Introduction to Ad Hoc Networks

Outline

- Introduction
- Ad hoc networks
  - Principles and applications
  - General characteristics

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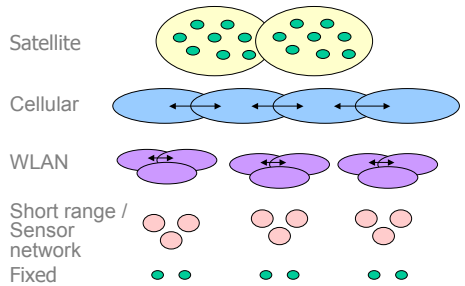
Introduction

- A wireless network is a communication system in which user terminals access the network services through a wire-less link
- Examples: radio link, infrared link,…

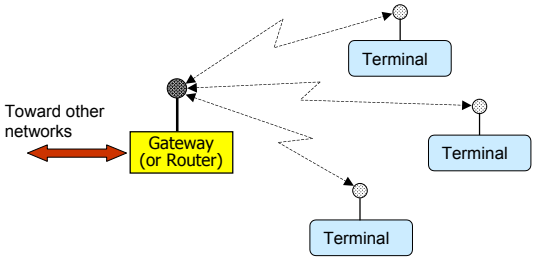
System Classification
Coverage and Mobility



System Classification
Architecture

- **With fixed infrastructure**: e.g., cellular networks and some local networks
- **No fixed infrastructure**: ad hoc networks (e.g., some local networks, short-range and sensor networks)

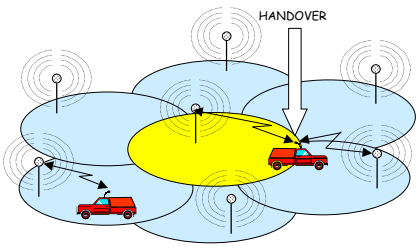
Wireless Networks with Fixed Infrastructure



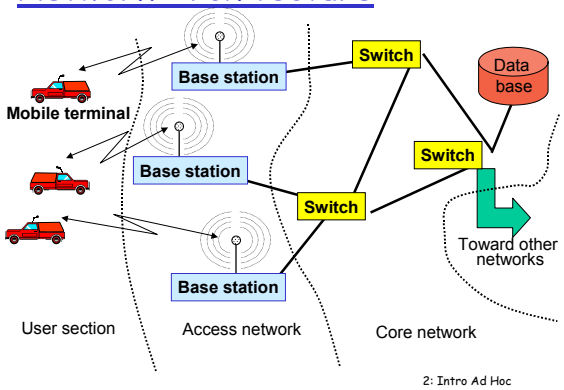
An Example: Cellular Networks

1. The network coverage is given by a group of adjiacent and / or overlapping spatial areas, so-called *cells*
2. In each cell there is a BS which controlling the transmission within the cell
3. The user terminal can move from a cell to another while maintaining its traffic connection active

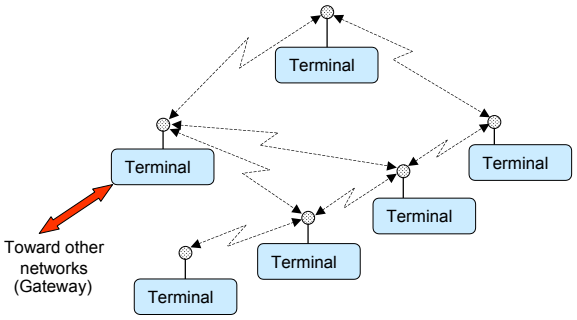
Coverage and Mobility



Network Architecture



Wireless Networks without Fixed Infrastructure



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"Ad Hoc Network" Definition

- In Latin, "ad hoc" literally means "for this purpose only"
- It can be regarded as a "spontaneous network," i.e., that automatically "emerges" when nodes gather together

Ad Hoc Network

- May be:
  - An autonomous system of nodes connected by wireless links forming an arbitrary graph (stand-alone fashion), or
  - Connected to a fixed infrastructure
- Network nodes are battery-powered and free to move randomly

Ad Hoc Network Topology

- The network topology may change rapidly and unpredictably

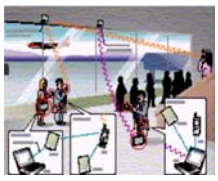
- Some devices may be part of the network only for the duration of a communication session or while in some close proximity to the rest of the network

Ad Hoc Networks Advantages

1. Ease of deployment
2. Speed of deployment
3. Decreased dependence on infrastructure

Applications

- **Personal communications**
  - cell phones, laptops
- **Cooperative environments**
  - taxi cab network
  - meeting rooms
- **Emergency operations**
  - policing and fire fighting
- **Military environments**
  - battlefield



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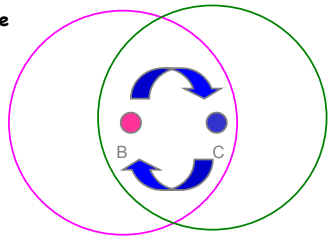
Terminology

- **Transmission range**
- **Receiving range**
- **Radio range**



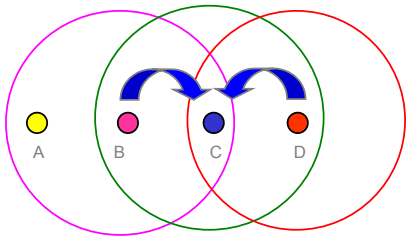
Terminology

- **Neighbor**: Given a network node, let's say A, any node that is in A's transmission range is said to be a neighbor of A. (The transmission range depends on the transmit output power)
- **Link:** Given two network nodes, A and B, a link between A and B may exist only if the distance between A and B is less than or equal to the nodes transmission range. A wireless link may be uni- or bi-directional

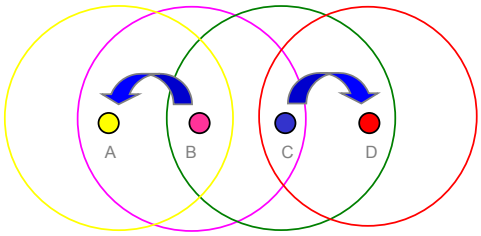
Channel Access
Medium Access Control (MAC)

- Limited wireless transmission range
- Packet losses due to transmission errors
- Broadcast nature of the wireless medium
  - **Hidden terminal problem**
  - **Exposed terminal problem**

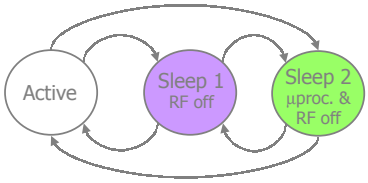
The Problem of Hidden Terminals



The Problem of Exposed Terminals



Power Conservation



- Random wake-up schedule during the connection phase and by turning the radio off during idle time

Energy Conserving MAC

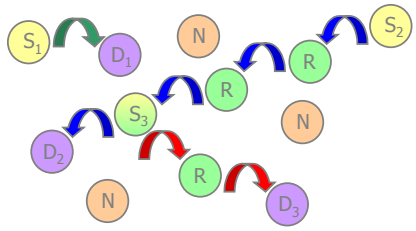
- Since mobile hosts operate through batteries, MAC protocols which conserve energy are of interest
- Proposals for reducing energy consumption typically suggest turning the radio off when not needed
  - Possible use of two different channels, one for data and another for control
  - A node powers off its radio while a neighbor is transmitting to someone else
  - If a node wakes up and finds that another one is transmitting to someone else, it goes back to sleep as long as the transfer will still last

Energy Conserving MAC

- **Disadvantages**
  - Need of a separate control channel
  - Nodes have to be able to receive on the control channel to be reactive to traffic dynamics. A node should switch off the interface for data channel, but not for the control channel
  - Delays in traffic delivery are unavoidable

Multihop Communications

Data routes may traverse multiple links to reach a destination



S=Source; D=Destination; R=Relay; N=Not participating

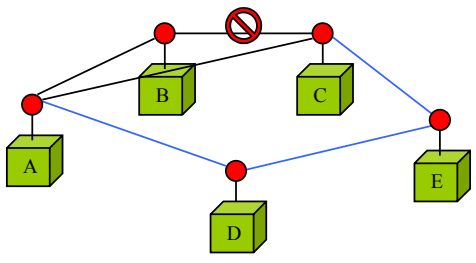
Multihop Communications
Advantages and Disadvantages

- **Advantages:**
  - May help in saving transmit energy resources
  - Reduces interference
  - Increases overall network capacity since the spatial domain can be reused for concurrent but physically separate sessions
- **Disadvantages:**
  - Increases the network traffic load !

Multihop Communications

- Need for coordination among the nodes
- Easy in military environment; difficult for civil applications (users naturally selfish)
- Algorithm to stimulate cooperation based on monetary penalization of the user denaying service

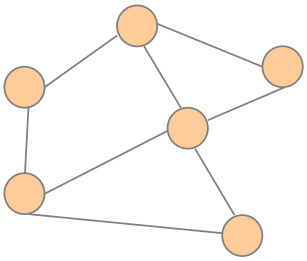
Network Formation and Traffic Routing



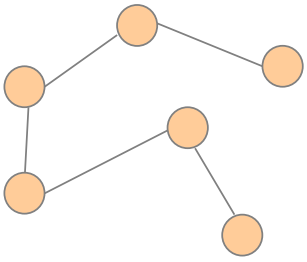
Network Topology

- **Flat:** All nodes are at the same hierarchical level
- **Tree:** Hierarchical architecture, easily extendible. Not a good choice for fault-tolerant networks
- **Cluster-Based:**
  - Nodes grouped into different sets (clusters)
  - Nodes identified as cluster-heads or ordinary nodes
  - The cluster-head is a central controller which coordinates communications within the cluster
  - There may be several hierarchical layers

Example: Flat



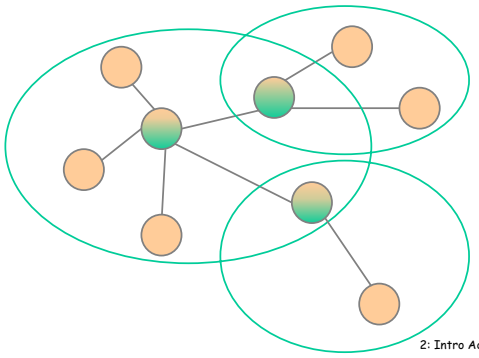
Example: Tree



N nodes

(N-1) links

Example: Cluster-Based



Possible Variations

- **Fully symmetric environment**
  - nodes have identical capabilities and responsibilities
- **Asymmetric capabilities**
  - transmission ranges may differ
  - battery life at different nodes may differ
  - processing capacities may differ
- **Asymmetric responsabilities**
  - some nodes may act as leaders of nearby nodes (e.g., as cluster-heads)

Possible Variations

- **Network architecture**
  - Nodes may co-exist (and co-operate) with an infrastructure-based network
  - Nodes may operate as an independent system of the fixed network
- **Traffic characteristics may differ**
  - bit rate
  - time constraints
  - reliability requirements
  - unicast / multicast / geocast

Possible Variations

- **Mobility patterns may differ**
  - people sitting at an airport lounge
  - taxi cabs
  - kids playing
  - military squads
  - work / home environments
- **Mobility characteristics**
  - speed
  - predictability
    - direction of movement
    - pattern of movement

Important Issues and Requirements

1. Autonomous and spontaneous nature of nodes

   ➡ Distributed algorithms to support security

   Reliability and consistency of exchanged and stored information

2. Time-varying network topology (no pre-existing central administration)

   ➡ Scalable routing and mobility management techniques to face network dynamics

Important issues and Requirements

3. Fluctuating link capacity and network resources

   ➡ Enhanced functionalities to improve link layer performance, QoS network support and end-to-end efficiency

4. Low-power devices

   ➡ Energy conserving techniques at all layers