

# Teaching the Internet of Things: From STEM to STEAM

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# Outline

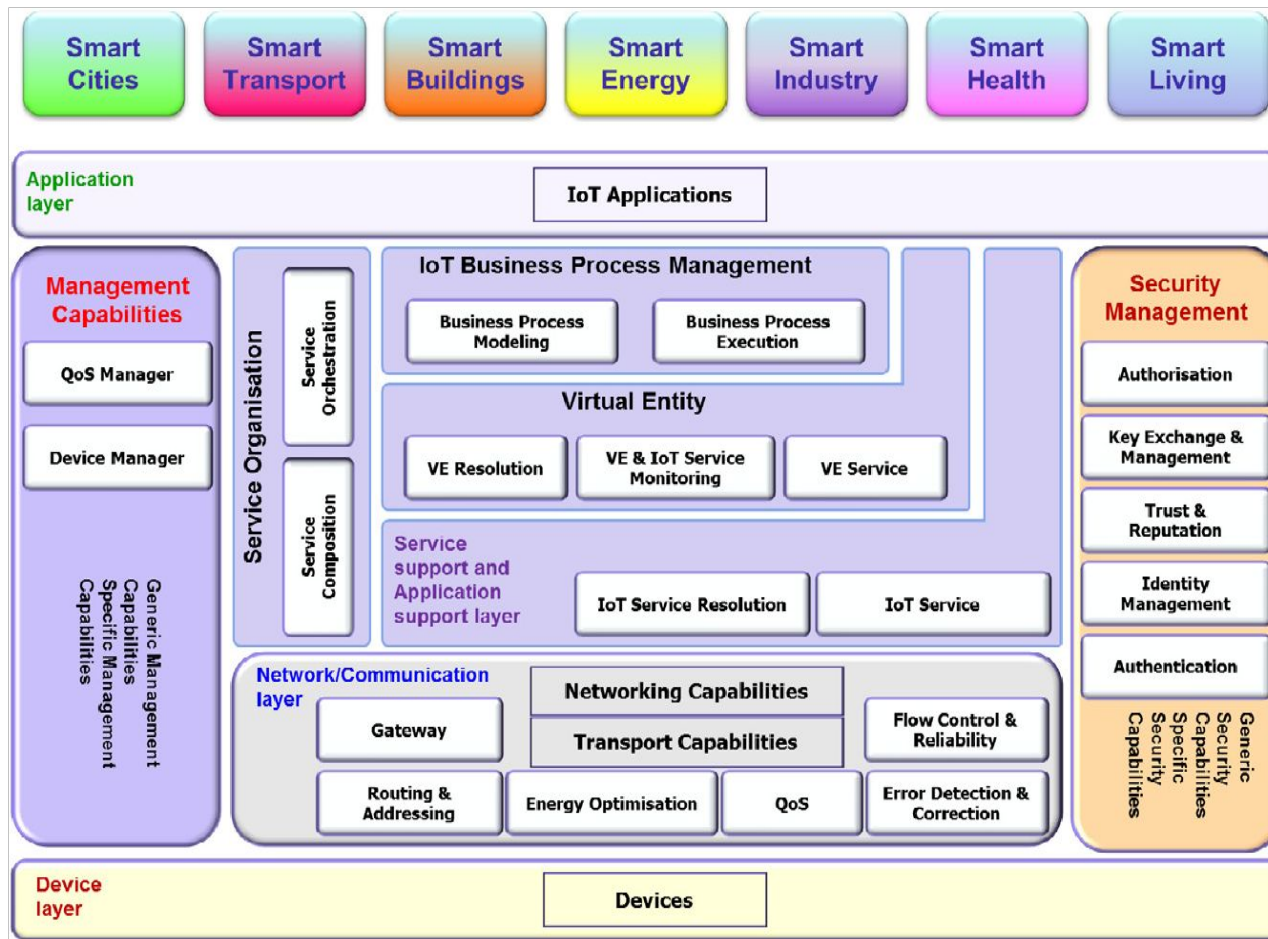
- The Internet of Things (IoT) definition, architecture, complexity levels, protocols, and application programming interfaces (APIs)
- IoT hype cycle, startups, landscape, alliances, standards, and value chain
- Development board examples: Arduino YÚN, BeagleBone Black Revision C, LinkIt Smart 7688 Duo, Particle Photon, Raspberry Pi 3B, and Tessel 2
- Cloud platform examples: gspread, ThingSpeak, *etc.*
- Communication models: request/response (*e.g.*, Django) and publish/subscribe (*e.g.*, Paho)
- Data analysis and visualization

# IoT Definition by ITU-T

A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual “things”

- have identities, physical attributes, and virtual personalities
- use intelligent interfaces
- are seamlessly integrated into the information network
- often communicate data associated with users and their environments

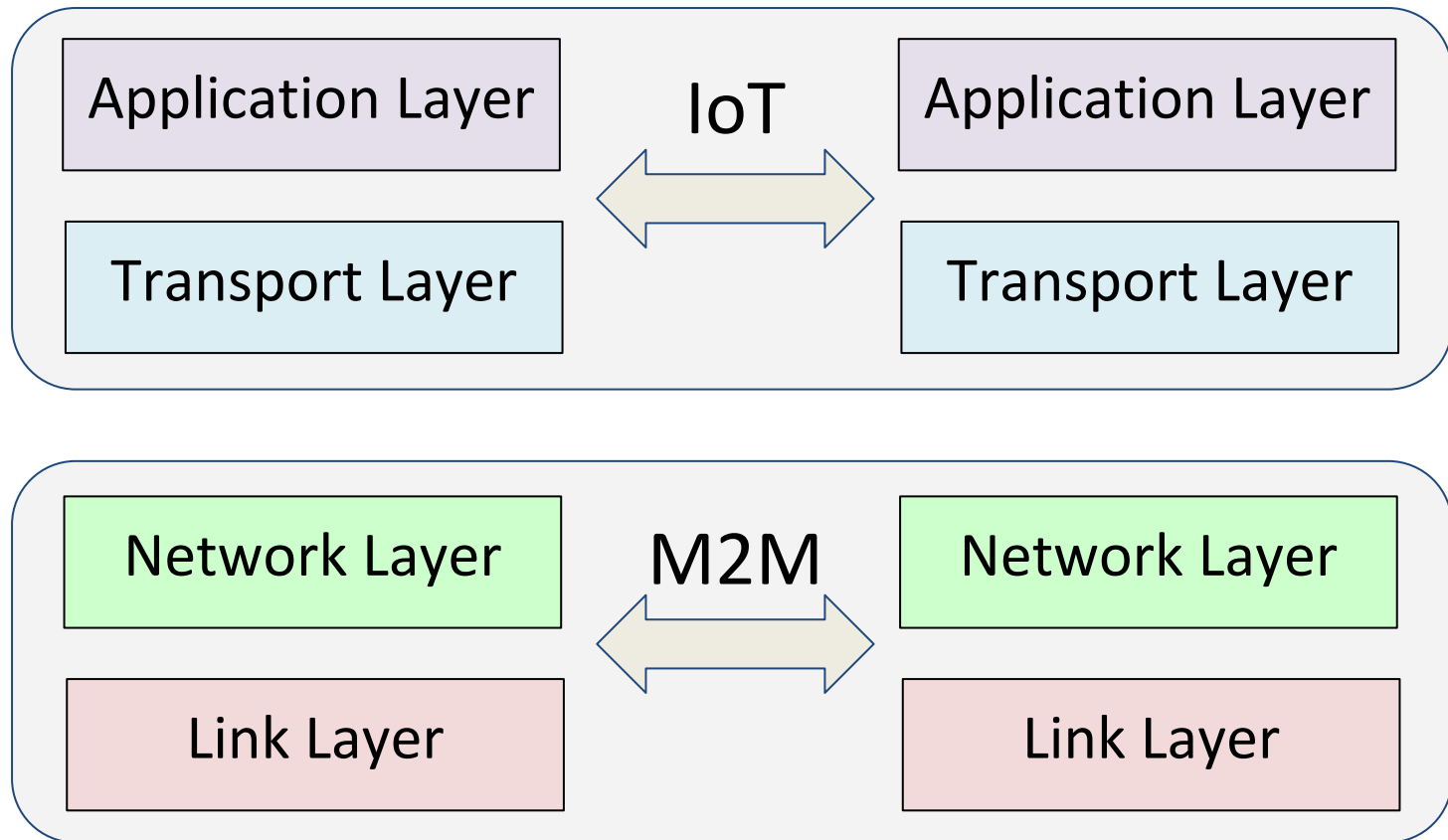
# IoT Architecture by ITU-T



<http://www.internet-of-things-research.eu/documents.htm>



# IoT vs. Machine-to-Machine (M2M)



<http://www.internet-of-things-book.com/>

# Complexity Levels of IoT Systems

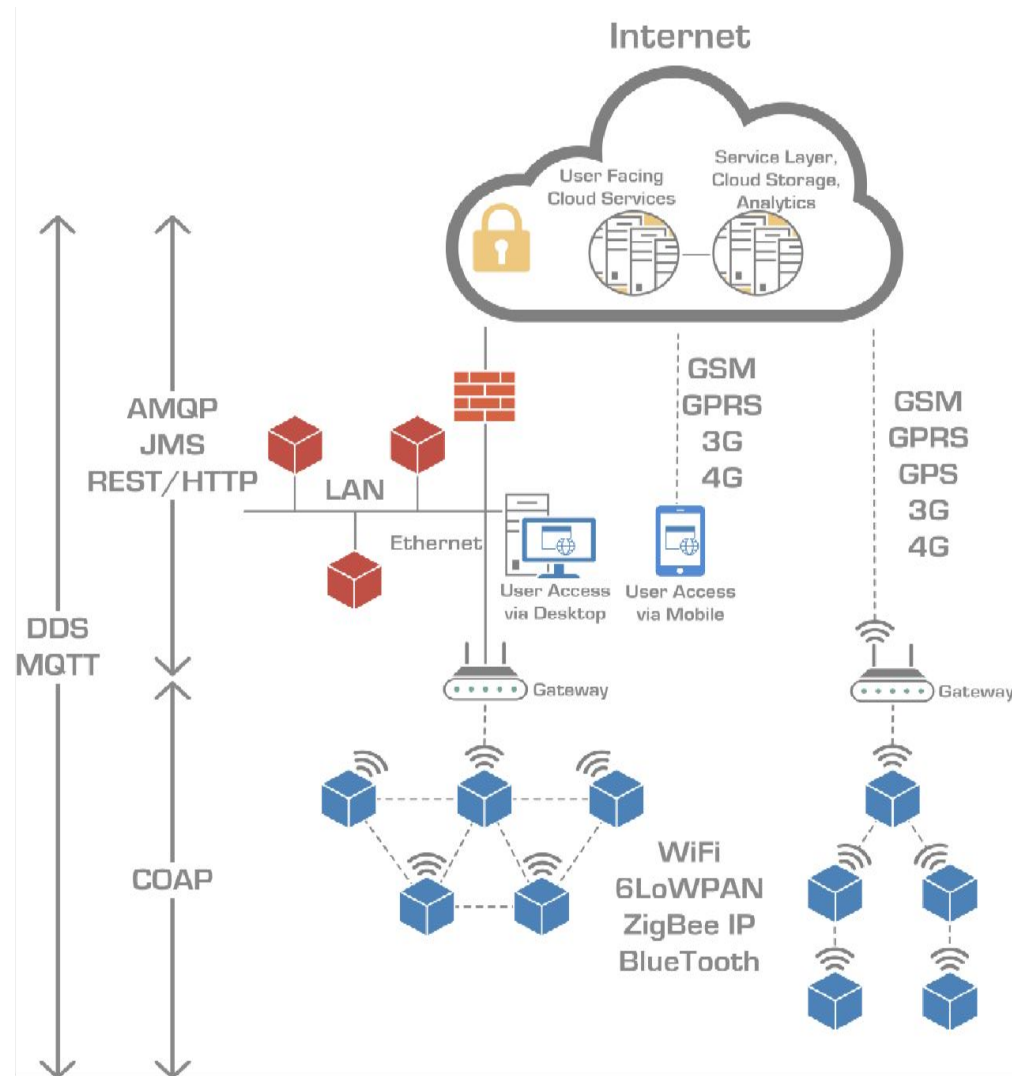
Level	Node	Analysis	Storage	Example
1	Single	Local	Local	Home Automation
2	Single	Local	Cloud	Smart Irrigation
3	Single	Cloud	Cloud	Vibration Monitoring
4	Multiple	Local	Cloud	Noise Monitoring
5	Multiple + Coordinator	Cloud	Cloud	Forest Fire detection
6	Multiple + Centralized Controller	Cloud	Cloud	Weather Monitoring

<http://www.internet-of-things-book.com/>

# IoT Protocols

AMQP	Advanced Message Queuing Protocol
CoAP	Constrained Application Protocol
DDS	Data Distribution Service
HTTP	Hypertext Transfer Protocol
JMS	Java Message Service
MQTT	Message Queue Telemetry Transport
REST	Representational State Transfer
WAMP	Web Application Messaging Protocol
XMPP	Extensible Messaging and Presence Protocol

# IoT/M2M Protocols



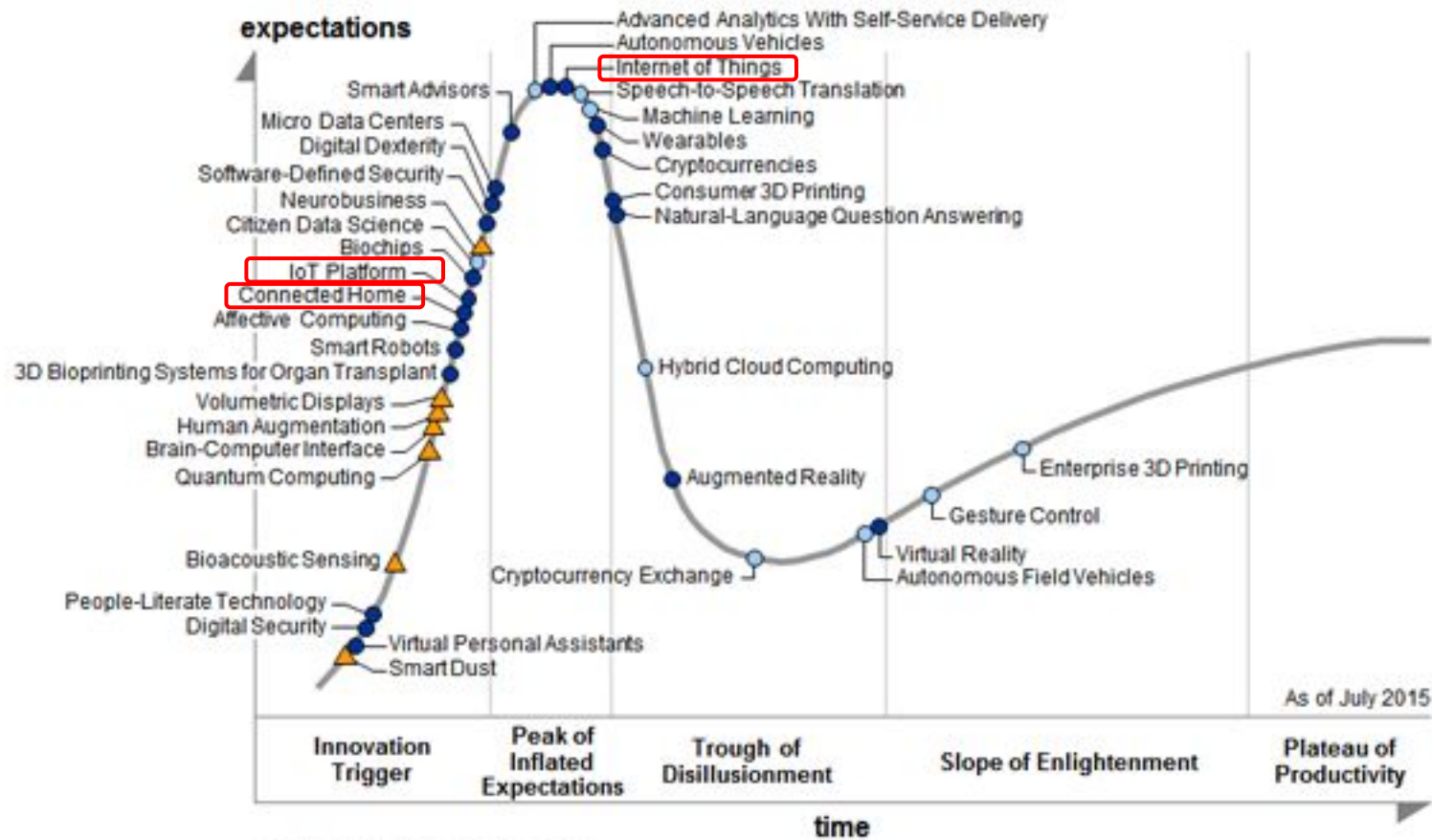
**6LoWPAN:** IPv6 over Low power Wireless Personal Area Networks

# What is an API?

- API is a set of routines, protocols, and tools for building software applications
- It specifies how software components interact and are used when programming graphical user interface (GUI) components
- Example: **Django REST API** for smart lighting

```
/lighting
  controller.py
  db.sqlite3
  /lighting
    settings.py
    urls.py
  manage.py
  /myapp
    admin.py
    models.py
    serializers.py
  /templates
    /myapp
      index.html
  views.py
```

# IoT Hype Cycle 2015



As of July 2015

Plateau will be reached in:

- less than 2 years
- 2 to 5 years
- 5 to 10 years
- ▲ more than 10 years
- ⊗ obsolete before plateau





<http://www.gartner.com/newsroom/id/3114217>

# IoT Startups on AngelList

Internet of Things Startups

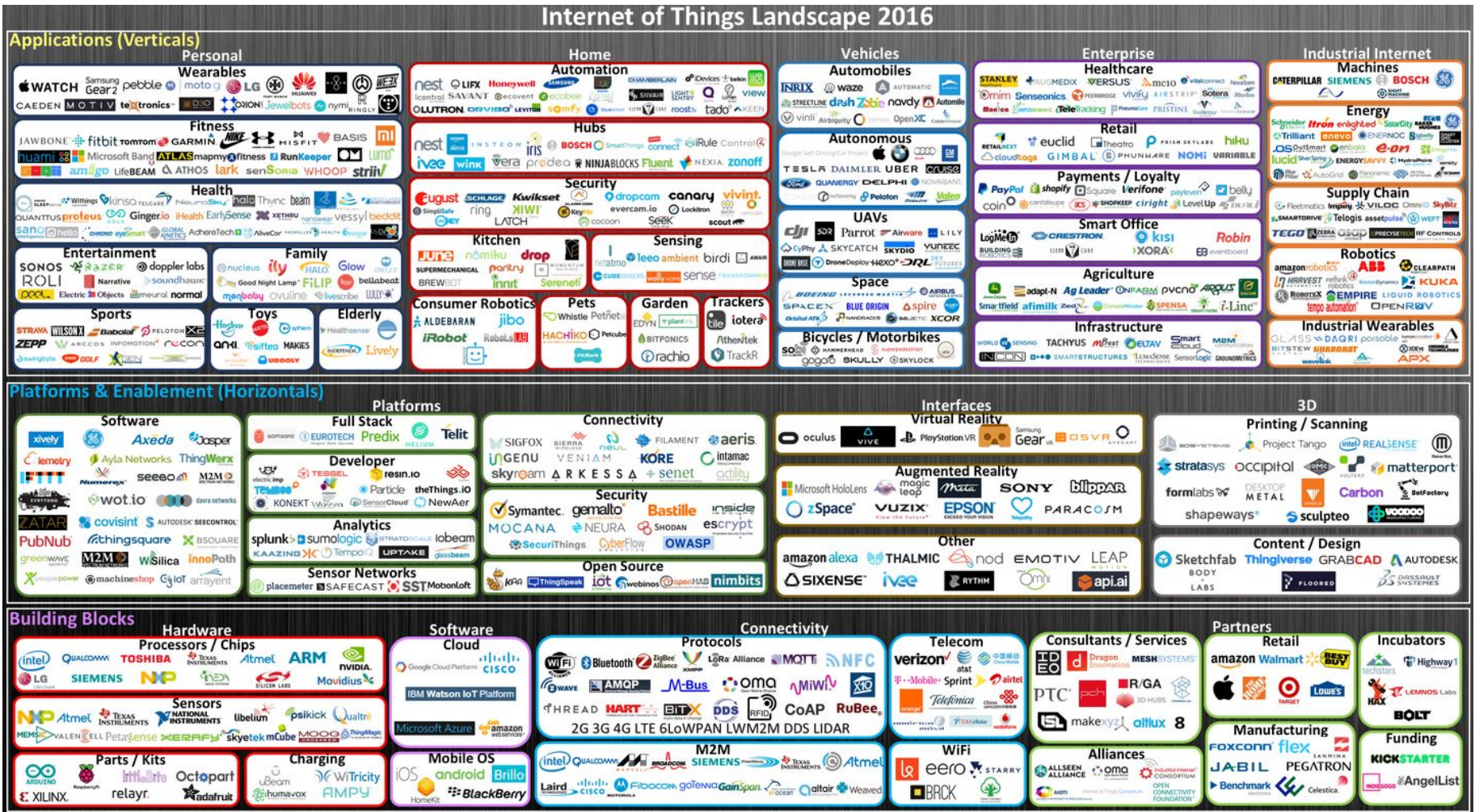
\$4.8M AVERAGE VALUATION

2,072 COMPANIES 1,365 INVESTORS 7,627 FOLLOWERS 938 JOBS

Company	Joined	Followers	Signal	
 <b>IMRSV</b> Emotion Recognition using Web... New York City · Internet of Things	Jul '11	471		
 <b>SmartThings</b> Hello, Smart Home <a href="http://vimeo...">http://vimeo...</a> Palo Alto · Home Automation	Nov '12	425		<a href="#">VIEW JOBS</a>



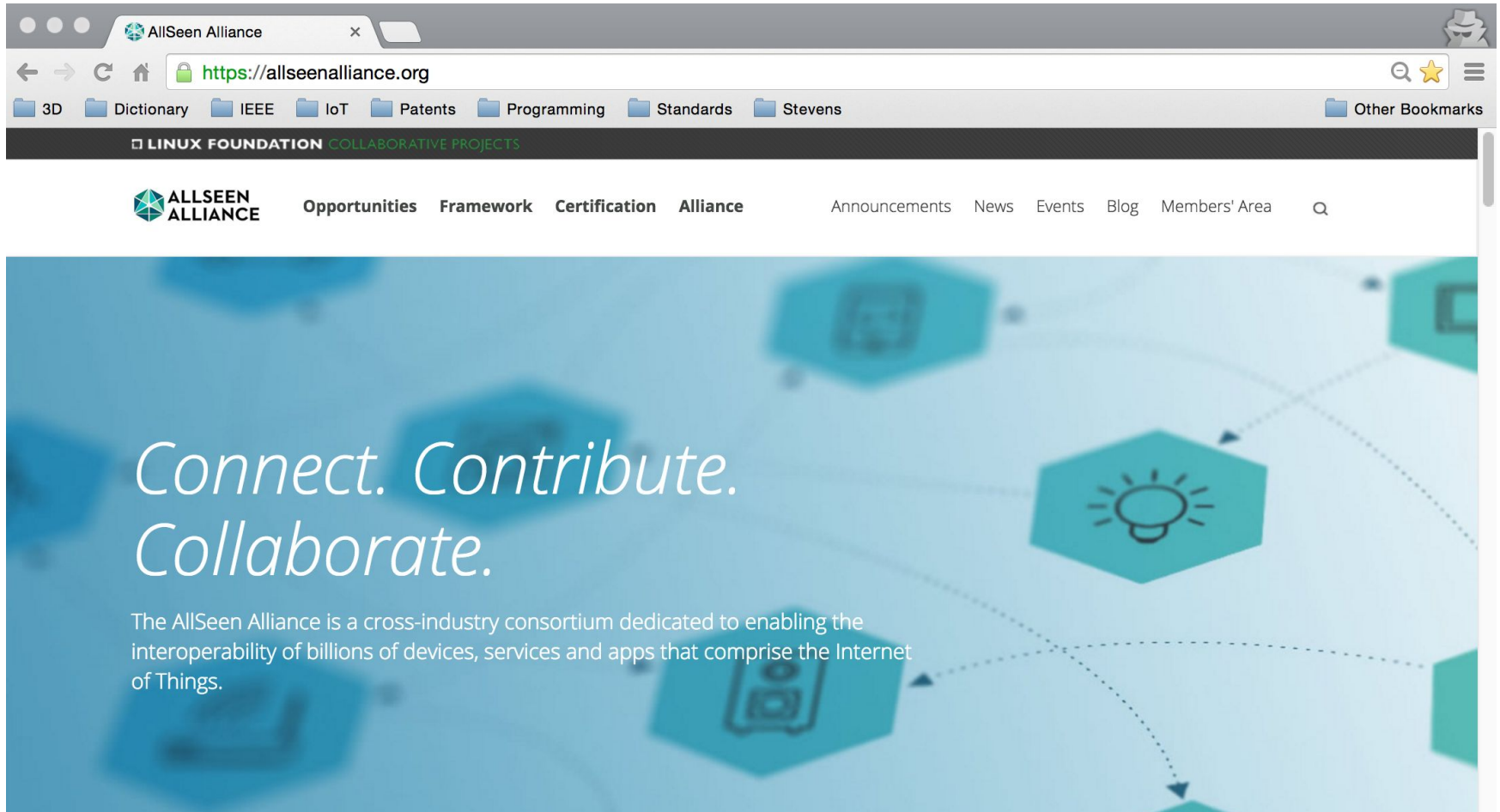
# IoT Landscape 2016



<http://mattturck.com/2016/03/28/2016-iot-landscape/>



# Allseen Alliance



The image shows a browser window displaying the Allseen Alliance website. The browser's address bar shows the URL <https://allseenalliance.org>. The browser's bookmark bar includes folders for 3D, Dictionary, IEEE, IoT, Patents, Programming, Standards, and Stevens. A dark banner at the top of the page features the Linux Foundation logo and the text "COLLABORATIVE PROJECTS". The main navigation menu includes "ALLSEEN ALLIANCE" (with a logo), "Opportunities", "Framework", "Certification", "Alliance", "Announcements", "News", "Events", "Blog", and "Members' Area". The main content area has a blue background with a network diagram of hexagons and icons. The text "Connect. Contribute. Collaborate." is prominently displayed in white, followed by a paragraph: "The AllSeen Alliance is a cross-industry consortium dedicated to enabling the interoperability of billions of devices, services and apps that comprise the Internet of Things."

ALLSEEN ALLIANCE

Opportunities Framework Certification Alliance

Announcements News Events Blog Members' Area

*Connect. Contribute.  
Collaborate.*


The AllSeen Alliance is a cross-industry consortium dedicated to enabling the interoperability of billions of devices, services and apps that comprise the Internet of Things.

# Open Interconnect Consortium

oic Open Interconnect Consorti x

openinterconnect.org

3D Dictionary IEEE IoT Patents Programming Standards Stevens Other Bookmarks

 OPEN INTERCONNECT CONSORTIUM<sup>SM</sup>

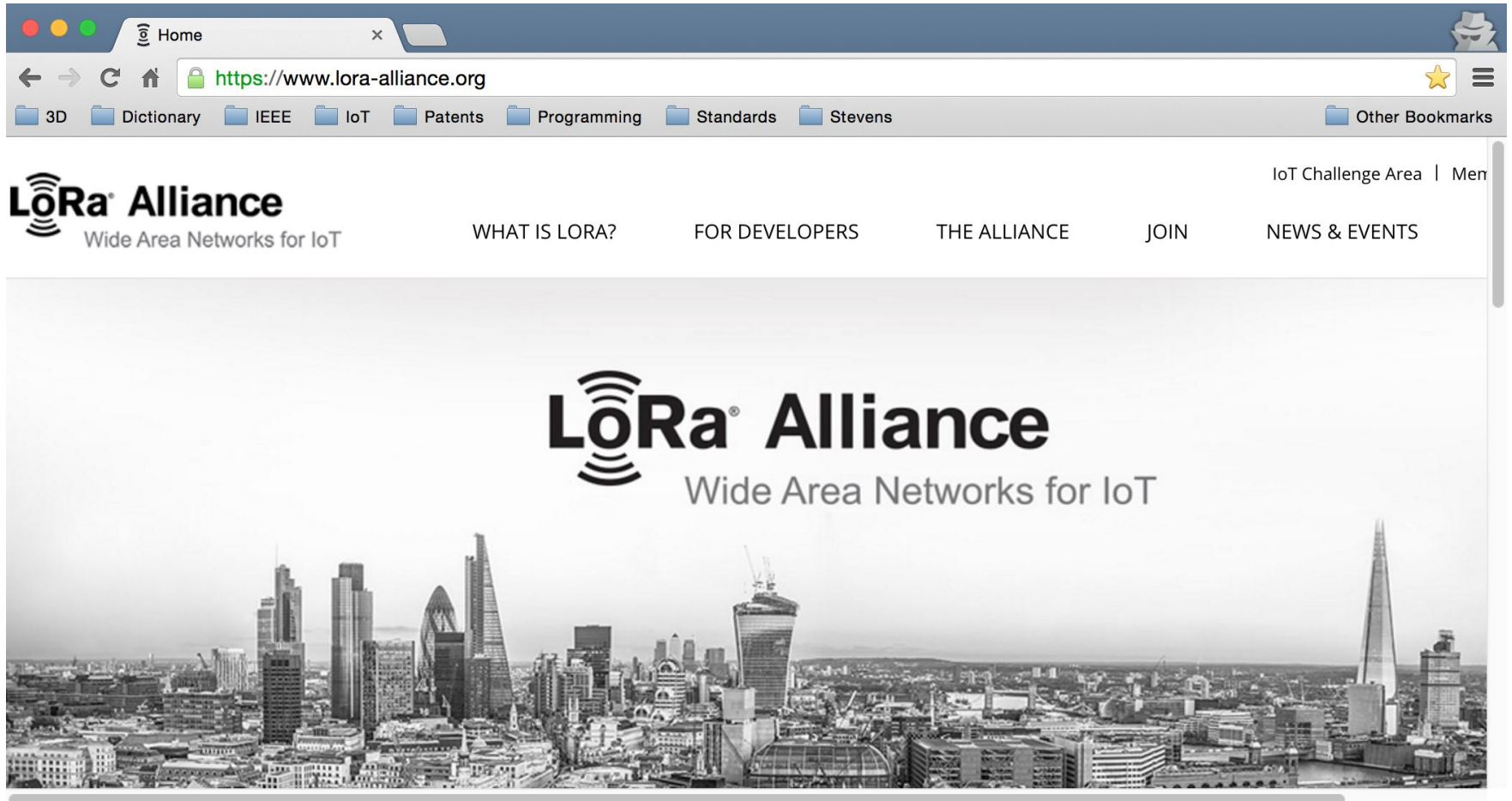
[HOME](#) [ABOUT US](#) [JOIN US](#) [NEWS AND EVENTS](#) [DEVELOPER RESOURCES](#) [CONTACT US](#)

DELIVERING INDUSTRY STANDARDS AND OPEN SOURCE SOLUTIONS

The Open Interconnect Consortium is focused on delivering a specification, an open source implementation, and a certification program for wirelessly connecting devices.

[LEARN MORE](#)

# Long Range (LoRa) Networks



The image shows a browser window displaying the LoRa Alliance website. The browser's address bar shows the URL <https://www.lora-alliance.org>. The website header features the LoRa Alliance logo on the left, which includes the text "LoRa Alliance" and "Wide Area Networks for IoT". To the right of the logo is a navigation menu with the following items: "WHAT IS LORA?", "FOR DEVELOPERS", "THE ALLIANCE", "JOIN", and "NEWS & EVENTS". In the top right corner of the website, there is a link for "IoT Challenge Area | Men". The main content area of the website is a large banner with a grayscale cityscape background. The banner features the LoRa Alliance logo and the text "LoRa Alliance" and "Wide Area Networks for IoT" centered over the image.

# ISO/IEC JTC 1/SWG 5

The screenshot shows a web browser window with the IEC website. The address bar displays the URL: [www.iec.ch/dyn/www/f?p=103:14:0:::FSP\\_ORG\\_ID,FSP\\_LANG\\_ID:10270,25?q=jtc1%20sc%2038](http://www.iec.ch/dyn/www/f?p=103:14:0:::FSP_ORG_ID,FSP_LANG_ID:10270,25?q=jtc1%20sc%2038). The browser's bookmark bar includes folders for 3D, Dictionary, IEEE, IoT, Patents, Programming, Standards, and Stevens. The website header features the IEC logo and the text "International Electrotechnical Commission" and "International Standards and Conformity Assessment for all electrical, electronic and related technologies". Navigation links include "myIEC", "Subscribe", "Sitemap", "FAQs", and "Contact us". A secondary navigation bar contains links for "You & the IEC", "About the IEC", "News & views", "Standards development", "Conformity assessment", "Members & experts", "Developing countries", "Webstore", and a search bar. A breadcrumb trail reads: "Standards development > How we work > Technical Committees & Subcommittees > ISO/IEC JTC 1 > SWG 5". The main content area is titled "ISO/IEC JTC 1 Information technology" and includes tabs for "Scope", "Structure", "Projects / Publications", "Documents", "Meetings", and "Collaboration Tools". Below these tabs, it indicates "Subcommittee(s) and/or Working Group(s) > ISO/IEC JTC 1/SWG 5". A vertical "Feedback" button is on the right. Two blue boxes are visible: "SWG 5 Convenor & Members" with a document icon, and "Title & Task" containing the text "SWG 5 Internet of Things (IoT) Terms of Reference".

IEC - ISO/IEC JTC 1/SWG 5

www.iec.ch/dyn/www/f?p=103:14:0:::FSP\_ORG\_ID,FSP\_LANG\_ID:10270,25?q=jtc1%20sc%2038

3D Dictionary IEEE IoT Patents Programming Standards Stevens Other Bookmarks

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International Electrotechnical Commission

International Standards and Conformity Assessment for all electrical, electronic and related technologies

You & the IEC | About the IEC | News & views | Standards development | Conformity assessment | Members & experts | Developing countries | Webstore | Search... | Advanced search

Standards development > How we work > Technical Committees & Subcommittees > ISO/IEC JTC 1 > SWG 5

ISO/IEC JTC 1 Information technology

Scope | Structure | Projects / Publications | Documents | Meetings | Collaboration Tools

Subcommittee(s) and/or Working Group(s) > ISO/IEC JTC 1/SWG 5

Log in | En | Fr

SWG 5 Convenor & Members

Title & Task

**SWG 5**  
Internet of Things (IoT)  
Terms of Reference

Feedback

# IEEE P2413

The screenshot shows a web browser window with the URL <https://standards.ieee.org/develop/project/2413.html>. The browser's address bar and tabs are visible at the top. Below the browser window, the IEEE Standards Association website is displayed. The header includes the IEEE logo and the text "IEEE STANDARDS ASSOCIATION". A navigation menu contains links for "Find Standards", "Develop Standards", "Get Involved", "News & Events", "About Us", "Buy Standards", and "eTools". The "Develop Standards" link is highlighted. The main content area features a blue banner with the text "IEEE PROJECT" and "P2413 - Standard for an Architectural Framework for the Internet of Things (IoT)". Below the banner, a paragraph describes the Internet of Things (IoT) and the standard's purpose. To the right, there is a "RELATED MATERIALS" section with a link to "Approved PAR" and a "Standards Help" section with a "Feedback" button. A "STATUS:" box indicates the project is an "Active Project".

IEEE.org | IEEE Xplore Digital Library | IEEE Standards | IEEE Spectrum | More Sites

**IEEE STANDARDS ASSOCIATION** Contact FAQs  standards.ieee.org only

Find Standards **Develop Standards** Get Involved News & Events About Us Buy Standards eTools

**IEEE PROJECT**  
P2413 - Standard for an Architectural Framework for the Internet of Things (IoT)

The Internet of Things (IoT) is predicted to become one of the most significant drivers of growth in various technology markets. Most current standardization activities are confined to very specific verticals and represent islands of disjointed and often redundant development. The architectural framework defined in this standard will promote cross-domain

**STATUS:**  
Active Project ?

**RELATED MATERIALS**  
[Approved PAR](#)

**Standards Help**  
IEEE-SA Standards Development Services are proven to expedite the process by 40%. [Click here to learn more!](#)



# oneM2M



The image shows a browser window displaying the oneM2M website. The browser's address bar shows the URL [www.onem2m.org](http://www.onem2m.org). The website's header features the oneM2M logo on the left, the text "Standards for M2M and the Internet of Things" in the center, and a "Member Login" button on the right. Below the header is a navigation menu with links for HOME, ABOUT, MEMBERSHIP, INSIGHTS, TECHNICAL, and NEWS, each with a dropdown arrow. A search bar is located to the right of the navigation menu. The main content area features a large heading "Global Partnership" and a sub-heading "8 of the world's leading ICT standards bodies, 6 global ICT fora, over 200 companies from all industrial sectors". To the right of the text is a 3D graphic of interlocking gears, with one gear being red and the others being silver.

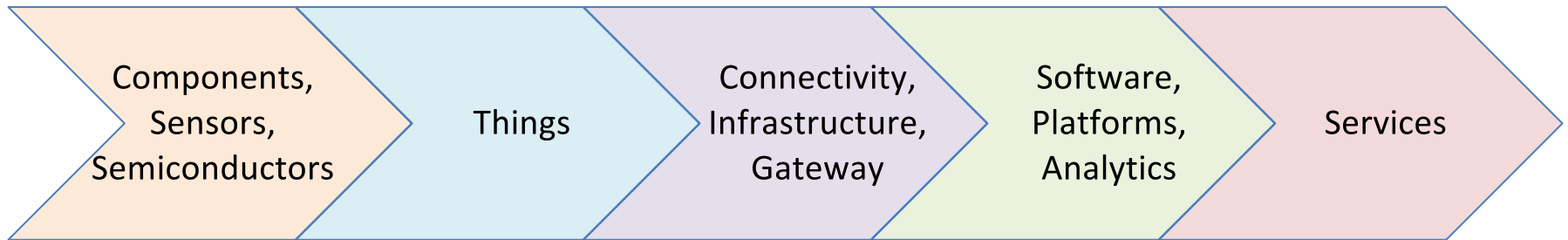
oneM2M Standards for M2M and the Internet of Things Member Login

HOME ABOUT MEMBERSHIP INSIGHTS TECHNICAL NEWS Search...

## Global Partnership

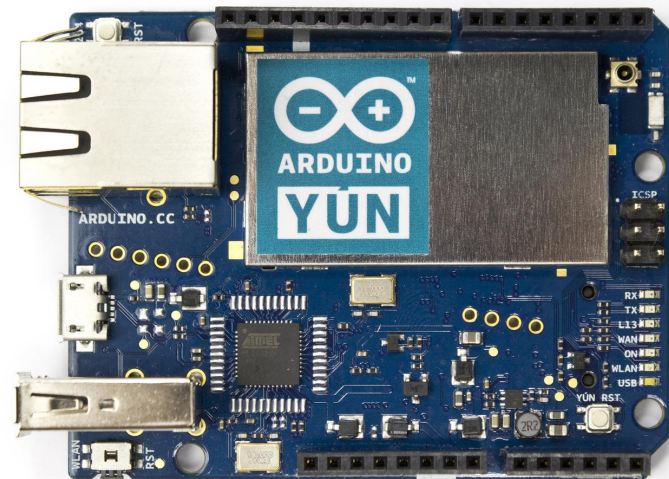
8 of the world's leading ICT standards bodies, 6 global ICT fora, over 200 companies from all industrial sectors

# IoT Value Chain



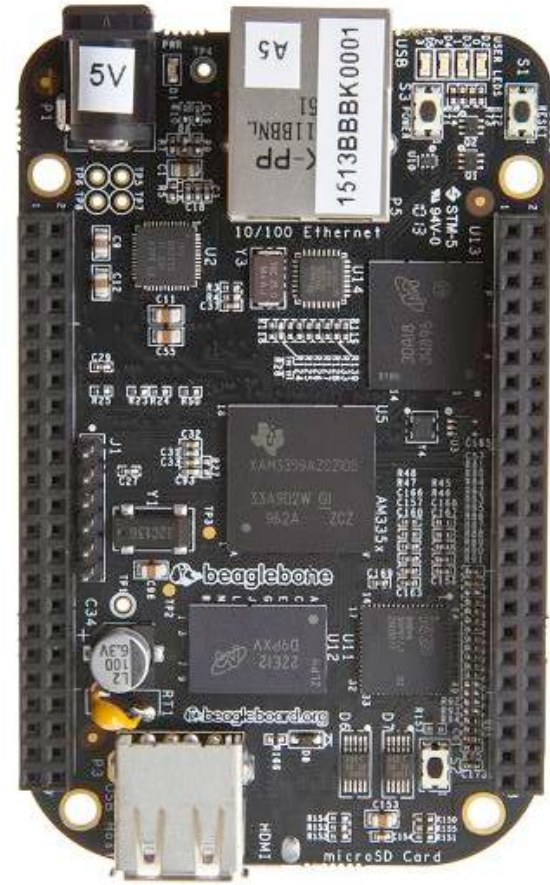
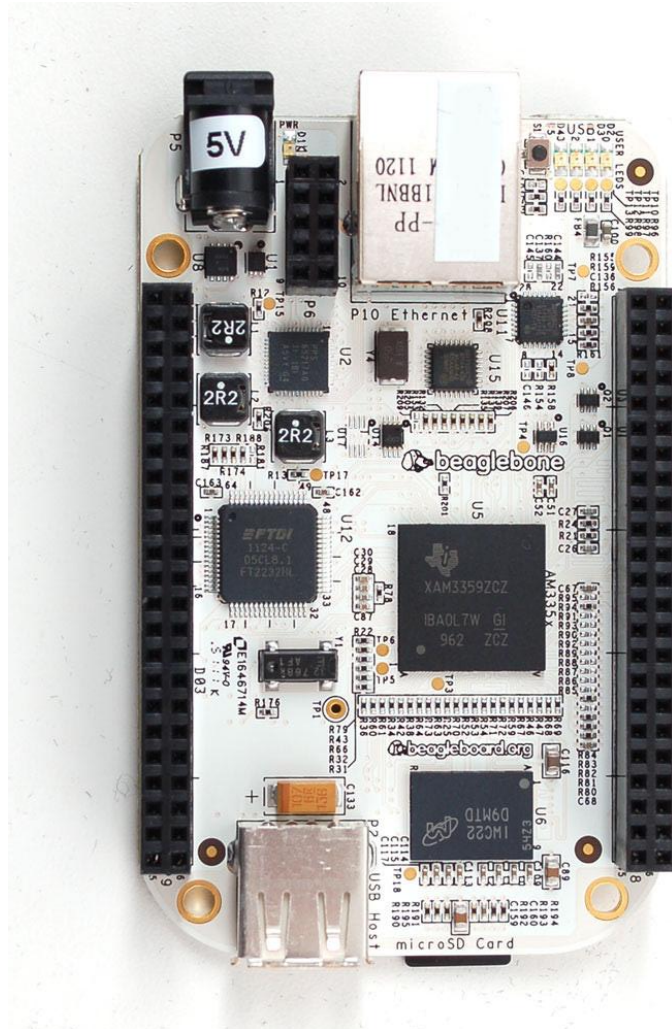
- The IoT can enable transformation of business and industry
- Enterprises can experiment with **small-scale** projects to gauge benefits while also monitoring what is happening in other industries, as a source of ideas
- A compelling business case and justifications must be developed, quantified, and articulated before **large-scale** deployment can happen

# Arduino UNO and YÚN

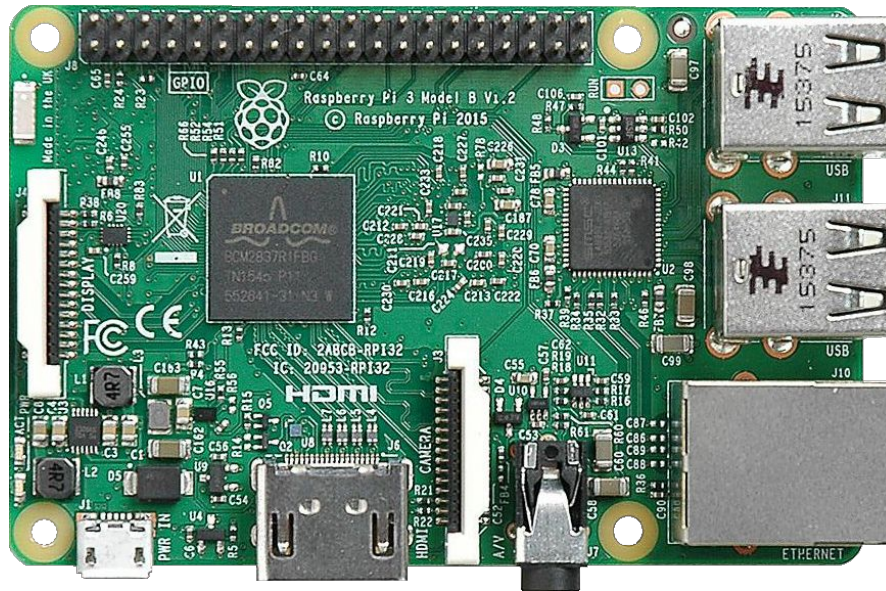
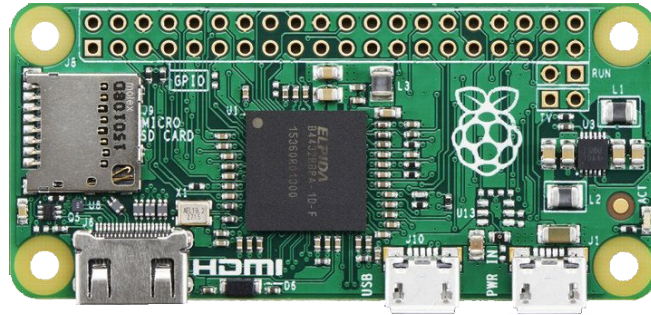




# BeagleBone and BeagleBone Black

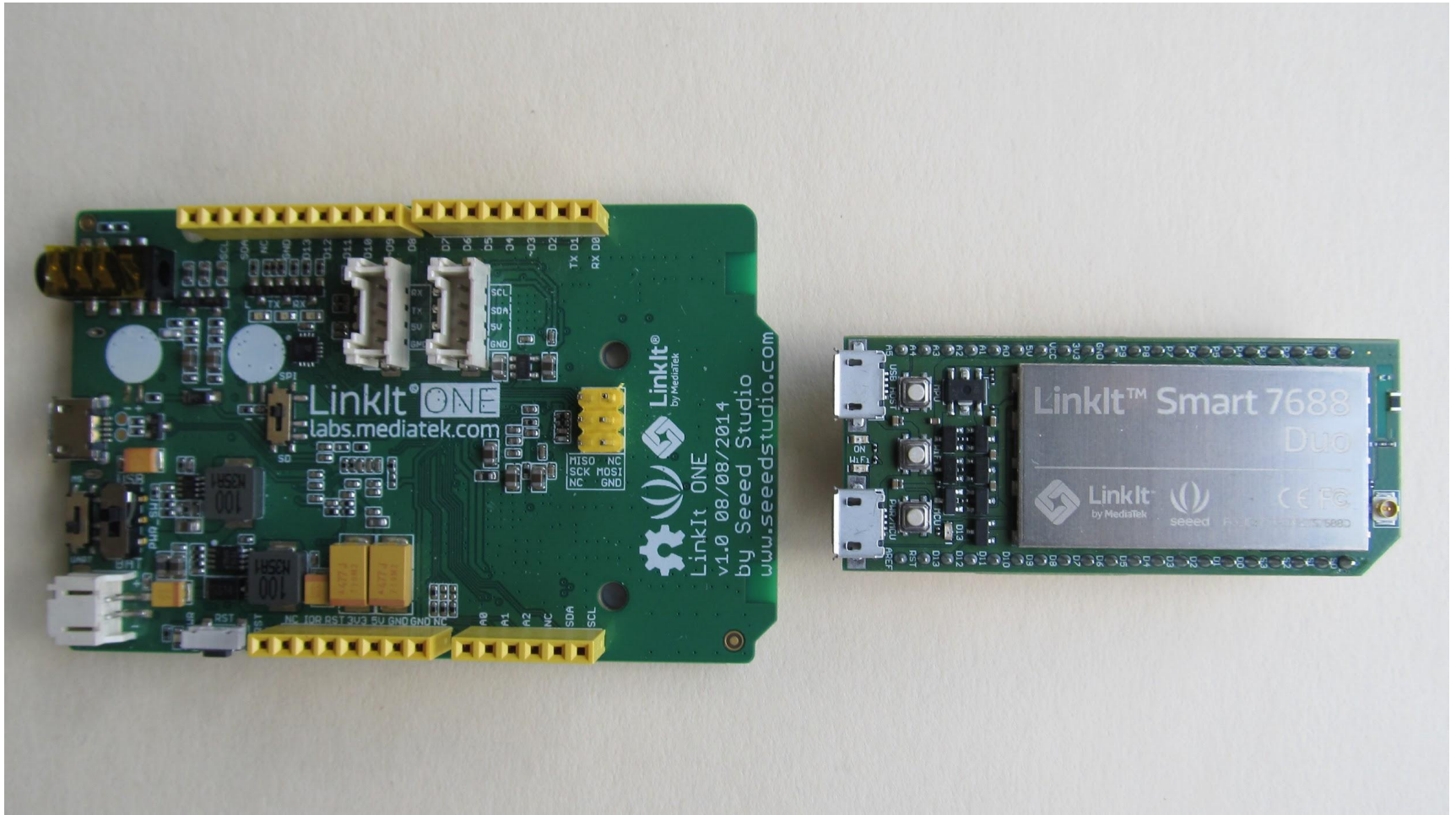


# Raspberry Pi Zero and 3B

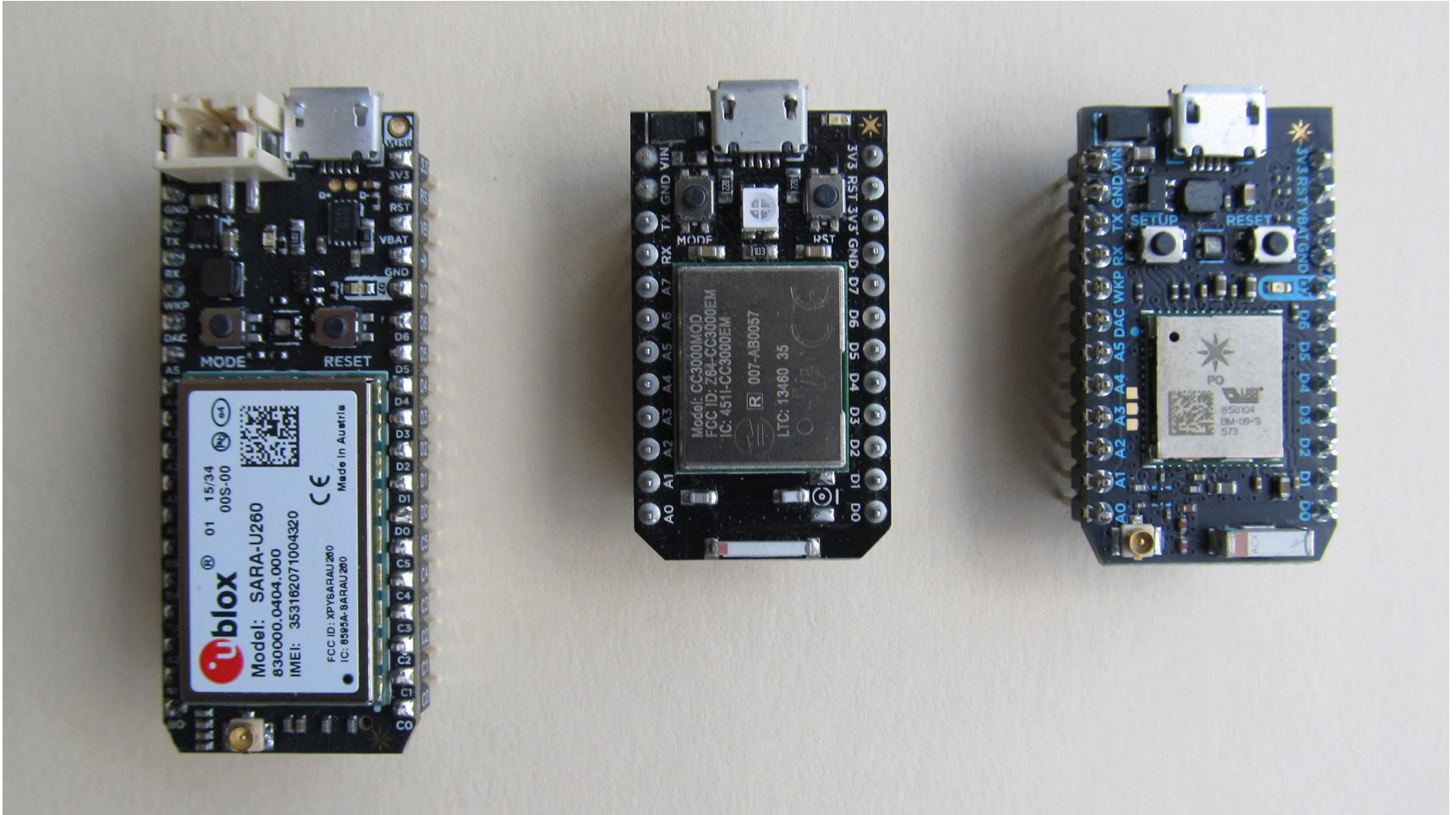




# LinkIt ONE and Smart 7688 Duo

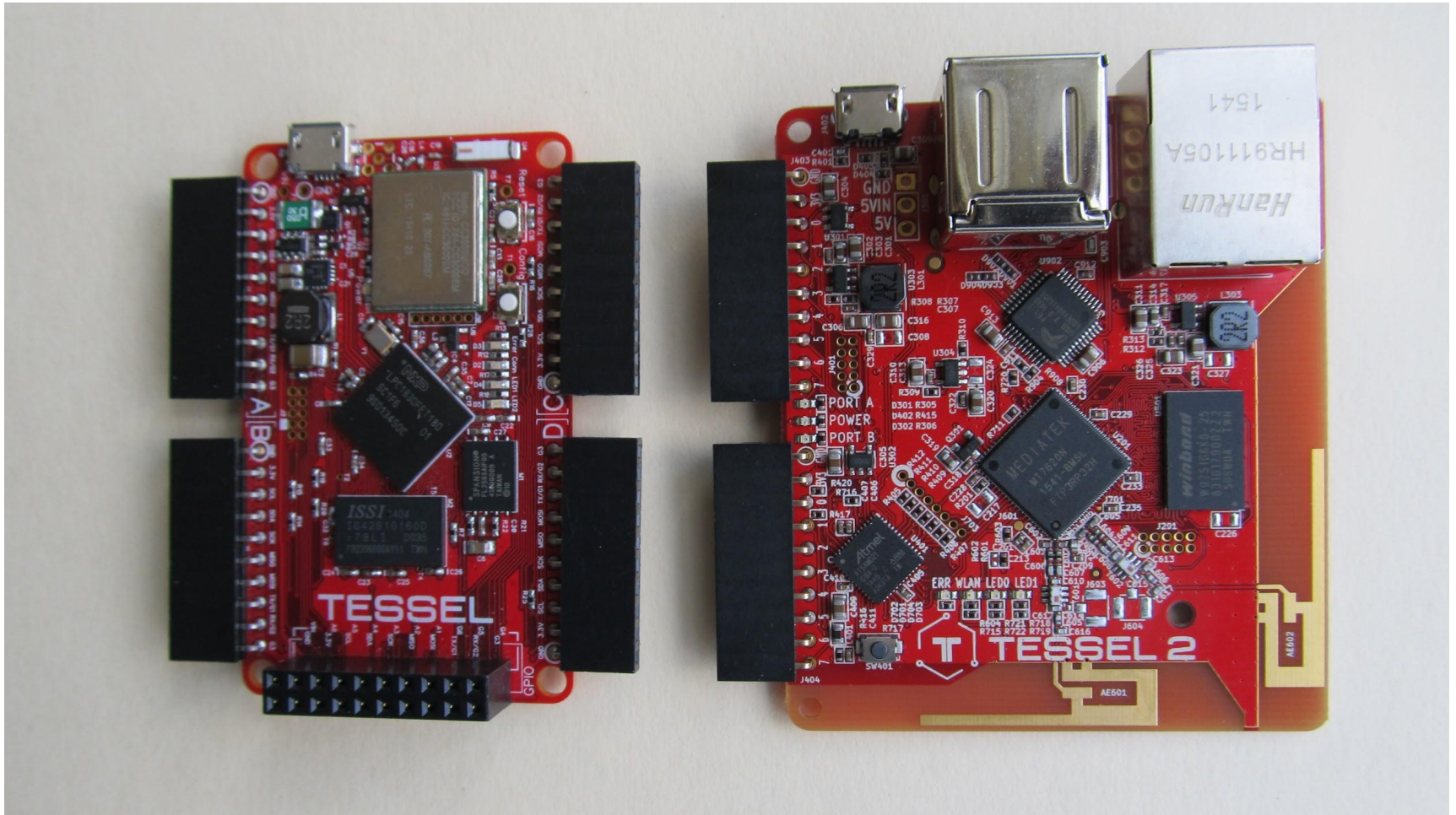


# Particle Electron, Core, and Photon





# Tessel and Tessel 2



# Development Board Examples

	Arduino YÚN	BeagleBone Black Rev. C	Raspberry Pi 3B	LinkIt Smart 7688 Duo	Particle Photon	Tessel 2
Analog Input Pins	12	6		12	8	10
Digital I/O Pins	20	65	26	27	18	16
Micro SD Card	Yes	Yes	Yes			
Ethernet/Wi-Fi	Both	Ethernet	Both	Wi-Fi	Wi-Fi	Both
Programmable USB	Micro-B	Mini-B		Micro-B	Micro-B	Micro-B
Linux OS	Linino	Debian	Raspbian	OpenWrt		OpenWrt
HDMI video		Micro-HDMI	HDMI			
Desktop IDE	Arduino	Cloud9	IDLE	Arduino	Atom	
Web IDE	Temboo				Atom	
Node.js	Ideino	Default		Default	Default	Default
Price	\$74.95	\$48.00	\$35.00	\$15.90	\$19.00	\$44.45

# Cloud Platform Examples

AWS IoT	<a href="https://console.aws.amazon.com/iot/">https://console.aws.amazon.com/iot/</a>	PrivateEyePi	<a href="http://www.privateeyepi.com/">http://www.privateeyepi.com/</a>
Beebotte	<a href="https://beebotte.com/">https://beebotte.com/</a>	Pushbullet	<a href="https://www.pushbullet.com/">https://www.pushbullet.com/</a>
Blynk	<a href="http://www.blynk.cc/">http://www.blynk.cc/</a>	relayr	<a href="https://www.relayr.io/">https://www.relayr.io/</a>
Carriots	<a href="https://www.carriots.com/">https://www.carriots.com/</a>	SAMI	<a href="https://www.samsungsami.io/">https://www.samsungsami.io/</a>
Eclipse IoT	<a href="http://iot.eclipse.org/">http://iot.eclipse.org/</a>	Temboo	<a href="https://temboo.com/">https://temboo.com/</a>
EVERYTHING	<a href="https://evrythng.com/">https://evrythng.com/</a>	ThingSpeak	<a href="https://thingspeak.com/">https://thingspeak.com/</a>
Exosite	<a href="https://exosite.com/">https://exosite.com/</a>	ThingWorx	<a href="http://www.thingworx.com/">http://www.thingworx.com/</a>
Fluxstream	<a href="https://fluxstream.org/">https://fluxstream.org/</a>	Watson IoT	<a href="http://www.ibm.com/internet-of-things/">http://www.ibm.com/internet-of-things/</a>
Google Cloud	<a href="https://cloud.google.com/solutions/iot/">https://cloud.google.com/solutions/iot/</a>	Weaved	<a href="https://www.weaved.com/">https://www.weaved.com/</a>
GroveStreams	<a href="https://grovestreams.com/">https://grovestreams.com/</a>	WebIOPi	<a href="http://webiopi.trouch.com/">http://webiopi.trouch.com/</a>
Heroku	<a href="https://www.heroku.com/">https://www.heroku.com/</a>	wot.io	<a href="http://www.wot.io/">http://www.wot.io/</a>
Instapush	<a href="https://instapush.im/">https://instapush.im/</a>	Xively	<a href="https://xively.com/">https://xively.com/</a>
Ionic	<a href="http://ionic.io/">http://ionic.io/</a>	Yeelink	<a href="http://www.yeelink.net/">http://www.yeelink.net/</a>

# Arduino



- Arduino started in 2005 as a project for students at Interaction Design Institute Ivrea in Ivrea, Italy
- The name “Arduino” comes from a bar (now Movida) in Ivrea, where some of the founders of the project used to meet
- The bar was named after Arduino d’Ivrea, king of Italy from 1002 to 1014, popularly romanticized as a dedicated nationalist who sought to free his country from foreign domination



# The Pythons in 1969



- Back: Graham Chapman, Eric Idle, Terry Gilliam
- Front: Terry Jones, John Cleese, Michael Palin
- The group's influence on comedy has been compared to The Beatles' influence on music



# Raspberry Pi



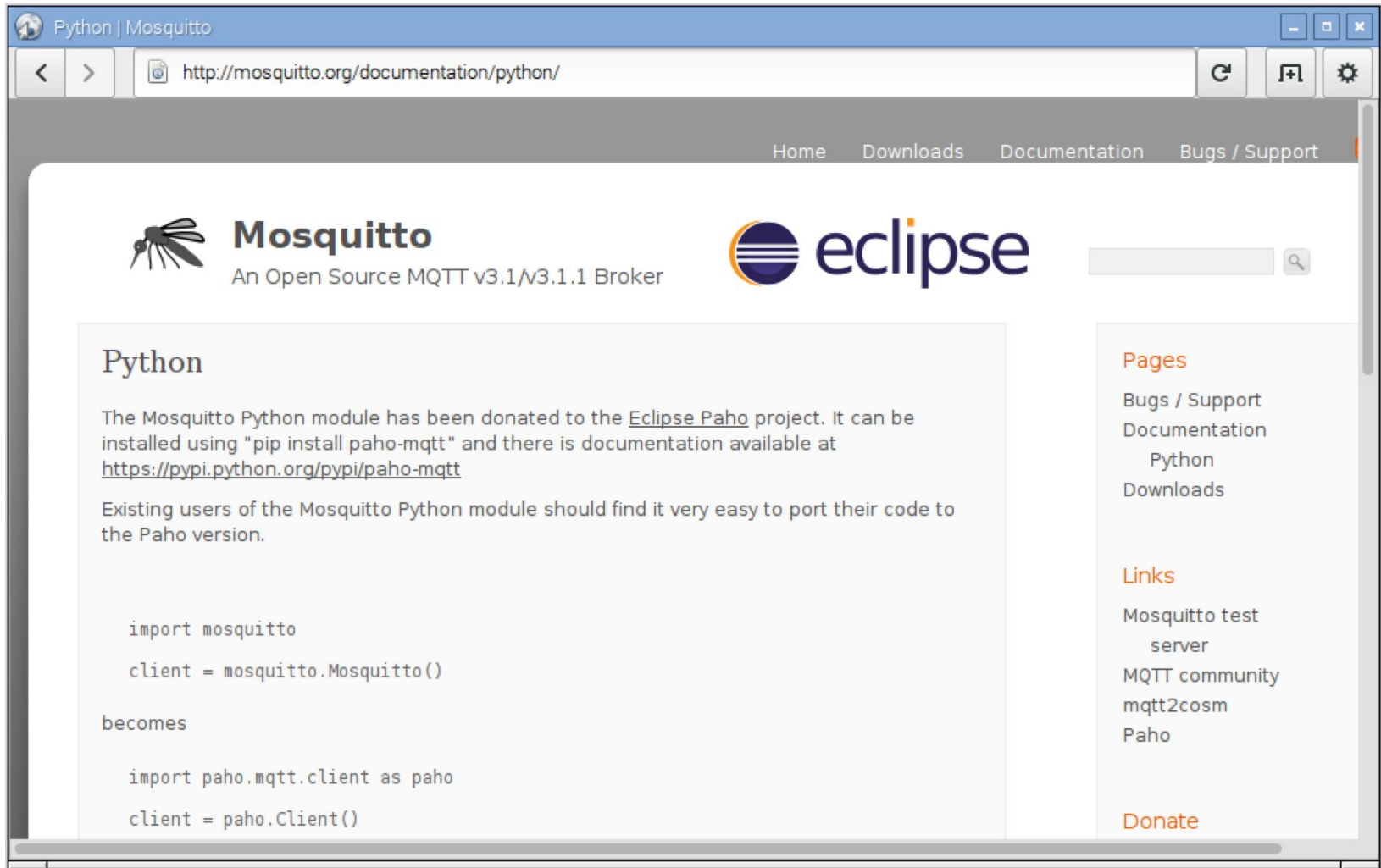
- A nostalgia for naming computers after fruit
- Kids like blowing a raspberry
- Pi is short for Python
- Let users see the guts of devices that they usually don't see
- Feature Broadcom system on a chip (SOC) BCM2835 in 2011, BCM2836 in 2014, and BCM2837 in 2015
- Tech specs for all models: [https://en.wikipedia.org/wiki/Raspberry\\_Pi](https://en.wikipedia.org/wiki/Raspberry_Pi)
- Official history: <https://www.raspberrypi.org/about/>
- Teacher training initiative: <https://www.raspberrypi.org/picademy/>

# Django Reinhardt 1910-1953



- Jean “Django” Reinhardt was a Belgian-born French jazz guitarist and composer of Romani ethnicity
- His nickname “Django” with the D silent is Romani for “I awake”
- He created a whole new fingering system built around his left index and middle fingers
- He could not read or write musical notation

# Mosquitto Python → Eclipse Paho



The screenshot shows a web browser window displaying the Mosquitto Python documentation page. The browser's address bar shows the URL `http://mosquitto.org/documentation/python/`. The page features the Mosquitto logo (a mosquito) and the Eclipse logo. The main content area is titled "Python" and contains the following text:

The Mosquitto Python module has been donated to the [Eclipse Paho](#) project. It can be installed using "pip install paho-mqtt" and there is documentation available at <https://pypi.python.org/pypi/paho-mqtt>

Existing users of the Mosquitto Python module should find it very easy to port their code to the Paho version.

```
import mosquitto

client = mosquitto.Mosquitto()

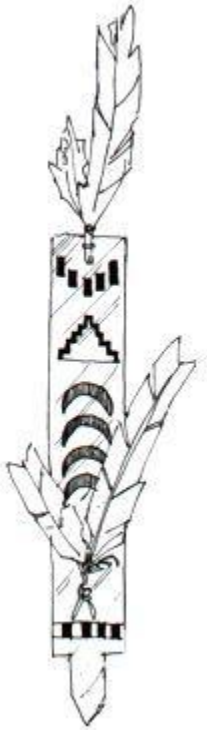
becomes

import paho.mqtt.client as paho

client = paho.Client()
```

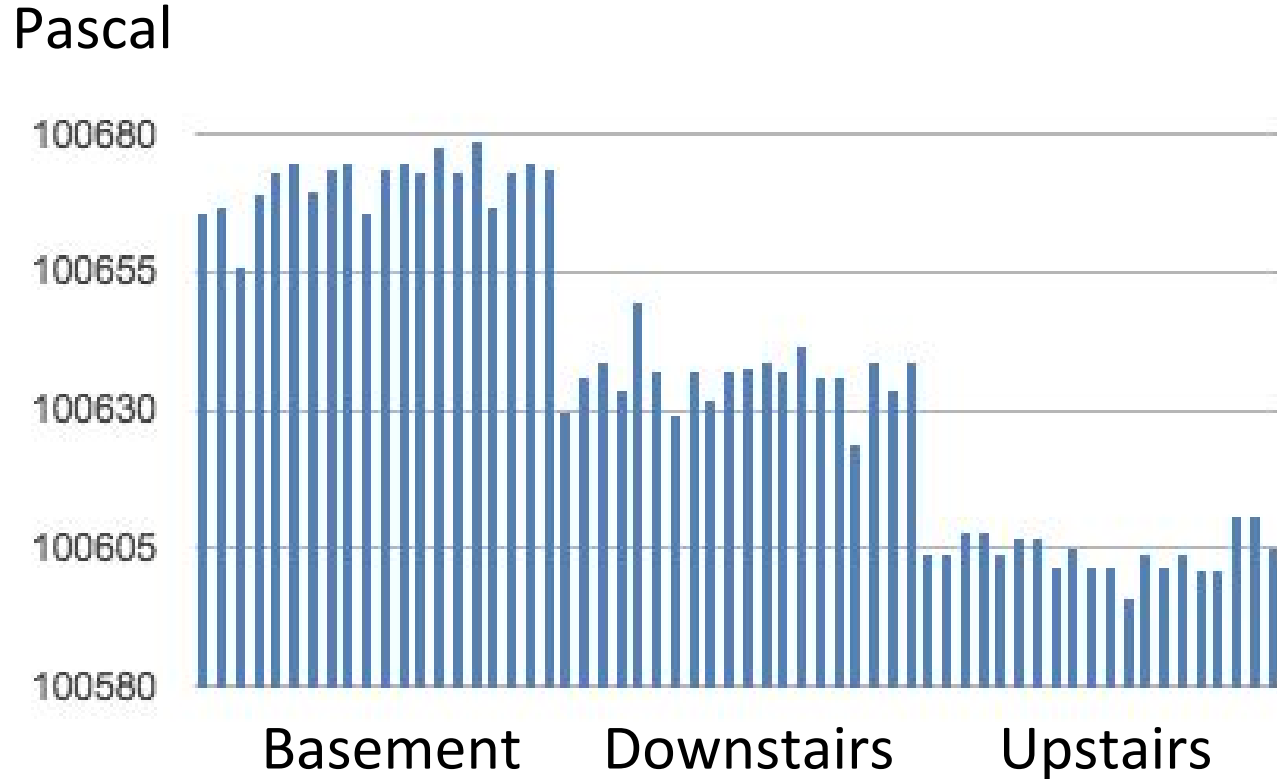
On the right side of the page, there are sections for "Pages" (listing Bugs / Support, Documentation, Python, Downloads) and "Links" (listing Mosquitto test server, MQTT community, mqtt2cosm, Paho). A "Donate" link is also visible at the bottom of the right sidebar.

# Paho



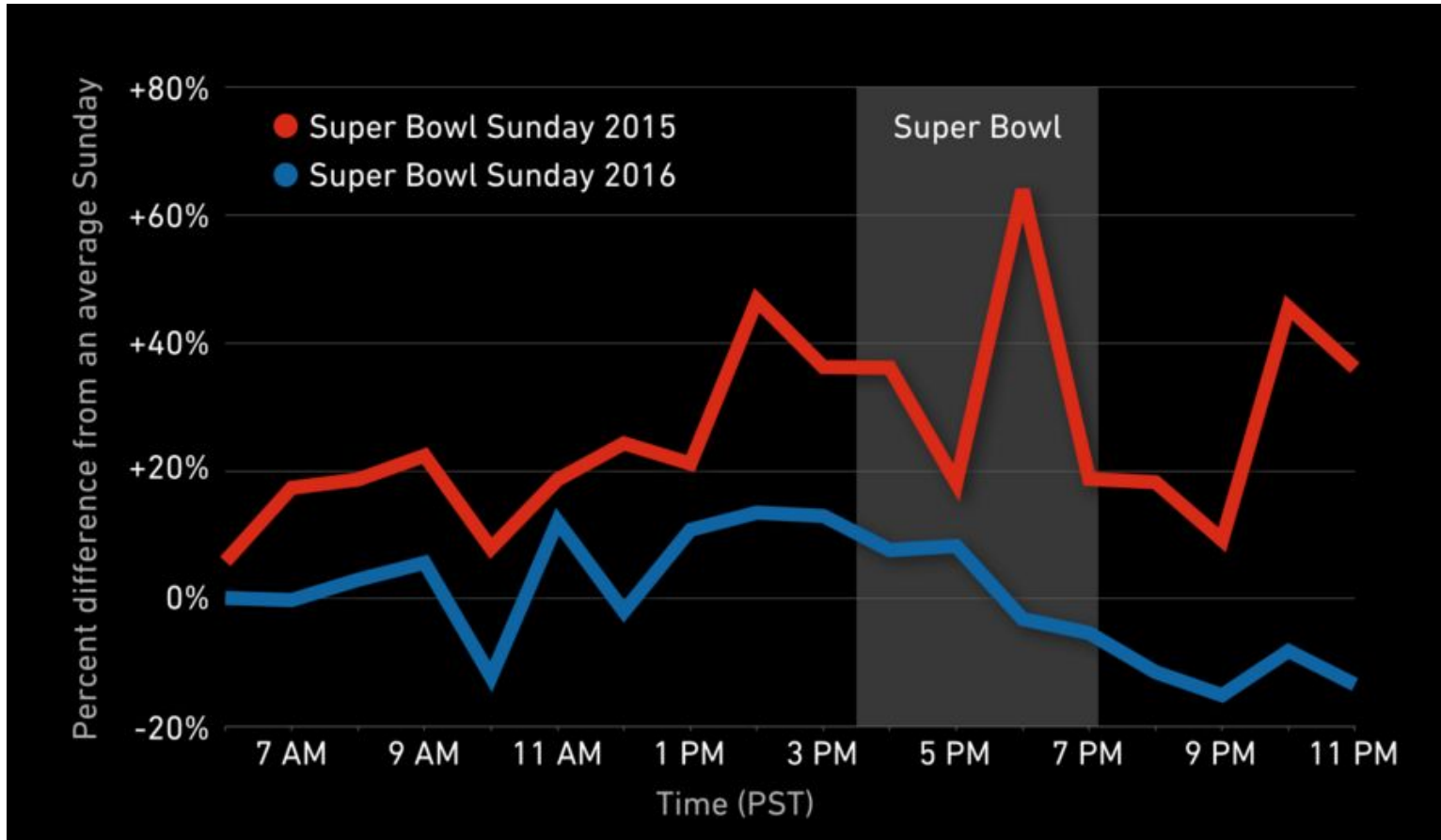
- A paho is a Hopi Indian plumed prayer stick
- The Hopi people are a group of indigenous Native American people from the Four Corners (the southwestern, northwestern, northeastern, and southeastern corners of Colorado, New Mexico, Arizona, and Utah, respectively)
- According to the 2000 US census, they have a population of approximately 7,000 members in the Hopi Reservation of northeastern Arizona
- They perform nine religious ceremonies inherited from ancient rituals

# BMP180 Pressure Data



# Data Visualization

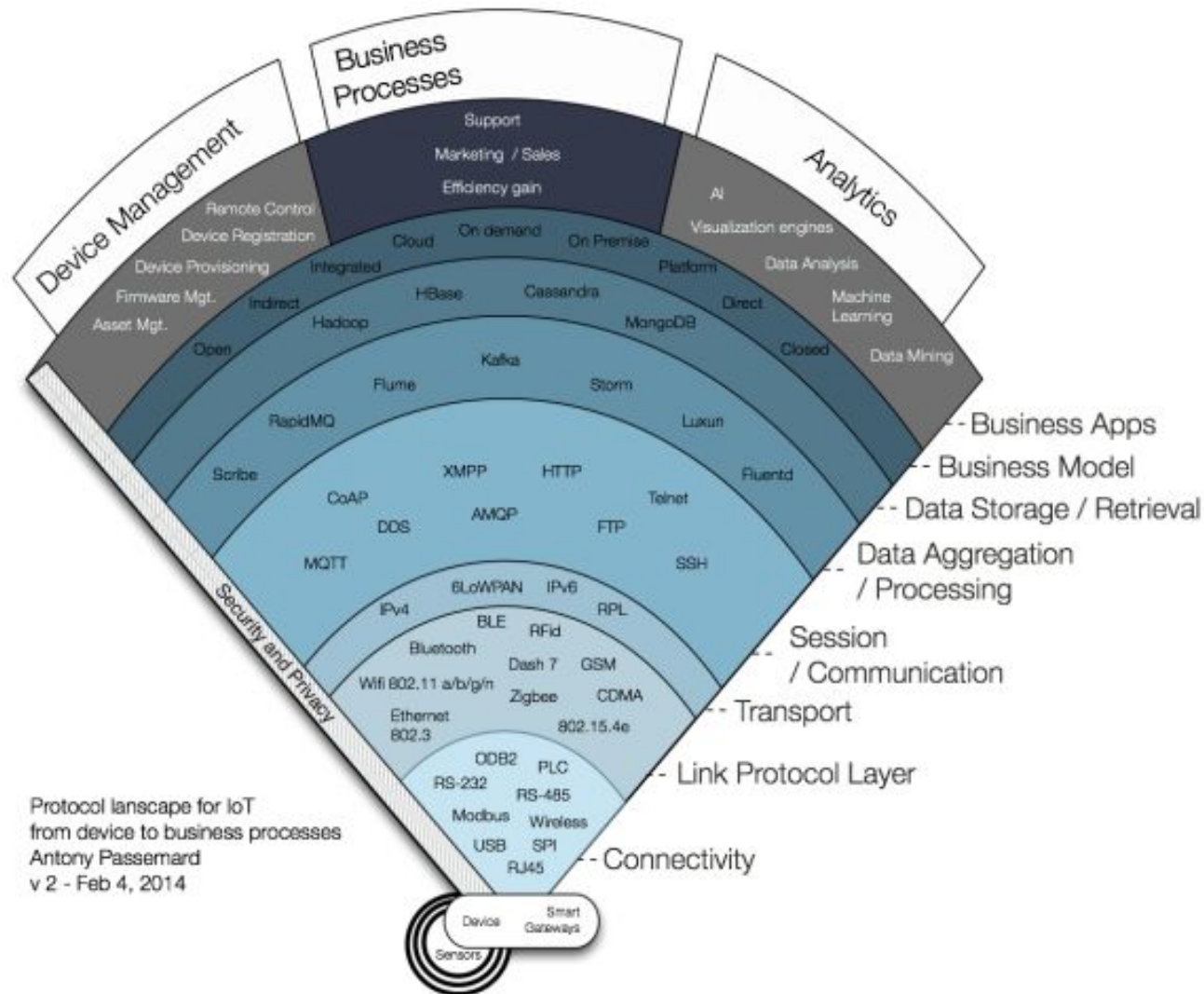
Hard accelerations and breaks from a subset of Automatic drivers



<http://blog.automatic.com/super-bowl-50/>



# From Sensors to Business Value





# Summary

- IoT is not always active – it's mostly RESTful
- Not all data sent to the cloud
- IoT is not about adding connectivity to all things
- IoT is about how sensors, devices, things, and services can be integrated to create value
- Value is derived from making sense of data, turning it into knowledge and meaningful action
- Access to data *shall* have differential restrictions