# TCIPG

# Trustworthy Time Synchronous Measurement Systems

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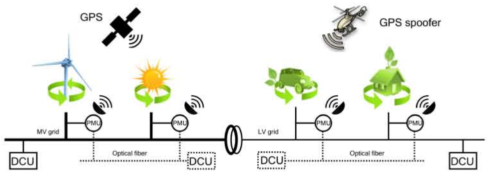
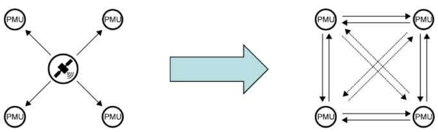
## Goals

Power state estimation relies on global clock time references, like the GPS, to synchronize dislocated Phase Measurement Units (PMU)



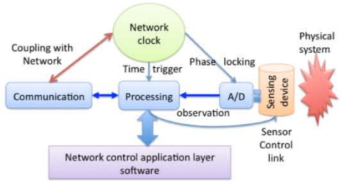

- Remove the dependency between the PMU's and the global time reference with a decentralized synchronization strategy inspired by the synchronous dynamics of the clock oscillator models




- Design synchronization signals resilient to jamming and with a low probability of detection/interception to secure the network synchronization → exploit spread-spectrum technologies
- Reduce the operating costs of the PMUs by integrating the synchronization signals and the transmission of PMU sensor data within the power-line channel (PLC) and still guarantee reliability, security, and scalability
- Develop of a single system-on-chip for communication and sensing

## Fundamental Questions/Challenges

- Convergence of the PCO synchronization with PLC frame exchanges. How will it impact the PMU measurements and the state estimation?
- Inter-cluster and intra-cluster interference. How robust is the synchronization in the presence of a jammer?
- Real-time constraints and error rate performance of an outdoor PLC. How do we design the communication protocol, its MAC/PHY layer and how do we select the channel model?

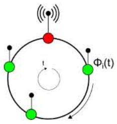



- The design of a cross-layer integrated architecture that is scalable → complexity, computations and memory requirements are not a function of the number of sensors deployed

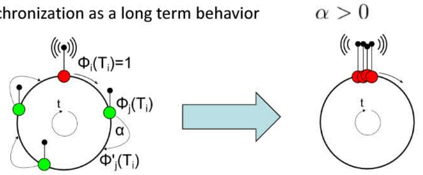
## Research Plan

- Exploit our research efforts and results on Pulse Coupled Oscillators (PCO) to synchronize the network and the PMU measurements
  - Periodical state evolution and coupling with linear updates

$$\Phi_i(t) = \left(\frac{t}{T_{\text{PCO}}} + \phi_i\right) \bmod 1 \qquad \Phi_i'(T_j) = (1+\alpha)\,\Phi_i(T_j)$$

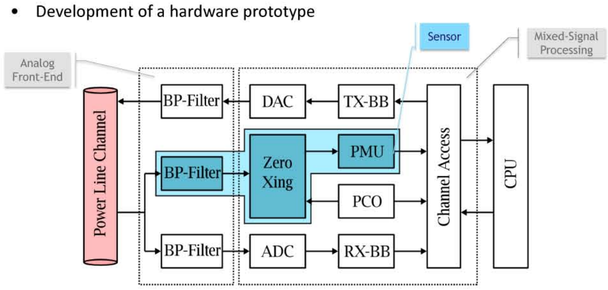



  - Synchronization as a long term behavior $\alpha > 0$




- Modify the synchronization signaling to achieve a low probability of interception/detection

- Determine a protocol for transmitting phasor data reliably and securely and integrate it with decentralized state and frequency estimation
- Phasor measurement → couple level crossing events of the electrical AC signal with PCO clock events (network clock)
- Development of a hardware prototype



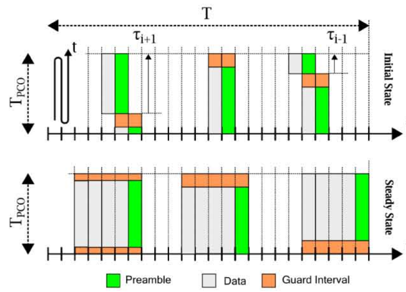

## Research Results

In an initial research effort, we proposed a Coupled Oscillator Time Division Multiplexing (COTDM) protocol that achieves:

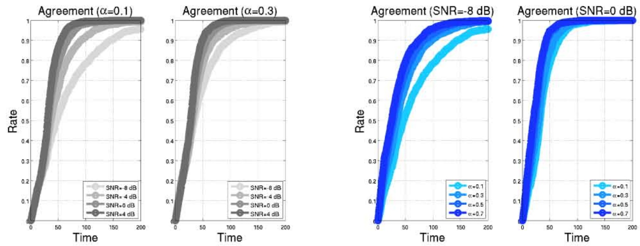
- PCO synchronization through a carrier sensing (CS) algorithm at the PHY layer that measures the time of arrival of every sensed preamble

$$\Phi_i'(T_j) = \min\left(\Phi_i(T_j) + \alpha\,(1 - \hat{\tau}_j), 1\right)$$

- TDM slotted transmissions following the initial synchronization phase




- PCO Agreement Rate




## Broader Impact

- Smart Grid applications like electrical metering
- Co-existence with proposed standards like G.hnem or G3-PLC
- A single device synchronously capturing data over wide areas has a broad application in the sensing of physical phenomena

## Future Efforts

- Bottom-up protocol definition and channel modeling
- Complete the research on accuracy of phasor reconstruction
- Raise funding for Nemo, Inc.