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Master programmes in Artificial Intelligence 4 Careers in Europe

University of Cyprus

MAI650 Internet of Things

Vasos Vassiliou

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Connecting Europe Facility

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CS6xx Internet of Things (8 ECTS)

Course purpose and objectives: The purpose of the course is to provide an overview on IoT tools and applications and to introduce to students hands-on IoT communication concepts through lab exercises.

Learning outcomes: Upon completion of this course, students will be able to explain the definition and usage of the term “Internet of Things” in different contexts. More specifically, the students will know how to apply the knowledge and skills acquired during the course to build and test a complete, working IoT system involving prototyping, programming and data analysis

Teaching methodology: interactive face-to-face lectures, group activities and discussions, in class/lab activities, student presentations and guest lectures or significant recorded public lectures

Assessment: Final exam (50%), midterm exam (20%) and assignments/project (30%).

Main text:

Rajkumar Buyya, Amir Vahid Dastjerdi, Internet of Things Principles and Paradigms, Morgan Kaufmann; 1st edition, 2016

J. Biron and J. Follett, "Foundational Elements of an IoT Solution", O'Reilly Media, 2016.

Other reading:

Jamil Y. Khan and Mehmet R. Yuce, Internet of Things (IoT) Systems and Applications, 2019, ISBN 9789814800297

David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Robert Barton, and Jerome Henry, IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things, 2016, Cisco Press.

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INTRODUCTION

Introduction to IoT

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INTENDED LEARNING OUTCOMES

Upon completion of this introductory unit, students will be:

1. familiar with the IoT concept.
2. familiar with the basic principles of IoT applications
3. familiar with the main duties of different IoT roles
4. familiar with common IoT application development tools and method

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Introduction

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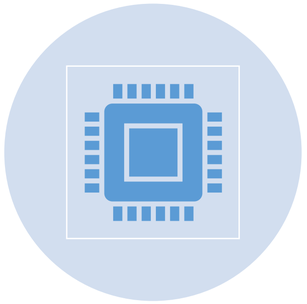
The Internet of Things – Definition



Internet of Things (IoT) was first mentioned in 1999 by Kevin Ashton

IoT : network of physical entities (things)

Term Things refers to *everyday physical entities* that are now becoming connected

Term Internet illustrates the interconnection between these networks

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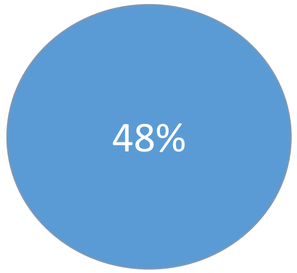
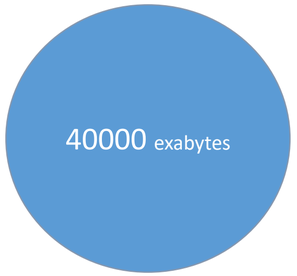
The Internet of Things

500 billion devices



Adoption of IoT



Data created

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IoT Impact

Significant on citizens, consumers, businesses, and governments

But how?

Health	Safety	Convenience	Education	Environment	Manufacturing	… and more

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IoT Challenges

Security, trust, privacy and data integrity

Centralized vs Decentralized IoT

Connectivity and scalability

Data process and analysis

Standards within IoT

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The “Things”

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The "Things" characteristics

Ability to collect data and interact with the environment

Often constrained devices with limited processing capabilities

Have the ability to transmit data

Consisted of hardware and software

Have a specific purpose: generally meant to do one single task

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Type of Sensors
Temperature
Pressure
Flow
Level Sensors
Humidity sensors
Tilt sensors
And more more other

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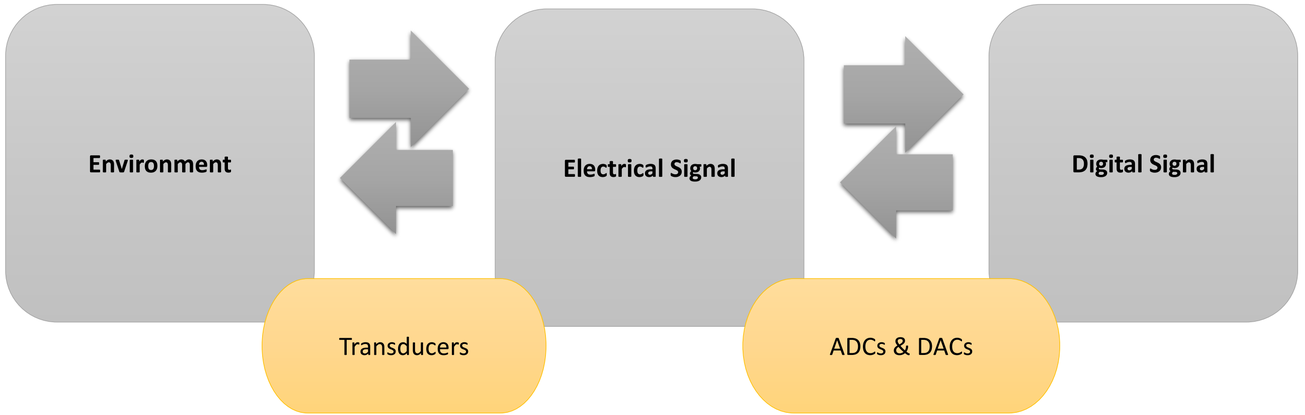
Generic sensor



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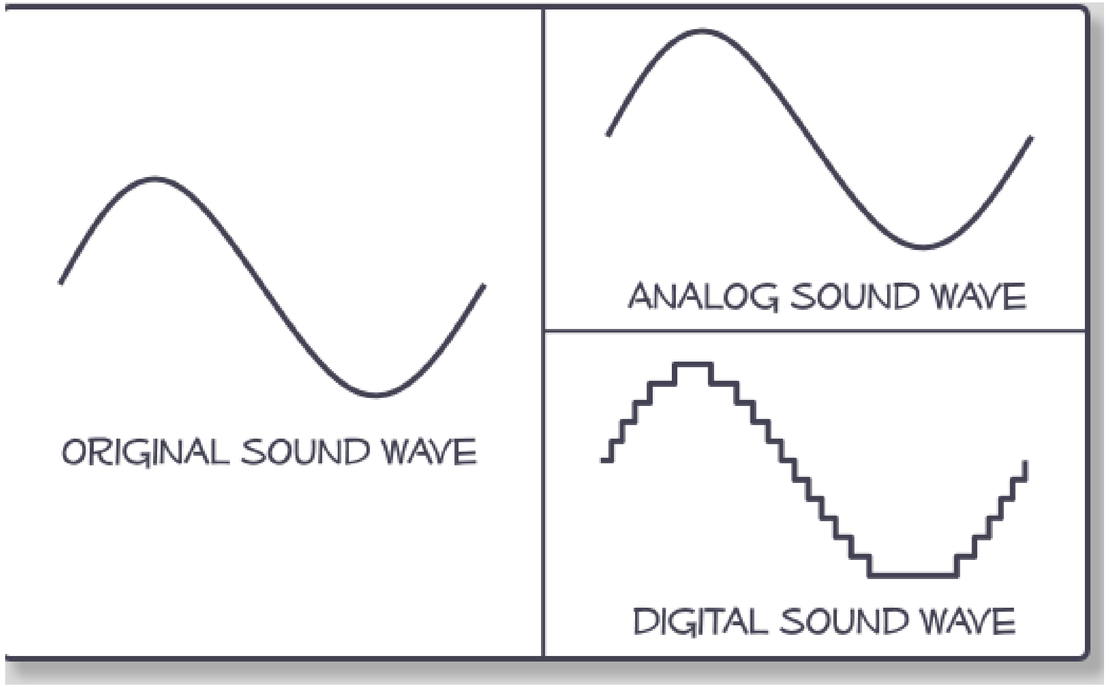
Analog and Digital Converters

ADC: Analog to Digital Conversion, converts an analog voltage to a digital value

DAC: Digital to Analog Converter (less common): converts a digital value to an analog voltage



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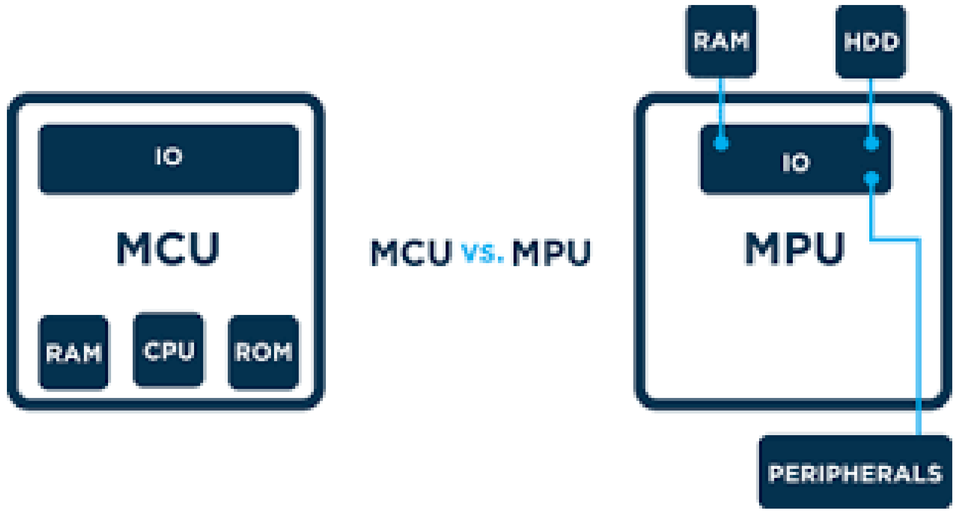
Hardware

There is a reason they call it hardware — it is hard," Tony Fadell, father of the iPod

IoT Hardware families:

Microcontroller based devices – MCU

Microprocessor based devices – MPU



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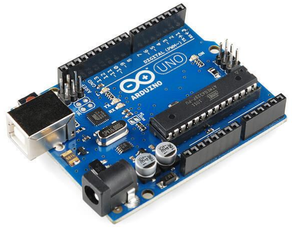
Microcontroller based devices – MCU

"A microcontroller (or MCU, short for microcontroller unit) is a small computer (SoC) on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals." (Wikipedia)



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Microprocessor based devices – MPU

- Microprocessor is an IC which has only the CPU inside them
- They use same kind of CPU architecture than your PC or your smartphone
- Run a full Operating System: usually Linux-like
- PC with no keyboard, mouse nor screen

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Examples of "Things" products

Smart Locks

Smart Coffee Makers

Tracking Devices

Smart Thermostats

Smart Watch

Home Security devices

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Communication Protocols and Technologies

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Communication Protocols

- Enable the communication between the IoT objects
- The distance the data can be communicated affects the communication technology to be used.
- IoT communication standards and technology can be grouped based on the size of the network

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IoT Communication Protocols and Technology

- Bluetooth
- WiFi
- ZigBee
- Z-Wave
- 6LoWPAN
- MQTT IoT
- LoRaWAN
- WirelessHART
- CoAP
- AMQP
- DDS
- NFC
- Cellular
- Sigfox
- Thread
- EnOcean

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Bluetooth

- Open standard for development of personal area network (PAN).
- Its features include low cost, low power and short range typically about
  10 meters.
- It can exchange information with other Bluetooth device over a radio.
- It is used for creating a small network of devices that are close to one another.
- It supports IEEE802.15.4 and works at 2.4GHz frequency range.

Standard: Bluetooth 4.2 core specification
Frequency: 2.4GHz (ISM)
Range: up to 50m
Data Rates: 1Mbps (Smart/BLE)

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WiFi HaLow

Standard: Based on 802.11ah
Frequencies: 900 MHz band
Range: up to 1000m
Data Rates: up to 347 Mbit/s

- WiFi HaLow consumes lower power than a traditional WiFi
- Support IP connectivity, which is important for IoT applications.
- The range of WiFi HaLow is nearly twice that of traditional WiFi.
- Because of the relatively lower frequency, the range is longer since higher frequency waves suffer from higher attenuation

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Zigbee

- It is based on the IEEE 802.15.4
- Created by the ZigBee Alliance;
- It is basically designed for low power consumption allowing batteries to essentially last for ever.
- ZigBee makes possible completely networked homes where all devices are able to communicate and be controlled by a single unit

Standard: ZigBee 3.0 based on IEEE802.15.4
Frequency: 2.4GHz
Range: 10-100m
Data Rates: 250kbps

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LoRAWAN

Standard: Z-Wave Alliance ZAD12837 / ITU-T G.9959
Frequency: 900MHz (ISM)
Range: 30m
Data Rates: 9.6/40/100kbit/s

- Primarily for home automation.
- It is a mesh network using low-energy radio waves to communicate.
- Works in sub GHz frequency band- 900 Mhz, 100kbps.
- Operates on mesh network architecture with one primary and multiple secondary controllers.

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6LoWPAN

- 6LoWPAN enable the efficient use of IPv6 over low-power wireless networks on simple embedded devices.
- Use of an adaptation layer between the 802.15.4 link layer and the transport layer

Standard: RFC6282 - IEEE802.15.4
Frequency: 2.4GHz
Range: N/A
Data Rates: N/A

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LoRAWAN

Standard: LoRa-Alliance
Frequency: 868MHz
Range: 10km
Data Rates: up to 50 kbps

- LoRa is a patented spread-spectrum radio modulation originally developed by Cycleo
- An industry collaboration focused on promoting LoRa, LoRa Alliance , was unveiled. The LoRa Alliance is a non-profit, open membership organization

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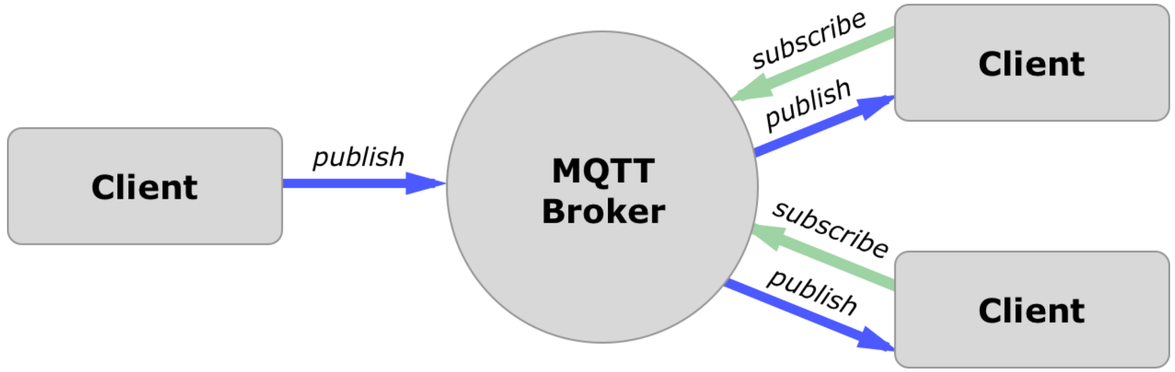
MQTT

- It stands for Message Queuing Telemetry Transport. MQTT is based on clients and a server.

- Lightweight messaging protocol that uses publish / subscribe operations to exchange data between clients and the server



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Architectural Design and IoT Applications

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IoT Applications Overview

Things –
Generate Data

Analytics & Insights –
Based on Data Generated

Notifications & Actions –
Based on Insights

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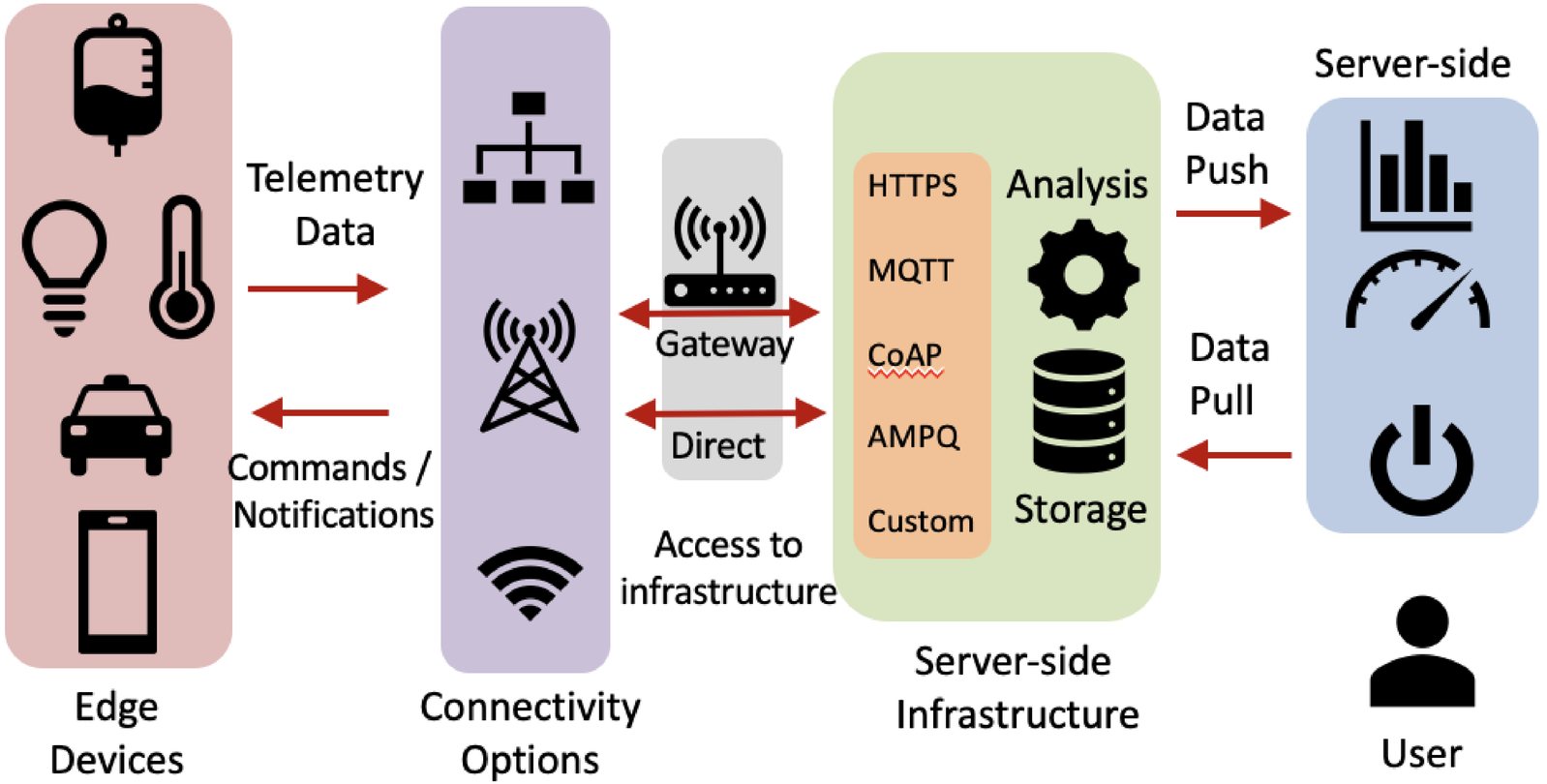
High Level IoT Architecture



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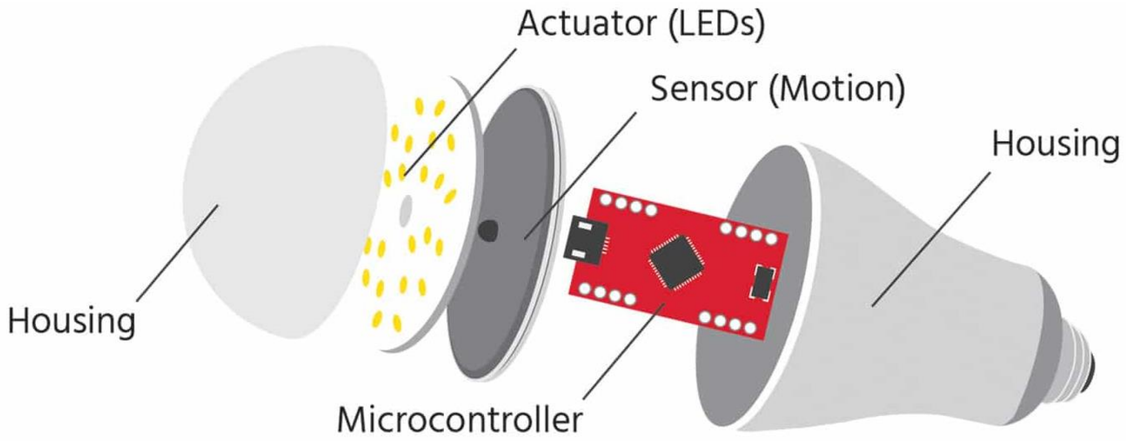
Key aspects of IoT Architecture

- IoT Edge Device
  - Sensing & actuation components
  - Monitors physical entities (things)
  - Change state of physical entities (e.g. switch on/off)



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Key aspects of IoT Architecture

- IoT Edge Gateway
  - Physical device or software program that sits between edge devices and server-side

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Key aspects of IoT Architecture

- Server-side Infrastructure
  - physical servers, virtual servers, cloud-based services
  - provisioned with a vast range of capabilities:
    - storage (hard disk, databases),
    - networking,
    - processing power,
    - data pre-processing,
    - natural language processing (NLP),
    - artificial intelligence (AI),
    - machine learning (ML)

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Key aspects of IoT Architecture

- Server-side Infrastructure
  - Collect / store / process / analyze sensor data
  - Perform intelligent decision-making
  - Send commands / notifications to edge devices

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Data headache

- Edge devices generate continuous stream of data
- Time interval between successive data updates is very small, usually minutes, seconds or even milliseconds
- Massive amount of generated data: Big Data!
- Quite often there is a need to process big data almost instantaneously
- Big Data cannot be stored and processed on typical IoT edge devices and IoT gateways

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Is server-side computing a solution?

- Server-side computing challenges:
  - High network latency and connectivity disruption due to bandwidth limits
  - Data become available to infrastructure providers

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Fog and Edge Computing for IoT

- Push server capabilities closer to where the data originates:
  - storage
  - processing
  - intelligence

- Benefits:
  - reduce the amount of data sent to the cloud
  - minimize network congestion and end-to-end latency
  - improve security and privacy
  - improve system response time

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Server-side Computing Options

- Physical Servers (Dedicated Servers)
- Virtual Servers (Virtual Machines)
- Containers

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Server-side Computing Options

- Cloud Computing
  - Provision of shared resources (hardware, data, applications) as a service over a public or a private network.
  - Customers are adopting cloud-based infrastructures because of the rich data-oriented services

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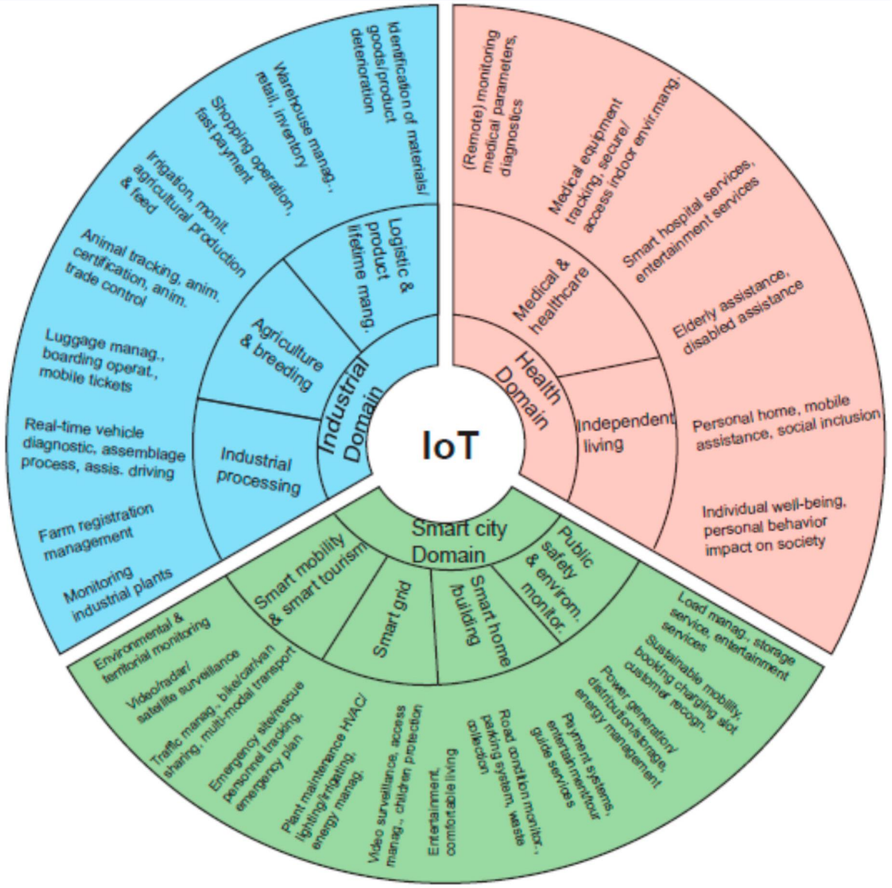
Major IoT Application Domains



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IoT System Design Requirements

- When designing a system, a number of functional and non-functional requirements need to be fulfilled.

- Functional requirements relate to the actual functionality that the system needs to have.
  - Provided by system implementation

- Non-functional requirements (*quality attributes*) relate to the quality of the system.
  - Introduced mainly by the software architecture

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Software Architectural Styles in IoT

- Client-Server (Request/Reply)
- Peer-to-Peer
- Pipes and Filters
- Event-Based
- Publish-Subscribe
- Service-Oriented
- REST (Request/Reply on top of HTTP)
- Layered
- Microkernel

The specific module on Architectural Design and Applications emphasizes on:

- ❖ General description of each style
- ❖ Design elements (components, connectors, constraints)
- ❖ Effect of each style on quality attributes

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Security and Privacy in IoT

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Security and Privacy

- IoT is connected to the largest untrusted network, the Internet, making it more vulnerable and appealing for malicious interventions.

- Some IoT application rely on accurate and on time information, for example:
  - Smart City
  - Smart Transportation
  - Monitoring critical infrastructures
  - Smart thermostat

- Loss of information can result to inaccurate environmental measurements and erroneous decision making.

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Security and Privacy

- Users' Privacy may be compromised
  - Smart City applications can draw attention to perpetrators as the IoT applications become massive databases for the city.
  - Citizens cannot control the security level of the IoT and their privacy may be compromised

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IoT Attacks

- Attacks aim in diminishing or eliminating a network's capacity to perform its expected function
  - Exploiting vulnerabilities in the system

- Security is a prominent area in the IoT and needs to be considered in all IoT architectural components.

- Three categories of attacks
  - Intrusion
  - Blocking
  - Malware

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Types of Attacks

Intrusion

- Unauthorized access to a system

Blocking

- Denial of Service Attack (DoS)
- Distributed DoS (DDoS) e.g. Mirai

Malware

- Penetration of malicious software in an IoT aimed at performing unwanted and unauthorised actions. Examples: Ransomware, Viruses, Trojan horse and spyware

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Mirai Botnet – September 2016

Scan the Internet for the IP address of Internet of things (IoT) devices

Holds a list of IP Address ranges that it will not infect, including private networks and addresses allocated to the United States Postal Service and Department of Defense

Uses a table of more than 60 common factory default usernames and passwords, and logs into them to infect them

Overall, IP addresses of Mirai-infected devices were spotted in 164 countries.

500 000 known Mirai botnets

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Mirai Botnet – September 2016

Username	Password
root	xc3511
admin	vizxv
support	admin
user	888888
Administrator	xmhdipc
service	default
supervisor	juantech
guest	123456
admin1	54321
administrator	support
666666	(none)
888888	password
ubnt	root
tech	12345
Mother	user

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Goals of Security

Providing Secure Connectivity

Secure Remote Access

Ensuring Privacy

Providing Nonrepudiation

Confidentiality, Integrity, and Availability

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Business Value

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IoT technology has made the concept of smart homes possible, and now the time for smart workplaces has arrived.

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Business IoT

- Business is introduced in the Internet of Things.

- IoT stands for “**common items connected to the internet**”,
  - IoT Business will be companies that connect to the internet.

- Business can adopt the idea of IoT in two different ways:
  1. Inside: the employees and the building.
  2. Outside: the products/services.

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BUSINESS VALUE

"the core principles or standards that guides the way of the business"

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Business value

“What does the business stand for?”

An informal term that includes all forms of value that determine the health and well-being of the business.

While business plans and strategies change, the core value of the business remains the same.

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From traditional Business to IoT Business

The business world changes with the introduction of IoT, in the following ways:

- Inventory Tracking and Management
- Data sharing and Perception
- Productivity and Efficiency
- Remote Work
- Skilled Workers
- Create new Consumer demands
- Improved Customer Engagement
- Shorter Buying Cycles

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Business Risks in adopting IoT

Is it safe for the business to fully adopt the IoT?

The risks to the business and infrastructure when adopting IoT are:

Modular architecture of hardware and software	DDoS attack	Complexity of Vulnerabilities	Scalability of Infrastructure

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Examples of industries using IoT to great benefit

Healthcare IoT	It provides better patient experiences through connected healthcare data systems and better management of administered medicine through IoT monitoring solutions.
Manufacturing and Industrial IoT	It is deployed through connected sensors and predictive maintenance systems, leading to decreased downtime and higher product quality and output.
Marketing IoT	It delivers real-time behavioral marketing and predictive social media analytics.

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Summary

- ❑ Present what the Internet of Things is, why is important and what are the major challenges of IoT
- ❑ Talk about the IoT devices, the “Things” which are the connected physical entities
- ❑ Present the major communication protocols and technologies used in Internet of things
- ❑ Talk about the Internet of Things Architecture and Applications
- ❑ Present the major Security and Privacy issues in IoT
- ❑ Discuss the business value of IoT

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