ECE 1175
Embedded System Design

Internet of Things

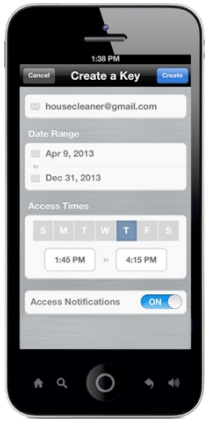
Wei Gao

Internet of Things

- Mostly about embedded devices that interact with the physical world, not the Internet
  - “humans optional”

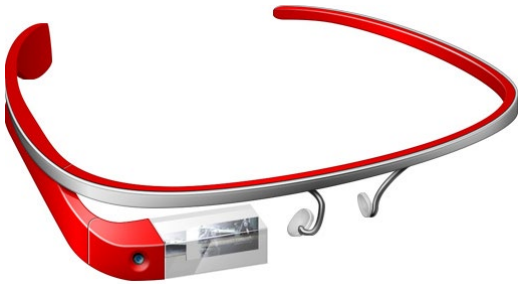
- Software-controlled networked devices

Evolution of Physical Devices



More Evolutions

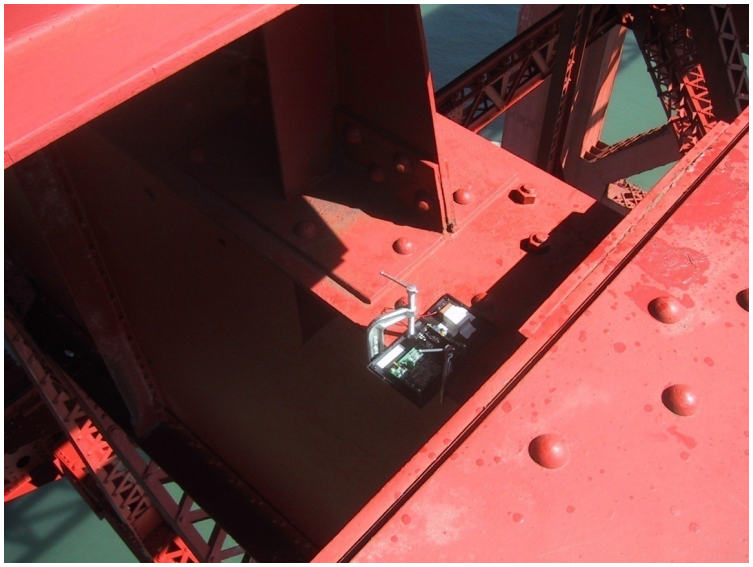
Computerization



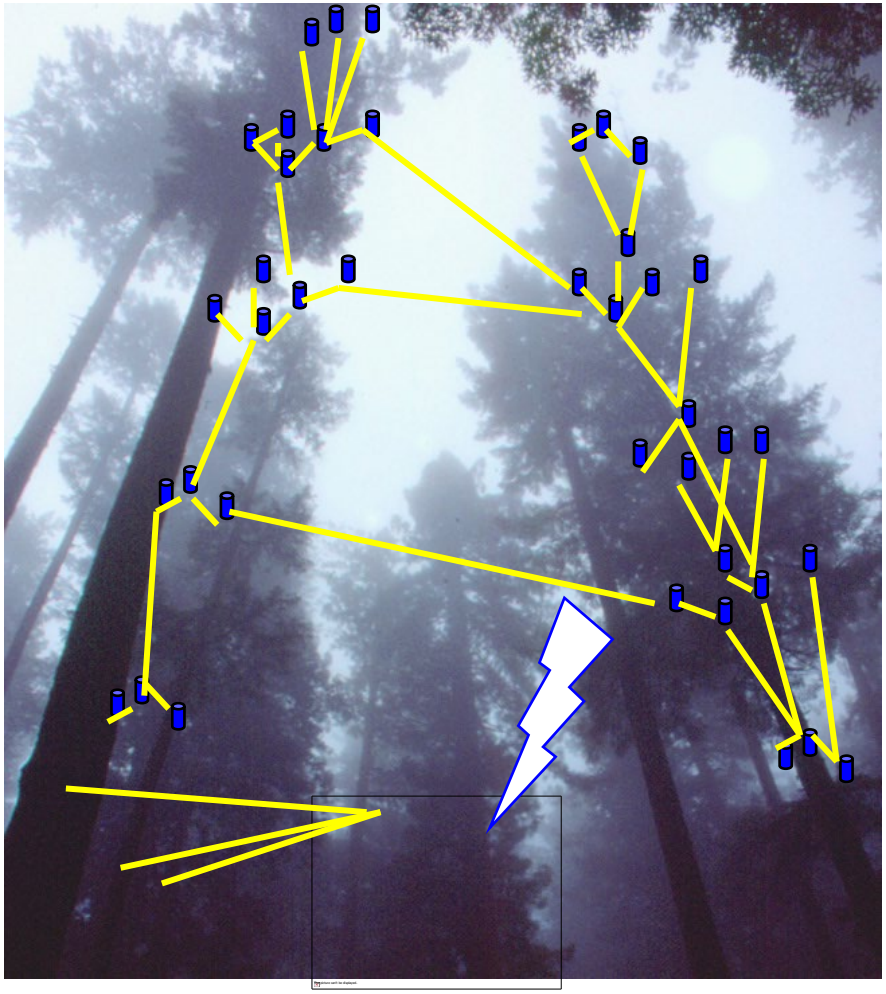
Evolution of Terms

- Wireless Sensor Networks (pre-2000s)
- Cyber-Physical Systems (2000-2010)
- Internet of Things (2015-now)

Wireless Sensor Networks

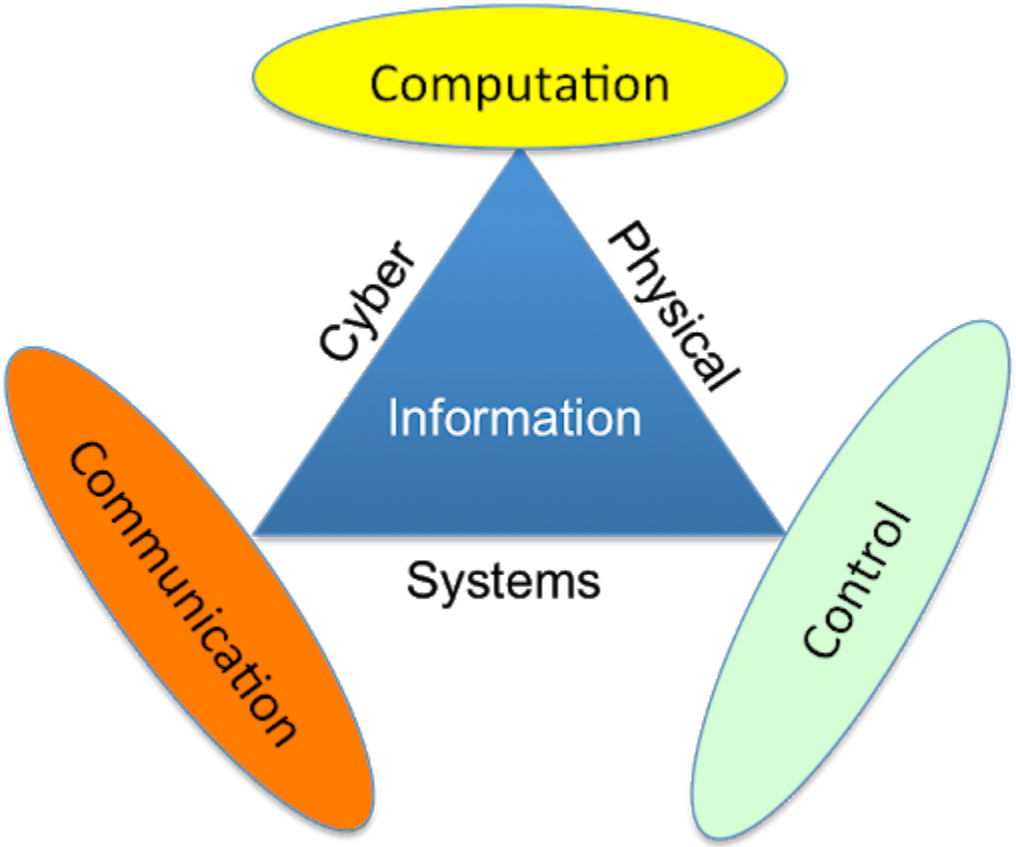


Structure health monitoring

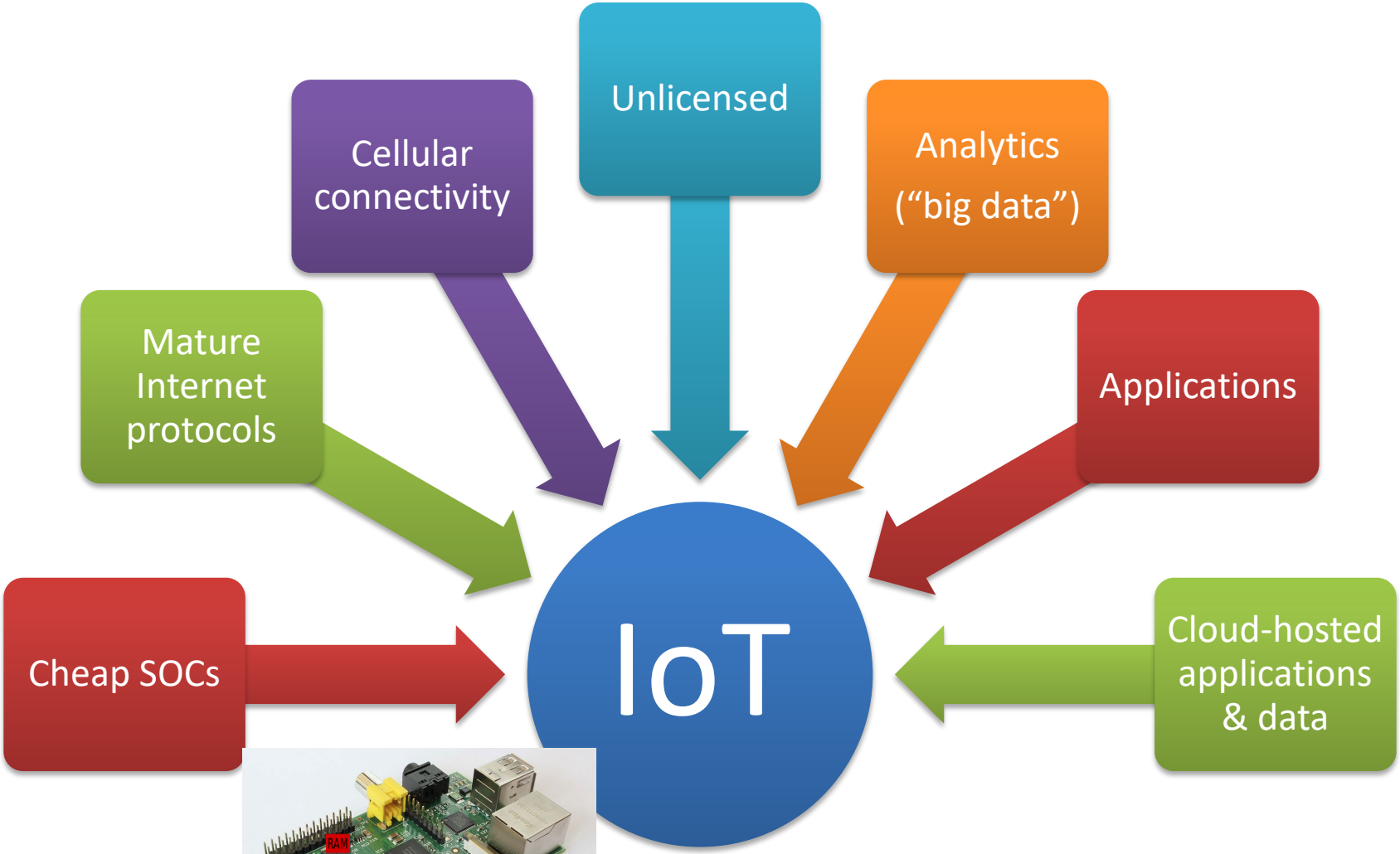


Environmental surveillance

Cyber-Physical Systems



Internet of Things



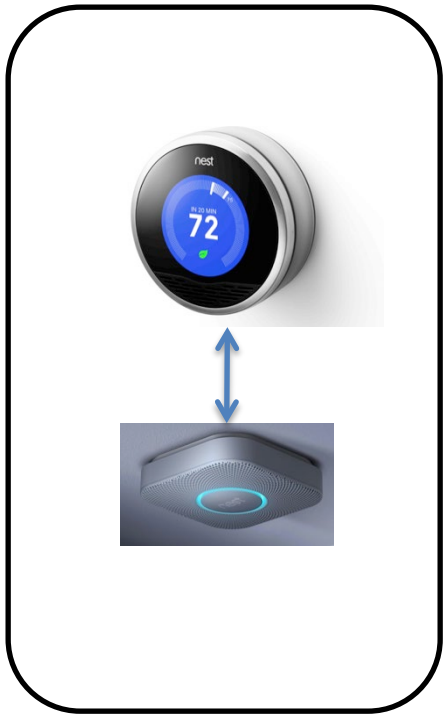
Design Challenges

	Node	Network	Program	Example
IoT	re-usability	interoperability	heterogeneous & loosely coupled	VoIP thermostat
CPS	real-time guarantees	predictability & redundancy	model verification	avionics industrial control
WSN	energy efficiency	minimize communication	homogeneous minimal OS	structural monitoring (bridge)

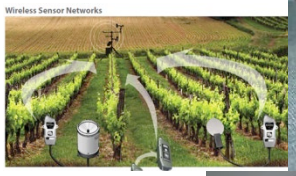
Where does IoT make sense?

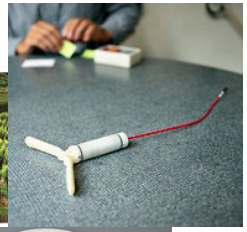
- Automate manual data extraction
  - health, car, electric/gas meter, …
- Remote maintenance
  - vending machines, appliances, cars & trucks, trains, pumps, …
- Incorporate additional information
  - thermostats, light switches, traffic lights, parking meters, …
- SDM = Software-Defined Mechanics
  - locks, light switches
- But where does it solve more than 1st world problems?
  - commercial maintenance and OpEx savings
  - in-home customizable assistive technology

IoT Islands vs. IoT Ecosystem

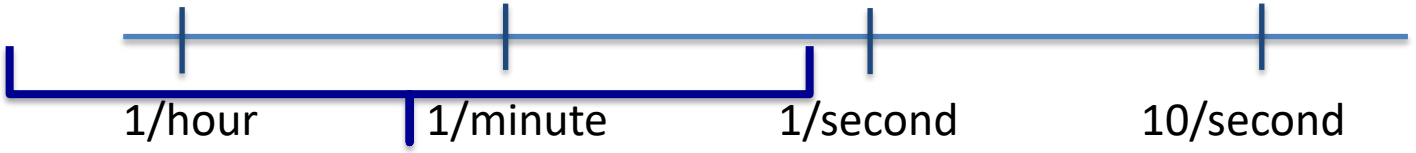


IoT varies in communication needs





sensors



actuators

Communication Challenges: Concurrency

< 2010

212 555 1212

500 123 4567
(and geographic numbers)

OnStar by GM

500 123 4567
533, 544

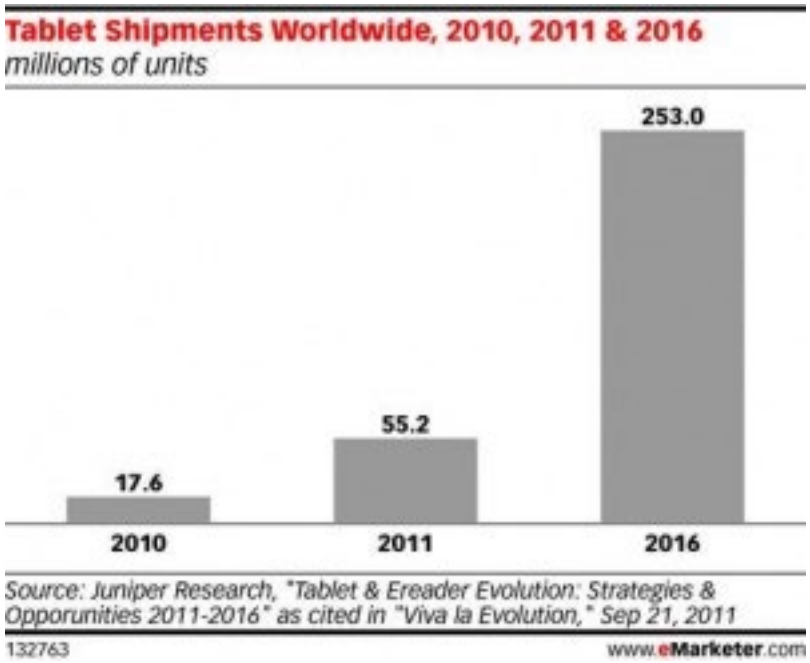
5 mio.

311,000

64 mio.

44.9 mio.

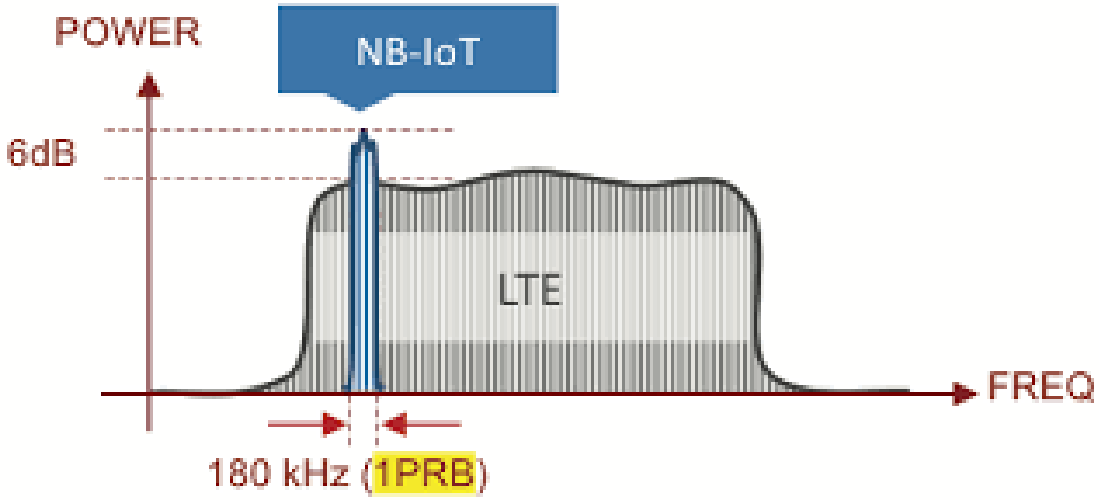
254 mio.



10 billion +1 #'s available

Solution to Communication

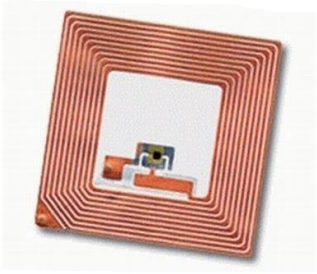
- Narrowband-IoT (NB-IoT)

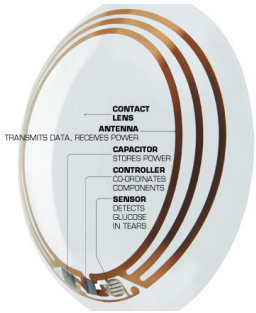


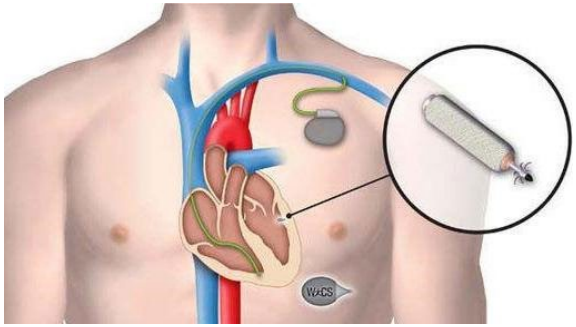
Sensing & Computing Challenge: Lifetime

- Battery-powered devices

- Batteryless devices





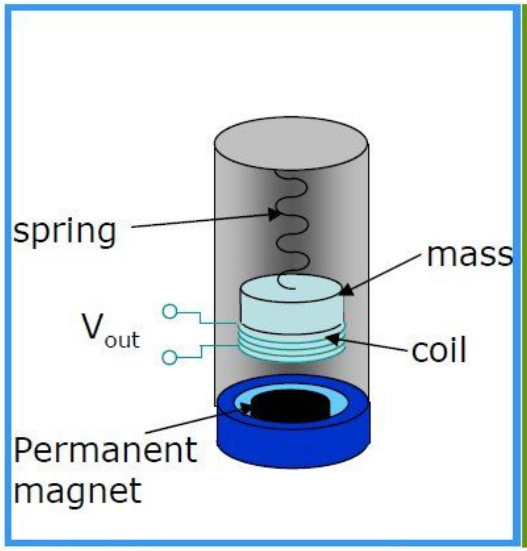


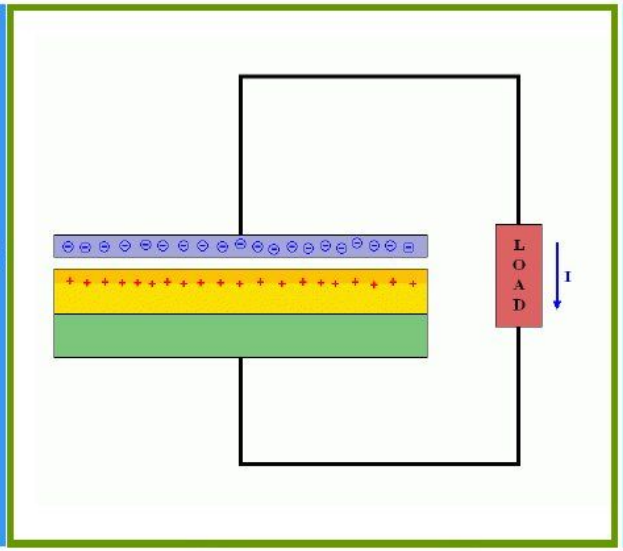
Solution: Energy Harvesting

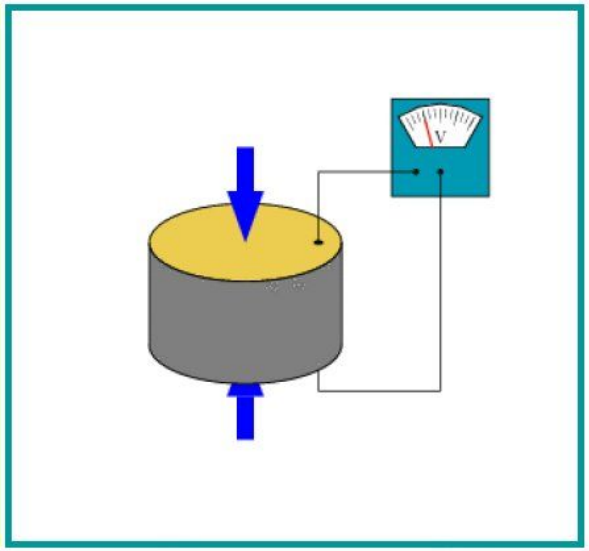
- Electrical power generation at miniatured devices
- Sources of energy
  - Solar/wind power

  - Kinetic movement
  - RF signals

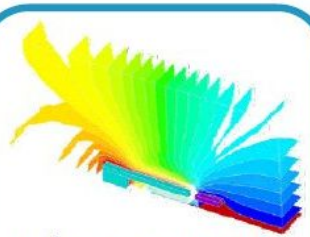
Energy Harvesting from Kinetic Movement



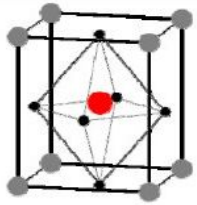




Electro-magnetic

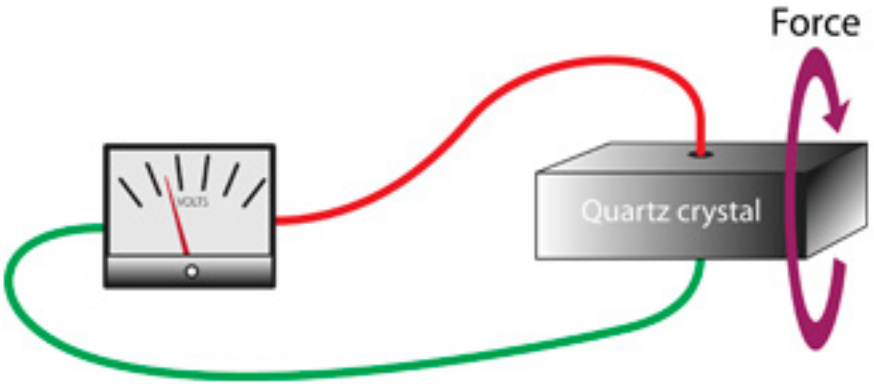


Electrostatic

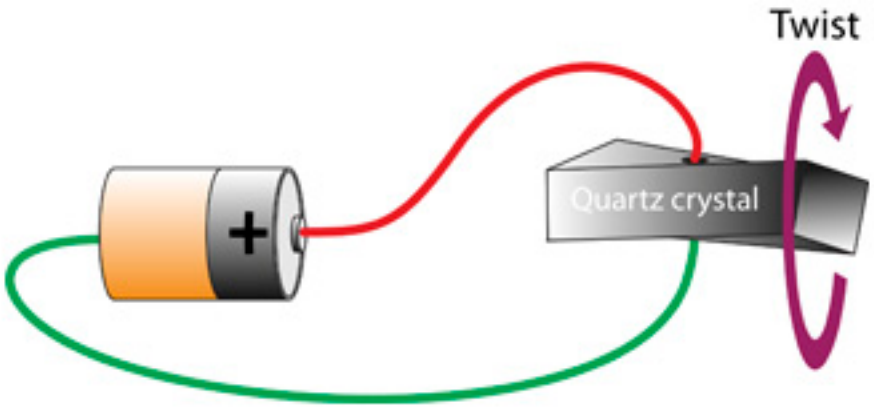


Piezoelectric

Piezoelectric



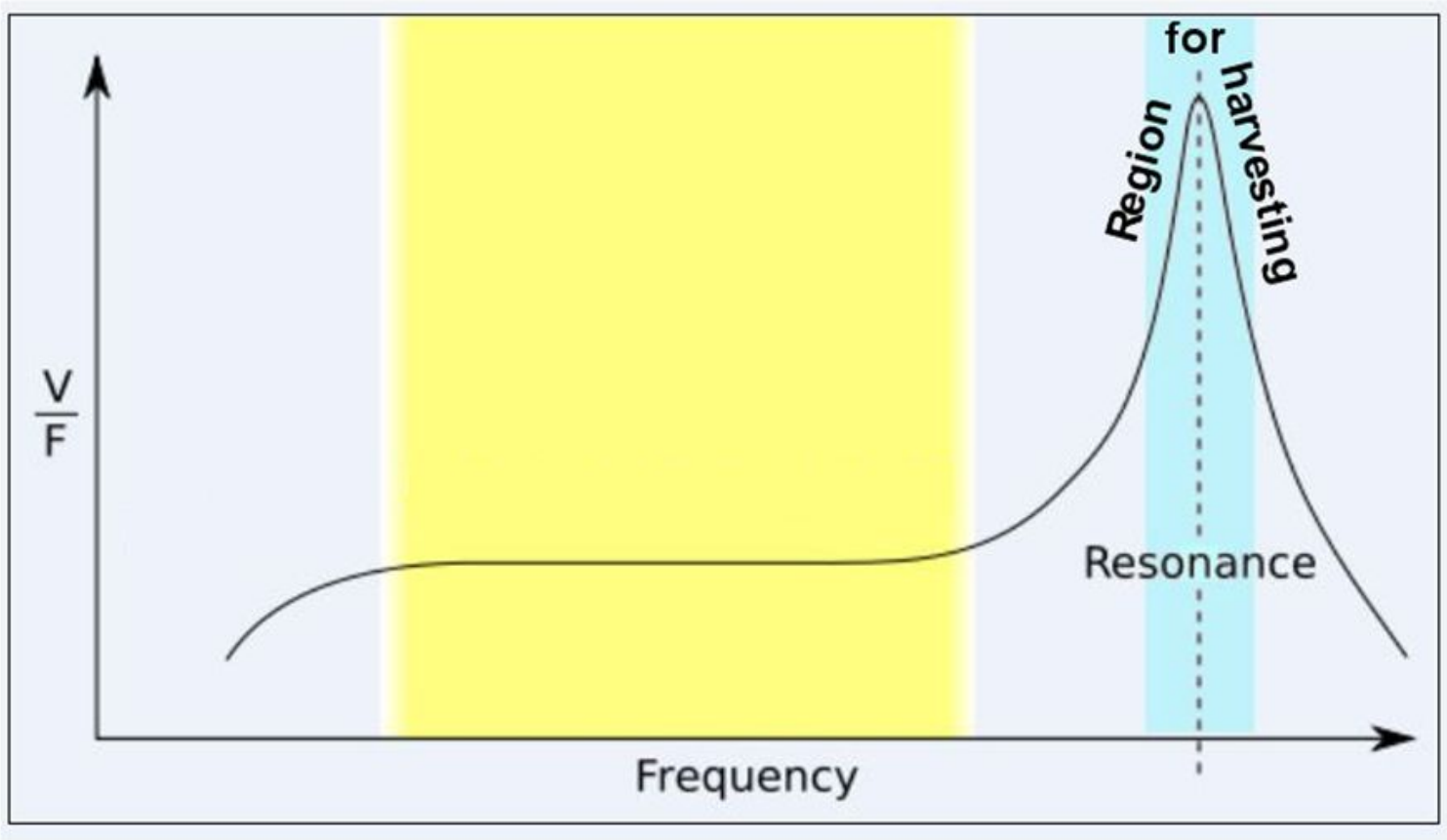
Piezoelectricity is the ability of certain materials to produce a voltage when subjected to mechanical stress.



Piezoelectric materials also show the opposite effect, where application of an electrical field creates mechanical stress (size modification) in the crystal.

Piezoelectric Frequency Response

- Vibrations at a certain frequency band

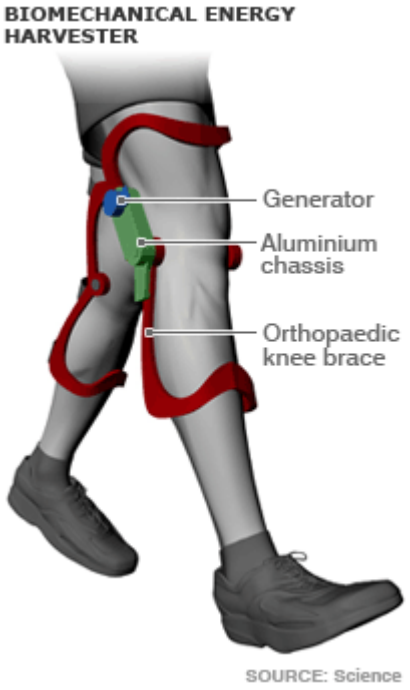


Application - Wearables

- Smart clothes

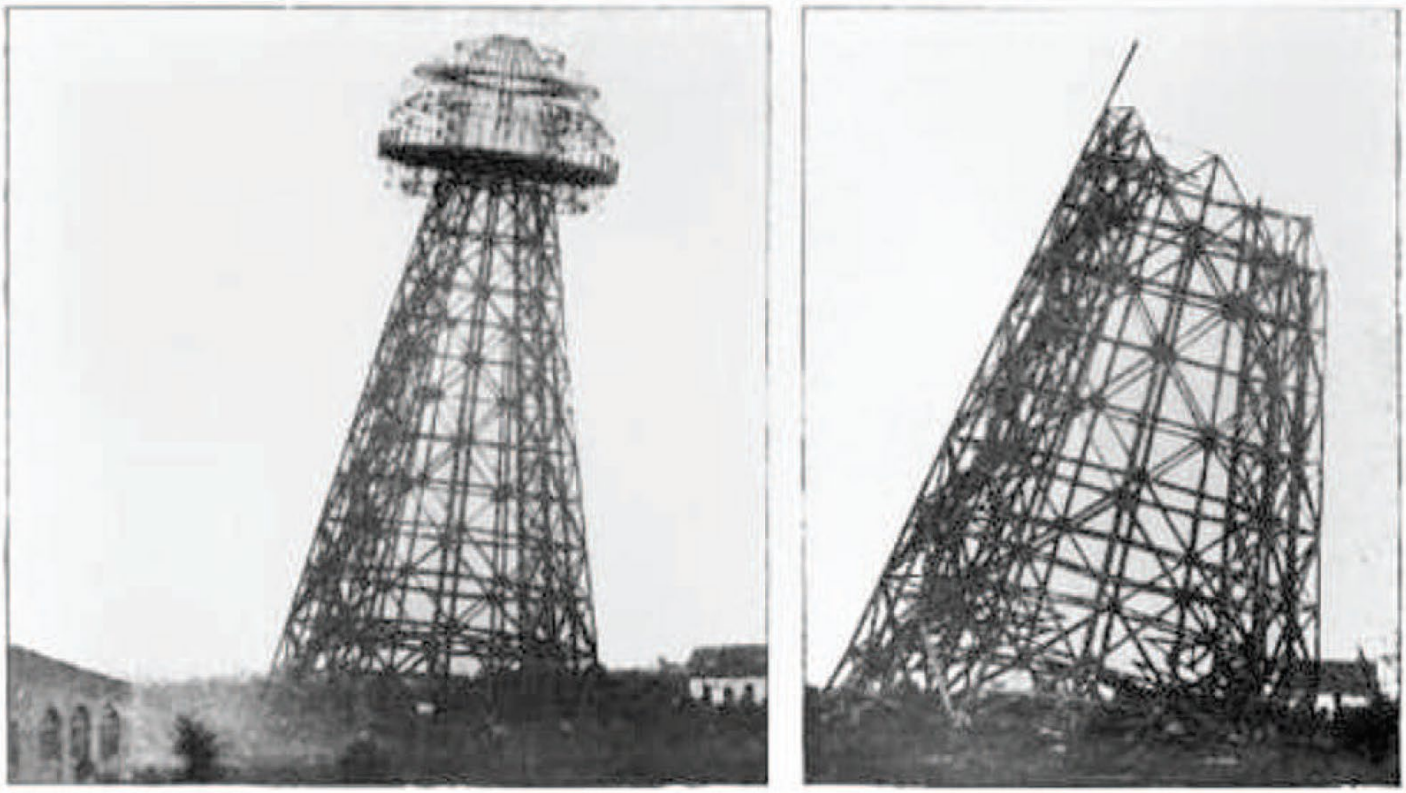
Application - Wearables

- Biomechanical systems



Energy Harvesting from RF Signals

- Early story: Tesla's dream
  - Transmitting 300kW power via 150kHz RF waves



Energy Harvesting from RF Signals

- What do we have now:
  - Transmitting 5W power via 150kHz RF waves

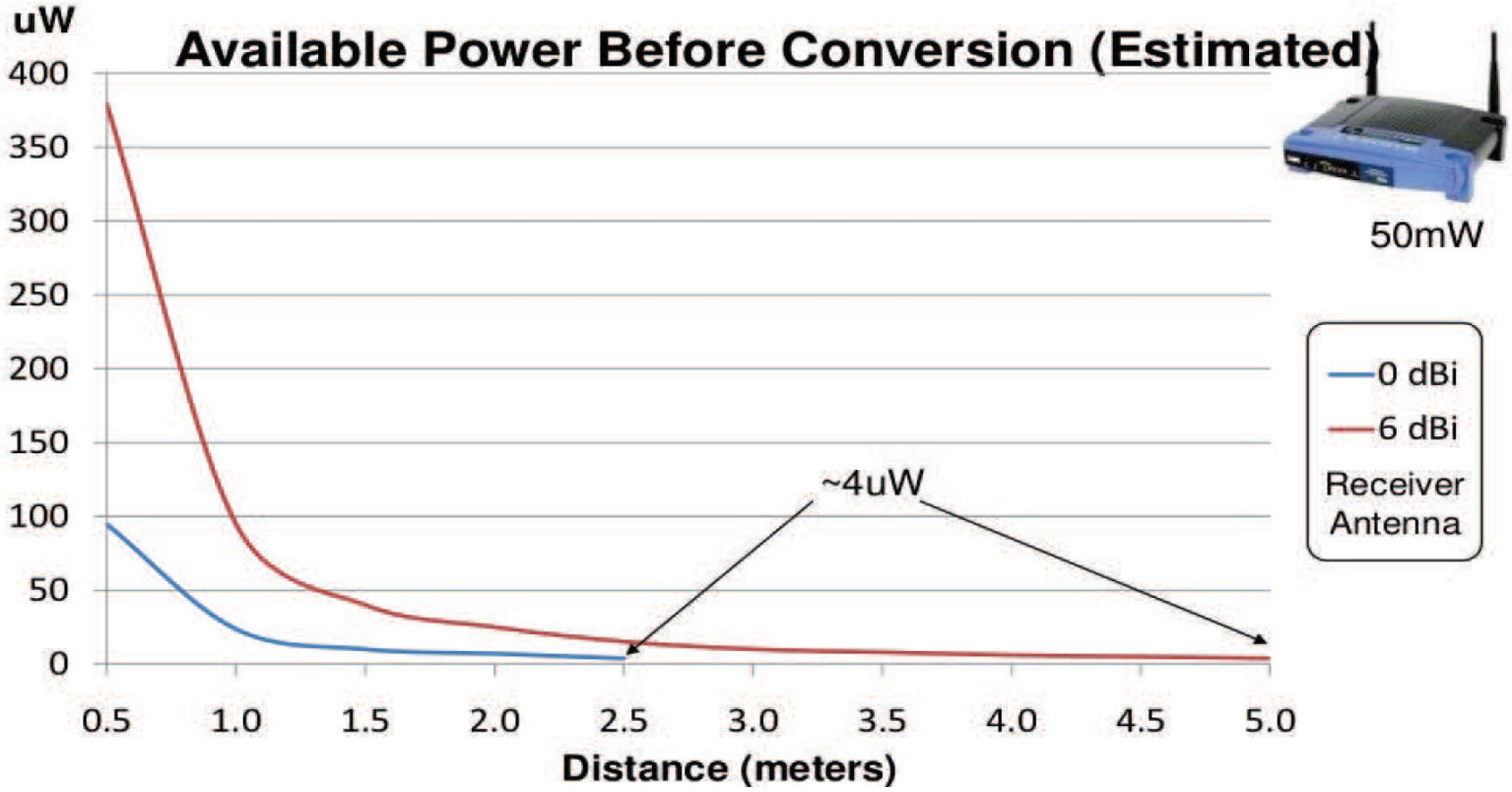
Energy Harvesting from RF Signals

- What do we expect?

Power

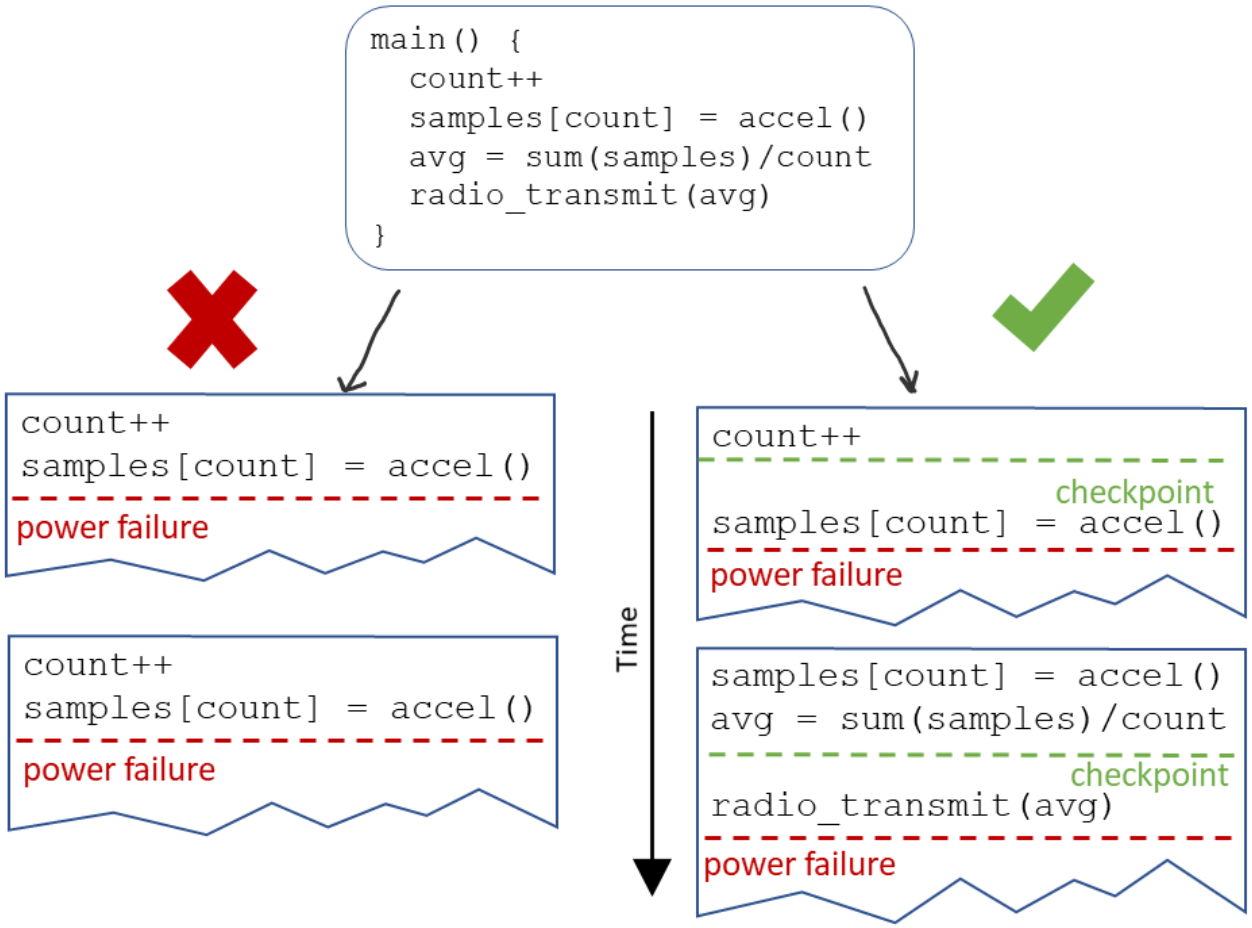
Key challenge

- EM power attenuation over distance



Intermittent Computing

- You may lose power in the middle of computing!



Summary

- Internet of Things: computerize every physical "thing"
- A connected ecosystem
- Brings new challenges in communication, sensing and computing
  - Big concurrency
  - The power source
- Solutions
  - NB-IoT
  - Energy harvesting