EBU4375: SIGNALS AND SYSTEMS

TOPIC 4-1: WHICH IS BETTER ANALOG OR DIGITAL?

Queen Mary
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ACKNOWLEDGMENT

These slides are partially from lectures prepared by

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AGENDA

1. Recap – what have we learned so far?
2. Analog or Digital?
3. Role of IoT bridging both worlds
4. What are signals and systems in IoT

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1: OVERVIEW OF EBU4375 SCOPE

The main topics covered by this course are organised as follows:

- Topic 1: CT and DT signals and systems in the time domain.
- Topic 2: CT signals and systems in the frequency domain.
- Topic 3: DT signals and systems in the frequency domain.
- **Topic 4: Sampling theory and communication systems.**

1: WHAT HAVE WE LEARNT SO FAR?

1. CT and DT **signals in the time domain**: basic signals, representation, properties, classification, manipulations in the time domain (shift, reflection, amplification) . . .
2. CT and DT **systems in the time domain**: properties, LTI systems, impulse response, convolution . . .
3. CT and DT **signals in the frequency domain**: Fourier series and Fourier transform.
4. CT and DT **systems in the frequency domain**: Frequency response, filtering, types of ideal filters.

Will Continuous time signals and systems ever meet the world of discrete time?

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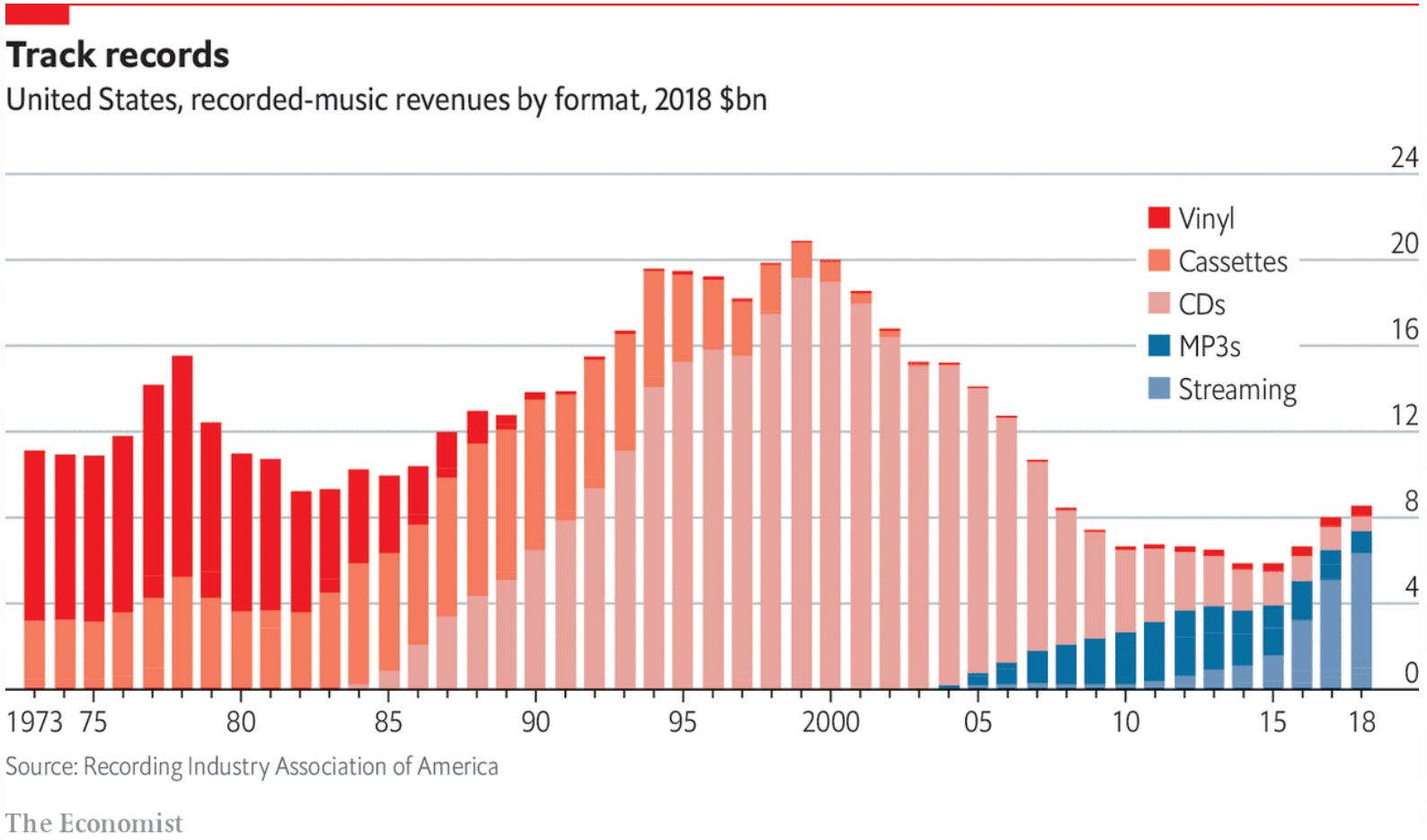
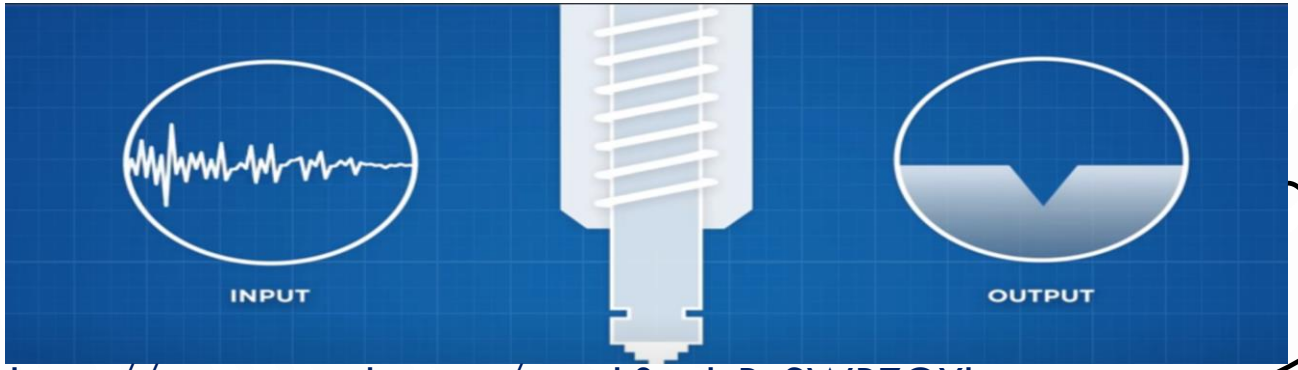
2: ANALOG OR DIGITAL?

- Please put the recording on hold and login to QM+
- Go to Topic 4
- Take 10 minutes to answer the questions in T4-Q1
- You can retry as many times as you wish – these questions are not graded.
- Feel free to discuss with your friends before you chose a winner!

2: WHY ARE VINYL MAKING A COMEBACK?

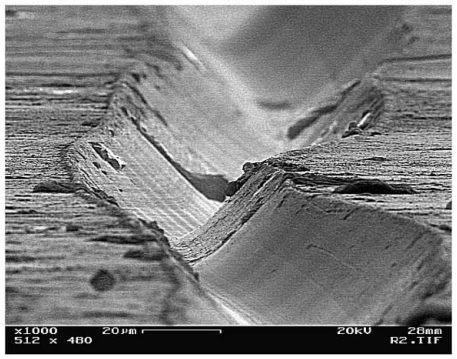


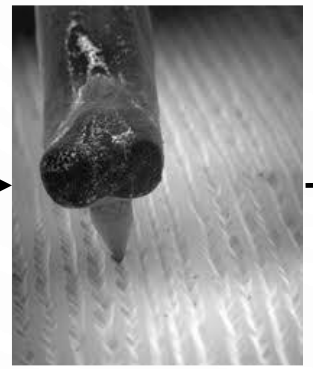
2: VINYL: FROM GROOVES TO SOUNDS



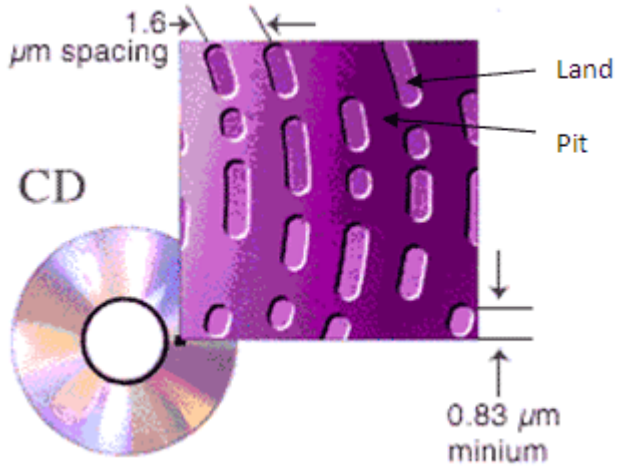
https://www.youtube.com/watch?v=IzRvSWPZQYk

- The highest Vinyl capacity (LP) is 44 minutes (12inch – 33RPM).
- Increasing the RPM increases the quality but reduces the capacity.
- First Vinyl recording in 1948.

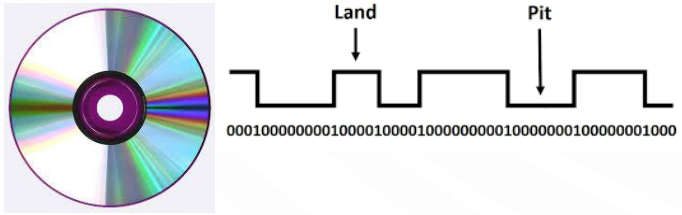




2: FROM BITS TO SOUND



- The typical music CD capacity is 74 minutes.
- First commercial CD in 1982.
- CD are rapidly replaced with MP3 and both by streaming music.
- CD: 1,411 kbps > MP3: 320kbps ≥ streaming



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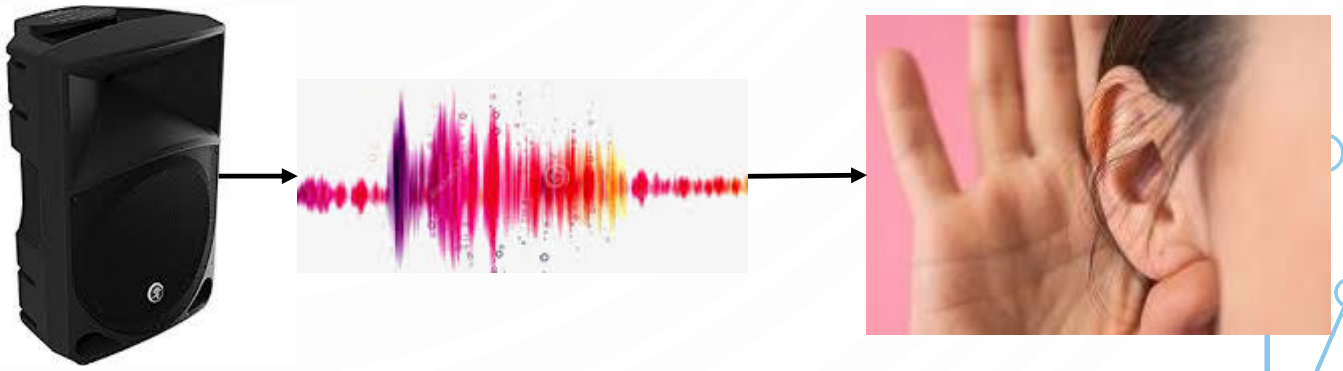

https://www.theguardian.com/technology/2014/aug/21/mp3-cd-24-bit-audio-music-hi-res

2: ANALOG TO DIGITAL

- If MP3 is worse than CDs, why is it becoming more popular?
- What is the relation between quality, duration of track, and file size?
- What is the relation between Analog and Continuous time signals?
- What is the relation between Digital and Discrete time signals?

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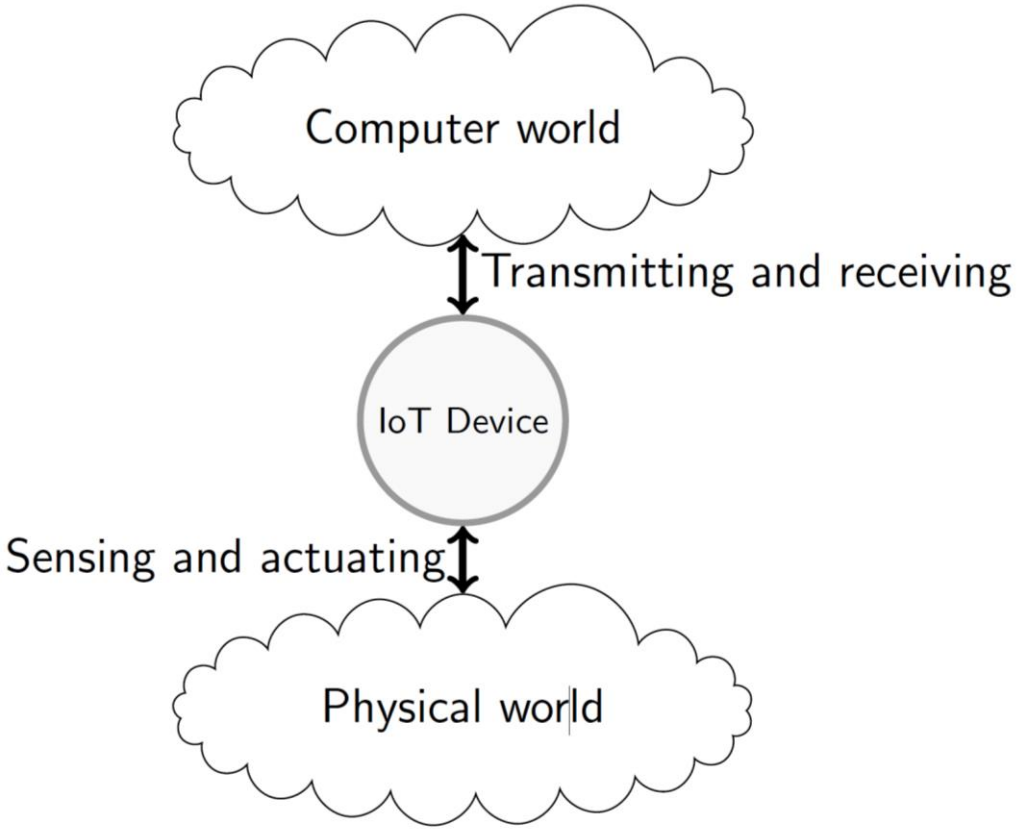
3: WHAT IS THE INTERNET OF THINGS (IoT)?

According to Wikipedia, the **Internet of Things (IoT)**...

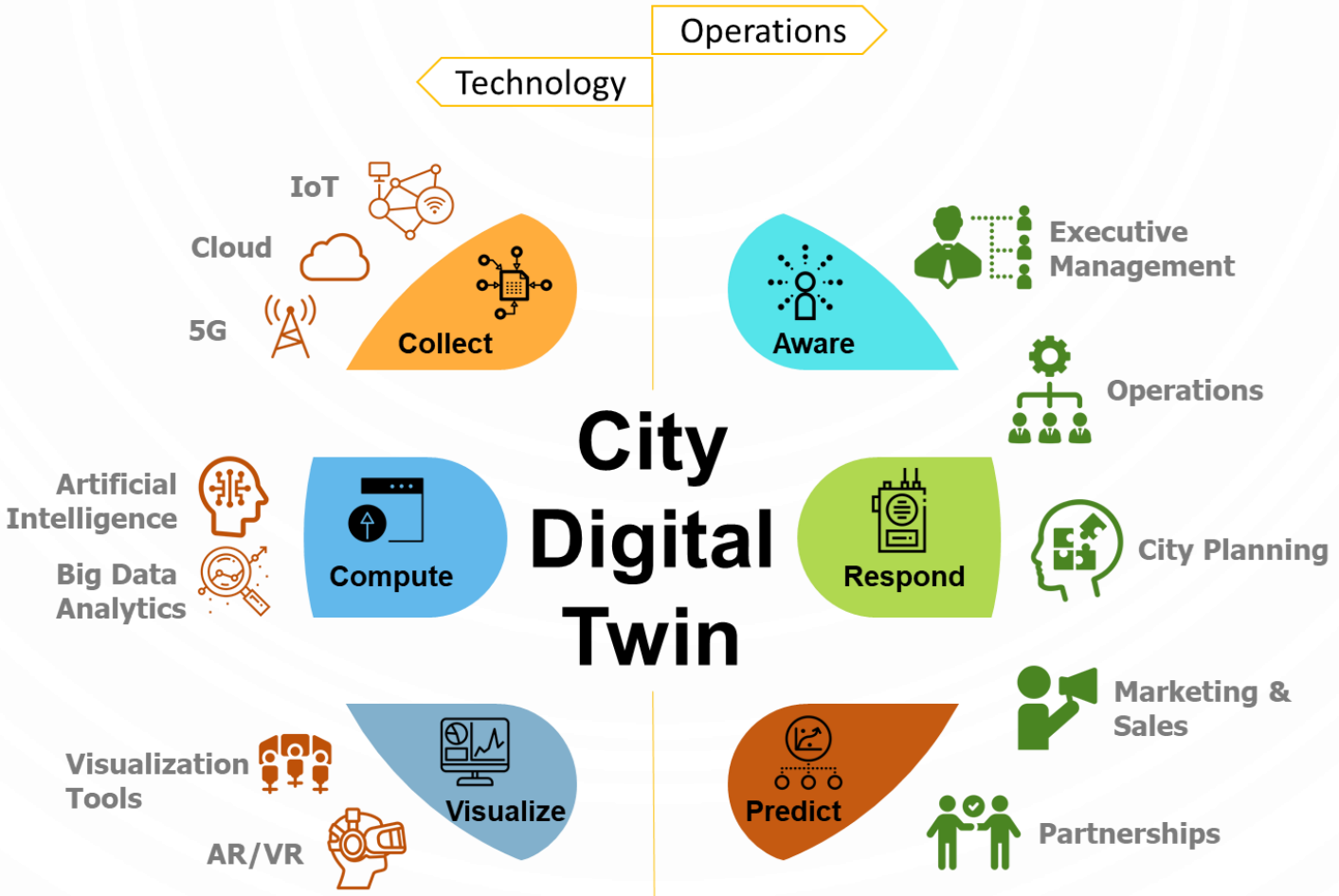
- ... describes the **network of physical objects**—"things"—that are embedded with **sensors, software,** and other technologies for the purpose of **connecting** and **exchanging data** with other devices and systems over the Internet.
- IoT devices consist of **hardware** and **software** components and at least must implement **sensing/actuating** and **communications** functionalities.

3: WHAT IS THE INTERNET OF THINGS (IoT)?

- … [create] opportunities for more **direct integration** between the **physical** world and **computer-based systems.**
- In other words, **IoT devices** connect the **physical world** with the **computer world,** moving information from one world to the other.

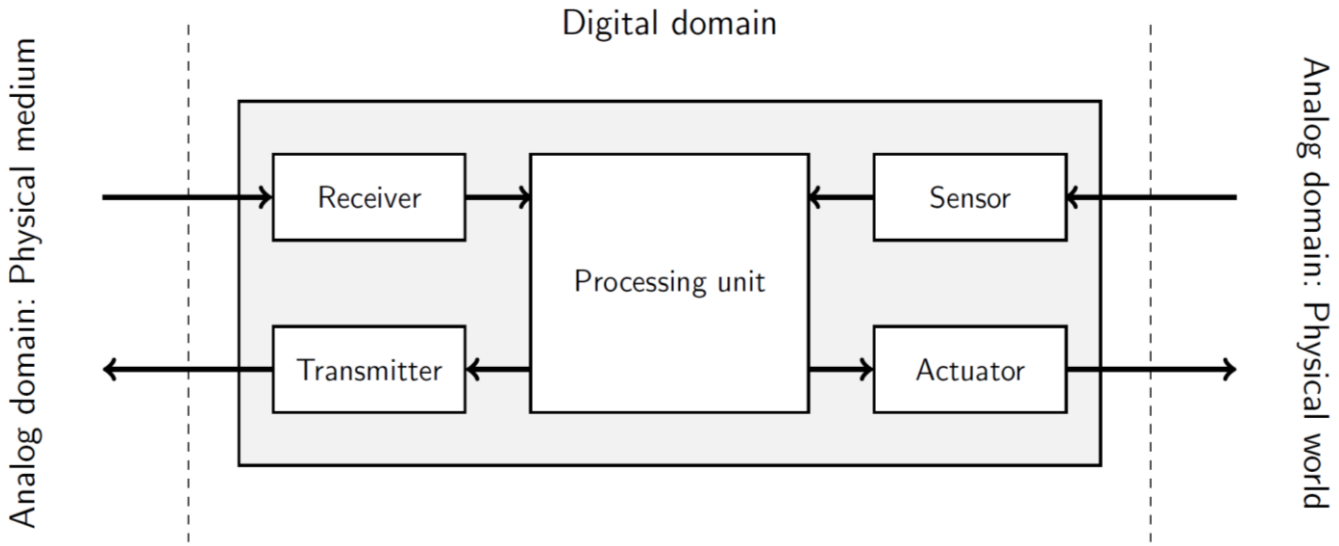


3: HAVE YOU HEARD OF DIGITAL TWINS?



https://e.huawei.com/uk/eblog/industries/insights/2020/how-digital-twins-enable-intelligent-cities

3: ROLE OF IoT DEVICE



IoT devices must be able to interact with the physical world (sensing and actuating) and with the computer world (transmitting and receiving) via analogue interfaces.

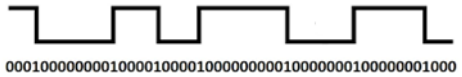
The question arises, **why do IoT devices use digital technology**?

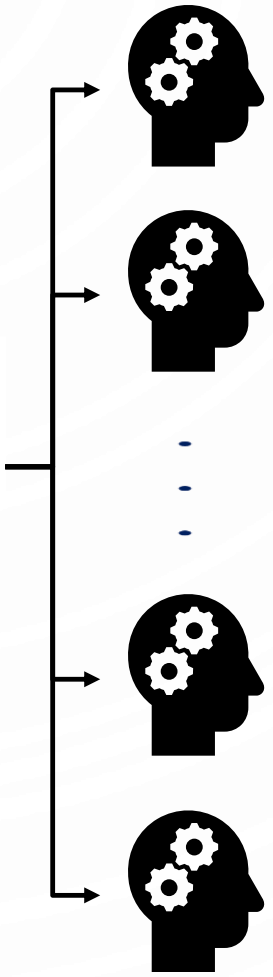
3: SOURCES OF INFORMATION

Physical medium
Analog domain

Acoustic
IoT sensor

Digital domain





Detect violence in the city

Detect water leakage

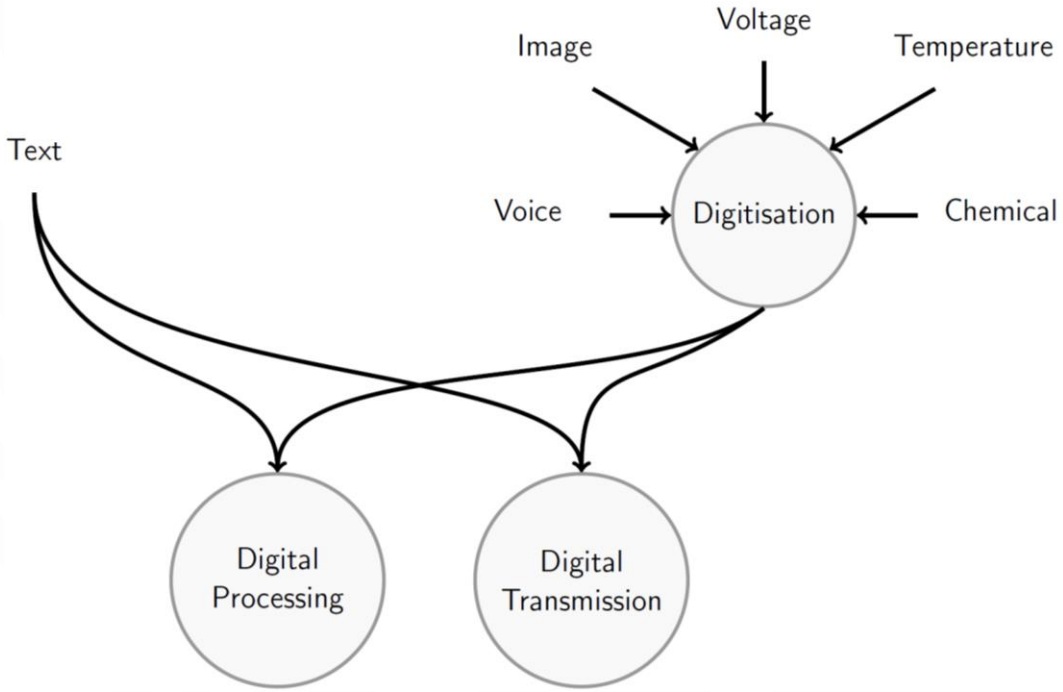
Remote car maintenance

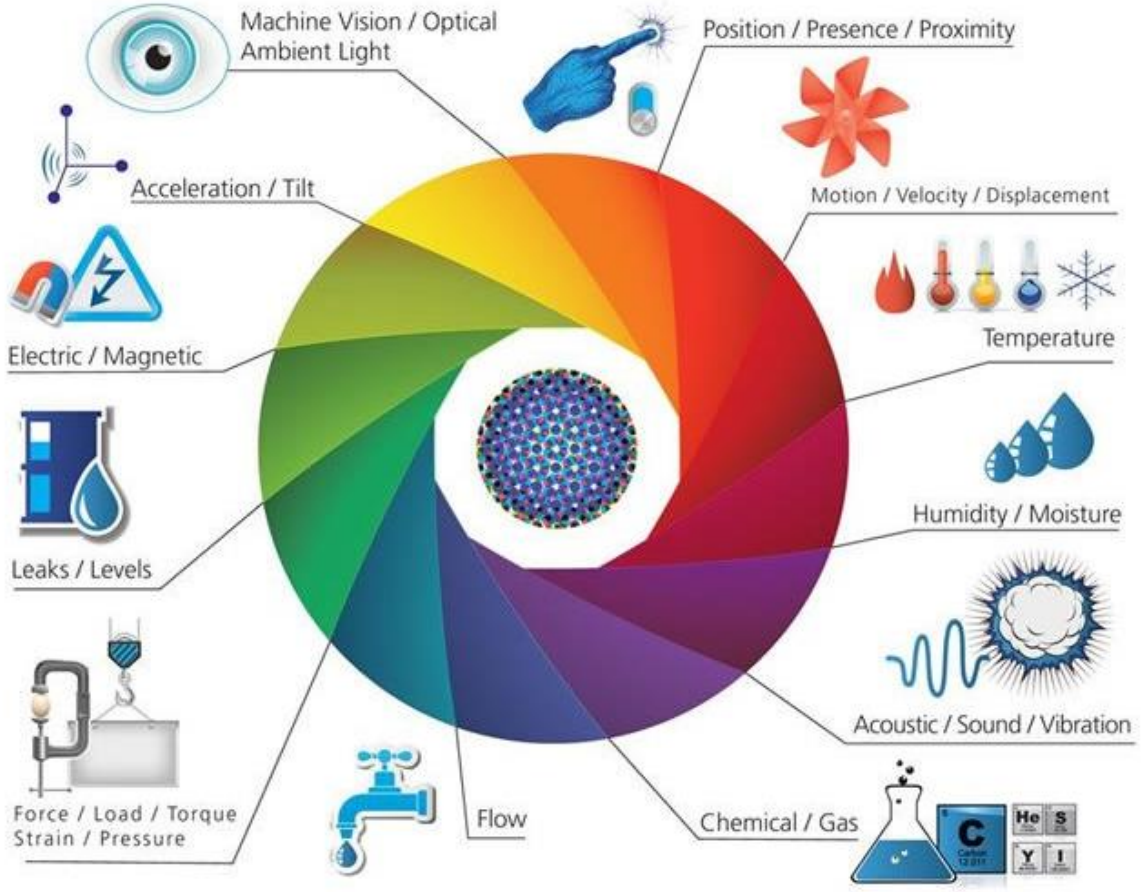
Detect COVID cough

3: SOURCES OF INFORMATION

Digital information

Analog information

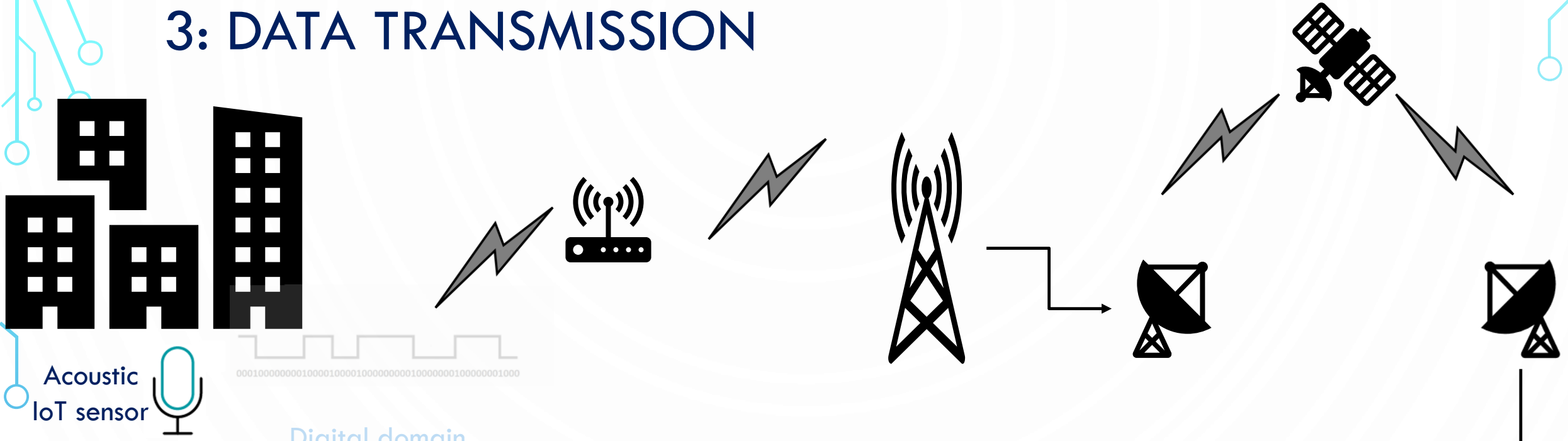




https://www.avsystem.com/blog/iot-sensors-iot-actuators/

The question remains, **why do IoT devices use digital technology**?

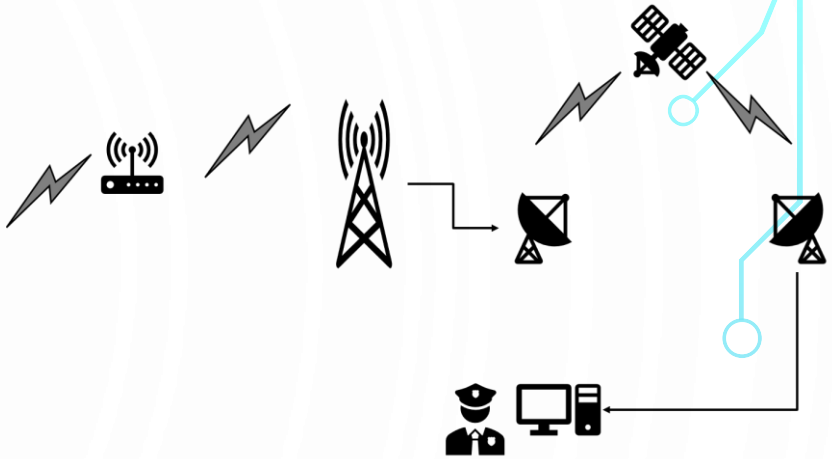
3: DATA TRANSMISSION



The role of the IoT device:

1. Collect info
2. Process the info (e.g., detect violence)
3. Generate digital data
4. **Transmit:** Digital data or Analog data?

3: DATA TRANSMISSION



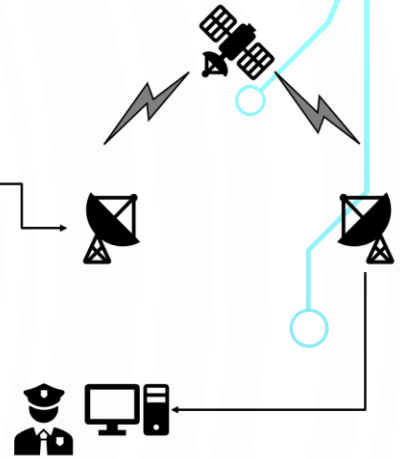
When a signal travels through a channel, it suffers:

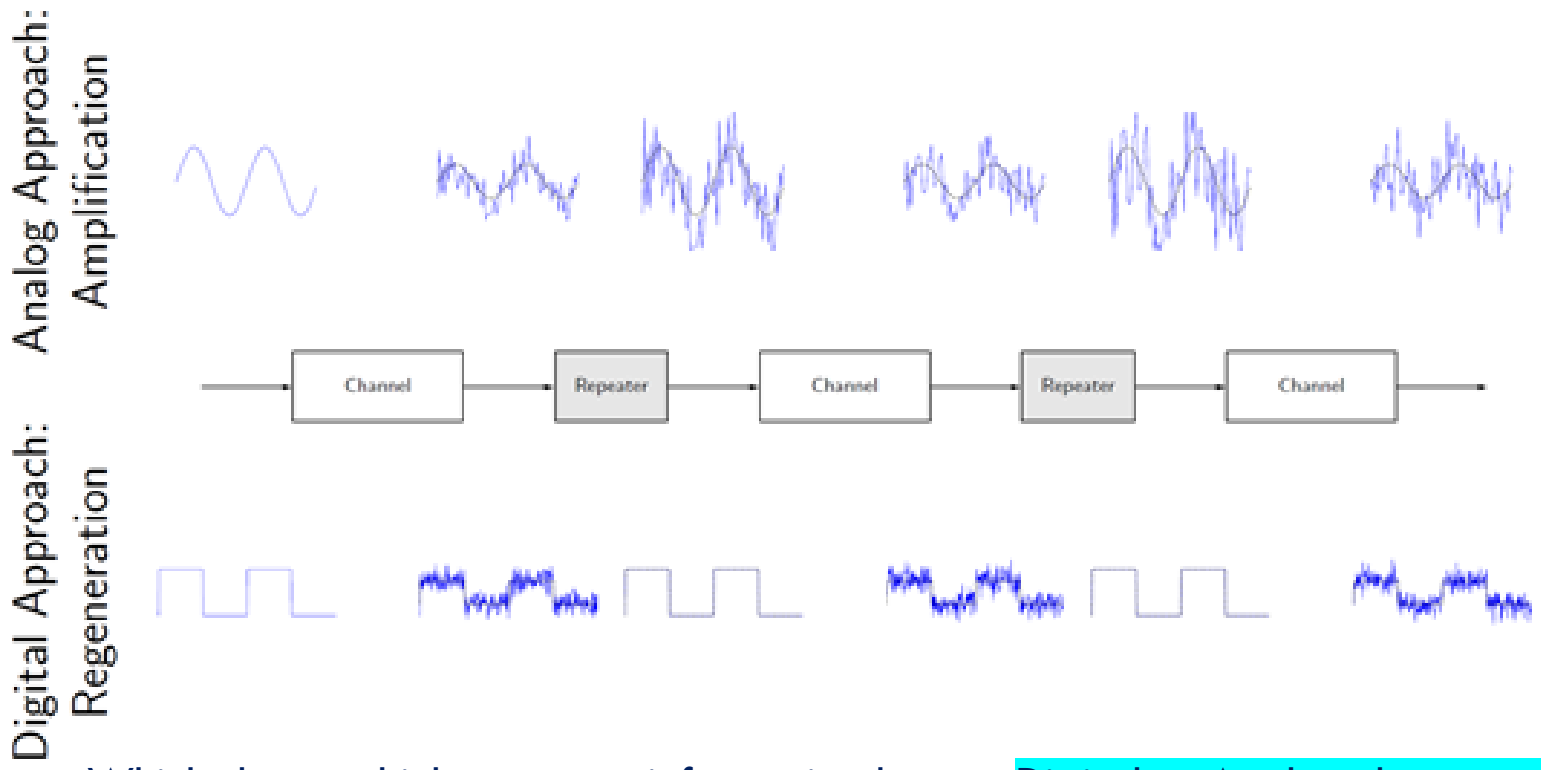
- Attenuation.
- Distortion.
- Noise contamination.

Special equipment called **repeaters are inserted** along the way to compensate these effects.

- In **analog systems** continuously-varying waveforms are transmitted. In order to preserve the transmitted waveforms, repeaters essentially **filter, equalise** and **amplify** the signal.
- In **digital systems** sequences predefined waveforms (symbols) are transmitted. In this case, repeaters **regenerate** such waveforms.

3: AMPLIFICATION V.S. REGENERATION





Which do you think preserve information better: Digital or Analog data transmission?

In any case, **signals need to be processed** to generate data and to survive transmission

3: WHAT IS SIGNAL PROCESSING?

Signal processing consists of **operating with signals**, i.e. perform **mathematical operations** on them. Examples of such mathematical operations are:

- Addition of two signals.
- Linear filtering.
- Modulation.

In order to apply signal processing techniques, it is necessary to **design a system** that **implements** the corresponding **mathematical operations**.

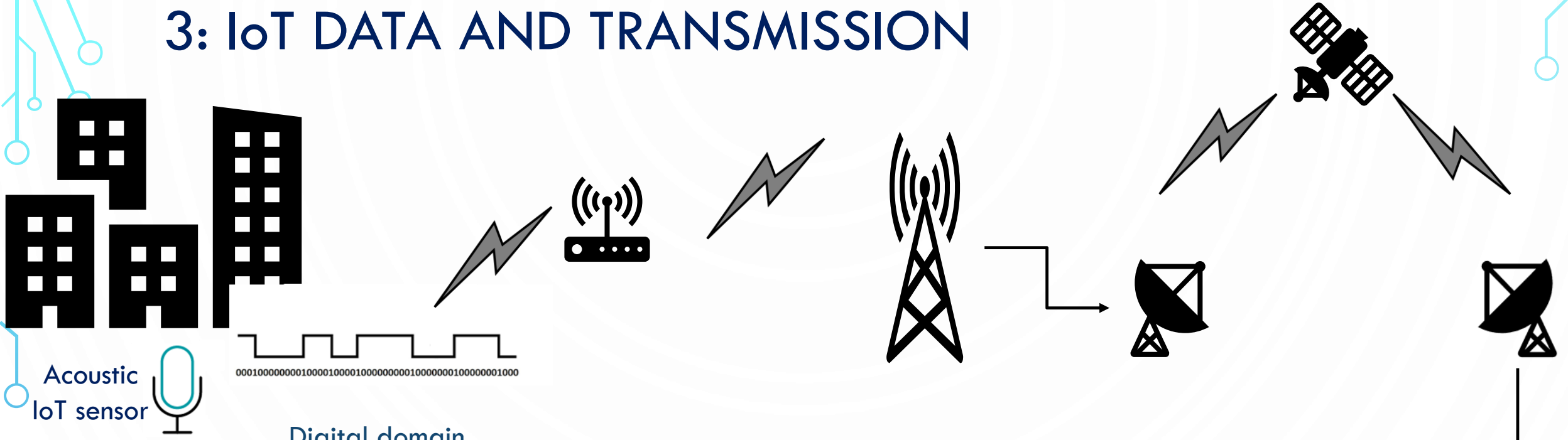
3: HOW TO PROCESS SIGNALS?

How do we implement a system for signal processing?

- Signals from the **analog world** are **continuous-time** and the systems that process them are **analog electronic circuits** (capacitors, resistances, etc).
- Signals from the **digital world** are **discrete-time** and the systems that process them are **digital electronic circuits** (such as microprocessors).

Digital systems offer **many advantages** over analog ones and hence, IoT devices internally represent the information in digital format, irrespective of the information source.

3: IoT DATA AND TRANSMISSION



The role of the IoT device:

1. Collect info
2. Process the info (e.g., detect violence)
3. Generate digital data
4. **Transmit:** Digital data.

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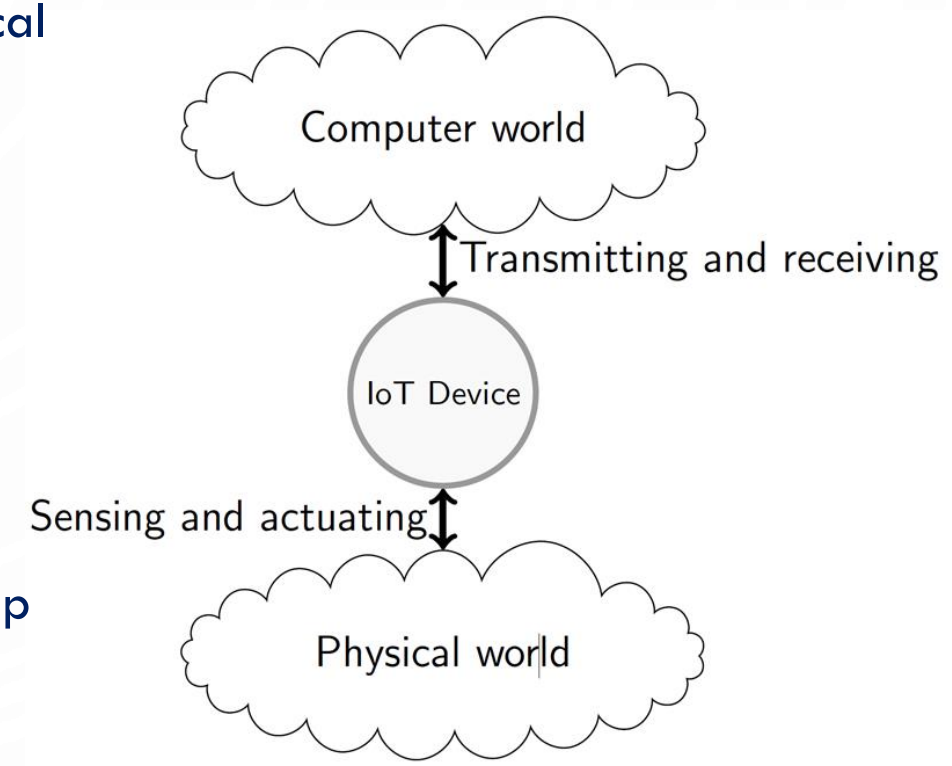
4: WHAT IS INFORMATION?

IoT **devices** allow us to **move information** between the physical world and the computer world. But,

- What is information?
- How do we quantify information?
- How do we extract and represent information?
- How do we protect information?

Signals are the entities that carry information. Therefore, understanding the basics of Signals and Systems is the first step towards understanding information!

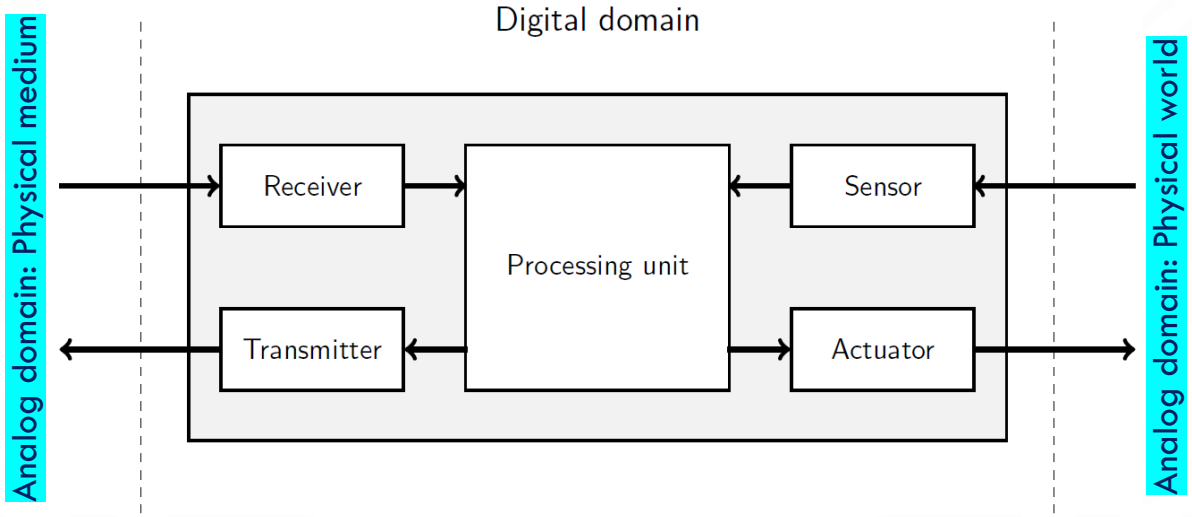
In future courses, you will learn about **Information Theory**.



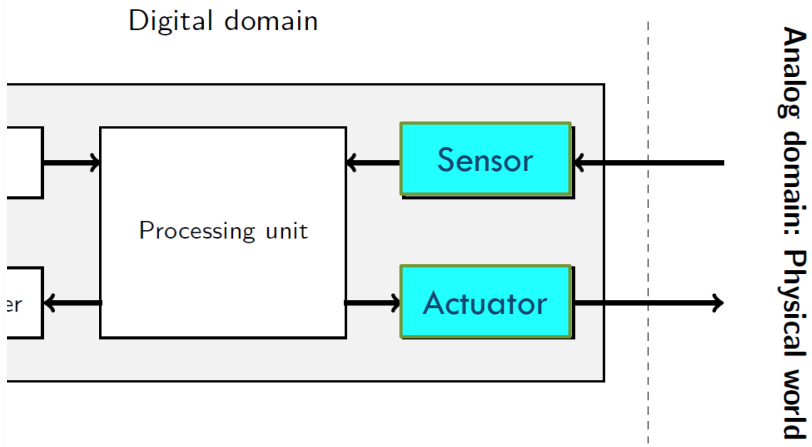
4: OUR PHYSICAL WORLD IS ANALOG

The nature of the **physical world is analog** and hence **information is carried by continuous-time signals**. Knowledge of Signals and Systems allows us to understand how to:

- Extract information from signals in the physical world.
- Use signals to transmit and receive information through a physical medium.



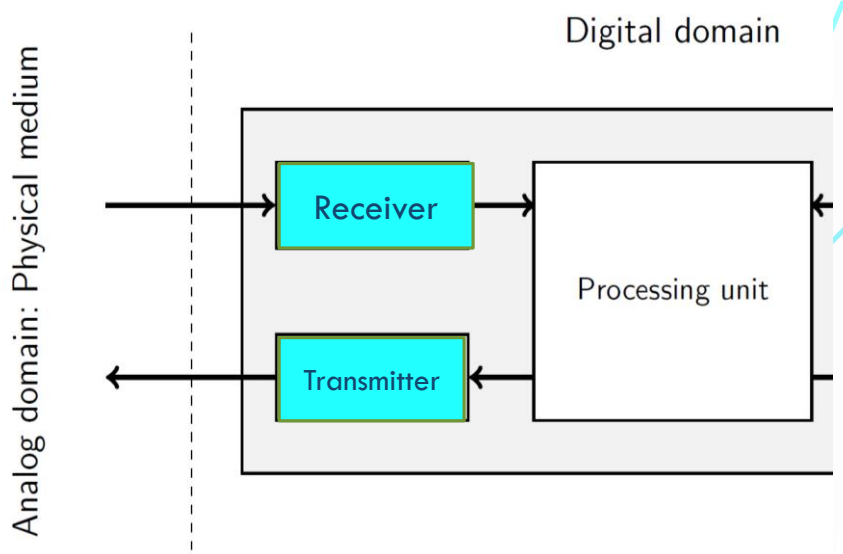
4: BUT IoT DEVICES ARE DIGITAL!



- **Sensors** must **convert** the **continuous-time** signals from the physical world into **discrete-time** signals that can be processed by the IoT device.
- **Actuators** must **convert discrete-time** signals from the IoT device into **continuous-time** signals for the physical world.

Signals and Systems knowledge shows us how to convert signals from one type to another without loosing information. The first process is called **sampling** and the second process **interpolation**.

4: BUT IoT DEVICES ARE DIGITAL!



When information signals are **transmitted** through a **physical medium**, they are attenuated, distorted and contaminated by noise and other signals.

Signals and Systems knowledge helps us understanding how signals deteriorate during transmission and **designing techniques for best transmitting and receiving** information signals.

4: ELECTRONIC SUBSYSTEMS IN IoT DEVICES

IoT devices will contain different electronic subsystems to implement the functionalities that we have discussed, for instance:

- Microprocessors, digital signal processor (DSP).
- Analog to digital converters (ADC) and digital to analog converters (DAC).
- Sensors (temperature, chemical...) and actuators (servos).
- Wired or wireless communication units (USB, WiFi, Ethernet...).

SUMMARY

We have studied:

- Continuous-time signals and systems. This is necessary to understand signals in the physical world.
- Discrete-time signals and systems. This is necessary to understand how signals are processed and transmitted by an IoT device and other computer-based systems.

This week we are going to learn about:

- Sampling, interpolation and digital signal processing. This is necessary to understand conversion from continuous-time to discrete-time and vice-versa, and how information is treated in digital systems.
- Communications systems. This is important to understand how digital information is transmitted over a physical medium.