IoT: Client Devices

IoT Markets

Financial Growth

McKinsey

Potential impact of 3.9 to 11.1 trillion USD by 2025 (originally 6.25T)

IDC

5.91 Billion (today) to 1.3 trillion USD by 2019

Markets and Markets

USD 157 billion USD in 2016 to 662 billion USD by 2021

Devices & Connections

Cisco

16.3 billion M2M connections in 2015 to 26.3 billion by 2020

Gartner

6.4 billion devices in 2016, 20.8 billion devices in 2020

Markets & Markets, Ericsson, TechNavio, Machina

33%, 23%, 32%, 16% estimated compounded annual growth rate

Market Segments

Consumer-based market segment smallest

Home, Lifestyle, Health, Mobility

Organization-Based segment largest

Retail, Healthcare, Energy, Mobility, Cities, Manufacturing, Services

Overall Conclusions

Market is big, getting bigger

Overall financial projects all reach into the trillions by 2020s

Explosion in connections and devices

Some confusion in connection and device magnitude, still in mid-billions

Lots of uncertainty

Estimates range over an order of two financially and CAGR

IoT: Client Devices

Future Growth and Potential Problems

Scale

Billions of connections

How are we going to address these devices?

Billions of devices

How are we going to integrate these into homes, companies?

Apps, Services, etc.

How many apps and services will be in place to support these?

Security

Credentials & Keys

We can’t even change default credentials, why not?

Services

Programming applications isn’t new, why can’t we do it right in IoT?

Operating Systems

It’s not like we harden systems well in general, but we need to do better

Surveillance

Collected Data

How much data are companies going to collect between IoT and apps?

Companies and Conglomerates

Companies collecting as much as they can; what about conglomerates?

Governments

How about privacy protections from governments?

Sustainability

Billions of Devices

Each device is low power, but it adds up

Billions of connections

These are wireless connections - will congestion be a problem?

Data storage

Cloud computing may be more economical, but we’re talking lots of data

IoT: Client Devices

What is the Internet of Things?

Internet of Things

So what exactly is this *Internet of Things?*

Things we Think About

Cloud Cameras

Typical programmable, home-based, cloud-enabled cameras with embedded micro-controllers

Smart Plugs

Programmable power outlets you can use from your cell phone, integrate with smart home hubs, and use remotely

Smart Bulbs

Programmable bulbs that provide things like voice control, remote management, and energy savings

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Typical programm… …as with embedded micro…

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Programmable p… …one, integrate with smart home…

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Things We Don't Think About

Medical Devices

Pacemakers, medical monitors, insulin pumps, capital equipment tracking devices

Tracking Hardware

Used in warehouses and business, tags that allow you to track material goods; inventory, locations, etc.

Utility Metering

Smart grid integration, lower energy billing costs, remote surge energy monitoring and control, other remote management

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Industrial Devices

What is the Internet of Things?

The internet of things are networks of devices connected to the larger internet. The devices are:

- Small
- Cheap
- Low-power
- Low-margin

What is the Internet of Things?

And they usually have:

- An Operating system
- Network Communication
- Computational Power
- Application software

IoT: Client Devices

Where did the Internet of Things come from?

Consumer Computing

Chips/System-on-chip smaller and cheaper

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features phones, smart phones, other space constrained computers

Old protocols (X10) and home automation

Replaced by things like bluetooth, wifi, 6LoWPAN, wifi HaLow

Smart homes

Domain of the super-rich, inspiring things like Nest, smart plugs, etc.

Open Source Software

Linux Linux Linux!

Many IoT devices use non-real-time linuxes

Open-source boot chains

Das U-Boot

GCC, widespread cross-compilation

GCC has supported cross-compilation, mainstreaming today

The Internet

Widespread internet connectivity

Fast, always on internet connectivity enables device access

Low prices

Internet prices are low, and getting lower

Easy home-based wireless networks

Home wifi networks are easier and easier to configure and install

Cloud Computing

Inexpensive infrastructure & scaling

Very cheap to start, easier to manage scale

Uptime for the masses

Reliable service deployment made easier

Much lower barriers to entry

Pay as you go, start small with cloud only, migrate to hybrid strategies

IoT: Client Devices

Business-facing Use (II)

Business Uses

Infrastructure (adoption slower than expected)

- Road management
- Power management
- Water, waste, general utilities

Business Uses

Transportation (high growth expectations)

- Interstate trucking
- Fleet management
- Driver performance monitoring

Business Uses

Retail (growth/adoption much lower than predicted)

- Shoplifting sensors
- Targeted advertising
- Customer tracking
- Inventory placement

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Business-facing Use (I)

Business Uses

Health (growth projections mixed)

- Patient monitoring & measurement
- diagnosis aids

Business Uses

Military (expected growth in this segment ill-defined)

- Monitoring
- Perimeter sensing
- Surveillance

Business Uses

Energy (growth expectations high)

- Energy use
- Conservation
- Power management & distribution (smart grids/meters)

Business Uses

Manufacturing (growth expectations high)

- Asset tracking
- Supply chain management
- Inventory management
- Asset monitoring and management

IoT: Client Devices

What are they?

Typical Clients

Cameras

Cloud connected cameras with streaming video, programmable

Smart Plugs

Programmable schedules, monitor power usage, from smart phone

Thermostats

Learns usage, can tell when people are home, access from phone

Hardware

Nest

Lithium Ion Battery, ARM Cortex A8, 38 MB memory

Nest Dropcam

Ambarella A5s SoC using ARM A11

Overall

Low processing power, small space, low power requirements

Software

Das U-Boot

Free bootloader, open source, multi-stage, prepares and loads OS

Linux

Open source operating system, frequently used with Busybox in IoT

Applications

Vendors can run applications and services on the booted linux image

Communication

Wifi

2.4 GHz common, sometimes 5 GHz

Zigbee

Low power, personal area networks (PAN), low data rate

6LoWPAN

IP6 over low power PAN

IoT: Client Devices

Communications

IoT-Specific

Zigbee (IEEE 802.15.4)

Cheap, low-power, line-of-sight, short range; used for PANs

6LoWPAN

IPv6 for PAN; can transmit over Zigbee (very common configuration)

Wifi HaLow (IEEE 802.11ah)

Sub 1GHz, extended range, low-power; great for rural, smart metering

General Purpose

Wifi

Standard run-of-the-mill IEEE 802.11 wifi, interface with home networks

Bluetooth/BLE

Common for media devices, fitness devices, wearables

Radio/RFID

Used in industrial applications; inventory monitoring, equipment tracking

Other Layers

TCP/IP

Most systems (all using Linux) can use TCP/IP sockets, etc.

HTTP/HTTPS

Devices consume HTTP/HTTPS APIs, they don’t usually provide them

Thrift, Protocol Buffers

Not common, but have been used; binary format, low overhead is nice

Proprietary, Other

Over TCP/IP

TDDP, proprietary binary protocol used by TP-Link devices

Over HTTP/HTTPS

JSON, REST-style APIs, SOAP not very common today

Thread Group (see OpenThread)

Closed documentation, royalty free; encrypted, uses other IoT protocols

OpenThread is the Open Source version of this, released by NEST

IoT: Client Devices

Services

Common Types

Data Aggregation

Data transmitted from remote devices, data collected for later review

Device Control & Management

Controlling local devices, direct from Apps or via remote services, or both

Reporting & Administrative

Not usually standalone; almost always accompanies control or aggregate

Technologies

Web Technologies

Accessing services via browsers, using HTTP/HTTPS for data transfer

Apps

Most all consumer IoT devices have accompanying apps

Device Integration

Devices pass data to services, receive commands from services

Hosting

Cloud

Very common, especially in early startup phase

Private

Pure private is uncommon today, though companies will lease/colocate

Private clouds, colocated server farms, depends on company

Hybrid

Most common for mature companies today; public bursting, private baseline

Architectures

Multiple Endpoints

Possible endpoints: devices, apps, browsers

Multiple access patterns

Unidirectional, bidirectional; depends on the device

High Availability

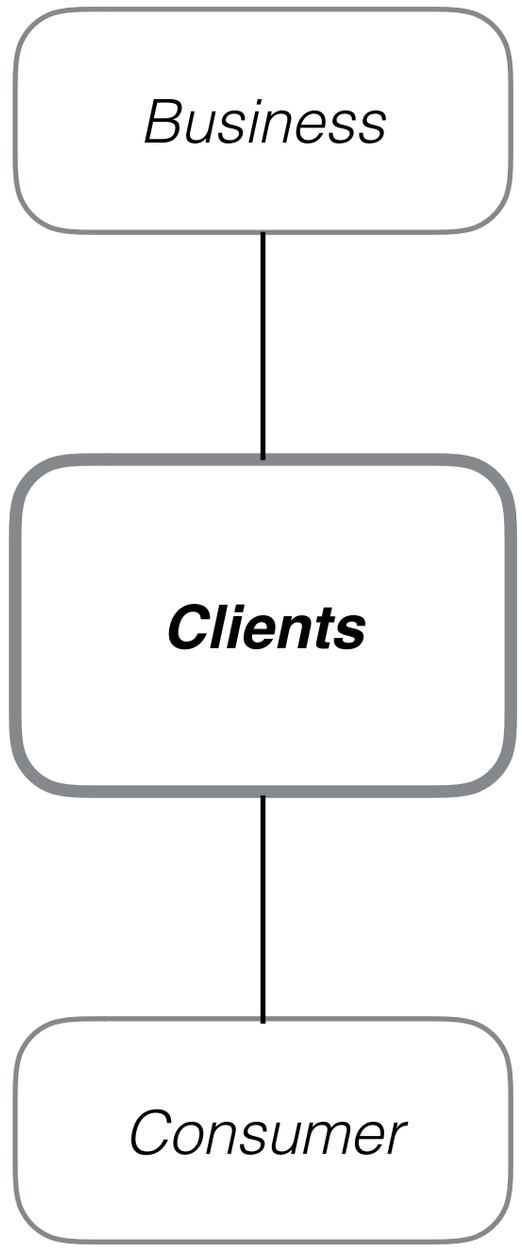
Services must be available, no downtime acceptable

IoT: Client Devices

An IoT Reference Model

IoT Reference Model

IoT Reference Model



IoT Reference Model

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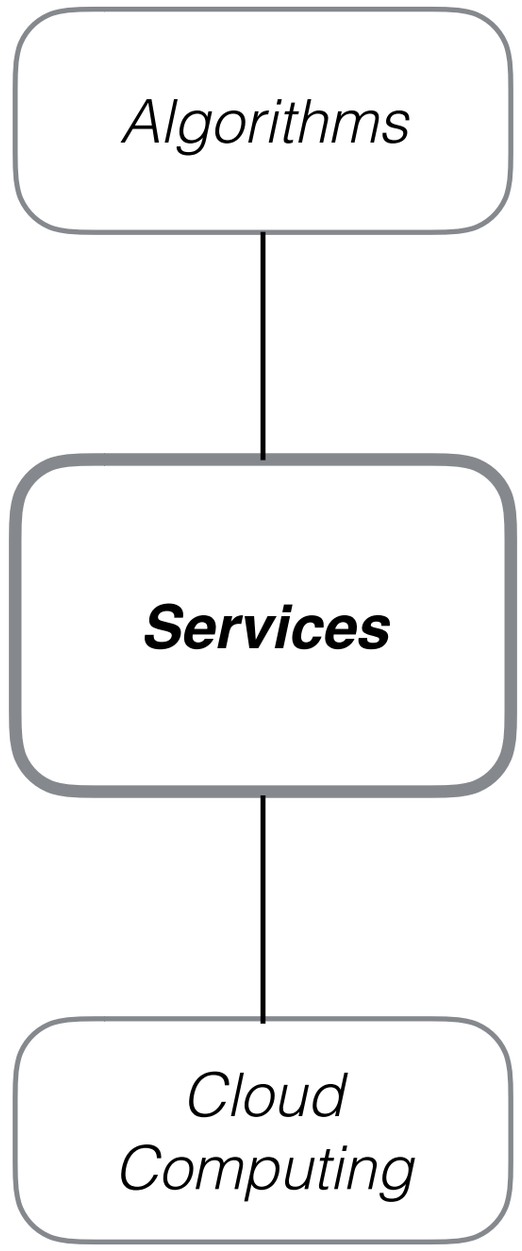

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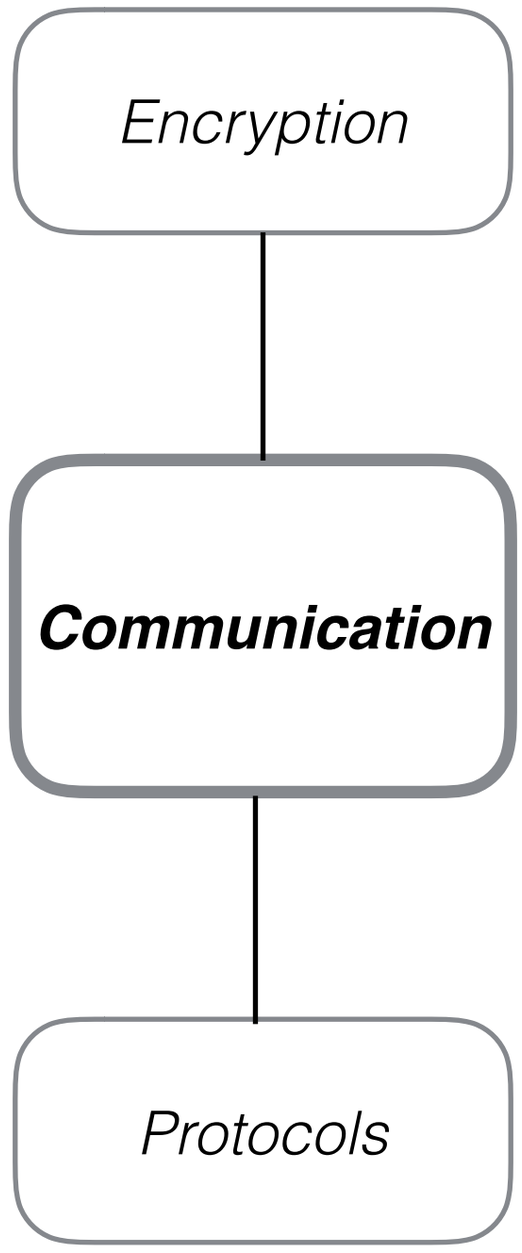

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