ELEC0032 – Networking Systems
(previously referred to as ELEC310P)

Course Introduction

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University College London

Autumn 2019

Housekeeping

- Room.
- Timeslot.
- Format.

Today’s Agenda

- Introduction to the module.
- Overview of the OSI model abstraction layers.
- Comparison of the OSI model to the conceptual IoT stack.
- Review of design considerations and trade-offs at each layer.

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Course Content

- **Physical** layer considerations including wireless technologies, topologies and networks.
- **MAC** layer issues including protocols and architectures targeted to IoT applications.
- **Network and transport** basics including TCP/IP, DNS and security.
- **Data analytics** which comes under the umbrella of applications and services.

Course Learning Outcomes

- **Show** technical understanding of key design considerations and trade-offs in an end-to-end networking system.
- **Specify** technologies required to meet a design requirement.
- **Evaluate** standards, proprietary systems and published research to determine available solutions at different layers.
- **Demonstrate** the ability to analyse and assess the performance of a system with the aid of industry-standard tools.

Today's Learning Outcomes

- Name the topics that will be covered in this module.
- Recognise the **connection** between the different topics.
- Compare and contrast the **OSI model** to the conceptual IoT stack.
- Identify the **design considerations** at each layer.
- List the **trade-offs** associated with each layer.
- Breakdown a networking system into distinct parts.

Where does ELEC0032 fit in?

ELEC0017 (previously ELEC210P):

- Connected CC3200 to the Internet over WiFi.
- Sent and received data using MQTT.
- Stored data and ran services using IBM Cloud (previously known as Bluemix).

This Module – ELEC0032:

- Dive deeper and explore the 7-layer OSI model and the IoT stack.

ELEC0033 (previously ELEC311P):

- Combine knowledge and skills from ELEC0017 and ELEC0032.
- Build a complete, end-to-end IoT system.

Course Topics

4-APP: Applications Layer

- **Topic**: Data Analytics
- **Lecturer**: Dr Ryan Grammenos (RG)

3-NET: Network and Transport Layer

- **Topic**: IP and Transport Protocols
- **Lecturer**: Dr Ioannis Psaras (IP) – On behalf of Prof. Miguel Rio

2-MAC: Media Access Control Layer

- **Topic**: MAC Designs and Protocols
- **Lecturer**: Dr Laura Toni (LT)

1-PHY: Physical Layer

- **Topic:** Wireless Technologies, Topologies and Networks
- **Lecturer**: Professor John Mitchell (JM)

Lecturing Staff – Who's Who?

Ryan Grammenos

John Mitchell

Laura Toni

Ioannis Psaras

Course Schedule (also on Moodle)

Academic Week	Date	Session	Topic	Lecturer
6	04/10/2019	1	Introduction	RG
7	11/10/2019	2	APP-DATA	RG
8	18/10/2018	3	APP-DATA	RG
9	25/10/2019	4	TCP/IP	IP
10	01/11/2019	5	TCP/IP	IP
11	08/11/2019	READING WEEK	READING WEEK	READING WEEK
12	15/11/2019	6	MAC	LT
13	22/11/2019	7	MAC	LT
14	29/11/2019	8	PHY	JM
15	06/12/2019	9	PHY	JM
16	13/12/2019	10	Summary - Tutorial	RG/LT

Assessment

- Unseen written exam – 90%.
  - Term 3.
- Coursework – 10%.
  - One introductory quiz worth 1%.
    - **Deadline: Next Friday, 11th October, 2pm.**
  - One technical assignment on data analysis and simulation using MATLAB.
    - Worth 9%.
    - MATLAB resources are available on Moodle.
    - Issued on Friday 18th October.
    - **Deadline: Friday 15th November, 2pm.**

Tour of Moodle

Q&A

QUESTIONS? / DISCUSSION!

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What do we mean by Abstraction?

The 7-layer OSI Model

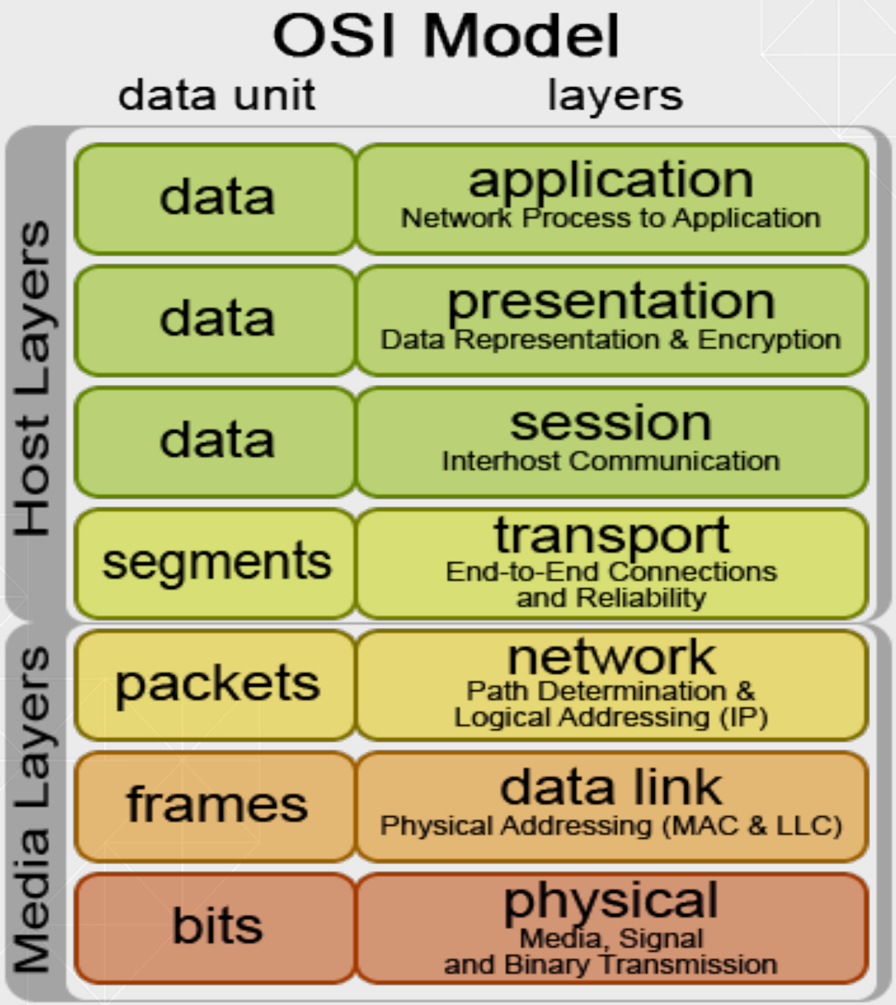
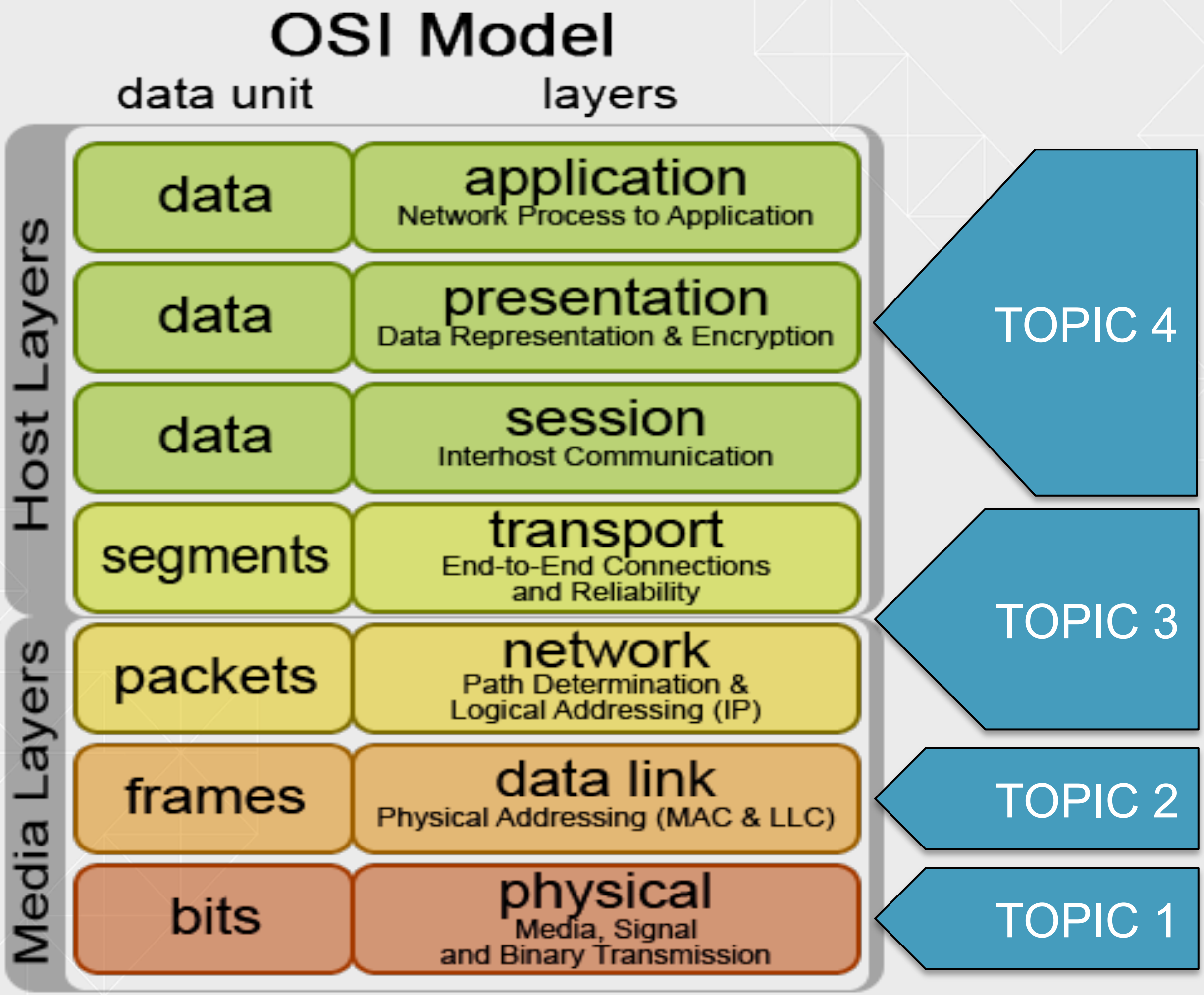


Image source: https://en.wikipedia.org/wiki/File:Osi-model.png

ELEC0032 and the OSI Model



Q&A

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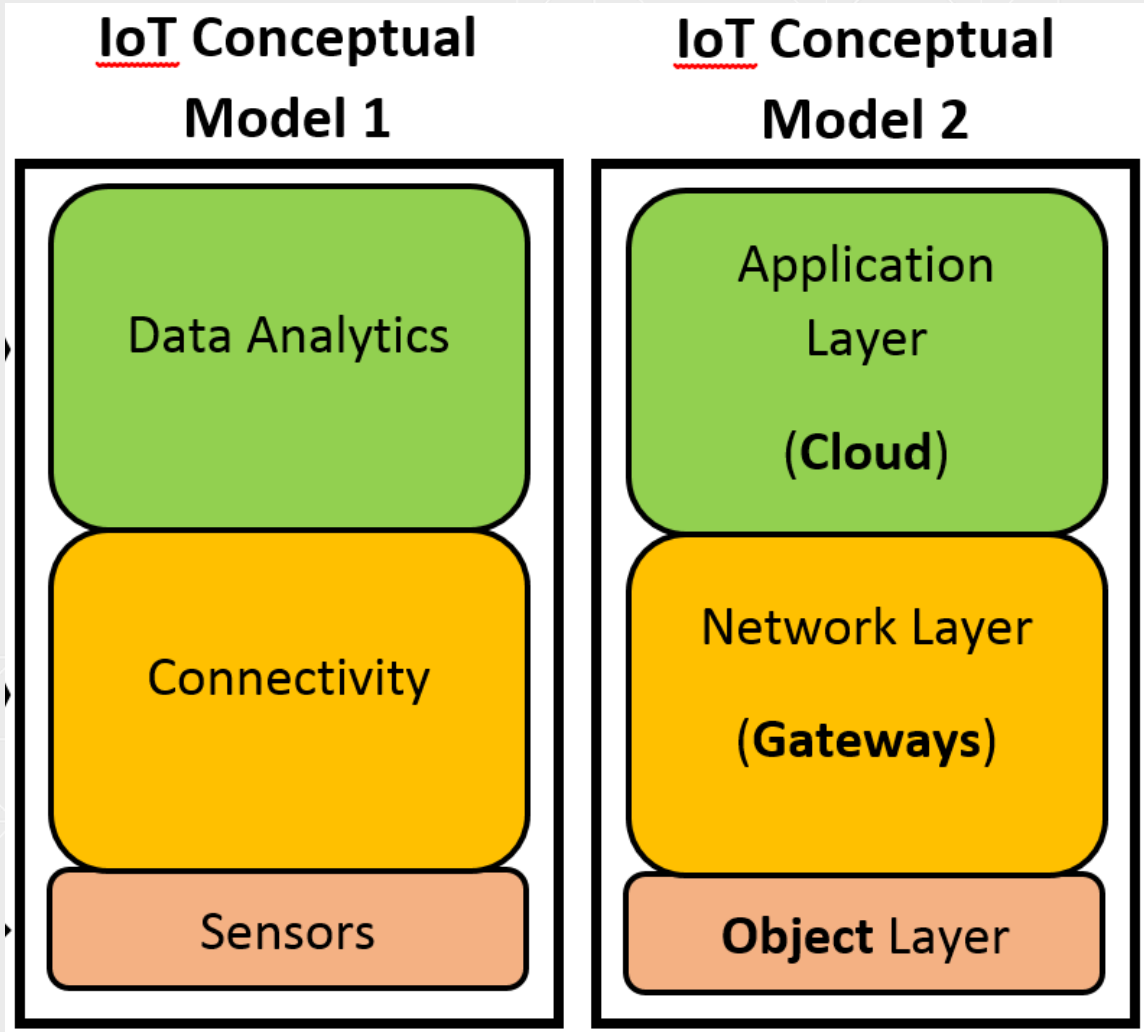
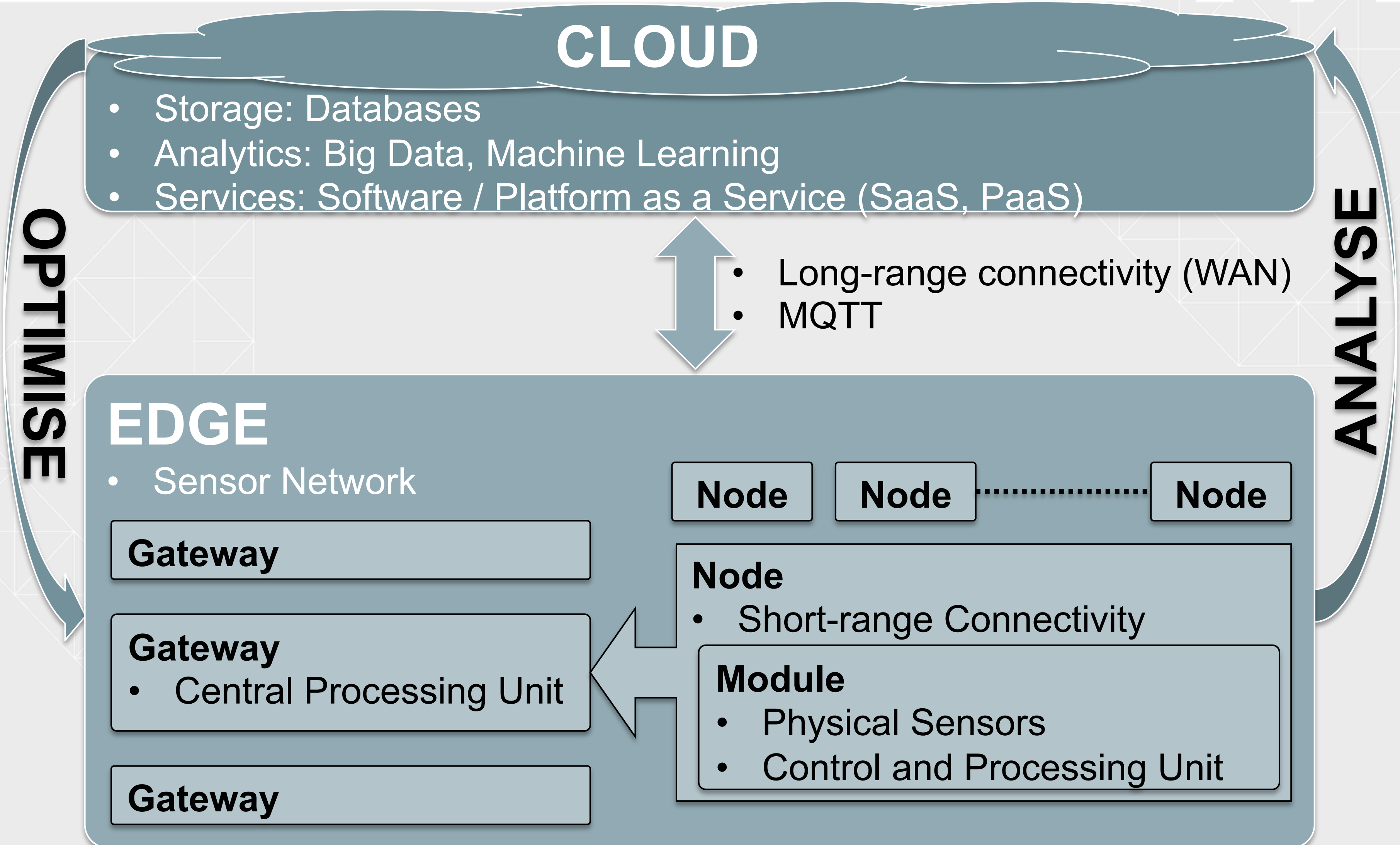
What do we mean by Conceptual?

Conceptual IoT Models



The IoT Stack - Framework



The IoT Stack - With Examples

OPTIMISE

ANALYSE

CLOUD

- Storage: Databases
- Analytics: Big Data, Machine Learning
- Services: Software / Platform as a Service (SaaS, PaaS)

2

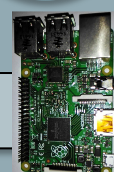
Node

- Long-range connectivity (WAN)
- MQTT

EDGE

- Sensor Network

1B



Gateway

Gateway
- Central Processing Unit

Gateway

Node

Node

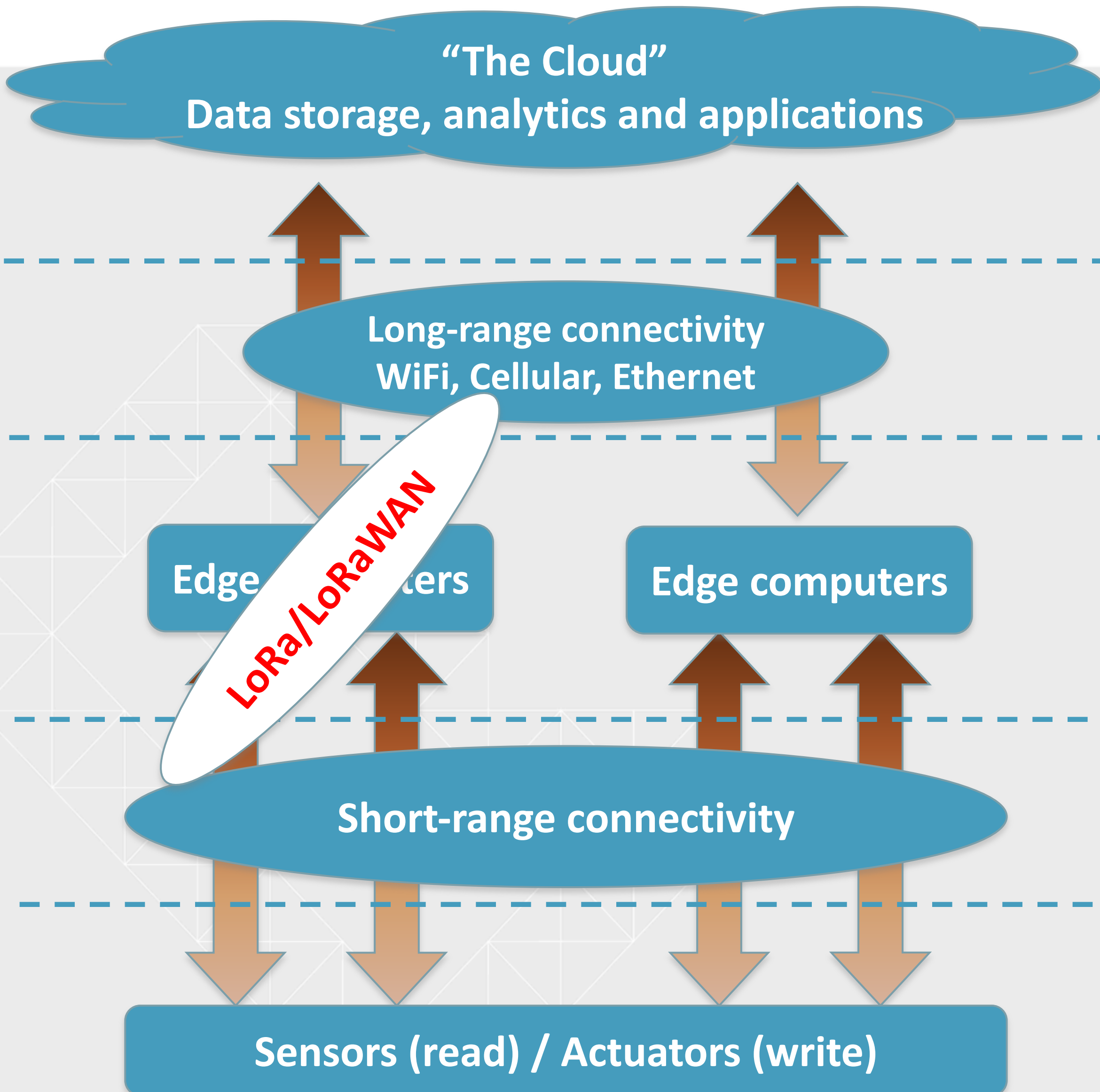
Node

1A

Node
- Short-range Connectivity

Module
- Physical Sensors
- Control and Processing Unit

The IoT Stack – Building Blocks



IBM Bluemix, AWS, Thingspeak, Thingworx, ThingBox, EasyIOT, Microsoft IOT, Intel IOT

WiFi, Cellular, Ethernet

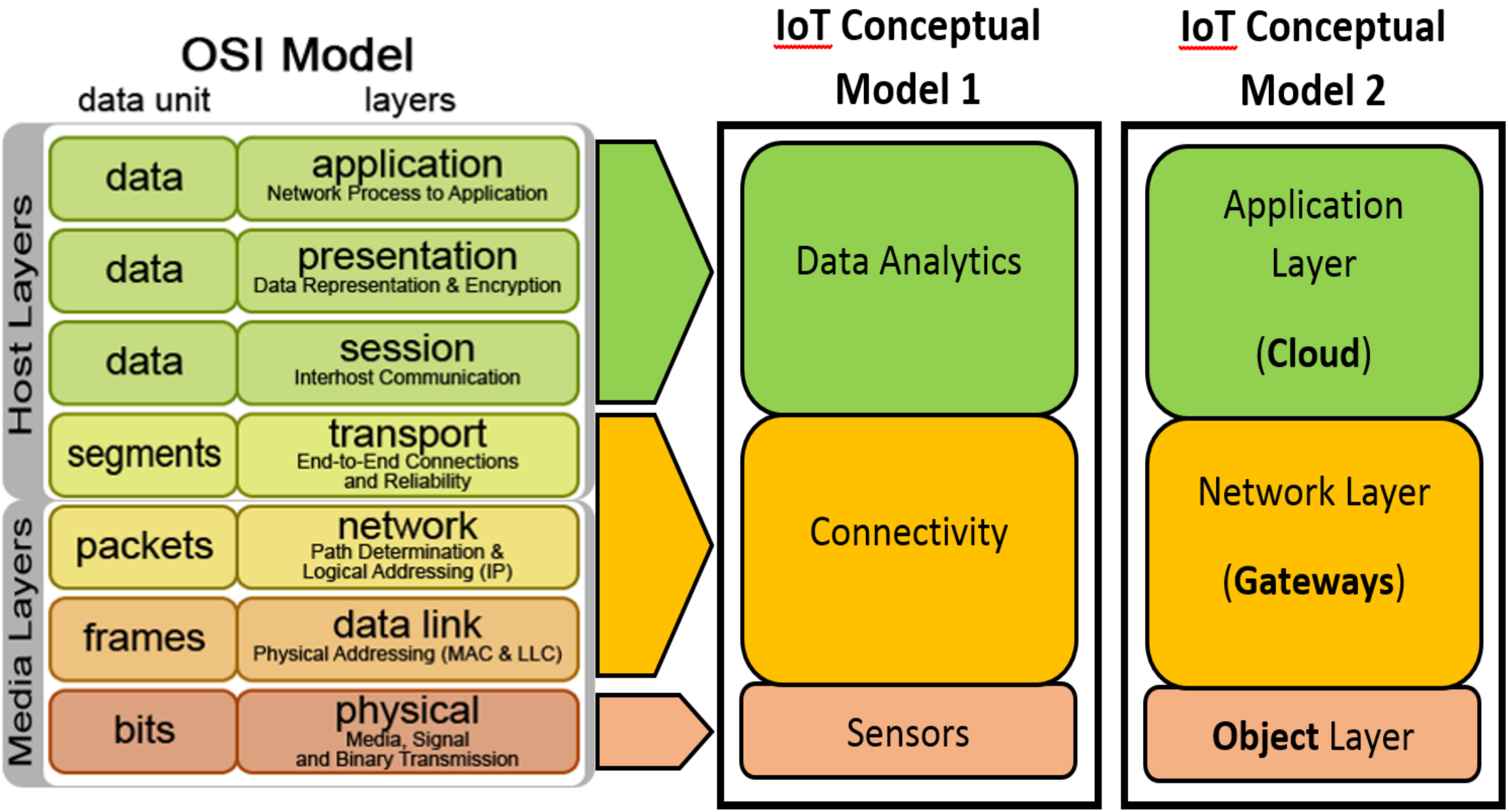
St-Nucleo, TI Launchpad, Raspberry Pi, ARM mBed, Nordic Semiconductor nRF, smartphone

Bluetooth (Low Energy), Zigbee, RFID

Sensors : *Temperature, light, acceleration, GPS, pressure, humidity, radiation, gas, touch*

Actuators : Switching, lighting, displays, stepper motors, servos

Conceptual IoT Models



So what is ELEC0032 actually about?

What does the OSI Model actually mean?

First some history…

- In the 1970's, two separate organisations (both based in Switzerland) were at work to define a common networking model.
- One organisation was the International Organization for Standardization (ISO). The other was the Comité Consultatif International Téléphonique et Télégraphique (CCITT).
  - The CCITT is now known as the International Telecommunications Union - Telecommunications standarization sector (ITU-T).
- In 1983, they decided to join forces and form a single standard called **The Basic Reference Model for Open Systems Interconnection**, which has since then been referred to more commonly as the Open Systems Interconnection (OSI) Model.
- The final document was published in 1984.

What does the OSI Model actually mean?

Open Systems Interconnection (OSI) Reference Model

The Open Systems Interconnection (OSI) reference model describes how information from a software application in one computer moves through a network medium to a software application in another computer. The OSI reference model is a conceptual model composed of seven layers, each specifying particular network functions.

The model was developed by the International Organization for Standardization (ISO) in 1984*, and i*t is now considered the primary architectural model for intercomputer communications. The OSI model divides the tasks involved with moving information between networked computers into seven smaller, more manageable *task* groups. A task or group of tasks is *then* assigned to each of the seven OSI layers. Each layer is reasonably self-contained, so that the tasks assigned to each layer can be implemented independently. This enables the solutions offered by one layer *to be updated* without adversely affecting the other layers. The *following list details the seven layers of the* Open System Interconnection (OSI) reference model:

Image source: https://www.cisco.com/cpress/cc/td/cpress/fund/ith/ith01gb.htm

So this module…

…is (wireless) communications tuned to IoT

Q&A

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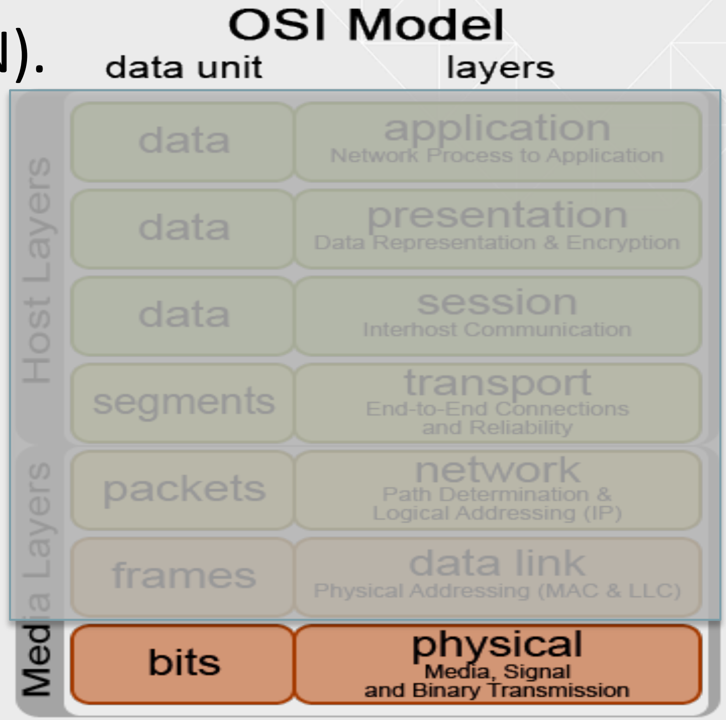
What do we need to consider at the Physical (PHY) layer?

PHY Topics

- Review of topic and new developments.
- Issues of wireless networks (range vs power), connectivity (star vs mesh).
- Wireless technologies (PAN, LAN, WAN).



PHY Design Considerations

- Range.
  - Relates to Transmit Power (max limited by regulation?) and frequency.
- Data rates.
  - Bandwidth and modulation scheme – determined by the standard.
- Life time requirements.
  - Transmit Power (Range), technology, battery options.
- Good for small packets or synchronous data.
  - Protocols and implementation.
- Interfaces.
  - Manufacturer.

PHY Trade-offs

Signal:

- Bit Error Rate (BER).
  - In noisy channels.
  - In lossy and noisy channels.
- Power.
- Bandwidth.

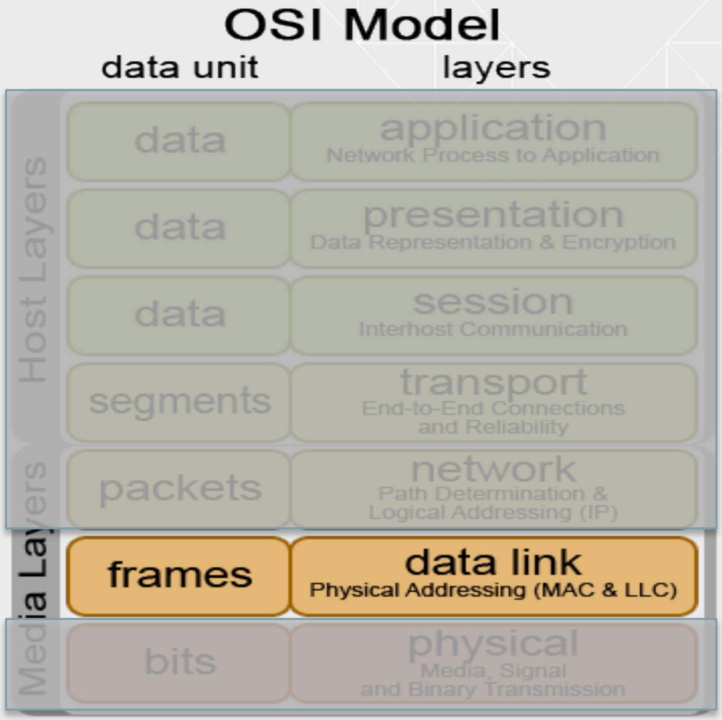
System:

- Capacity.
- Coverage.
- Interference.

What do we need to consider at the Media Access Control (MAC) layer?

MAC Topics

- Motivation - Why MAC?
- Partitioning the channel.
- Sharing the channel.
- MAC in IoT systems.
  - Main tradeoff in IoTs.
  - Current IoT protocols.
  - Some examples.



MAC Design Considerations

- MAC protocols regulate the channel access.
- A well-designed MAC Protocol should be:
  - Energy efficient (long lifetime of the network).
  - Reliable (low packet loss rate).
  - scalable (with the number of nodes) and adaptive to changes (nodes may die).
- Low latency.
- High throughput (good utilization of the channel resources).
- Fair (channel resources equally utilized among users).

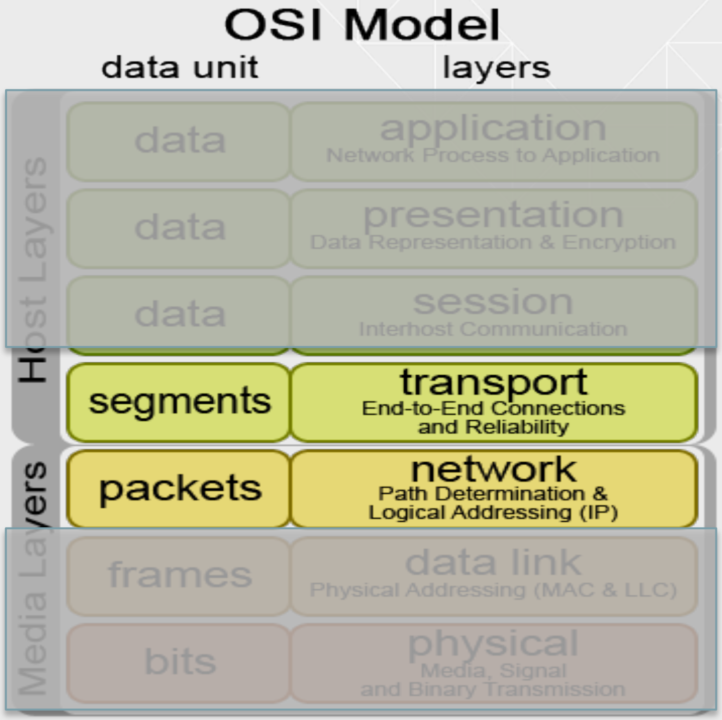
MAC Trade-offs

- Complexity vs. Efficiency.
  - Topology?
- Reliability vs. Power efficiency.
  - Throughput?
- Power efficiency vs. Delay.
  - Overhead?

What do we need to consider at the Network and Transport layer?

NET Topics (Network and Transport)

- Scaling transport.
- Issues of small packets.



Network and Transport Design Considerations

- Transmission medium.
  - Channel quality.
- Resource availability and reliability.
- Back-off mechanism.
- Scalability.
- Security and privacy.

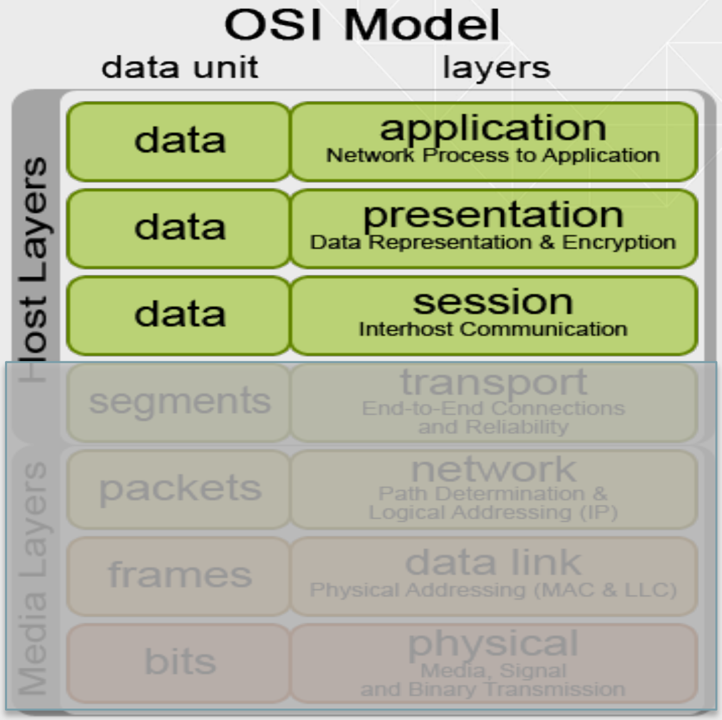
Network and Transport Trade-offs

- Quality of Service (QoS).
- Throughput.
- Overhead.

What do we need to consider at the Data Analytics (Application) layer?

APP Topics (Data Analytics)

- Types of analytics.
- Data retrieval and storage.
- Time-series analysis.
- Statistical learning.



APP (Data Analytics) Design Considerations

- What do you do with the sensor data?
- How do you design a data analytics strategy?
- Do you process data at the edge or in the cloud?
- Do you need to pre-process the data?
- Are we designing for prediction or inference?

APP (Data Analytics) Trade-offs

- Resources at the edge versus resources in the cloud.
- But more importantly, need to consider algorithm trade-offs:
  - Flexibility versus complexity and accuracy.
  - Prediction accuracy versus model interpretability.
  - Bias versus variance (bias-variance trade-off).

Q&A

QUESTIONS? / DISCUSSION!

References

[1] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications," in *IEEE Communications Surveys & Tutorials*, vol. 17, no. 4, pp. 2347-2376, Fourth quarter 2015.

[2] Keysight technologies – Internet of Things: https://www.keysight.com/main/editorial.jspx?cc=DJ&lc=eng&ckey=2670326&nid=-11143&id=2670326

[3] Cisco Press – Interworking Basics: https://www.cisco.com/cpress/cc/td/cpress/fund/ith/ith01gb.htm

[4] HiveMQ - MQTT Essentials: https://www.hivemq.com/blog/mqtt-essentials-part-3-client-broker-connection-establishment

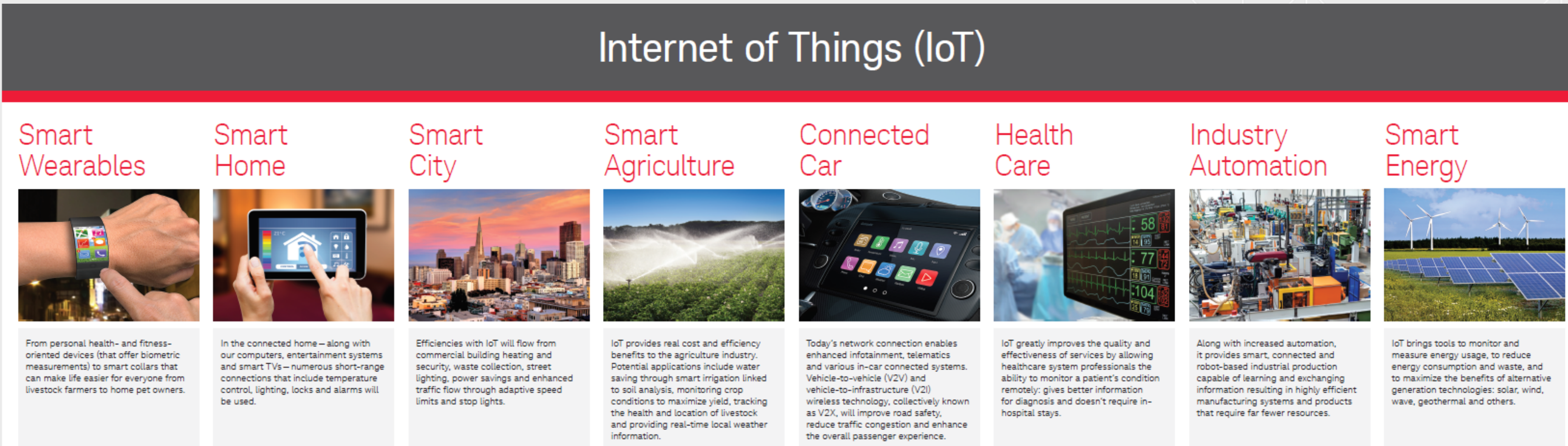
APPENDIX

EXTRA SLIDES

System Considerations

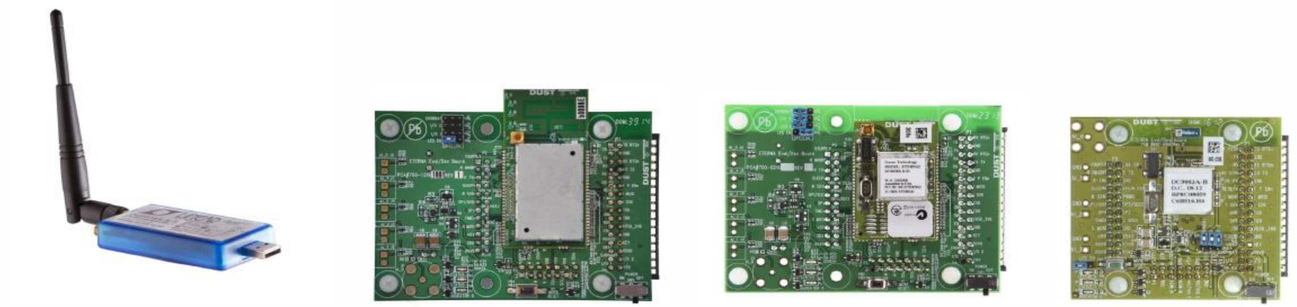
User Expectations
System Specifications

Internet of Things – Applications



https://www.keysight.com/main/editorial.jspx?cc=DJ&lc=eng&ckey=2670326&nid=-11143&id=2670326

We have the networking technology!



(a) DC2274: Low-power wireless manager *(1 deployed)*
(b) Long-range prototype board *(3 deployed)*
(c) DC9018: External antenna mote *(2 deployed)*
(d) DC9003: chip antenna mote *(16 deployed)*

dust networks™

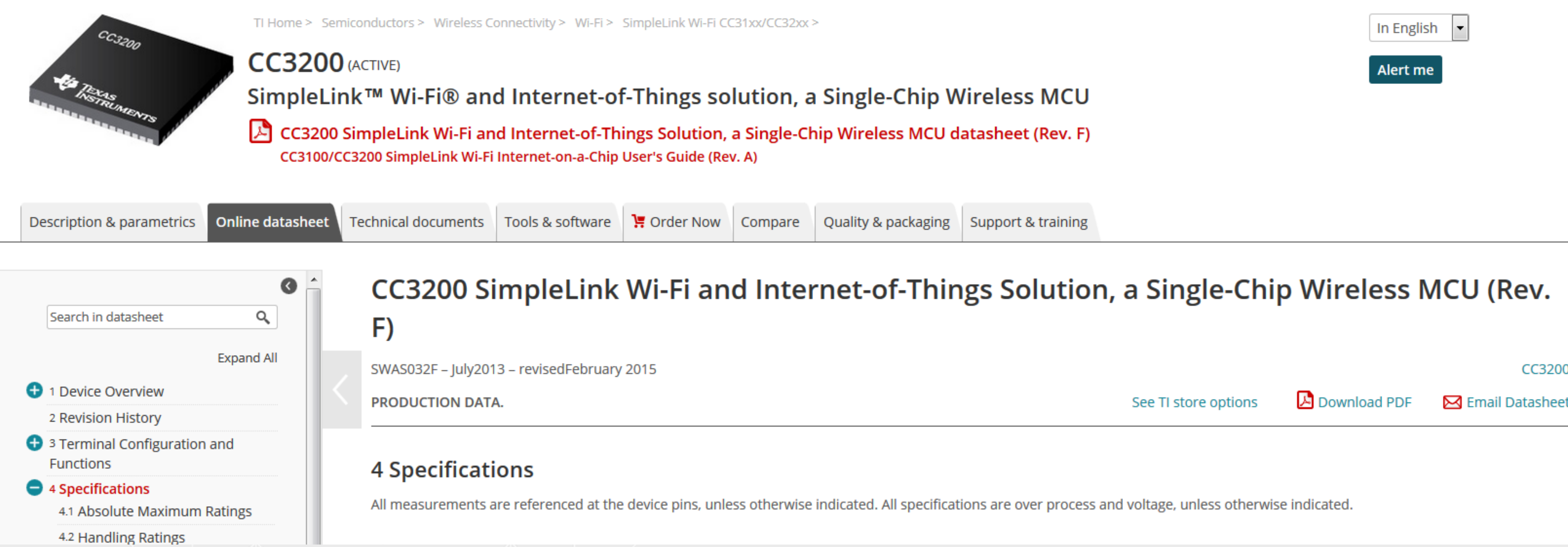
METRONOME SYSTEMS

- >50,000 SmartMesh networks deployed
- >99.999% end-to-end reliability
- >10 years of battery lifetime
- Developed as part of the REALMS associate team

Inria

Courtesy of Thomas Watteyne

System Considerations


TI Home > Semiconductors > Wireless Connectivity > Wi-Fi > SimpleLink Wi-Fi CC31xx/CC32xx >

In English

Alert me

CC3200 (ACTIVE)

SimpleLink™ Wi-Fi® and Internet-of-Things solution, a Single-Chip Wireless MCU

CC3200 SimpleLink Wi-Fi and Internet-of-Things Solution, a Single-Chip Wireless MCU datasheet (Rev. F)

CC3100/CC3200 SimpleLink Wi-Fi Internet-on-a-Chip User's Guide (Rev. A)

Description & parametrics | Online datasheet | Technical documents | Tools & software | Order Now | Compare | Quality & packaging | Support & training

Search in datasheet

Expand All

1 Device Overview

2 Revision History

3 Terminal Configuration and Functions

4 Specifications

4.1 Absolute Maximum Ratings

4.2 Handling Ratings

CC3200 SimpleLink Wi-Fi and Internet-of-Things Solution, a Single-Chip Wireless MCU (Rev. F)

SWAS032F – July2013 – revisedFebruary 2015

CC3200

PRODUCTION DATA.

See TI store options

Download PDF

Email Datasheet

4 Specifications

All measurements are referenced at the device pins, unless otherwise indicated. All specifications are over process and voltage, unless otherwise indicated.

http://www.ti.com/product/CC3200/datasheet/specifications#SWAS03182390

Engineering Trade-offs

Balancing the IoT

- Local versus cloud processing.
  - Bandwidth.
- Delay versus accuracy.
  - Overhead for sophisticated algorithms.
- Power versus speed.
  - Power consumption.
  - Cost.
- Performance versus security.
  - Encryption and authentication add to the complexity.
  - Increased features lead to a greater overhead and thus complexity.
  - High performance and functionality are usually inverse proportional to security (and privacy).

Key Facts and Considerations

The IoT is becoming a reality **thanks to**:

- **Cheap** silicon (sensors, microcontrollers, wireless modules).
- **Fast** (wireless) connectivity (cellular, WiFi, Gigabit Ethernet, optical fibre).
- **Ubiquitous** connectivity (anytime, anywhere).
- **Miniaturisation** (think of the TI SensorTag).
- **Easy** to get started and use development kits for the IoT.

However, we need to **think carefully** about:

- **Scalability** for the IoT.
- **Retrofitting** for the IoT.
- **Integrating** technologies according to appropriate design patterns.
- **Model**: Business to business (B2B) or business to consumer (B2C).
- **Disruptive** (known and unknown) innovations.