IEEE-1588 Frequency and Time & Phase Profiles at ITU

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Agenda

- IEEE-1588 Profiles
- IEEE Std 1588™-2008 Telecom profiles at ITU-T
- Frequency Profile
- Time & Phase Profile

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IEEE-1588 Profiles

- IEEE-1588 defines profile as “The set of allowed Precision Time Protocol (PTP) features applicable to a device”
- “The purpose of a PTP profile is to allow organizations to specify specific selections of attribute values and optional features of PTP that, when using the same transport protocol, inter-work and achieve a performance that meets the requirements of a particular application.”
- A PTP profile should define
  - Best master clock algorithm options
  - Configuration management options
  - Path delay mechanisms (peer delay or delay request-response)
  - The range and default values of all PTP configurable attributes and data set members
  - The transport mechanisms required, permitted, or prohibited
  - The node types required, permitted, or prohibited
  - The options required, permitted, or prohibited
- IEEE-1588 also specifies how a profile can extend the standard
  - By the use of the TLV mechanism
  - By specifying an optional best master clock algorithm
  - By specifying an optional management mechanism
  - By specifying a new transport mapping referenced by a profile
  - By allowing the use of a unicast model provided that the behavior of the protocol is preserved

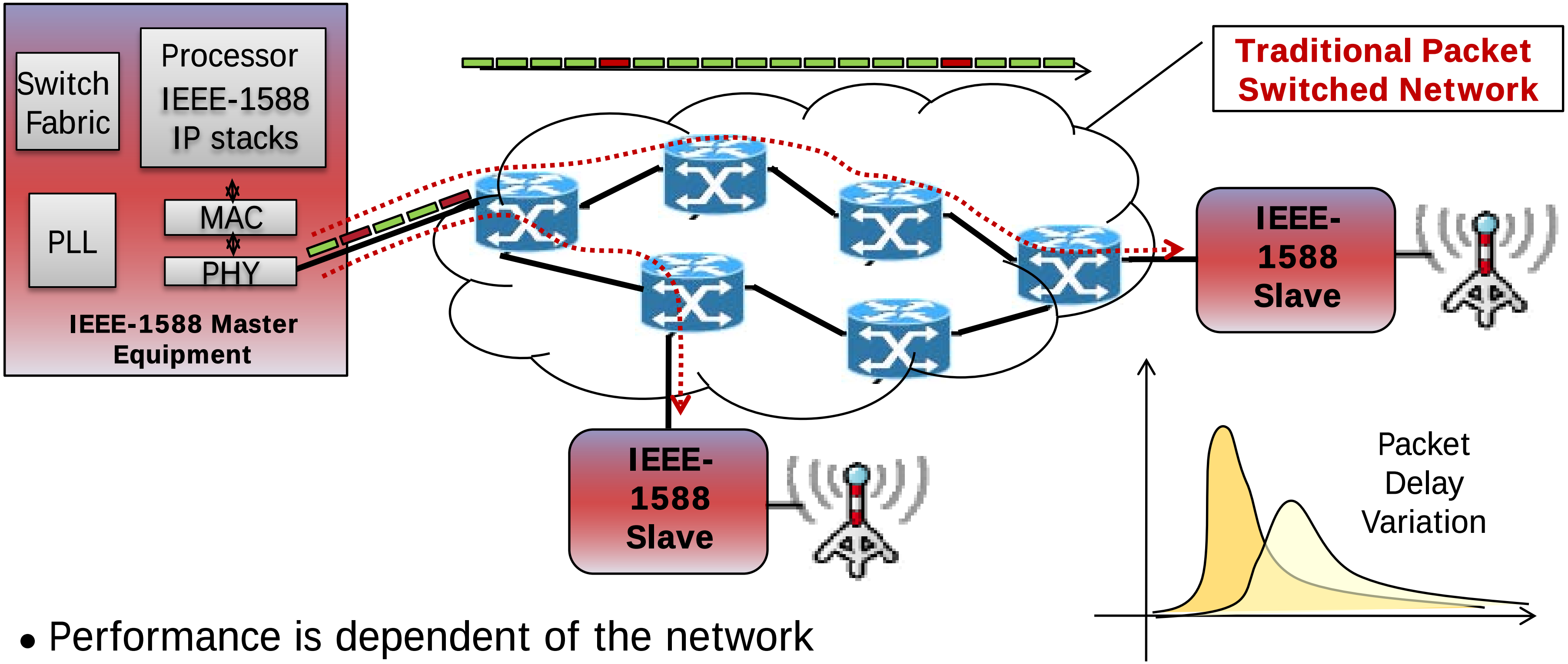
* IEEE Std 1588-2008 IEEE Standard for a Precision Clock Synchronization Protocol, copyright 2008 IEEE. All right reserved.

IEEE Std 1588™-2008 Telecom profiles at ITU-T

- ITU-T Q13/15 is working on developing IEEE Std 1588™ -2008 Profiles to address Telecom applications
  - ITU-T G.8265.1, Precision time protocol telecom profile for frequency synchronization, was consented in June 2010
  - ITU-T G.8275.1, PTP Profile for time/phase distribution – work is on-going
- ITU-T Q13/15 is also working on architectural requirements that are the basis for the definition of the PTP profiles
  - ITU-T G.8265, Architecture and requirements for packet-based frequency delivery, was consented in June 2010
  - ITU-T G.8275, Architecture of time/phase distribution
- The PTP profile itself only consists of the protocol interoperability
- The performance aspects are also addressed by ITU-T
  - PDV studies, PDV metrics, network PDV accumulation, etc...
  - Network wander and jitter accumulation with a chain a boundary clocks

FREQUENCY PROFILE

No IEEE-1588 support from Network



- Performance is dependent of the network
  - The clock recovery algorithm is adaptive in nature, therefore the performance is impacted by packet delay variation in the network
  - Need to filter the PDV by the PTPv2 slave (proprietary mechanisms)
- The quality of the clock delivered to the application depends on several factors
  - The quality of the oscillator at the slave, the packet delay variation of the network, the number of timing packets per second

PTP Options and Configurable Attributes

- One-way versus two-way mode
  - Both one-way and two-way modes are supported in the Frequency Profile
- Unicast versus Multicast mode
  - Only Unicast mode is allowed in the Frequency Profile
  - Unicast Message negotiation is used
- One-step versus two-step clock mode
  - Both one-step and two-step clocks are supported in the Frequency Profile
- PTP mapping
  - IEEE1588-2008 annex D - Transport of PTP over User Datagram Protocol over Internet Protocol Version 4 is supported in the Frequency Profile
- PTP Message rates
  - Sync /Follow-up – min rate: 1 packet every 16 seconds, max rate: 128 packets per second
  - Delay_Request/Delay_Response – 1 packet every 16 seconds, max rate: 128 packets per second
  - Announce – min rate: 1 packet every 16 seconds, max rate: 8 packets per second, default: 1 packet every 2 seconds
  - Signaling messages – no rate is specified

Unicast request mechanism

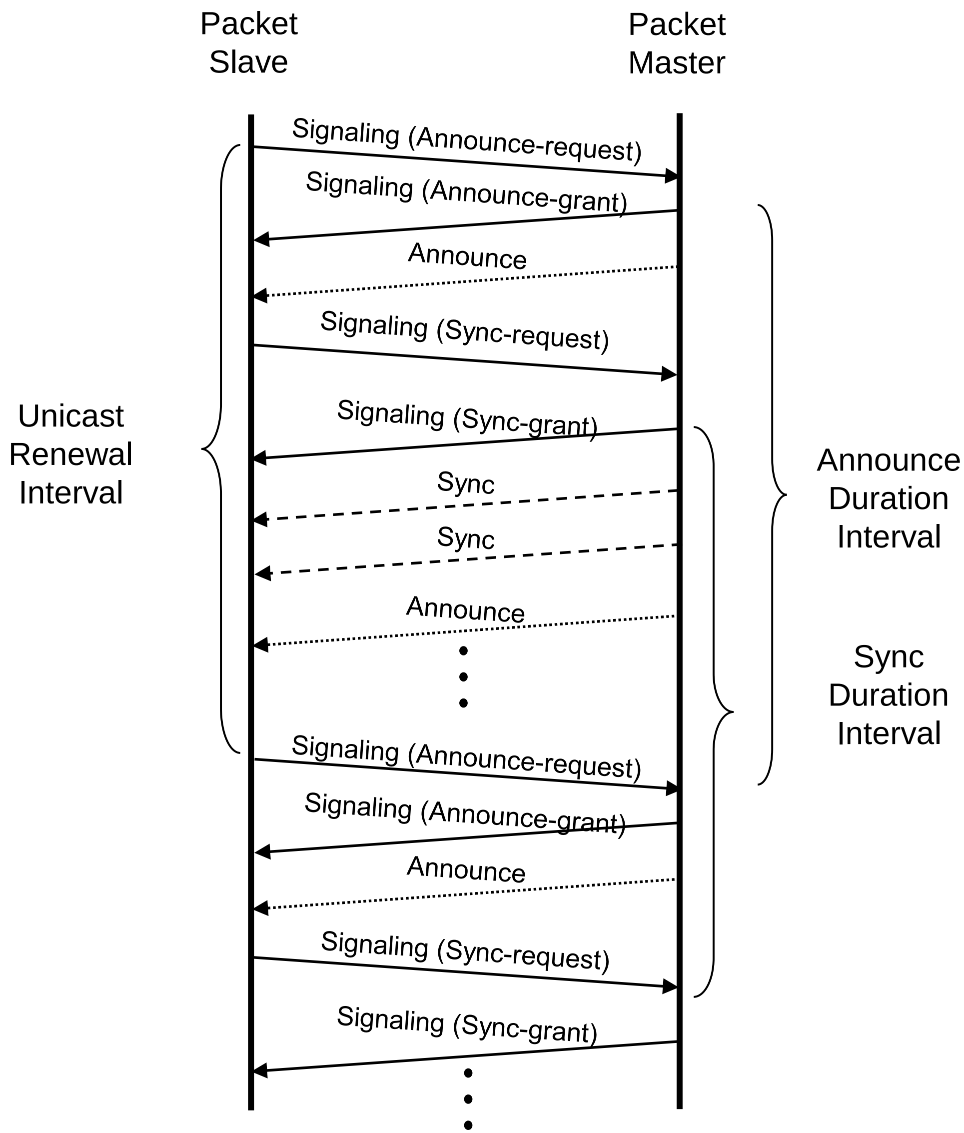


Figure 1 / ITU-T G.8265.1: Unicast Negotiation Example

- In unicast mode, PTPv2 slaves request synchronization service by sending a PTPv2 Signaling message in unicast using the "unicast message negotiation"
- It allows unicast sessions between two nodes with agreed packet rates for Sync, Announce, and Delay_Req messages.
- The mechanism enables a "keep-alive" period, in order to detect the inactive slaves

Best Master Clock Algorithm (BMCA)

- PTP allows the following options for the BMCA
  - The default BMCA specified in the IEEE-1588 standards
  - An alternate best master clock algorithm specified in a profile
- PTP specifies the requirements for an alternate best master clock algorithm
  - Provision must be made to provide the states required for operation of the PTP state machines and state decision
  - The alternate best master clock algorithm may be dynamic or static
  - A static algorithm will simply configure the recommended state values on the ports of the node on which it is running.
  - The state decision codes for use in updating the data sets must be provided as an output of the alternate best master clock algorithm

IEEE-1588 Default BMCA

- All the clocks that are part of the same domain will organize themselves into a master-slave hierarchy based on the BMCA
- Announce messages are exchanged among potential grandmasters
- BMCA is run locally on each port
  - It compares its own data set with the data set that is received by Announce messages to determine which one is the better clock
- Two separate algorithms are part of the BMCA
  - Data set comparison algorithm
  - State decision algorithm

IEEE-1588 Default BMCA cont'd

- The data set comparison algorithm uses the attributes contained in the Announce messages with the following priority
  - Priority1 (defines clock priority, it is a user configurable designation)
  - clockClass (defines clock traceability)
  - clockAccuracy (defines clock accuracy)
  - offsetScaledLogVariance (defines clock stability)
  - priority2 (defines finer grained clock priority, it is a user configurable designation)
  - clockIdentity (defines clock unique identifiers, serves as a tie-breaker)
- The state decision algorithm determines the state of the port based on the results of the data set comparison algorithm
  - The ports states can be MASTER, SLAVE, or PASSIVE

BMCA Telecom Requirements

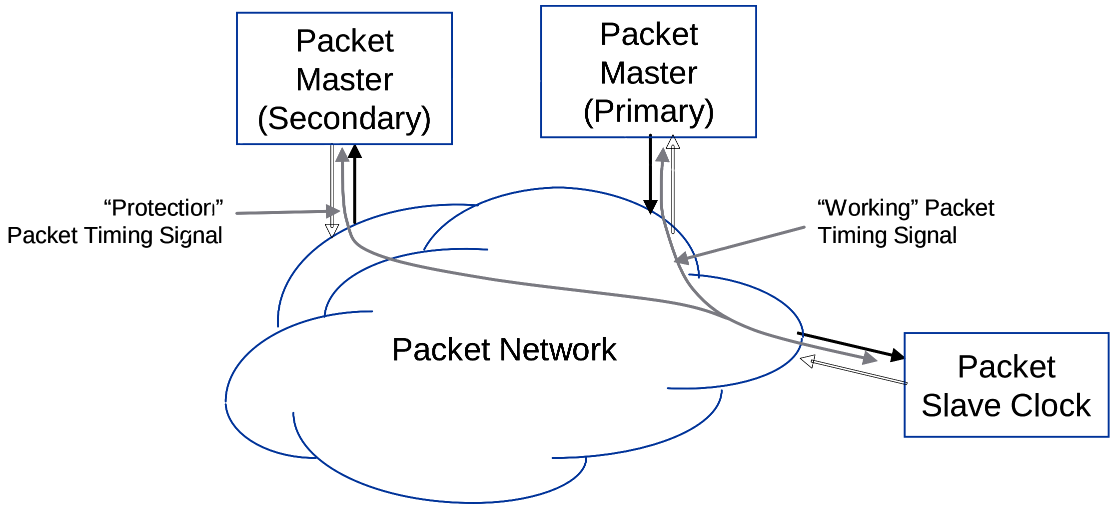


Figure 2 / ITU-T G.8265.1: Packet network timing (frequency) protection

- Telecom architecture allows several masters delivering timing messages (e.g. Sync, Delay_resp) to slaves at the same time
- Slaves should have the possibility to switch from one primary master to a backup master in case of failure
- Different slaves must be able to select different masters
- The Master selection mechanism must be compatible with ITU-T Recommendation G.781 - Synchronization Layer Functions (SDH and Synchronous Ethernet)

Alternate BMCA

- For the alternate BMCA in G.8265.1, each master is isolated by a separated PTP domain that is done through the unicast communication
  - Grandmasters do not exchange Announce messages.
  - Masters are always active
  - Slaves are always slave-only clocks

- The Master selection process is based on the Quality Level (QL)-enabled mode per ITU-T Recommendation G.781
  - Quality Level (QL)
    - The Clock Class attribute in the Announce messages in PTP is used to carry the SSM QL value
    - Master with the highest Quality Level that is not in a failure condition will be selected
    - In case of Masters with similar QL, the Master with the highest Priority is selected.
  - Priority
    - Each master has a priority value that is locally maintained in the Telecom slave.
  - Packet Timing Signal Fail (PTSF)
    - PTSF-lossSync, PTSF-lossAnnounce, PTSF-unusable

- G.8265.1 introduces the concept of a Telecom Slave
  - Consists of multiple PTP slave-only clock instances.

Telecom Slave

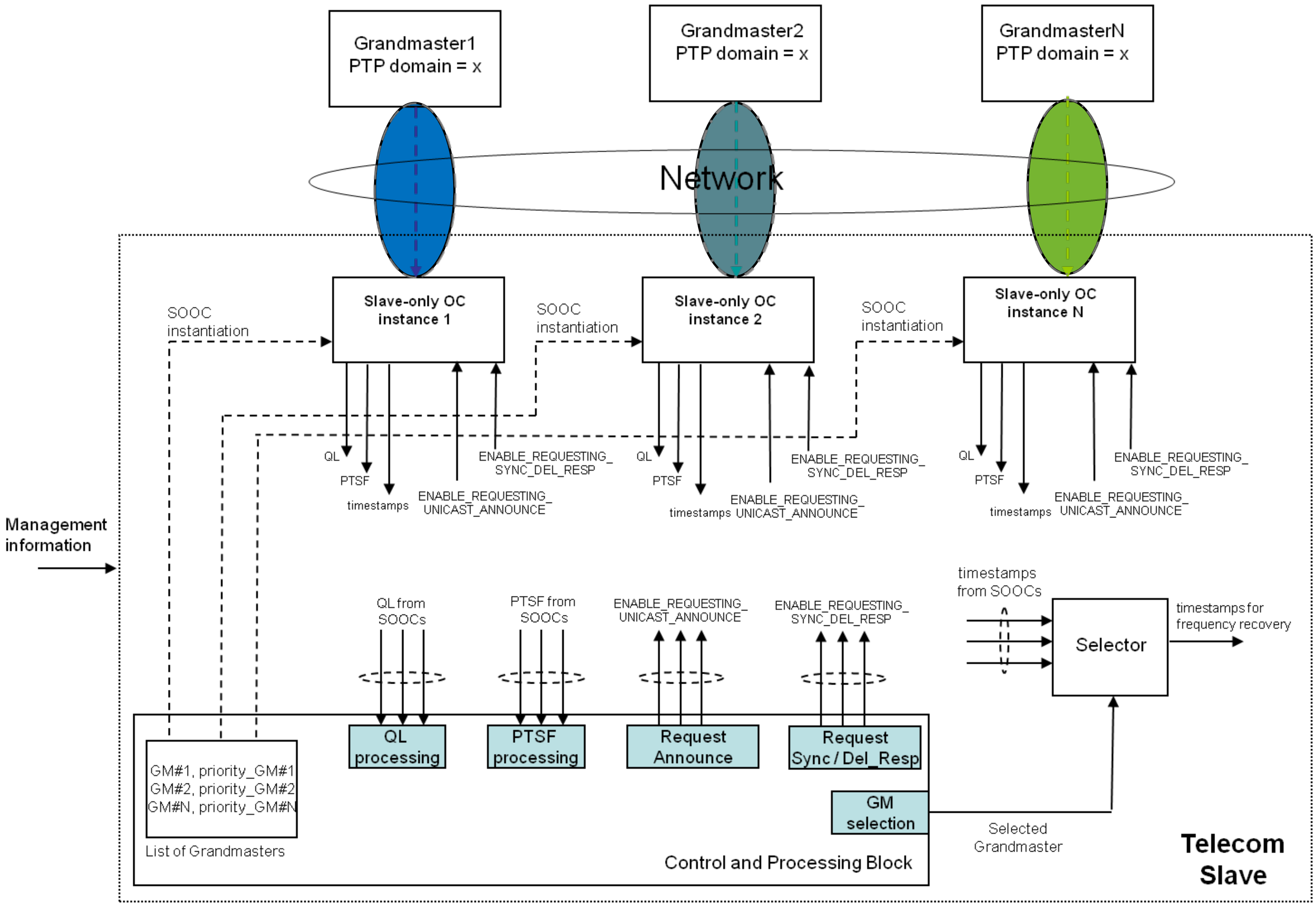
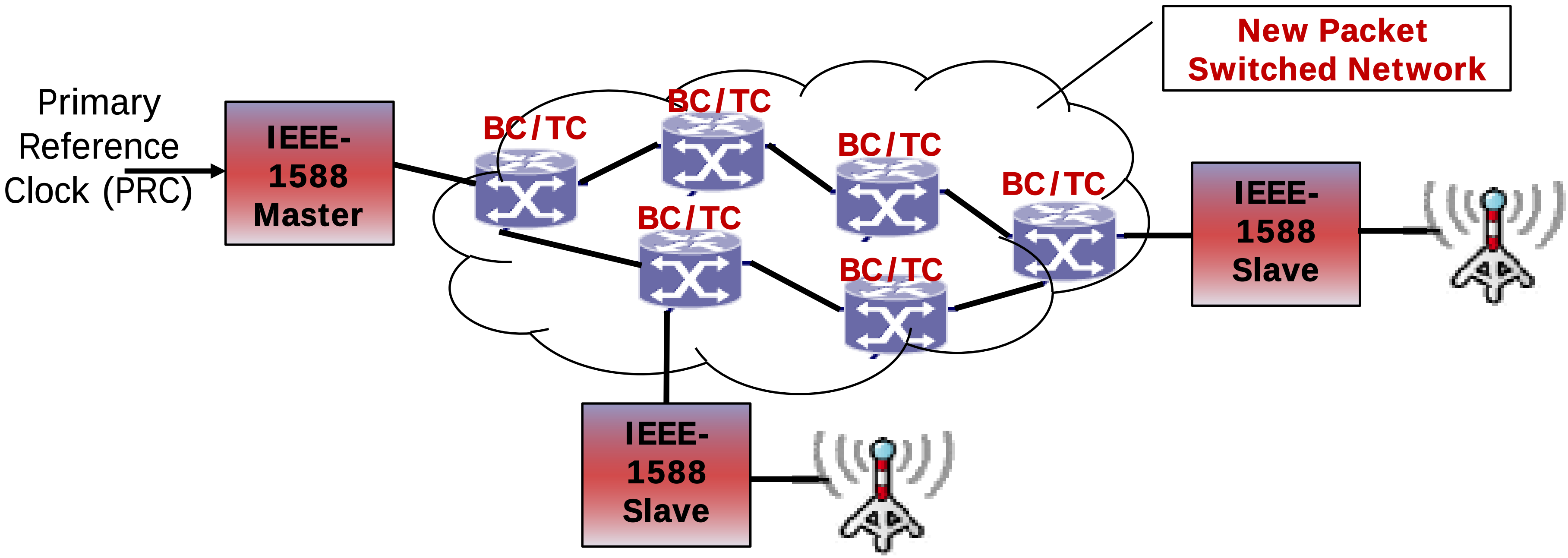


Figure 3 / G.8265.1: Telecom Slave Model

TIME & PHASE PROFILE

IEEE-1588 with support from Network



- Boundary Clocks (BCs) and Transparent Clocks (TCs) can be used to overcome the performance issue due to packet delay variation
- First Profile, G.8275.1, will use Synchronous Ethernet in conjunction with Boundary Clock
- Transparent Clock is for further study
- Simulation work with a chain of 20 Boundary clocks is on-going
  - Synchronous Ethernet has been used in the simulation

Time & Phase Profile - On-going work at ITU

- IEEE-1588 Time & Phase Profile is part of a wider work at ITU targeting stringent requirements for phase synchronization
  - Targeting accuracy class levels 4, 5 and 6 of Table 1 of G.8271

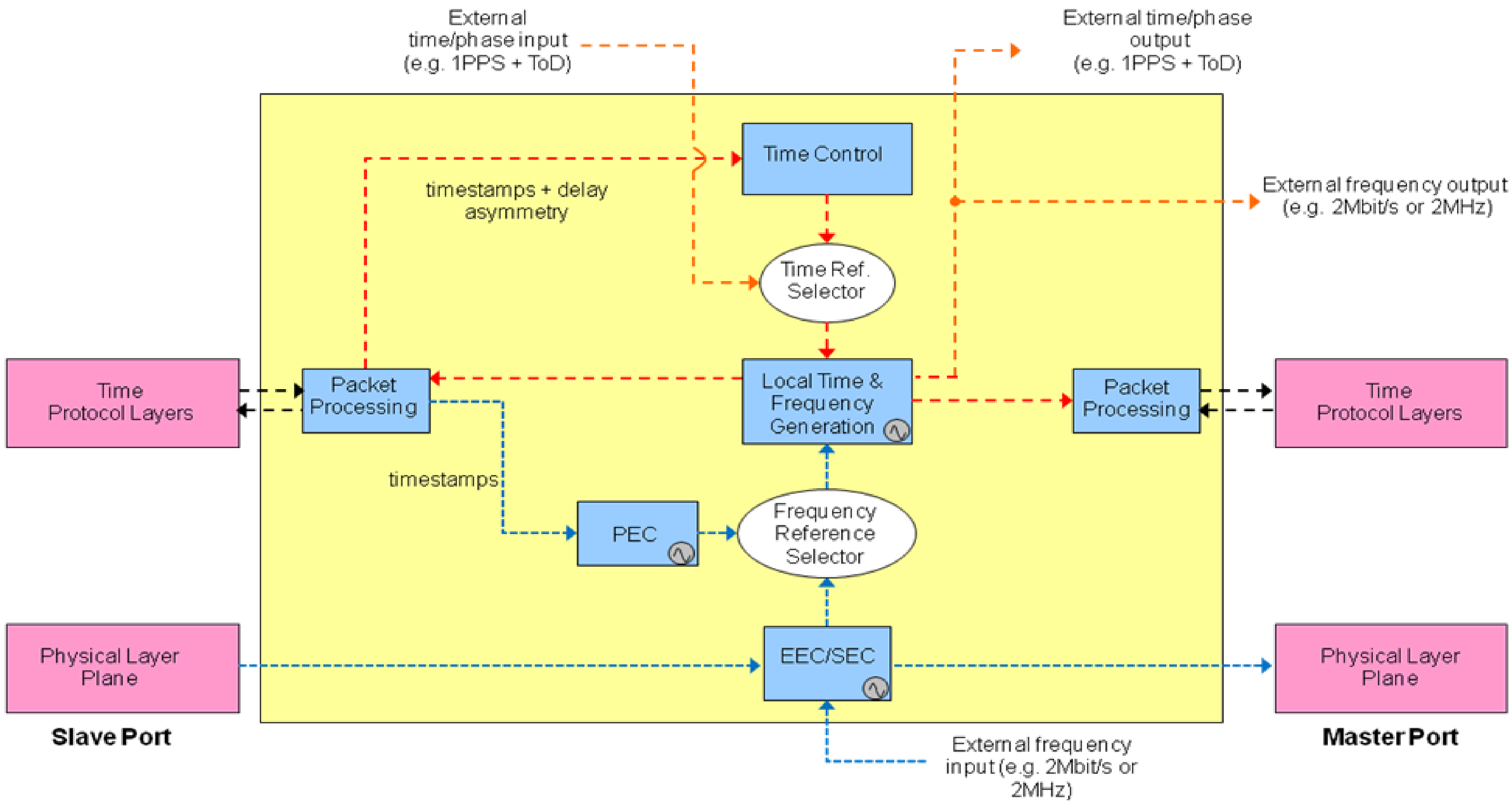
Level of Accuracy	Range of requirements (Note 2)	Typical Applications
1	1 ms – 500 ms	Billing, Alarms
2	5 µs – 100 µs (Note 1)	IP Delay monitoring)
3	1.5 µs -5 µs	LTE TDD (large cell) Wimax-TDD (some configurations)
4	1 µs - 1.5 µs	UTRA-TDD, LTE-TDD (small cell)
5	x ns - 1 µs	Wimax-TDD (some configurations)
6	< x ns (x tbd, between 500 and 1000 ns).	Some LTE-A features (Note 3)

Table1/G.8271 – Time and Phase requirement classes

PTP Options and Configurable Attributes

- On-going work on the usage of the PTP Options and configurable attributes for phase and time profile
- Unicast versus Multicast mode – no decision has been made
  - Unicast and Multicast have been proposed for the Time & Phase profile
- PTP mappings have been proposed – no decision has been made
  - IEEE1588-2008 annex D - Transport of PTP over User Datagram Protocol over Internet Protocol Version 4
  - IEEE1588-2008 annex E - Transport of PTP over User Datagram Protocol over Internet Protocol Version 6
  - IEEE1588-2008 annex F - Transport of PTP over Ethernet
- PTP Message rates - no decision has been made
  - Sync message – simulations have been run with 1 packet per second and 8 packets per second
  - Delay_Request/Delay_Response – simulations have been run with 1 packet per second and 1 packet every 8 seconds

Boundary Clock Model



G.8273.2 / Figure A. 1: Boundary Clock Model

Summary

- ITU-T is working on Telecom profiles for IEEE-1588
- PTP Profile for frequency delivery without support from network nodes was consented in June 2010
  - ITU-T G.8265.1, Precision time protocol telecom profile for frequency synchronization
- Architectural requirements for the frequency profile was consented in June 2010
  - ITU-T G.8265, Architecture and requirements for packet-based frequency delivery
- Work is on-going at ITU for PTP Profile for phase/time
  - ITU-T G.8275.1, PTP Profile for time/phase distribution
- Work is on-going at ITU for the architectural requirements for phase/time
  - ITU-T G.8275, Architecture of time/phase distribution

THANK YOU!

References

- IEEE Std 1588™-2008, IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
- ITU-T G.8265, Architecture and requirements for packet-based frequency delivery
- ITU-T G.8265.1, Precision time protocol telecom profile for frequency synchronization