Designing and Building for End-to-End Solutions

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Capstone & Guest Lecture – IoT course
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Introduction to Internet of Things (IoT)
Definition from IEEE

The Internet of Things (IoT) is a self-configuring and adaptive system consisting of networks of sensors and smart objects whose purpose is to interconnect “all” things, including everyday and industrial objects, in such a way as to make them intelligent, programmable and more capable of interacting with humans.
Gartner Hype Cycle for Emerging Technologies 2014
Gartner Hype Cycle for Emerging Technologies 2015

- Advanced Analytics With Self-Service Delivery
- Autonomous Vehicles
- Internet of Things
- Speech-to-Speech Translation
- Machine Learning
- Wearables
- Cryptocurrencies
- Consumer 3D Printing
- Natural-Language Question Answering
- Hybrid Cloud Computing
- Augmented Reality
- Gesture Control
- Virtual Reality
- Autonomous Field Vehicles

- Bioacoustic Sensing
- People-Literate Technology
- Digital Security
- Smart Dust
- Virtual Personal Assistants
- Quantum Computing
- Brain-Computer Interface
- Human Augmentation
- Volumetric Displays
- Smart Robots
- 3D Bioprinting Systems for Organ Transplant
- IoT Platform
- Connected Home
- Affective Computing
- Neurobusiness
- Citizen Data Science
- Biochips
- Software-Defined Security
- Digital Dexterity
- Smart Advisors

- Innovation Trigger
- Peak of Inflated Expectations
- Trough of Disillusionment
- Slope of Enlightenment
- Plateau of Productivity

- Plateau will be reached in:
  - less than 2 years
  - 2 to 5 years
  - 5 to 10 years
  - more than 10 years
  - obsolete before plateau

- As of July 2015
THE INTERNET OF THINGS

2003  
2010  
2015  
2020 Estimated 50 billion things

During 2008, the number of things connected to the internet exceeded the number of people on Earth.

Number of Connected Objects Expected to Reach 50bn by 2020

Penetration of connected objects in total ‘things’ expected to reach 2.7% in 2020 from 0.6% in 2012

The Connected Life by 2020

Revenue Opportunity For Mobile Network Operators in 2020

<table>
<thead>
<tr>
<th>Category</th>
<th>Revenue Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected Devices</td>
<td>$1.2 Trillion</td>
</tr>
<tr>
<td>Mobile Connected Devices</td>
<td>$202 Billion</td>
</tr>
<tr>
<td>Automotive</td>
<td>$69 Billion</td>
</tr>
<tr>
<td>Consumer Electronics</td>
<td>$35 Billion</td>
</tr>
<tr>
<td>Connected Devices in vertical sectors</td>
<td>$202 Billion</td>
</tr>
<tr>
<td>Internet of Things (People, Process, Data, Things)</td>
<td>Doubles every 1.3 years</td>
</tr>
<tr>
<td>Internet of Everything</td>
<td>Doubles every 1.4 years</td>
</tr>
<tr>
<td>Fixed Computing (You go to the device)</td>
<td>Doubled every 200M years</td>
</tr>
<tr>
<td>Mobility / BYOD (The device goes with you)</td>
<td>Doubled every 10B years</td>
</tr>
</tbody>
</table>
1969
The Internet Emerges
The first nodes of what would eventually become known as ARPANET, the precursor to today's Internet, are established at UCLA and Stanford universities.

1982
TCP/IP Takes Shape
Internet Protocol (TCP/IP) becomes a standard, ushering in a worldwide network of fully interconnected networks called the Internet.

1990
A Thing Is Born
John Romkey and Simon Hackett create the world's first connected device (other than a computer): a toaster powered through the Internet.

1999
The IoT Gets a Name
Kevin Ashton coins the term "Internet of things" and establishes MIT's Auto-ID Center, a global research network of academic laboratories focused on RFID and the IoT.

2005
Getting Global Attention
The United Nations first mentions IoT in an International Telecommunications Union report. Three years later, the first international IoT conference takes place in Zurich.

2008
Connections Count
The IPSO Alliance is formed to promote IP connections across networks of "smart objects." The alliance now boasts more than 50 member firms.

2011
IPV6 Launches
The protocol expands the number of objects that can connect to the Internet by introducing 340 undecillion IP addresses (2128).

2013
Google Raises the Glass
Google Glass, controlled through voice recognition software and a touchpad built into the device, is released to developers.

2014
Apple Takes a Bite
Apple announces HealthKit and HomeKit, two health and home automation developments. The firm's iBeacon advances context and geolocation services.
Architecture Block diagram
Architecture Diagram - IoT

- Cloud Solution
- Remote User
- Local User
- Connected Device
- Router/Hub
- Internet
Protocols
Protocols define format, order of messages sent and received among network entities, and actions taken on message transmission and/or receipt.
What is a Protocol?

- **Human Protocols:**
  - What is the time?
  - I have a question
  - Introductions

- **Characterized by:**
  - Specific Message sent
  - Specific Actions taken when messages received or on events

- **Network Protocols:**
  - Machines rather than Humans
  - All Communication Activity between Computers is governed by protocols
Human Protocol
Computer Network Protocol

Hi
Hi
Got the time?
2:00

time

TCP connection request
TCP connection response
Get http://www.awl.com/kurose-ross
<file>
Internet: Nuts and Bolts View

- Network of Networks
  - Interconnected ISPs

- Protocols Control Sending and Receiving of Data as Messages or Packets
  - E.g. Ethernet, 802.11, TCP, IP, FTP, HTTP, etc.

- Internet Standards
  - RFC: Request for Comment
  - 7736 Documents as of 12/15
  - IETF: Internet Engineering Task Force
Internet: Service View

- Infrastructure that provides services to applications:
  - Web, VoiP, Email, Games, E-Commerce, Social Networking, etc..

- Provides Programming Interfaces to Apps
  - Hooks that allow sending and receiving app programs to “connect” to the internet
  - Provides Service Options.
  - Analogous to Postal Service
Networking technologies for IoT – BLE & 6LoWPAN
Bluetooth 4.0: Use-cases

Connecting the things we carry with us:
• Watches: remote display from other devices
• Tags: locate objects or keep track of them (e.g. warming if you walk away)
• Health & fitness sensors (e.g. pedometer in your shoes)
• Body sensors (e.g. blood pressure, pulse rate, blood glucose, etc)

Accessing the things around us:
• Fobs: use proximity as a security/access control means
• Home and office automation

Low duty cycle M2M communication:
• Sensors and controls in home, office and factories

Communication within a system
• Car to car wheels/tiers

Connecting anything that has intrinsic data to the internet
Bluetooth 4.0: Opportunities

New classes of gadgets
• Around a person
• Around a house
• In your car

New application on PCs and smart phones
• Use those devices

New web services
• Anything can connect to the web

New Social Applications
• Your beer glass can talk to your Facebook page
Bluetooth 4.0: Example of products

- **Kensington**: Proximity tag
- **Nokia**: Precious Tag
- **Lifesense**: Blood Pressure Monitor
- **Ruwido/Swisscom**: Remote Control
- **UnderArmor**: Heart Rate Monitor
- **Kwikset**: Smart door lock
- **Schneider**: Notebook protector
6LoWPAN

- 6LoWPAN is an acronym of IPv6 – Low power wireless personal area networks
- Concluded working group in the internet area of the IETF
- To apply for smallest devices and low power devices
- Limited processing capabilities should be able to participate within IoT
- Defined encapsulation and header compression mechanism that allow packets to be sent and received IEEE 802.15.4 based networks
- Desired working connection within local-area networks, metropolitan area networks and wide area networks
- The concept was created because engineers felt like the smallest devices were being left out from the Internet of Things. 6LoWPAN can communicate with 802.15.4 devices as well as other types of devices on an IP network link like Wi-Fi. A bridge device can connect the two.
6LoWPAN – Flow

6Lowpan: what does it mean?

Low Power
Low Data rate
Low Cost

Wireless Personal Area Networks

IPV4
Addr: 32 bits

IPV6
Addr: 128 bits
Introduction to IPv6
Internet Protocol, Version 6 (IPv6)

• The Internet Engineering Steering Group approved the IPv6 recommendation and drafted a Proposed Standard on November 17, 1994
• Core set of IPv6 protocols became an IETF Draft Standard on August 10, 1998
  – This included RFC 2460, which obsoleted RFC 1883
What’s New in IPv6?

• Extended address space
  – The address format is extended from 32 bits to 128 bits
    ▪ This is enough to provide a billion IP addresses for every star in the universe (~ $10^{29}$)
      – [http://www.space.com/26078-how-many-stars-are-there.html](http://www.space.com/26078-how-many-stars-are-there.html)
      – It also allows for hierarchical structuring of the address space in favor of optimized global routing
Autoconfiguration

One of the most intriguing new feature of IPv6 is its Stateless autoconfiguration mechanism

• When a booting device in the IPv6 world comes up and asks for its network prefix, it can get one or more network prefixes from an IPv6 router on its link
• Using this prefix information, it can autoconfigure for one or more valid global IP addresses by using either its MAC identifier or a private random number to build a unique IP address
General Header Structure

**IPv4 Header**
- Version
- IHL
- Type of Service
- Total Length
- Identification
- Flags
- Fragment Offset
- Time to Live
- Protocol
- Header Checksum
- Source Address
- Destination Address
- Options
- Padding

**IPv6 Header**
- Version
- Traffic Class
- Flow Label
- Payload Length
- Next Header
- Hop Limit
- Source Address
- Destination Address

Field’s Name Kept from IPv4 to IPv6
- IHL
- Type of Service
- Identification
- Flags
- Fragment Offset
- Time to Live
- Protocol
- Header Checksum

Fields Not Kept in IPv6
- Options
- Padding

Name and Position changed in IPv6
- Traffic Class

New Field in IPv6
- Flow Label
IoT Hardware platform
IoT Platform – Hardware and Software

Hardware:

- ARM mBed
- Intel - Edison
- Intel - Galileo
- Intel – Arduino 101
- ARC - Bluetooth model
Hardware communication protocol
Introduction - Communication

- **Protocol**: A set of rules and regulations is called a protocol.

- **Communication**: Exchange of information from one system to another system with a medium is called a communication.

- **Communication Protocol**: A set of rules and regulations that allow two electronic devices to connect to exchange the data with one and another.
Inter Integrated Circuit – I2C

- Protocol introduced by Philips Semiconductor in 1982
- Lower speed devices:
  - Standard mode: 100 kbit/s
  - Full speed: 400 kbit/s
  - Fast mode: 1 mbit/s
  - High speed: 3.2 Mbit/s
- Master/Slave communication.
- Slave has unique address bits.
- Master device sends the address of the target, slave device and read/write flag.
- The address is match any slave device that device is ON, remaining slave devices are disable mode.
- Once the address is match communication proceed between master and that slave device and transmitting and receiving the data.
Universal asynchronous receiver/transmitter - UART

- Translates data in Serial and Parallel.
- Also known as RS 232.
- Transmits bits serially at a mutually agreed speed without providing a clock.
- The speed is known as the baud rate such as: 9600 baud, 115200 baud, or 10 Mbaud.
- Single wire in each direction (VCC and Ground).
- Asynchronous, as there is no clock signal.
General Purpose Input and Output SPECS - GPIO

Both input and output are controllable by the user at runtime:

• No pre-defined pins. Go unused by default.
• GPIO Pins can be enabled/disabled.
• May be exposed to the developer for configuring / state set up.
IoT Cloud Platforms
CLOUD PLATFORM

Cloud

- AWS IoT
- Azure - Microsoft
- Bluemix – IM
- GE – Predix
- Open IoT - National University of Ireland
Sensor components
How to build end to end IoT solutions
5

Prototype

Build prototype using evaluation board and Open source cloud components

Assembling sensor and electronics
Writing device drivers
Writing APIs for cloud infrastructure
Client integration such as Desktop, Tablet, Mobile, etc.,

THE LINUX FOUNDATION
OpenIoTSummit
dew MOBILITY
Field Testing (3-6 months) → Beta version (1 - 2 months) → Production → Release and Documentation
Few IoT Examples
Project Examples
Assistance Living and Smart Cities Projects
Environmental Projects

• Air Pollution Monitoring: Control of CO2 emissions of factories, pollution emitted by cars and toxic gases generated in farms.

• Indoor Air Quality: Monitoring of toxic gas and oxygen levels inside chemical plants to ensure workers and goods safety.

• Earthquake Early Detection: Distributed control in specific places of tremors.

• Forest Fire Detection: Monitoring of combustion gases and preemptive fire conditions to define alert zones.

• Waste Management Detection: Detection of rubbish levels in containers to optimize the trash collection routes.
Project Examples

- Crowd Sensing Data
- Linked Sensors
- Sensors Discovery
- Super Stream Collider
- Vision Band Smart
- Help BuzzMe
- Smart Helmet
- Smart Locking
- Smart Glow Lighting
- Smart Trials
- Smart Bin
IoT for Smart Garbage Monitoring
SMART BIN - WASTE MANAGEMENT (DESIGN AND ARCHITECTURE)
ARMmbed IoT platform (Prototype)
ASSEMBLY 1 (Field Deployment)
ASSEMBLY 2 (Field Deployment)
Battery Connection (Test Run)
Message Test
24 Hour test result
(Laptop Application)
SENSED TRIALS - CITIZENS’ MOBILITY (DESIGN AND ARCHITECTURE)
IoT for Trail (Field Deployment)

Bishop peak
Test results (Tablet App)

<table>
<thead>
<tr>
<th>Trail</th>
<th>Traffic</th>
<th>Temperature</th>
<th>UV</th>
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<tr>
<td>bishops</td>
<td>3</td>
<td>78.064095</td>
<td>9.45055</td>
</tr>
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</table>

![Trail Traffic](image)
Irrigation and Sprinkle control
(Design and Architecture)
IoT for Irrigation (Field Deployment)
Integration (Data Collection)
Test results (Web Services)
Smart Glow Lighting System

IoT Device

Sound Sensor
UV Sensor
Motion Sensor

IoT Cloud

Sends Desire Output (LED signaling)
Control and Configuration (Street Light usage)
Data Analysis (use of street frequency)

Task and Applications

OPENIoT

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OpenIoT Summit
Thank you

Shivakumar Mathapathi
Co-Founder & CTO - Dew Mobility
Capstone & Guest Lecture – IoT course
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