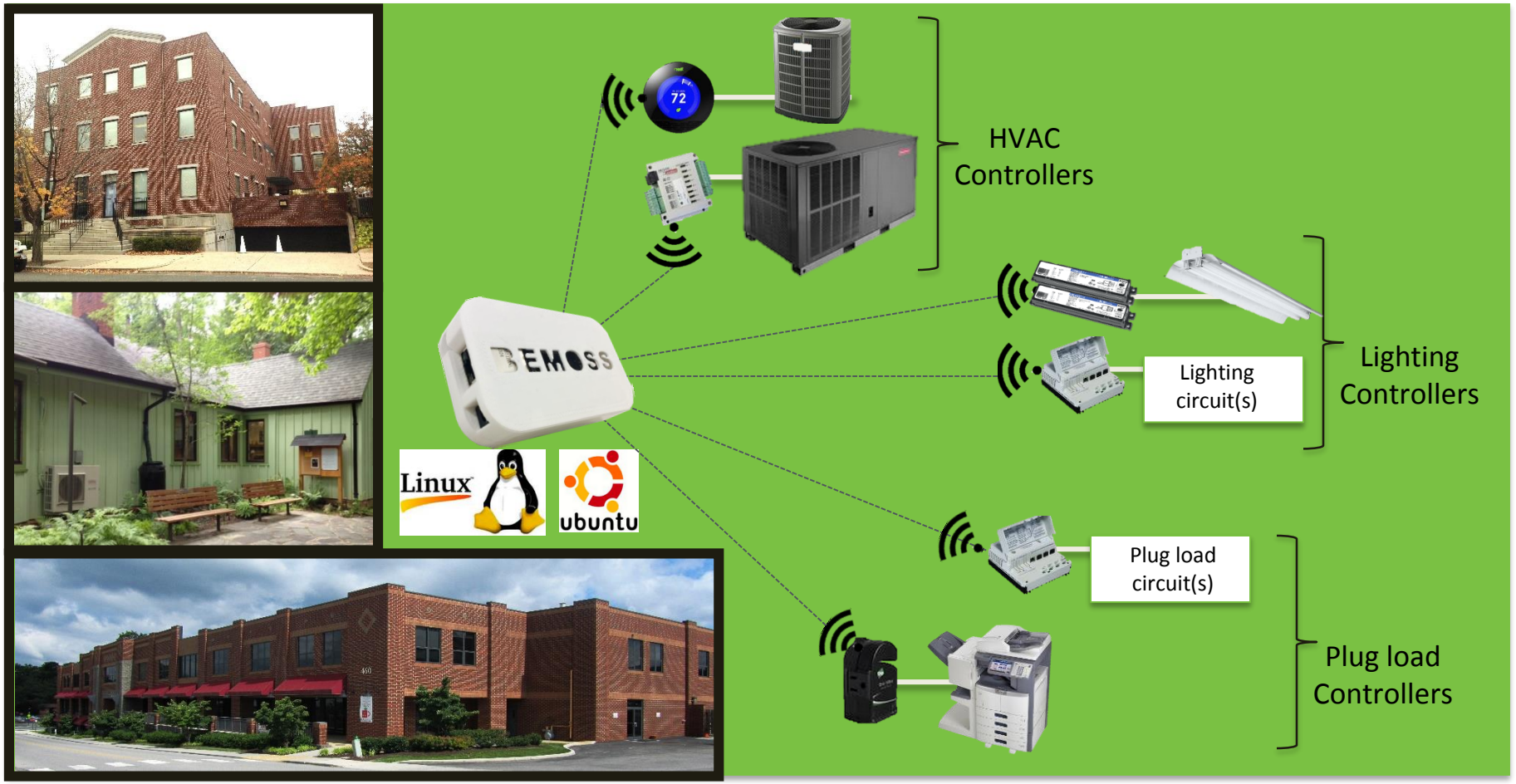
BEMOSS: An Agent Platform to Enable Grid-Interactive Building Operation with IoT Devices



April 13, 2015

2015 Workshop on Big Data Analytics in CPS: Enabling the Move From IoT to Real-Time Control
Seattle, WA

Manisa Pipattanasomporn
(mpipatta@vt.edu)
Virginia Tech

Outline

- What is BEMOSS?
- BEMOSS Features
- BEMOSS Software Architecture and its Development
- BEMOSS Multi-Agent System
- BEMOSS Applications with IoT Devices
- Laboratory Setup
- Summary and Future Research

What is BEMOSS?

BEMOSS is a Building Energy Management Open Source Software (BEMOSS) solution that is engineered to improve sensing and control of equipment in small- and medium-sized commercial buildings.

BEMOSS monitoring and control:

Three major loads in buildings

- HVAC
- Lighting loads
- Plug loads

BEMOSS value:

Improves energy efficiency and facilitates demand response implementation in buildings.

BEMOSS Advisory Committee

BEMOSS is developed in consultation with industry

BEMOSS advisory committee has representatives from 21 organizations:

Key BEMOSS Features

- #1 Open source & open architecture
- #2 Interoperability
- #3 Plug & play
- #4 Scalability & reliability
- #5 Security
- #6 Industry involvement

BEMOSS is Built upon Open-Source Software

VOLTTRON™ was used as a platform to host our BEMOSS solution. It is open-source and not hardware specific.

Linux

ubuntu

Other software used:

python

C++

jQuery
write less, do more.

JavaScript

PostgreSQL

django

Bootstrap

ZeroMQ

sMAP

BEMOSS Interoperability

Communication Technologies

- ❑ Ethernet (IEEE 802.3)
- ❑ Serial Interface (RS-485)
- ❑ ZigBee (IEEE 802.15.4)
- ❑ WiFi (IEEE 802.11)

Data Exchange Protocols

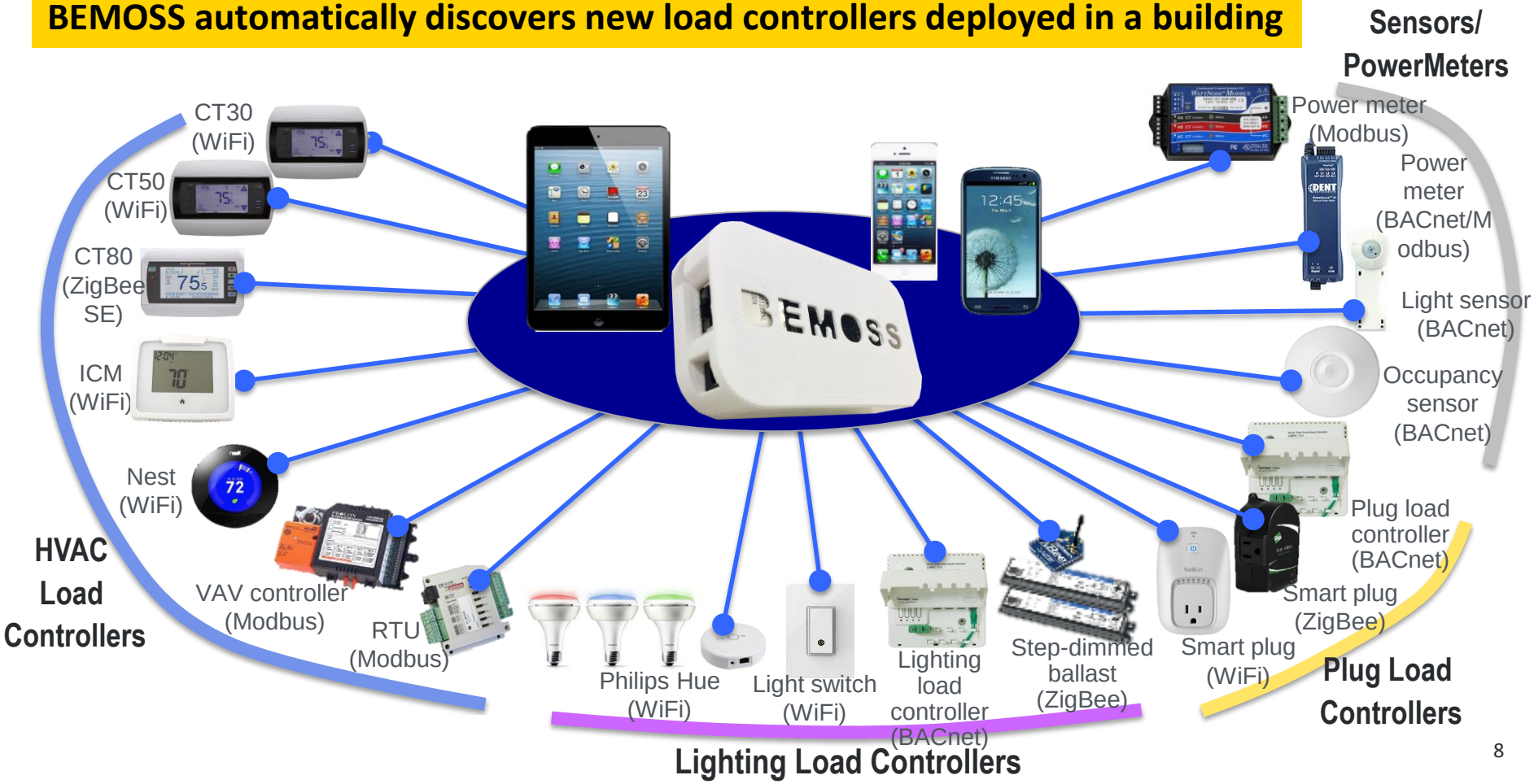
- ❑ BACnet (IP and MS/TP)
- ❑ Modbus (RTU and TCP)
- ❑ Web (e.g., XML, JSON, RSS/Atom)
- ❑ ZigBee API
- ❑ Smart Energy (SE)
- ❑ OpenADR (Open Automated Demand Response)

BEMOSS Plug & Play

With BEMOSS discovery agent, we know:

- The device is present in the building.
- Device model number, e.g., 3M-50.
- What the device can do, e.g., monitor temperature and adjust set point.

BEMOSS automatically discovers new load controllers deployed in a building



BEMOSS on Various Embeddable Devices

beagleboard

CPU: **1GHz ARM Cortex-A8**
RAM: **512MB SD**
Ethernet: 10/100 RJ45
USB 2.0: Available
Price: **$55**
Size: 3.4”x2.1”

pandaboard

CPU: **Dual core 1.2GHz**
ARM **Cortex-A9**
RAM: **1GB SD**
Ethernet: 10/100 RJ45
USB 2.0: Available
Price: **$220**
Size: 4.5”x4.0”

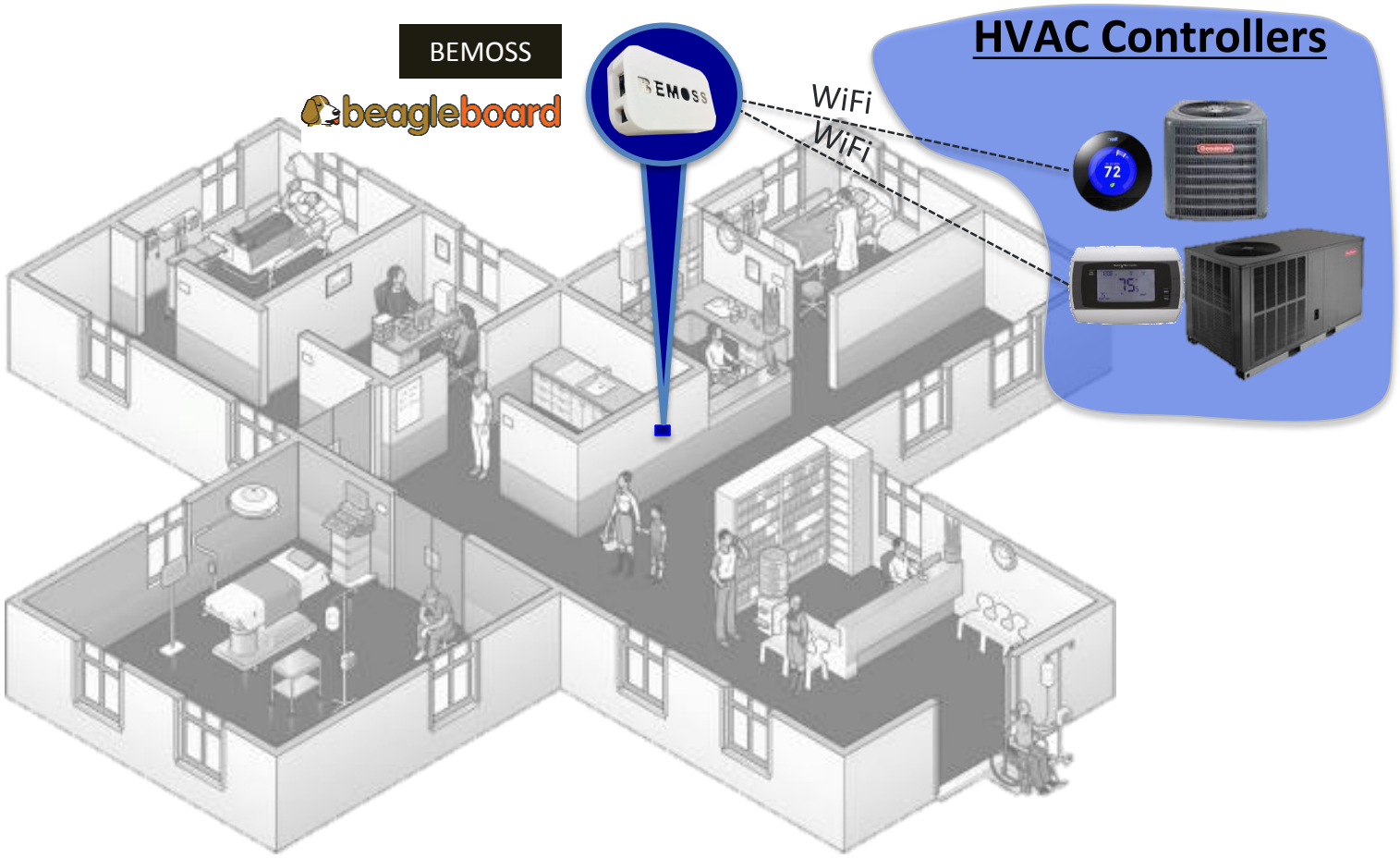
Other options:

- **T1 board from China ($77)**
  - 1.5GHz quad core
  - 1GB RAM
- **Raspberry Pi 2 ($35)**
  - 900 MHz quad core
  - 1GB RAM

This enables low-cost deployment, and expandability.

BEMOSS: Solutions for Small Buildings

(e.g., multi-tenant office bldg.)



BEMOSS: Solutions for Small Buildings

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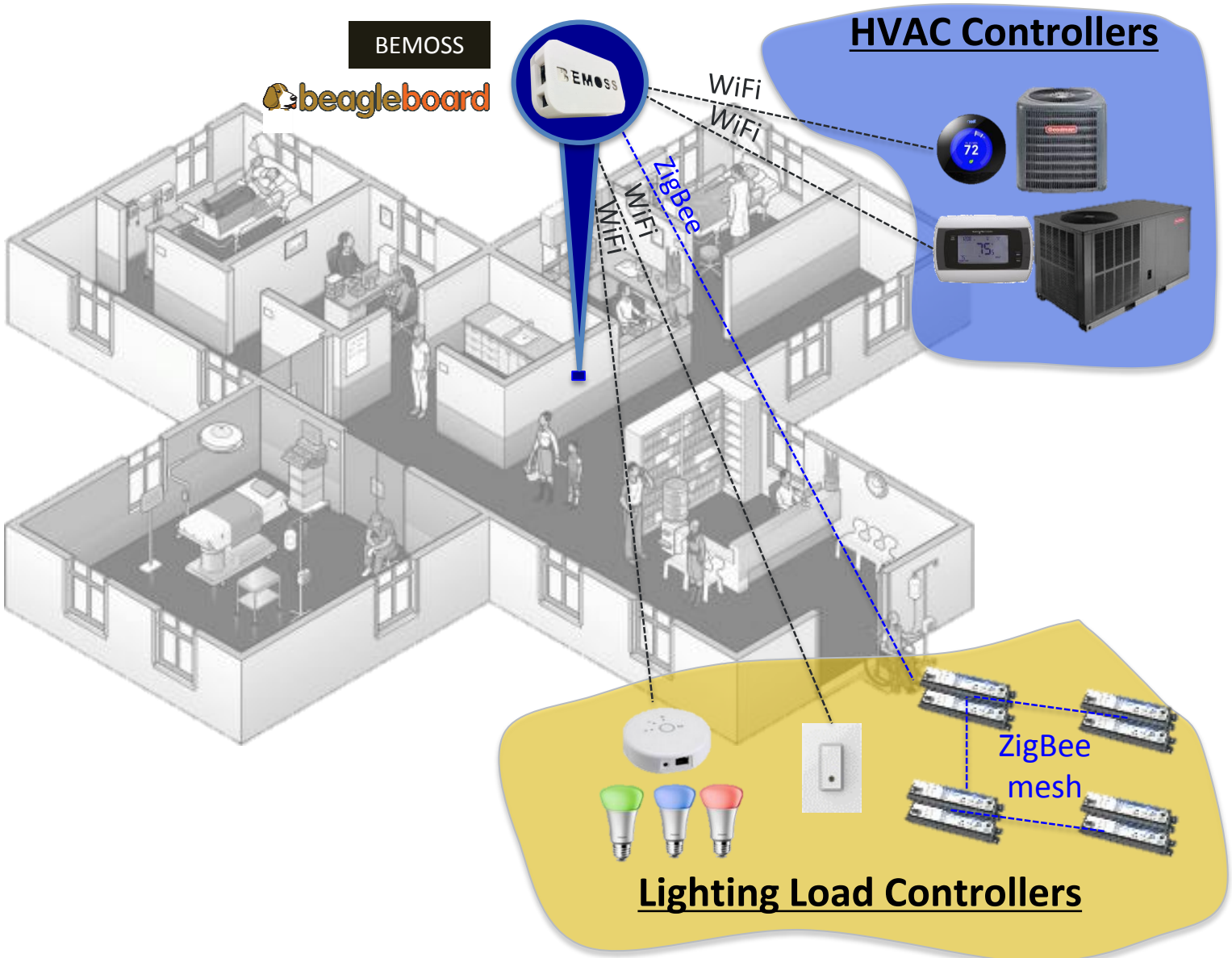

BEMOSS: Solutions for Small Buildings

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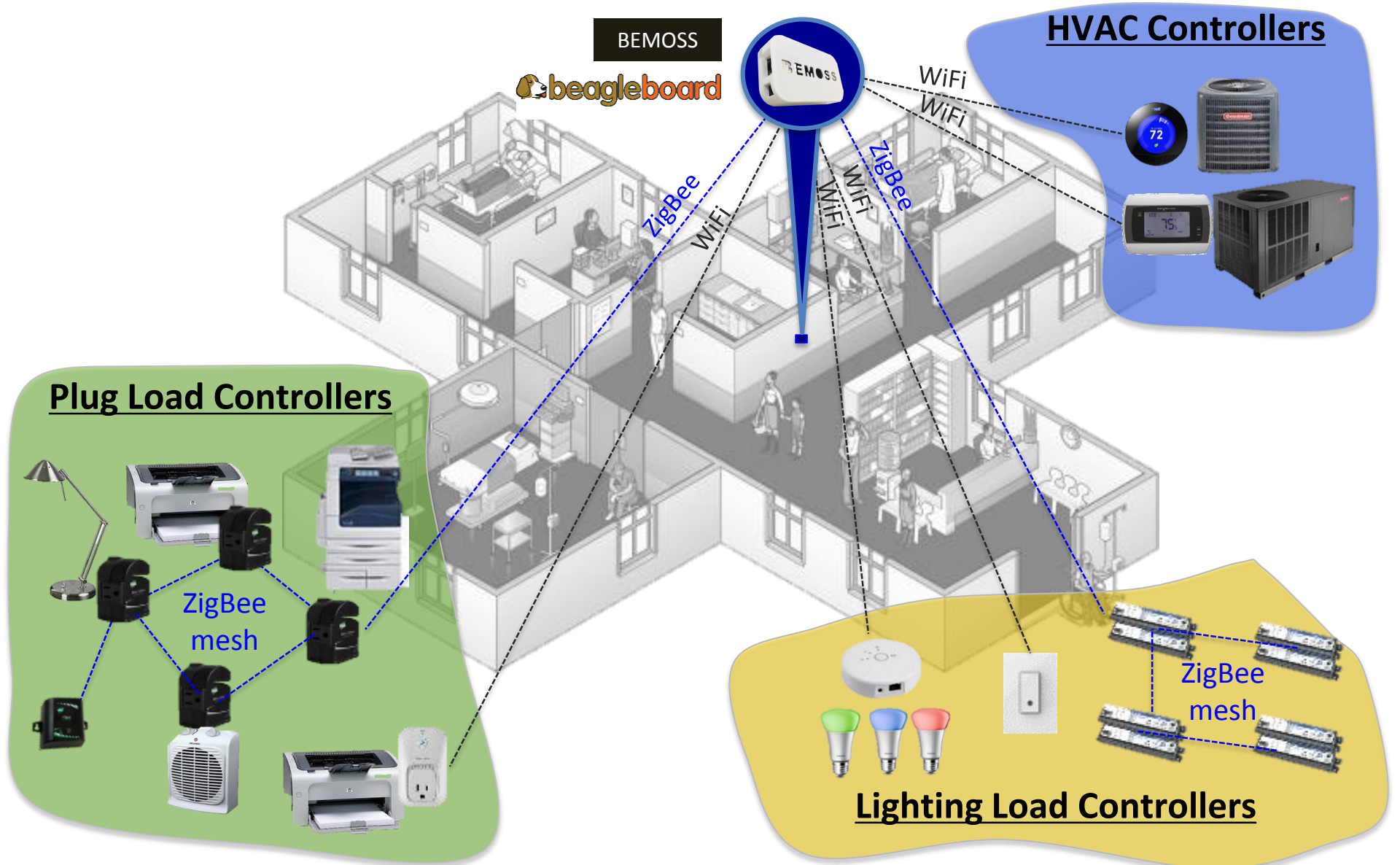
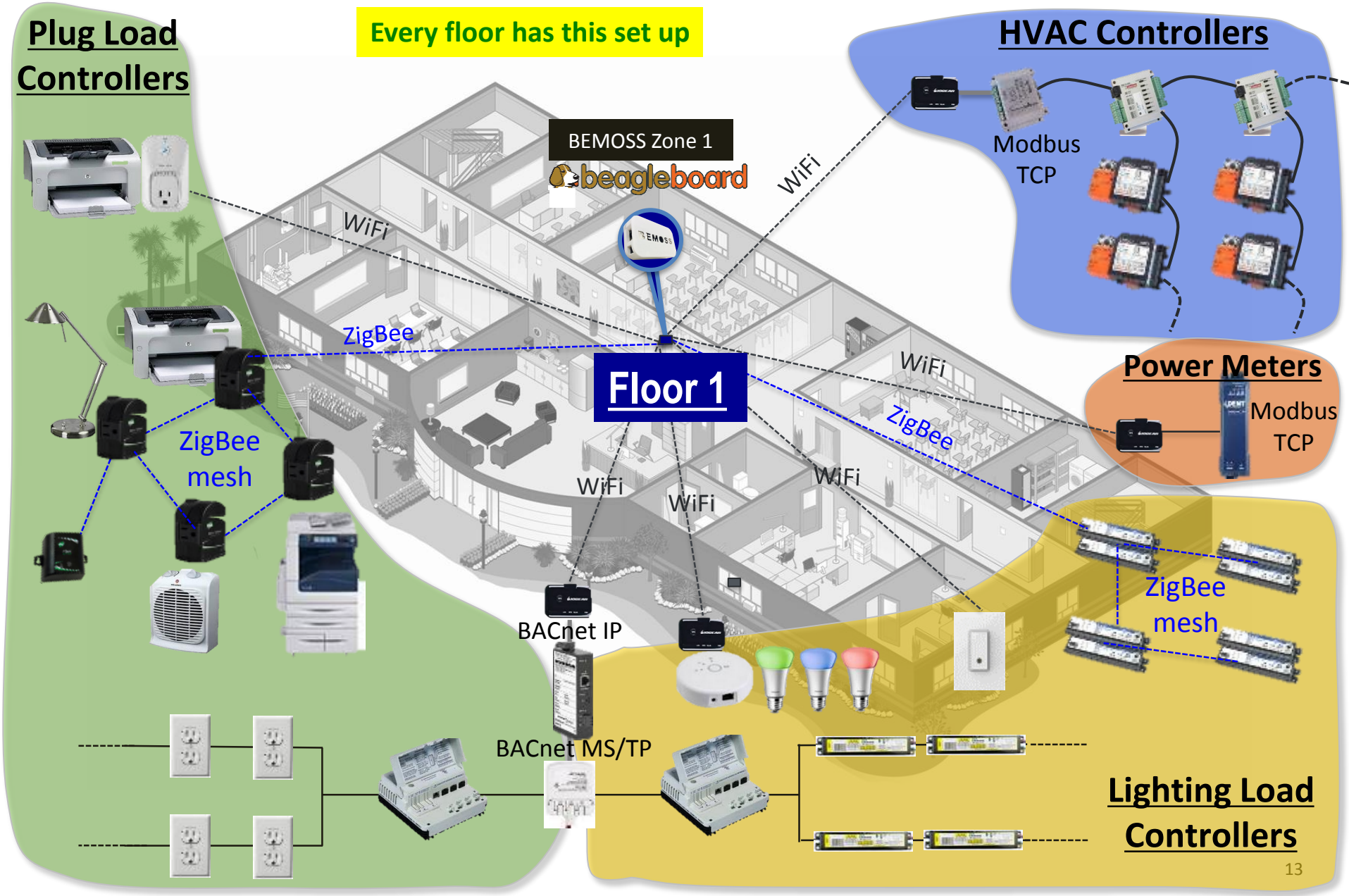
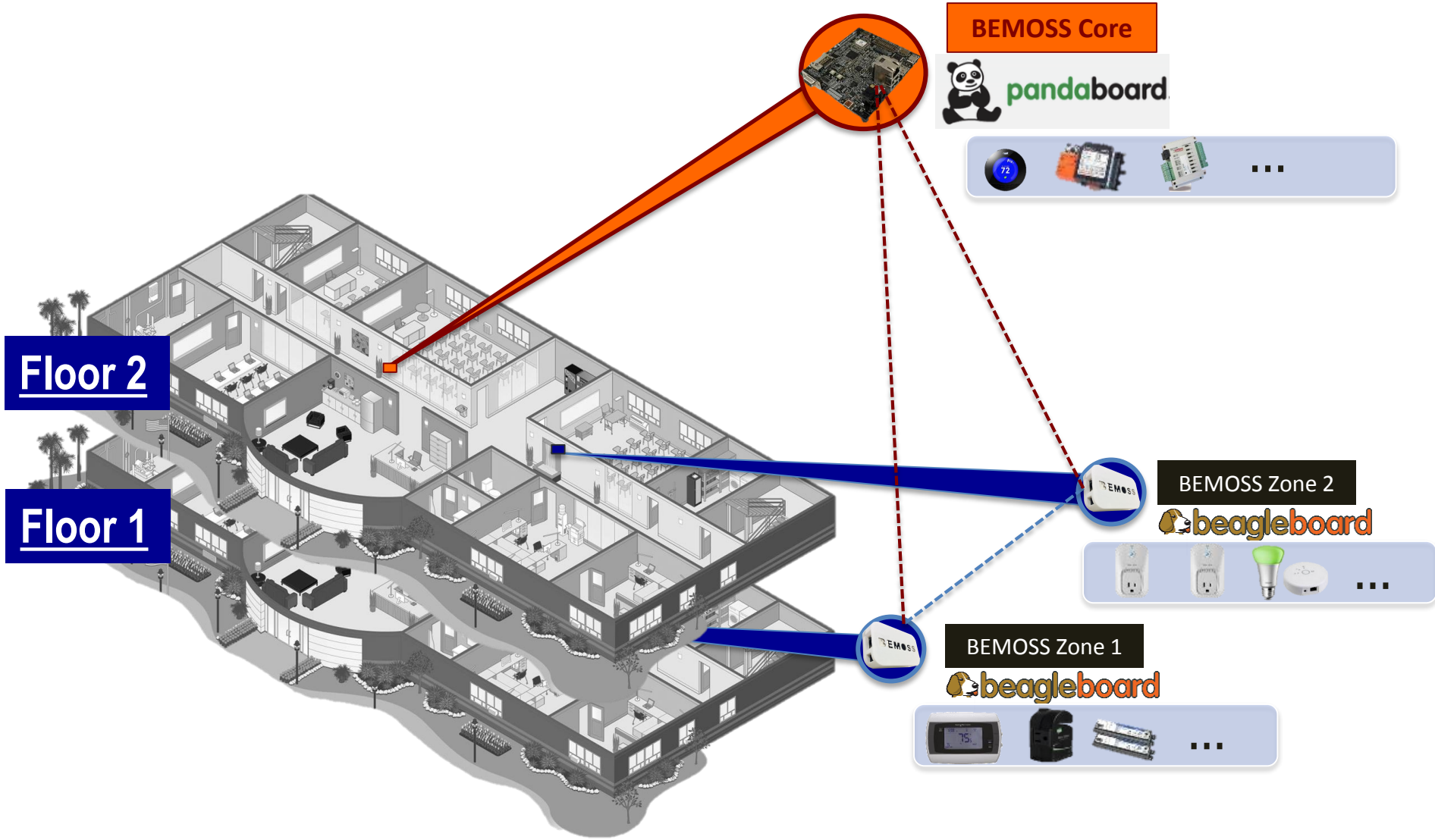


BEMOSS Scalability

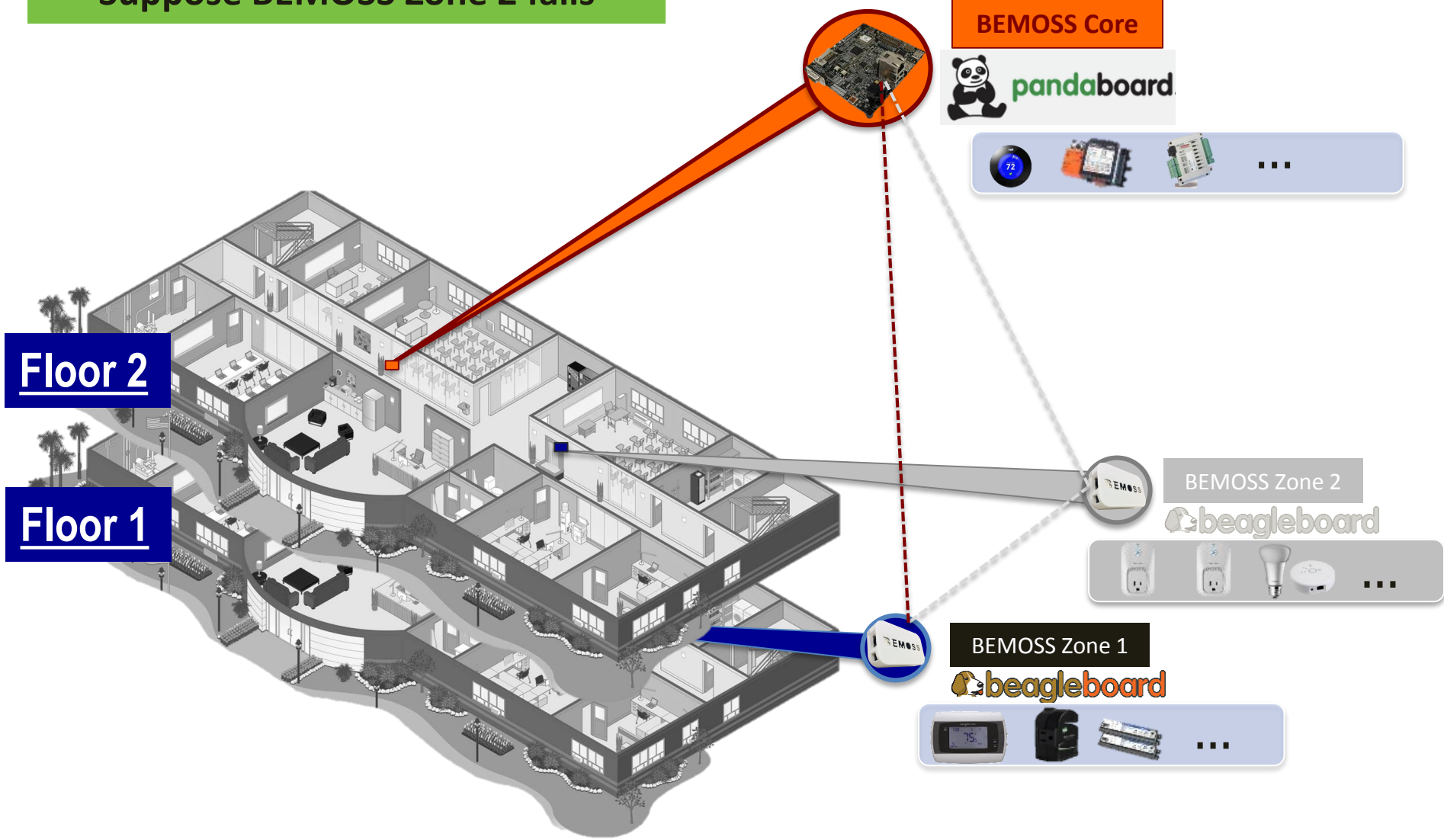


BEMOSS Scalability



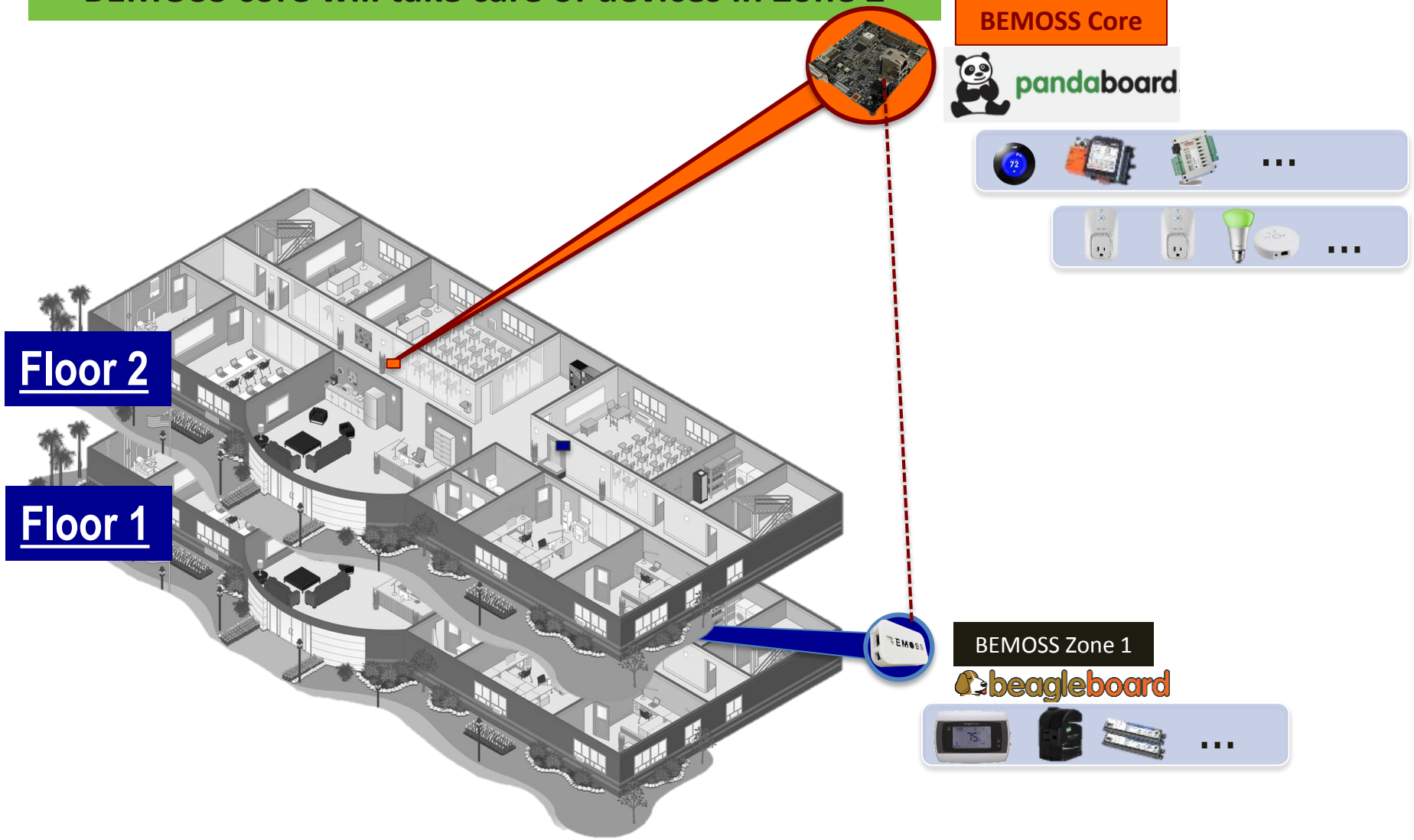
BEMOSS Reliability and Redundancy

Suppose BEMOSS Zone 2 fails



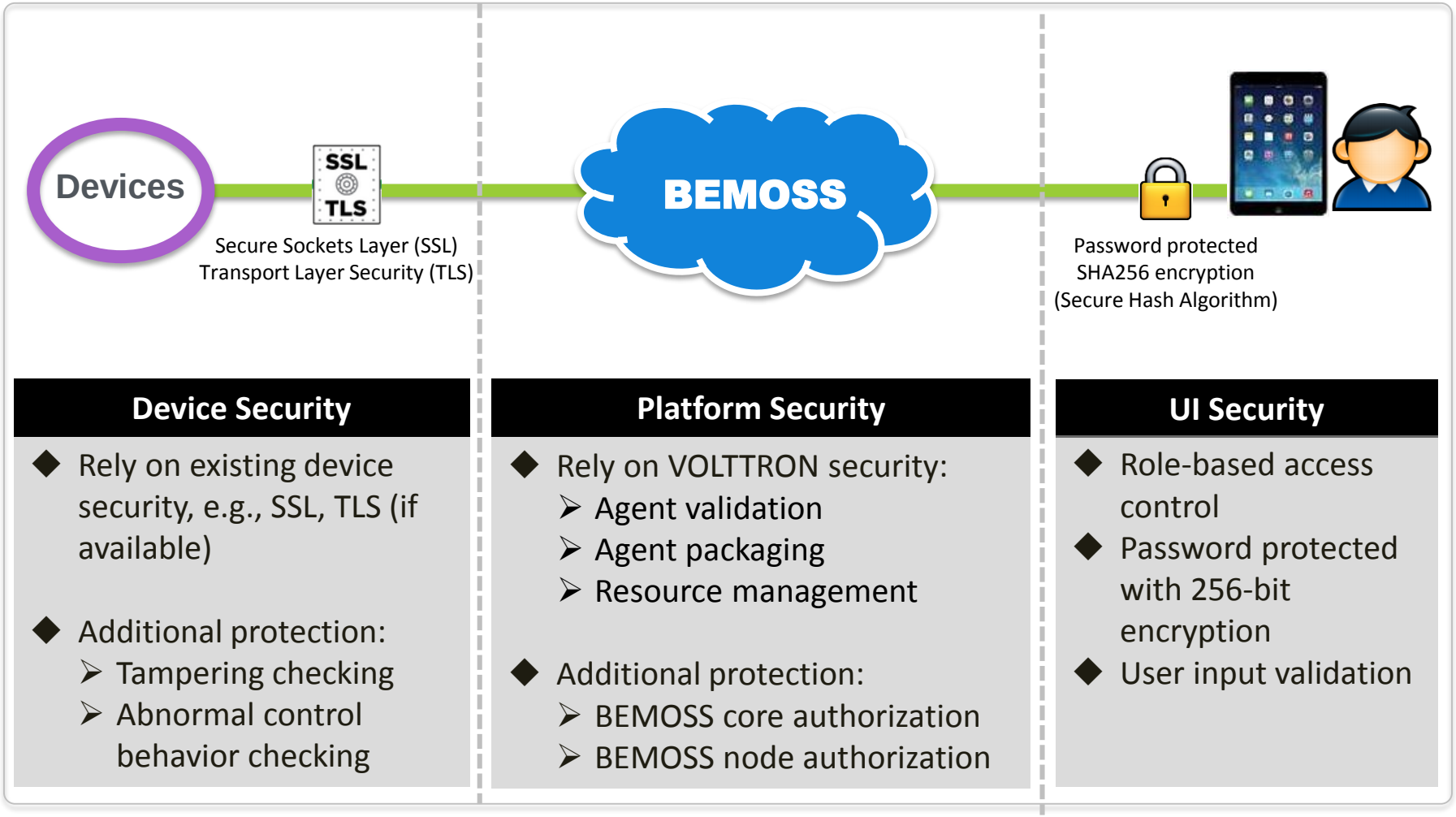
BEMOSS Reliability and Redundancy

BEMOSS core will take care of devices in Zone 2



BEMOSS Security

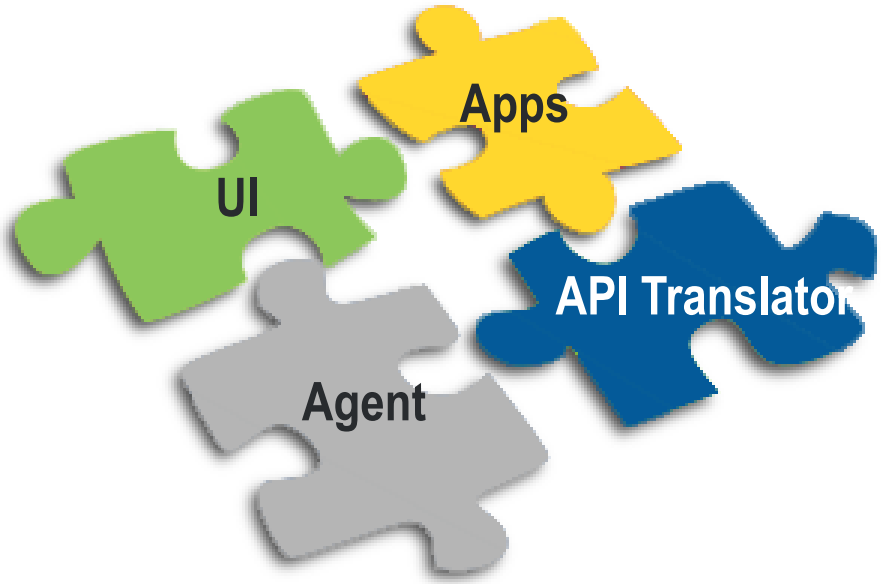
BEMOSS utilizes built-in security features provided by VOLTTRON™, and provides enhanced security features.



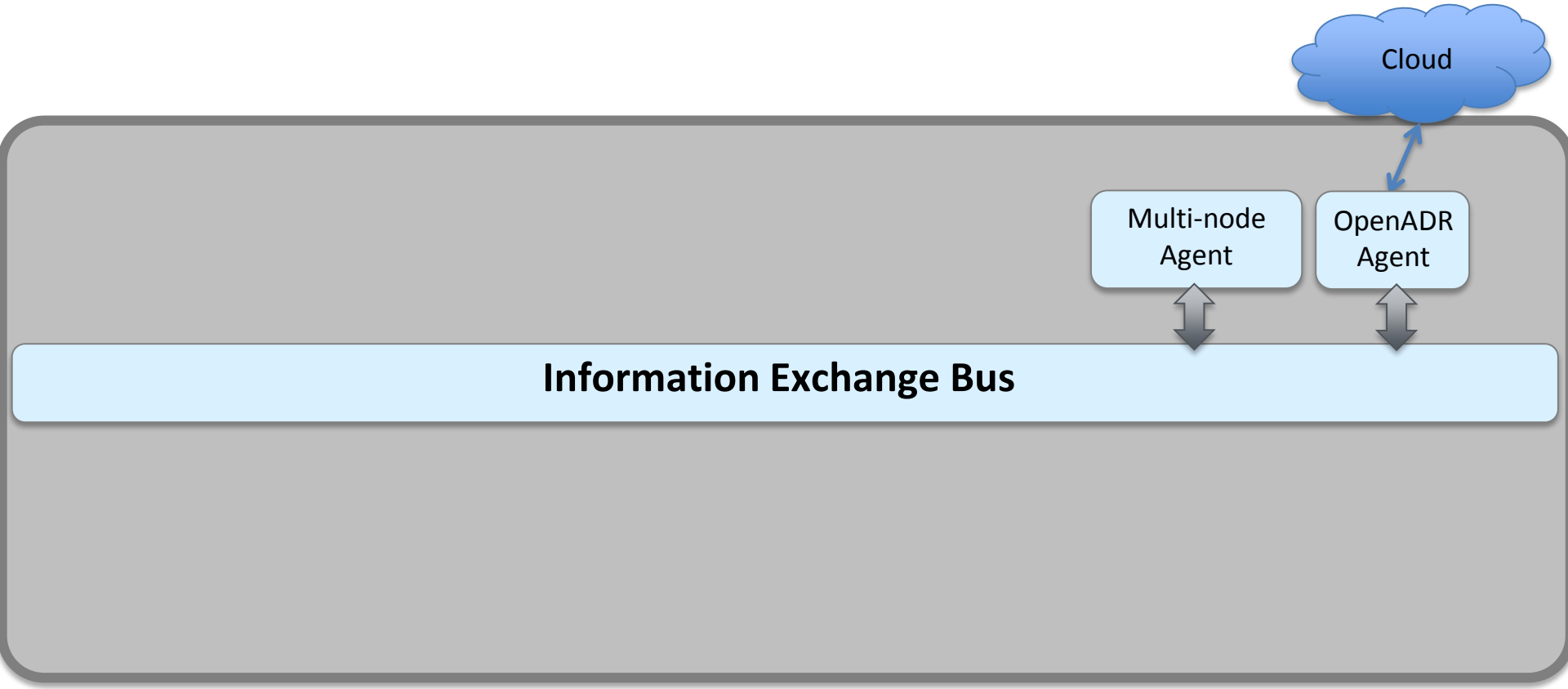
Device Security	Platform Security	UI Security
◆ Rely on existing device security, e.g., SSL, TLS (if available) ◆ Additional protection: ➢ Tampering checking ➢ Abnormal control behavior checking	◆ Rely on VOLTTRON security: ➢ Agent validation ➢ Agent packaging ➢ Resource management ◆ Additional protection: ➢ BEMOSS core authorization ➢ BEMOSS node authorization	◆ Role-based access control ◆ Password protected with 256-bit encryption ◆ User input validation

BEMOSS

BEMOSS Architecture & Its Development



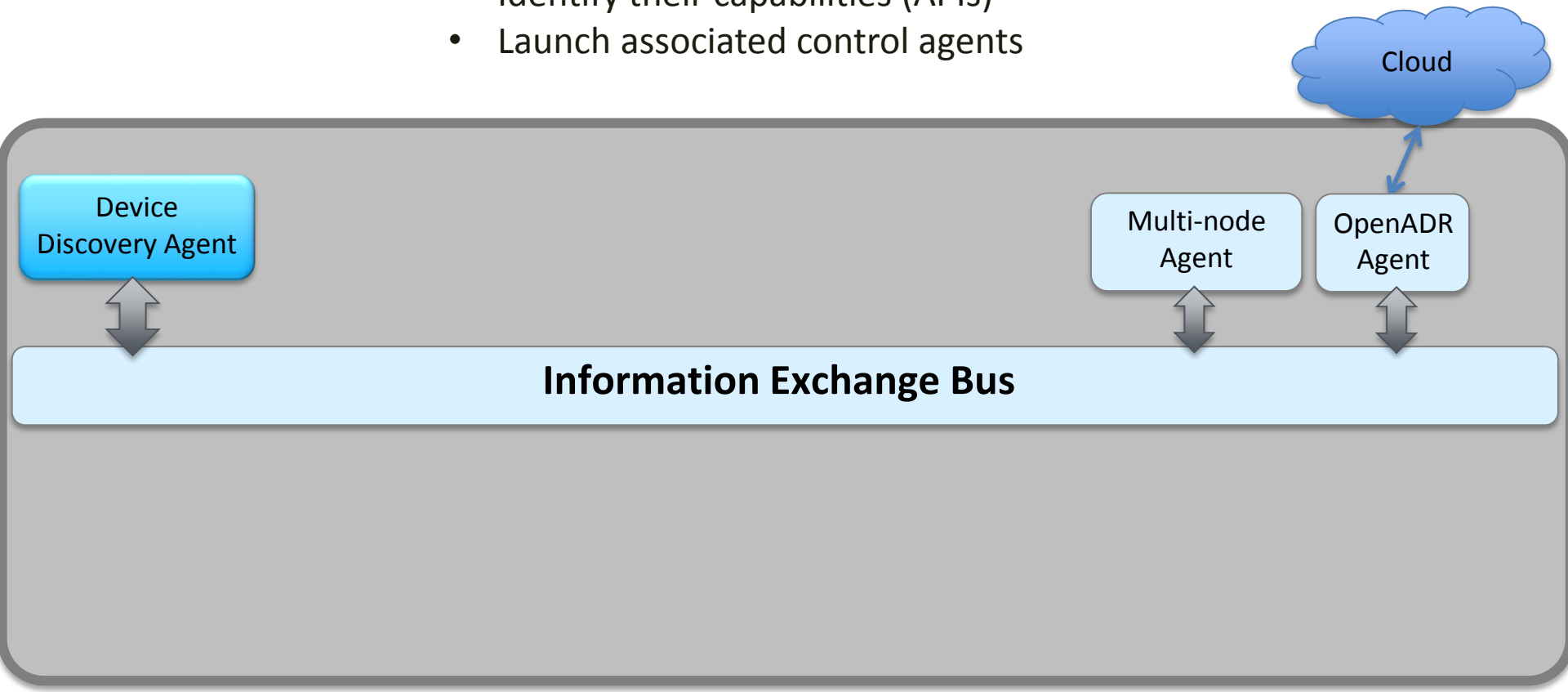
BEMOSS Package Resides on VOLTTRON™



+ BEMOSS Discovery Agent

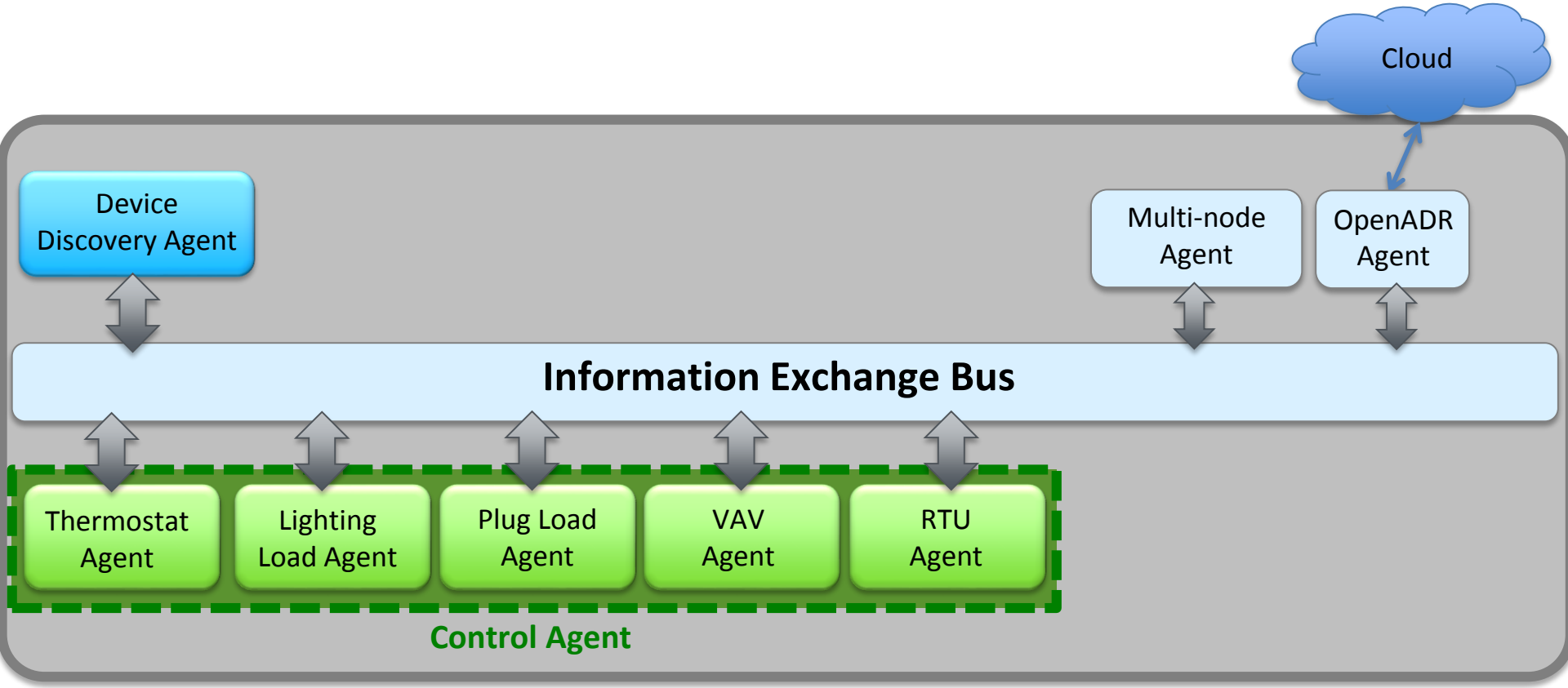
Device discovery agent

- Detect the presence of devices in buildings
- Query addresses, model numbers
- Identify their capabilities (APIs)
- Launch associated control agents



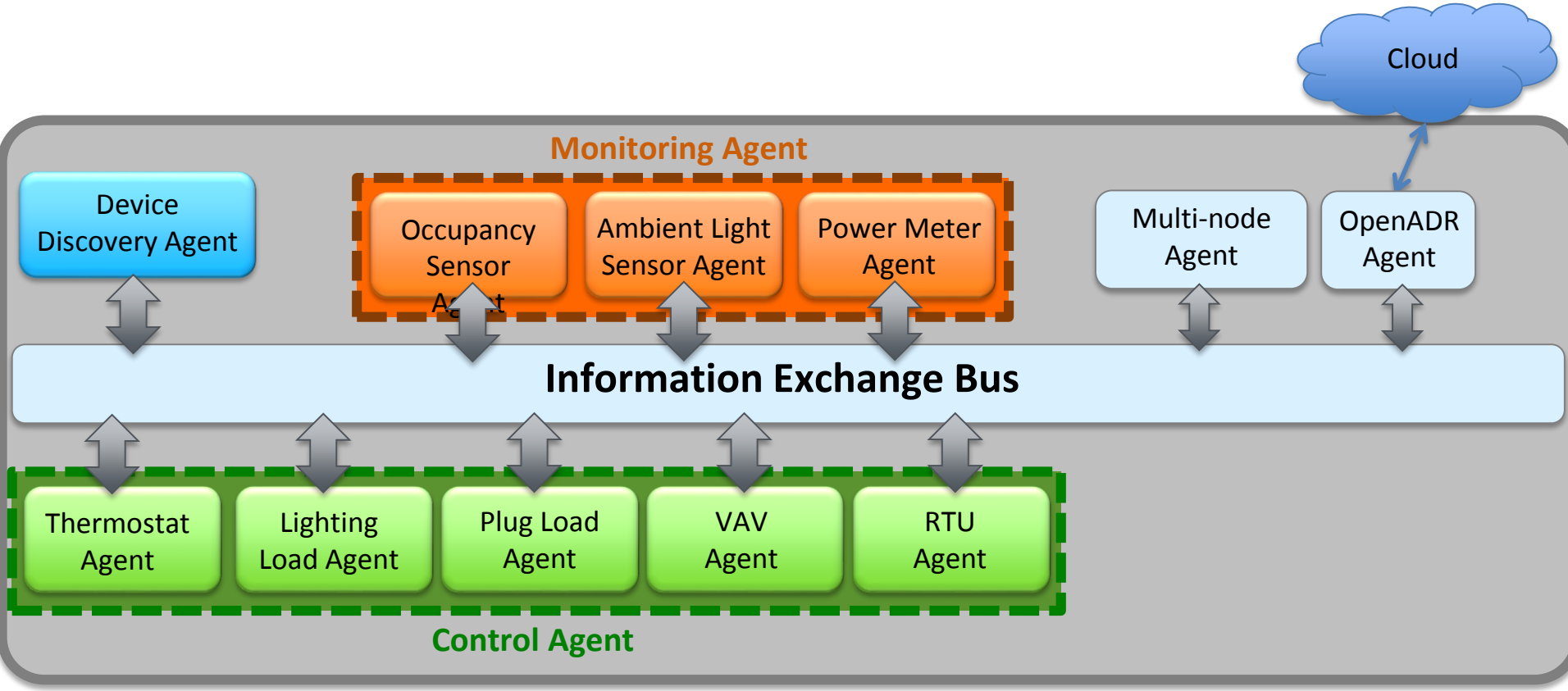
+ BEMOSS Control Agents

Control agent • Control associated HVAC, lighting and plug load controllers, and obtain their readings



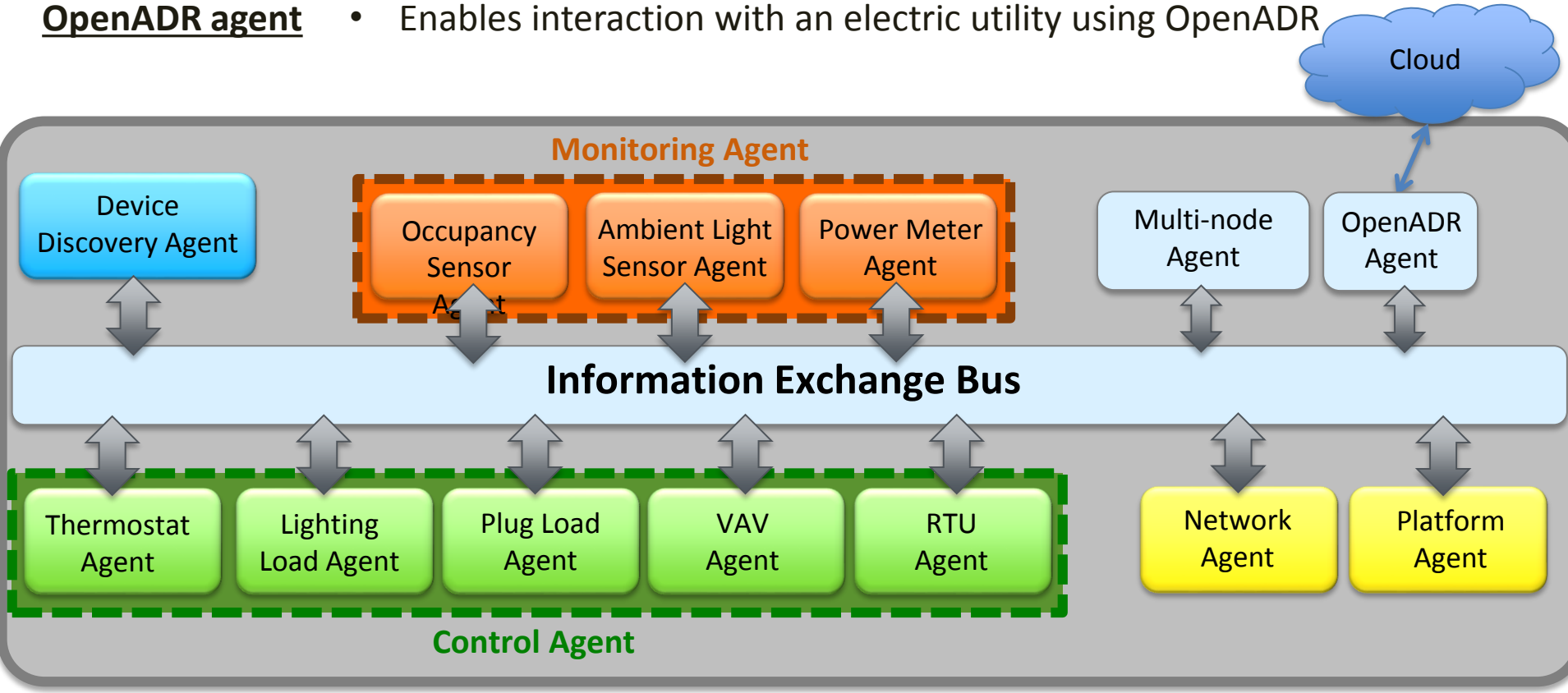
+ BEMOSS Monitoring Agents

Monitoring agent • Obtain readings from sensors/power meters



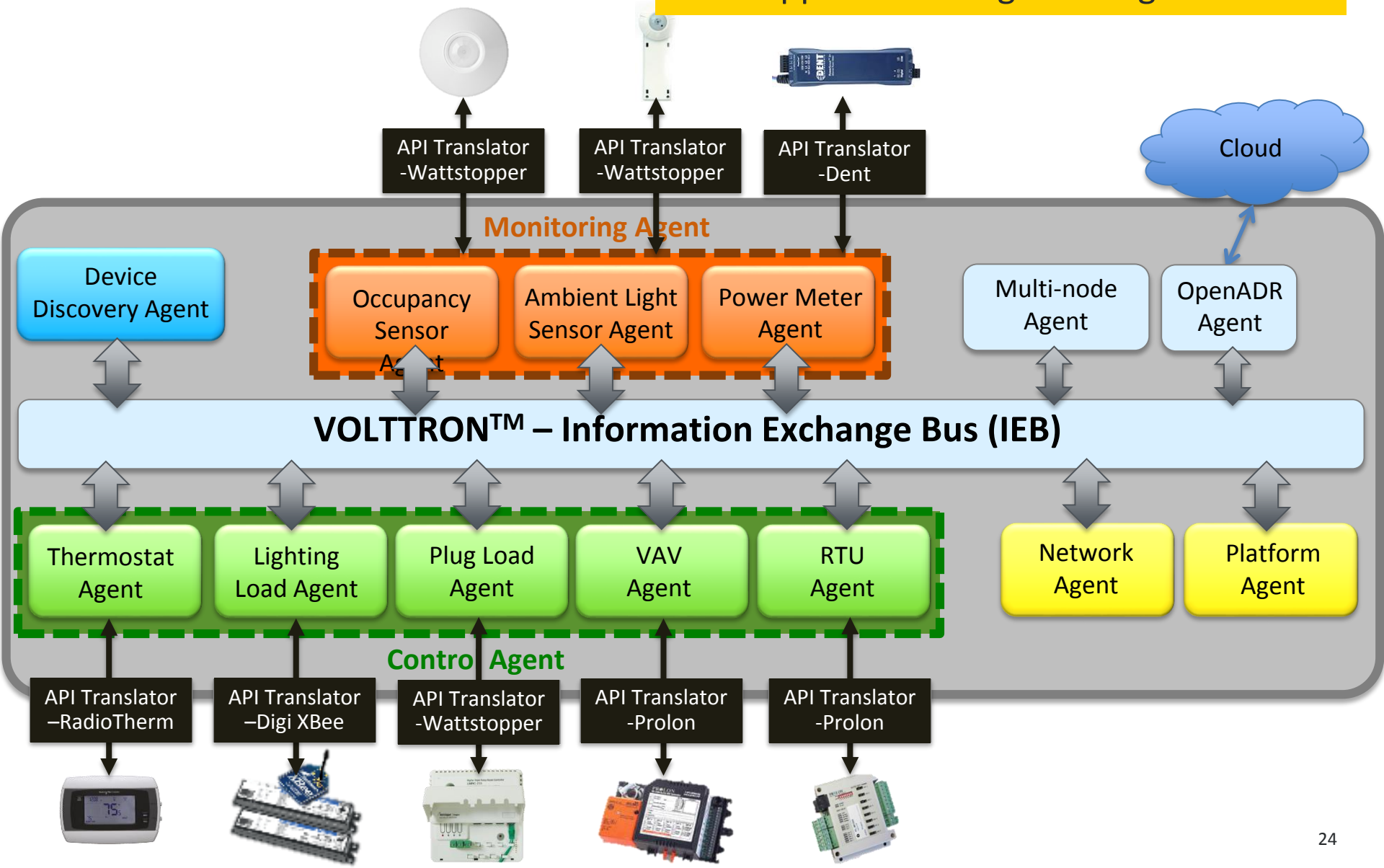
+ BEMOSS Network and Platform Agents

Network agent • Facilitates agent mobility
Multi-node agent • Facilitates multi-node communication
Platform agent • Monitors number of agents and their functions
OpenADR agent • Enables interaction with an electric utility using OpenADR



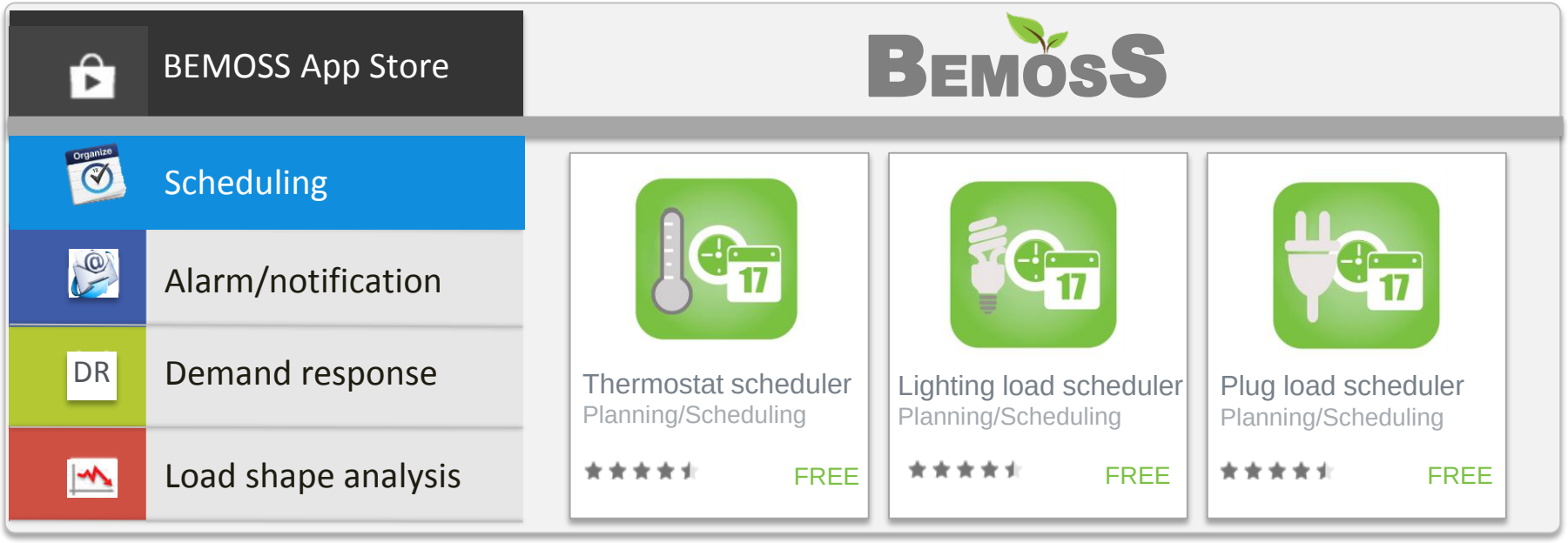
API Translator Allows BEMOSS Agents to Talk to Devices

API = Application Programming Interface



+ BEMOSS Apps

Four BEMOSS Apps were developed: scheduling (3) and alarm/notification (1)



Apps Developed
Thermostat scheduler
Lighting scheduler
Plug load scheduler
Alarm/notification

Programming Language:

P = python

+ Add BEMOSS UI

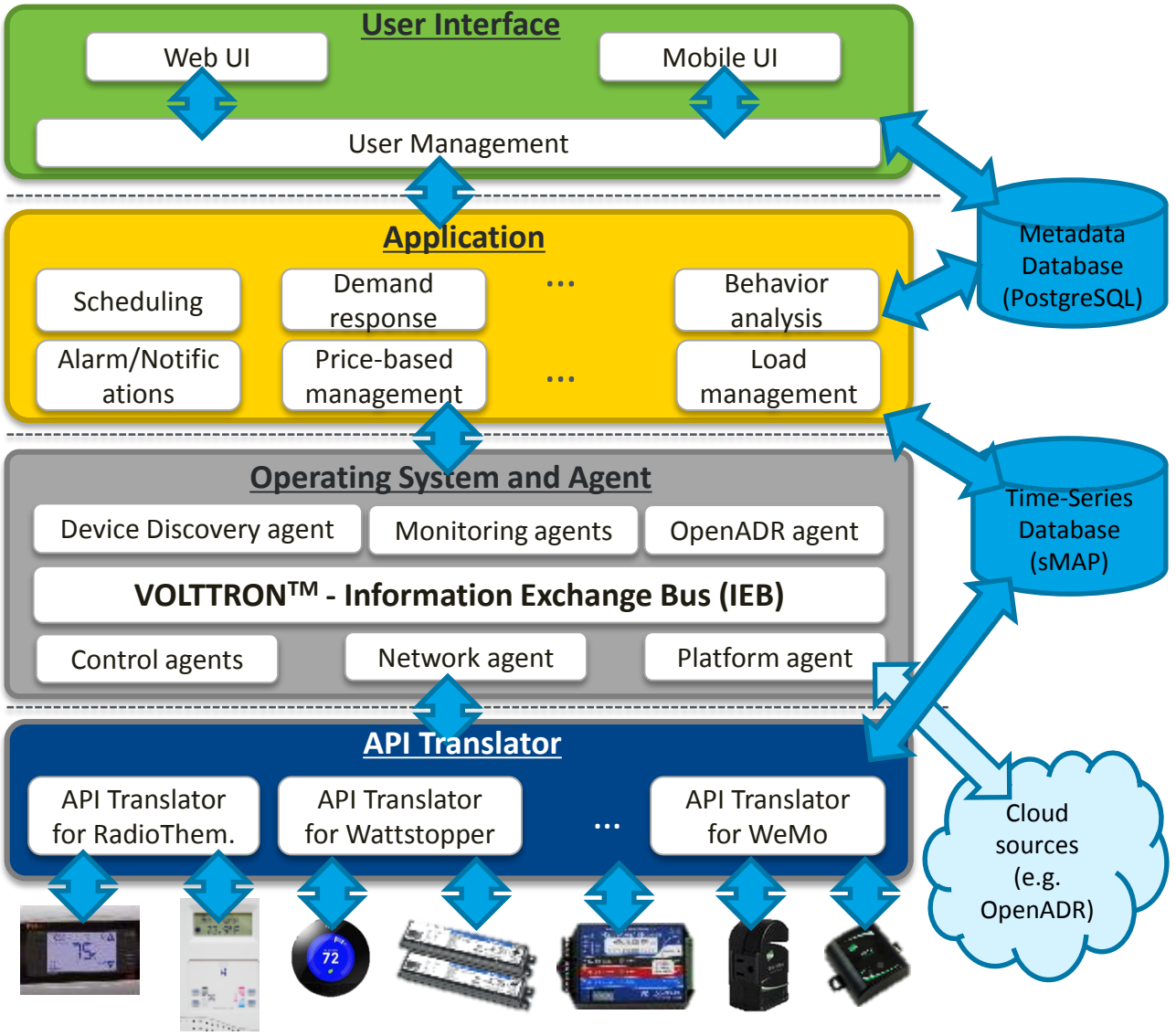
BEMOSS UI key features:

- Interactive
- Graphing representation of data
- Report printing
- User management (i.e., user registration, login/logout capabilities)
- Designed for open standards:

ZeroMQ

UI Pages
Dashboard
Thermostat
Lighting load controller
Plug load controller
Sensor
Power meter
Historical data
Scheduler
Network and device status
Alarm and notification
Login and registration
Error handling
Setting, user management, report printing

BEMOSS Software Architecture



BEMOSS Accessible Devices

BEMOSS currently can monitor and control the following devices

Device Model	Vendor	Protocol
HVAC controller		
CT30 - WiFi USNAP	RadioThermostat	WiFi
CT50 - WiFi USNAP	RadioThermostat	WiFi
CT80 - WiFi/ZigBee SE USNAP	RadioThermostat	ZigBee SE
Nest thermostat	Google	WiFi
EXL-01610 thermostat	Exact Logic	BACnet MS/TP
VC1000 series VAV	Prolon	Modbus TCP
PL-M1000RTU controller	Prolon	Modbus TCP
Lighting load controller		
Philips Hue	Philips	WiFi/Ethernet
WeMo light switch	Belkin	WiFi
Step-dimmed ballast	Douglas	ZigBee(customized)
LMRC-210 controller	Wattstopper	BACnet
Plug load controller		
WeMo smart plug	Belkin	WiFi
Digi XBee smart plug	Digi	ZigBee API
LMPL-201 controller	Wattstopper	BACnet
Sensor		
Digi XBee sensor	Digi	ZigBee API
LMPC-100 sensor	Wattstopper	BACnet
LMLS-400 photosensor	Wattstopper	BACnet
Power meter		
Dent PowerScout 3+, Ethernet	Dent	BACnet IP
	Dent	Modbus TCP
Dent PowerScout 3+, Serial	Dent	BACnet MS/TP
	Dent	Modbus RTU
Wattnode WNC-3Y-208-MB	Wattnode	Modbus RTU

BEMOSS Integration with Emerging IoT Devices/Software

Limitless Possibilities w/ BEMOSS and emerging IoT devices

SmartThings – integrating w/ motion sensor, smart plug, etc.

If This Then That – serving as channel for alarms/notifications

Smart Plug – WeMo smart plug, Digi smart plug, etc.

BEMOSS

iBeacon – providing location-based info of BEMOSS accessible devices

Smart Thermostats– Nest, RadioThermostat, etc.

Smart Lighting Load Controllers – WeMo light switch, Philips Hue, etc.

BEMOSS Potential Applications

- Integration of machine learning algorithms to get better understanding of power consumption in buildings

- Integration of algorithms to manage a large amount of data collected from load controllers/sensors

- Integration of algorithms to allow management of multiple buildings in a transaction-based energy network

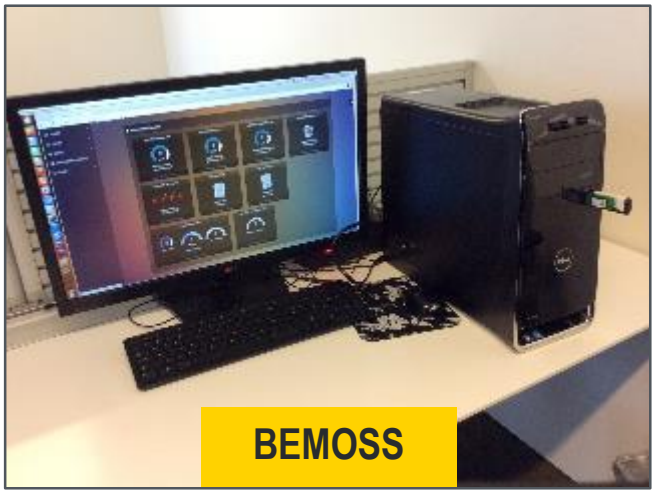
BEMOSS App Developer Community

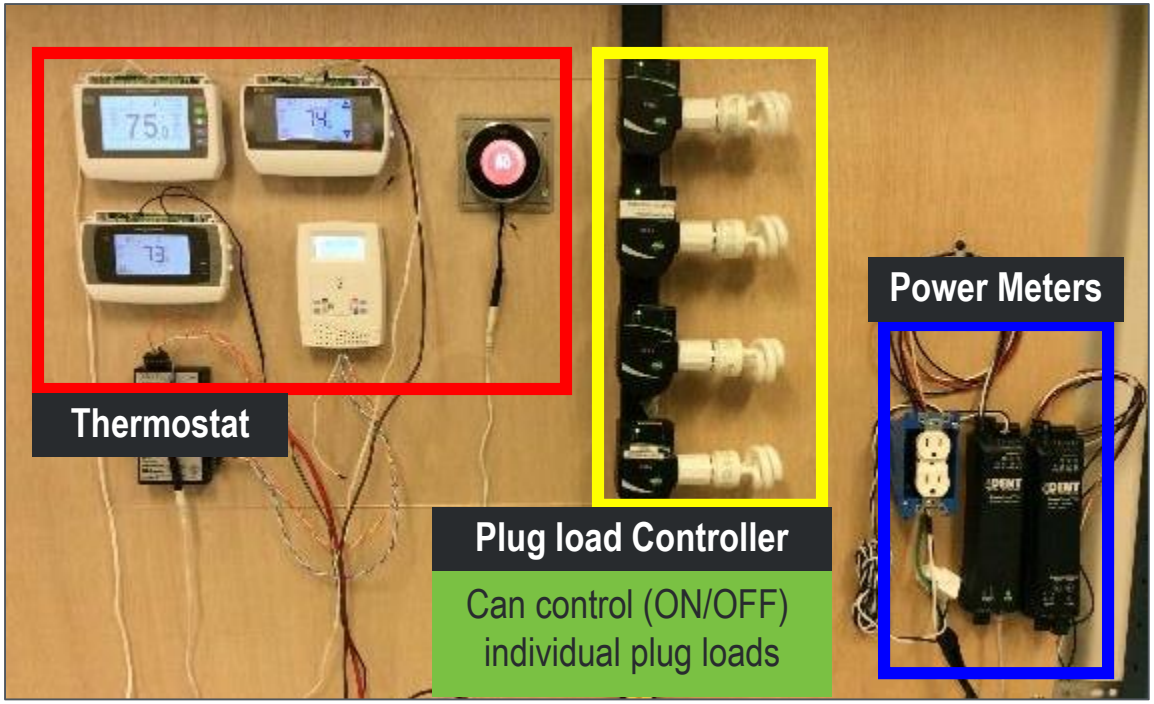
BEMOSS COMMUNITY

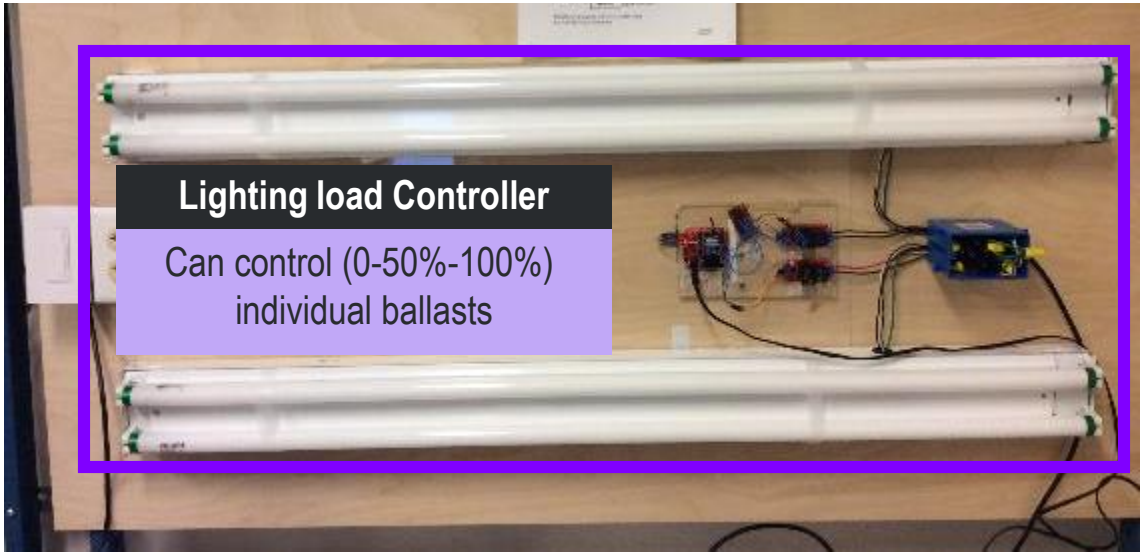
BEMOSS

Laboratory Setup

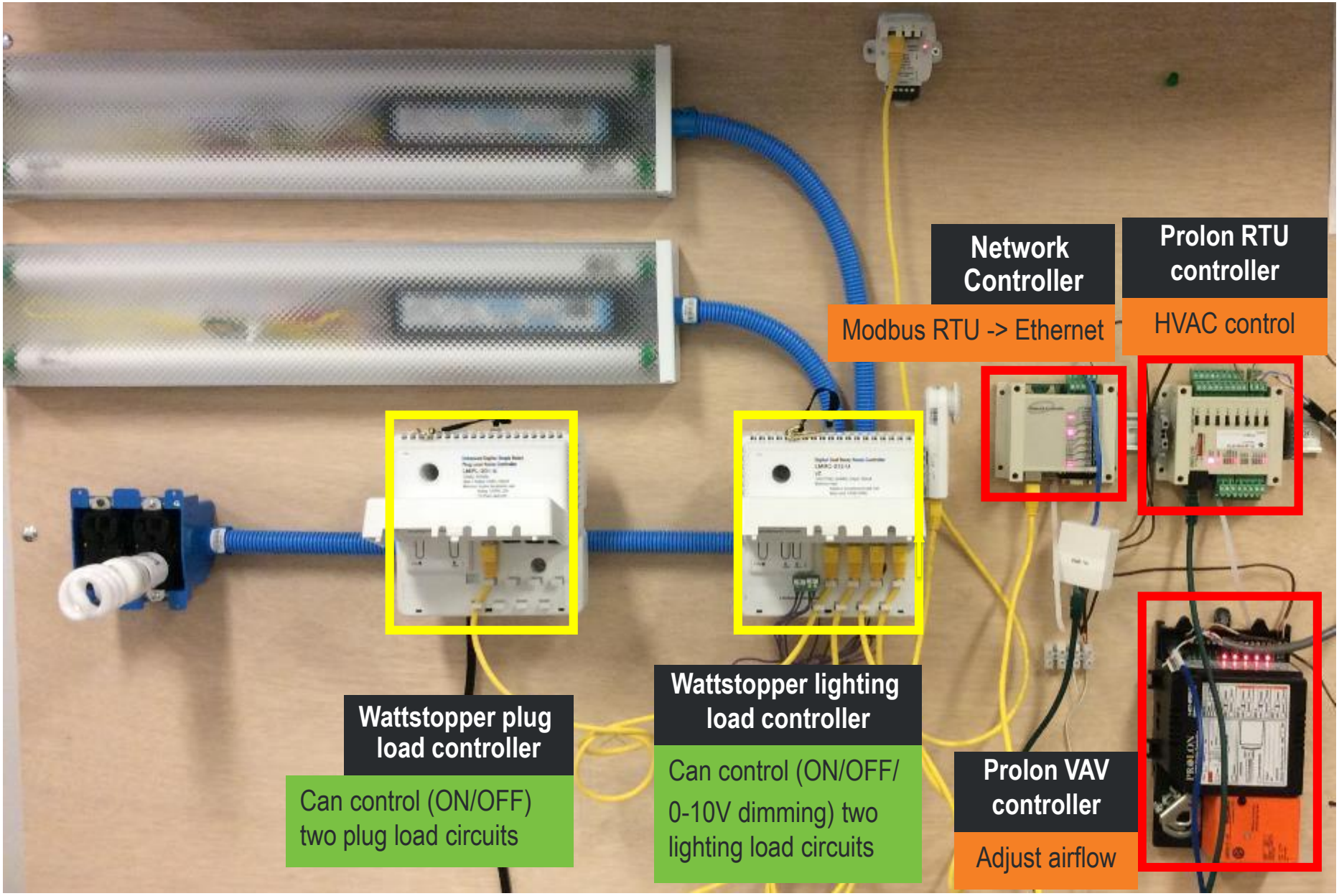
BEMOSS Laboratory Setup







Lighting/Plug Load Controllers & VAV/RTU Controllers



Thank You from BEMOSS Team

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- Multi-node communication
- App development
- Hardware integration
- AI & machine learning

Avijit Saha
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- API translators
- Multi-agent development
- Ease-of-installation & use
- Auto-discovery, plug-n-play
- Hardware integration

Kruthika Rathinavel
(Graduate Student)
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- User interface

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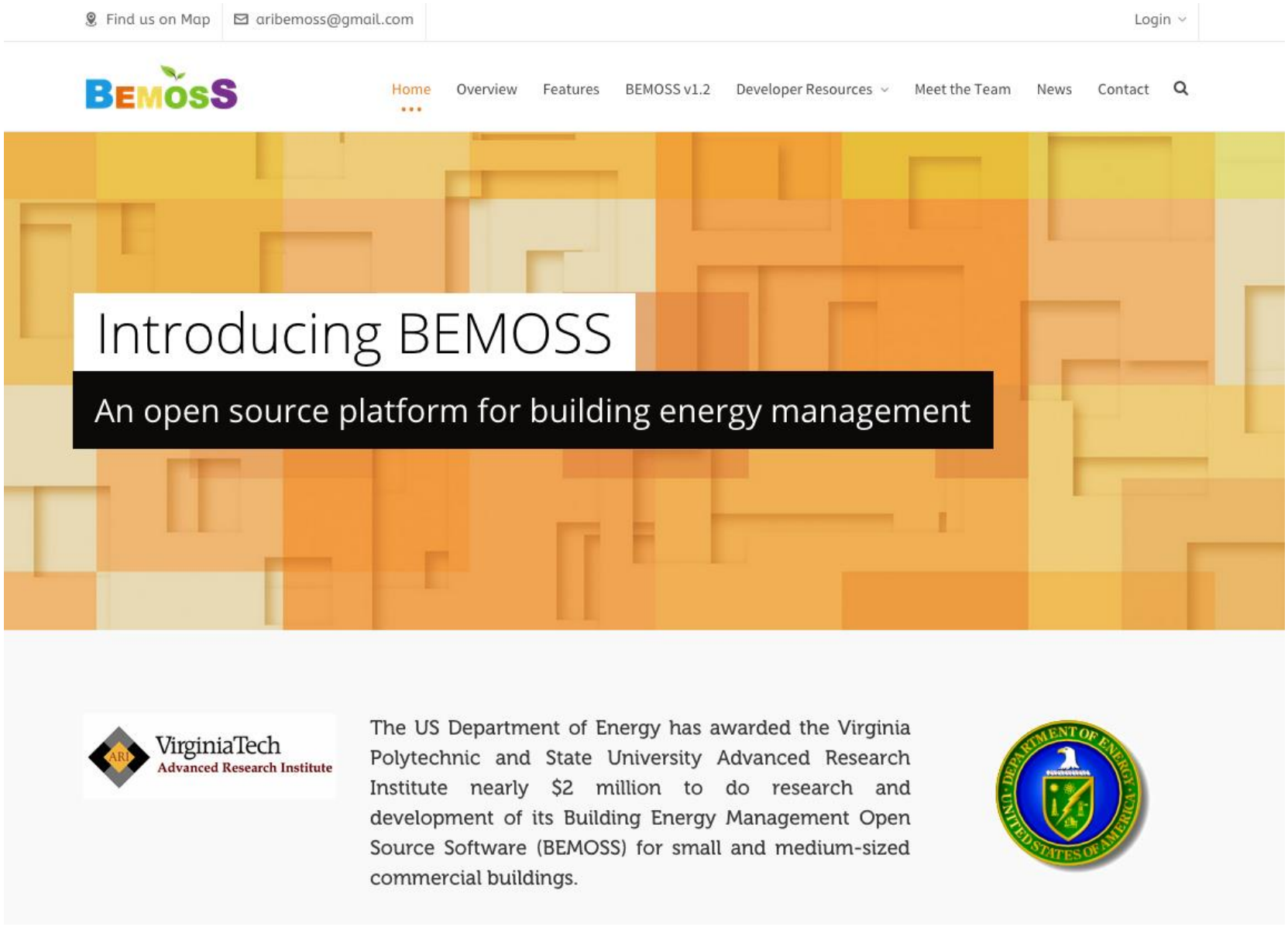
BEMOSS.org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Introducing BEMOSS
An open source platform for building energy management
VirginiaTech
Advanced Research Institute
The US Department of Energy has awarded the Virginia Polytechnic and State University Advanced Research Institute nearly $2 million to do research and development of its Building Energy Management Open Source Software (BEMOSS) for small and medium-sized commercial buildings.

BEMOSS Wiki Page

BEMOSS

Building Energy Management Open Source Software

Building Energy Management Open Source Software (BEMOSS) is an operating system that is engineered to improve sensing and control of equipment in small- and medium-sized commercial buildings. BEMOSS aims to offer: scalability, robustness, plug and play, open protocol, interoperability, cost-effectiveness, as well as local and remote monitoring. This allows BEMOSS to work with load control devices form different manufacturers that operate on different communication technologies and protocols. BEMOSS supports the following prevalent communication technologies: Ethernet (IEEE 802.3), Serial (RS-485), ZigBee (IEEE 802.15.4) and Wi-Fi (IEEE 802.11); and protocols: BACnet, Modbus, Web, ZigBee API, OpenADR and Smart Energy Profile (SEP) protocols.

The alpha (Sept 2014) release of BEMOSS is **"BEMOSS Lite"**, which supports thermostats that use a Wi-Fi USNAP module (CT30 and CT50), Philips Hues, and WeMo smart plugs. Click **here** to find out more about currently supported devices and what to expect when the full BEMOSS operating system is released.


BEMOSS Overview


BEMOSS Features

BEMOSS Lite


Installation Guide


Developer Resources


BEMOSS Team