Suat Özdemir, PhD

Wireless Sensor Networks and Cyber Physical Systems

Outline

- Wireless Sensor Networks (WSN)
- Design Challenges
- Security of WSN
- Applications
- Cyber Physical Systems (CPS)
- Design Challenges
- Applications

Wireless Sensor Networks (WSN)

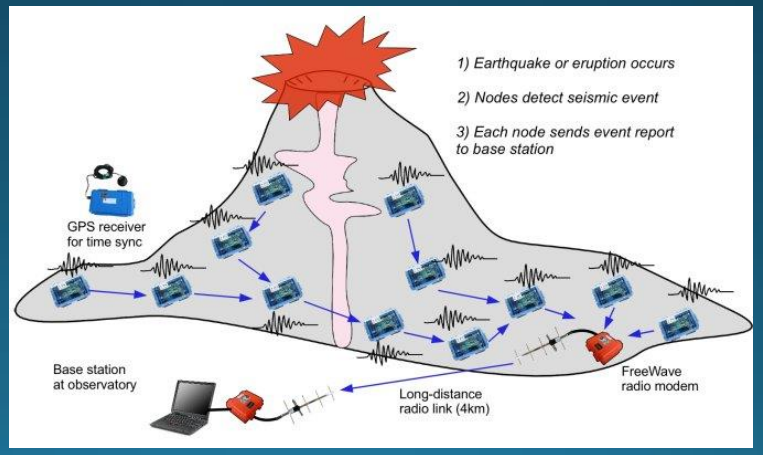
Wireless Sensor Networks

- An infrastructure comprised of sensing (measuring), computing, and communication elements that gives an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment.
- Typical applications include, but are not limited to,
  - data collection
  - monitoring
  - surveillance
  - medical telemetry
  - control and activation

Wireless Sensor Networks

- The environment can be
  - the physical world
  - a biological system
  - a manifacturing plant
  - an IT framework

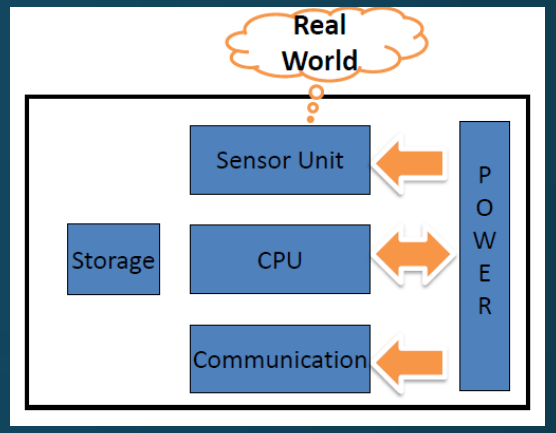
http://ceng.gazi.edu.tr/~kavem/



http://fiji.eecs.harvard.edu/Volcano

Sensor Nodes

- Low-power processor
- Limited memory
- No or limited mobility
- Low-power communication
  - Low data rate
  - Limited range
- Scalar sensors:
  - Temperature, light, etc.
  - Cameras, microphones
- Powered by battery
  - long-time operation in unattended areas



ISense Core Module 2 with Security Module
32 Bit RISC Controller, 4-32MHz
128kB RAM, 512kB Flash
IEEE 802.15.4 compliant radio, 250kbit/s
Range of up to 600m
4 channel 11-bit ADC

Differences Between Sensor Networks and Ad Hoc Networks

- Greater number of sensor nodes
- Sensor nodes are densely deployed
- Sensor nodes are failure-prone
- Topology of sensor net changes frequently
- Broadcast, not point-to-point
- Node limitations: power, computational capabilities, memory
- No global identification for sensor nodes

Design Challenges

- Scalability
- Production cost
- Self-configuring systems that adapt to unpredictable environment.
  - Ad hoc deployment; inaccessible areas; changing environments.
- Data processing inside the network.
  - Exploit computation near data to reduce communication.
  - Collaborative signal processing.
  - Achieve desired global behavior with localized algorithms (distributed control).
- Long-lived, unattended, untethered, low duty cycle systems.
  - Energy as a central concern.
  - Communication-processing tradeoff.
- Security

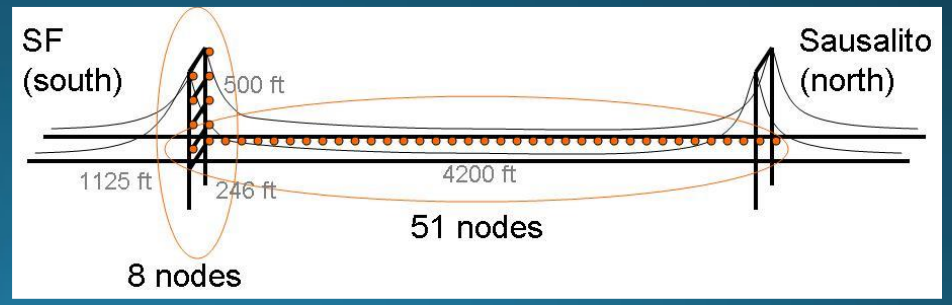
Security

- No physical security for sensor nodes
  - invalidates most of the security protocols
- Secret key sharing
  - who are my neighbors?
- Privacy
  - mission critical tasks
- Authentication
  - identification of newly added sensor nodes
- Denial-of-service attacks
  - easy to exhaust sensor nodes' energy
- Integration of security and other services
  - Due to resource constraints it is a must

Applications

Structural Health Monitoring

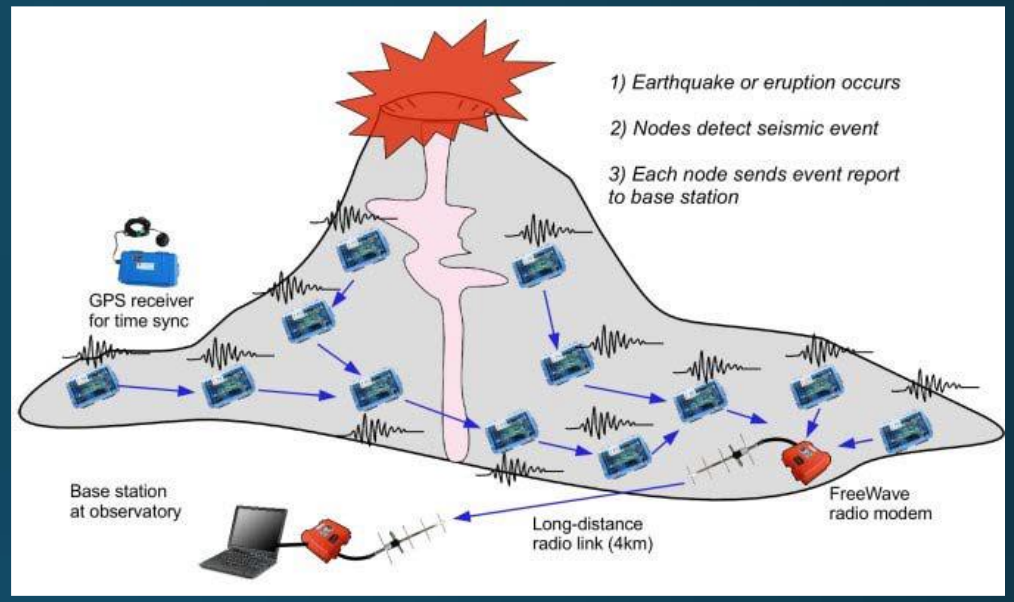
- Golden Gate Bridge
- Nodes are distributed over the main span and the tower
  - collecting ambient vibrations synchronously at 1kHz rate
- 46-hop network, with a bandwidth of 441B/s at the 46th hop.
- Low cost data collection without interfering with the operation of the bridge.

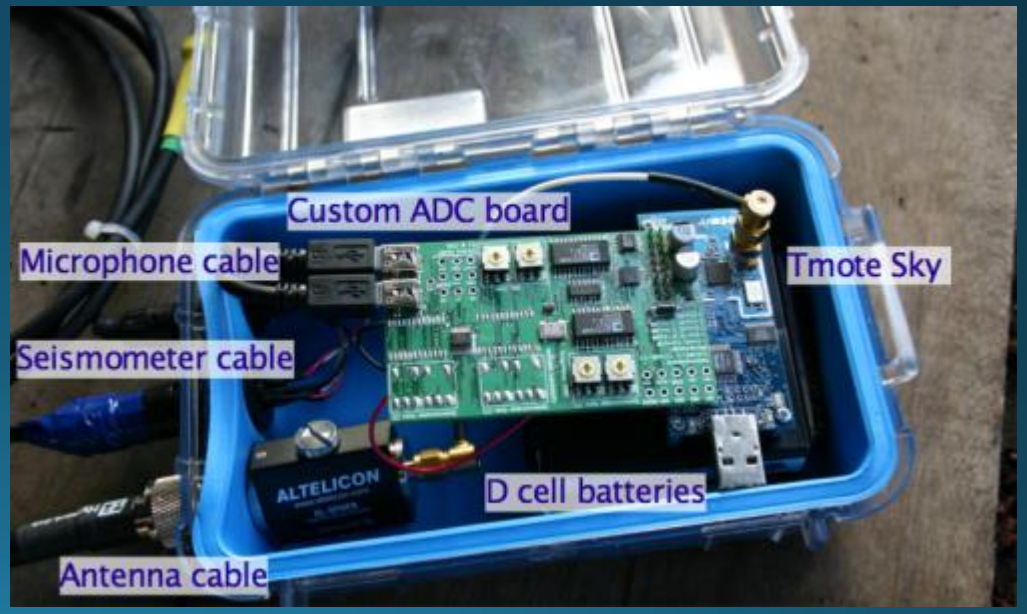


http://www.cs.berkeley.edu/~binetude/ggb/

Volcano Monitoring

- Tungurahua volcano, Ecuador
- 16 nodes deployed over a 3 km aperture on the upper flanks of the volcano, and measured both seismic and infrasonic signals with high resolution (24 bits per channel at 100 Hz)
- Challenge: how to maximize the data collection
  - subject to resource constraints.





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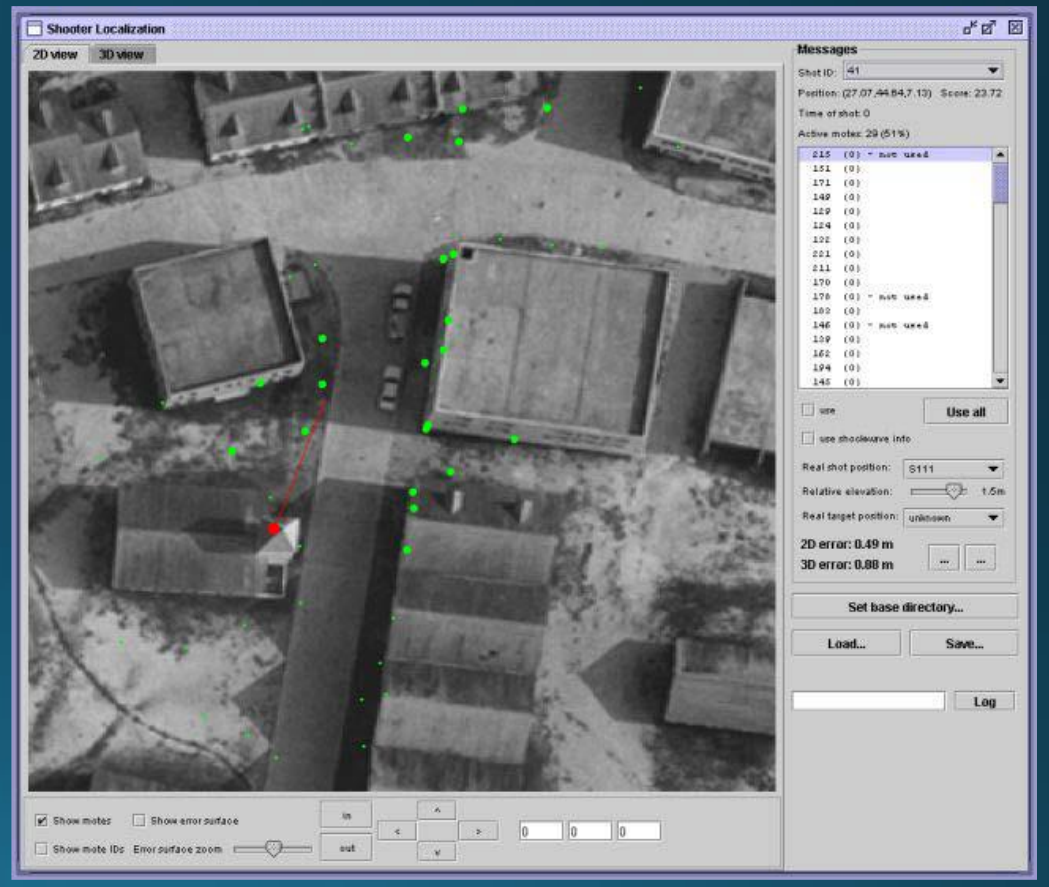
Shooter Localization

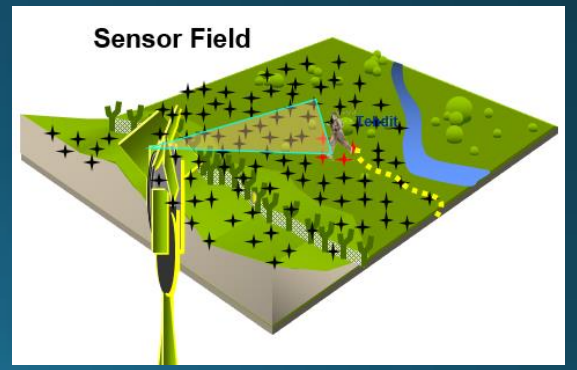
- WSN determines the shooter location and the bullet trajectory
- Basic idea: using the arrival times of the acoustic events at different sensor locations, the shooter position can be accurately calculated using the speed of sound and the location of the sensors.



http://w3.isis.vanderbilt.edu/projects/nest/applications.html

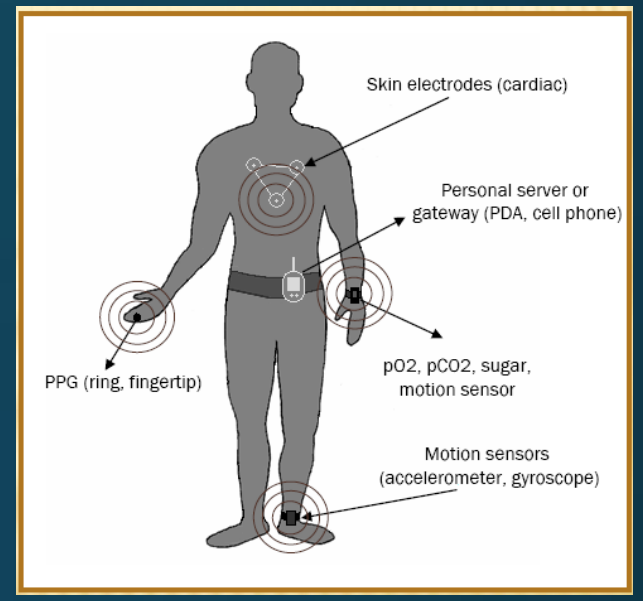
Critical Area Surveillance

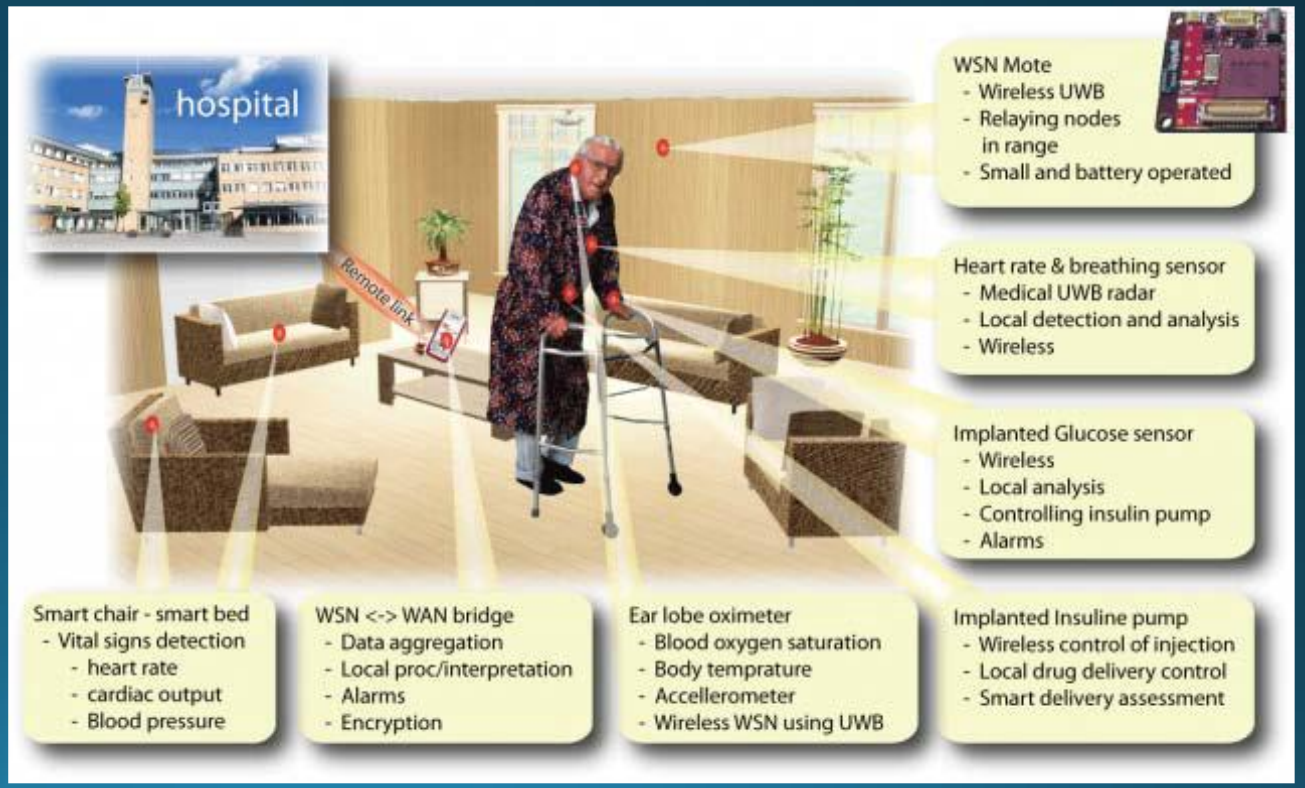
- Tracking a target (intruder) in a critical region
- A number of seismic and PIR sensors
- 2 Thermal Camera
- Hybrid system
- Two-way information exchange



Health Monitoring

- Body Area Networks
  - WSN can be on/beside/in body
- Medical monitoring, e.g. heart rate, blood pressure
- Remote monitoring and localization for aged people at home; patient at hospital





Cyber Physical Systems (CPS)

Cyber is…

- Not only software
- Not only networking
- Not only embedded computing
- It implies the integration of…

Computation

Communication

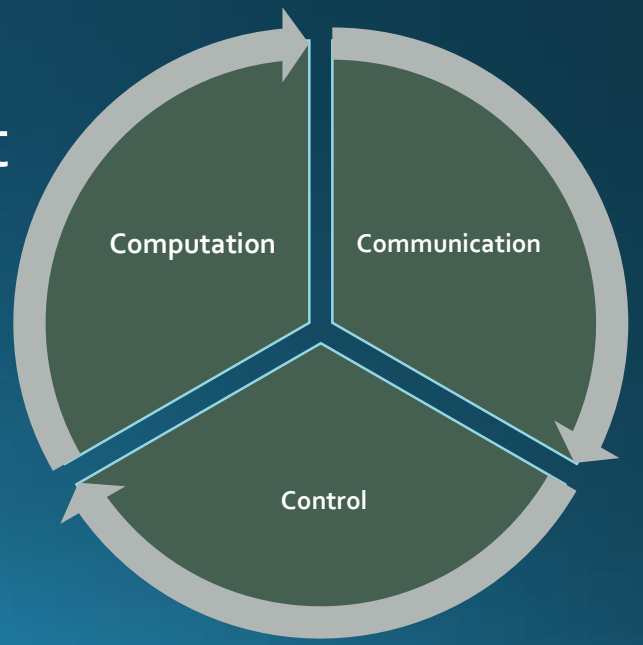
Control

Physical Systems

- Natural and human-made systems governed by the laws of physics and operating in continuous time

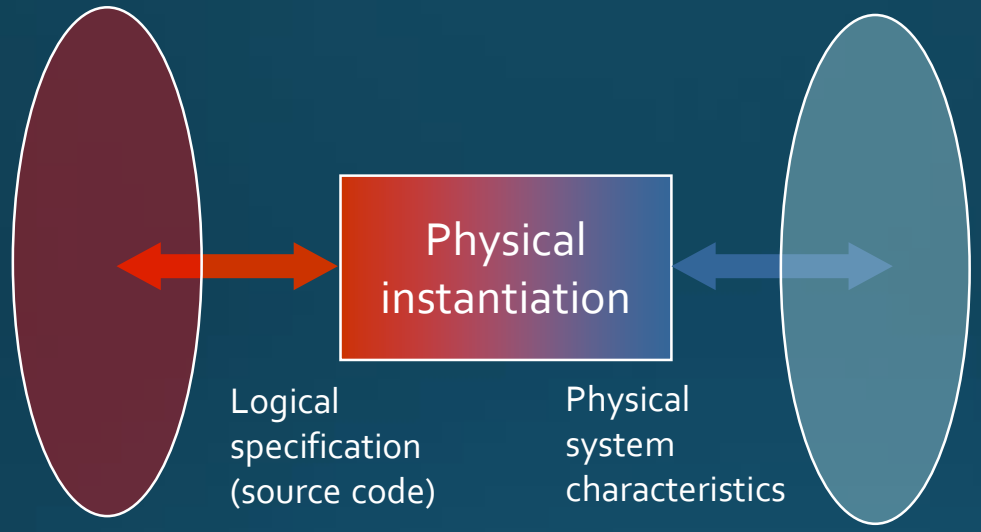
Cyber-Physical Systems

- Systems in which the cyber and physical systems are tightly integrated at all scales and levels
- Integrates computation and physical processes
- Uses embedded computers and networks to compute, communicate, and control the physical processes
- Receives feedbacks on how physical processes affect computations and vice versa
- Does not have to be wireless
- Sensor network + control capability??



Design Challenges

Computing System Composition Domain



Physical System Composition Domain

"Cyber" Models
Modeling Languages
- Structure
- Behaviors

Mathematical Domains
- traces/state variables
- "semantic units"

Physical Models
Modeling Languages
- Structure
- Behaviors

Physical Laws
- Physical variables
- Physical Units

No perfect digitization of the continuous world !!!

Applications

Cooling A Data Center

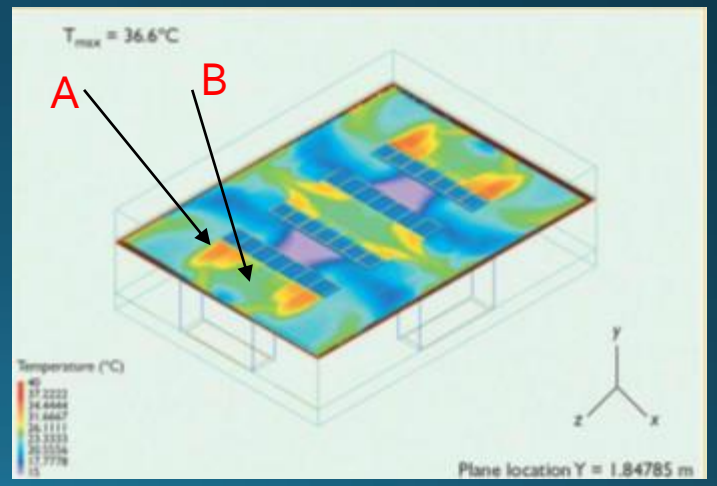
- 3 percent of all power in the world flows into data centers of some type
- Cooling equipment uses at least 50 percent of total energy
- A key challenge is to minimize the cooling requirement and improve the overall energy efficiency, toward optimizing the operations of data center

Cooling A Data Center

- Different workloads generate different power consumption
- Some locations in data center are easier to cool than others
- Moving tasks from Zone A to Zone B
  - lower overall power consumption

distribute tasks among the servers to minimize the temperature

cyber ⟷ physical



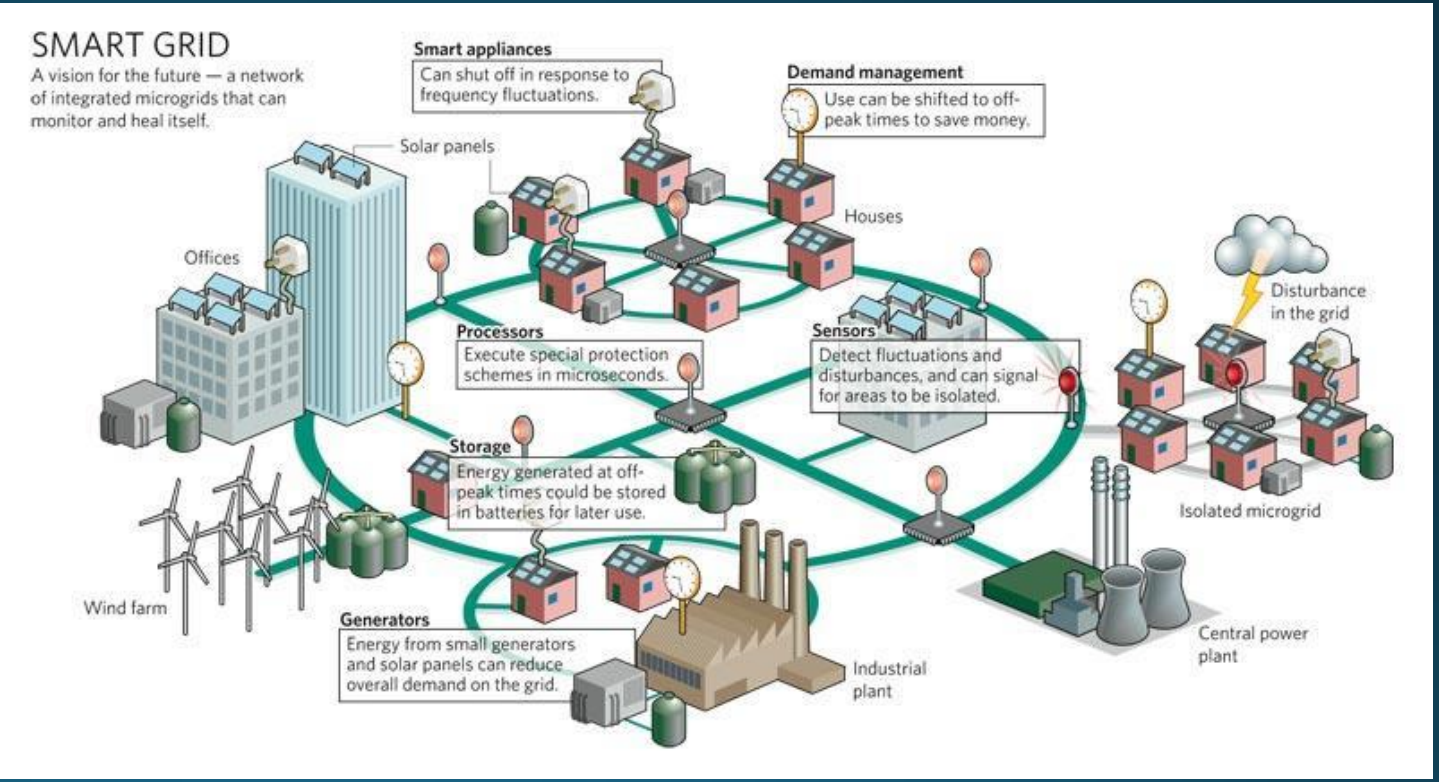
Smart Grid

Currently

- Reactive equipment protection
  - 25 July 2010, Washington D.C., 250000 people lost power
  - 14 Jan. 2012, Marmara Region, 20 Million people lost power due to NG transformer failure

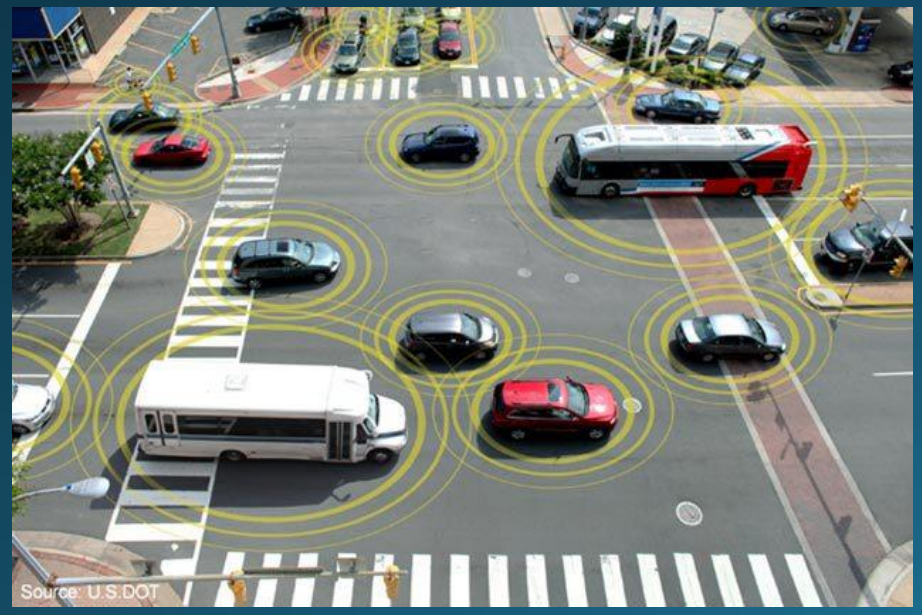
With CPS

- Monitor energy consumption
- Plan energy production
- Control home appliances



Smart Traffic

- Adaptive and Cooperative Technologies for Intelligent Traffic
- Smart traffic lights and cars
- Aims for safety and fuel efficiency



Suat Özdemir

suatozdemir@gazi.edu.tr

http://ceng.gazi.edu.tr/~ozdemir