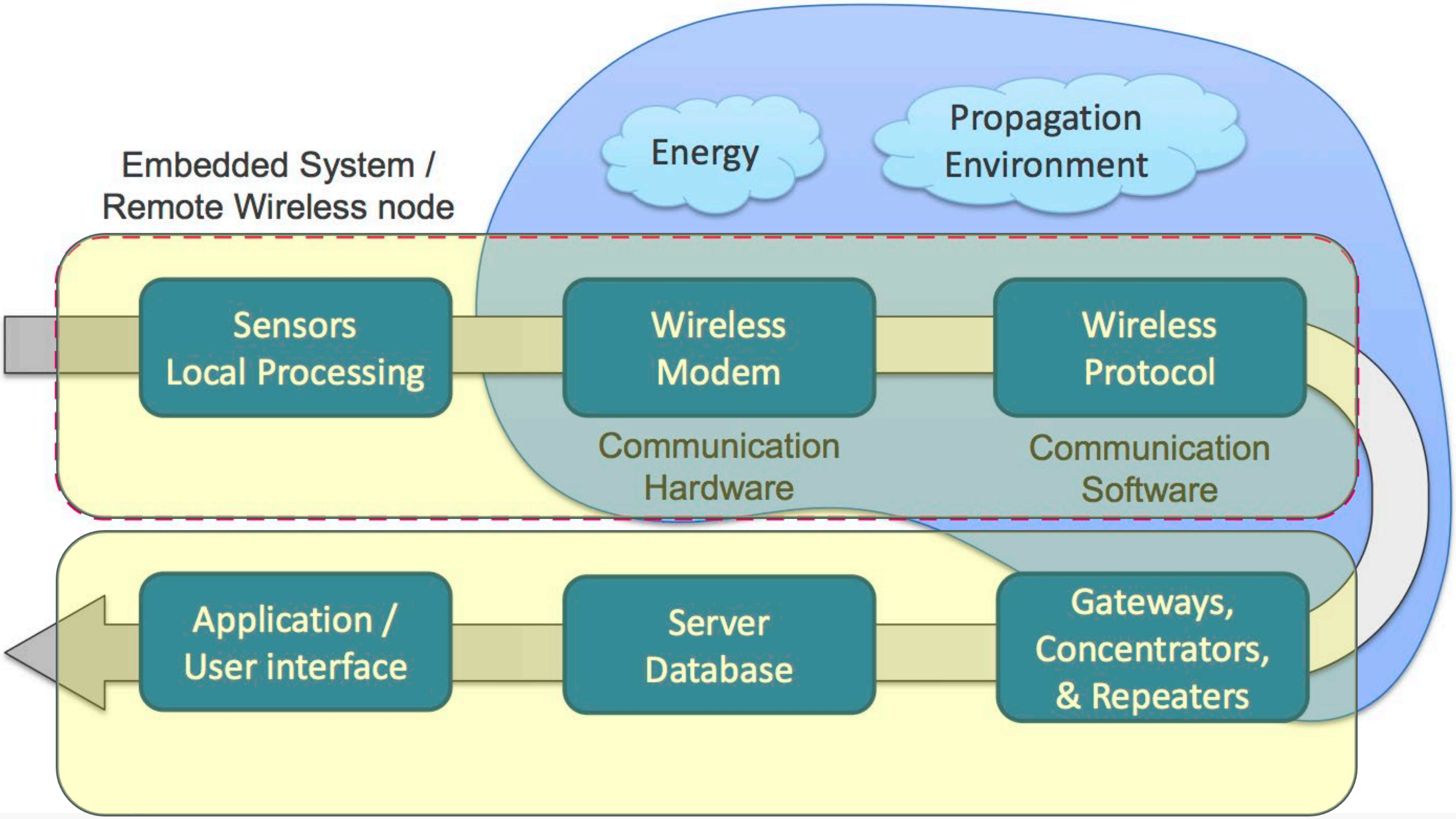
Haute école d'ingénierie et d'architecture Fribourg
Hochschule für Technik und Architektur Freiburg

INTERNET DES OBJETS
NODE ARCHITECTURE

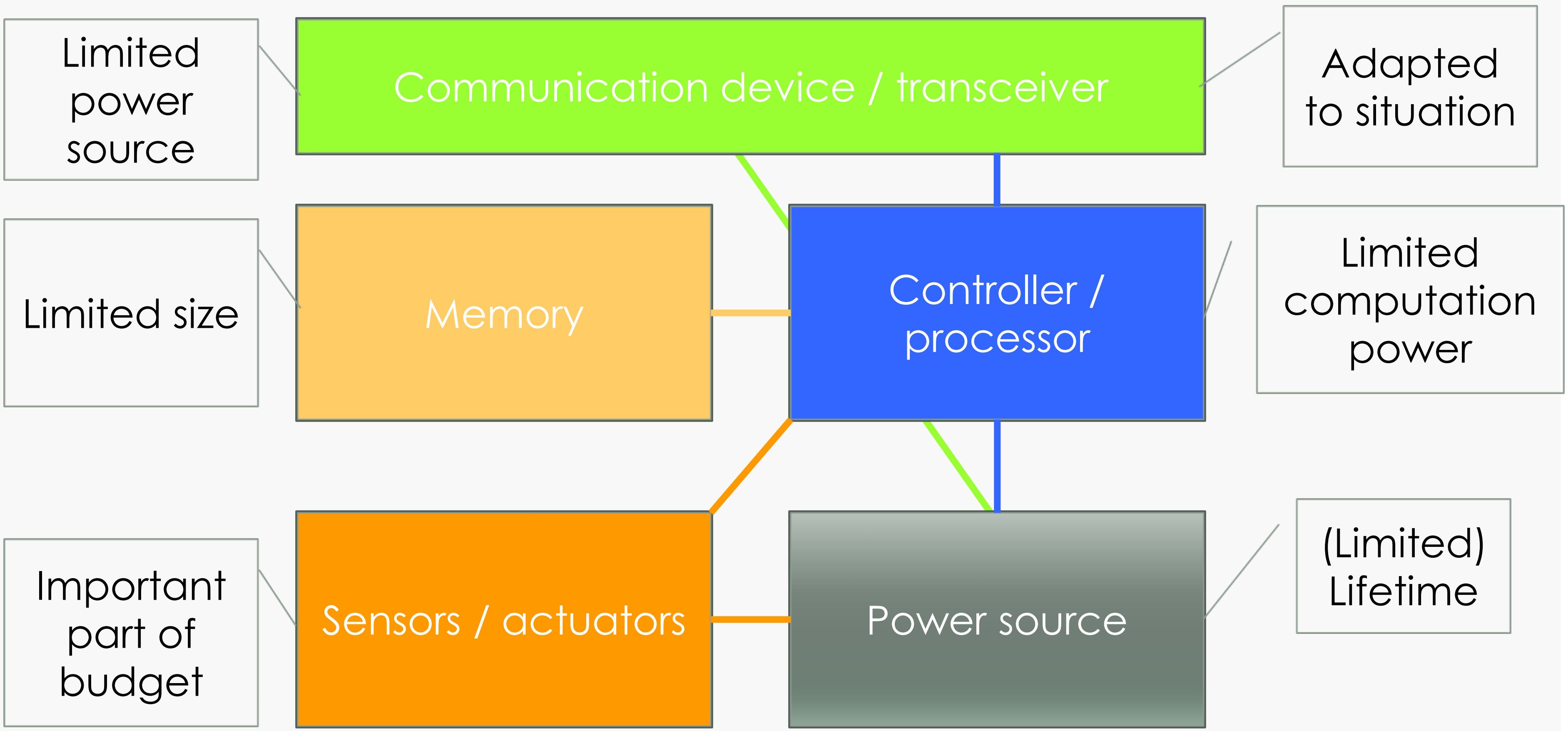
SERGE AYER - HEIA-FR – TÉLÉCOMMUNICATIONS
CLASSES ISC-2D // 2023-2024

INTERNET OF THINGS: ARCHITECTURE

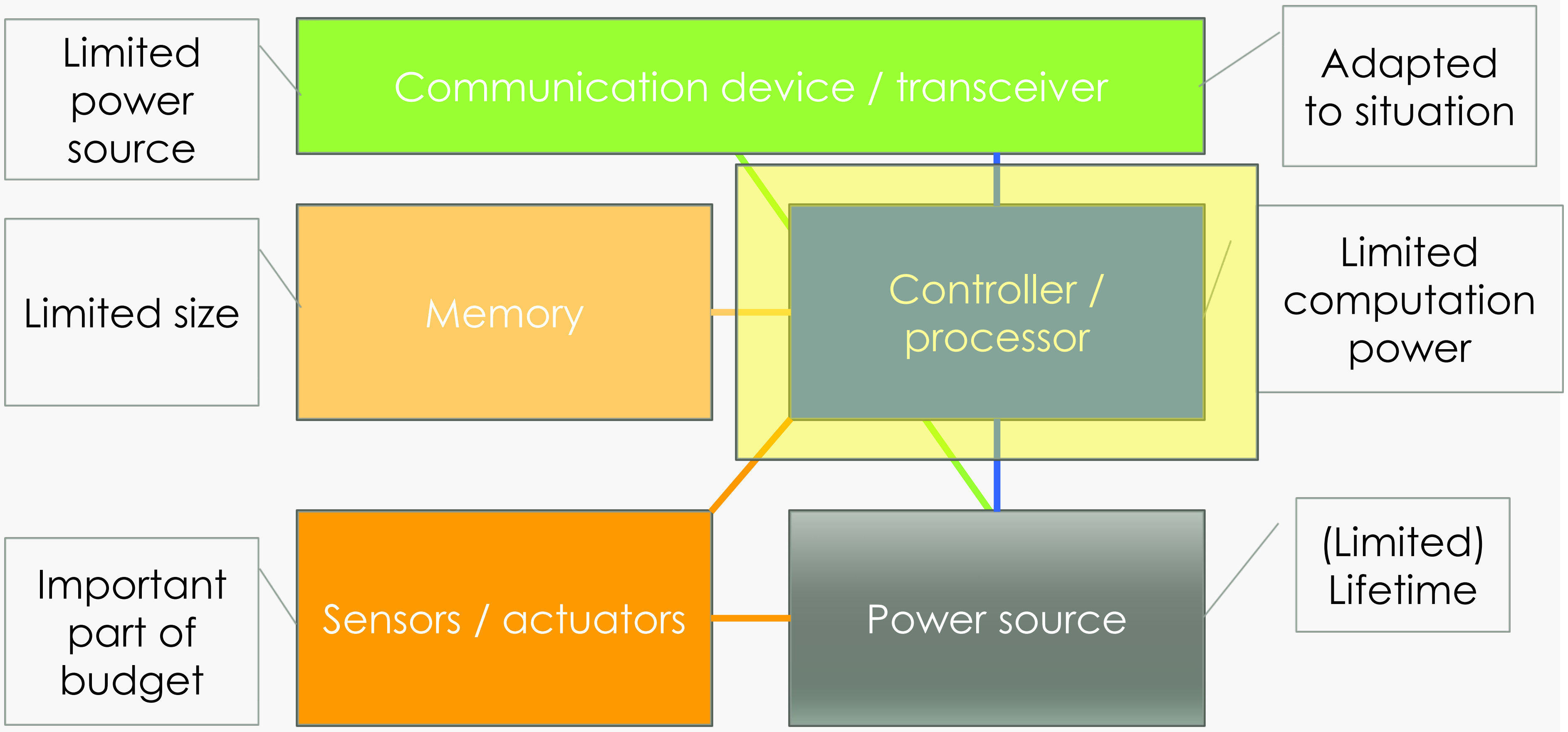


Source: Wireless Sensor Networks / IoT: an overview of wireless technologies, Alain-Serge Porret, CSEM

TYPICAL NODE ARCHITECTURE



MICROCONTROLLER/MICROPROCESSOR



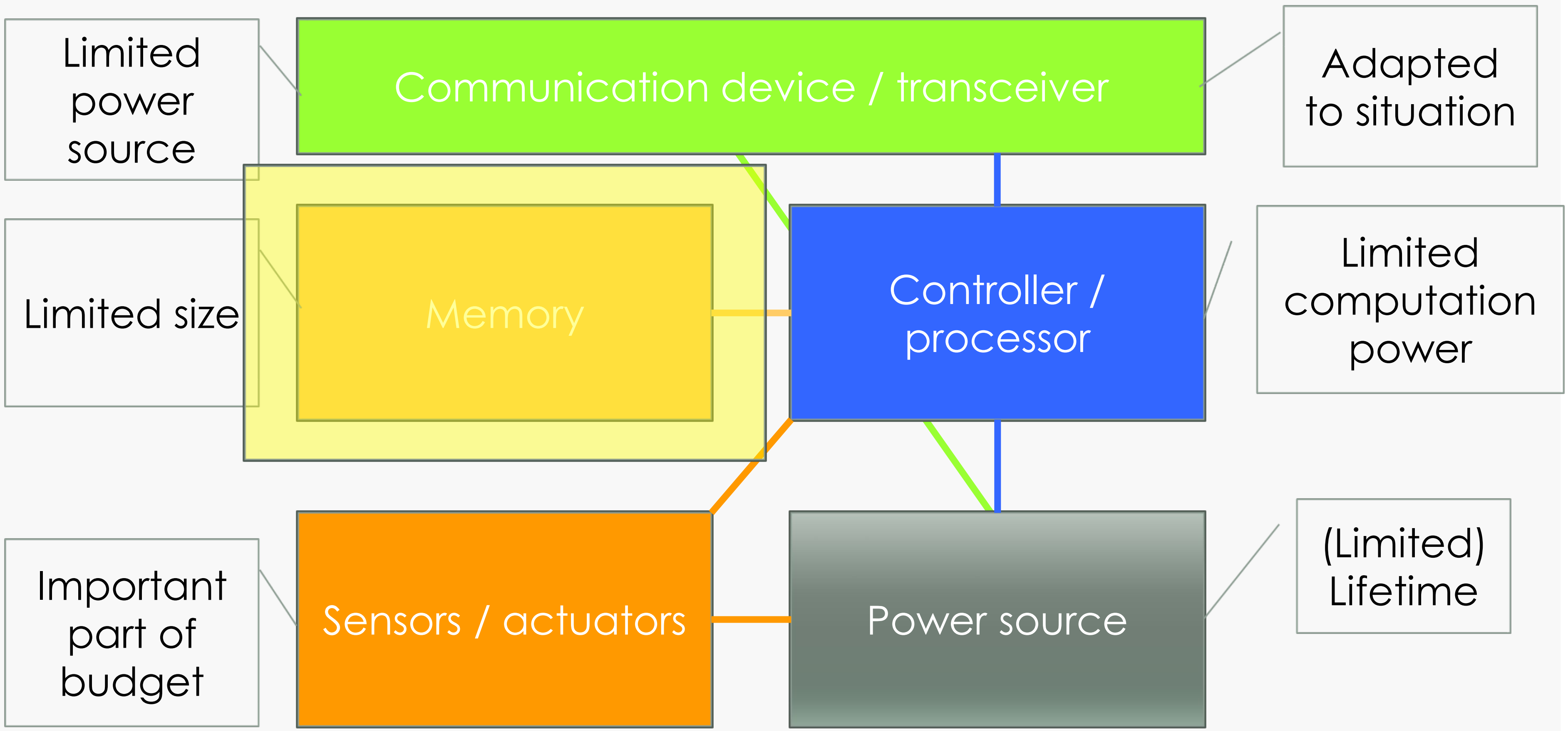
MICROCONTROLLER/MICROPROCESSOR

- The microcontroller is the core of the node
- Mission:
  - Collects data from the sensors
  - Process this data
  - Decides when and where to send it
  - Receives data from other peer devices
  - Decides on the actuator's behaviors
- Part of the processing may be time critical

MICROCONTROLLER/MICROPROCESSOR

- Choice of controller architecture as trade-offs between:
  - Flexibility
  - Performance
  - Energy efficiency
  - Costs
- Choice among:
  - Micro-controllers (general purpose) such as ARM processors
  - Digital Signal processors (DSPs)
  - FPGAs
  - ASICs
- System on Chip (SOC) is very frequent as well
  - Integration of multiple components (controller, memory, communication) in a single integrated circuit

MEMORY

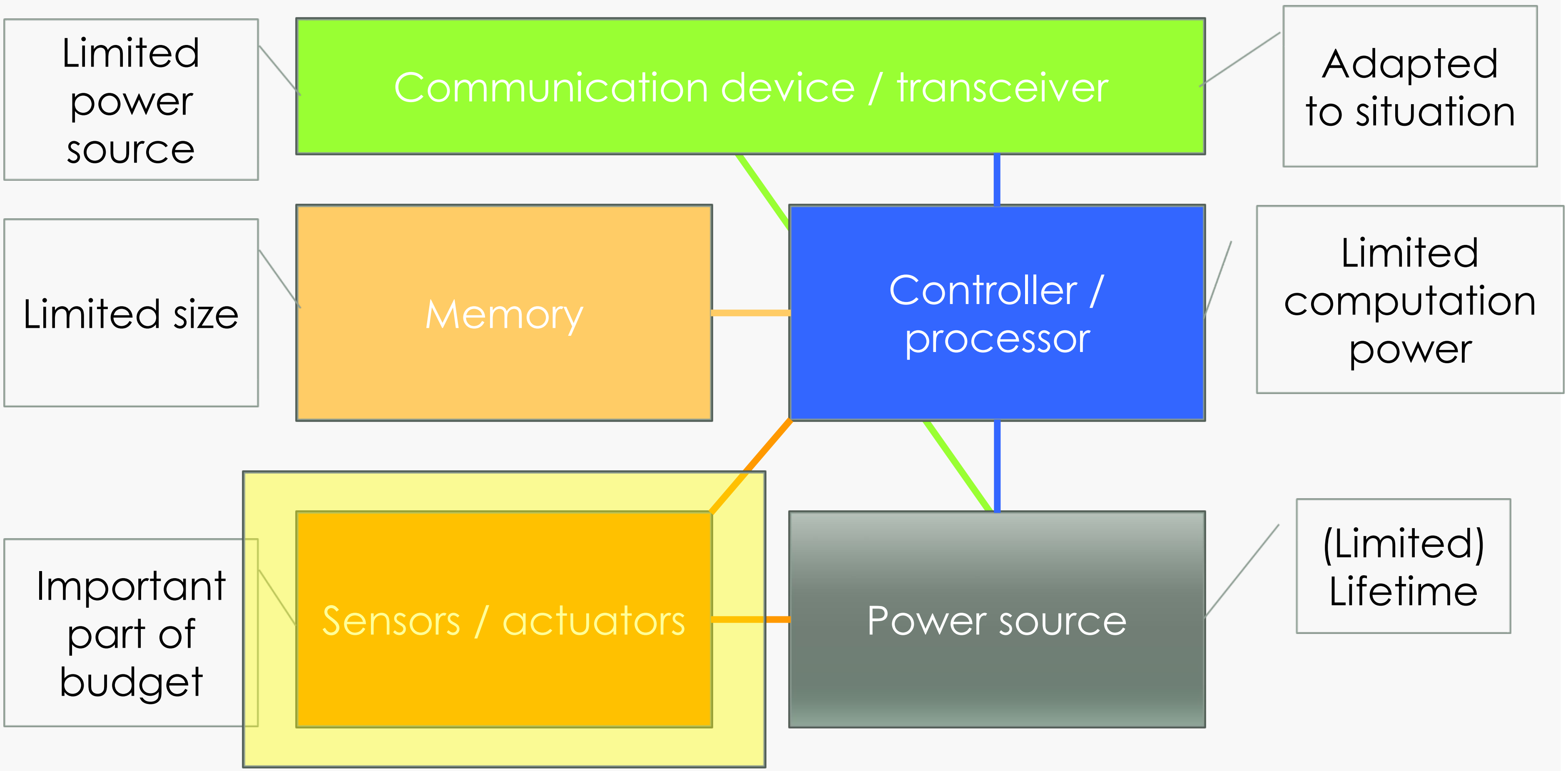


Limited power source
Communication device / transceiver
Adapted to situation
Limited size
Memory
Controller / processor
Limited computation power
Important part of budget
Sensors / actuators
Power source
(Limited) Lifetime

MEMORY

- RAM (Random access memory)
  - SRAM (Static RAM)
  - DRAM (Dynamic RAM)
- ROM (Read only memory)
- EEPROM (Electrically Erasable Programmable ROM)
- Flash memory
  - NOR-Flash
  - NAND-Flash
- Very often: on-chip memory (SOC)

SENSORS/ ACTUATORS



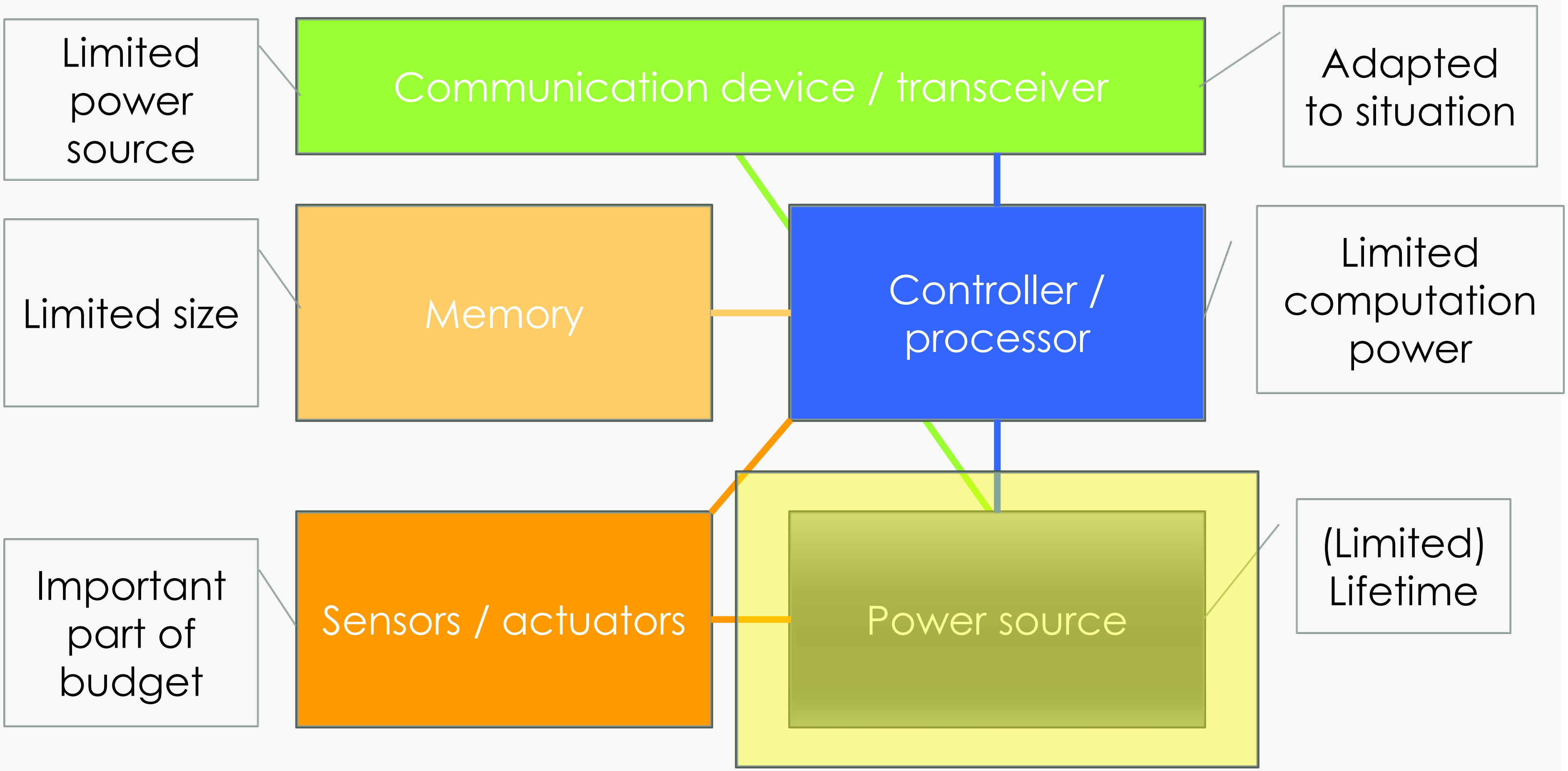
SENSORS

- Passive
  - Measure a physical quantity without active probing
  - Very often self-powered, obtaining the energy they need from the environment
  - Examples: thermometer, light sensor, vibration, microphone, humidity, mechanical stress, chemical sensors
  - Very often short-distance
- Passive, narrow-beam
  - Same but with a well-defined notion of direction of measurement
- Active
  - Get a measurement by probing the environment
  - Very often requires a power source
  - Examples: sonar, radar, seismic sensors
- In all cases, sensors have a specific area of coverage

ACTUATORS

- Actuator:
  - Device containing at least one configurable property or output that can and should be controlled by some other entity or device
- Very often for actuators are for actuating motion
  - Electrical
  - Hydraulic
  - Pneumatic
- Make it possible to automate real-world processes
- Is often paired with a controlling sensor
  - “Never trust an actuator”

POWER SOURCE



POWER SOURCE

- Goal: provide as much energy as possible at
  - Smallest cost
  - Smallest volume
  - Smallest weight
  - Smallest recharge time (if applicable)
  - Biggest longevity
- Options:
  - Primary batteries – not rechargeable
  - Secondary batteries – combined with energy harvesting

BATTERY REQUIREMENTS

- Capacity/energy:
  - Maximize energy per volume, measured in J
  - 1 Wh = 3600 J or 1kWh = 3.6 MJ
  - Typical smartphone battery = 16 Wh = 4200 mAh = 57600 J

Primary batteries			
Chemistry	Zinc-air	Lithium	Alkaline
Energy (J/cm^3)	3780	2880	1200
Secondary batteries			
Chemistry	Lithium	NiMHd	NiCd
Energy (J/cm^3)	1080	860	650

BATTERY REQUIREMENTS

- Low self-discharge / Long shelf live:
  - Under some technologies, batteries are operational only for a few months, even without power drawn from them
- Capacity under load
  - Relationship between current and discharge time
- Efficient recharging at low current
- Voltage stability (to avoid DC-DC conversion)
  - Typically, battery's voltage is reduced as its capacity drops
- Operating temperature
- Cost per energy unit
  - Some technologies are prohibitively expensive (e.g. graphene would make the cost of a smartphone battery around 1500$, as compared to 0.02$ raw material of lithium-ion batteries)

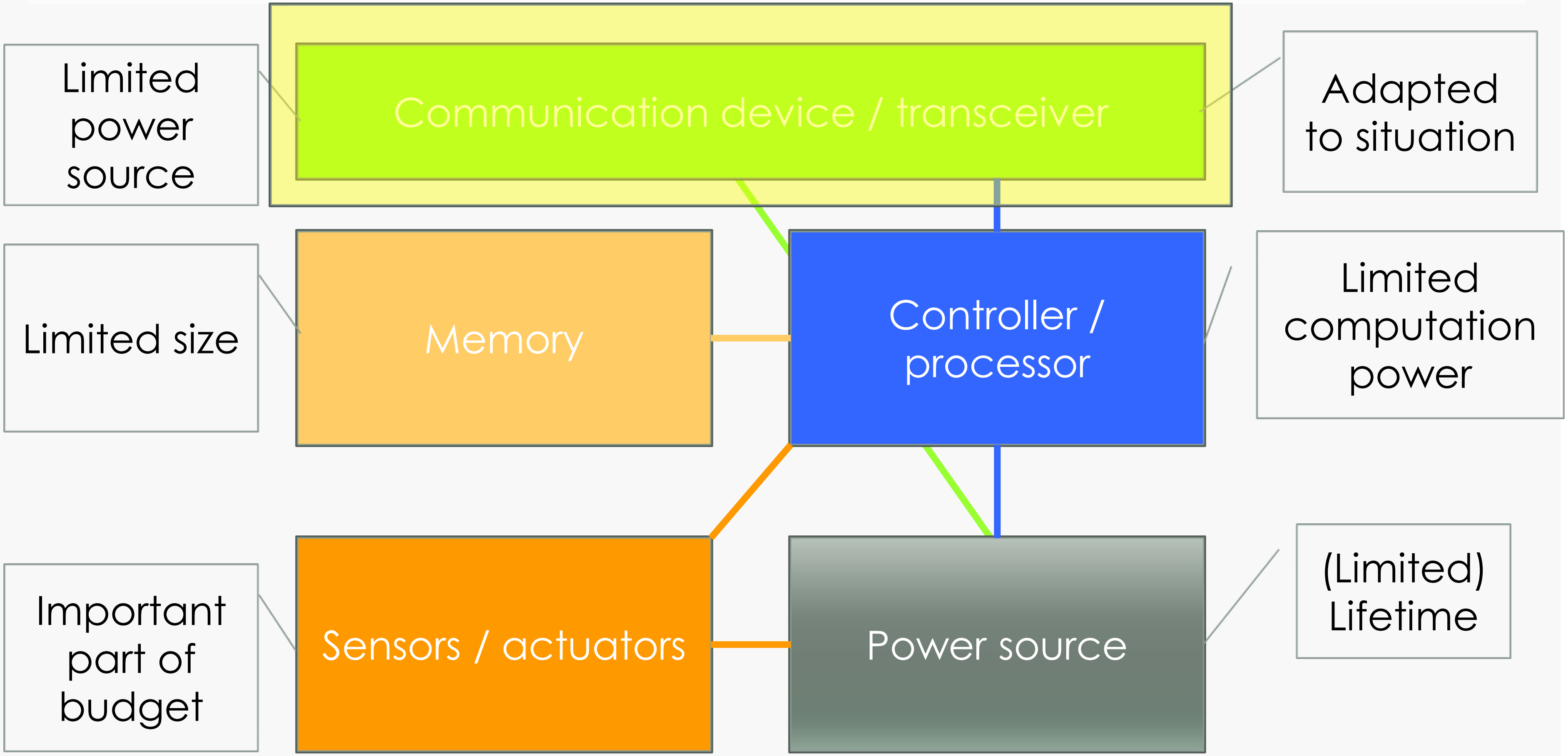
ENERGY CONSUMPTION

- Consumption for instructions
  - Energy per instruction: 1 nJ
  - Assume 1 GHz operation mode
  - Daily consumption is: 1 J/s * 60 * 60 * 24 = 86400 J/day
  - Not possible with either primary or secondary batteries !
  - Battery lifetime is expected to be at least of 1-2 years
- Do NOT run the node at full operation all the time
  - A typical scenario in an IoT architecture is the cyclic sleep scenario, in which a short-range and low-power wireless sensor node periodically sends a data packet to a remote ‘hub’ with intervening sleep intervals
  - Run in power safe mode when nothing to do
    - Processor: active, idle and sleep modes
    - Radio: turn-on/off transmitter and/or receiver

ENERGY HARVESTING/SCAVENGING

- Process by which energy is
  - derived from external sources,
  - captured, and
  - stored for small, wireless autonomous devices
- Typical use:
  - Wearable electronics
  - Wireless sensor networks
- Sources:
  - Solar power
  - Thermal energy
  - Wind energy
  - Salinity gradients
  - Kinetic energy

COMMUNICATION DEVICE



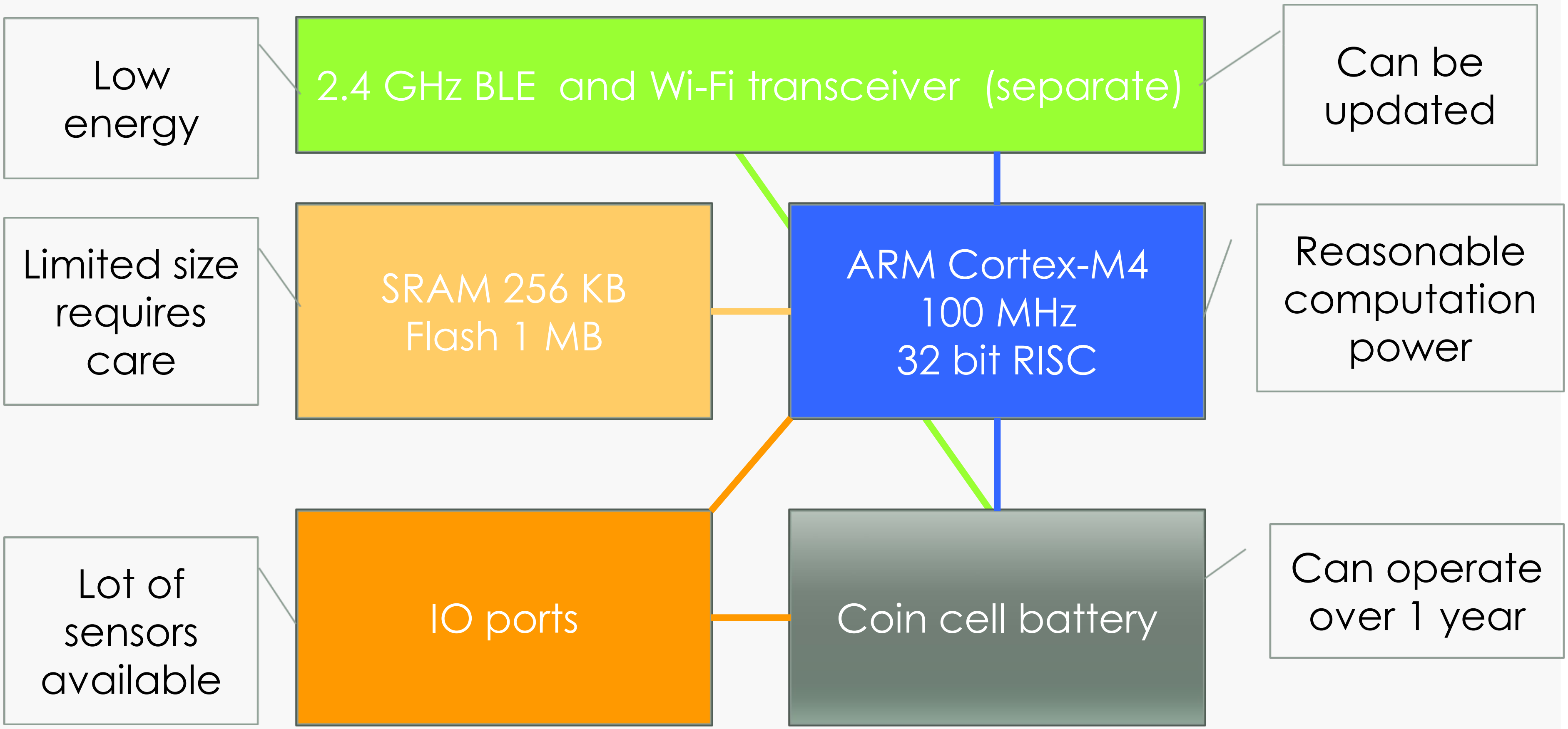
COMMUNICATION DEVICE

- Hardware, including RF, must be conceived for optimizing power consumption in typical IoT scenarios
  - Wake-up listening
- Software, including communication software, must be conceived to minimize
  - Idle listening: listening when no data is available
  - Overhearing: listening to data dedicated to others
  - Oversending: emitting while there is no receiver
  - Collisions: two parties are using the same resource at the same time
  - Protocol overhead: data that is not directly used for the applications

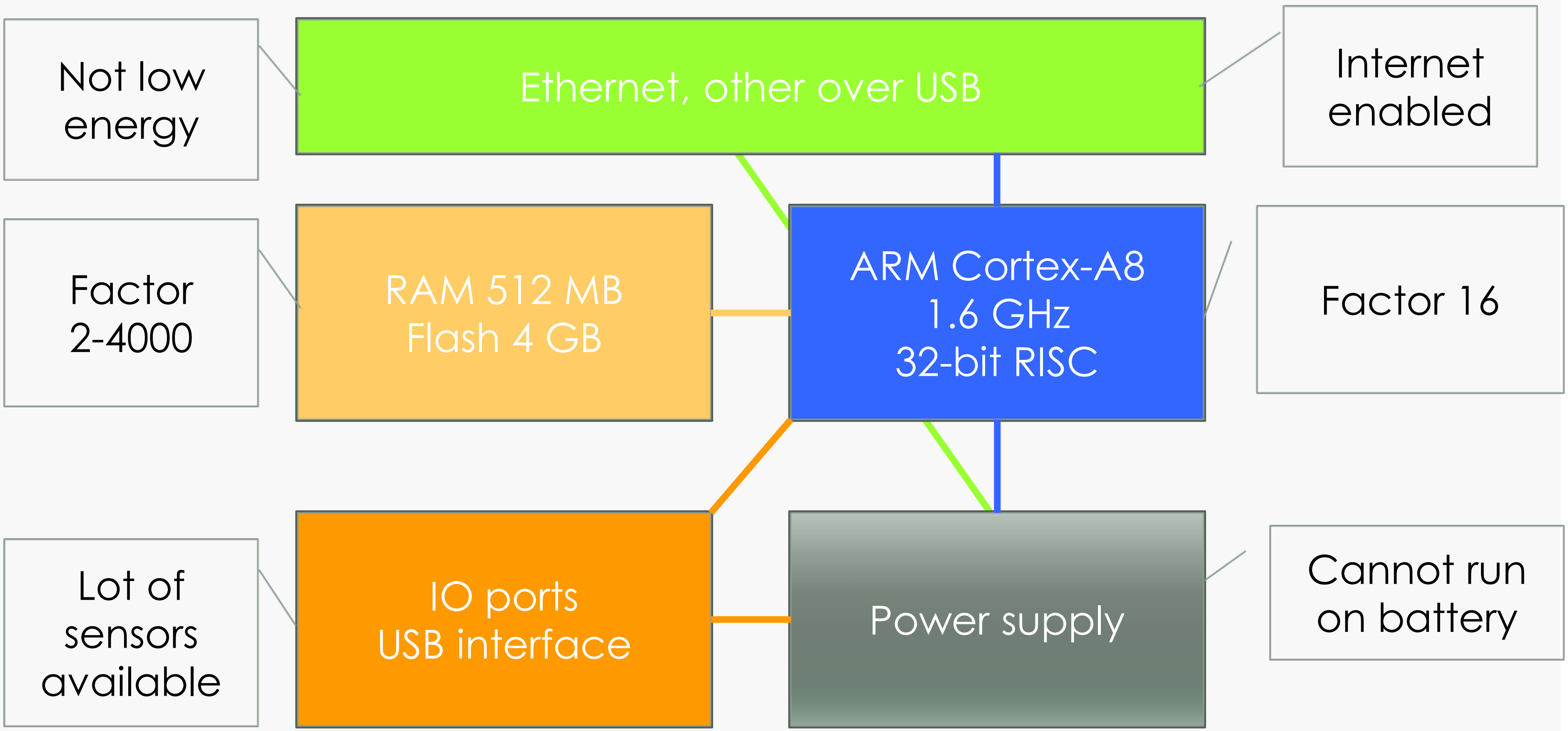
CHALLENGES FOR IOT SYSTEMS

- Hardware
  - Cost – has to be low
  - Sensors – have to be small
  - Lifetime – maximize
  - Robustness and fault tolerance – adapted to the application
  - Configuration – easy and self
- Software
  - Security
  - Robustness
  - Operating system – optimized for low power

OUR DEVELOPMENT PLATFORM 32F412 DISCOVERY/ STM32F412ZG



BEAGLEBONE


Not low energy
Ethernet, other over USB
Internet enabled
Factor 2-4000
RAM 512 MB
Flash 4 GB
ARM Cortex-A8
1.6 GHz
32-bit RISC
Factor 16
Lot of sensors available
IO ports
USB interface
Power supply
Cannot run on battery