Internet of Things
Hardware Platform

Overview

- Sensors & Actuators
- Node Architecture
- Communication Architecture

Sensors & Actuators

Sensors Characteristics

- Sensors:
  - They are mainly input components in IoT
  - They are devices that receive a stimulus and responds with an electrical signal
  - Basically three types:
    - Passive, omnidirectional (e.g. mic)
    - Passive, narrow-beam sensor (e.g. PIR)
    - Active sensors (e.g. sonar, radar, etc.)
  - Unit of measurements:
    - SI: modernized metric system.

Quantity	**Name**	**Symbol**
Length	Meter	m
Time	Second	s
Electric current	Ampere	A
Luminous intensity	Candela	cd
...		

Transfer Function

- A transfer function for a sensor: a mathematical function representing the input-output relation.
  - Input: a physical measured parameter
  - Output: usually an electrical output signal.
- It describes the system response of a sensor.

- The simplest form of transfer function is a linear function which can be described as follows.

$$S = a + bx$$

where x is the input, b is the slope (and sometimes called sensitivity), and a is the offset (or the output when the input is zero).

Sensors Technology
A Quick Overview

- Capacitive
  - A change in capacitance with a change in environment
    - Can detect liquids and objects based on their dielectric constant
    - Can take human body capacitance as input
  - For detection of displacement, humidity, acceleration, human contact, etc.

- Resistive
  - A change in resistance with a change in environment
    - Physical changes include light, force, heat, magnetic field, etc.
  - For detection of light, force, heat, etc.
  - Applications include camera, street lights, music instruments, weight sensing, touch screen, etc.

Sensors Technology
A Quick Overview

- Magnetic
  - There are several approaches for magnetic sensing, eg. Hall effect sensor, magneto-diode, magneto-transistor, etc.
  - Generally, they detect magnetic fields or their alteration by ferromagnetic objects.
  - For measuring of rotary movement, Earth's magnetic field, etc.

- Inductive
  - A change in the amplitude of an emitted high frequency electromagnetic field the oscillations.
  - For detection of metallic object and different metals
  - Common in vehicle detection

Sensors Technology
A Quick Overview

- Thermoelectric
  - A creation of voltage when there is a different temperature on each side of an object
  - For measurement of temperature

- Pyroelectric
  - A temporary voltage generated from a certain material when it is heated or cooled
  - For human/animal motion detection, flame detection, NDIR (Non Dispersive IR) gas analysis, etc.
  - Common in PIR (Passive InfraRed) sensors

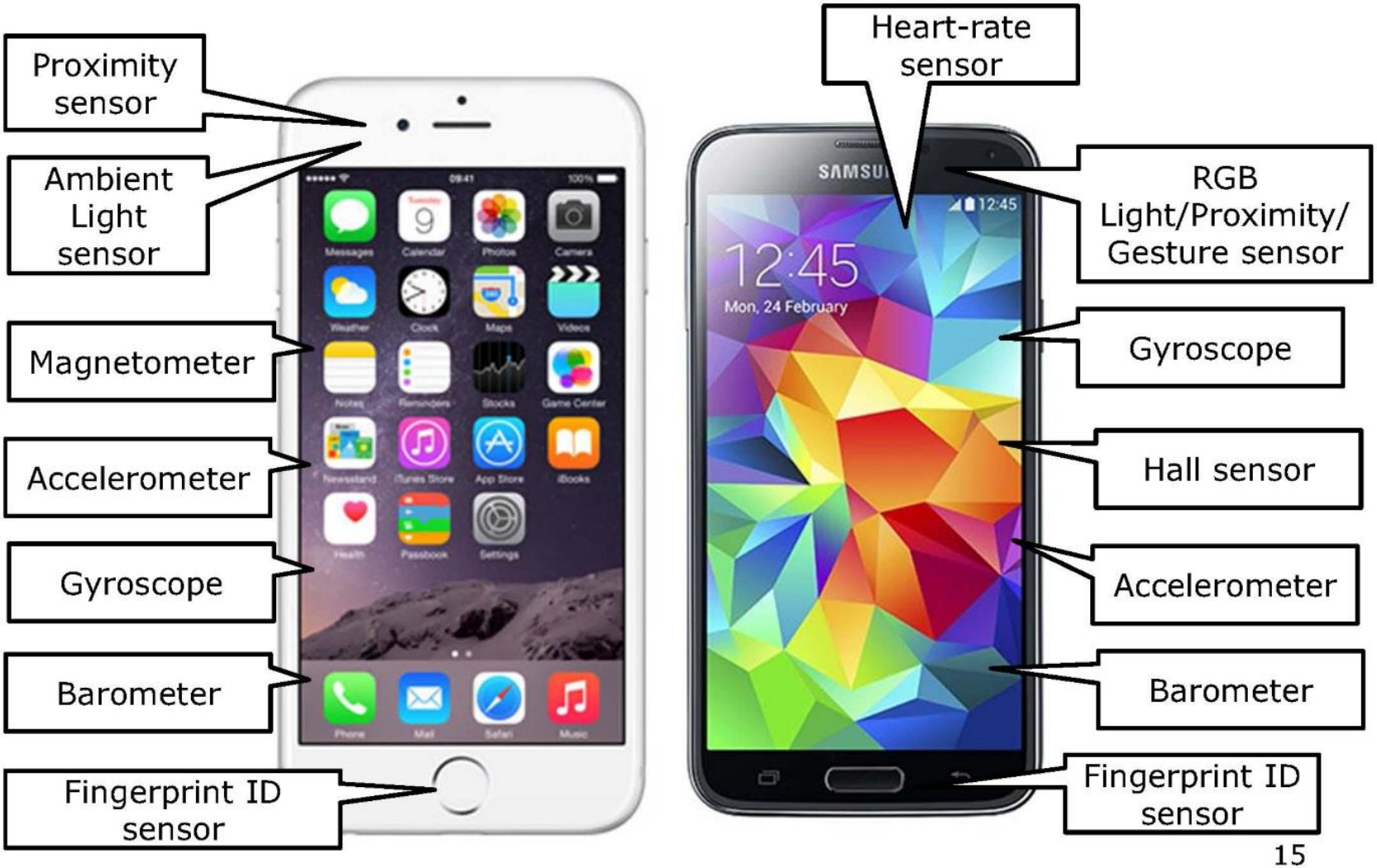
Sensors Technology
A Quick Overview

- Sound level
  - A generation of electrical voltage signals with vibration of air
  - Two popular approaches: inductive (dynamic microphone) and capacitive (condenser microphone)
  - Common sensing application: Sound meter

Sensors Technology
A Quick Overview

- Other sensing technologies
  - Electromechanical sensors
    - Involving of mechanical devices.
    - Some examples:
      - Fluid flow measurement (e.g. mechanical flow meters), Microelectromechanical systems (e.g. MEMS gyroscopes), etc.
  - Electrochemical sensors
    - Involving interaction between electricity and chemistry.
    - Some examples:
      - CO detector, pH meter, etc.

Sensors in Modern Smart Phones



Actuators

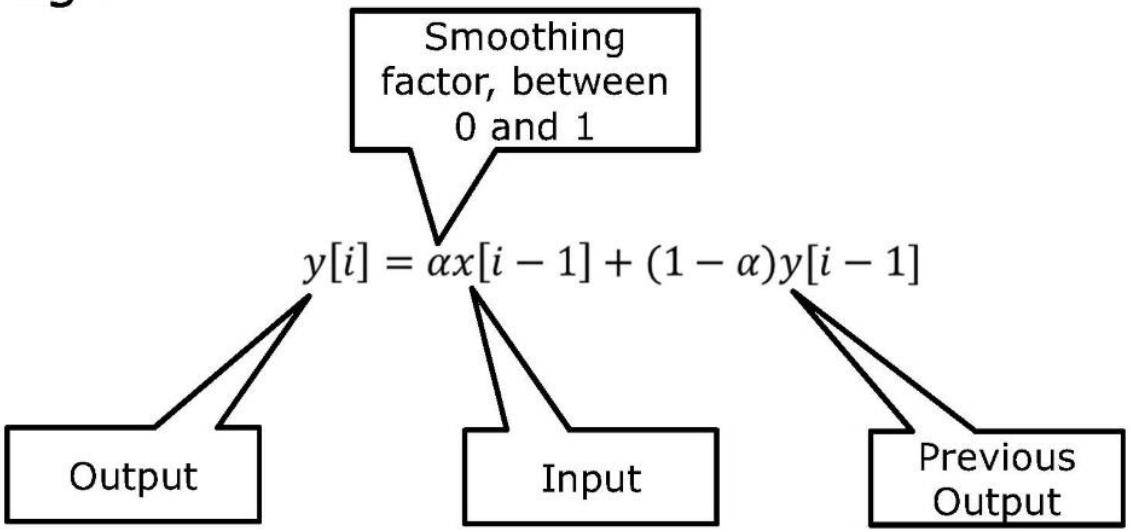
- They are mainly output components
- Generally 4 types:
  - Hydraulic: use hydraulic power, powerful but slow
  - Pneumatic: use compressed air, rapid delivery
  - Electric: use electricity, versatile ←for IoT
  - Mechanical: use other mechanical energy
- They alter the surrounding. Some examples:
  - Adding light, heat, sound, moisture, etc.
  - Moving objects
  - Displaying messages
  - and others…

Signals

- Sensors produce a series of digital signals
- Signals may contain noise
- Implementing complicated digital filters may not be desirable, as they are relatively complex in computation and high in power consumption
- Simple data smoothing may be sufficient to remove some noise

Exponential Smoothing

– It's a class of Autoregressive integrated moving average



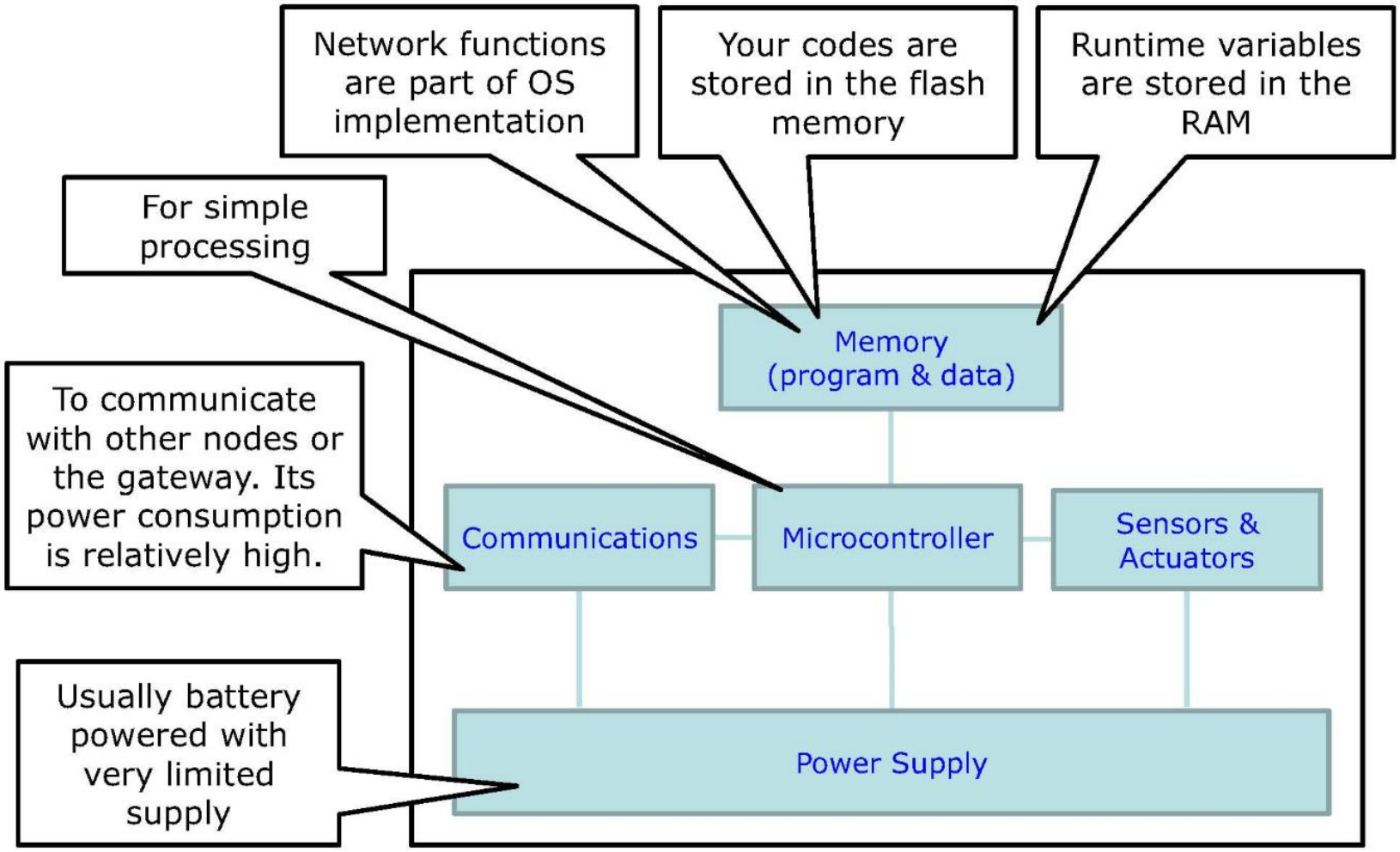
– The output is contributed by the current reading and the previously computed value

Node Architecture

A Thing

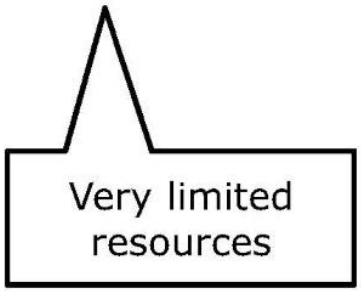
- We can turn almost every object into a "thing".
- A "thing" still looks much like an embedded system currently.
- A "thing" generally consists of four main parts:
  - Sensors & actuators
  - Microcontroller
  - Communication unit
  - Power supply
- A "thing" has the following properties:
  - It's usually powered by battery. This implies limited source of energy.
  - It's generally small in size and low in cost. This limits their computing capability.
  - It doesn't usually perform complicated tasks.
- Power consumption is the main design issue.

Hardware Components

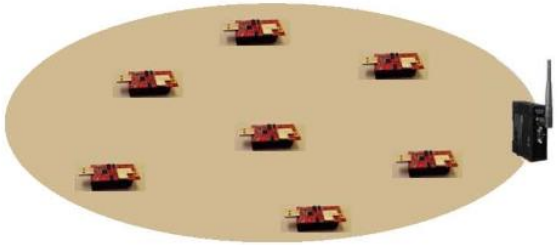


XM1000: Processor and Memory

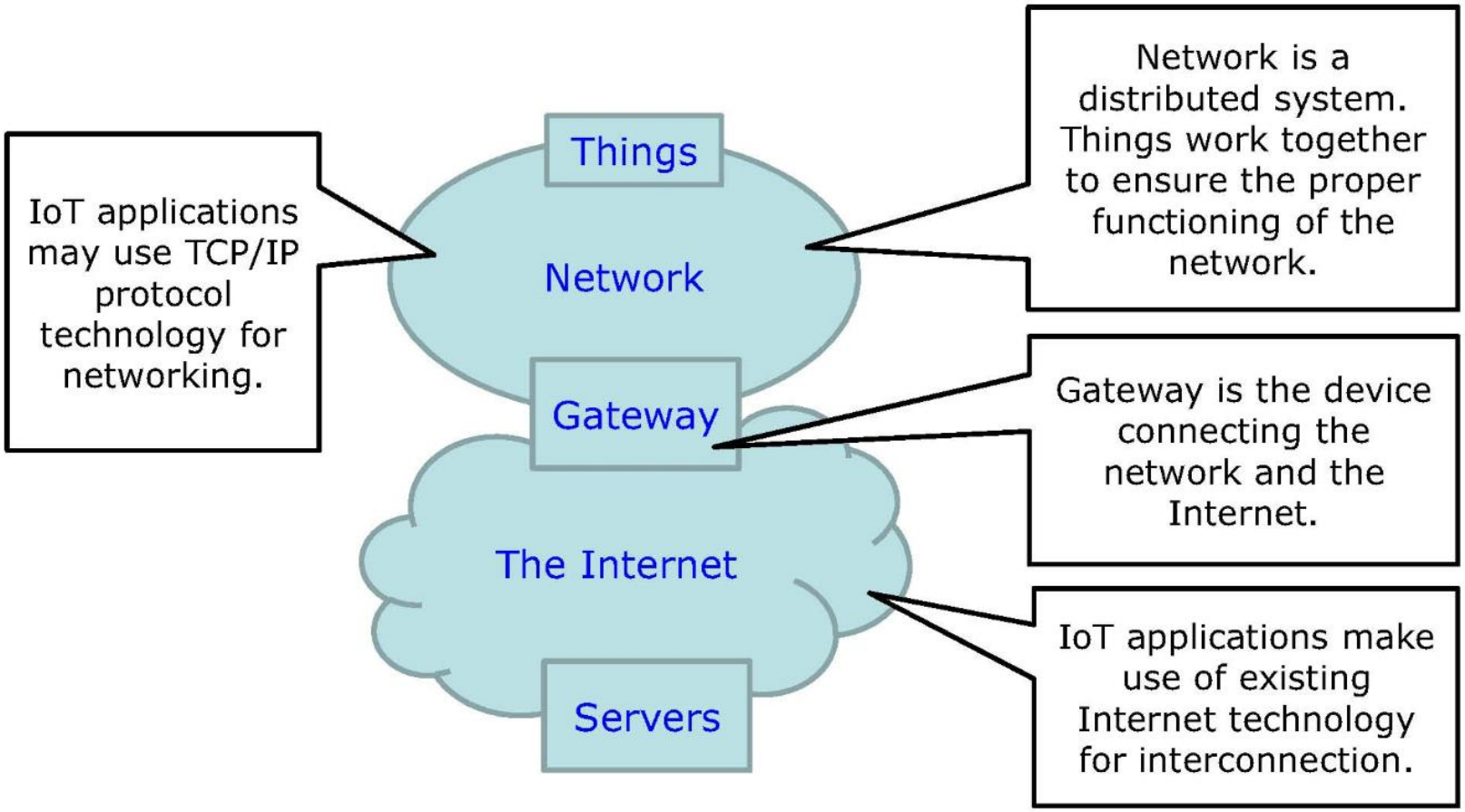
Item	Specification	Description
Processor		
Processor Model	TI MSP430F2618	Texas Instruments MSP430 family 16-Bit RISC Architecture 62.5-ns Instruction Cycle Time
Memory	116KB 8KB 1MB	Program flash Data RAM External Flash (ST® M25P80)
ADC	12bit resolution	8 channels
Interfaces	UART, SPI, I2C USB	Serial Interfaces External System Interface (FTI® FT232BM)



Communication Architecture



IoT Networking

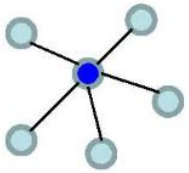
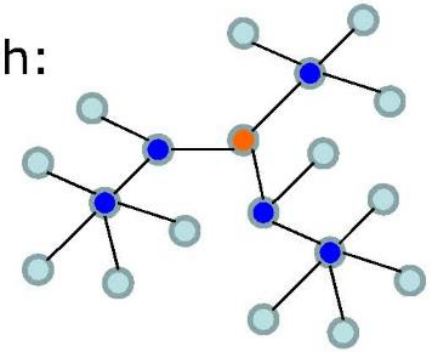


We focus on IEEE 802.15.4

IEEE 802.15.4 Standard

- IEEE 802.15.4 Standard specifies communication technologies for low-rate wireless personal area networks (LR-WPANs).
  - Including PHY & Medium Access Control (MAC)
- Three possible frequency bands (unlicensed):
  - 868.0-868.6 MHz, 902-928 MHz, 2.4-2.485 GHz
- Maximum data rate: 250 kb/s
  - Different modulation schemes are used in different frequency bands
- References:
  - IEEE Std. 802.15.4™, 2005
  - Marco Naeve, Eaton Corp., IEEE 802.15.4 MAC Overview, 2004

IEEE 802.15.4 MAC: Configuration

- Network topologies:
  - Star: 
  - Mesh: 
  - PAN Coordinator
- Device classes:
  - Full Function Device (FFD): can act as a coordinator for a PAN (●), communicate with any other device
  - Reduced Function Device (RFD): only communicate with coordinator

Questions?