Precise Timing in a Residential Ethernet Environment

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Agenda

- Introduction to Residential Ethernet
- Timing synchronization in ResE
- Differences between IEEE 1588 and ResE
- Using ResE as an IEEE 1588 subnet

Introduction to Residential Ethernet

What is Residential Ethernet?

- Simple enhancement to IEEE 802.1 bridges to support streaming QoS
  - 2 ms guaranteed latency through 7 bridges
  - Admission controls (reservations) for guaranteed bandwidth
  - Precise timing and synchronization services for timestamps and media coordination
    - May require extra timing service from 802.3 MAC
- Trade group to provide trademark "enforcement" of otherwise optional features
  - Require useful bridge performance, network management, PoE management, auto-configuration features

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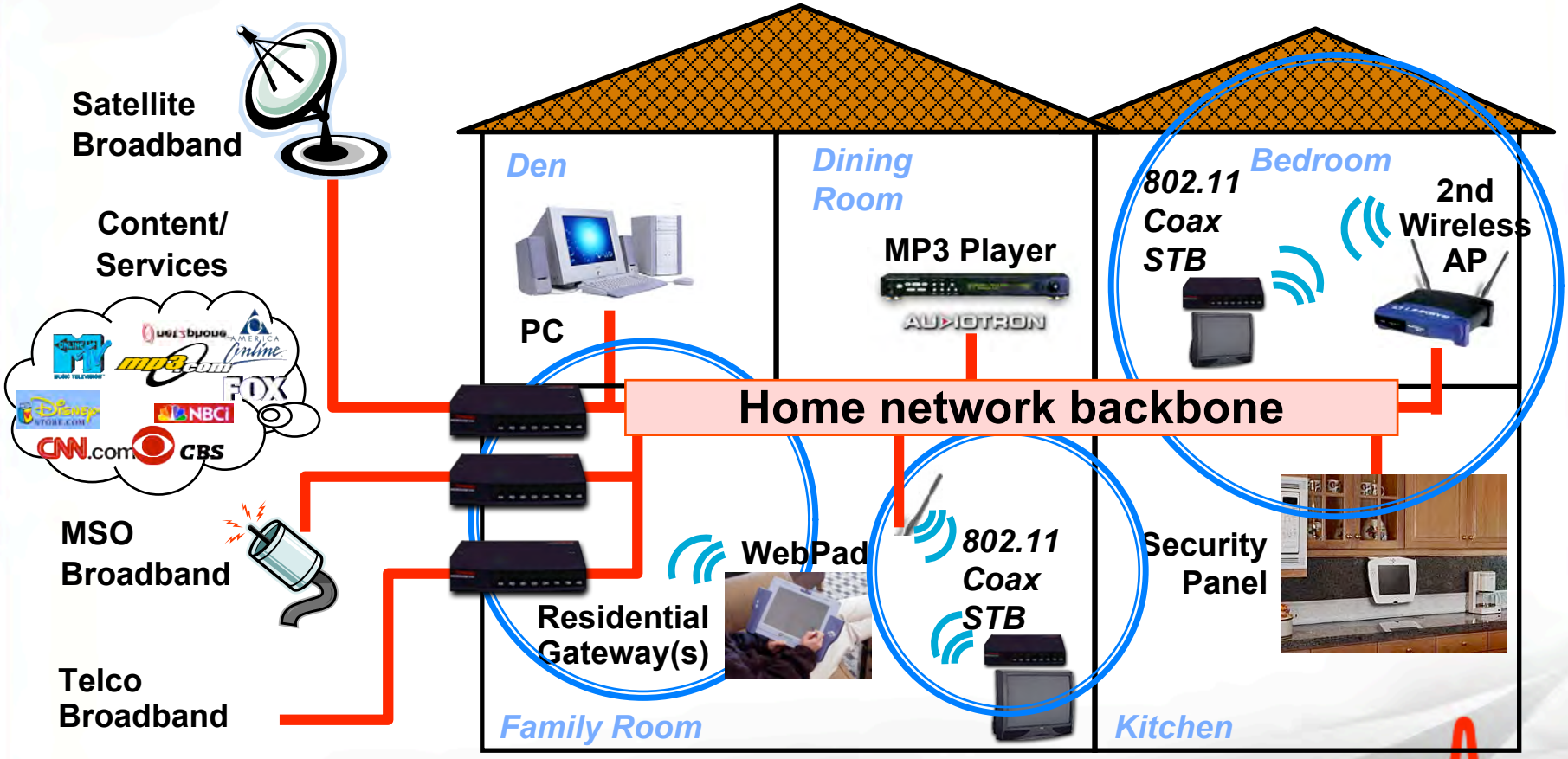
Why is it needed? (1)

- Common IT-oriented networks have inadequate QoS controls
- All use 802.1 “priorities” (actually, “traffic class”)
  - Ethernet is the best
    - … but it’s easy for the customer to misconfigure or overload
    - … no guarantees
  - Wireless has inadequate bandwidth and excessive delays for whole-home coverage
    - … 802.11n and UWB work for non-critical applications, or short range
    - … no guarantees
    - … and the backbone for the wireless attachment points is?

Why is it needed? (2)

- Proposed CE-based networks need new media or are expensive
  - MoCA requires coax everywhere, and is not cheap, and does not carry power, and has modest performance
    - … but it's part of the solution
  - Power line is not cheap, has modest performance, is susceptible to interference, and is blocked by protection circuits
    - … but it's part of the solution
  - 1394b/c long distance requires optical fiber or CAT-5, is not cheap
    - … but even this is part of the solution

Digital Home Media Distribution



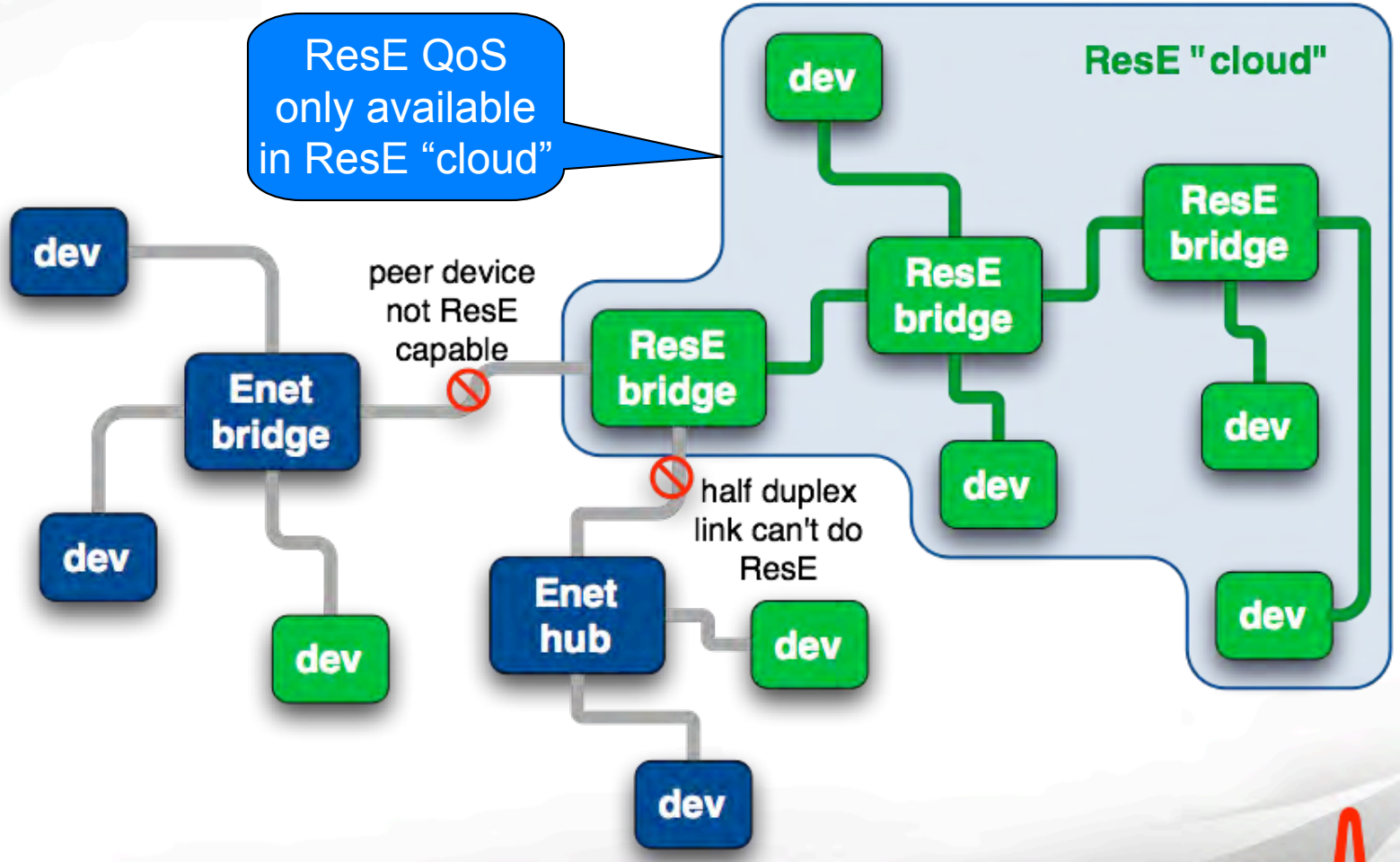
Where will Residential Ethernet be used?

- Backbone for home
  - Highest quality/lowest cost way to interconnect wireless A/Ps
  - "Perfect" QoS, requires the least customer interaction
- Within the entertainment cluster
  - Trivial wiring, no configuration, guaranteed 100/1G/2.5G *per device*, not just *per room*
  - PoE for speakers, extra storage (HD/optical), wireless A/Ps, other lower-power devices
  - Ideal long-term replacement for 1394
- Numerous non-"residential" applications
  - Professional audio/video studios
  - Industrial automation
  - Test and measurement

Proposed architecture

- Propose changes to both IEEE 802.3 (Ethernet) and IEEE 802.1Q (bridges/switches)
- Three basic additions to 802.3/802.1
  - Traffic shaping and prioritizing,
  - Admission controls, and
  - Precise synchronization

Topology & connectivity



Traffic Shaping and Priorties

- Endpoints of ResE network must “shape traffic”
  - Schedule transmissions of streaming data to prevent bunching, which causes overloading of network resources (mainly switch buffers)
  - Probably limit by “x bytes in 125usec” and “x bytes in 2ms” depending on traffic class
- Mapping between traffic class and priorities

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Traffic Class?

- 802.1p introduced 8 different traffic classes
  - Usually implemented as strict priorities
  - Highest (7 & 8) reserved for network management (low utilization)
  - Next two for streaming (5 & 6)
  - Lowest four for “best effort”
- Proposal:
  - Class 6 is for lowest latency streaming
    - Roughly 125usec per bridge hop: interactive audio/video
  - Class 5 is for moderate latency streaming
    - Perhaps 2ms per bridge hop: voice over IP, movies

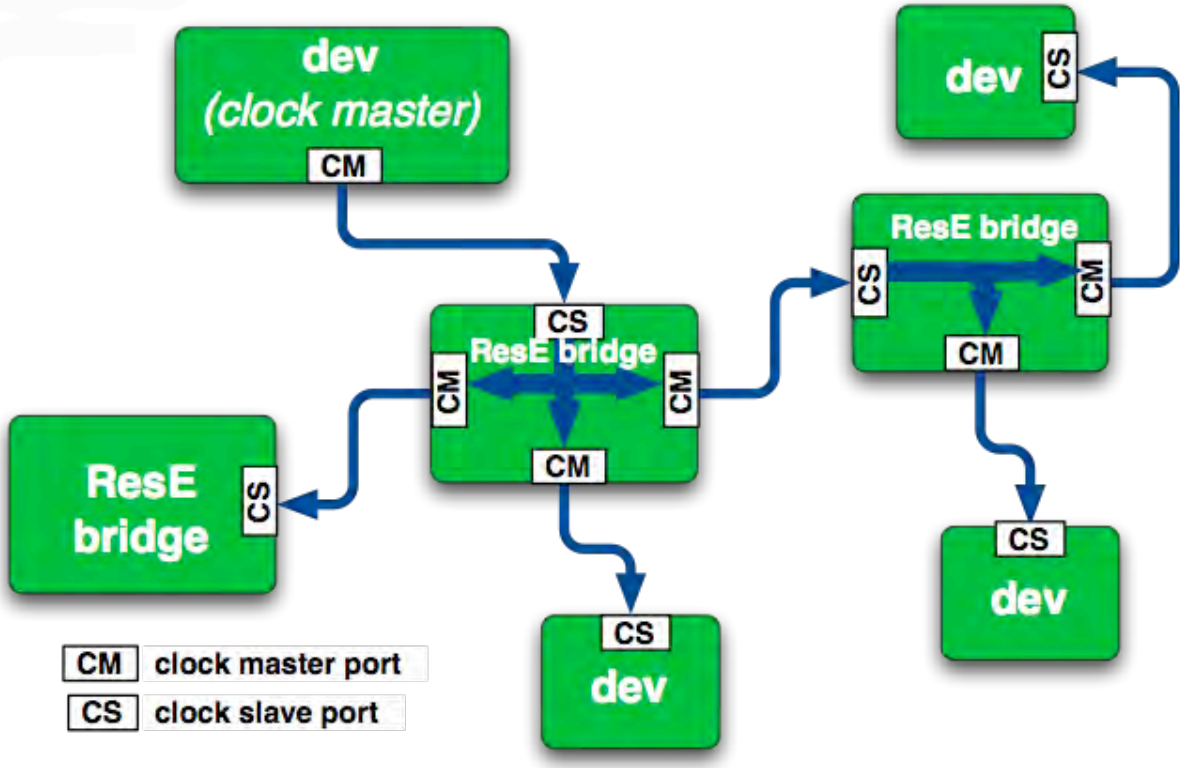
Admission controls

- Streaming priority mechanism can reliably deliver data with a deterministic low latency and low jitter
  - but only if the network resources (bandwidth, in particular) are available along the entire path from the talker to the listener(s).
- For ResE it is the listener's responsibility to guarantee the path is available and to reserve the resources.
- Done via a new 802.1ak "Multiple Registration Protocol" application: SRP ("Simple Registration Protocol")
  - Registers streams as multicast address/bandwidth needed pairs

Precise synchronization

- ResE devices will periodically exchange timing information
  - both devices synchronize their time-of-day clock very precisely.
- This precise synchronization has two purposes:
  - to enable streaming traffic shaping and
  - provide a common time base for sampling data streams at a source device and presenting those streams at the destination device with the same relative timing.

Network master clock



- There is a single device within a ResE "cloud" that provides a master timing signal.
  - All other devices synchronize their clocks with this master.

Master clock selection

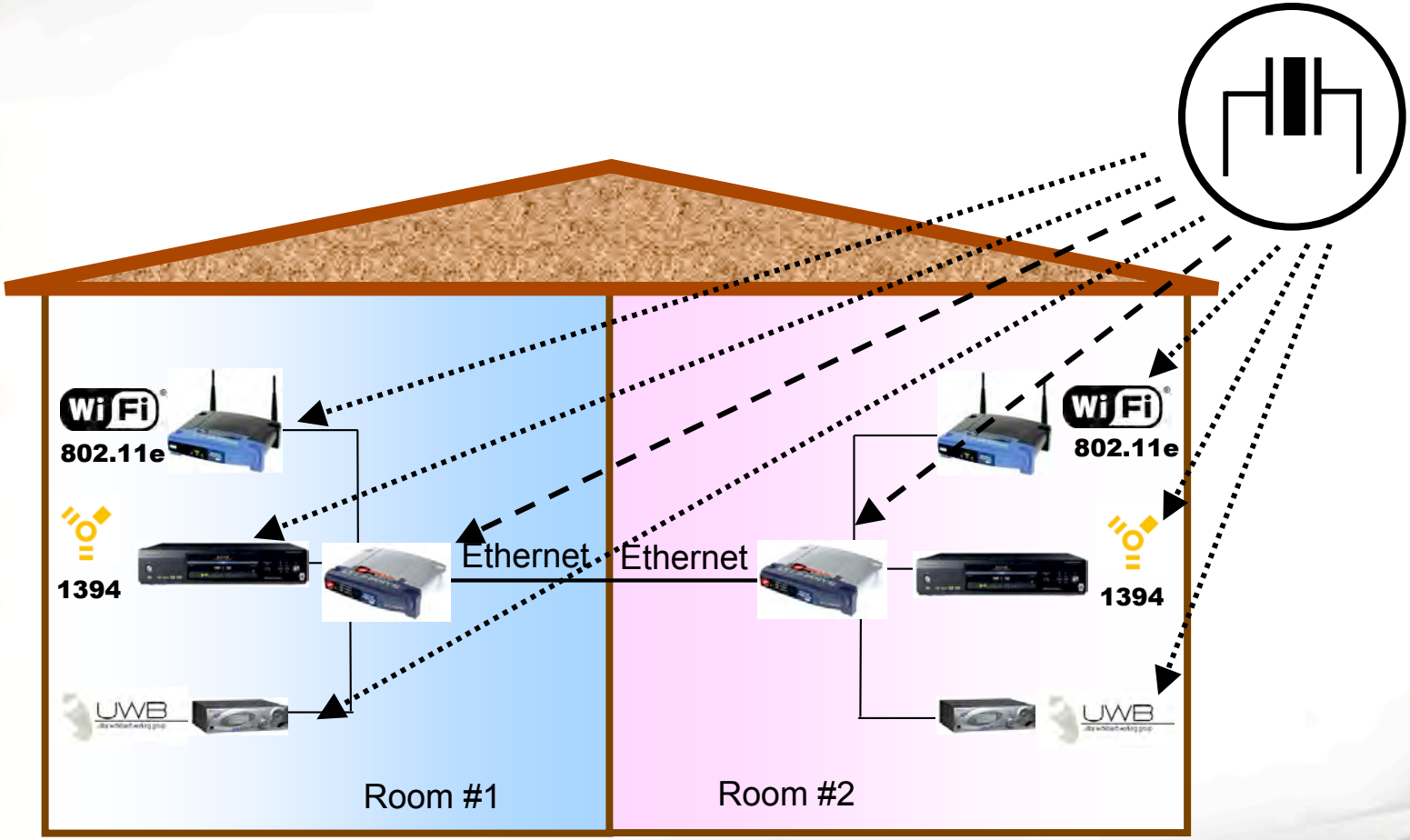
- Selection of the master is largely arbitrary (all ResE devices will be master-capable), but can be overridden if the network is used in an environment that already has a “house clock”.
  - Professional A/V studios
  - Homes with provider 1588 service

Changes needed in existing products

- Endpoint device needs
  - Timer
  - Streaming traffic transmit FIFO(s)
    - (streaming receive use existing FIFO)
  - Best to have dedicated ports for streaming data
    - MPEG-TS, I^2S, etc., like existing 1394 links
- Bridges
  - ResE MACs
  - Streaming routing/filtering
    - similar to asynch logic
  - Admission control firmware
    - similar to 802.1 multicast and VLAN management
  - Timing propagation

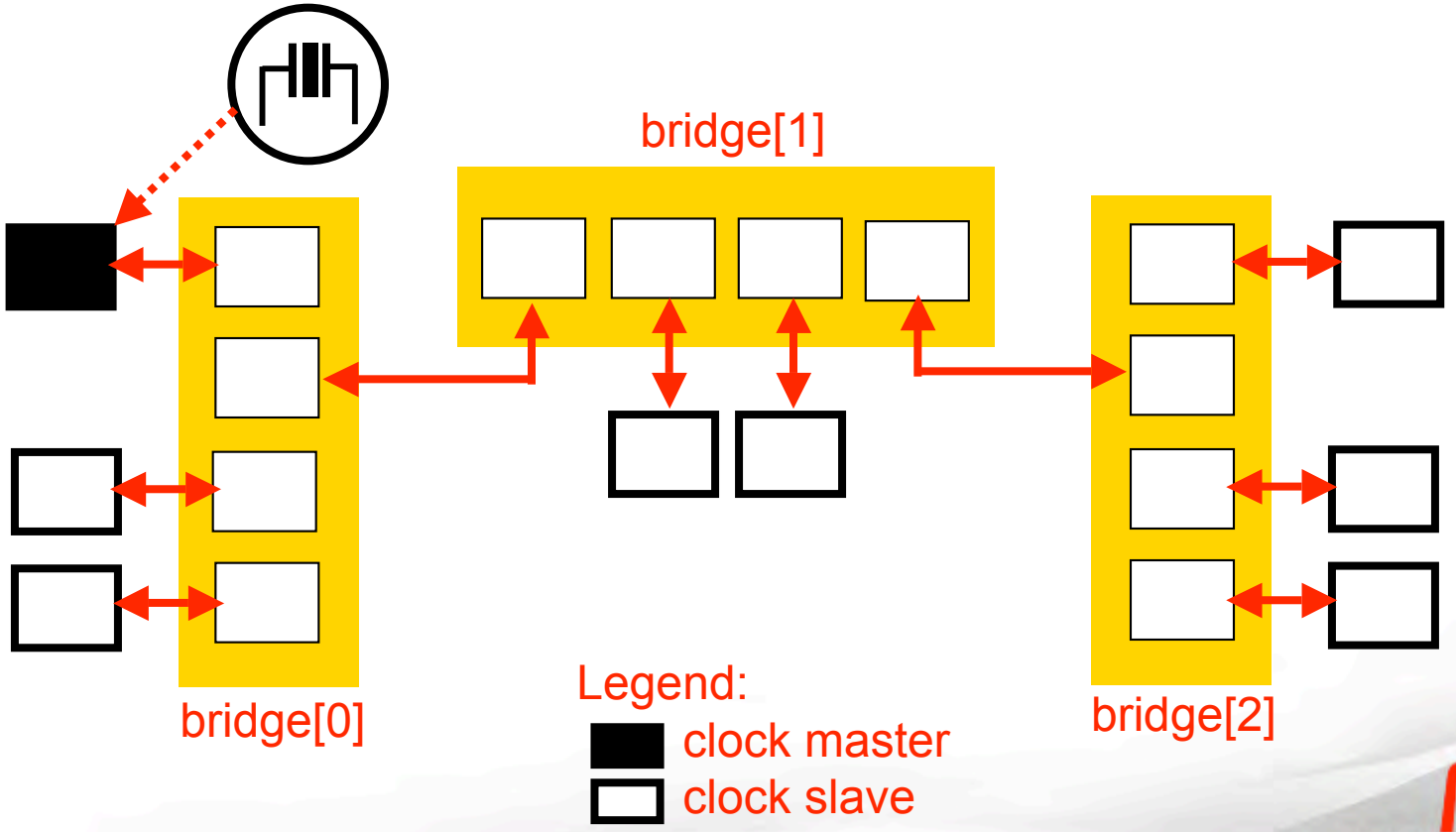
Timing Synchronization in ResE

House reference clock



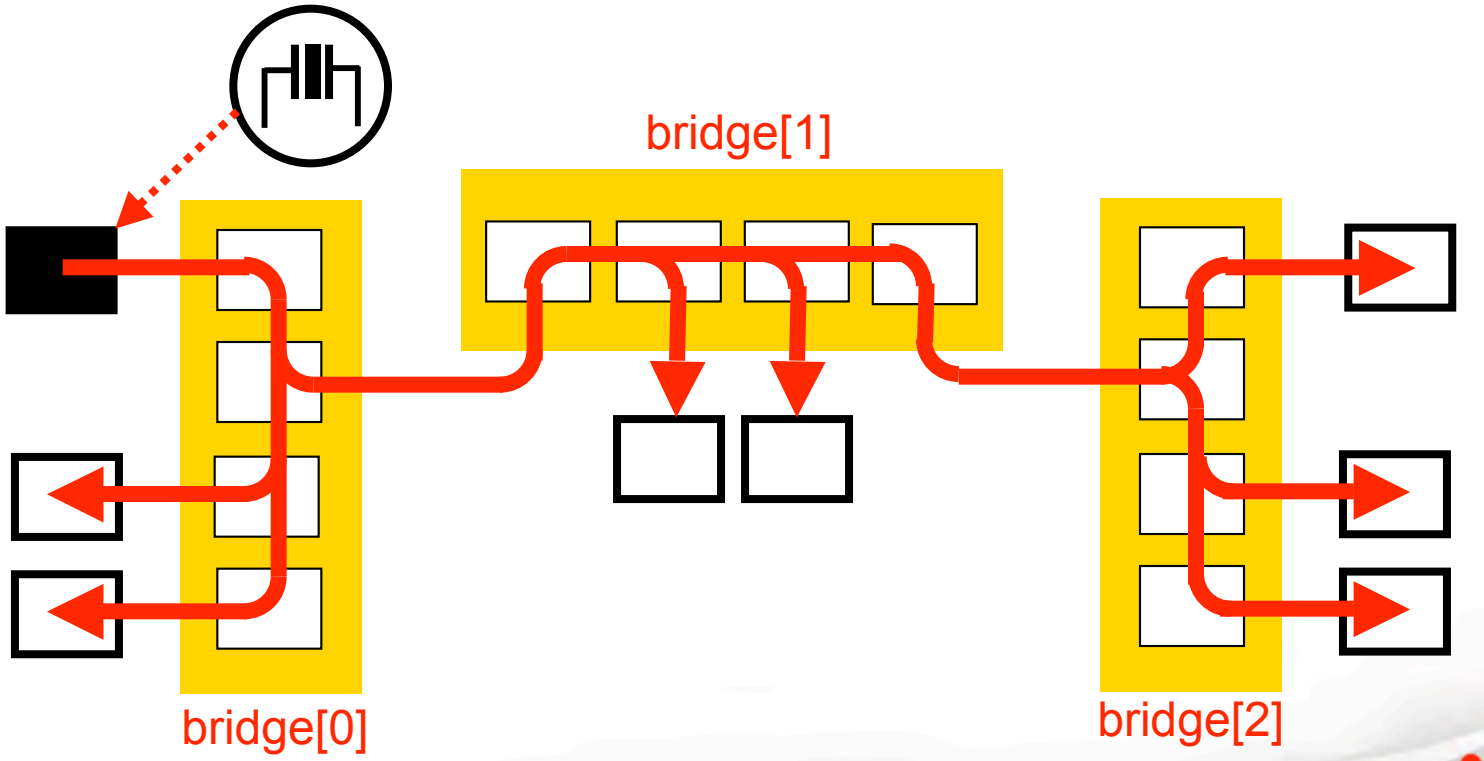
Cascaded TOD synchronization

Physical topology constraints



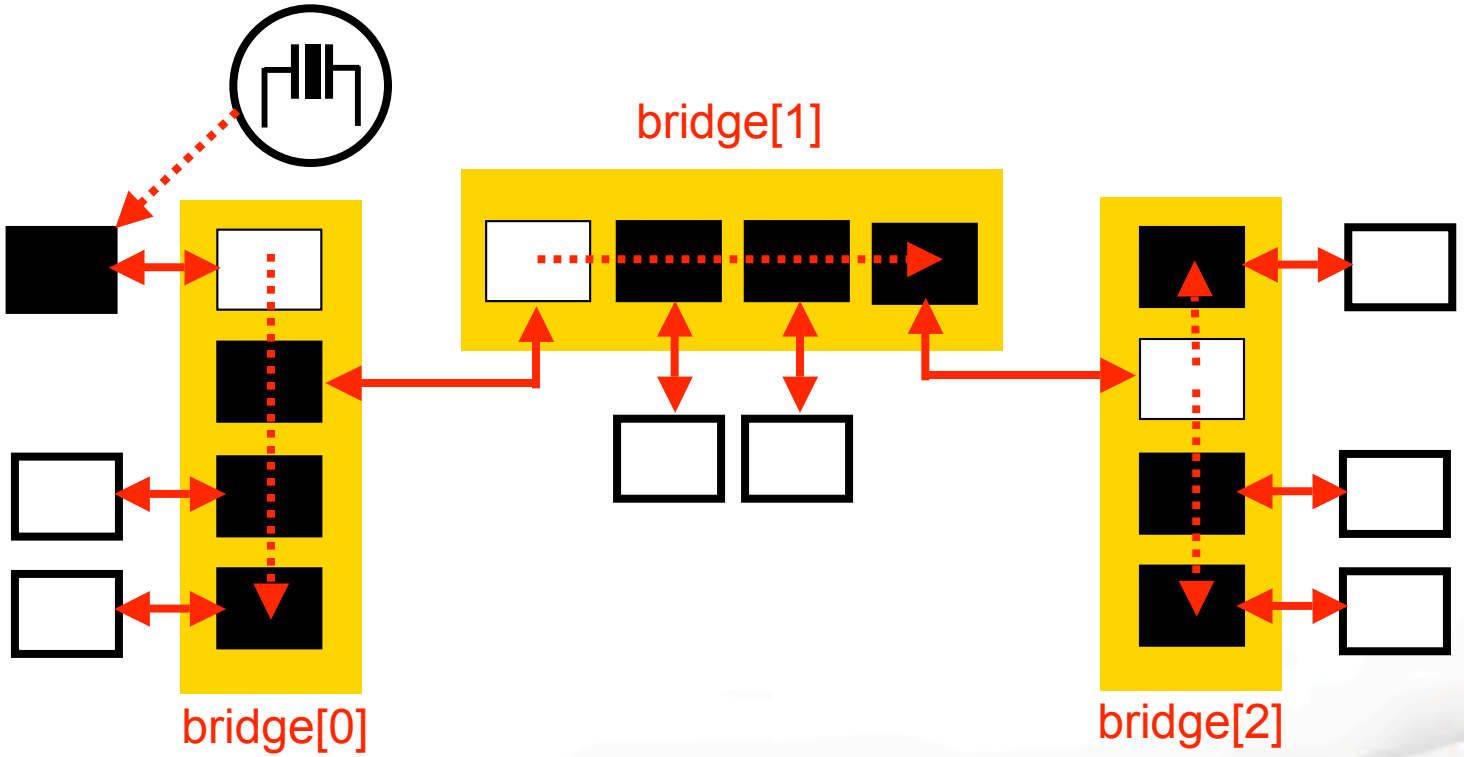
Cascaded TOD synchronization

Wall-clock distribution model



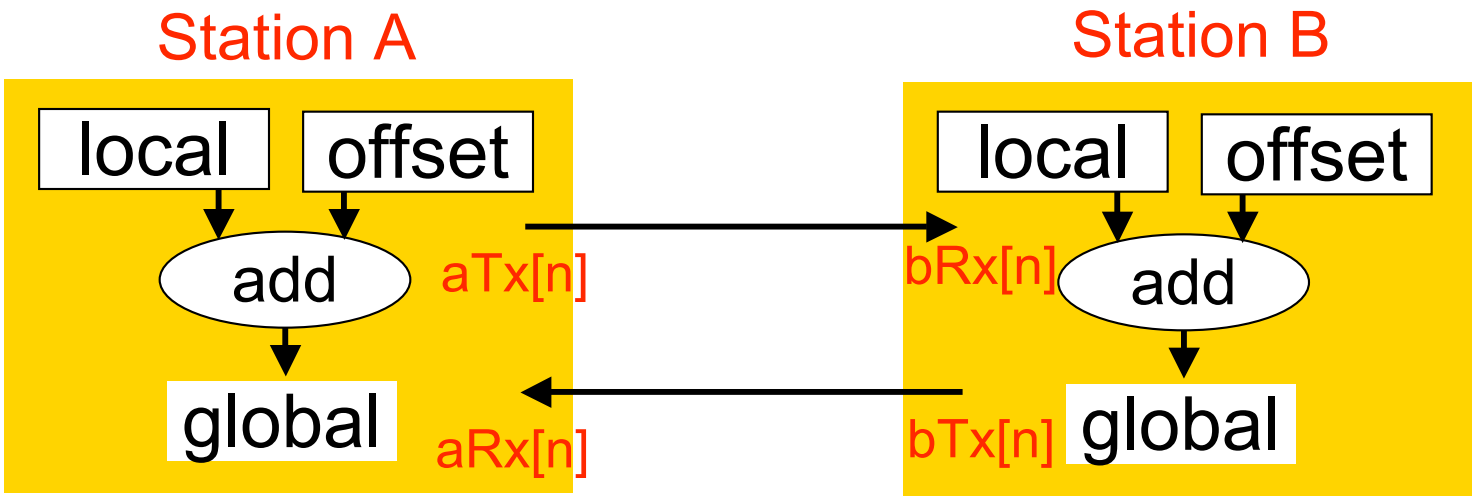
Cascaded TOD synchronization

Cascaded adjacent-synchronization hierarchy



Adjacent-station synchronization

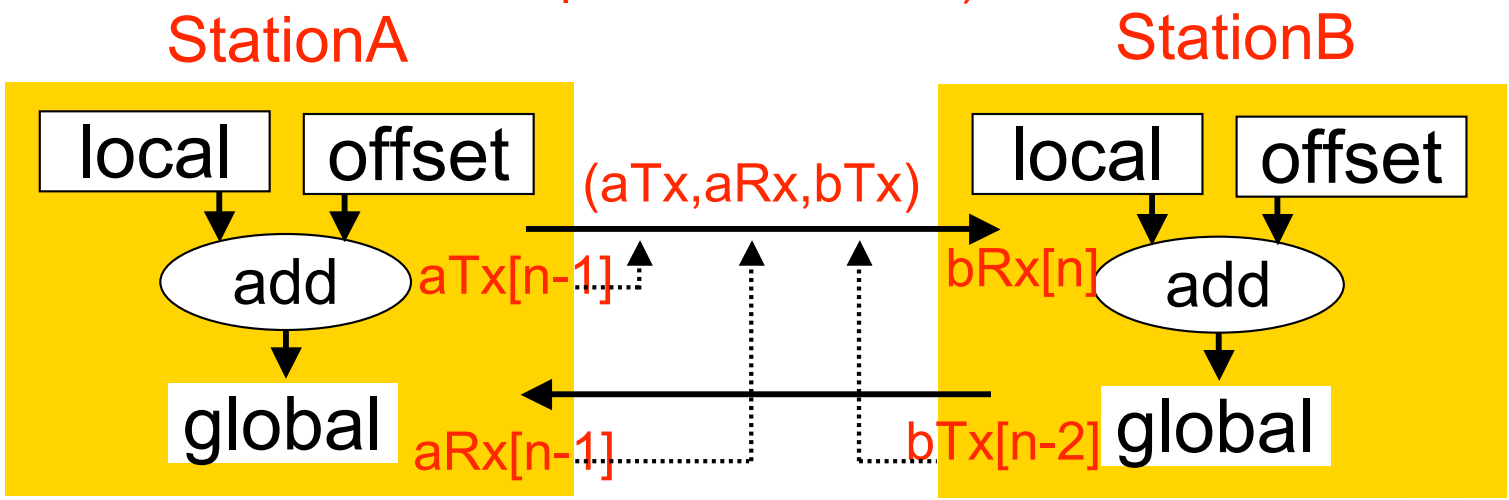
Timing snapshots



Adjacent-station synchronization

Snapshot value distribution

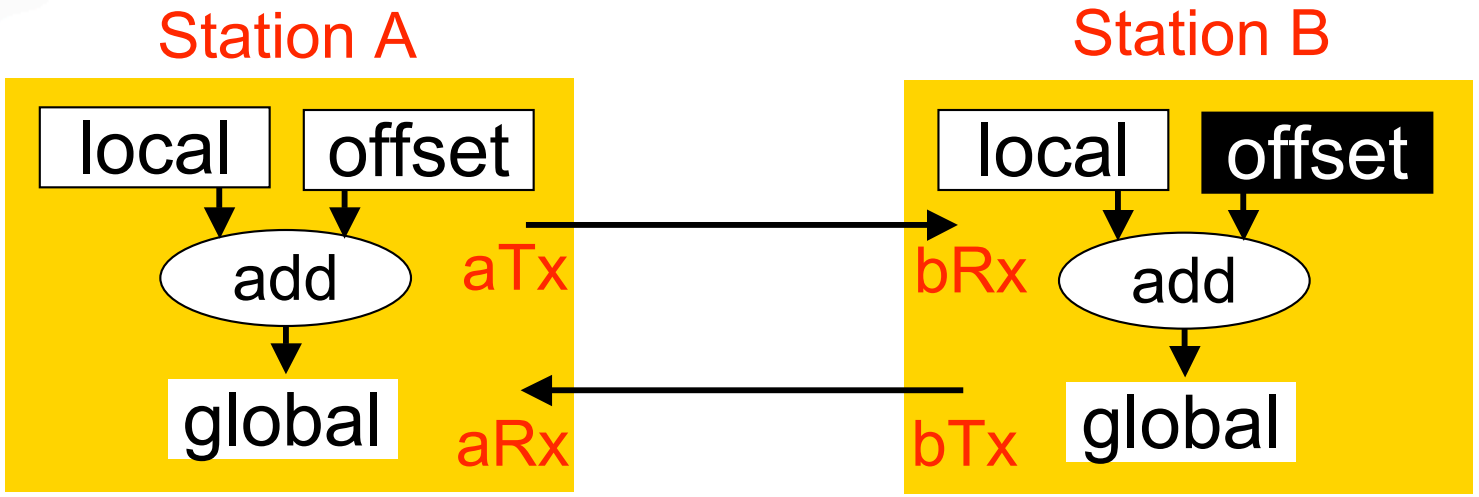
(information for stationB is time A sent previous snapshot, time A received B's previous snapshot, and time B sent snapshot before that)



Transmit timings are always for previous snapshot because they are recorded when the snapshot was sent, and are not available while the packet is in the process of being sent

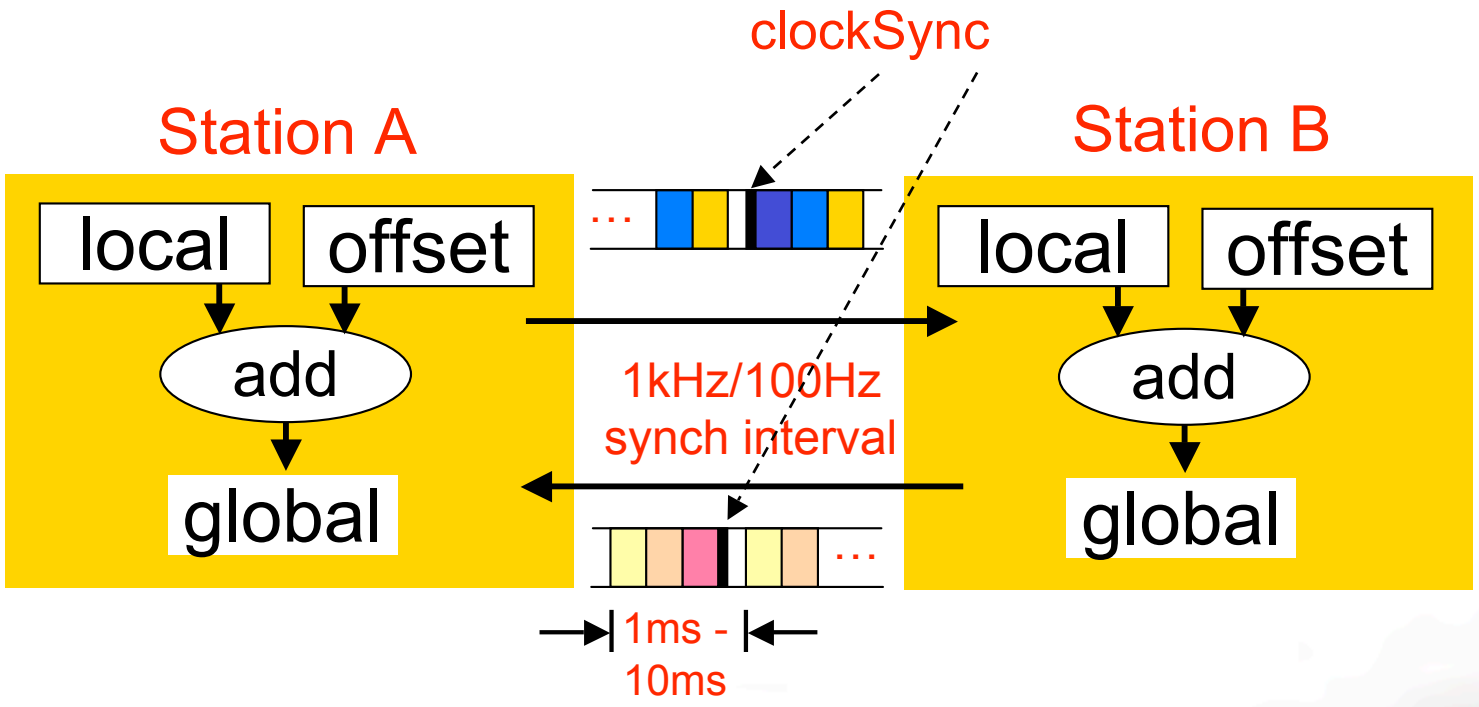
Adjacent-station synchronization

StationB offset adjustments



- **rxDelta = (bRx[n-1] – aTx[n-1]);**
- **txDelta = (bTx[n-1] – aRx[n-1]);**
- **clockDelta = (rxDelta – txDelta) / 2;**
- **cableDelay = (rxDelta + txDelta) / 2;**
- **offsetB = offsetA – clockDelta;**

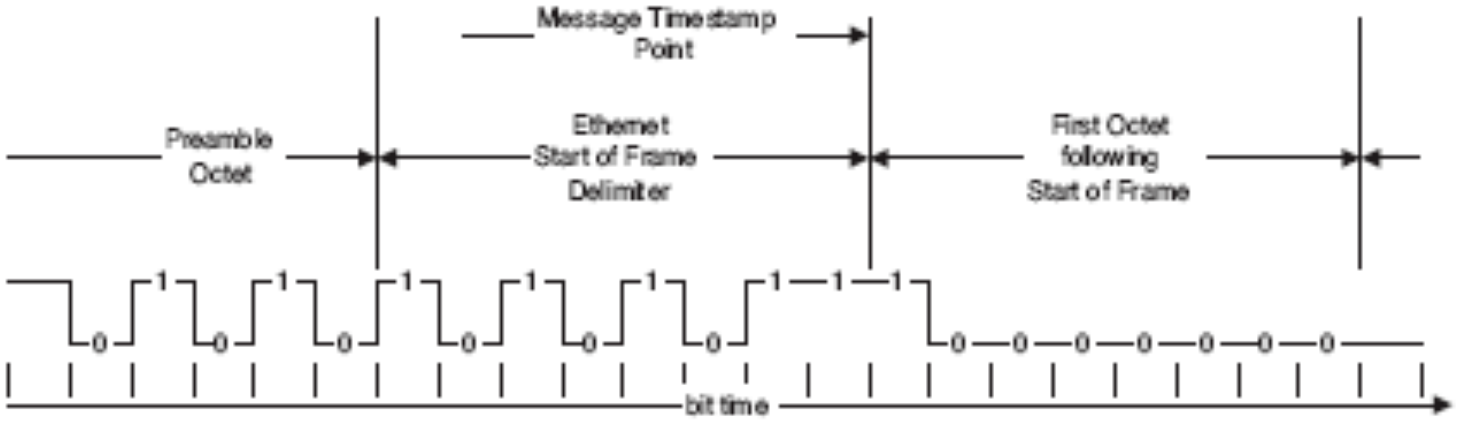
Adjacent station synchronization



Timing specifics…

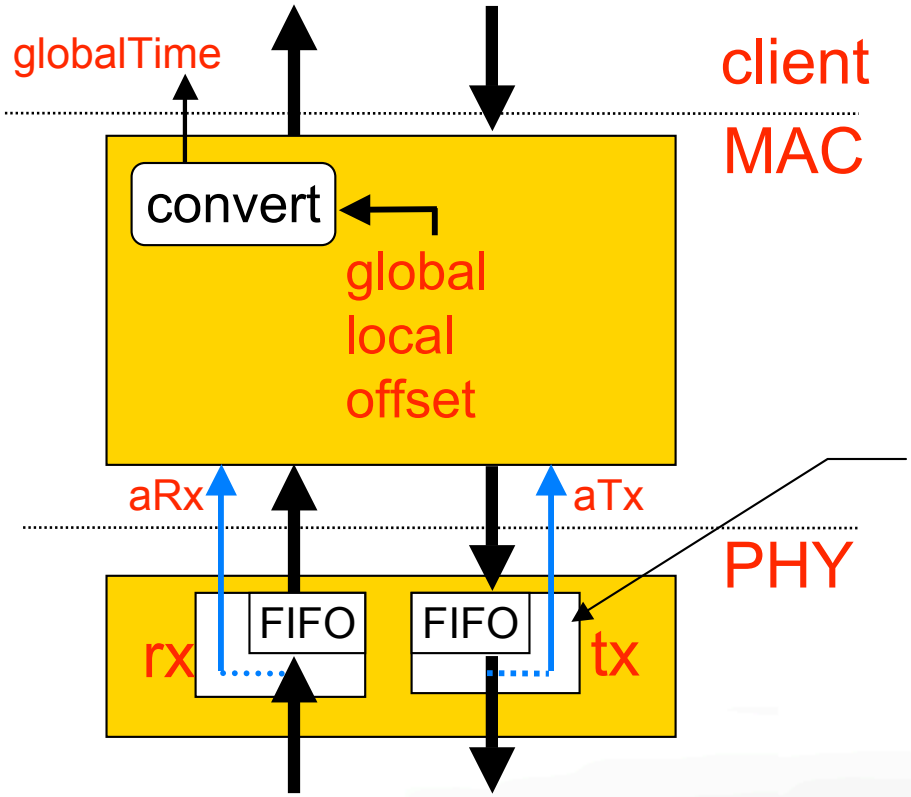
- Could add to 802.3 PHY specs:

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



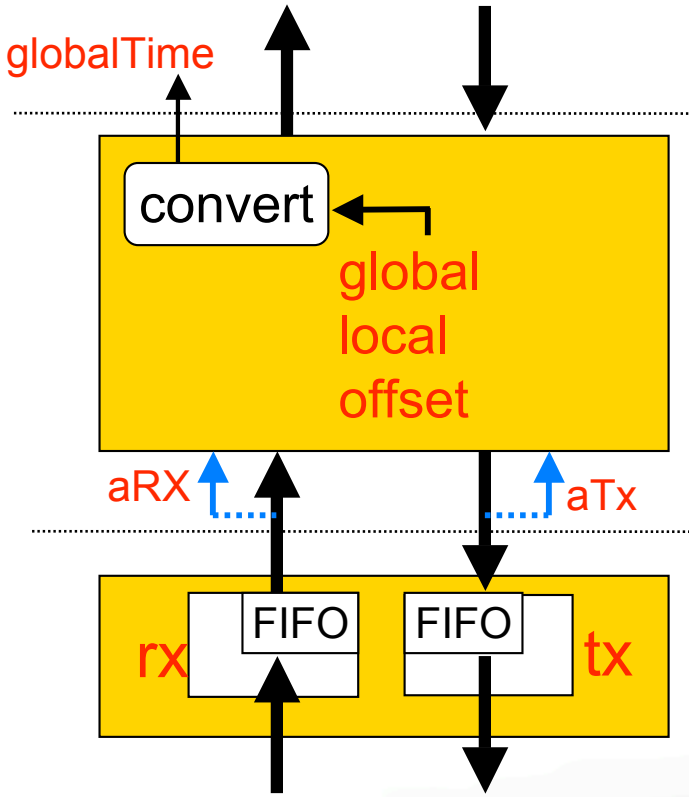
- But realistically, more likely to get "when first data symbol of frame is transmitted to or received from PHY"
  - Less precise … but ResE has frequent clock updates

A PHY-based design model



Harder to implement, since PHY design changes

A MAC-based design model



Easier to implement, since no change to PHY

Notes:

FIFOs add uncertainty, but PHY buffers are small (0-32 bits)

Differences Between ResE and 1588

Differences: No Options

- ResE must have “consumer-friendly” cost structure
  - 5 port 100baseT switches sell for US$30
  - Needs to use low cost time reference (standard crystal, much less than US$1)
- No IT manager in the home
  - Must be really self-configuring
  - Use UPnP or similar management

Differences: Two-way Only

- Scaling and cost structure dictate requiring just one method
- Two-way only for all purposes is simplest
- OK because only 100baseT and better will be used
  - And small packets (everything will fit in Ethernet-minimum 64 bytes)
  - And frequent updates (1ms - 10ms)

Differences: Direct Layer 2 Point-to-point

- ResE runs only on full duplex links
- No intermediate devices between participating nodes
  - No hubs, no non-participating switches, no routers
- Frame transport delay is tightly bound
  - Media and PHY coding/decoding are only uncertainties

Differences: Single Method for Clock Cascading

- All ResE switches are similar to boundary clocks
- Only a single method to be used for synchronizing master/slave clocks within switch
  - Garner/Hollander presentation will outline proposed methods and performance analysis

Using ResE as an IEEE 1588 Subnet

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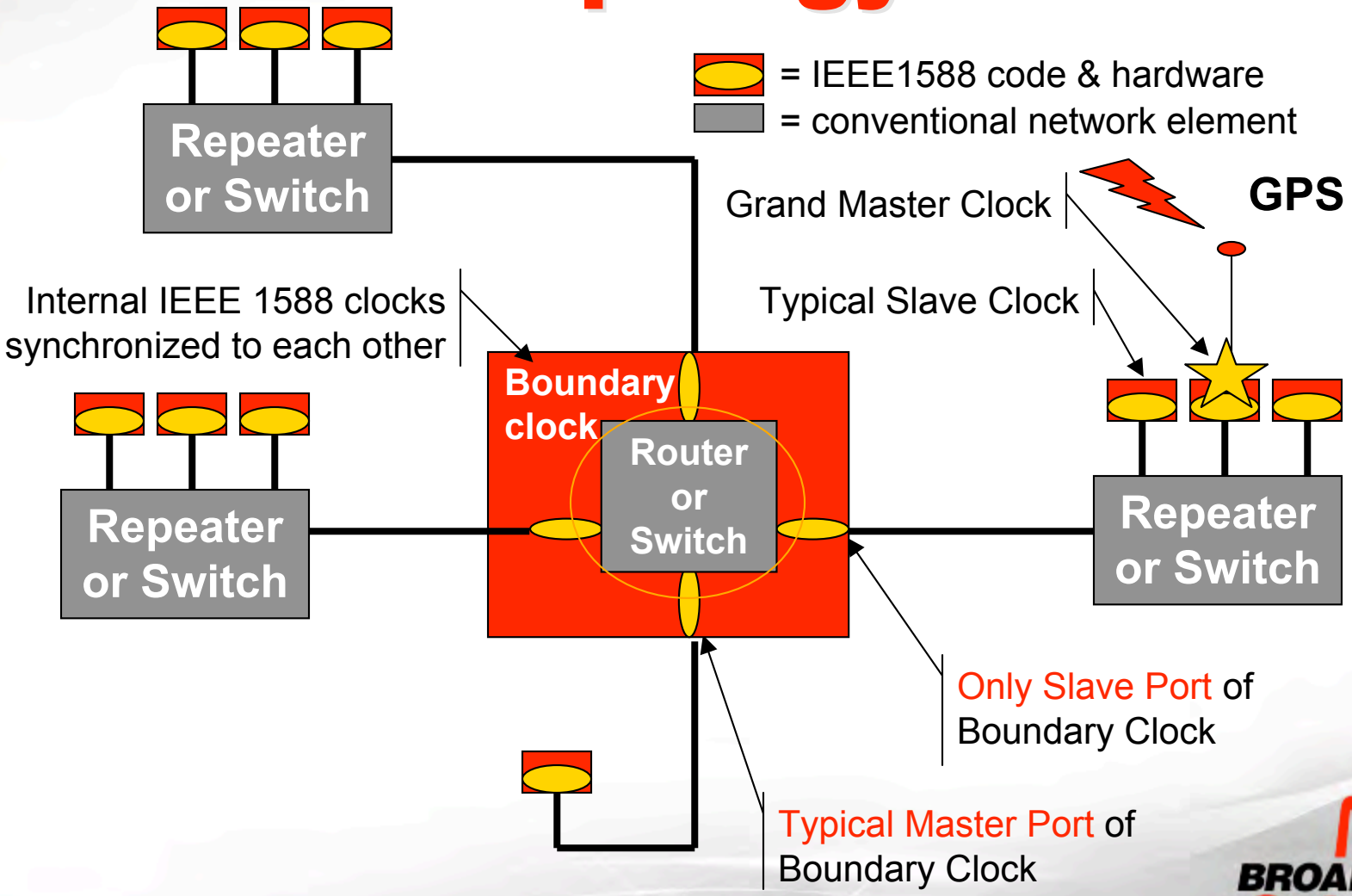
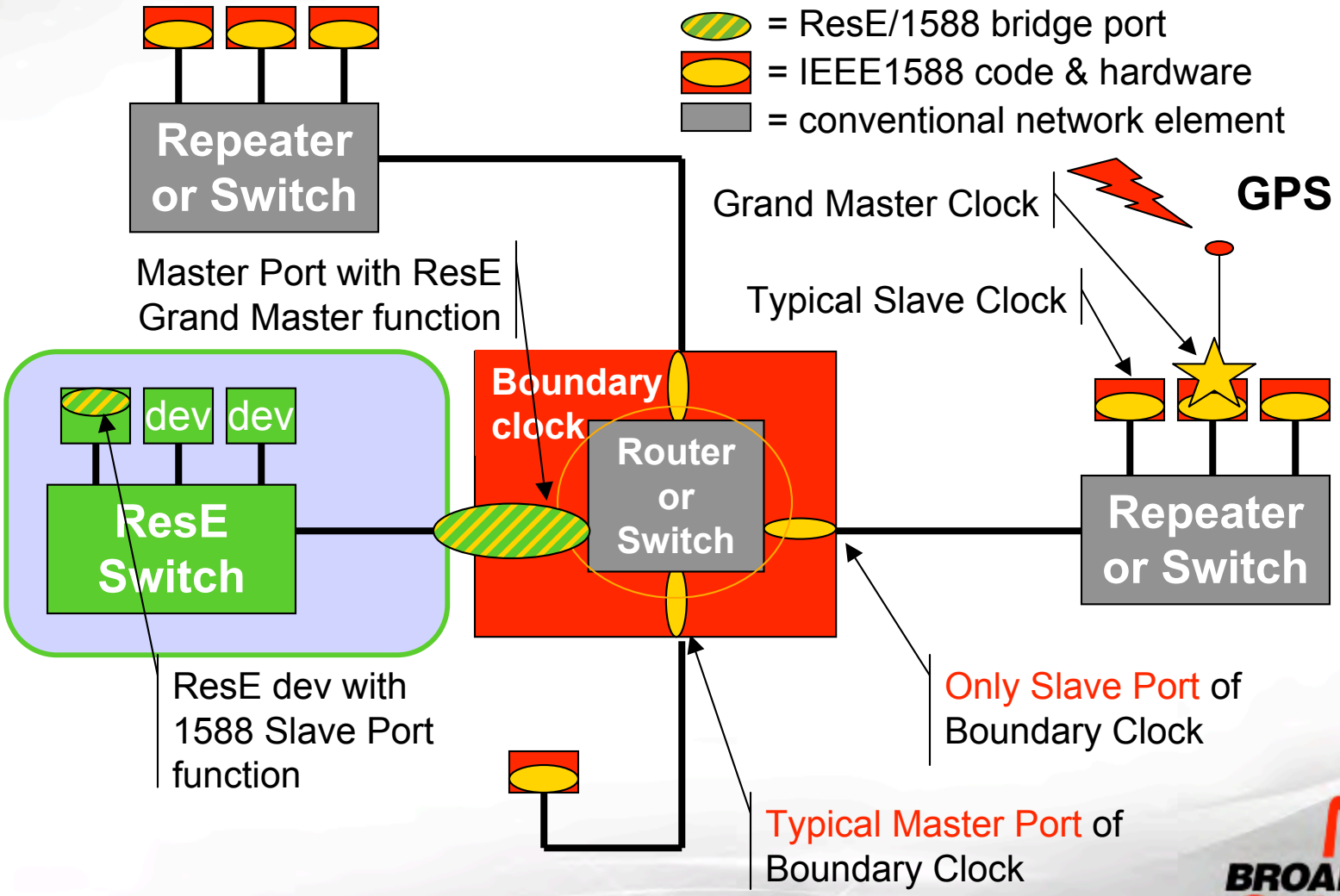
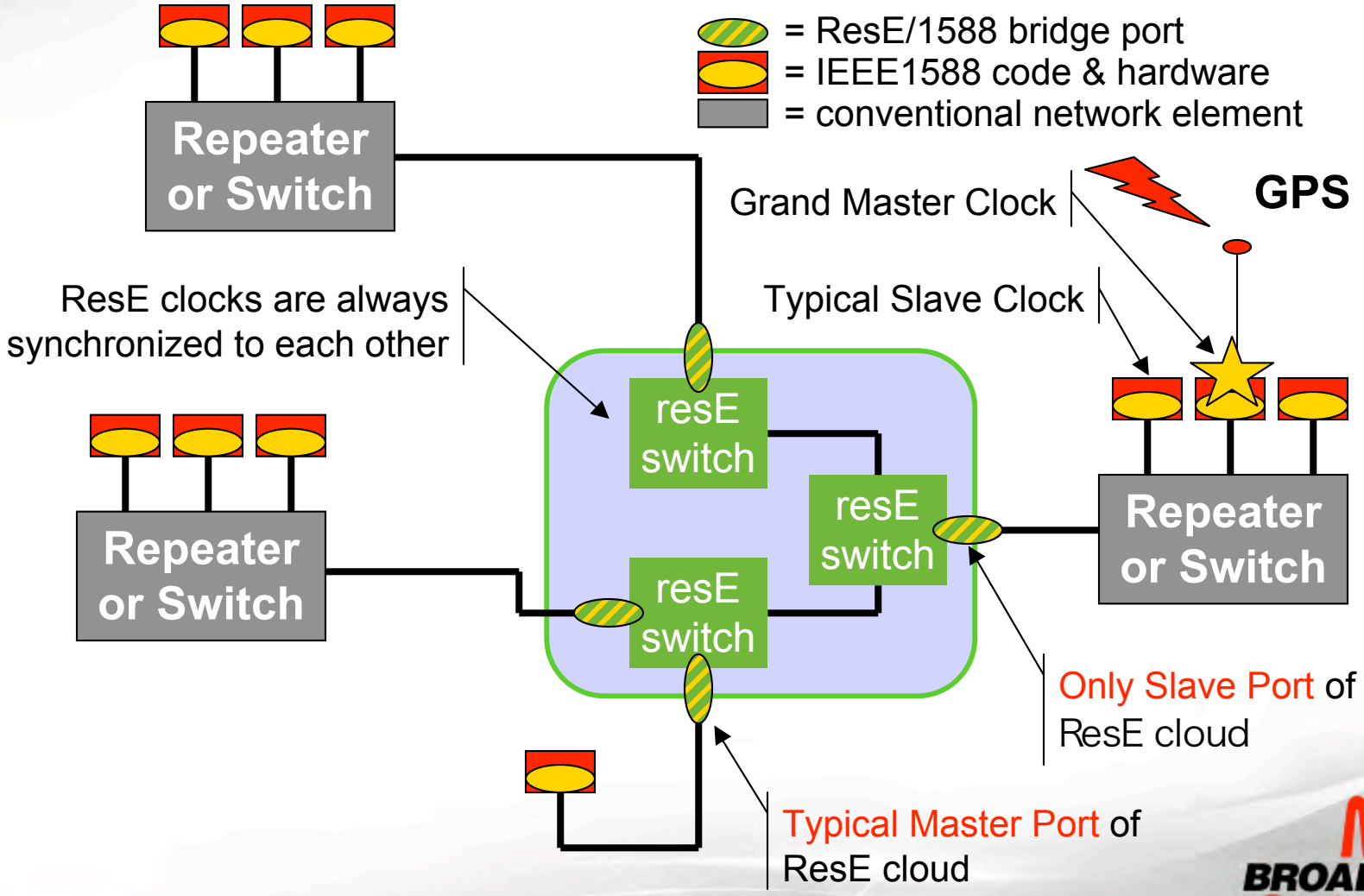
IEEE 1588 Multiple Subnet Topology



Using ResE as a Subnet



Using ResE as a Boundary Clock



Conclusions

- Residential Ethernet represents another building block in timing-aware systems
- ResE can be used as an element in a 1588 architecture
  - Providing the performance is adequate
  - Can provide either boundary clock or subnet functionality