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Identify QoS requirements of WAMC applications and Infrastructure Solutions

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STRONgrid

Smart Transmission Grids Operation and Control

KTH - NTNU - AALTO - DTU - UI

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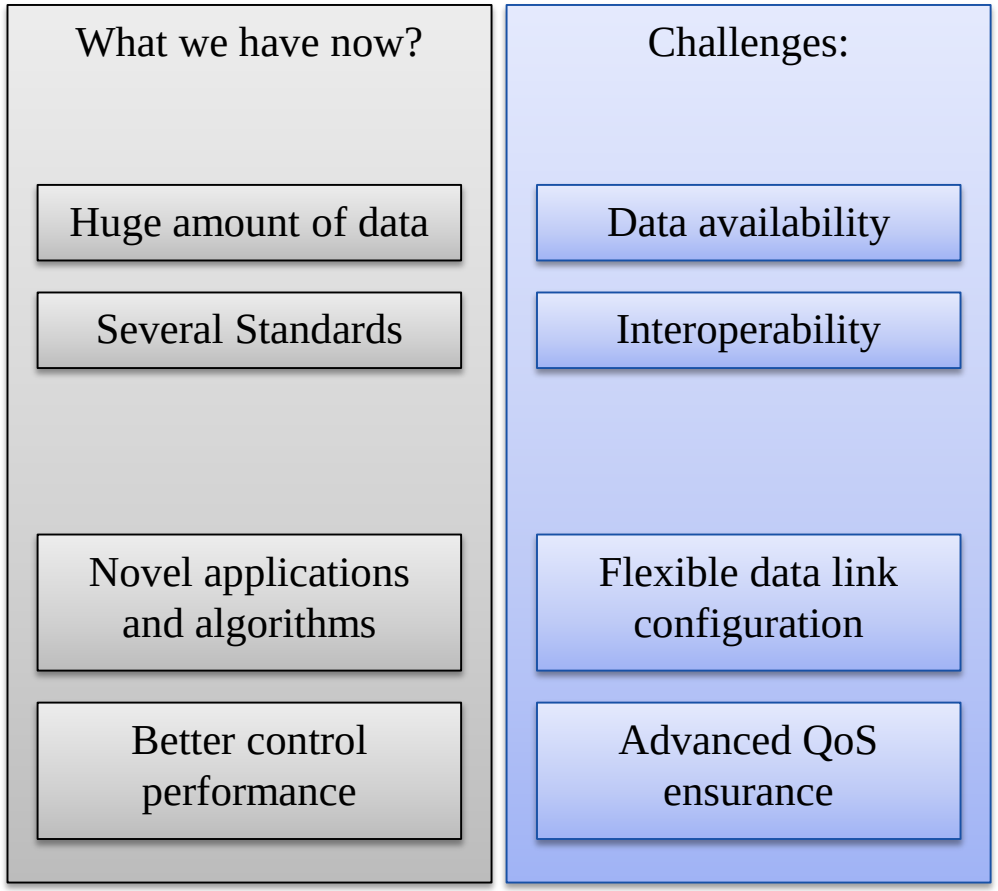
Agenda

- Background and challenges
- Objectives and research map
- So far achieved
- Some thoughts

Background and Challenges

- Development of ICT and Power System
  - New Equipments:
    - (IED, MU, PMU, PDC, etc.)
  - New Standards:
    - (IEC61850, C37.118, DNP3, etc.)
- Power System Applications
  - Distributed Control
  - Multi-Agent System Control
  - Cloud computing



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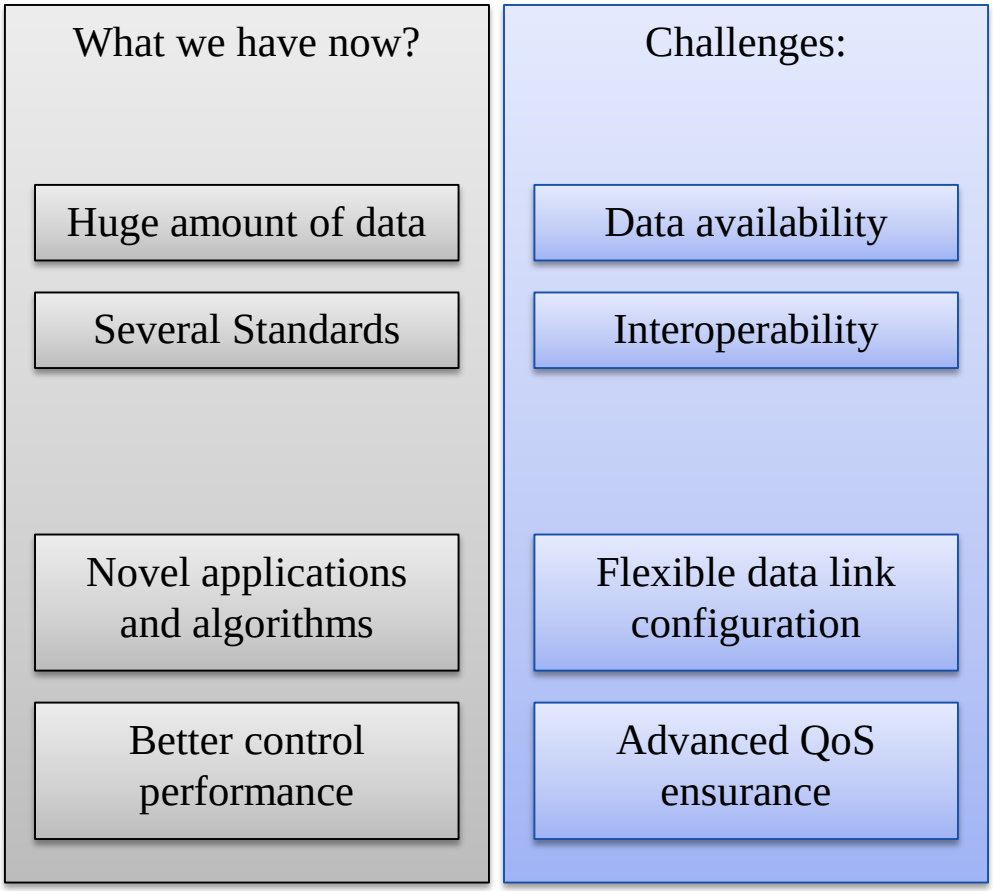
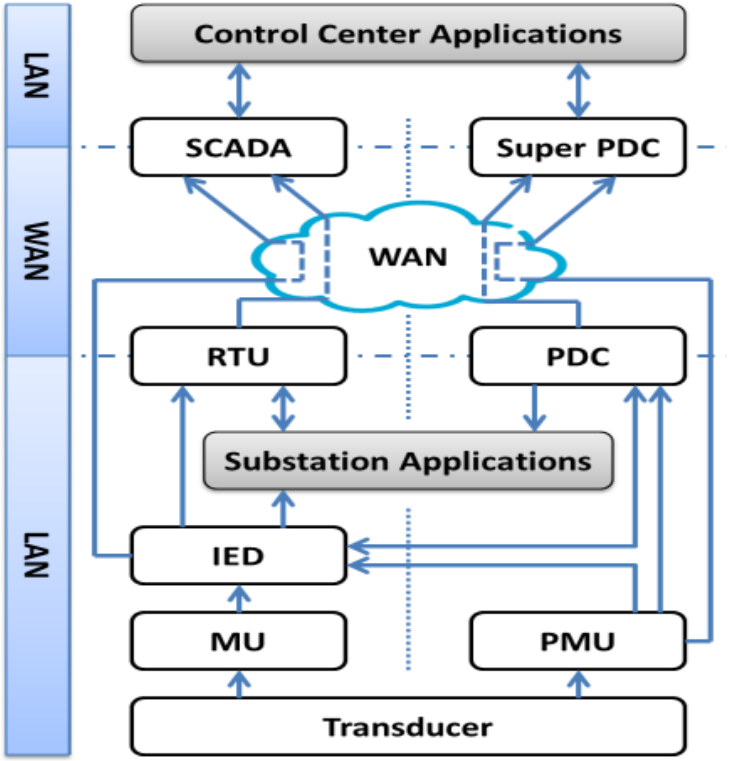
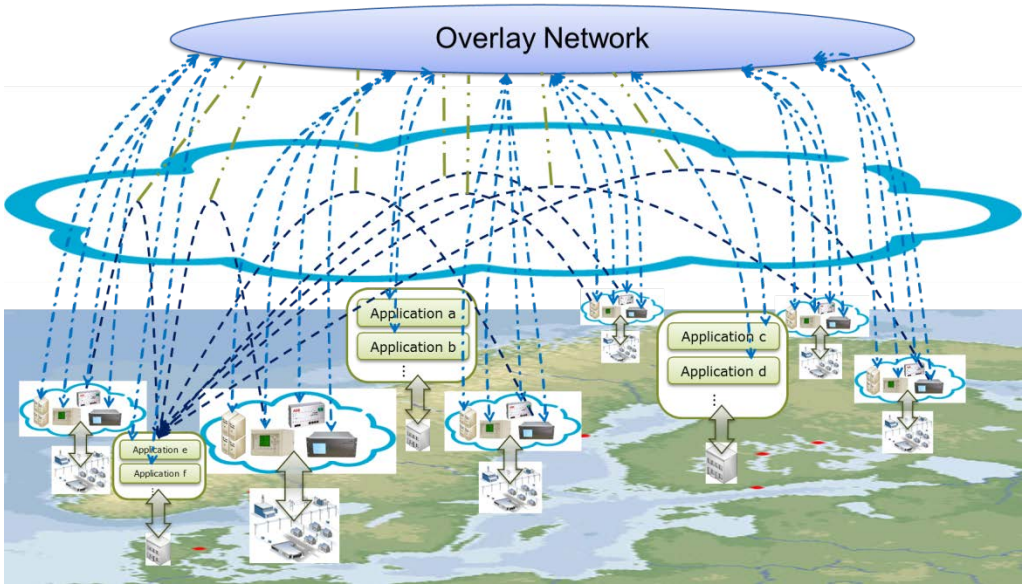
Background and Challenges



- Data availability
  - Sharing data from different data source to the application
- Data interoperability
  - Different equipments and different standards
- Data link flexibility
  - Data link configuration flexibility and data delivery path flexibility
- Data delivery Quality of Service
  - Latency, Report Rate, Packet loss, Packet jitter, security, and etc.

Objectives and Research map

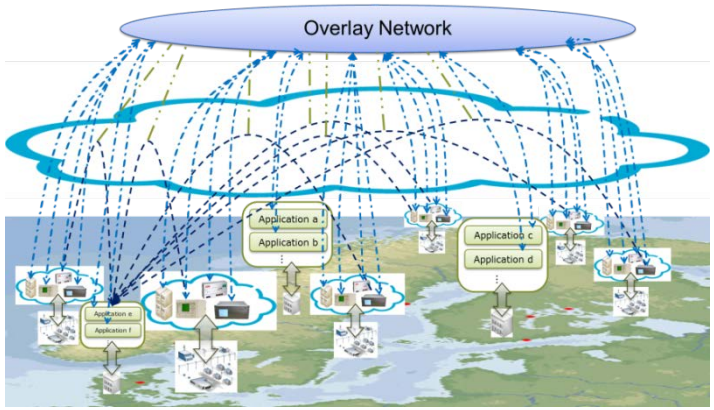


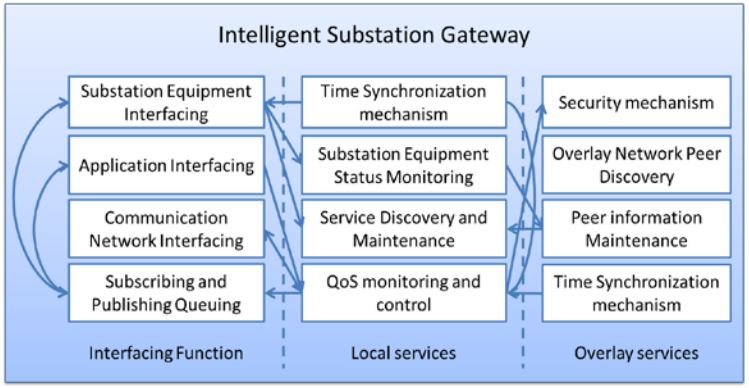


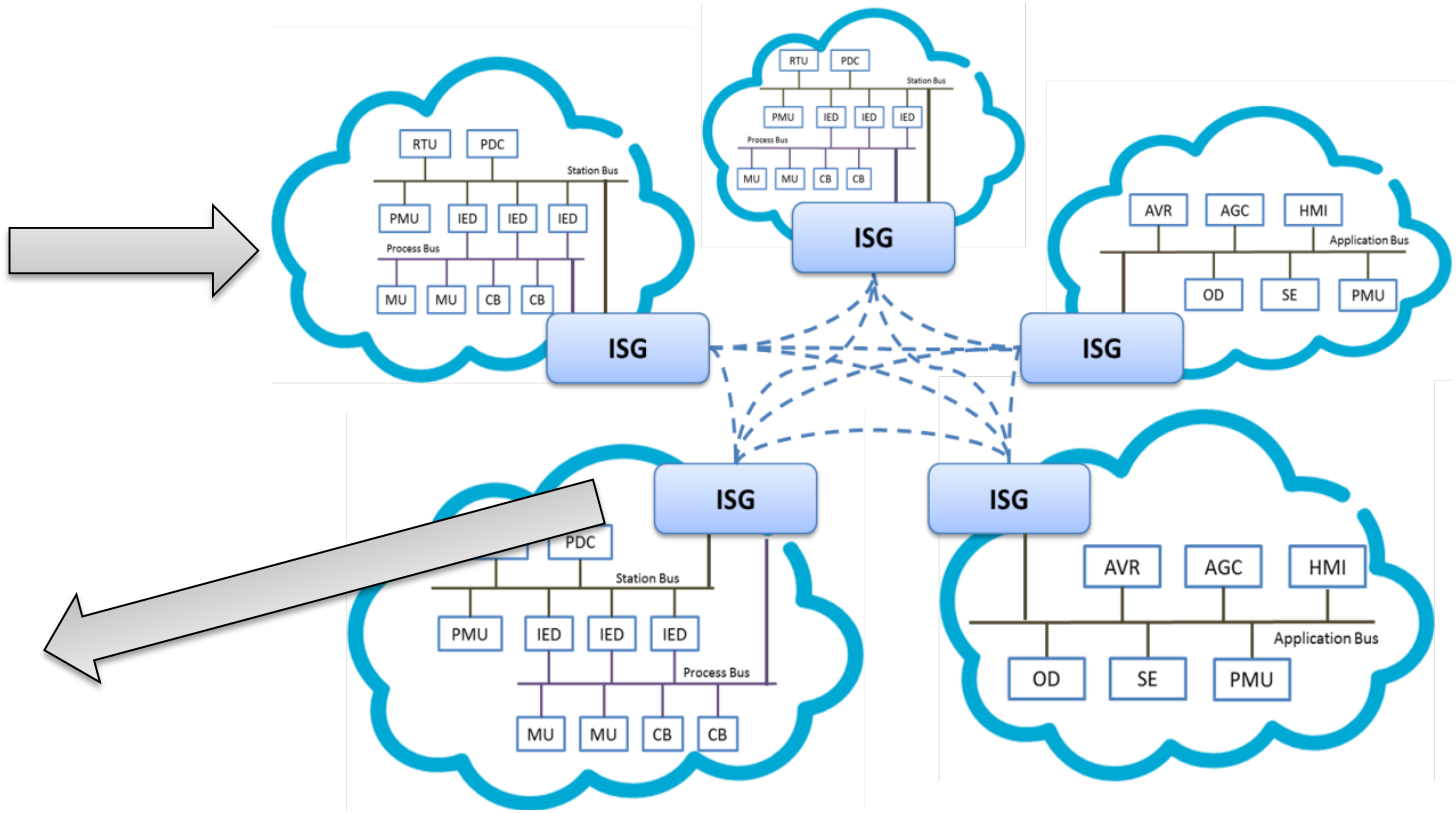
- Unnecessary delay
- Less flexiable
- Less available

Objectives and Research map

- Overall Architecture
  - Intelligent Substation Gateway



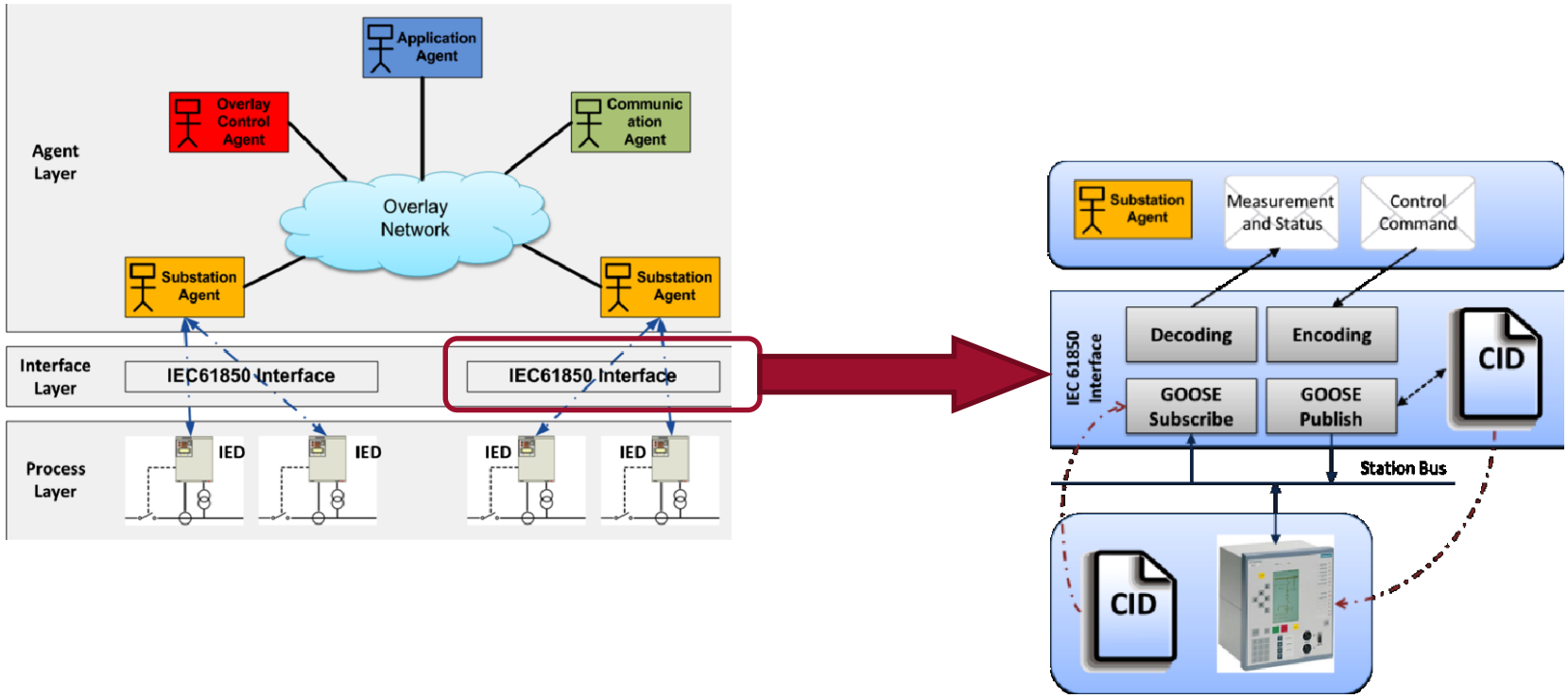




Yiming Wu, Lars Nordström, Arshad Saleem, Kun Zhu, Nicholas Honeth, Mikel Armendariz , ”Perspectives on Peer-to-Peer Data Delivery Architectures for Next Generation Power Systems”. in Proceedings of ISAP 2013, Tokyo, Japan.

So far achieved

- Data interoperability:
  - IEC61850 GOOSE interface for MAS

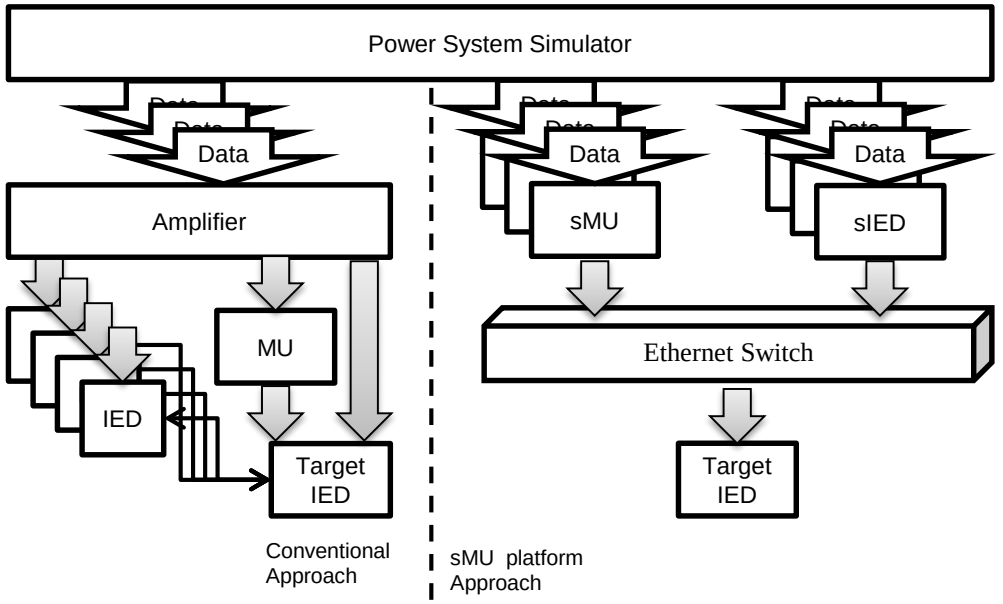


Yiming Wu, Arshad Saleem, Nicholas Honeth, Lars Nordström, ”IEC61850 Interface based Multi-agent Distribution Networks Operation and Control Architecture”. in Proceedings of ISGC&E 2013, Jeju, Korea.

So far achieved

- Data interoperability:
  - IEC61850 SV interface

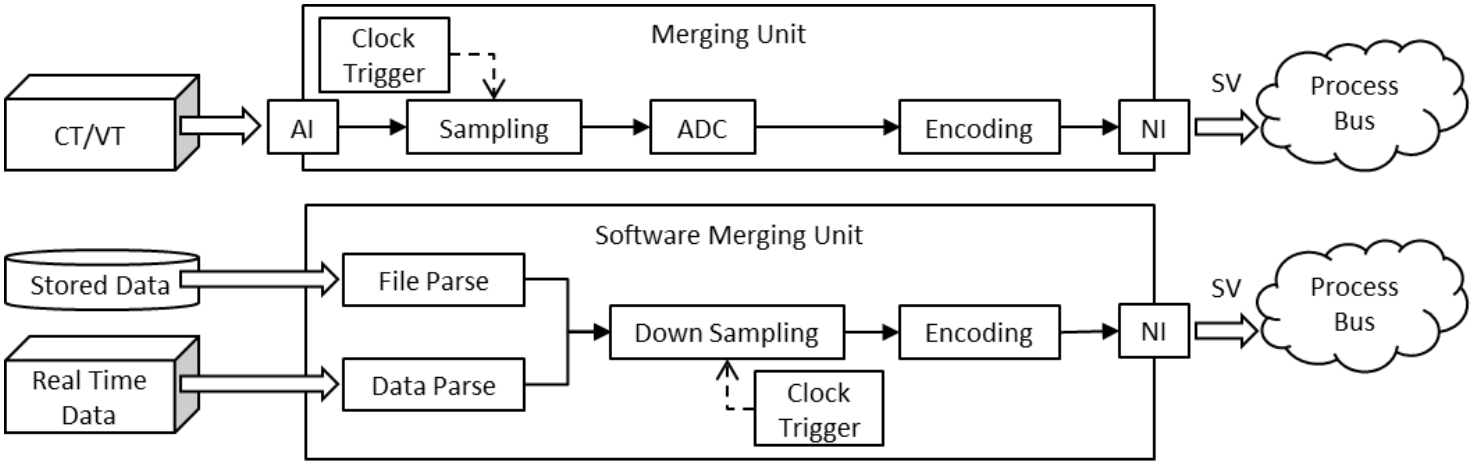
- IEC61850-9-2 Sampled Value
- Light Edition
- 4000 packets/second

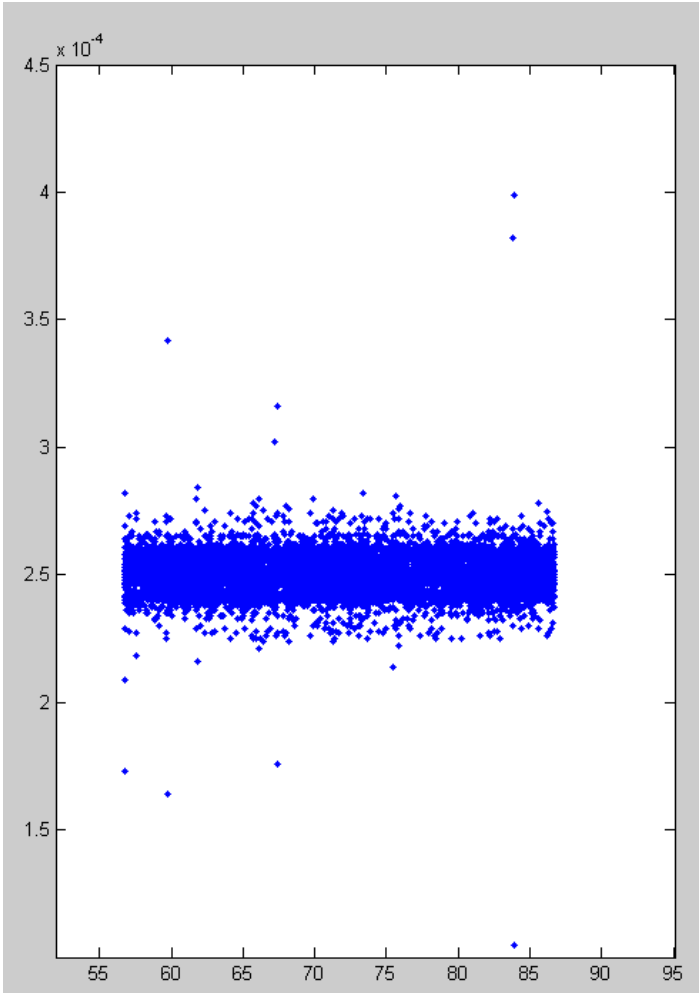


Yiming Wu, Zhanpeng Shi, Nicholas Honeth, Lars Nordström, ”Software Merging Unit based IED Functional Test Platform”. Accepted by PES GM 2015.

So far achieved

- Data interoperability:
  - IEC61850 SV interface

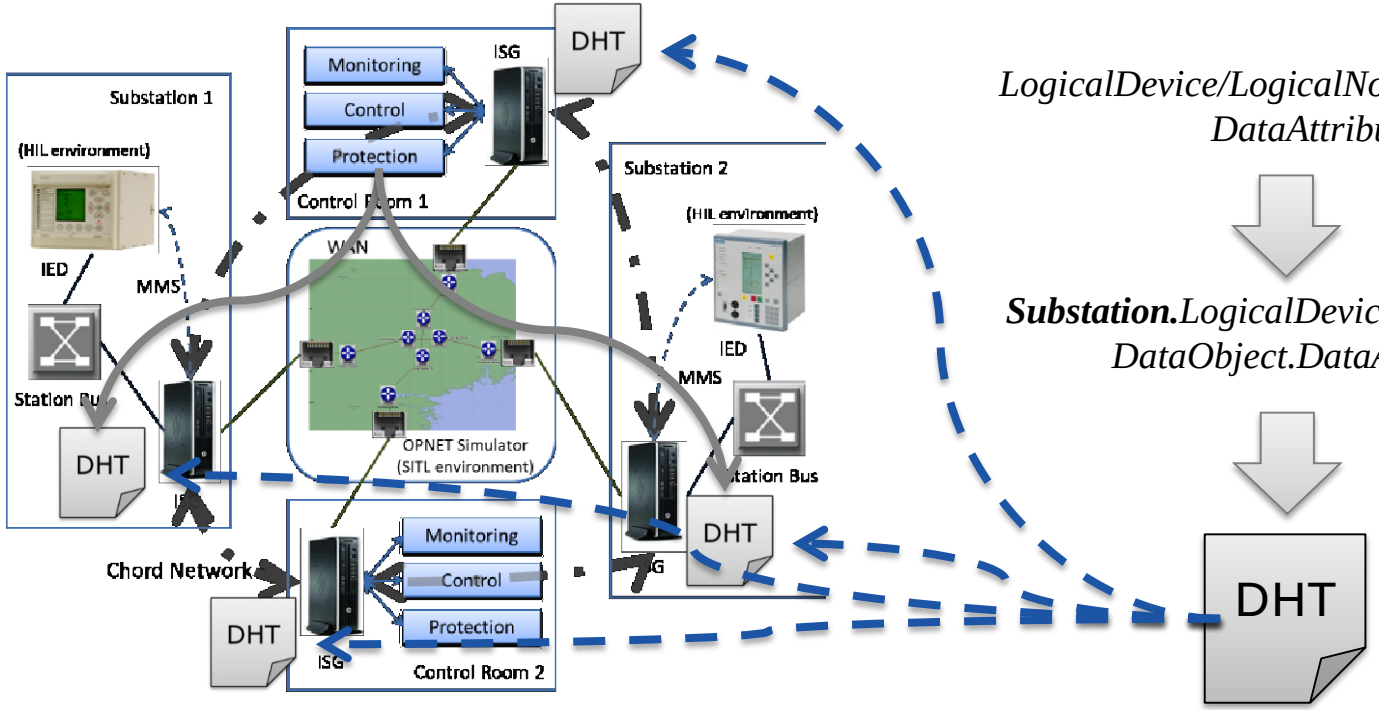




Yiming Wu, Zhanpeng Shi, Nicholas Honeth, Lars Nordström, "Software Merging Unit based IED Functional Test Platform". Accepted by PES GM 2015.

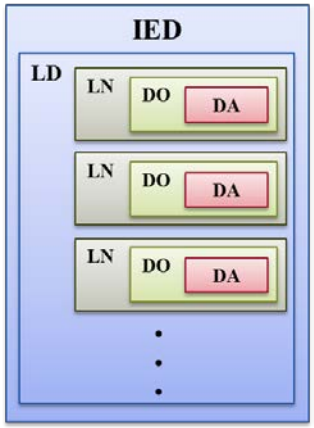
So far achieved

- Data availability:
  - DHT for data source lookup



LogicalDevice/LogicalNode.DataObject.DataAttribut

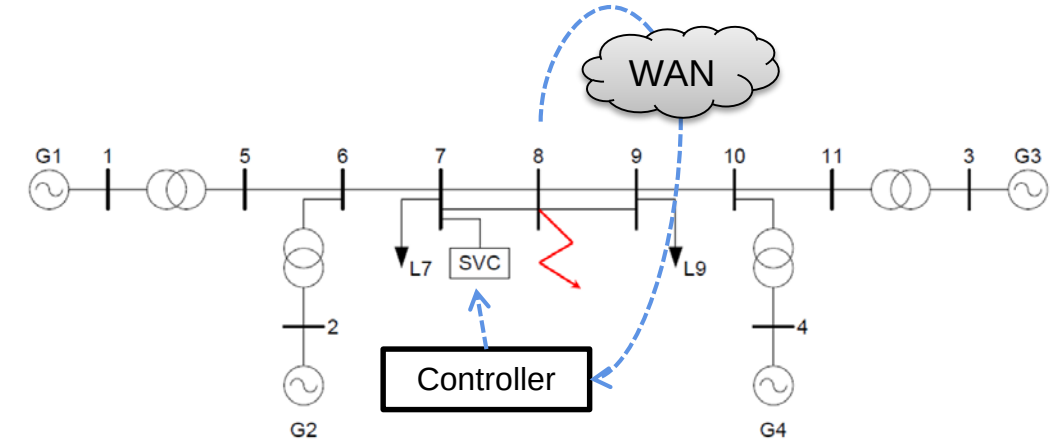
Substation.*LogicalDevice/LogicalNode.DataObject.DataAttribute*

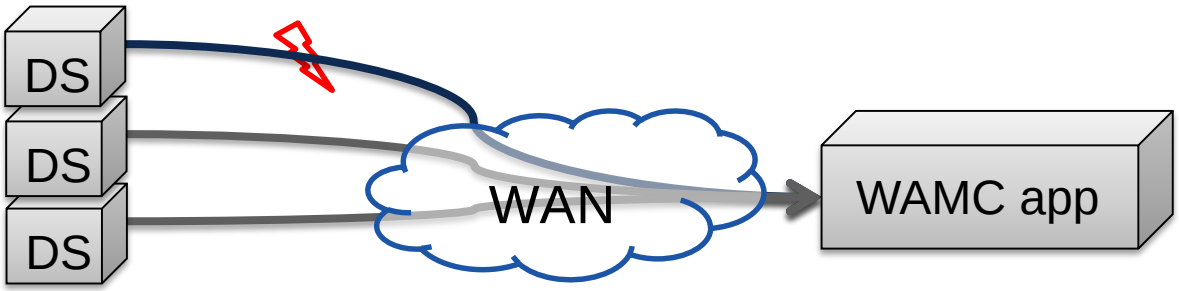


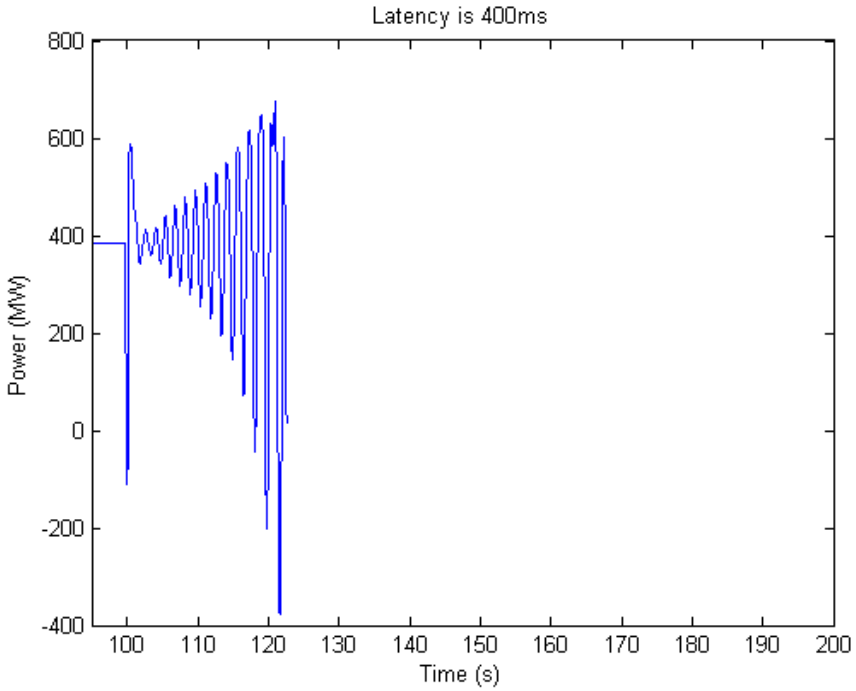
Yiming Wu, Lars Nordström, Arshad Saleem. ”IEC61850 Logical Node Lookup Service Using Distributed Hash Tables”. in Proceedings of IEEE PES Innovative Smart Grid Technologies Conference (2014 ISGT), Washington, USA.

So far achieved

- QoS ensurance - Stateful Data Delivery Service
  - Motivation
    - Data delivery performance affect on power system applications







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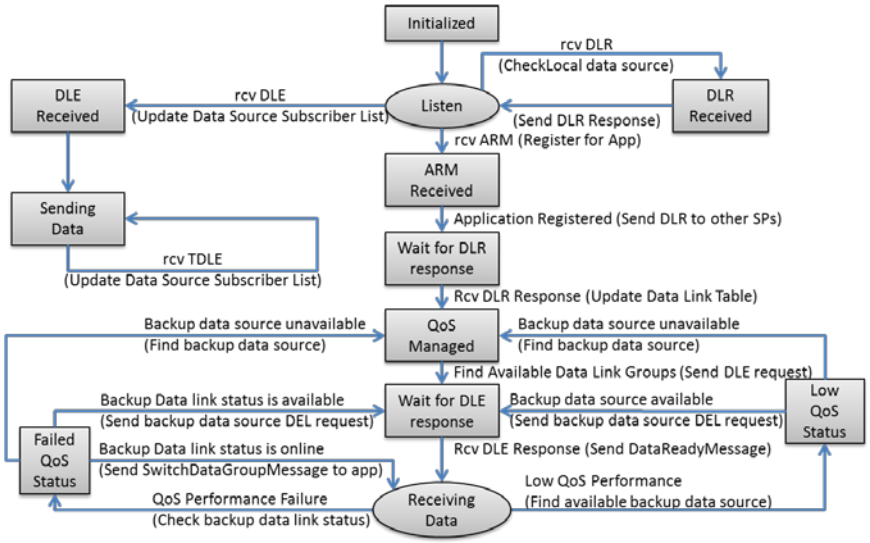
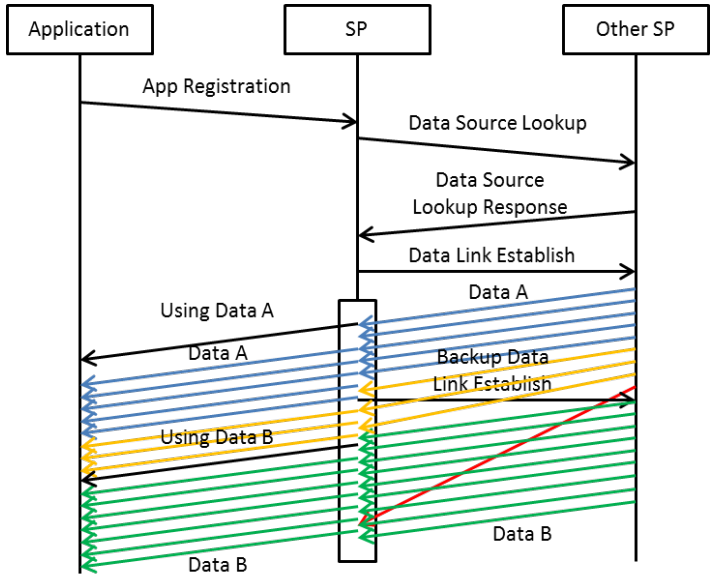
So far achieved

- QoS ensurance - Stateful Data Delivery Service
  - How it ensure the QoS for the application?
    - Real time QoS performance monitoring
    - Adaptive data link configuration
    - Feedback to WAMC application

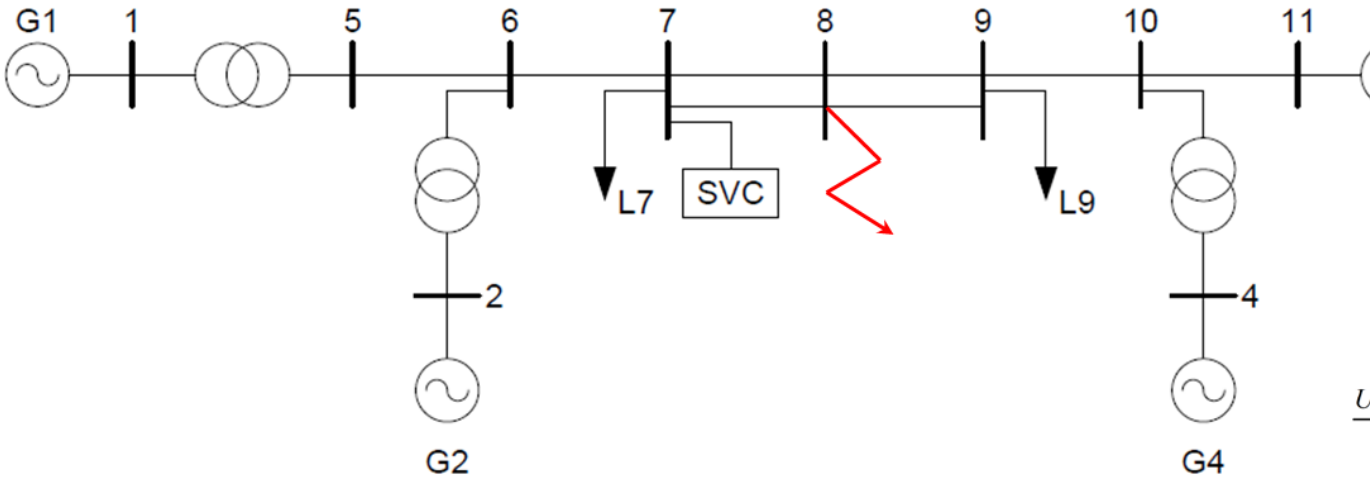


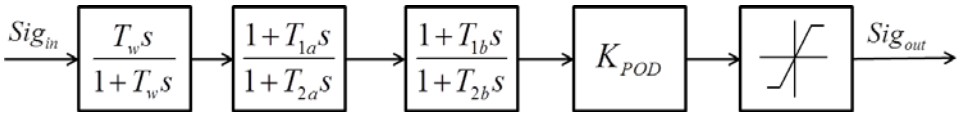


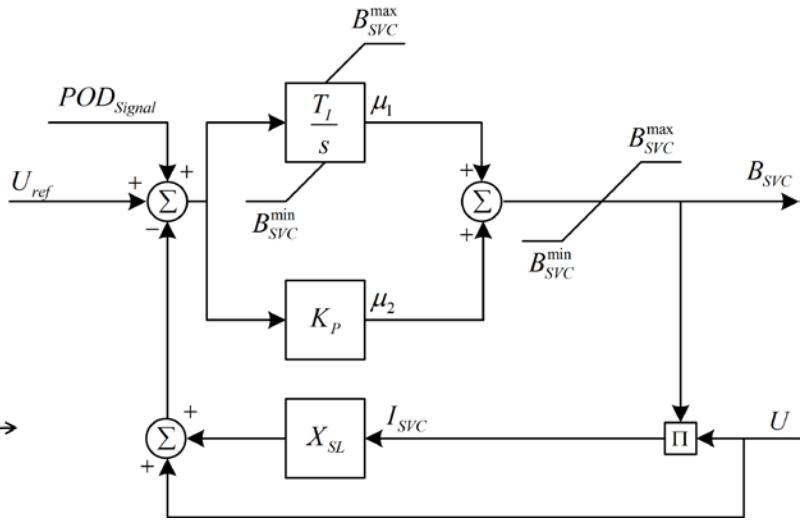
Yiming Wu, Davood Babazadeh, Lars Nordström, ”Stateful Data Delivery Service for Wide Area Monitoring and Control Applications”, in Proceedings of The 1st International Workshop on Trustworthiness of Smart Grids (ToSG 2014), Atlanta, USA

So far achieved

- QoS ensurance - Stateful Data Delivery Service
  - Case study
    - Power system model and Power Oscillation Damping Controller Model







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So far achieved

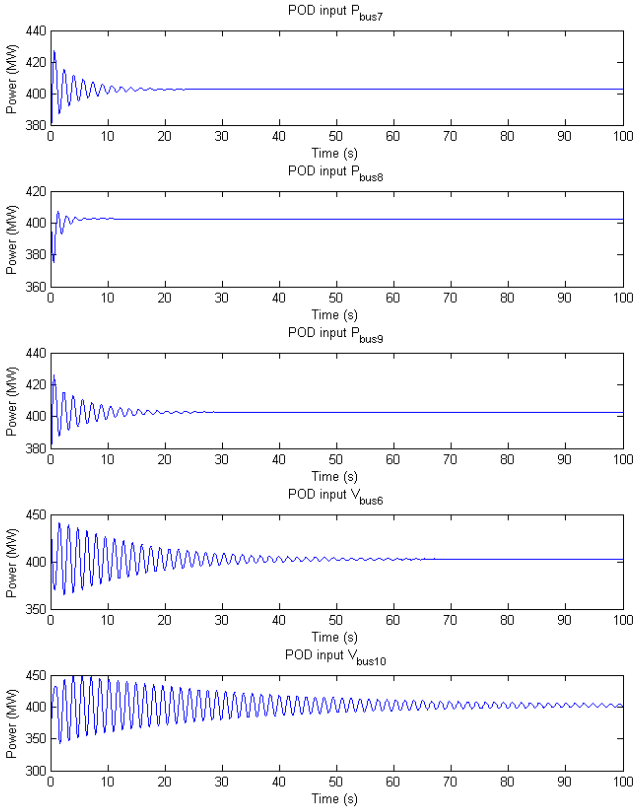
- QoS ensurance - Stateful Data Delivery Service
  - Case study
    - System analysis and data sources selection

Dominant inter-area modes

Mode No.	EigenValue	*Frequency (Hz)*	*Damping ratio*
1	$0.0592 \pm 4.1014i$	0.6528	−0.0144
2	$-0.2478 \pm 0.5074i$	0.0808	0.4388
3	$-0.5568 \pm 7.0769i$	1.1263	0.0784
4	$-0.5775 \pm 7.2993i$	1.1617	0.0789

Observability

Signal Name	Observability
P_{B7}	0.0327
P_{B8}	0.0323
P_{B9}	0.0319
V_{Bus6}	0.0029
V_{Bus10}	6.5664×10^{-4}



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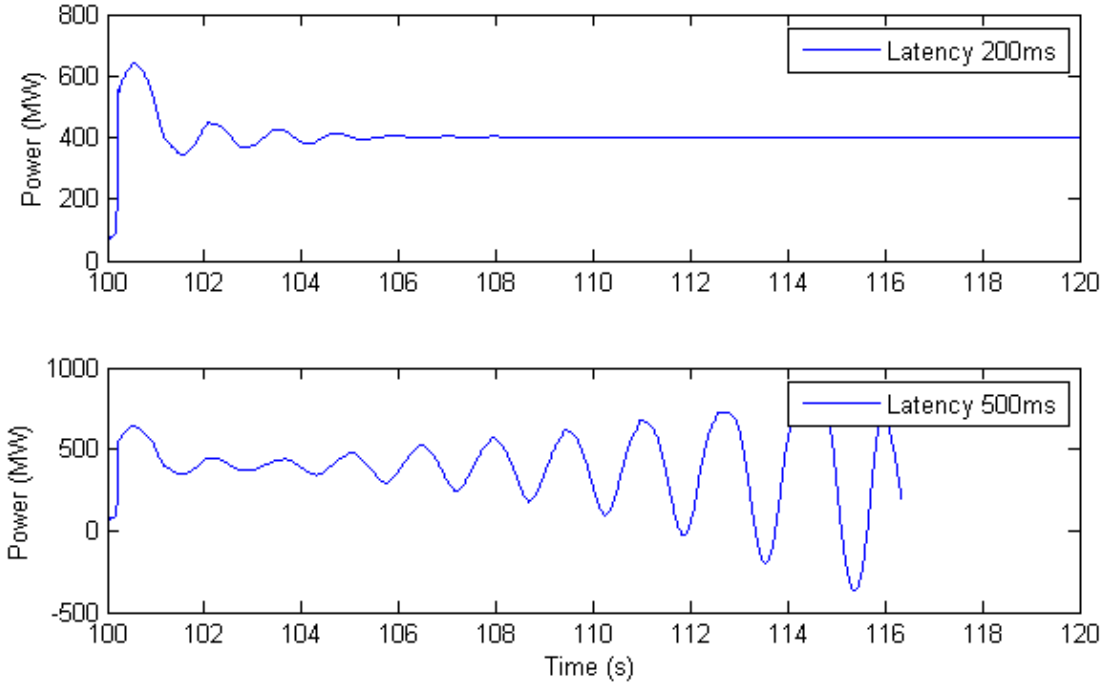
So far achieved

- QoS ensurance - Stateful Data Delivery Service
  - Case study
    - Latency requirement based on different input signal

Latency requirement

Signal Name	Latency Requirement (ms)
P_{B7}	400
P_{B8}	200
P_{B9}	450
[redacted]	



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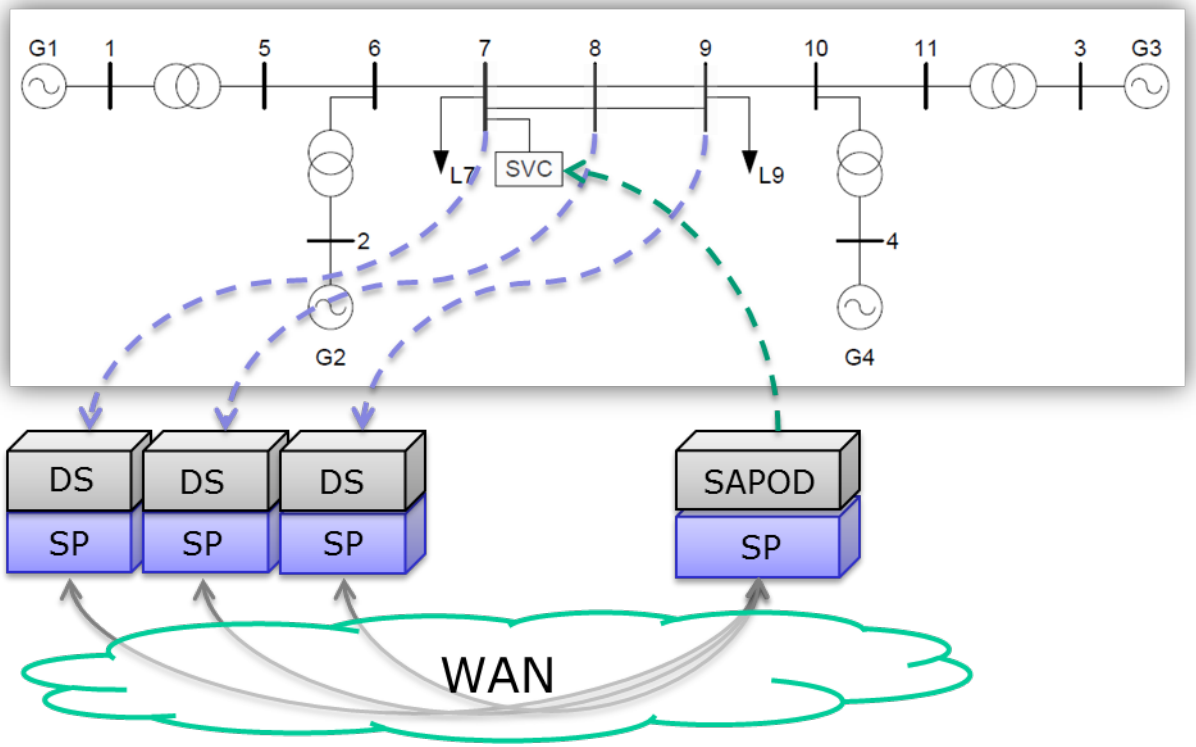
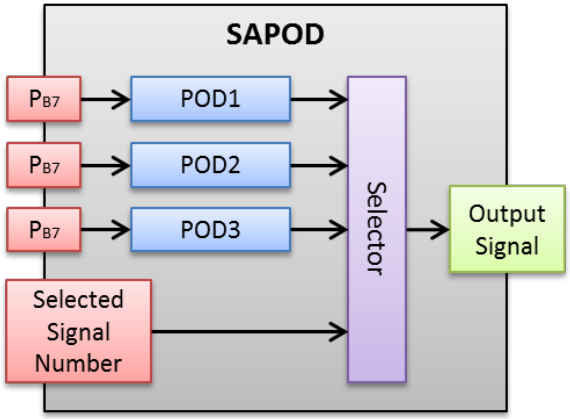
So far achieved

- QoS ensurance - Stateful Data Delivery Service
  - Case study
    - SAPOD model and simulation implementation





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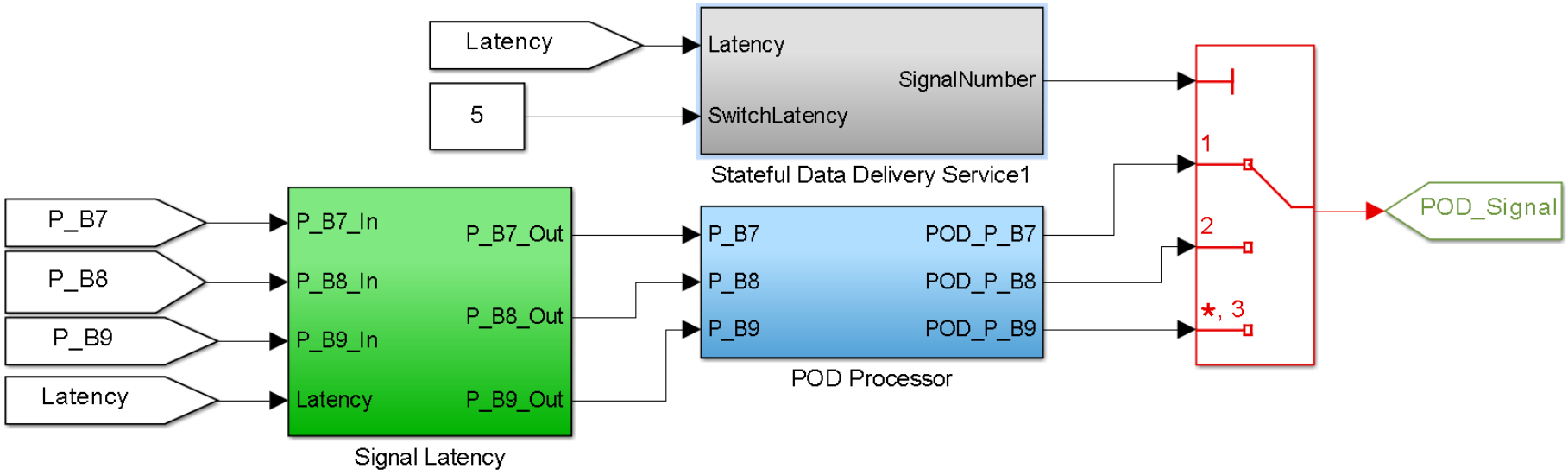
So far achieved

- QoS ensurance - Stateful Data Delivery Service
  - Case study
    - SAPOD model and simulation implementation



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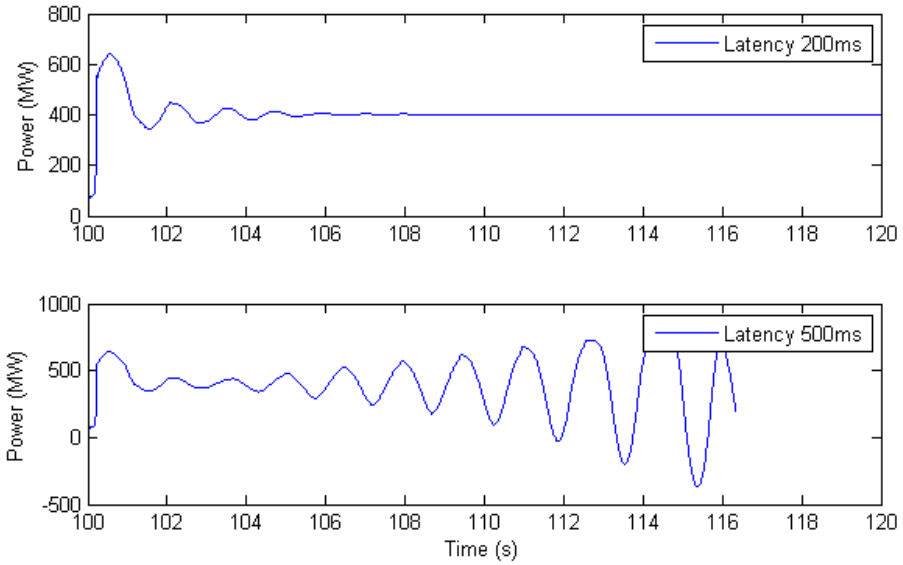
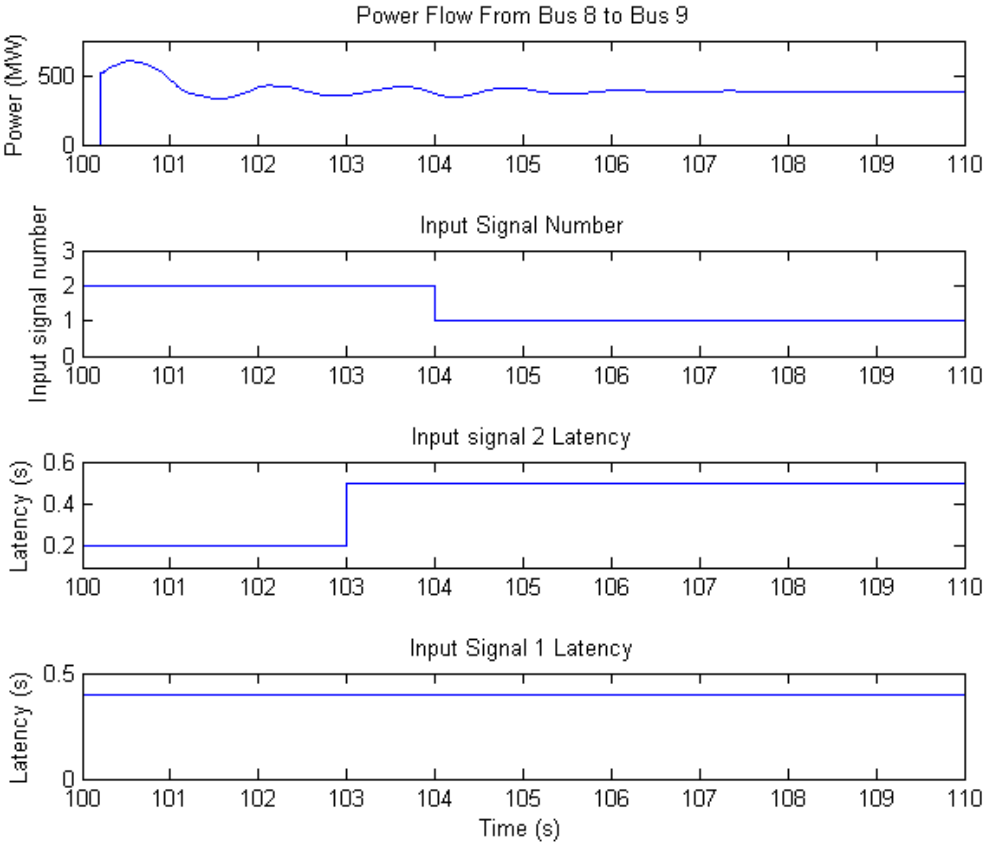
So far achieved

- QoS ensurance - Stateful Data Delivery Service
  - Case study
    - Simulation results



Without SDDS



With SDDS

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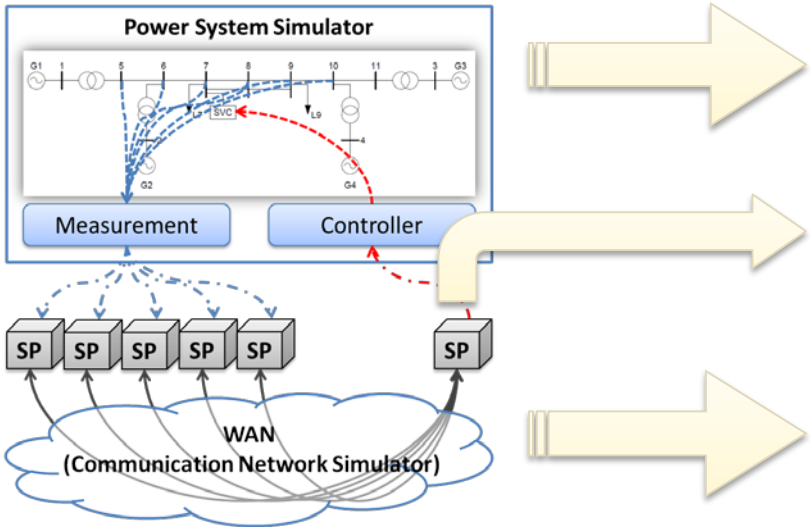
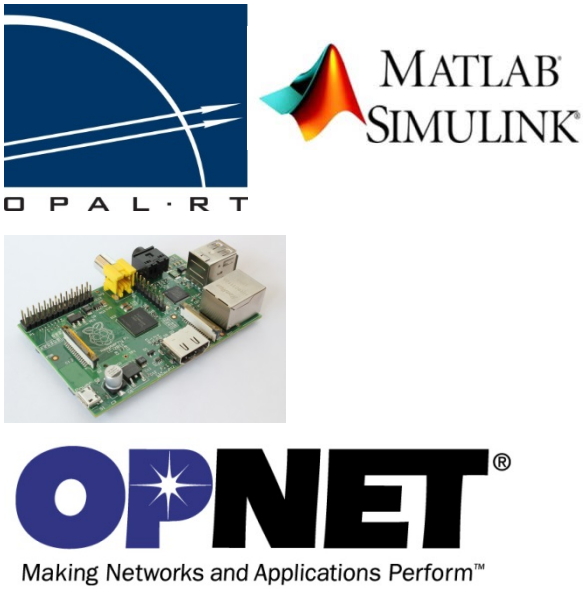
So far achieved

- QoS ensurance - Stateful Data Delivery Service





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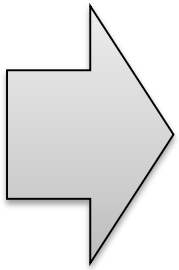
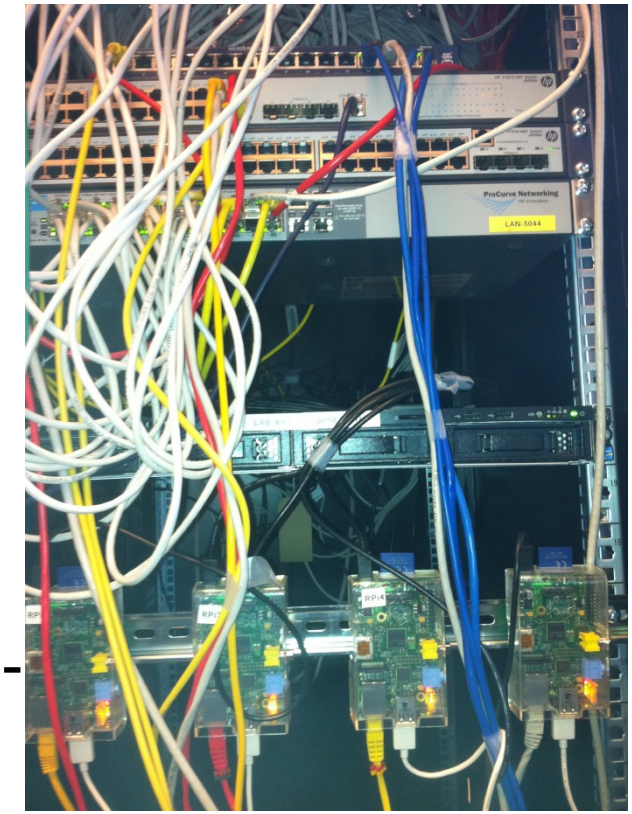
So far achieved

- QoS ensurance - Stateful Data Delivery Service

```
private AppDataLinkInfo appDataLinkInfo;
//private int inUsingDataSourceGroupNum;
//private int backupDataSourceGroupNum;
private ApplicationProperty appProperty;
private ReceivedDataBuffer receivedDataBuffer;
private List<ReceivedDataObject> receivedDataList;
private SendDataBuffer sendDataBuffer;
private ApplicationQoSRequirement appQoSReq;
private DataLinkTable dataLinkTable;

//public QoSManagerAssistant(int inUsing_DataSourceGroupNum, int backup_DataSourceGroupNum, ApplicationProperty app_Pr
public QoSManagerAssistant(AppDataLinkInfo app_DataLinkInfo, ApplicationProperty app_Property, ReceivedDataBuffer rece


    //inUsingDataSourceGroupNum = inUsing_DataSourceGroupNum;
    //backupDataSourceGroupNum = backup_DataSourceGroupNum;
    appDataLinkInfo = app_DataLinkInfo;
    appProperty = app_Property;
    appQoSReq = app_QoSReq;
    dataLinkTable = dataLink_Table;
    sendDataBuffer = sendData_Buffer;

    receivedDataBuffer = receivedData_Buffer;
    receivedDataList = receivedDataBuffer.getReceivedDataList();
    //Initialize for sendDataBuffer
    List<DataObject> inUsingDataList = appProperty.getDataSourceList(appDataLinkInfo.getInUsingDataSourceGroupNum());
    for(int i=0; i<inUsingDataList.size();i++){
        String dataName = inUsingDataList.get(i).getDataName();
        int maxLatency = appQoSReq.getAppLinkQoSLatencyReq(appDataLinkInfo.getInUsingDataSourceGroupNum()+"@"+dataLink
        int reportRate = appQoSReq.getAppLinkQoSReportRateReq(appDataLinkInfo.getInUsingDataSourceGroupNum()+"@"+dataL
        sendDataBuffer.updateSendDataObjectBasicParameters(dataName, maxLatency, reportRate);
        System.out.println("[QoSManagerAssistant]: send data buffer has updated for data" + dataName + " with latency
    }
}

public void run() {
    System.out.println("[QoSManagerAssistant]: Started!");
    while(true){
        //Get data list from the application property according to the inUsingDataSourceGroupNum
```





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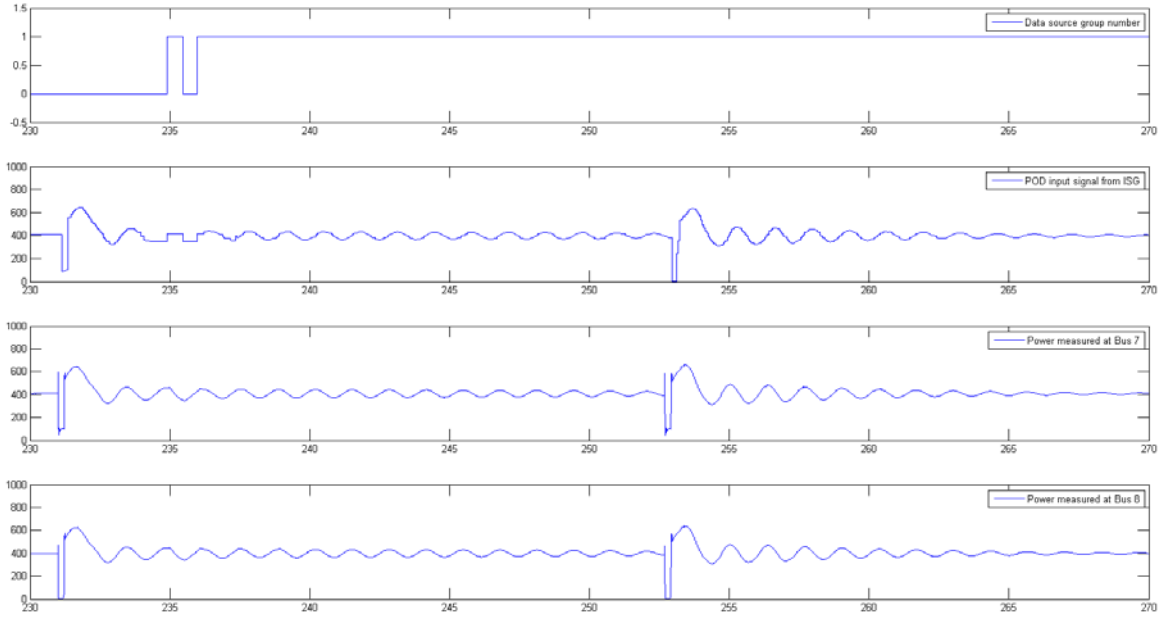
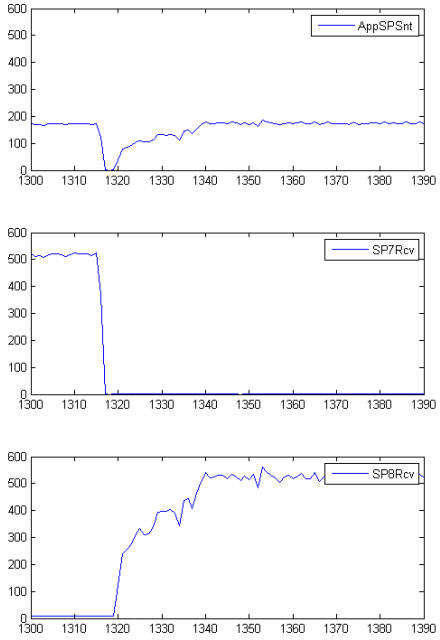
So far achieved

- QoS ensurance - Stateful Data Delivery Service
  - Preliminary Co-simulation Result



Result from OPAL-RT



Result from OPNET

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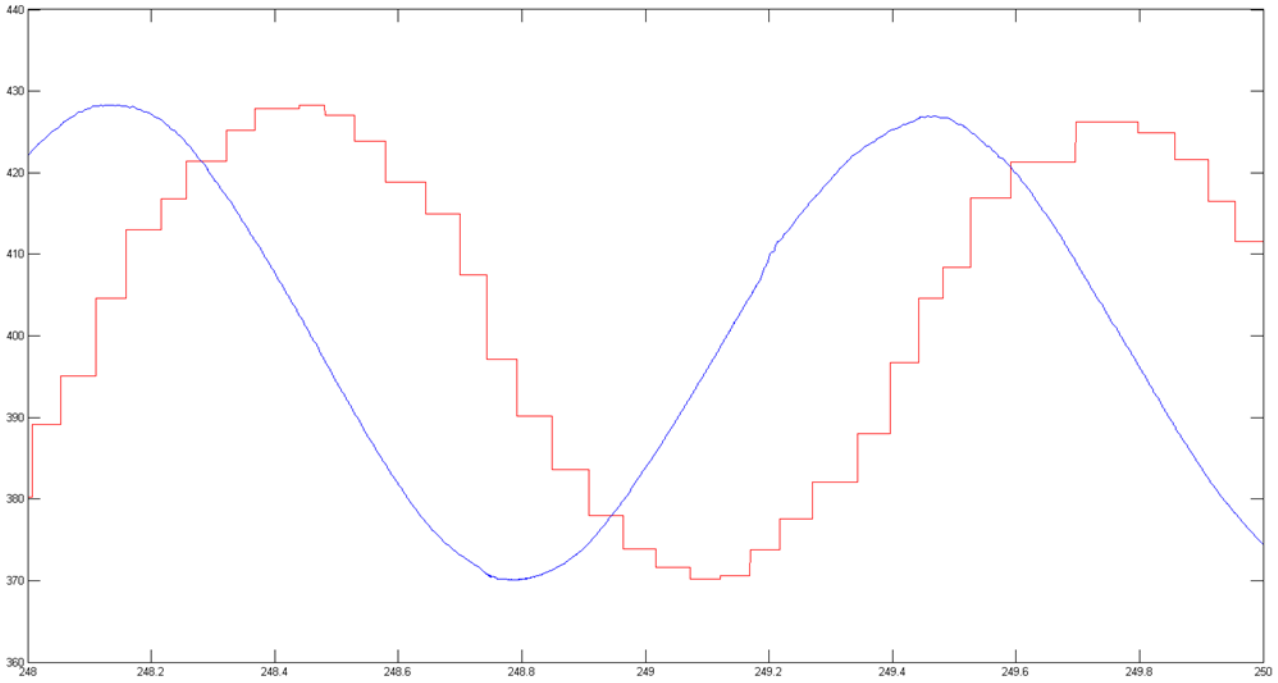
So far achieved

- QoS ensurance - Stateful Data Delivery Service
  - Side benefit to WAMC application design
    - Deterministic latency for WAMC application



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Some thoughts

- QoS ensurance should be specific application oriented
  - Classsification based QoS in some cases might not able to fulfill the requirements of WAMC applications
  - Applications for same control or protection objectives might have different requirements depending on which data source they are using, which algorithm they are applied
- Latency can be regarded as deterministic input from application design point of view
  - Lots of paper using stochastic methods to model the latency and study the controller performance under such situation
  - When time out function is applied, received data will have the same latency instead of stochastic characteristic
- No ICT infrastructure included in IEEE models
  - IEEE reliability Model
  - IEEE 14 Bus, 30 Bus, 118 Bus, 300 Bus, etc.
- QoS requirements should be included in results of WAMC applications

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THANK YOU!