INTELLIGENT SENSORS AND SENSOR NETWORKS

Otman A. Al-Basir,

Spring 2020

BASICS

SENSOR NETWORKS

A large number of low-cost, low-power, multifunctional, and small sensor nodes interconnected wirelessly to accomplish a common task

INGREDIENTS & PURPOSE

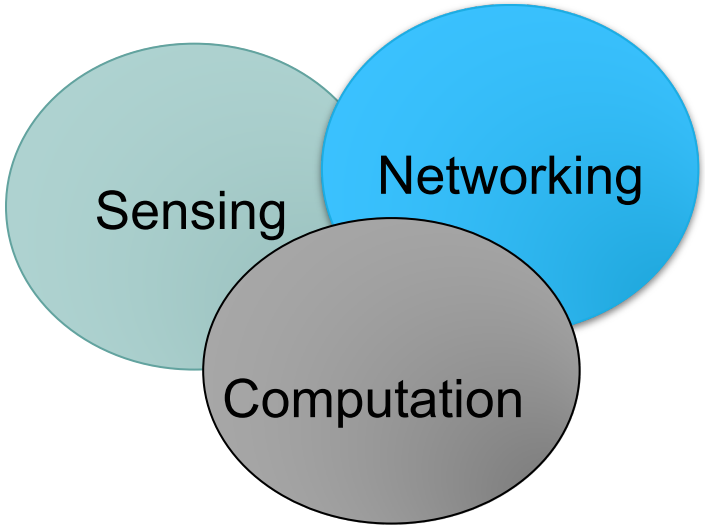
A sensor network is an infrastructure comprised of

- Sensing (measuring),
- Computing, and
- Communication elements

for the purpose of

- Instrumenting,
- Observing, and
- Reacting

Of/to events and phenomena in a specified environment.



SENSORS AND SENSOR NETWORKS

Sensor Network:

- A combination of two or more elements, subsystems and parts necessary to carry out one or more functions
- To interact with the real world, a network requires
  - Sensors: inputs devices
  - Actuators: output devices
  - Connectivity among its elements and the environment
  - Processing: signals, information and knowledge

Sensor

- A device that receives and responds to a stimulus
- Stimulus: mechanical, thermal, magnetic, electric, optical, chemical…
- Response: an electrical signal (in most cases)

INTELLIGENCE

Intelligence

- The ability to combine
  - A priori knowledge (available before experience) and
  - Adaptive learning (from experience)
- The ability to act, mentally and externally, and by acting it reaches its objectives more often than by pure chance
- The ability to cooperate with others to achieve efficiency and effectiveness.
- The ability to adapt.

INTELLIGENT SENSING

A smart sensor is a sensor that provides functions beyond those necessary for generating a correct representation of a sensed or controlled quantity (IEEE 1451.2)

- *This function typically simplifies the integration of the transducer into applications in a networked environment*

WHAT DOES THAT MEAN?

A sensor that is capable of modifying its internal behavior to optimize the collection of data from the external world

- *The concepts of adaptation and compensation are central to the Intelligent Sensor philosophy*

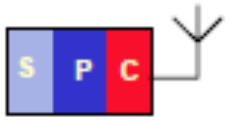
A device that combines a sensing element and a signal processor on a single integrated circuit

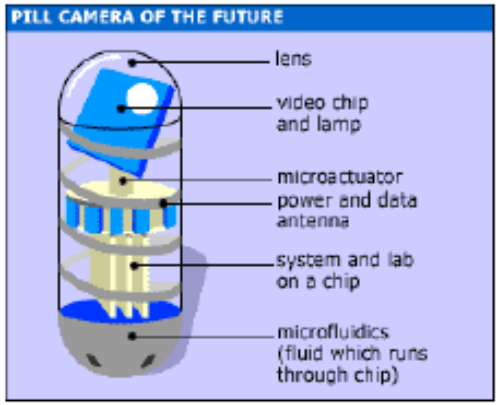
- *The minimum requirements of the signal processor are not clear*
  - *Basic integrated electronics (signal conditioning, ADC)*
  - *A micro-processor*
  - *Logic functions and decision making*
- *This ability typically simplifies the integration of the transducer into applications in a networked environment*

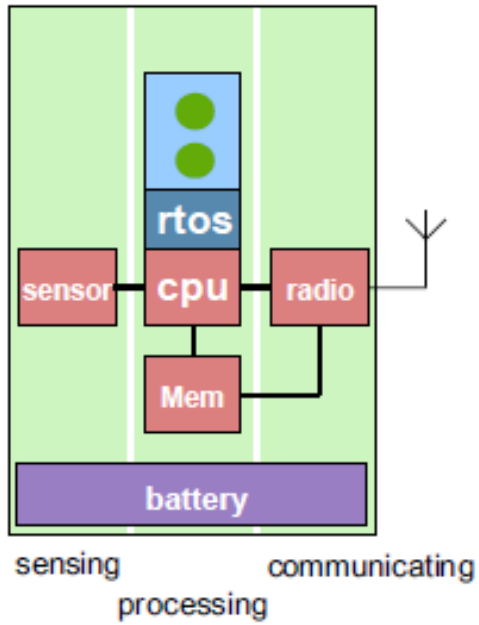
BUILDING BLOCKS OF INTELLIGENT SENSORS

The principal sub-systems within an intelligent sensor are

- Primary sensing element(s)
- Excitation control
- Amplification and Analogue filtering
- Data conversion
- Compensation
- Digital information and communication processing
- Battery
- RTOS



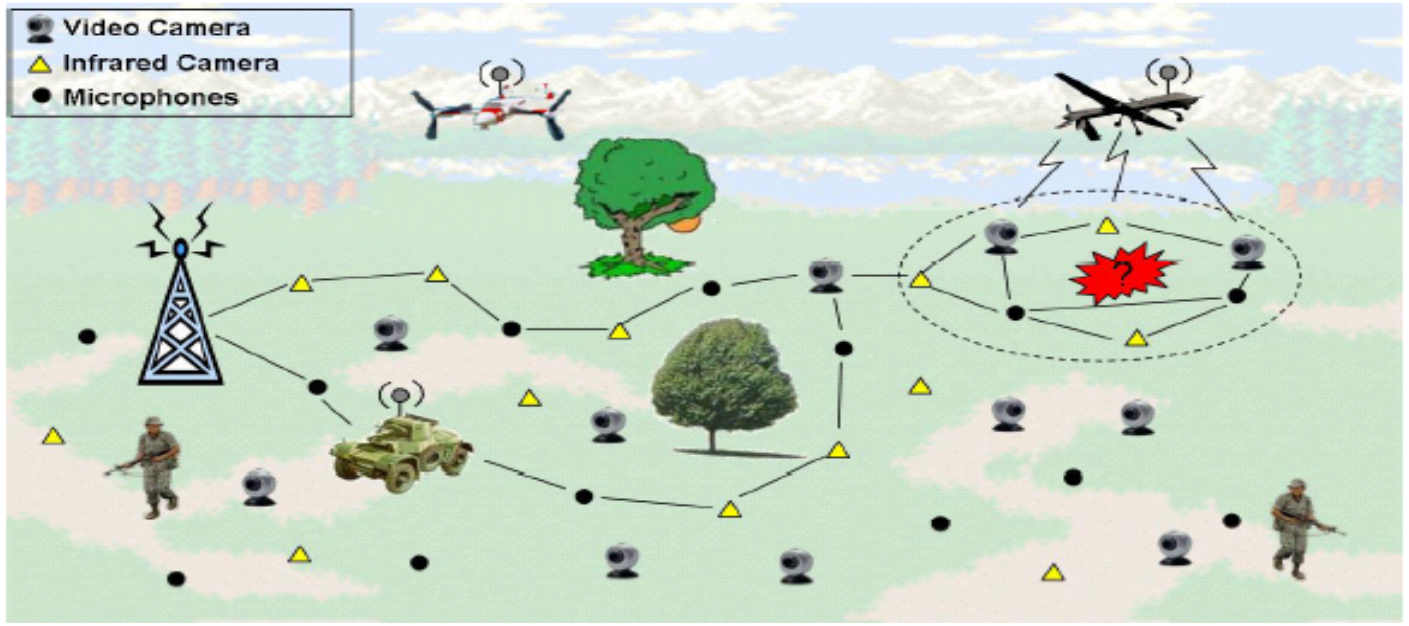




SCALE AND POWER FRONTIERS

- Microcontrollers:
  - 1-10 mW active, 1 uW passive => 10-100 uW average
- Micro-sensors (MEMS, Materials, Circuits)
  - acceleration, vibration, gyroscope, tilt, magnetic, heat, motion,
  - pressure, temp, light, moisture, humidity, barometric
  - chemical (CO, CO2, radon), biological, microradar,
  - actuators (mirrors, motors, smart surfaces, micro-robots)
- Micro-Radios
  - CMOS, short range (10 m), low bit-rate (200 kbps), 1-10 mW
- Micro-Power
  - Batteries: 1,000 mW*s/mm3, fuel cells
  - solar (10 mW/cm2, 0.1 mW indoors), vibration (~uW/gm), flow
- 1 cm3 battery => 1 year at 1 msgs/sec

SENSOR NETWORK



Why are we interested in SN ?

•A new way of sensing for global awareness

• New technologies of observing the world bring us new discoveries.

MORE ON WSN CHARACTERISTICS

- A very large number of nodes, often in the order of thousands
- Asymmetric flow of information, from the observers or sensor nodes to a command node
- Communications are triggered by queries or events
- At each node there is a limited amount of energy which in many applications is impossible to replace or recharge
- Almost static topology
- Low cost, size, and weight per node
- Prone to failures
- More use of broadcast communications instead of point-to-point

THE PROMISE

- A networked population of cheap and small sensors that communicate and exchange knowledge with each other.

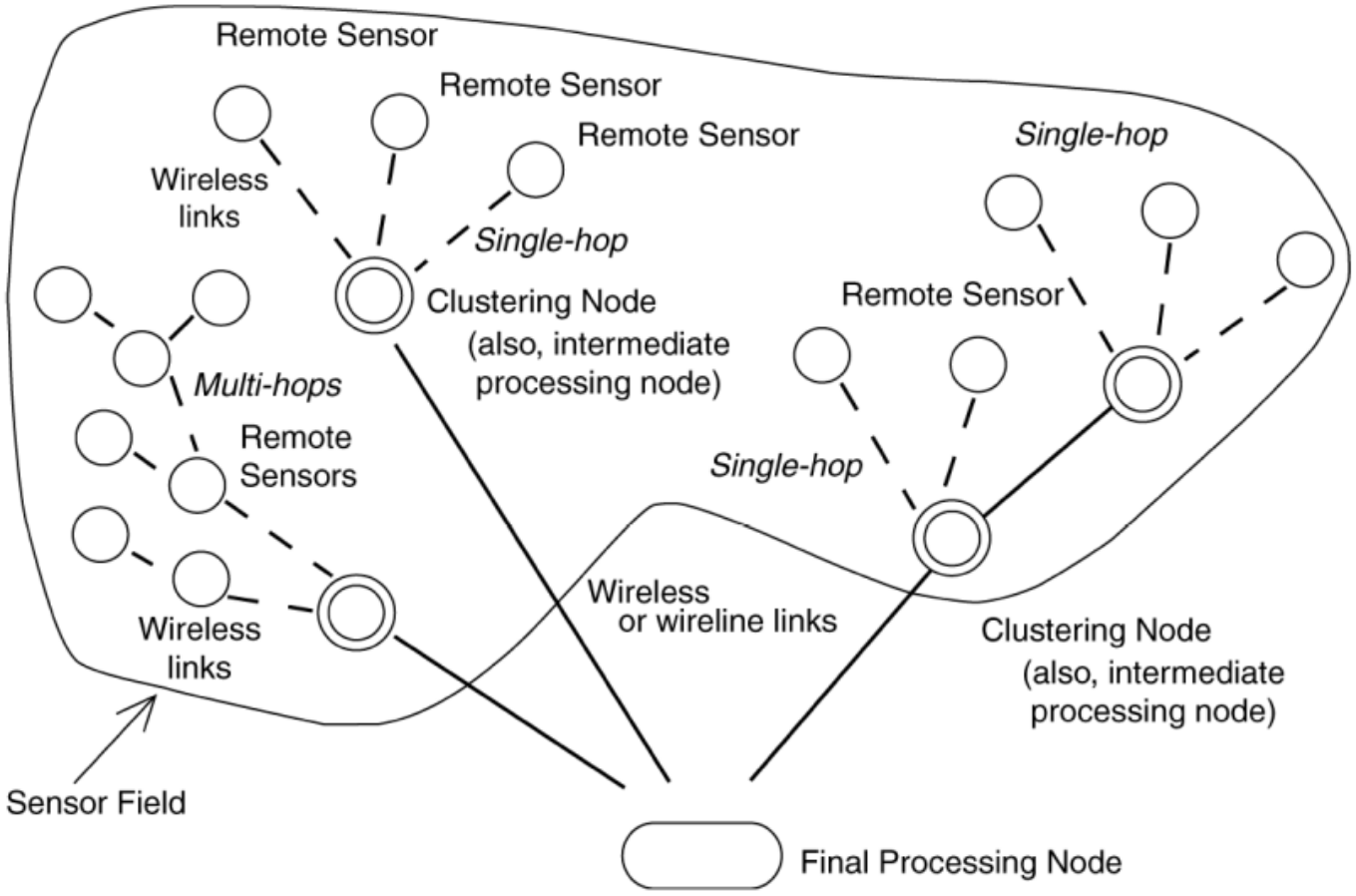
- Networked sensors have much greater potential to achieve more complex sensing and reasoning of the physical environment than single complex and overly expensive sensors.

….. The creation of ultra-powerful sensing from inexpensive simple sensors!

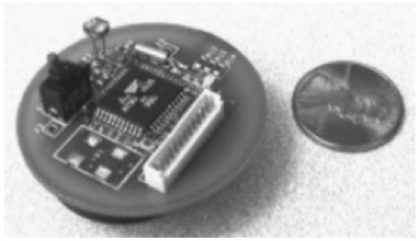
NETWORK UNIQUE CHARACTERISTICS

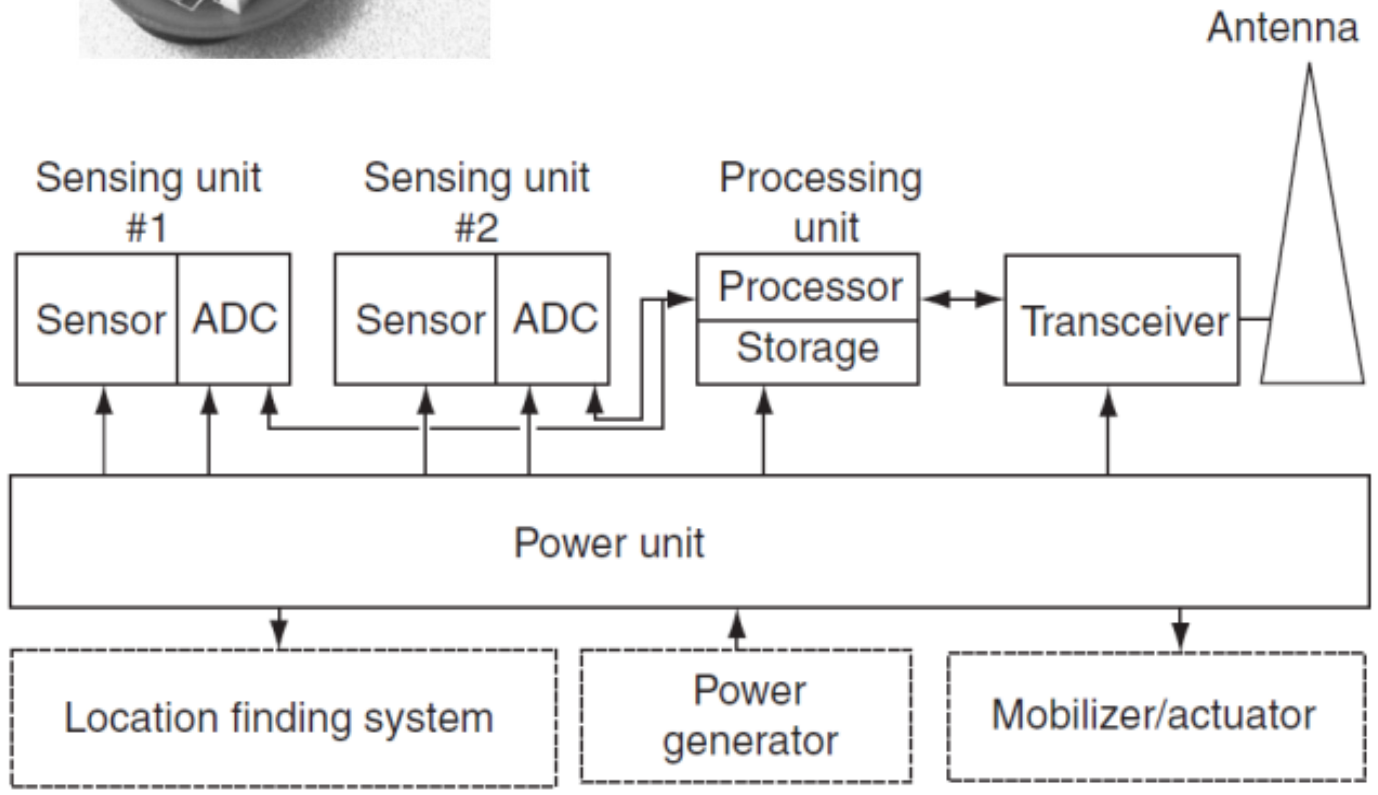
- Coverage:
  distance/area covered, number of events, number of active queries.
- Spatial diversity:
  dense spatial sampling, multi-entity sensing, multiple sensing modalities.
- Survivability:
  robust against node/link failures
- Ubiquity:
  quick/flexible deployment, ubiquitous access, information timeliness.

TYPICAL NETWORK ARRANGEMENT



SENSING NODE COMPONENTS





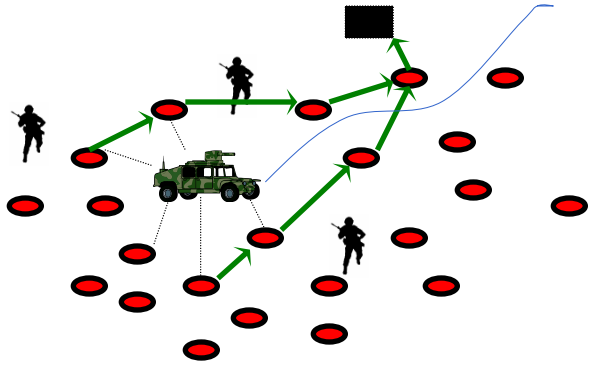
ADC = Analog-to-Digital Converter

APPLICATIONS

- Smart buildings
- Security
- Personalization
- Environmental control
- Traffic management
- Medical monitoring, diagnostics and treatment
- Interactive toys
- Infrastructure maintenance
- Surveillance (security, fire, earthquake, ..)
- Interactive museums

APPLICATION EXAMPLES

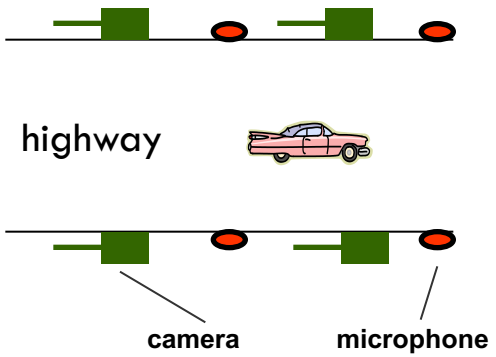
- Battlefield
  - Detection, classification and tracking
    - Vehicle tracking
      - Sensors to localize the vehicle
      - Communicate using geographic routing to base station
      - Robust against node and radio link failures



- Habitat Monitoring
  - Micro-climate and wildlife monitoring
    - Examples:
      - ZebraNet (Princeton)
      - Seabird monitoring in Maine's Great Duck Island (Berkeley & Intel)

APPLICATIONS.. CONT

- Structural, seismic
  - Bridges, highways, buildings
    - Examples: Coronado Bridge San Diego (UCSD), Factor Building (UCLA)
  - Smart roads
    - Traffic monitoring, accident detection, recovery assistance
      - Examples: ATON project (UCSD)
  - Contaminants detection



DEPLOYMENT CLASSES