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DOE/BTO Summary Wrap-Up

Meeting on the Software Framework for Transactive Energy

Conducted by PNNL for BTO, and Hosted by Case Western Reserve University

Cleveland, OH

July 23-24, 2014

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Meeting Objectives/Background

On behalf of DOE/BTO, PNNL held the meetings to:

- Increase awareness of VOLTTRON and the Transactional Network concept by convening stakeholders - including industry members, researchers, software developers and practitioners - to build a community of early adopters.

- Present overview and current/future applications of VOLTTRON, outline use cases, and showcase its potential to address several optimizations, such as buildings' energy efficiency, EV charging, and renewables integration.

- Get frank feedback from VOLTTRON users on strengths and weakness of the platform.

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Meeting Agenda – July 23

- DOE/BTO Purpose and Context
- Motivation for Transaction-Based Reference Platform
- VOLTTRON Introduction /History
- VOLTTRON Technical Overview/Features

Developing Applications of VOLTTRON: Experience and Lessons Learned

- ORNL - Use of VOLTTRON Platform for Advanced Control of Building Equipment
- LBNL - Using VOLTTRON Platform for Measuring Savings/Fault Detection in Lighting Systems
- PNNL - Experience in Developing Apps/Agents for VOLTTRON Platform
- VA Tech - VOLTTRON as Platform for Building Energy Management Open Source (BEMOSS) App

Meeting Agenda – July 24

- VOLTTRON Development Primer: How to create an application, how to use services
- Demonstration: Virginia Tech Operating System (OS) built on VOLTTRON for Energy Management in Buildings
- A Community of VOLTTRON Users: An Introduction
- A Community of VOLTTRON Users: Suggestions for Development
- The Case Western Reserve University Campus Grid
- Suggestions for DOE/BTO Proposed Future Development and Commercialization of VOLTTRON Platform

Industry and Academic Participants

Key Meeting Takeaways - *Programmatic*

1. Need to **increase VOLTTRON outreach efforts**
    a. IEEE and ACM (Virginia Tech Professor S. Rahman offered to host Volttron session at Feb IEEE meeting in DC if desired by DOE)
    b. Sponsor Annual User Development meeting piggybacking on existing meetings/conferences
2. Need **detailed roadmap for VOLTTRON development**, with public input
3. Need to present a **straw man for VOLTTRON community structure**, and then get public input on it.
4. Need to **define scope of VOLTTRON Nation**. Is it very broad (Transactive Energy), narrower (Buildings to Grid) or narrower still (Building Controls).
5. Need to **quantify the potential economic value** (business case) of services VOLTTRON would create
6. **DOE** should always **support foundational development** but **industry will drive** future **enhancements** and specialized/proprietary agents
7. **Clarify VOLTTRON licensing models. DOE intent is open source.**
8. Need **VOLTTRON security enhancement plan (**Agent-to-agent security as they are added; Consider how/where implemented)

Key Meeting Takeaways – *Technical (1 of 2)*

1. VOLTTRON has been developed to be very general-purpose, but **standards would help application developers**. Some of these standards may fall out of other ongoing research. Including apps to platform services, app to app, and common data/representation models.
2. Set of **simple, clear, specific agents** (including a non-Python agent) **which demonstrate how to work with platform services**. These agents could also serve as templates for building more complex agents.
3. The **contributed applications need more documentation** to understand what they are doing. These complex applications provide more realistic examples of operation than the simple example agents.
4. **Re-examination of publish/subscribe with a scalable methodology**. As part of this, seek comments and peer review and test alternative methods.
5. **Allow agents to communicate peer-to-peer** in cases where data (especially large amounts) does not need to be shared with other agents on the message bus.
6. **Implement a Directory Service for capability discovery** so that it is easier for apps to discover devices, services, and other apps.

Key Meeting Takeaways – *Technical (2 of 2)*

7. **Robust developer tool suite needed**
    7. Unit Tests
    8. Ability to easily debug agent communication
    9. Library of simulated devices to facilitate running apps w/o access to real devices
    10. Algorithm Toolbox for common algorithms benefitting multiple apps
8. Provide a **clear distinction between capabilities of the base platform and applications which are built on top** of it, e.g. Virginia Tech's system.
9. There is **market interest in embedding VOLTTRON in consumer products** and routers. Investigate how this might be done.
10. **Determine how to distribute products built on VOLTTRON** (Appstore concept). First instance would be VA Tech OS
11. **Build an automated configuration capability** to enable:
    7. Plug and Play
    8. Auto discovery and configuration
    9. Auto mapping of device points to a common data format

Presentations at the Meeting

DOE/BTO Purpose and Context (Hernandez, PNNL)

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, DNP3, 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 network mapper)
- Supports modern application development environments

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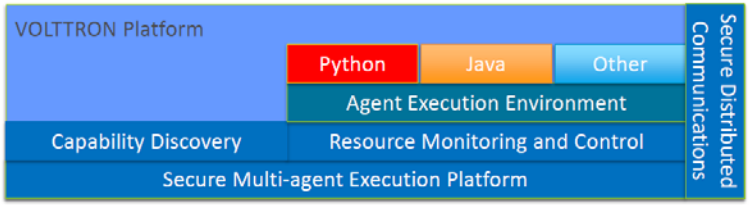
VOLTTRON™ Platform

- 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



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- The group recognized challenges associated with integrating variable renewable generation with existing control solutions
- Group acknowledged VOLTTRON solution attributes were correct if truly open-source/agent-based
- A financial settlement capability is an additional necessary component
- An appropriate long term management plan for software platform is critical for market adoption

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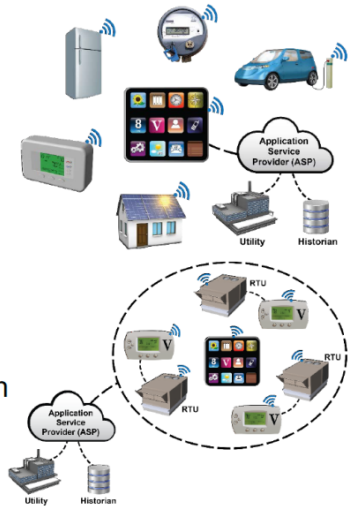
VOLTTRON Introduction & History (Haack, PNNL)

What is VOLTTRON?

- VOLTTRON is an application platform (e.g. Android, iOS) for distributed sensing and control applications
- VOLTTRON is not a protocol
  - A protocol, such as SEP2.0. or OpenADR, are implemented as applications
- VOLTTRON is not an application such as demand response
  - Demand response can be implemented as an application on top of VOLTTRON
- VOLTTRON is open, flexible and already benefits from community support and development



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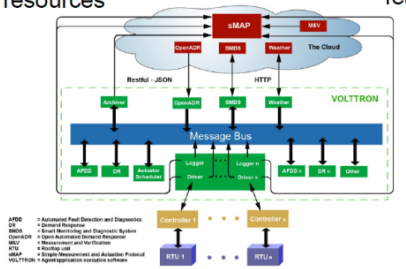
Transactional Network

- Integrating platform for DOE funded demonstration
  - Coordinate behavior of rooftop HVAC units
  - Deploy researcher control algorithms
  - Provide single point of contact for
    - Appliances
    - Data historian
    - External resources
- Components
  - Researcher control algorithms
  - Cloud applications and resources
  - HVAC and other appliances
- Open Source Requirement
  - Re-implementation of platform omitting patented features



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- Project History
  - Started as internal PNNL R&D aimed at enabling distributed sensing and control
  - Demonstrated in simulation, hardware testbed, and deployment at instrumented home
  - Re-implemented and released open source for Transactional Network project
  - Integrating platform for applications, devices, and remote resources
- Project Future
  - Integrate PNNL IP features into current version of software
  - Enhance capability of software

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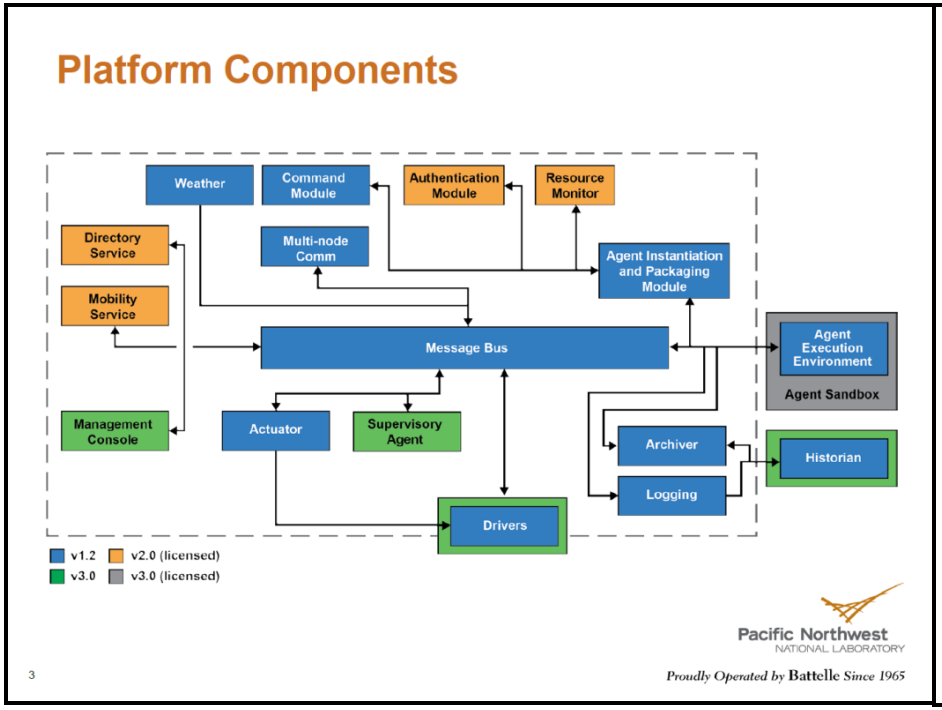
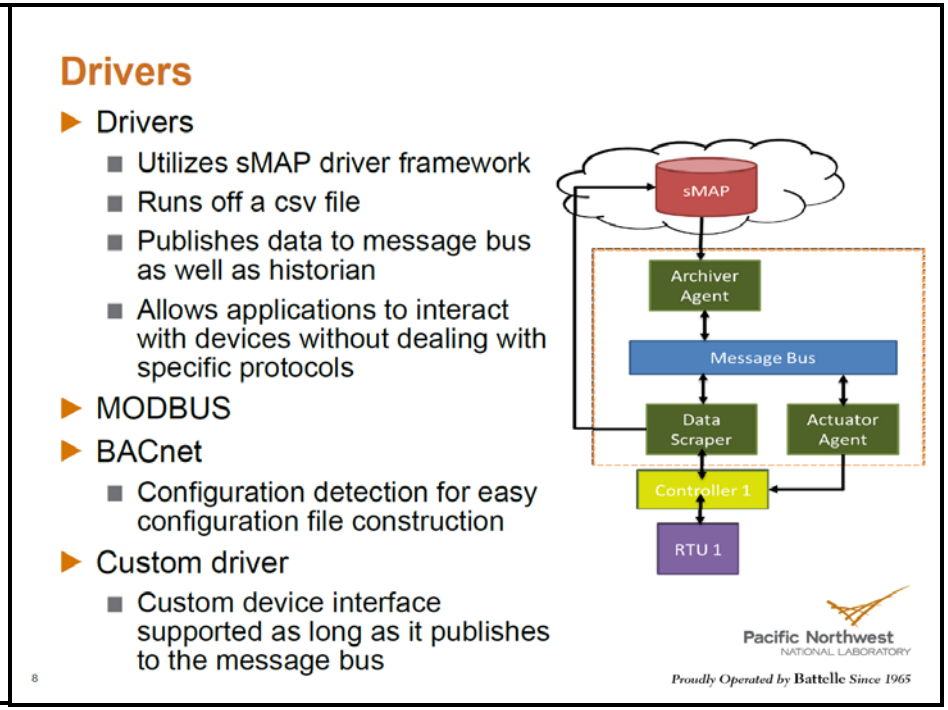
VOLTTRON Technical Overview & Features (Carpenter, PNNL)





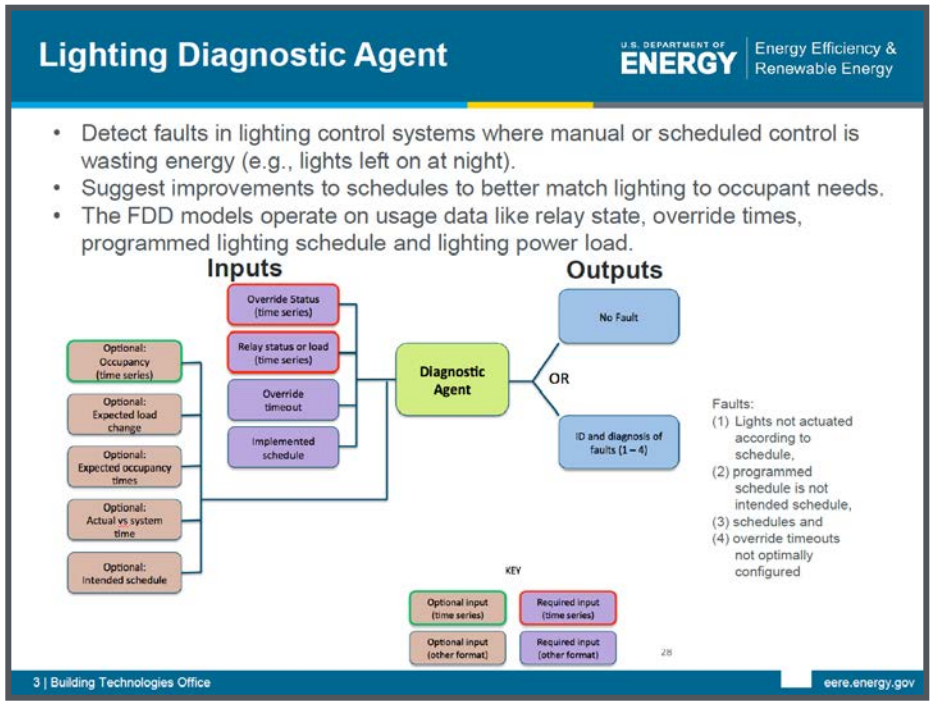
Objectives

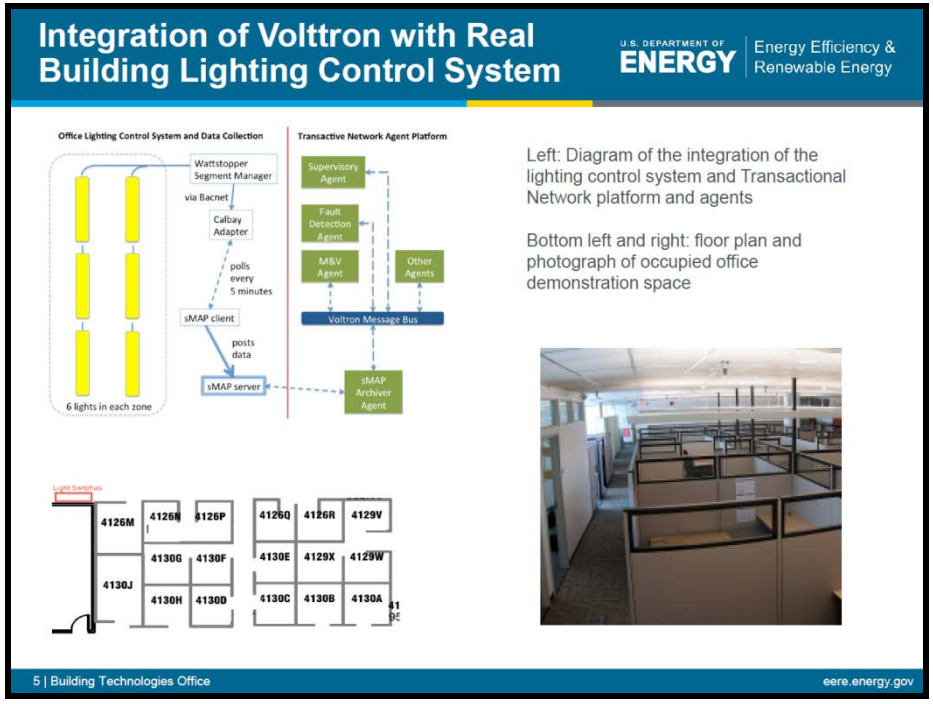
- Lower barrier of entry for app developers to work w/ devices to achieve TE goals
- Provide platform - allows apps to receive data from devices, perform analysis, and send control signals regardless of underlying protocol used by those resources
- Utility classes and examples to ease app development

Needs

- Need standardization on data/agent communication
- Management console for ease of platform management
- Residential deployment to demonstrate capabilities

Developing Applications of VOLTTRON: LBNL (Brown)





- Demonstrated fault detection and diagnostics for lighting control systems
- Demonstrated automated measurement and verification in Volttron platform
- Focus on integration of Volttron with lighting systems and whole-building metering
- Offered suggestions for future transactional network improvements in standard interfaces to building systems and utility communications

Developing Applications of VOLTTRON: ORNL (Kuruganti)

Application Focus

- Develop control techniques for reducing peak demand and improve energy efficiency of rooftop units and supermarket refrigeration systems and integrate photovoltaic sources
- Low-cost, "low-touch" retrofit of control technology into buildings and refrigeration systems to facilitate transactive opportunities for energy efficiency and with the electric grid
- Demonstrate applications using Volttron platform

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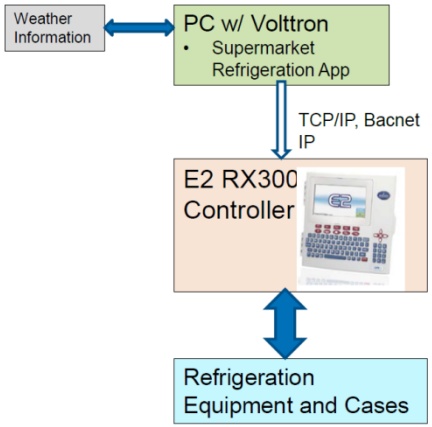
OAK RIDGE National Laboratory

Deployment Architecture #2



Volttron Applications Identified

1. Smart Defrost
   A. Demand Response
   B. Intelligent Defrost (sensing, algorithms, etc.)
2. Peak Reduction
   A. Coordination of Defrost and operation of all cases.
   B. Capacity Modulation for Peak Reduction
3. Equipment Prognostics

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- Demonstrated peak reduction of multi-RTU using retrofit control app
- Prototyped demand defrost of refrigeration system
- Focus on advanced control techniques via low-touch retrofits for adding transactive capability to building equipment
- Summarized ORNL experience re VOLTTRON plusses and minuses

Developing Applications of VOLTTRON: PNNL (Katipamula)

PNNL VOLLTTRON Applications

- **Demand Response Agent**
  - Make rooftop units (RTUs) grid responsive
- **Automatically Detect and Diagnose Faults for RTUs**
  - Detect economizer and ventilation failures as they occur and notify building operator to correct them
  - Smart monitoring and diagnostics system for conditioned-based maintenance service
- **Intelligent Duty Cycling**
- **Embedded Advanced RTU Controls – Partner Solution**
  - Improve operational efficiency of RTUs through use of advanced RTU controls leading to energy and carbon emission reductions over 50%

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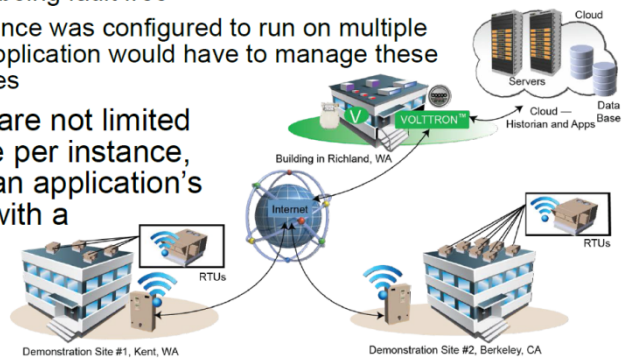
How do we to Handle Multiple RTUs?

- Each RTU has a
  - Separate instance
  - Each instance is configured to monitor, control, and produce diagnostic results for one RTU
  - Some diagnostics are contingent on earlier diagnostics being fault free
  - If each instance was configured to run on multiple RTUs the application would have to manage these contingencies
- Applications are not limited to one device per instance, especially if an application's interactions with a device are passive



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- Demonstrated how apps/agents built to work with VOLTTRON
- Highlighted integration development tools and plug-ins necessary to develop apps
- Conducted walk down on app development using Automated Fault Detection/Diagnostics app
- Listed VOLTTRON services the AFDD app uses and how those services used
- Outlined lessons learned in development/deployment of apps
- Summarized PNNL experience re VOLTTRON plusses and minuses

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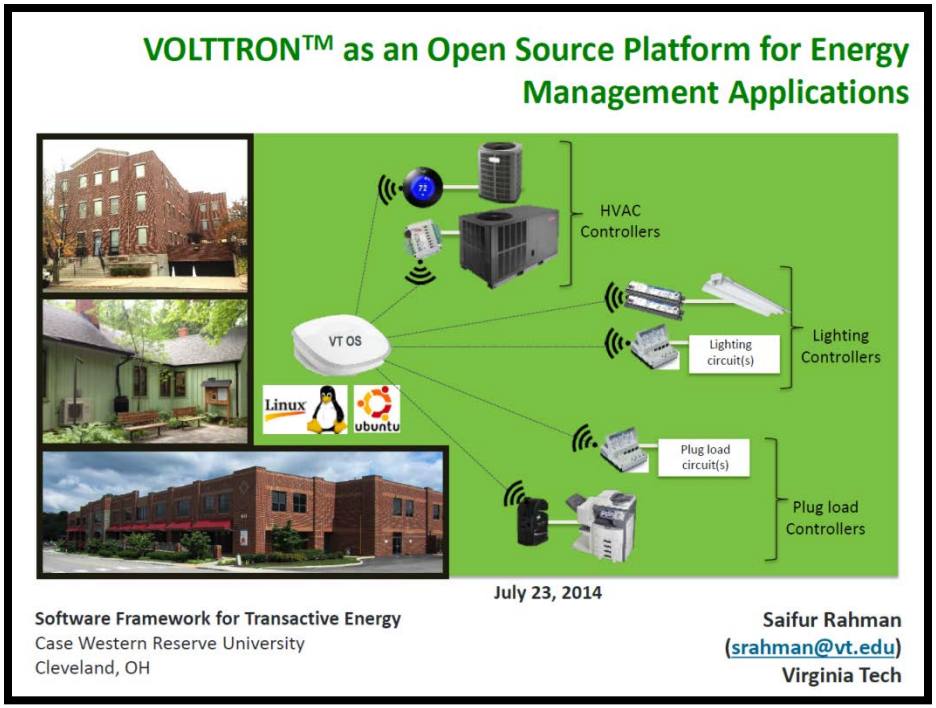
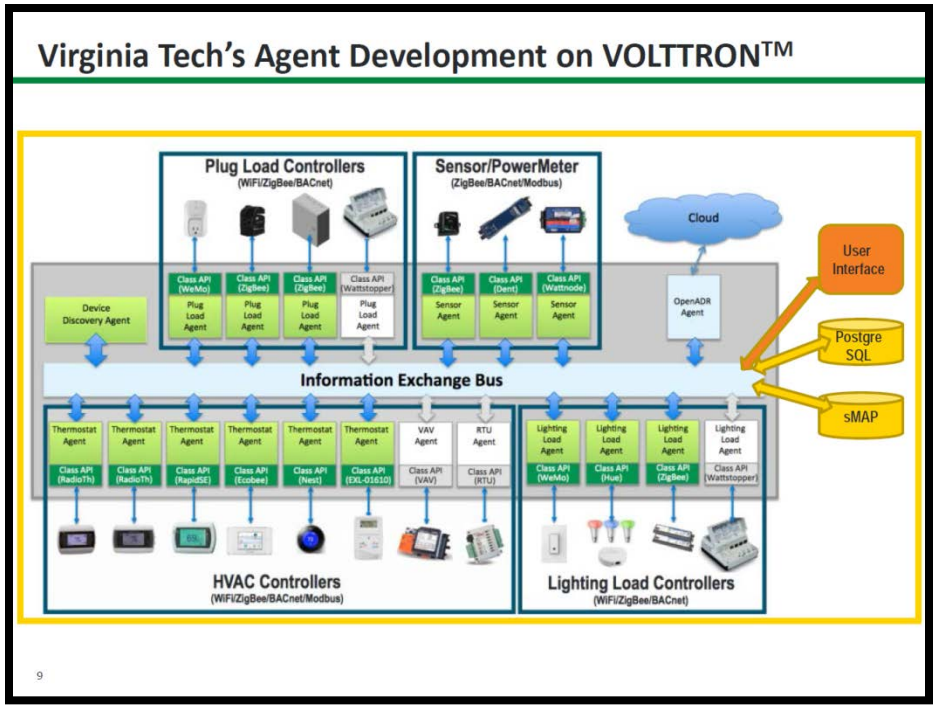
Developing Applications on VOLTTRON: VA Tech (Rahman)





- Open Source, open architecture for third party developer contribution
- Plug-and-Play feature allows the discovery of diverse sensors/controllers
- Interoperability allows working with different communication protocols
- Scalability allows expansion of the system as needs grow in the building

VOLTTRON Development Primer: How to create an application, how to use services (Haack & Carpenter, PNNL)

Installing the Platform

- Clone project from Git: https://github.com/VOLTTRON/volttron.git
- Run: ./bootstrap
  - Can take some time
- Launch platform
- Build and deploy ListenerAgent
  - volttron/scripts/build-agent.sh ListenerAgent
  - chmod +x Agents/listeneragent-0.1-py2.7.egg
  - bin/volttron-ctrl install-executable Agents/listeneragent-0.1-py2.7.egg
  - bin/volttron-ctrl load-agent Agents/ListenerAgent/listeneragent.launch.json
  - bin/volttron-ctrl start-agent listeneragent.launch.json
  - To see that it's running: bin/volttron-ctrl list-agents
  - Publishes a heartbeat message
  - Subscribes to all messages

https://github.com/VOLTTRON/volttron/wiki/BuildingTheProject

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Scheduler

```
def publish_schedule(self):

    headers = {
                'AgentID': self._agent_id,
                'type': 'NEW_SCHEDULE',
                'requesterID': self._agent_id, #The name of the requesting agent.
                'taskID': self._agent_id + "-TASK", #The desired task ID for this task.
                                                    #It must be unique among all other scheduled tasks.
                'priority': 'LOW', #The desired task priority, must be 'HIGH', 'LOW', or 'LOW_PREEMPT'
            }


    msg = [
            ["campus/building/device1", #First time slot.
             "2014-1-31 12:27:00",      #Start of time slot.
             "2014-1-31 12:29:00"],     #End of time slot.
            ["campus/building/device1", #Second time slot.
             "2014-1-31 11:26:00",      #Start of time slot.
             "2014-1-31 11:30:00"],     #End of time slot.
            ["campus/building/device2", #Third time slot.
             "2014-1-31 12:30:00",      #Start of time slot.
             "2014-1-31 12:32:00"],     #End of time slot.
            #etc...
        ]
    self.publish_json(topics.ACTUATOR_SCHEDULE_REQUEST, headers, msg)
```

- Steps for using Scheduler
  - Publish schedule request
  - Get success/error
  - If success, wait for schedule announce and then take action via Actuator
- Priorties
  - High, Low, Low_Preempt

https://github.com/VOLTTRON/volttron/wiki/ActuatorAgent

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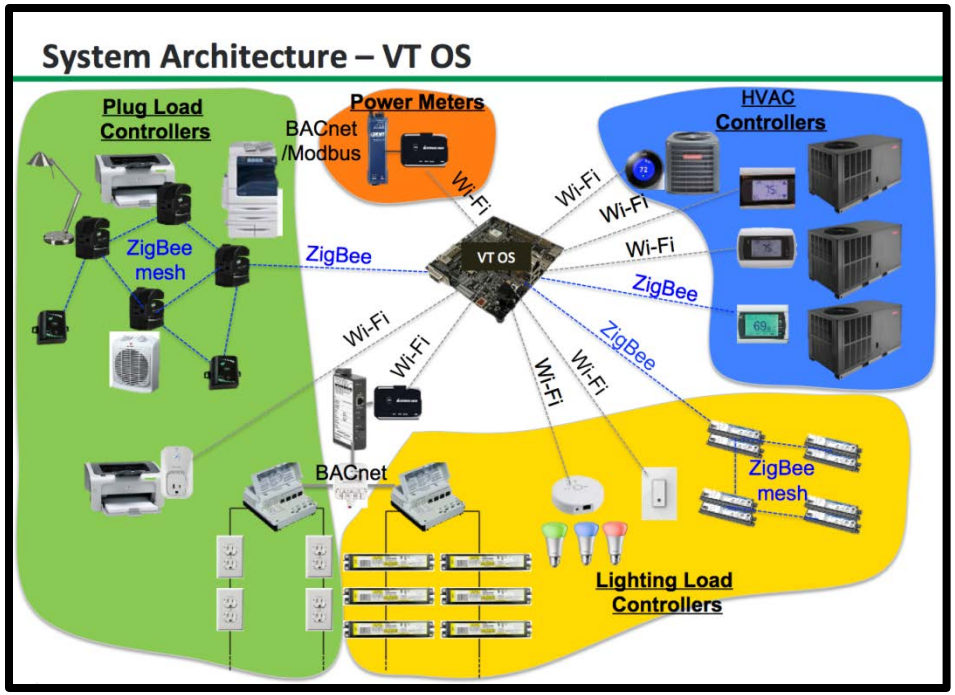
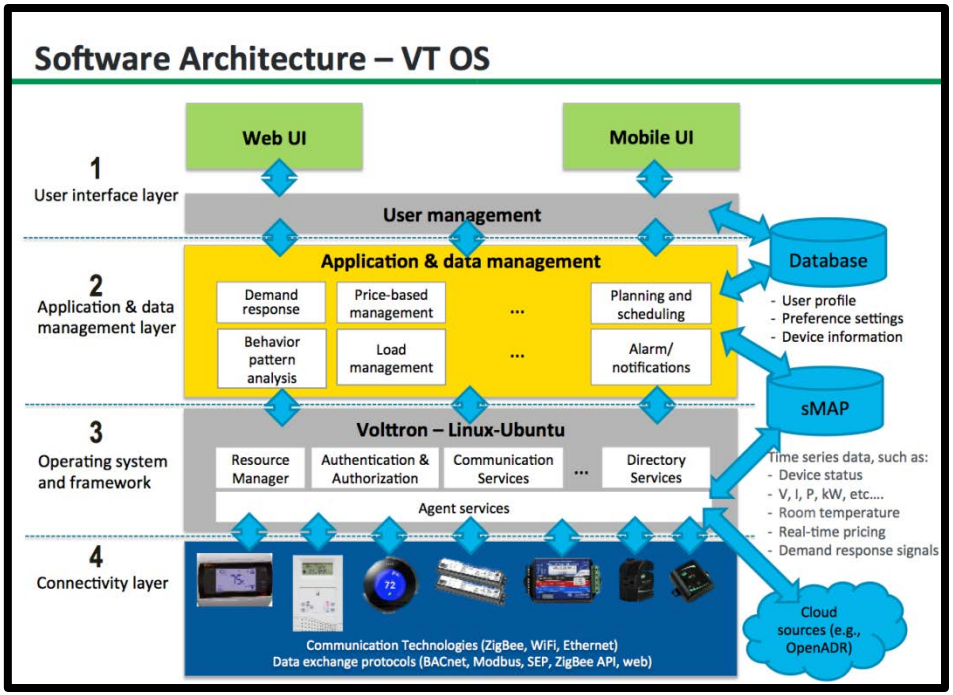
- Development Walkthrough
  - Starting platform, building, deploying agents
  - Overview of example agent
  - Examination of Base Agent
  - Service interaction example
- Next steps
  - Follow-up webinars for topics of interest

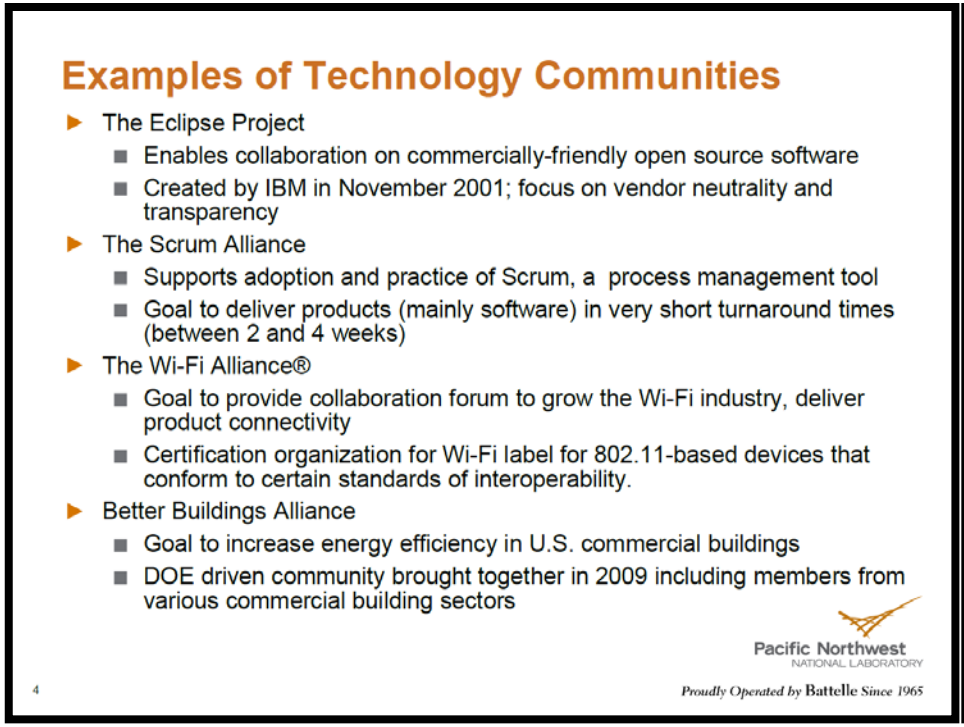
Virginia Tech OS built on VOLTTRON for Building Energy Management (Pipattanasomporn and Kuzlu, VA Tech)

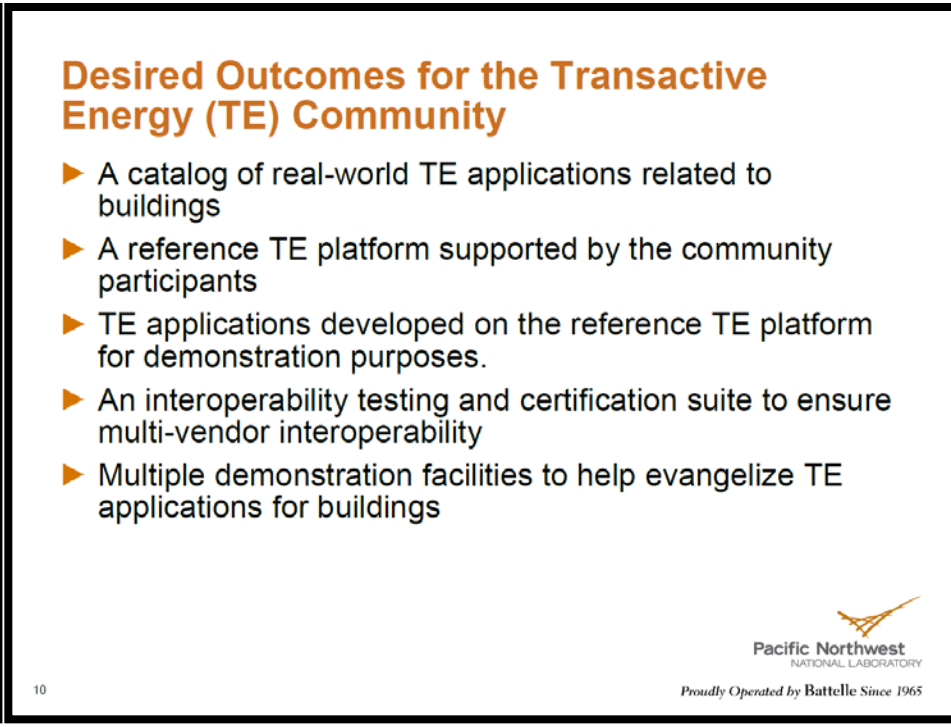




- VT OS is an open source, open architecture platform built on VOLTTRON™.
- VT OS allows all supported devices to be discovered automatically as they are deployed in buildings.
- VT OS allows integration of different load controllers from different vendors, using different communication technologies and data exchange protocols.

A Community of VOLTTRON Users: Suggestions for Development (Katipamula, PNNL)





- Outlined what a technology community does, including various examples and possible structures of technology community
- Listed desired outcomes of Transactive Energy community
- Listed potential initial actions for community, if formed
- Provided an example community that PNNL recently created – GridLab-D (Grid Analytics Association that is managed by NRECA)