Distributing Phase—with Sub-Microsecond Accuracy—Unaffected by PDV

ITSF 2008 Munich

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Phase Synchronization overview

“to boldly sync …”

Agenda:

1. **Background information on Phase synchronization**
2. **Goal – Ubiquitous availability of Phase**
3. **One example application needing Phase**
4. **Distributing Phase – ideally common for**
   - > Local distribution
   - > Node distribution
   - > Network distribution
5. **PPS over Ethernet**
6. **Phase synchronous Ethernet**
7. **Service phase and Network phase**

8. **Extras (leftovers)**

Background
Frequency, Time and Phase

- **Frequency**
  - > **TAI International Atomic Time** (**Temps Atomique International**)
  - > weighted average from about 300 atomic clocks in national laboratories worldwide.
  - > Caesium ticks at **9,192,631,770 hertz**

- **Time**
  - > **Count of ticks from an epoc [+ leap seconds + …]**
  - > **Based upon TAI**
  - > E.g. `SAT 01NOV2008 HELSINKI FI MUNICH DE 0920` Local time (UTC+3)

- **Phase**
  - > Count of frequency over a period of time
  - > Pulse Per Second is most common measure of phase
  - > The “LSB of TIME”
  - > I.e. In the case of IEEE1588

Pulse-per-second (PPS) Signal Interfacing

"Alice is trying to find the PPS signal connector".

from Professor Dave Mills webpage on NTP

Now PPS connectors are not often seen

Especially on backplanes there're far, far between.

Dr.Zeuss

- **PPS support can also be hard to find on:**
  - > IP/MPLS switches,
  - > Telecoms measurement equipment,
  - > NPUs, ASICS etc…

Phase synchronization – who needs it?

- **Lets have a quick overview of the transport network…**
  - > Frequency synchronization – long distributed via transport network
  - > How could phase be delivered by the transport network?

- **Applications:**
  - > One Way delay (e.g. for SLA monitoring)
  - > Mobile – MBMS, TDD, Single frequency, CDMA, WIMAX networks…

- **GPS is not always available/ desirable/ practical**

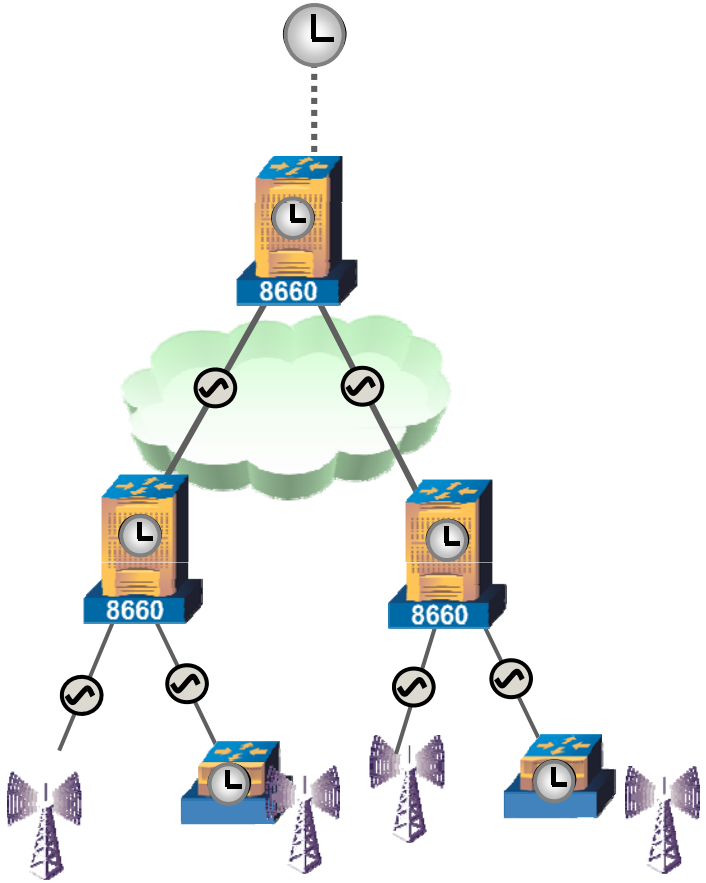
- **“I want my own phase” (service phase) supplied over the network.**
  (Synchronous Residual Time Stamp for Phase)

Question - Can PPS at 1us accuracy be delivered ubiquitously across a transport network without being impacted by PDV?

”Evolution” of Transport network synchronization (from internal operation to a service)

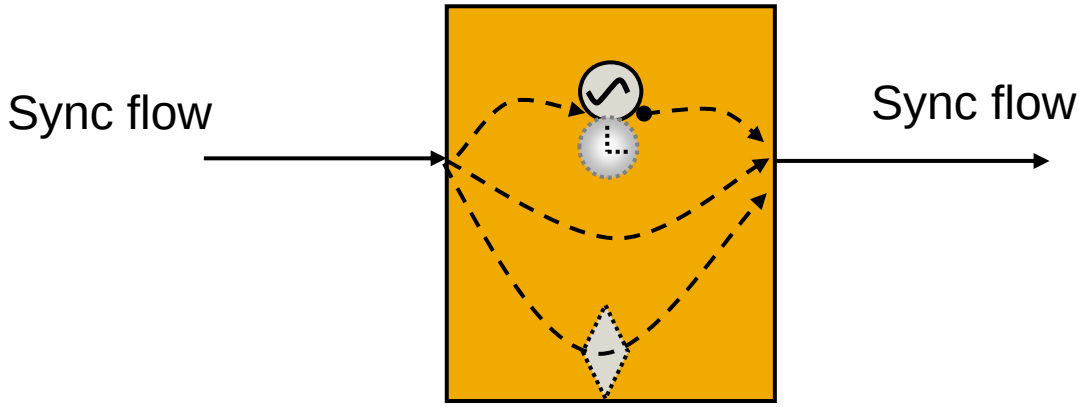
Every network consists of nodes connected by links
Links are synchronous (SDH, PDH, Ethernet, Base-band modems…)

1. **Let Clocks appear and synchronize the nodes!**
2. **Packet rebellion - Down with the clocks!**
3. **Client outcry – the clocks are back (G.826x)**
4. **Clocks transformed – support for Phase**



Synchronization has become a service of the transport network!

Synchronization flow
Processing options within a node



1. Terminate Flow; Synchronize node; Regenerate flow
2. Process on-the-fly E.g. IEEE1588 with Transparent clock.
3. Transparently forwarded to egress (as data)

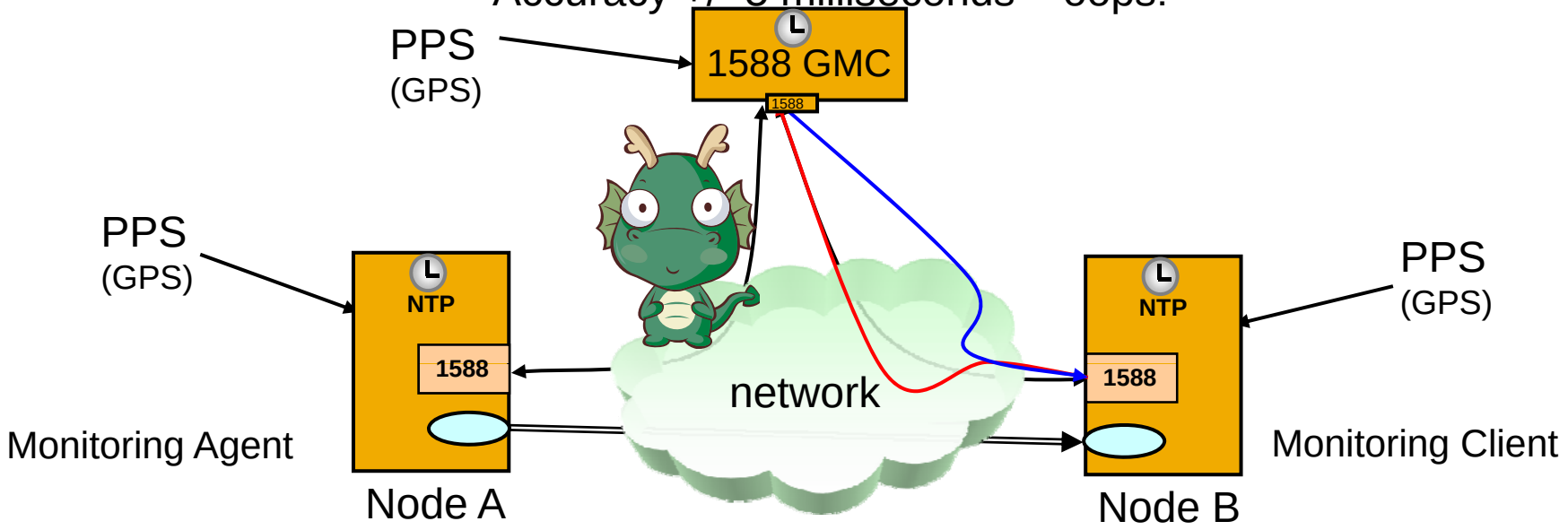
Requirement for 1us means the sync. flow is processed in EVERY node

Example: accurate OWD measurement Node A to Node B Target accuracy (+/- 100usecs)

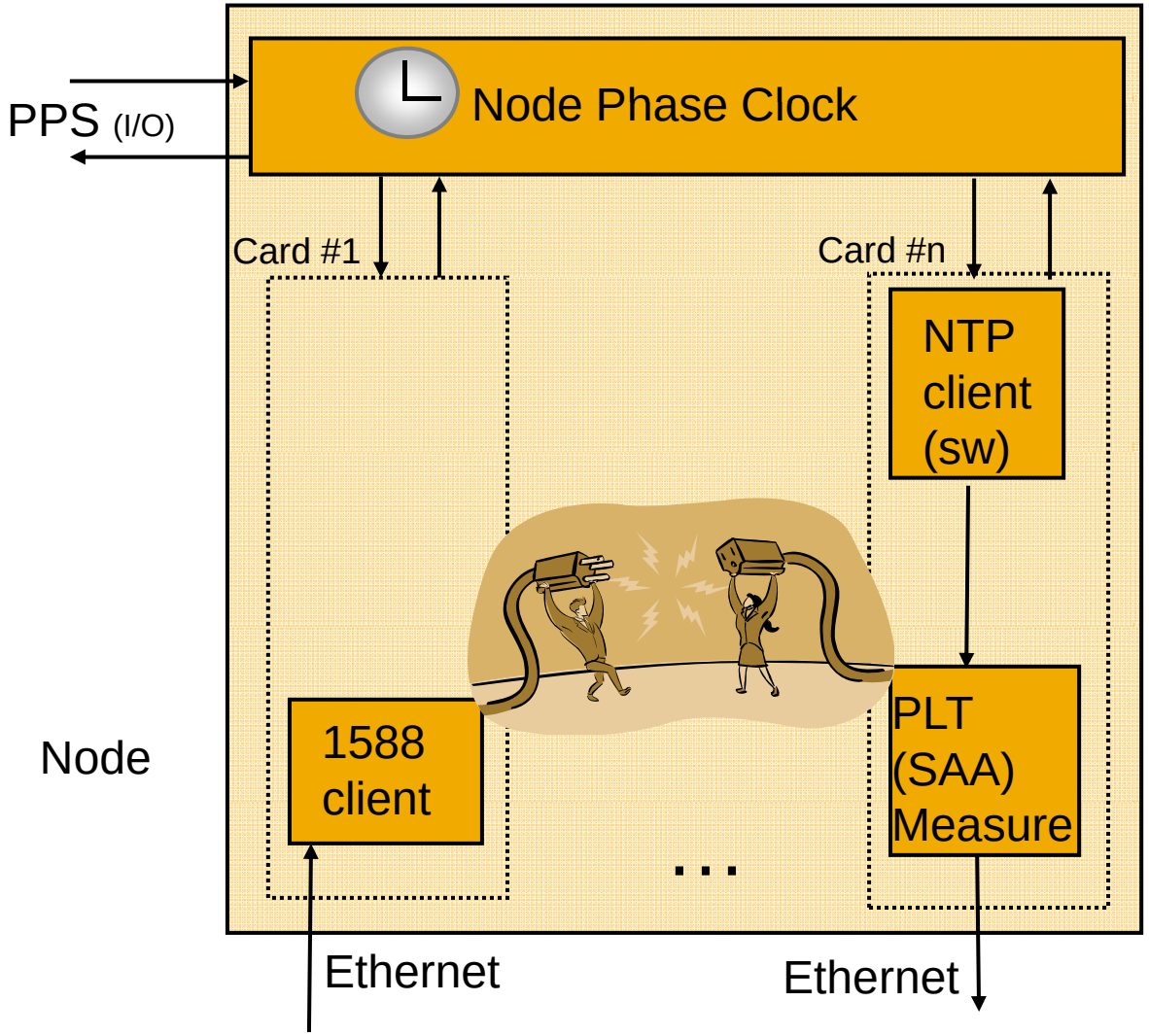
Remaining Problems (no solution):

1. Asymmetrical routing
2. PDV dragon

Could Use GPS…
Could use 1588 Clients
But no PPS inputs!
Yes IF the Node (Agents) can be phase synchronized?
Accuracy +/- 5 milliseconds – oops!



Phase synchronization across a network… Actually starts in the first node



- **Not application specific**
  - > Clock for PLT
  - > Clock for X & Y…
- **Add node phase clock**
  - > Similar to frequency
  - > Minimal cost delta

Packet Loop Tester

Service Assurance Agent

IEEE1588 is just a (small) part of the puzzle

Let's Synchronize our watches…

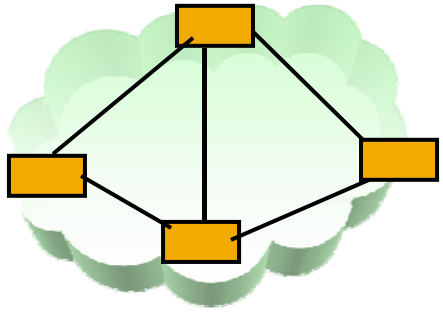
I.e. main points to date…

- **Client Applications exist that require phase synchronization.**
- **Market interest in using transport network provide a synchronization service**
- **State of readiness in "datacoms" boxes is low, but Telecoms NGN…**
- **Nodes require:**
  - > Phase input output ports (PPS);
  - > Phase transfer within node
  - > Phase clock – which is the basis for…
  - > Synchronization flow processing

Let's look at a transport network
Nodes + Links = Topology

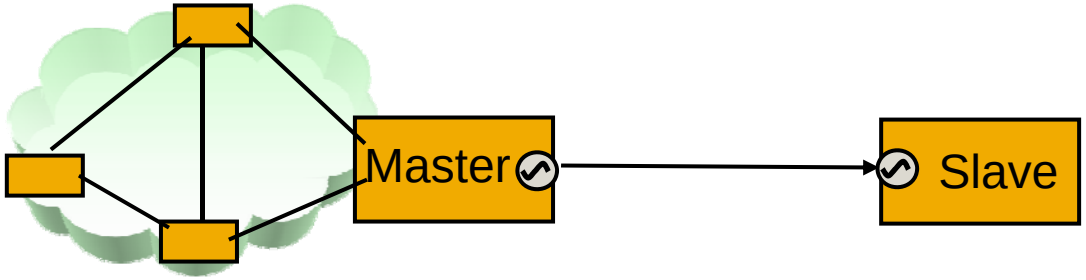
- **"End-to-End" Versus "link-by-link"**
  - > Packet Delay Variation – depends on bit-rate, queuing, shaping, QOS…
  - > Accurate phase synchronization requires processing in nodes

- **Properties of links**
  - > Links are usually glass fibre
  - > Probably carrying Ethernet directly (includes also WDM)



Remember - Transport nodes simple (Client nodes can be more) complex

IEEE1588 overlay for link-by link phase synchronization Transport Network



- **Discovery – for a point-to-point link?**
- **Best Master Clock selection – multiple masters?**
- **[illegible] other end?**
- **Topology – another [illegible]**
- **Options – for protocol, protocol encapsulations, Timescales, [illegible]**

1588 is for client devices !

Simpler solution needed for Transport networks!

Comparison between IEEE1588 and PSE
For synchronizing a transp

We want both!

	Phase Synchronous Ethernet	IEEE 1588
Topology	Follows existing (SSM) topology	New topology
Addressing	Implicit – same as for Frequency (delta is 0)	IP uncast/multicast or Mac unicast/multicast
Message size	4 b	9
Encapsulation	TLV of existing ESMC (SSM)	PTP/UDP/IP/Ethernet or PTP/Ethernet
Management	Delta for phase "On or Off"	PTP management messages (clock Id; clock domain; Port Id; clock selection algorithm; timescale …)
Modelled on	WAN (Synchronous Ethernet)	LAN
Physical interface (for phase input/output)	PPS	PPS

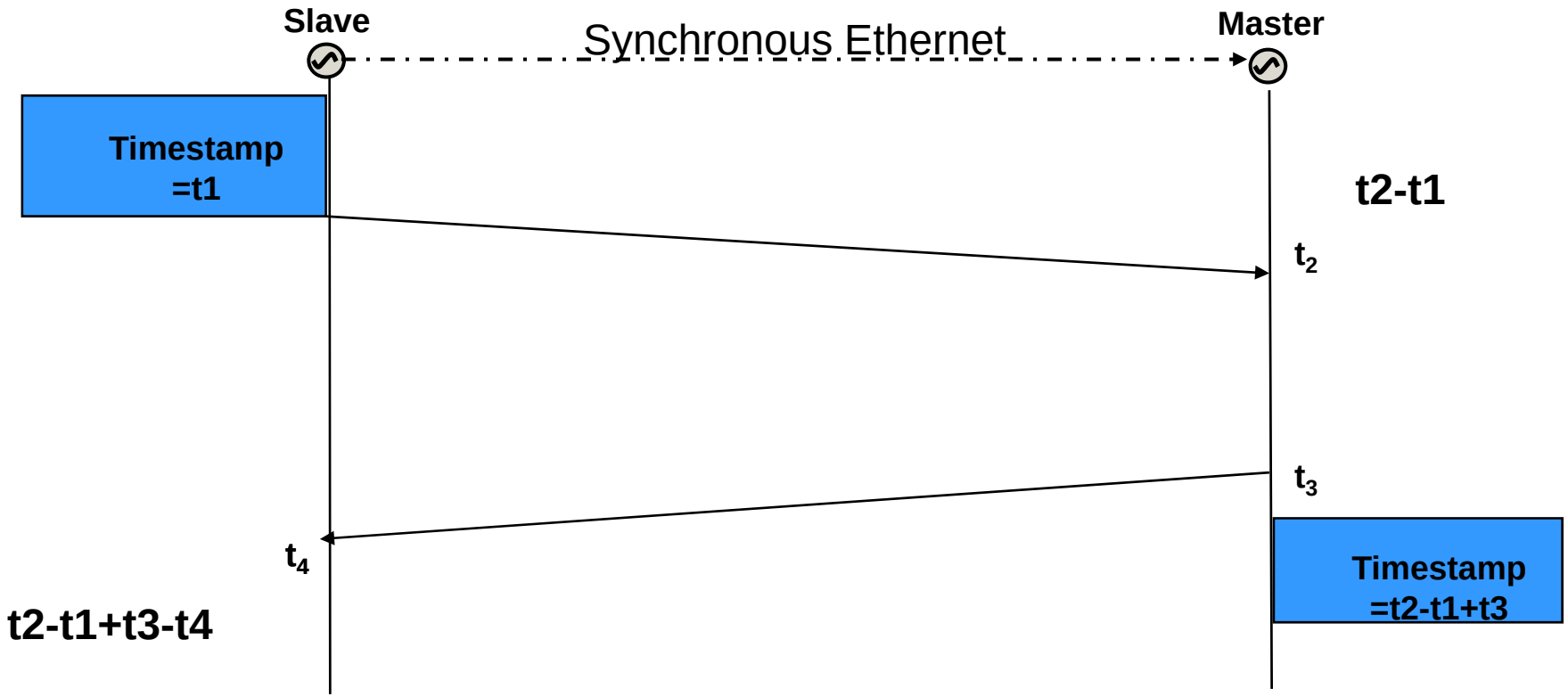
Simplicity...

Or flexibility?

How to transmit “PPS” over Ethernet

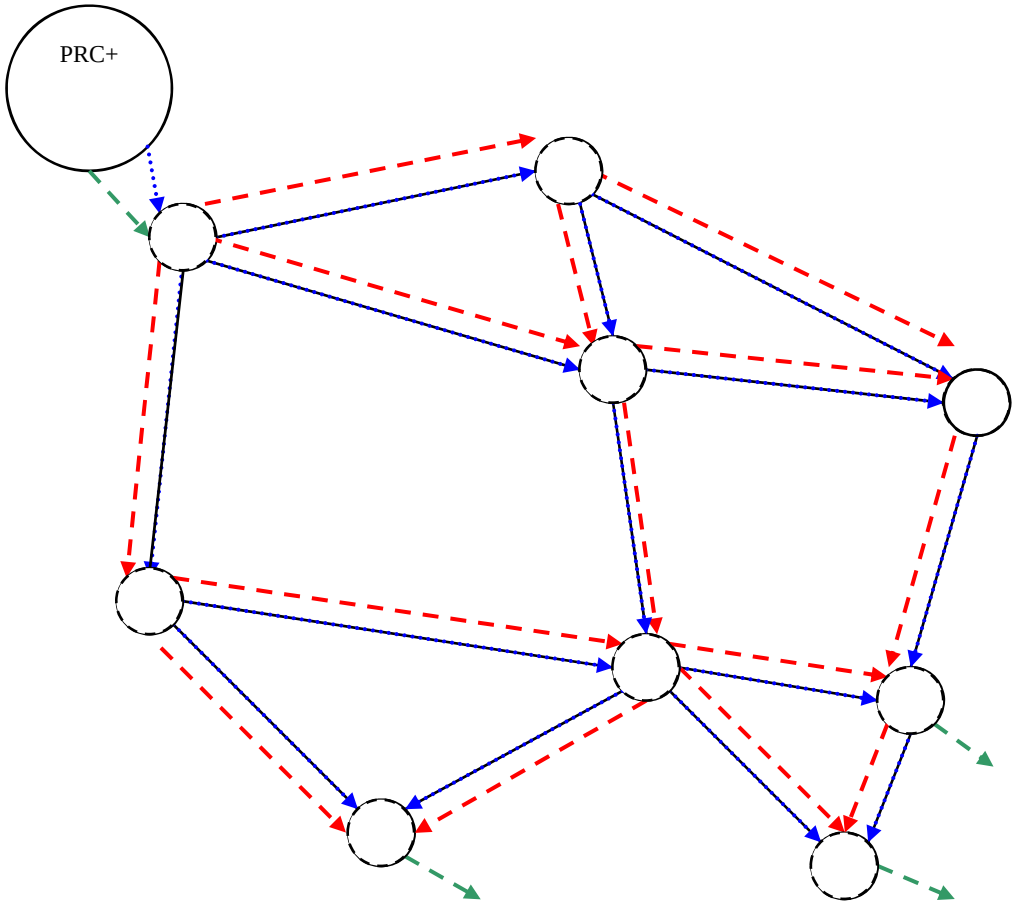
- **Classic 4 timestamps approach**
  - > Principle as per NTP, IEEE1588 etc.
- **extremely simple**
  - > A Single 4 byte value exchange
- **Runs over existing Ethernet protocol**
  (E.g. Ethernet Synchronization Message Channel)

Classic 4 timestamps – optimized two-way algorithm
4 bytes per direction (per second)



Clock offset = (t2-t1+t3-t4)/2

Phase Synchronous Ethernet PSE
Identical topology to Synchronous Ethernet

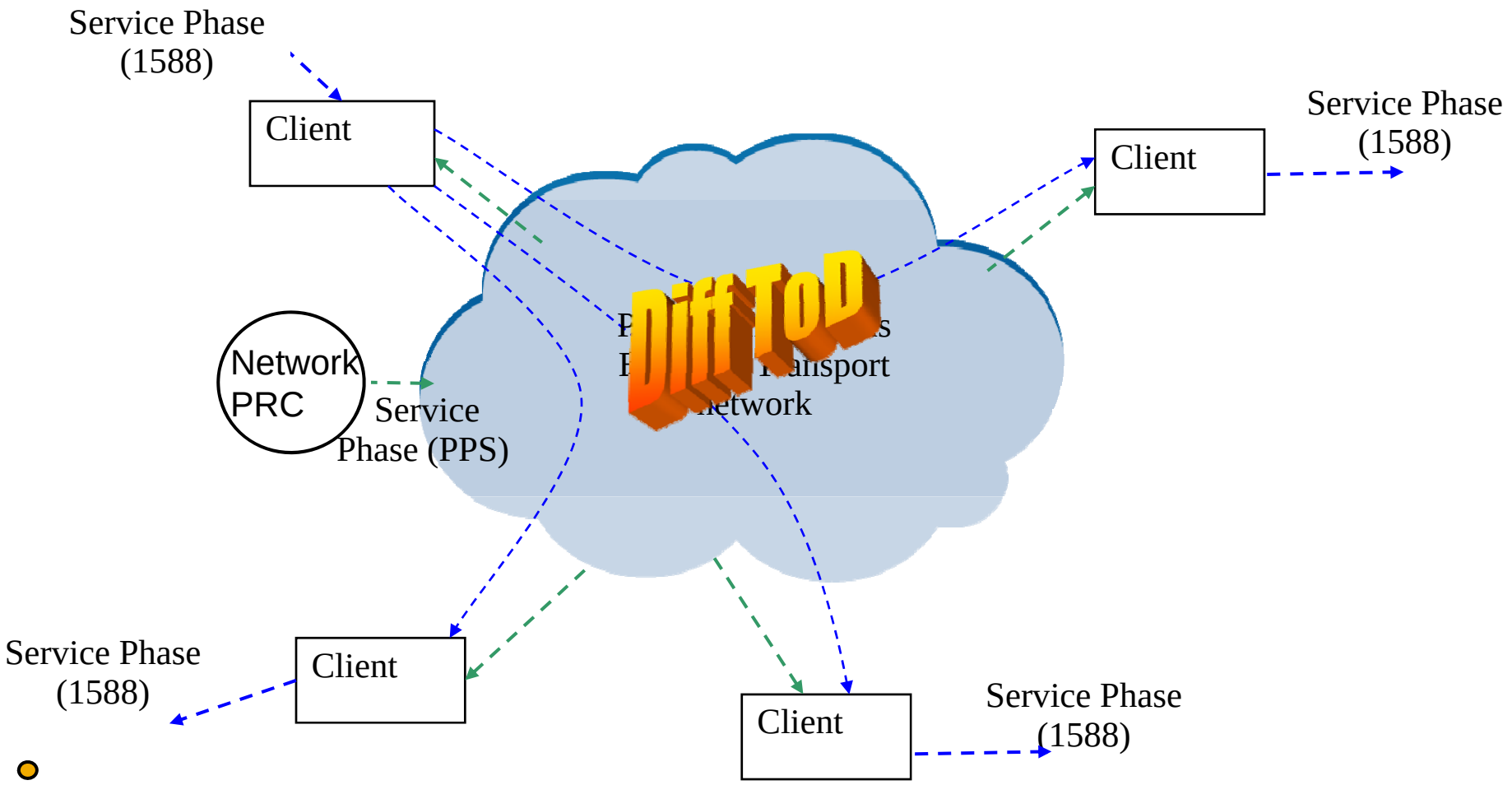


Phase Distribution (ESMC)

Clock Distribution (Synchronous link)

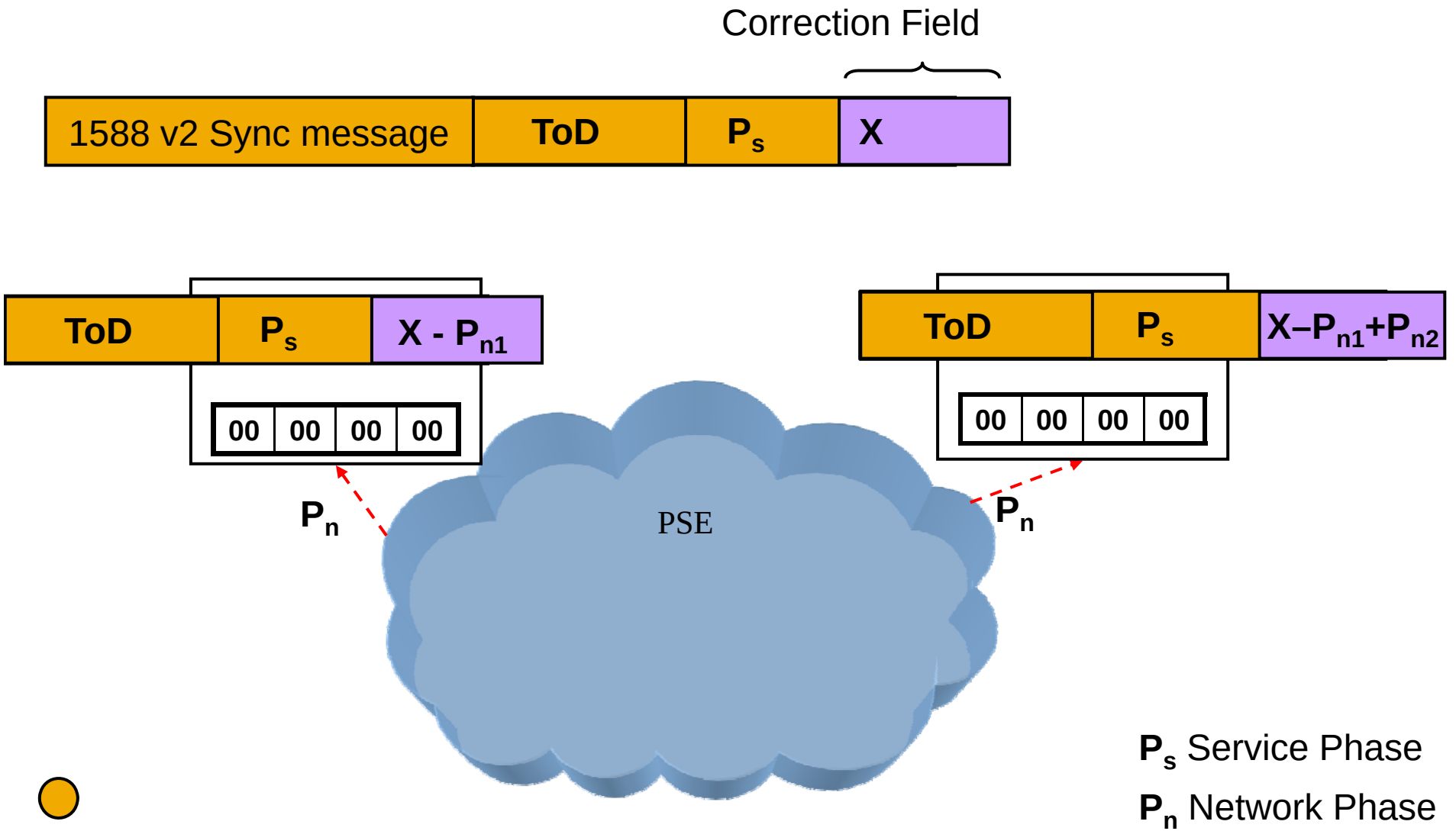
Pulse Per Second (PPS)

Service phase – transported over Network phase as a difference IEEE1588 used in Client network (transparent to transport network)



Differential Time of Day

Service phase – transported over Network phase as a difference IEEE1588 used in Client network (transparent to transport network)



Differential Time of Day (Diff ToD)

- **Same approach as SRTS uses for frequency**
  - (carries service clock as a difference to Network clock)

- **IEEE1588 features can be put to good use… especially the Correction field**
  - Adds the phase difference of the Service phase to the Network phase.

- **Advantages**
  - Simple for transport network
  - Flexible for Client network
  - Clear demarcation of transport and Client networks

Summary

1. **PSE provides 1PPS network phase alignment across transport infrastructure**
   - > No PDV dragons,
   - > No Asymmetric synchronization topologies
   - > Very Small delta to existing frequency Synchronization Management

2. **Each End user can have autonomous Service phase and ToD.**
   - > ToD layer management requires no transport operator involvement
   - > Ongoing Proposal to ITU-T SG15 Q13 (Telecom Profile Differential ToD method)

3. **IEEE1588 is an integral part of Diff ToD.**

Phase Synchronous Ethernet + Diff ToD form the simplest mechanism for offering a synchronization service via a telecoms network

Thank You

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TSE Management Interface – Info Model specification

- **Add e.g. the following attribute to the ethrSyncTTPBid MO:**

ethrSyncTTPBid::ethTseMode

Description:

Time Synchronous Ethernet (TSE) operating mode.

Syntax:

TseMode	0 = disabled	(= default)
	1 = master	
	2 = slave	

Clear ideas that didn't quite make it

Other PPS over Ethernet Implementation techniques.
Ethernet is synchronous - one of those 8ns spaced pulses is the PPS

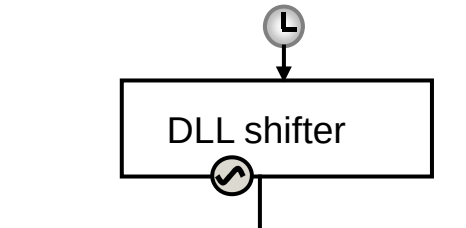
1. **The ”pulse event” can be sent at the specified GPS pulse time**
   - > Clock phase jump. (See experimental results)
   - > by scheduling the link such that the line is kept clear at the transmit instance (flow control the Mac).
   - > Transmitting a known symbol, or symbol sequence
     (IEEE 803.2 hasn’t defined a PPS symbol)

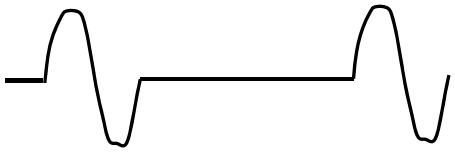
2. **The ”pulse event” is sent at or after the specified GPS pulse time**
   - > correction value allows correction, by the number of phy clock cycles the pulse is delayed.

3. **Offset (in phy clock cycles) until next second**
   - > sent continuously, say in IFG

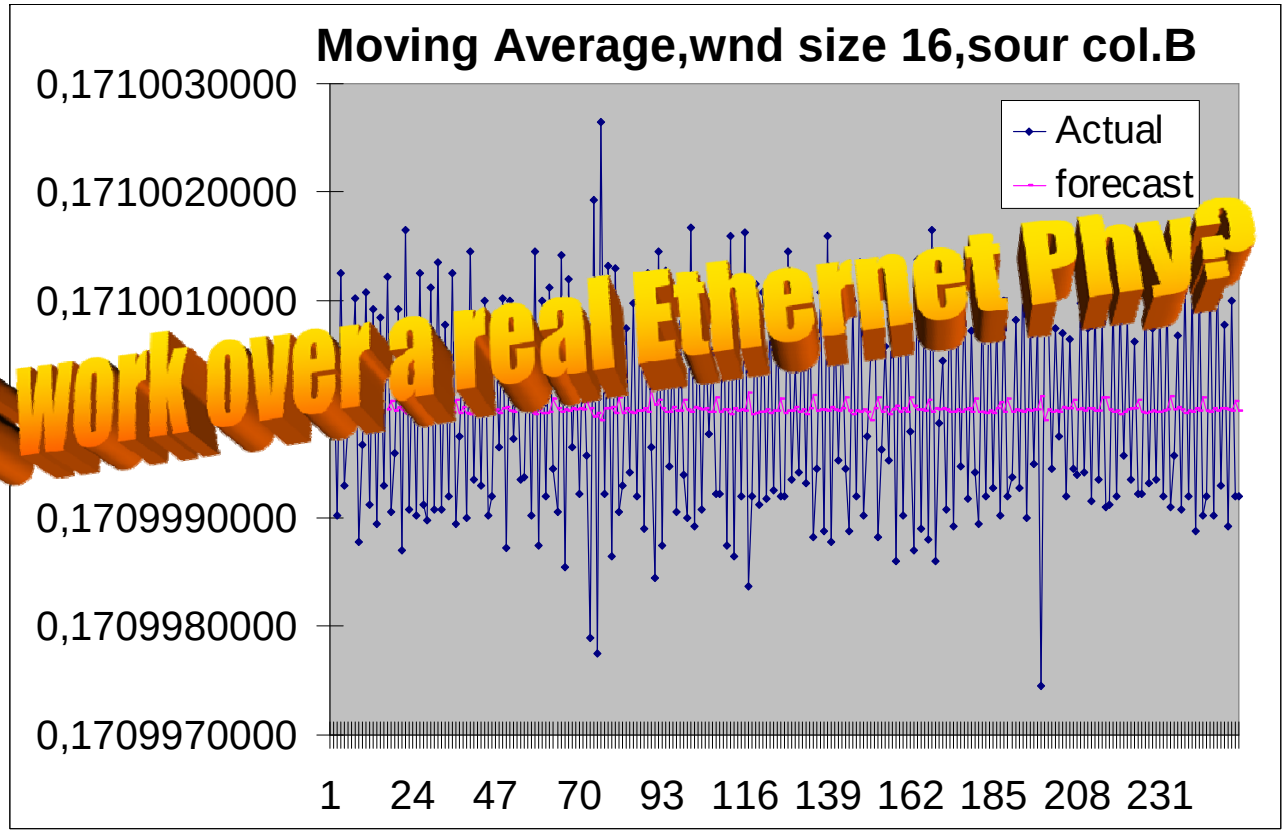
All Require Media Delay compensation (Round Trip Time) measurement

Experimental accuracy achieved with phase pulse detection





Phase pulses to Tx DLL



How would this work over a real Ethernet Phy?

30ns accuracy (after averaging) using FPGA boards

Measurement options using Round Trip Time

1. **Direct Round-Trip Time**

2. **Round-trip Trip with “prepare”**
   (e.g. 802.3ah intrusive loopback)

3. **Round-trip Time with “residence”**