IEEE 1588
Packet Network Synchronization Solution

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Packet Network Synchronization Basics for Telecom

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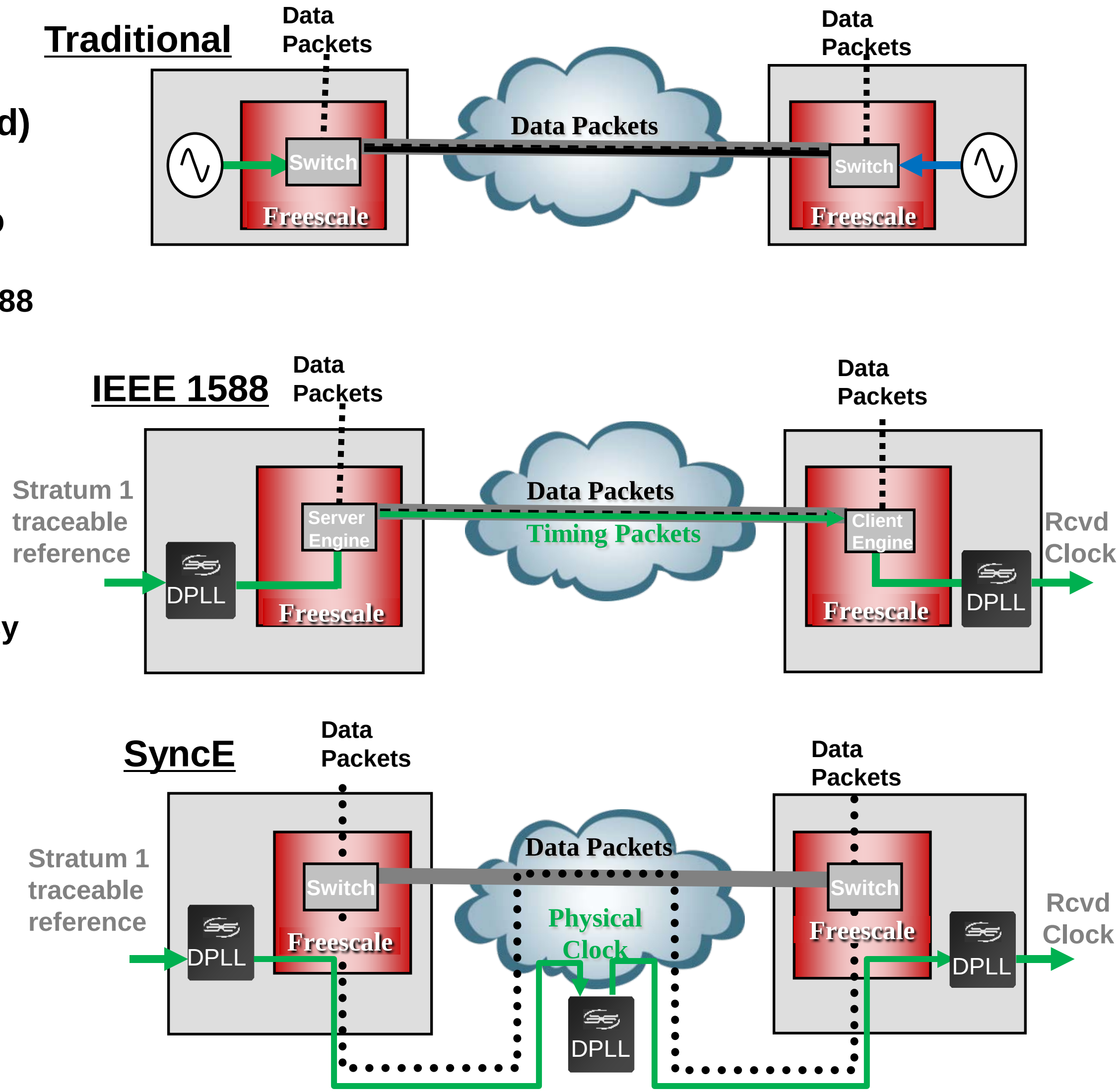
Packet Networks Synchronization Solutions

- Deployment of Traditional Packet Networks are Asynchronous (self timed)
- When Synchronization is required, two dominant solutions are deployed
  - Protocol Layer Synchronization IEEE 1588
  - Physical Layer Synchronization or Synchronous Ethernet (SyncE)
- IEEE 1588
  - Packet-based and load and network dependent
  - Works on existing packet networks
  - Distributes time of the day and frequency
- SyncE
  - Physical layer based, point-to-point, independent of network loading
  - Requires H/W upgrade on each physical interface to accommodate locking to a reference clock
  - Transfers frequency, not phase or time information



Evolution of Synchronization

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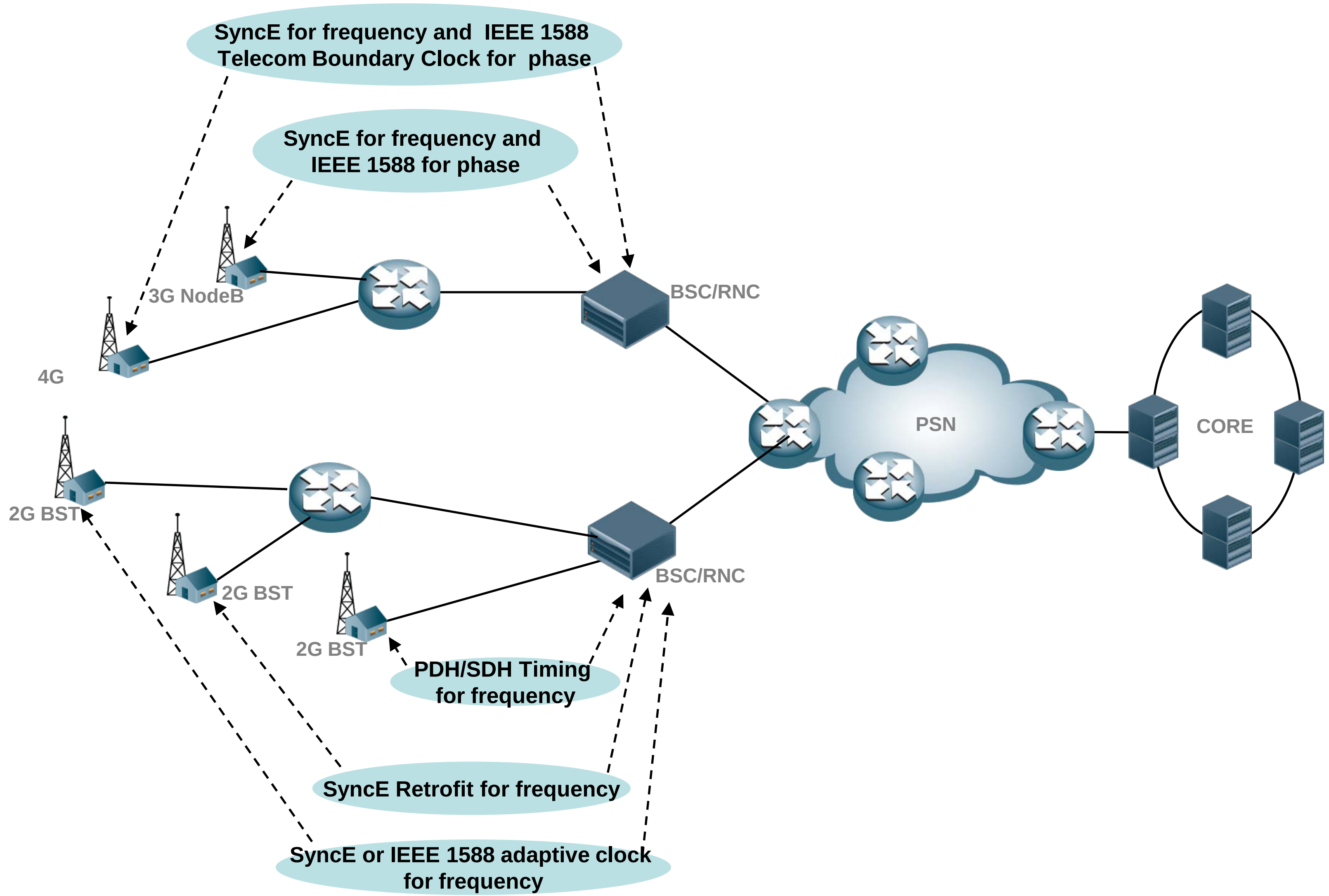
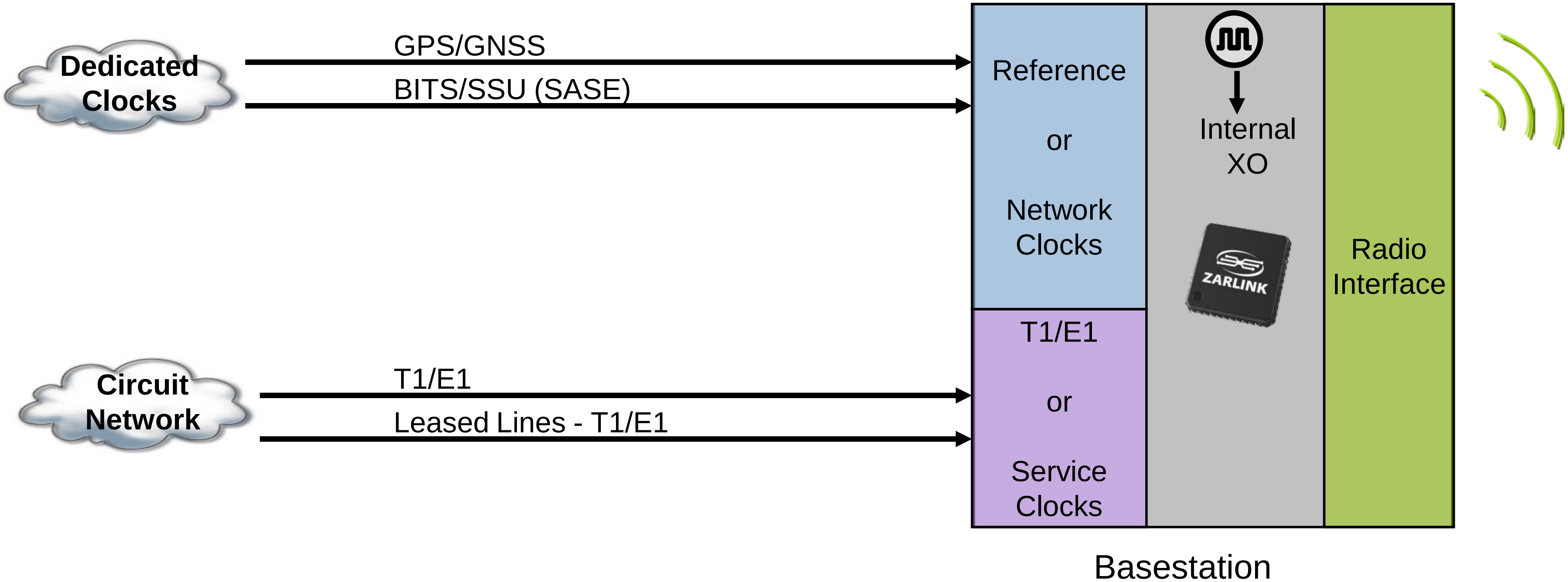
Evolution of Synchronization



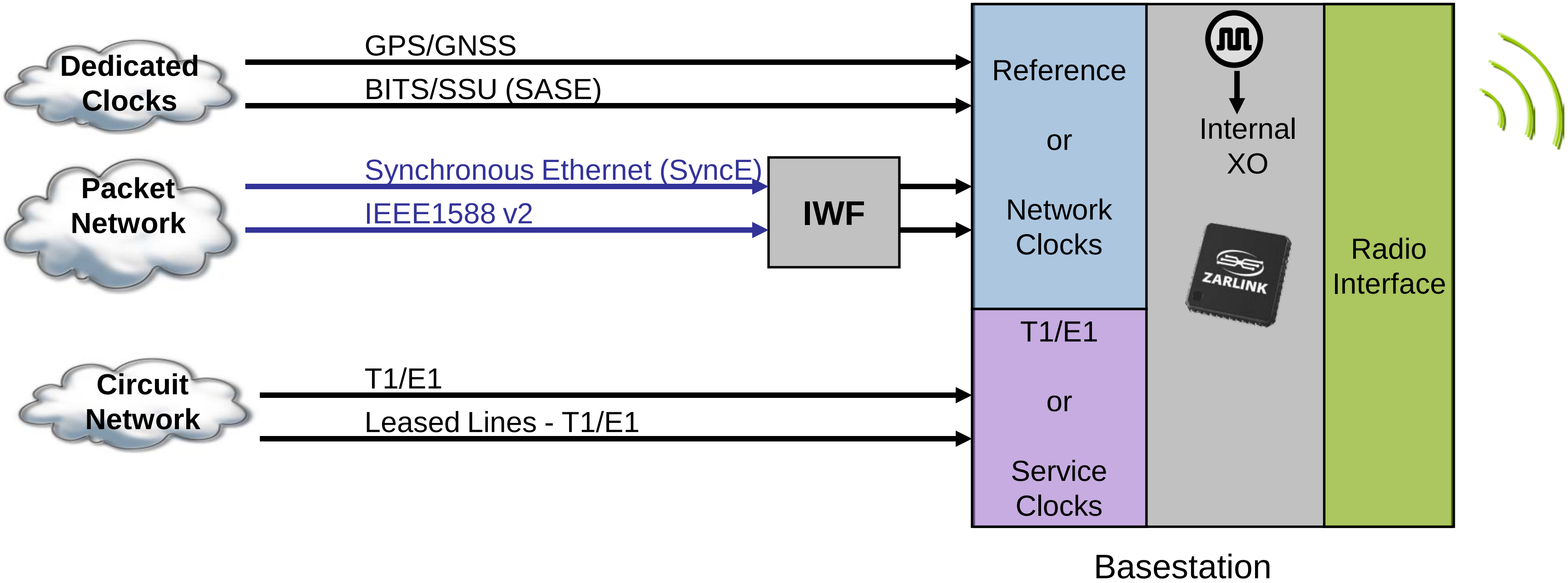
2G Synchronization Sources

- **Primarily basestation has access to T1/E1 line**
  - **Provided by backhaul operator, if different than mobile operator, as 'leased line'**
  - **Synchronization carried on T1/E1 used for Abis interface**
- **Some use of GPS/GNSS or local BITS/SSU**



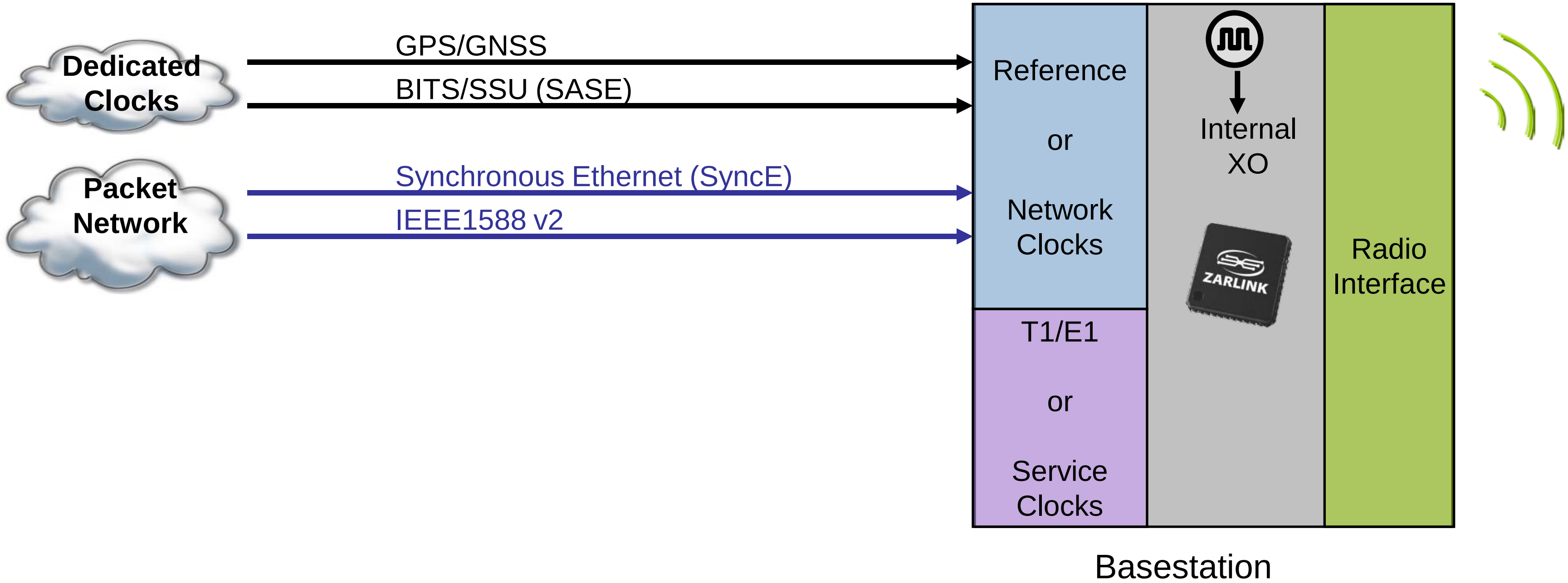
3G Synchronization Sources

- **Legacy**
  - **Primarily basestation has access to T1/E1 line**
  - **Local BITS/SSU sometimes available**
  - **SONET/SDH connections may be available closer to the cell-site, but normally not connected directly to basestation**
  - **Increased use of GPS/GNSS in USA or for TD-SCDMA**
- **Evolving**
  - **Now see SyncE and IEEE 1588 references available at cell-site**
  - **Likely converted before connecting to basestation**
  - **Some 3G basestations may have embedded SyncE or IEEE 1588 capability**



4G Synchronization Sources

- **Dominated by packet-based synchronization**
  - **Synchronous Ethernet**
  - **IEEE 1588 clients embedded into basestation**
- **Use of GPS/GNSS for some TDD services, especially in United States**



Standards Development and Operator Deployments

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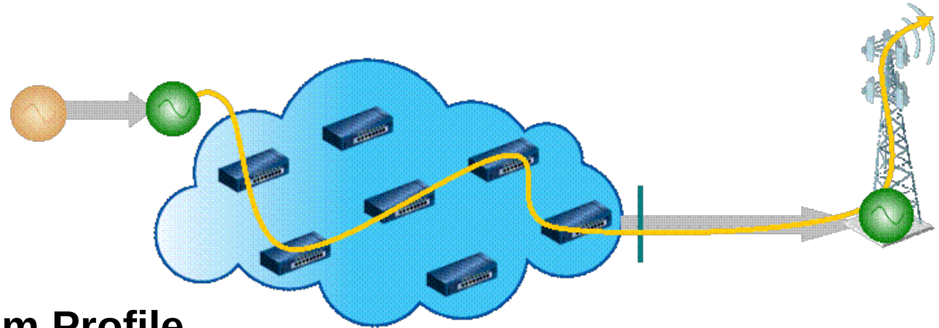
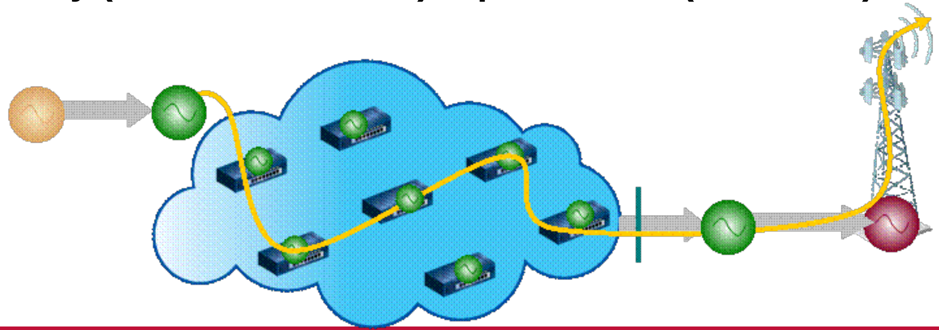
Telecom Profile for Frequency vs. Telecom Profile for Phase

- **Frequency Telecom Profile**
  - **A PSN may be inserted between the server and client, that is not aware of protocol layer synchronization packets (e.g. IEEE 1588-2008)**
  - **Only support frequency (MTIE, TDEV, FFO) transfer**



- **Phase Telecom Profile**
  - **The PSN has 'on-path support' where each switch / router is aware of protocol layer synchronization packets (e.g. IEEE 1588-2008 Boundary Clock)**
  - **Support frequency (MTIE, TDEV, FFO) & phase/time (PPS, ToD) transfer**



Standards by Category & Technology

Category	PDH (E1)	PDH (T1)	SDH	SONET	SyncE	OTN	PSC-A (CES)	PEC Frequency (No On-Path Support / Unaware)	PEC Phase/Time (Unaware Networks)	PEC Phase/Time (With On-Path Support / Aware)
Network Limit	G.823	G.824 T1.101	G.825	G.825 T1.105	G.8261	G.8251	G.8261 G.8261.1 (D)	G.8261 G.8261.1 (D)	No Plan to Standardize	G.8271 (D)
Equipment	G.812	G.812 T1.101 GR-1244	G.813	G.813 T1.105 GR-253	G.8262	G.798		G.8263.1 [Mastr] (D) G.8263.2 [Slave] (D)	No Plan to Standardize	G.8272 [PRTC] (D) G.8273.1 [Master] (D) G.8273.2 [BC w/SyncE] (D) G.8723.2 [BC wo/SyncE] (ND)
Architecture							G.8265	G.8265	No Plan to Standardize	G.8275 (D)
OAM	G.781	G.781	G.707 G.781 G.783	GR-253	G.8264			G.8265.1	No Plan to Standardize	G.8275.1 (D)
Protocol							Y.1413 Y.1453	1588-2008 [OC] NTPv4 G.8265.1	1588-2008 [OC, BC]	1588-2008 [OC, BC, TC] NTPv4 G.8275.1 (D)
Definitions	G.810	G.810	G.810	G.810	G.8260		G.8260	G.8260	No Plan to Standardize	G.8260
Test	O.171		O.172			O.173	G.8261	G.8261	No Plan to Standardize	

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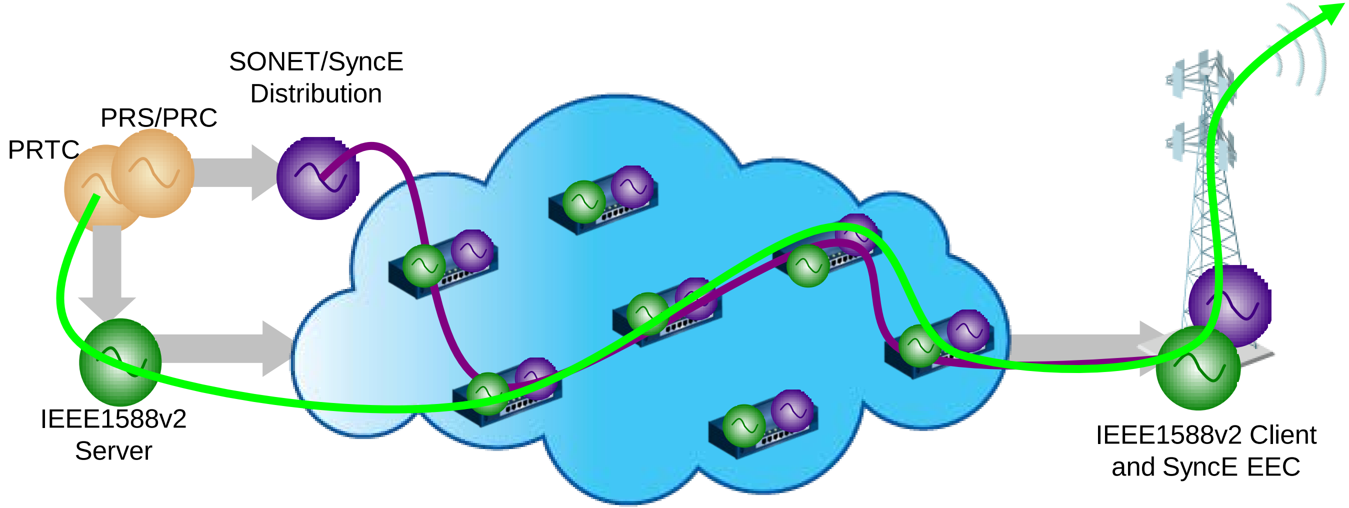
Types of Timing Standards: Standards by Category

- Network Limits
  - ITU-T G.823 (E1), G.824 (T1), G.825 (SDH), G.8251 (OTN), G.8261 (SyncE, PSC-A, CES, PEC Frequency)
  - ITU-T G.8261.1 (PEC Frequency), G.8271.1 (PEC Phase)
  - ANSI T1.403, T1.101, T1.105 (SONET)
- Service Limits
  - MEF 22 (CES for MBH), MEF 22.1 (CES, SyncE, PEC for MBH)
  - BBF MFA 20 (CES, SyncE, PEC for MBH)
- Equipment Limits
  - ITU-T G.811 (PRC), G.812, G.813 (SONET/SDH), G.8262 (SyncE)
  - ITU-T G.8263.1 (PEC Master Frequency), G.8263.2 (PEC Slave Frequency)
  - G.8272 (PEC PRTC Phase), G.8273.1 (PEC Master Phase), G.8273.2 (PEC BC Phase)
  - ANSI T1.101
  - Telcordia GR-1244-CORE, GR-253-CORE
- Protocol
  - IEEE 1588-2002 (PTP v1), 1588-2008 (PTP v2)
  - ITU-T G.8265.1 Telecom Profile for PEC Frequency (uses OC, new BMCA)
  - ITU-T G.8275.1 Telecom Profile for PEC Phase (uses OC, BC)
  - IETF RFC5905 (NTPv4), RFC5906 (NTPv4 Autokey), RFC1305 (NTPv3), RFC2030 (SNTPv3), RFC3550 (RTP)
- OAM
  - ITU-T G.781 (QL, SSM), G.8264 (SyncE ESMC)
  - ITU-T G.8265.1 Telecom Profile for PEC Frequency (QL via clockClass, new BMCA)
  - ITU-T G.8275.1 Telecom Profile for PEC Phase (QL via clockClass, new BMCA)
  - IETF RFC5907 (NTPv4 MIB), RFC5908 (NTPv4 DHCP)
- Definitions
  - ITU-T G.810, G.8260 (PEC, PSC-A, CES)
  - ITU-T G.8260 (PEC Frequency, PEC Phase)
- Test
  - ITU-T O.171 (PDH), O.172 (SDH), O.173 (OTN)

In development

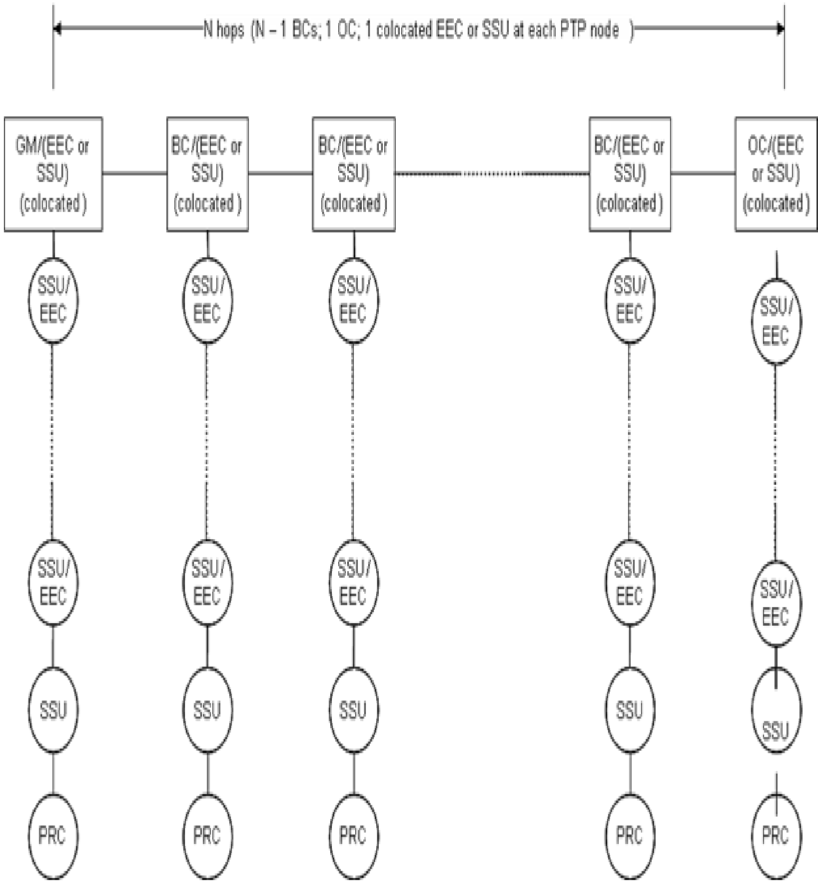
Convergence of IEEE 1588 and SyncE

- **ITU are focused on converged IEEE 1588 & SyncE**
  - **Targeted for completion by Sept 2012**
  - **IEEE 1588 only (without SyncE) BC model not agreed**
  - **TC will only be considered after BC is completed**
  - **China Mobile contributions related to field deployments and other operator RFPs**
- **PSN with SyncE-enabled and 1588-aware switches/routers acting as BC**
  - **The technologies work together, as SyncE provides frequency synchronization for IEEE 1588**
  - **All nodes in the PSN support SyncE/SONET frequency synchronization**
  - **All nodes in the PSN support IEEE 1588 Boundary Clock protocol**
    - **Used for phase & time synchronization, but not frequency synchronization**
  - **End-to-end high performance frequency accuracy, phase and time synchronization**



Convergence of IEEE 1588 and SyncE

- **Standardization will adopt IEEE 1588 + SyncE as first model**
- **ITU-T Contributions on IEEE 1588 + SyncE**
  - C599 GVA ZTE & CMCC (BC+SyncE)
  - WD29 LAI Huawei & CMCC (BC+SyncE)
  - WD13 SJC Huawei & CMCC (BC+SyncE)
  - WD14 SJC Huawei & CMCC (BC compare synt & non-synt)
  - WD64 SJC ZTE & CMCC (BC+SyncE)
  - C897 SZH ZTE & CMCC (BC+SyncE)
- **ITU-T Working plan for IEEE 1588 + SyncE**
  - C1510 and C1511 GVA Huawei have agreed to use for first simulations
  - No agreement on simulations without SyncE
  - TC is postponed until after work on BC is completed



HRM2 From G.8271 Draft

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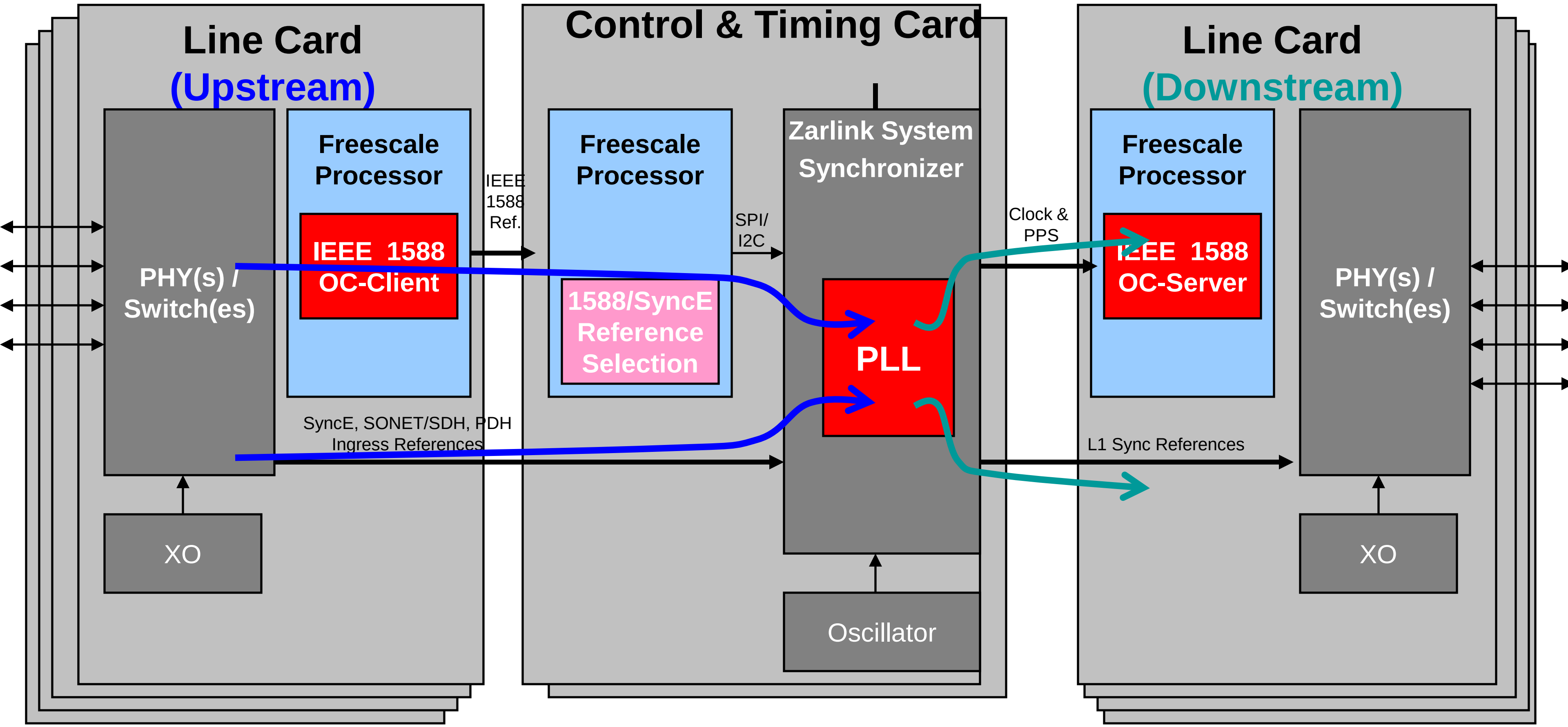
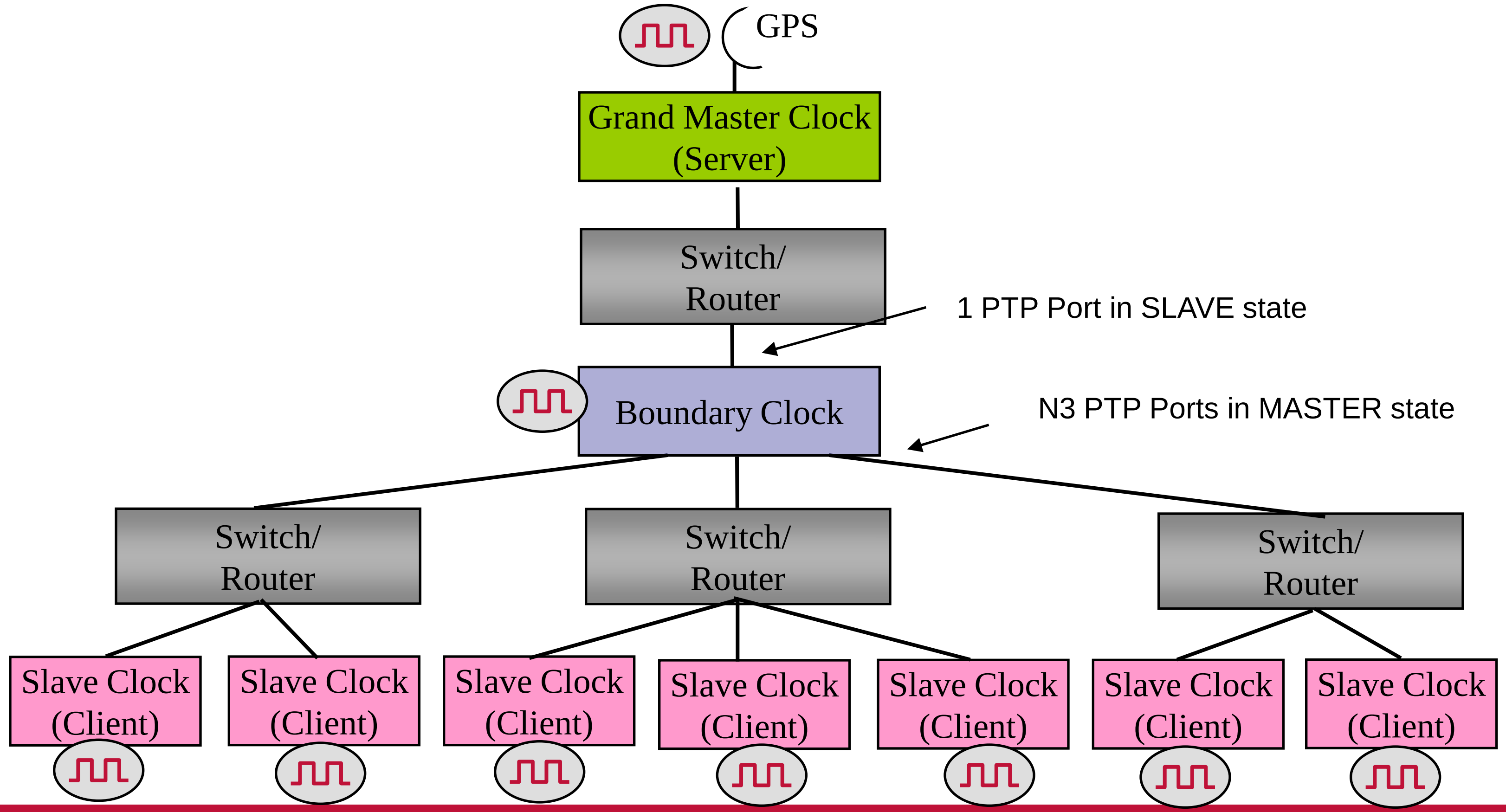
Convergence of IEEE 1588 and SyncE

- **Logical Flow of 1588 and SyncE through a network element**
- **Synchronization technology needs to concurrently accept and support IEEE 1588 and SyncE clocks**



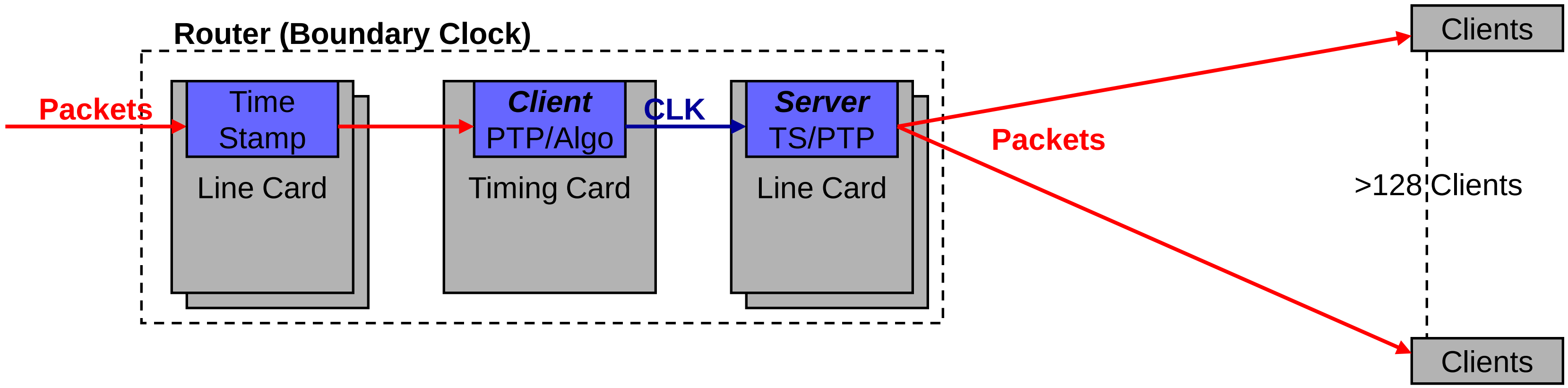
IEEE 1588: Boundary Clock

- A boundary clock is used to break a large network into smaller groups
- A clock is recovered and re-generated at the boundary clock
- A boundary clock has 1 PTP port in SLAVE state and PTP ports in MASTER state
- A boundary clock determines the PTP port to put into SLAVE mode based on default BMCA



Telecom-Boundary Clock / Boundary 'Node'

- **Distributed architecture with centralized 1588 algorithm allows to monitor servers from different line cards with logical & physical diversity**



- **A Telecom-BC is different than an IEEE 1588-2008 BC**
  - **Different reference selection criteria**
  - **May support multiple slave connections to monitor multiple servers**
  - **May support specific alarm handling and traditional telecom G.781 features**

Synchronization
Redundancy & Reliability

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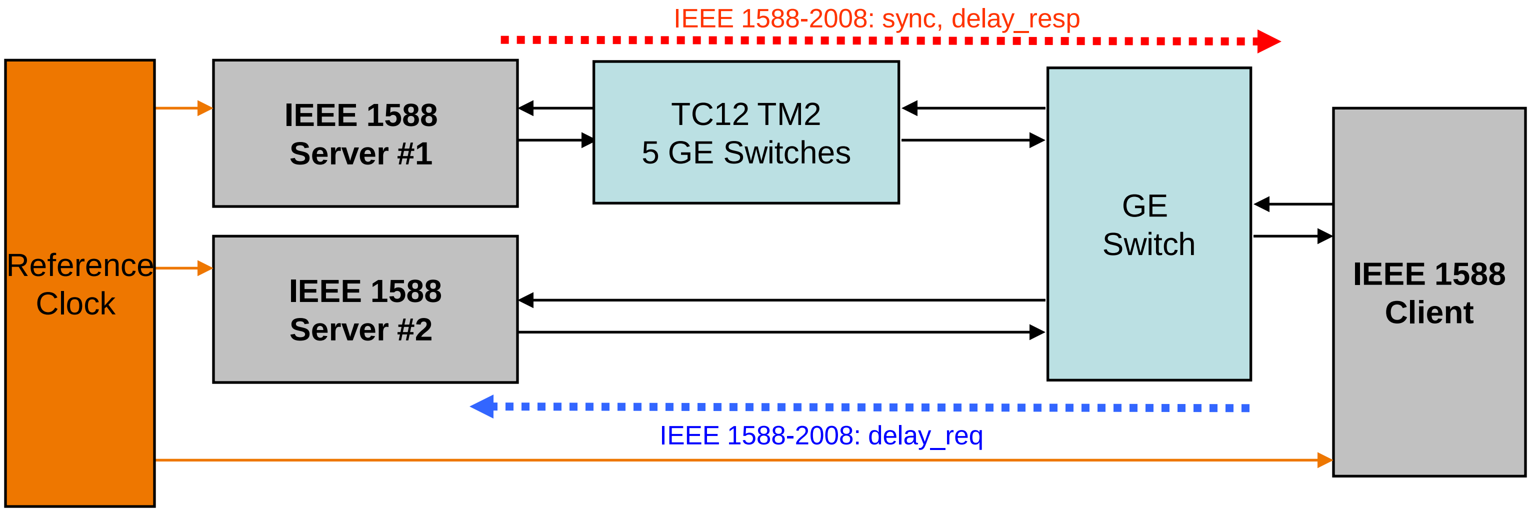
Synchronization Redundancy & Reliability

- During IEEE 1588 failures, SyncE enables low phase movement for long-term stability
- GPS, SyncE & PTP failures are not likely to occur at the same time
  - Reduces need for expensive oscillator during holdover as holdover periods shortened
- Multiple PTP server monitoring on diverse logical & physical paths
- Zarlink provides critical hitless reference switching features
  - Packet to Packet, Packet to Electrical, Electrical to Packet, Electrical to Electrical
  - Zarlink PLL accepts both physical layer (GPS, SyncE) and protocol layer (IEEE 1588) references

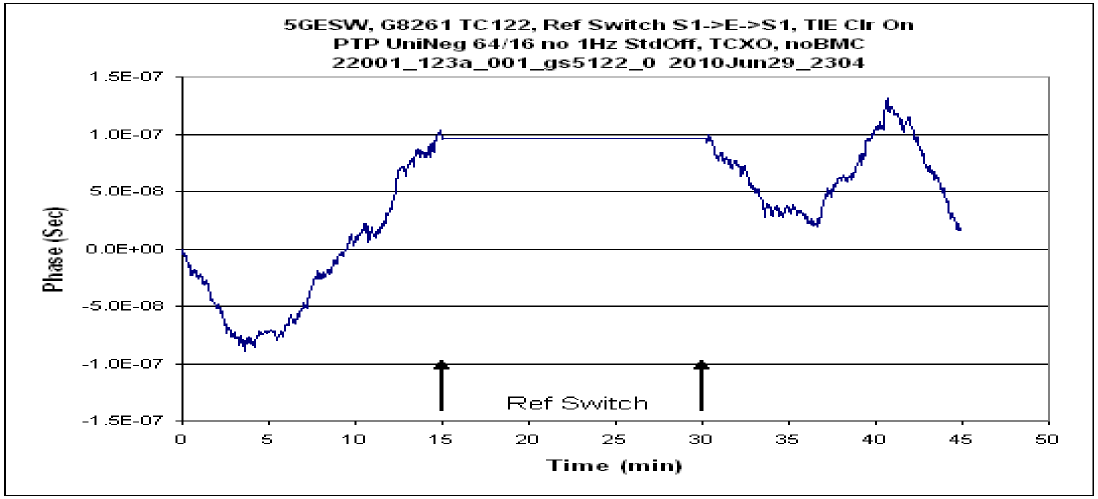
Synchronization Redundancy & Reliability
Test Setup: IEEE 1588 to SyncE to IEEE 1588

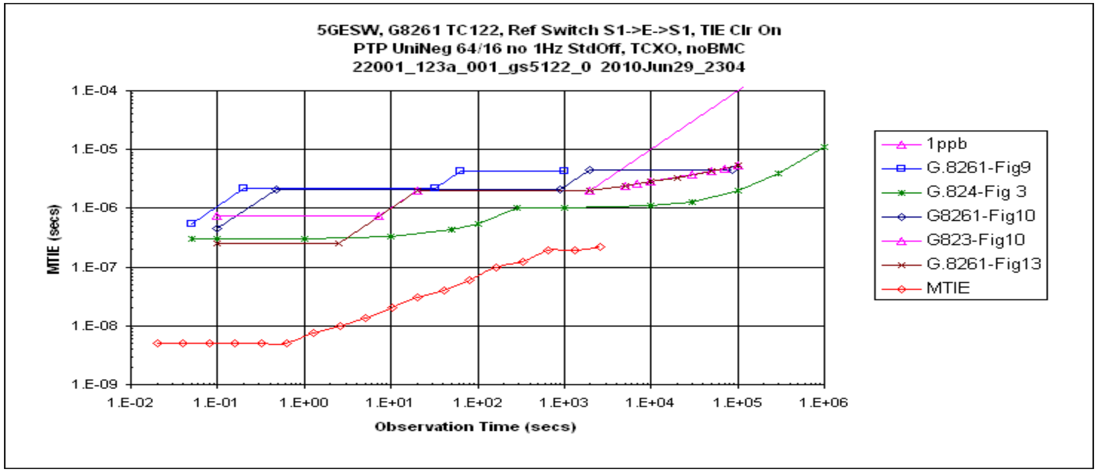


- **Background Traffic Flows**
  - **Traffic Model 2 – 60% 1518 byte packets, 10% 576 byte packets, 30% 64 byte packets, over 5 GE switches**
- **Appendix VI.5**
  - **Server#1 → Client: Link static traffic (Test case 12, fwd/rev 80%/20%)**
  - **Server#2 → Client: Link with no traffic**
- **Reference switching**
  - **The first reference switching is done 15 minutes elapsed lock time (e.g. 30 minutes)**
    - **Switching to Server#2 or Electrical**
  - **The second reference switching is 15 minutes later**
    - **Switching back to Server #1**

Synchronization Redundancy & Reliability

Test Results: IEEE 1588 to SyncE to IEEE 1588





- **Test Notes**
  - **TIE Clear ON**

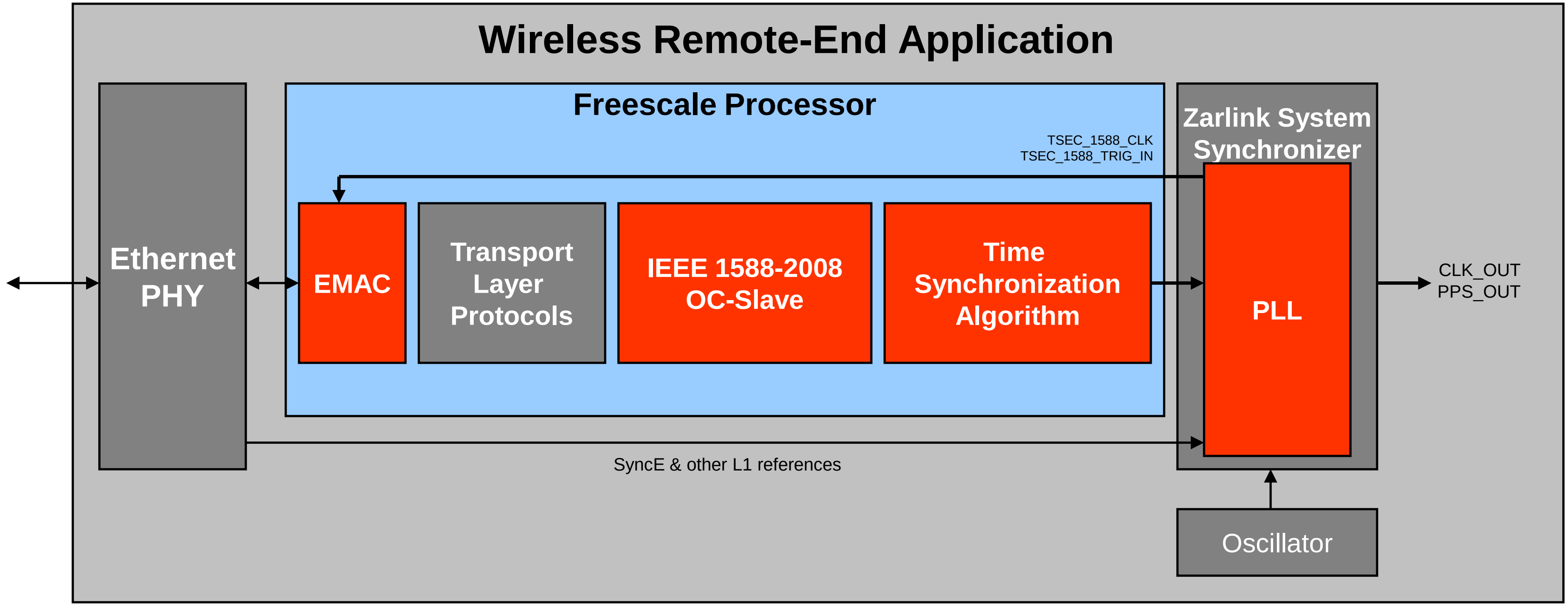
Precise Frequency Control and Increases Clock Management Complexity

- **Frequency control with 40 bit accuracy**
  - **To offers better than 0.001ppb controllability**
- **Stratum 2/3E quality for Holdover accuracy**
  - **Entry into holdover can be forced even for a valid input reference**
  - **Holdover engine with ultra low bandwidth filter for longer holdover history**
  - **Can employ an older holdover value in case of slow SW response to decide to enter holdover**
- **1PPS output signal is phase aligned to the output clocks**
  - **Simplifies line card design, no need to re-latch or re-align the 1PPS signal on the line card**

System Design Considerations/ Hardware Architecture

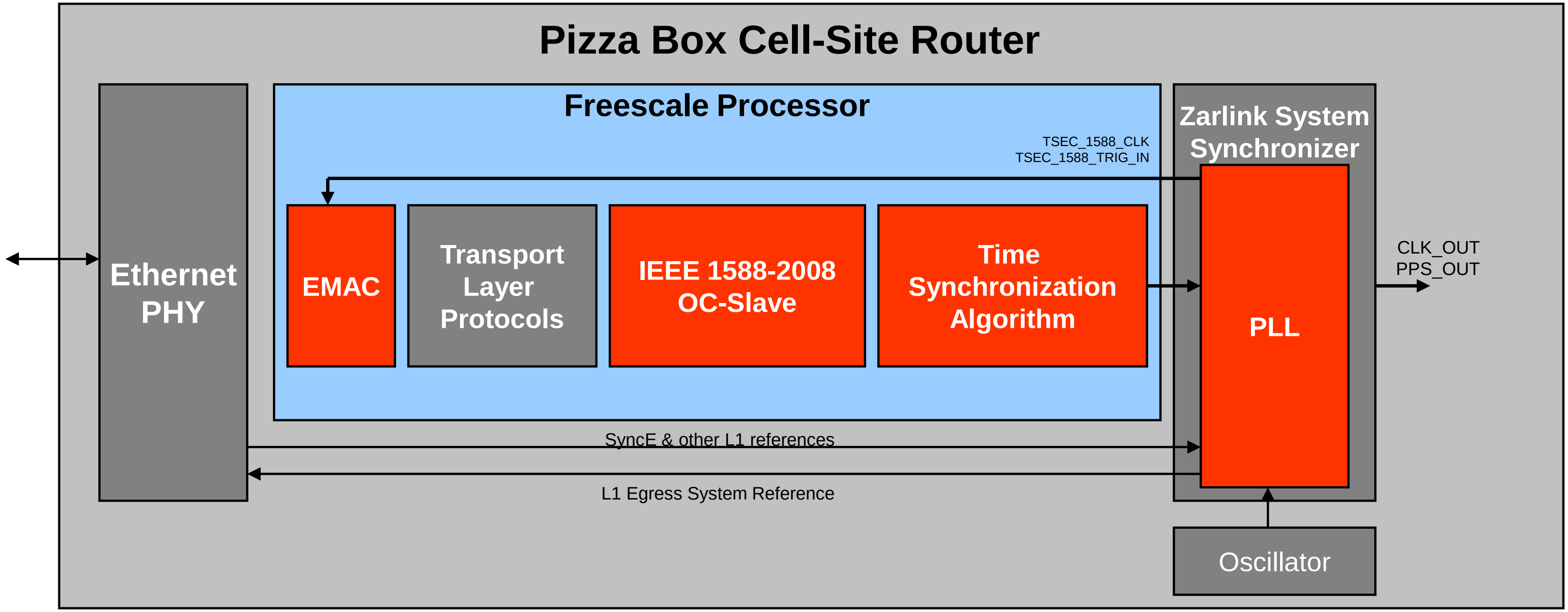
Wireless Remote-End Application IEEE 1588 with SyncE

- **Freescale Host Processor provides protocol synchronization solution uses IEEE 1588-enabled MAC**
- **Addition of System Synchronizer enables Synchronous Ethernet support with reduced jitter clocks**
- **Software modules for IEEE 1588 and Servo Algorithm interact with System Synchronizer to allow reference switching between diverse synchronization sources**



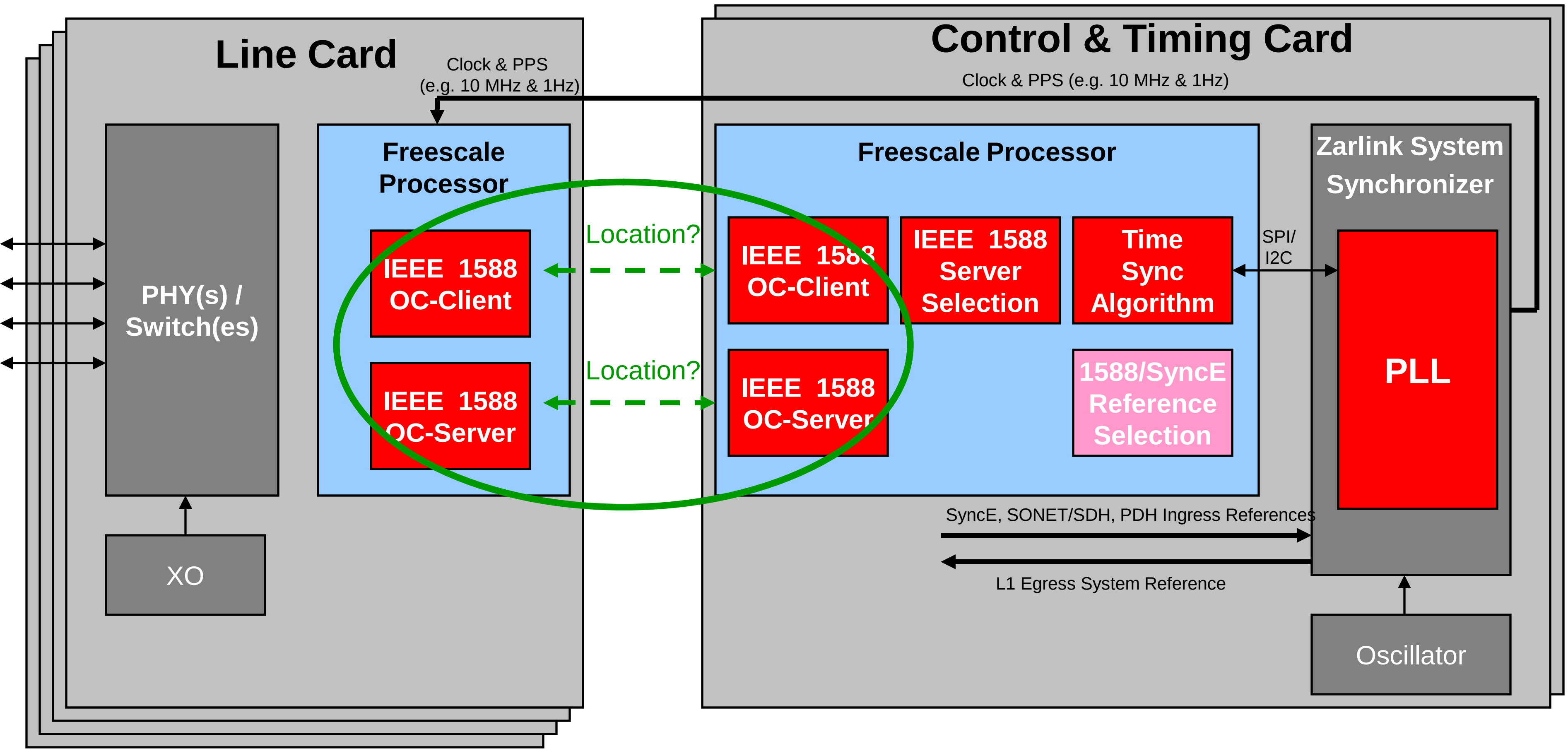
Cell-Site Switch/Router Pizza Box

- Freescale Host Processor provides protocol synchronization solution uses 1588-enabled MAC
- Addition of external System Synchronizer enables Synchronous Ethernet support with reduced jitter clocks
- Software modules for IEEE 1588 and Servo Algorithm interact with System Synchronizer to allow reference switching between diverse synchronization sources



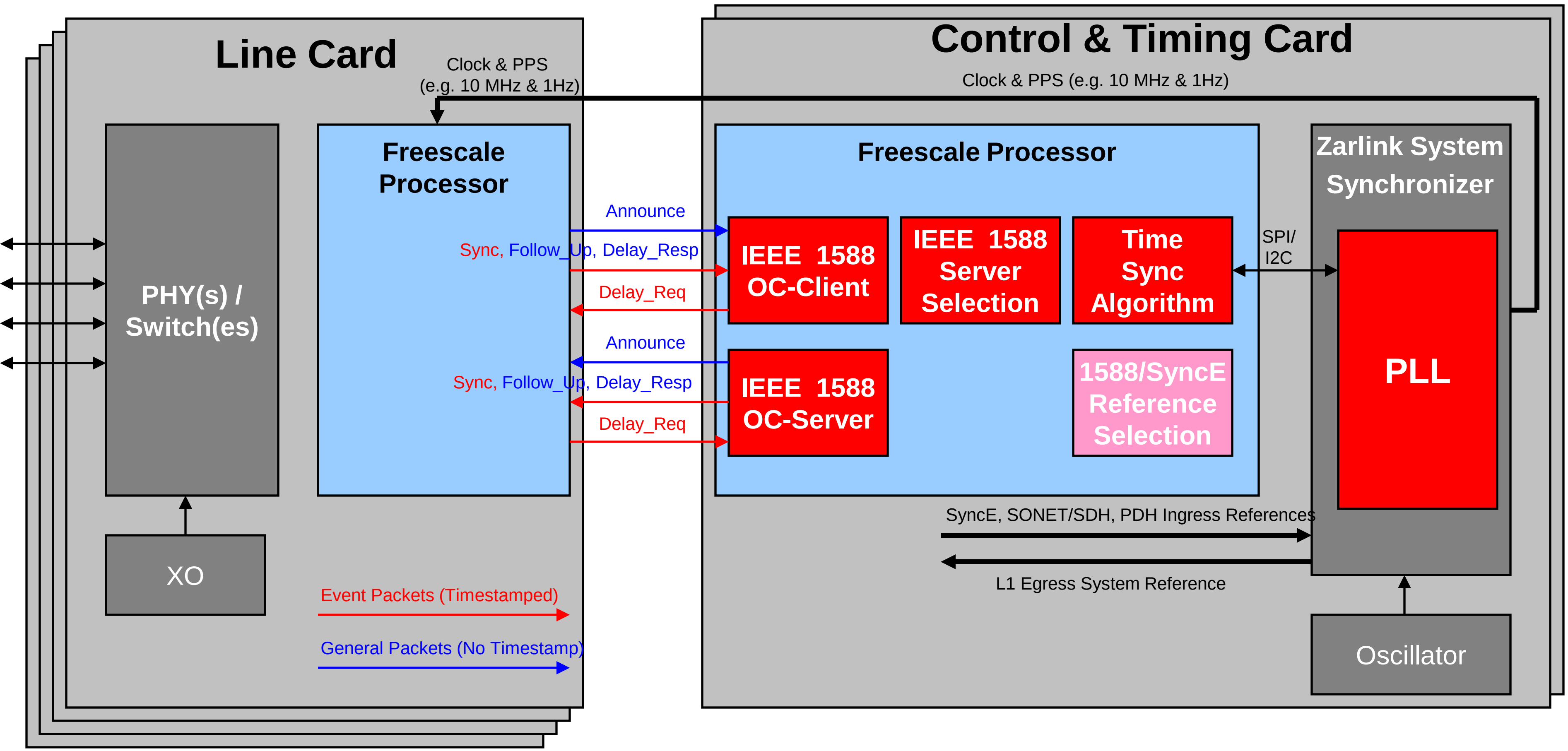
Mobile Backhaul Switch/Router with Centralized Synchronization Module

- **Where to locate the IEEE Client & Server modules inside a larger, distributed system?**



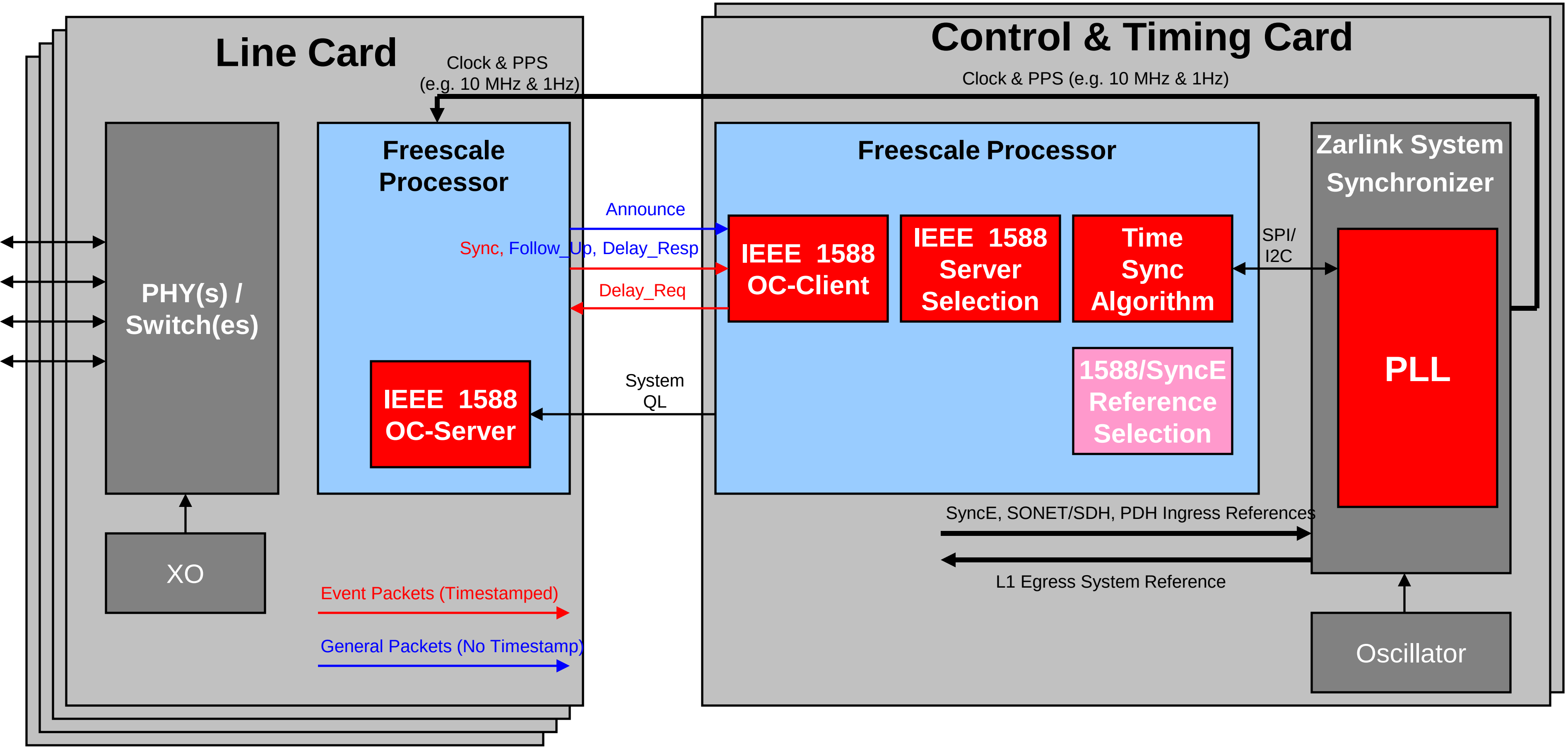
Mobile Backhaul Switch/Router with Centralized Synchronization Module

- **Centralization of IEEE 1588 on the timing card**
- **May have difficulty to scale capacity in Server mode**



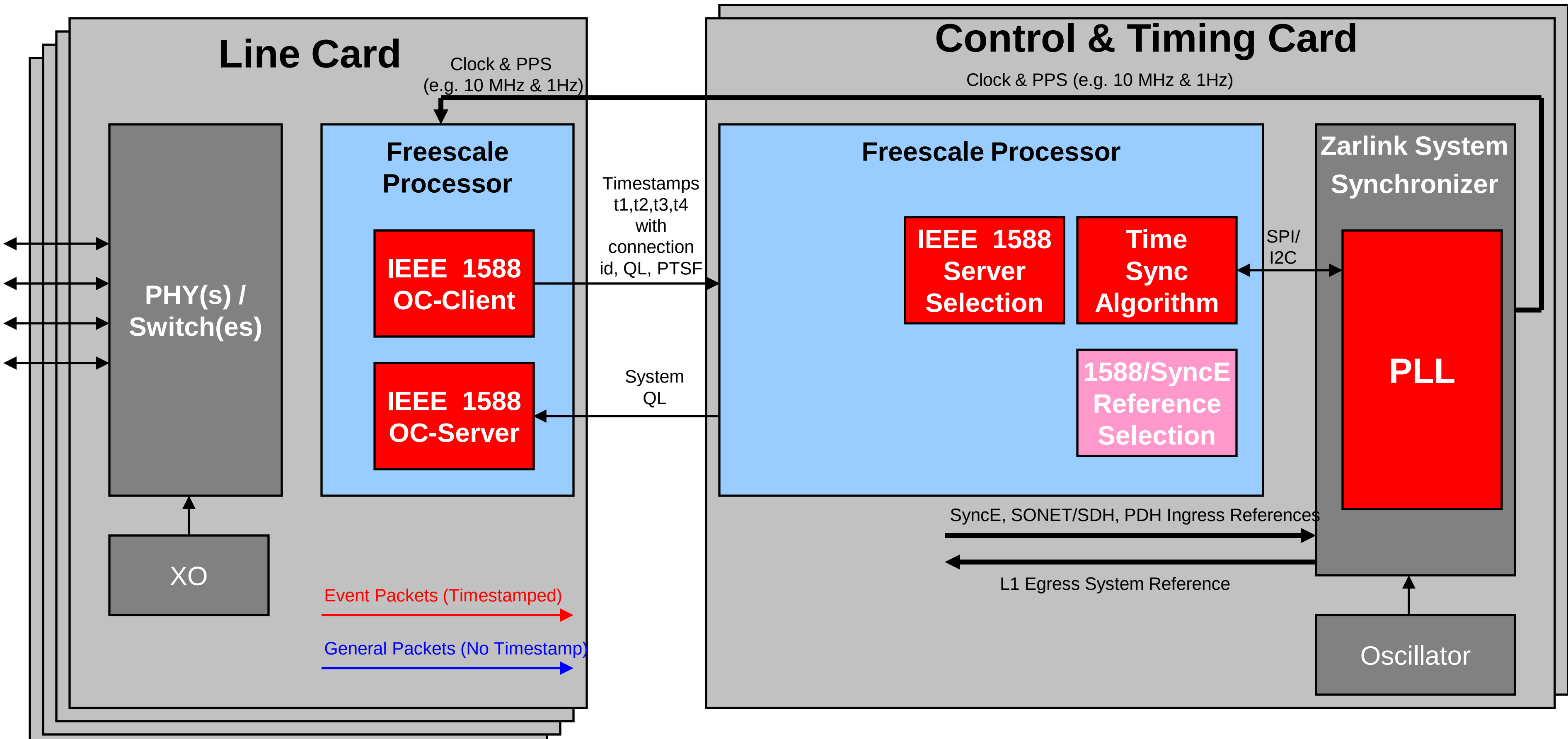
Mobile Backhaul Switch/Router with Centralized Synchronization Module

- **Server now can scale with individual line card design**
- **Reduced timestamp accuracy with client on the timing card**



Mobile Backhaul Router with Centralized Synchronization Module

- **Server and client now can scale with individual line card design**
- **Server and client protocol handled on line card, leaving timing card to focus on synchronization (similar to traditional implementations of SONET/SDH)**
- **Highest performance and most scalable**



System Design Considerations/ Software Architecture

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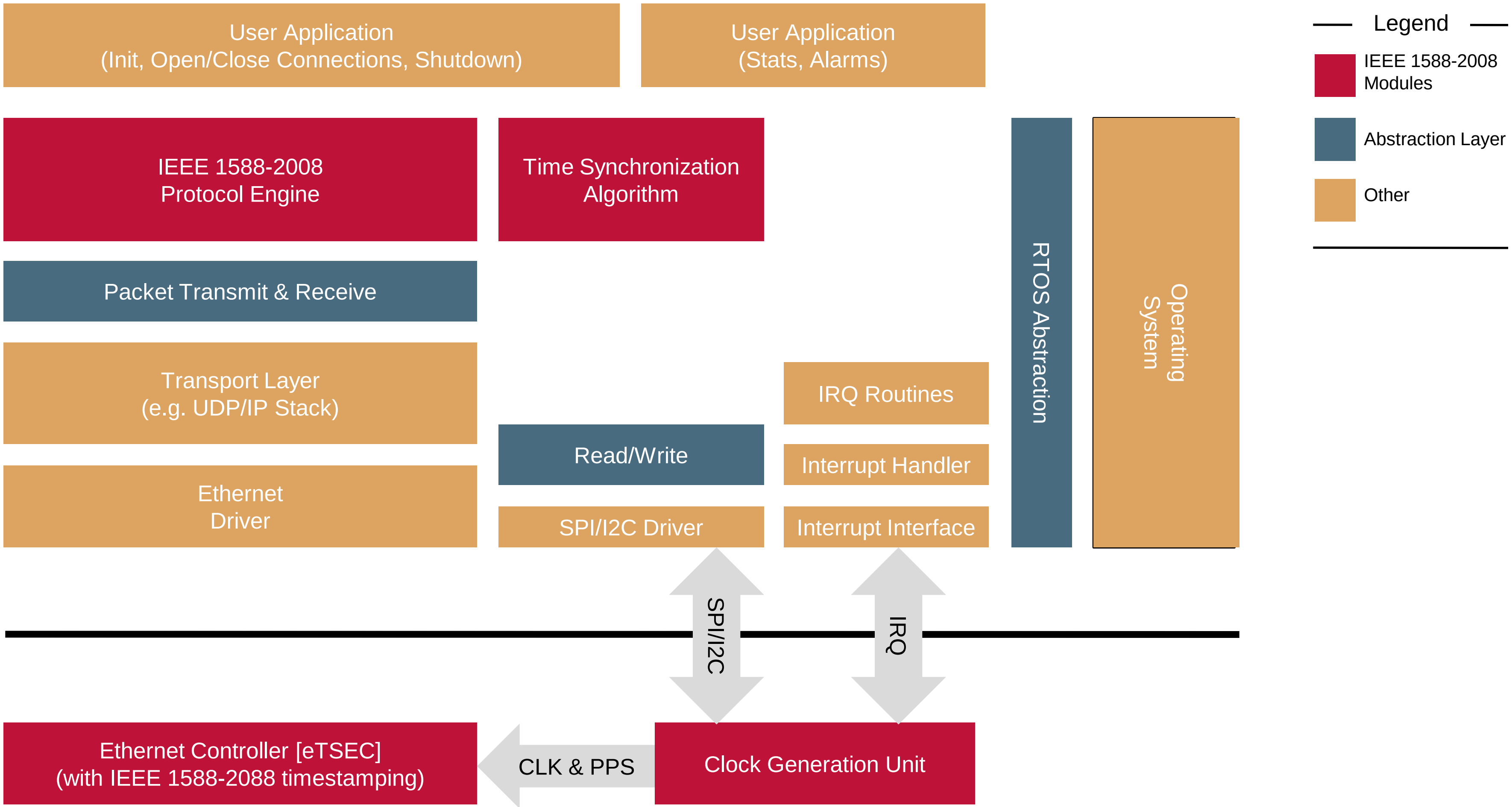
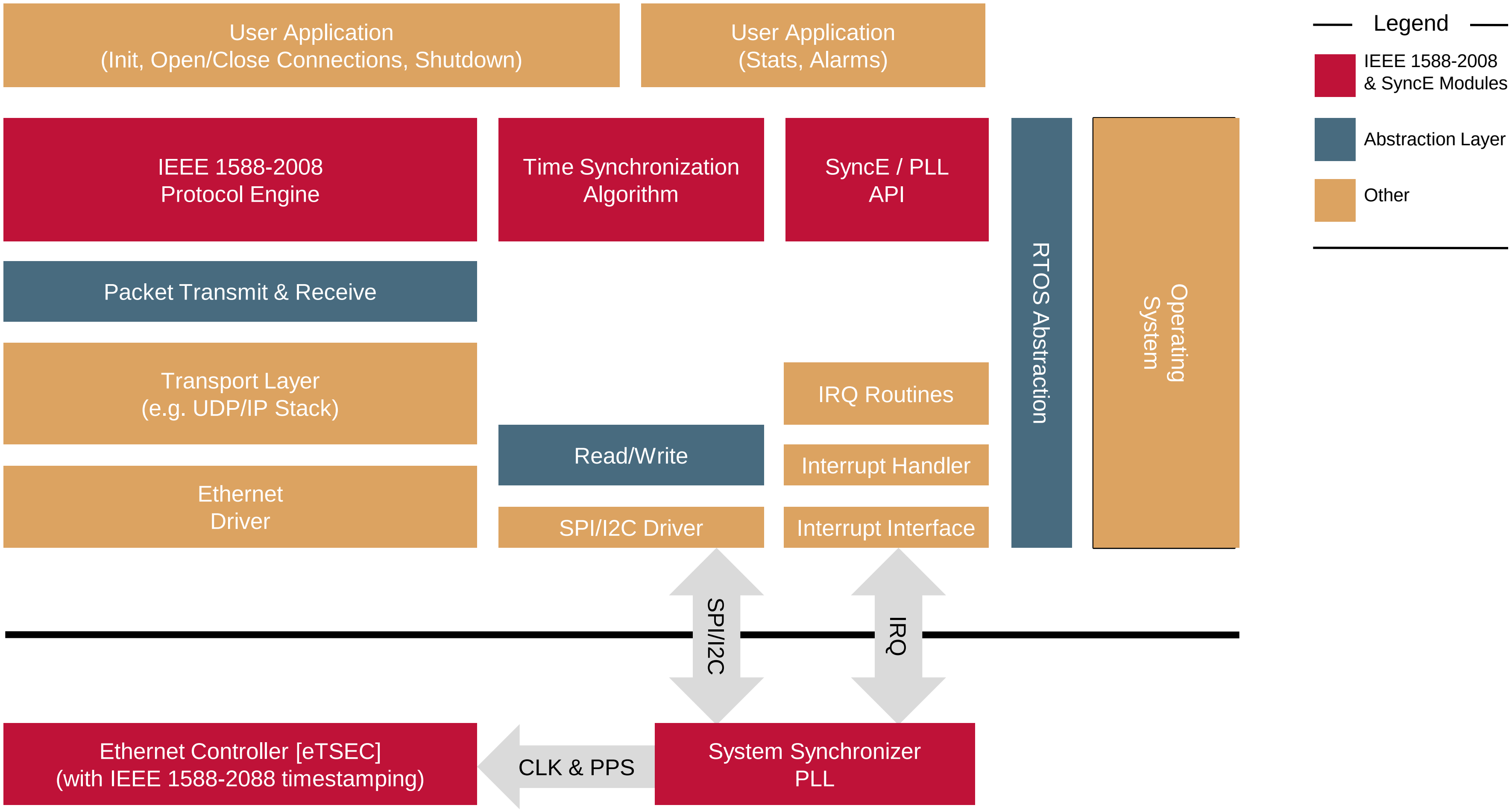
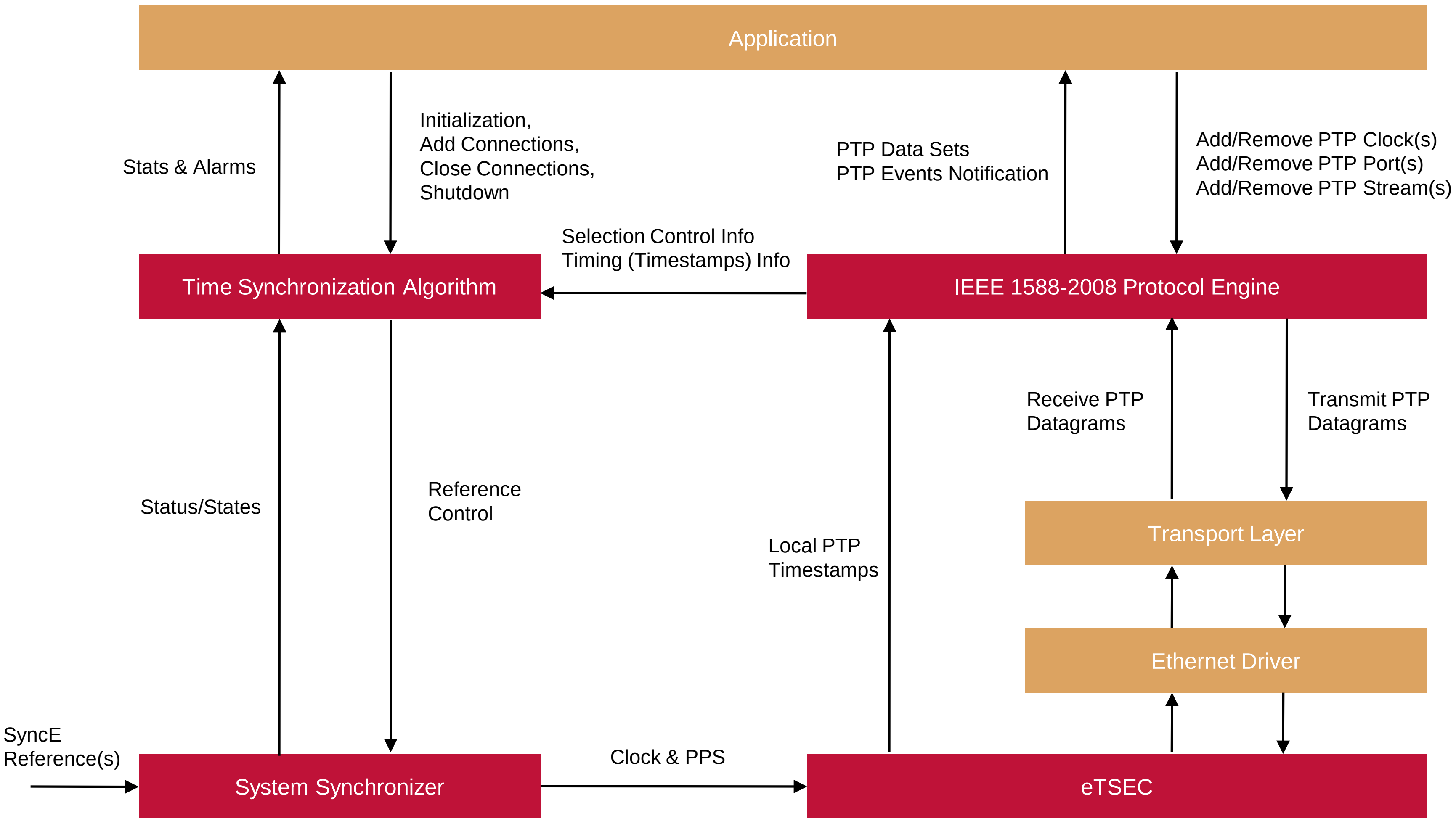
Software Architecture without SyncE



Software Architecture with SyncE



Software Flow with SyncE



Thank You

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