"The Clock, not the Steam Engine, is the key machine of the modern industrial age."

Lewis Mumford (1895 - 1990) US urban planner and historian

Advanced Communications

"IEEE1588 v2 and its role in Telecom Networks"

November 2006

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So what's changing in IEEE1588 v2?

- V2 equipment is to be defined according to an industry-specific profile as much as to the IEEE standard
- V2 offers better accuracy
  - up to 1000 sync messages per second
    - this is excessive for Telecom, but has benefits for high accuracy in Test & Measurement applications (special networks)
  - correction field to carry measurable inaccuracies
- V2 bandwidth consumption is much lower
  - Timing messages are now more optimally-sized
  - Unicasting is permitted
- V2 permits various Master Clock selection methods:
  - Manual
  - Semi-automatic
  - Fully-automatic
- V2 offers more Clock types
  - Transparent Clocks
- V2 offers better security
  - Configurable network
  - HASH codes

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So what is the industry-specific profile?

V2 equipment intended for the telecom industry should be able to provide the right feature set and performance, as well as meet the new IEEE 1588 standard.

- Features should include:
  - Default message rate supported
  - Minimum number of Slaves Clocks supported (for a Master Clock device)
  - Clock-selection mechanism supported
  - Minimum output noise performance

The profile should be defined by a widely-recognised industry body (e.g., the ITU for a telecoms application)

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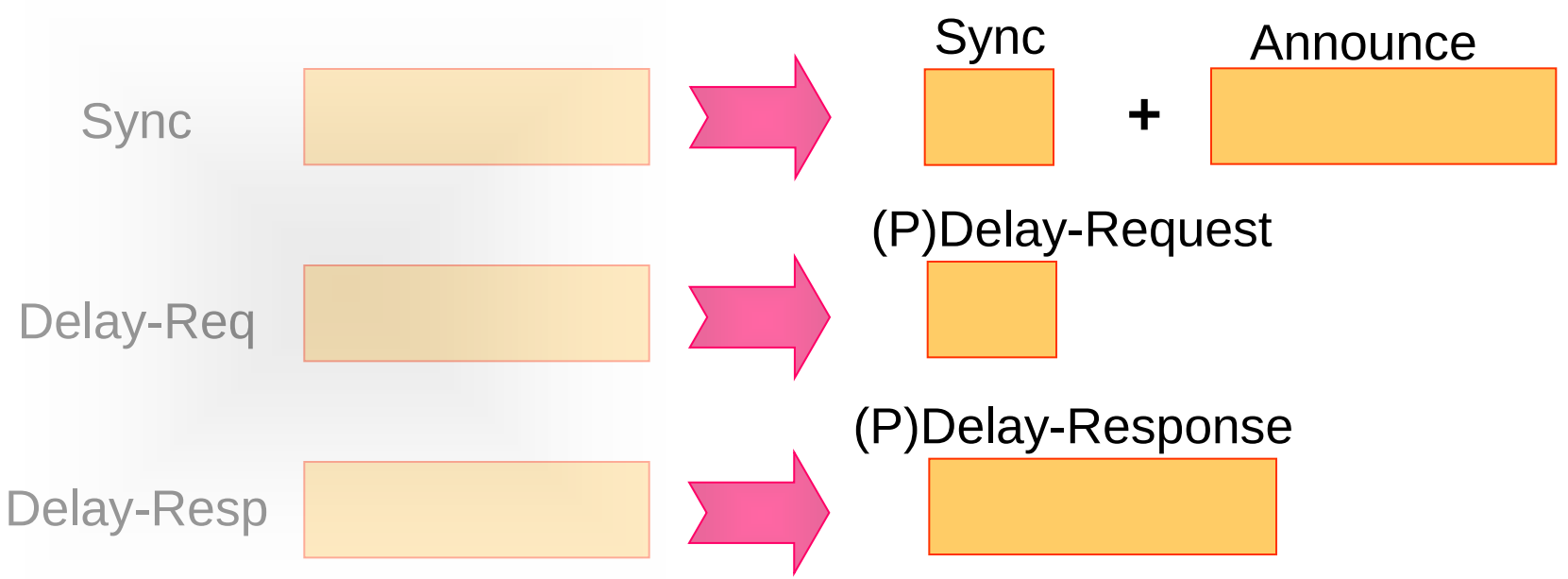
How have the message formats changed in v2?



Event Messages: Sync, (P)Delay-Req: 64-byte message

General Messages: Announce, Follow-up + (P)Delay-Resp messages: 200+ byte messages

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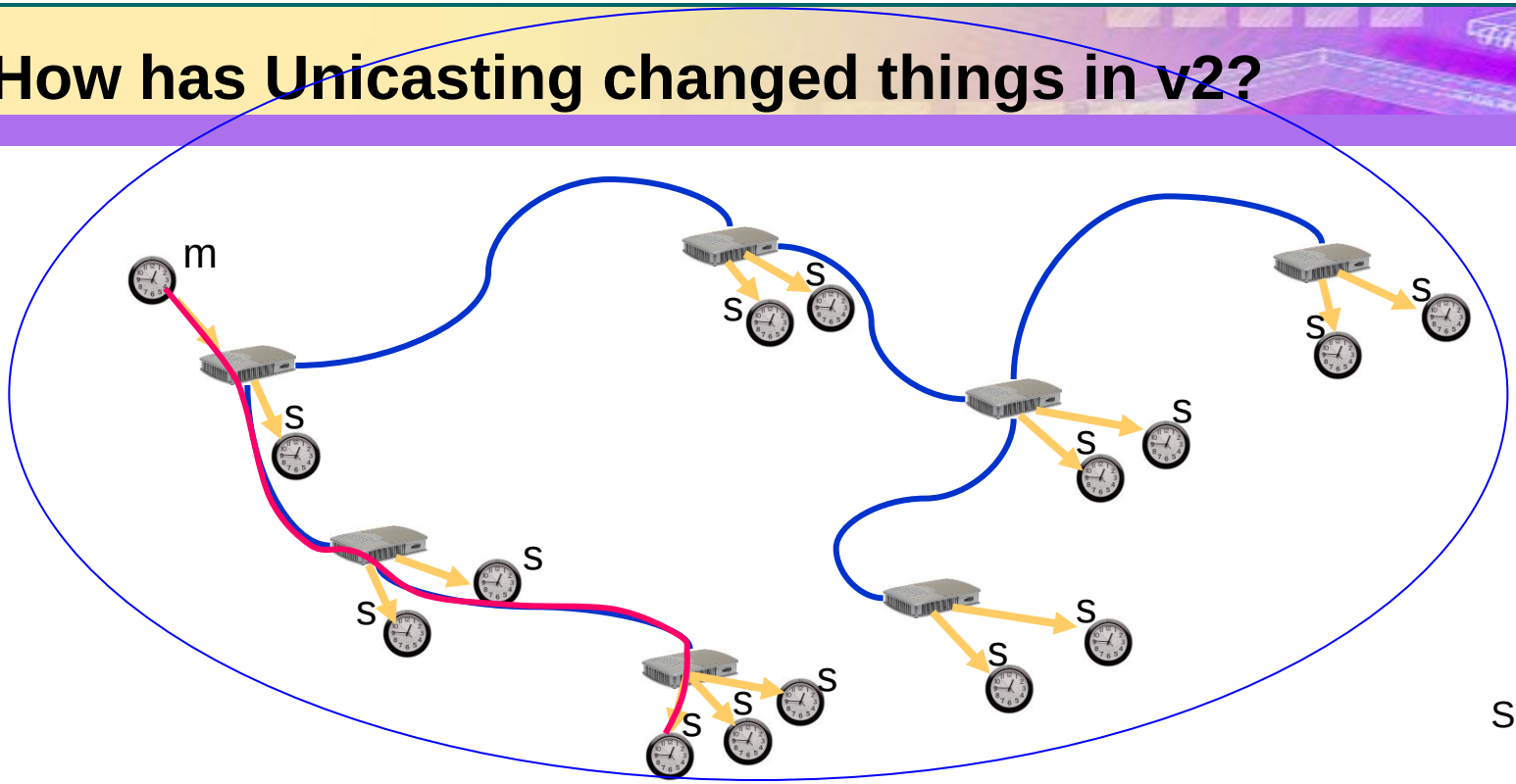
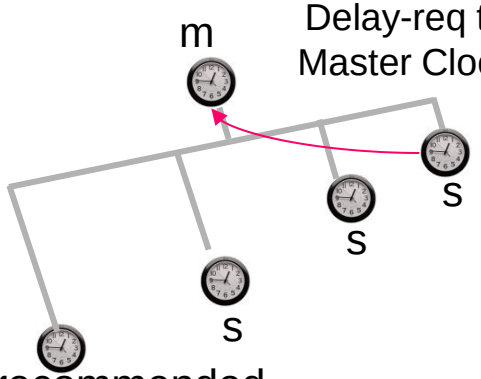
How has Unicasting changed things in v2?



Slave Clock sending Delay-req to Master Clock



Bandwidth on Slave Clock port and network link consumed by unicast Delay-Req/Delay-Resp messages: much reduced.
Bandwidth of Master Clock port and network link consumed by unicast Delay-Req/Delay-Resp messages: as per V1
Bandwidth of Master Clock port and network link consumed by unicast Sync messages: higher than v1.
- mixing Multicast Sync with unicast Delay-Req/Delay-Resp not recommended
- can lead to asymmetric path delays

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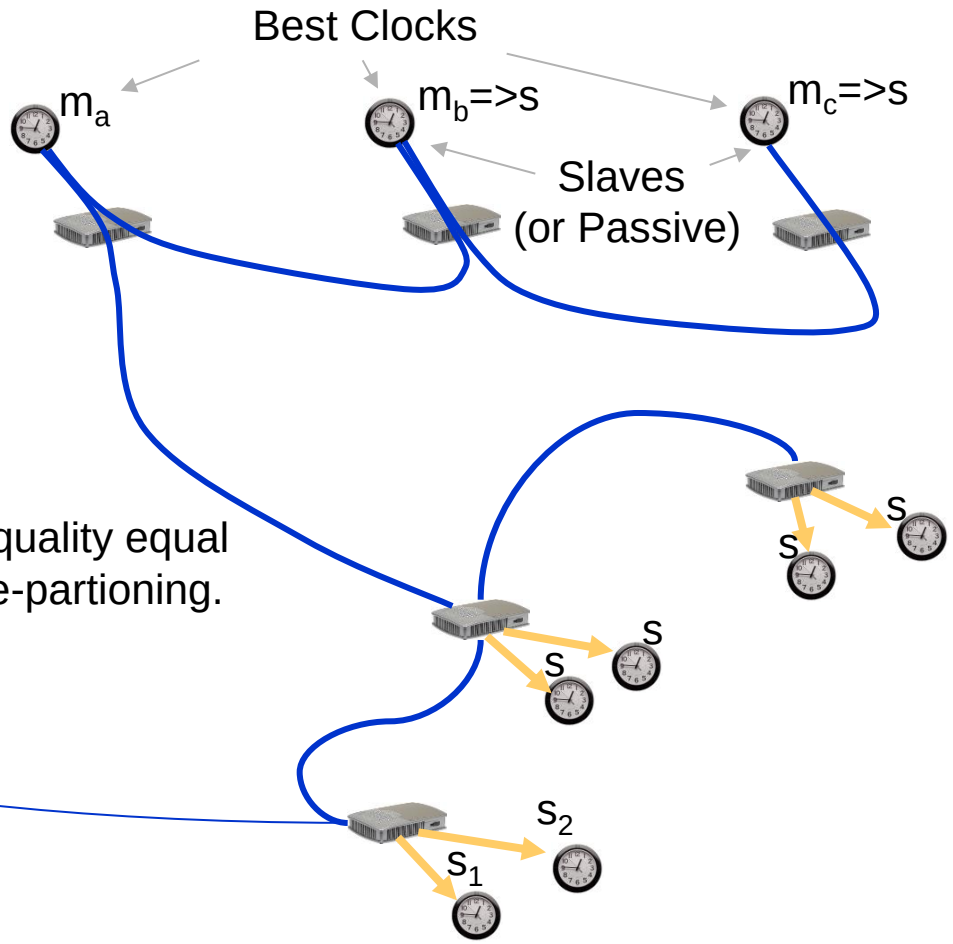
How does selection of Master Clock work in v2?

Best Master Clock algorithm results in m_a being selected as Master Clock by network (as per V1)

Method 1



Addition of new candidate Master, of quality equal to current Master, results in network re-partioning.

Security risk: If m_d is a rogue clock, slaves s_1 and s_2 could be misled.

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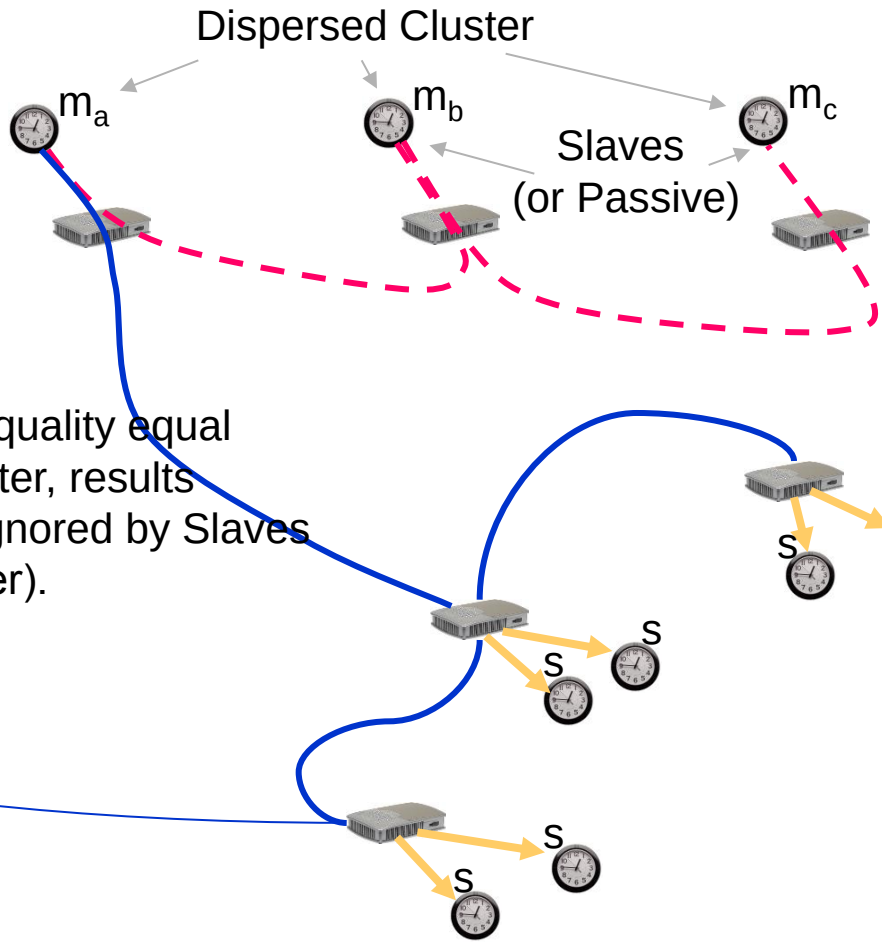
Alternative, with better security: Cluster of Masters

Modified Best Master Clock algorithm, running amongst candidates, results in m_a being selected as Master Clock by cluster and, hence, by network

Method 2



Addition of new candidate Master, of quality equal to current Master, but not in the cluster, results in no network re-partioning. New Master ignored by Slaves (it's not an Acceptable Master).

Master-centric selection. Rogue Masters not in cluster, so ignored

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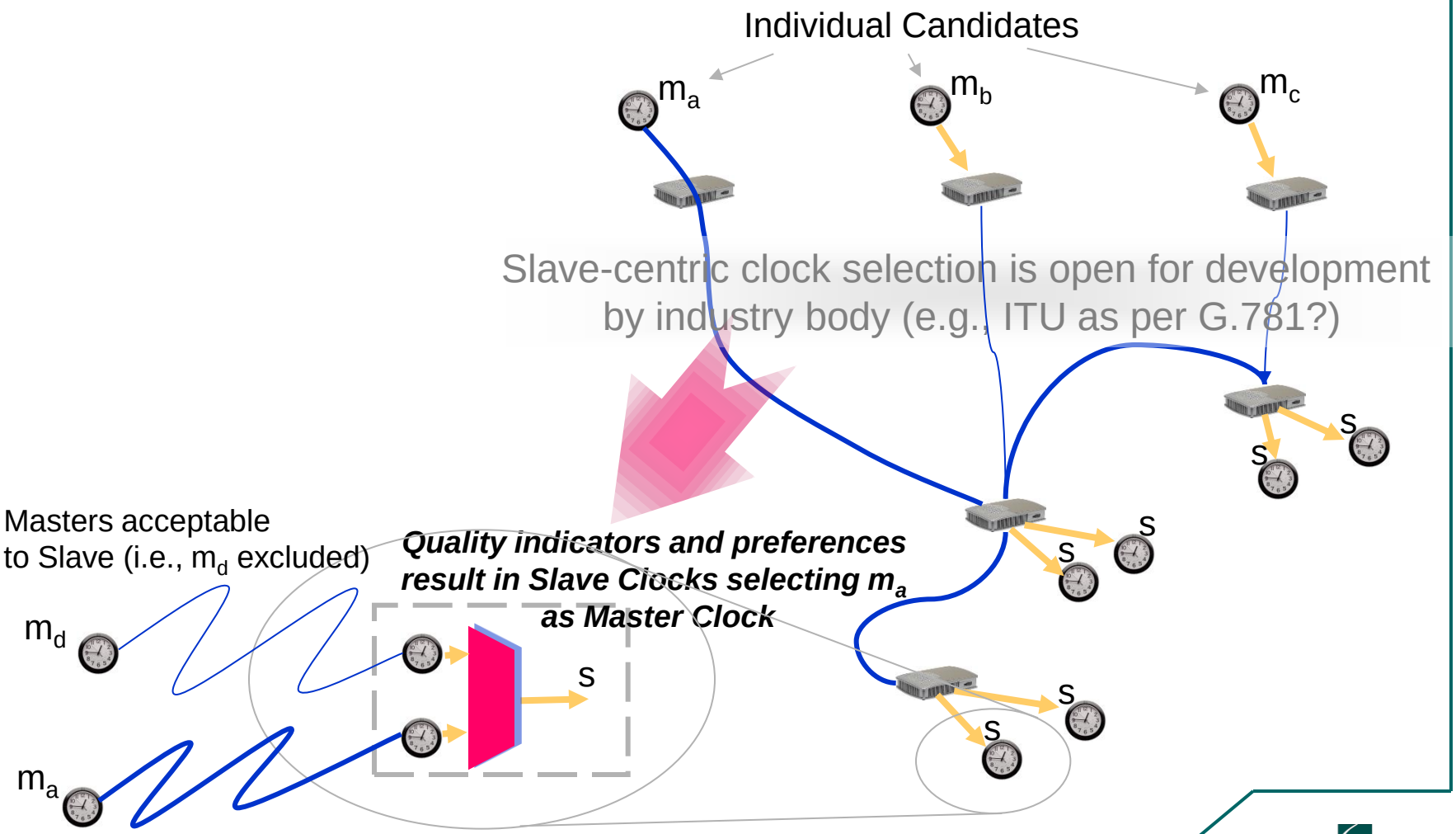
An alternative for telecom networks: Slave-centric selection

Security: Rogue Master Clocks are not in Acceptable Master tables in Slaves, so ignored.

Method 3



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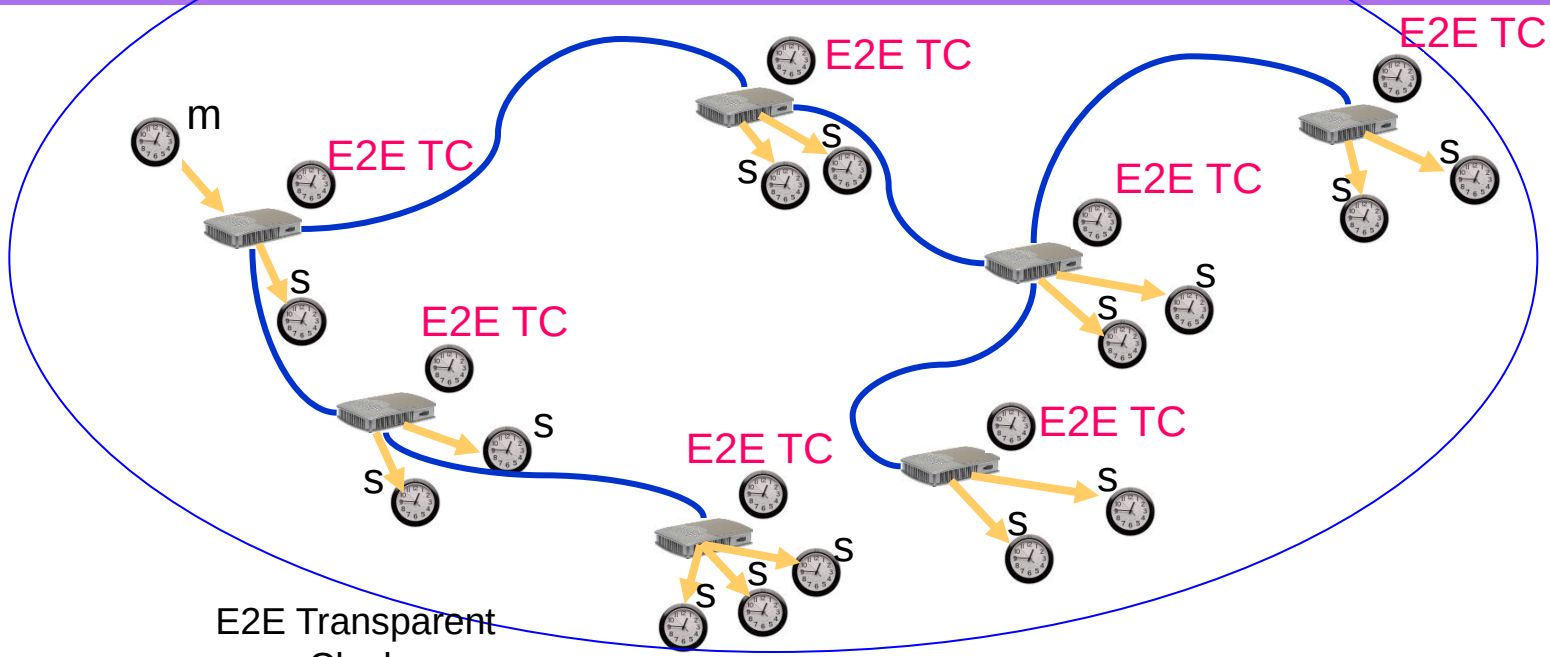
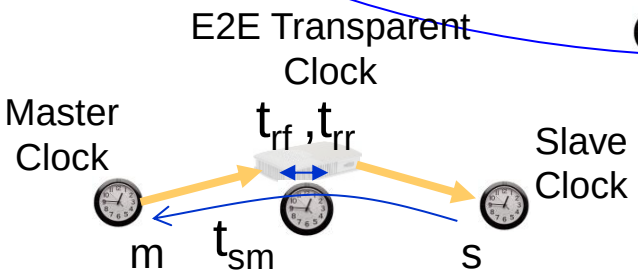
End-to-End Transparent Clocks





New estimate:

slave time = timestamp value + Σt_{rf} + (t_{sm} – Σt_{rr})

⇒ E2E Transparent clocks measure queue delay in each direction

⇒ still assume cable delays same in each direction

Weakness:

Cable delay is out of date following a network route change.

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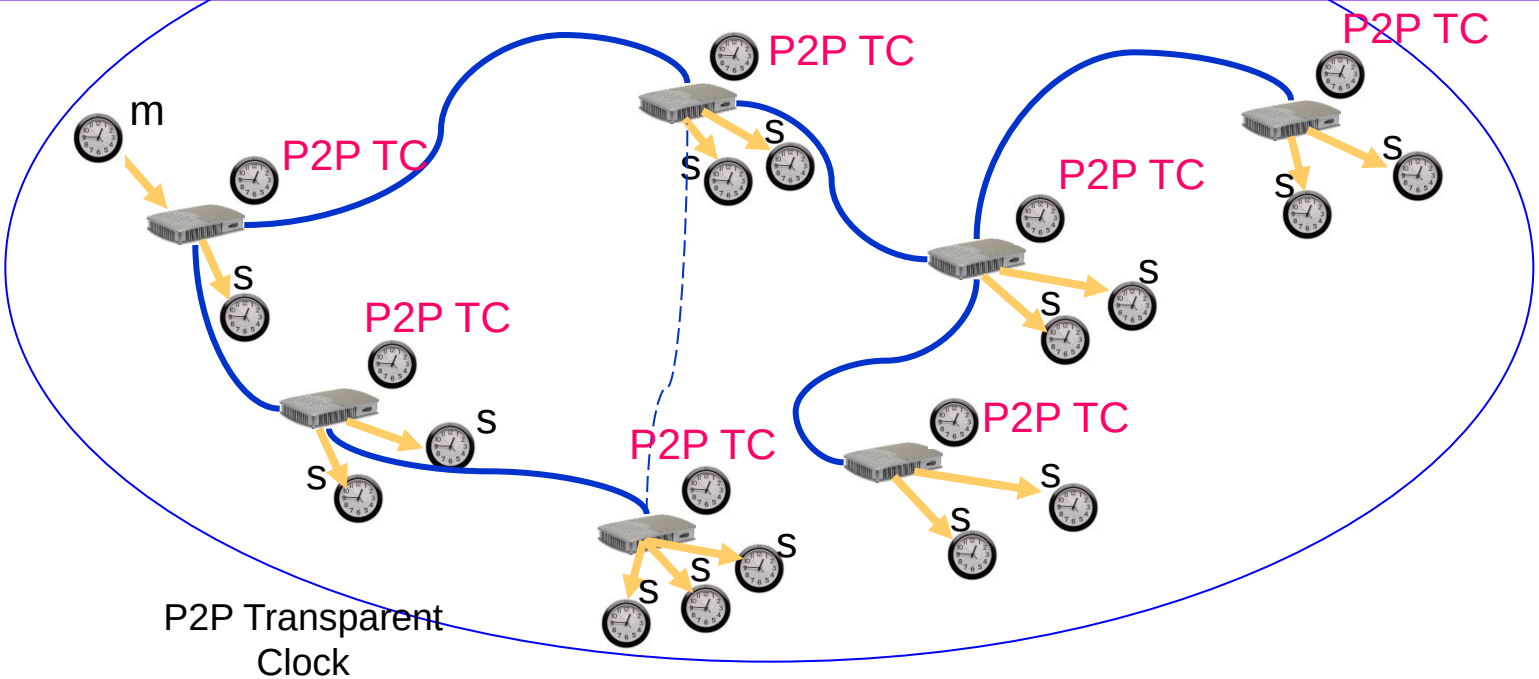
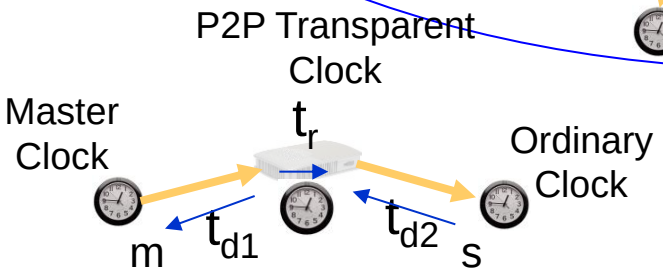
Peer-to-Peer Transparent Clocks





New estimate:

slave time = timestamp value + $\Sigma(t_{df} + t_{rf}) + t_{d2}$

$\Rightarrow$ P2P Transparent clocks measure queue delay in forward direction, plus cable delay to upstream peers (including back-up paths)

$\Rightarrow$ still assume cable delays same in each direction

Strength:

Cable delay of new path is already known before a network route change, giving hit-less route change.

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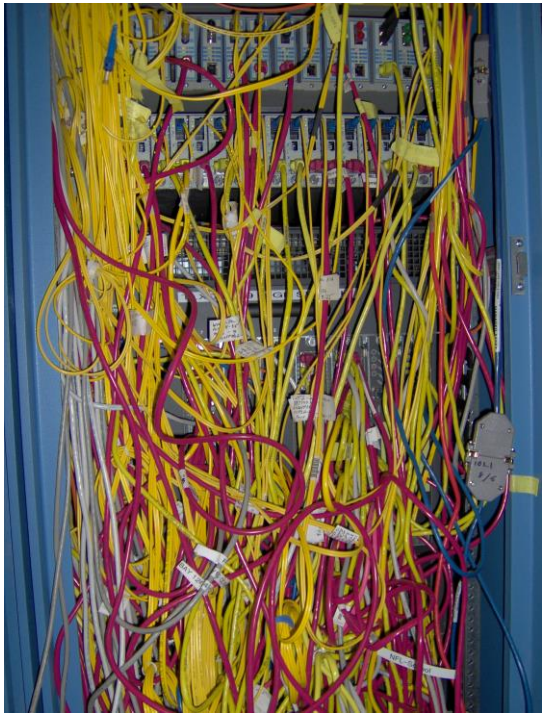
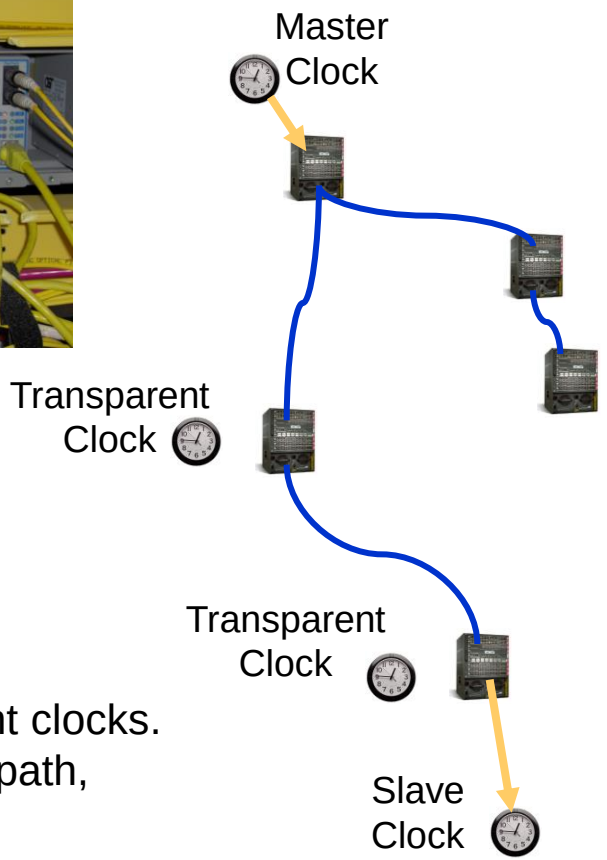
Transparent Clocks in Telecom Networks?





1588-capable Media Converters become transparent clocks. Selectively upgrade Media Converters along timing path, leaving others alone

- Cheap, simple, scalable upgrade.

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What else?

Compatibility with V1 equipment

- Generally, maintaining backwards-compatibility means v2 devices fall back to v1-mode operation.
- ...but there are risks attached to this, and special precautions have to be designed in:

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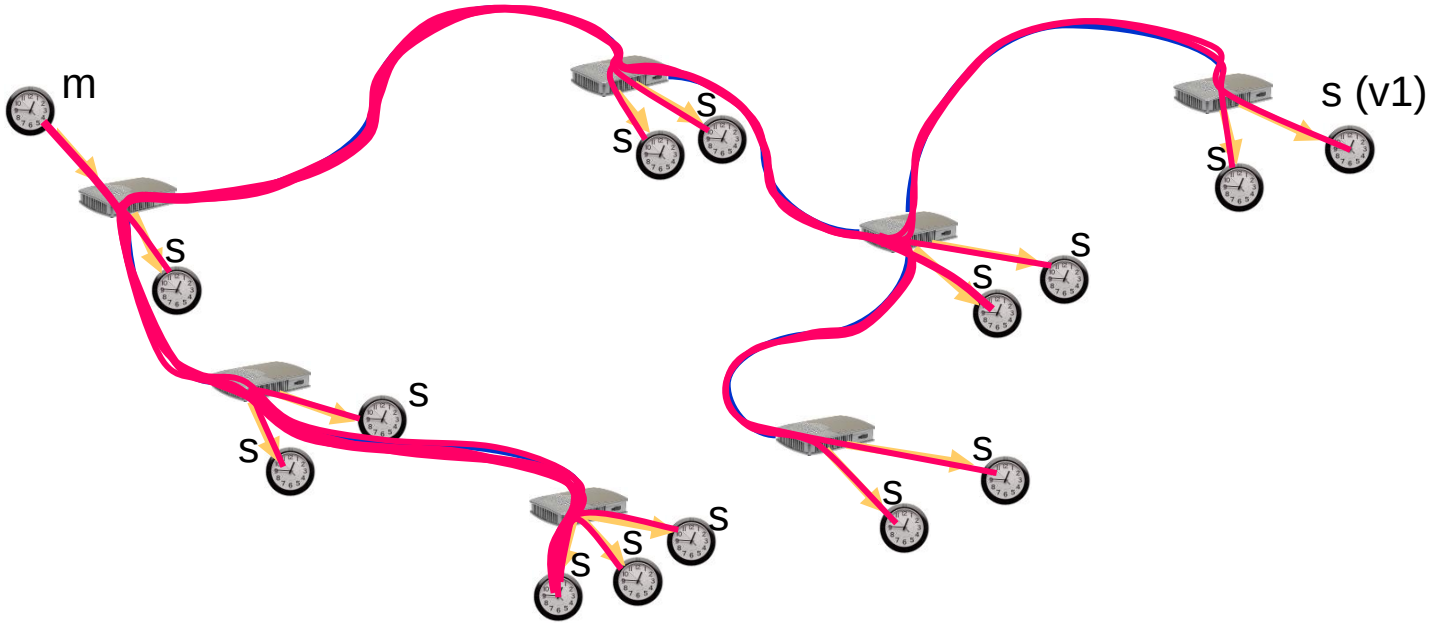
Consequence of adding a v1-only device to a v2 network

- V2 Master with V1-only Slave
  - Without precautions, adding a v1-only Slave could cause the whole network to fall back to v1 mode – with poorer performance, less features, and maybe excessive bandwidth consumption



Master has to fall back to v1 mode for that Slave only
- could run separate sessions in different subdomains

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What else?

Schedule of Completion

- Most-urgent technical work completed
- Draft standard written
- ...but being refined constantly
- Final face-to-face meeting in February 2007
- Vote among qualified participants after face-to-face
- Consent by IEEE
- ....should all be over by Spring 2007

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Summary: IEEE 1588 Operation in Telecom Applications

- Version 1 of IEEE1588 came out in September 2002
- Widely adopted by Industrial Control, Process Automation and Test & Measurement industries
- Unsuited for direct use in Telecom
  - Message rate too slow for cheap oscillators
  - Bandwidth consumption too high
  - Inappropriate clock selection
- …but Telecom needed a timing over packet technology

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Summary: IEEE 1588 Operation in Telecom Applications

- Studies, presentations, discussions, and a little bit of arm-bending, got a PAR opened in April 2005 to enhance 1588
- Message-rate increased
  - Permits cheaper oscillators
- Message formats optimised
  - Saves bandwidth
- Unicasting permitted
  - Saves even more bandwidth
- New Clock-selection methods, more appropriate to telecoms use, permitted
- New clock type (the Transparent Clock) defined
  - …and is, in many cases, suitable for adding-on to existing equipment
- Compatibility with V1 equipment made possible (sort of)
- Version 2 of the standard due out Spring 2007

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Thanks

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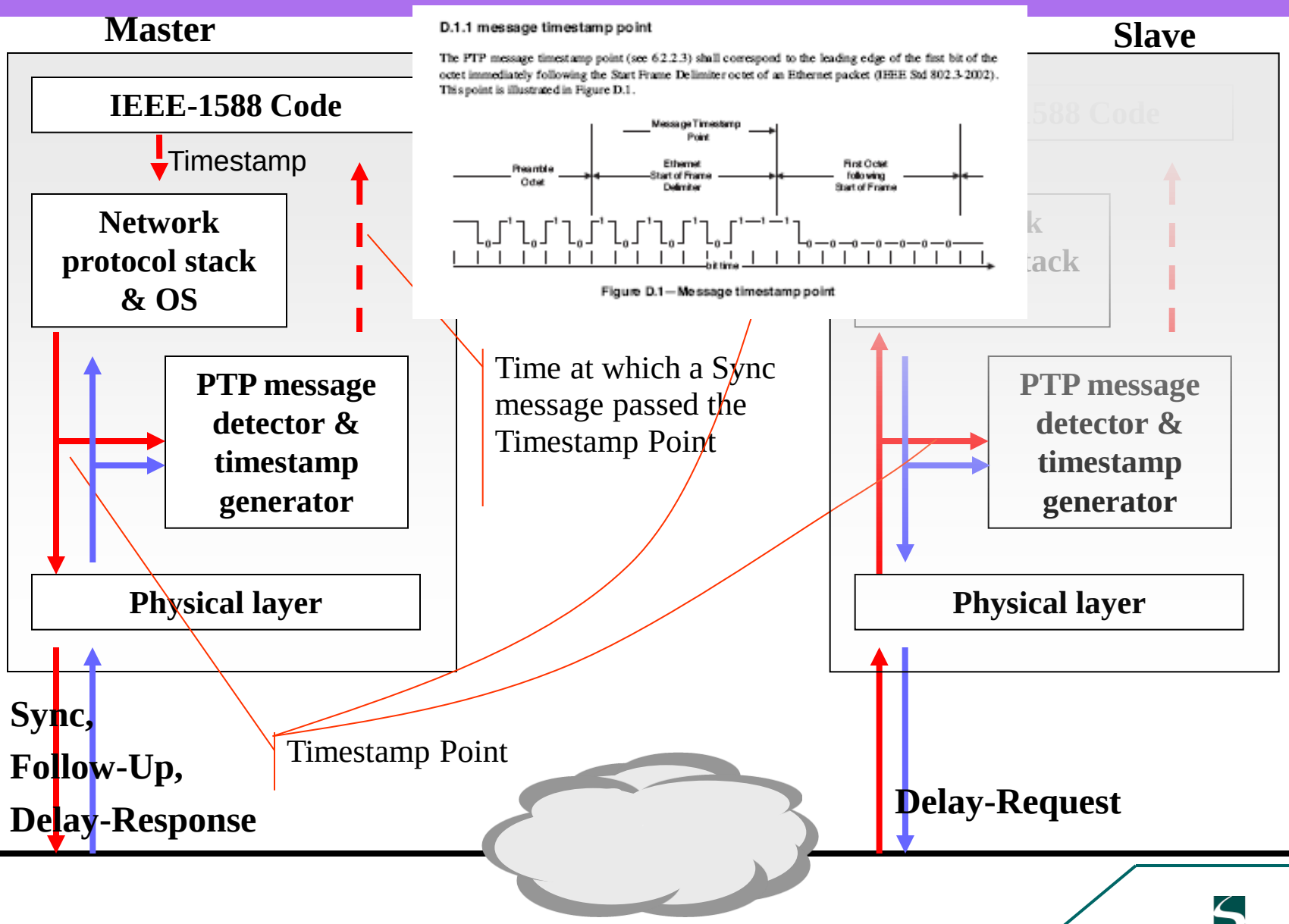
Fundamental Master-Slave Operations



D.1.1 message timestamp point

The PTP message timestamp point (see 6.2.2.3) shall correspond to the leading edge of the first bit of the octet immediately following the Start Frame Delimiter octet of an Ethernet packet (IEEE Std 802.3-2002). This point is illustrated in Figure D.1.

Figure D.1—Message timestamp point

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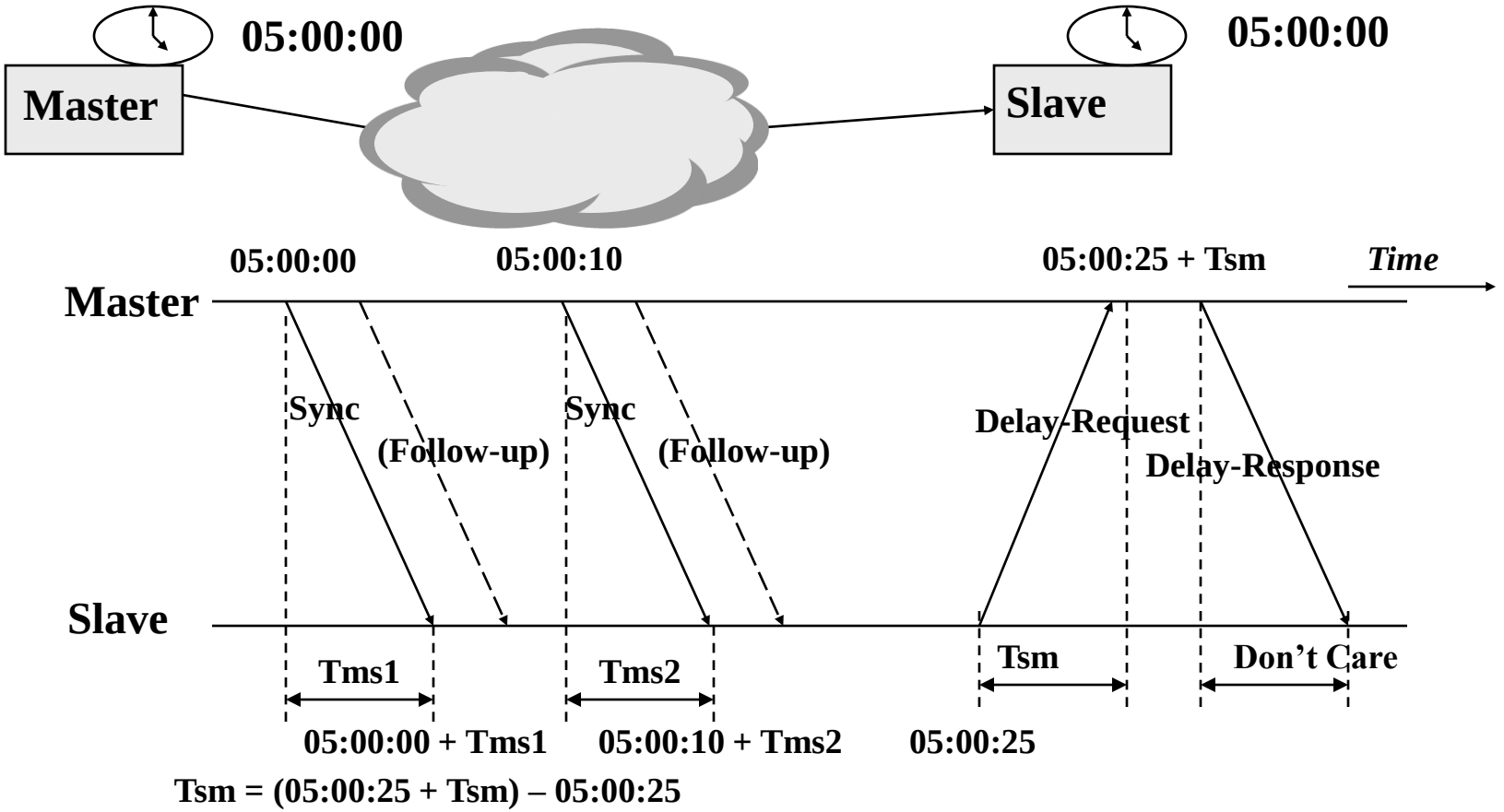
Master<>Slave Message flows:



Working Assumption: Propagation Delays always the same, and equal in both directions: Tms1 = Tms2 = Tsm

⇒ *Slavetime @ Receipt of message = MasterTimestamp + Tms*

⇒ *Offset = 0 (ideal result)*

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