Communication Network Analysis in Wide Area Measurement System

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Every power system application (SE, Transient Stability etc.) has its own time requirements to process and respond.
Motivation

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  - Threshold time includes end-to-end delay of communication network, power system applications processing time, decision time
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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.
Scope of this project: Analysis of end-to-end communication delay in WAMS

Communication architecture for WAMS
### Project Timeline

<table>
<thead>
<tr>
<th>Plan</th>
<th>Plan phases and implementation</th>
<th>10 days</th>
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</thead>
<tbody>
<tr>
<td>Study of NS 2 Simulator</td>
<td>Understanding architecture, components, and its existing input-output interfaces</td>
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<td></td>
<td>Creating sample models for dive more into NS 2</td>
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<td></td>
<td>Modeling of generic communication components in the NS 2</td>
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<td>Creating generalize NS 2 wrapper for WAMS</td>
<td>Design of input configuration format where WAMS communication can be modeled without interaction with simulation software</td>
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<td>Design of python scripts where it import config and exports system needed .tcl scripts</td>
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<td></td>
<td>Validation and testing of the wrapper</td>
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<tr>
<td>Model WAMS communication scenarios through developed NS 2 wrapper</td>
<td>Literature survey on WAMS communication systems and prepare the exhaustive list of its protocols, components, and other network elements</td>
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<td></td>
<td>Model IEEE 14 bus system through wrapper</td>
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<td></td>
<td>Validate and test the system</td>
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<tr>
<td>Observe the Bandwidth and Latency (Bal.) requirements, and its analysis on few WAMS applications</td>
<td>Get the Bal for the designed model</td>
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<td>Analysis of the model: as varying communication parameters and traffics</td>
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<td>Document the project with all above scenarios and results</td>
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</table>
Two node communication in Ns 2 (phase 1)

Basic Components in modeling communication between two nodes
Methodology (phase 2)

Input Configuration file → Python wrapper → Tcl script → Ns 2 simulation → Analysis

Methodology for Analysis of PMU Communication Network

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Abbrev. Title
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

Motivation
Approach
Case Studies
Conclusion
NS 2 patch

- Implemented two classes, \textit{PMUApp} and \textit{PDCApp} that extend \textit{Application} class of ns 2
- \textit{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
Link failure between Node 2 & Node 14

Error modeling Node 14
Results of 14 bus system simulation

\[ \text{Loss} = \left( \frac{S_p - D_p}{S_p} \right) \times 100 \]

\( S_p, \ D_p \) are the packets generated at source and received at the destination respectively.
Case Study- Power Grid of India (Pilot projects)

- **PMU Locations**
  - Vindhyachal
  - Kanpur
  - Moga
  - Hisar
  - Dadri
  - Bassi
  - Agra
  - Kishenpur
  - Karcham Wangtoo

- **SPDC Location**
  - NLDC Delhi

- **PDC Location**
  - NRLDC Delhi
  - WRLDC Mumbai
  - SRLDC Bengaluru
  - NERLDC Shilong
  - ERLDC Kolkata

**PMU Locations**

**PDC Locations**

**Locations**

- 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)

<table>
<thead>
<tr>
<th>Nodes</th>
<th>Average Latency (ms)</th>
<th>Link Failure (Loss %)</th>
<th>Error Model (Loss %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pmu-pdc</td>
<td>4.0</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td>pdc-spdc</td>
<td>7.2</td>
<td>0</td>
<td>12.0</td>
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</tbody>
</table>

Table: Network simulation results for Indian Power Grid
The ns2 wrapper with ns 2 patch enables verifying the efficiency of any designed PMU communication network without explicitly coding each scenario.

Multiple designs can then be compared with each other to come up with a robust and scalable network design that meets 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


