IEEE 1394 cluster, there is more than one remote AV/C target, user intervention is required. One approach is for each relay agent to implement a web server that permits a user to pair a legacy AV/C controller with the desired remote AV/C target. Ideally, the webpage proffered by the relay agent should present the user with icons that represent the different IEEE 1394 clusters that comprise the residential network. Zooming in on the relay agent's cluster should reveal icons that represent legacy AV/C controllers while zooming in on a remote cluster should reveal icons that represent remote AV/C targets.. By clicking on a legacy controller and a remote target, the user would establish a target surrogate persona; the persona would persist indefinitely until deleted or replaced by the user.

All of the above, of course, begs the question as to which device is used to browse the relay agent's webpage. Any computer would suffice, but might not be conveniently located from the user's perspective. Likewise, any HANA device with a rich user interface, *i.e.*, a display and point-and-click capability, would be adequate.

Annex E
(informative)

Bibliography

[B1] IETF RFC 791, Internet Protocol, September 1981

[B2] IETF RFC 826, An Ethernet Address Resolution Protocol

[B3] IETF RFC 1123, Requirements for Internet Hosts—Application and Support, October 1989

[B4] IETF RFC 1533, DHCP Options and BOOTP Vendor Extensions, October 1993

[B5] IETF RFC 2616, Hypertext Transfer Protocol—HTTP/1.1, June 1999