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Real-Time Data Mediation for Synchrophasor Application Development Compliant with IEEE C37.118.2 (BabelFish)

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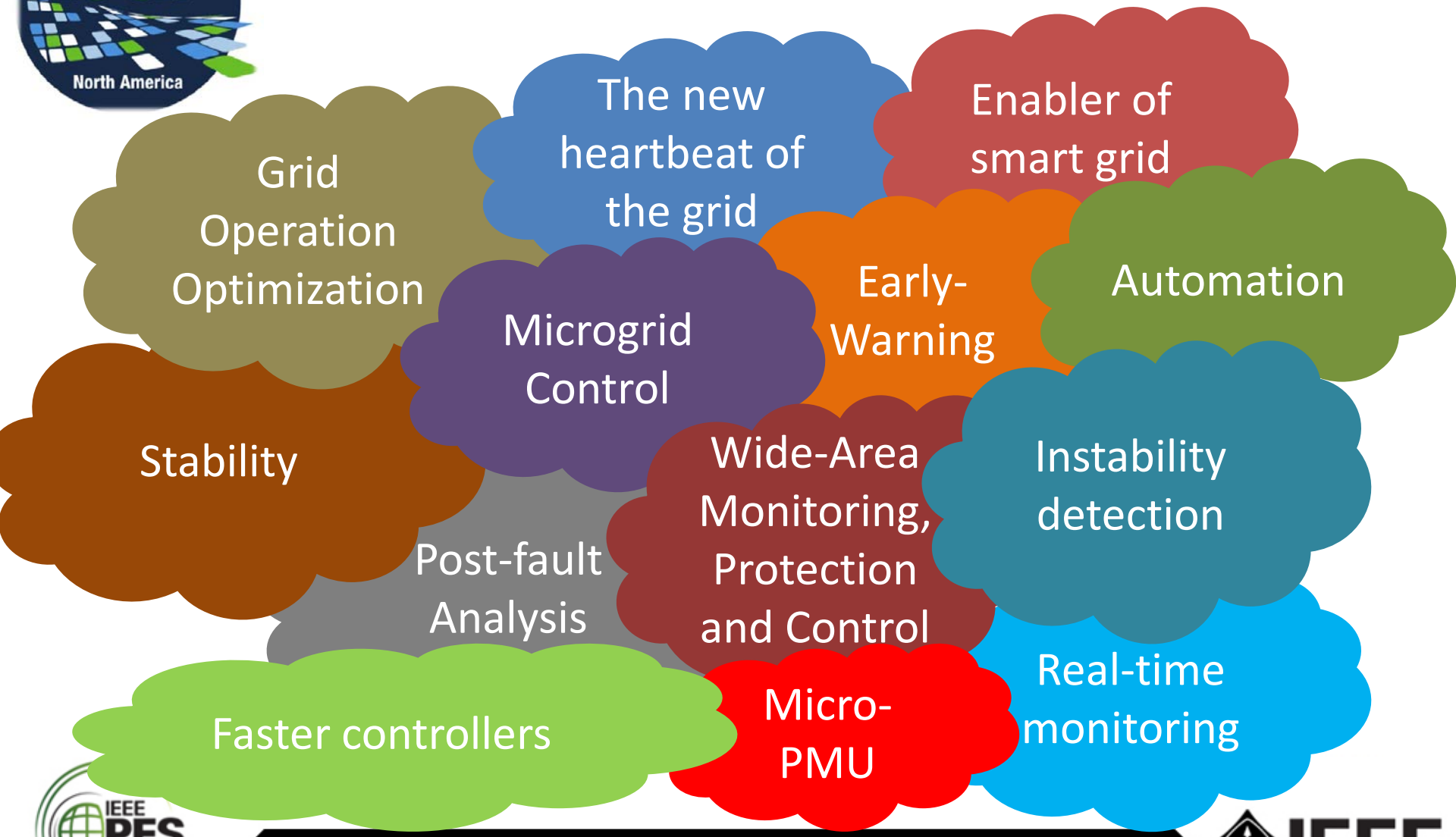
Outline

- Motivation
- Background
  - Synchronized Phasor Measurements (Recap)
  - IEEE C37.118 - 2 protocol frame
- BabelFish: IEEE C37.118.2 Real-Time Data Mediator
  - Software Architecture: Modularity
  - User Interface
  - RT-HIL Testing in SmarTS-Lab
- Roadmap to future work
- Conclusions

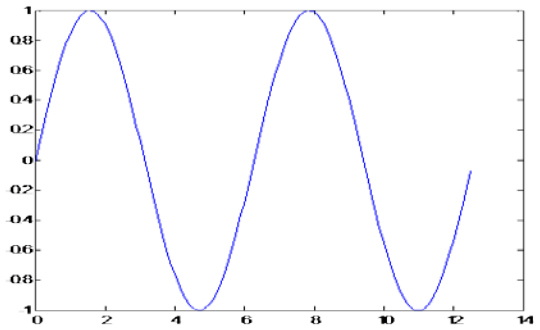
Motivation


Grid Operation Optimization
The new heartbeat of the grid
Enabler of smart grid
Microgrid Control
Early-Warning
Automation
Stability
Wide-Area Monitoring, Protection and Control
Instability detection
Post-fault Analysis
Real-time monitoring
Faster controllers
Micro-PMU

Motivation

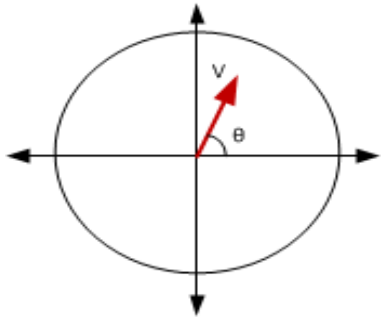
- Power systems depend on software applications
- These software applications require real-time data acquisition
- Power system data is communicated to these software applications using numerous different communication protocols
- For *fast software prototyping and testing*, *communication protocol parsing* is required.

Synchrophasor Fundamentals

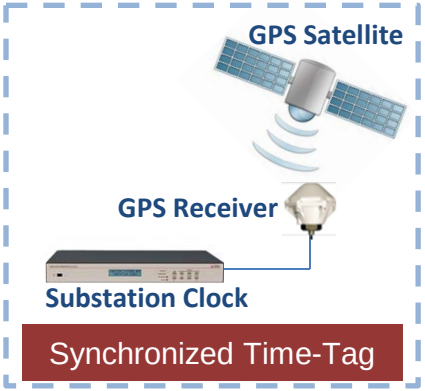


Sinusoidal waveform

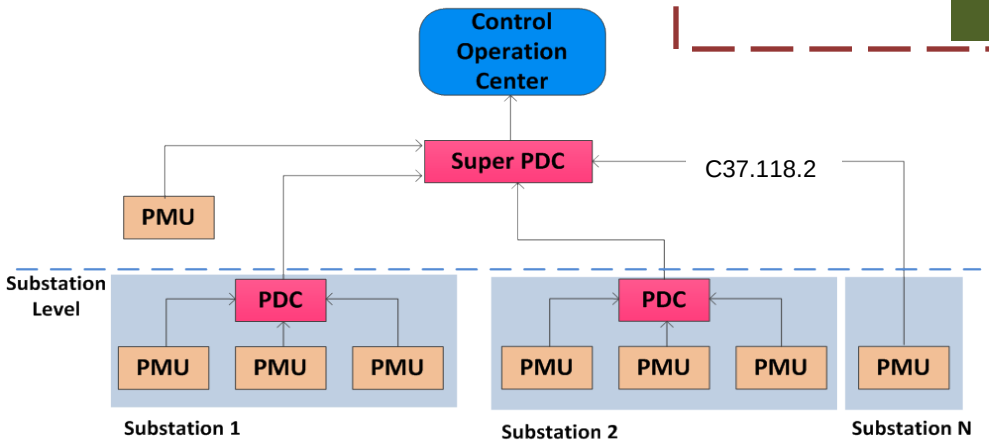
Represented as



Phasors



Synchrophasors



Typical Hierarchical Communication Layout of PMUs and PDCs

- Data rate upto 50 / 60 msgs per sec
- Numerous potential applications like islanding detection, state estimation, early warning systems, model validation, SIPS, RAS, etc

IEEE Std. C37.118.2 : Synchrophasor Data Transfer for Power Systems

Frame Format for Synchrophasor Data Protocol

Total number of bytes in the frame including CHK

Second of century (SOC) counts the number of seconds that have occured since January 1, 1970

Measured values that are to be transmitted/received by the PMU/PCD . The measurements can be phasors, frequency, rate of change of frequency, analog, digital etc.

SYNC (2 byte)	FRAMESIZE (2 byte)	IDCODE (2 byte)	SOC (4 byte)	FRAC SEC (4 byte)	DATA 1 (2/4/8 byte)	DATA 2 (2/4/8 byte)	– – –	DATA N (2/4/8 byte)	CHK (2 byte)

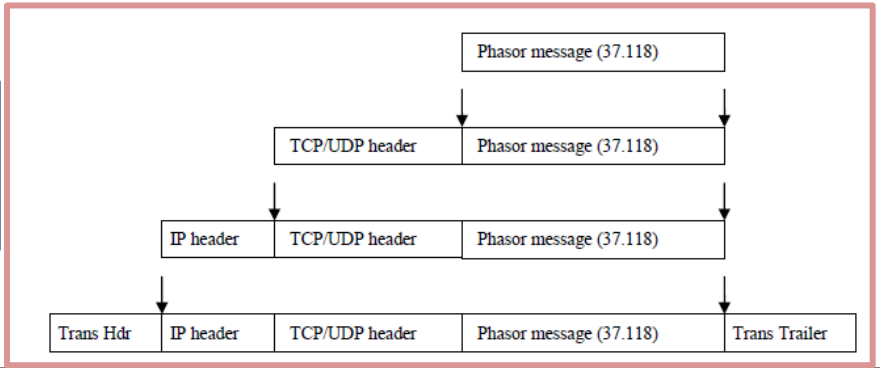
All frames start with SYNC which provides synchronization and identifies the type of messge i.e. data, configuration, header or command

Identifies unit which is sending or receiving message. It is identification number of the PMU / PDC assigned by user

Fraction of a second (3byte)	Time Quality Flas (1 byte)
24 bit integer which is actual fraction of second count	8 bit time quality flag that determines quality of time being reported i.e. maximum time error as determined by PMU clock

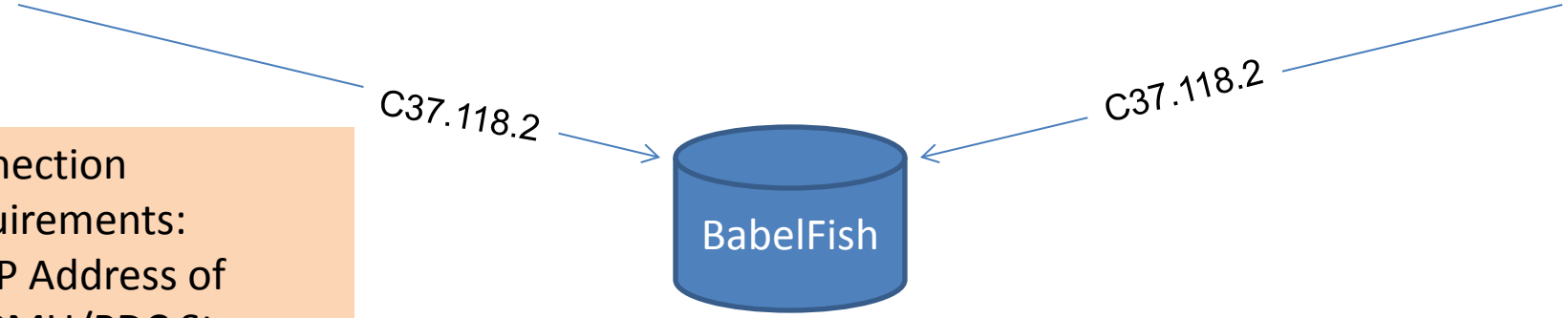
All frames terminate with CHK which is 2 byte CRC-CCIT.

Application Layer Protocol which uses TCP/UDP over IP for network communication



C37.118.2 Data Mediation (BabelFish)

CHK	DATA 3	DATA 2	DATA 1	FRACSEC		SOC	IDCODE	FRAMESIZE	SYNC	
8943	FREQ 2byte	FREQ 2byte	FREQ 2byte	857458	X0000001	654321678	189	20	X0001001	AA (hex)



DATA 3	DATA 2	DATA 1	Time
50.05	50.04	50.04	15:45:18.52

Connection Requirements:

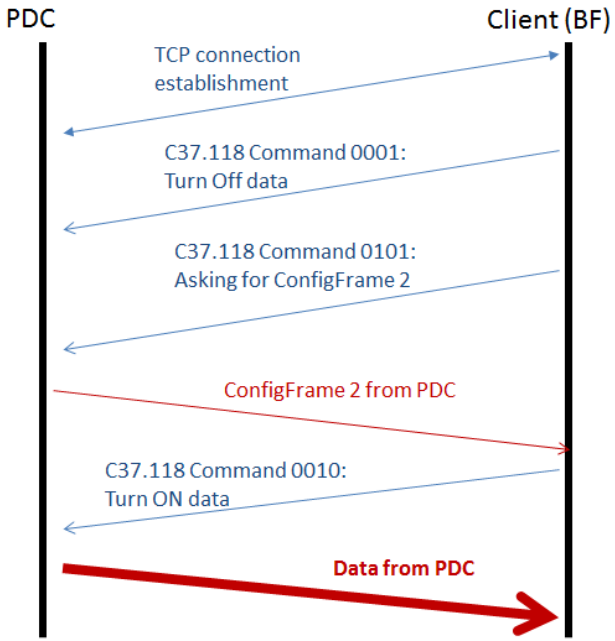
1. IP Address of PMU/PDC Stream
2. Device ID Code
3. Port Number

Features:*Fast prototyping of PMU based applications*

- Provide Access to raw-measurements in real-time that are wrapped inside PMU/PDC stream (Phasor, Analog, Digitals)
- Choice to select data of interest
- Phasor can be presented in either rectangular or polar coordinates.
- Transmit data-of-interest using TCP/UDP
  - End user can receive data independant of platform, OS

BabelFish Compliance with IEEE C37.118.2

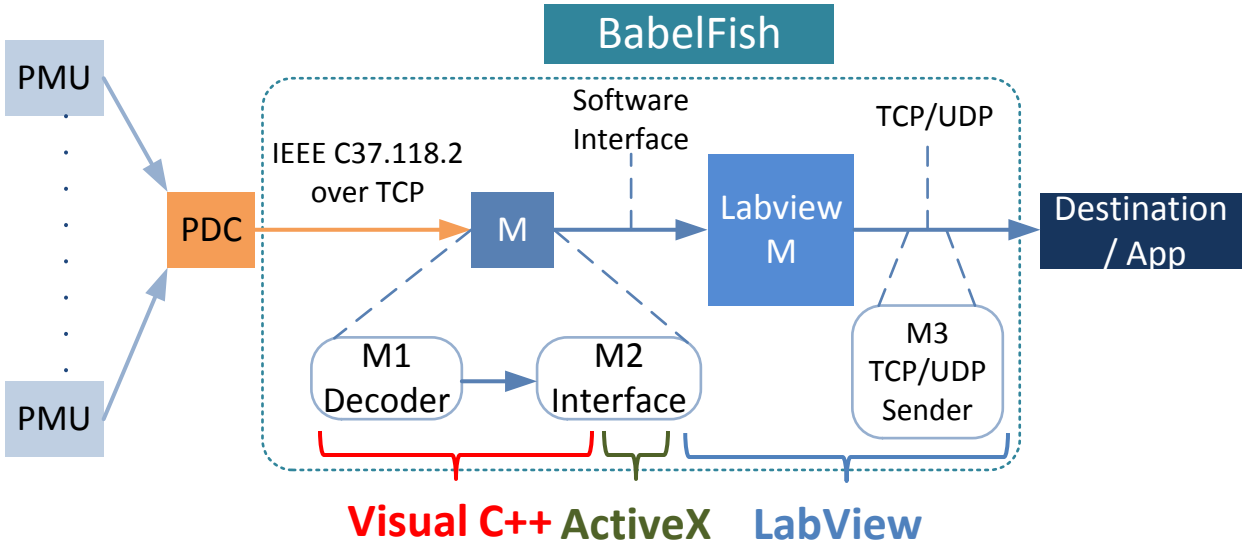
Required messages to be compliant with the IEEE C37.118.2 protocol for connecting the BabelFish (BF) mediator to a PMU/PDC



IEEE C37.118.2 specifies 4 types of

1. Data Frame (contains measured data and is *sent by PMU/PDC*)
2. Header Frame (Human readable information of PMU and is *sent by PMU/PDC*)
3. Configuration Frame 1 (denotes the PMU/PDC capability and is *sent by PMU/PDC*)
4. Configuration Frame 2 (measurements currently being *sent by PMU/PDC*)
5. Command Frame (*received by PMU/PDC*)

BabelFish Mediator Functionalities (Modular Architecture)



M1: Real-Time reading module (IEEE C37.118.2 compliant)

M2: Interfacing reading module to Labview

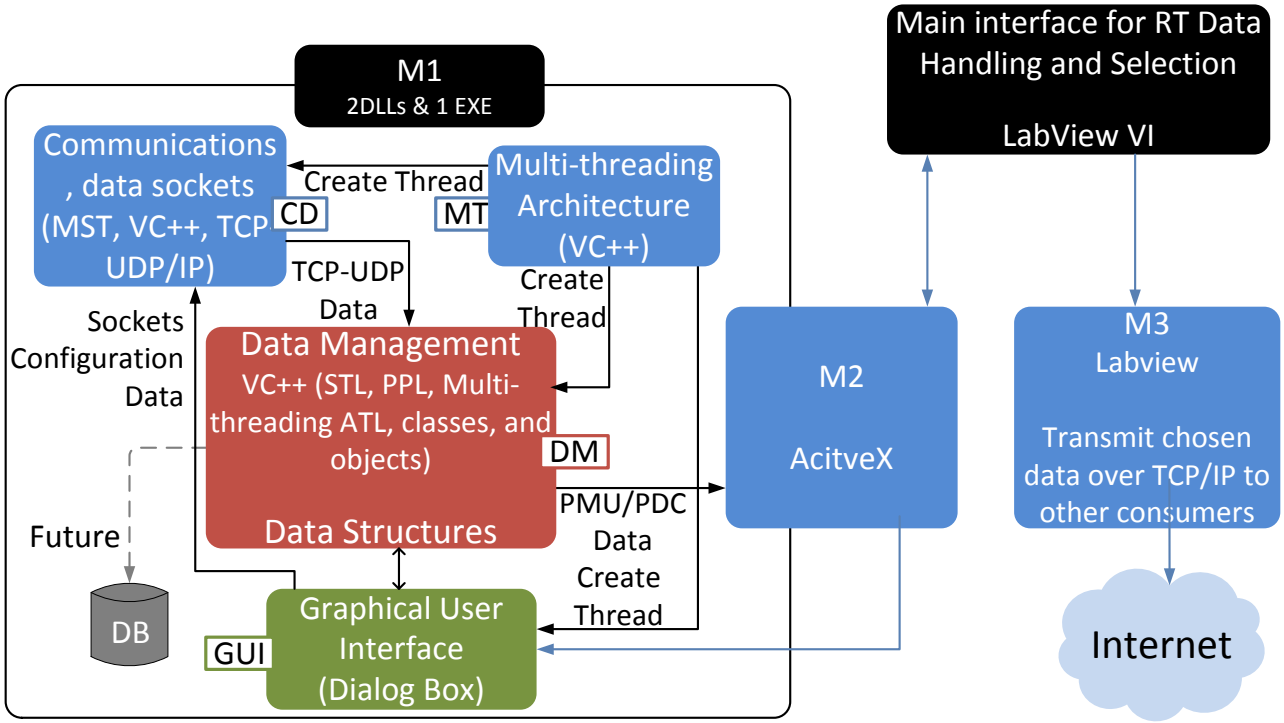
M3: Sends data-of-interest to end user

LabviewM:

Advantages of Modularity:

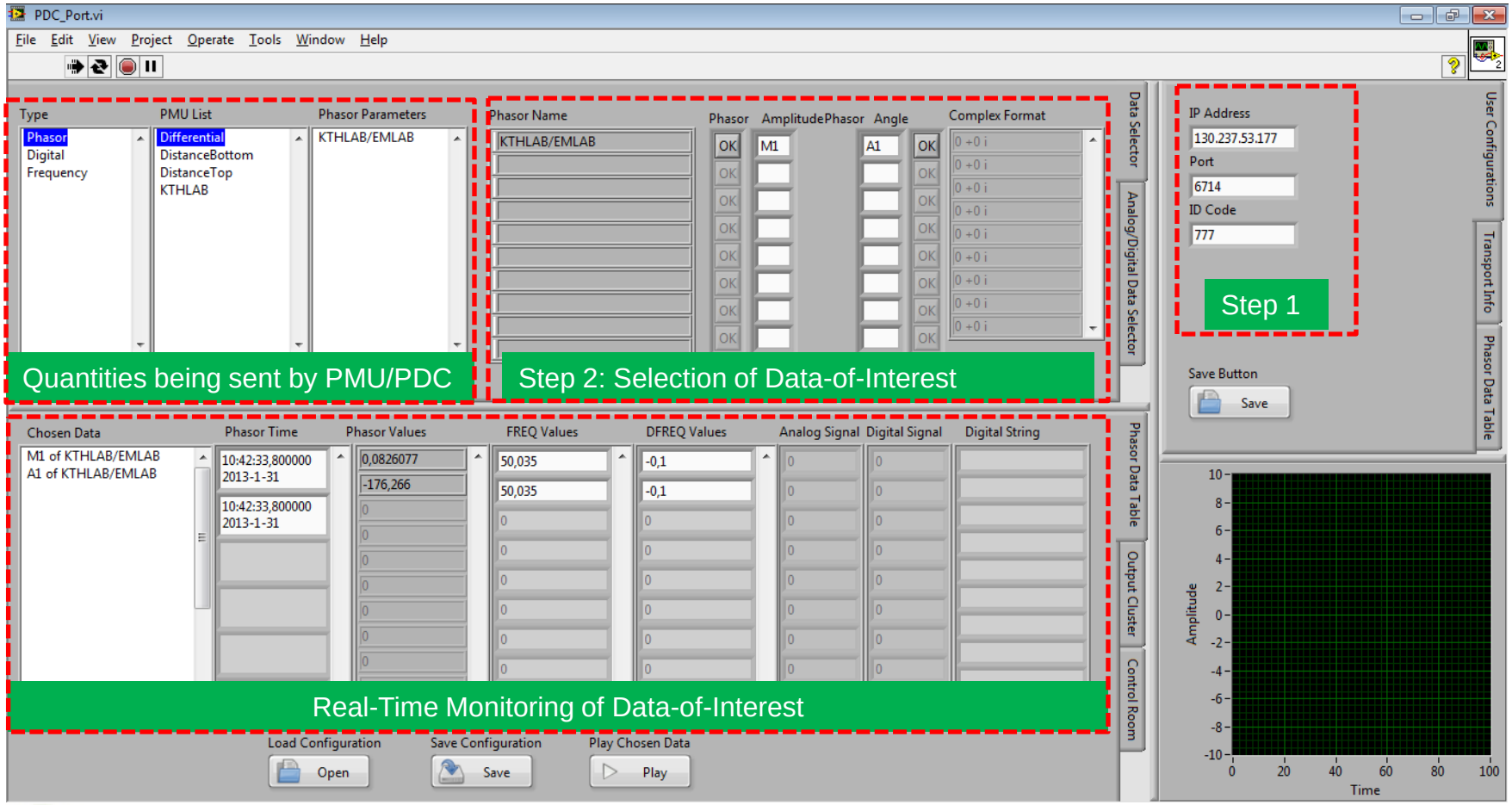
- Faster Reading
- Less computation power
- Smaller memory sizes
- Scalability

BabelFish
(Software Functional Architecture)



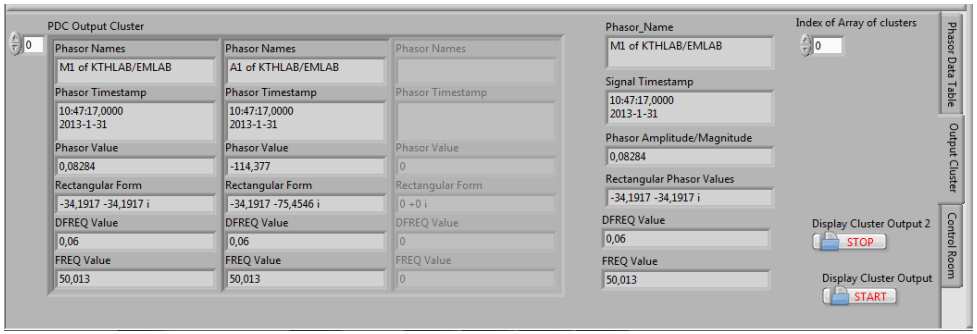
Modular software architecture of BabelFish

BabelFish
(Graphical User Interface)

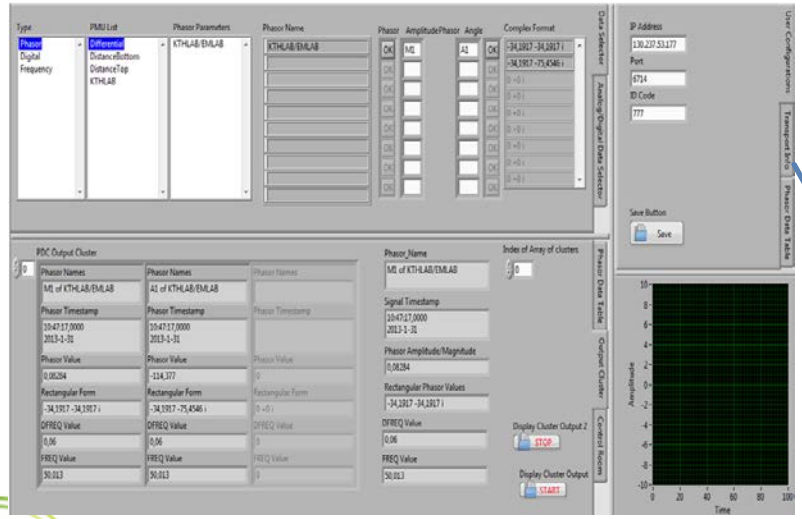


BabelFish
(Graphical User Interface)

Labview Module presenting the chosen data in the lower part in the tab entitled “Output Cluster



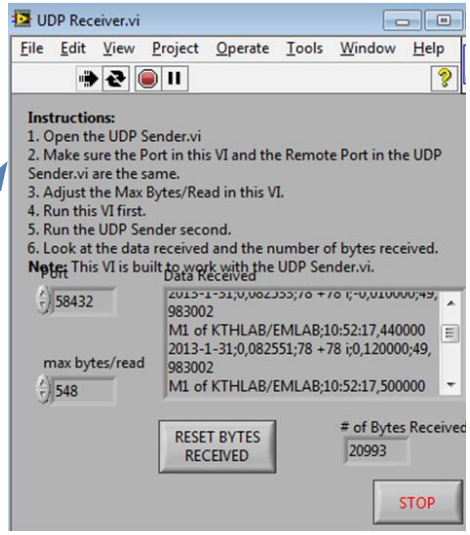
Sender (LV M+M3)



Data-of-Interest sent to end user using UDP

Cloud Network

Destination (UDP Receiver)



Sending a set of chosen PDC data from the LV Module to a remote destination over the Internet

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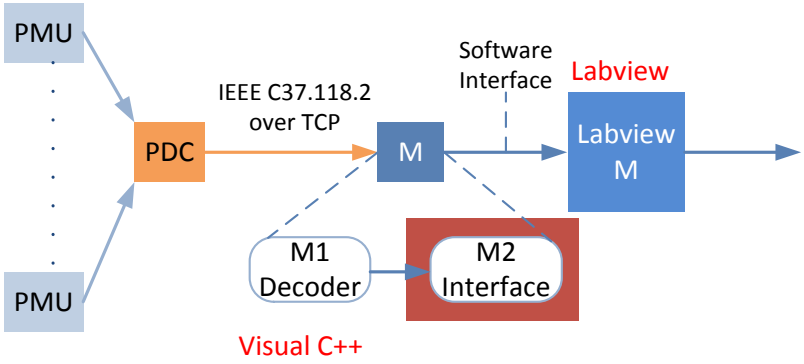
Performance and QoS Assessment



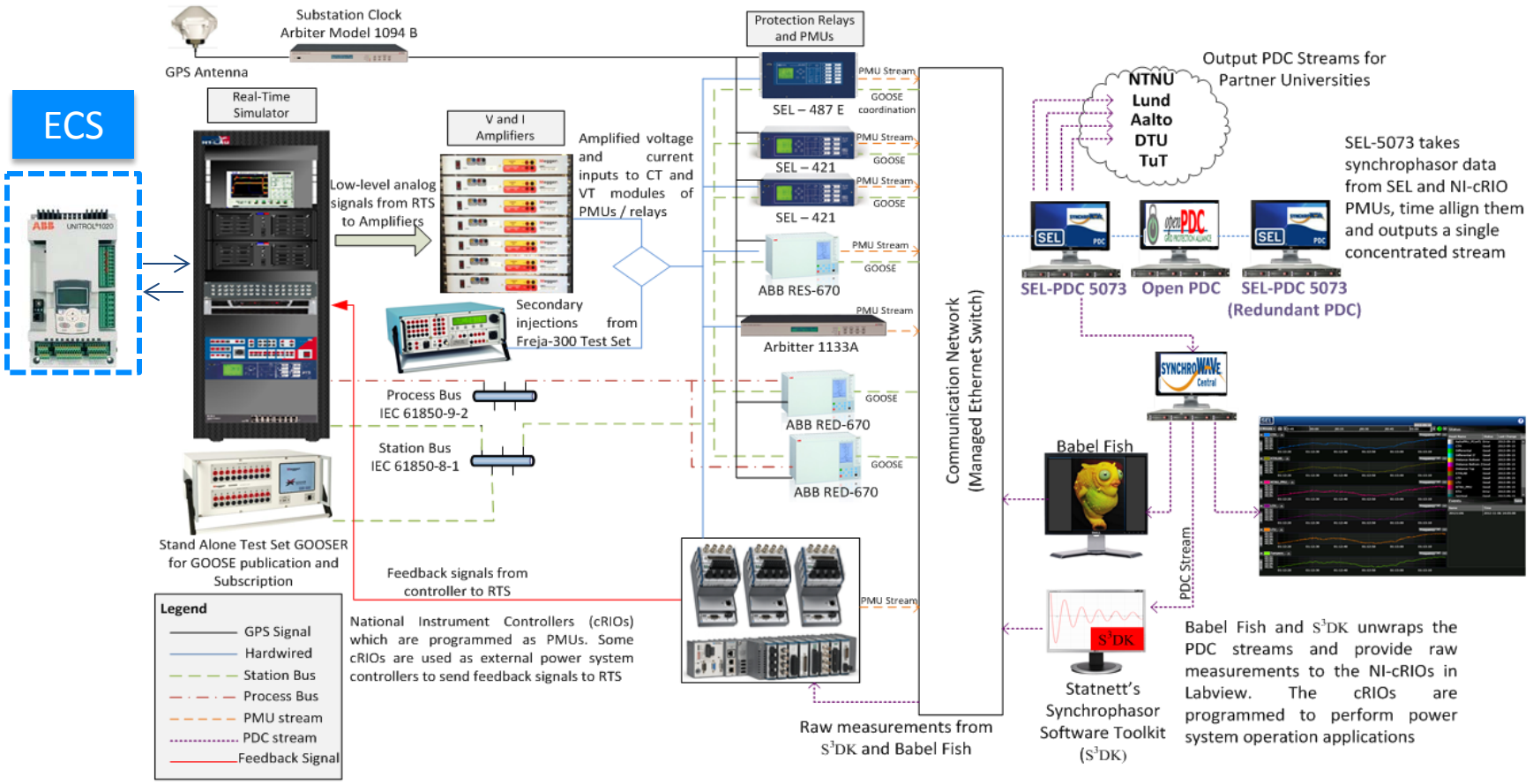
QoS Tests for 3 different Schemes
(100 Statistical Tests) [values in ms]

Parameter	Text Based	Streaming	ActiveX
Average Delay	2.54	1.49	0.2
Min. Delay	0	0	0
Max. Delay	8	13	1
Std. Deviation	1.17	1.34	0.40

- Tests performed on a Desktop PC with Intel Core i5 CPU with 4 GB RAM using Windows 7 OS.
- Test carried out with PDC stream having 6 PMUs and each PMU transmitting 4 parameters.

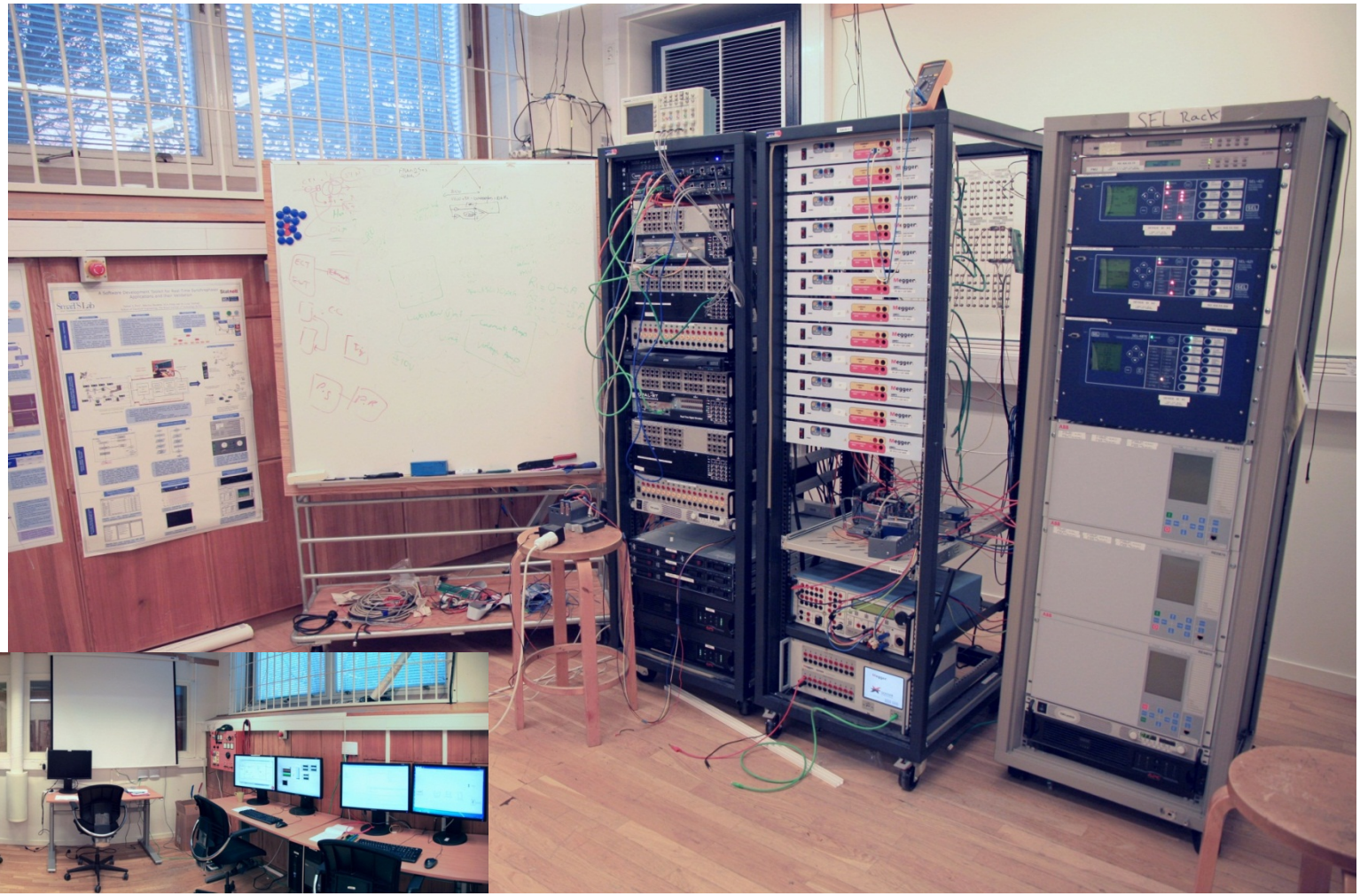
Integration of BabelFish in SmarTS Lab

Smart Transmission Systems Laboratory

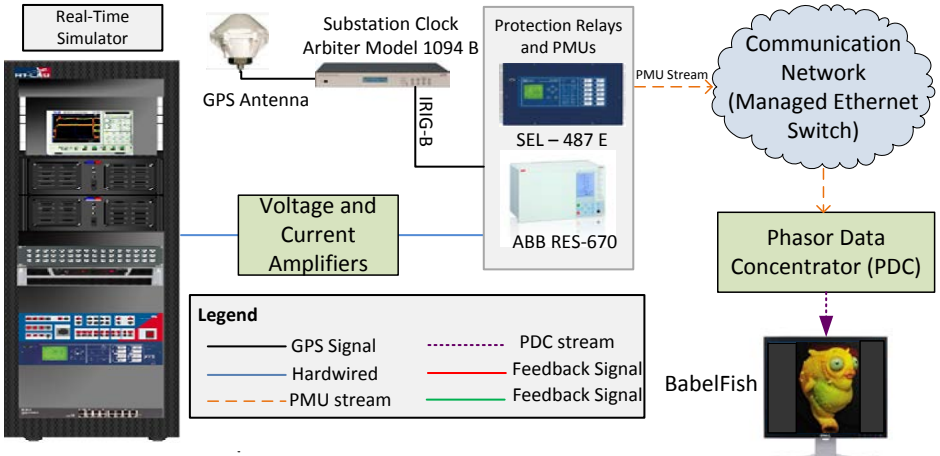


Our SmarTS Lab Architecture

Smart Transmission Systems Laboratory



Real-Time Execution of BabelFish



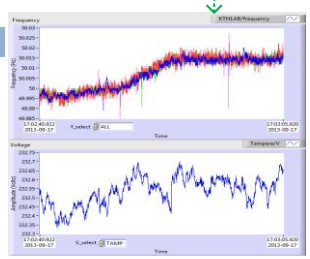
1

Remote UDP clients on different programming platform using user selected synchrophasor data from BF for further data manipulation

2

Selected synchrophasor data being received in National Instrument controllers using UDP for performing power system control applications

3



User selected synchrophasor data through BF being used in a power system monitoring application

Conclusions/Recommendations

- Conclusion
  - Transforming textual written standard for protocol into coded application requires a modular design strategy.
  - Possible combinations of Operating systems, TCP versions, TCP/IP suite, Hardware resources, parallel processing, graphical design issues should be taken into account during design.
  - Real-Time QoS requirements (end-to-end delay) needs to be addressed before a final choice of OS, programming language and HW resources is made.
  - Stress Tests should be performed after the development to validate whether end-to-end delays are within acceptable limits or not.
- Further Research
  - Development of a BabelFish for embedded controllers, which would allow real-time excecution in embedded systems (e.g. controls, protections, etc.)
  - Support for IEC 61850-90-5

Acknowledgements

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- iITC: Iyad Al-Khatib

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Thank you!

- Questions?
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The scientific man does not aim at an immediate result. He does not expect that his advanced ideas will be readily taken up. His work is like that of the planter - for the future. His duty is to lay the foundation for those who are to come, and point the way. (*Nikola Tesla*)

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