Communication Network Analysis in Wide Area Measurement System

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- System operators must perform an action according to the grid disturbance within its threshold time
  - Threshold time includes end-to-end delay of communication network, power system applications processing time, decision time
- In this project the significant artifact is the end-to-end delay
  - Need to ensure the latency requirements of applications are met

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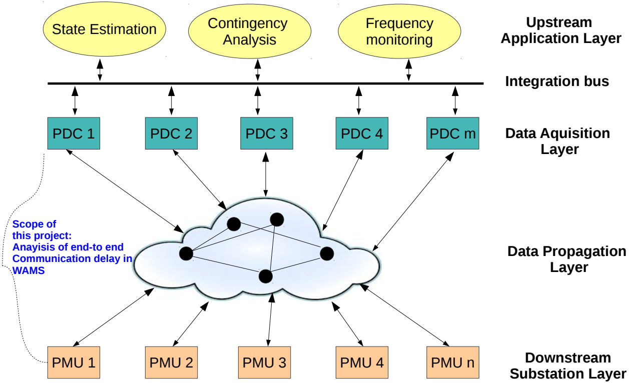
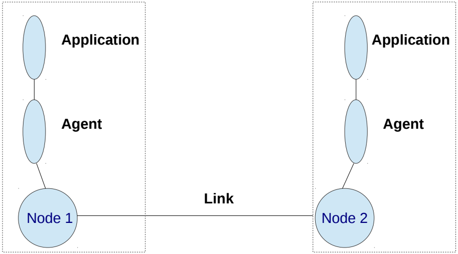


Communication architecture for WAMS

Project Timeline

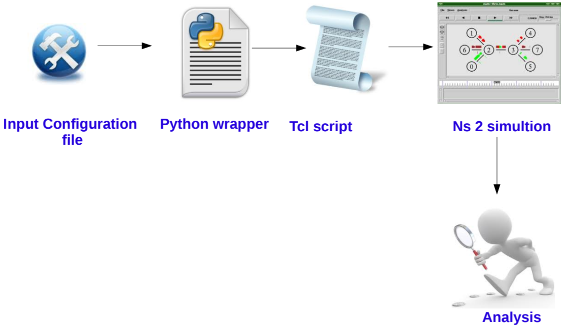
Plan	Plan phases and implementaion	10 days	10 days	10 days	10 days	10 days	10 days
Study of NS 2 Simulator	Understanding architecutre, components, and its existing input-output interfaces						
	Creating sample models for dive more into NS 2						
	Modeling of generic communication components in the NS 2						
Creating generalize NS 2 wrapper for WAMS	Design of input configuration format where WAMS communication can be modeled without interation with simulation software						
	Design of python scripts where it import config and exports system needed .tcl scripts						
	Validation and testing of the wrapper						
Model WAMS communication scenarios through developed NS 2 wrapper	Literature survey on WAMS communciaiton systems and prepare the exaustive list of its protocals, components, and other network elements						
	Model IEEE 14 bus system through wrapper						
	Validate and test the system						
Observe the Bandwidth and Latency (BaL) requirements, and its analysis on few WAMS applications	Get the BaL for the designed model						
	Analysis of the model: as varying communication parameters and traffics						
	Document the project with all above scenarios and results						

Two node communication in Ns 2 (phase 1)



Basic Components in modeling communication between two nodes

Methodology (phase 2)

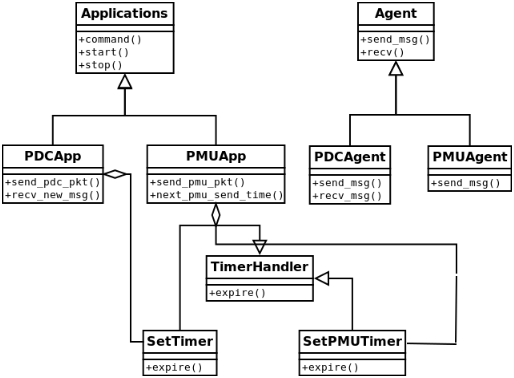


Methodology for Analysis of PMU Communication Network

Structure of configuration file

```
Distribution: name,id,parameters
Processing_delay: id,distribution_id
Traffic: traffic_id,type_of_traffic,flow_id,rate, packet size
Agent: agent_id,agent_type,traffic_id
Node: id,node_type,agent_id
Link: link_id,src_id,dst_id,bandwidth,propagation_delay,
queuing principle, queue size
```

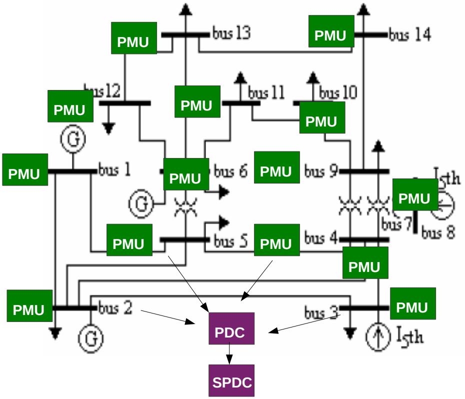
UML class diagram for Ns2 patch



NS 2 patch

- Implemented two classes, *PMUApp* and *PDCApp* that extend *Application* class of ns 2
- *PDCApp* maintains a fixed size timestamp buffer(TSB)
- The timeout and processing delay of PMU packet is modeled as a normal distribution.

Case Study- 14 bus system (phase 3)



Simulation Setup for 14 bus system

- 14 PMUs placed at each substation
- Link capacity between PMU-PDC and PDC-SPDC : 1Mb/s
- Propagation delay : 1ms
- Scenarios : link failure, node error
- Simulation duration : 10s
- Link Failure for 2 secs (6.0s to 8.0s)
- Error model : uniform distribution

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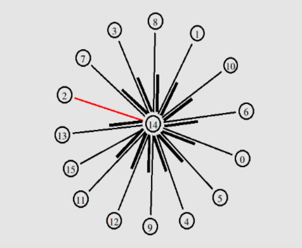
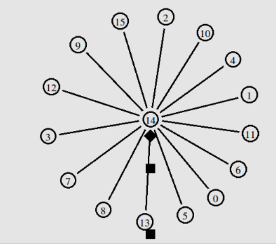




Link failure between Node 2 & Node 14

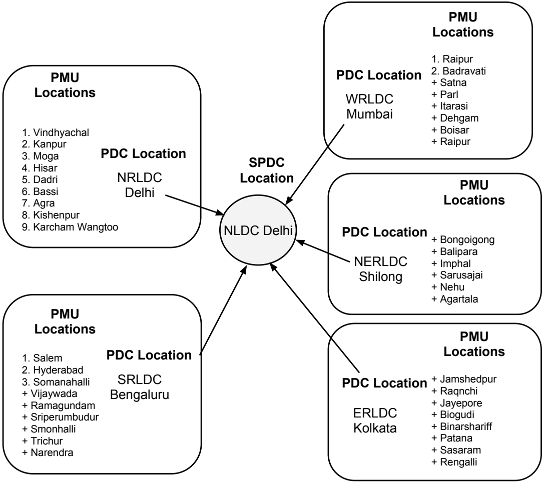
Error modeling Node 14

Results of 14 bus system simulation

$$Loss = (\frac{S_p - D_p}{S_p}) * 100$$

S_p, D_p are the packets generated at source and received at the destination respectively

Case Study- Power Grid of India (Pilot projects)



40 PMUs
5 PDCs
1 SPDC

+ Locations where PMUs are yet to be installed

Simulation Setup

- Nodes in the network : 40 PMUs, 5 PDCs and 1 SPDC
- Link bandwidth : OC-3 (155 Mb/s)
- Propagation delay : Based on geographical distances between the nodes
- Simulation duration : 10s
- Link Failure for 2 secs (6.0s to 8.0s)
- Error model : uniform distribution

Results (Indian Pilot projects)

Nodes	Average Latency (ms)	Link Failure (Loss %)	Error Model (Loss %)
pmu-pdc	4.0	2.5	0
pdc-spdc	7.2	0	12.0

Table: Network simulation results for Indian Power Grid

Conclusion

- The ns2 wrapper with ns 2 patch enables verifying the efficiency of any designed PMU communincation network without explictly coding each scenario
- Multiple designs can then be compared with each other to come up with a robust and scalable network design that meet the latency requirements of the applications

Future Work

- Study the impact of latency on the power system applications
- Verify the simulation results with realistic scenarios

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