Communication Architecture for Wide-Area Control and Protection of the Smart Grid (Task 2.1)

Prashant Kansal, Yannan Wang, Pradeep Yemula, Anjan Bose

Washington State University

pkansal@wsu.edu, yannan.wang@email.wsu.edu, pyemula@eecs.wsu.edu, bose@wsu.edu

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Objective of the paper

- To present a conceptual architecture for smart grid communications
- To describe a process to simulate, design and test the adequacy of the communication systems and their impact on the wide area control systems

Need for Communications in Smart Grid

- With the proliferation of phasor measurement units, fast and accurate measurements are available
- Smart grid applications are designed to exploit these high throughout real-time measurements
- Real-time wide area control applications have strict latency requirements in the range of 100 msec to 5 sec
- A fast communication infrastructure is needed which can handle a huge amount of data

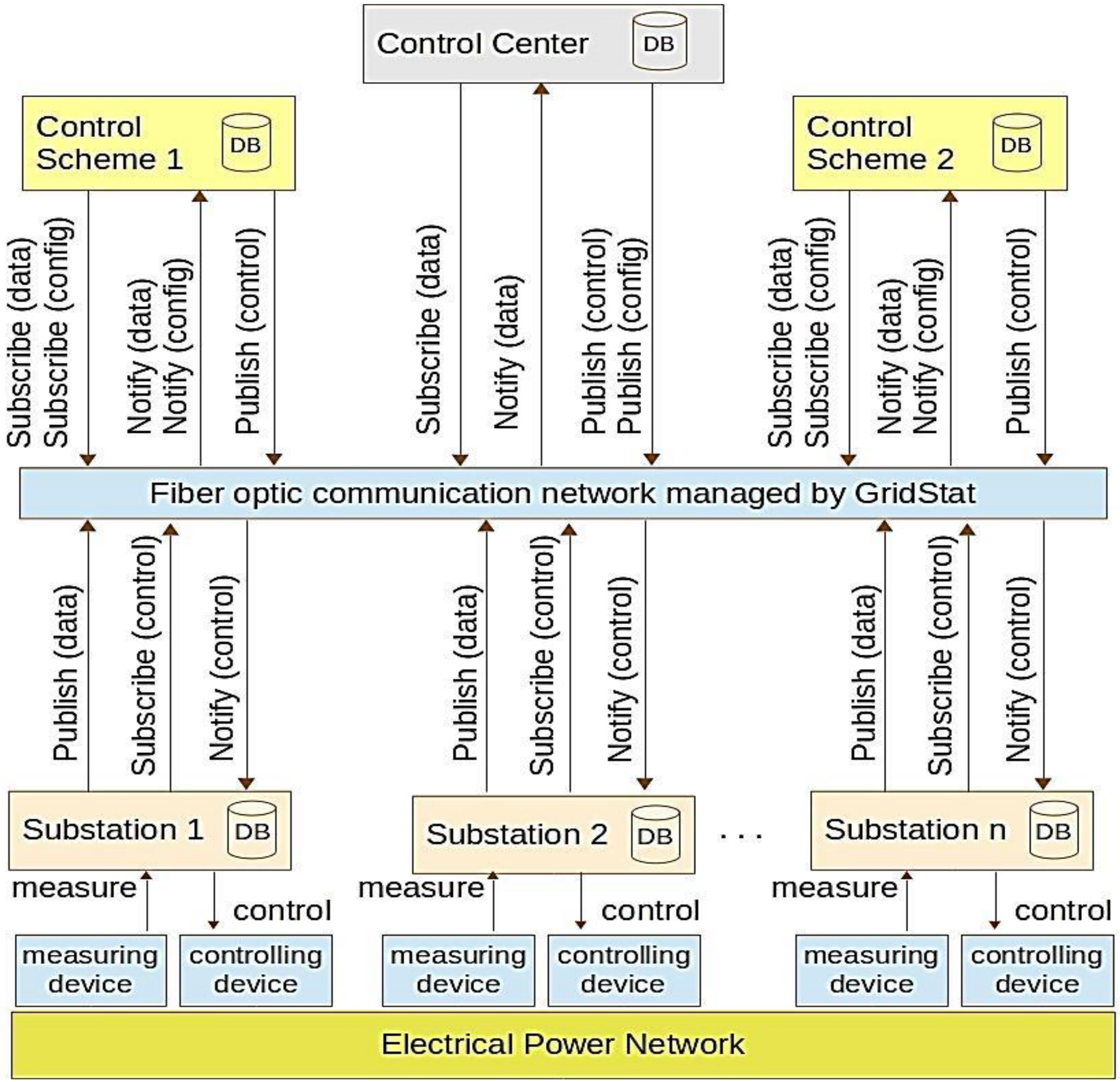
Applications classified based on latency and data requirement

Main Application	Applications based on this	Origin of Data/Place where we need the data	Data	Latency requirement	Number of PMUs we may need	Data time window
Transient Stability	Load trip, Generation trip, Islanding	Generating substations/ Application servers	Generator internal angle, df/dt, f	100 milliseconds	Number of generation buses (1/20 buses)	10-50 cycles
State Estimation	Contingency analysis, Power flow, AGC, AVC, Energy markets, Dynamic/ Voltage security assessment	All substations/ Control center	P,Q, V, theta, I	1 second	Number of buses in the system	Instant
Small Signal Stability	Modes, Modes shape, Damping, Online update of PSS, Decreasing tie-line flows	Some key locations/ Application server	V phasor	1 second	1/10 buses	Minutes
Voltage Stability	Capacitor switching, Load shedding, Islanding	Some key location/ Application server	V phasor	1-5 seconds	1/10 buses	Minutes
Postmortem analysis	Model validation, Engineering settings for future	All PMU and DFR data/ Historian. This data base can be distributed to avoid network congestion	All measurements	NA	Number of buses in the system	Instant and Event files from DFRs

Architectural Considerations

Location of Data	• *closer to the source of data* • *databases distributed at substations*
Location of Applications	• *bring applications to data instead of data to the applications*
Movement of Data	• *a communication middleware moves the data using publish subscribe architecture*
Format for Data and Control	• *Frames defined under the C37.118 standard*

Communication Architecture for Smart Grid



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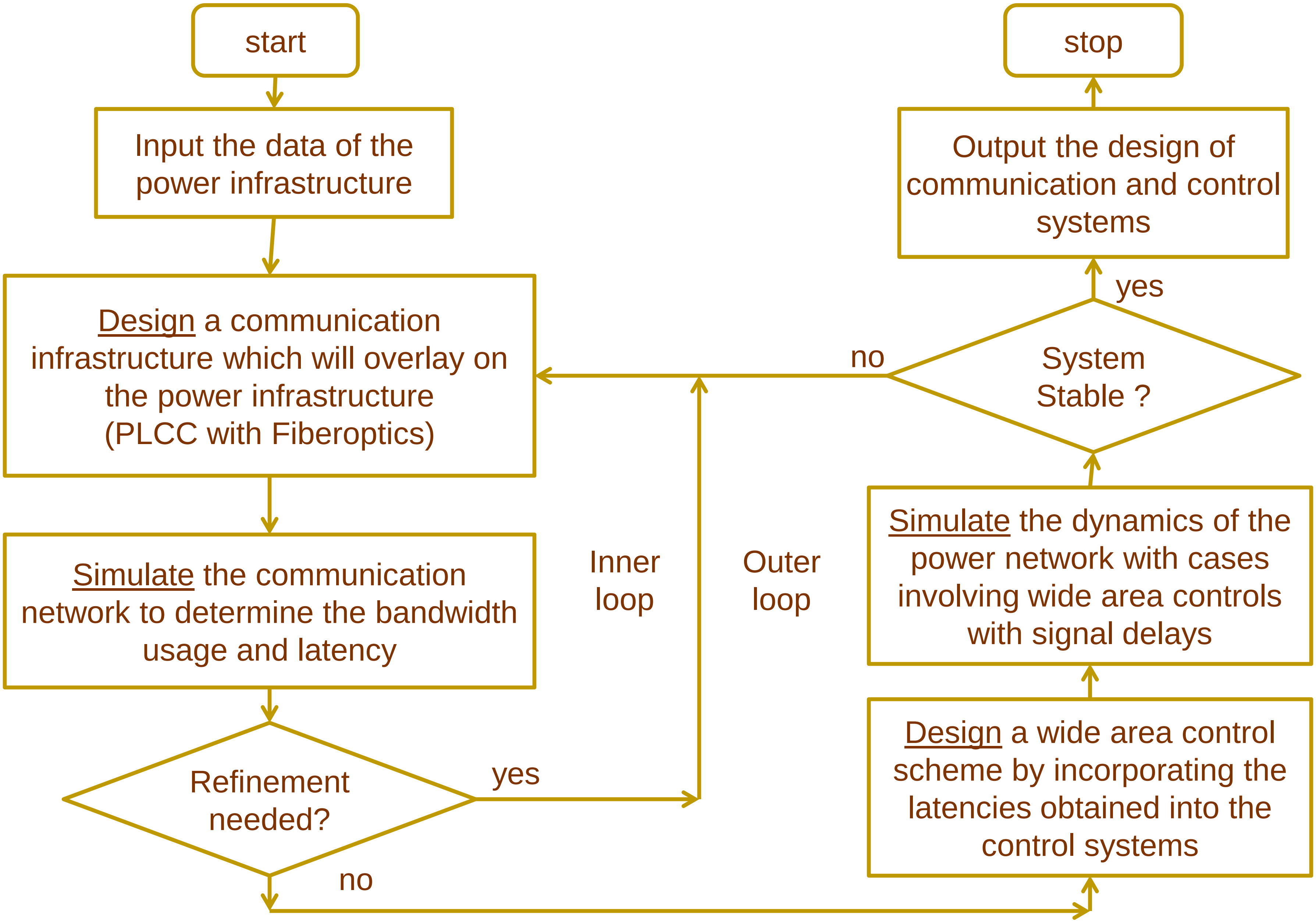
Process for design of communication system



Analysis on WECC 225 Bus System

WECC Statistics after Node Reduction

S.No.	Parameter	Value
1	Buses	225
2	Substations (S/S)	161
3	Control Center (CC)	1
4	Control Scheme (CS)	16
5	Generating S/S	31
6	Control S/S	58
7	CS S/S	160

Different Traffic Types

S.No.	Traffic Type
1	S/S to CC
2	CC to S/S
3	CS substation to CS
4	CS to CS substation
5	S/S to S/S
6	CS to CC

Bandwidth and Latency for WECC

Link Bandwidth Usage for WECC system

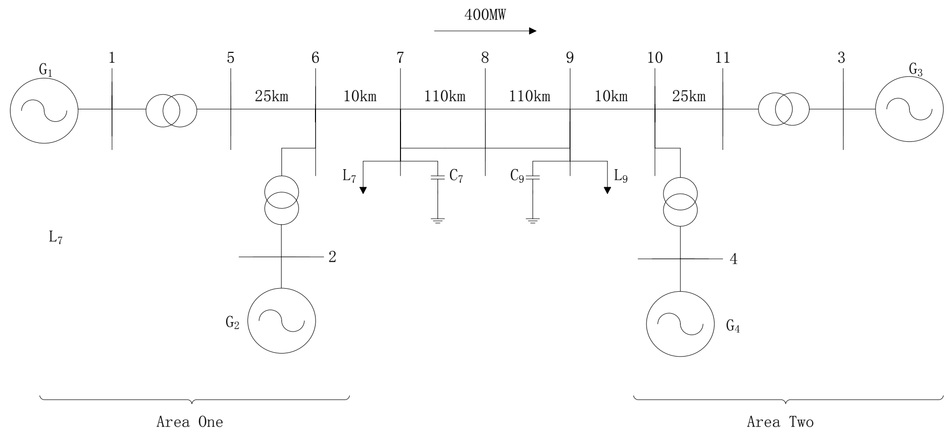
Network Topology	Max. of used links (Mbps)	Min. of used links (Mbps)	Average of used links (Mbps)	Median of used links (Mbps)	% of unused Gw2Gw links
Min S.T.	58.75	0.10	5.46	0.39	28.6%
1CC links	45.60	0.08	3.34	0.62	11.4%
3CC links	46.80	0.10	2.97	0.51	11.7%
5CC links	44.09	0.08	2.03	0.38	10.8%

Maximum delays for different traffic types WECC system

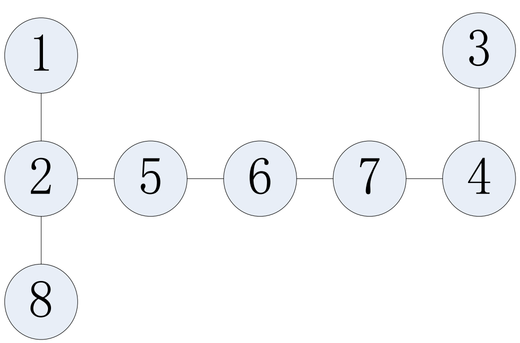
Network Topology	Type1 (ms)	Type2 (ms)	Type3 (ms)	Type4 (ms)	Type5 (ms)	Type6 (ms)
Min S.T.	49.9	40.3	45.1	46.3	44.0	40.3
1CC links	26.2	27.6	26.6	27.1	29.4	23.9
3CC links	19.2	19.1	25.2	25.5	29.3	16.4
5CC links	11.7	5.2	13.8	12.9	15.6	4.5

Effect of Communication Latency

Two Area – 4 machine system



Communication Network for the system

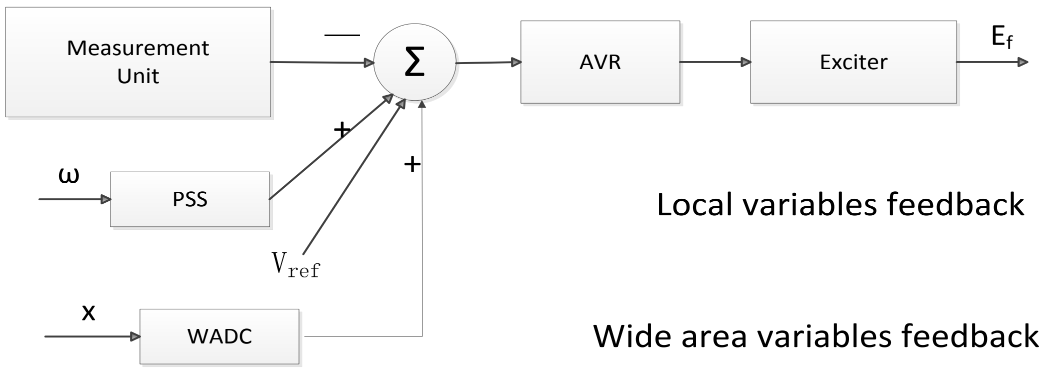


1-7: Substation
8: C/C
-:communication links between substations

NS-3 simulation results

Bandwidth (Mbps)	Average Time Delay (ms)	Delay between nodes 3- 8 (ms)
10	39	79
3	132	210

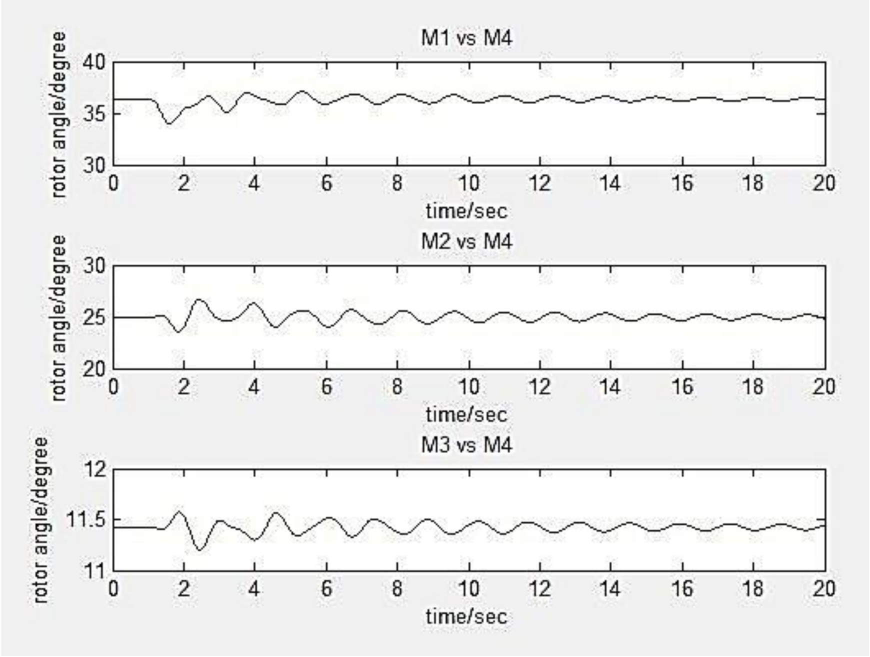
Wide area damping controller with latency



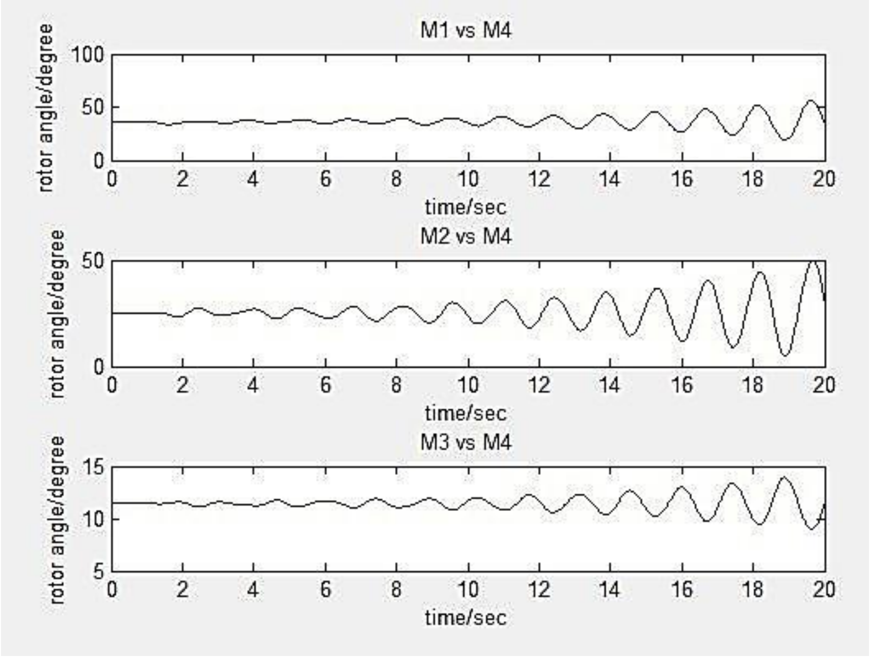
Local variables feedback

Wide area variables feedback

Controller with 10 Mbps link (79 ms delay)



Controller with 3 Mbps link (210 ms delay)



Conclusions

- as PMU data volumes and data rates increase, centralized control may no longer be scalable
- wide area power system control evolving towards distributed applications and databases
- new decentralized architectures needed
- bandwidth and latency considerations critical in design of communication infrastructures
- latency has impact on the performance of wide area controllers

Conclusions - 2

- The architecture and the process described in this work aim towards development of a holistic approach for design of new decentralized and scalable architectures using distributed applications and distributed databases for wide area control of future smart grids.