CNS-1239423: CPS: Synergy: Self-Sustainable Data-Driven Systems In the Field

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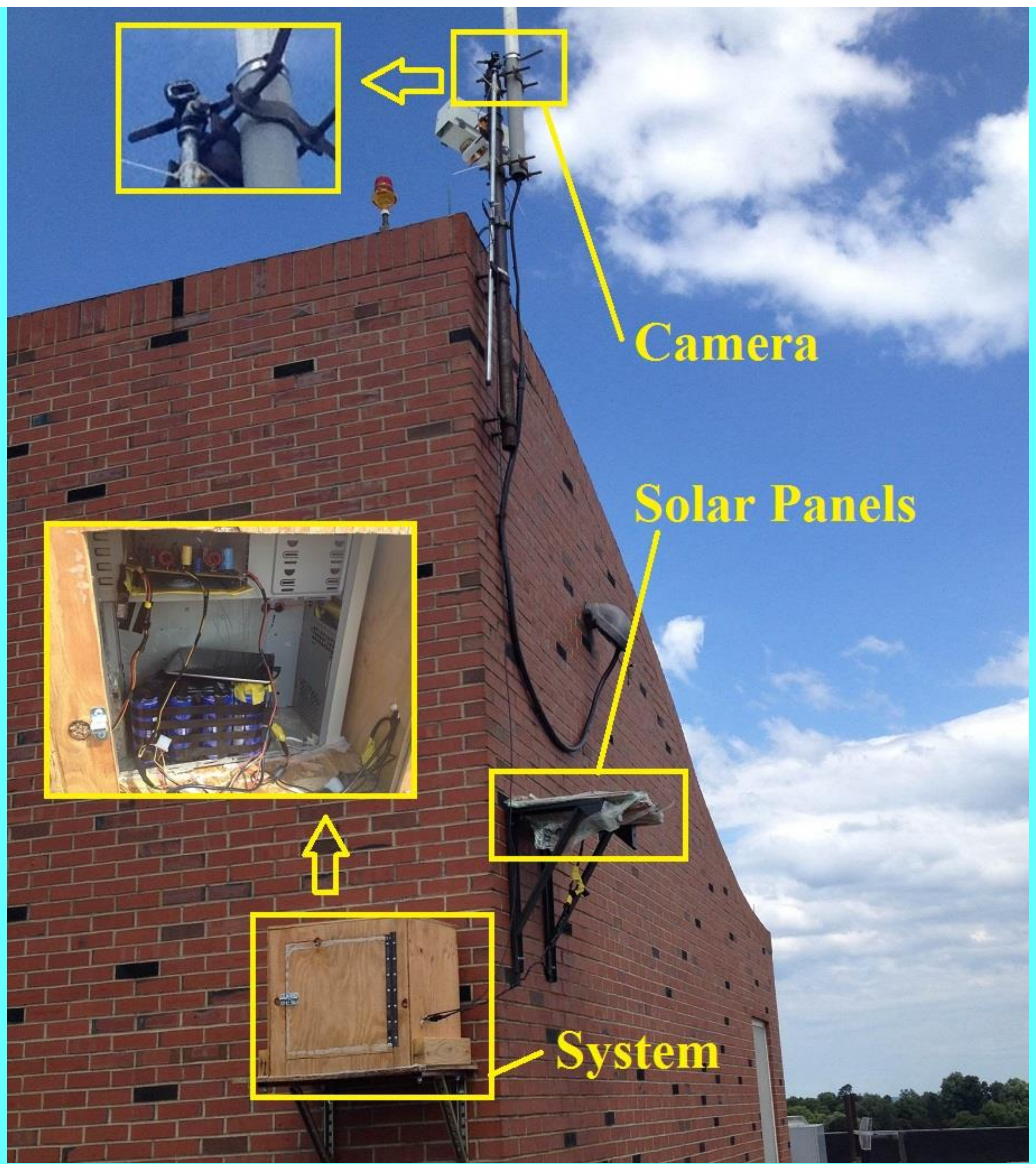
Background and Overview

- Continuous, high-speed data processing in the field is important for applications such as road safety and environmental monitoring.
- Current self-sustainable systems rely on rechargeable batteries that suffer from adverse environmental impact and limited lifetime.
- We demonstrate the feasibility of using the supercapacitors as the energy buffering mechanism for continuous field operations.
- We investigate and optimize field wireless communication mechanism, particularly on using multiple transmission/receive antennas.
- We utilize synergistic hardware/software techniques, including system-level energy modeling and control.

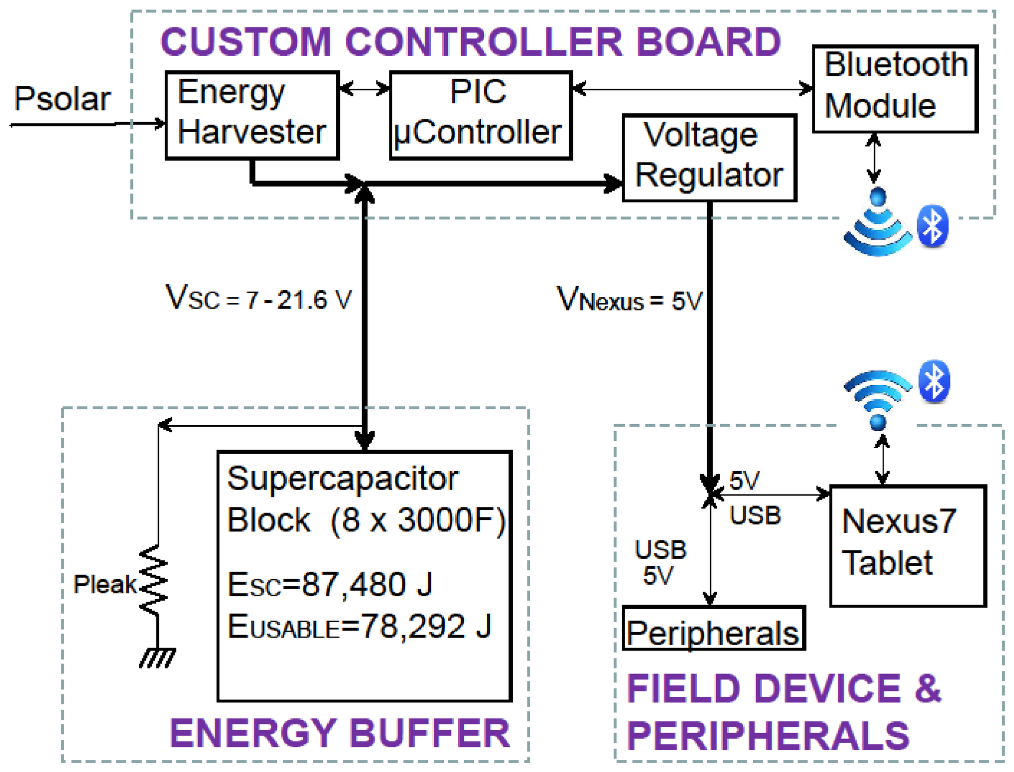


Summary of Results

- Simple voltage-to-energy relationship $E=C \cdot V^2/2$ in supercapacitors enables precise energy buffer modeling and time-to-depletion prediction.
- Supercapacitor self-discharge (or leakage) is a minor issue in practice; voltage-dependent capacitance variation is a critical problem.
- We propose energy/QoS optimization through periodic low-power data capture and bursts of data processing at a higher CPU configuration.
- Our working prototype has been deployed at a campus building rooftop (center picture) where it analyzes nearby road / parking lot traffic patterns.
- We find that optimized antenna configuration produces high energy benefits.
- Our energy harvesting models have been incorporated into the latest release of the ns-3 network simulation code.

Prototype System Construction

- System includes the supercapacitor energy buffering, Nexus 7 tablet, and custom controller.



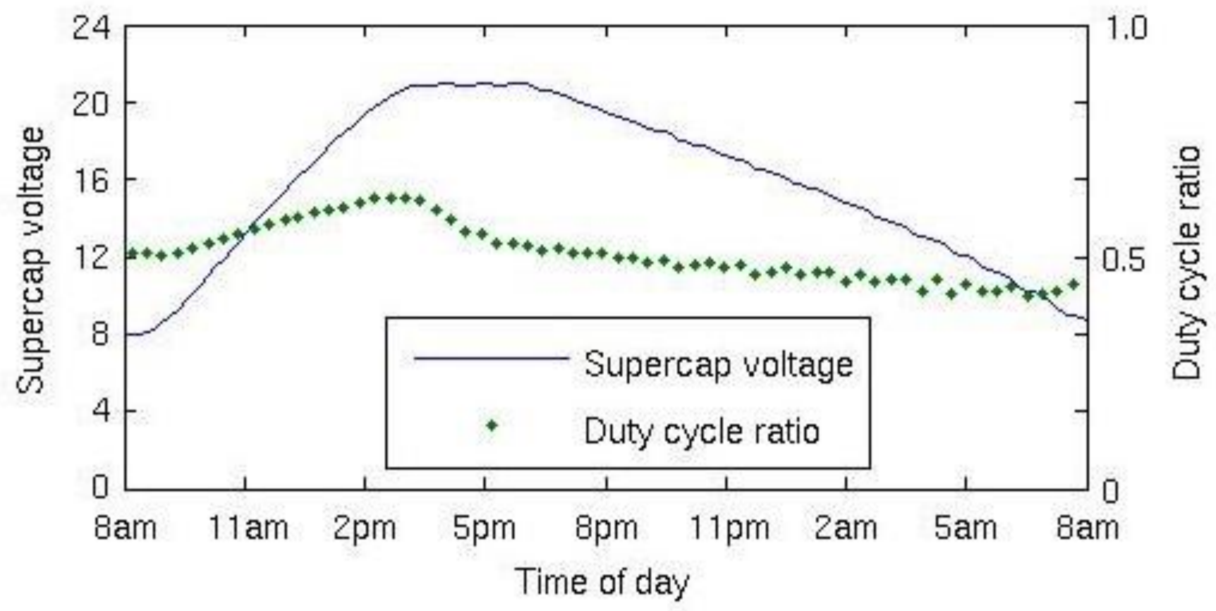
- Application areas include traffic analysis and motion detection through camera traps.

Energy Modeling and Control

- Supercapacitor self-discharges (or leaks).
- Results: small effect on modeling accuracy when leakage is far smaller than power load.

- Effective supercapacitor capacitance depends on the terminal voltage (less capacitance at lower voltage level).
- Results: proper modeling reduces the error from 7-9% to 2-3%.

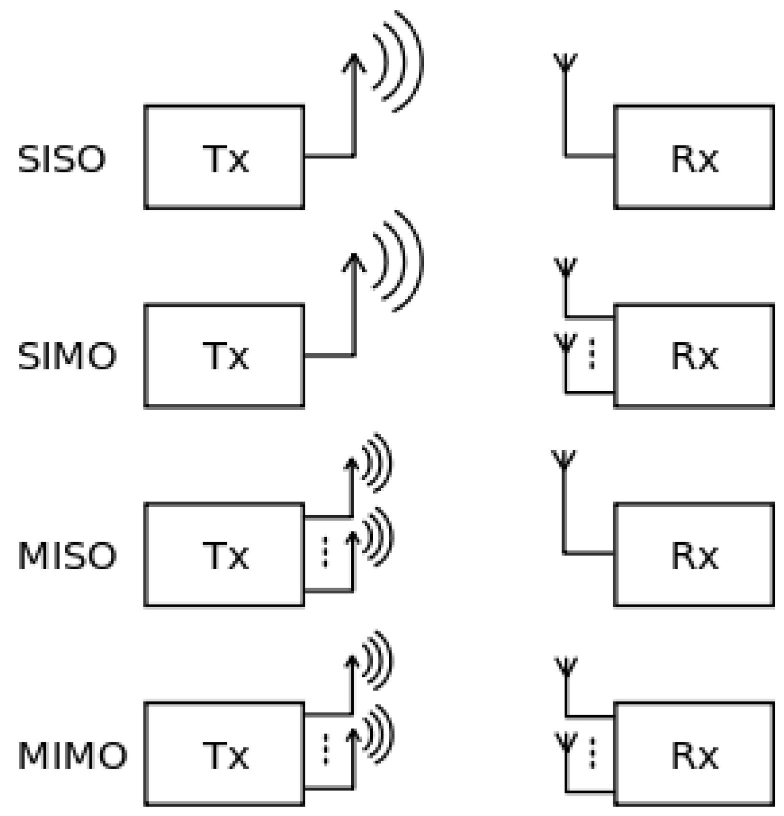
- System duty-cycle ratio and supercapacitor voltage change in a typical 24-hour duration. The solar supply lasts from 8AM to 6PM



- Stable quality-of-service despite the variation of available energy.

Optimized Antenna Configuration

- Consider using multiple antennas at the transmitter and receiver.
- Spread transmission power among different antennas to increase performance.
- Less transmission energy but higher circuit energy than single transmitter/receiver antenna.



- Dynamic antenna selection – choosing appropriate configuration adaptively – leads to substantial energy efficiency improvement .