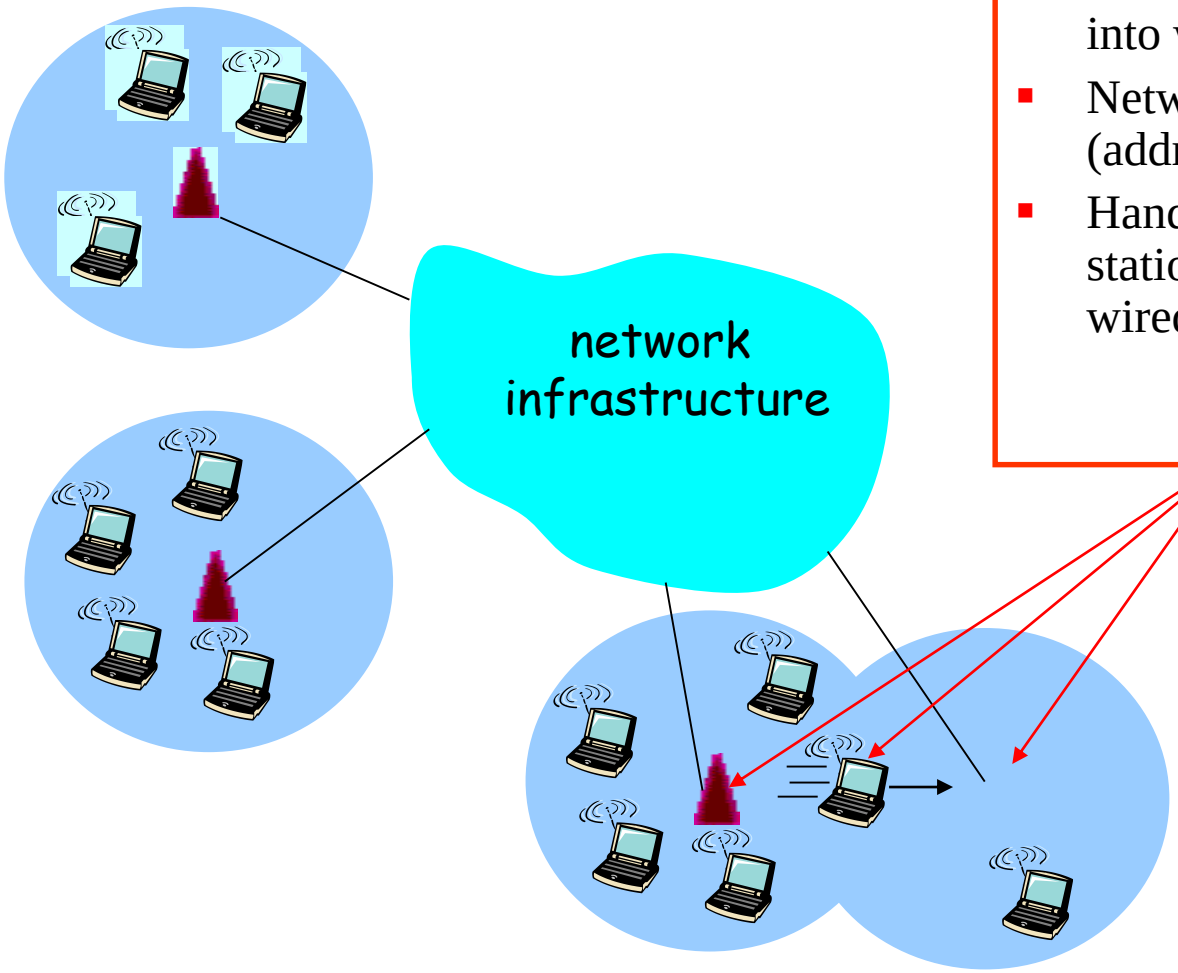
Wireless & Ad Hoc Networks: A Brief Overview

- Two types of wireless networks:
  - Infrastructured network:
    - base stations are the bridges
    - a mobile host will communicate with the nearest base station
    - handoff is performed when a host roams from one base to another

Infrastructured Network

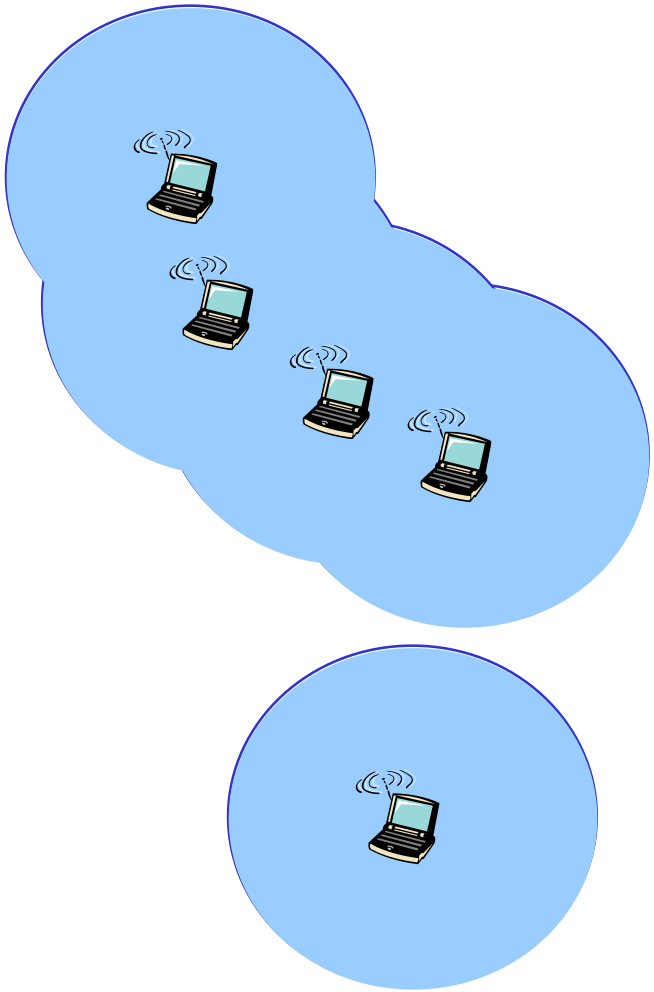


- Base station connects mobiles into wired network
- Network provides services (addressing, routing, DNS)
- Handoff: mobile changes base station providing connection to wired network

Infrastructure-less Network

- Ad hoc network:
  - Infrastructure-less: no fixed base stations
  - Without the assistance of base stations for communication
  - Due to transmission range constraint,
    - two mobile hosts (MHs) need multi-hop routing for communication
  - Quickly and unpredictably changing topology

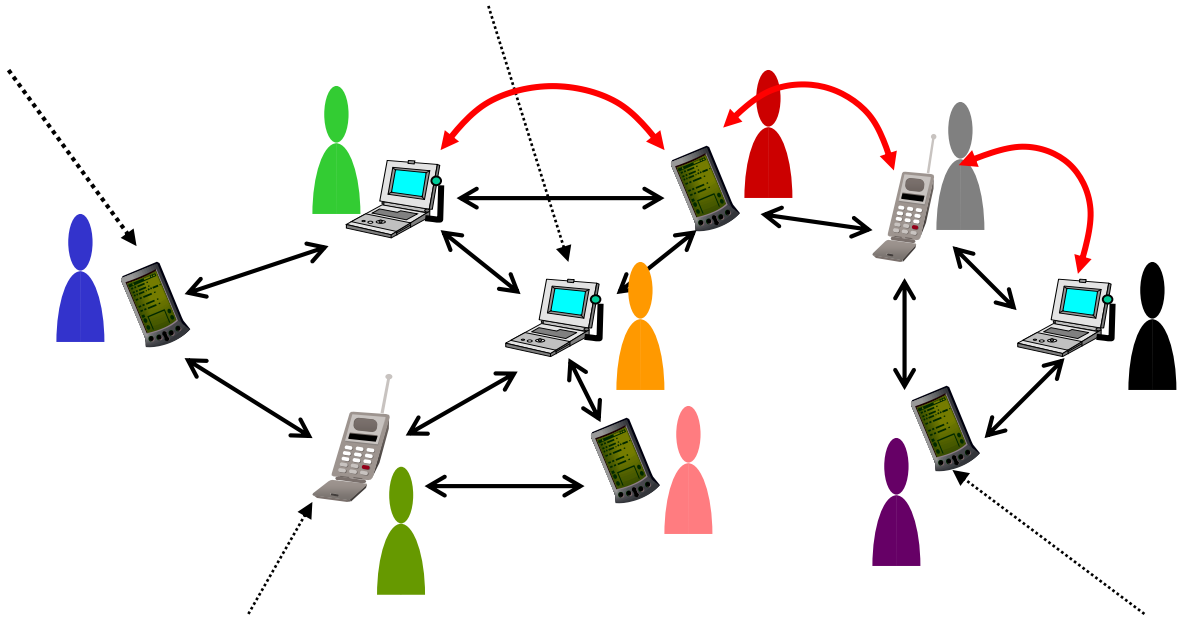
Ad Hoc Network



- No base stations
- Nodes can only transmit to other nodes within link coverage
- Nodes self-organize and route among themselves

Mobile Ad Hoc Network (MANET)

- A set of mobile hosts, each with a transceiver
- No base stations; no fixed network infrastructure
- Multi-hop communication
- Needs a routing protocol which can handle changing topology

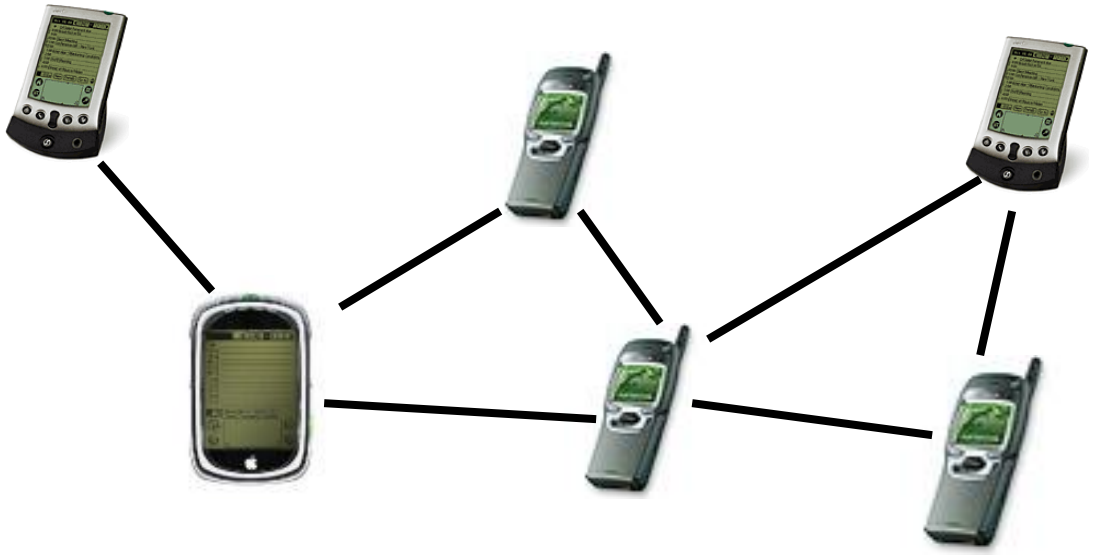


Types of Wireless Networks

	Infrastructure-based	Infrastructure-less
Single hop	Base station connected to larger wired network (e.g., WiFi wireless LAN, and cellular telephony networks)	No wired network; one node coordinates the transmissions of the others (e.g., Bluetooth, and ad hoc 802.11)
Multi-hop	Base station exists, but some nodes must relay through other nodes (e.g., wireless sensor networks, wireless mesh networks)	No base station exists, and some nodes must relay through others (e.g., mobile ad hoc networks, vehicular ad hoc networks)

Wireless Networks: A Taxonomy

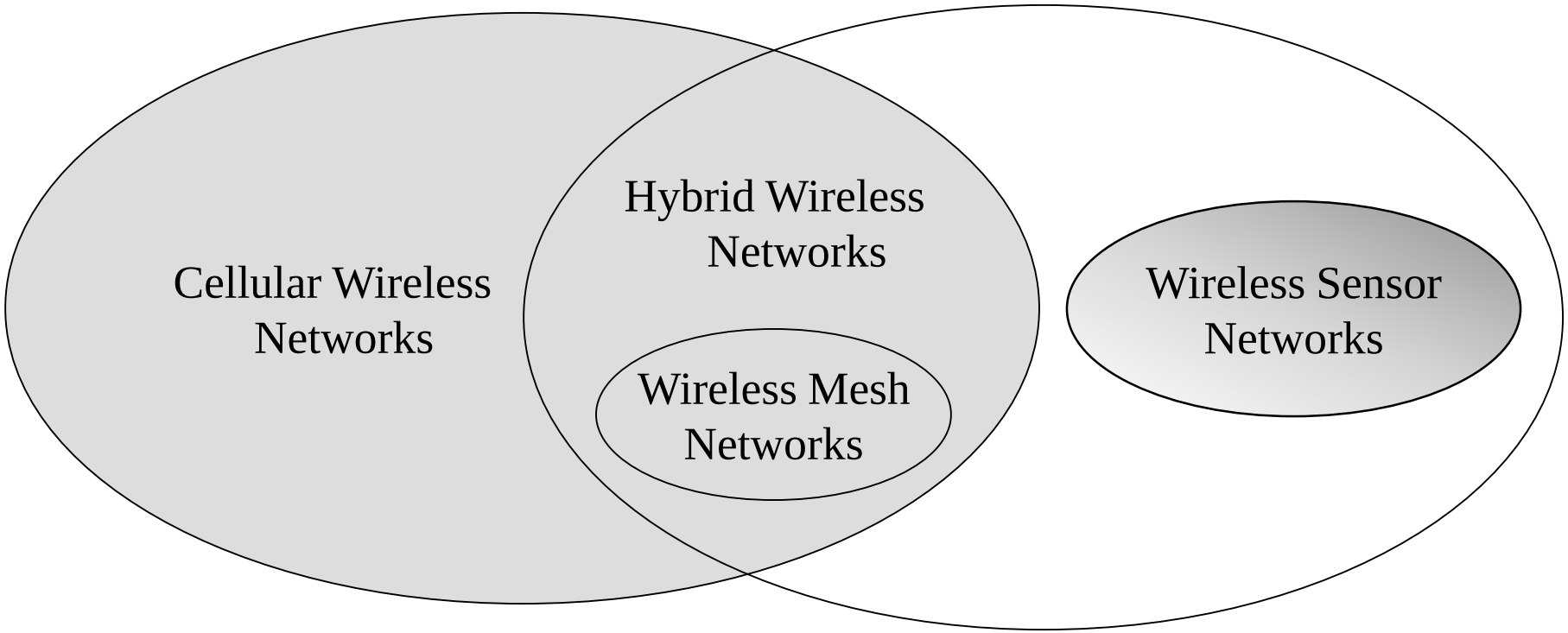
- ***Single hop networks***
- Cellular networks
- Satellite networks



- ***Multi-hop self-organized networks***
- Conference, battlefield, rescue
- Peer to peer networks
- ***Ad hoc networks***

Cellular and Ad Hoc Wireless Networks

- The following figure represents different wireless networks.
  - Infrastructure: cellular wireless networks
  - Ad hoc: wireless sensor networks
  - Hybrid: mesh networks



Comparisons between Cellular and Ad Hoc Wireless Networks (I)

Cellular Networks	**Ad Hoc Wireless Networks**
Fixed infrastructure-based	Infrastructureless
Guaranteed bandwidth (designed for voice traffic)	Shared radio channel (more suitable for best-effort data traffic)
Centralized routing	Distributed routing
Seamless connectivity (low call drops during handoffs)	Frequent path breaks due to mobility
High cost and time of deployment	Quick and cost-effective deployment
Reuse of frequency spectrum through geographical channel reuse	Dynamic frequency reuse based on carrier sense mechanism
Easier to employ bandwidth reservation	Bandwidth reservation requires complex medium access control protocols

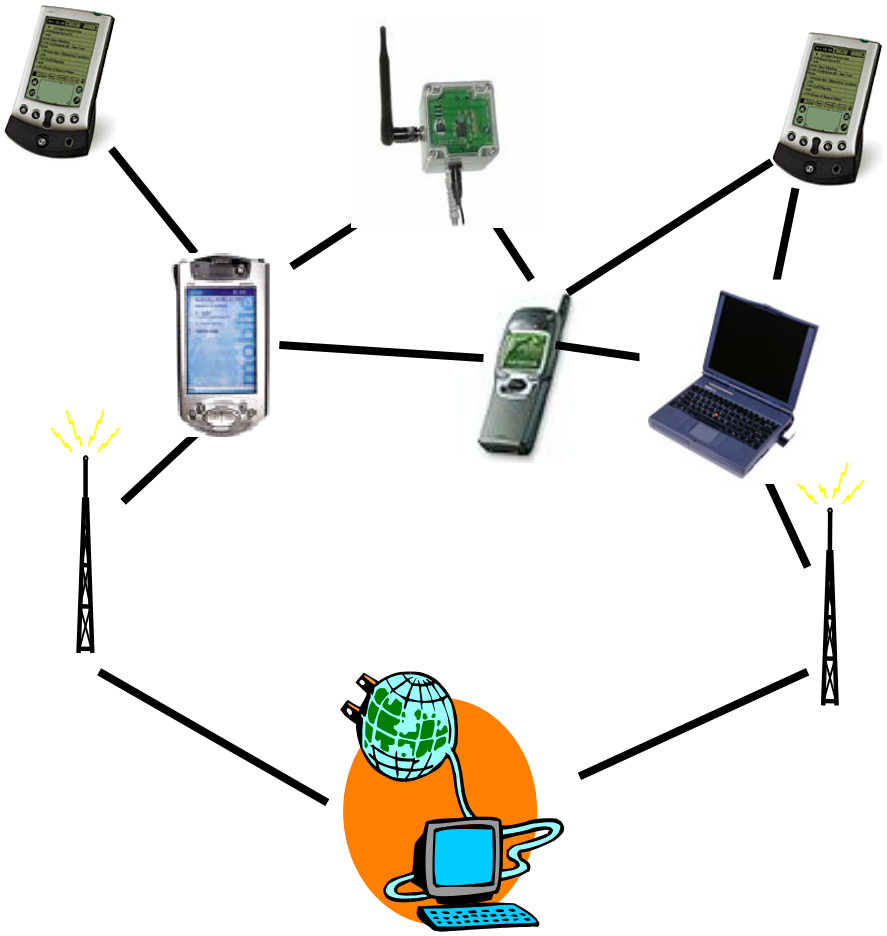
Comparisons between Cellular and Ad Hoc Wireless Networks (II)

Cellular Networks	**Ad Hoc Wireless Networks**
Application domains include mainly civilian and commercial sectors	Application domains include battlefields, emergency search and rescue operations, and collaborative computing
High cost of network maintenance (backup power source, staffing, etc.)	Self-organization and maintenance properties are built into the network
Mobile hosts are of relatively low complexity	Mobile hosts require more intelligence (should have a transceiver as well as routing/switching capability)
Major goals of routing and call admission are to maximize the call acceptance ratio and minimize the call drop ratio	Main aim of routing is to find paths with minimum overhead and also quick reconfiguration of broken paths

Hybrid Wireless Networks

- Hybrid Wireless Networks
  - Multi-hop cellular networks (MCNs) *allows the transmission through the base stations or multi-hop of mobile nodes*.
  - Integrated cellular ad hoc relay (iCAR) is a system that combines conventional cellular technology with Ad hoc Relay Station (ARS) technology. In this system, cellular stations will relay or reroute calls from the congested cell to an adjacent one that is not congested.
- Advantages
  - Higher capacity than cellular networks
  - Increased flexibility and reliability in routing
  - Better coverage and connectivity

Hybrid ad hoc wireless networks

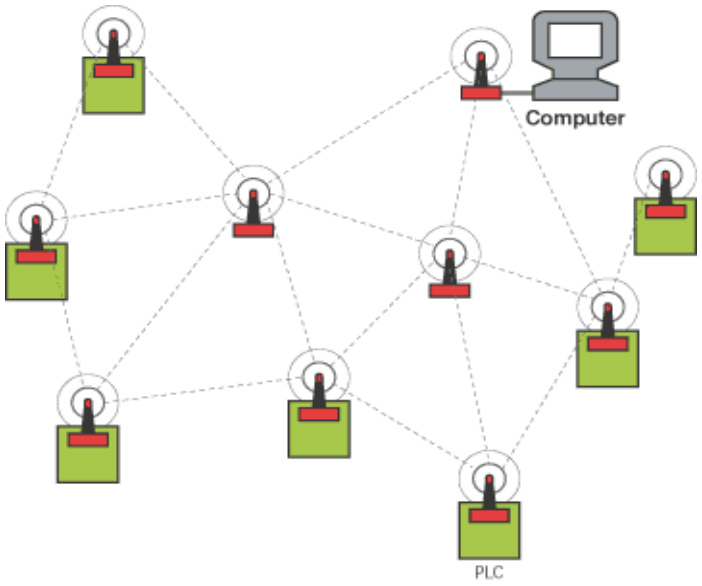


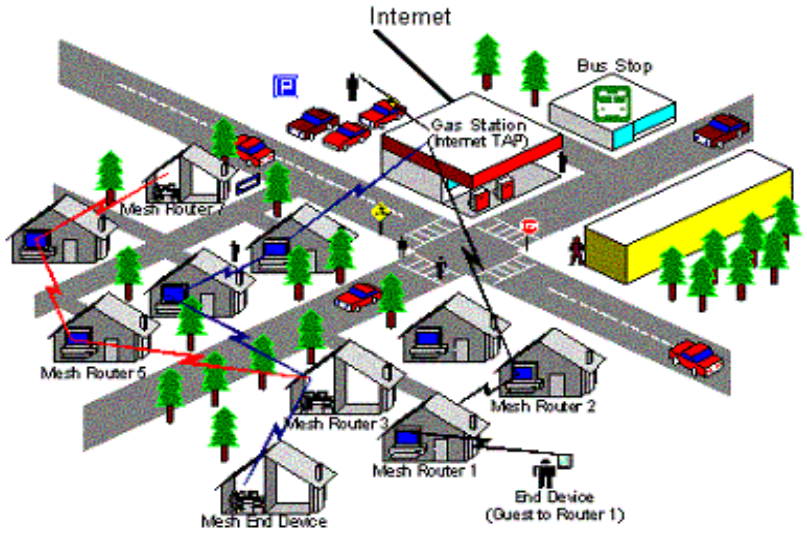
- Sensor networks
- Multi-hop cellular networks
- Mesh/rooftop networks: wireless fast Internet access
- Vehicles on highway

Multi-hop cellular networks in crowded environments

Routing via other mobile phones, instead of directly to base station, can save bandwidth and energy

Wireless Mesh Networks



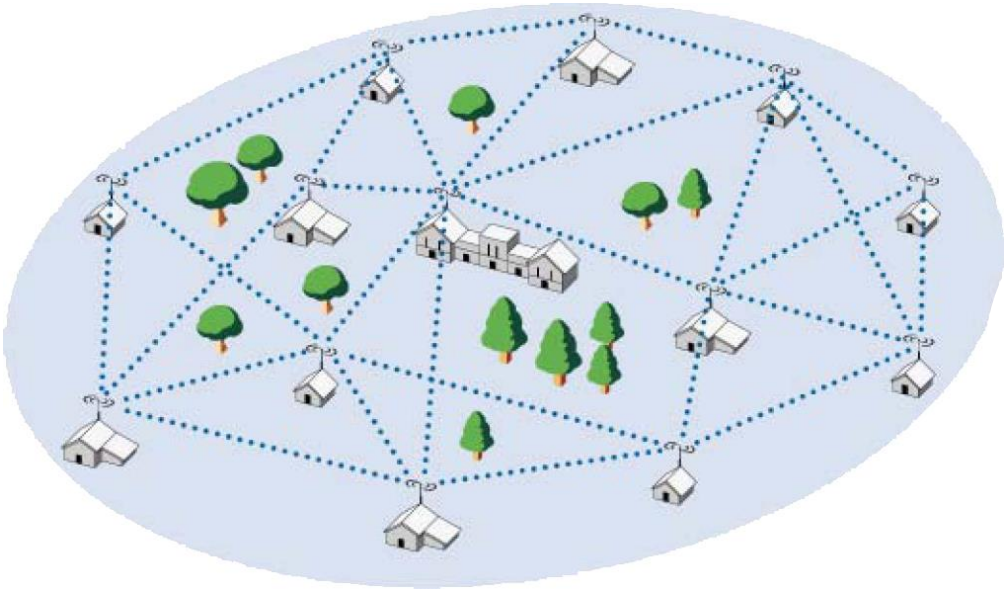


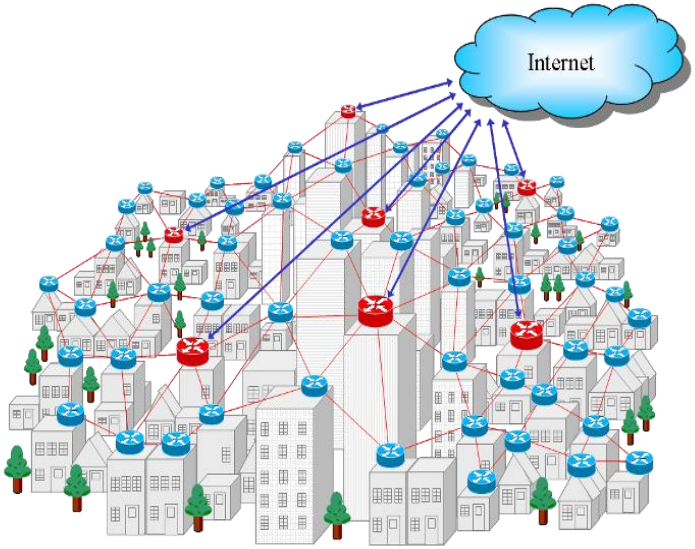
- In a wireless mesh network, multiple nodes cooperate to relay a message to its destination. The mesh topology enhances the overall reliability of the network, which is particularly important when operating in harsh industrial environments.

Wireless Mesh Networks (cont'd)

- The investment required in wireless mesh networks is much less than in the cellular network counterparts.
- Such networks are formed by placing wireless replaying equipment spread across the area to be covered by the network.
- The possible deployment scenarios include:
  - Residential zones (where broadband Internet connectivity is required)
  - Highways (where a communication facility for moving automobiles is required)
  - Business zones (where an alternate communication system to cellular networks is required)
  - Important civilian regions (where a high degree of service availability is required)
  - University campuses (where inexpensive campus-wide network coverage can be provided)

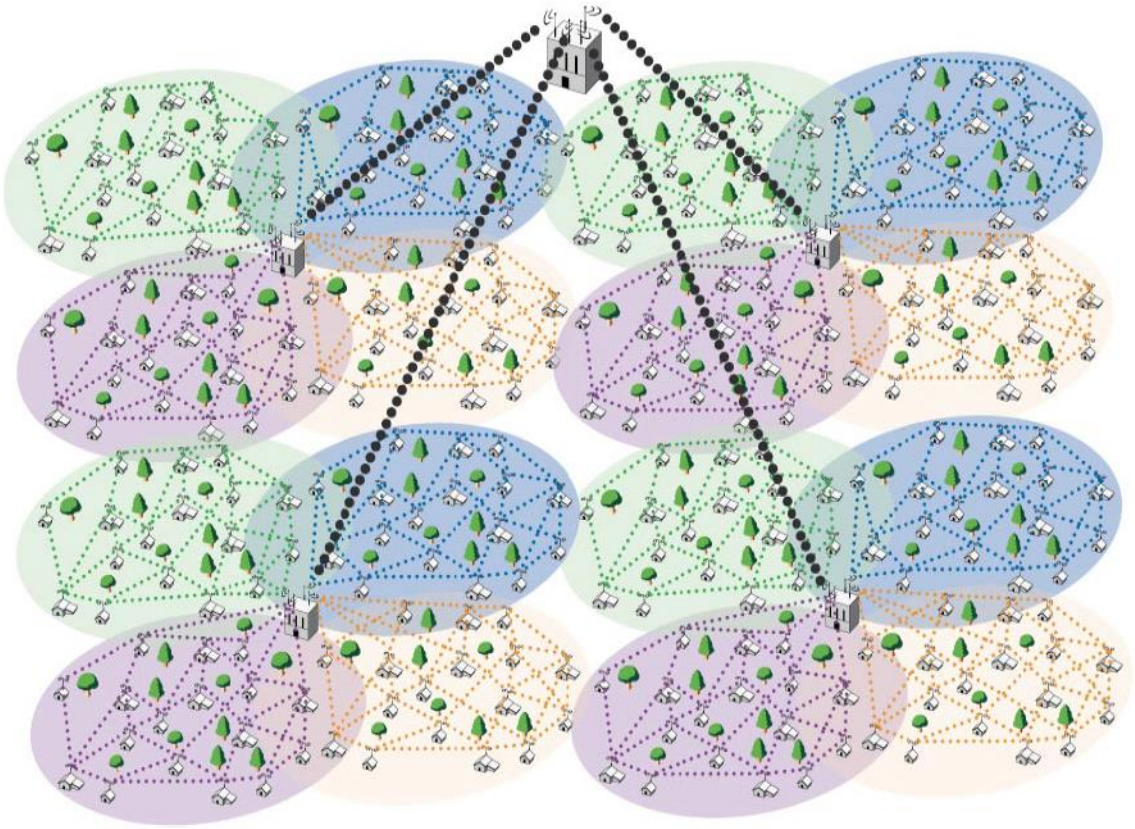
Wireless Mesh Networks for Residential Broadband Internet





- Each subscriber unit is part of the infrastructure
- Multi-hop routing enables full coverage
- Network self-configures and self-heals

Hierarchical Wireless Mesh Networks



Wireless Mesh Networks - Summary

- A group of nodes that communicate directly with each other.
- No need for Access Point to mediate the wireless connection.
- Each node operates as a host and as a router.
- Self-organized and self-configured.

Ad Hoc Networks vs Wireless Mesh Networks

Ad Hoc Networks

- Multihop
- Nodes are wireless, possibly mobile
- No infrastructure
- Most traffic is user-to-user

Wireless Mesh Networks

- Multihop
- Nodes are wireless, some mobile, some fixed
- May rely on infrastructure
- Most traffic is user-to-gateway

Applications of Ad Hoc Networks

- Personal area networking
  - cell phone, laptop, ear phone, wrist watch
- Military environments
  - soldiers, tanks, planes
- Civilian environments
  - taxi cab network
  - meeting rooms
  - sports stadiums
  - boats, small aircraft
- Emergency operations
  - search-and-rescue
  - policing and fire fighting

Challenges in Mobile Environments

- Limitations of the Wireless Network
  - packet loss due to transmission errors
  - variable capacity links
  - frequent disconnections/partitions
  - limited communication bandwidth
  - broadcast nature of the communications
- Limitations Imposed by Mobility
  - dynamically changing topologies/routes
  - lack of mobility awareness by system/applications
- Limitations of the Mobile Computer
  - short battery lifetime
  - limited capacities

Wireless Sensor Networks (WSNs)

- Special type of ad hoc networks that are used to provide a wireless communication infrastructure among the sensors deployed in a specific application domain.

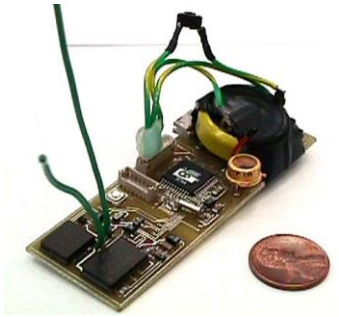
- Distinct properties of WSNs:
  - Mobility of nodes are not needed in most cases in wireless sensor networks.
  - The size of the network is much larger than that in a typical ad hoc wireless network.
  - The density of nodes in a sensor network varies with the domain of application.
  - The power constraints in sensor networks are much more stringent than those in ad hoc wireless networks.
  - Data/information fusion aims at processing the sensed data at the intermediate nodes and relaying the outcome to the monitor node.
  - The communication traffic pattern varies with the domain of applications.

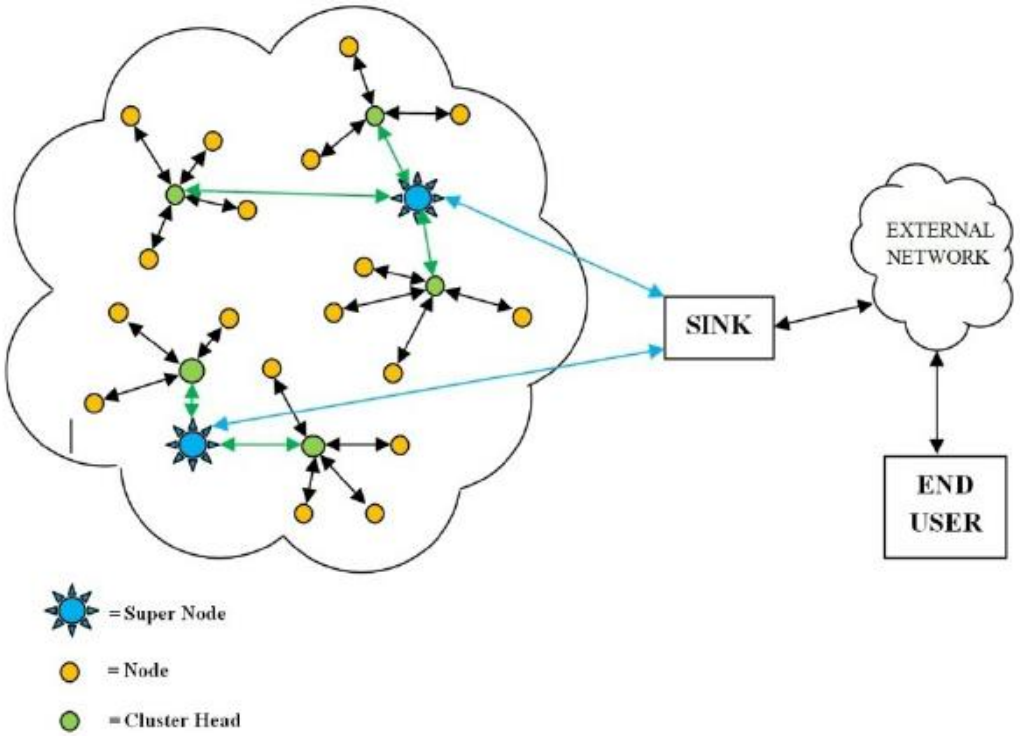
Wireless Sensor Networks

Sensors may measure:

- Distance, Direction, Speed
- Humidity, Soil makeup
- Temperature, Chemicals
- Light, Vibrations, Motion
- Seismic data, Acoustic data
- Strain, load, pressure

- Self-configure into wireless multi-hop network

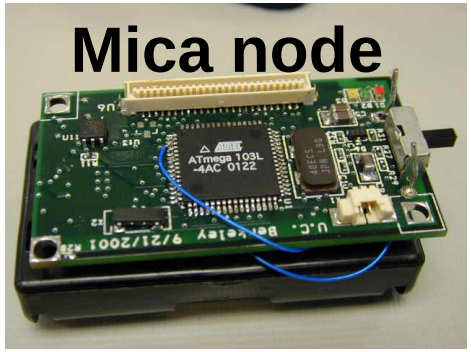


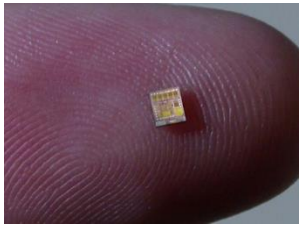


Applications

- Nature
  - Wildlife – Great Duck Island (Berkeley 2002)
  - Monitor atmosphere (NCAR)

- Home
  - Security (commercial)
- Mobile/Robotic sensor networks





Applications.. more..

Environment

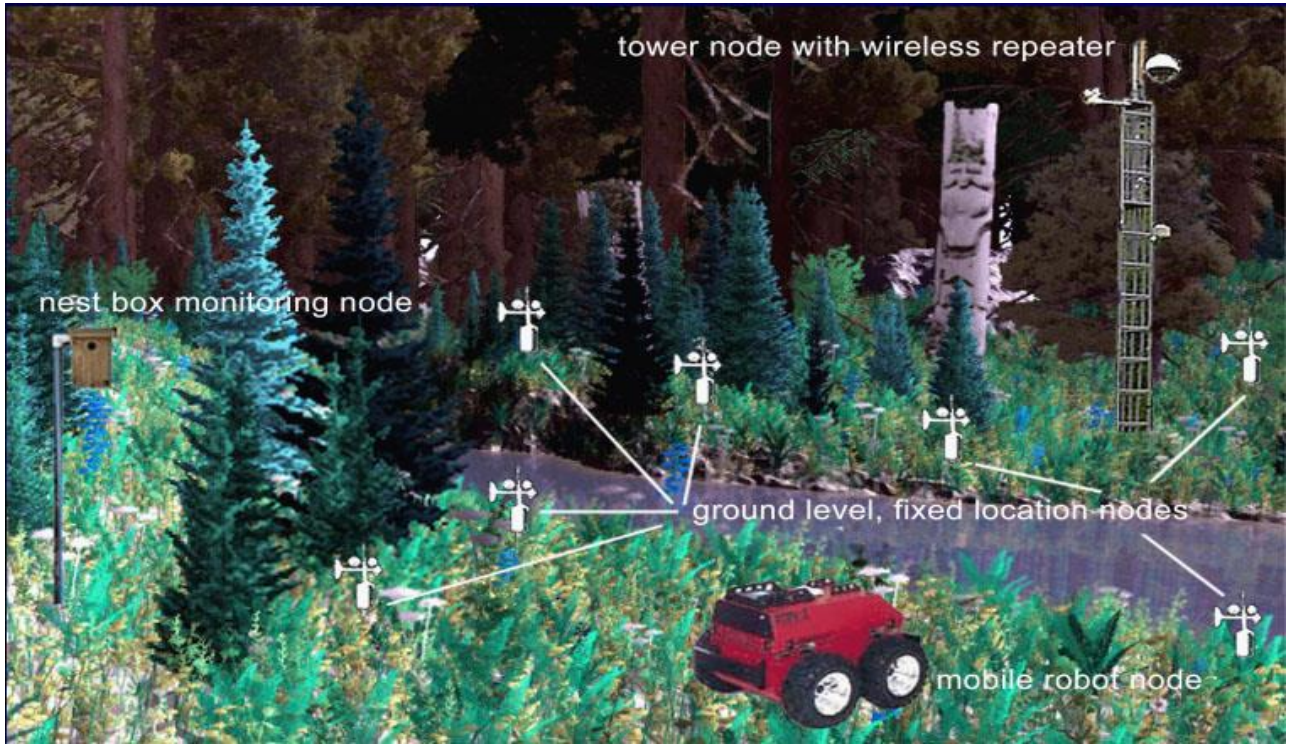
Agriculture

Pollution

Meteorological

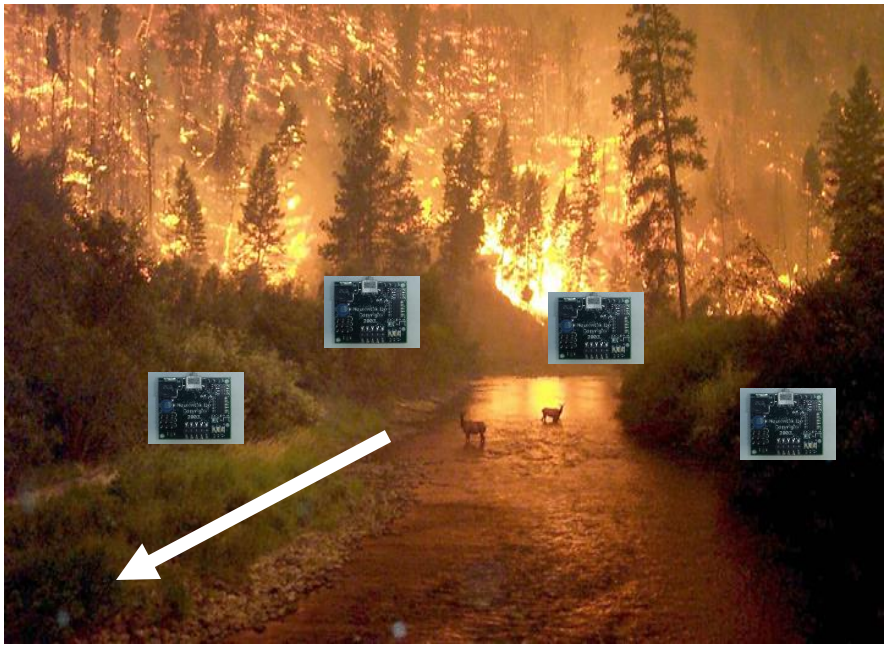
Flood detection

Habitat monitoring UCLA



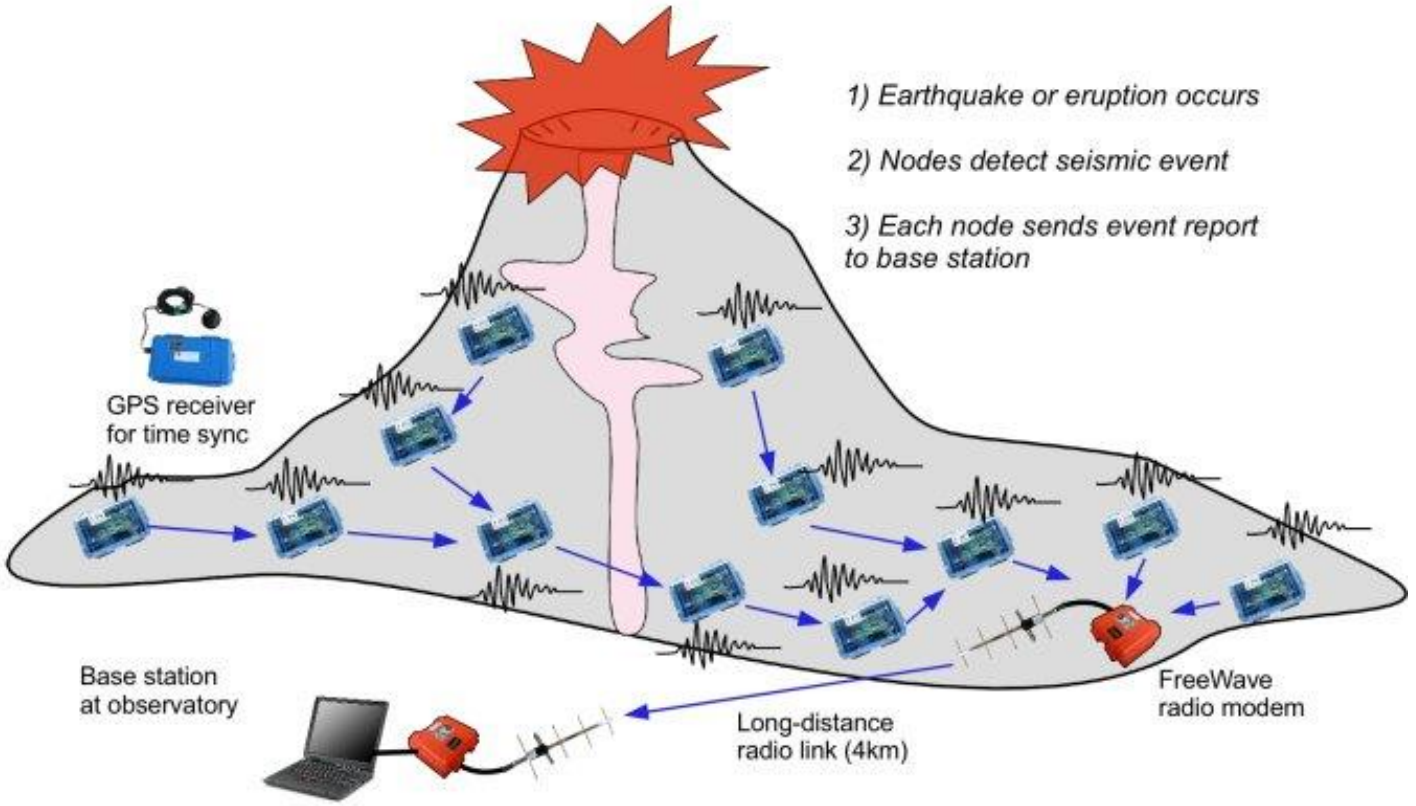
Forest Fires

- Provide finer granularity weather data via sensor networks
- Improved prediction and management of forest fires



Measure Temperature, Relative Humidity, Wind Speed and Direction

Earthquake Monitoring



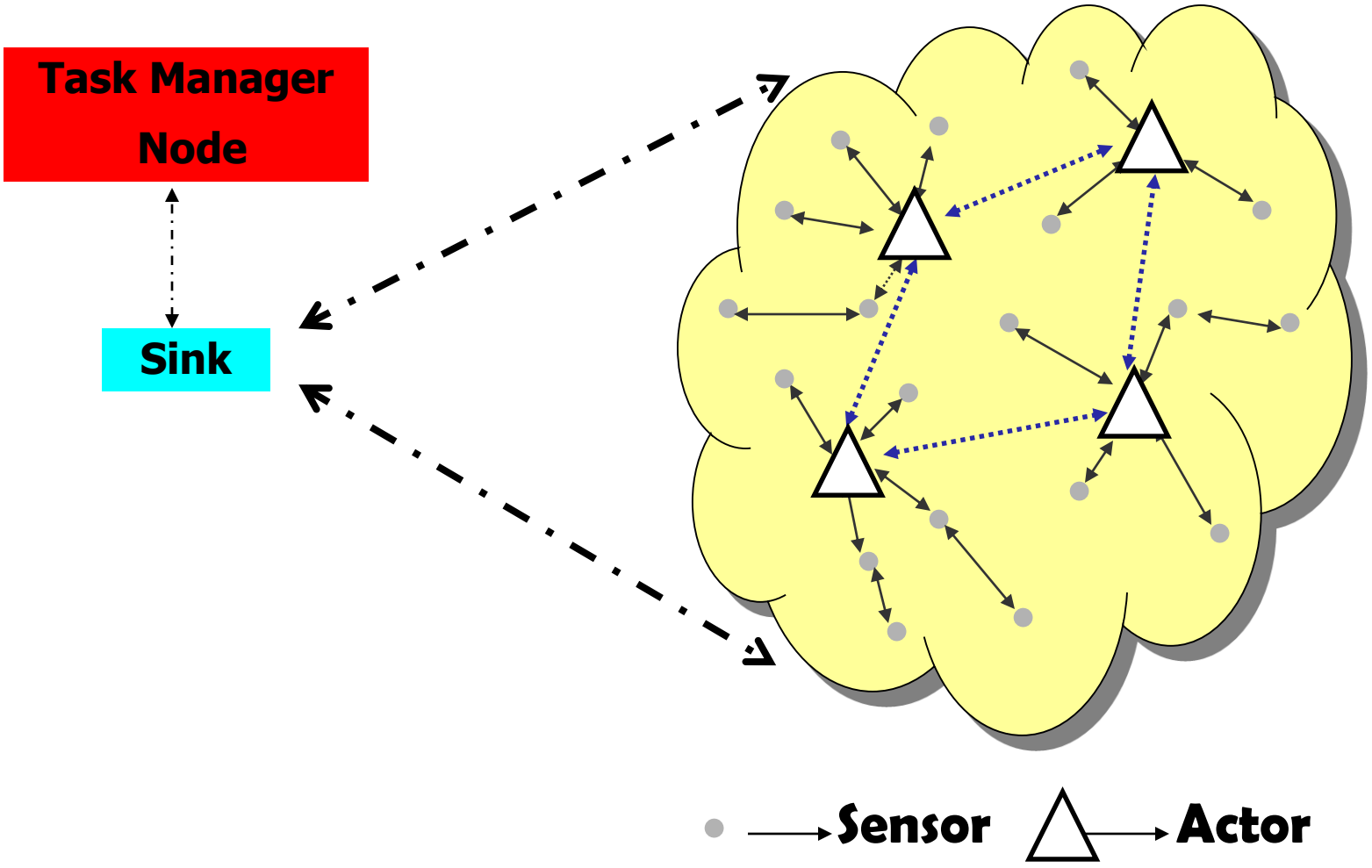
Military Applications

– Situational Awareness and Command & Control for military.

Ad hoc peer-to-peer wireless networking, or mobile mesh networking, can link battlefield forces without fixed infrastructure.

Wireless Sensor and Actor Networks

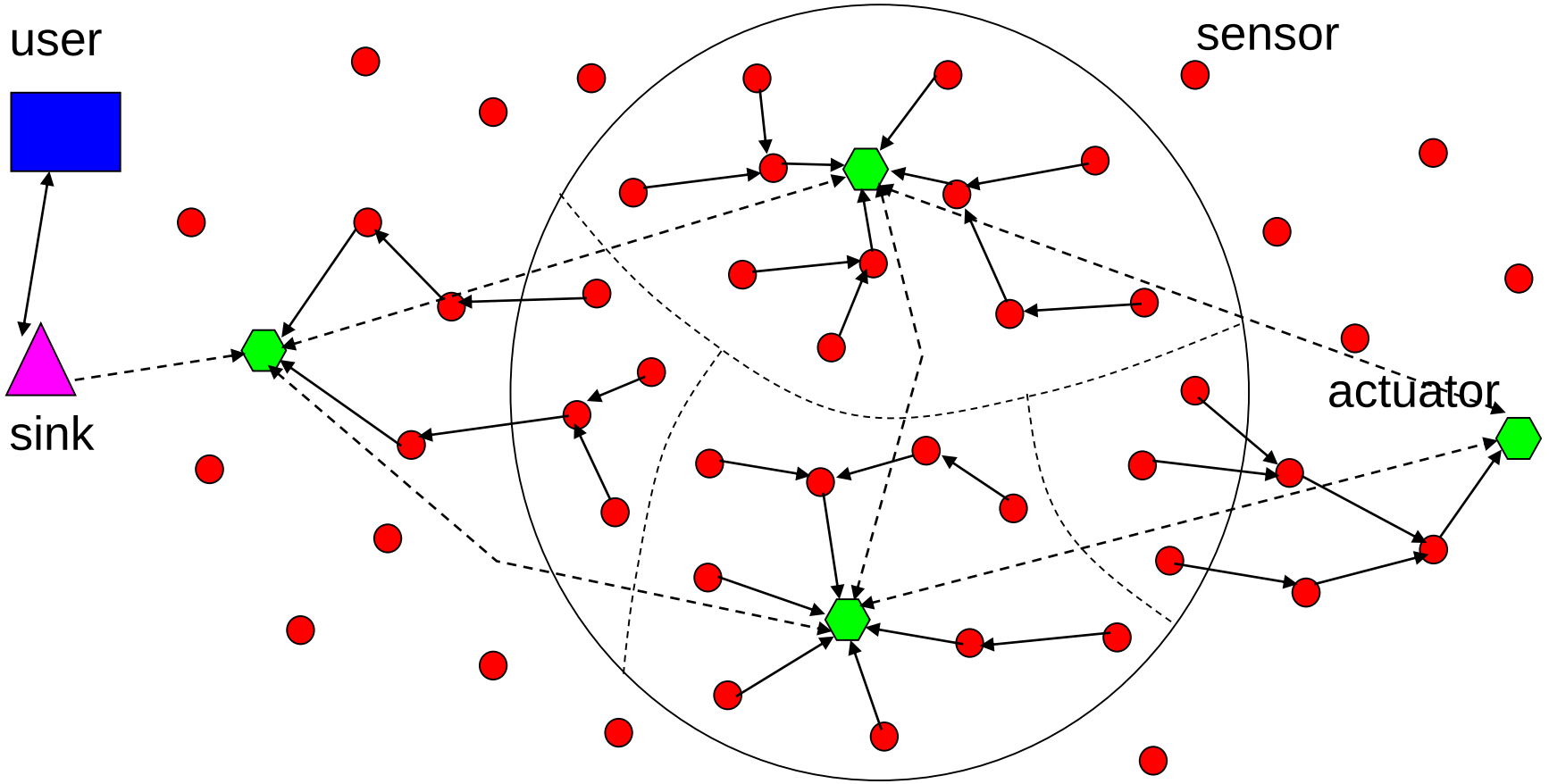
Actors: active nodes, higher energy and computation, action possible, may be mobile



Networked robots/actuators

Coordinated actuator movement

- move/place sensors to improve area coverage
- move to help sensors determine positions
- move to create fault tolerant network



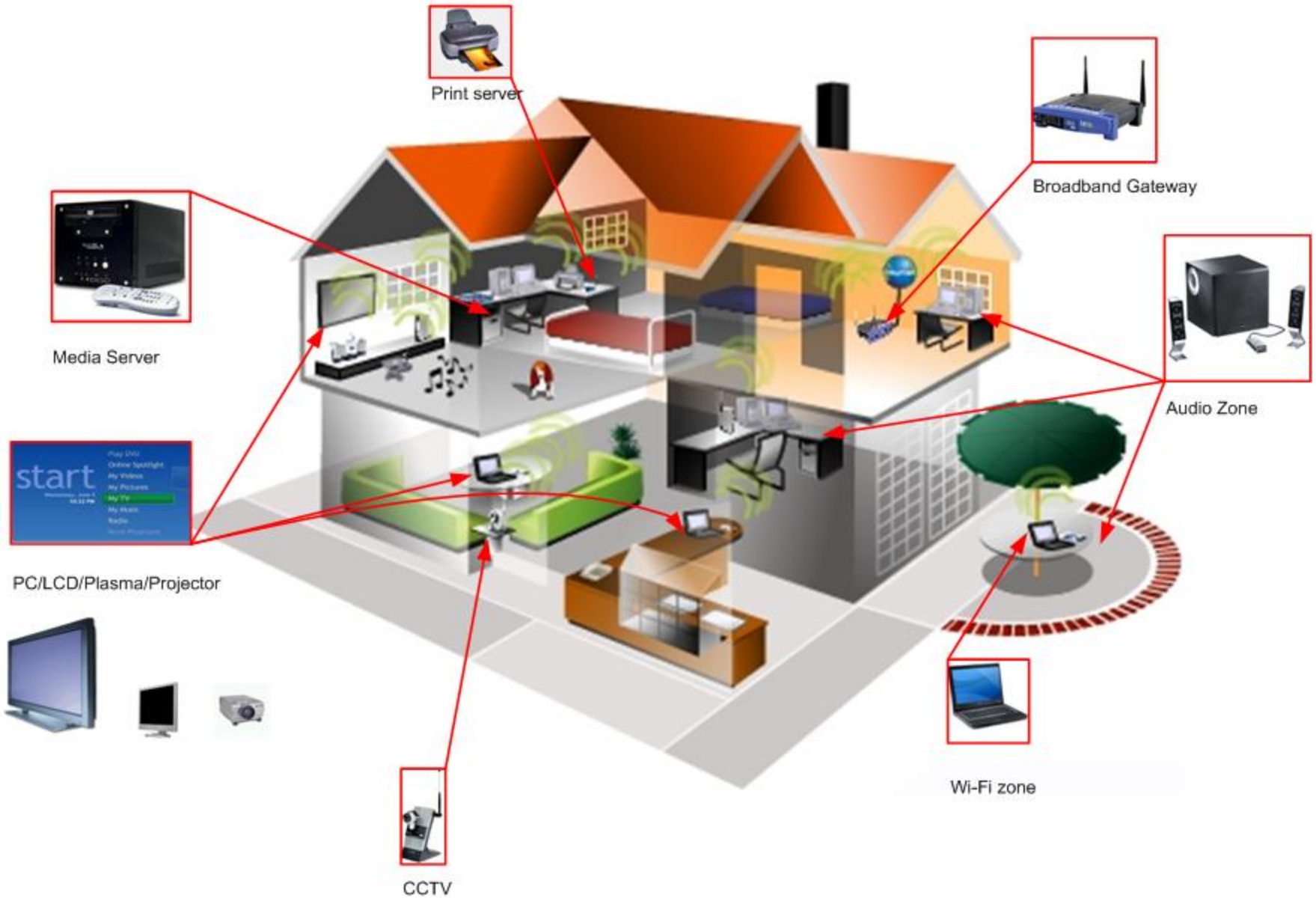
Mobile Sensor Networks

Mobile Sensor Networks Reality

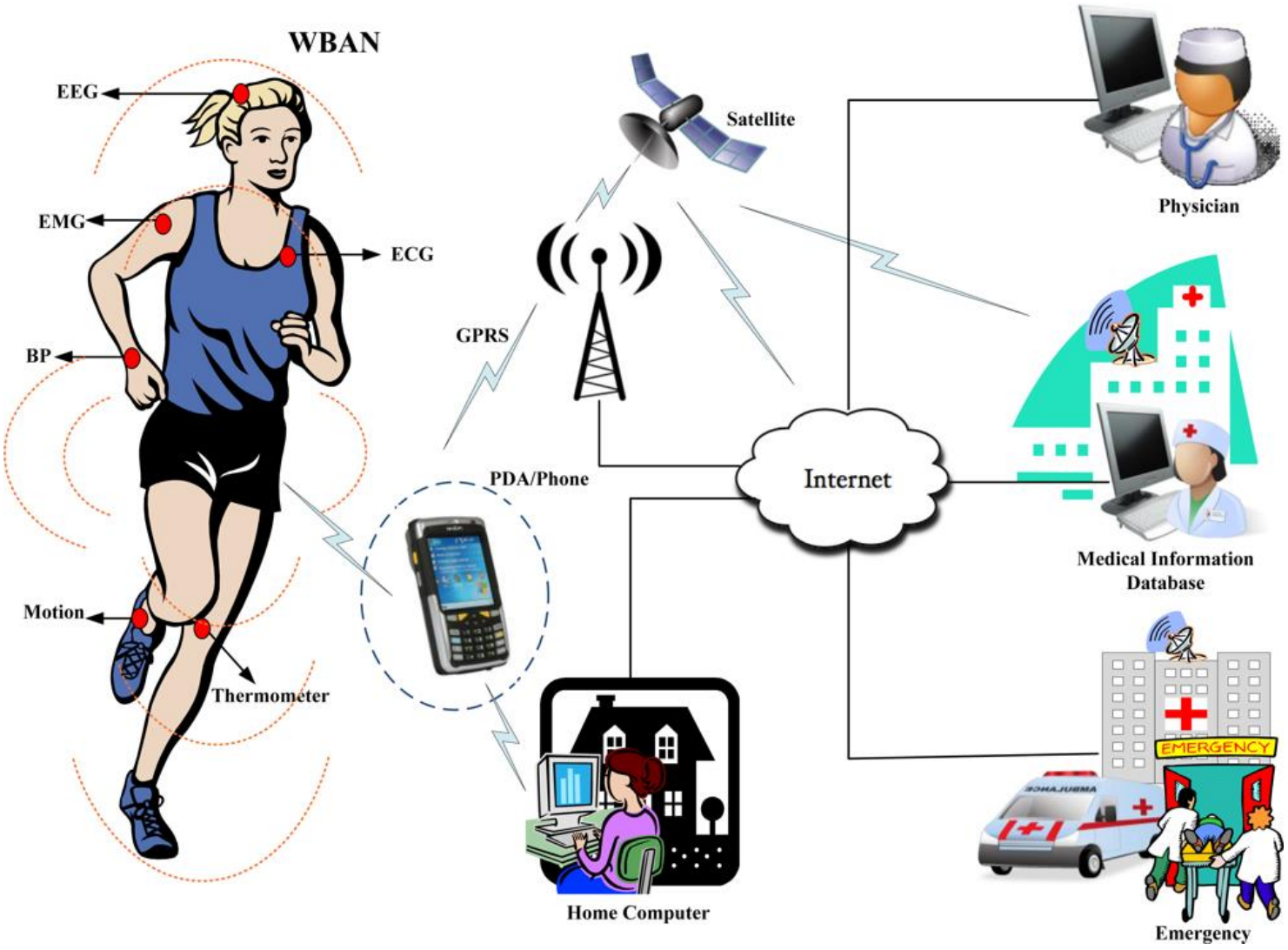
- Very constrained resources
- Depending on application: harsh conditions (water)
- May not last long for various reasons
  - Impossible to change batteries
- Network can be very sparse

Digital Home Network

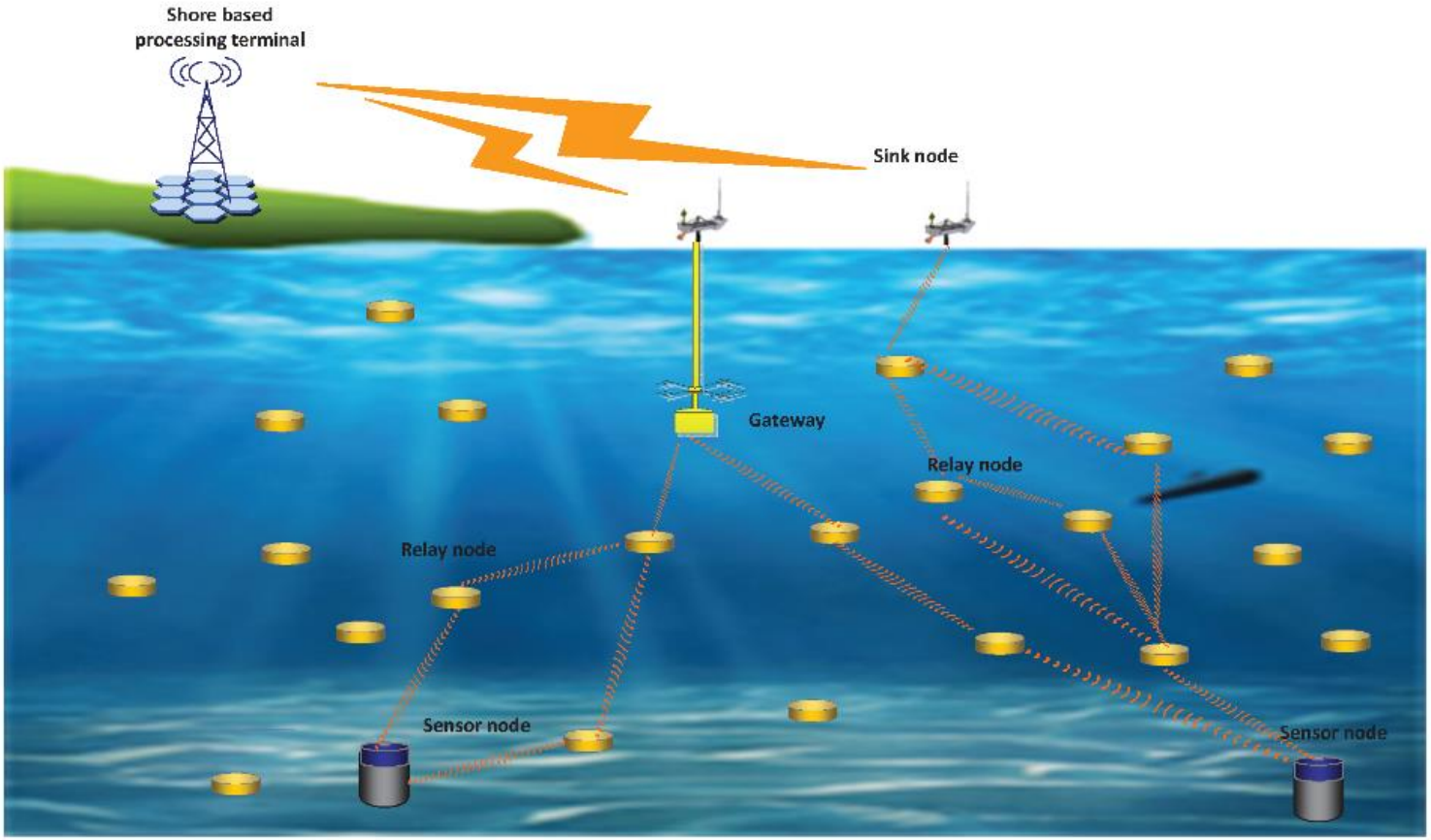
Wired and Wireless



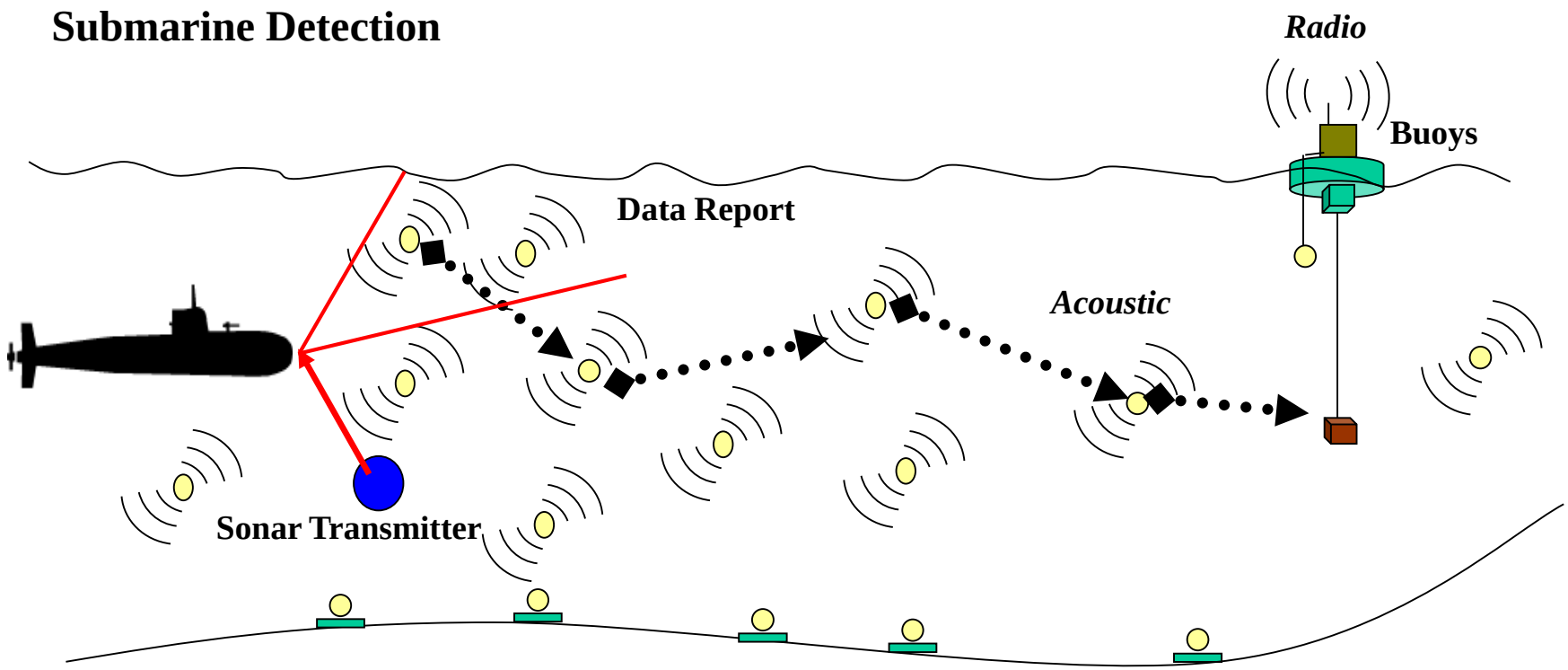
Wireless Body Area Networks



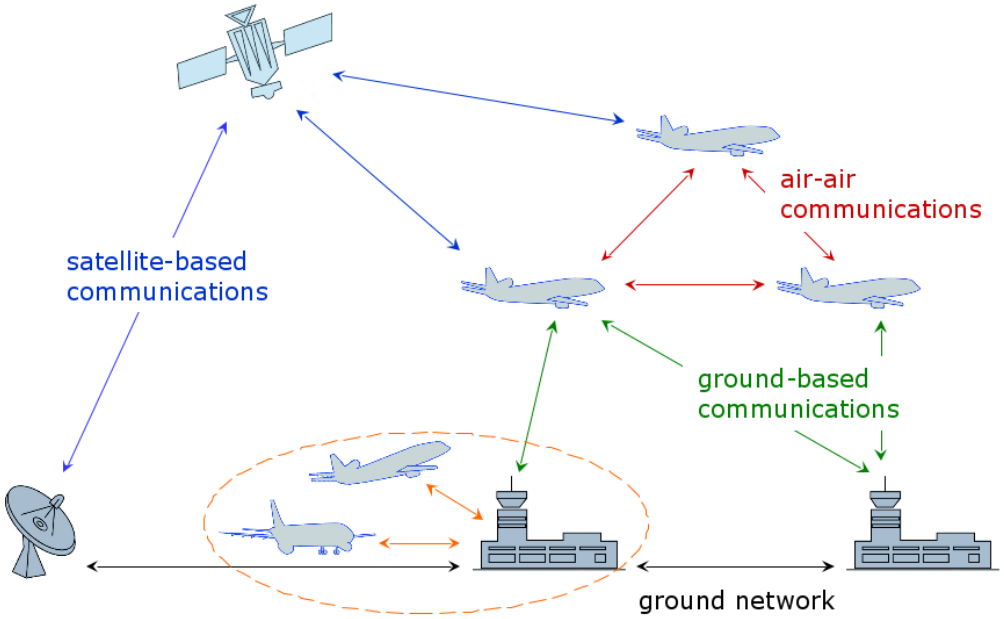
Underwater Sensor Networks

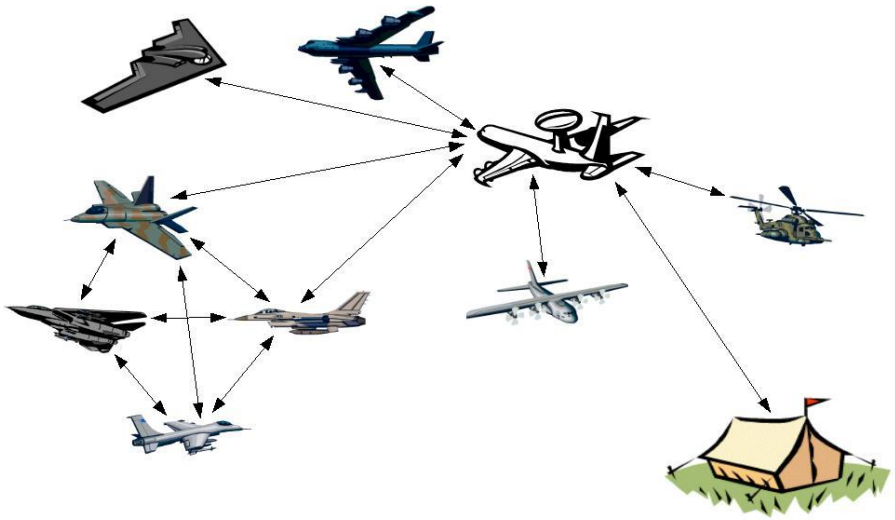


Underwater Sensor Network



Aeronautical Ad Hoc Networks

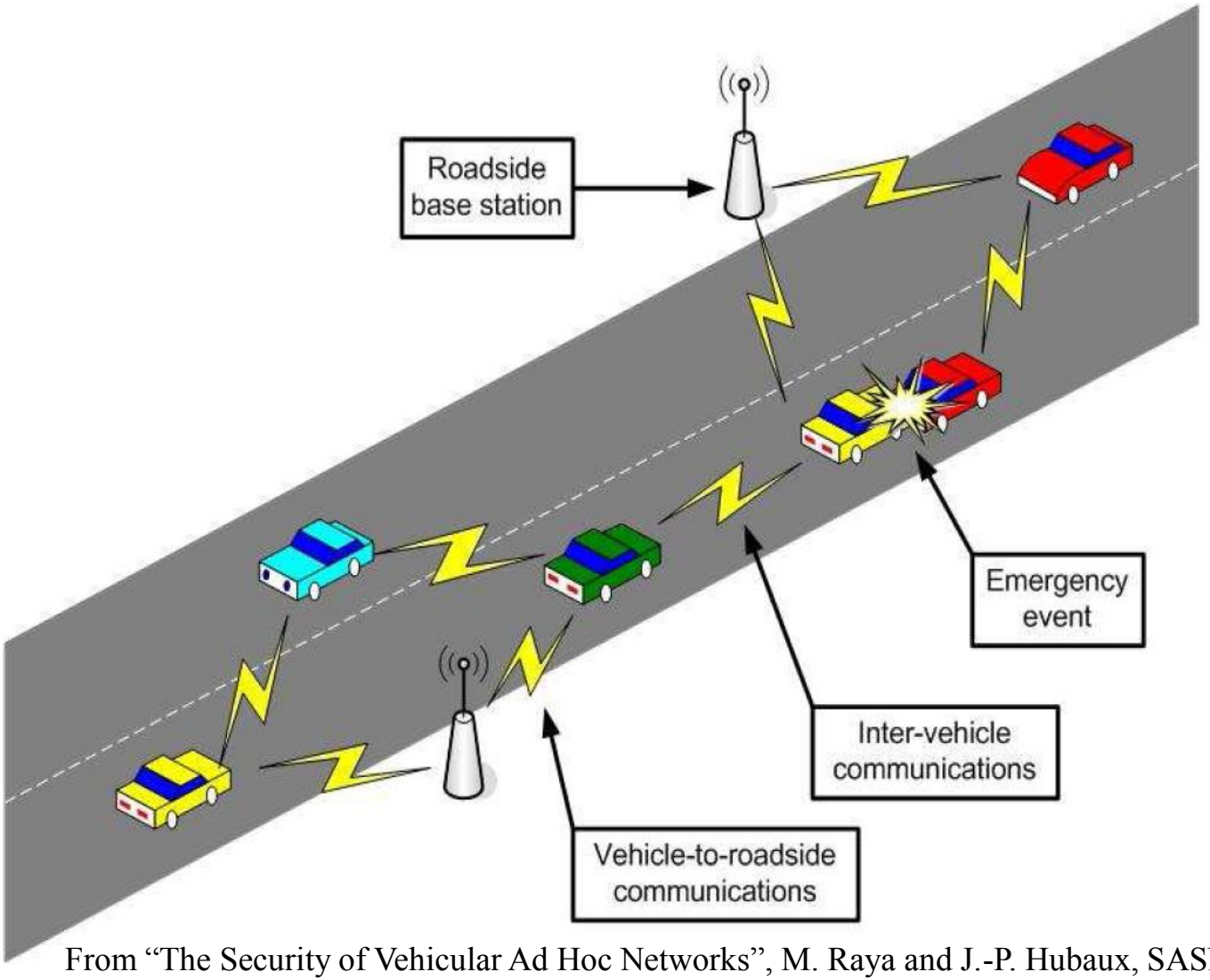




Vehicular Networks (VANET)

VANET

V2V / V2I Architecture



From “The Security of Vehicular Ad Hoc Networks”, M. Raya and J.-P. Hubaux, SASN 2005