Clock synchronization
(a Residential Ethernet SG presentation)

David V James   **JGG**
Alexei Beliaev   **Gibson**
George Claseman   **Micrel**

House reference clock

Precise time synchronization

talker

FIFO

FIFO

**IEEE 802.3 RE Study Group
San Francisco**
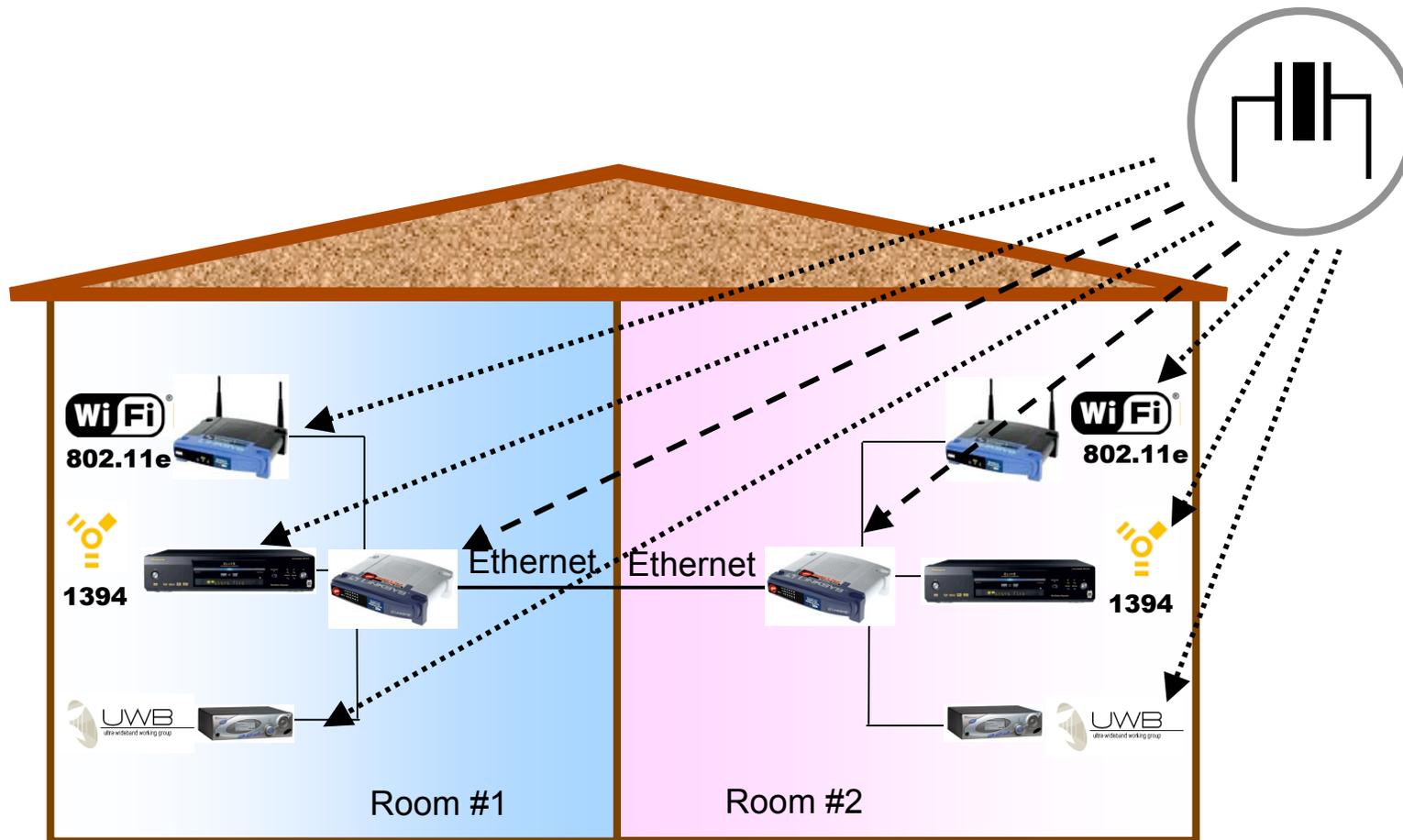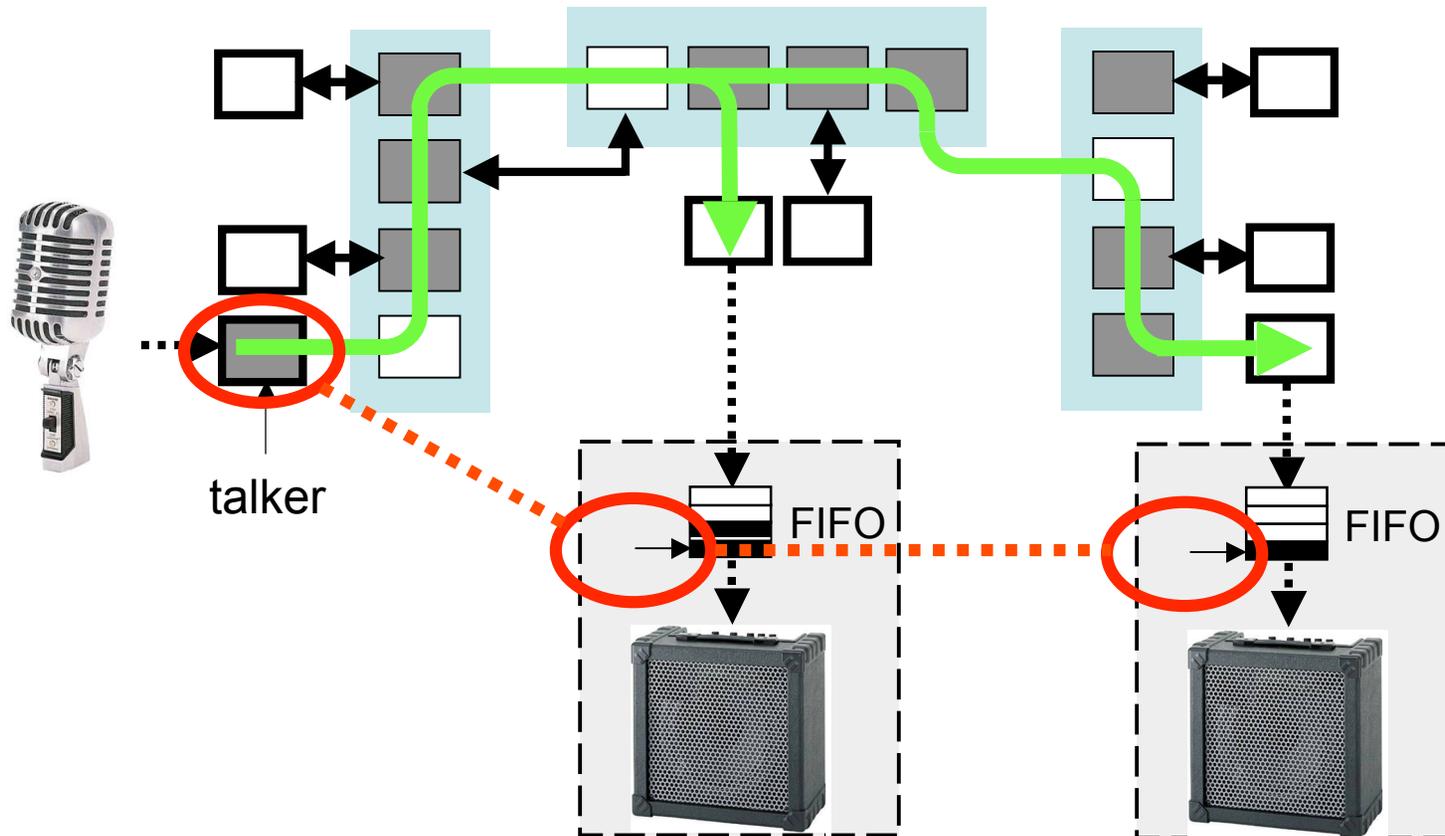
Cascaded TOD synchronization

Wall-clock distribution model

bridge[1]

bridge[0]

bridge[2]
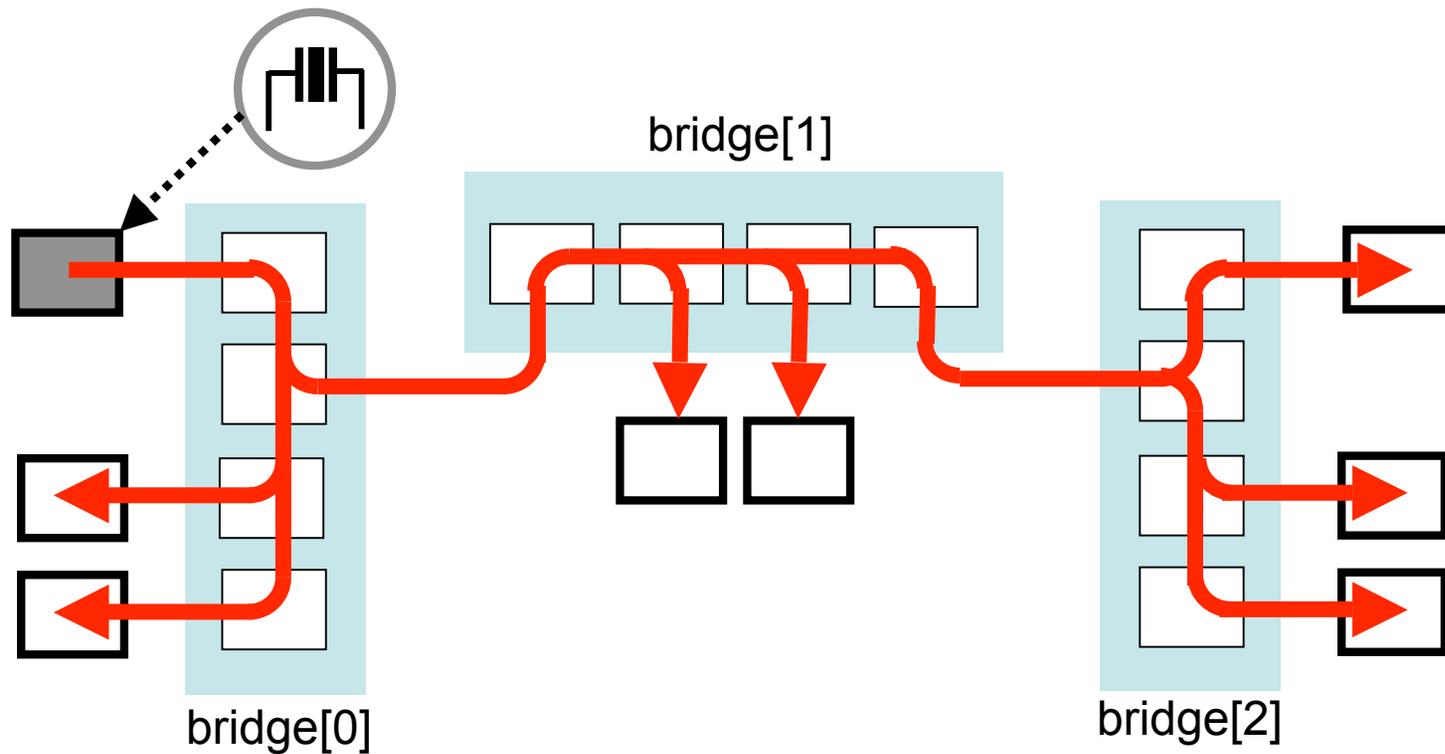
Cascaded TOD synchronization

Cascaded adjacent-synchronization hierarchy

bridge[1]

bridge[0]

bridge[2]

Legend:
clock master
clock slave
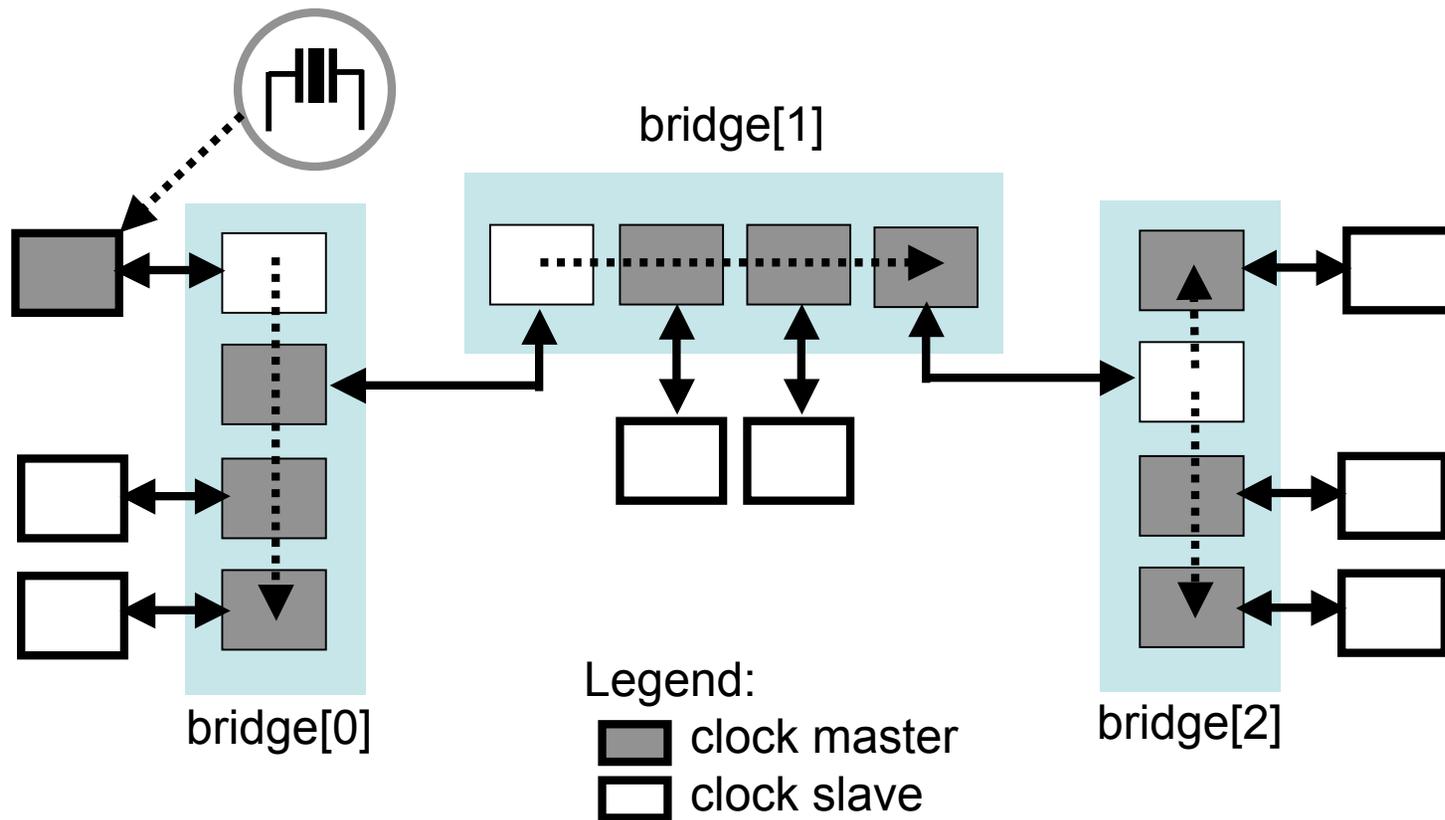
Grand master selection

Grand-master selection protocol

July 2005

Grand-master precedence

transmitted values

| sl | sn | eui64 | hops | pl | pn | GM precedence (smaller) |

| system | uniqueness | age | port |

| sl | sn | eui48 | hops | pl | pn | STP precedence (smaller) |

| system | uniqueness | age | port |

stationID (byte swapped EUI-64)

1394 precedence

1394 precedence (larger)

preferred

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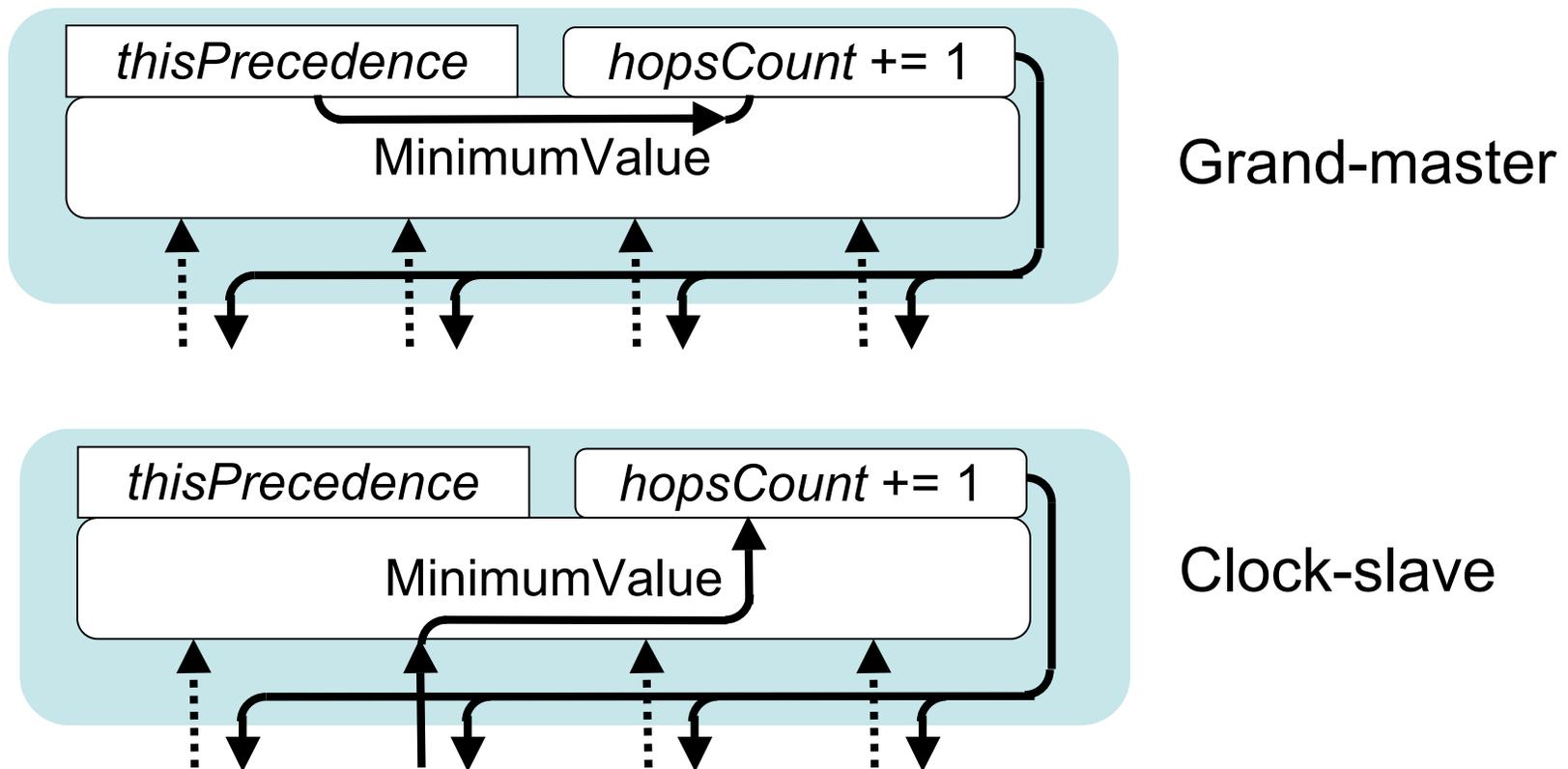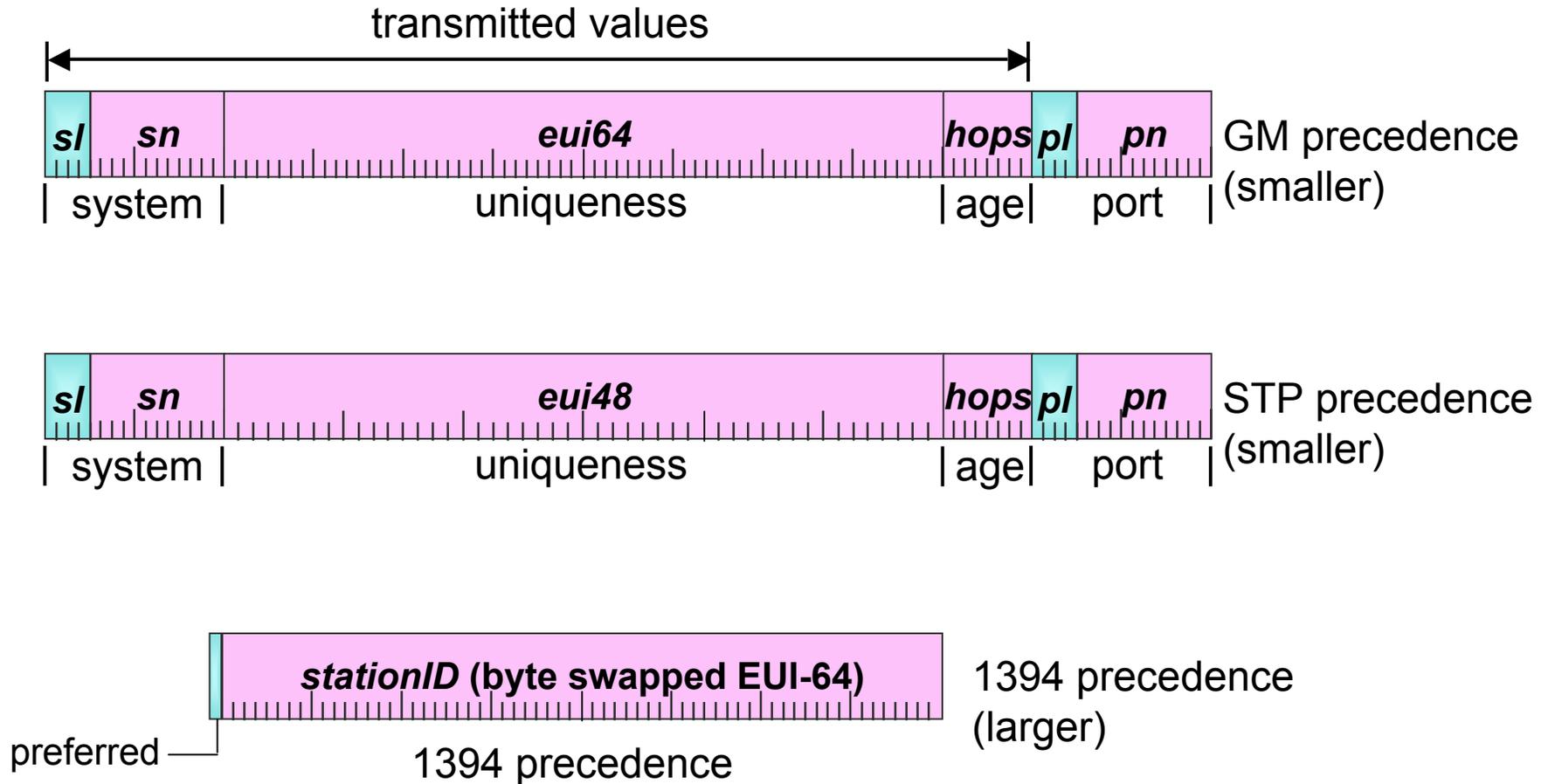
# Basic snapshot assumptions
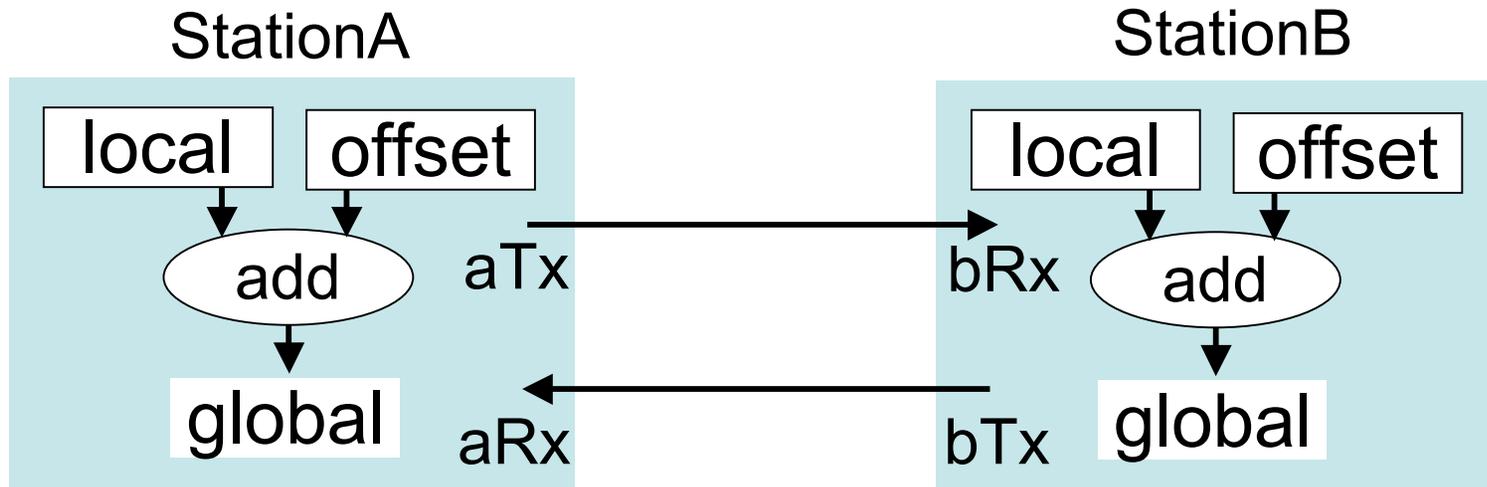
StationA

StationB

- – Periodic distribution (10 ms)
  - • Simple non-time-critical processing
  - • Master/slave independence
- – Pipelined computation
  - • Enables SW-centric implementations

# Adjustable *timeOfDay* timer
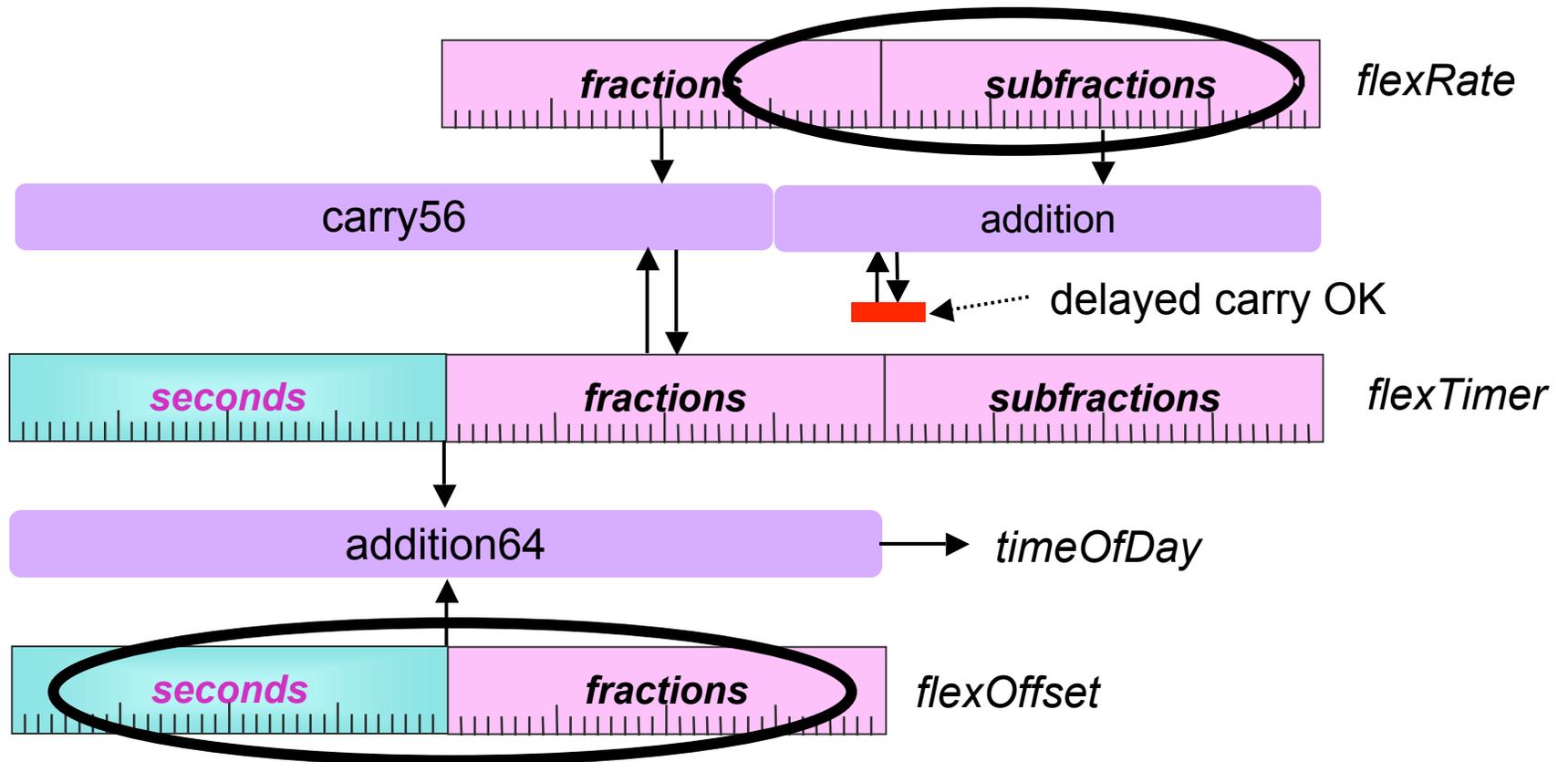
Adjacent-station synchronization

Snapshot value distribution
(information for stationB)
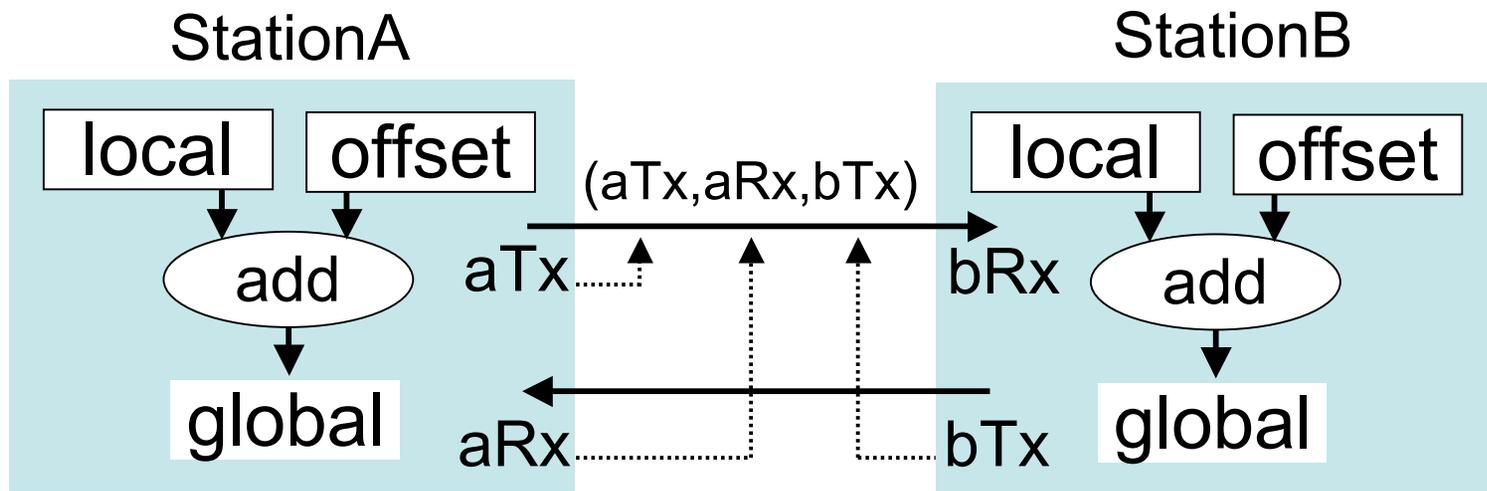
Adjacent-station synchronization

Snapshot value distribution
(information for stationA)

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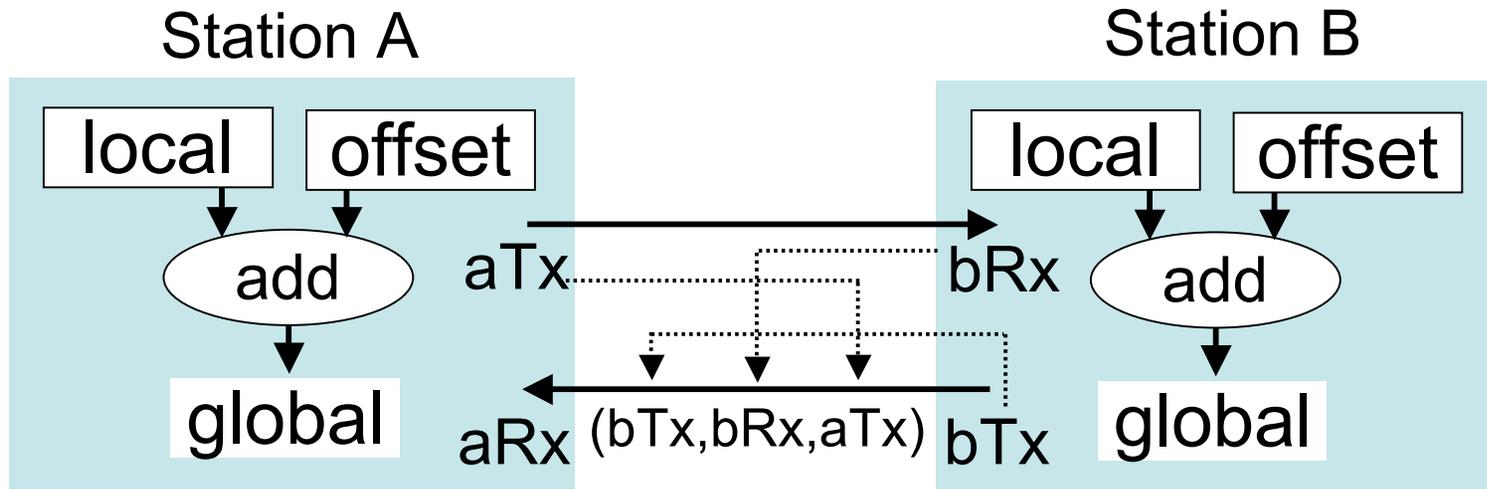
Adjacent-station synchronization

StationB offset adjustments
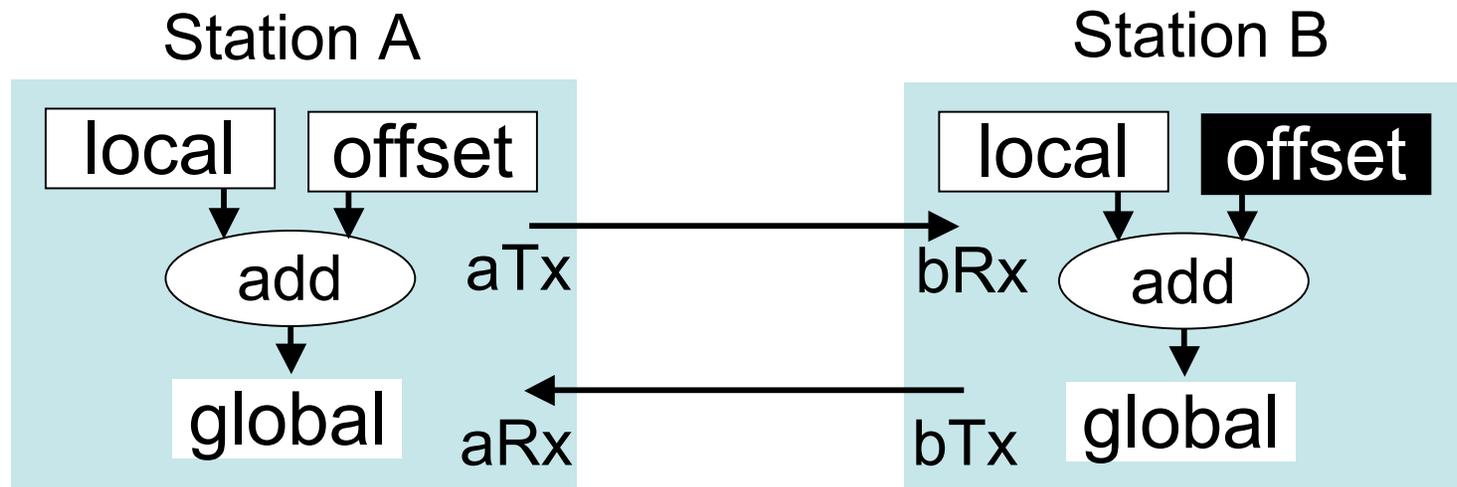
Station A   Station B

- rxDelta = (bRx – aTx);
- txDelta = (bTx – aRx);
- clockDelta = (txDelta – rxDelta) / 2;
- cableDelay = (txDelta + rxDelta) / 2;
- offsetB = offsetA + clockDelta;

Clock slave details (1)

StationB

Clock-slave details (2)

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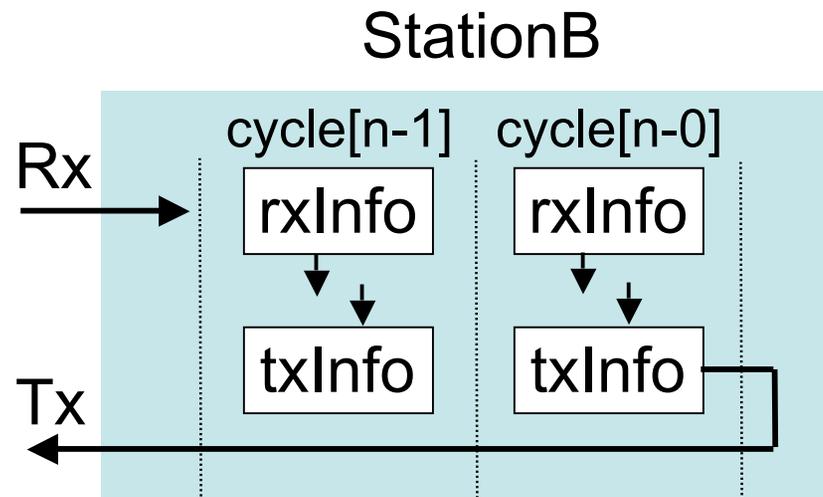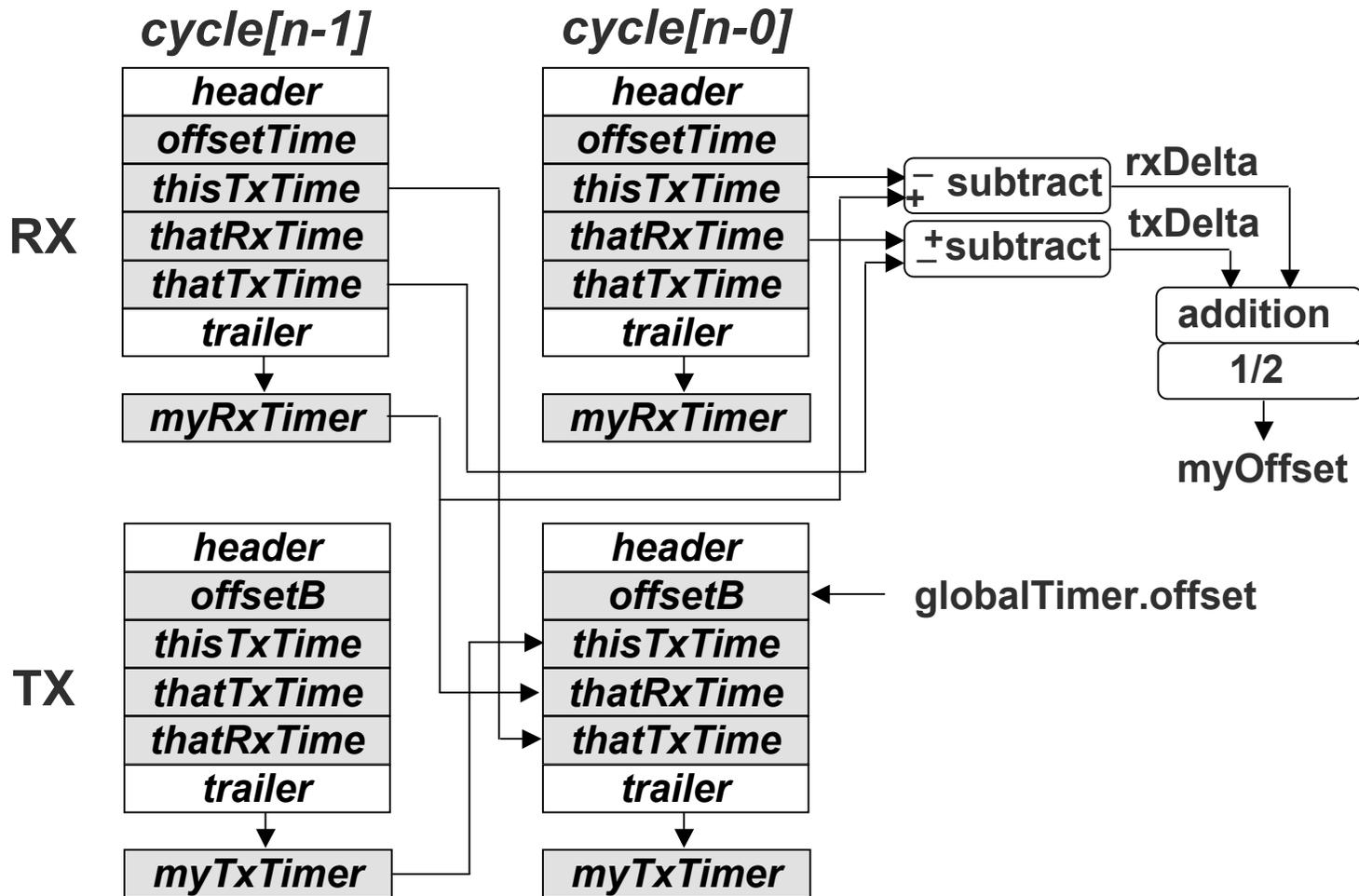
Rate-calibration timer
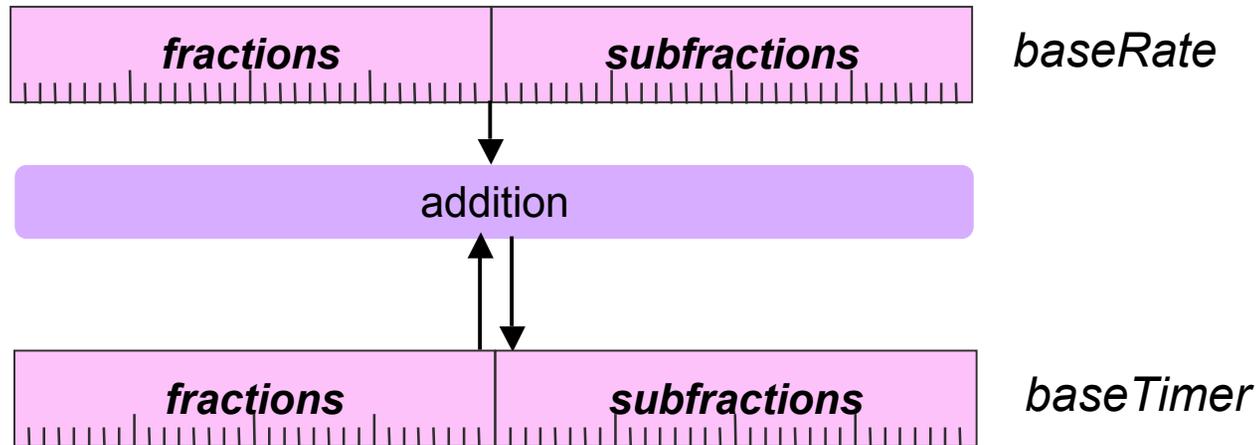
Adjacent-station synchronization

StationB rate adjustments

Station A   Station B
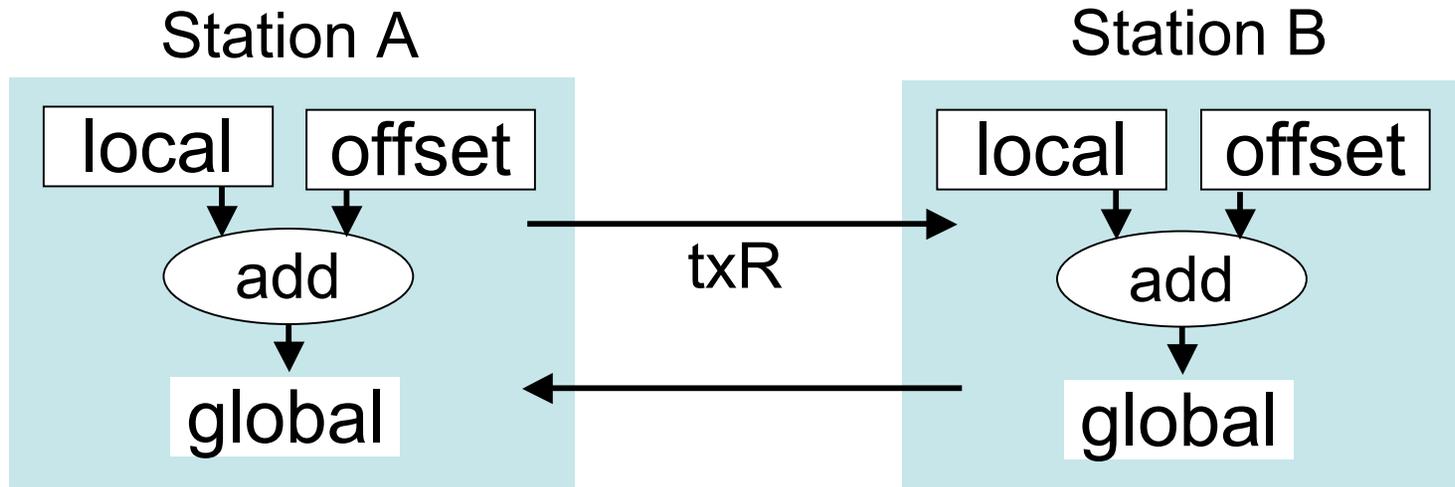
- aDelta = (localA[n+1] – localA[n+0]);
- bDelta = (localB[n+1] – localB[n+0]);
- diffRate = (bDelta – aDelta) / aDelta;

Timing specifics…
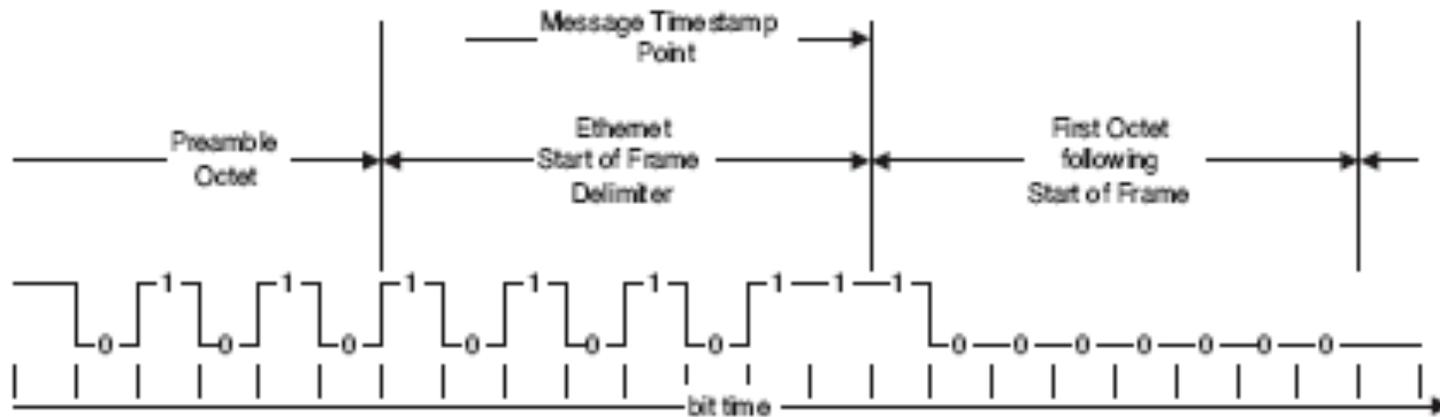
(from IEEE 1588-2002, subclause D.1.1, page 127)

A viable design model
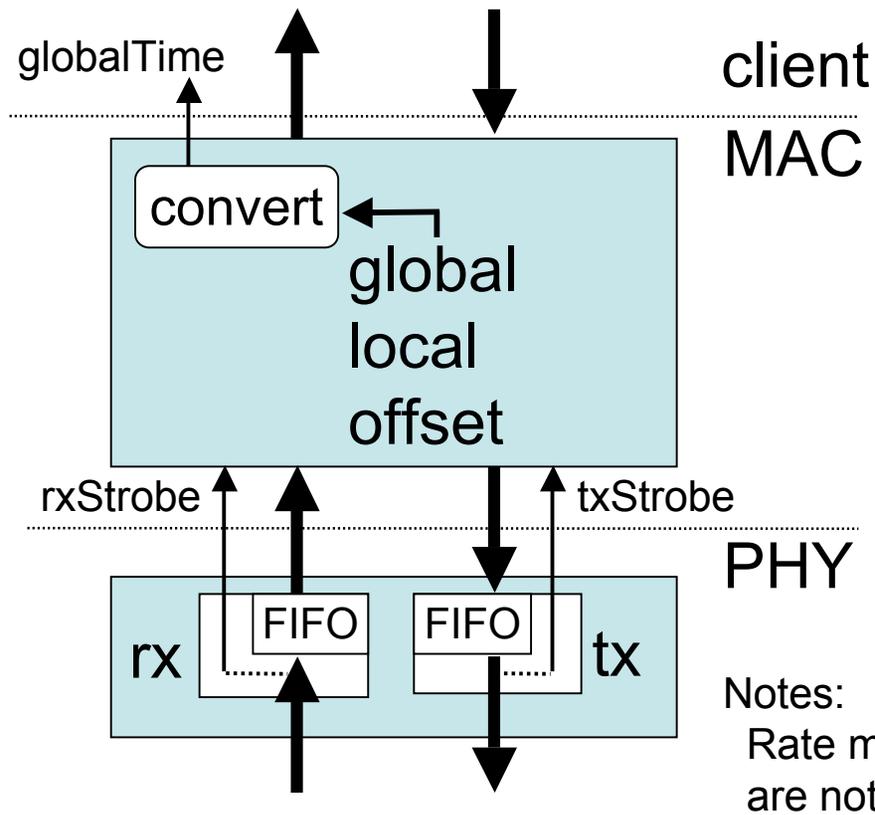
Notes:
Rate matching FIFOs
are not within our scope.

Residential Ethernet
(an unofficial cumulative slide set; 2005Mar11)

Maintained by David V James

Overview
(a Residential Ethernet SG presentation)

Categories of work

- Service discovery (out of scope)
  - Identify/control "talkers" and their available "plugs"
- Subscription (802.1 centric)
  - Establish conversation between talker and listener(s)
  - Reject unless: $linkBandwidth < linkCapacity$
- Clock synchronization
  - Synchronous reception, forwarding, and presentation
- Pacing
  - Talkers must not be well behaved
  - Bridges should "sustain" such behaviors
- Formats
  - Frame formats and content (stream IDs, time stamps)
  - Time aware service interfaces

Leveraged protocols

- ## Spanning tree protocol (STP)
  - Defines the grand-master precedence format
  - But, we use a distinct value and distribution protocol (The STP root and grand master could be distinct!)

- ## NTP (RFC-1305) and SNTP (RFC-2030)
  - Definition of the 64-bit time-of-day value

- ## IEEE 1588-2002
  - Techniques for delayed-sampling synchronization

Cascaded TOD synchronization

Physical topology constraints
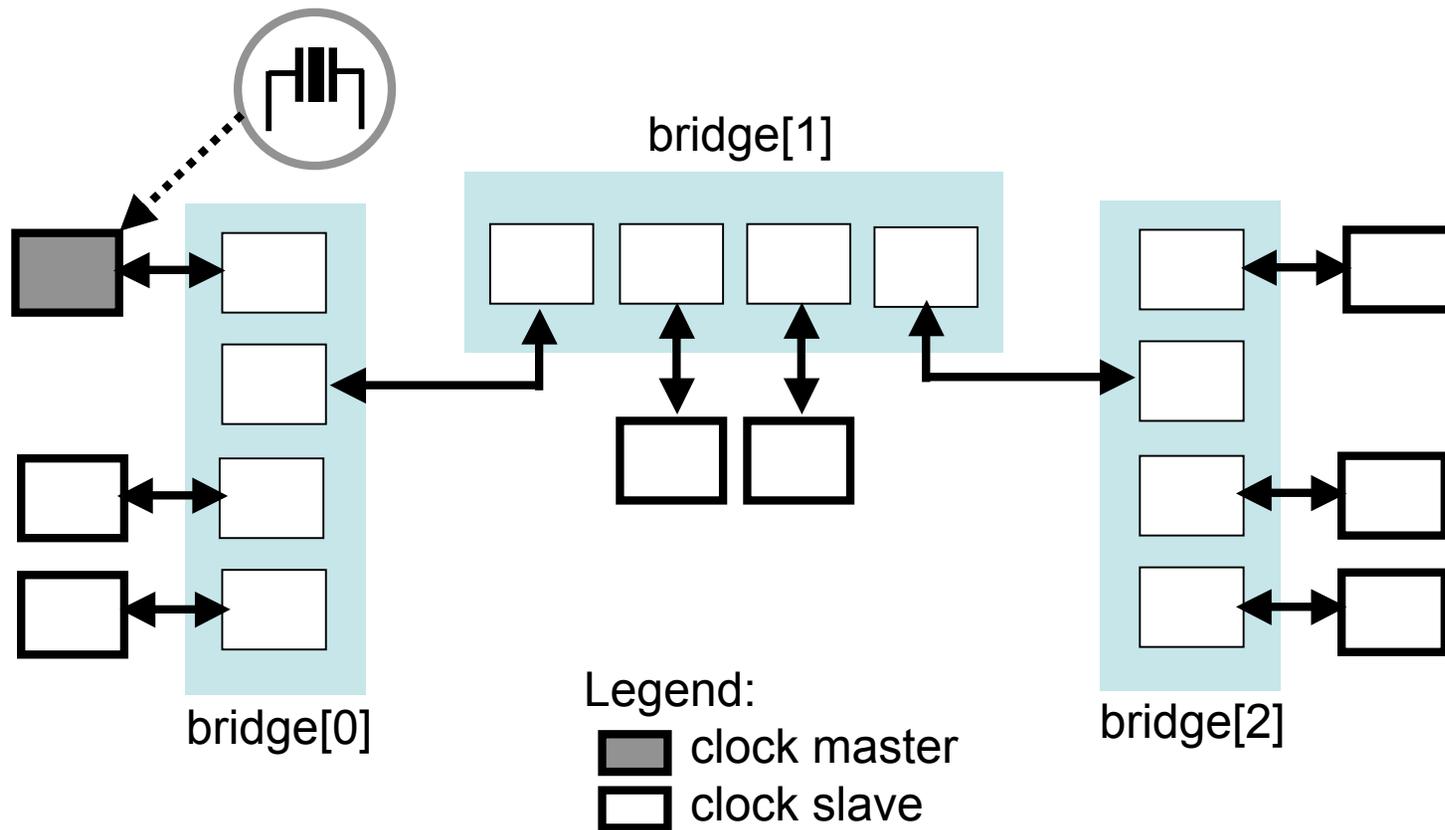
bridge[1]

bridge[0]

bridge[2]

Legend:

clock master

clock slave

Synchronized reception/presentation
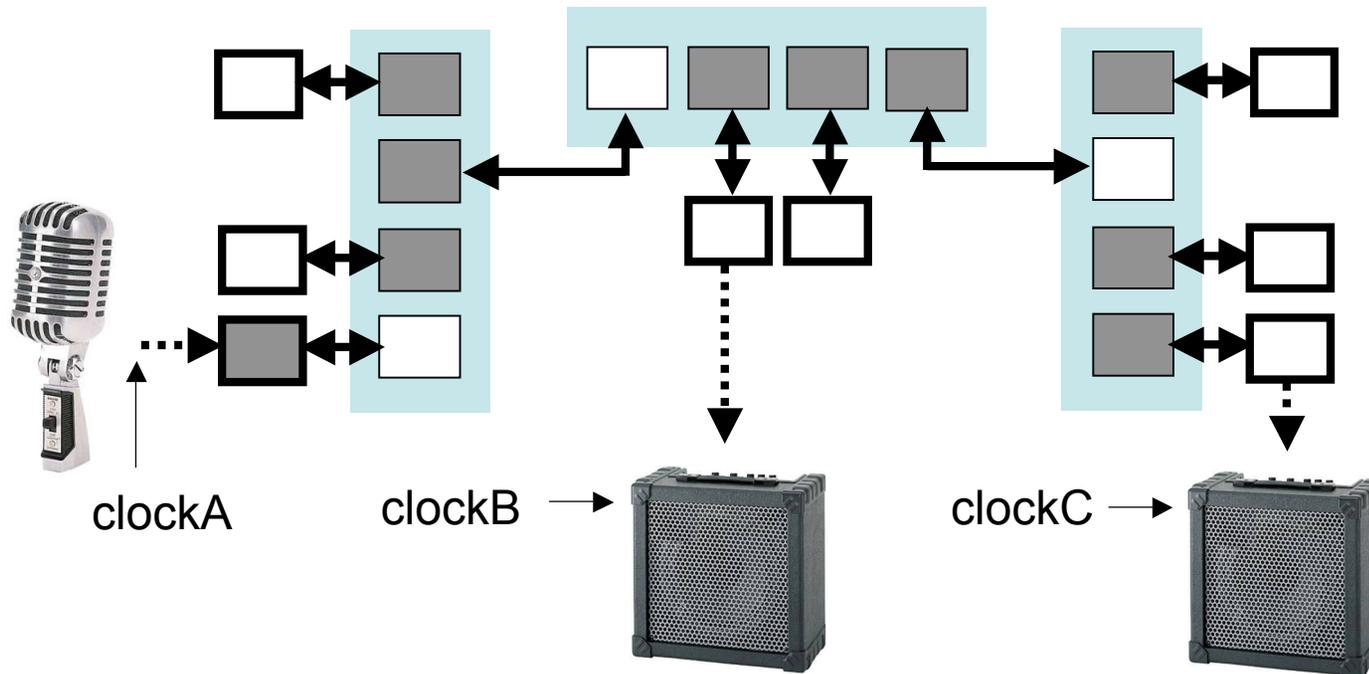
No long-term drift: clockA, clockB, clockC
Clock jitter: sub nanosecond (after PLL)

Precise time synchronization

talker

FIFO

FIFO

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What is the application?
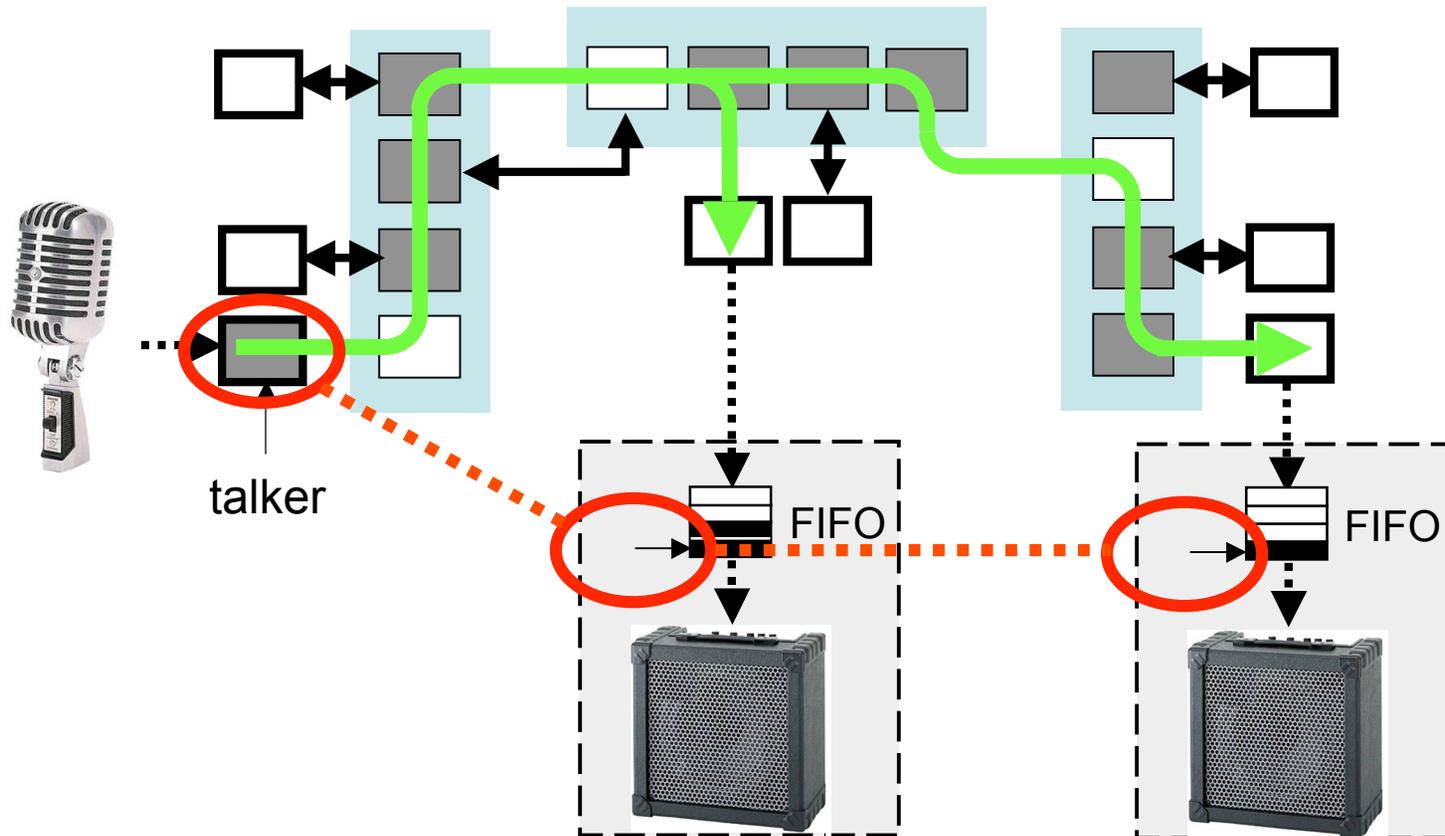
talker

listener   listener
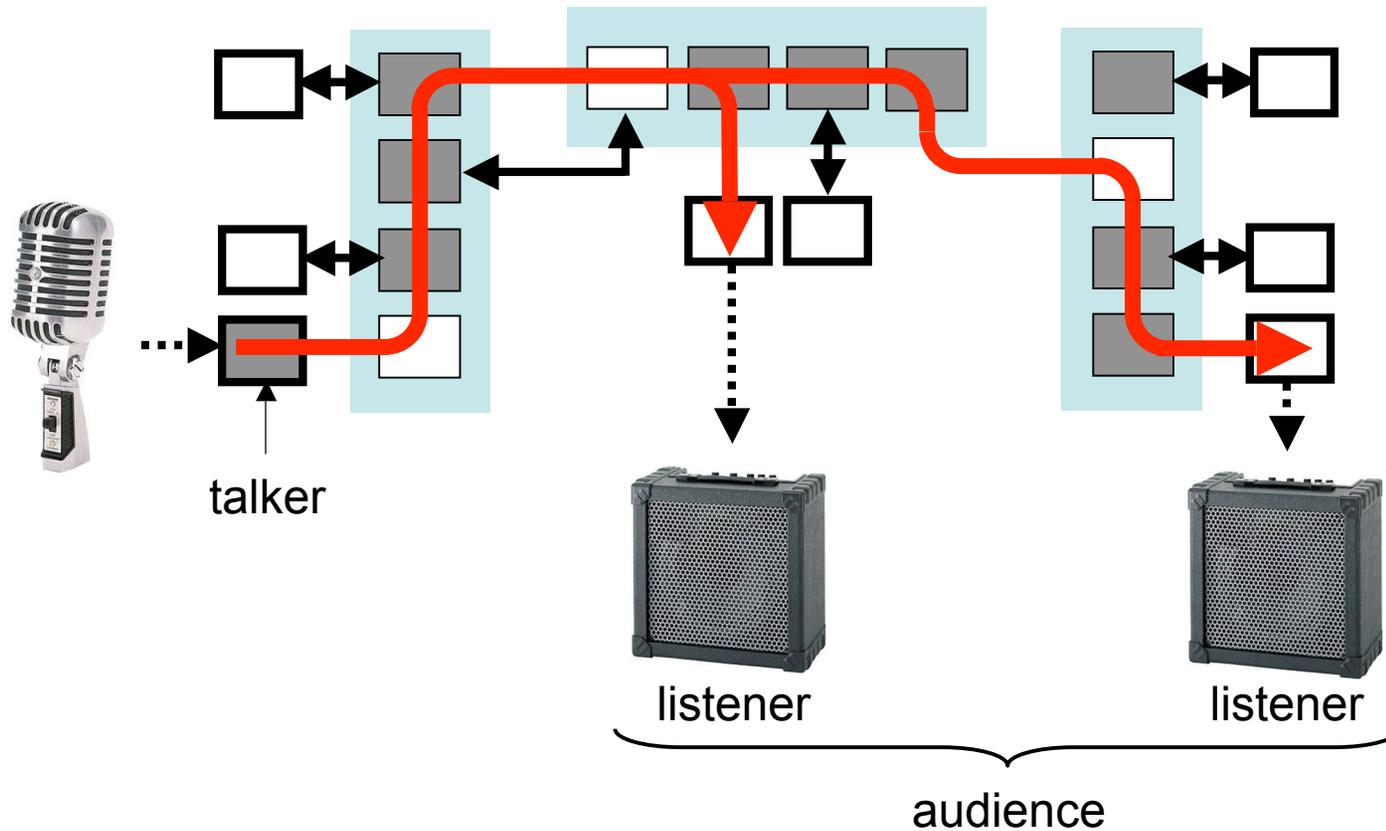
audience

Subscription requirements

talker

FIFO

FIFO

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Ethernet compatibility (yes!)

legacy bridge

Legend:
legacy bridge
legacy endpoint

Vocabulary terms (1)

talker

listener

listener

audience

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Vocabulary terms (2)

– audience
  - The set of listeners associated with a talker
– clock master
  - A bridge or end station that provides a link clock reference
– clock slave
  - A bridge or end station that tracks the clock reference
– grand clock master (grand master)
  - The clock master that provides the network time reference
– listener
  - A sink of a stream, such as a television or acoustic speaker
– path
  - A logical concatenation of links and bridges for a stream

Vocabulary terms (3)

- service discovery*
  - The process used to identify/control/configure talkers
- stream
  - An RE frame sequence with a distinct streamID
- subscription**
  - Establishing committed paths between talker and listener(s)
- talker
  - A source of a stream, such as a cable box or microphone

* A complete solution/vocabulary includes out-of-802 scope activities
** A complete solution/vocabulary includes out-of-802.3 scope activities

Residential Ethernet
(Problem components)

David V James   JGG

Clock synchronization
(a Residential Ethernet SG presentation)

David V James   JGG
Alexei Beliaev   Gibson
George Claseman Micrel

Clock synchronization

What?

Time-of-day format options

(NTP RFC-1305, SNTP RFC-2030)

seconds	fractions
>150 years	<250 ps

(IEEE 1588)

(+epoc)

seconds		nanoseconds

(EPON)

ticks

16 ns

OR

(…)

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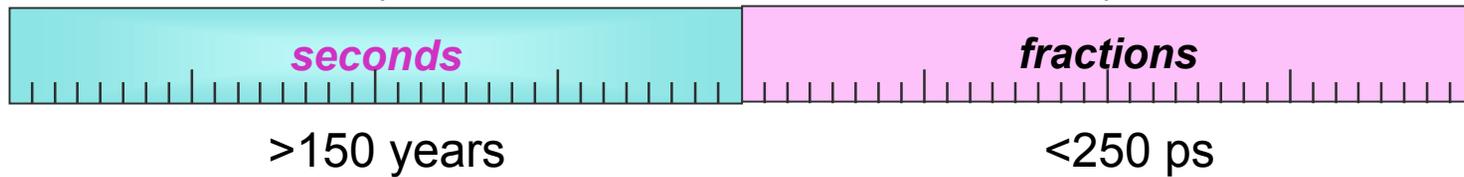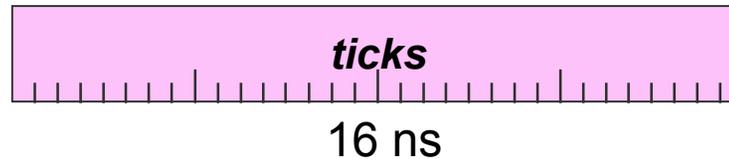
Format selection criteria

- – Highest possible precision
 - Binary number (not BCD)

- – Complete solution
  - 64-bit number

- – Consistent with 1588, etc.
  - 32-bit seconds component

- – Simple computations
  - 64-bit: seconds and fractions-of-second

- – Client interface?
  - A logical interface (doesn't really matter)

Synchronized time-of-day clocks

How?

Adjacent-station synchronization

Timing snapshots
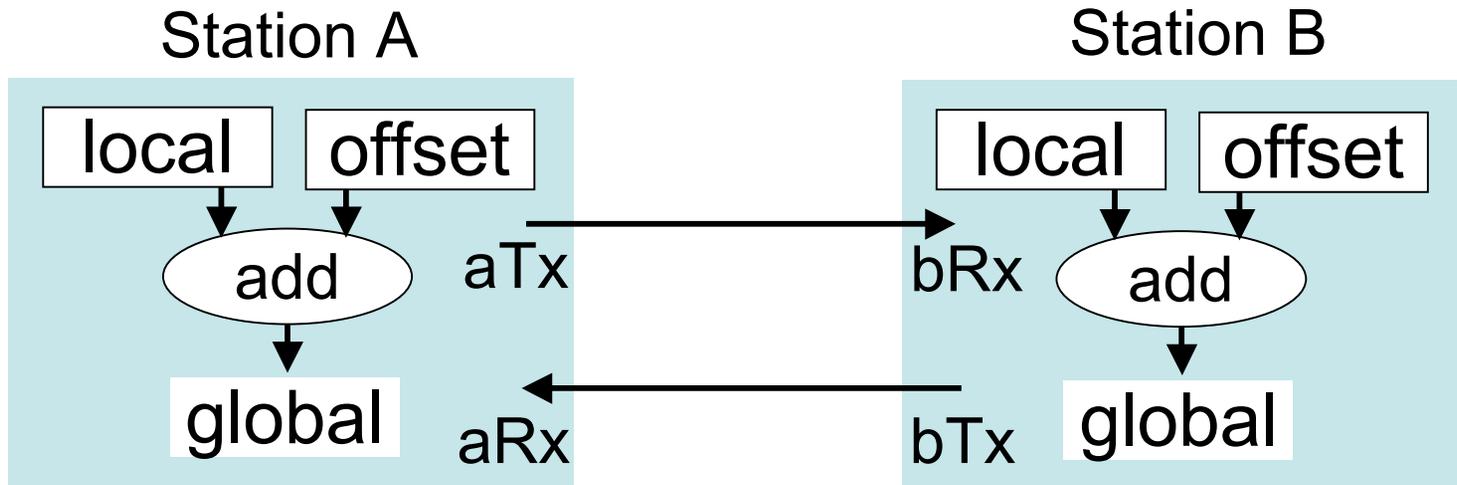
Adjacent station synchronization

clockSync frame format…

cycle[n-1]

cycleStart	→	header	→	(cycleCount)
isoch0		syncInfo		thisOffset
isoch1		selectInfo		thisTxTime
isoch2		trailer		thatRxTime
				thatTxTime

isoch

async0

asynch
async1
async2

asyncN

cycle

increasing time
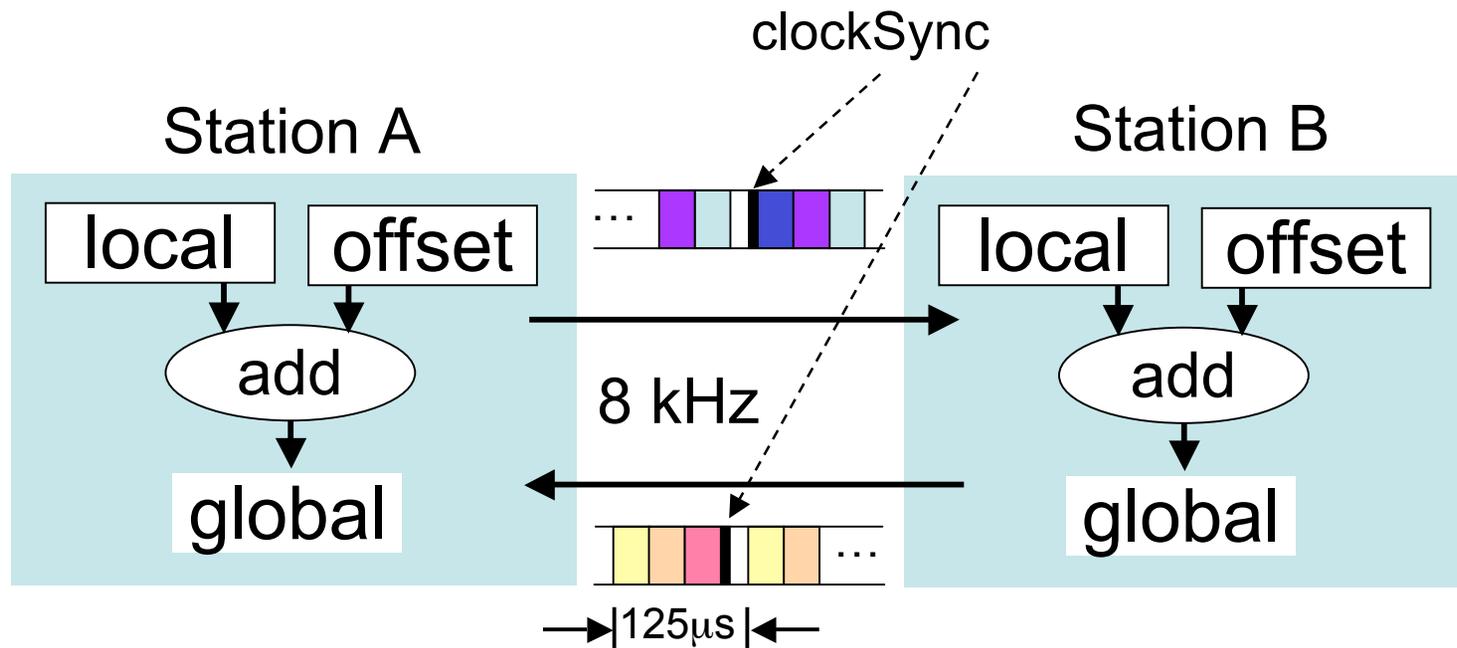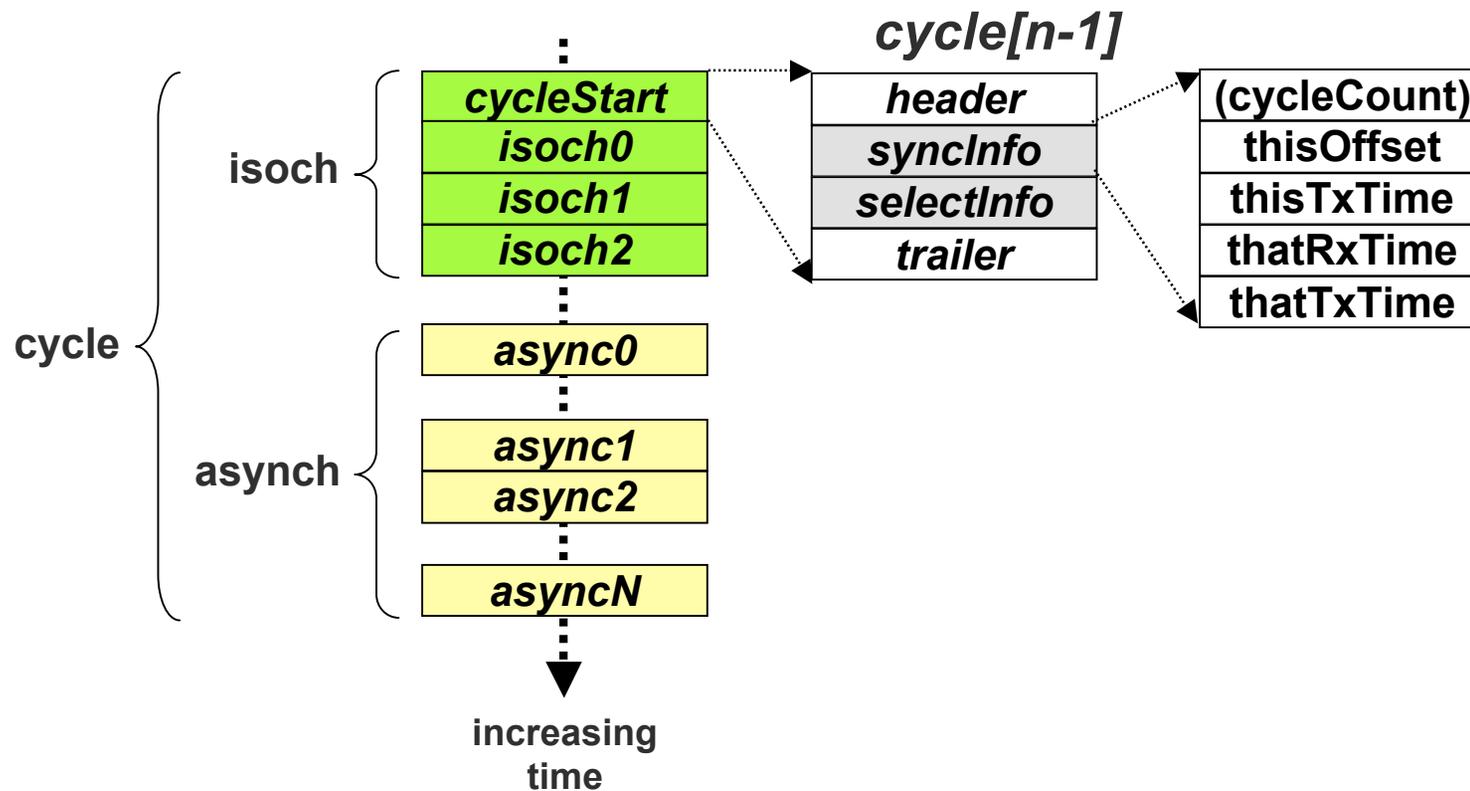
Why synchronous clock-syncs?

- Simple
  - Uses existing isochronous transmission state machine
  - Like IEEE 1588, requires only frame-sent snapshots
- Timely
  - Quasi-periodic transmissions
- Responsive
  - Sampling-to-adjustment delays are minimized
- Efficient
  - *sequenceNumber* is the *cycleCount*
- Consistent
  - Just another isochronous frame…

Conversion example: 1394

(NTP RFC-1305, SNTP RFC-2030)

seconds	fractions

a

$b = (a*125)>>7$

b

cycles	fractions

c

$d = (c*3)>>6$

d

Notes:
  Two 32-bit additions for b:
   $b = ((a<<7) - (a<<2) + a) >> 7;$
  One 16-bit addition for d:
   $d = ((c<<2) + c) >> 6;$

sec	cycle	offset

(IEEE 1394 CYCLE_TIME)

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Conversion example: EPON

(NTP RFC-1305, SNTP RFC-2030)

seconds	fractions

$$a$$

$$b = (a*193125) >> 24$$

$$b$$

nanoTicks

(nanoTick = 16ns)
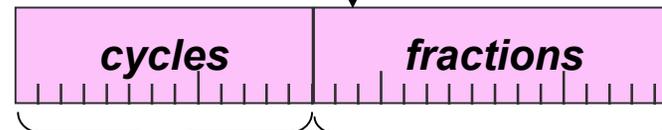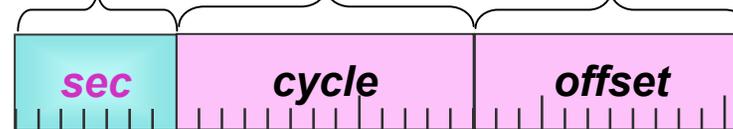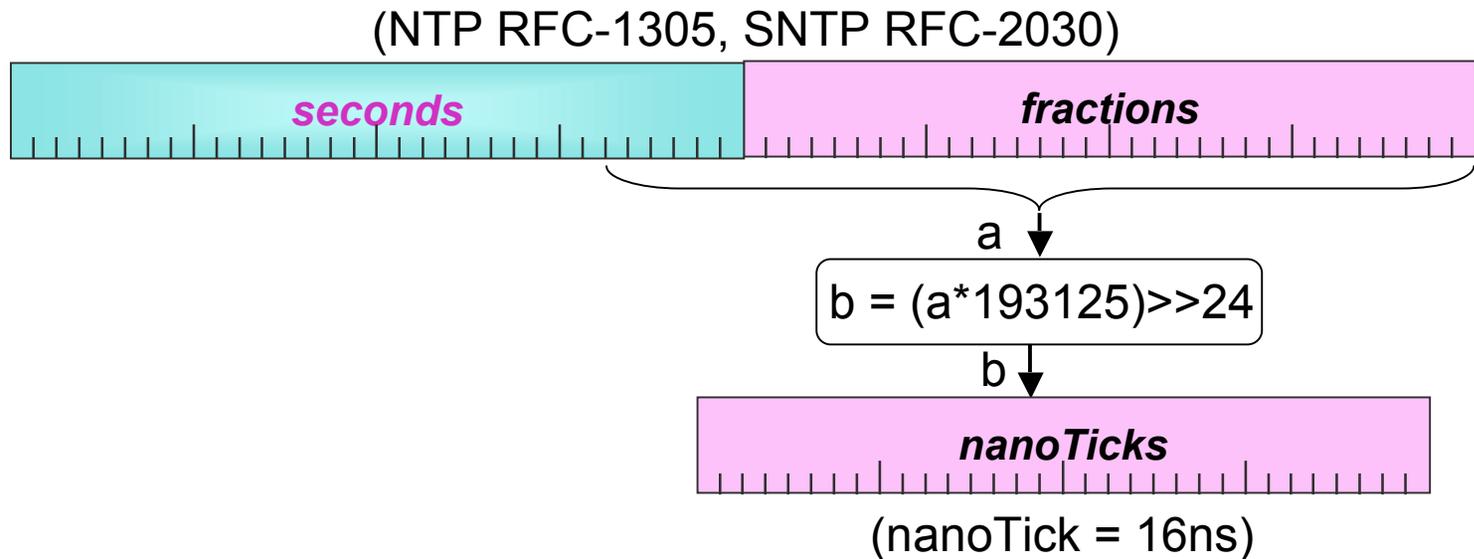
Notes:
  Thus, eight 36-bit additions compute a very precise b value:
  b= ((a<<17)+(a<<16)-(a<<12)+(a<<9)+(a<<6)+(a<<5)+(a<<2)+a) >>24;

Passby PLLs (proposal 1)
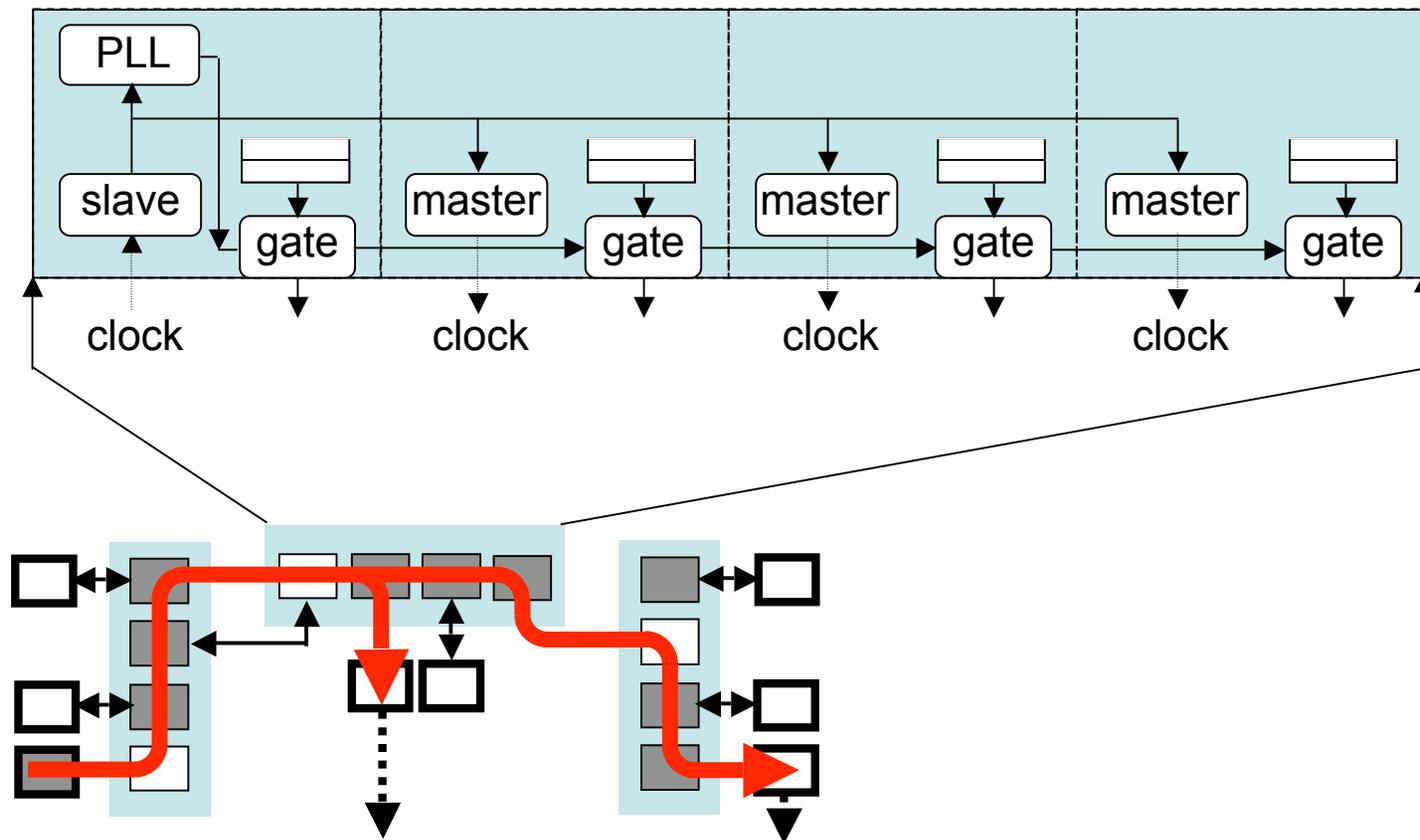
Passthrough PLLs (option 2)
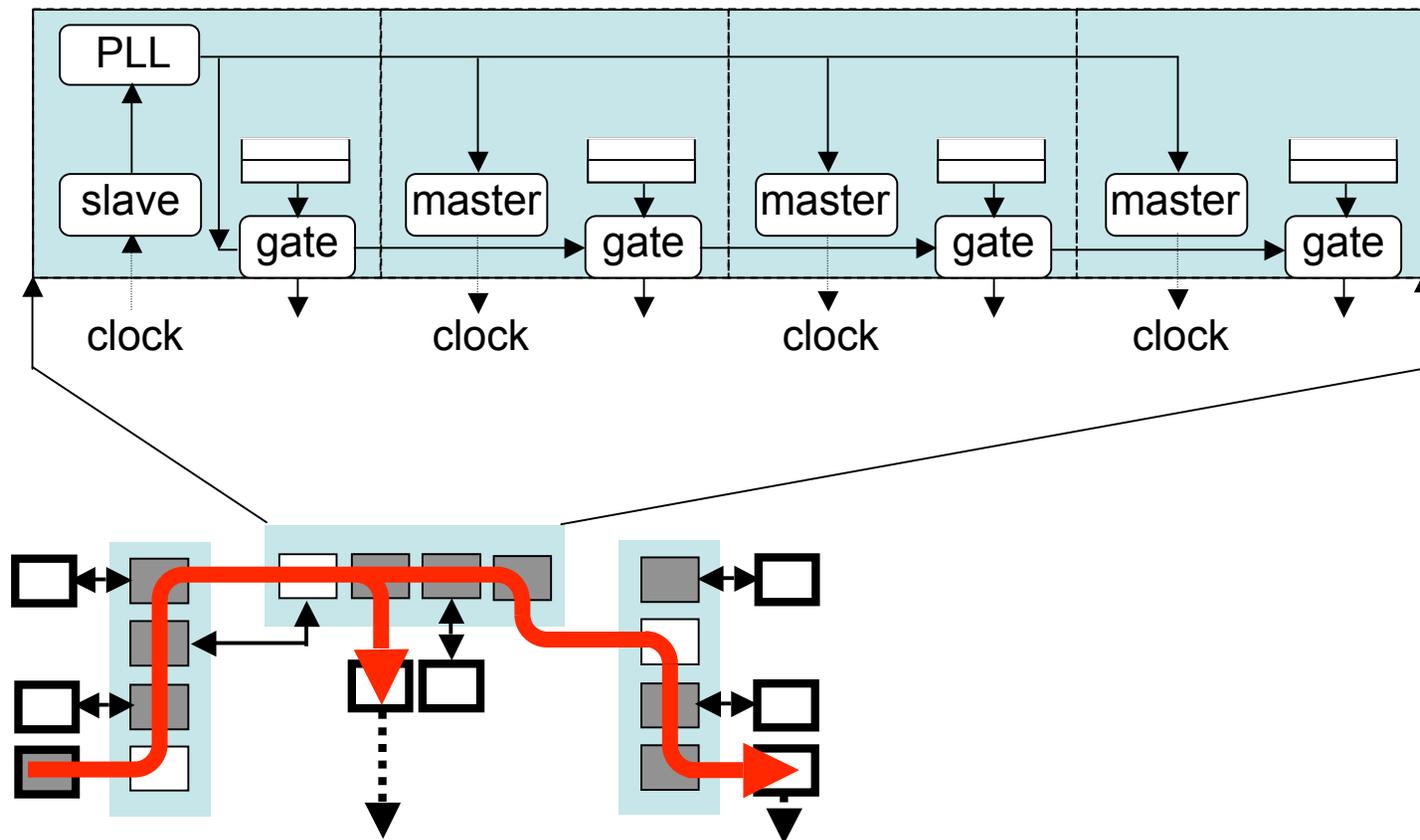
Synchronized time-of-day clocks

Why?

Consider possible congestion…

rx0   rx1   rx2   rx3   tx4

Bursting causes jitter

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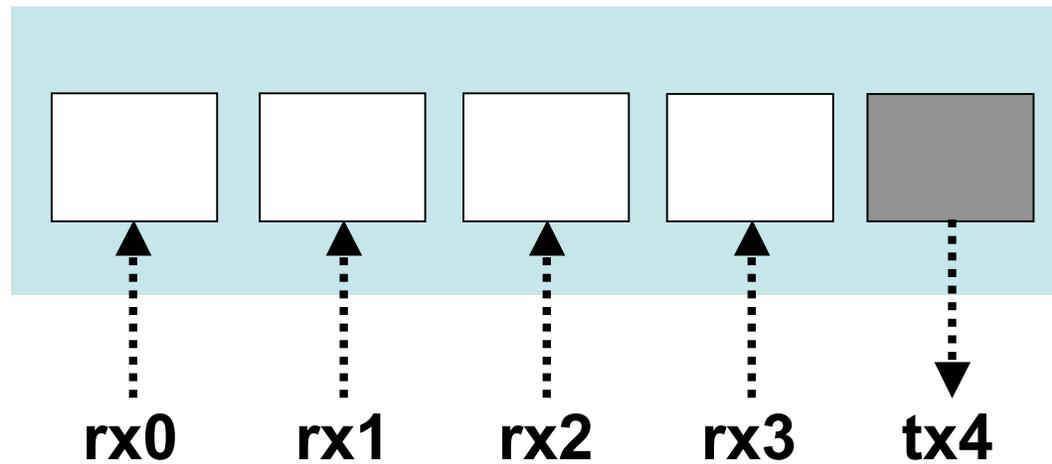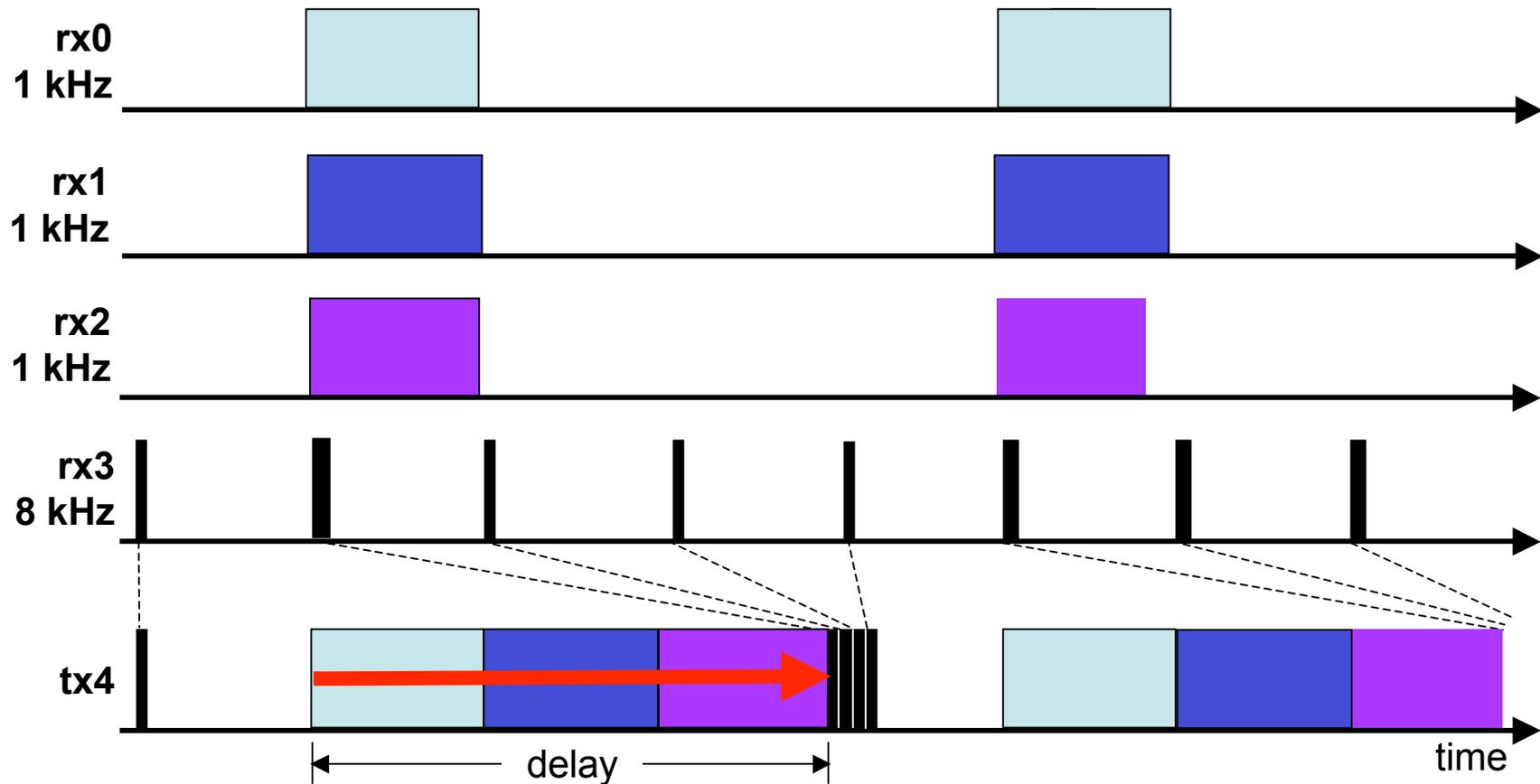
Bunching causes jitter
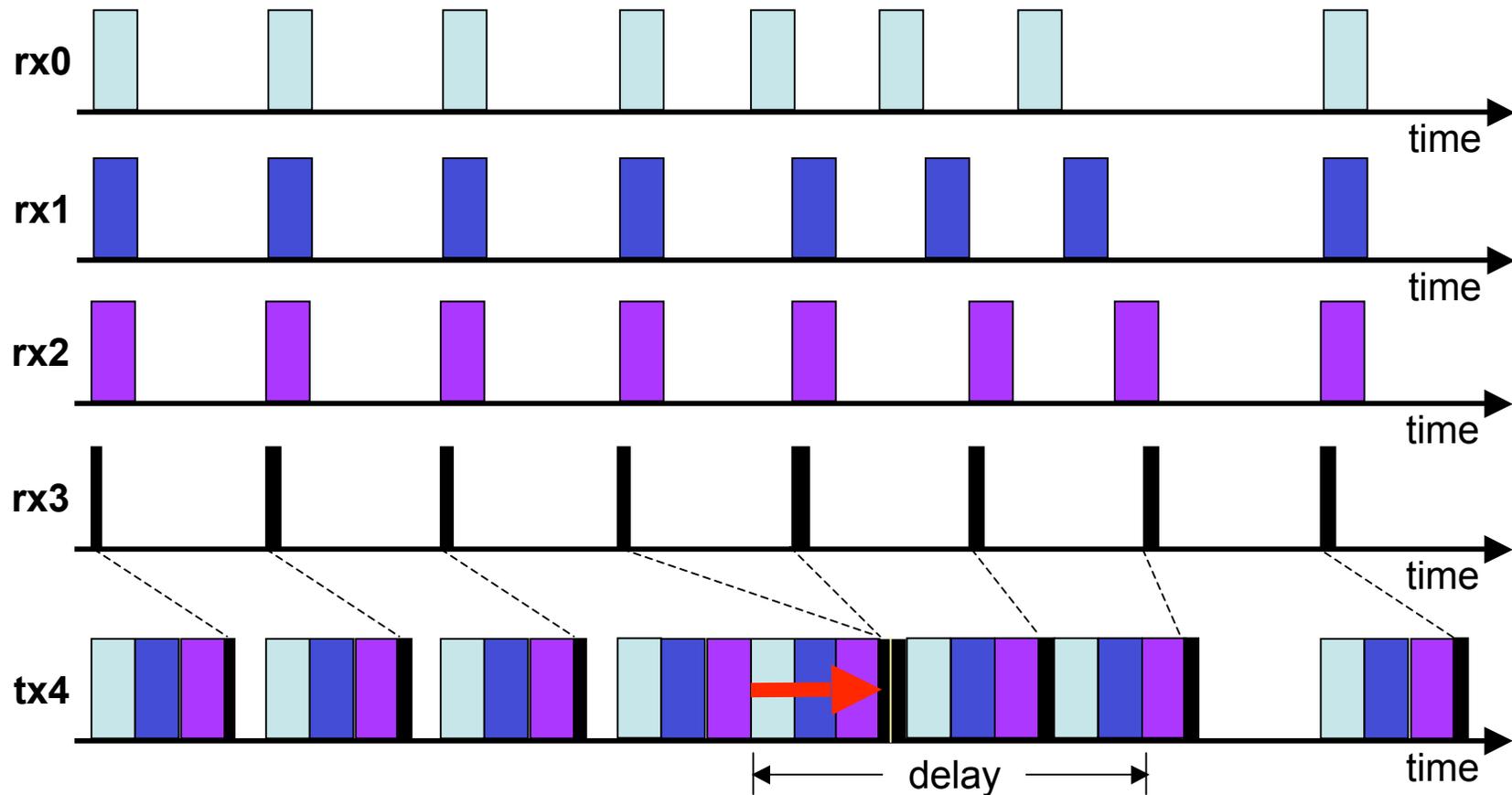
Bridge re-clocking contains jitter

bridge

receive

(etc.) ← cycle-stamp ← receive

cycleCount

isochronous

… → gate → high → transmit

asynchronous

… → low
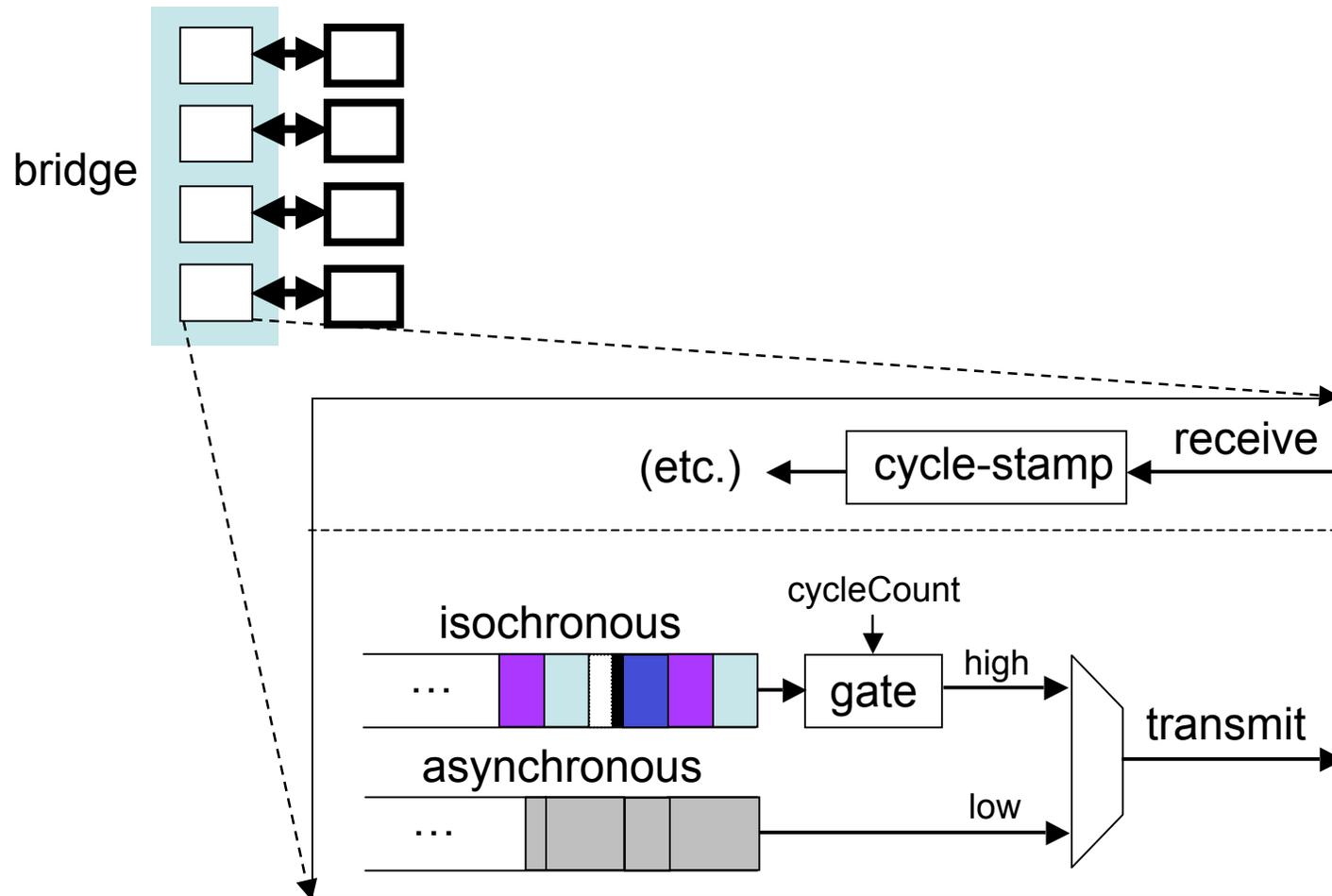
Frame transmission timings
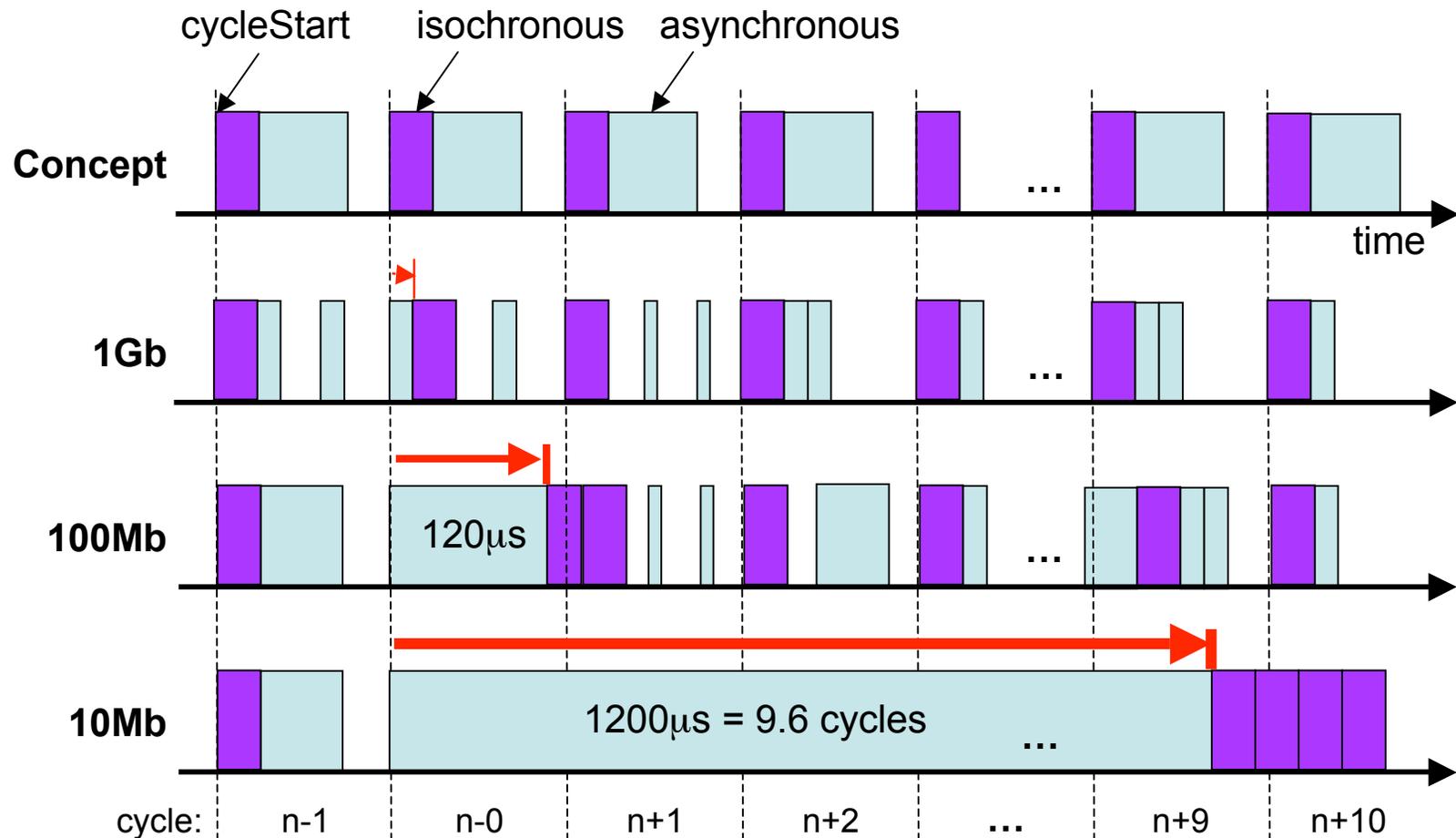
Synchronized reception/presentation
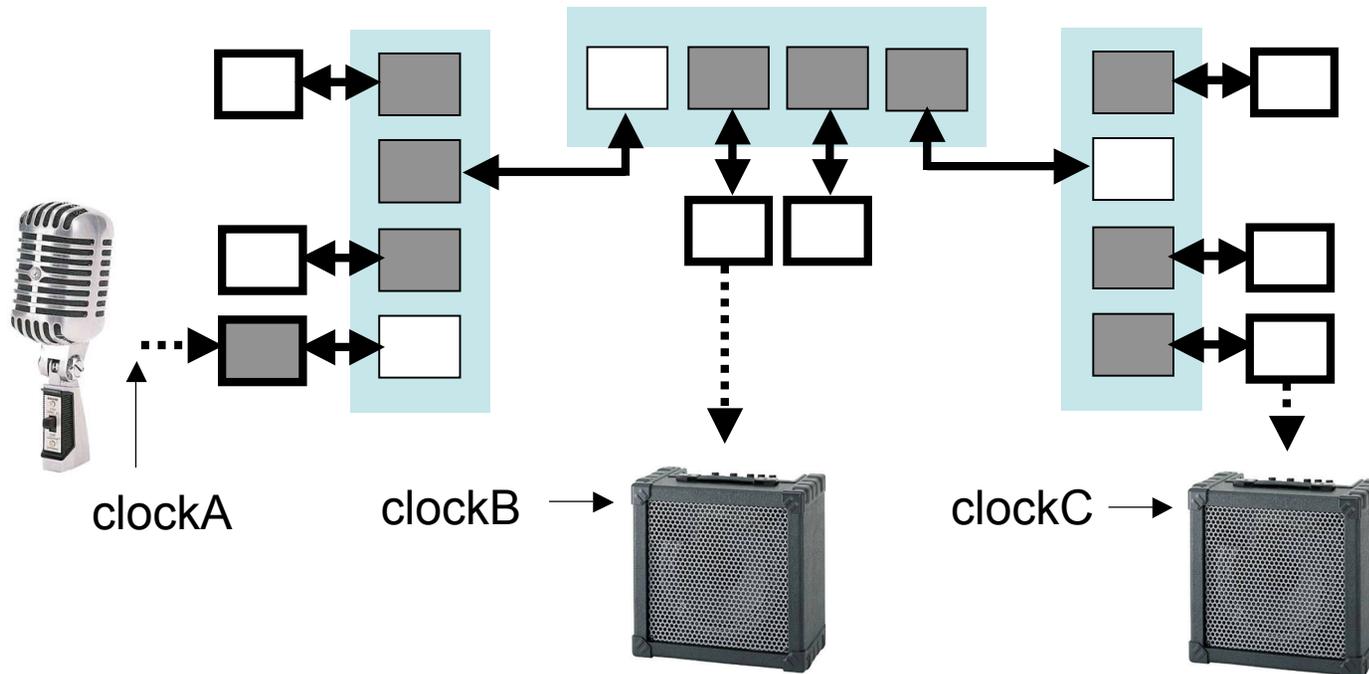
No long-term drift: clockA, clockB, clockC
Clock jitter: sub nanosecond (after PLL)

In summary

- Time-of-day synchronization (house clock)
  - Global synchronization is required
  - Implemented as cascaded adjacent synchronizations
- Time synchronization formats
  - Binary time is accurate with simple add/subtract
  - Clock-master voting: 48+ or 64+ selection priorities
- Time-of-day applications
  - Synchronous reception and presentation, within applications
  - Synchronous re-clocking within bridges
- Time-of-day distribution
  - Pipelined sampling for highest accuracies
  - Cable delays can be derived, based on the same information

Synchronized time-of-day clocks

Questions?

Synchronized time-of-day clocks

Backup slides…

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Residential Ethernet
## (an unofficial cumulative slide set; 2005Mar11)

Maintained by David V James

Categories of work

- Service discovery (out of scope)
  - Identify/control "talkers" and their available "plugs"
- Subscription (802.1 centric)
  - Establish conversation between talker and listener(s)
  - Reject unless: *linkBandwidth < linkCapacity*
- Clock synchronization
  - Synchronous reception, forwarding, and presentation
- Prioritized queues
  - Talkers and 100Mb bridge ports must be gated
- Formats
  - Frame formats and content (stream IDs, time stamps)
  - Time aware service interfaces

Ethernet compatibility (yes!)

legacy bridge

Legend:

□□□□ legacy bridge

🟥 legacy endpoint

Vocabulary terms (1)

talker

listener

listener

audience

Vocabulary terms (2)

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* A complete solution/vocabulary includes out-of-802 scope activities
** A complete solution/vocabulary includes out-of-802.3 scope activities

Subscription
(some possibilities)

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Delay-matching <u>listener</u> FIFOs
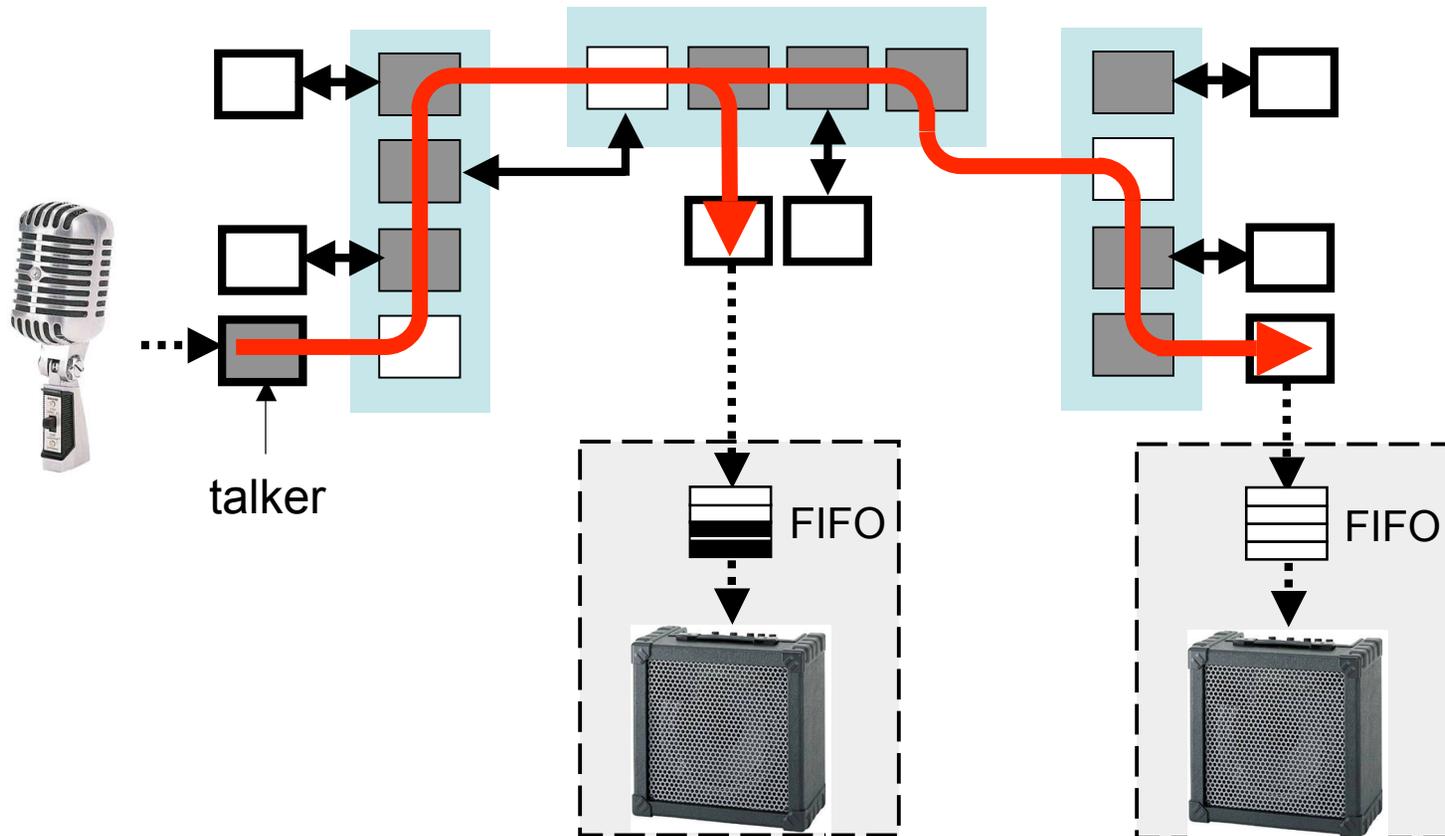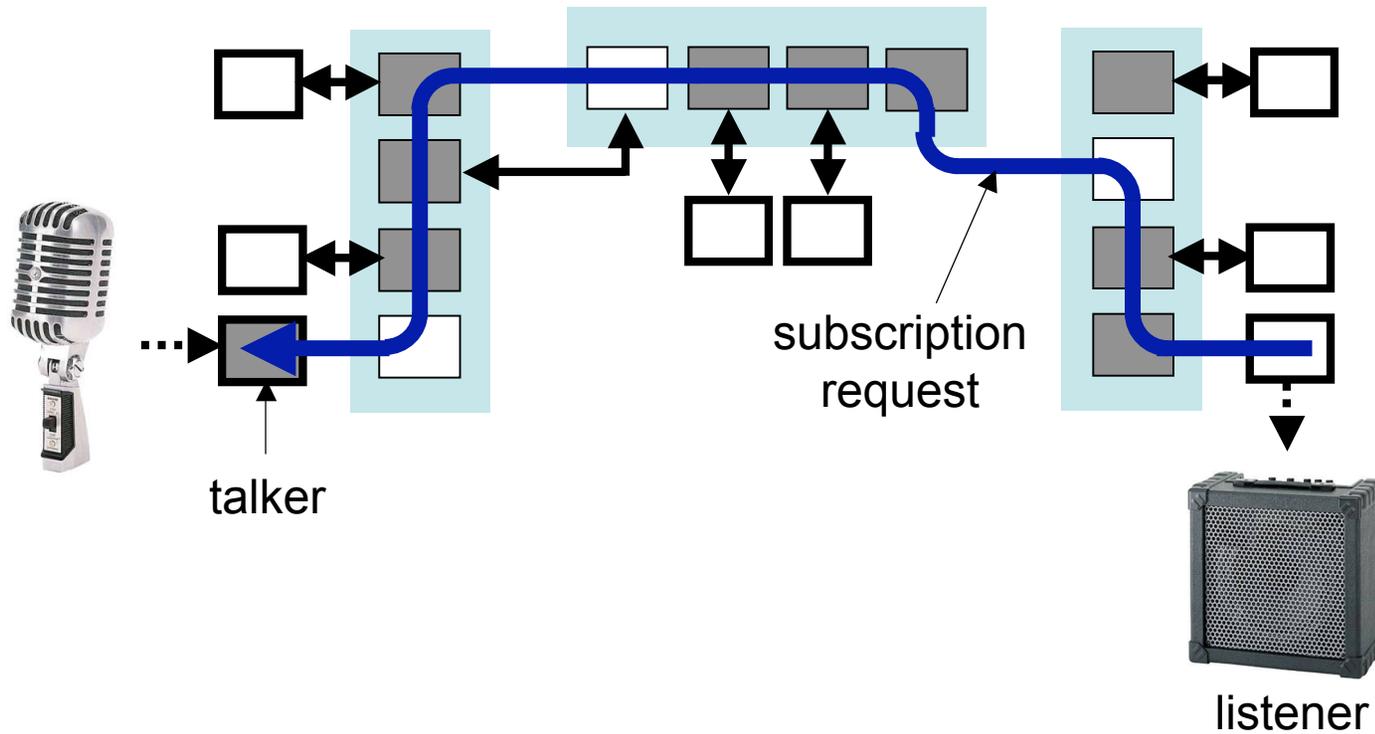
talker

FIFO

FIFO

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First access request

subscription request

talker

listener

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First access response

talker

subscription
response

listener

Second access request

talker

subscription
request

listener

listener

**IEEE 802.3 RE Study Group
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Second access response

talker

subscription response
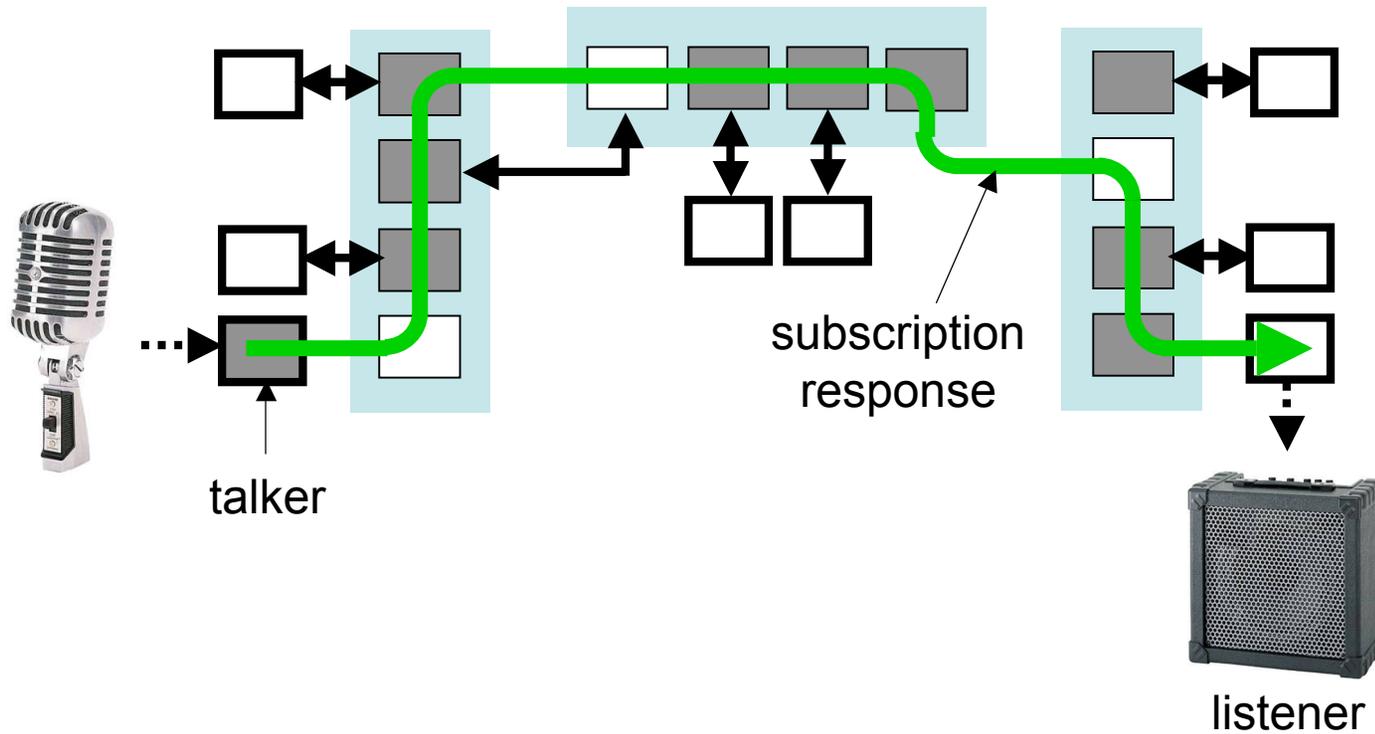
listener

listener
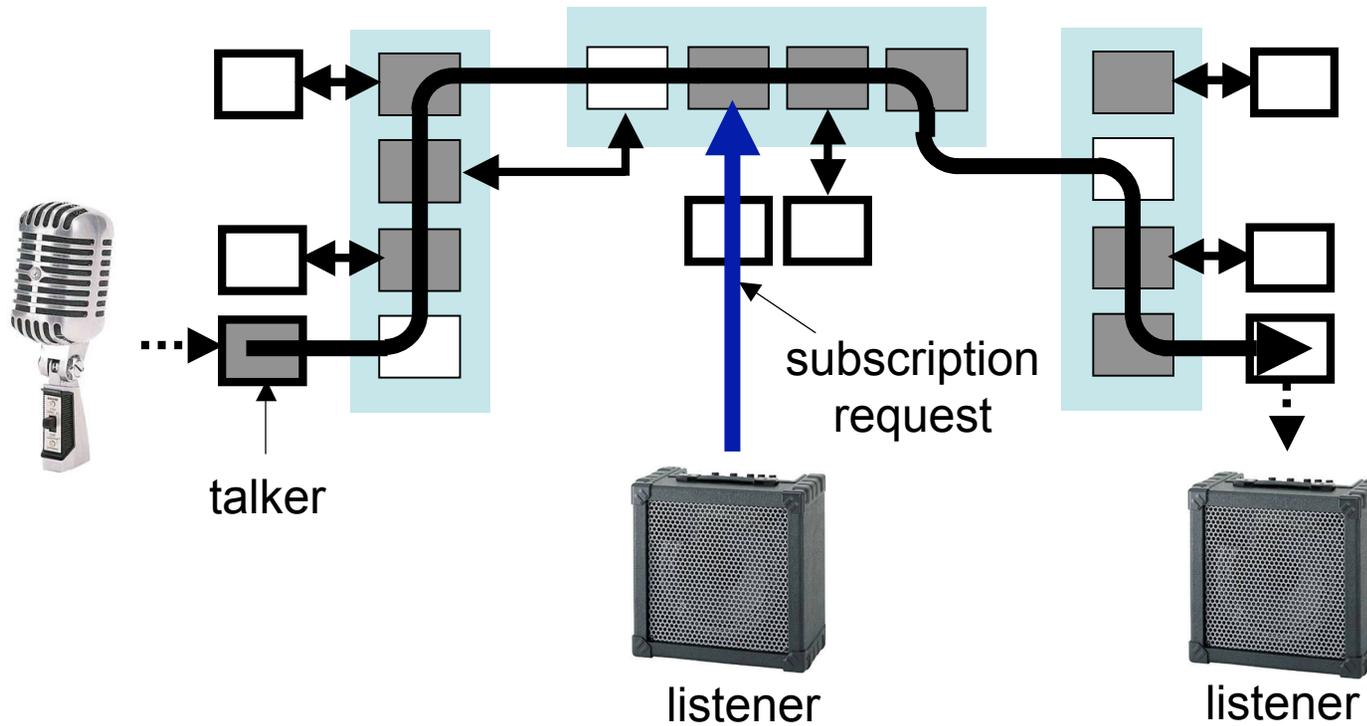
Established paths

talker
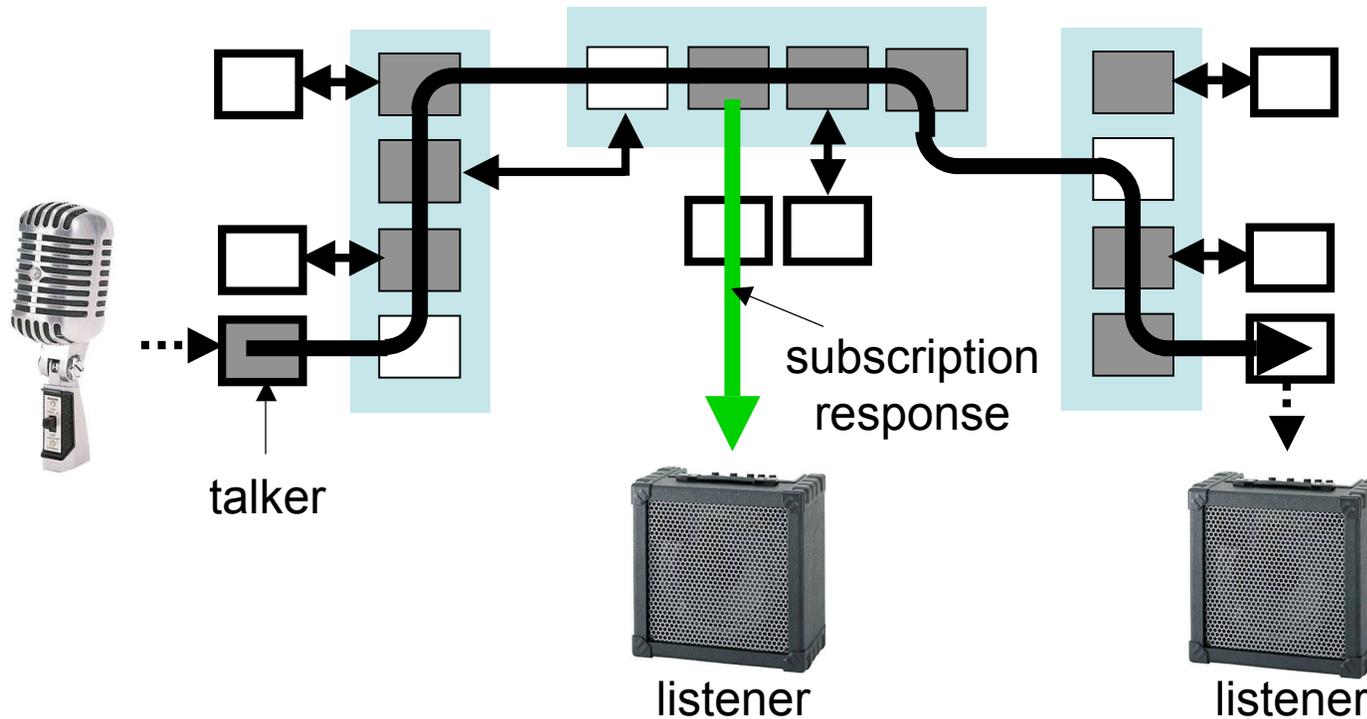
paths

listener
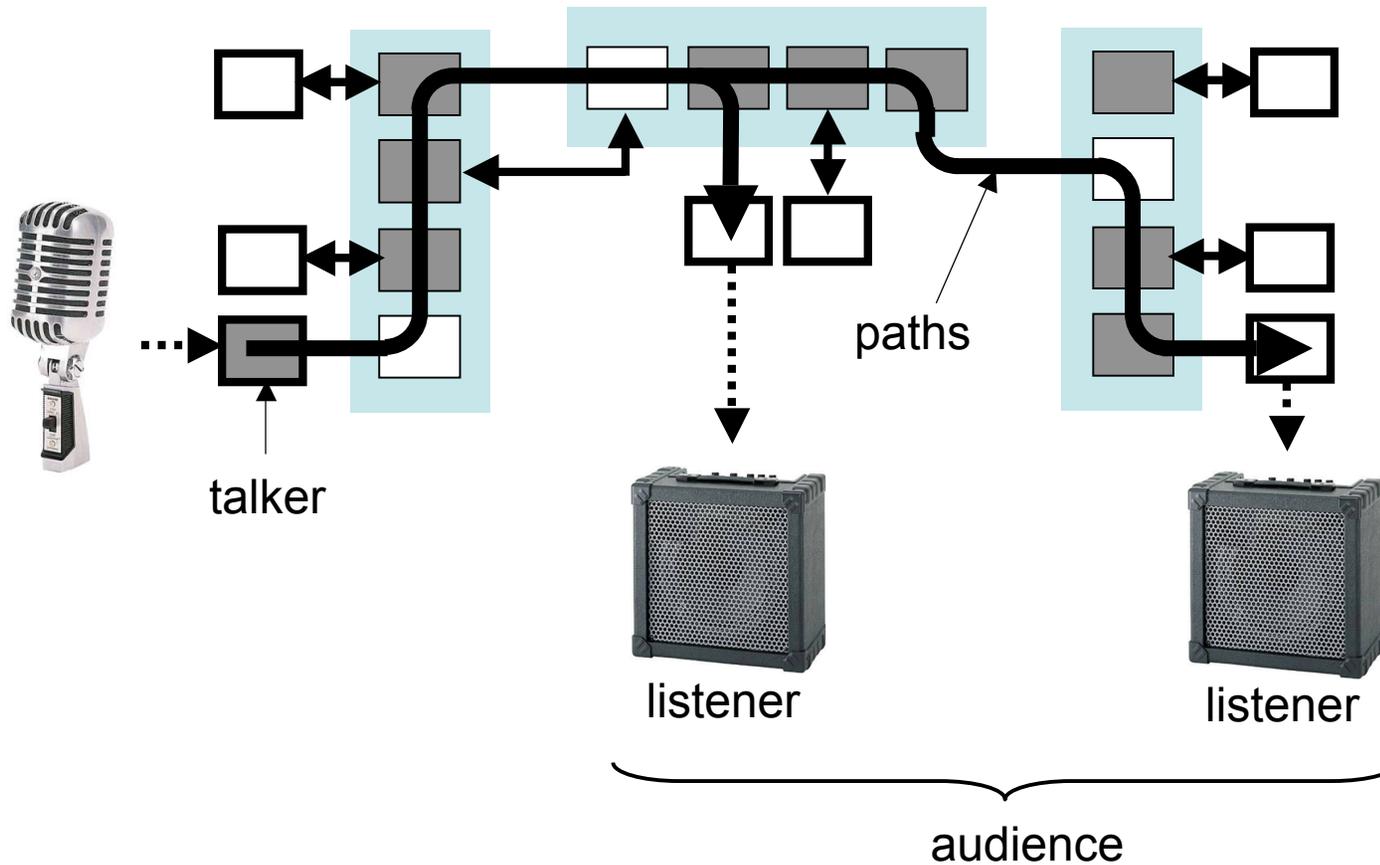
listener

audience

Teardown: talker➔audience

talker

listener

listener

teardown

audience

Teardown completed

talker

listener

listener

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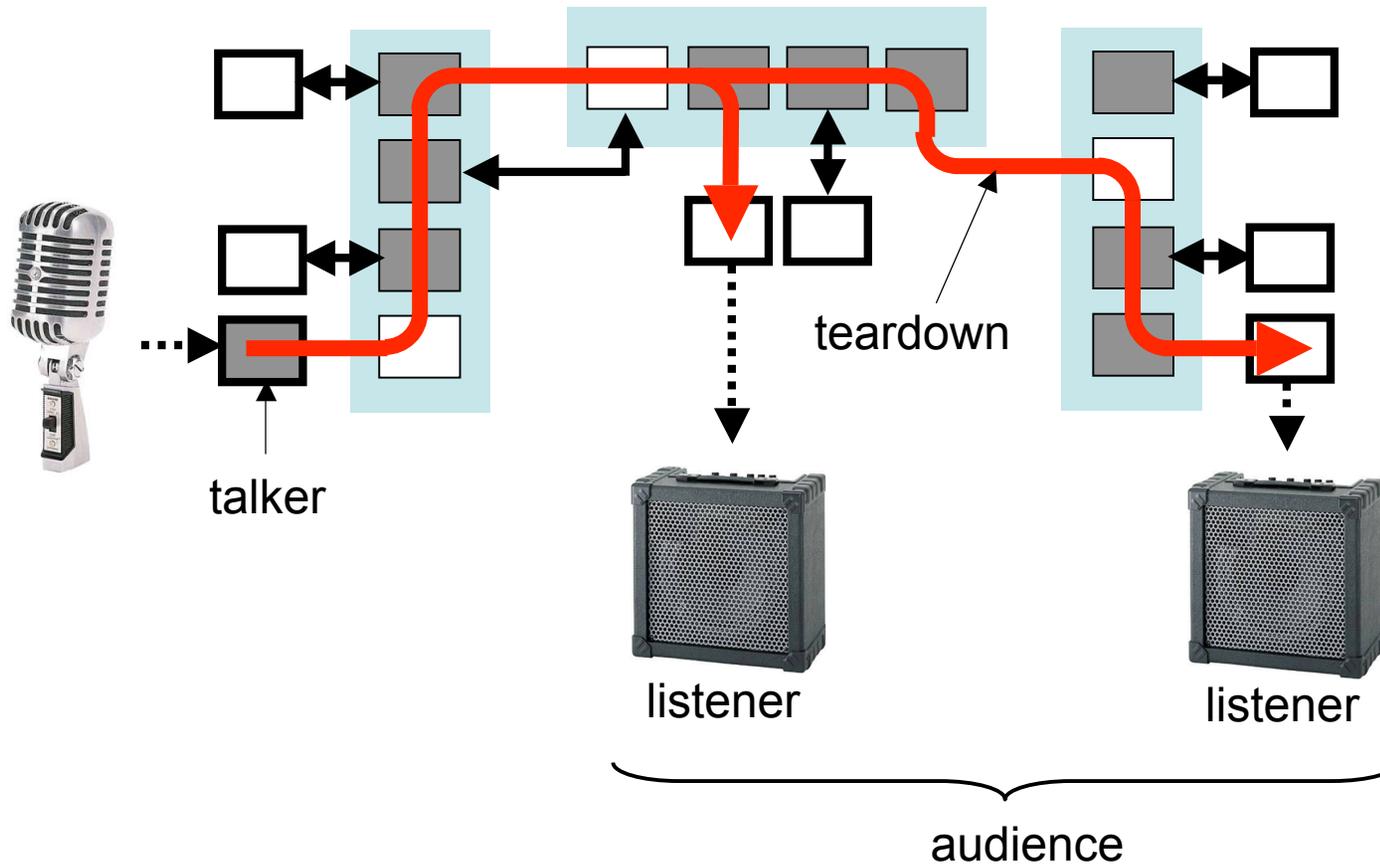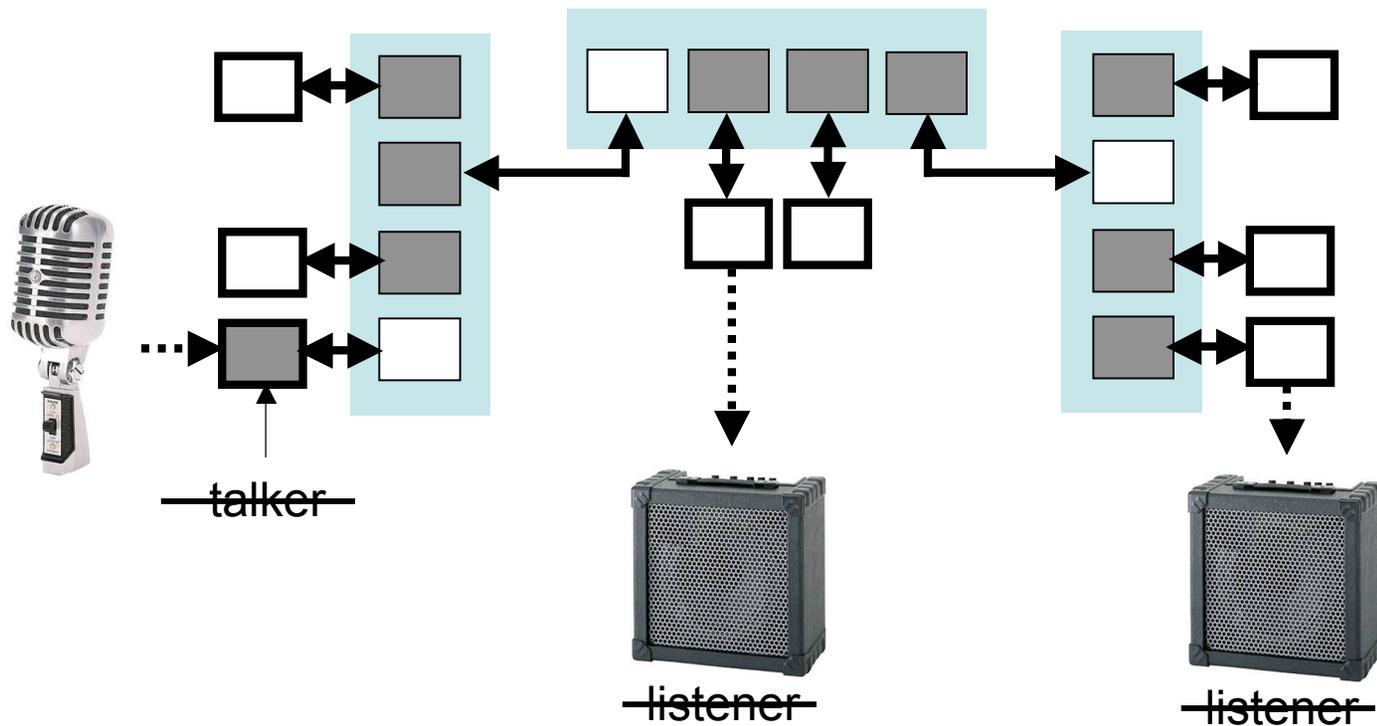
Third-party activations
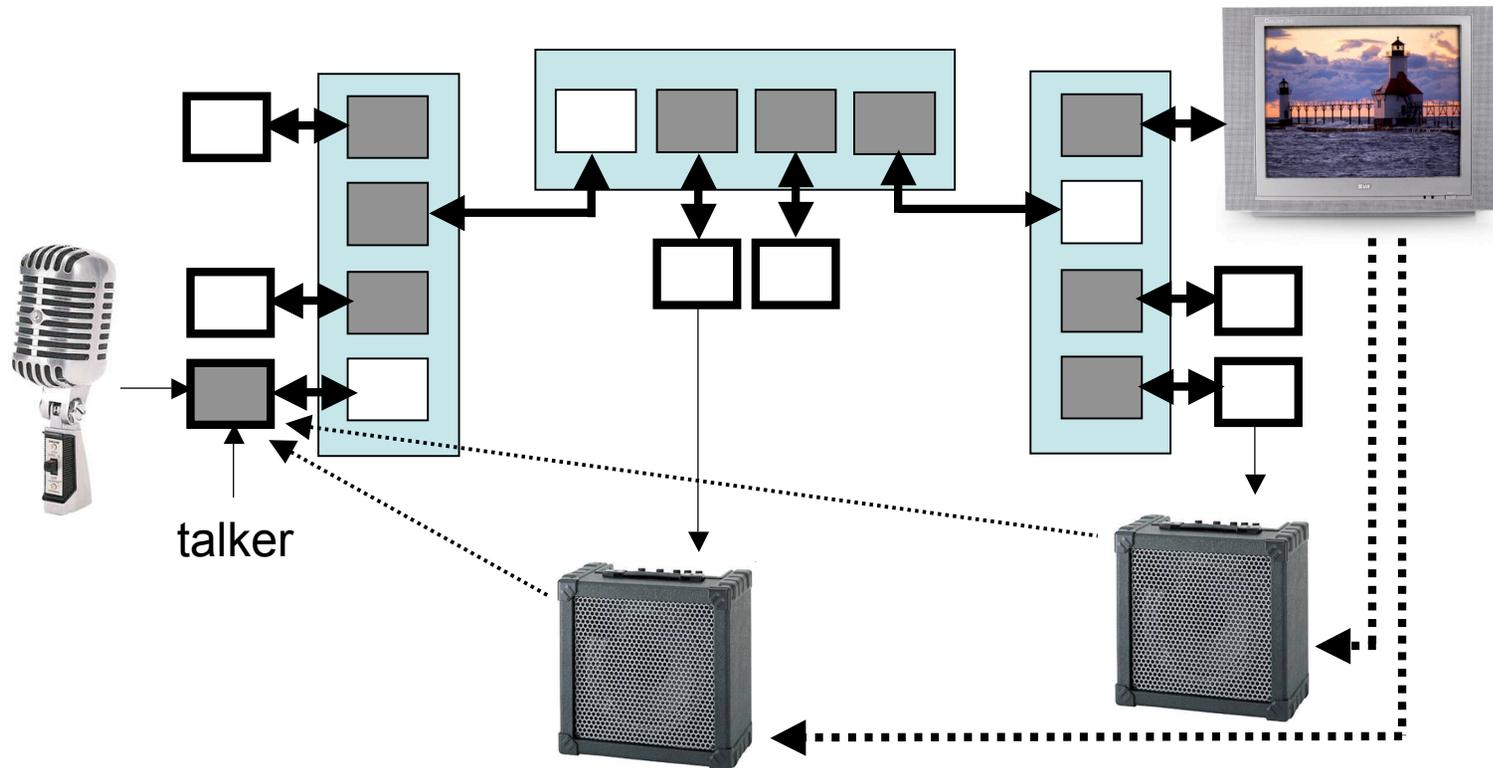
talker

Legend:

◀┅┅┅ Third-party activates the listener, provides talker's streamID

◀┈┈┈┈ Listener subscribes to the talker's streamID

Listener-initiated heartbeats (RSVP)

- RSVP based timeout strategy
  - Periodic local listener confirmations
  - Confirmations are really just subscription requests
  - Tolerate single-frame losses
  - Tolerates configuration changes
- Talker "leaves" if no requests observed
- Listener "leaves" if no responses returns
- Talker "responses"
  - Is the flow of isochronous traffic sufficient?

Subscription requests

Frame format

destinationAddress	**Endpoint talker**
sourceAddress	**Local listener**
type/length	
otherInfo	**Endpoint listener** **Talker's plug** **Required bandwidth**
FCS	
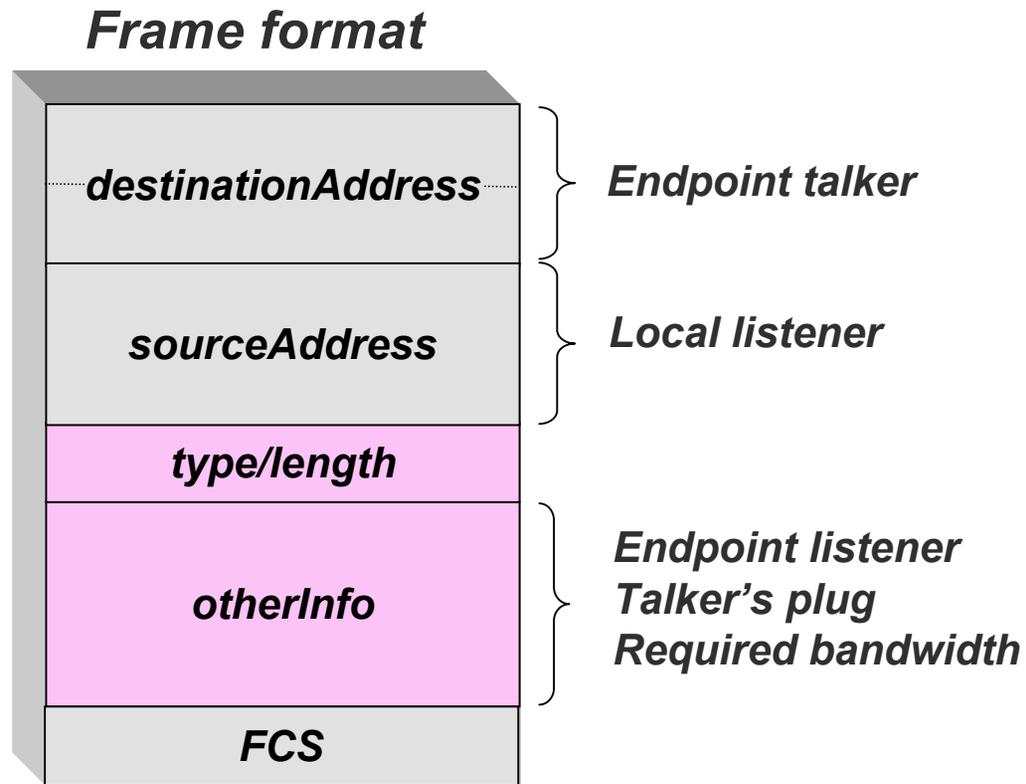
Stream addressing?

- A New Resource ReSerVation Protocol (RSVP)

  (Again, in the Internet context a data source can be specified by the source host address plus source port number. We only refer to the source host address here.)

Stream addressing?
(a possibility)

Frame

destinationAddress

sourceAddress

type/length

otherInfo

FCS

sourceAddress | plugID

static assignments
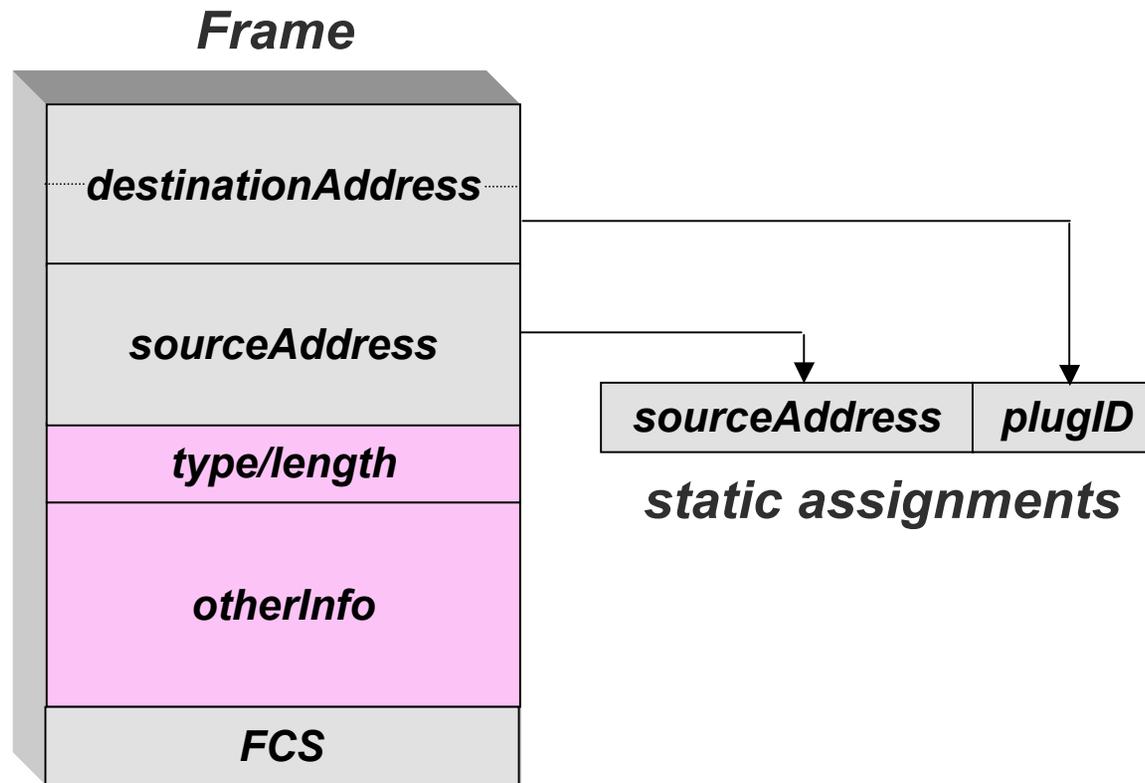
StreamID details
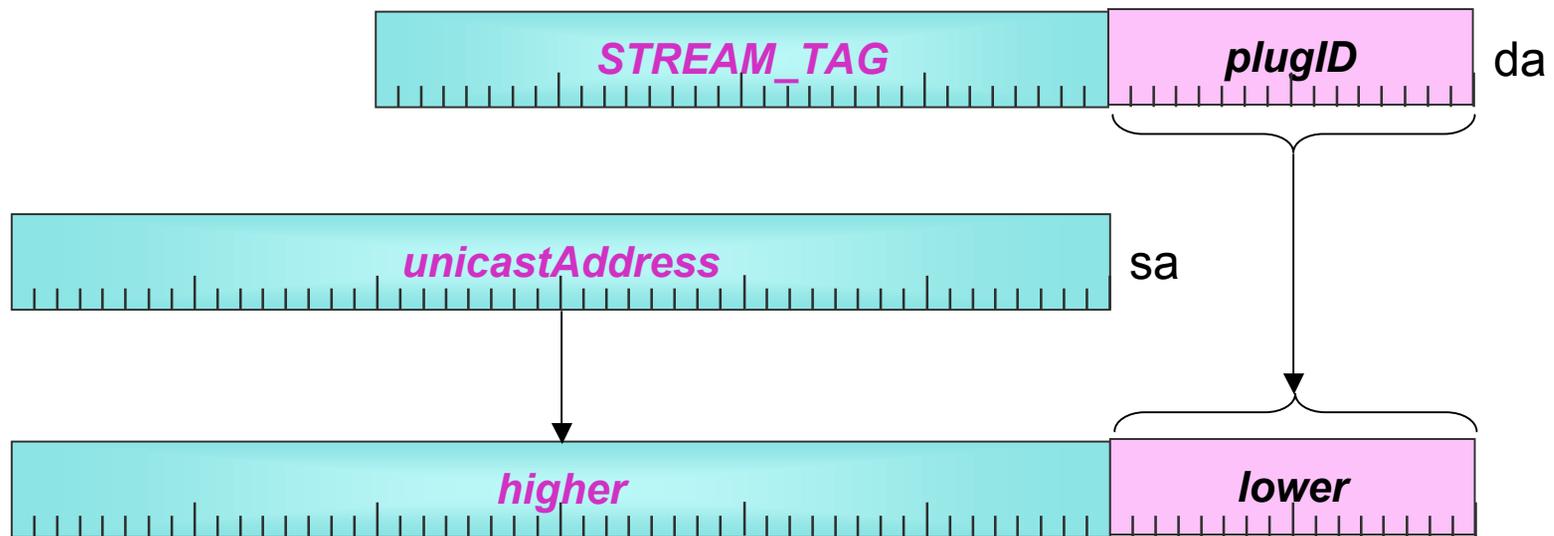
Are bridge changes necessary?

– End-station throttling (assuming highest priority)

   • With 1Gb/s switches, this may be sufficient

– Source device spreads transmissions evenly

   • Bunching may be tolerable within the home (needs study)

   • Must ensure that nothing else uses the highest priority

– But, some access control changes needed anyway

   • Bridges are naturally encountered along the path

   • Central topology database is thus unnecessary

Summary

- We need an RSVP-like lower level protocol
  - Restricted to 1-to-N traffic
  - Restricted to "no-filter" streams

- The IP admission control alternative
  - Out of scope
  - Layering violations (non-IP synchronous traffic?)
  - Not generally supported by residential bridges
  - Multiple components (and synchronized use) required:
    - A multicast address server?
    - IGMP/snooping for multicast setup?
    - RSVP/snooping for bandwidth negotiation?

Clock synchronization
(a Residential Ethernet SG presentation)

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San Francisco

Leveraged protocols

- ## Spanning tree protocol (STP)
  - Defines the grand-master precedence format
  - But, we use a distinct value and distribution protocol (The STP root and grand master could be distinct!)

- ## NTP (RFC-1305) and SNTP (RFC-2030)
  - Definition of the 64-bit time-of-day value

- ## IEEE 1588-2002
  - Techniques for delayed-sampling synchronization

Overview

- ## What?
  - The clock slaves time-of-day tracks the grand master
  - No requirement for slaves to be clock-synchronous

- ## How?
  - Periodic exchanges of small messages

- ## Why?
  - Bridges: synchronized 125us cycles
  - Applications: accurate presentation times