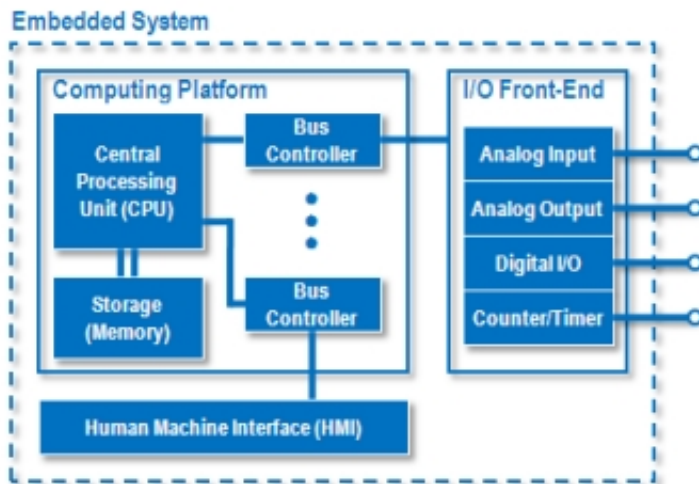


C03053 – Embedded Systems

1. What is Embedded System?



Connect to external I/O
such as sensors, motors,
LEDs, and more



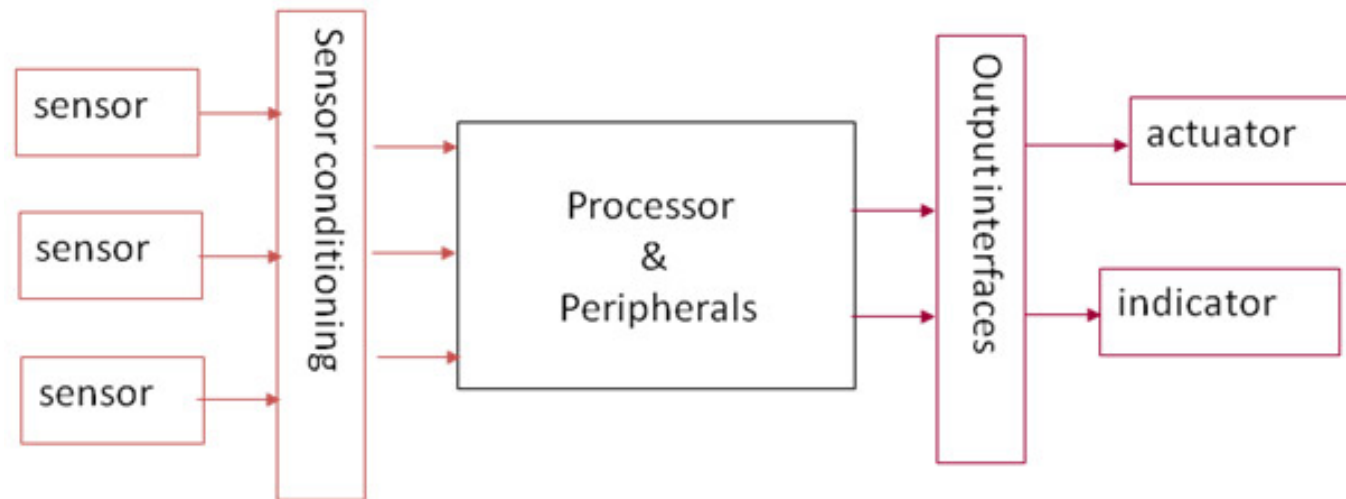
Contents

- Definition and Concept
- Characteristic
- Design Challenge
- Design Metric



What is Embedded System ?

- An embedded system is
 - **A computer system** that is **embedded** into **another larger system**.
 - Example: Cars, airplane, weapon, ...
- An embedded system is designed to perform a/some **dedicated task(s)**
 - Lighting control
 - Camera control



Embedded System Applications

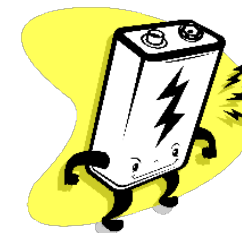
- Require very high performance

- Communications
- Multimedia
- Graphics



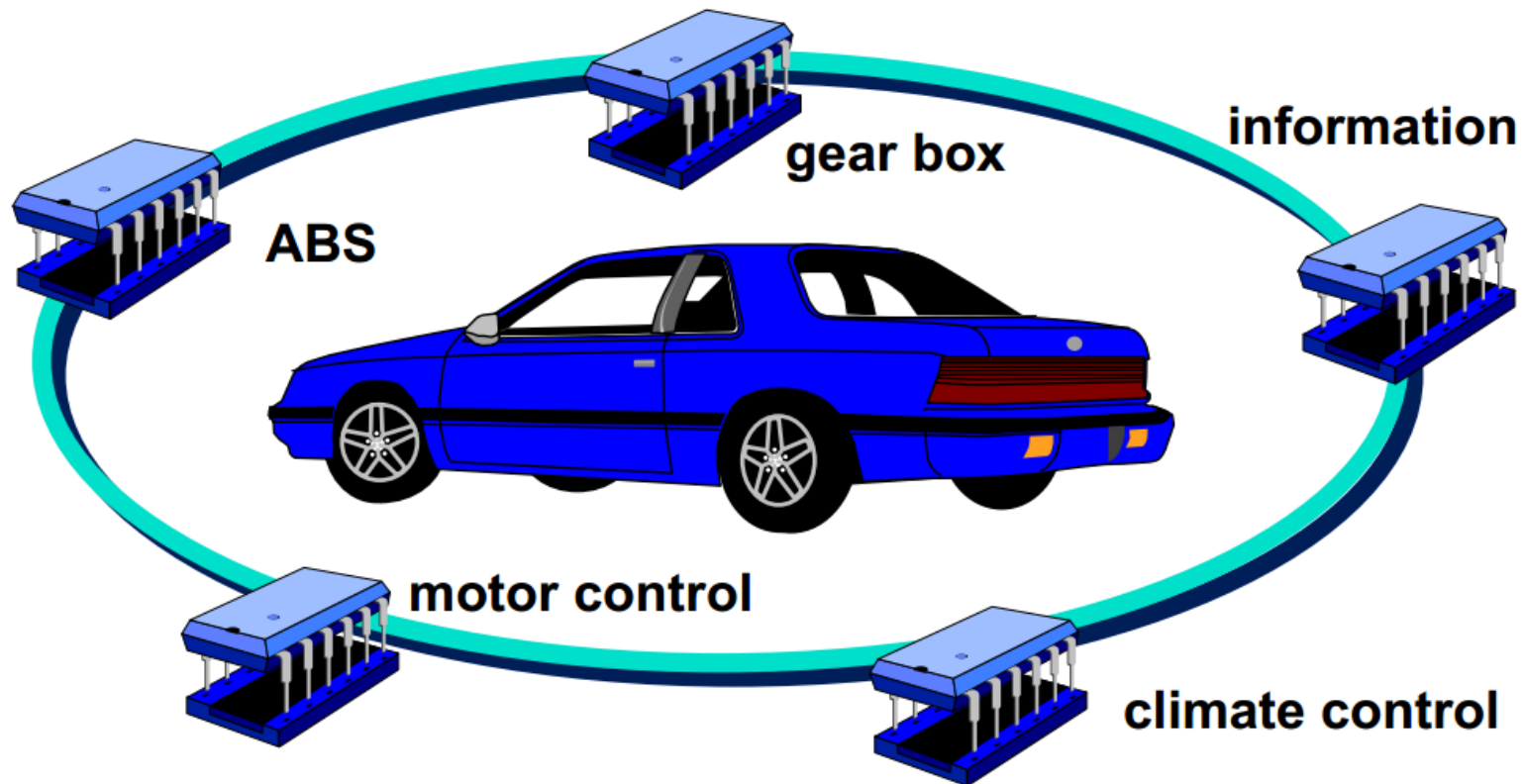
- Must also meet strict design goals

- Real-time performance
- Power/energy consumption
- Cost



Example – Automotive

- Car as an integrated control, communication and information system.



Example – Consumer Electronics

- MP3 audio, digital camera, **home electronics**

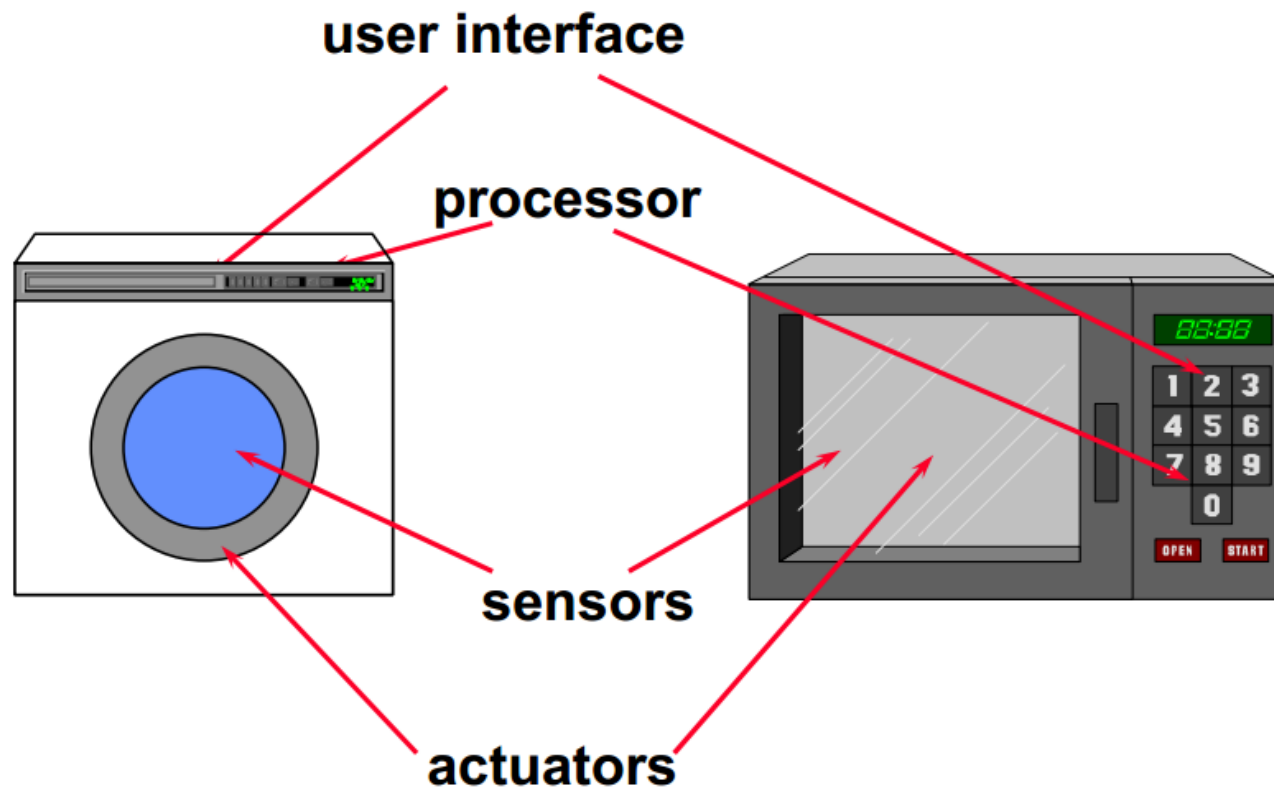
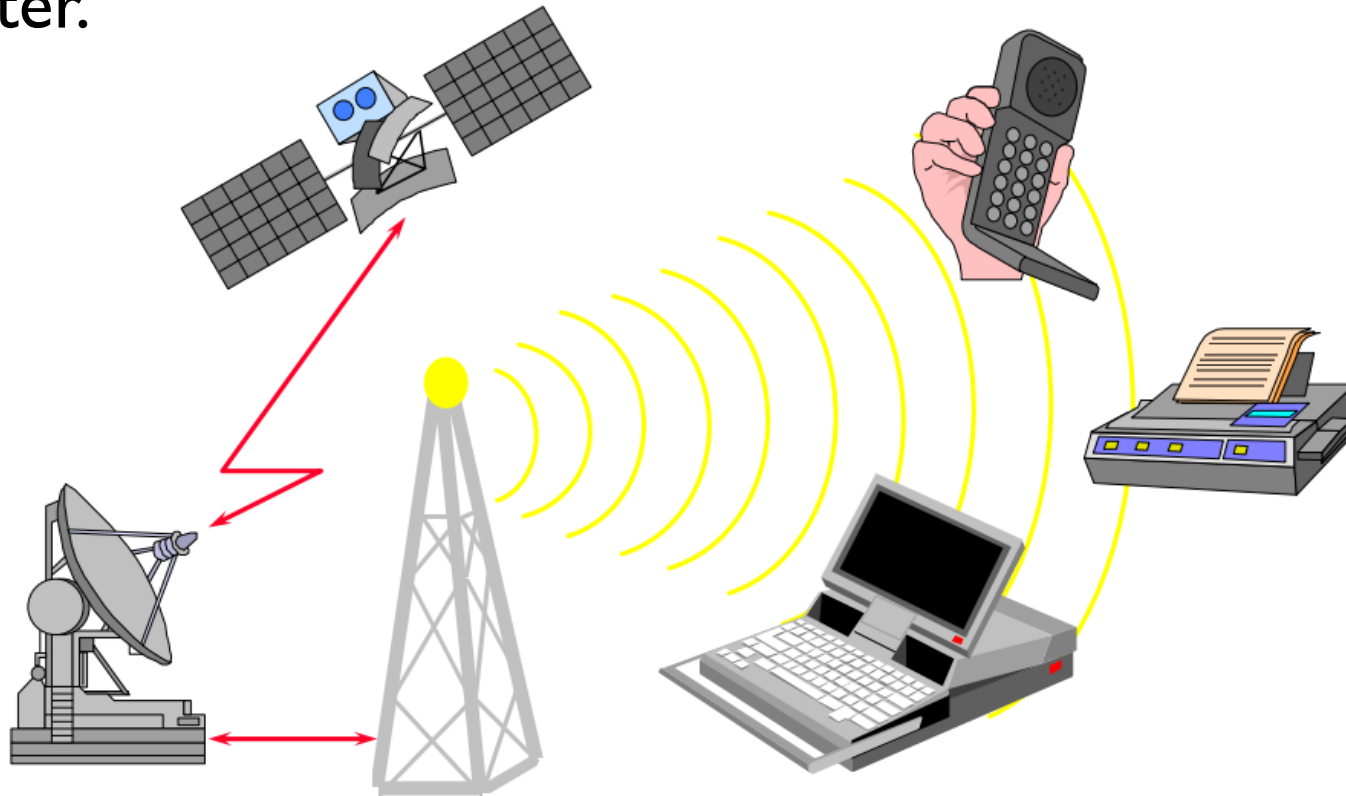


Image Source: Internet

Example – Information Systems

- Wireless communication (mobile phone, wireless LAN, etc), end-user equipment, router.



Common Characteristics of Embedded Systems

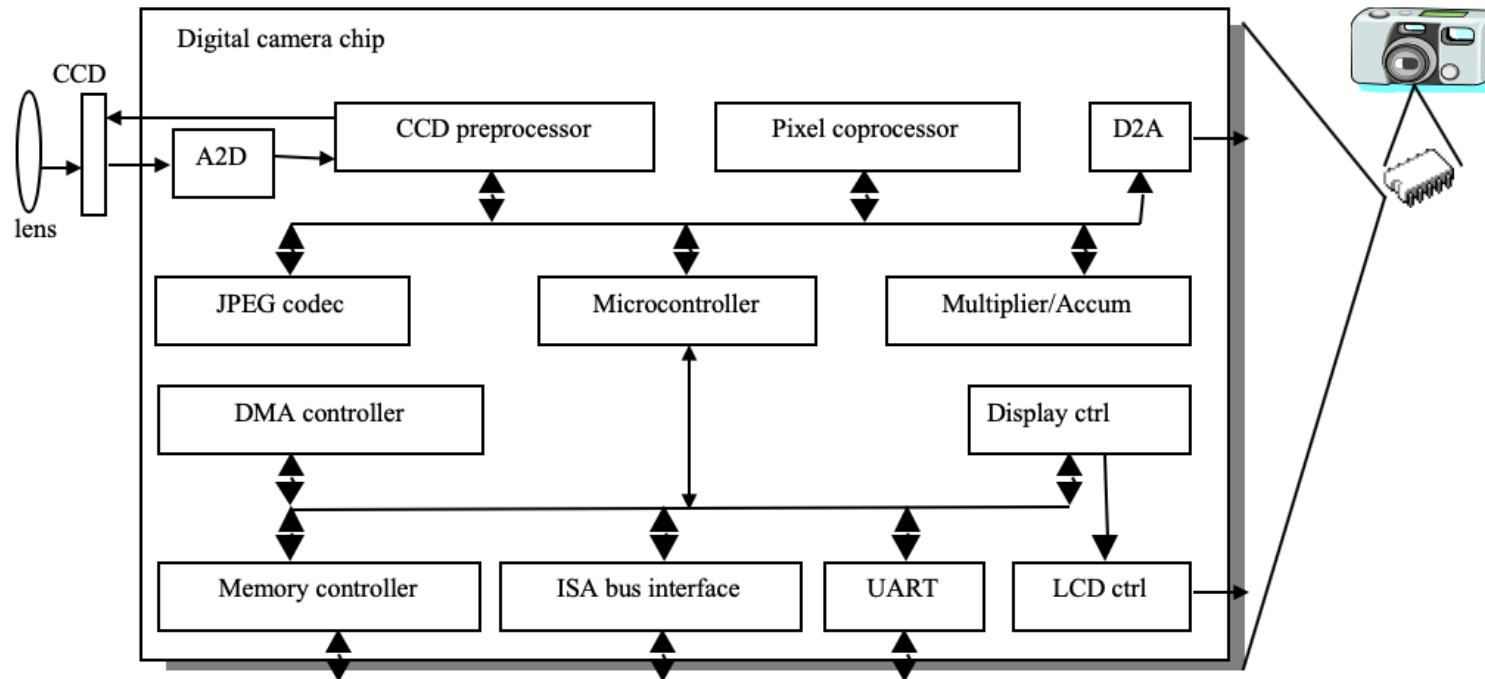
- Single-functioned
 - Executes a single program, repeatedly

- Tightly-constrained
 - Low cost, low power, small, fast, etc.

- Reactive and real-time
 - Continually reacts to changes in the system's environment
 - Must compute certain results in real-time without delay



An Embedded System Example



- Single-functioned -- **always a digital camera**
- Tightly-constrained -- **low cost, low power, small, fast**
- Reactive and real-time -- **only to a small extent**

Embedded Systems – Design Challenge

- Obvious design goal
 - Construct an implementation with desired functionality

- Key design challenge:
 - Simultaneously optimize numerous design metrics

- Design metric
 - A measurable feature of a system's implementation
 - Optimizing design metrics is a key challenge



Embedded Systems – Common Design Metrics

■ Unit cost

- The monetary cost of manufacturing each copy of the system, excluding NRE cost

■ NRE cost (Non-Recurring Engineering cost)

- The one-time monetary cost of designing the system

■ Size

- The physical space required by the system

■ Performance

- The execution time or throughput of the system

■ Power

- The amount of power consumed by the system

■ Flexibility

- The ability to change the functionality of the system without incurring heavy NRE cost



Embedded Systems – Common Design Metrics

- **Time-to-prototype**
 - The time needed to build a working version of the system
- **Time-to-market**
 - The time required to develop a system to the point that it can be released and sold to customers
- **Maintainability**
 - The ability to modify the system after its initial release
- Correctness, Safety, CPU Technologies, Integration Level, Form Factor, Application Specific Hardware, User Interface, Connectivity, Security



Embedded Systems – Other Design Metrics

- CPU Technologies
- Integration Level
- Form Factor
- Application Specific Hardware
- User Interface
- Connectivity
- Security



The CPU

■ General purpose

- 32-bit, 64-bit long time ago.
- Clock-rate reach several GHz.
- Included Floating Point Unit (FPU) and/or Graphic Processing Unit (GPU) with parallel processing capability.

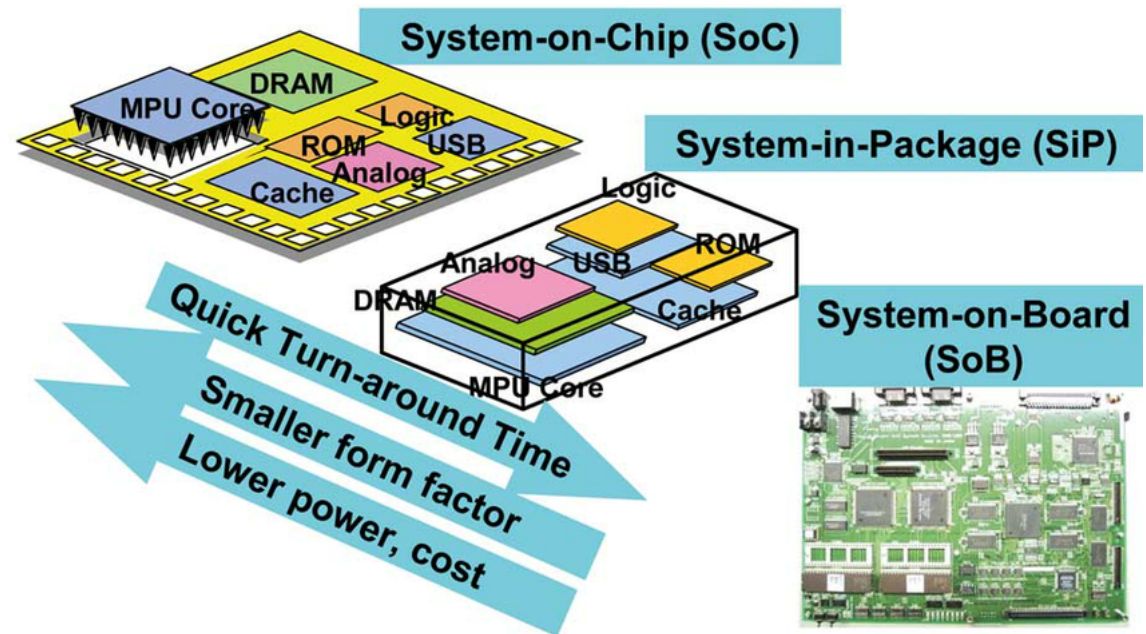
■ Embedded System

- Large range of compute capability.
- Still many 8-bit and 16-bit in small ES (PIC, AVR,...).
- Now, many systems requires 32-bit, 64-bit CPU (ARM, ATOM,...)



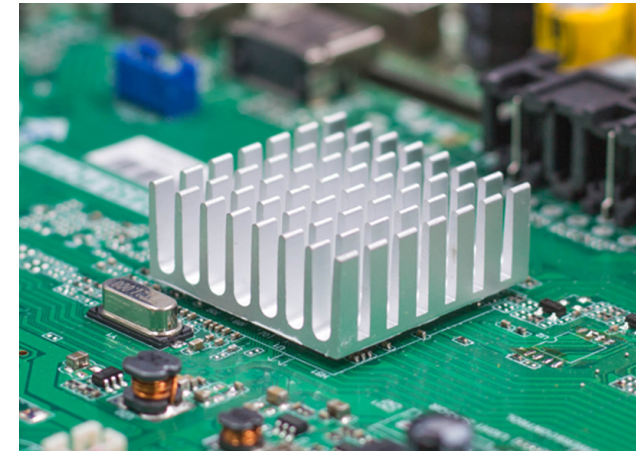
Integration Level

- Early Embedded Systems
 - Separate CPU + Peripherals + ...
 - Cost highly
- SoC (System on a Chip)
 - Many ICs are integrated into a single Chip
 - High-density → Low-cost
 - CPU + Memory + IO or CPU + Memory + ADC
 - Many levels of integration



Power Consumption

- Many ES rely on battery
 - Power consumption is very important
- Apply power optimization technique
 - Sleep mode
- Heat is also very important
 - Heat sink must be efficient
 - E.g. Cell phone



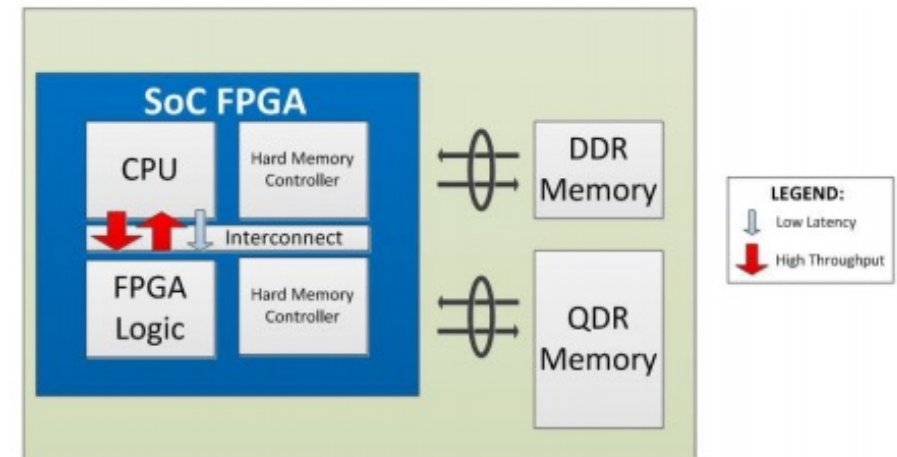
Form Factor & Expansion

- Size, pin-out, connector.
- Define some standard (Ex COM) help software development, hardware expansion
- Sometime for expansion, resources are reserved (DRAM, Flash). But these have trade-off and need to be consider carefully.



Application Specific Hardware

- Can any SoC suit the user requirements?
- Adding other ASIC or FPGA: trade-off
 - ASIC can show better performance
 - But FPGA can show the flexibility
- Future ES: **SoC + FPGA**
- Many parts of ES need **certification**
 - E.g. **radio frequency** need to be licensed (US, Japan,...)
- Consider to use pre-certified module



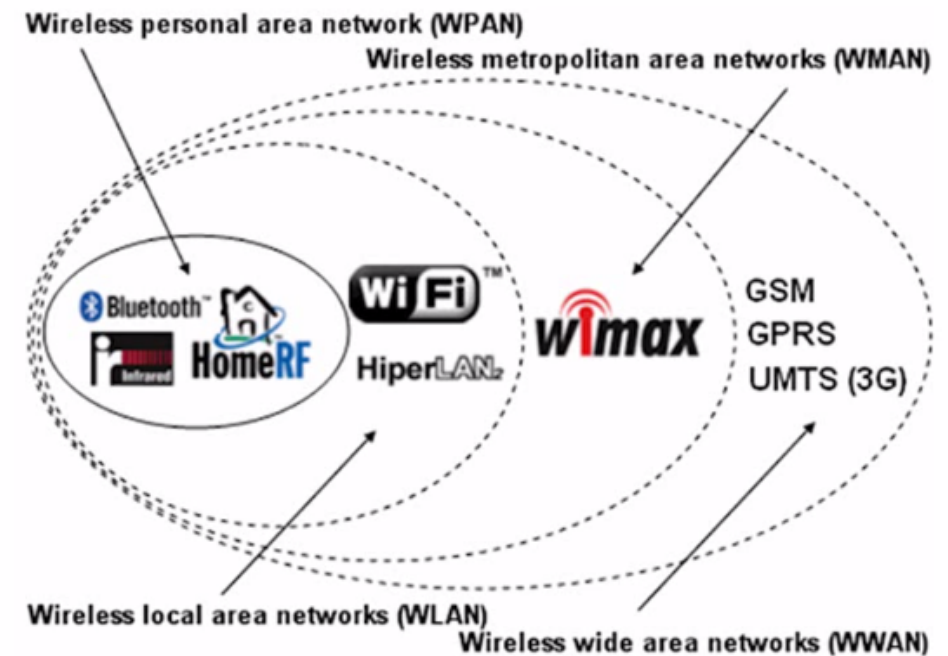
User Interface

- Many ES is interactive
 - Headed provide the display
 - E.g. touch screen. The appearance of application
 - Headless: no display.
 - Use console, key/button, or via web page



Connectivity and Security

- For current and future ES, connectivity is very important
 - Wifi, Xbee, Bluetooth, LoRa
 - 3G/4G/5G
 - ...
- **Ubiquitous:** every device can connect each other
- When the **connectivity is easy**, the **security become critical**



Further Reading

- Audio Lecture

- https://lectures.tik.ee.ethz.ch/es/recordings/ES_I/ES_I.html

