Advanced Communication Technologies (CCE534)

Lecture 3

IoT Architecture and Core IoT Modules

(Part 2: Actuators, Controllers, and Power)

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Endpoints (sensors and Actuators)

Endpoints:

- The Internet of Things (IoT) begins with endpoints that are the things associated with the internet
- Those endpoints are either sources of data (Sensors) or devices that perform an action (Actuators).
- It is referred usually as input and output transducers as they convert or transduce energy of one kind into another.

Endpoints (sensors and Actuators)

Actuators:

- Actuators are mainly the output components in the IoT Ecosystem.
- An actuator is the mechanism by which a control system acts upon an environment
- An actuator requires a control signal and a source of energy.
- Upon receiving a control signal, the actuator responds by converting the energy into another form that change the environment like mechanical motion, audio or video output, and turning lights, etc.

Endpoints (sensors and Actuators)

General Actuators Types:

- **Generally 4 types:**
  - ✓ **Electric: use electricity to activate output to the environment**
  - ✓ **Hydraulic: use hydraulic power, powerful but slow**
  - ✓ **Pneumatic: use compressed air, rapid delivery**
  - ✓ **Mechanical: use other mechanical energy**

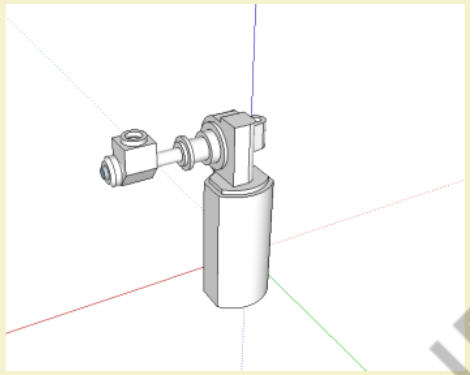


Fig: A motor drive-based rotary actuator

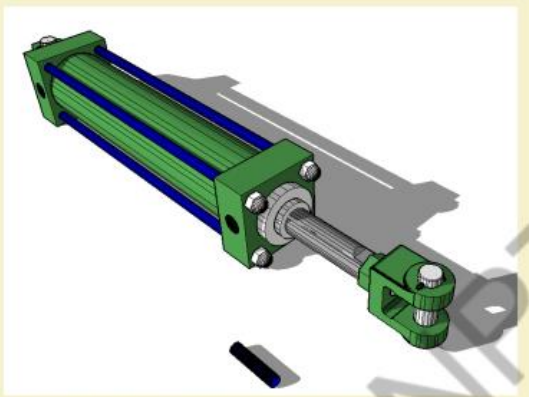


Fig: An oil based hydraulic actuator

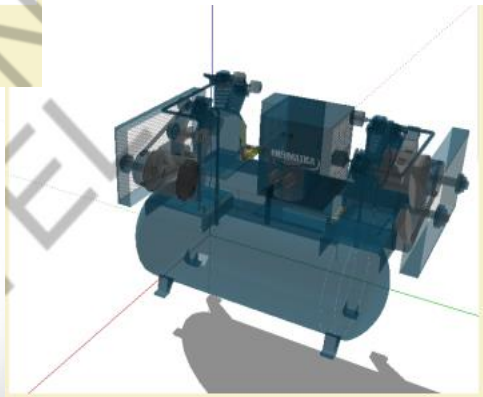


Fig: An air pump acts as a pneumatic actuator

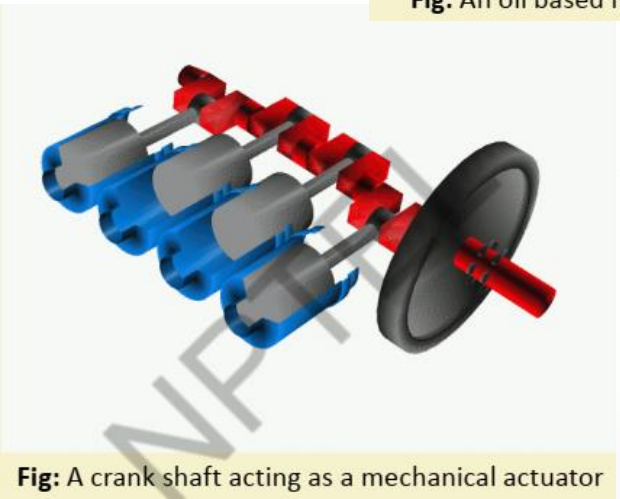
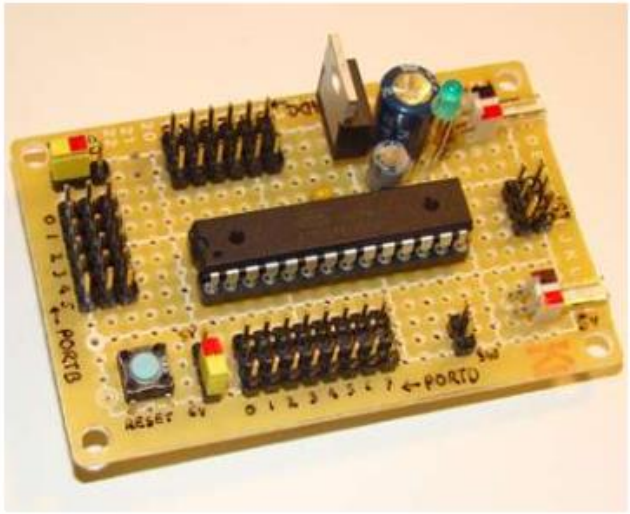


Fig: A crank shaft acting as a mechanical actuator

IoT Node Controller (Brain)

- **Several types of controllers can be used in IoT nodes including the following modules:**

1. Microcontroller Chips



- Small programmable device
- There are different types from different vendors (PIC, Microchip,…etc.)

IoT Node Controller (Brain)

- **Several types of controllers can be used in IoT nodes including the following modules:**

2. Arduino Family

- Small programmable device
- Easily connectable
- Open source
- Has a simple to use software
- Multiple cheap peripherals and sensors modules that are ready to be connected directly

IoT Node Controller (Brain)

- **Several types of controllers can be used in IoT nodes including the following modules:**

3. Raspberry Pi

- A mini Computer board
- Runs Linux
- More software oriented programming
- Full Networking System

IoT Node Controller (Brain)

- **Several types of controllers can be used in IoT nodes including the following modules:**

4. Other Platforms

Intel® Galileo
$50
400 MHz Quark x86
256 MB RAM

Intel® Edison
$70

1 GHz Dual Core Atom x86
1 GB RAM
WiFi
BLE
4 GB Flash

Parallella
$99
1 GHz Dual Core Zynq ARM
16 or 64 Epiphany CPUs

UDOO Neo
$50
i.MX 6 Solo ARM, GPU
ARM M4
512 MB or 1 GB RAM

Powering IoT Nodes:

- Every IoT node needs power to function
- Several techniques can be used according to application and constraints

✓ Grid-based Nodes
  - The IoT node is connected using an adaptor to the electricity grid
  - Usually the power consumption of the IoT node in this model is not an issue since it is not energy-limited

✓ Energy-limited Nodes
  - The IoT node is not connected to the electricity grid but use another source
  - The power consumption is critical for energy-limited

Powering IoT Nodes:

- ✓ Types of Energy-limited Nodes:
  a) Battery-based Nodes
  b) Energy-Harvesting Enabled Nodes
  c) Backscattering Enabled Nodes (Battery-less)

Powering IoT Nodes:

a) Battery-based Nodes

Type	2x AAA	CR2032	CR123A	CR2
Material	Alkaline	LiMnO2*	Lithium	Lithium
Voltage	3 V	3 V	3 V	3 V
Capacity	1000 mAh	225 mAh	1500 mAh	800 mAh
Diameter	10.5 mm (x2)	20 mm	17 mm	15.6 mm
Height	45 mm	3.2 mm	34 mm	27 mm
Weight	24 g	3 g	17 g	11 g

*Lithium Manganese Dioxide

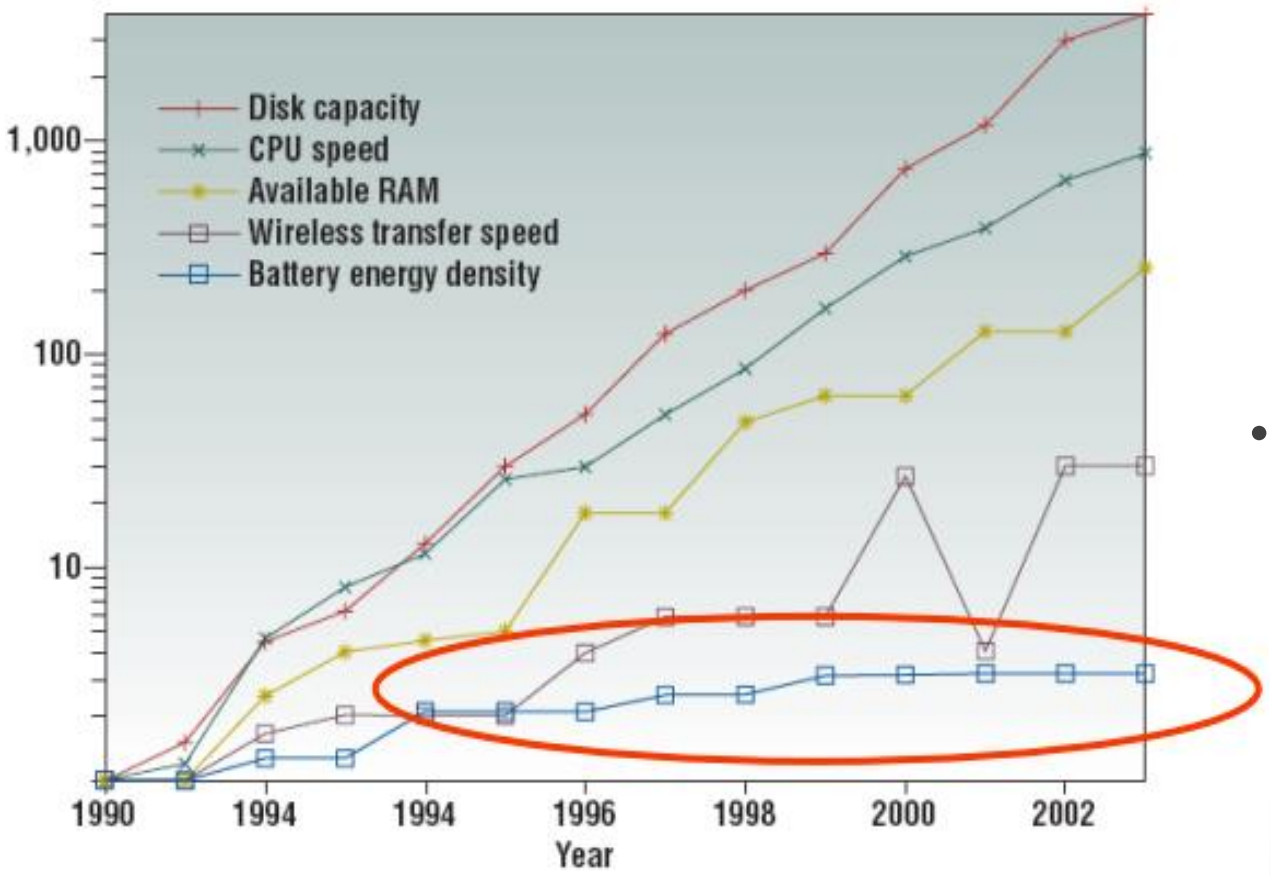
Powering IoT Nodes:

a) Battery-based Nodes

- The battery replacement is a problem in this type, especially for IoT nodes deployed in dangerous areas or hostile environments.
- Additionally, the batteries replacement is not practical in IoT systems with large number of nodes.
- The IoT node size is limited by the battery type

Powering IoT Nodes:

a) Battery-based Nodes



Mobile Computing Improvement – Paradiso, *et al.* Pervasive Computing, IEEE, 2005.

Relative Improvement in Laptop Technology

- **Battery improvement is the slowest trend**

Powering IoT Nodes:

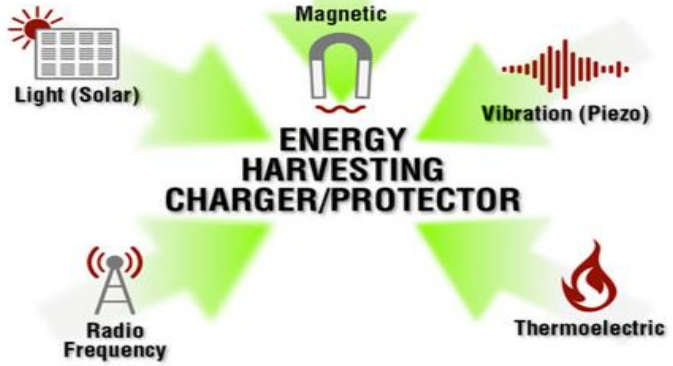
b) Energy-Harvesting (EH) Enabled Nodes

- EH also known as Power Harvesting or Energy Scavenging, is the process in which energy is captured from a variety of ambient energy sources and converted into usable electric power.
- Energy harvesters provide a very small amount of power for low-energy electronics.
- EH allows electronics to operate where there's no conventional power source, eliminating the need for wires or replacement of batteries.
- EH systems generally includes circuitry to charge an energy storage cell, and manage the power, providing regulation and protection.

Powering IoT Nodes:

b) Energy-Harvesting (EH) Enabled Nodes

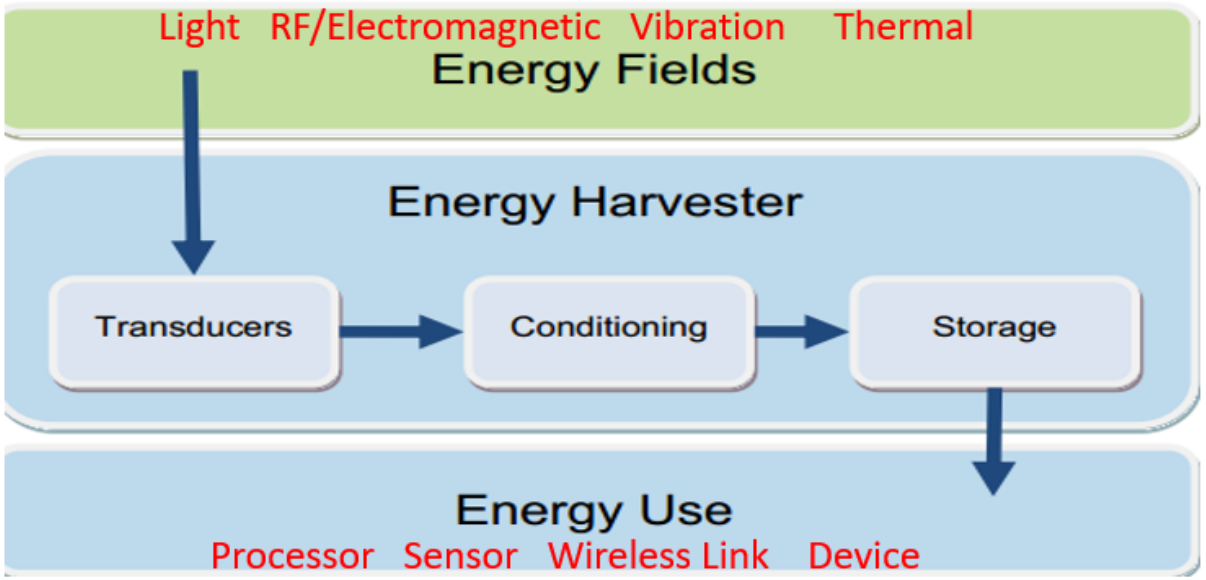
- EH-powered systems need reliable energy generation, storage and delivery
- Must have energy storage as energy source is not always available (solar at night, motor vibration at rest, etc.)
- There are 4 main ambient energy sources present in our environment:
  1. Mechanical energy (vibrations, deformations)
  2. Thermal energy (temperature gradients or variations)
  3. RF energy (radio transmissions)
  4. Solar energy (sun)



Powering IoT Nodes:

How Energy Harvesting works?

- An energy harvester comprises one or more transducers, power conditioning, and energy storage.
- These technologies work together to collect energy and deliver power to the device.
- On the other hand, the device which uses the energy needs to be designed to work with energy harvesting as the power source.



Powering IoT Nodes:

How Energy Harvesting works?

- **The transducer:** converts energy from one energy type to a another energy type, usually electricity.

- **Power conditioning:** is necessary because the natural output of the transducer can be intermittent, and at the wrong frequency, voltage and current to directly drive the device.
  - ✓ **A DC-DC converter microchip** takes in power from the transducer and convert to voltages which can then be stored or used.

Powering IoT Nodes:

How Energy Harvesting works?

- **Energy storage**: is needed to balance the energy supply and energy demand.
- Usually a rechargeable battery, capacitor, or supercapacitor is used as the storage element.

Powering IoT Nodes:

Design Considerations for Energy Harvesting

1. Know the available energy in the environment
   - ✓ Indoor solar is in tens to hundreds of micro watts
2. Determine the Energy conversion efficiency
3. Avoid components with excessive leakage
4. Calculate the application power consumption in all modes of operations
5. Use sleep mode when possible to save energy
6. Design energy-efficient protocols
7. Use suitable energy storage elements

Powering IoT Nodes:

c) Backscattering Enabled Nodes (Battery-less)

- Backscattering communication is used to enable low-size, low-cost, and massive IoT connections
- We exploits the ambient RF energy in the environment by re-modulating the received RF signals using the information to be transmitted.
- There is no need of battery (battery-less), however there is some hybrid systems that merge between RF EH and RF backscattering.
- The ambient RF signals may be
  - ✓ Radio/TV transmission
  - ✓ Cellular Signals
  - ✓ WiFi signals
  - ✓ Dedicated RF source
- The most widely-used backscattering type is the RFID

Assignment

- Prepare a report on one of the following topics
- Prepare a 20-30 minutes presentation based on your report
- Students are divided into teams of 4
- The evaluation is 10 degrees
- Best team will get 2 degrees bonus
- Use references but write using your own words (No copy and past)

1. Backscattering Communications: Categories and Applications
2. Radio-frequency Harvesting: Circuits and Applications
3. Solar Energy Harvesting

References

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Thank You