Software Engineering Challenges in the Smart Grid

3rd International Workshop on Software Engineering Challenges for the Smart Grid

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Overview

- Challenge Overview
  - Security
  - Simulation
  - Devices
  - Testing
  - Human Factors
- Solution
- VOLTTRON Example
- Conclusion

Challenges

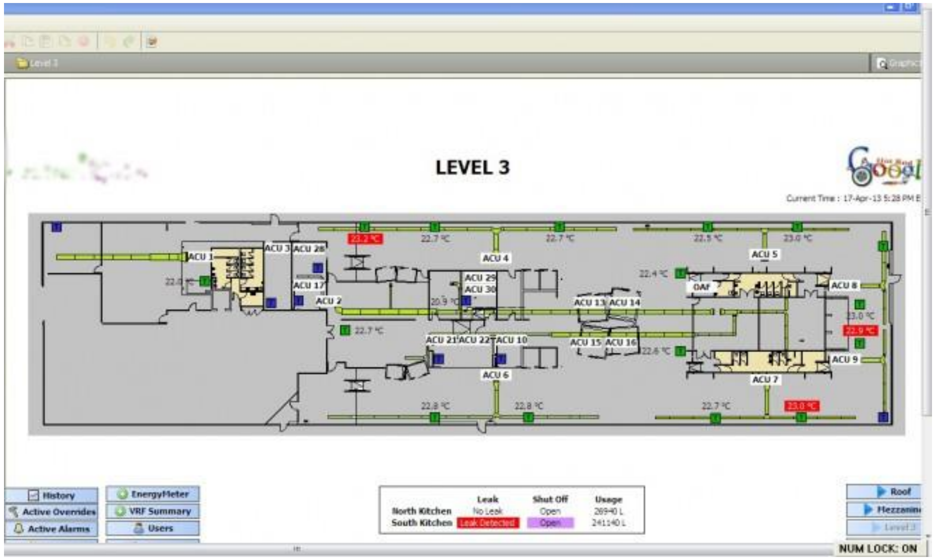
- Application Challenges
  - Integrating Variable Distributed Generation
    - Wind
    - Solar
  - Integrating Storage at multiple layers
  - Integrating Electric Vehicles
  - Managing End-Use Loads
    - Residential
    - Commercial
    - Industrial
  - Enabling energy coordination and trading between buildings
- Technology Challenges
  - Rapid Deployment Of Networked (Grid, Buildings, …) Sensors And Controllers
  - Scalable control and diagnostics
  - Security

Challenges

- Large amount of data generated by sensors goes unutilized due to high volume. Off-line analysis helps but is insufficient.
- Appliances/devices unable to coordinate energy usage due to proprietary solutions and lack of underlying distributed control algorithms and platforms.
- Growing ownership of Electric Vehicles will increase effect of load peaks
  - Increase in energy market purchases
  - Increase in maintenance due to equipment stress (e.g. transformers)
- Require techniques to better integrate renewables at all scales: Rooftop PV to Wind Farms, to Energy Storage
- Agent Based approach is a natural fit for this area, but
  - Agent based energy efficiency solutions often do not progress beyond simulation

Security Failure

- Researchers hacked Google building in Australia
- Control systems accessible over internet
  - Unpatched
  - Hardcoded passwords
- Target data breach caused by stolen credentials from third party controls vendor



Simulation vs. Reality

- VOLTTRON hardware demo
  - Algorithm worked perfectly in simulation
  - Initially failed when applied to real systems
- Potential stumbling blocks
  - Perfect knowledge
  - Time steps
  - Lack of diversity
  - Hidden factors

Interacting with Devices

- Proprietary Protocols
  - Vendors don’t necessarily have incentive to be open
- Lack of standards or too many standards
  - Communicating with multiple devices could require speaking multiple protocols
- Device-specific characteristics
  - Time-scale
  - Responsiveness
  - Available information
  - Critical priority

Testing and Verification

- Back to simulation vs. reality problem
  - Testing applications without access to appliances
  - Testing at scale
  - Test coverage, edge cases
- Who watches the watcher
  - Software and hardware responsibilities for safe operation

Human Factor

- Utility Operators
  - Conservative
  - Risk Averse (for good reason)
- Vendors
  - Does it help them sell appliances?
- Consumers
  - Lower bill
  - No decrease in quality of service
- Other developers
  - Ease of use
  - Power

Technology Solution Attributes

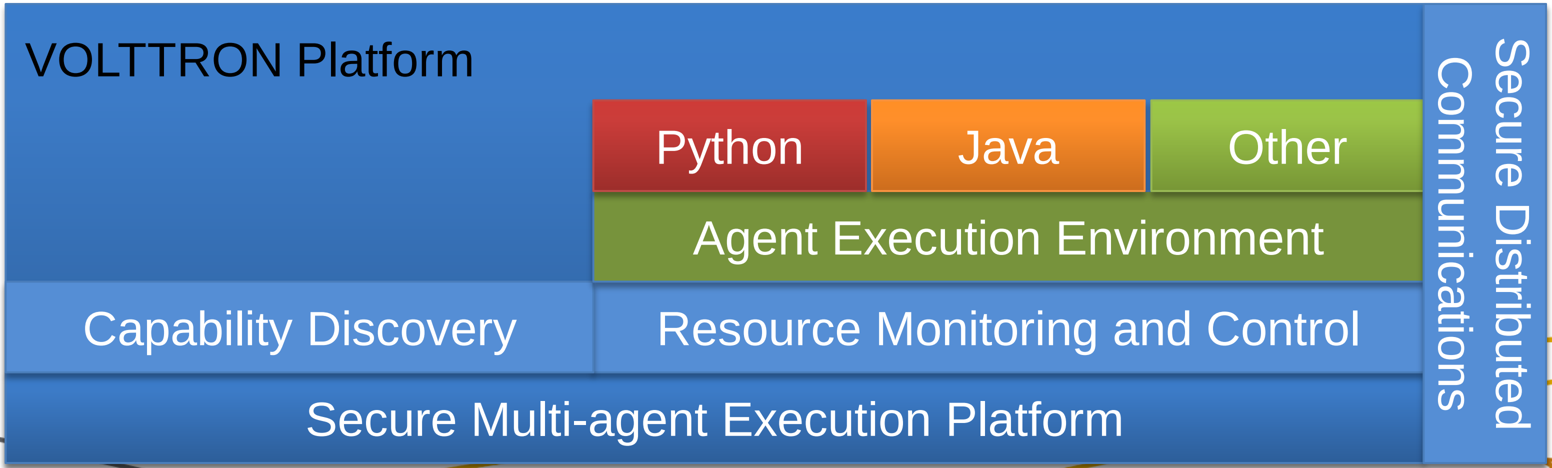
- Open, flexible and modular software platform
  - Ease of application development
  - Interoperable across vendors and applications
  - Hides power and control system complexities from developers
  - Object oriented, modern software development environment
  - Language agnostic. Does not tie the applications to a specific language such as Java
- Broad device and control systems protocols support built-in
  - ModBUS, BACNet, and others
  - Multiple types of controllers and sensors
  - Low CPU, memory and storage footprint requirements
  - Supports non-Intel CPUs
- Secure
  - Security libraries and cryptography built-in
  - Manage applications to prevent resource exhaustion (CPU, memory, storage)
  - Robust against denial-of-service (e.g. does not crash when scanned via NMAP)
  - Supports modern application development environments

Managing Load on Distribution Transformer

- One distribution transformer serving residential neighborhood
- Multiple electric vehicles per household
- 107 degree day
- Goal: Keep the transformer temperatures below a desired threshold to extend lifetime and reduce risk of fault
- Use VOLTTRON to coordinate EV charging and other load behavior across residences to:
  - Keep aggregate power used by multiple residences below a limit related to transformer temperatures
  - Give priority to vehicles that need to leave soon (e.g. pick up kids from soccer)
  - Temporarily absorb start-up demand from A/C compressors and motors.

Approach: VOLTTRON™ Platform

- VOLTTRON is a software platform for next generation distributed control applications for integrating buildings and power grid
  - Proven through simulation, prototypes and field deployments
  - Flexible, Modular and Language-agnostic
  - Open-source, easy to extend, already being used by external collaborators
  - Maintain security and manage platform resources
  - Services for applications to find each other



VOLTTRON Success Stories

- Ideal platform for Department of Energy to use for transactive energy research and demonstrations
- Enables decentralized, distributed or hierarchical control applications with fast, and easy code development
- Demonstrated with real hardware
  - Hardware testbed
  - EV Charging coordination at PNNL SmartHomes
  - Transactional Network Program
- Downloaded and used by:
  - Virginia Tech
  - LBNL
  - ORNL
- Funded by PNNL's Future Power Grid Initiative

Conclusion

- Business as usual is not an option
- We have solutions, but they must transition to real world applications
- Great opportunities but great challenges and responsibility

VOLTTRON Info

- Open Source
- Active development
- https://github.com/VOLTTRON/volttron/wiki
- volttron@pnnl.gov