Internet of Things (IoT)
Level – 1 Training

A Virtual Instructor-Led Training for
RBEI, Coimbatore & Bengaluru

14-15th Jul, 2021

Facilitated By:
Vijai Simha
simhav@gmail.com
LinkedIn: http://in.linkedin.com/vijaisimha

Introduction and Context Setting

Workshop Facilitator: Vijai Simha

Vijai Simha – (LinkedIn)

Entrepreneur
- Founder & CEO of NeoCortex Networks, an IoT Startup, based out of Bengaluru, India
- Develops impactful IoT solutions by leveraging emerging IoT Communication Protocols in Industrial & Enterprise IoT
- Currently on developing solution for the Healthcare (Logistics) Domain

Consultant – IoT Solution Architecting
- Helps Industries, Enterprises and Startups with Envisioning, Architecting & Deployment of End-to-End IoT Solutions.

Corporate Training
- Topics Include
  - IoT, Advanced IoT, Industrial IoT
  - Systems Thinking
  - Engineering Program Management & Product Management
- Clients Include: Robert Bosch, Qualcomm, Ericsson, Dell-EMC, Philips, Daimler, Cummins, Renault, Volvo & Mahindra
- Participants include Senior Management, Directors, Architects, Managers and Engineers.
- Postgraduate Certificate Program in Product Management offered by IIM Indore & Jigsaw Academy (Faculty and Mentor)

Professional Experience
- Vijai is a versatile technology professional with 23+ years of experience in IoT, Embedded systems, DSP and Communication Software Development.
- Long stint of 17 Years at Sasken Communication Technologies, Bengaluru
- Roles : Started out as a Software Developer, but moved on to handle multiple Managerial, Technical & Pre-Sales Roles
- Responsible for seeding and managing ODCs (Offshore Development Centers) for Japanese and American Tier-1 Semiconductor Vendors.
- His last role at Sasken was to Head Sasken's Engineering Division at Sasken, Hyderabad.

Vijai is an alumnus of IIM, Bangalore (Executive General Management Program) and has a Bachelor's Degree in Electronics and Communications Engineering.

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Classroom Training

- Interactive
- Physical Rapport & Eye-Contact
- Two-way Communication

Vs

Online Training (Pre-recorded)

- One-way Communication
- No Rapport / Connect between participant and trainer
- Rich graphics through videos

Vs

Virtual Instructor-Led Training

- Digital Connect/Rapport
- Two-way Communication
- Opportunity for highest interactions – Chats & Audio

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Guidelines for Participation in VILT

- Stay tuned to the class..
- Interaction is the key! Please communicate using Chat Window as often as possible
- Please unmute on need basis or on instruction… Please mute yourself when not speaking.
- Please close Email applications and Whatsapp or other applications that may distract you. We shall have 10-minute breaks after every 90 mins (approx.) for you to check on important mails.
- But after the break, please ensure you come back into the training, physically & mentally ☺
- Feel free to provide feedback to the instructor… either publicly or privately

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Introduction

- Check Your Microphone
- Introduce Yourself
  - Who ?
    - Name, background & experience
    - Team & role
  - Why ?
    - Purpose & motivation for attending the training
  - What ?
    - What do you expect to achieve at the end of 2 days

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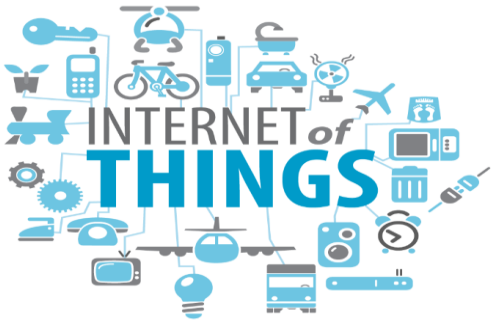


Module 1

What is IoT ?

What is Internet of Things ?

Embed 'Things'
with computing intelligence
and connect them to the internet

Derive actionable insights
from the data received from 'Things'
and respond effectively

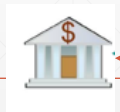
Example 1

IoT Use Case
Transport

Uber OLA

Smart Meter

Smart Meter

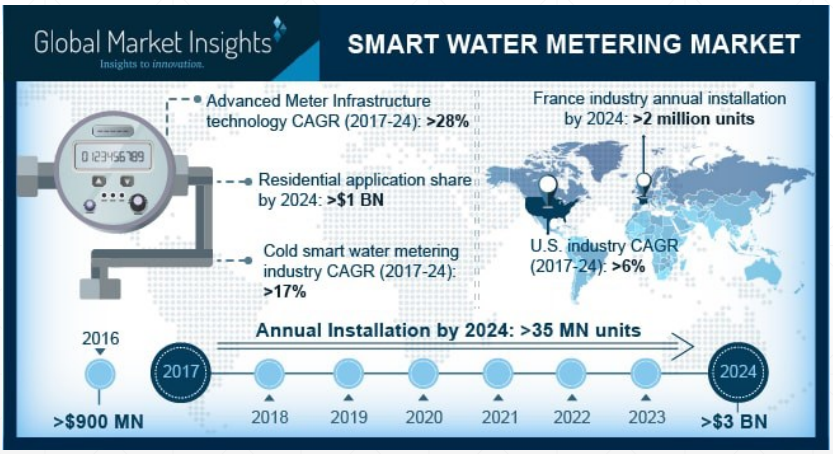


IoT Use Case
Smart Cities

Example 2: Smart Electric Meter

IoT Use Case
Smart Cities

Smart Water Meter



Will IoT Take Away Jobs ?

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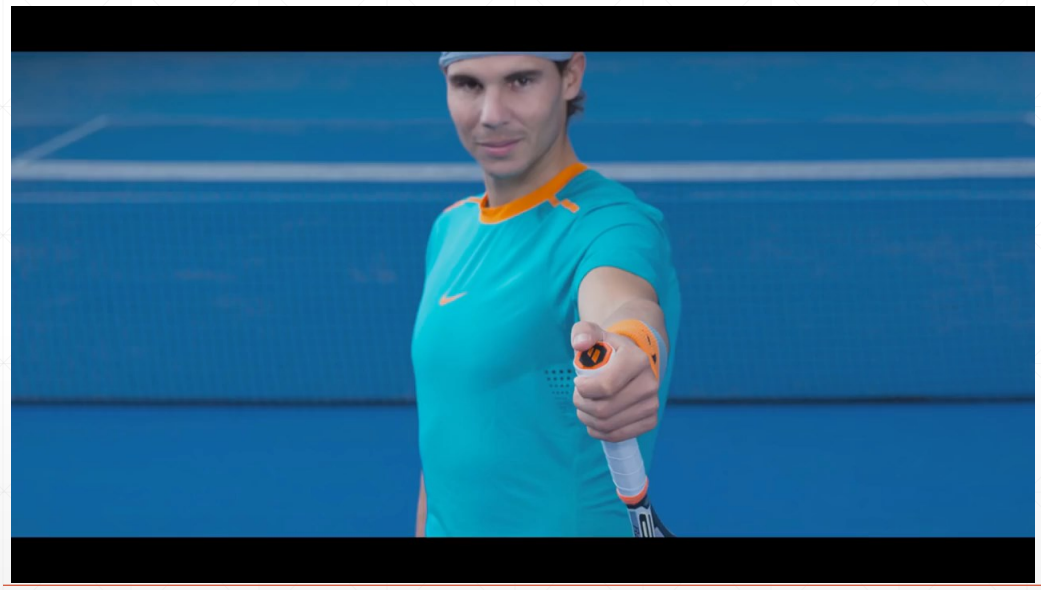
Example 1: Babolat Play : Smart Tennis Racket

IoT Use Case
Sports



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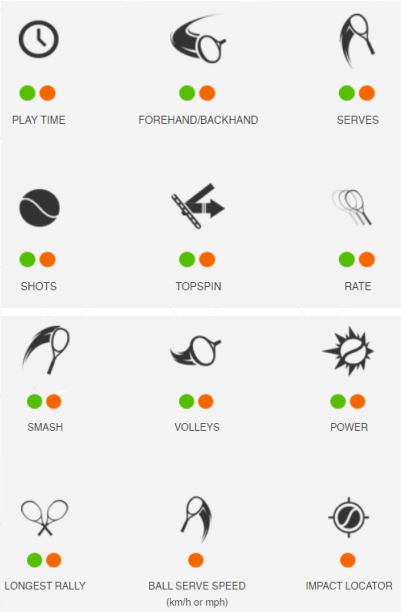
Smart Tennis Racket

ANALYZE YOUR GAME
MOVE TO THE NEXT LEVEL
SHARE YOUR PERFORMANCE

KNOW YOUR GAME
CHALLENGE YOUR FRIENDS
JOIN THE COMMUNITY



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If you were a Tennis Coach,

would you recommend the Babolat Play

to your trainees ?

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Smart Tennis Racket
Perspective: Tennis Coach (Suresh)

Traditional Coaching

- One-to-one Coaching – So, higher fee per person
- Need to coach rich people, but they don't want it
- It's painful to watch this loser struggle

Tennis with Babolat Play

- Coaching in batches – 20 students per batch – lower cost per person
- Can address a larger market – middle class included
- Partner with Schools, Corporates
- Looks like I can make a career out of this!!
- Wow! This is interesting

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Smart Tennis Racket
Perspective: Tennis Learner/Player (Me)

Traditional Coaching

- Tennis is for Princes ☹
- Coach nags me while looking at his phone
- Practice is boring
- I'd love some company

Tennis with Babolat Play

- I can afford it now!!
- Wow! I have objective data now.. The coach was nagging me too much
- I served at 99 kmph yesterday. Tomorrow, will aim 100 kmph!!
- I'll put my stats on Facebook!! And brag with my friends
- Let me find a doubles partner who has a better serve
- I want Agassi to coach me… let me share my data with him

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Smart Tennis Racket
Perspective: Tennis Federation

Traditional Coaching

- How do we get a Champion from these rich spoilt brats in Metros ??

Tennis with Babolat Play

- Let's check candidates from Tier-2, Tier-3 towns!!
- Centralized remote talent search team

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Smart Tennis Racket
Perspective: Babolat (Manufacturer)

Traditional Coaching

- Do racquets stay good after 2 years ?
- How to increase revenues & profitability?

Tennis with Babolat Play

- Better Engineering with Product Feedback (Data) from the field
- Personalized Racquets – Higher margins as well as wider customer base.
- Additional Monetization – "Data is the new oil"

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	Traditional Coaching	Tennis with Babolat Play
Tennis Coach (Suresh)	• One-to-one Coaching – So, higher fee per person • Need to coach rich people, but they don't want it • It's painful to watch this loser struggle	• Coaching in batches – 20 students per batch – lower cost per person • Can address a larger market – middle class included • Partner with Schools, Corporates • Looks like I can make a career out of this!! • Wow! This is interesting
Trainee (Vijai - Me)	• Tennis is for Princes • Coach nags me while looking at his phone • Practice is boring	• I can afford it now!! • Wow! I have objective data now.. The coach was nagging me too much • I'll put my stats on Facebook!! And brag with my friends • Let me find a doubles partner who has a better serve • I want Agassi to coach me… let me share my data with him
Tennis Federation	• How do we get a Champion from these rich spoilt brats in Metros ??	• Let's check candidates from Tier-2, Tier-3 towns of India!! • Remote talent search team in Bengaluru
Babolat (Company)	• How to increase my revenues & profitability? • Do my racquets stay good after 2 years ?	• Personalized Racquets – Higher margins as well as wider customer base. • Additional Monetization – "Data is the new oil" • Better Engineering with Product Feedback (Data) from the field

One Smart Tennis Racket ……. Can change the dynamics of an Industry

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The Post-Covid19 World

Probably,
the biggest Black Swan event
of our lives?

A **black swan** is an **unpredictable event** that is beyond what is normally expected of a situation and has potentially severe consequences.

- Shift towards Remote Working
- Higher Focus on Operational Efficiencies
- Increased Sensitivity towards Human Risk (Health)
- Most Industries have 'Paused'. Higher willingness to change.

Much Higher Opportunity for IoT to make an Impact in Near-Future

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Human Intelligence

Sense

Nervous System

Connect

Analyze

Action

Respond

Machine Intelligence

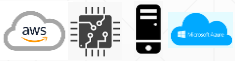
Embed 'Things' with Sensors

Smart Things

Send Data to the Internet

Communication Protocols

Analyze Data to Derive Actionable Insights



Computing on Cloud/Edge/Node

Respond effectively

Actuators, UI/UX, Apps

How do we structure this Workshop ?

Concepts
Technologies
Skills

Abstract

Specific & Readily Applicable

Longer Lifecycle
Transferable

Shorter Lifecycle
Not directly Transferable

Insight-driven; Experience matters

Facts & Procedure-driven Google-able (self-learning)

It is a VILT Workshop!

Context & Trends

Collaborative Learning (Teams of 3-4)

Agenda : Session 1 : Jul 14th 2021

Module 1: Understanding IoT and it's Impact

- What is IoT?
- Industry 4.0
- Avatars of IoT
- Key Enablers – Reasons for IoT now
- Key Challenges in IoT
- Formal definitions of IoT

Module 2: Key Application Areas and Use Cases

- Key Application Areas and Exemplary Use-cases
- IoT Ecosystem : Key Players and their Perspectives
- IoT Progression – From Thing to System-of-Systems
- Group Brainstorming Activity 1

Agenda : Session 2 : Jul 14th 2021

Module 3: IoT Architecture and Reference Model

- Industrial Internet System (IIS) Architecture Model
- IoT World Forum Reference Model
- The IT-OT Paradigm
- Typical Architectural Patterns in IoT

Module 4: Terminal Nodes and Device Platforms

- Terminal Node – Typical components & block diagram
- Hardware Platforms for IoT
- Operating Systems & Frameworks – Concepts & Choices
- Comparative Analysis of Exemplary Platforms – Raspberry Pi 3, Intel Curie etc.
- Arduino ecosystem and its relevance

Module 5: Sensors & Actuators

- Sensors – Types and classifications
- Actuators
- Tags, Identifiers & RFID

Agenda : Session 3 : Jul 15th 2021

Module 6: Gateways

- Need for Gateways and Local Aggregation Modules
- Smartphone as a Gateway

Module 7: Leveraging Cloud Computing for IoT

- Brief into to Cloud Computing
- Characteristics of Cloud Computing
- Deployment Models – Private Cloud, Public Cloud & Hybrid Cloud
- Service Models – IaaS, PaaS, SaaS
- Webservices, Microservices & Serverless Architectures
- Prevalent Cloud Computing Platforms
- Data Ingestion and Storage
- Big Data – brief introduction

Module 8: Communication Protocols

- Communication Requirements for IoT Systems
- Types of Networks - WAN, LAN, PAN & BAN
- Communication Protocols – Choices & Comparison
- Cellular Communication – 2G, 3G & 4G
- Short-range Wireless – Bluetooth, WiFi & NFC
- Long-range Wireless – Zigbee, LORA, SigFox etc.
- Networking Stack Overview
- Importance of IP, IPv6 and 6LoWPAN
- Application Layer Protocols – Concepts & Choices
- HTTP, MQTT, CoAP, AMQP

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Agenda : Session 4 : Jul 15th 2021

Module 9: Analytics and Visualization : An Overview from an IoT Context

- Importance of Analytics in IoT
- Exemplary Use-cases for Analytics
- Types of Analytics and their complexity
- Visualization & Dashboarding

Module 10: Cloud IoT PaaS Platforms

- Typical features provided in Cloud-based IoT PaaS Platforms
- Leading IoT PaaS Platforms
- Microsoft Azure IoT Architecture & Components
- AWS IoT Architecture & Components

Putting it all together

- The Tech Trinity for Digital Transformation IoT – AI/ML - Blockchain
- Moving from Hobby Projects to Enterprise-grade IoT
- IoT Security
- Ten Step Process for building IoT Prototype ..and Product

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What about Hands-on Activities on IoT Hardware Boards?

- Exercises on Hardware Boards
  - Resources for Hands-on Exercises will be provided to participants
  - Interested participants may choose and procure the boards on their own and execute (Arduino, Raspberry Pi, NodeMCU)
- Why are we NOT including the hands-on exercises as part of the session
  - Logistics issues due to most people working from home
  - The focus of the program is to provide insights that would be difficult to find elsewhere. And we are quite stretched on time. Hands-on activities need to be 'experienced' which takes time. It's better for
  - Huge number of resources available freely (online) for anyone who wants to do hardware projects (starting from High School Kids). Not much of a point covering this in a paid workshop. That too for experienced professionals.
  - Not all participants are found to be keen on doing the projects

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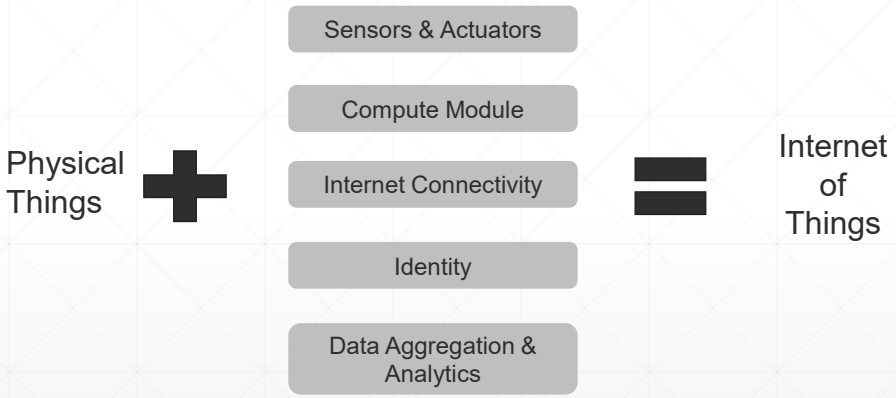
What is Internet of Things (IoT) ?



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Avatars of IoT:
Old Wine in New Bottle ?

What's the difference ?

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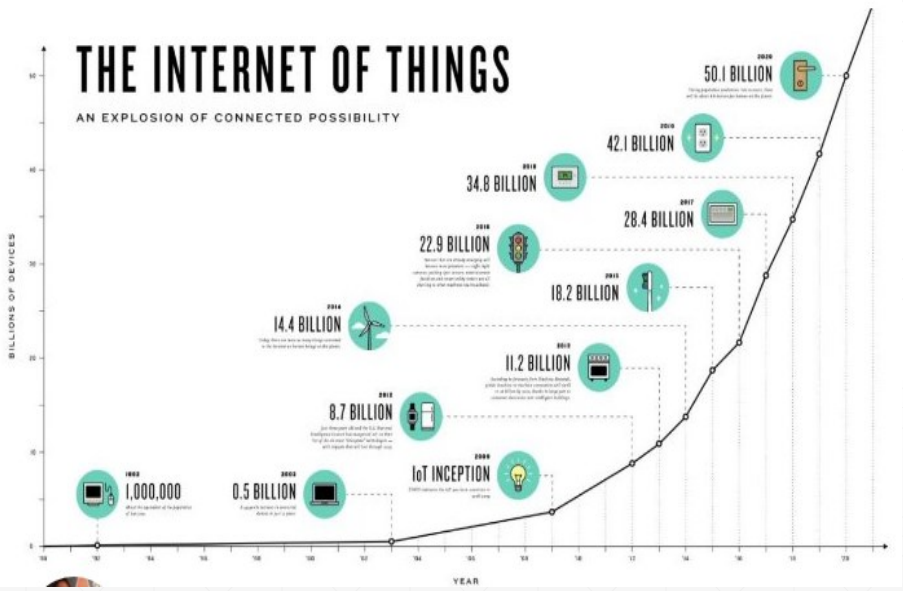

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IoT Predictions (by 2020-22)

Some Big Numbers:

- 14 billion Connected Devices | Bosch SI
- 50 billion Connected Devices | Cisco
- 309 billion IoT Supplier Revenue | Gartner
- 1.9 trillion IoT Economic Value Add | Gartner
- 7.1trillion IoT Solutions Revenue | IDC

Some small numbers:

Peter Middleton, Gartner:
"By 2020, component costs will have come down to the point that connectivity will become a standard feature, even for processors costing less than

$1 "

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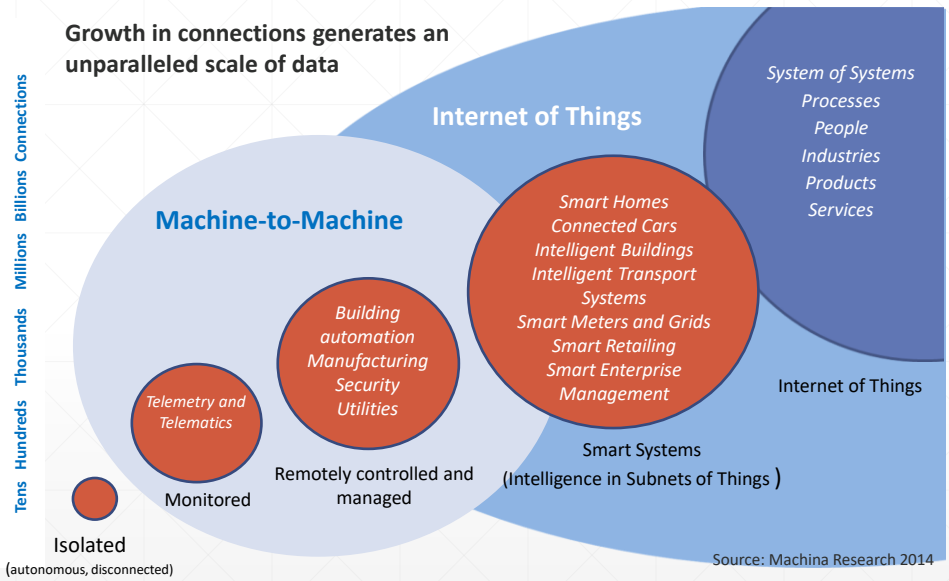
Growth in connections generates an unparalleled scale of data



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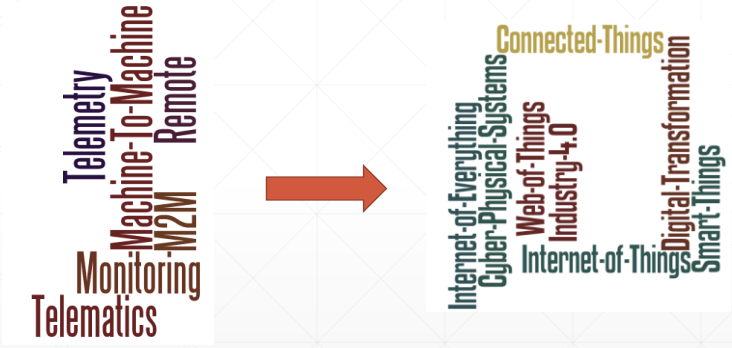
Avatars of IoT: Old Wine in New Bottle ?



Key Challenges in IoT

- **Scale** (Few Hundreds to Millions)
- **Lower Cost** (Unit Cost)
- **Internet** (IPv6 / 6LoWPAN)
- **Systems Approach**

What's the difference ?

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World Economic Forum
The Fourth Industrial Revolution

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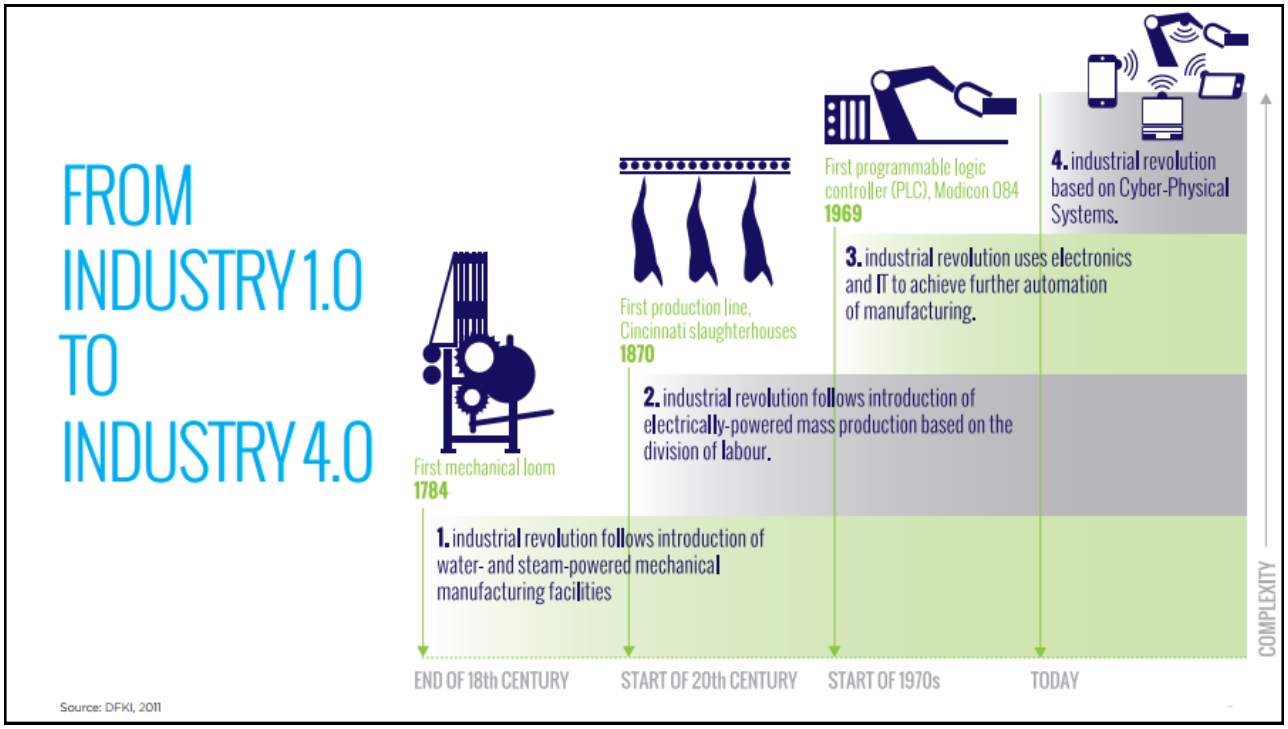
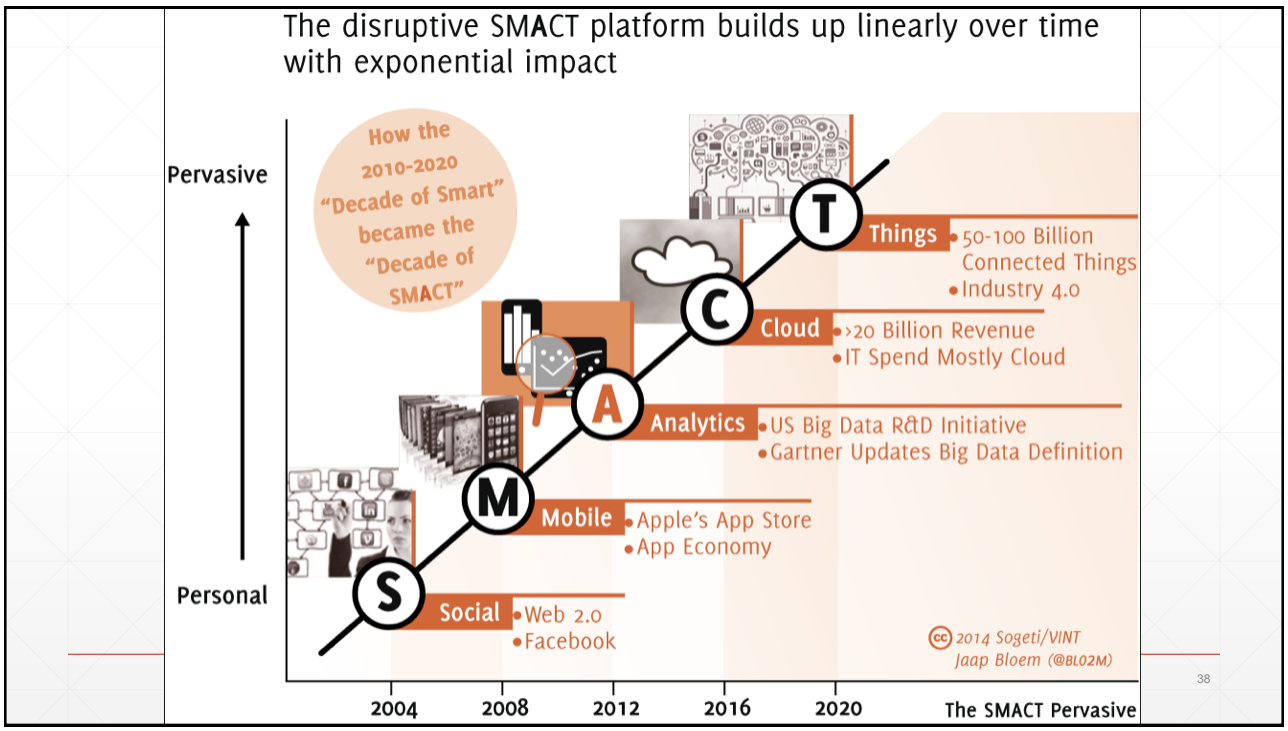

FROM INDUSTRY 1.0 TO INDUSTRY 4.0
First mechanical loom
1784
First production line, Cincinnati slaughterhouses
1870
First programmable logic controller (PLC), Modicon 084
1969
1. industrial revolution follows introduction of water- and steam-powered mechanical manufacturing facilities
2. industrial revolution follows introduction of electrically-powered mass production based on the division of labour.
3. industrial revolution uses electronics and IT to achieve further automation of manufacturing.
4. industrial revolution based on Cyber-Physical Systems.
COMPLEXITY
END OF 18th CENTURY
START OF 20th CENTURY
START OF 1970s
TODAY
Source: DFKI, 2011


The disruptive SMACT platform builds up linearly over time with exponential impact
How the 2010-2020 "Decade of Smart" became the "Decade of SMACT"
Pervasive
Personal
S
Social
•Web 2.0
•Facebook
M
Mobile
•Apple's App Store
•App Economy
A
Analytics
•US Big Data R&D Initiative
•Gartner Updates Big Data Definition
C
Cloud
•>20 Billion Revenue
•IT Spend Mostly Cloud
T
Things
•50-100 Billion Connected Things
•Industry 4.0
2004
2008
2012
2016
2020
The SMACT Pervasive
© 2014 Sogeti/VINT
Jaap Bloem (@BLO2M)
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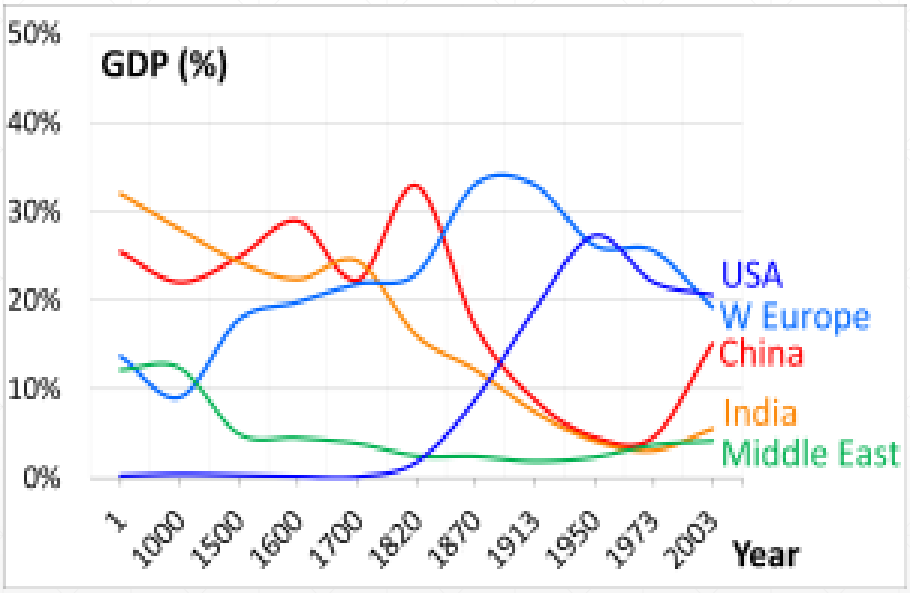

Economic History: World's major economies and their % GDP contribution over 2000 years

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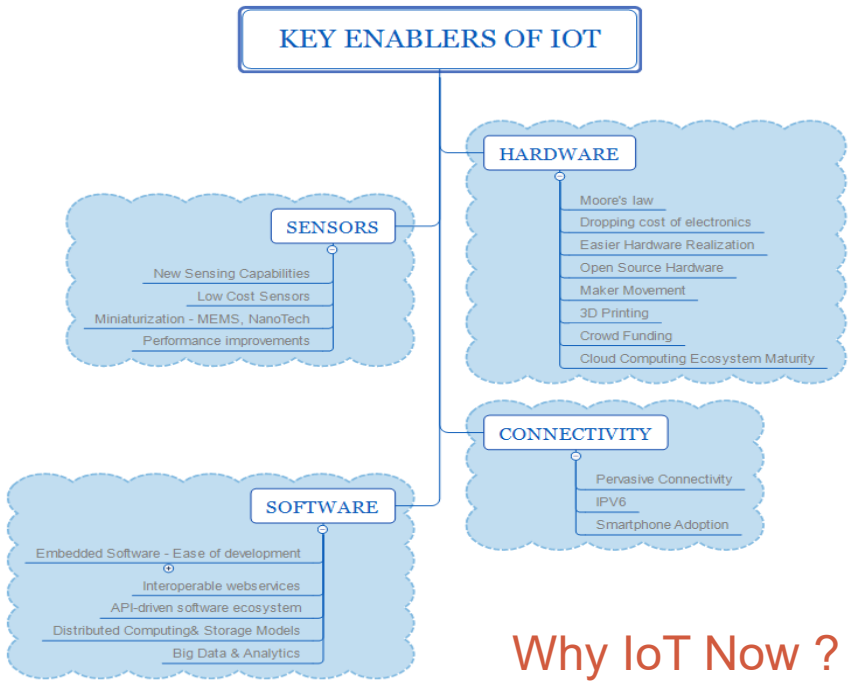
Source: Wikipedia



Why IoT Now ?

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Hello Maker | Find more at: www.hellomaker.org

MAKER MINDSET

What is it and why does it matter?

1 PLAYING
Being free to play and explore is the primary way kids learn to solve problems, think creatively, become independent and and develop resilience

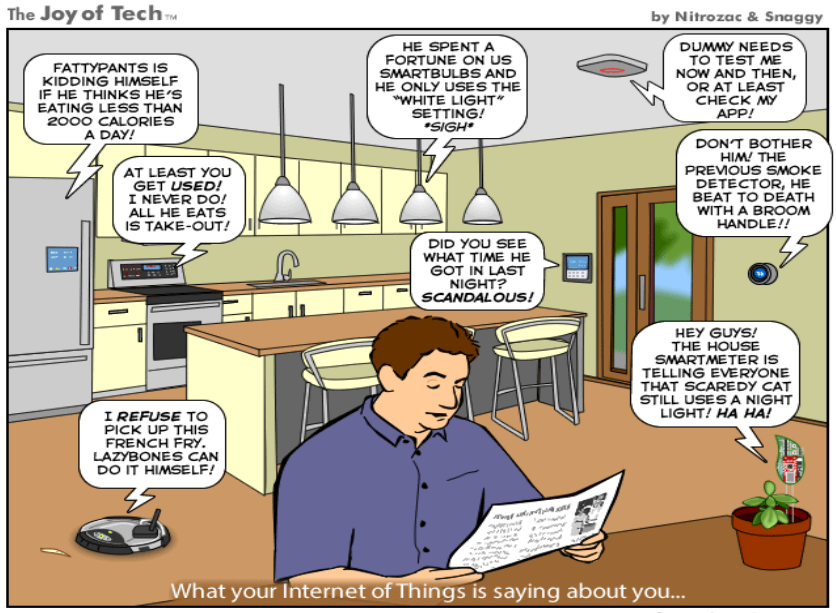
2 DOING
Take action on your ideas and putting them to the test, even if they don't work out on your first try

We are all makers

3 FAILING
With a maker mindset, mistakes are not failures; they are learning experiences that are often just as, if not more, valuable than success

4 LEARNING
Learn and experiment with hands-on activities to nurture a strong sense of personal agency to overcome challenges

The Maker Movement Even the Kids!



Module 2: Application Areas

Examples and Case Studies

IoT Use Case
Wearables

IoT Use Case
Healthcare

Cardiac Design Labs

Body Worn device
- 12 Lead continuous ECG
- Light weight and ambulatory
- Transmits all data via Bluetooth

Patient Bedside Tablet
- Intelligent Cardiac Clinical Analytics Engine
- Detects Arrhythmia and Coronary Heart diseases
- Real time continuous telemetry (2G/ 3G)

Cloud Server
- Detected episodes and .diagnosis uploaded in the server
- Secure, encrypted access

MIRCaM Doctor's App
- Allows to remotely access diagnosis and episodes
- Sends alerts and notifications

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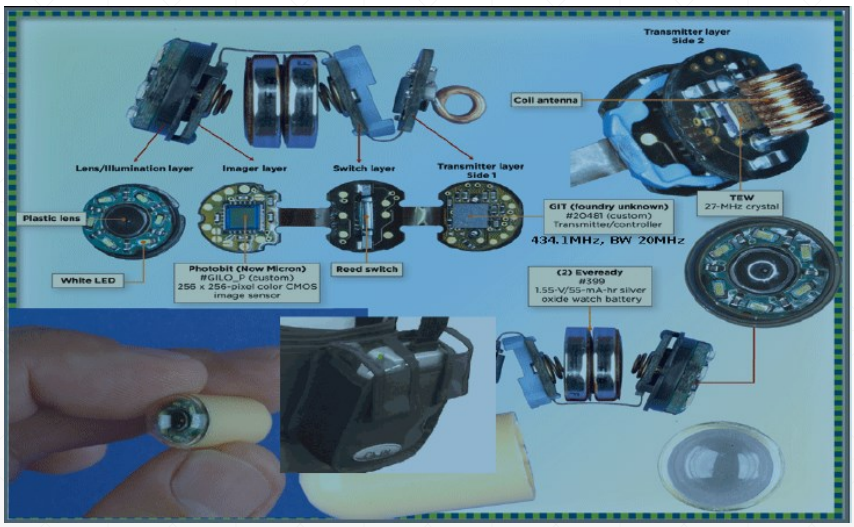
IoT Use Case
Healthcare

Pillcam



https://www.weforum.org/videos/22026-this-pill-can-take-pictures-of-the-inside-of-your-gut

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IoT Use Cases
Automotive

Automotive IoT Use-cases

- Connected car systems monitoring
- Smart driving assistance
- Cloud-based infotainment solutions
- Automated emergency management
- Real-time fleet management
- Driver safety systems
- Optimized logistics
- Predictive maintenance

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IoT Use Case
Sports

Smart Tennis Racket

Track your game with Babolat's breakthrough innovation. See where you stand in the global ranking and by category within your online community.

http://en.babolatplay.com/

IoT Use Case
Manufacturing

Textile Manufacturing

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IoT Use Case
Environment

Forest Fire Detection

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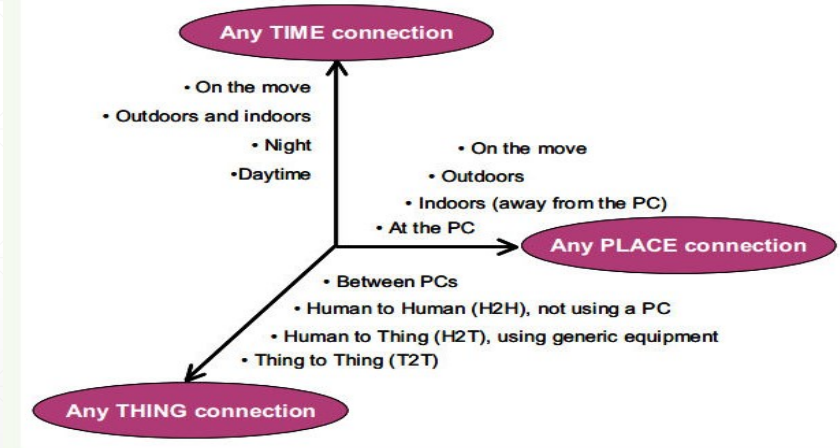
The IoT Paradigm Shift



Source: ITU-T

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Basically, Everywhere!!

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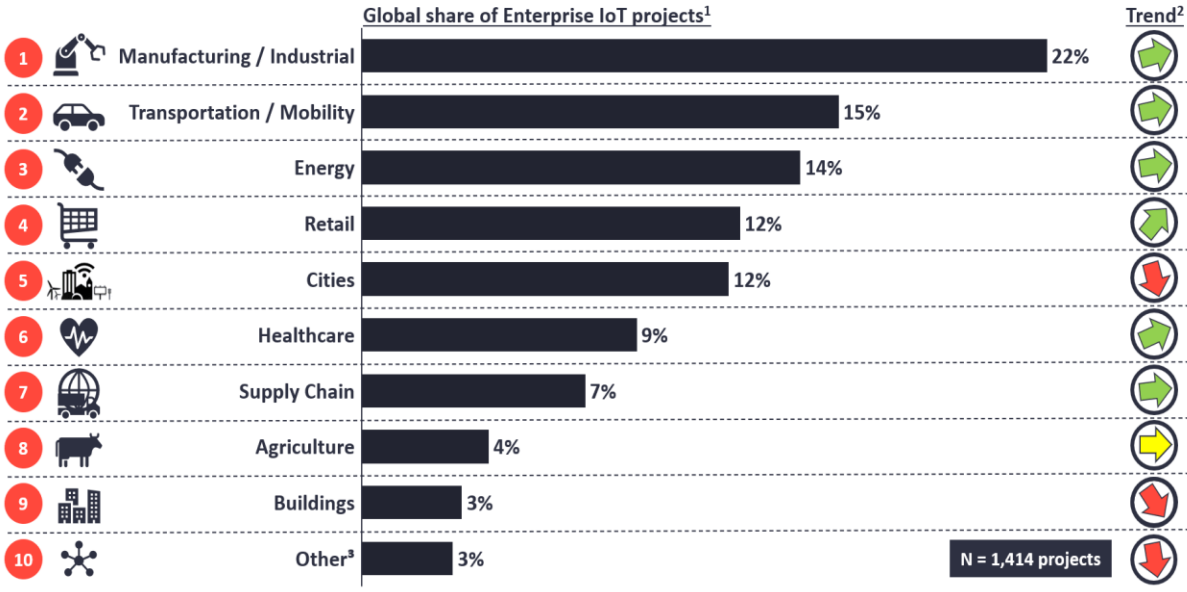
IOT ANALYTICS

Insights that empower you to understand IoT markets

Top 10 IoT Application areas 2020



Note: 1. Based on 1,414 publically known IoT projects (not including consumer IoT projects eg smart home, wearables, etc.) 2. Trend based on relative comparison with % of projects in the 2018 IoT Analytics IoT project list e.g., a downward arrow means the relative share of all projects has declined, not the overall number of projects. 3. Other includes IoT projects from Enterprise & Finance sectors. **Source:** IoT Analytics Research - July 2020

The Post-Covid19 World

Probably,
the biggest Black Swan event
of our lives?

A **black swan** is an **unpredictable event** that is beyond what is normally expected of a situation and has potentially severe consequences.

- Shift towards Remote Working
- Higher Focus on Operational Efficiencies
- Increased Sensitivity towards Human Risk (Health)
- Most Industries have 'Paused'. Higher willingness to change.

Much Higher Opportunity for IoT to make an Impact in Near-Future

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IoT Use Case
Industrial IoT

Industrial Internet and Logistics

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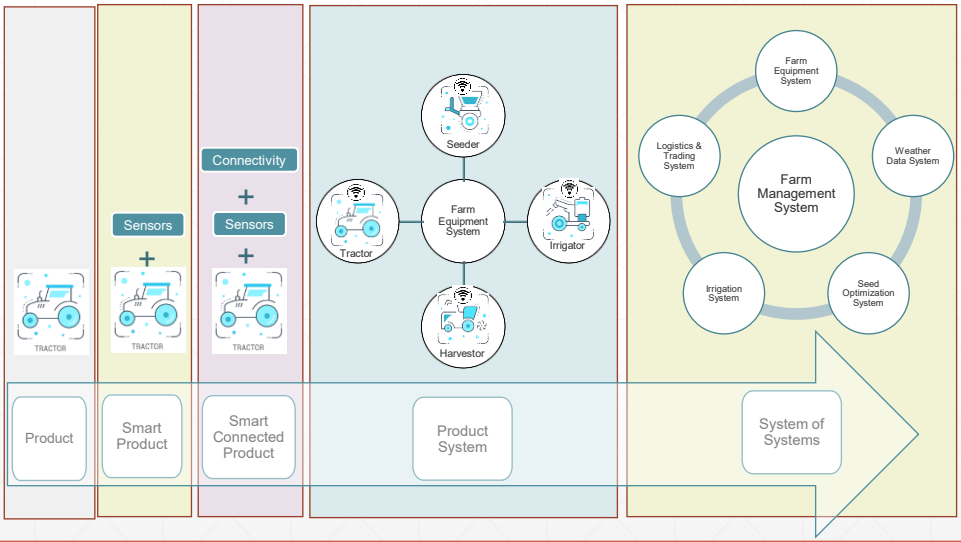
Stove ?
Shoe ?
Cooker ?
Bulb ?
Water Meter?
AC ?
Cricket Bat ?
But, What is the Value Proposition?
Car ?
Do Smart Connected Products Make Sense?
Fan ?
Tractor ?
Should we convert 'All' Things into Smart Connected Products ?
Refrigerator ?
Solar Panel ?
Flute ?
Comb ?
Wrist Watch?
Turbine ?
Dog Collar ?

Are these independent devices working in isolation ?

IoT Progression – From Thing to System-of-Systems



Activity 1: Brainstorming on IoT Use Cases
(Team Size: 3-4 Members)

1. Make a table with 5 columns
2. Choose a Product
3. Identify **features** that can make this a Smart Product
4. How can we make this a Smart Connected Product (SCP) ?
   What **features** does this enable ?
5. Ideate and make a list of **services you can offer the user** as a Product System that includes other Smart Connected Products in addition to your Smart Connected Product.
6. Ideate and make a list of **services you can offer to the user** as a System of Systems that includes other Product Systems in addition to your Product System.

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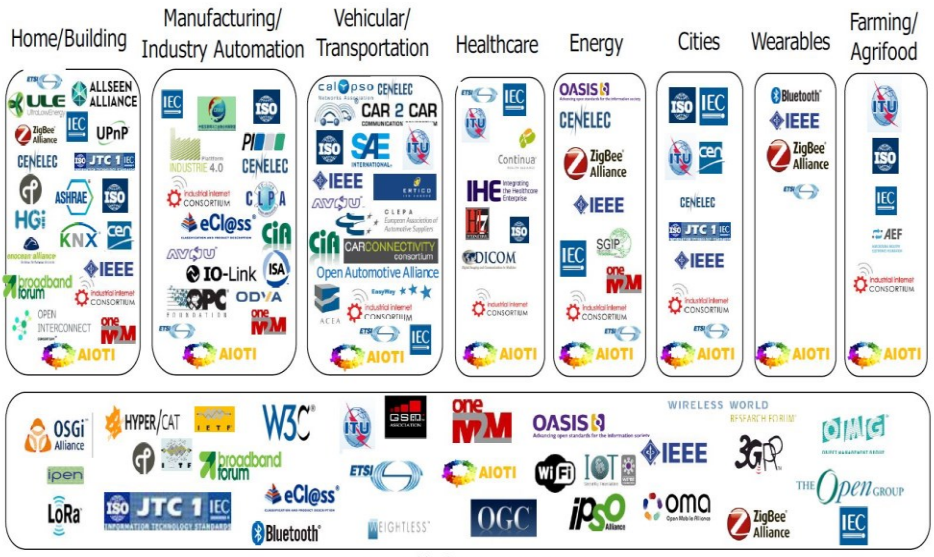
Module 3
IoT Architecture and Reference Models

IoT SDOs and Alliances Landscape (Vertical and Horizontal Domains)



Source: AIOTI WG3 (IoT Standardisation) – Release 1.3

IoT World Forum – Reference Model

IoT World Forum Architecture Committee

Ayla, BITSTEW SYSTEMS, Cisco, EPRI, FANUC, Gartner, GE, GM, Grundfos, IBM, Idaho Power, IDC, intel, Itron, Kaazing, Oracle, Panduit, parc, Qualcomm, Renesas, Rockwell Automation, salesforce, Samsung, SAP, SmartThings, Starbucks, Thales, TTTech

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Layer 7 : Collaboration & Processes
Involving People & Business Processes

Layer 6 : Application
Reporting, Analysis & Control

Layer 5 : Data Abstraction
Aggregation & Access

Layer 4 : Data Accumulation
Storage (Data Stores)

Layer 3 : Edge Computing
Data Element Analysis & Transformation

Layer 2 : Connectivity
Communication & Processing Units

Layer 1 : Physical Devices
The 'Things' in IoT

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Layer 7 : Collaboration & Processes
Involving People & Business Processes

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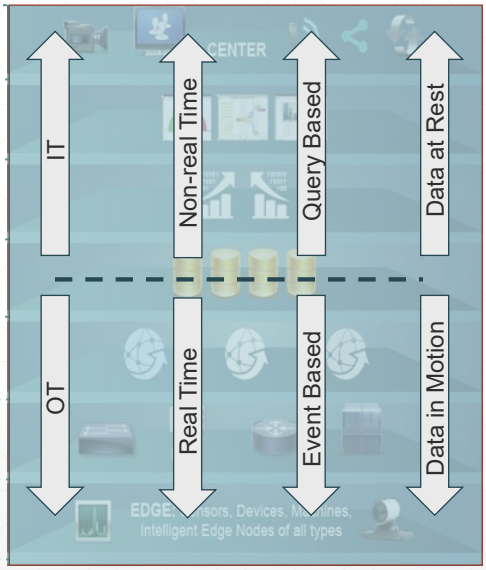
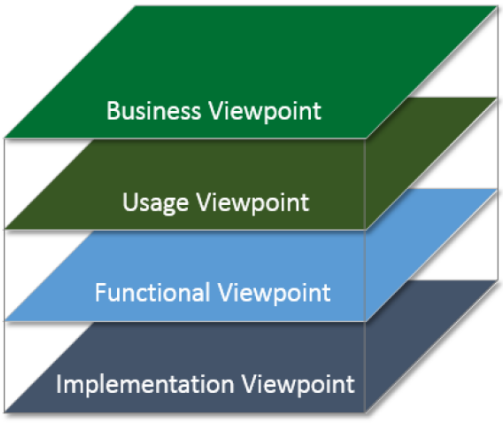
Layer 1 : Physical Devices
The 'Things' in IoT



65

Industrial Internet System (IIS) - Reference Architecture
(Industrial Internet Consortium)



Industrial Internet System (IIS) - Architectural Perspectives

66

Source: IIC

Industrial Internet System (IIS) – Business Viewpoint

Figure 4-1 Value and Experience Model

67

Source: IIC

Industrial Internet System (IIS) – Usage Viewpoint

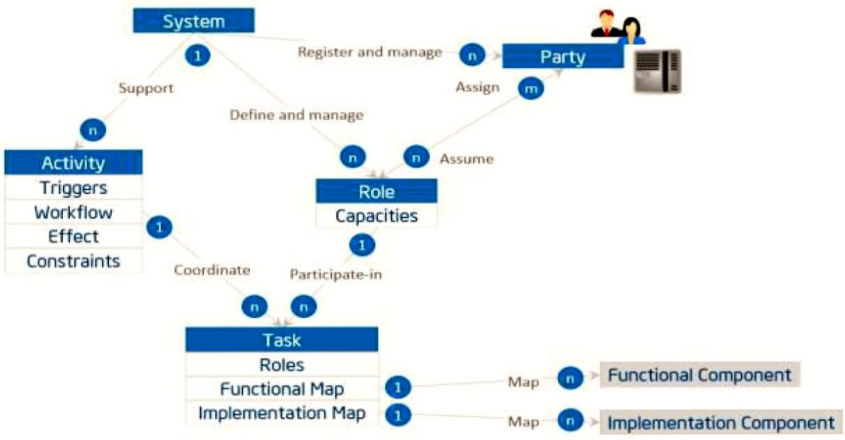
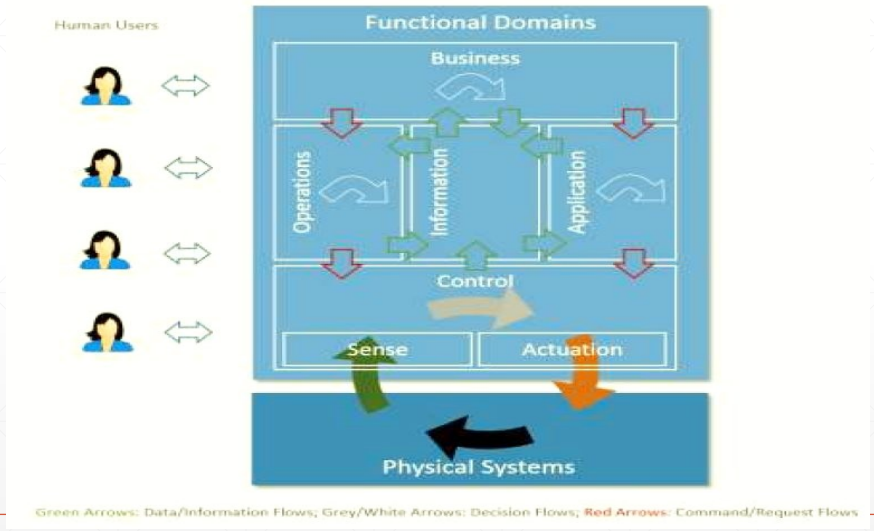


Figure 5-1 Role, Party, Activity and Task

68

Source: IIC

Industrial Internet System (IIS) – Functional Domains



69

Source: IIC

Implementation Viewpoint

- Technical representation of IIS
- Relates to the technologies and system components required to implement the activities and functions prescribed by usage and functional viewpoints.
- Typical Architectural Patterns
  - Three-tier architectural pattern
  - Gateway-mediated edge connectivity and management architecture pattern
  - Edge-to-cloud architecture pattern

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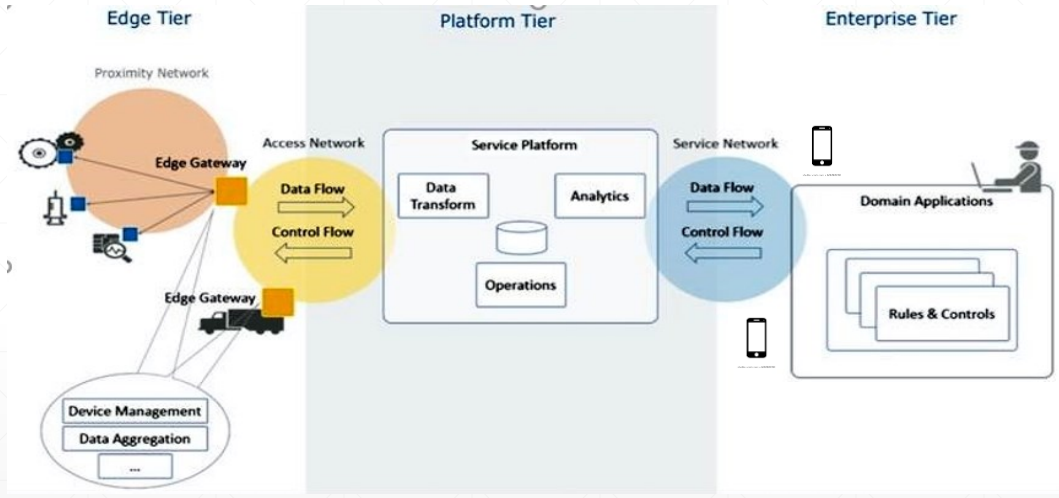
Typical IoT Architecture



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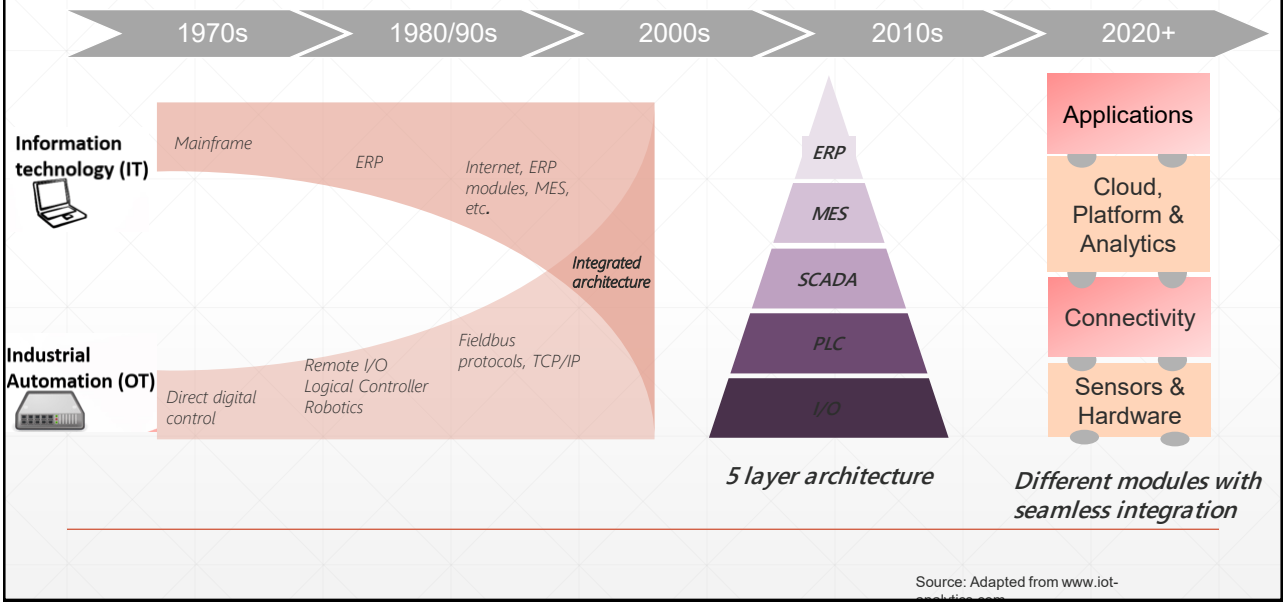
Evolution of IT-OT Convergence



Source: Adapted from www.iot-

Module 4: Terminal Nodes

The 'Things' in IoT

What is an Embedded System ?

An "Embedded System"

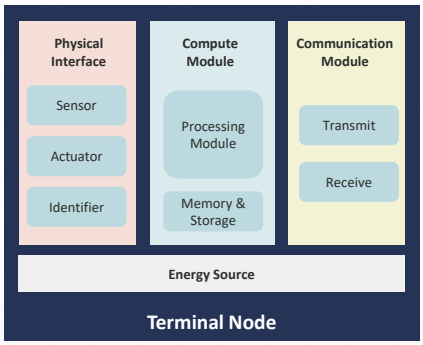
is a computing system

with one or few dedicated functionalities

housed within a larger mechanical or electrical system.

Example: Washing Machine Controller

Typical IoT System Design:
Terminal Node / Embedded Node / Edge Node



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Internet of Things (IoT)
Level – 1 Training

A Virtual Instructor-Led Training for
RBEI, Coimbatore & Bengaluru

15th Jul, 2021

Day 2

Facilitated By:
Vijai Simha
simhav@gmail.com
LinkedIn: http://in.linkedin.com/vijaisimha

What is Internet of Things ?

Embed 'Things'
with computing intelligence
and connect them to the internet

Derive actionable insights
from the data received from 'Things'
and respond effectively

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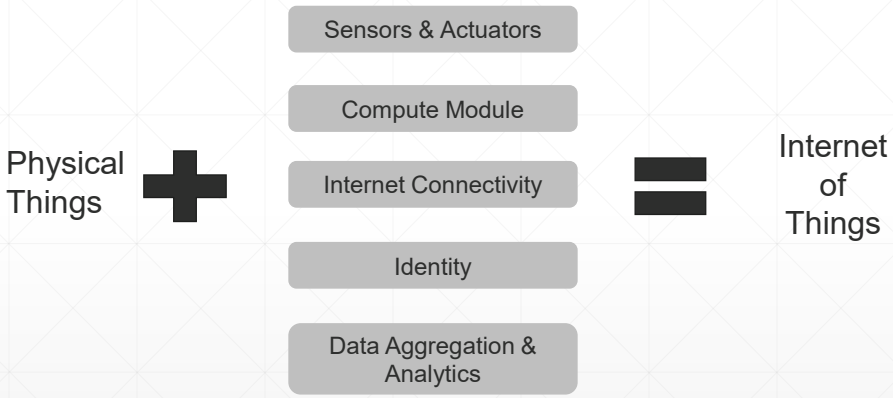
What is Internet of Things (IoT) ?



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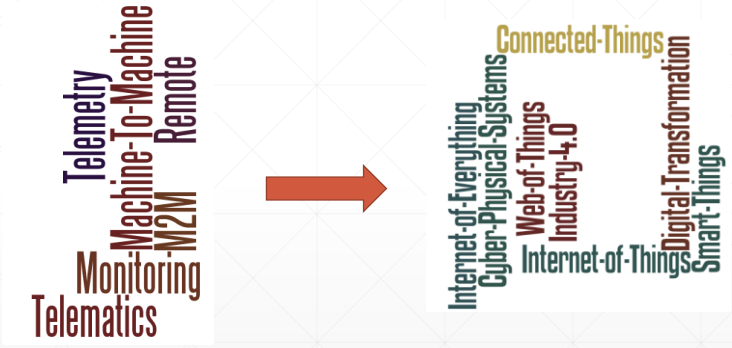
Avatars of IoT: Old Wine in New Bottle ?



What's the difference ?

Key Challenges in IoT

- **Scale** (Few Hundreds to Millions)
- **Lower Cost** (Unit Cost)
- **Internet** (IPv6 / 6LoWPAN)
- **Systems Approach**

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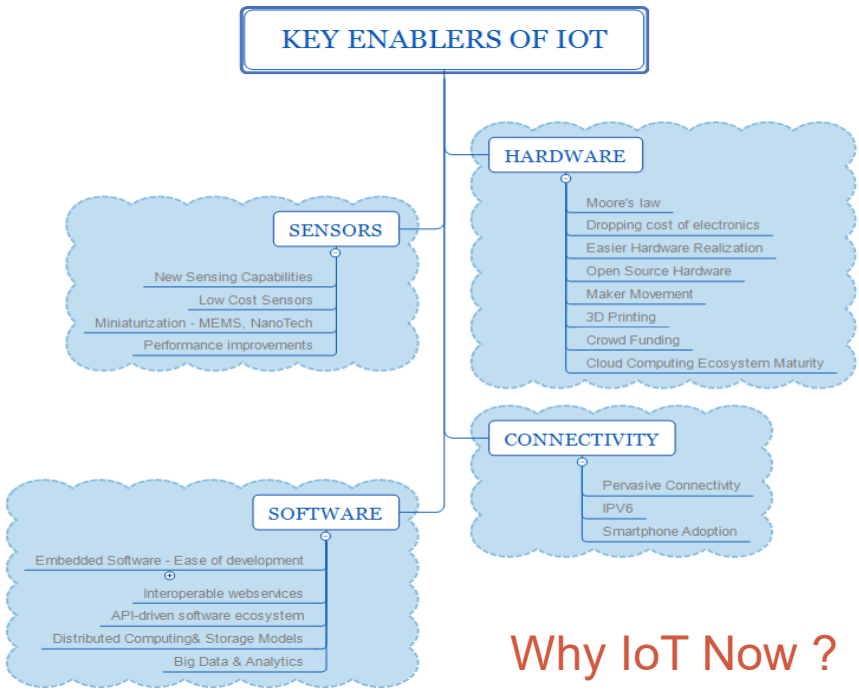

Why IoT Now ?

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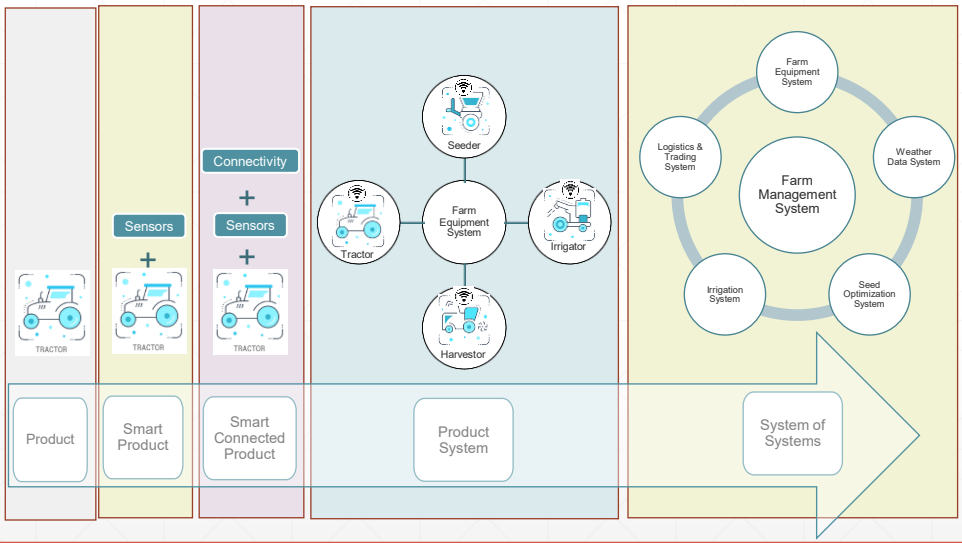
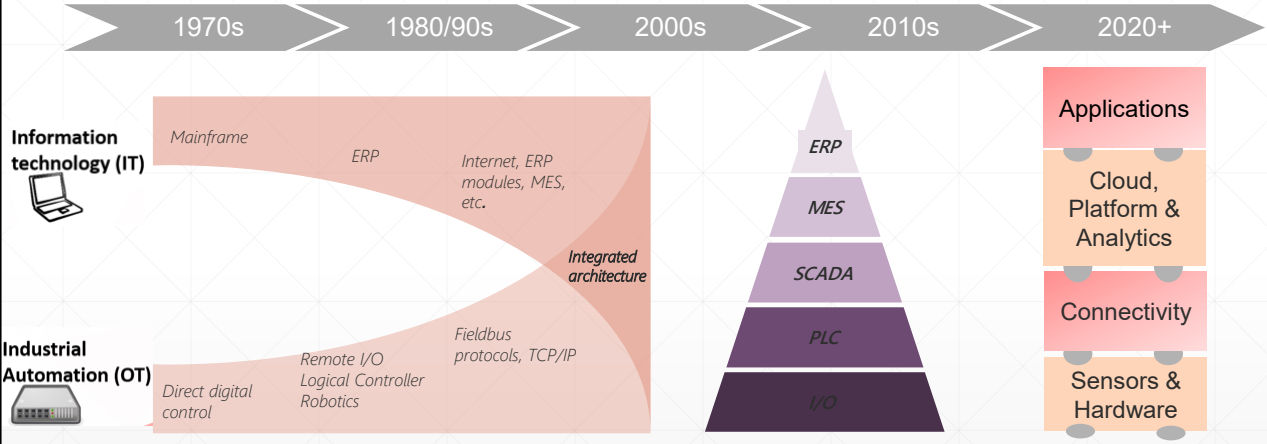
IoT Progression – From Thing to System-of-Systems



Evolution of IT-OT Convergence

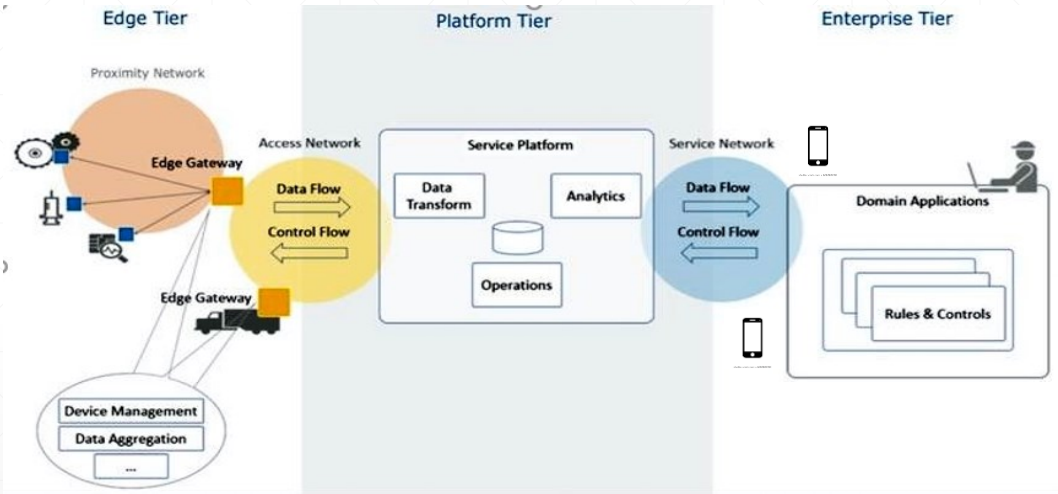


5 layer architecture

Different modules with seamless integration

Source: Adapted from www.iot-

Typical IoT Architecture



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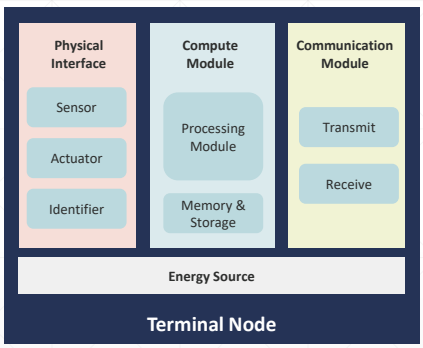
Typical IoT System Design: Terminal Node / Embedded Node / Edge Node



System Design Criteria

Computation · *Memory* · *Size* · *Latency* · *Cost* · *Power* · *Reliability* · *Maintainability* · *Security*

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Terminal Node: Typical Stack

Applications	•IoT Application Layer – Control Code •Sensor Interfacing •UI/UX •Interface with Cloud •Node Analytics
Operating Systems	•Contiki •ARM mBed •Zephyr •Linux •Android Things
Hardware Boards	•SensorTag (Uses TI CC2640 SoC) •nRF52 Development Kit (Uses nRF52 SoC) •Arduino Uno (Uses Atmega328P) •Raspberry Pi 4(Uses BCM2711 with uses Cortex-A72 cores) •Dragonboard 410c
SoC Platforms	•Nordic nRF52 •TI Simplelink CC1x, CC2x, CC3x, RF430 •Broadcom BCM2711 •Qualcomm Snapdragon •Intel Edison, Curie
Processor Cores	•ARM : Cortex-M Series, Cortex-A Series, Cortex-R Series •Tensilica XTensa •ATMega328P* •Intel Quark

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What is a Processor Core ?

And

What is an SoC ?

Software Applications	•IoT Application Layer – Control Code •Sensor Interfacing •UI/UX •Interface with Cloud •Node Analytics
Operating Systems	•Contiki •ARM mBed •Zephyr •Linux •Android Things
Hardware Boards	•Arduino Uno •SensorTag •nRF52 Development Kit •Raspberry Pi 4 •Dragonboard 410c
SoC Chips	•Nordic nRF52 •TI Simplelink CC1x, CC2x, CC3x •Broadcom BCM2711 •Qualcomm Snapdragon •ESP32, ESP8266
Processor Cores	•ARM : Cortex-M Series, Cortex-A Series, Cortex-R Series •RISC-V •Tensilica XTensa

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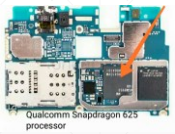
SoC : System on Chip

Desktop Motherboard with Intel CPU (Processor)

Smartphone PCB with ARM-based Qualcomm SoC (Snapdragon 625)



https://www.qualcomm.com/media/documents/files/snapdragon-625-processor-product-brief.pdf

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Qualcomm Snapdragon Block Diagram

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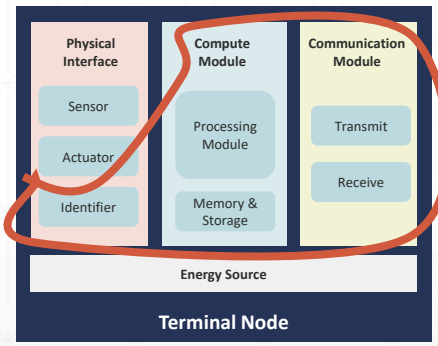
SoCs: Wireless MCUs



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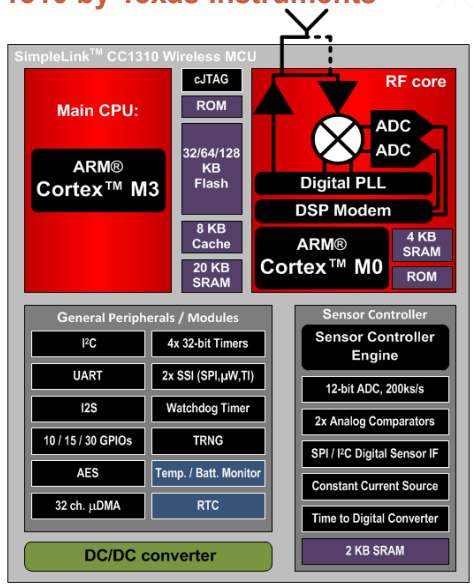
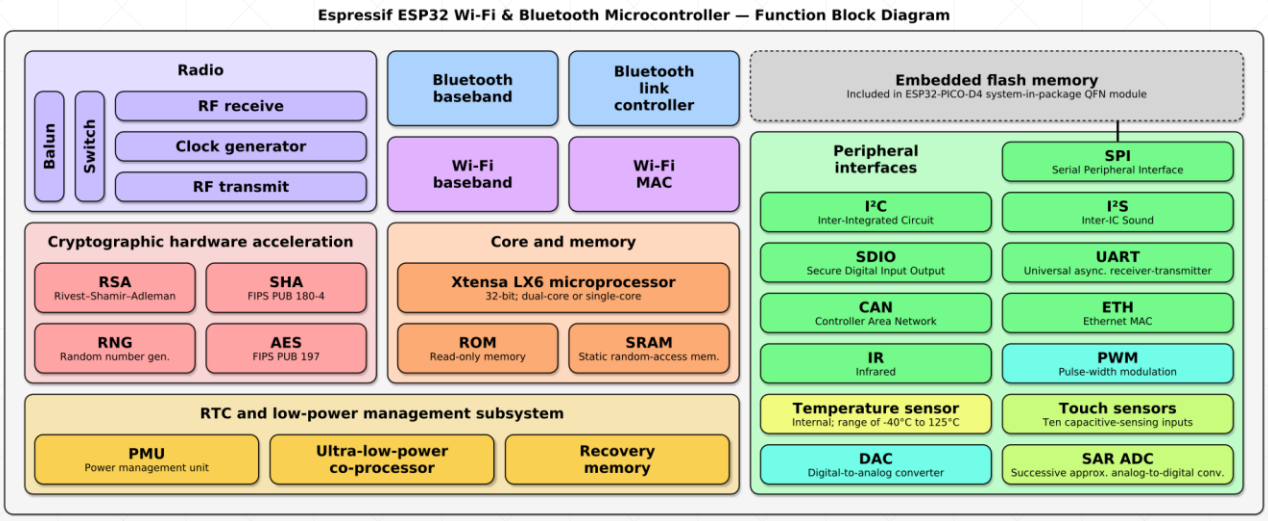
Typical SoC for IoT: CC1310 by Texas Instruments



TI CC1310 MCU Block Diagram



Software Applications	•IoT Application Layer – Control Code •Sensor Interfacing •UI/UX •Interface with Cloud •Node Analytics
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Processor Cores	•ARM : Cortex-M Series, Cortex-A Series, Cortex-R Series •RISC-V •Tensilica XTensa •ATMega328P*

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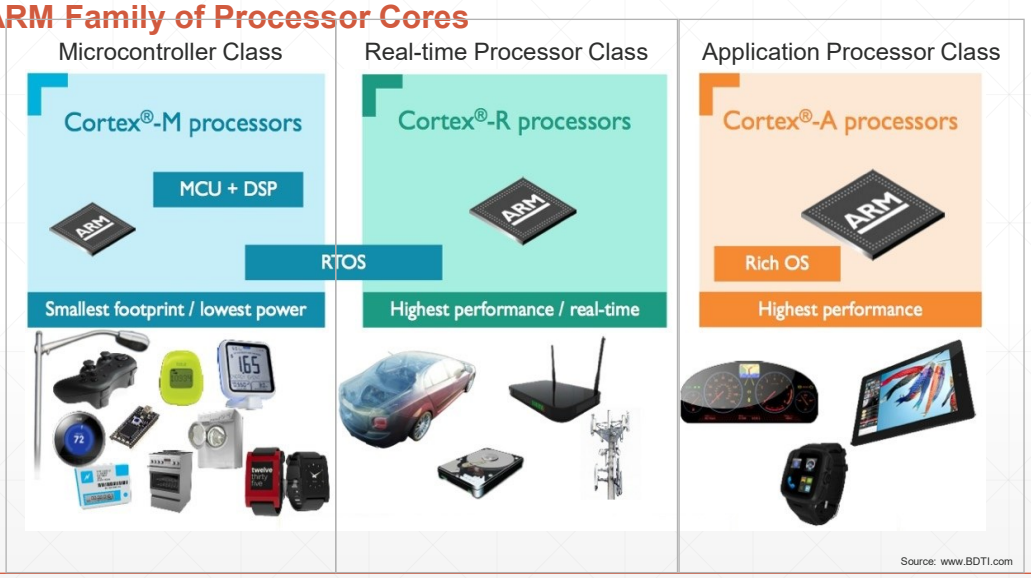
ARM Family of Processor Cores



Source: www.BDTI.com

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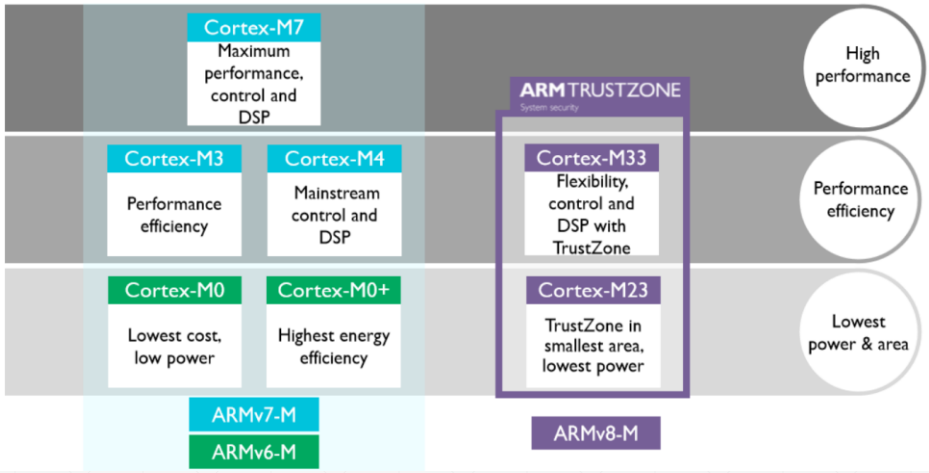
ARM Cortex-M Family



Source: ARM

95

ARM Cortex-M instruction variations

Arm Core	Cortex M0[1]	Cortex M0+[2]	Cortex M1[3]	Cortex M3[4]	Cortex M4[5]	Cortex M7[6]	Cortex M23[7]	Cortex M33[12]	Cortex M35P
ARM architecture	ARMv6-M[9]	ARMv6-M[9]	ARMv6-M[9]	ARMv7-M[10]	ARMv7E-M[10]	ARMv7E-M[10]	ARMv8-M Baseline[15]	ARMv8-M Mainline[15]	ARMv8-M Mainline[15]
Computer architecture	Von Neuman	Von Neumann	Von Neumann	Harvard	Harvard	Harvard	Von Neumann	Harvard	Harvard
Instruction pipeline	3 stages	2 stages	3 stages	3 stages	3 stages	6 stages	2 stages	3 stages	3 stages
Thumb-1 instructions	Most	Most	Most	Entire	Entire	Entire	Most	Entire	Entire
Thumb-2 instructions	Some	Some	Some	Entire	Entire	Entire	Some	Entire	Entire
Multiply instructions 32x32 = 32-bit result	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Multiply instructions 32x32 = 64-bit result	No	No	No	Yes	Yes	Yes	No	Yes	Yes
Divide instructions 32/32 = 32-bit quotient	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Saturated instructions	No	No	No	Some	Yes	Yes	No	Yes	Yes
DSP instructions	No	No	No	No	Yes	Yes	No	Optional	Optional
Single-Precision (SP) Floating-point instructions	No	No	No	No	Optional	Optional	No	Optional	Optional
Double-Precision (DP) Floating-point instructions	No	No	No	No	No	Optional	No	No	No
TrustZone instructions	No	No	No	No	No	No	Optional	Optional	Optional
Interrupt latency (if zero-wait state RAM)	16 cycles	15 cycles	23 for NMI 26 for IRQ	12 cycles	12 cycles	12 cycles	15 no security ext 27 security ext	TBD	TBD

Source: Wikipedia

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What is Full HD ?

Processor Cores & MicroControllers

Applications	•IoT Application Layer – Control Code •Sensor Interfacing •UI/UX •Interface with Cloud •Node Analytics
Operating Systems	•Contiki •ARM mBed •Zephyr •Linux •Android Things
Hardware Boards	•Arduino Uno •Raspberry Pi •Dragonboard 410c •SensorTag / Nordic Thingy:52
SoC Platforms	•Nordic nRF52 •TI Simplelink CC1x, CC2x, CC3x, RF430 •Intel Edison, Curie •Qualcomm Snapdragon
Processor Cores	•ARM : Cortex-M Series, Cortex-A Series, Cortex-R Series •Intel Quark •ATMega328P

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IoT Device Hardware Platforms

Arduino Uno

Raspberry Pi 3

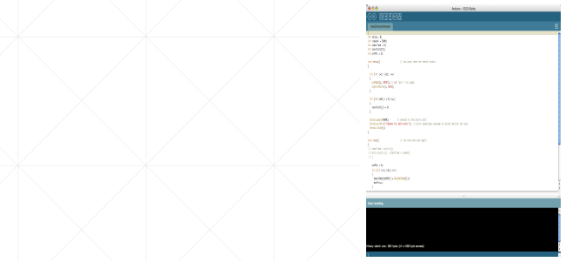
NodeMCU

Dragonboard 410c

Nordic nRF52840 DK

Arduino

- Open Source Prototyping Platform
- Easy-to-use hardware and Software
- Targeted at Makers – Artists, Hobbyists, Students & Professionals



Development Environment

Hardware

Community

Arduino Ecosystem

101

```
arduino-dht11-interfacing | Arduino 1.6.12
File  Edit  Sketch  Tools  Help
arduino-dht11-interfacing

#include <dht.h>

#define DHT11_PIN 7

// Instantiate an object to hold functions & variables related to DHT11 sensor
dht DHT;

void setup()
{
  // Initialize the serial port to operate at baud rate of 9600 bps
  Serial.begin(9600);
}

void loop()
{
  // Sense temperature and relative humidity from DHT11 Sensor
  int chk = DHT.read11(DHT11_PIN);

  // Print the values to the serial port
  Serial.print("Temperature = ");
  Serial.println(DHT.temperature);
  Serial.print("Humidity = ");
  Serial.println(DHT.humidity);

}

2                                   Arduino/Genuino Uno on COM4
```

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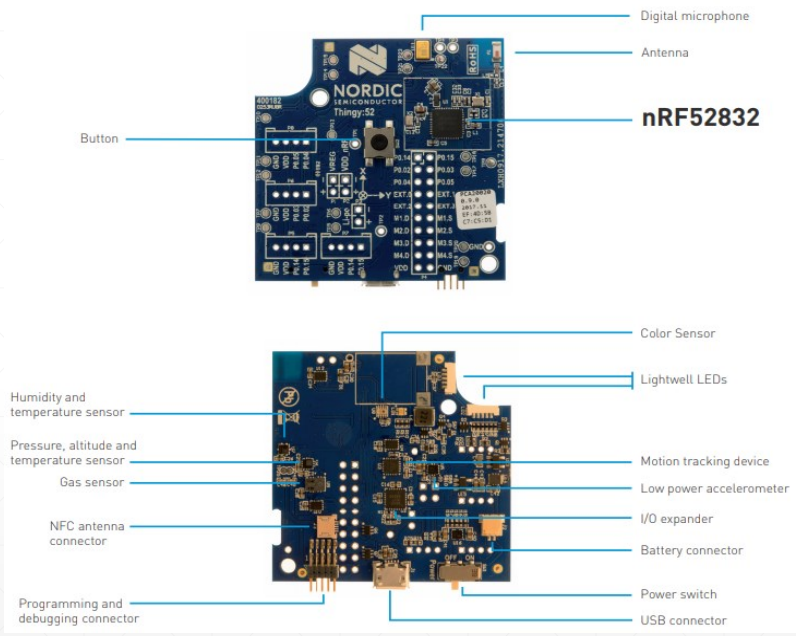
Nordic Thingy:52



Texas Instruments SensorTag

- 10 sensors including support for light, digital microphone, magnetic sensor, humidity, pressure, accelerometer, gyroscope, magnetometer, object temperature, and ambient temperature.
- Lower power
  - Longer battery life from your coin cell and enabler of battery less applications
- High performance ARM Cortex M3 (CC2650)
- Cloud connectivity
  - Access and control your SensorTag from anywhere
  - Seamless integration with mobile apps

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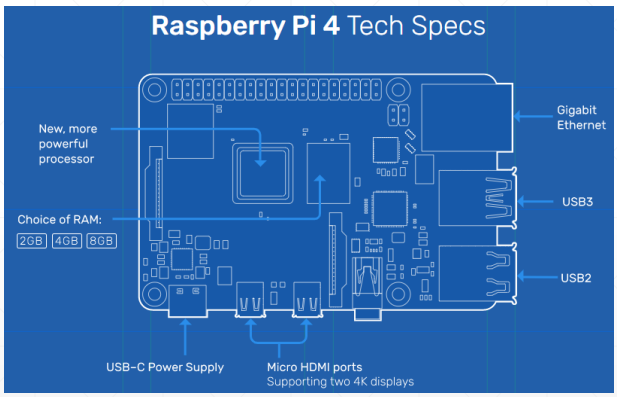
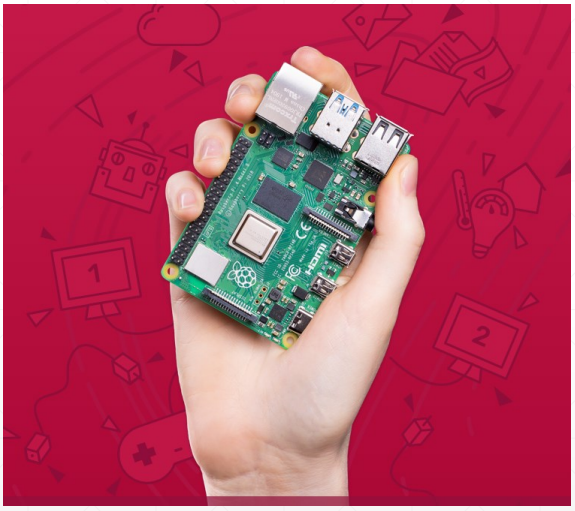
Raspberry Pi 4 : The ₹3000 Single-Board Computer (SBC)





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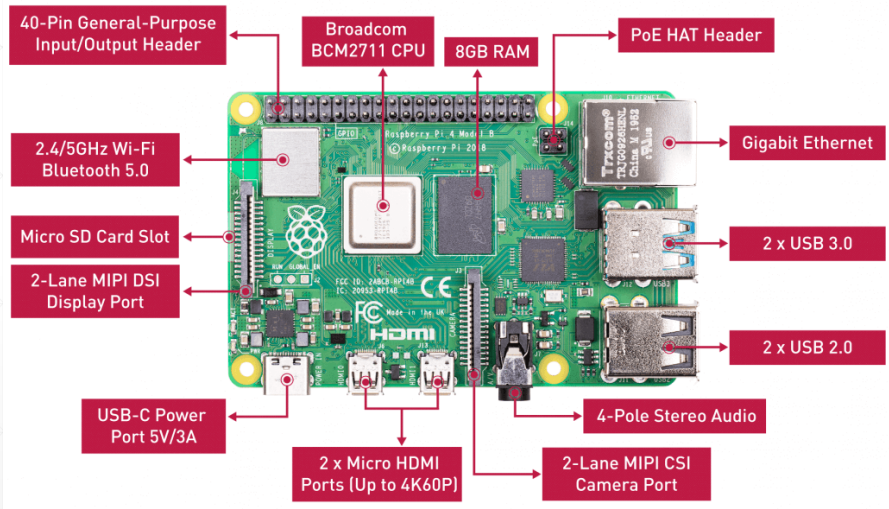
Raspberry Pi 4



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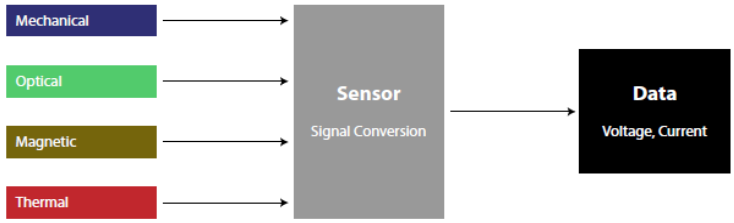
Module 5

Sensors and Actuators

Overview

Sensors



A Sensor is a device that

measures a physical quantity

and responds with a corresponding electrical signal.

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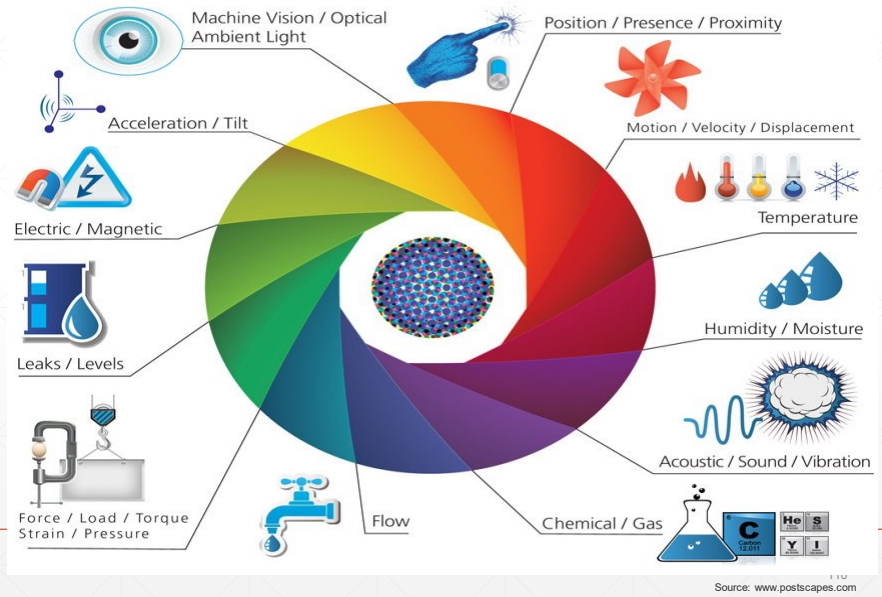
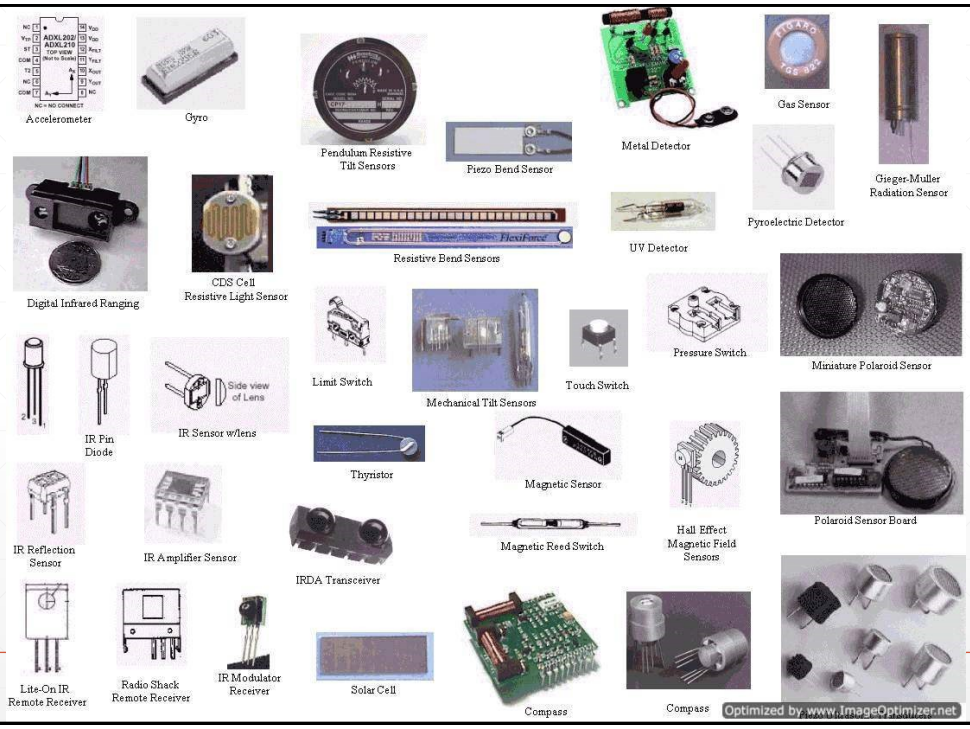
Sensors

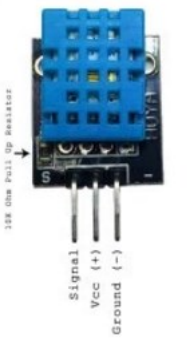


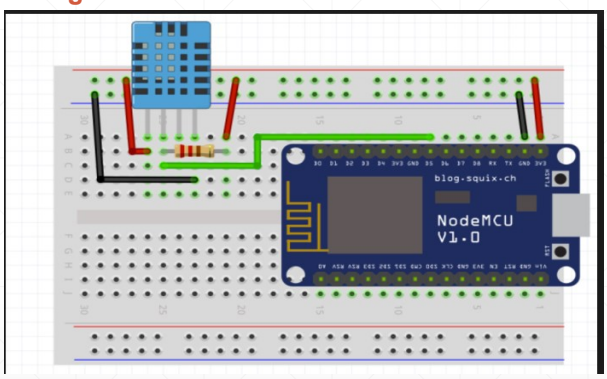
Source: www.postscapes.com



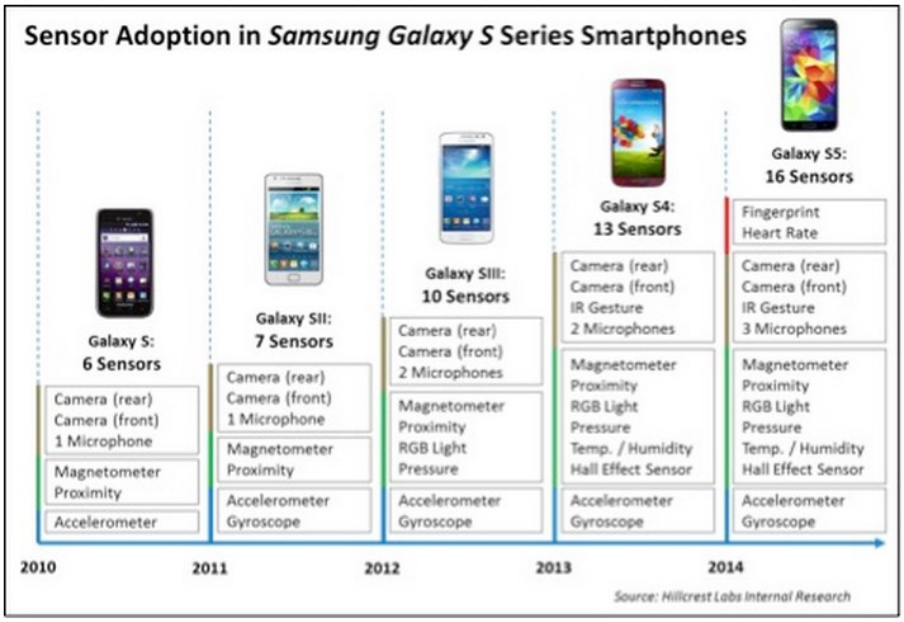
Temperature and Humidity Sensing

Arduino – DHT11 Interfacing





UNO		NodeMCU
+3.3V	->	Vcc
GND	->	Gnd
D2 (GPIO4)	->	Signal



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Sensors – Measurement Methods

Measurement Method	Description	Example
Contact	Requires physical contact with quantity of interest.	ECG, EEG, Pulse Oximeter
Non-Contact	Does not require direct physical contact.	Optical, PIR (Passive Infrared Sensor)
Sample Removal	Involves invasion collection of a representative Sample.	Blood glucose Sensor Water Quality Sensor

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Sensors - Sensing Methods & Techniques

Type	Examples
Mechanical Sensors	Accelerometers – Motion sensors Gyroscope - Rotation Strain Gauges Flex Sensors
Optical Sensors	Photodetectors Infrared (IR) Fiber Optic Interferometers
Semiconductor Sensors	Gas Monitoring sensors Temperature Sensors Magnetic Sensors – Hall Effect Sensors Optical Sensors Ion-Sensitive FETs
Electrochemical Sensors	Potentiometric Sensors – pH Sensor Amperometric Sensors - Fire detection, Oxygen Sensing Conductometric Sensors -
Biosensors	Cholesterol Detection Food Quality Monitoring

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WHAT IS A GOOD SENSOR?

- Accuracy
- Precision
- Resolution
- Sensitivity
- Noise Rejection
- Does not influence the measured property
- Low Drift

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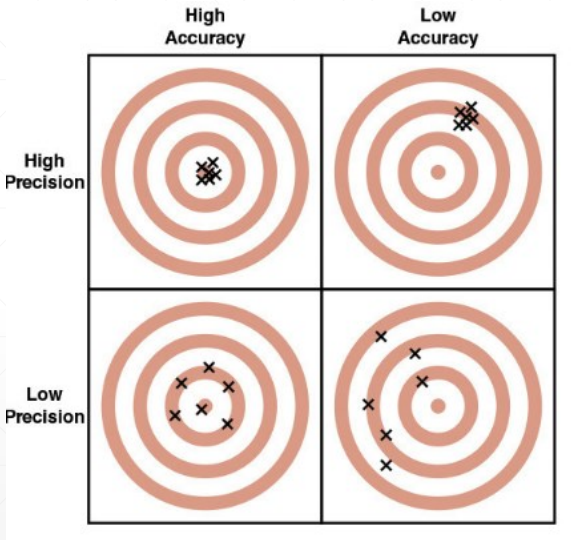
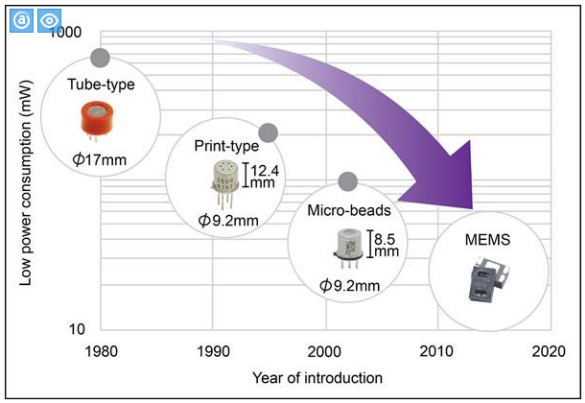
Precision and Accuracy



Trend 1: Miniaturization



Miniaturization of Gas Sensors Source: Professor Jeff Funk, New Generation MEMS Gas Sensors)

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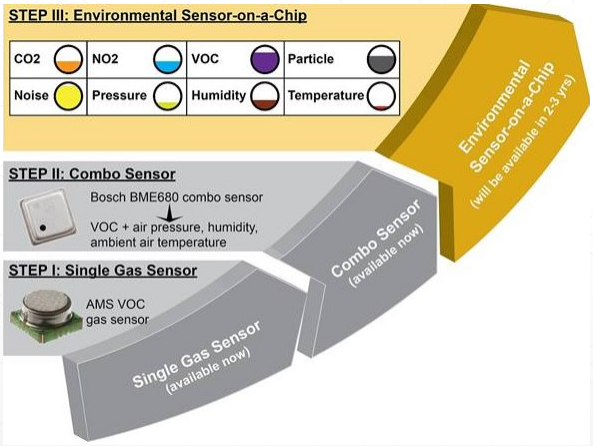
Trend 2: Integration, Sensor Fusion & Sensor Hubs



Source: Arrow.com

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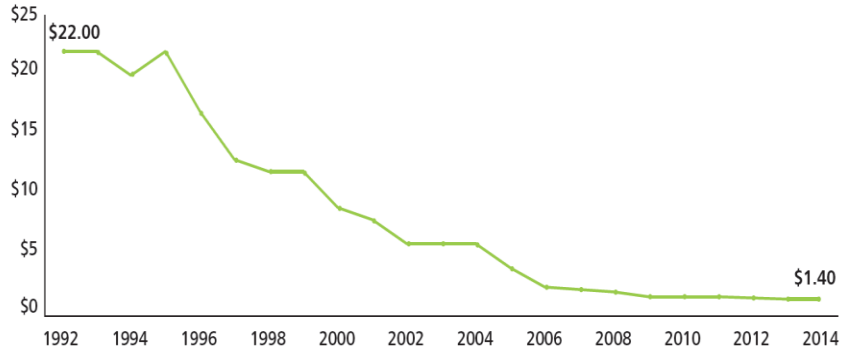
Trend 3: Cost Reduction

Sens

Figure 5. Sensors prices on the decline over the last 25 years



Source: Rob Lineback, IC Insights Inc. "The market for next-generation microsystems: More than MEMS!," http://itac.ca/uploads/events/execforum2010/rob_lineback_10-6-10-2.ppt, June 10, 2010, accessed January 28, 2015; Lee Simpson and Robert Lamb, *IoT: Looking at sensors*, Jeffries Equity Research, February 20, 2014, p. 4.

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Identification and Tags

- **Tags** are used to identify Physical Entities, to which the Tags are usually physically attached.
- The identification process is called “reading”, and it is carried out by specific Sensor Devices, which are usually called readers.
- This process can be
  - Optical (Ex: Barcodes and QR codes)
  - RF-based (Ex: NFC, Microwave car-plate recognition systems)


Bar Code


QR Code

NFC Tag


SIM / eSIM

TPM

MAC Address

API Key

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Actuators

Actuators modify the physical state of a Physical Entity.

- Changing the state (switch on/off, rotate, stir, inflate) of simple Physical Entities
- Activating/deactivating functionalities of more complex ones.
- Examples
  - Lights
  - Displays
  - Motors
  - Relays
  - Industrial Controls
  - Alarms

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Sensors in your Smartphone

- https://www.gsmarena.com/glossary.php3?term=sensors
- https://www.quora.com/how-many-different-sensors-are-available-inside-a-smartphone
- https://fieldguide.gizmodo.com/all-the-sensors-in-your-smartphone-and-how-they-work-1797121002

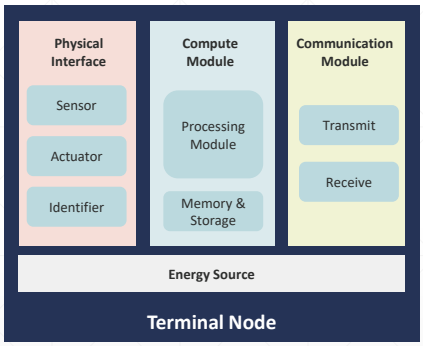
Online Sources to buy Sensors & IoT Components

- www.digikey.in
- www.mouser.in
- www.inkocean.in
- www.fabtolab.com

Module 6
Gateways

Overview

Typical IoT System Design Considerations



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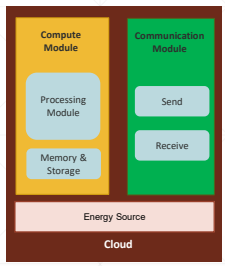
Terminal Node, Gateway and Cloud



System Design Criteria

Computation — *Memory* — *Size* — *Latency* — *Cost* — *Power* — *Maintainability* — *Reliability* — *Security*

Goal → **Performance Improvement Cost Reduction** → **Enhanced Efficiency At System Level**

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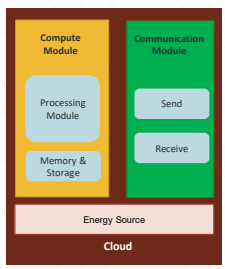

- **Cloud Computing**
- **Fog Computing**
- **Edge Computing**
- **Node Computing**
- **ROOF Computing**

ROOF: Remote Onsite Operations Facilitation

System Design Criteria

Computation — *Memory* — *Size* — *Latency* — *Cost* — *Power* — *Maintainability* — *Reliability* — *Security*

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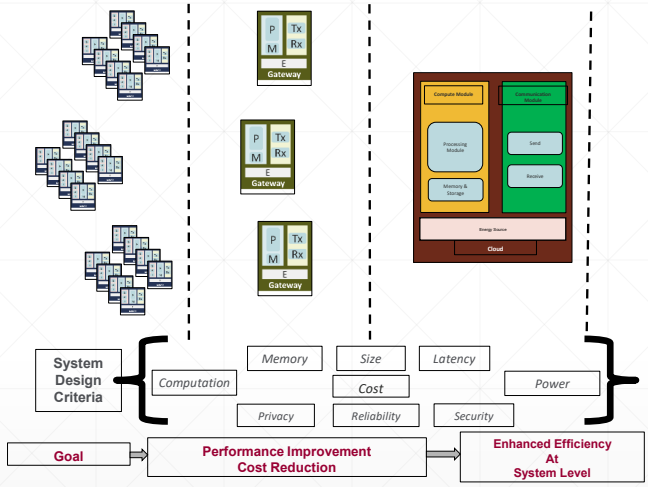
The Ideal IoT Solution Architecture

- When each functionality of the System (Sensing, Analysis, Storage & Response) is executed at the **Most Appropriate Location** (Node, Gateway or Cloud)
- Typically, Sensing will always happen at the Terminal Node.
- Analysis & Storage can happen either at the Terminal Node, Gateway or Cloud.



Cloud-Centric Architecture: Most of the processing is done on the Cloud

Node Analytics / Edge Analytics: Most of the processing is done on the Terminal Node or Edge Node

Fog-Computing: Significant portion of computing is concentrated in Gateways and Fog Nodes (Fog Node A marketing term to denote computing modules above the Edge but below the Cloud)

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Why do we need an IoT Gateway ?

- Local aggregation
- Deriving meaningful information from raw data
- Analytics (Local)
- Connecting to local devices with multiple connection protocols
- Management, Configuration and Commissioning
- Security

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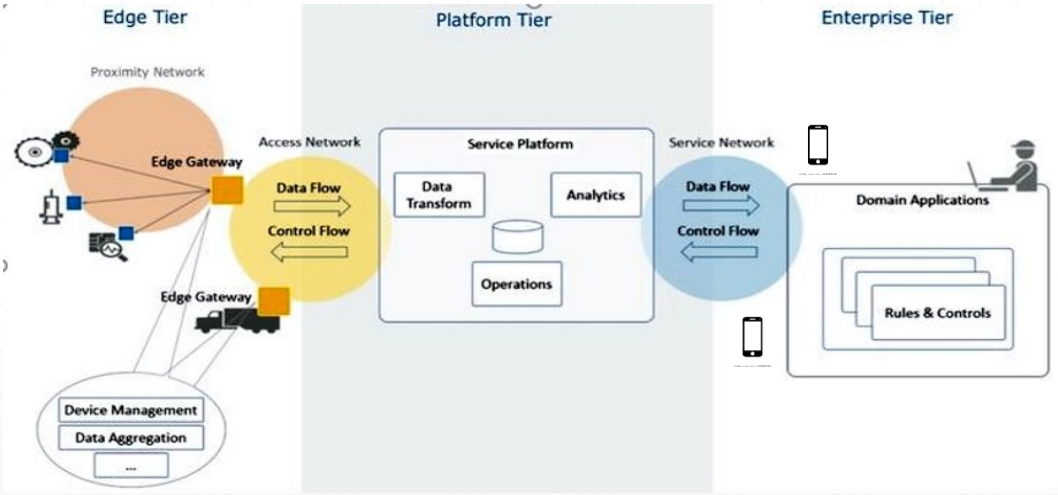
Typical IoT Architecture



Terminal Nodes | Cloud | Front-end (UI) Applications

Sense | Analyze | Respond

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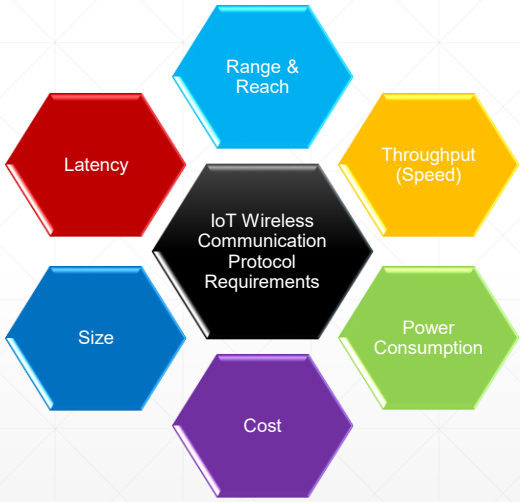
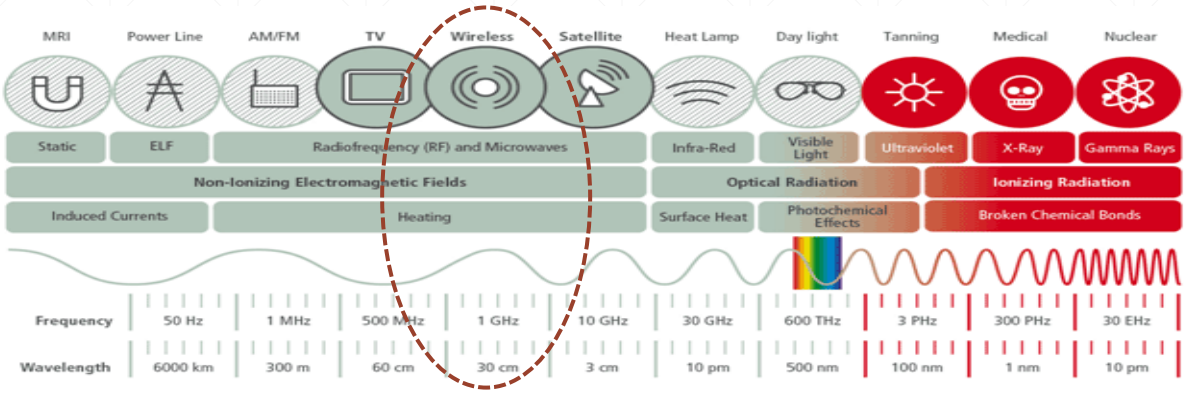
Module 7

Communication Protocols

Overview

Wireless Communication for IoT : Key Parameters

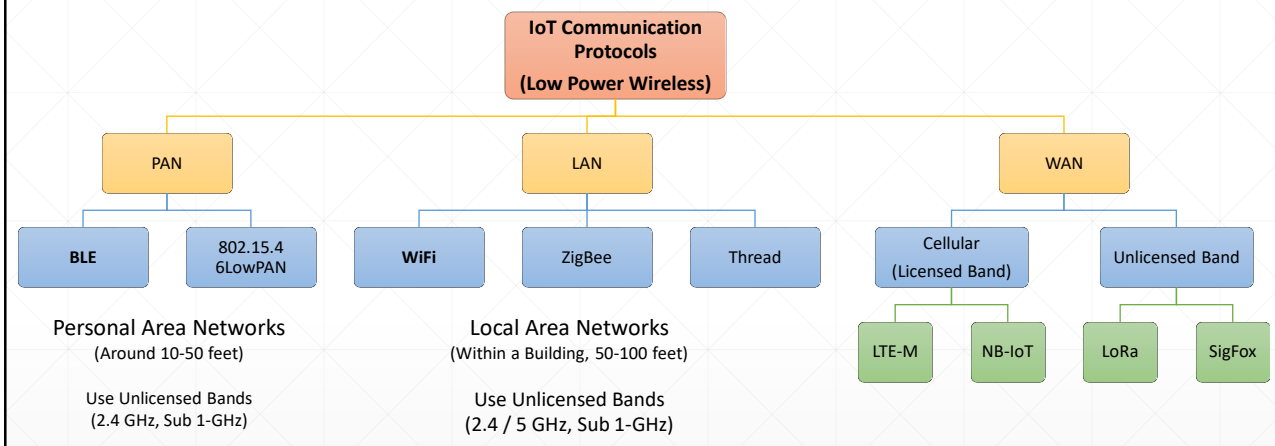




- Spectrum is considered National Resource
- In every country, Government Bodies (like TRAI) allocate specific bands that can be used for Civilian Purposes
- Some bands are Licensed to Telecom Operators like Airtel, Reliance Jio, Vodafone (via Auction?)
  - Cellular Services (2G, 4G, 5G, NB-IoT etc) are provided on these bands
- A few bands are allocated as 'License-free bands' and can be used by anyone
  - WiFi and BLE use 2.4 GHz, 5 GHz
  - Sub 1-GHz (865-867 MHz)

Why not use a Cellular Module ?

- Power Consumption is High
- Computationally intensive
- Needs Significant Memory (PM & DM)
- Higher Cost (SoC Cost + Network Usage Cost)
- Translates to larger Size (SoC + Battery)
- Availability of Cellular Network



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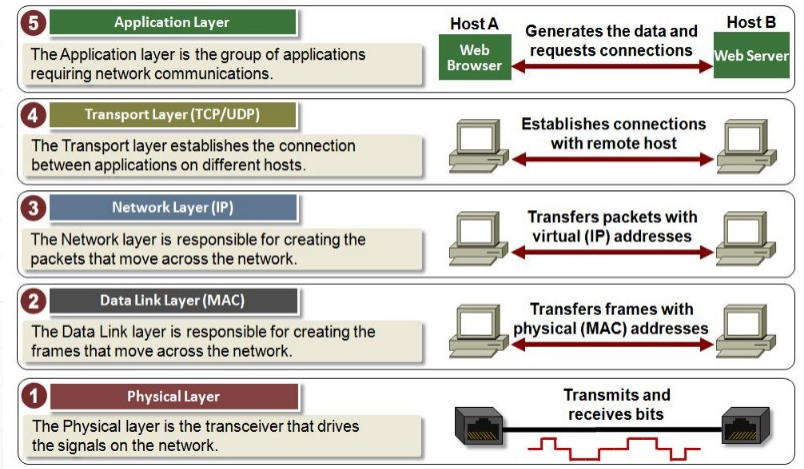
TCP/IP : Five Layer Model



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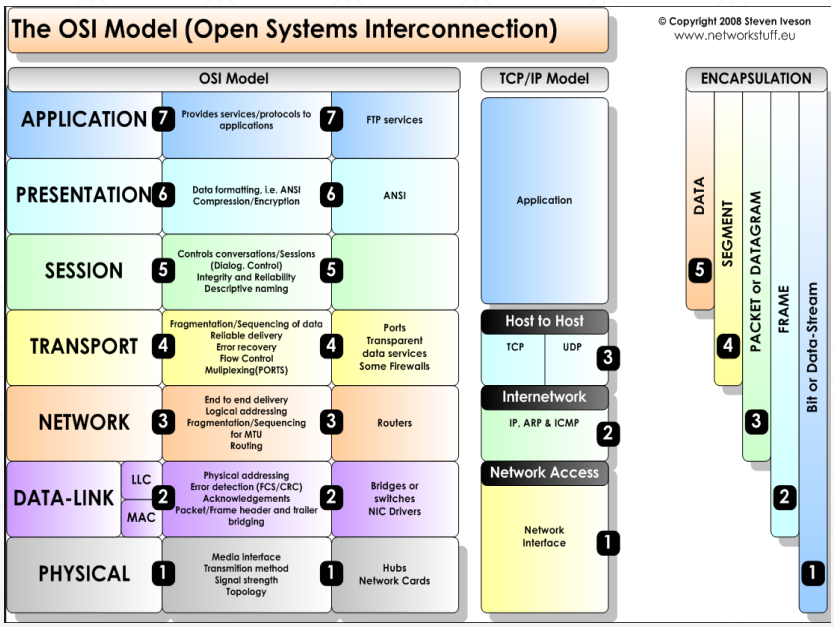

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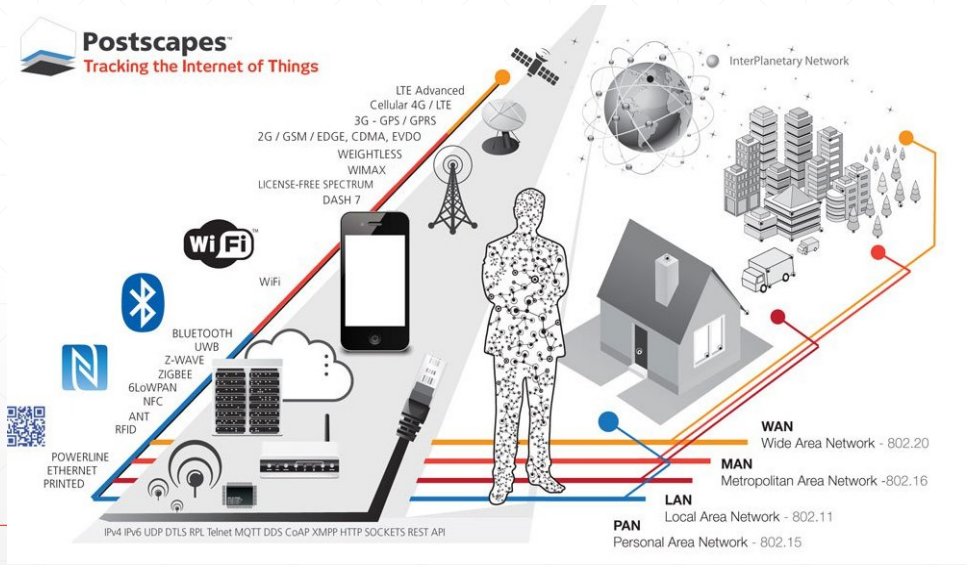
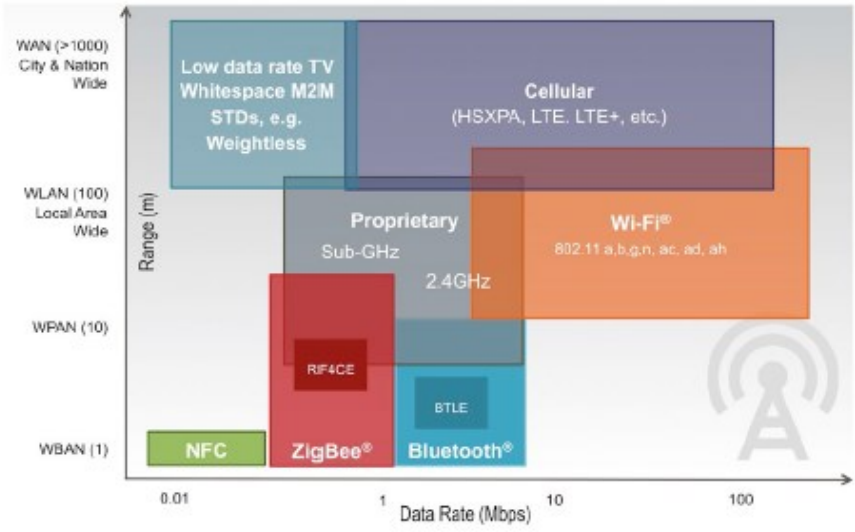
RF Communication : Landscape



Source : http://www.postscapes.com

Today's Wireless Landscape



Source: http://www.freescale.com

LPWAN Technologies : Comparison

	LoRa	SIGFOX	LTE-M	NB-IoT
Coverage	~ 10 Km	~ 12 Km	~ 11 Km	~ 15 Km
Frequency Band	Unlicensed	Unlicensed	Licensed (LTE)	Licensed (LTE)
Data Rate	10 Kbps	~ 100 bps	~ 10 Mbps	100 Kbps
Standardizartion	De-facto Standard	De-facto Standard	3GPP Rel. 8	3GPP Rel. 13 (planned)
Battery Life	~ 10 years	~ 10 years	~ 10 years	~ 10 years

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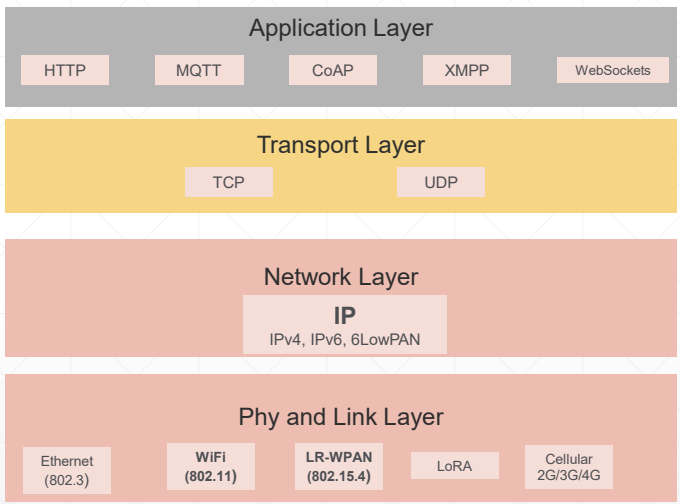
Networking Model – Protocols & Layers in IoT



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IPv4 & IPv6 : Comparison

IPv4	IPv6
IPv4 addresses are 32 bit length.	IPv6 addresses are 128 bit length.
IPv4 addresses represented in decimals.	IPv6 addresses represented in hexadecimals.
IPSec support is only optional.	Inbuilt IPSec support.
Fragmentation is done by sender and forwarding routers.	Fragmentation is done only by sender.
No packet flow identification.	Packet flow identification is available within the IPv6 header using the Flow Label field.
Checksum field is available in IPv4 header	No checksum field in IPv6 header.
Options fields are available in IPv4 header.	No option fields, but IPv6 Extension headers are available.
Address Resolution Protocol (ARP) is available to map IPv4 addresses to MAC addresses.	Address Resolution Protocol (ARP) is replaced with a function of Neighbor Discovery Protocol (NDP).
Internet Group Management Protocol (IGMP) is used to manage multicast group membership.	IGMP is replaced with Multicast Listener Discovery (MLD) messages.
Broadcast messages are available.	Broadcast messages are not available. Instead a link-local scope "All nodes" multicast IPv6 address (FF02::1) is used for broadcast similar functionality.
Manual configuration (Static) of IPv4 addresses or DHCP (Dynamic configuration) is required to configure IPv4 addresses.	Auto-configuration of addresses is available.

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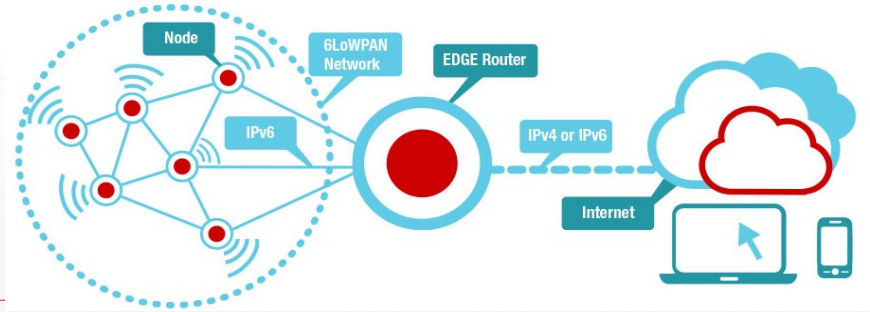
6LoWPAN

- IPv**6** over **L**ow power **W**ireless **P**ersonal **A**rea **N**etworks
- Low-power wireless mesh network where every node has its own IPv6 address, allowing it to connect directly to the Internet using open standards.
- Adaption layer for IPv6 over IEEE802.15.4 links



Source: http://www.ti.com

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6LoWPAN Advantages

Open IP Standard

- Open standards including TCP, UDP, HTTP, COAP, MQTT, and websockets
- End-to-end IP addressable nodes
- No gateway needed. A router connects the 6LoWPAN network to IP.

Mesh Routing

- One-to-many and many-to-one routing
- Robust and scalable, 1000+ nodes
- Self-healing
- Mesh routers can route data destined to others, while hosts are able to sleep for long periods of time

Multiple PHY support

- Freedom of frequency band & physical layer
- Use across multiple communications platforms (i.e. Ethernet / Wi-Fi / 802.15.4 / Sub-1GHz ISM)
- Interoperability at the IP level

Source: http://www.ti.com

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Application Layer : Communication Models / Patterns

- Request – Response
- Publish-Subscribe
- Exclusive Pair

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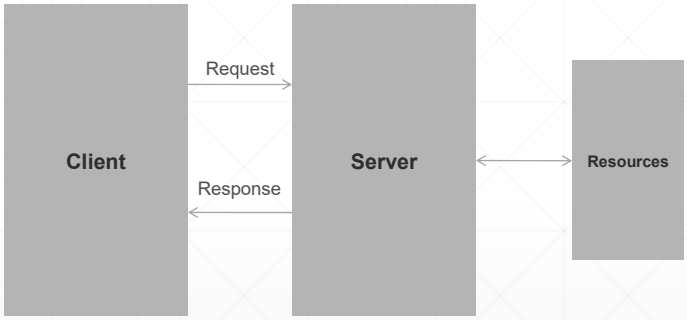
Request - Response



Example: HTTP

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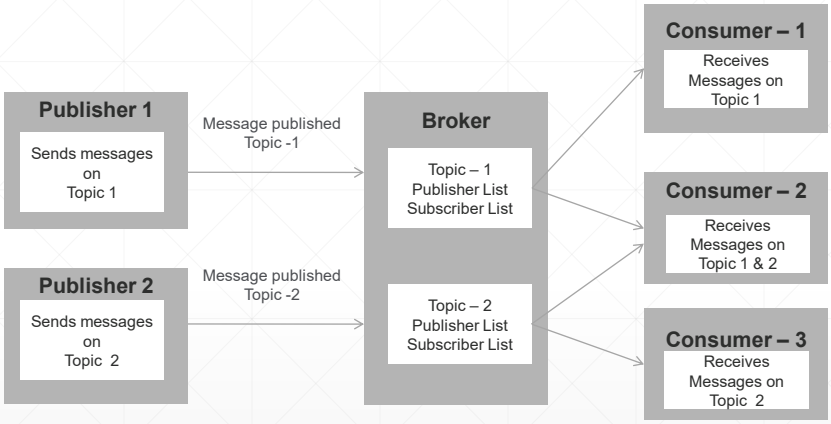
Publish - Subscribe



Example: MQTT (Message Queuing Telemetry Transport)

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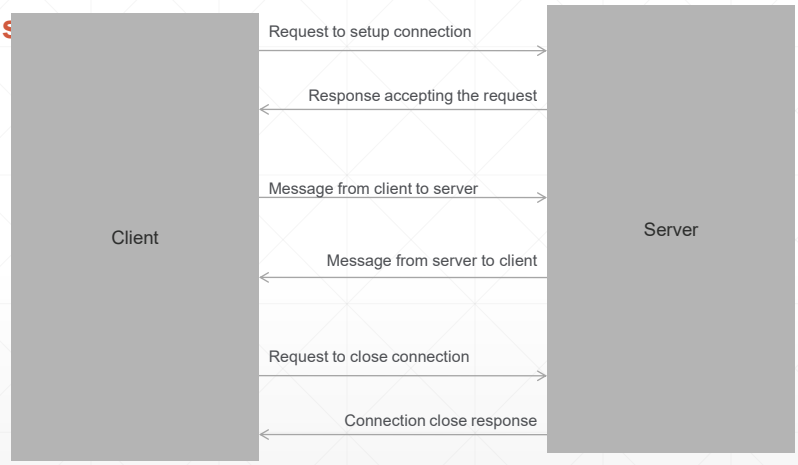
Exclusive Pair

Exclus



WebSocket APIs use Exclusive Pair Model

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Application Layer Protocols

- **MQTT - Message Queue Telemetry Transport**
  - Light-weight messaging protocol
  - Based on Publish-Subscribe Model
  - Uses TCP as the Transport Layer Protocol
  - IBM significantly involved in developing this protocol

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Some Wireless Trends

- WiFi 6
- Cellular – 4G, 5G (including NB-IoT), Femto Cells
- Bluetooth 5, 5.1 & 5.2
- Weightless – Adaptive usage of the unused TV spectrum
- Thread by Google
- GAGAN & NAViC

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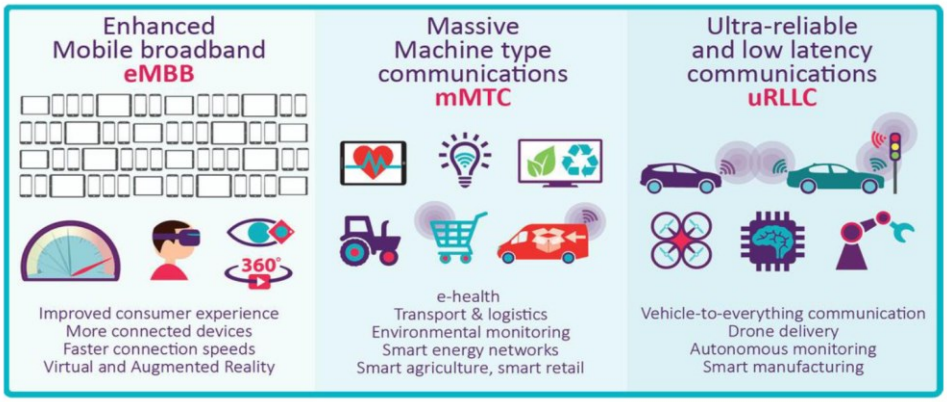
5G: The Next Frontier in Cellular Communication



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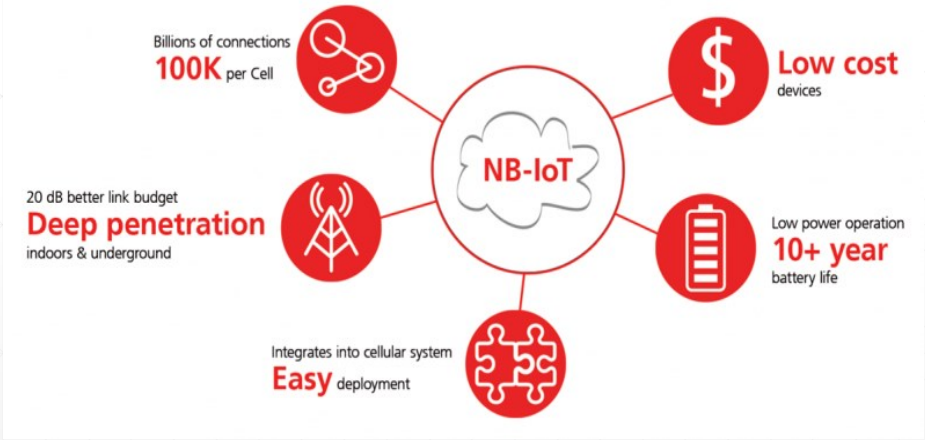
NB-IoT



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Communication Technologies - Comparison

	NFC	RFID	Blue-tooth®	Blue-tooth® LE	ANT	Proprietery (Sub-GHz & 2.4 GHz)	Wi-Fi®	ZigBee®	Z-wave	KNX	Wireless HART	6LoWPAN	WiMAX	2.5–3.5 G
Network	PAN	PAN	PAN	PAN	PAN	LAN	LAN	LAN	LAN	LAN	LAN	LAN	MAN	WAN
Topology	P2P	P2P	Star	Star	P2P, Star, Tree Mesh	Star, Mesh	Star	Mesh, Star, Tree	Mesh	Mesh, Star, Tree	Mesh, Star	Mesh, Star	Mesh	Mesh
Power	Very Low	Very Low	Low	Very Low	Very Low	Very Low to Low	Low-High	Very Low	Very Low	Very Low	Very Low	Very Low	High	High
Speed	400 Kbs	400 Kbs	700 kbs	1 Mbs	1 Mbs	250 kbs	11-100 Mbs	250 kbs	40 Kbs	1.2 Kbps	250 kbs	250 Kbs	11-100 Mbs	1.8-7.2 Mbs
Range	<10 cm	<3 m	<30 m	5-10 m	1-30 m	10-70 m	4-20 m	10-300 m	30 m	800 m	200 m	800 m (Sub-GHz)	50 km	Cellular network
Application	Pay, get access, share, initiate service, easy setup	Item tracking	Network for data exchange, headset	Health and fitness	Sports and fitness	Point to point connectivity	Internet, multimedia	Sensor networks, building and industrial automation	Residential lighting and automation	Building automation	Industrial sensing networks	Senor networks, building and industrial automation	Metro area broadband Internet connectivity	Cellular phones and telemetry
Cost Adder	Low	Low	Low	Low	Low	Medium	Medium	Medium	Low	Medium	Medium	Medium	High	High

Source: http://www.freescale.com

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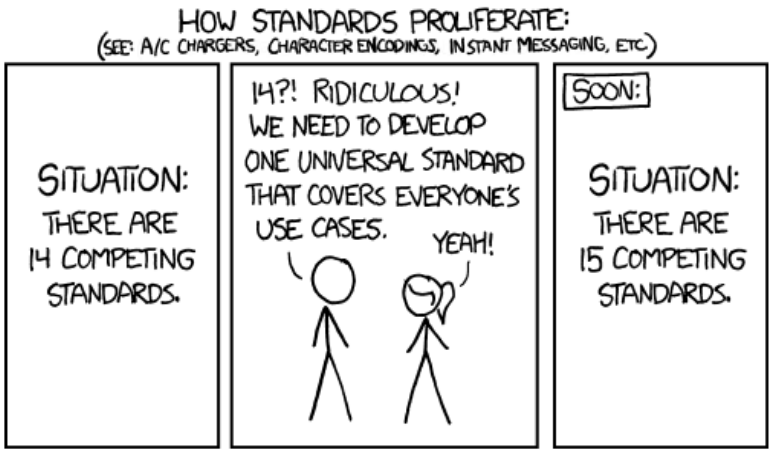

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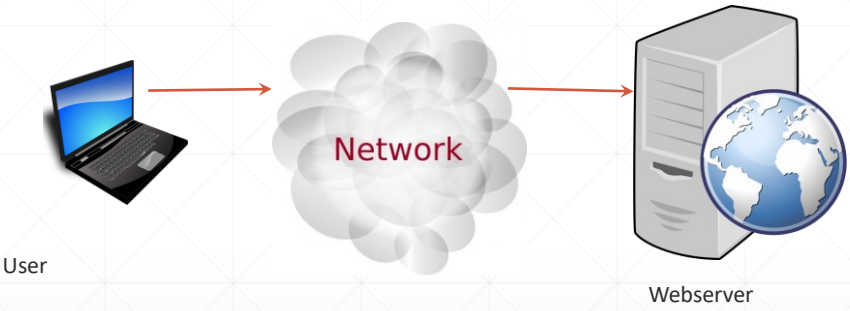
Module 8
Cloud Computing

Overview

Typical Setup



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What is cloud computing?

"the practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer."

- In plain English, this means performing computing operations using machines that you don't manage!

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Characteristics of Cloud Computing

- Resource Pooling
- Broad Network Access
- Rapid Elasticity
- Measured Service (Metering)
- On-demand Self-service

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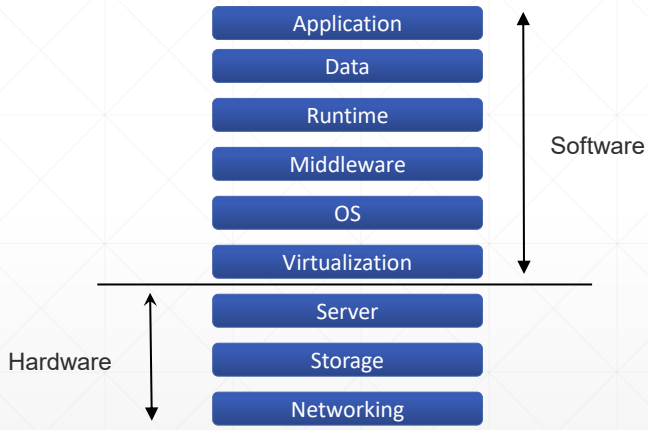
Typical Web Stack



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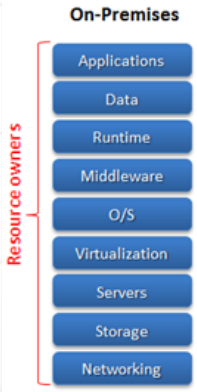
Cloud Computing - Service Models



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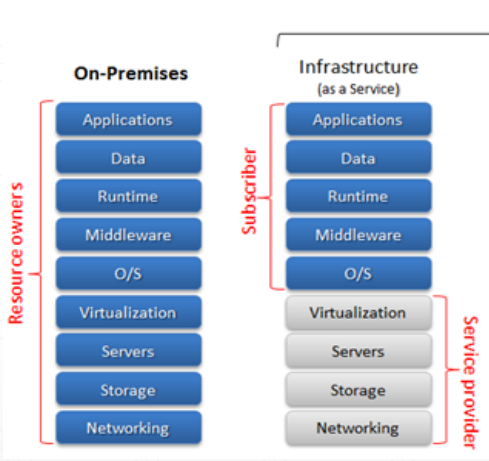
Source:
http://https://blogs.msdn.microsoft.com

Cloud Computing - Service Models



IaaS
(Eg: Amazon EC2) (I

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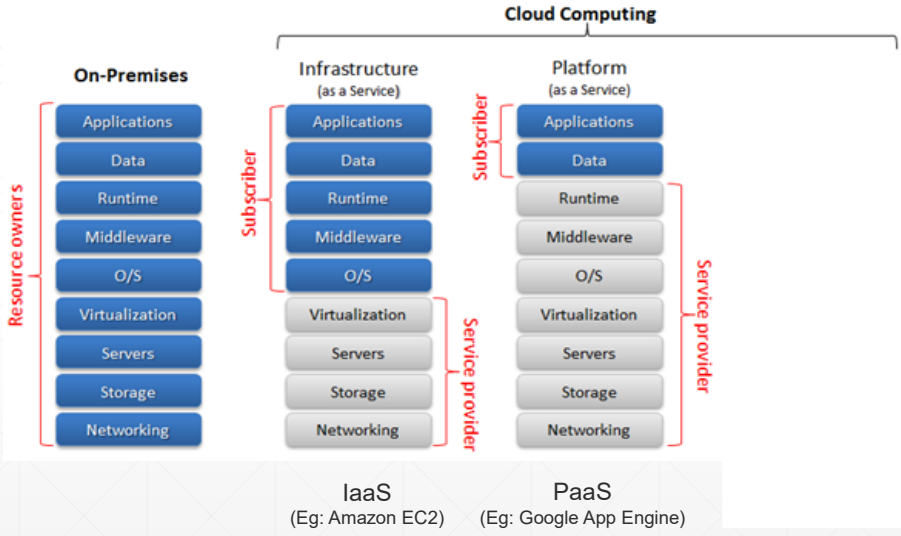
Source:
http://https://blogs.msdn.microsoft.com

Cloud Computing - Service Models



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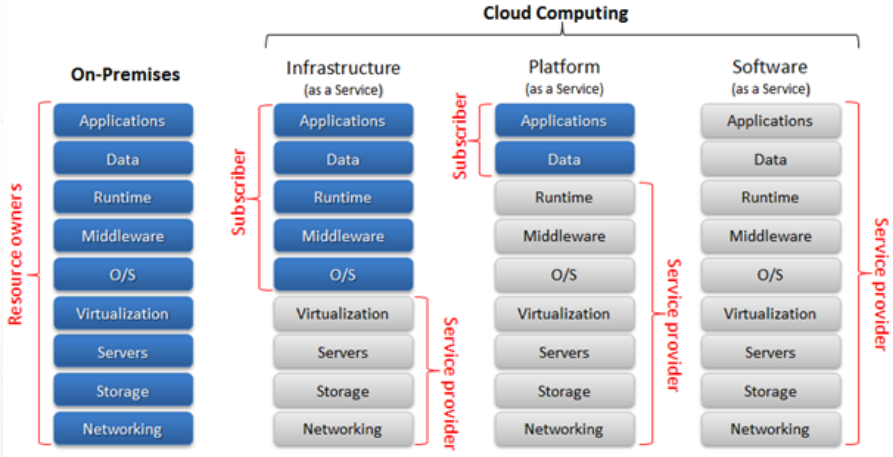
Source:
http://https://blogs.msdn.microsoft.com

Cloud Computing - Service Models



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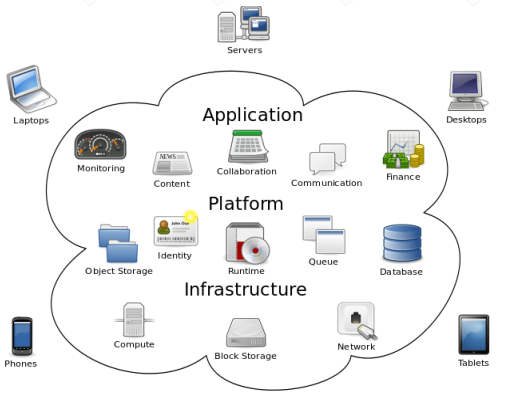
Source:
http://https://blogs.msdn.microsoft.com

Service Model - Examples



- On Premise
  - In-house IT within company
- Infrastructure-as-a-Service (IaaS)
  - Amazon EC2, MS Azure Virtual Machines, Rackspace
- Platform-as-a-Service (PaaS)
  - Google App Engine, MS Azure, Force.com, Thingspeak
- Software-as-a-Service (SaaS)
  - Gmail, Facebook, LinkedIn, Salesforce.com, MS Office 365

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Why use cloud?

- Cost
- Scalability
- Availability
- BigData Analytics
- Easy interfacing with other data and APIs
- Disaster Recovery
- Backup

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Webservices

- A webservice is a function or subroutine that can be accessed by other applications over web.
- Example – User login which is needed by all applications but can be provided by a single application.
- Useful when large number of clients (devices?) need to send data to server (cloud?).
  - Sample scenario – host a server in cloud and provide a mechanism for devices to post data to this server.

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RESTful Webservices

Representational State Transfer webservices are

- Lightweight webservice
- Use standard HTTP
- Allow actions such as GET, PUT, POST, DELETE actions - almost mapping with database CRUD operations
- Simpler alternative to SOAP and WSDL webservices
- Useful for IoT since devices typically do not have large computing power.

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Security Aspects

- Webservices need to be secured to avoid incorrect and unauthorized data to be posted.
- Security needs
  - Authentication – Ensuring that only authorized clients post data
  - Channel security – Encrypting the channel to prevent data tampering and snooping
  - Content Integrity & Security – Done at server to ensure data is correct, complete and accessible only by authorized entities

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Module 9: IoT PaaS Platforms

Overview

Cloud IoT Platforms: Typical Requirements

Data Services

- Device to Cloud Communication : Data & Metadata
- Cloud to Device Communication
- Data Aggregation and Storage
- Data Access Control
- Data Transformation & Processing

Control Services

- Device Provisioning & Commissioning
- Device Identity Management
- User Identity Management
- Device Authentication & Authorization
- OTA Updates – Configuration, Software & Firmware Updates
- Metering, Billing & Subscription

Services for Data Visualization and Data-dependent Actions

- Event Alerts & Rules Engine
- Visualization & Dashboarding
- APIs to Web and Mobile Applications
- Analytics – AI/ML
- Maps & Navigation Support
- AR/VR Interfaces
- Device SDK (Libraries to connect to cloud)

Example IoT Implementation Platforms

- AWS IoT Suite
- Azure IoT Suite
- Iotivity
- Thingspeak
- IBM – IoT Foundation Suite, Bluemix and Watson
- ThingWorx by PTC

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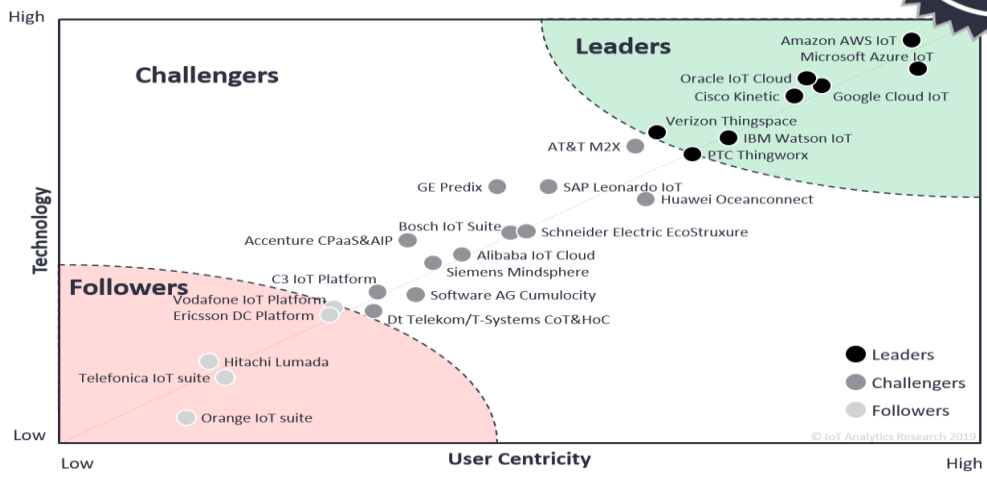
IOT ANALYTICS

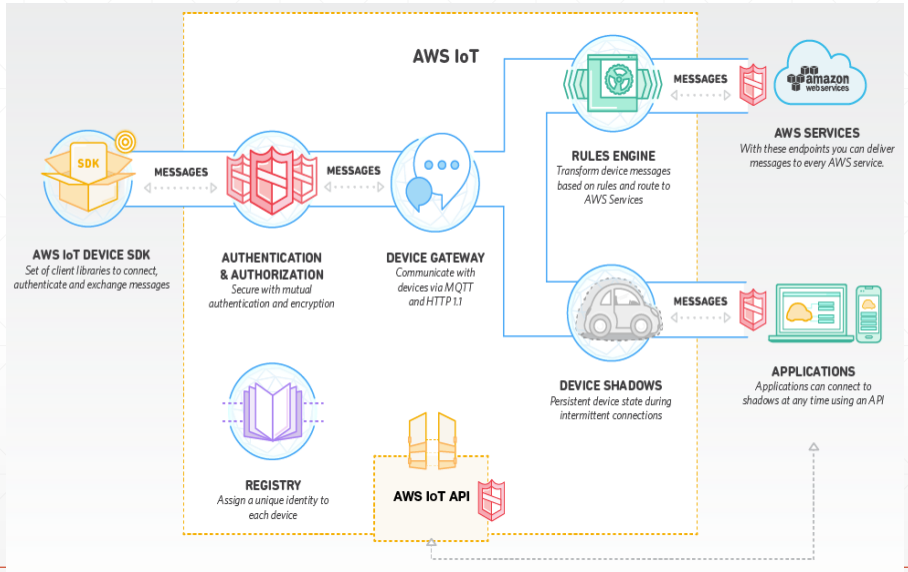
Leading IoT Platforms 2019

Based on customer reviews



Note: The ranking is entirely based on IoT Platform end-users views. User Centricity = Usability of the platform (incl. ease of use), Support (documentation, hotline, etc.), Value for money; Technology = Maturity of cloud services, application enablement, device management, connectivity management, data management & analytics, security, interoperability, and the completeness of the total offering (each considered independently) **Source(s)**: IoT Analytics Research – July 2019

AWS IoT Platform



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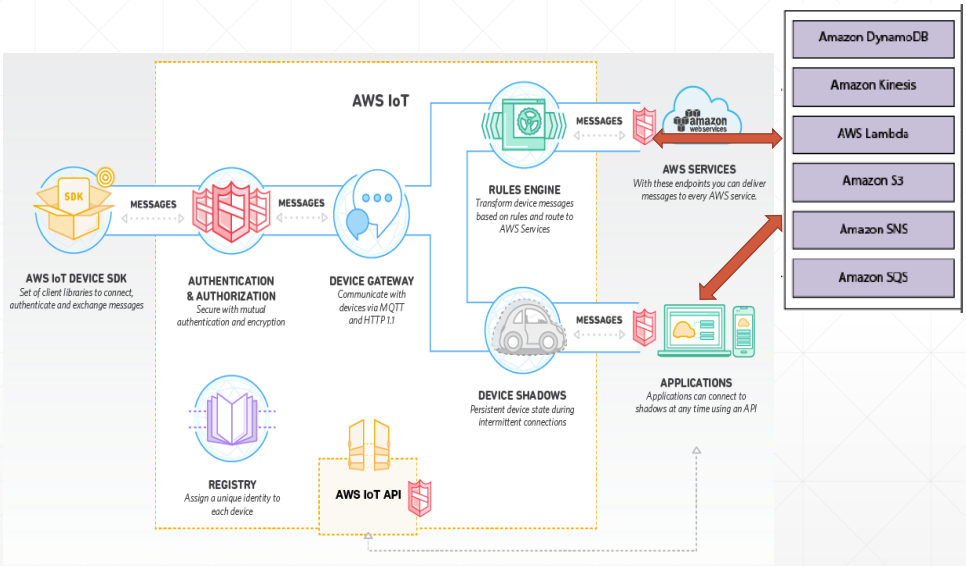
Source: Amazon

AWS IoT Platform



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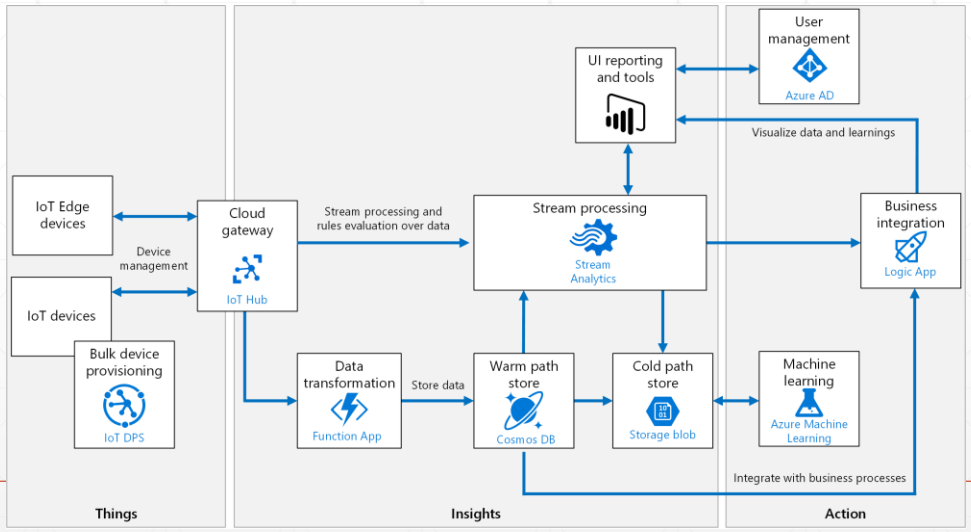
Source: Amazon

Microsoft Azure IoT Reference Architecture



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Trend 1: Digital Twin

- Dynamic Software Model of a Physical Asset
- Digital Representation of Real-time (Latest) Configuration & State Information
- Same Concept – Multiple Names
  - Device Shadow (AWS IoT)
  - Digital Twin (Microsoft Azure IoT, GE Predix etc)
  - ThingModel (PTC or ThingWorx)
  - Virtual Twin

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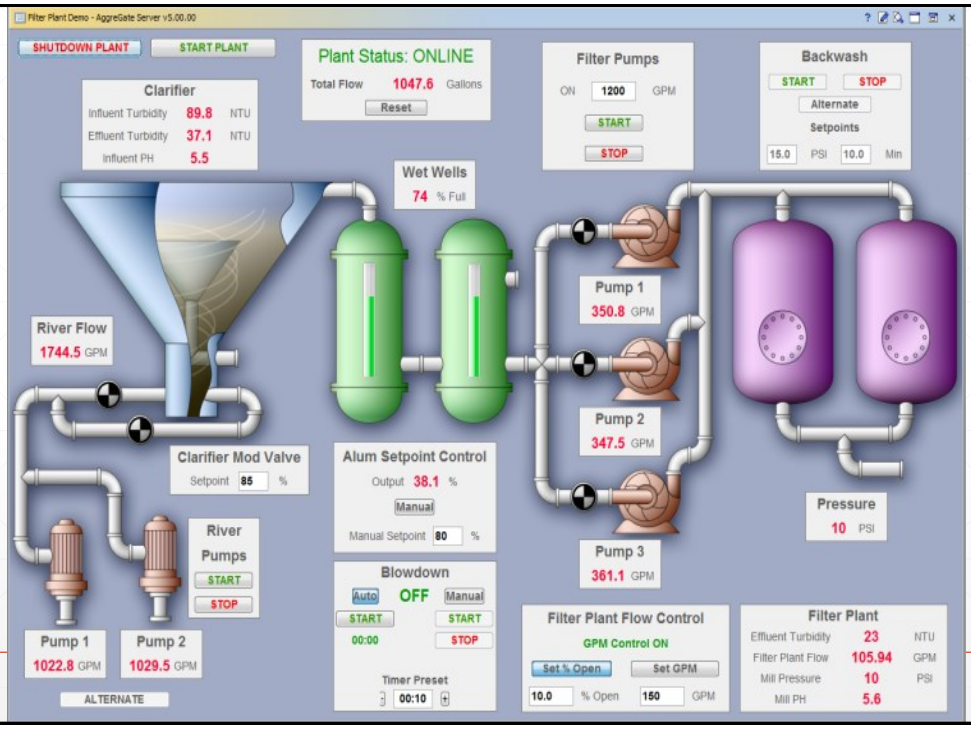

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Trend 2: Extend IoT Platform Features to the Edge Device

- Typical Challenges with Cloud IoT PaaS Deployments
  - Intermittent Connectivity
  - Round-trip Latency
  - Expensive bandwidth
  - Privacy & Security Concerns
- Solution: Replicate the IoT Platform Functionality at the Edge (or Local Gateway)
- Same Concept – Multiple Names
  - AWS GreenGrass
  - Microsoft Azure IoT Edge
  - Huawei Edge-Computing IoT (EC-IoT)

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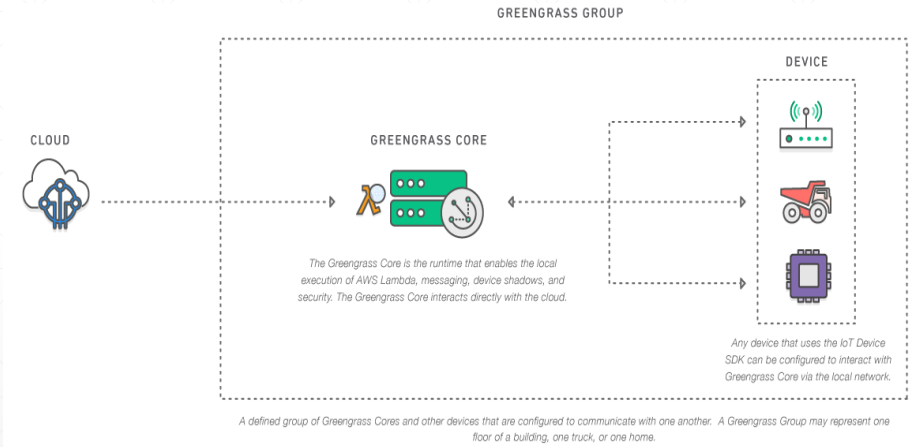
AWS GreenGrass



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Advantages of IoT Platforms on the Edge

- Connectivity Resilience : Seamless Operation with Offline & Intermittent Connectivity
- Enable Real-time decisions (local decisions)
- Perform Edge Analytics & AI on the Edge
- Connect New and Legacy Devices
- Decentralization of responsibility and decision making (IT-OT decoupling)

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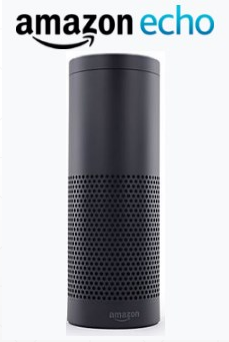
Trend 3: Alternate HMI or UX

- IoT Devices or End-notes are typically headless devices (no display, no keyboard)
- Support for alternate Human-Machine Interfaces (HMI) is emerging
  - Speech (Amazon Echo, Google Home)
  - Gestures (Intel RealSense)
  - Device Movement



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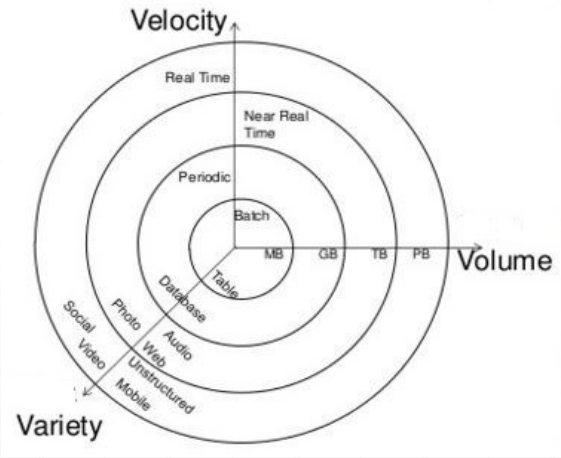
Module 10
Big Data & Visualization

Overview

Big Data

- Term used to identify data whose magnitude cannot be managed and processed by traditional tools and systems
- The range of big data is usually in excess of terabytes
- Example – Facebook, Twitter, Google Search

3 V's of Big Data



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Processing BigData

- One large machine usually not enough
- Concept is to divide and then process this data using an array of commodity machines
  - In short, use distributed computing!

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MapReduce

- Design methodology – divides the work into smaller manageable chunks which can then be tasked over to distributed machines to process
- The term MapReduce actually refers to two separate and distinct tasks
  - Map job - Takes a set of data and converts it into another set of data, where individual elements are broken down into tuples (key/value pairs).
  - Reduce job - Takes the output from a map as input and combines those data tuples into a smaller set of tuples. As the sequence of the name MapReduce implies, the reduce job is always performed after the map job.
- MapReduce libraries available in several languages – one of the more popular implementations is Apache Hadoop.

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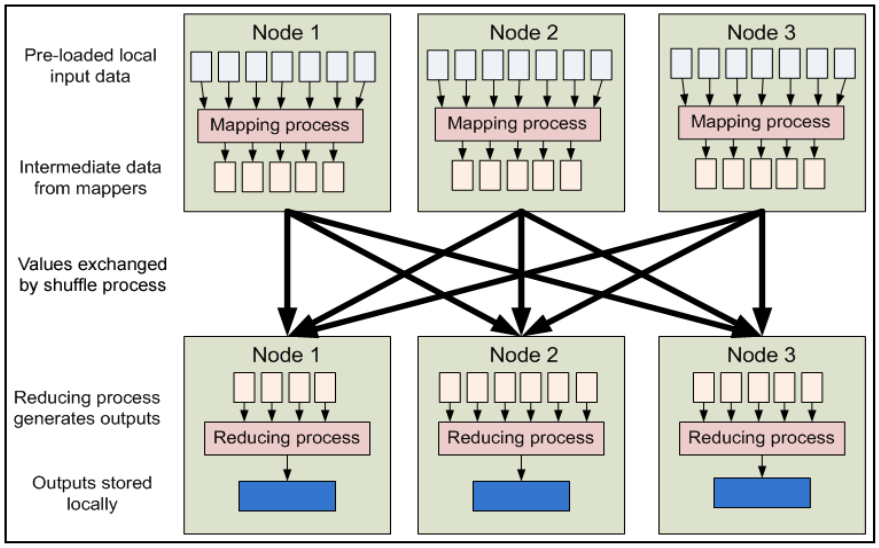
MapReduce



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Data Stores

- Cloud equivalent of database
- Standard DB versions
  - MySQL
  - Oracle
  - MS SQL
- Cloud Data stores
  - Cassandra
  - BigTable
  - MongoDB

- The trend is now to store data in column oriented databases rather than in the classical row oriented databases

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Data Stores

- Advantages of columnar databases
  - Can be highly compressed
    - Allows for very fast operations like MIN, MAX, SUM, COUNT, AVERAGE
  - Self indexing - uses less disk space

Column-oriented systems are more efficient when an aggregate needs to be computed over many rows but only for a notably smaller subset of all columns of data, because reading that smaller subset of data can be faster than reading all data. - wikipedia

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Module 11
Analytics & Visualization

Overview

Analytics – Types

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Descriptive Analysis

What Happened ?

Example -> [Wind Map]

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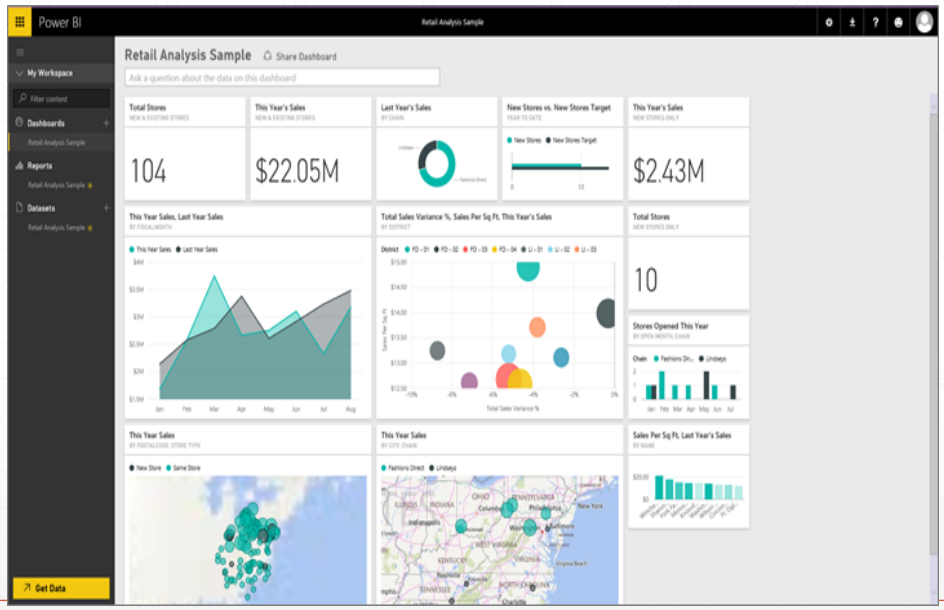

Diagnostic Analysis

Why did it happen?

Example -> Global Warming Causes

Predictive Analysis

What will happen :

Example -> Bus Batching

Industrial Internet Adoption Trend

World Economic Forum - 2016

Prevalent Visualization & Analytics Platforms

Visualization

- Tableau
- Splunk
- Kibana
- PowerBI
- Qlik
- D3.js

Analytics

- IBM Watson
- GE Predix
- Amazon ML
- Azure ML
- ThingWorx Analytics
- SAS
- Proprietary algorithms developed on R & Python

Stream Analytics

- Amazon Kinesis
- Apach Storm
- Apache Flink
- Azure Stream Analytics

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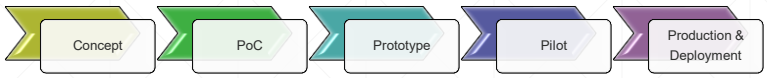
Module 12:

Putting it together

How to Build an IoT Prototype… and Product

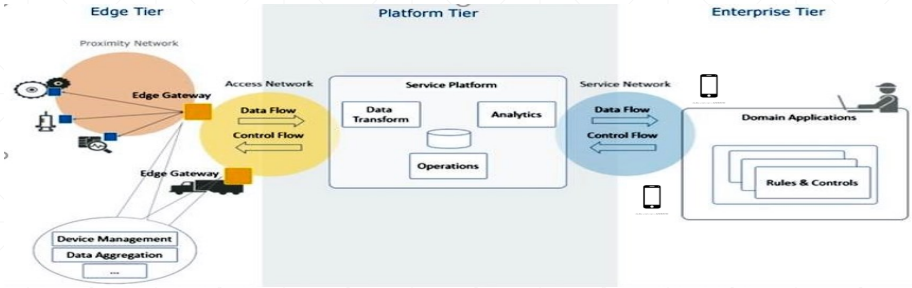
Stages in an IoT Product



10 Steps : Building an IoT Prototype… and Product

1. Conceptualize the Use-Case and articulate the Actionable Insights you want the system to provide
2. Identify the appropriate Sensors and Actuators… The interfaces to the Physical World
3. Design Solution Architecture
4. Decide the appropriate SoC. Some of the considerations for choice are
   - Processor Speed
   - Memory (RAM and Flash)
   - Power Consumption (Especially, during Idle time / Sleep)
   - Communication Protocols Supported (BLE / WiFi / 802.15.4)
   - Operating Systems, Middlewares, IDE & Debugger Support
   - Support for Device SDKs of Cloud PaaS Platforms
   - Ecosystem, Development Support & Community
   - **Cost (in small quantities and in large quantities)**
5. Choose a Prototyping Board (Hardware Development Kit/Board) that uses the chosen SoC
6. Choose Cloud PaaS, Visualization and Data Analytics Platforms
7. Quick PoC and Prototype. Iterate.
8. Pilot Deployment, Get User Feedback and Iterate.
9. Develop Form-Factor Hardware Device using the SoC
10. Deployment and Production.

Skill Development Opportunities in the IoT Space



- Semiconductors
- Electronics Hardware Design
- Embedded Systems
- Edge Processing
- Communication Protocols
- Battery & Power Optimization
- Sensors & Instrumentation
- Mechatronics

- Cloud Computing
- IoT PaaS Platforms (AWS IoT, Azure IoT)
- Database / Data Stores
- Big Data / Distributed Computing
- Backend Web Technologies
- AI / Machine Learning / Deep Learning
- Blockchain

- Mobile Application Development
- Web Technologies (Frontend)
- UI / UX
- Visualization and Dashboarding
- Domain Specialists
- Product Design

Product Management – Project Management – Business Analysis

Moving from Hobby Projects to Enterprise-grade IoT

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Web Resources for DIY IoT Projects

- Arduino IoT Project Repository
- Raspberry Pi Project Repository
- https://www.postscapes.com/diy-iot-projects/
- https://www.electronicsforu.com/iot-projects-ideas

- Books
- Arduino Cookbook - Michael Margolis - 3rd Edition
- Books by Simon Monk

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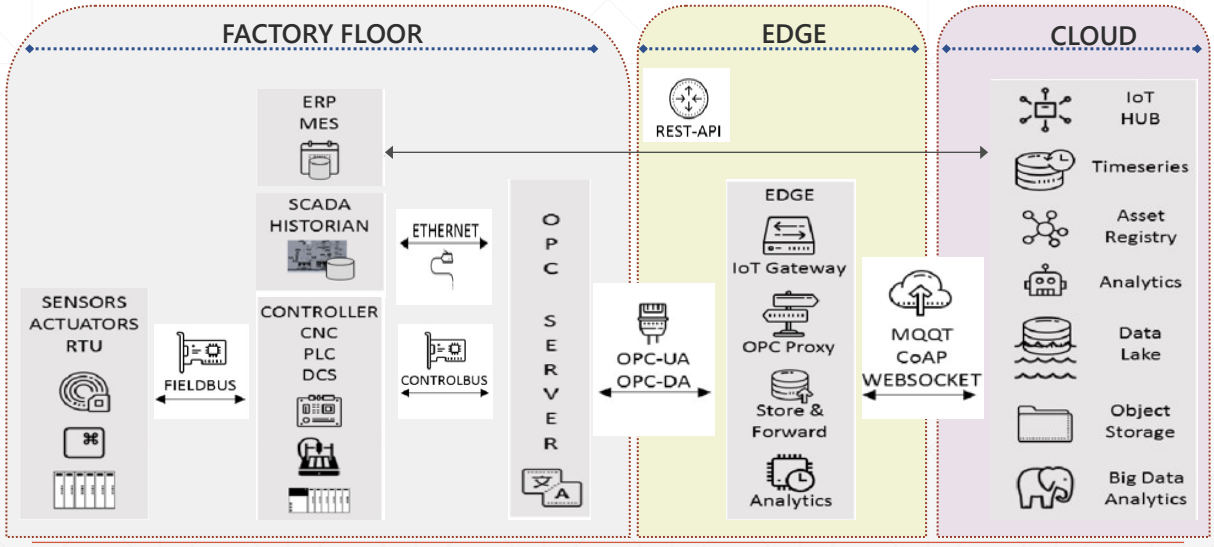
IoT and Incumbent Systems (PLC, DCS, SCADA etc)



Thank You!

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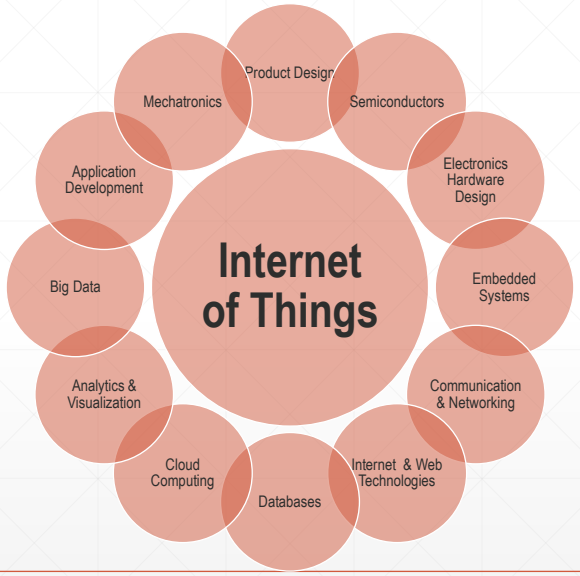
IoT – Related Areas and Skillsets



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IoT - Definition

"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 use intelligent interfaces,
and are seamlessly integrated into the information network,
often communicate data associated with users and their environments"

- ITU-T

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