Modeling of interdependencies in Smart Grid Monitoring

Michele Garau

Department of Information Security and Communication Technology - NTNU, Norway

Challenge and objectives

The strong interdependence between power system and ICT systems in Smart Grids requires new methodologies for modeling the power system as a Cyber Physical System (CPS), and finally analyzing the impact of ICT failures on the power grid operation

Research tasks

- Detect and model internal and external vulnerabilities
- Detect and model interdependencies between the subsystems that interact in the CPS
- Identify Metrics for dependability assessment

Approach

A novel methodological approach is implemented, that combines Stochastic Activity Networks (SAN) modeling and numerical analysis. The method is applied for a dependability and performance analysis of a 5G based monitoring system for state estimation in an IEEE standard distribution network.

Different sources of ICT failures and vulnerabilities are analyzed, as well as different state estimation approaches, and the impact of these failures are assessed over the WAMS capability to provide the correct data for calculating the state of the power network.

Significant results

The results reveal that the 5G based WAMS with traditional measurement devices present a mean estimation error along the grid buses close to the ideal case. Moreover, the adoption of PMU measurement in distribution networks shows a significant improvement in the accuracy of the voltage estimation.

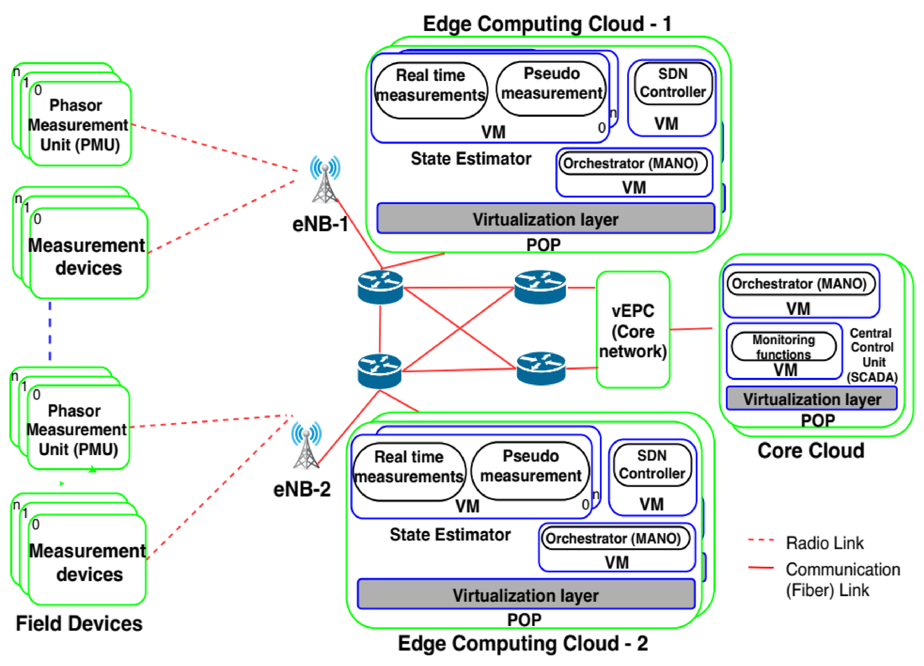
The results indicated the radio channel as the major cause of estimation error, which is considerably affected by external factors such as fading and rain conditions, that affect both state estimation mean estimation error and safety.

The close-to-ideal behavior of 5G-URLLC observed in the analysis enforces the prospect of a future adoption for smart grid monitoring application, both for traditional SCADA and PMU-based monitoring systems

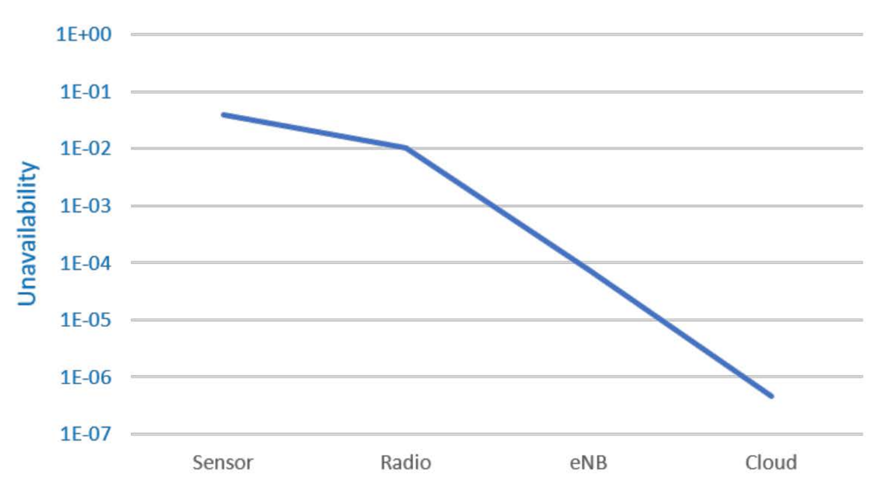
Figures

Failure rates and recovery times of the system components

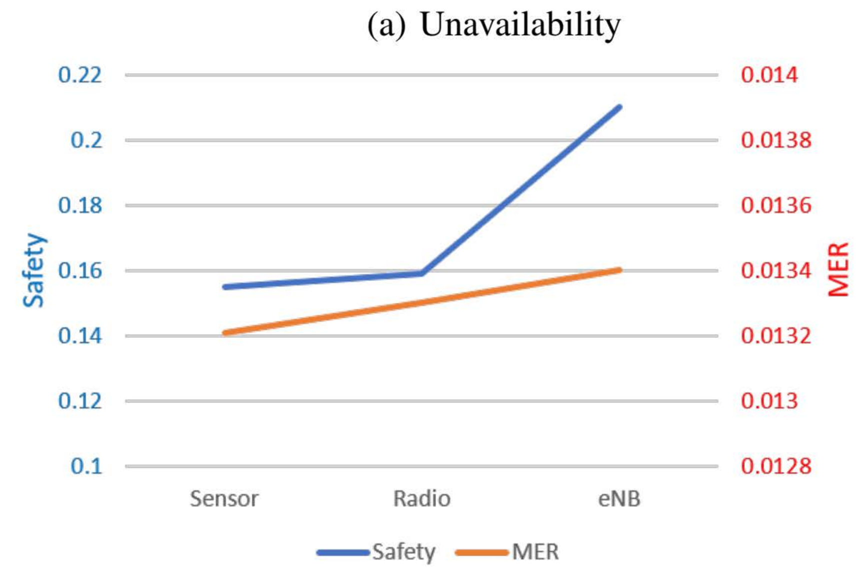
Component type	Failure rate $[days^{-1}]$	Mean recovery time [hr]
RTU / PMU	$2.6 \cdot 10^{-3}$	2
Fiber Line	$6 \cdot 10^{-6}$	6
Router/Switches	$5 \cdot 10^{-3}$	3
Host server (permanent failures)	$4.9 \cdot 10^{-3}$	2
Host OS (Software failures)	$1.667 \cdot 10^{-2}$	1 (repair) $1.667 \cdot 10^{-1}$ (reboot)
Virtual Machine Monitor	$8.3 \cdot 10^{-3}$	1 (repair) $1.667 \cdot 10^{-1}$ (reboot)
Virtual machines	$1.1 \cdot 10^{-2}$	1
eNB	$2 \cdot 10^{-4}$	10
Power supply failure	$1.9 \cdot 10^{-3}$	3
Radio Link	$8.64 \cdot (10^{0}–10^{1})$	$2.77 \cdot 10^{-4}$ (=100ms)



5G based Architecture for WAMS



(a) Unavailability



(b) Safety and mean estimation error

Comparison of different subsystems in 5G architecture

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