Protocol Adaptation Layer (PAL) for IEEE 1394 over IEEE 802.15.3 (“wireless 1394”)

Peter Johansson
Congruent Software, Inc.

IEEE 802 Tutorial
Portland, OR
July 13, 2004

What is a PAL?

- A “glue layer” on top of a lower level

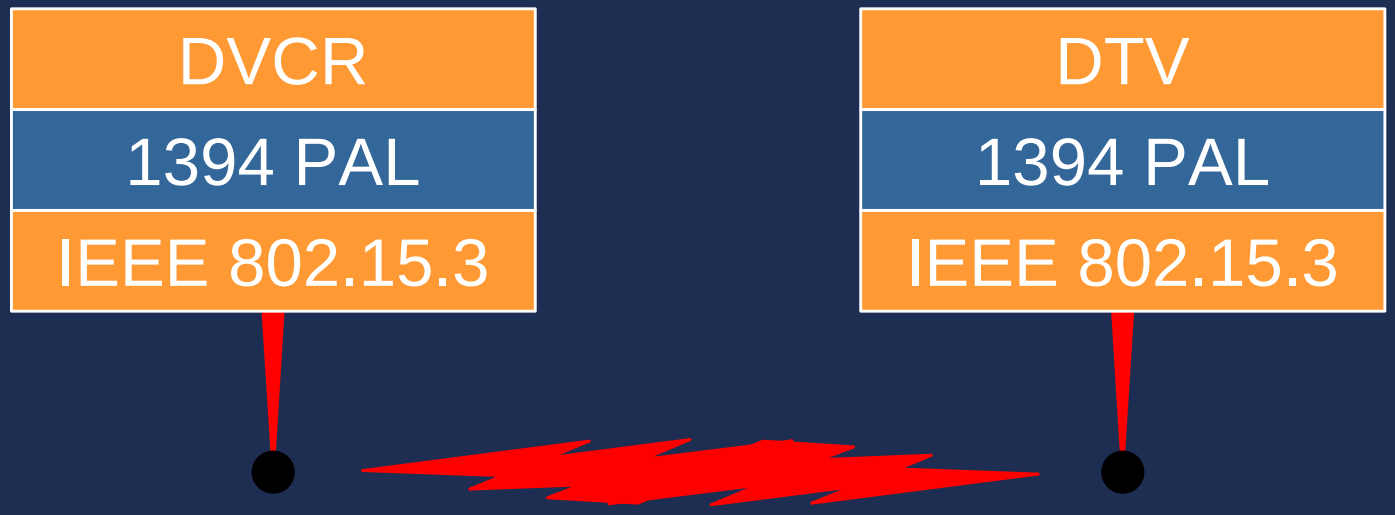
- Hides low-level details of underlying layer
- Mimics high-level behavior of target protocol
- For example, IP1394 is a PAL that permits Internet protocol to be carried by IEEE 1394

What use is a PAL?

- **Leverages applications already developed**

- **Applications developed for IEEE 1394 expect:**
  - Read, write and lock transactions
  - Infrastructure CSRs and configuration ROM
  - Asynchronous and isochronous streams

Wireless products enabled



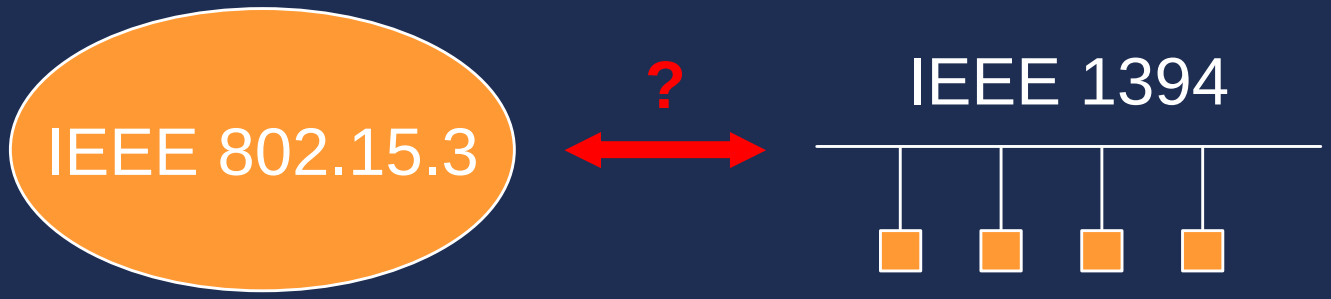
- **Firmware developed for (wired) IEEE 1394 products can migrate to wireless domain**
- **Minimize reengineering between wired and wireless domains**

1394 PAL ground rules

- **Shall support IEEE 1394 TRAN layer functions**
  - Read, write and lock
- **Shall support isochrony and streaming data**
- **Shall coexist with other users of the underlying IEEE 802.15.3 transport**
- **Should behave “like” IEEE 1394**
- **Should conceal differences between IEEE 1394 and IEEE 802.15.3 physical and MAC layers**

Connect wireless to wired?

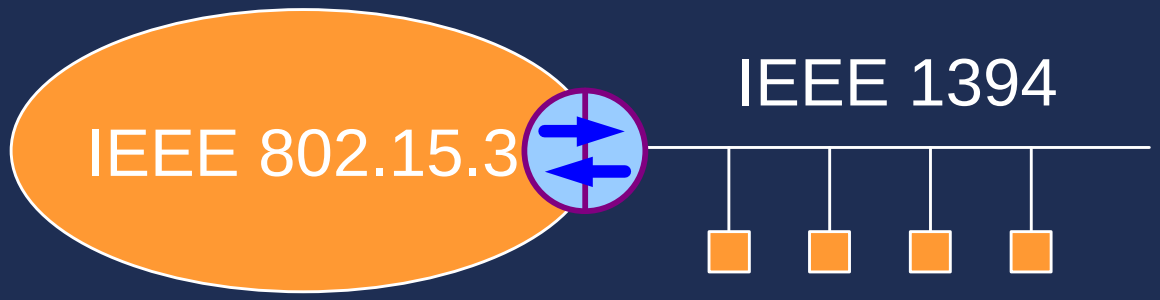
- **1394 PAL for IEEE 802.15.3 permits wireless devices to talk to each other**



- **Not always interesting unless wireless devices can also talk to (wired) IEEE 1394 devices**

Wired to wireless *via* bridges

- **IEEE P1394.1 bridge isolates physical and link (MAC) layer differences in each domain from the other**



- **IEEE P1394.1 preserves TRAN layer similarities**
  - Transaction routes configured autonomously
  - Explicit isochronous stream setup / tear down

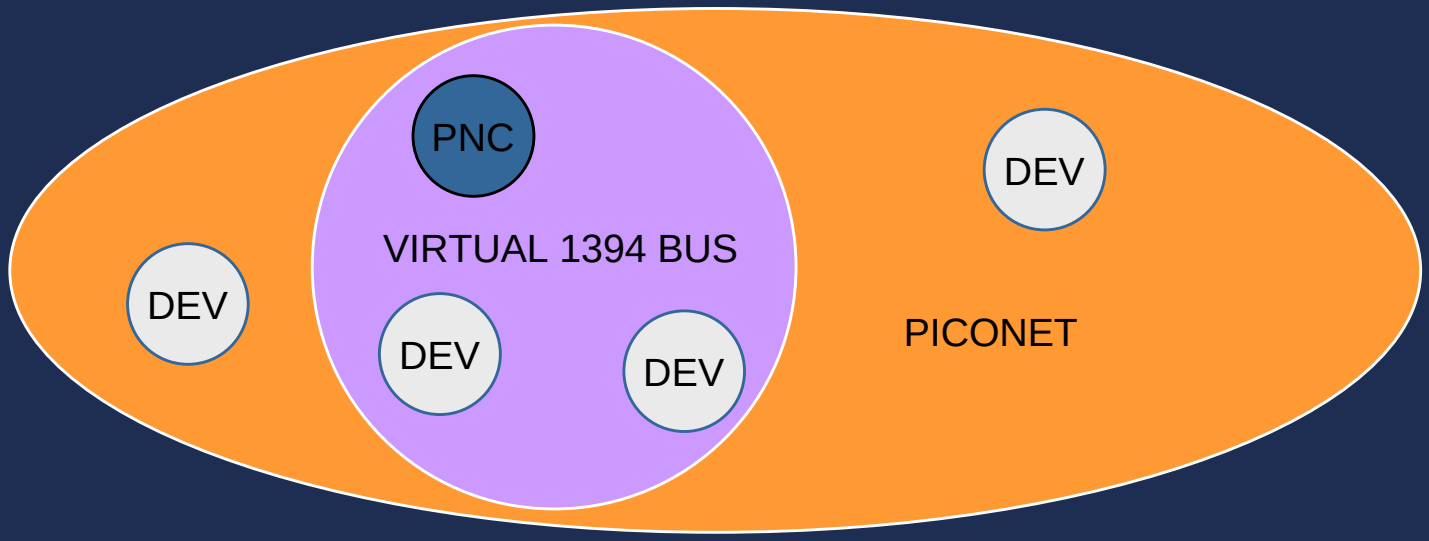
1394 TA project scope

Develop a document that specifies methods to *a)* mimic IEEE 1394 infrastructure (transactions, isochrony, stream data, configuration ROM and CSR architecture) using the facilities of IEEE 802.15.3 and *b)* implement IEEE P1394.1 bridge behaviors in the same domain. The methods are to be compatible with the simultaneous use of IEEE 802.15.3 by other protocols, *e.g.*, Internet protocol.

Summary of PAL features

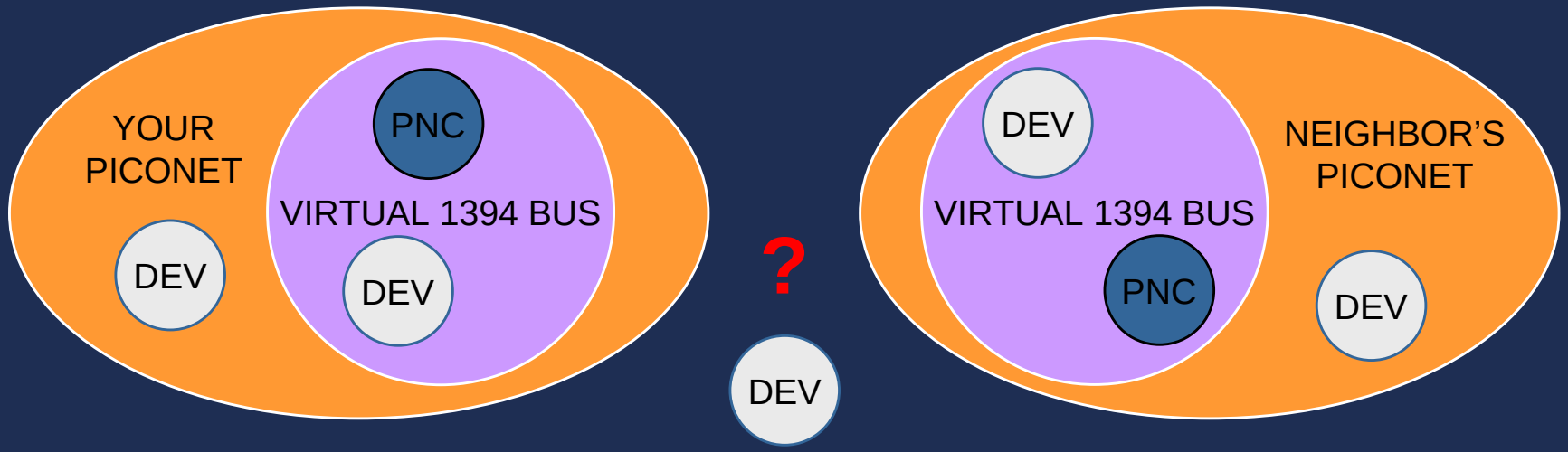
- Virtual bus management
- IEEE 1394 packet encapsulation
- Split transaction time-out
- Cycle time synchronization
- Isochronous streams
- Isochronous connection management
- Control and status registers
- Configuration ROM

Virtual 1394 bus within a piconet



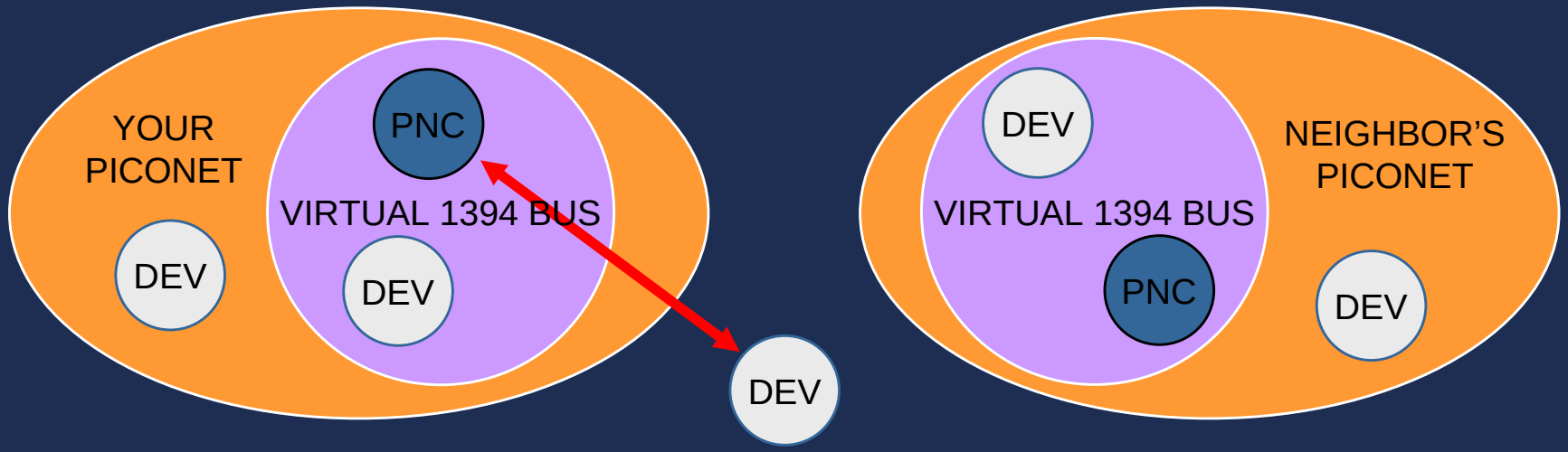
- **Wireless 1394 coordinator co-located with PNC**
  - Assigns 6-bit virtual IDs to wireless 1394 DEVs
  - Distributes synchronized cycle time

Bringing a new device home



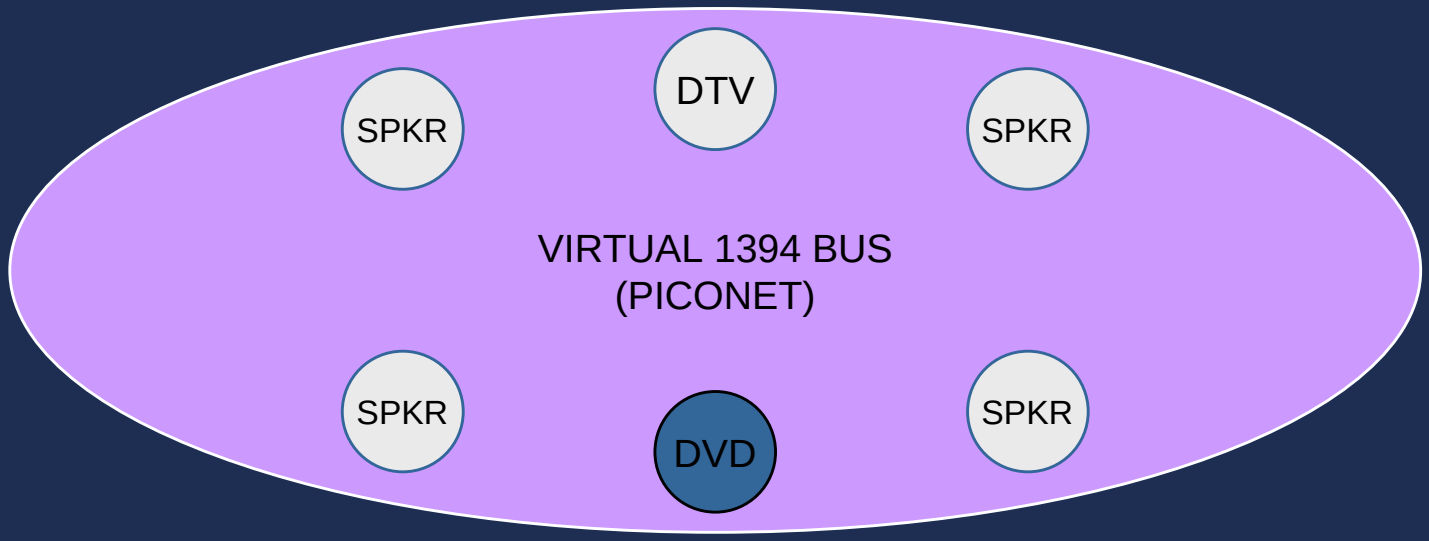
- **New, out-of-box device doesn't know it should associate with your piconet**
- **Possible metrics might choose incorrectly**
  - Radio signal from your neighbor's PNC might be stronger than your PNC's signal

Introducing a device to the right piconet



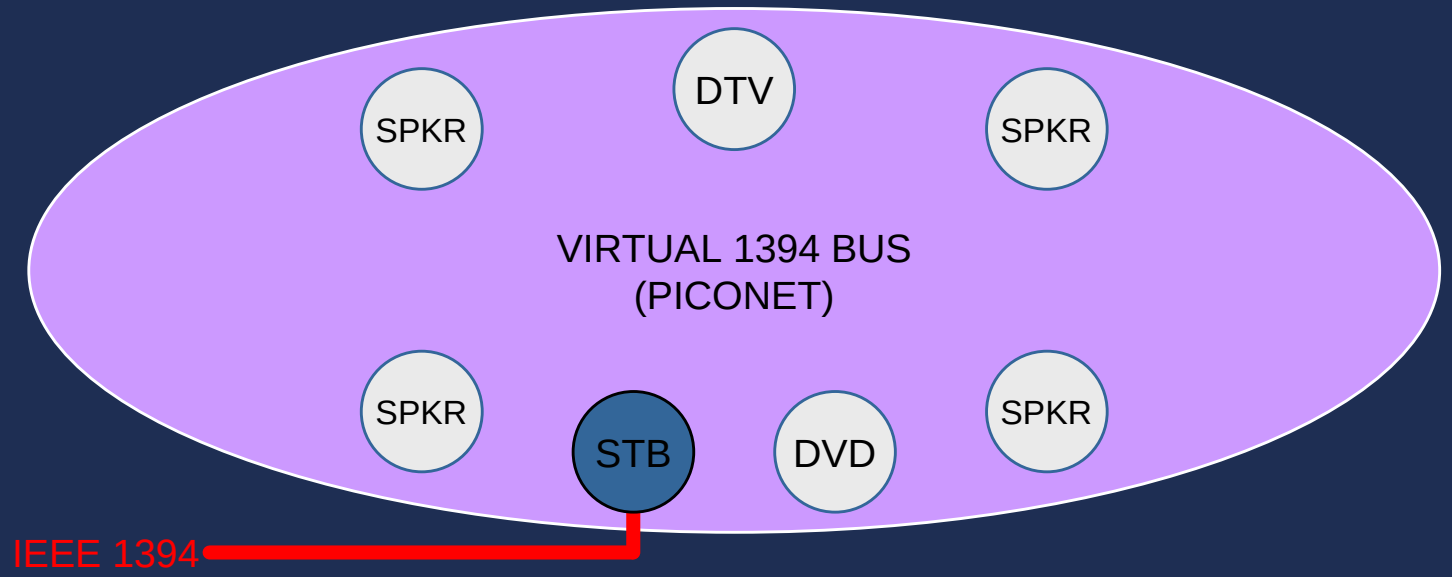
- New device flashes amber LED (disconnected)
- User first presses HANDSHAKE button on the PNC, next the new device's HANDSHAKE button
- Wireless 1394 coordinator admits only the one device whose HANDSHAKE button was pressed

Factory-configured components



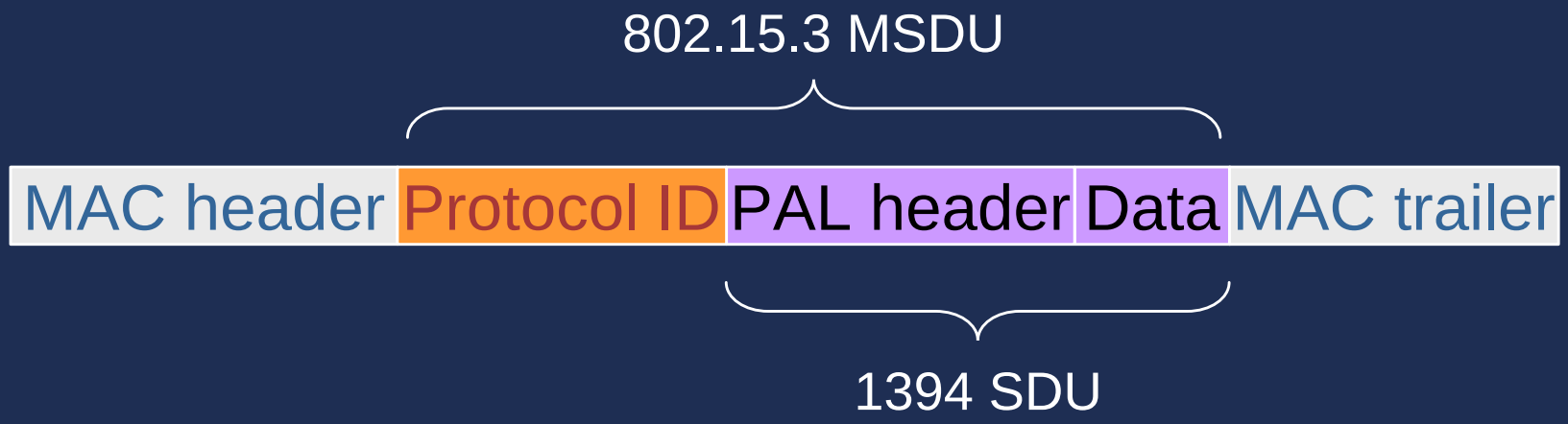
- **DVD player is both PNC and wireless 1394 coordinator**
  - Access Control List (ACL) factory-initialized with MAC-64 IDs of wireless DTV and speakers
  - DTV and speakers automatically connect to virtual 1394 bus coordinated by the DVD player

New wireless 1394 coordinator



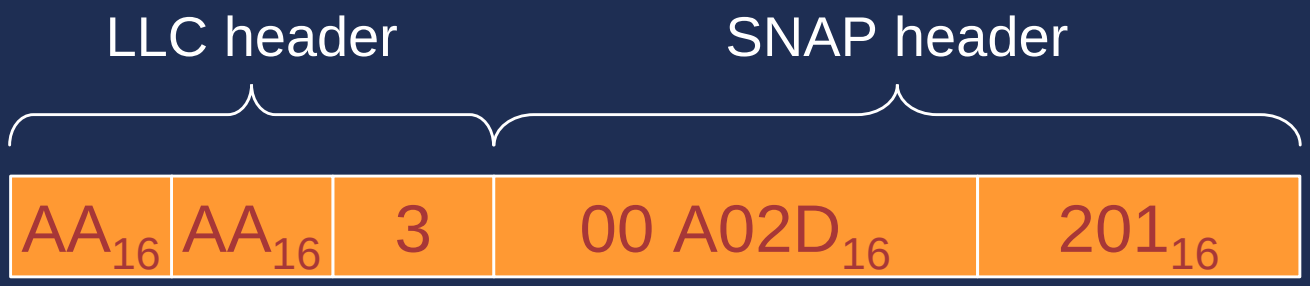
- Set DVD player's COORDINATOR switch off and STB's COORDINATOR switch on
- Introduce DVD player to STB (*via* HANDSHAKE)
- DVD transfers its ACL to the STB (DTV and speakers automatically connect to virtual 1394 bus coordinated by the STB)

IEEE 1394 packet encapsulation



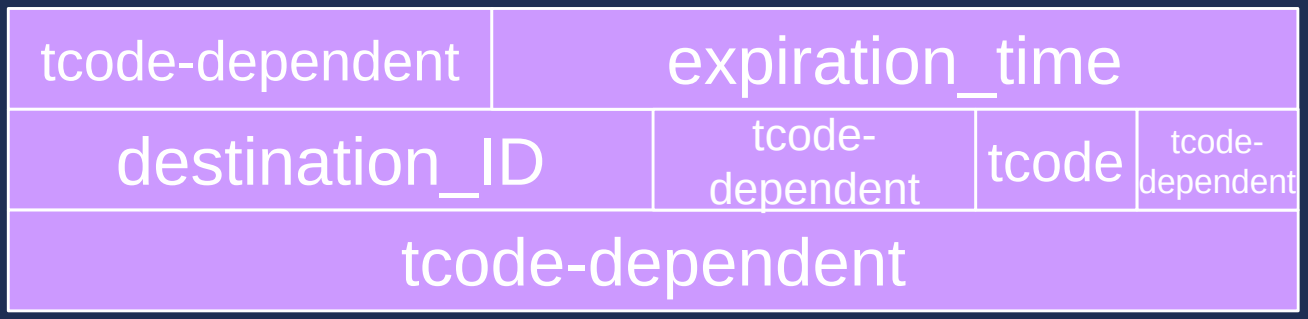
- **Protocol ID identifies format that follows**
  - Used only with 802.15.3 stream index zero
- **1394 SDU analogous to IEEE 1394 packet**
  - Multiple 1394 SDUs permitted in a single 802.15.3 MSDU (isochronous data)

Protocol ID for IEEE 1394 PAL



- **The 3-octet LLC header indicates that a SNAP header follows**
- **The 5-octet SNAP header consists of an OUI (*company_ID*) and a Protocol ID**
  - 00 $A02D_{16}$ is 1394 Trade Association OUI
  - 201_{16} specifies IEEE 1394 over IEEE 802.15.3

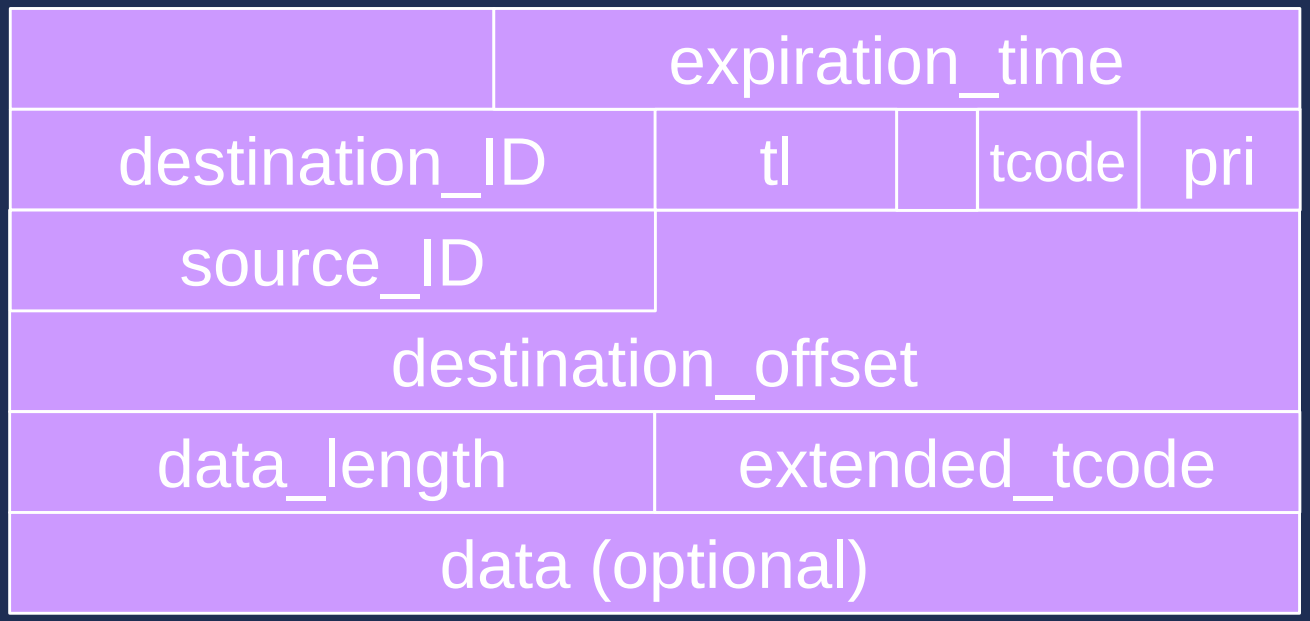
PAL header for 1394 SDU



- **Transaction code (*tcode*) determines format**

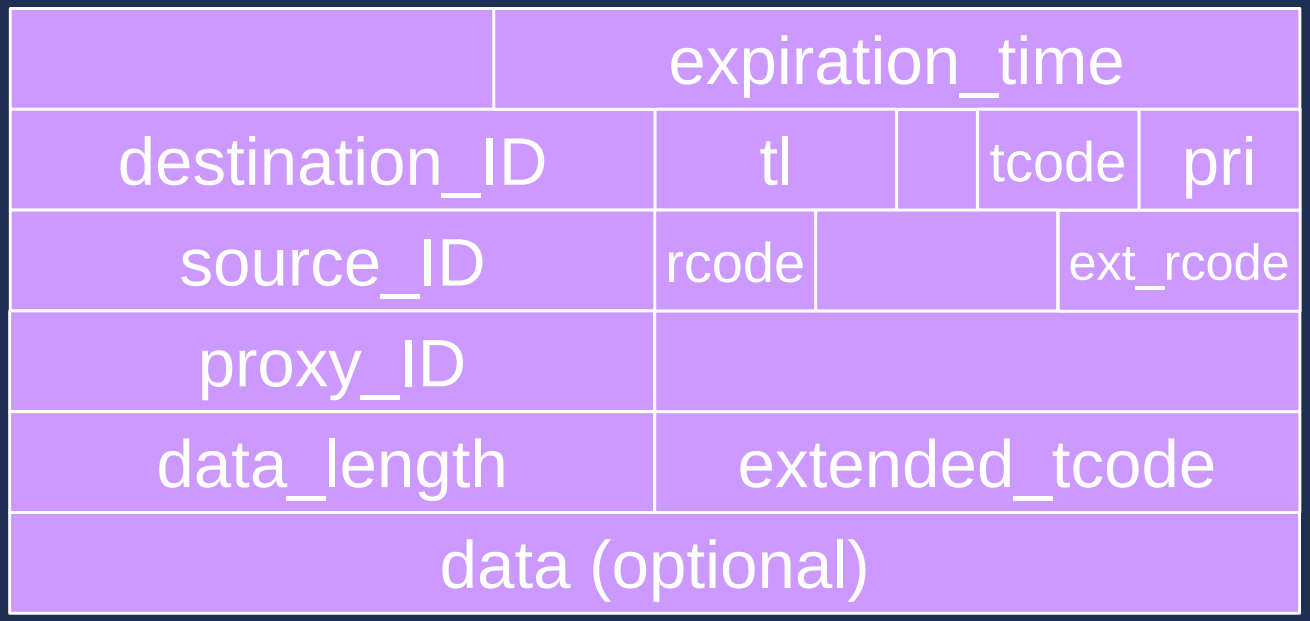
0, 1, 4, 5, 9	Request
2, 6, 7, B_{16}	Response
A_{16}	Stream (asynchronous or isochronous)
E_{16}	PAL control

PAL header for requests



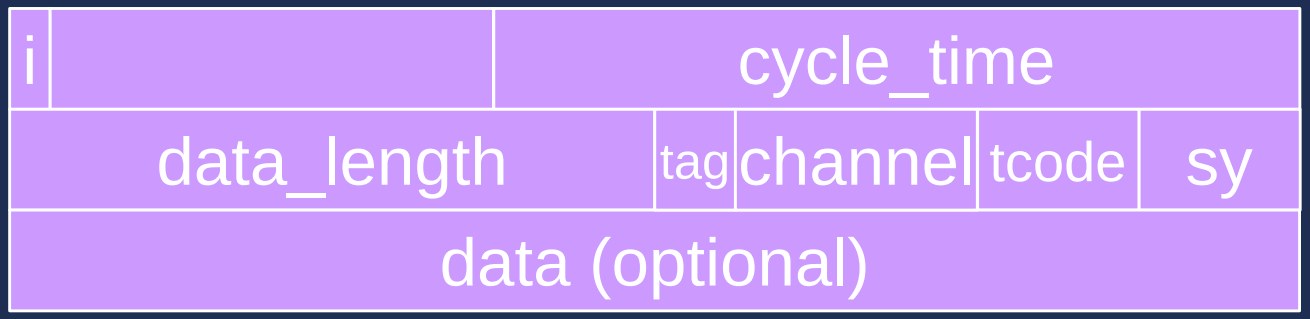
- **Data payload never present for read requests**
- **For write and lock requests, data payload present only if *data_length* is nonzero**

PAL header for responses



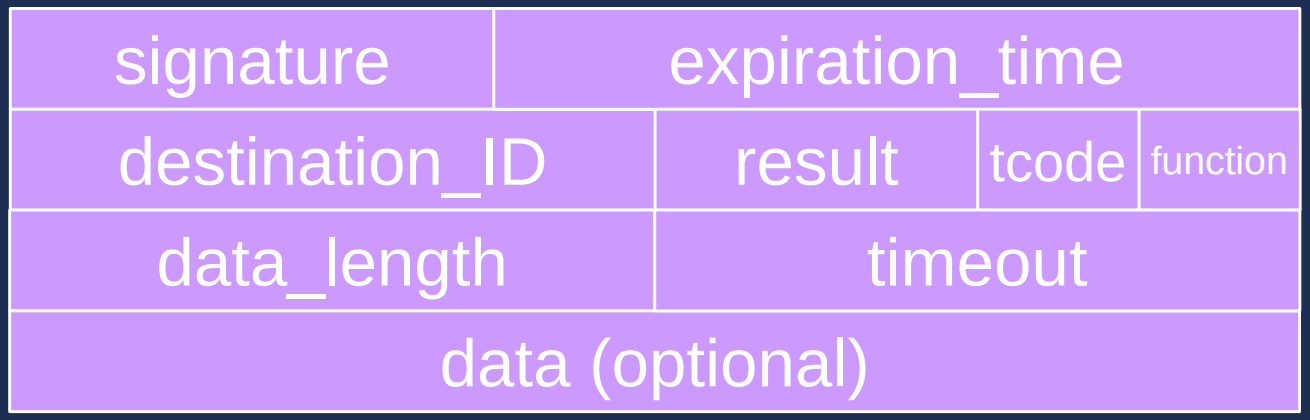
- **Data payload never present for write responses**
- **For read and lock responses, data payload present only if *data_length* is nonzero**

PAL header for stream data



- **Nonzero *isochronous* bit specifies isochronous stream**
  - Data indicated to application at *cycle_time*
  - Permits multiple isochronous packets in a single 802.15.3 MSDU
- **Data payload present only if *data_length* is nonzero**

PAL control header

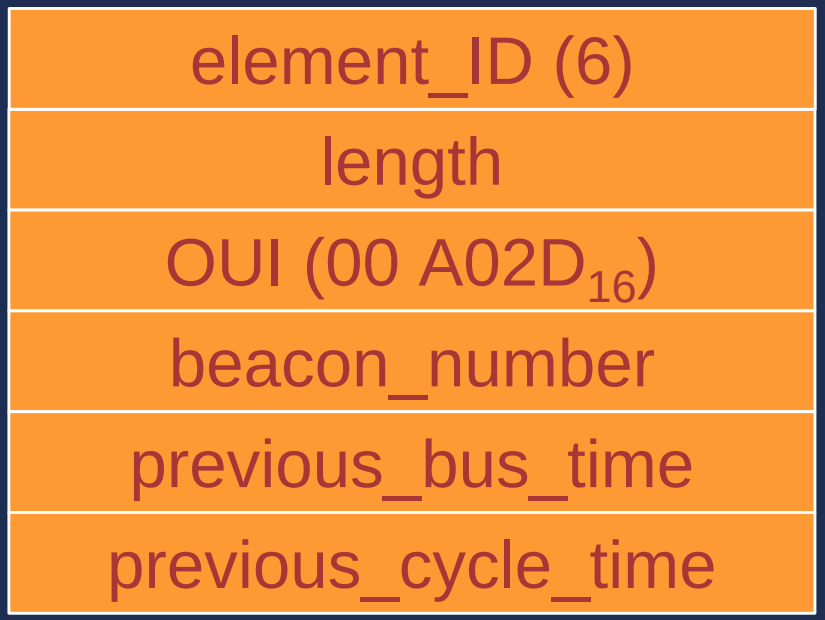


- **Used for control messages exchanged by PALs**
  - Virtual bus management
  - Isochronous connection management
- **Data payload present only if *data_length* is nonzero**

Split transaction time-out

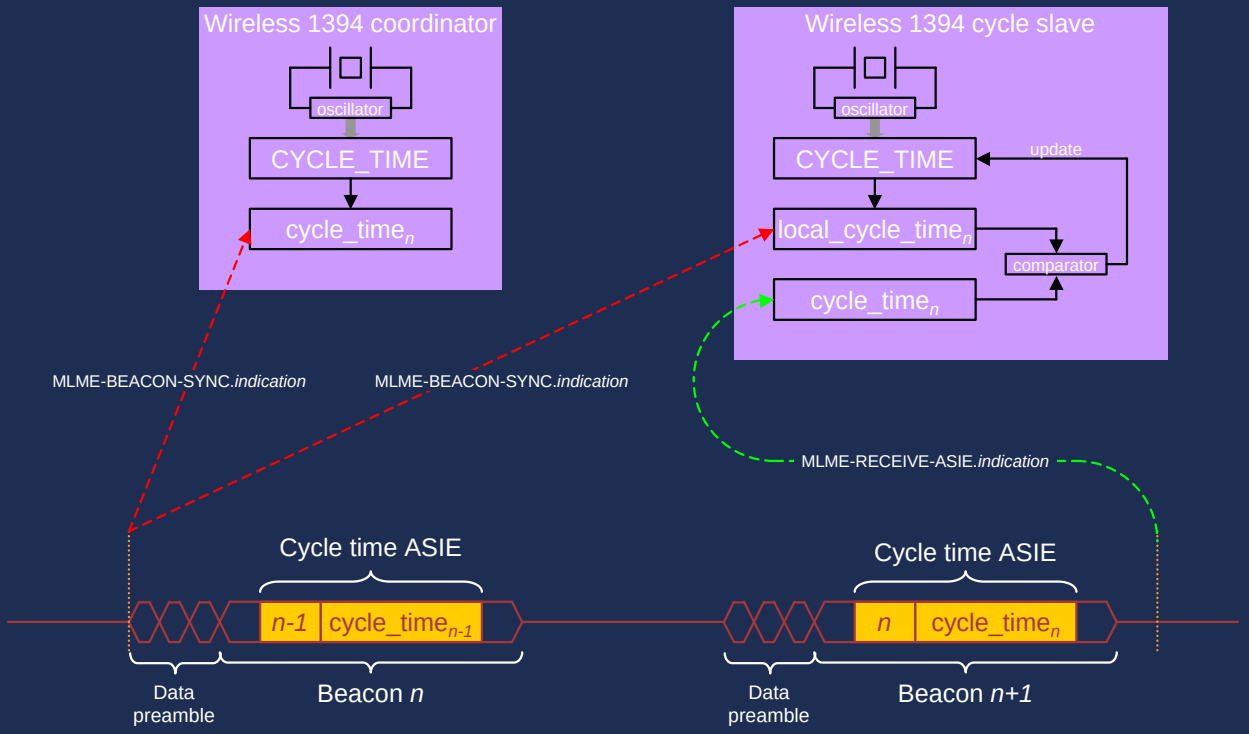
- **All wireless 1394 transactions are split**
  - Request subaction in one MSDU, response subaction in different MSDU
- **Difficult to control how much time the 802.15.3 MAC will use to transmit or retry an MSDU**
- **Split time-out controlled by *expiration_time***
  - Transmitting PAL calculates *expiration_time* for requests by adding SPLIT_TIMEOUT to cycle time
  - Receiving PAL discards requests and responses if *expiration_time* is earlier than cycle time

Cycle time broadcast in beacon



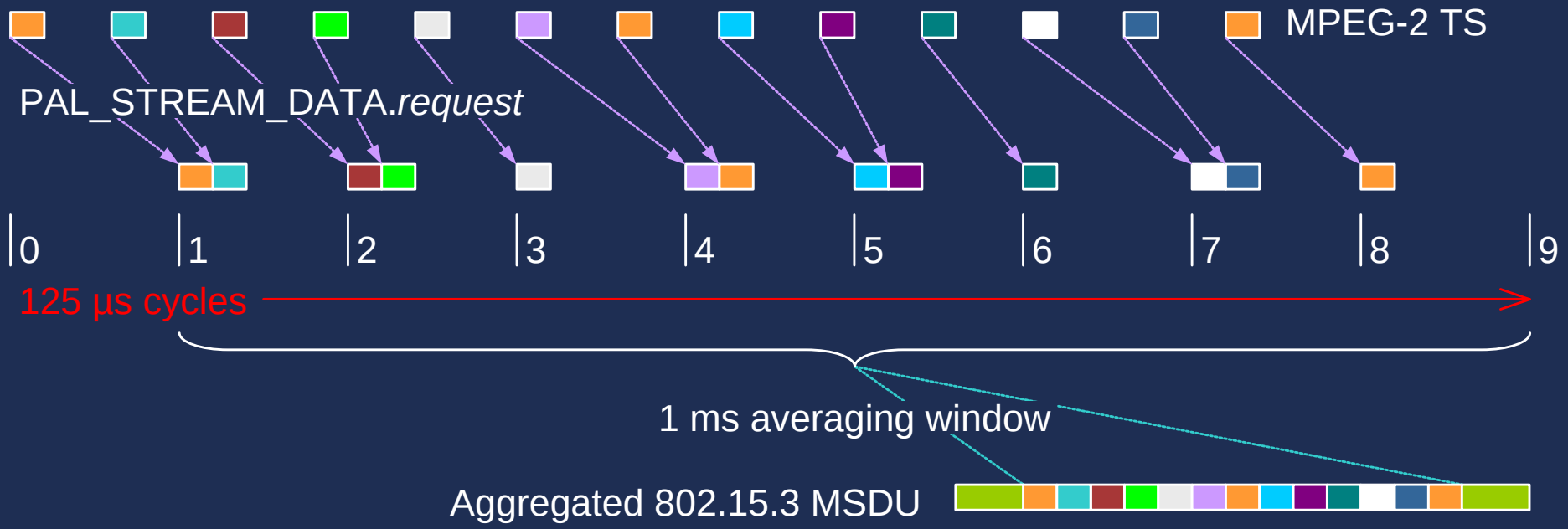
- **Each beacon contains an Application-Specific Information Element (ASIE) with master cycle time**
- **ASIE serves additional purposes:**
  - Identifies presence of wireless 1394 coordinator
  - Supports HANDSHAKE mode for DEV introduction

Cycle time synchronization



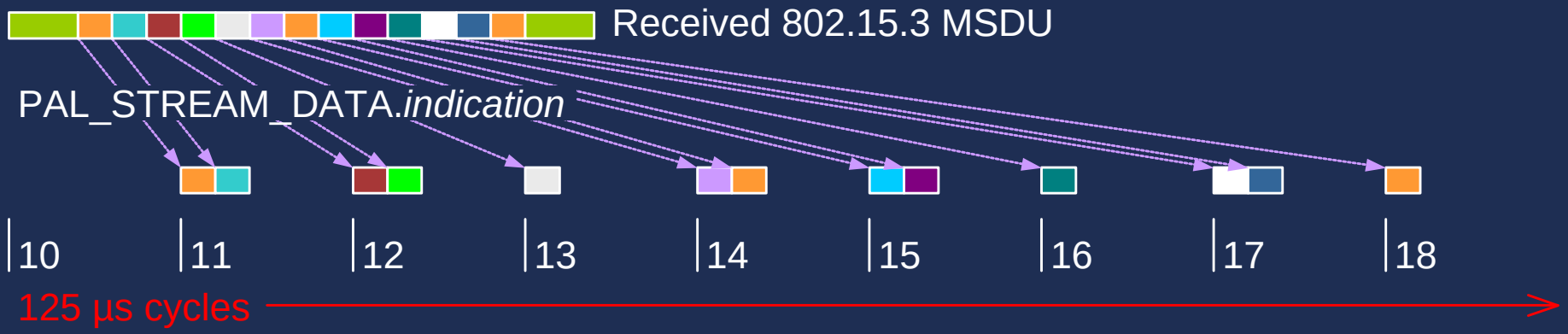
- **Upon MLME-BEACON-SYNC.*indication* , all wireless 1394 devices simultaneously sample CYCLE_TIME**
- **Wireless 1394 coordinator transmits its sample in the next beacon**

Isochronous aggregation by transmitting PAL



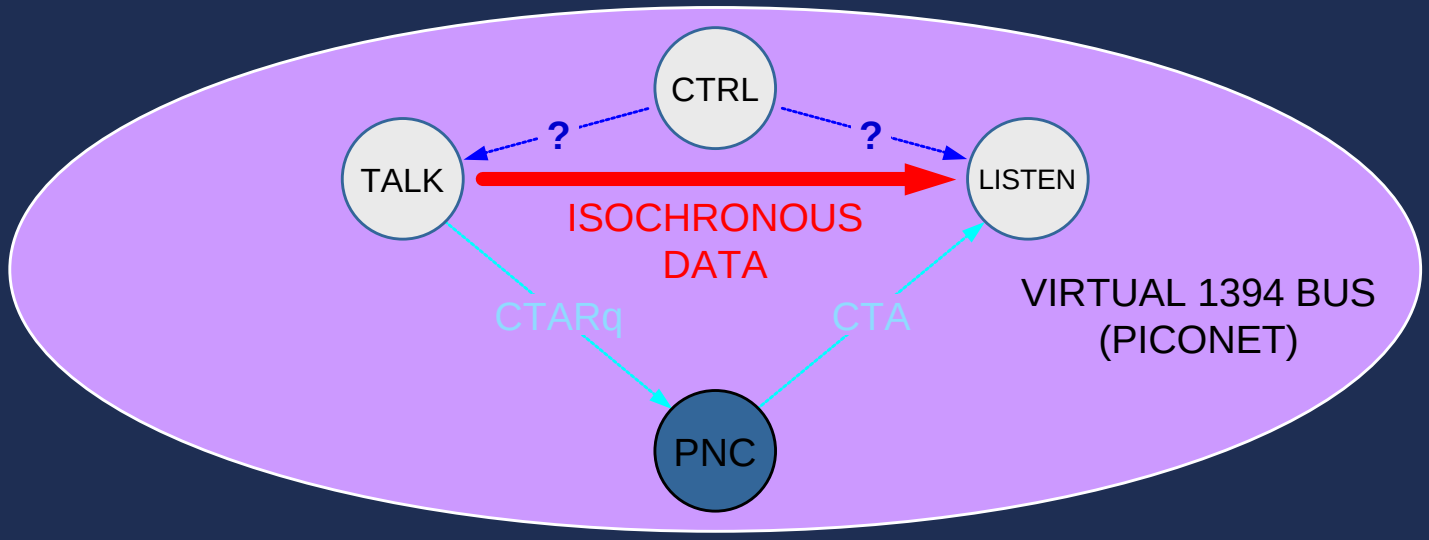
- AV application informs PAL of optimal averaging window size for isochronous stream
- PAL accumulates at least this much data before encapsulating multiple 1394 SDUs in a single MSDU

Isochronous replay by receiving PAL



- **Aggregated isochronous payload (2444 octets) requires approximately 200 µs to transmit**
  - Assume 100 mbps UWB PHY
- **Earliest possible MSDU receipt for cycle 11**
  - No allowance for retries
- **End-to-end latency of 1.25 ms for this example**

Isochronous connection issues

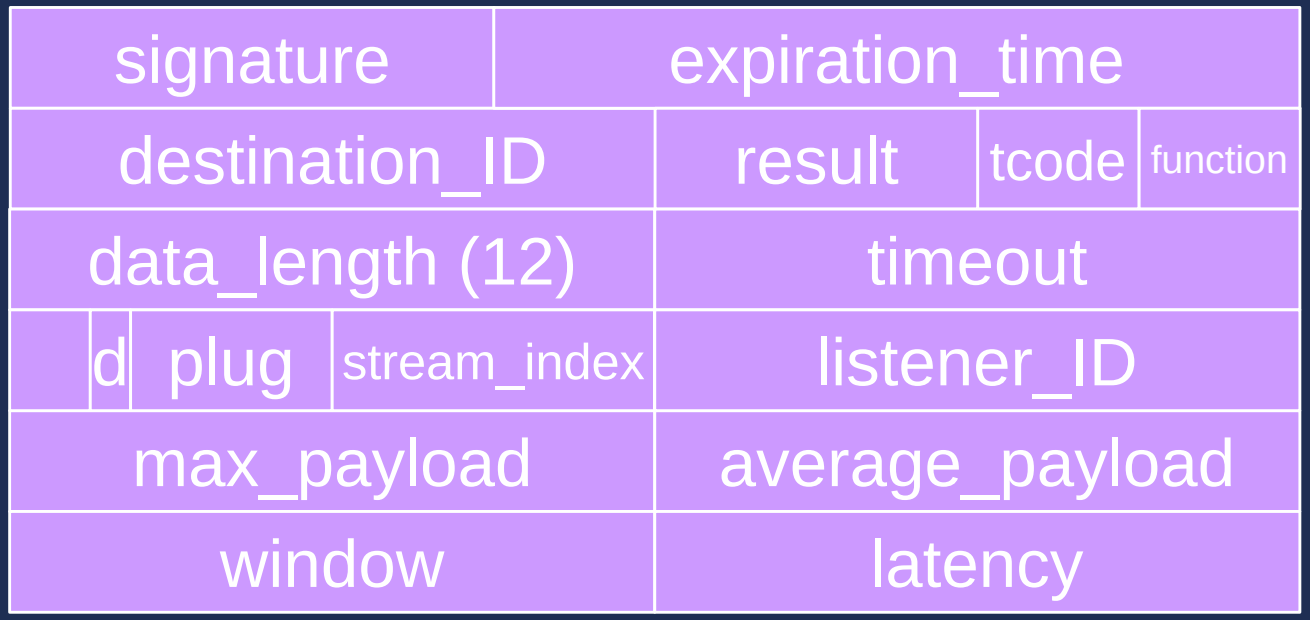


- Talker requests channel time from PNC
- Talker transmits on assigned stream index
- Listener receives from same stream index
- How does controller manage this?

Wireless input and output plugs

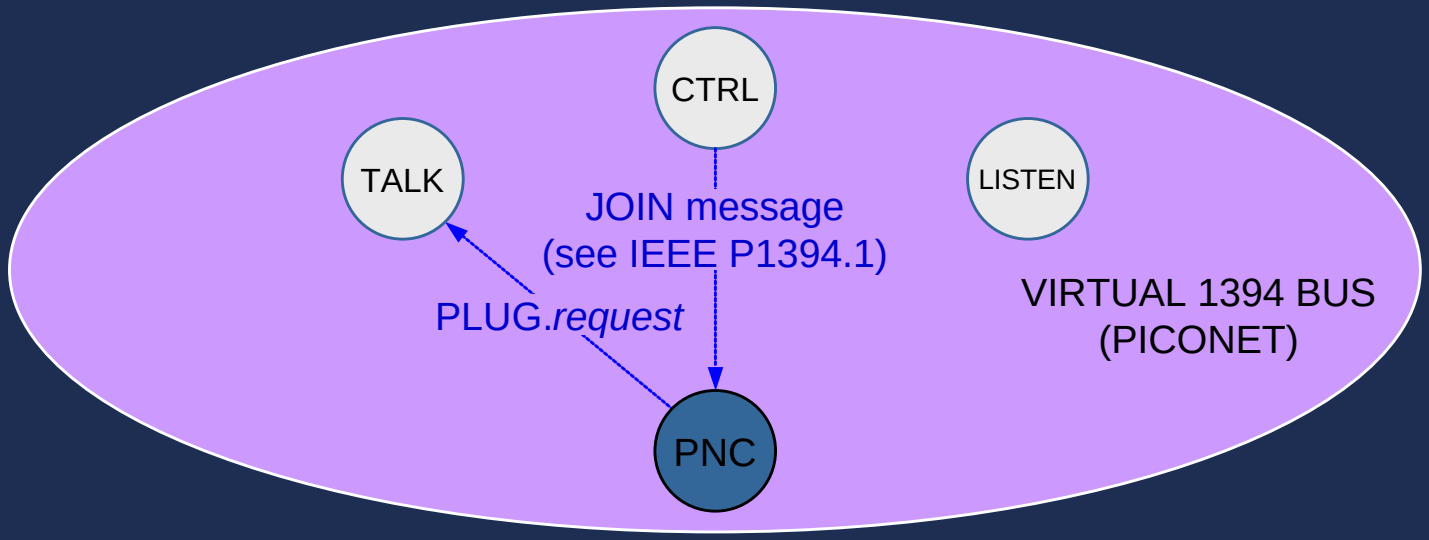
- **Patterned after IEC-61883 iPCR and oPCR—but different**
- **Internal PAL data structure (not exposed as a CSR)**
  - 802.15.3 stream index
  - Connections
  - Maximum and average data payload
  - Latency
  - Averaging window
- **Correlate stream index with device's internal destination or source for isochronous data**

Plug management SDU



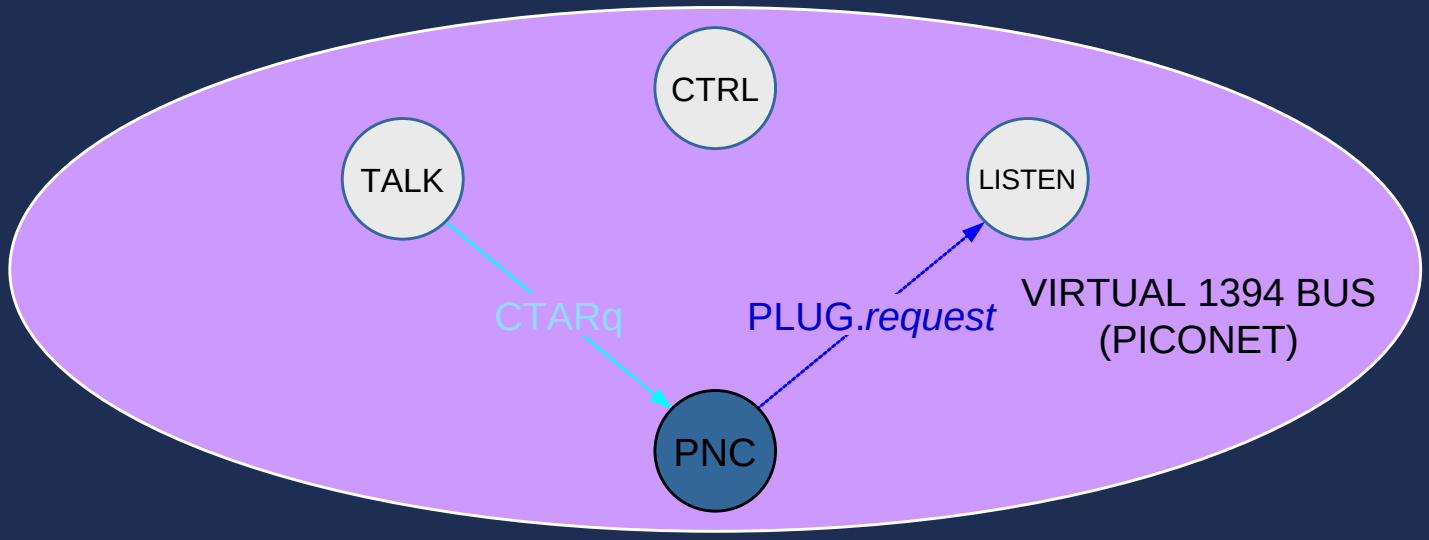
- **Supports two functions**
  - PLUG and UNPLUG
- **Recipient may reject function if *latency* too great**

Connection setup: JOIN message



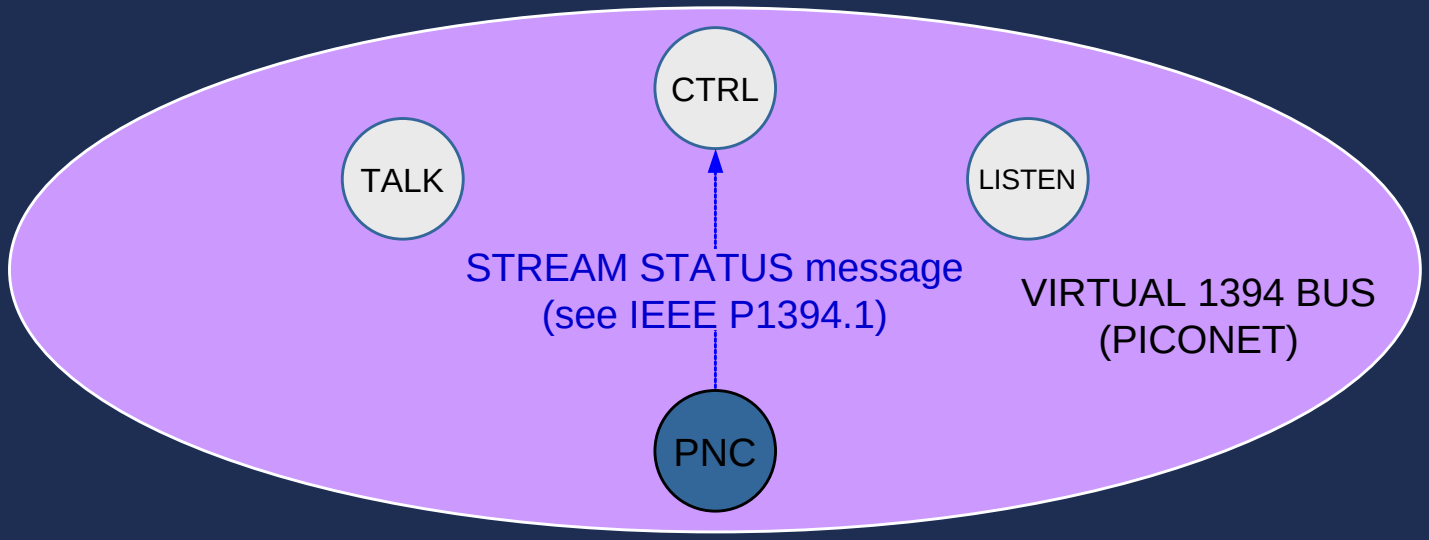
- **Controller transmits JOIN message to wireless 1394 coordinator at PNC**
  - Average payload, averaging window and latency
- **Wireless 1394 coordinator transmits PLUG request to talker**
  - Remembers JOIN information to monitor stream

Channel time allocation by talker



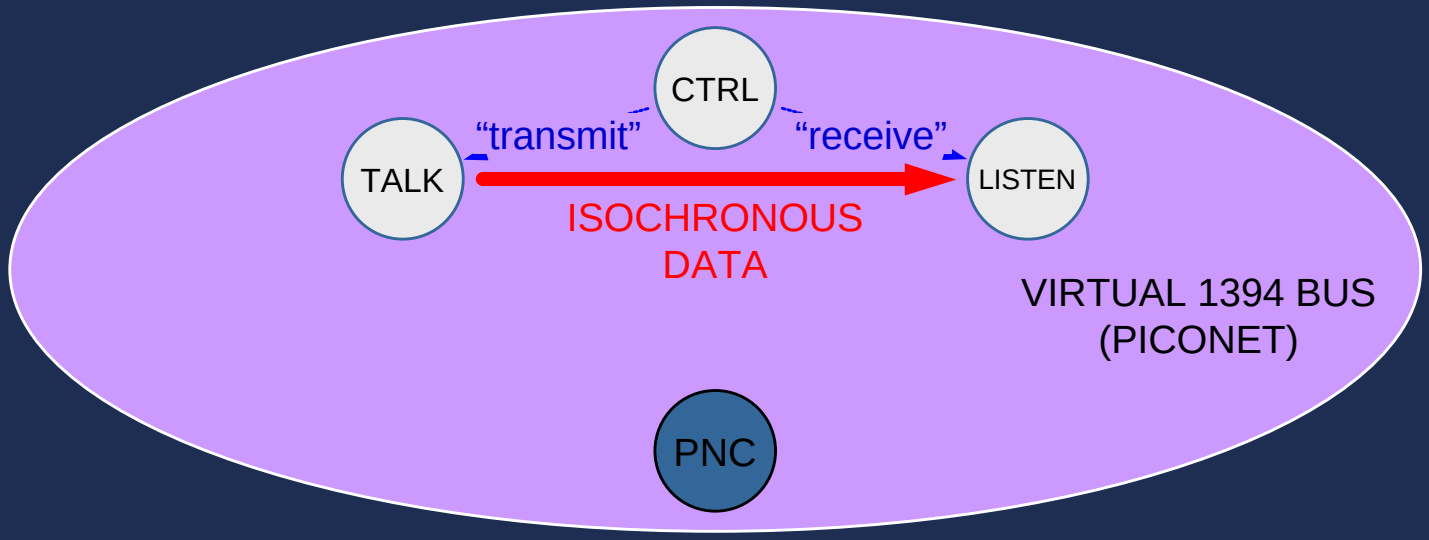
- **Talker requests channel time from PNC**
  - If channel time is available, PNC confirms request and assigns a stream index to identify the stream
- **Talker confirms PLUG request and informs wireless 1394 coordinator which stream index will be used**
- **Coordinator sends PLUG request to listener**

Connection established: STREAM STATUS message



- **After receiving PLUG confirmation from listener, wireless 1394 coordinator returns STREAM STATUS message to controller**
  - Channel time allocated by PNC
  - Both talker's and listener's plugs programmed
- **No isochronous data flowing yet**

Isochronous connection in use



- **Controller issues "receive" command to listener**
  - NOTE: AV/C monitors may not require a command
- **Controller issues "transmit" command to talker (*e.g.*, AV/C DIRECT SELECT command to a tuner)**
- **Isochronous data flow commences**

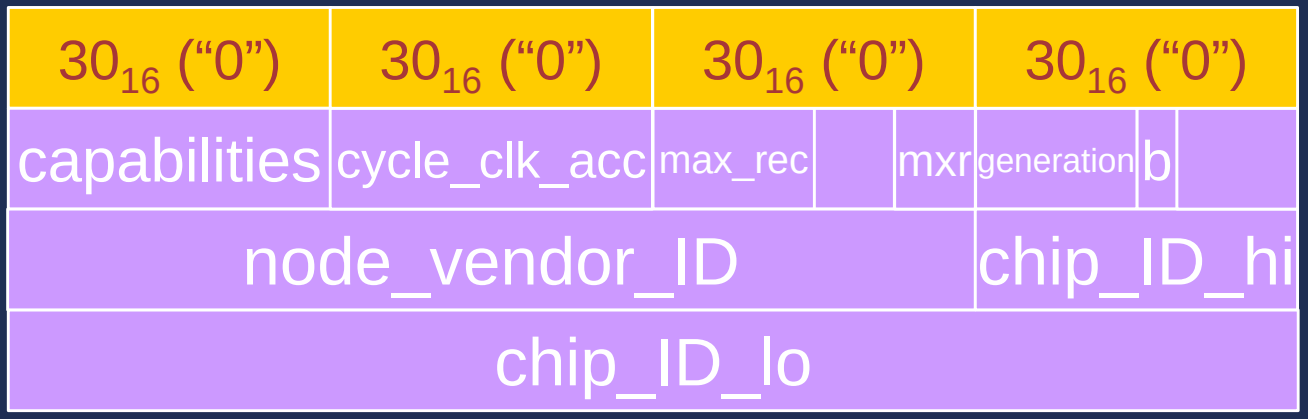
Control and status registers

- **Most CSRs are not applicable to wireless**
- **Wireless 1394 devices implement these CSRs**
  - RESET_START
  - MESSAGE_REQUEST and MESSAGE_RESPONSE
  - CYCLE_TIME and BUS_TIME
- **New CSRs specified by IEEE P1394.1 and wireless PAL**
  - QUARANTINE and NET_UPDATE_START
- **Bridge portals implement additional CSRs specified by IEEE P1394.1**

Configuration ROM

- **Supports all features specified by IEEE 1212 and IEEE 1394**
- **“Wireless 1394” differentiated by special entries in configuration ROM**
  - ASCII bus identifier in bus information block
  - Bus-dependent information directory

Bus information block



- **ASCII bus identifier is “0000”**
- **Consult bus-dependent information directory for more detail**

Bus information block *capabilities*

- **Isochronous resource manager, bus manager and power manager have no analogs in “wireless 1394”**
  - *irmc*, *bmc* and *pmc* bits are zero
- **IEEE P1394.1 cycle master adjustment methods don’t work for wireless**
  - *adjustable* bit is zero
- **Cycle master capability is optional**
  - *cmc* bit may be zero

Bus-dependent information directory

length (4)	CRC
12_{16}	specifier_ID (00 $A02D_{16}$)
13_{16}	version (201_{16})
21_{16}	revision (0)
31_{16}	wireless_plugs

- **Specifier_ID, Version and Revision entries identify the 1394 TA document that specifies the wireless PAL**
- **Wireless_Plugs describes the input and output wireless plugs implemented by the device**

Status

- **1394 Trade Association Specification**
  - TS2003010 (May 7, 2004)
  - Protocol Adaptation Layer (PAL) for IEEE 1394 over IEEE 802.15.3
- **Available for purchase**
  - http://www.1394ta.org/Technology/Specifications

Resources

1394 Trade Association

http://www.1394ta.org

IEEE P1394.1

High Performance Serial Bus Bridges

http://grouper.ieee.org/groups/1394/1

Contact information

Peter Johansson

Congruent Software, Inc.
98 Colorado Avenue
Berkeley, CA 94707

(510) 527-3926
(510) 527-3856 FAX

PJohansson@ACM.org