Key Developments in the Cal openBAS (UCB, UCD, LBNL)

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5/8/14

Typical OpenBAS

External Agencies

Management Interfaces

Repositories:
- sMAP Drivers
- Discovery registry
- Application registry
- Configurations

TimeSeries, Metadata Database

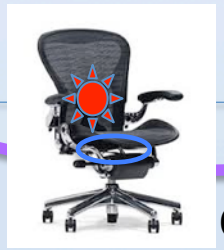
AC/Heat

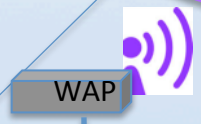
Lighting

OpenBAS "box" (e.g., embedded PC with sMAP source, Discovery)

Building Area Network

Connected Controllers





WAP

Lighting Gateway

Connected fixtures

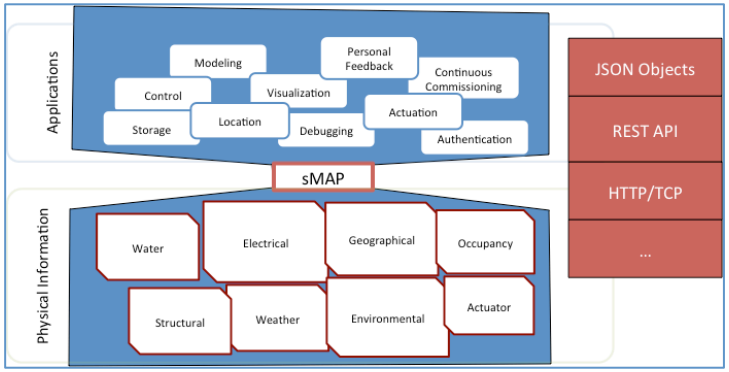
Ambient Interfaces

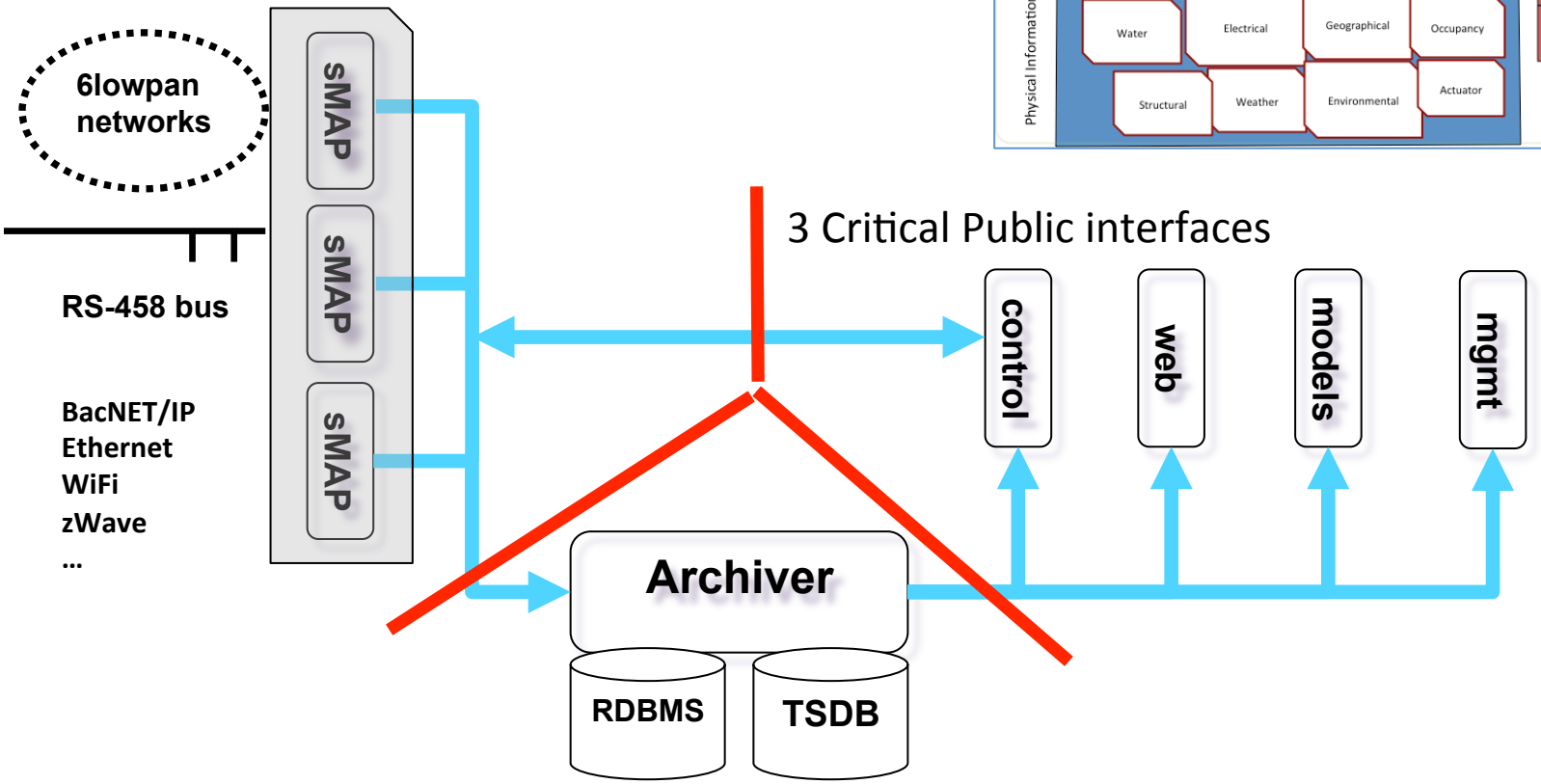
Personal Interfaces

Embrace the BAN (Building Area Network)

- Typical openBAS installation will have:
  - LAN (ethernet)
  - WiFi
  - LoWPAN
  - Proprietary links through a gateway
    - Zwave, LON, LED, …
- On premises gateway provides discovery function, stand-alone operation, configuration, applications
  - … local openBAS environment plus connection to others, to the cloud, …

Common start: sMAP open energy information system





- Represent, transmit data and metadata
- Abstract vast underlying heterogeneity into simple data model through open source drivers & gateways

- Provide fast access to archived data
- Fast RPCs
- Manage views, data cleaning

- Application-specific functionality built on exposed interfaces

- Incorporated into Voltron and many other solutions

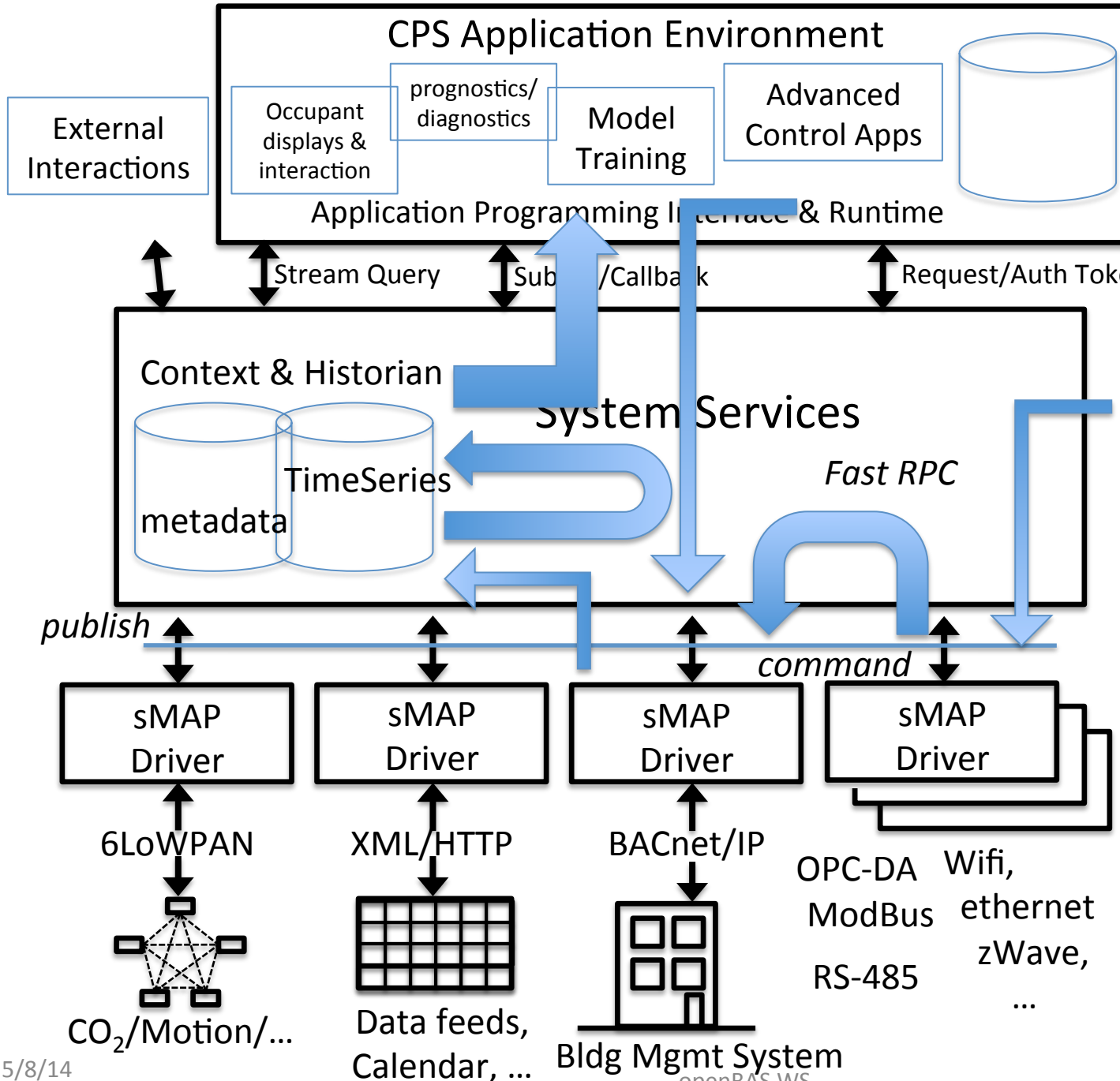
sMAP Drivers and Points

Name	Sensor Type	Access Method	Channels
ISO Data	**CAISO, NYISO, PJM, MISO, ERCOT, BPA**	**Web scrape**	**15081**
ACme devices	Plug-load electric meter	Wireless 6lowpan mesh	344
EECS submetering project	Dent Instruments PowerScout 18 electric meters	Modbus	4644
UC Berkeley submetering feeds	ION 6200, Obvius Aquisuite; PSL pQube, Veris Industries E30	Mosb	4269
Sutardja Dai, Brower Hall BMS, UCB broadwin	**Siemens Apogee BMS, Legrand WattStopper, Johnson Control BM Barrigner/Broadwin**		**4064 22,000**
UC Davis submetering feeds	Misc., Schneider El		34 (+)
Weather feeds	Vaisala WX Wundergro	k/Modbus,	33
CBE PMP toolkit	Dust motes;	V import; serial	874
NOA Weather Forecast	**Meteorologic etc)**	**Web**	**166000**
SDH Air Quality	CO2, Temp, TSR,	Wireless 6lowpan mesh	50
Soda Hall BMS	**Temp sensors, ai w sensors, other building infrastructure sensors**	**RPC**	**1600**
Tstats (RCA, Prolifics, …)	**Set points, temp, humidy, fan**	**Varied**	
Lighting Controllers (Hue, TCP, enlighted, …)	**State, status, hue, dim**	**Varied**	
Plug controllers	**Relay**	**Varied**	

~270,000 points
40 billion readings
150 GB compressed (10x)
300-600 write points per second typical

sMAP infrastructure advances

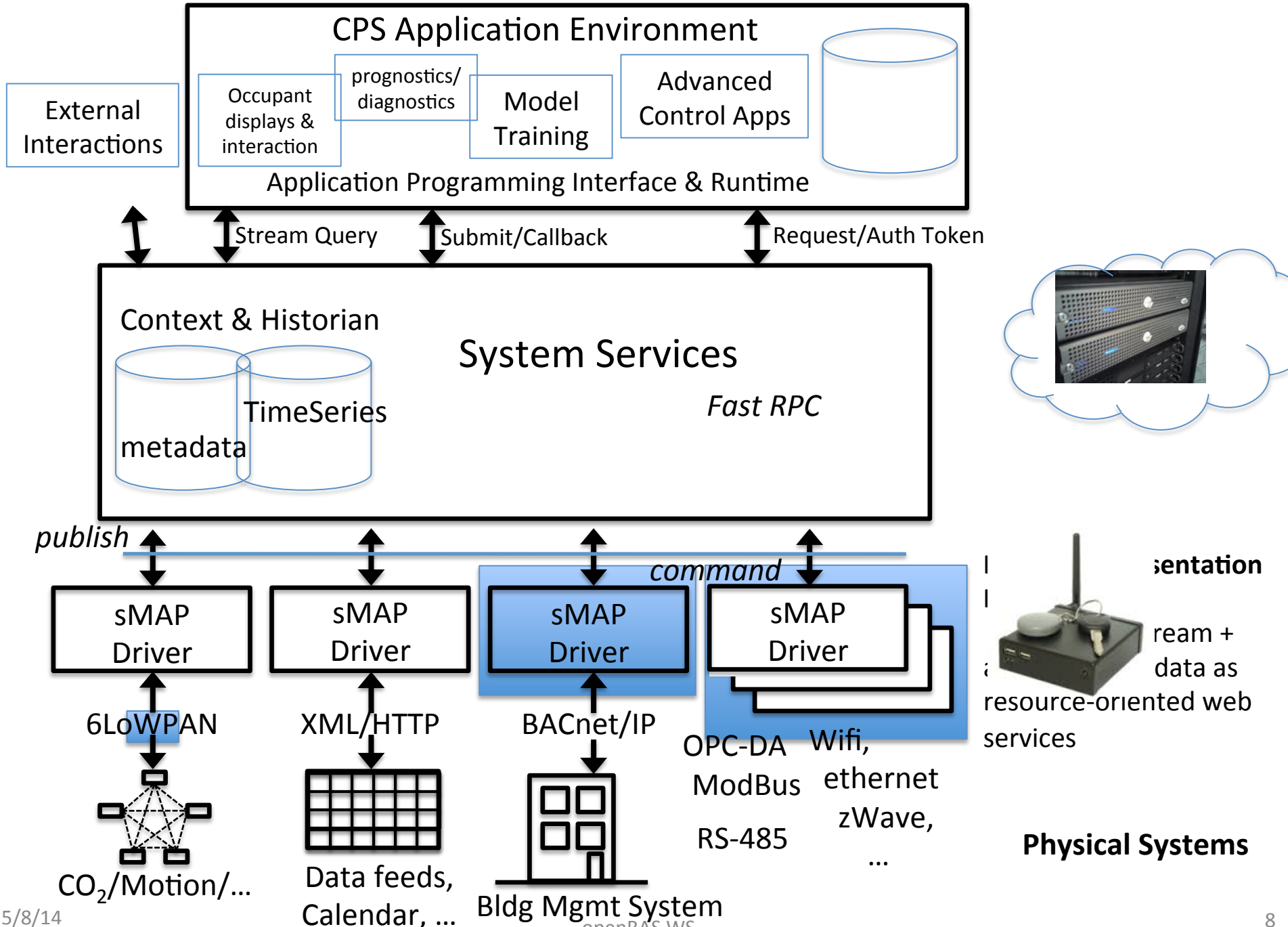
- Continued to harden & refine, improve distribution, expand driver (i.e., device) base and community
- Incorporated as "HPL" into a Building Operating System and Services
  - Addresses openBAS small-to-med commercial with ability to scale to broader market
- Developed data cleaning and analytics processing pipeline and query language
  - Model formation, auditing, diagnostics, prognostics, …
  - Visualization, portals, …
- Much richer support for programmatic interactions, authentication and security



Hardware Presentation Layer

- JSON data stream + attribute metadata as resource-oriented web services

Physical Systems


CPS Application Environment
External Interactions
Occupant displays & interaction
prognostics/ diagnostics
Model Training
Advanced Control Apps
Application Programming Interface & Runtime
Stream Query
Submit/Callback
Request/Auth Token
Context & Historian
metadata
TimeSeries
System Services
Fast RPC
publish
command
sMAP Driver
sMAP Driver
sMAP Driver
sMAP Driver
6LoWPAN
XML/HTTP
BACnet/IP
OPC-DA
ModBus
RS-485
Wifi,
ethernet
zWave,
…
CO2/Motion/…
Data feeds, Calendar, …
Bldg Mgmt System
sentation
ream +
data as
resource-oriented web
services
Physical Systems

Auto Discovery and Auto Configuration

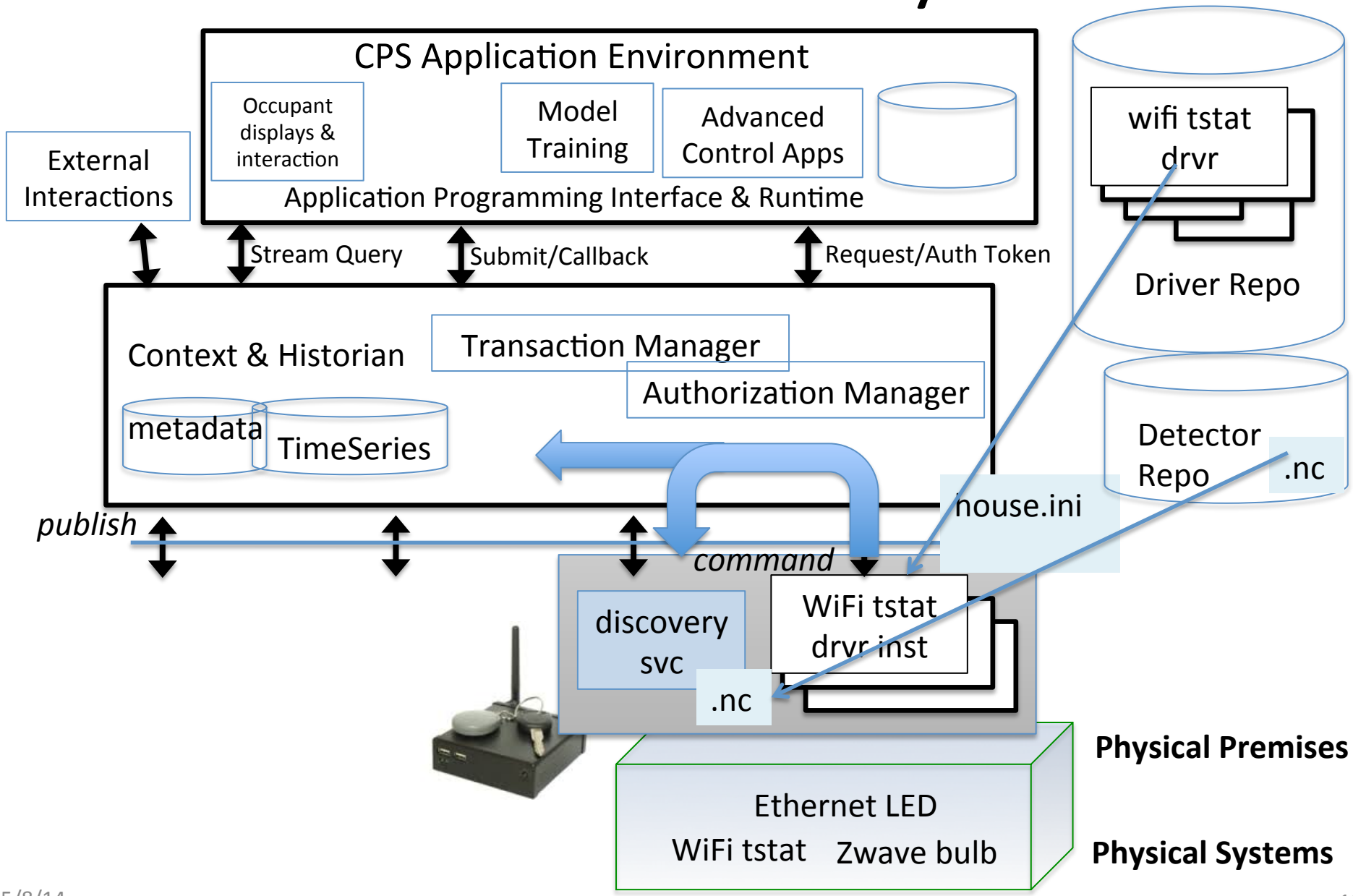
- Ideally, openBAS devices would speak an open standard discovery protocol
  - zeroConf, Bonjour, …

  But in reality, … most don't … and many won't
- Need autodiscovery of devices that speak no particular discovery protocol
  - => actively probe devices that join
  - => identify make & model through active probing
  - => locate and download drivers

⇒ build initial auto-configuration

⇒ Location & use specific metadata

Auto-Discovery

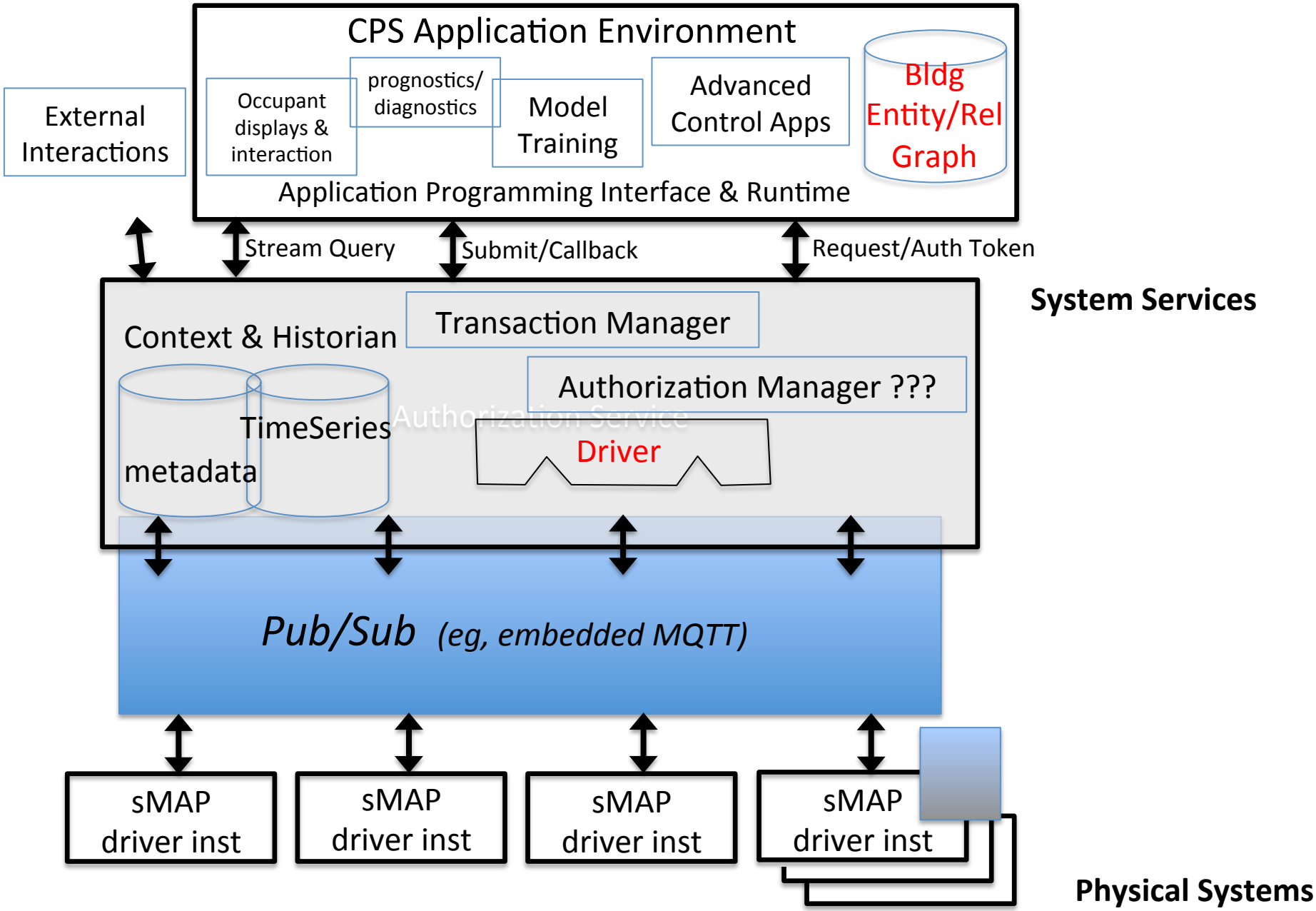


Publication & Syndication

- s in sMAP is for “simple”
- Simple (restrained) pub/sub paradigm naturally represented a resource-oriented architecture as RESTful web services
- Pull: openBAS applications demanded richer device-to-device interactions
  - i.e., a more general pub/sub model
- Push: pub/sub ‘classic’ MQTT went through an open source renaissance with Mosquito broker
  - Widely used in embedded networks

⇒integrated an improved MQTT with sMAP

⇒All resources are topics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Bldg Entity/Rel Graph
Application Programming Interface & Runtime
Stream Query
Submit/Callback
Request/Auth Token
System Services
Context & Historian
Transaction Manager
Authorization Manager ???
Authorization Service
TimeSeries
metadata
Driver
Pub/Sub (eg, embedded MQTT)
sMAP driver inst
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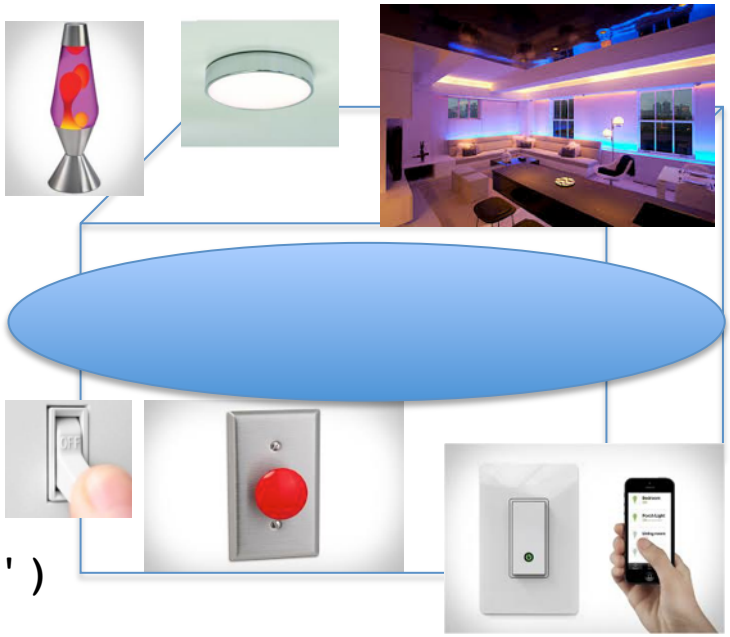
Physical Systems

openBAS application engine

- Execution container and simple domain-specific language for typical openBAS applications
  - Reconfigurable control, multi-zone coordinated control, multi-system coordinated control, model-predictive control, coordinated schedules, multi-modal sequence of operations, reactive management (DR, DCV, daylighting, …), …
- Target language for high level tools, user interfaces, portals, …

Ex: Reconfigurable control



```
mapping = {'switch0': ['light0'],
           'switch1': ['light1']}
```

```
import openbas.rules.rules as rules
from smap.client import SmapClient
c = SmapClient('http://localhost:8080')

@rules.when('switches/switch0/state', '==', 0)
def turnoff(*args):
    for light in mapping['switch0']:
        c.set_state('/lights/'+light+'/state_act',0)

@rules.when('switches/switch0/state', '==', 1)
def turnon(*args):
    for light in mapping['switch0']:
        c.set_state('/lights/'+light+'/state_act',1)
```

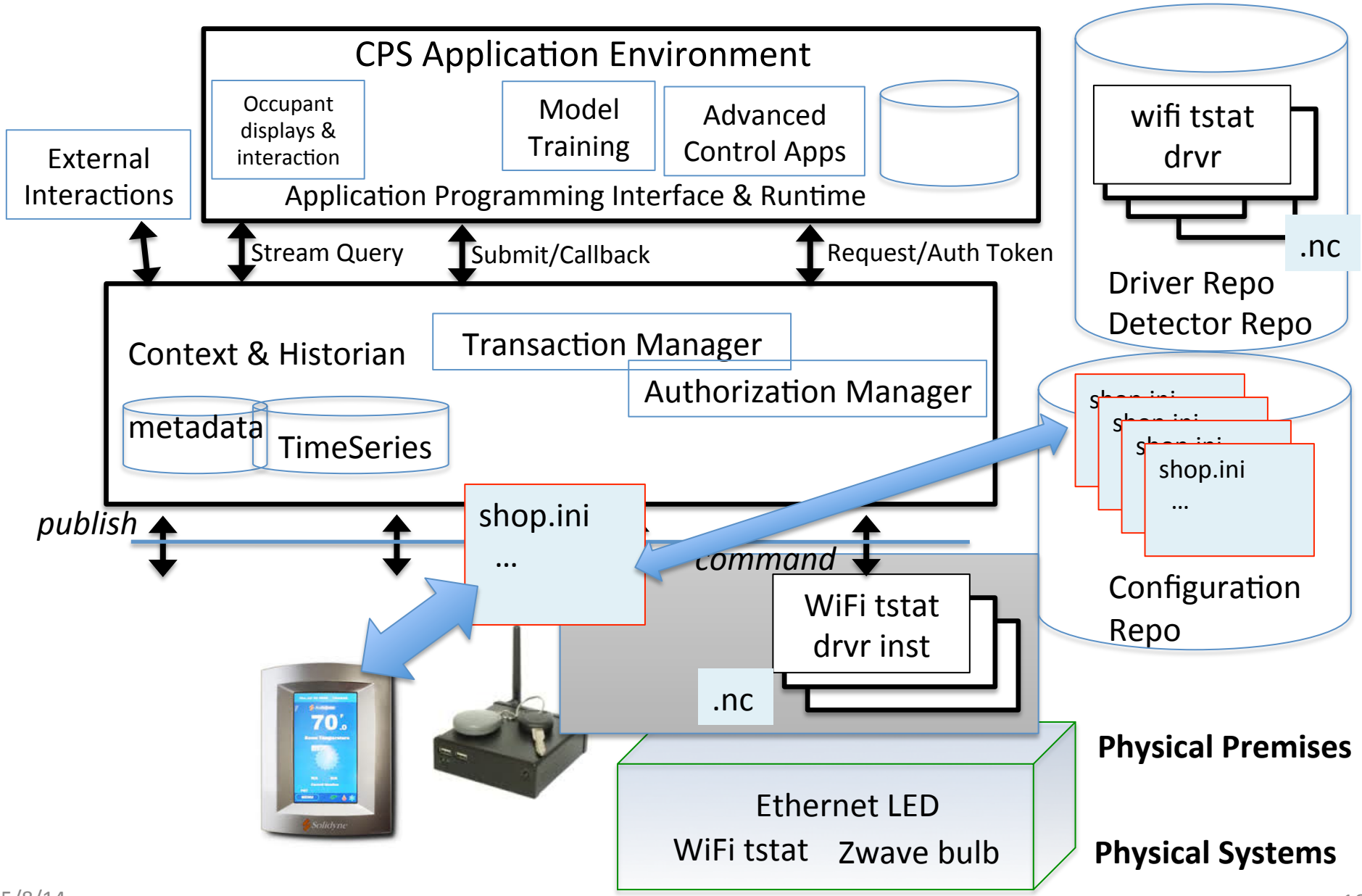
trigger

action

Total version control for CyberPhysical Systems

- Software and installation management has totally changed with version control (SVN, GIT) and network upgrade
- openBAS requires version control of drivers, applications, AND configurations
- Every change to the automated management of the physical space is commited and serialized

Total Version Control



ECTIONS HOME SEARCH

The New York Times

TECHNOLOGY

Hackers Lurking in Vents and Soda Machines

By NICOLE PERLROTH APRIL 7, 2014

Feb 5, 2014, 2:25pm CST

Report: Target hackers used HVAC company's credentials

John Vomhof Jr.
Staff reporter/broadcaster-
Minneapolis / St. Paul Business Journal
Email | Twitter | LinkedIn | Google+

The hackers behind the Target Corp. data breach reportedly entered the company through the vents.

BOSS Wide Area Verified Exchange

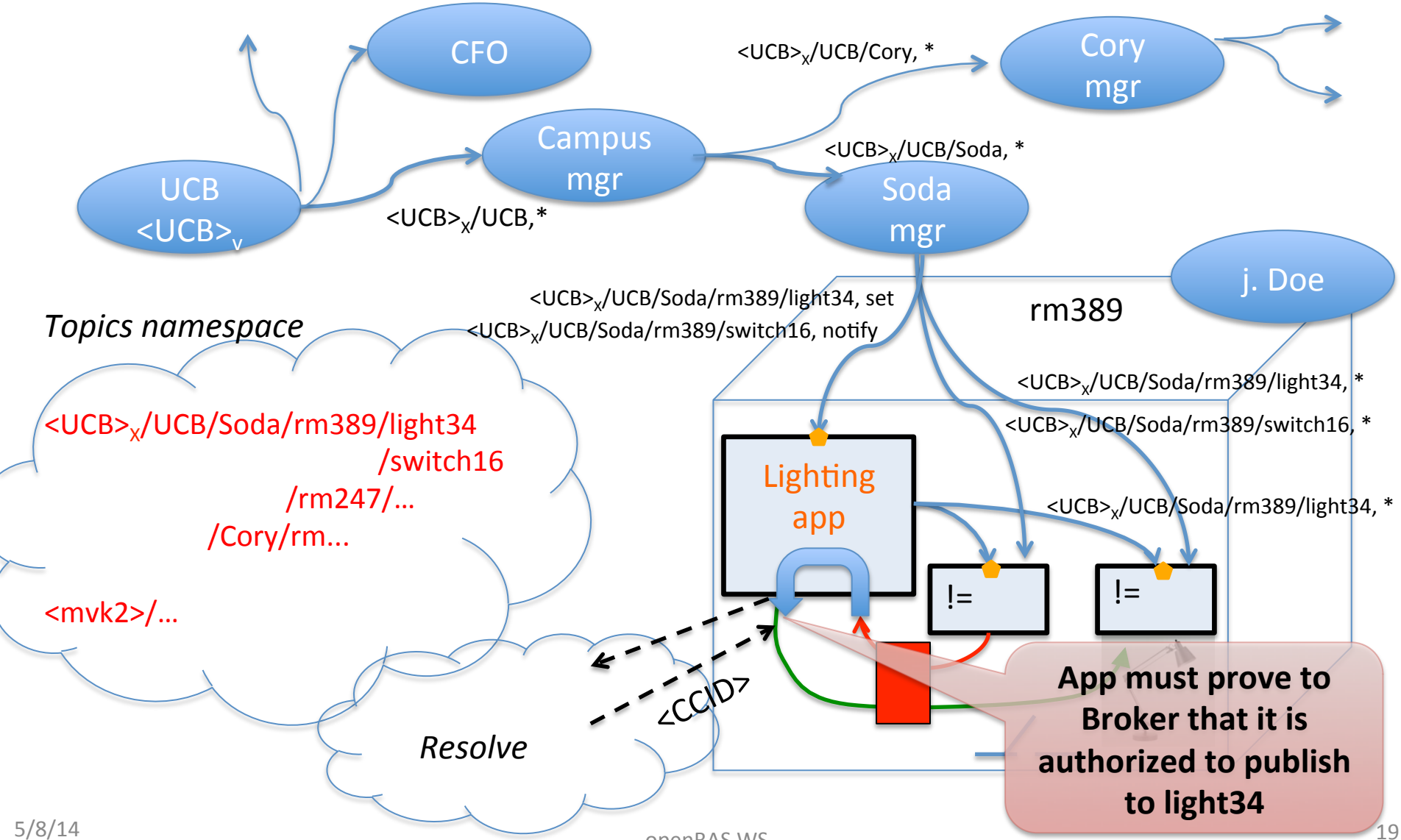
- Use the broker to prevent unauthorized access and denial of service
- Web of trust model, Decentralized
- Revocation
- Verify
  - Origin, Authorization of Operation, Target
- Limit
  - Processing of unauthorized ops, BW of fanout
- Tolerate
  - Intermittent connection

BOSSwave Illustration

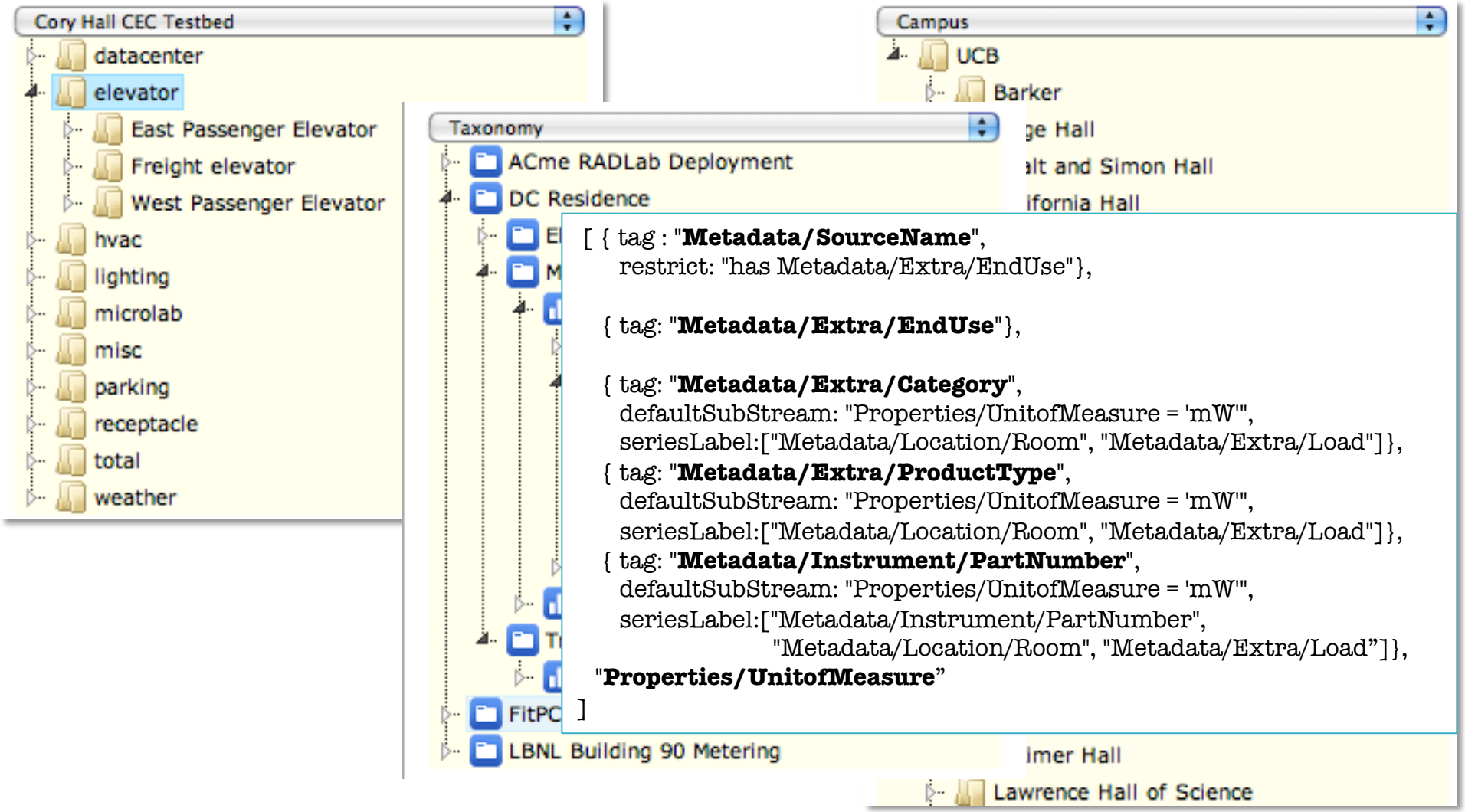
- WAVE URI : <nvk>/<path>/<op>

A $\xrightarrow[t,p]{}$ B_x D.o.T :

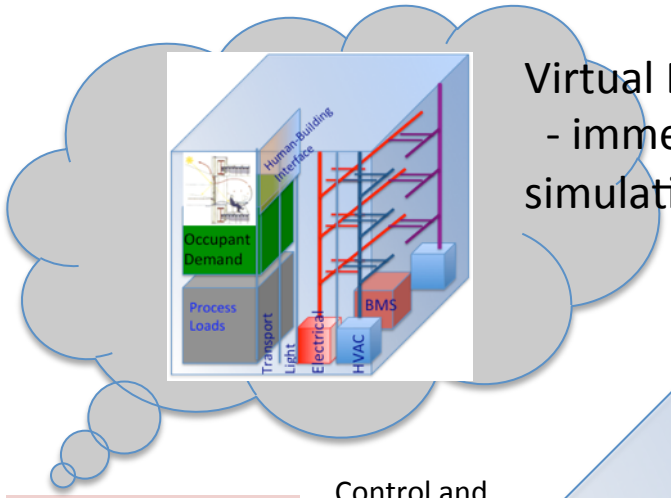
A grants B permission p to t, unforgeably



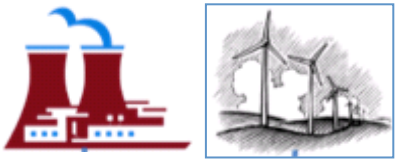
Auto-population of metadata – acquisition, boosting, and learning by example



Beyond CyberPhysical Building Systems



Virtual Building
- immersive, time travel, energy simulation, …



External

Planning

Visualization

Occupant Satisfaction

Multi-Objective Model-Driven Control

Empirical Models

Physical Models

BIM

Building Integrated Operating System

drvrs drvrs drvrs

Local Controllers

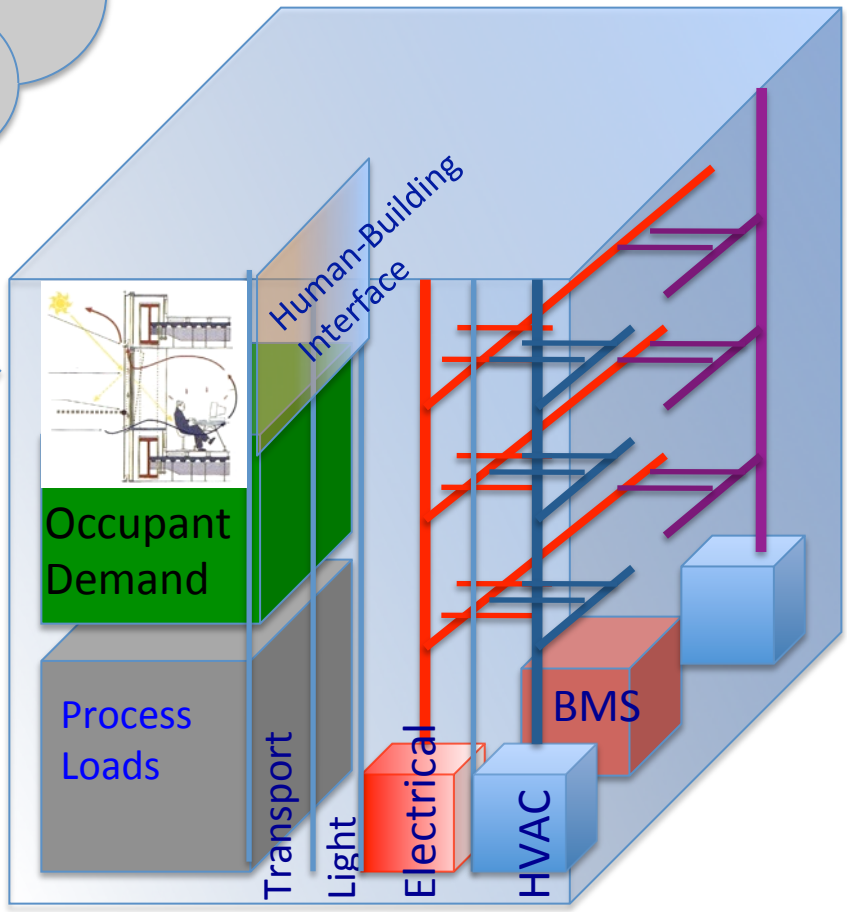
Security, Fault, Anomaly Detect &Management

Control and Schedule

Activity/Usage Streams

Pervasive Sensing

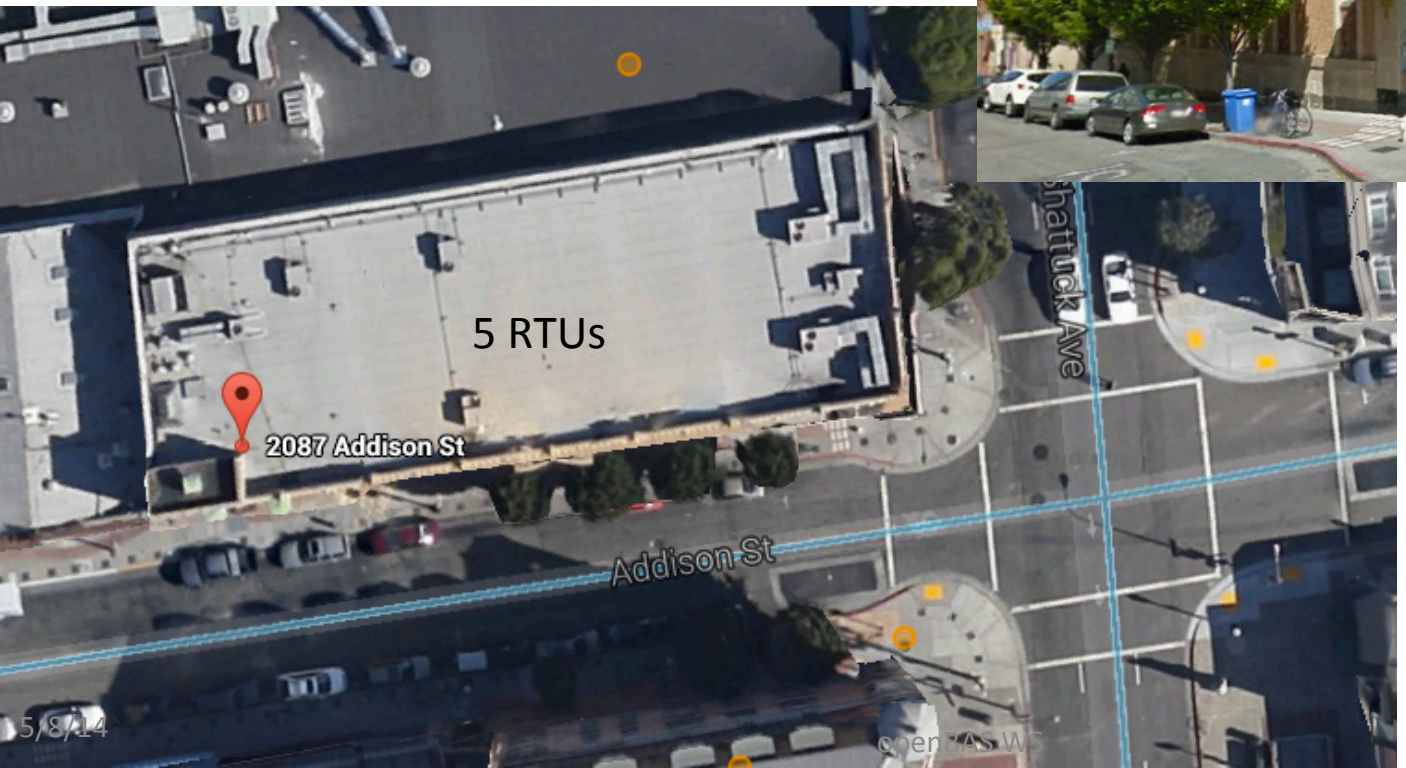
Legacy Instrumentation & Control Interfaces



Cyber Physical Building

final OpenBAS demo site: CIEE

2nd floor CIEE offices



Multiple Zones with 5 “stats”

Multi-zone Integrated thermal control
Wireless temp / co2 => advanced control
Integrated lighting, occupancy, thermal management
Integrated personal environmental control

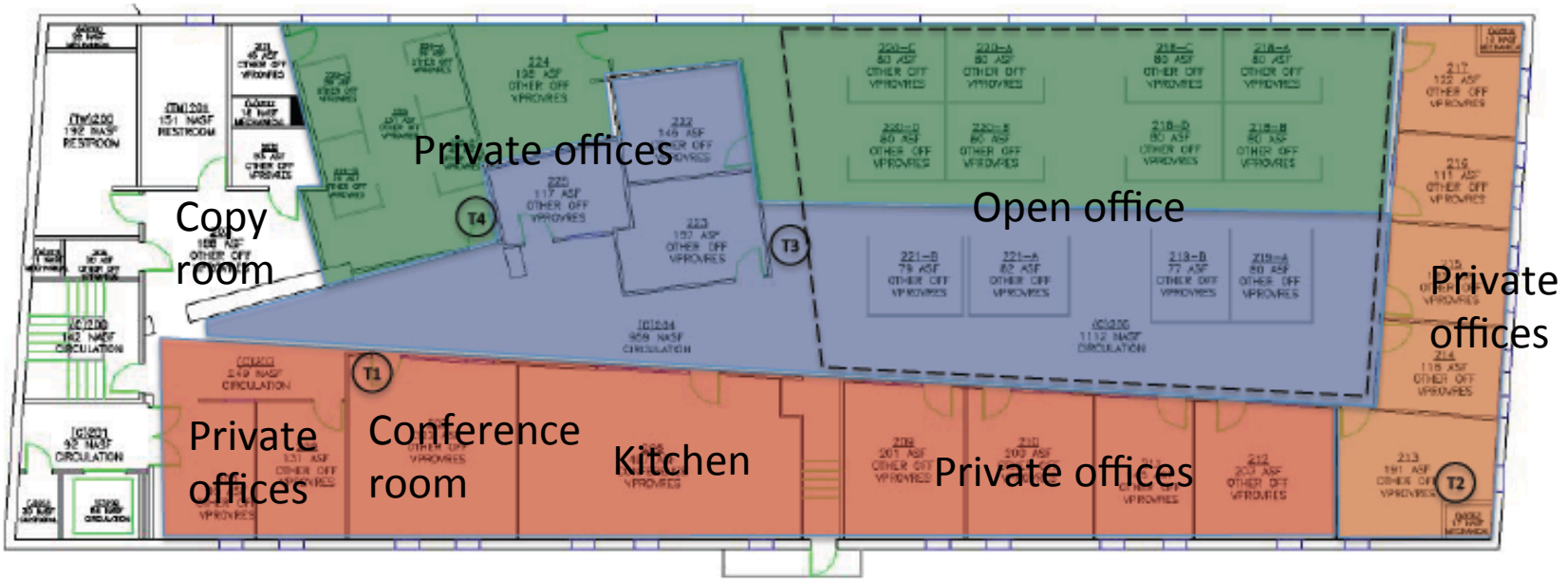
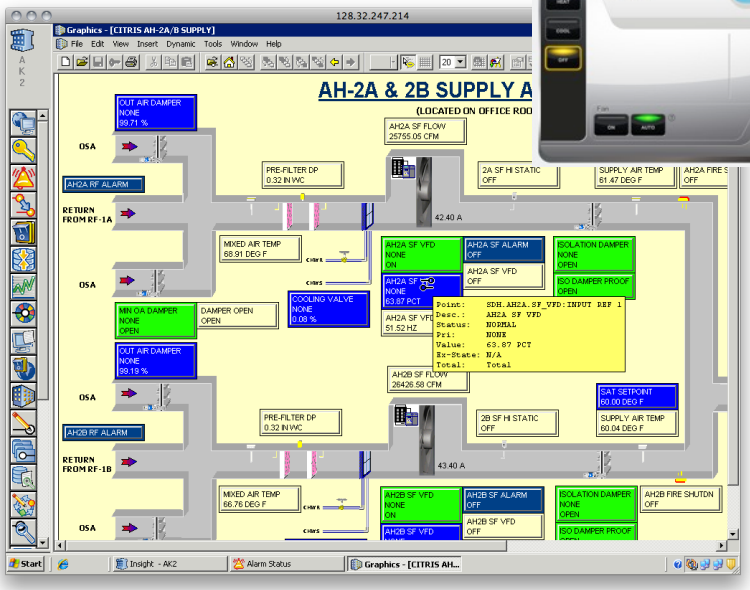


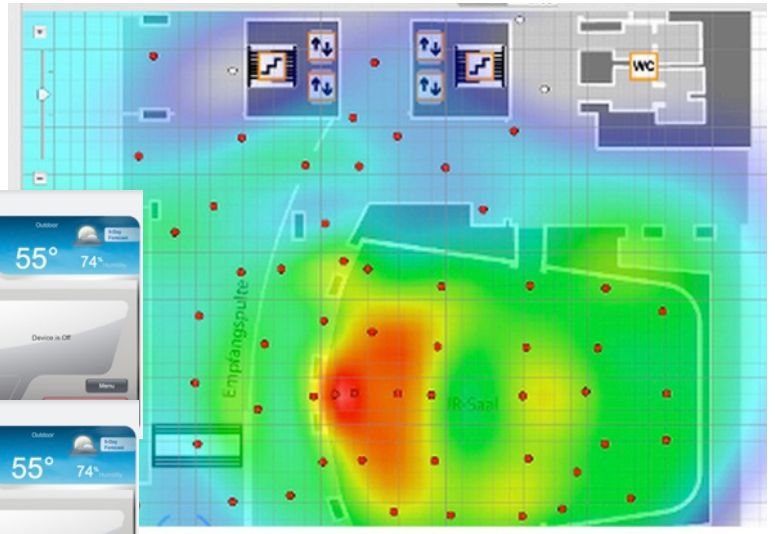
Figure 2: Thermal Zones and location of thermostats

And what will it look like when we re done?

Like a BMS



bunch of Xstats



Integrated Perspective