Connecting the Cloud to Things

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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.
The SwarmLab is an industry-university partnership pursuing “swarm technology.”
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.
In the last year...

IoT has hit the fan!
The Buzz around the Swarm

- Internet of Things (IoT)
- Industry 4.0
- Internet of Everything
- Smarter Planet
- Machine to Machine (M2M)
- T Sensors (Trillion Sensors)
- The Fog
- The Swarm

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Gartner Hype Cycle 2014

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

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The Goal of TerraSwarm

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

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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.
In the last year... Disasters!!

Cyber attacks:
- Target
- Home Depot
- JP Morgan Chase
- Anthem
- ...

Vulnerabilities:
- Shellshock
- Heartbleed
- ...

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Our Focus: The Internet of Important Things

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

Power generation and distribution

Military systems:

Automotive

Building Systems

Avionics

Telecommunications

Transportation (Air traffic control at SFO)

Instrumentation (Soleil Synchrotron)

Factory automation

Courtesy of Kuka Robotics Corp.

Courtesy of General Electric

Courtesy of Doug Schmidt

E-Corner, Siemens

Daimler-Chrysler

Courtesy of General Electric

Courtesy of Kuka Robotics Corp.
Typical IoT Architectures Today

- Smartphone App
- Gateway
- Cloud service (Vendor-provided)
- Wired, WiFi, ...
- Sometimes, via WiFi, local access
- Via WiFi, LTE, ...
- Zigbee, Zwave, proprietary, ...

Diagram:
- Smartphone App
- Gateway
- Cloud service
- Connections via WiFi, LTE, etc.
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...*

Cloud-based service

Vendor-Neutral Gateway

*SwarmBoxes: Always on, Pervasive, Wireless-to-wired bridge, with local proxies for cloud-based services and IoT devices*
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
January 15-16, 2015, the TerraSwarm team met in the Berkeley InventionLab to create the first prototype of the next generation infrastructure, the *immobiles*.

*TerraSwarm Research Center*  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 encryption
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

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

 Runs on a swarmlet host

 Runs wherever the service wants or needs

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

A swarmlet is to a swarm service as a browser is to a web service. A swarmlet runs on an accessor host, which acts as a local proxy for a remote device or service.

- **Actor**: Represents an entity that initiates or responds to a request.
- **Accessor**: Acts as an intermediary, processing data streams and time-stamped events.
- **swarmlet**: An instance of a service-specific link (e.g., HTTP, CoAP, WebSocket, GDP, ...).
- **swarm service**: Runs wherever the service wants or needs.

An accessor host instantiated and executes an accessor, which serves as a local proxy for a remote device or service.
A swarmlet host instantiates an accessor, providing a client with “access” to its service or device.

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### Inputs

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

There are no outputs.

### Actions

- Initialize
- Fire
- Wrapup

### Notes and Limitations
Robotic Swarms - Discovery

Robot wakes up in an unknown place

Credentials for WiFi

Broadcast discovery

reply
Robotic Swarms - Accessors

Reply with accessor

Search for accessors matching camera interface
Robotic Swarms - Accessors

Obtain image

Request image by firing accessor

Credentials for Camera
Robotic Swarms – Accessors

Reply with accessor

Search for accessors matching light interface
Robotic Swarms - Accessors

Turn on the light by firing accessor

Light goes on
Obtain image

Request image by firing accessor
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?