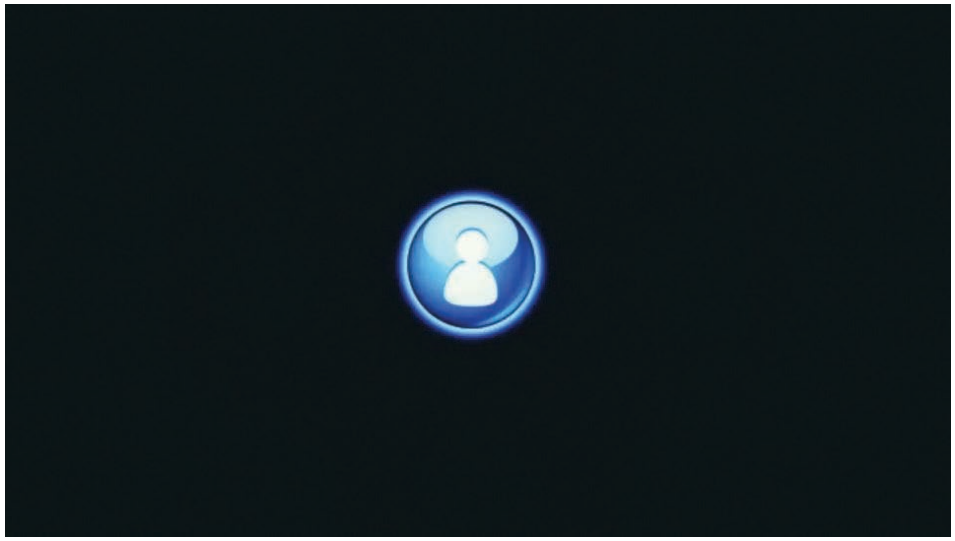

# Connecting the Cloud to Things

*Edward A. Lee*

*Invited Talk*

*Berkeley Cloud Workshop*

*February 27, 2015*



**Sponsored by the TerraSwarm Research Center, one of six centers administered by the STARnet phase of the Focus Center Research Program (FCRP) a Semiconductor Research Corporation program sponsored by MARCO and DARPA.**

# Berkeley Ubiquitous SwarmLab

The SwarmLab is an industry-university partnership pursuing “swarm technology.”

VISA IHI NEC SONY QUALCOMM ERICSSON TOSHIBA

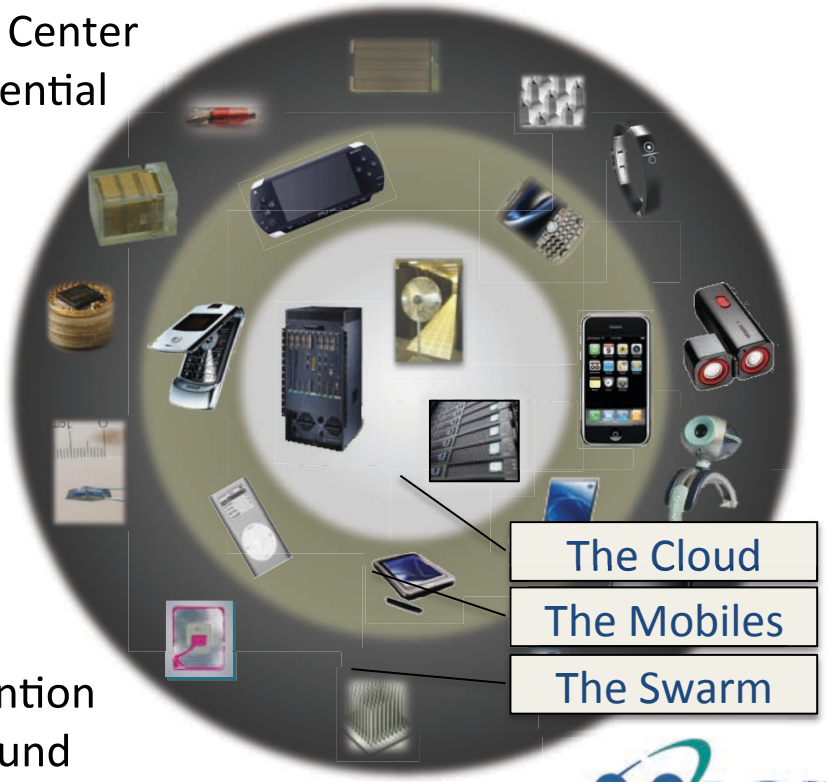
# The TerraSwarm Research Center 2013-2018

## What it is:

The TerraSwarm Research Center is addressing the huge potential (and associated risks) of pervasive integration of smart, networked sensors and actuators into our connected world.

## The Goal

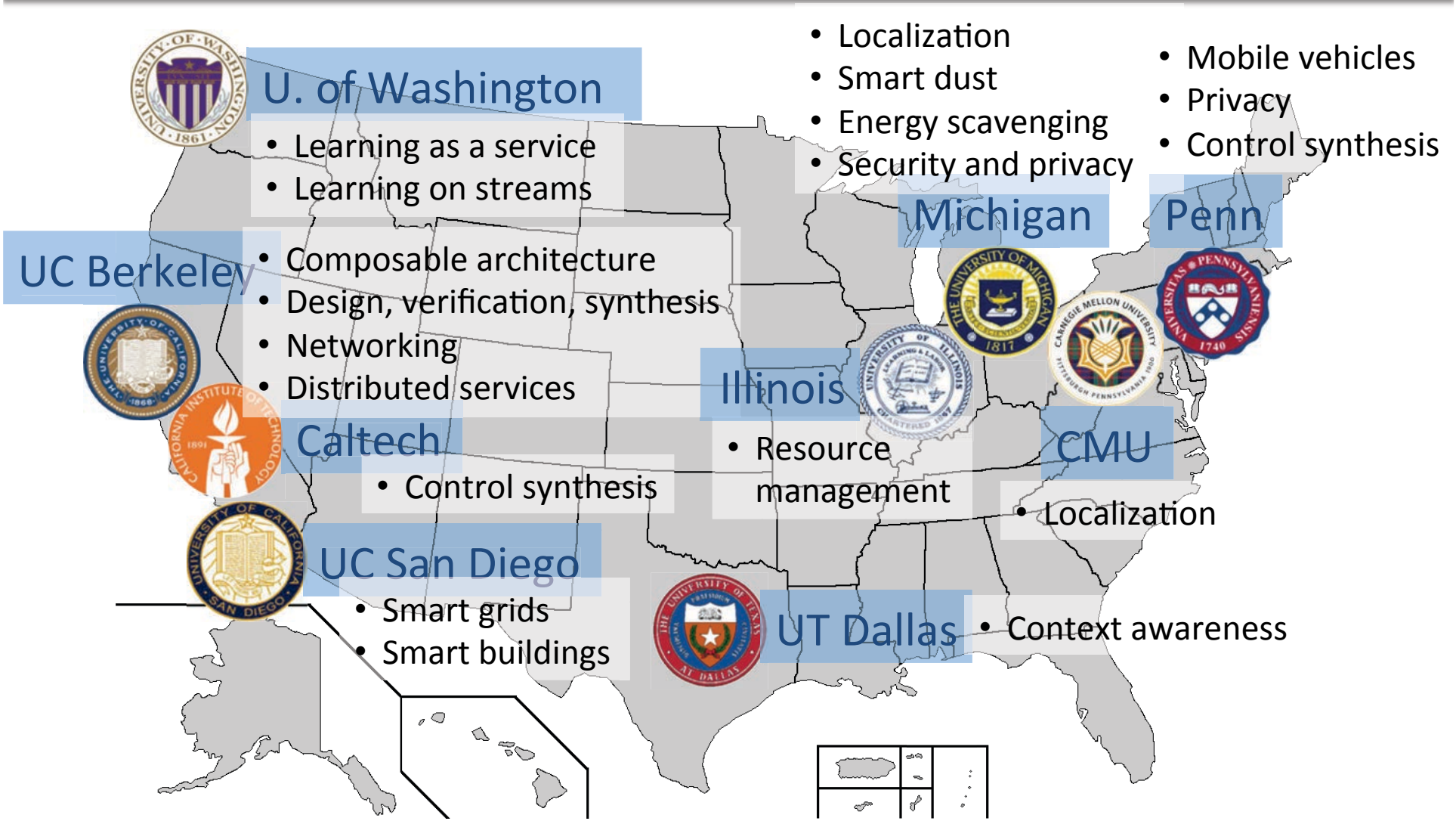
To lead the world in development of the platforms, methodologies, and tools that enable invention of creative, secure, and sound applications using networked sensors and actuators.




## The Sponsors:

DARPA
GLOBAL FOUNDRIES
IBM
intel
Micron
Raytheon
Texas Instruments
United Technologies

# TerraSwarm Sites



## U. of Washington
- Learning as a service
- Learning on streams

## UC Berkeley
- Composable architecture
- Design, verification, synthesis
- Networking
- Distributed services

## Caltech
- Control synthesis

## UC San Diego
- Smart grids
- Smart buildings

## Michigan
- Localization
- Smart dust
- Energy scavenging
- Security and privacy

## Illinois
- Resource management

## Penn
- Mobile vehicles
- Privacy
- Control synthesis

## CMU
- Localization

## UT Dallas
- Context awareness

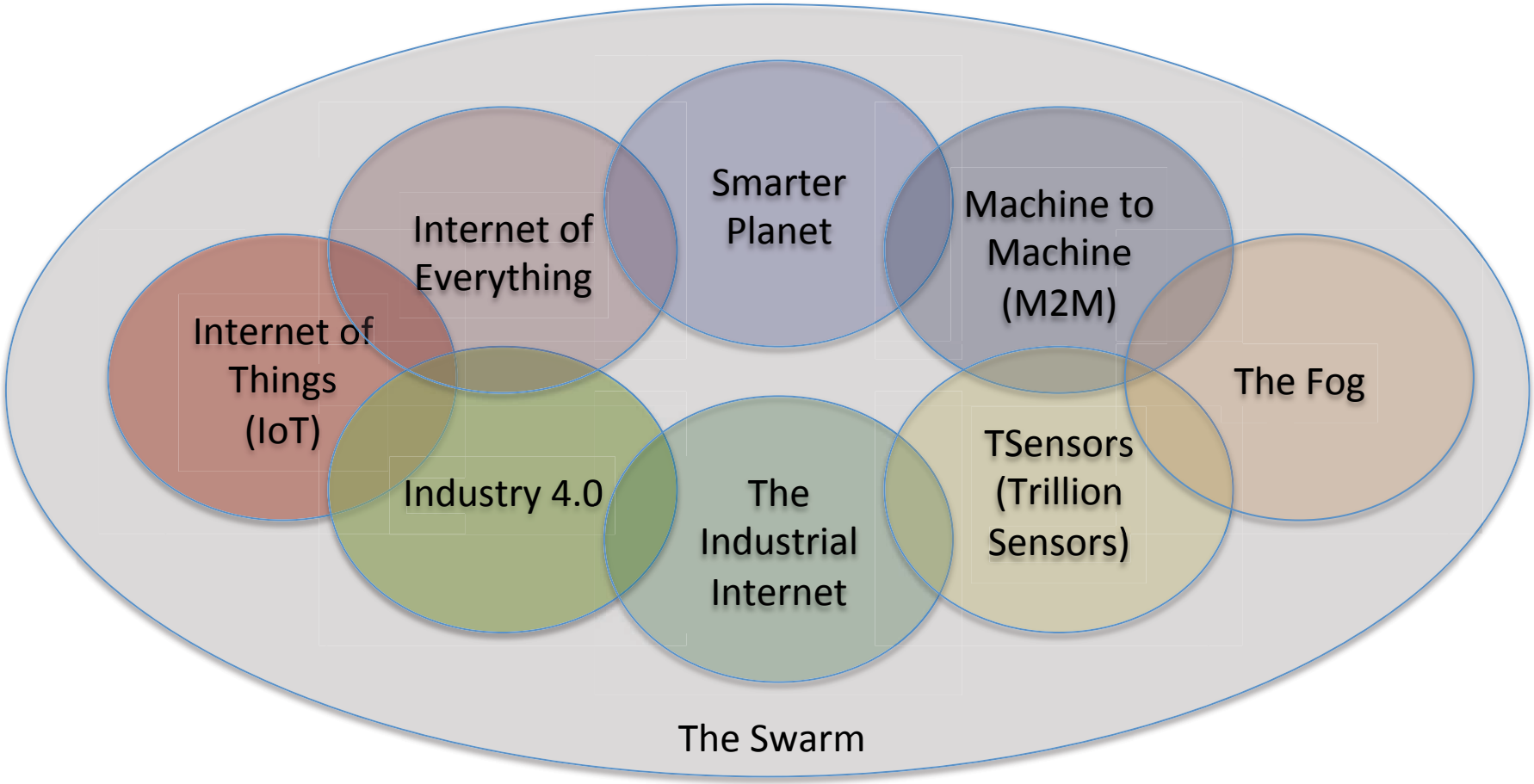
# In the last year…


# IoT has hit the fan!

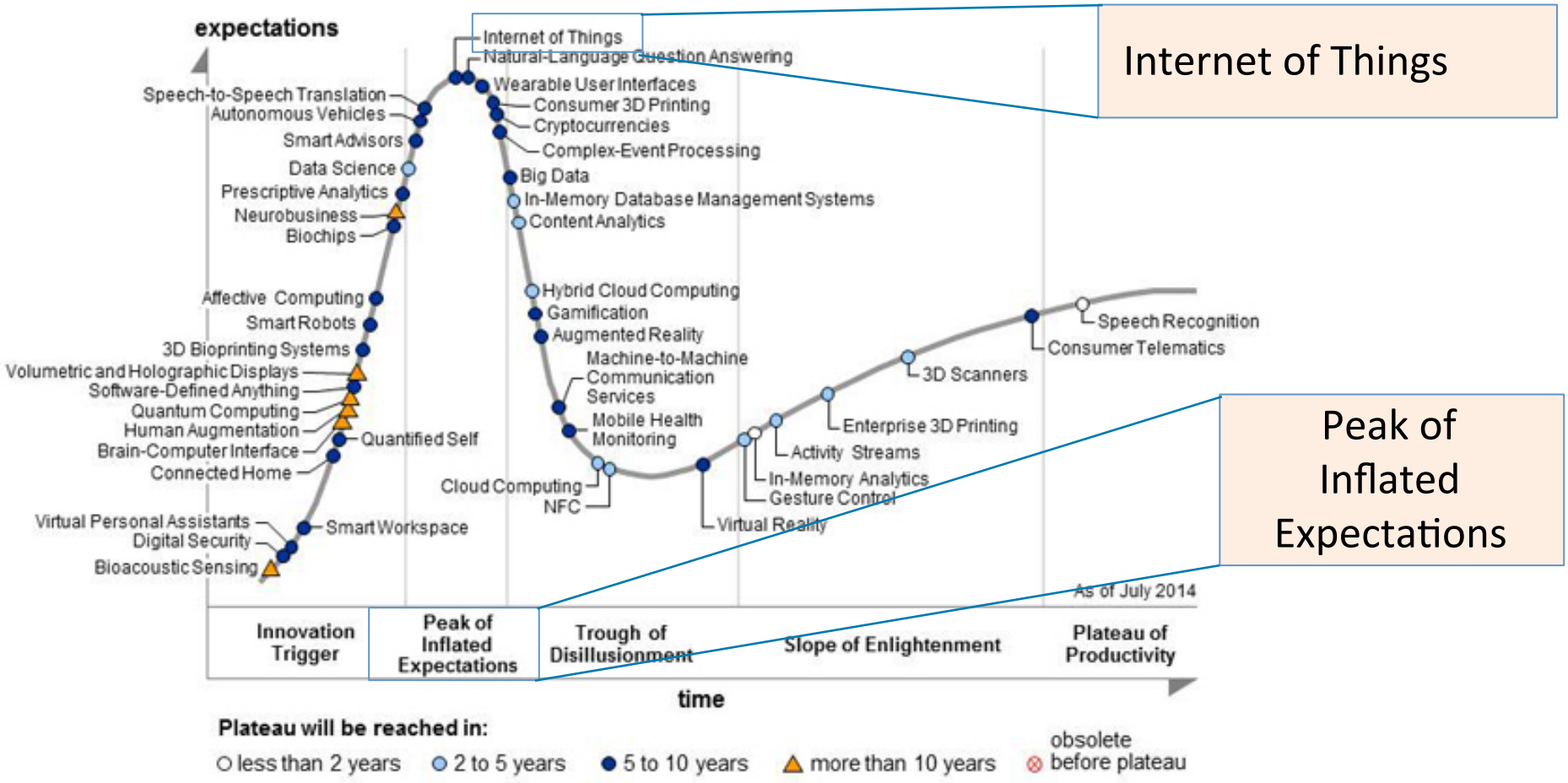


Image derived from: http://propercourse.blogspot.com

# The Buzz around the Swarm

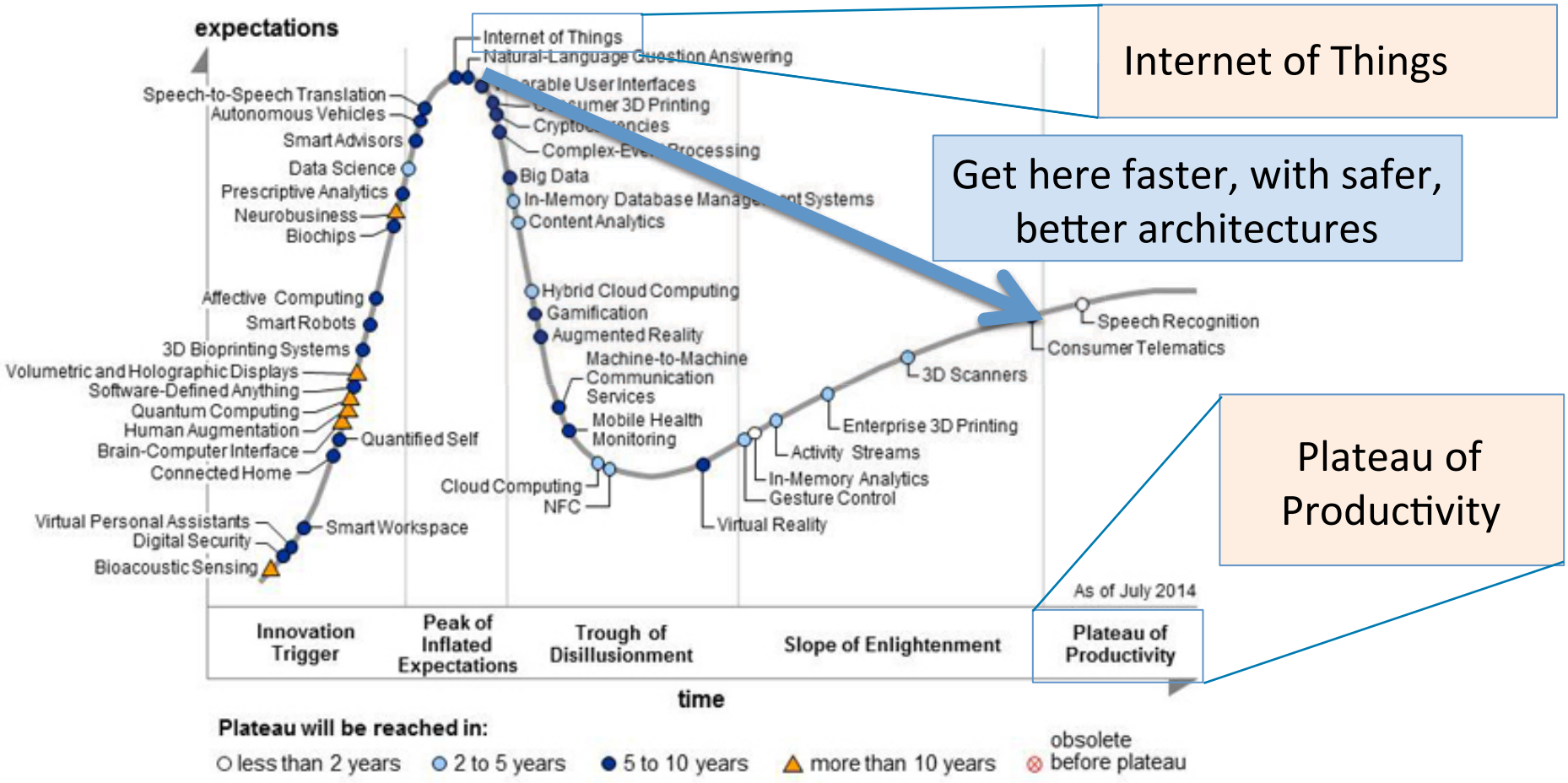


# Gartner Hype Cycle 2014




http://www.gartner.com/technology/research/hype-cycles/

# The Goal of TerraSwarm




http://www.gartner.com/technology/research/hype-cycles/

# In the last year… Startups!!!

designlines INTERNET OF THINGS

**News & Analysis**

## IoT Blooms in San Francisco

**Rick Merritt**

4/14/2014 09:00 AM EDT

7 comments

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SAN FRANCISCO — Less than an hour's drive north from Silicon Valley and a short walk from San Francisco's financial district, a new high-tech community is being born. Call it IoT Town.

Whistle

SKYCATCH

fitbit

AUTOMATIC


EE Times

Highway 1

LEMNOS Labs

WEARABLE WORLD

# In the last year… Disasters!!!

## Cyber attacks:

- Target
- Home Depot
- JP Morgan Chase
- Anthem
- …

## Vulnerabilities:

- Shellshock
- Heartbleed
- …

# Our Focus:
# The Internet of Important Things

Bosch-Rexroth

**Example:**

Print-on-demand printing press by Bosch Rexroth.

- 100s of microcontrollers
- Ethernet
- Clock synchronization
- TCP/IP
- Deterministic latency
- No packet losses
- Vast data source
- Safety-critical
- **Today: Isolated**
- **Tomorrow: Connected**

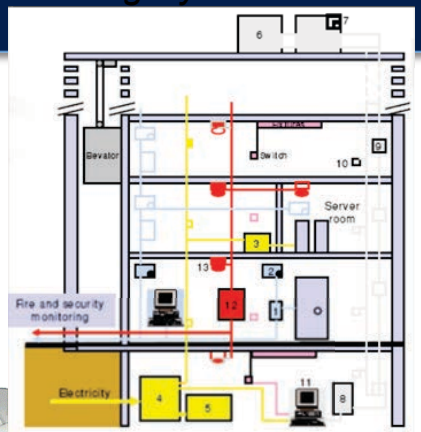
# Cyber-Physical Systems (CPS):

*Orchestrating networked computational resources with physical systems*

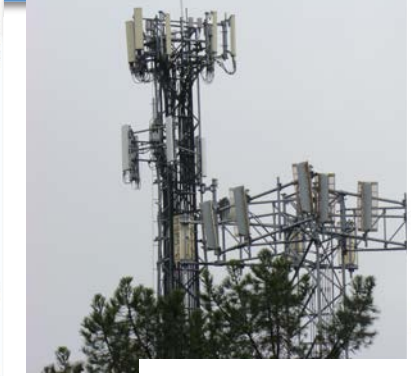
*Avionics*

*Transportation (Air traffic control at SFO)*

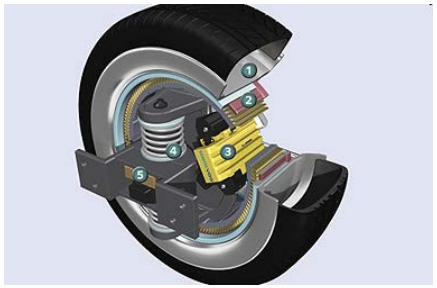
*Building Systems*



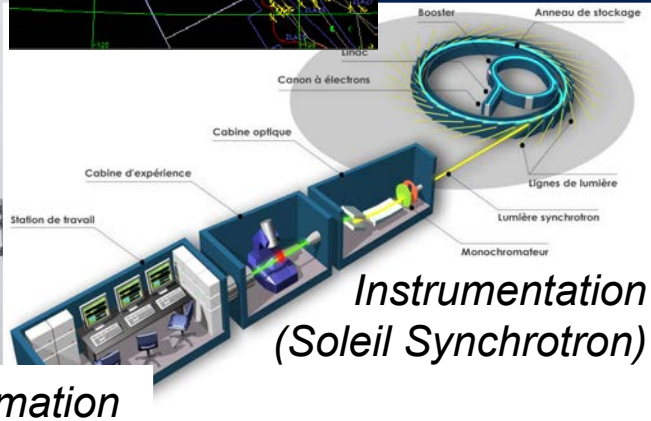

*Telecommunications*



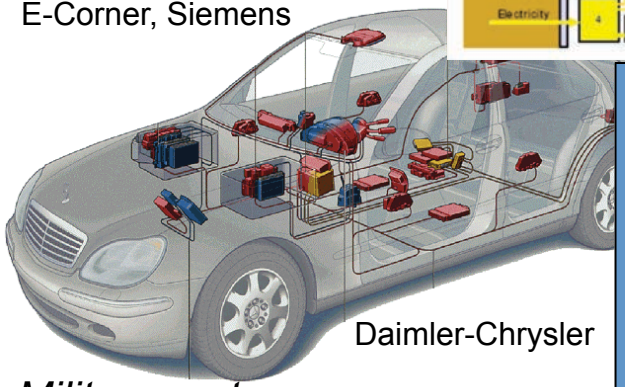
*Automotive*



E-Corner, Siemens




*Instrumentation (Soleil Synchrotron)*

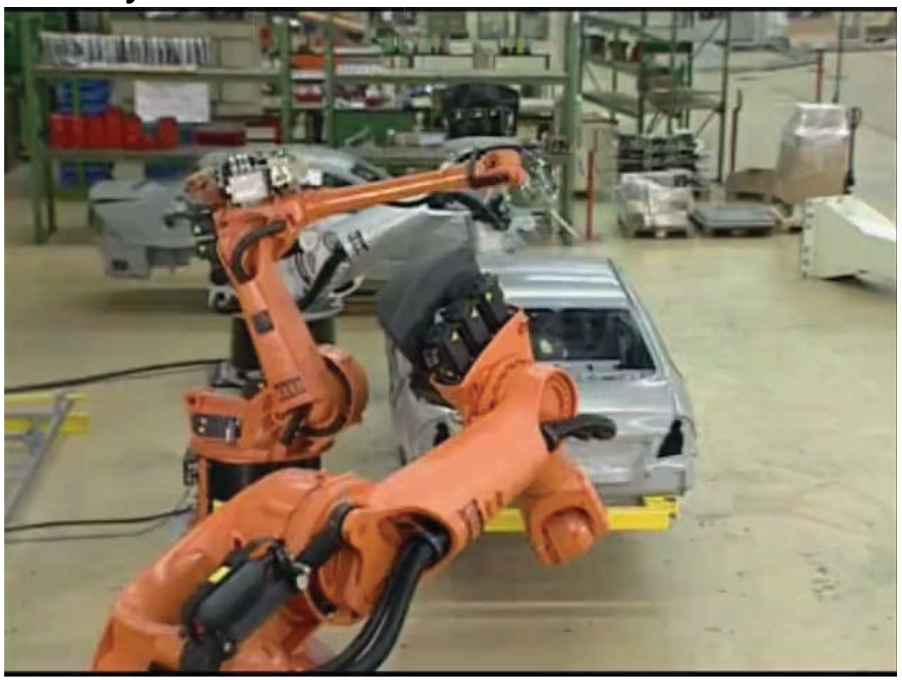


Daimler-Chrysler

*Power generation and distribution*

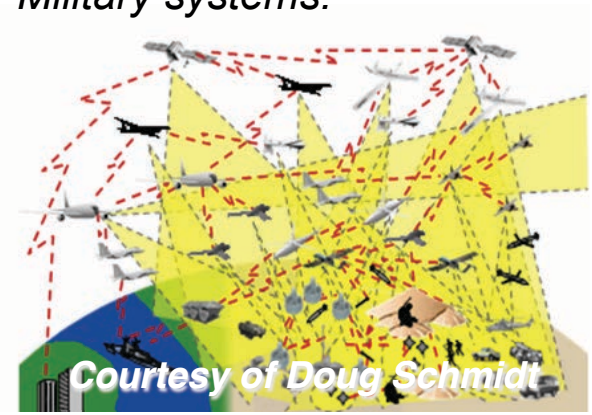
Courtesy of General Electric

*Factory automation*

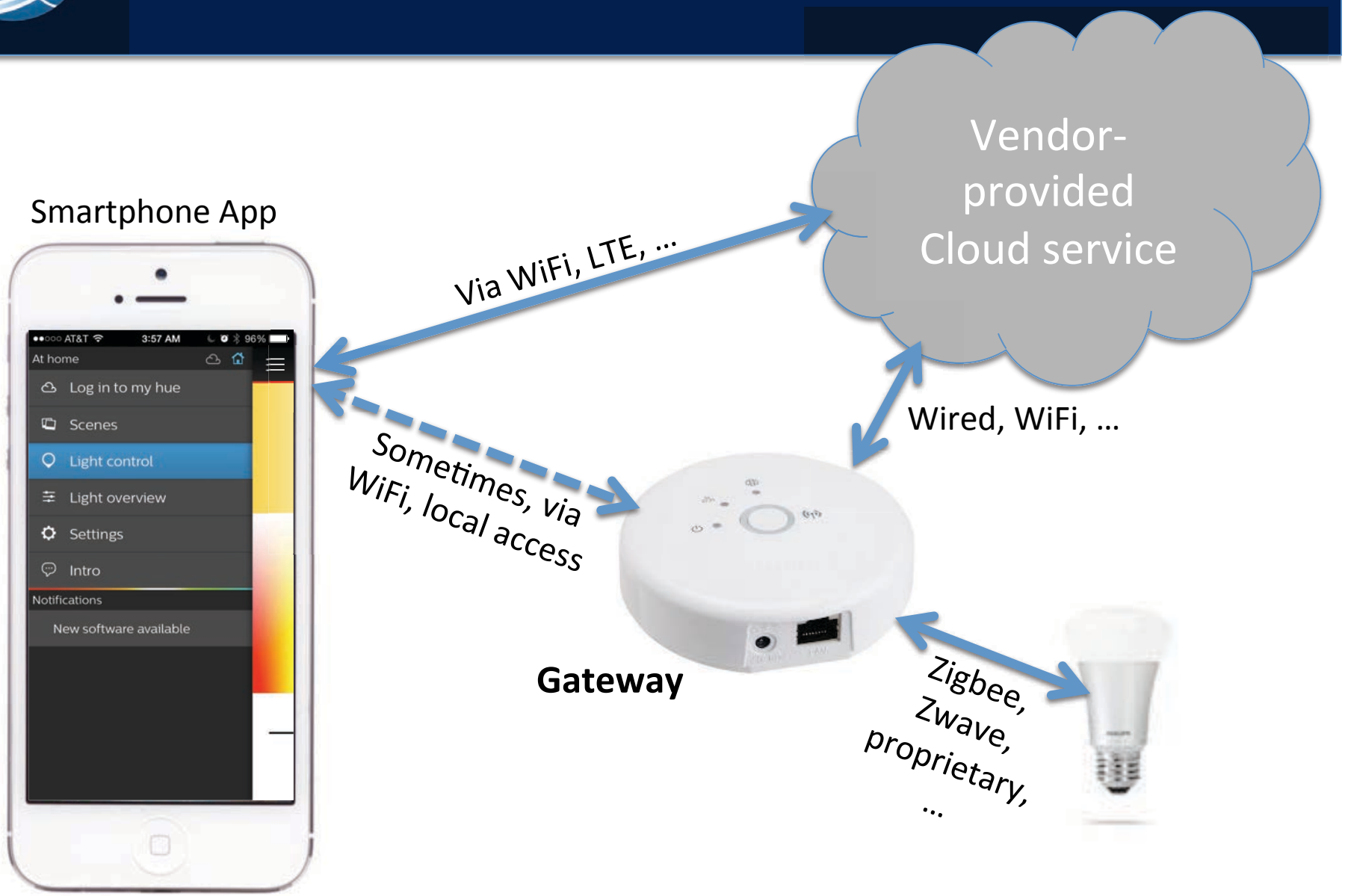


*Courtesy of Kuka Robotics Corp.*

*Military systems:*



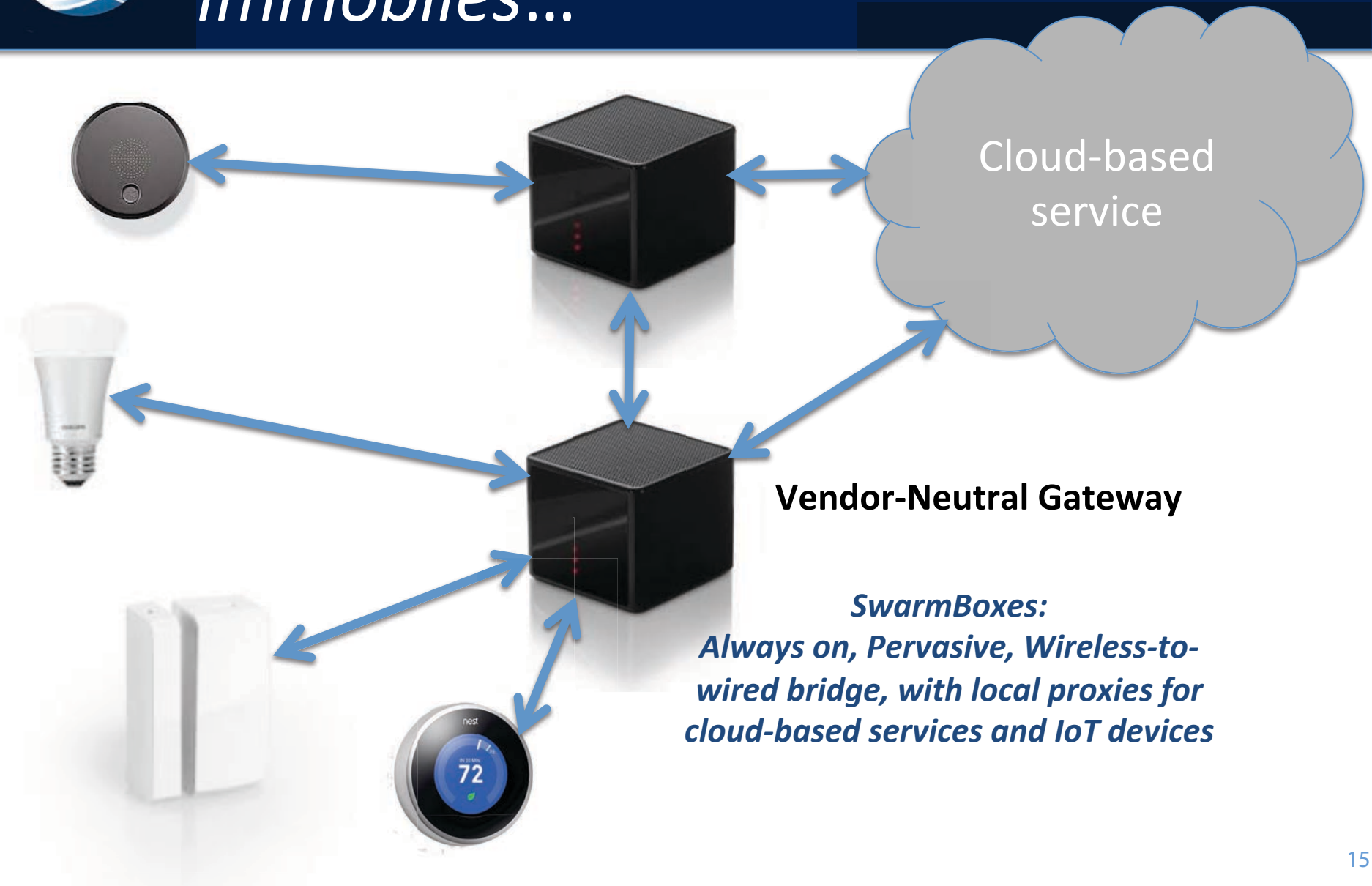
# Typical IoT Architectures Today



# Challenges

- Smartphone apps proliferate, increasing user complexity.
- Vendor-specific gateways don't scale well to many vendors.
- Latency of cloud-based services is substantial and uncontrollable.
- Security and privacy of the cloud: trust?
- Composition of services can only be done in the cloud (e.g. using IFTTT), increasing latency.
- Many moving parts makes systems less reliable, and tracking the source of problems can be hard.
- Hard to imagine using this technology in the *internet of important things* (IoIT)

# A New Infrastructure
## *Immobiles…*



# The Immobiles

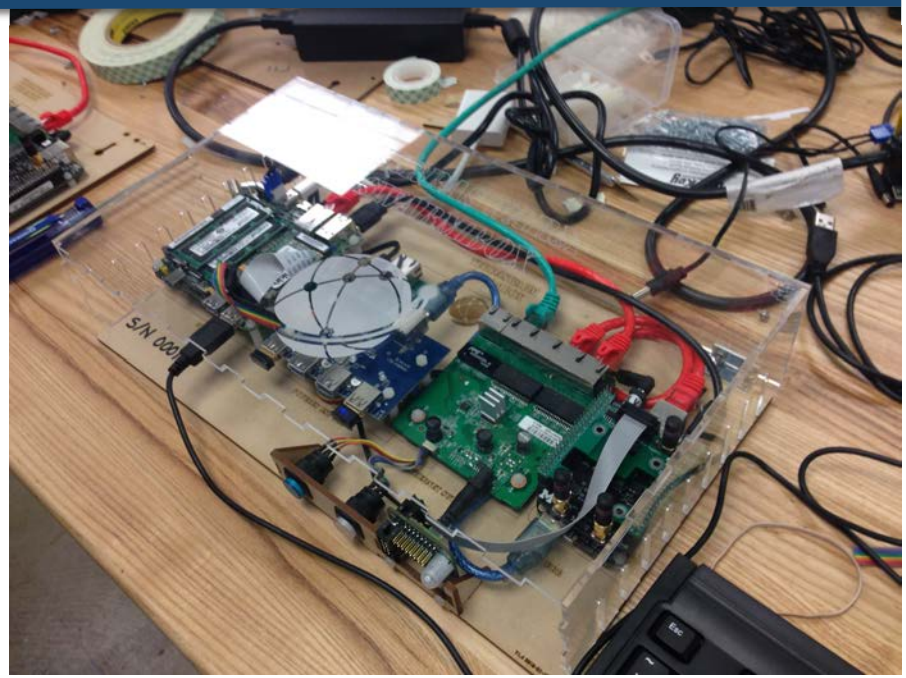
## Fingers of the Cloud Touching the Physical World

Exploiting locality:

- Keep data local by default (privacy)
- Provide service even with network outages (resilience)
- Differentiate clients who have physical access from those that don't (security)
- Provide basic services:
  - Location estimation
  - Access to local devices
  - Certificate authority
  - Publish-and subscribe
  - Discovery

# Our First Immobile: SwarmBox 0001

January 15-16, 2015, the TerraSwarm team met in the Berkeley InventionLab to create the first prototype of the next generation infrastructure, the *immobiles*.




SwarmBox 0001

# SwarmBox-Like Products Already Appearing…

Example:

Specs listed “preliminary” on 2/25/15:

Advantech WISE-3310 “200-Node Wireless IoT Network Controller”

- Dual Cortex-A9 1.0 GHz
- Linux 3.0.35 BSP embedded
- 6LoWPAN and IEEE 802.15.4e
- AES-128 bit encyrption

Advantech industrial computer

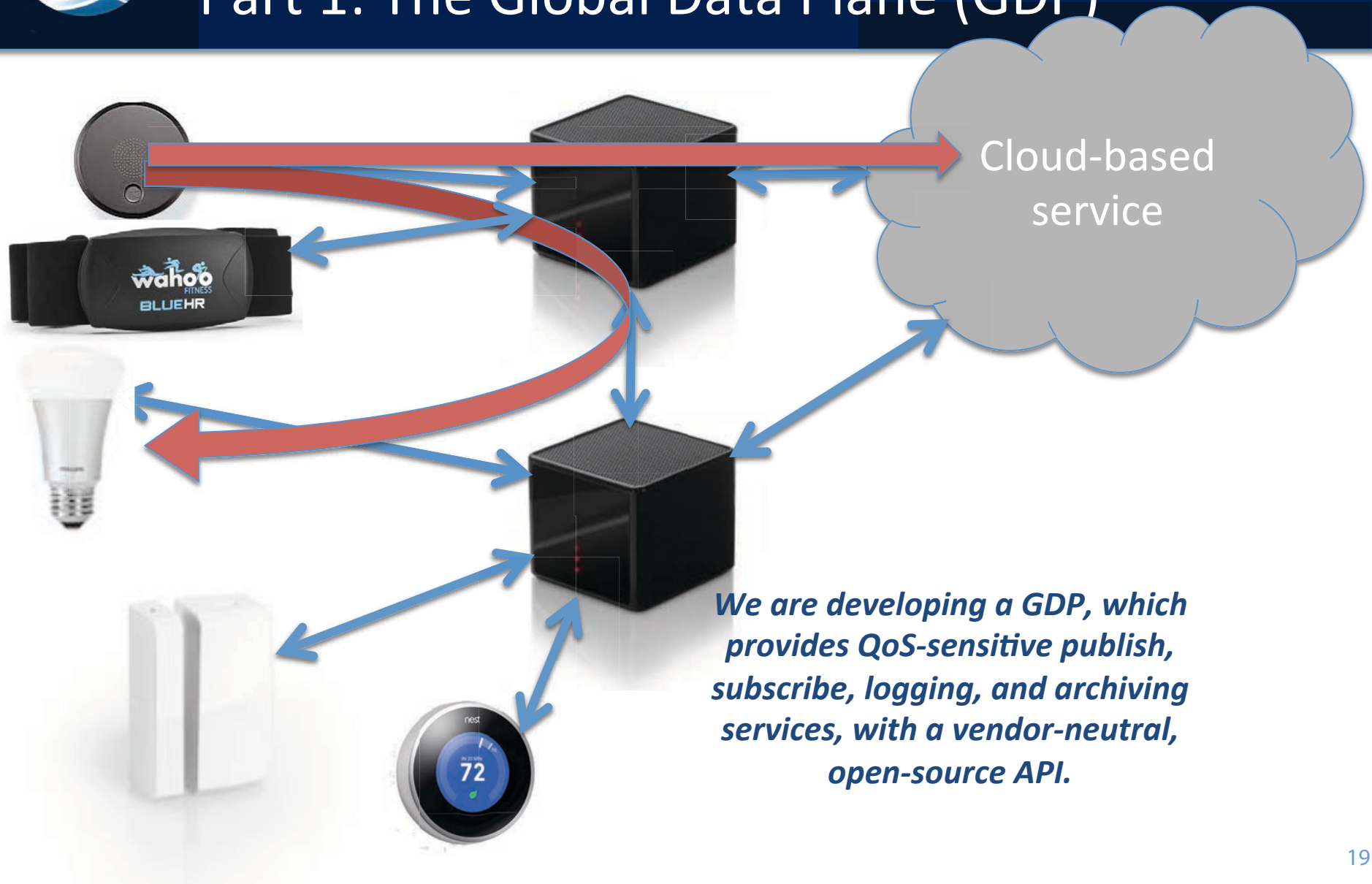
… and “Industrial Computers”

Total Control Solutions industrial PC

Logic Supply industrial computer

# Using the Immobiles

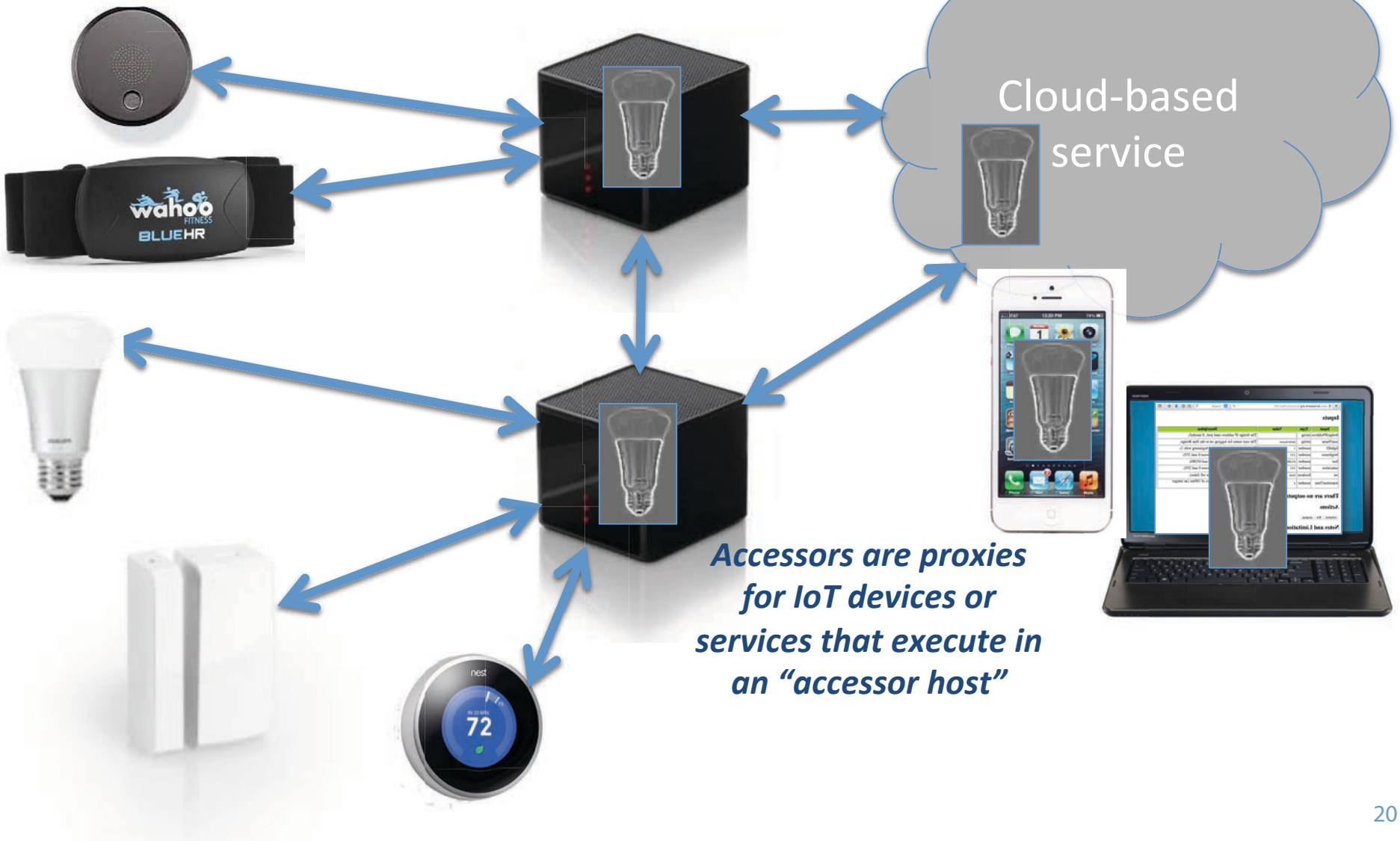
## Part 1: The Global Data Plane (GDP)




***We are developing a GDP, which provides QoS-sensitive publish, subscribe, logging, and archiving services, with a vendor-neutral, open-source API.***

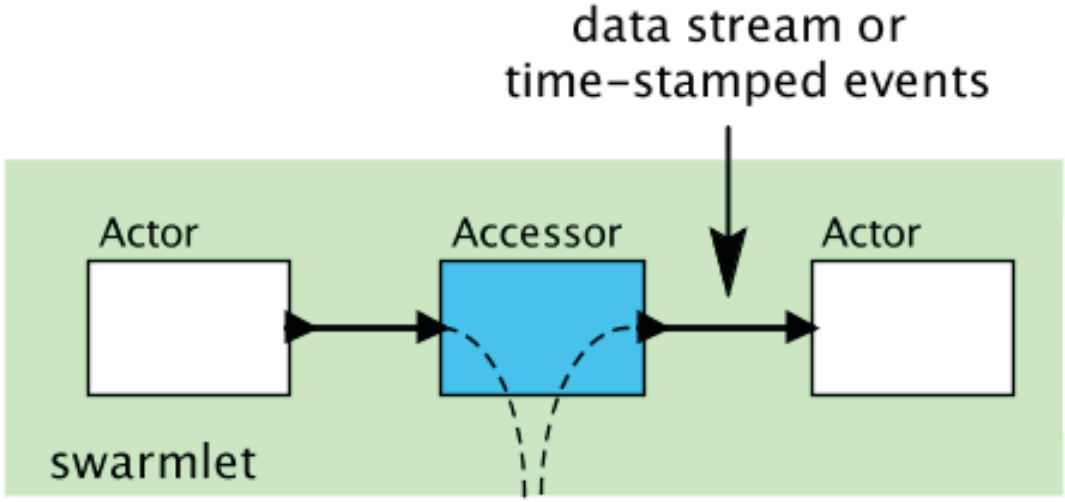
# Using the Immobiles

## Part 2: Accessors




***Accessors are proxies for IoT devices or services that execute in an "accessor host"***

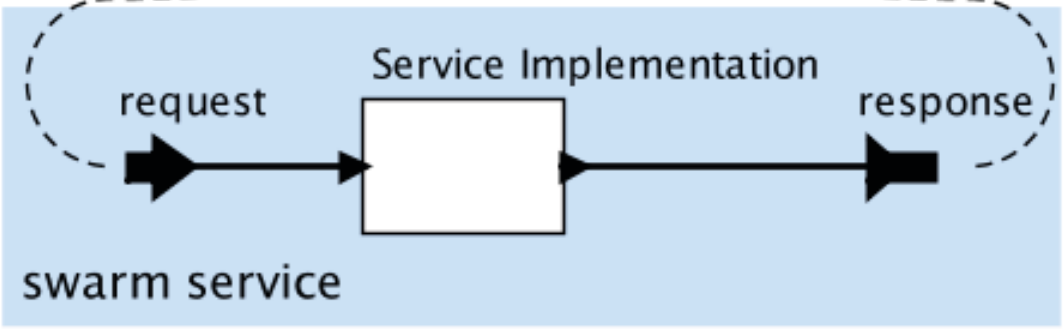
# Swarmlets and Accessors




Runs on a swarmlet host

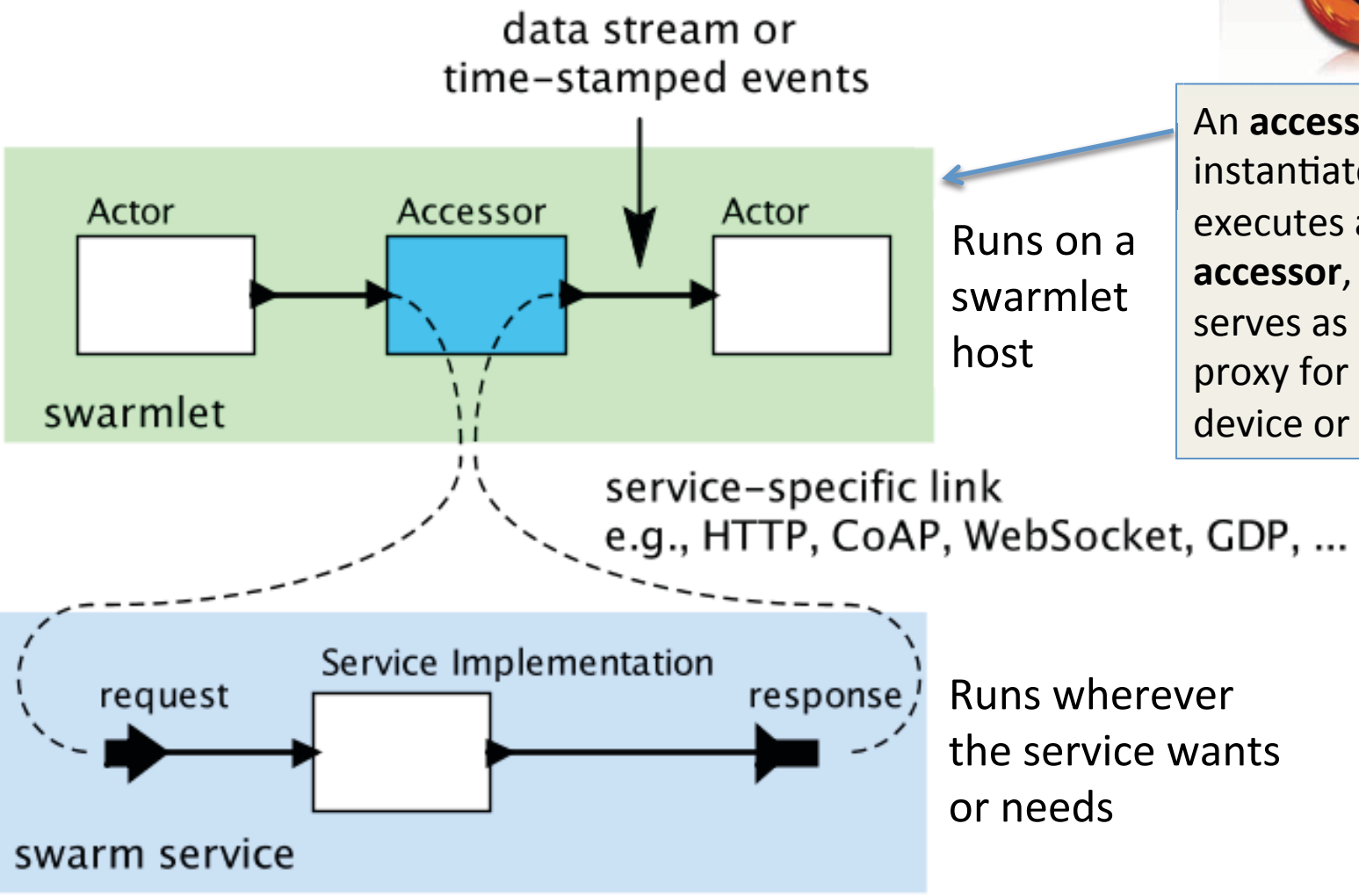
The Global Data Plane will provide transport, QoS, and archiving to distributed swarmlets.

service-specific link
e.g., HTTP, CoAP, WebSocket, GDP, ...




Runs wherever the service wants or needs

# A *Swarmlet Host* is to IoT what a browser is to I




Runs on a swarmlet host

An **accessor host** instantiates and executes an **accessor**, which serves as a local proxy for a remote device or service

Runs wherever the service wants or needs

# Swarmlet Host Prototypes
## Browsers, Node.js, Nashorn/Vert.x

www.terraswarm.org/accessors/Hue.xml

See http://terraswarm.org/accessors

**Inputs**

| Input | Type | Value | Description |
|---|---|---|---|
| bridgeIPAddress | string | | The bridge IP address (and port, if needed). |
| userName | string | ptolemyuser | The user name for logging on to the Hue Bridge. |
| lightID | number | 1 | The light identifier (an integer beginning with 1). |
| brightness | number | 255 | The brightness (an integer between 0 and 255). |
| hue | number | 65280 | The hue (an integer between 0 and 65280). |
| saturation | number | 255 | The saturation (an integer between 0 and 255). |
| on | boolean | false | Whether the light is on (true) or off (false). |
| transitionTime | number | 4 | The transition time, in multiples of 100ms (an integer between 0 and 65535). |

**There are no outputs.**

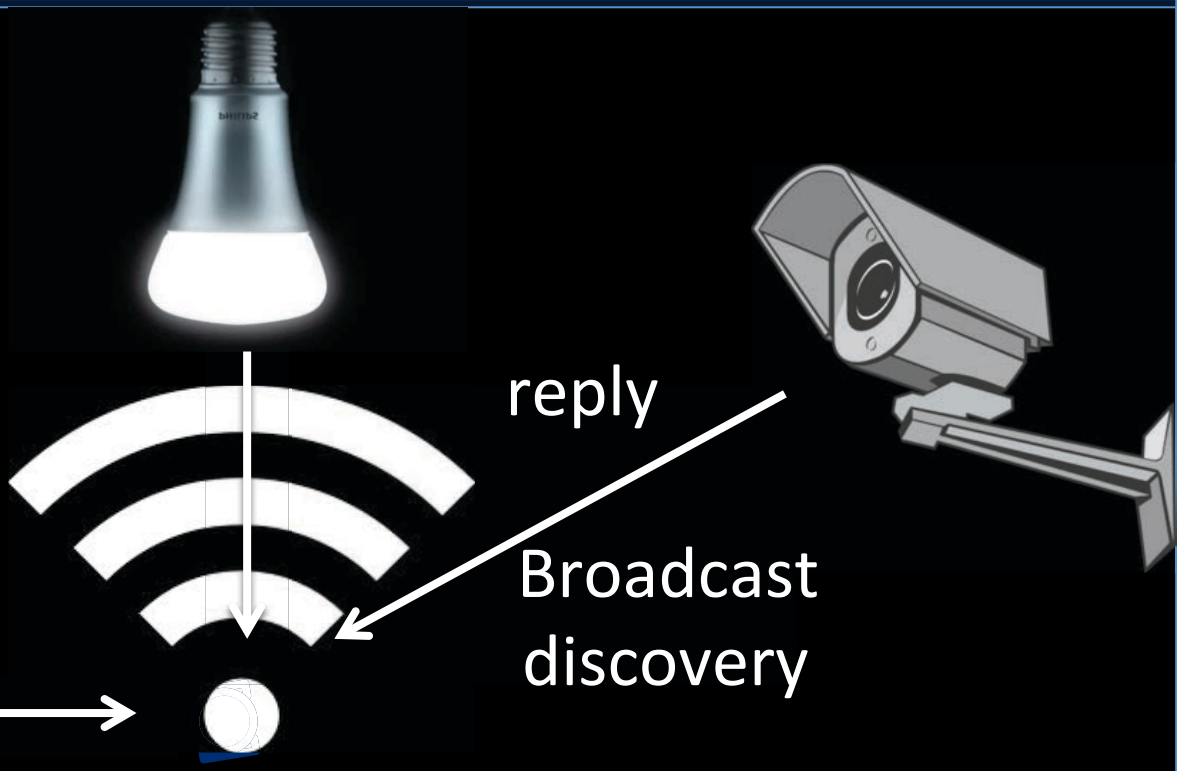
**Actions**

initialize fire wrapup

**Notes and Limitations**

A **swarmlet host** instantiates an **accessor**, providing a client with "access" to its service or device.

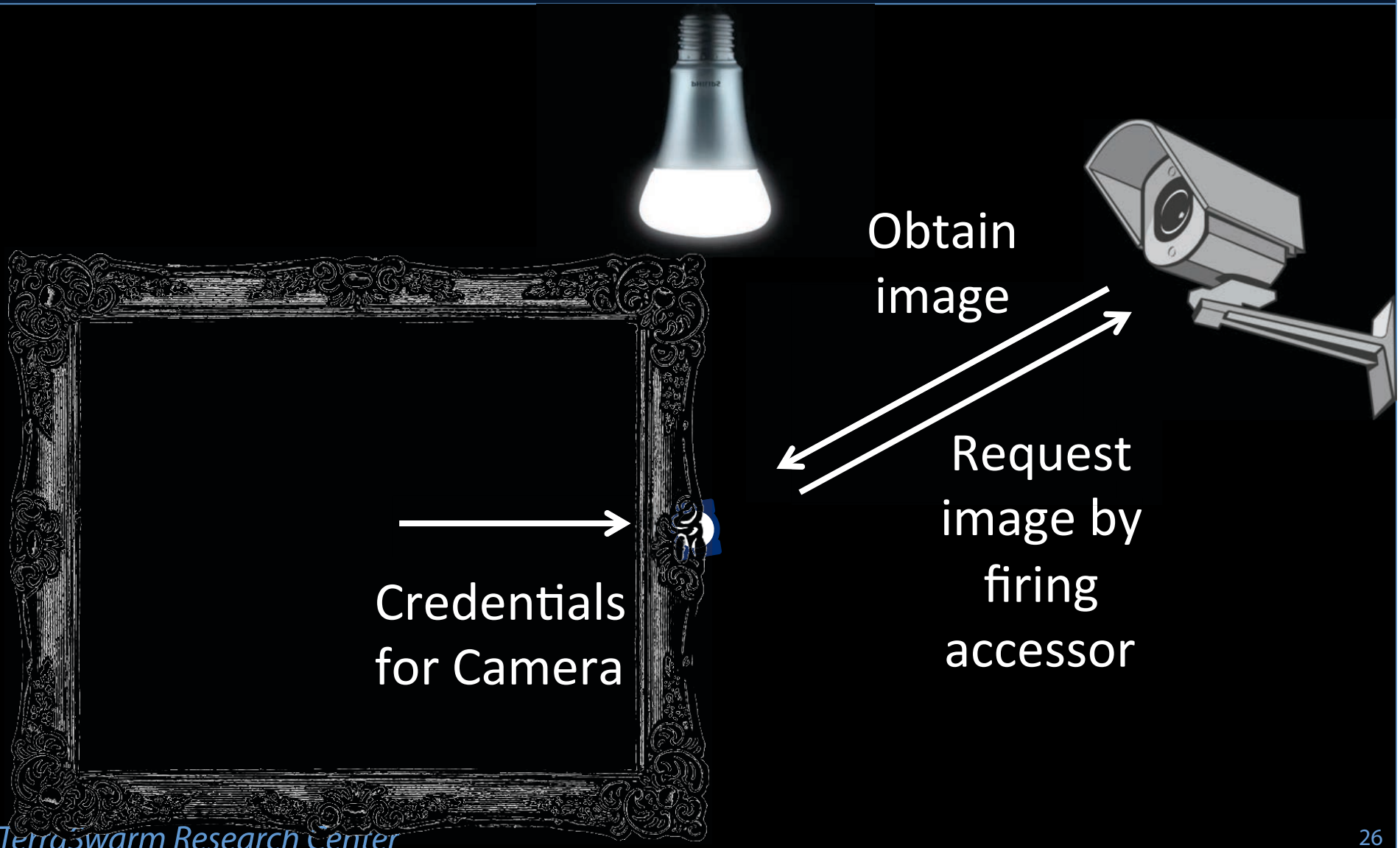
# Robotic Swarms - Discovery



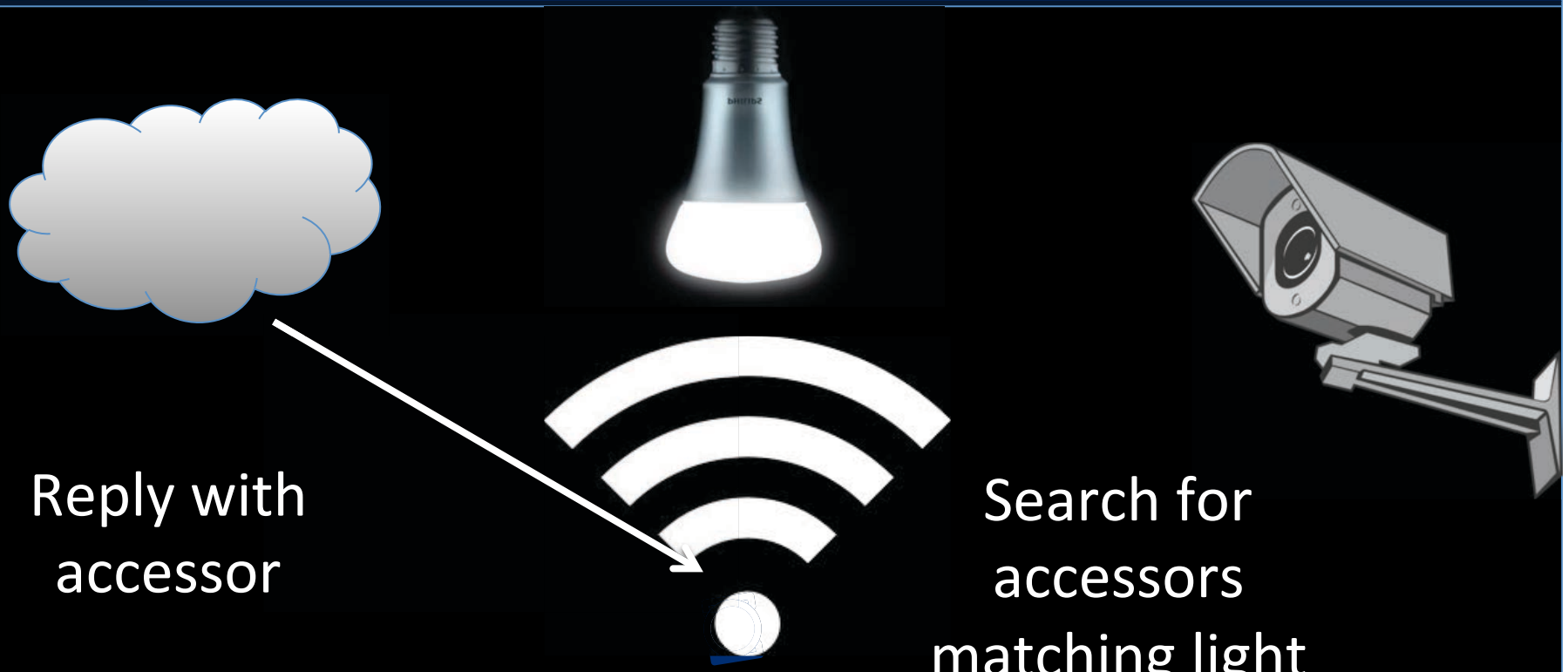

Robot wakes up in an unknown place

# Robotic Swarms - Accessors

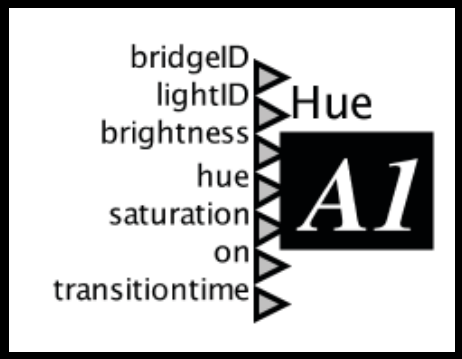
# Robotic Swarms - Accessors



# Robotic Swarms – Accessors

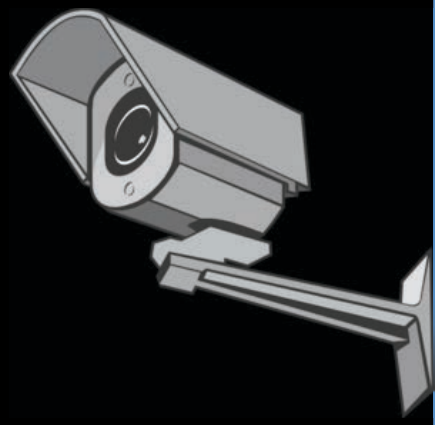


# Robotic Swarms - Accessors



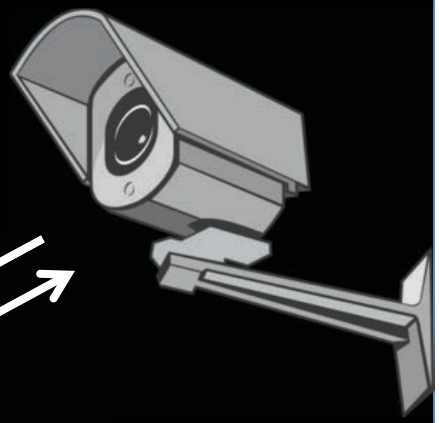

Turn on the light by firing accessor

Light goes on



# Robotic Swarms - Accessors





Obtain image

Request image by firing accessor

# Automotive Swarmlets
## Applying the accessor architecture


Real car


Racing simulator


Traffic simulator

**OBD-II**

**Vehicular data**

- Speed
- RPM
- Torque
- Error codes

**Machine Learning toolkit**

Driver's Behavior
e.g., drunk, texting

**Authentication toolkit**

Vehicle Integrity e.g.,
illegal access, counterfeit

**Localization toolkit**

Fleet management
e.g., taxi, car sharing

Insurance

OEM

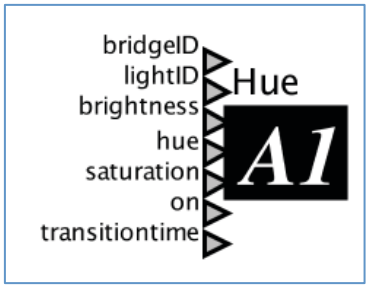
Subscription services

Public/private transport

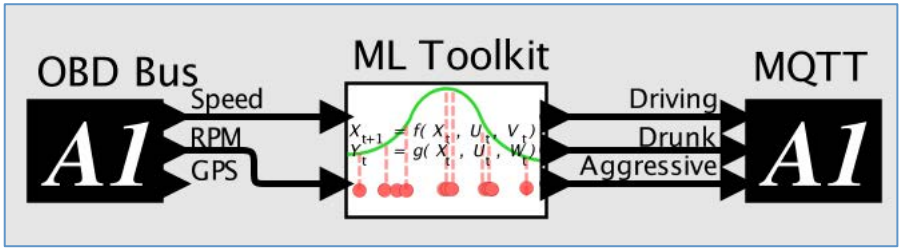
We are testing the accessor architecture on automotive application that use data from the On Board Diagnostics bus (OBD-II)

# Some of the Questions Being Addressed in TerraSwarm Research

- Interface
  - Subtyping?
  - Ontologies?
  - Contracts?
  - Discovery?
- Component
  - Languages?
  - Libraries?
  - Sandboxing?
  - Authentication?
  - Error handling?
- Composition
  - What MoCs?
  - Callbacks vs. actors?
  - Time stamping?
  - Always live swarmlets?
  - Graphical editing?




```
function fire() {
  var command = '{"on":false,';
  if (get(on) === "true") {
    command = '{"on":true,';
  } …
```



# Questions?