



Smart Grid Information Sharing Webcast: Synchrophasor Communications Infrastructure

December 17, 2013

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Objectives of the Project

- Improve understanding of latency in a synchrophasor based control system
 - Implemented with C37.118 and IEC 61850 GOOSE messaging
 - Multiple vendor equipment/components
 - Three scenarios
 - Unicast
 - Unicast + PDC
 - Multicast
- Apply lessons learned to possible implementations

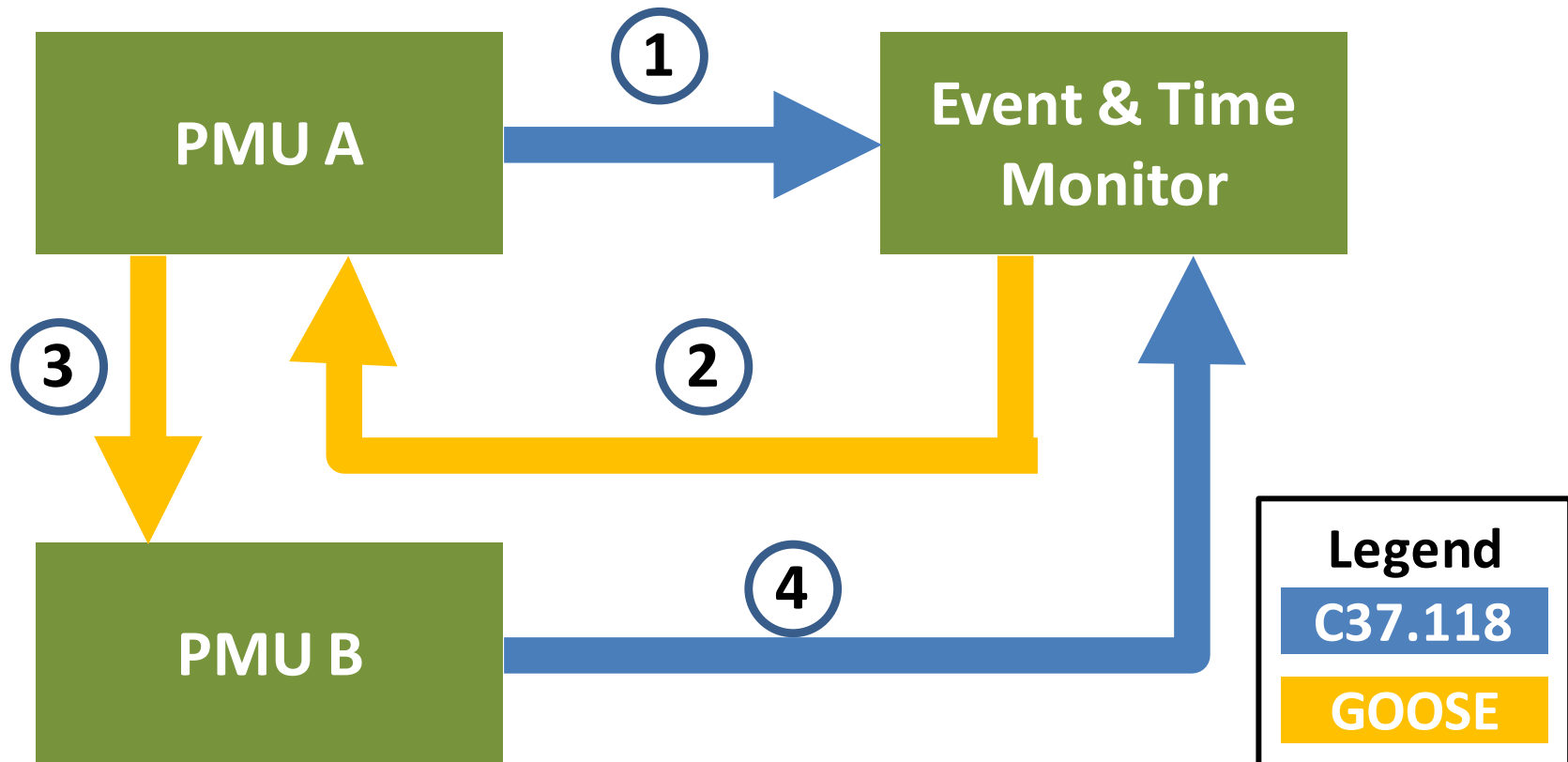
Why?

- Understand latency contributions by the network, transport protocols, different vendor equipment and system
 - Create awareness for approaches and methods that can be used to minimize the latency
- Understand issues affecting deployment of automated and semi-automated closed-loop distributed control systems

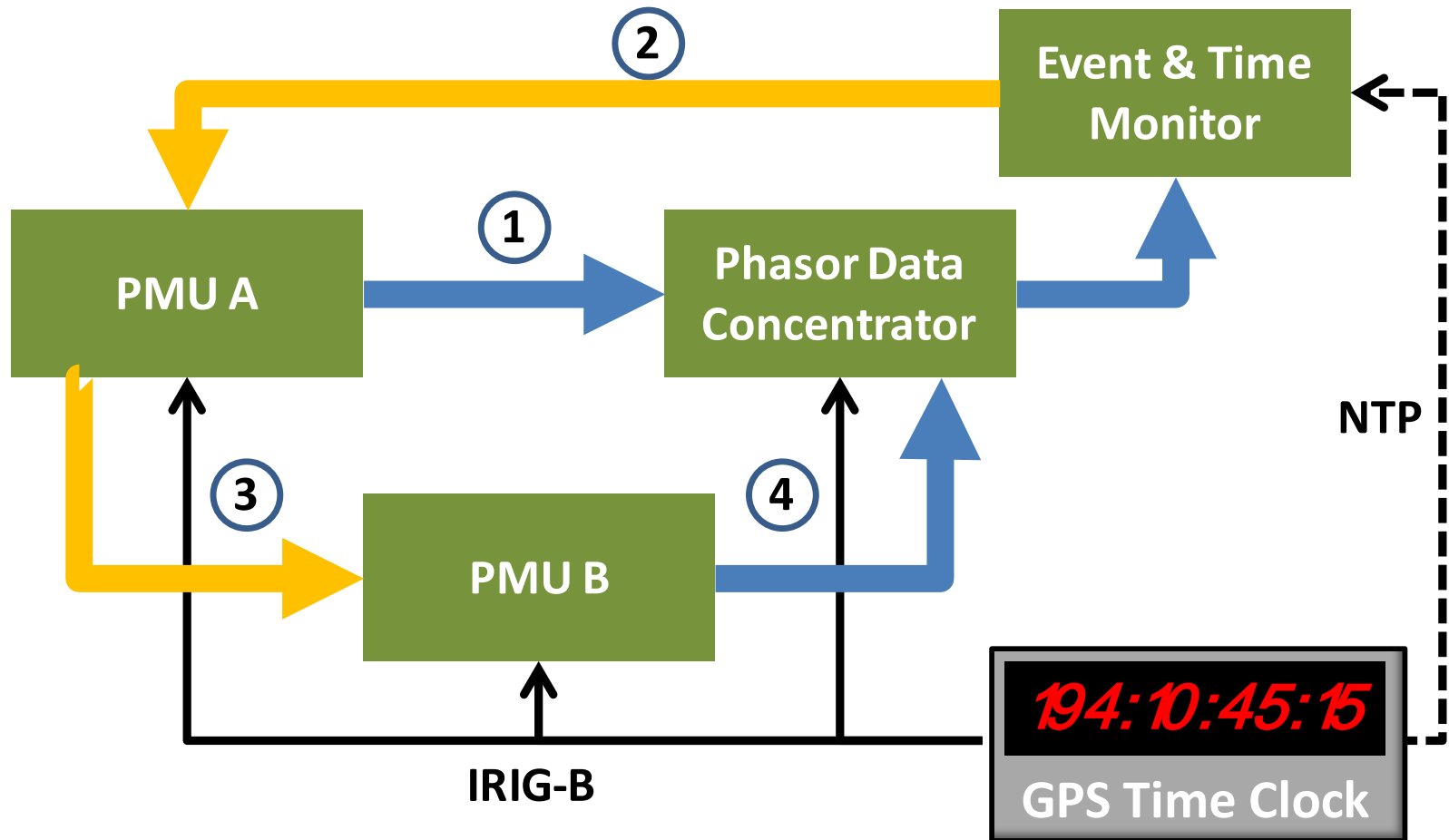
Questions:

- What are current system latency times measured from deployed systems?
- Sample architecture:
 - Event transmitted by PMU →
 - Through substation PDC →
 - Through utility “centralized” PDC →
 - To ISO application (possibly through an ISO PDC)
- Can optimizations be applied?

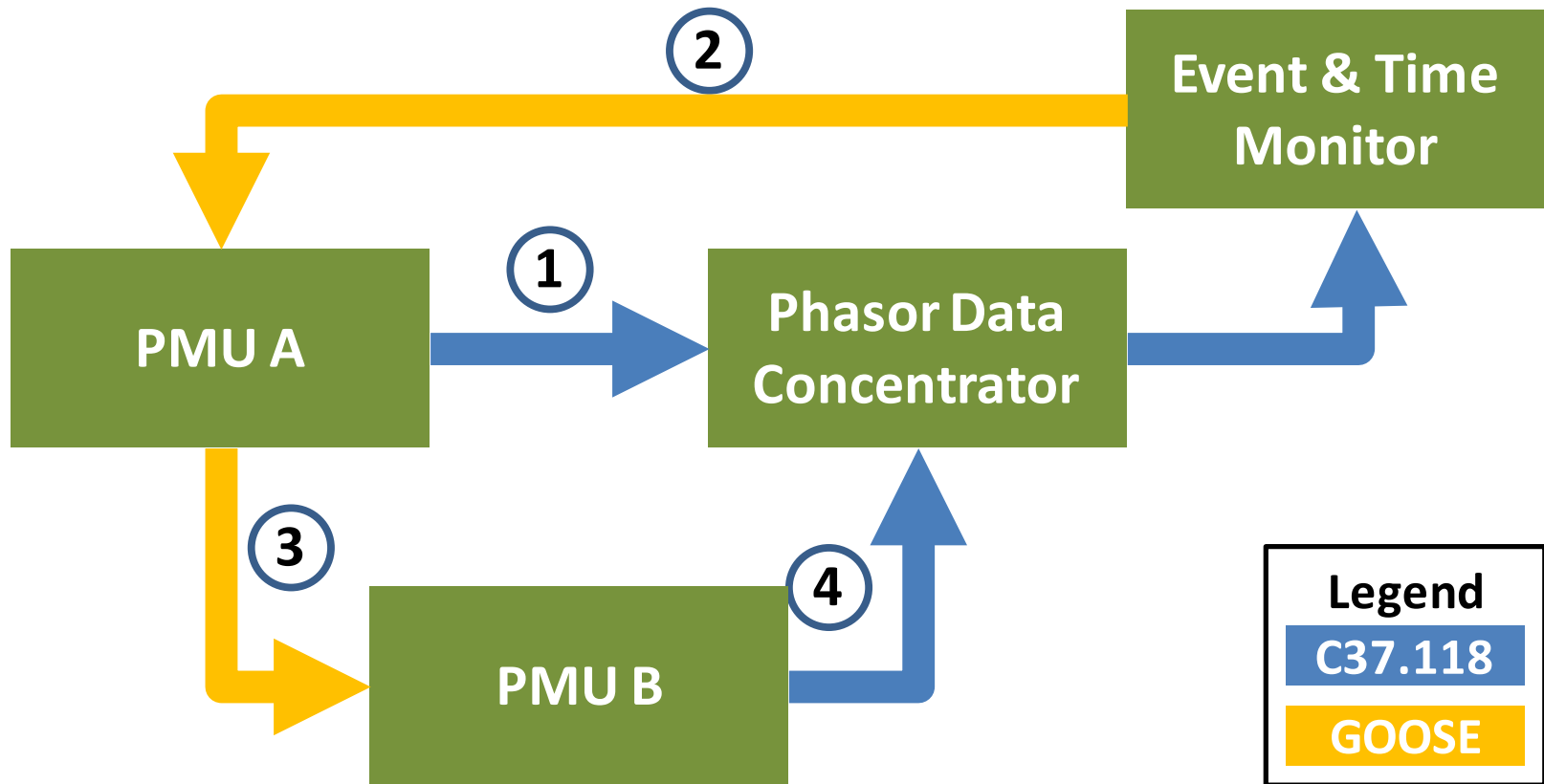
Simplified Control Signal Diagram



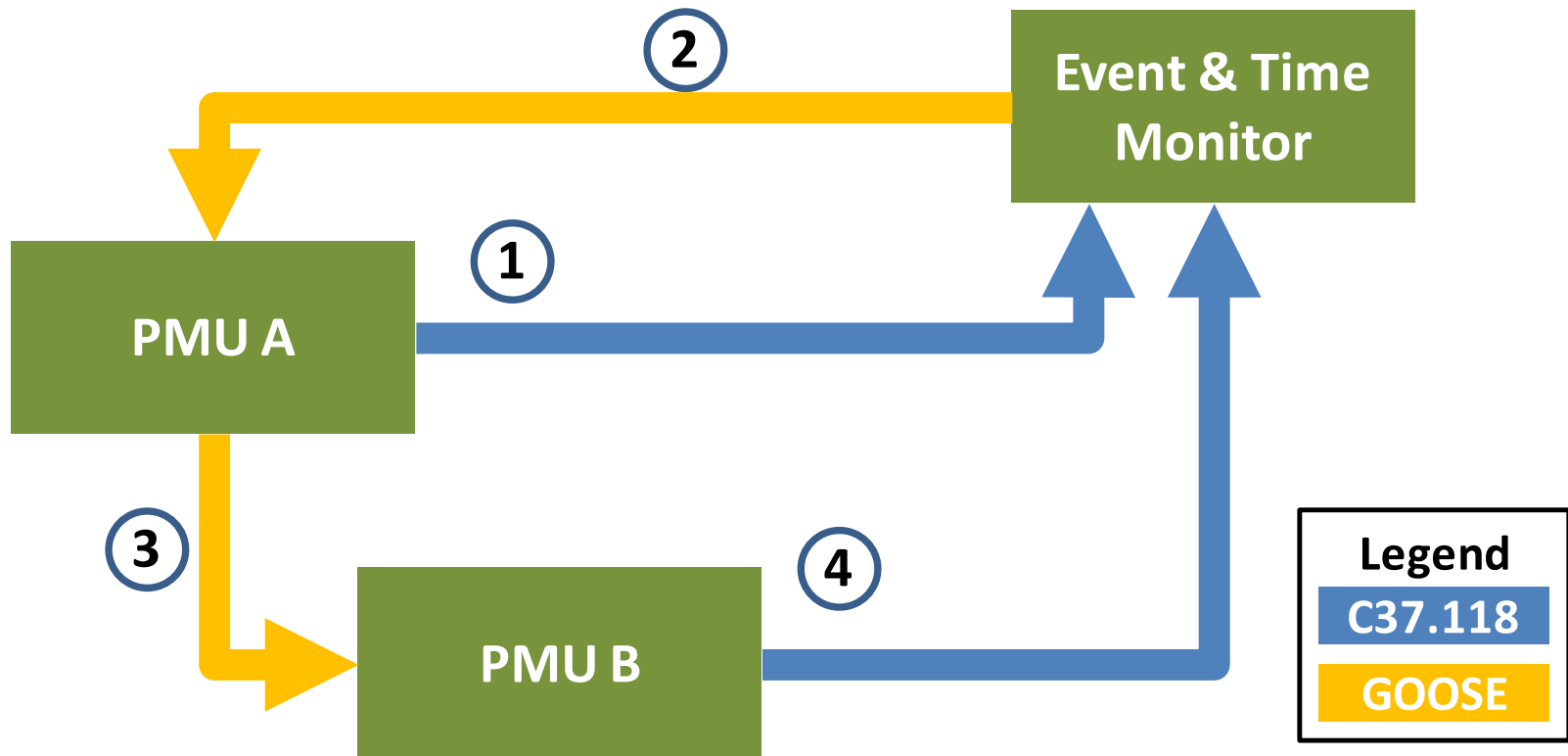
Test Bed Control Loop – Timing Arrangement



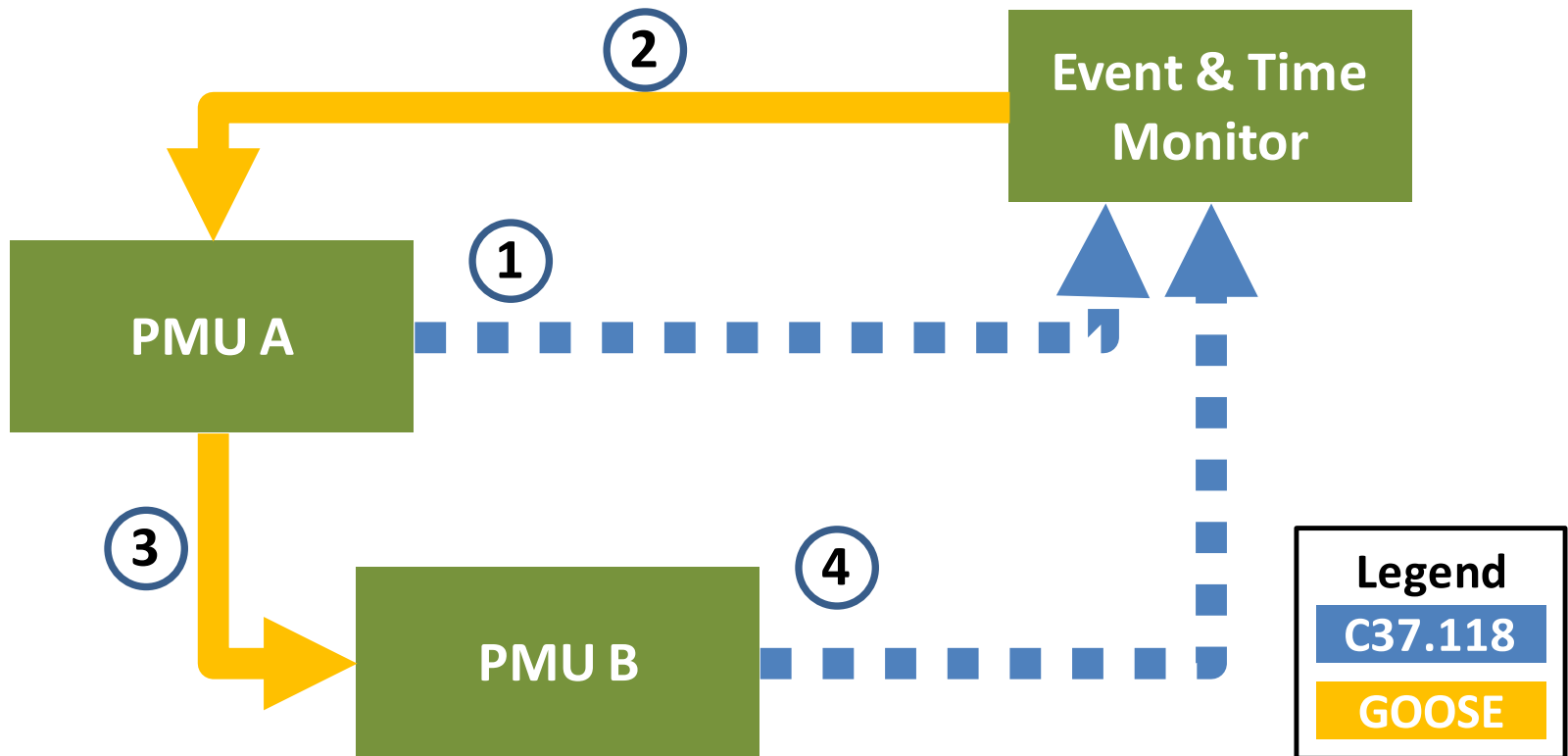
Configuration- IP Unicast with PDC



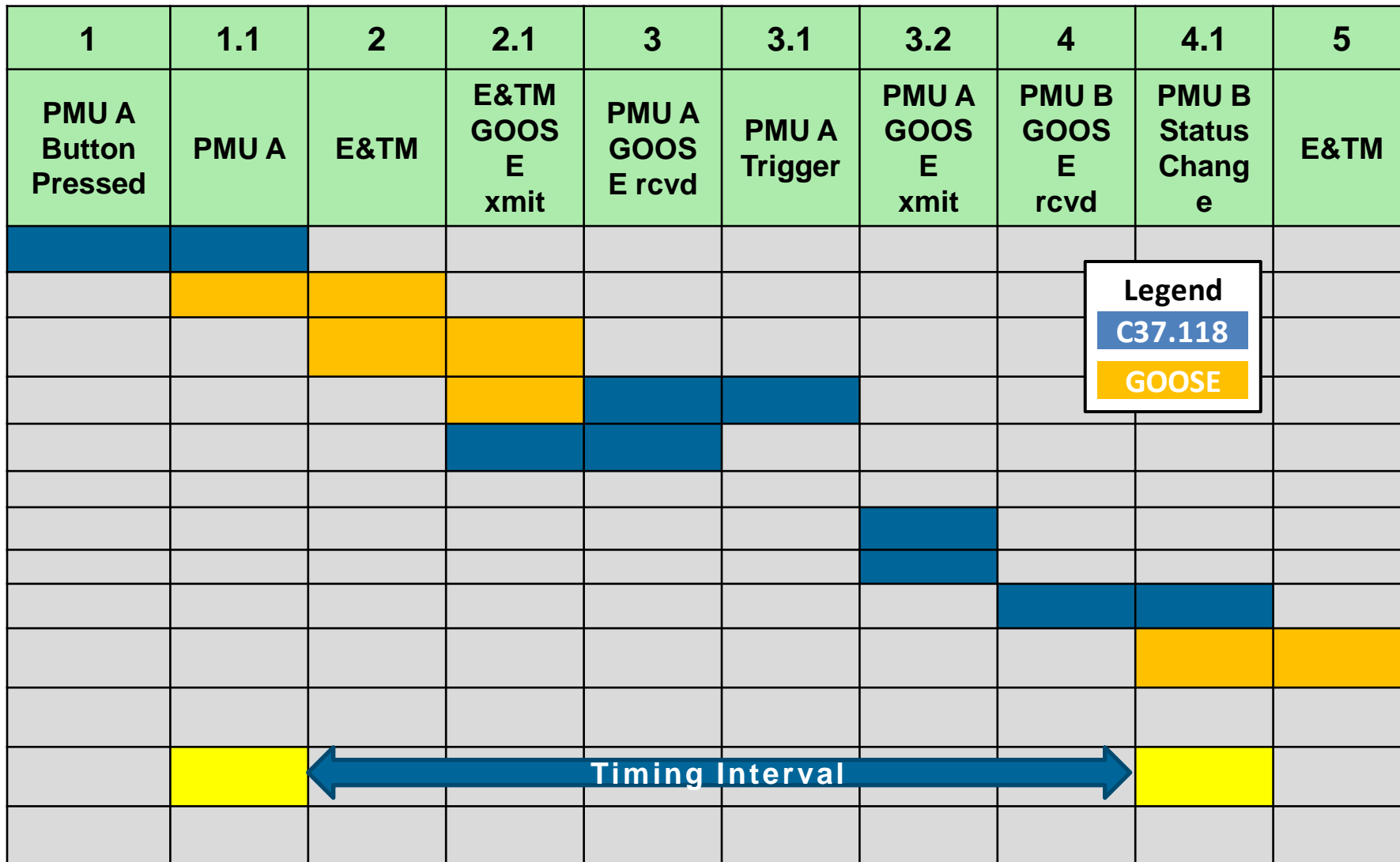
Configuration- IP Unicast without PDC



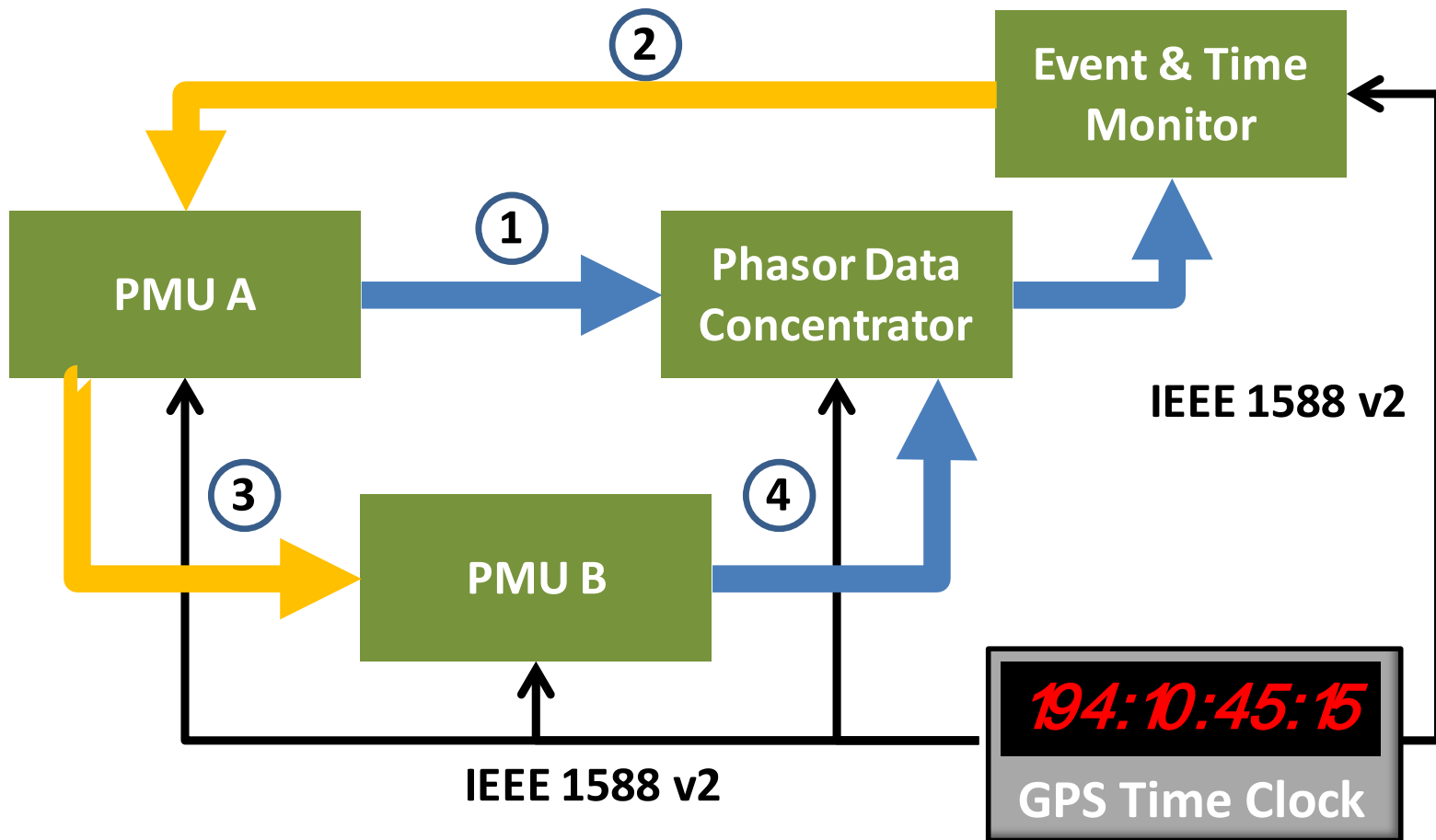
Configuration- IP Multicast



Timing Determination



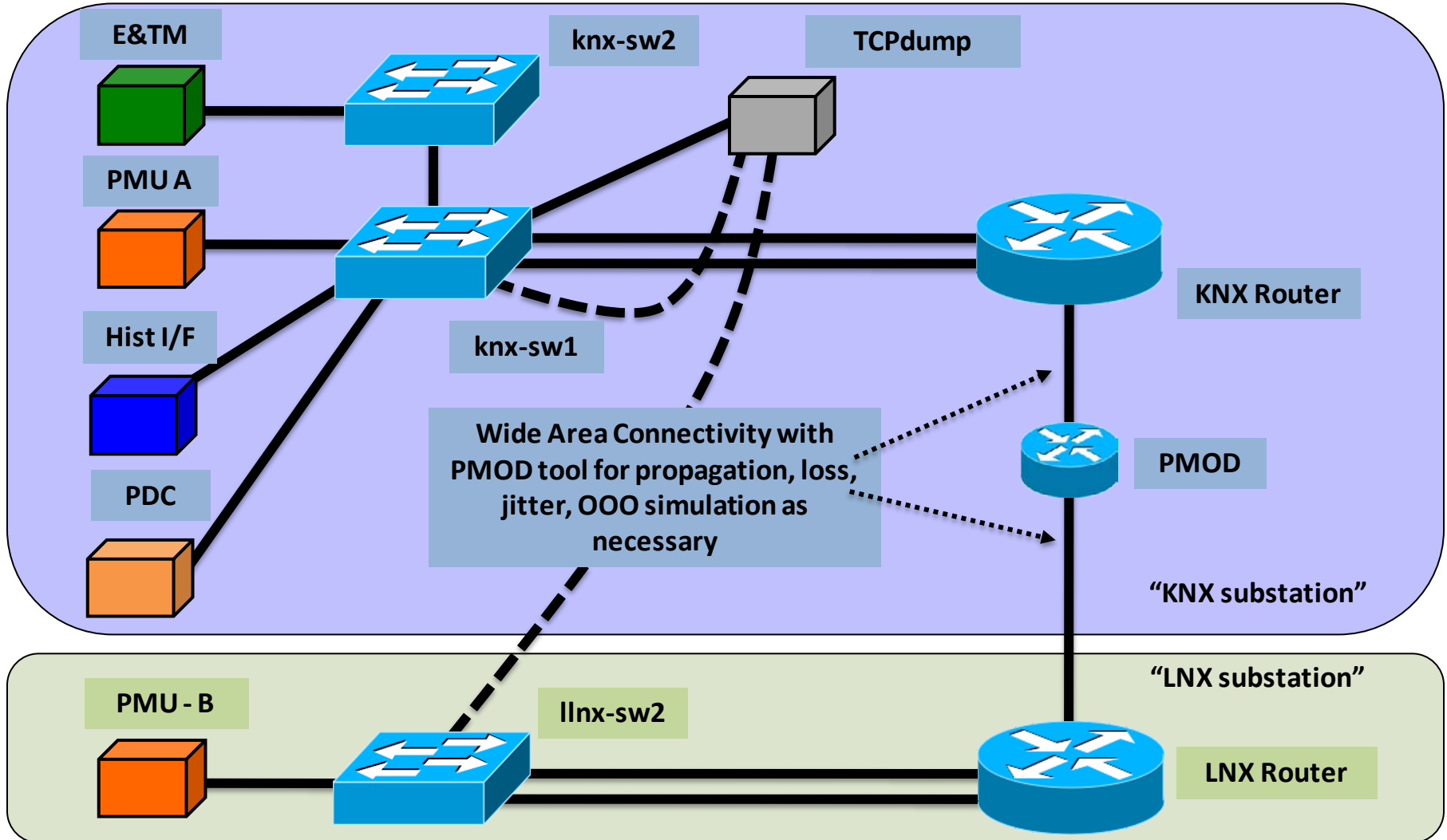
Test Bed Control Loop 1588 Timing



Testbed Network Diagram

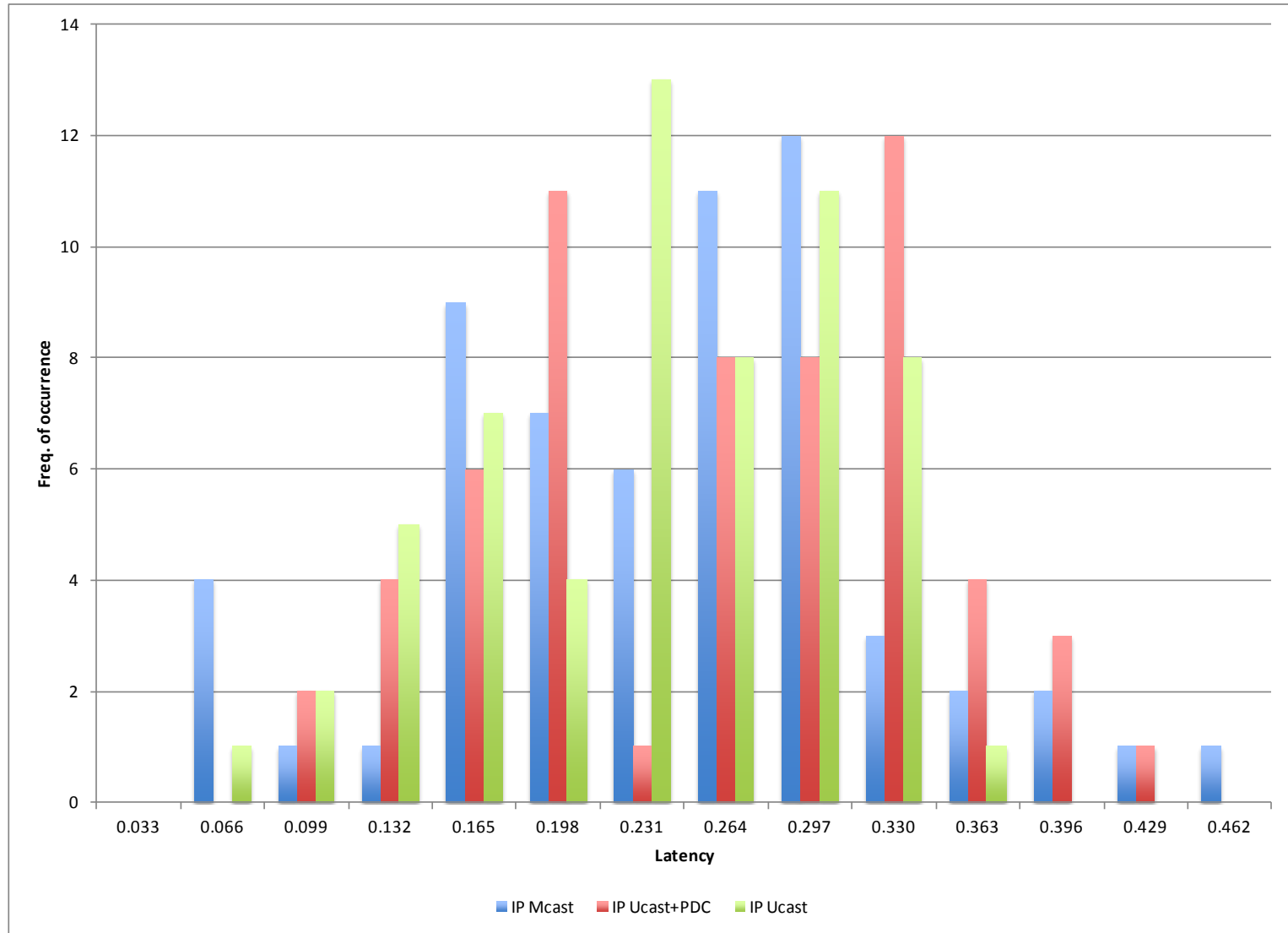
KNX and LNX substations:

- Layer 3 for C37.118 messages
- Layer 2 for GOOSE messages
- VLAN filtering for Layer 2 traffic



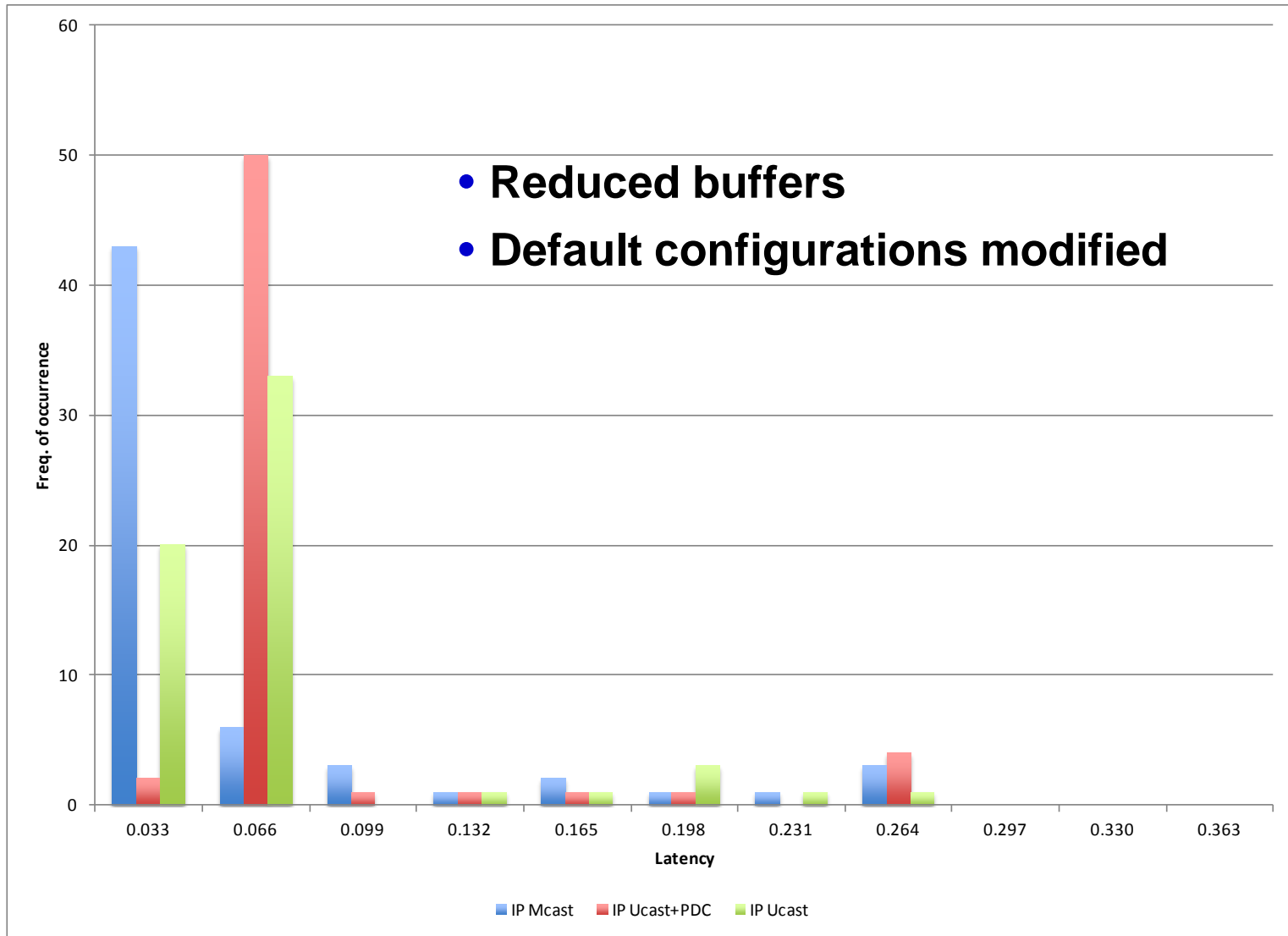
Test A: Latency Measurements

PMU sampling rate: 60 Samples/Second



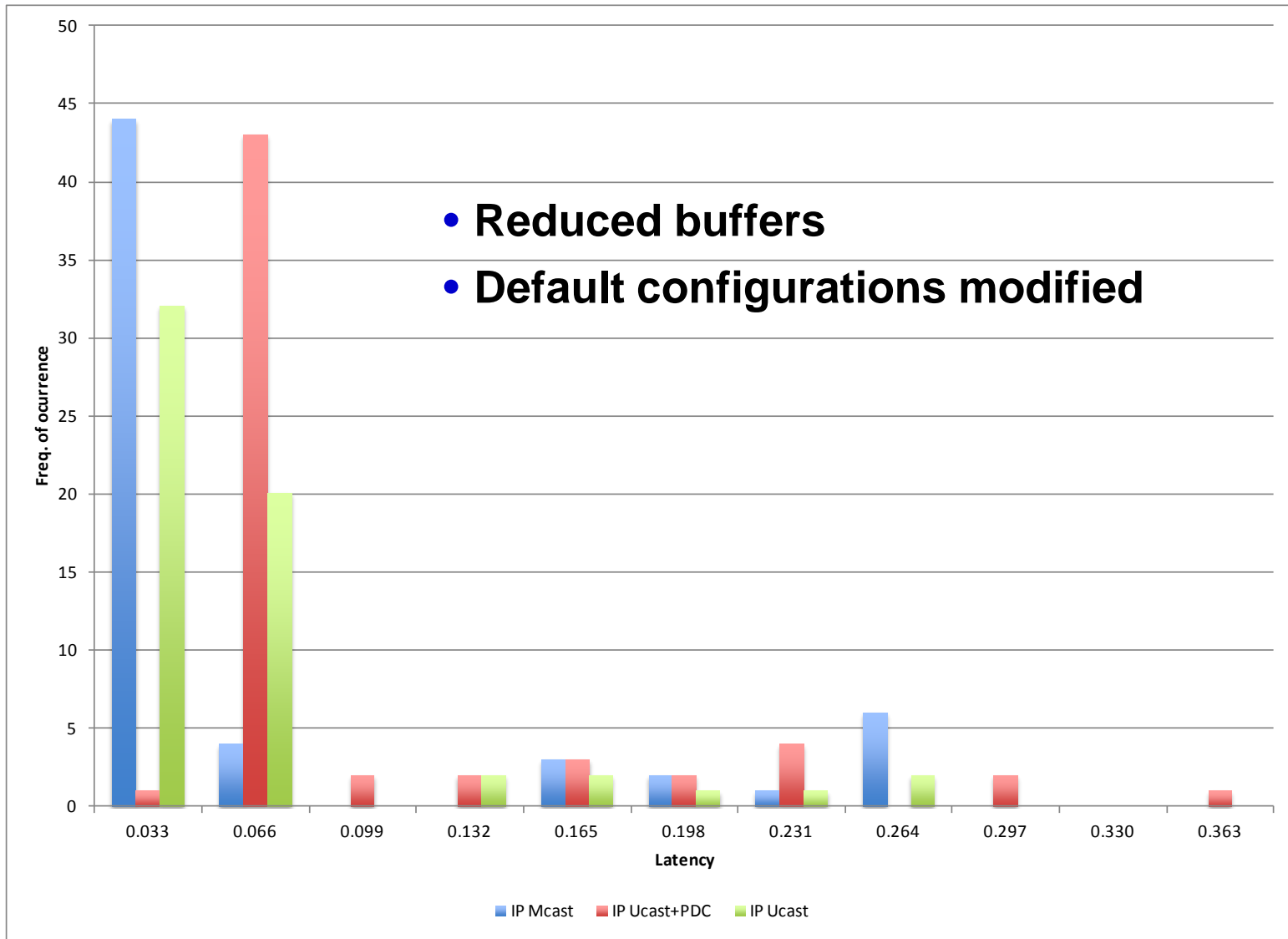
Test B: Latency Measurements

PMU sampling rate: 60 Samples/Second



Test C: Latency Measurements

PMU sampling rate: 30 Samples/Second



Optimizations - Buffering

The image displays three overlapping screenshots of the PI Interface Configuration Utility (PIC371187) software interface.

Top Left Screenshot: Buffering Settings
This window shows the "Buffering" configuration options. It includes a "Tools" menu with "Choose Buffer Type", "Buffering Settings", "Buffered Servers", "PI Buffer Subsystem Service", and "Parameter Details". The main area contains the following settings:

- Buffering Settings will use default values unless other values are specified.
- TCP/IP Port: [] Clear
- Maximum buffer file size (KB): [] Clear
- Primary memory buffer size (Bytes): [] Clear
- Secondary memory buffer size (Bytes): [] Clear
- Send rate (milliseconds): [1] Clear
- Pause time between PI Server data posts (Section [APIBUFFER]) (Parameter SENDRATE=#) (Default: 100, Pause rate (seconds) [API Buffer Server]).
- Pause rate (seconds) [API Buffer Server].
- Retry rate (seconds): []
- Maximum transfer objects:
 - Maximum theoretical send rate:
- Event queue file size (MBytes): []
- Event queue path: []
- Pause time when buffers are empty (milliseconds): []
- Maximum data rate per server connection (events/sec): []

Top Right Screenshot: PI Tuning Parameters
This window shows the "PI Tuning Parameters" section with the following settings:

- Interface Mode: Poll PI Tags
- Write Buffer Time: 15 ms
- Max Sleep: 1 ms
- Write Idle Flush Time: 2 ms

The "PI Servers" table below shows:

| Server Name | Username |
|----------------|----------|
| UtilityPServer | UAPNEW |

Bottom Screenshot: Main Configuration Utility
This window shows the main configuration interface for the "C37118" interface. It includes the following information:

- Interface: PIC37118-FromPDC (PIC371187) -> utilitypiserver
- Type: C37118 (PI IEEE C37.118)
- Description: []
- Versions: PIC37118.exe version 1.0.5.111 | Unlnt version 4.5.5.22
- PI Server Connection Status: utilitypiserver Writeable (indicated by a green checkmark)
- Path to XML Config File: C:\Program Files\PIPC\Interfaces\C37118\C37118_SEL3378.xml
- Device Configuration file Settings:
 - Session Configuration:
 - Sync Error Action: Mark as Questionable
 - Data Sorting Action: Mark as Questionable
 - Data Valid Action: Mark as Questionable
 - PMU Error Action: Mark as Questionable
 - Leap Second Action: Mark as Questionable
 - Write IO Timeout: Yes
 - Skip Config2 Cmd: No
 - Flush Events: No
 - Send Stop Cmd: No
- Additional Parameters: []

Optimizations/Configurations - PDC

Outputs

Add Output Copy Paste Export Delete

- PI C37.118 interface
- eDNA C37.118 interface
- PMU Connection Tester
- Telcordia

Output: PI C37.118 interface

Enabled

Output Name: PI C37.118 interface

PDC ID: 1500

Data Rate: 30 Msg per sec

Waiting Period: 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, 60, 120, 240, Any ms

Connection Settings

Transport Protocol: 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, 60, 120, 240, Any

IP Address: [Empty]

Command Port: [Empty]

Data Port: 60

Local IP Address: Any

Redundant Connection Settings

Transport Protocol: Disabled

Tags

Total Output Tags: 520

Edit

SEL-3373 Eth1 - PDC Assistant

SEL

New Open Save Save As Close Send Settings Connect Disconnect Local Services Help

Home

Settings

- Inputs
- Outputs
- Calculations
- Archives
- Loggers
- Globals

Status

- Real-time
- Diagnostic Logs

Data

- Retrieve Archives

Administration

- Device
- User Accounts

Real-time Status

Input Connections

| Name | PDC ID | Connection State | Time Quality | Received Data Frames |
|------------------|--------|------------------|--------------|----------------------|
| EPR1 KNX GEN60HF | 1200 | Receiving Data | Normal | 192147620 |
| EPR1 KNX GE D60 | 1250 | Receiving Data | Normal | 192156991 |
| EPR1 KNX 487E | 12120 | Receiving Data | Normal | 384308652 |

Network Latency

| Maximum | Average | Latency |
|-----------------------------|-----------------------------|---------|
| ~ 197 ms (00:00:00.1977840) | ~ 180 ms (00:00:00.1801150) | |

Frames

| Data | # Frames | Timestamp |
|-------------------------|----------|-------------------------|
| 384308652 | 3 | 01/07/2013 17:25:14.750 |
| 10/30/2012 20:22:59.418 | | |

Command: [Empty]

This is the approximate average network latency for this input over the last second. The value is calculated by subtracting the timestamp in the data frame from the arrival time. Note that the arrival time is measured locally, so if the local clock is not locked to a time source, then the resulting network latency will be skewed.

Input PMUs

| PMU Name | PMU ID | Input Connection | PMU State | PMU Status | Unlock Time |
|------------------|--------|------------------|-----------|------------|-------------|
| EPR1 KNX GEN60HF | 1200 | EPR1 KNX GEN60HF | Found | OK | Locked |
| EPR1 KNX GE D60 | 1250 | EPR1 KNX GE D60 | Found | OK | Locked |

Outputs

| Server | Connection State | Missing Data | Sent Data Frames |
|----------------------|------------------|--------------|------------------|
| PI C37.118 interface | Sending Data | No | 7403 |

Network Latency

| Input Connection | Average | Maximum |
|------------------|-----------------------------|-----------------------------|
| EPR1 KNX 487E | ~ 180 ms (00:00:00.1800530) | ~ 211 ms (00:00:00.2114990) |
| EPR1 LLNX 487E | ~ 180 ms (00:00:00.1802230) | ~ 215 ms (00:00:00.2155340) |
| Differences | ~ 0 ms (00:00:00.0001700) | ~ 4 ms (00:00:00.0040350) |

Output: PI C37.118 interface

Enabled

Output Name: PI C37.118 interface

PDC ID: 1500

Data Rate: 30 Msg per sec

Waiting Period: 1500 ms

Data Rate: 60 Msg per sec

Waiting Period: 200 ms

Phasor Domain: Rectangular

Connection Settings

Maximum amount of time to wait for all inputs to be received before processing a set of time-aligned data.

Summary Table of Test Results – Mode

| Mode | Samples / Cycle | IP Unicast | IP Unicast w/PDC | IP Multicast | Configuration |
|--------|-----------------|------------|------------------|--------------|-----------------------|
| Test A | 60 | .283 | .100 | .233 | Initial Configuration |
| Test B | 60 | .033 | .050 | .050 | Modified Config 1 |
| Test C | 30 | .033 | .066 | .033 | Modified Config 1 |

- **Test A: Buffers were significant compared to measurement window**
- **Tests B/C: PDC adds very minor delay**
- **Test C: Test network was not complex enough to differentiate IP Multicast from IP Unicast**

Conclusions/Observations

- Difficult to accurately measure latency and know the contributing components in the system
- Significant improvements in latency achieved through device settings, network traffic configuration, software interfaces
 - Network traffic, use of VLANs
 - Proper set up of buffers and subsystems in software components
 - Distance (propagation delays), PDC marginally add to overall latency
 - Need to understand the intricacies of all the equipment
- Still some unexplained latency behavior (variation and trends up/down)
 - Non real-time OS, use of virtual machines, other?
- Much more to learn, but understand the test bed better **and have it working!**

Future Testing Areas

- IEC 61850-90-5
- Security overlay on WAN link
- Additional network traffic/loading
 - Add alt vendor PMUs (additional traffic and PDC wait time)
- WAN propagation delays
- Network impairment / availability
- Traffic prioritization / isolation
- IEEE 1588 / PTP synchronization to windows servers
- Upgrade to PI Server 2012

Questions:

- What are the PMU latency measurements between your utility and the ISO?
- Is YOUR PMU architecture or WAMPAC system optimized to reduce latency?

Technical Update, Aug 2013: [3002000604 Synchrophasor Communication Infrastructure: Impacts on Latency Part II](#)

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