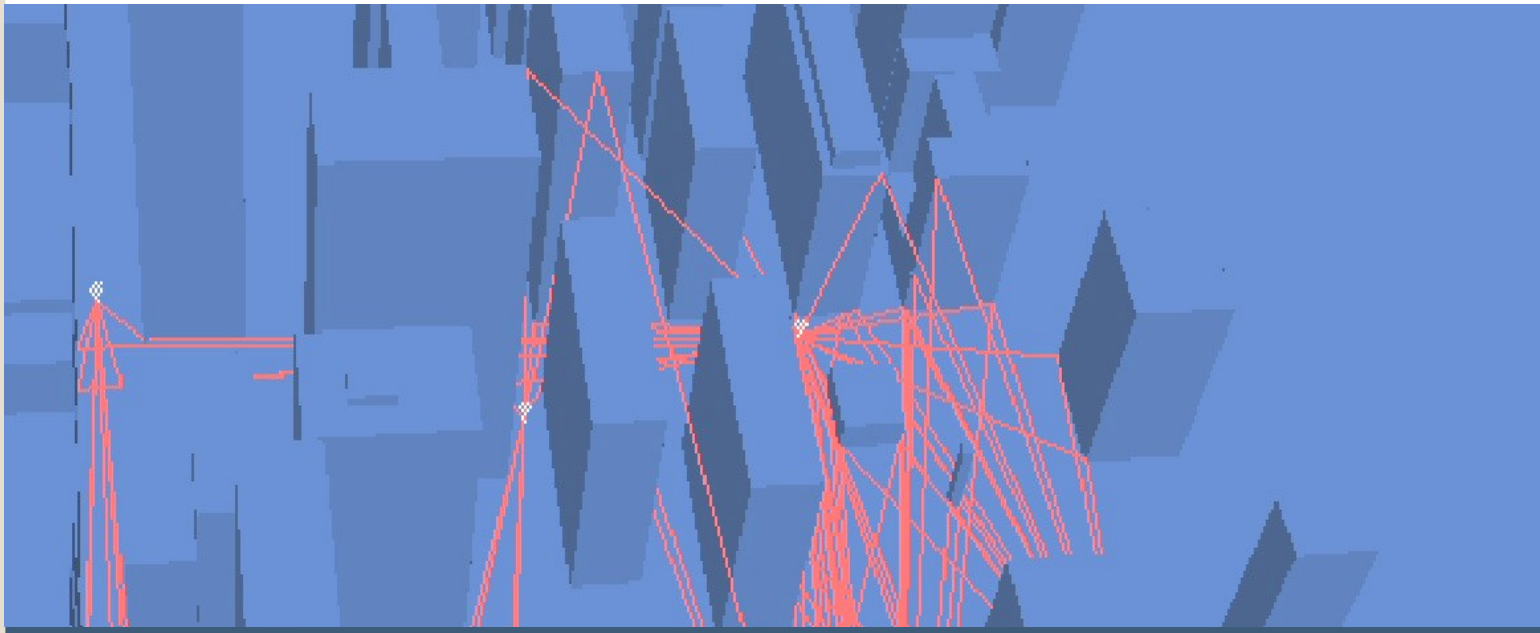
Introduction to wireless ad hoc networks

Towards ubiquitous networking



HERBIET Guillaume-Jean

ECE3076 Computer Communications / CS3251 Networking I
Georgia Tech Lorraine
11/07/2008

Wireless networks you might know

At home

- **Wi-Fi** : to interconnect computer, printers, gaming devices, etc.
- **Satellite** : for TV or connection to the Internet
- **Wi-Max** : starts being used in Europe to connect remote places to the Internet

At school

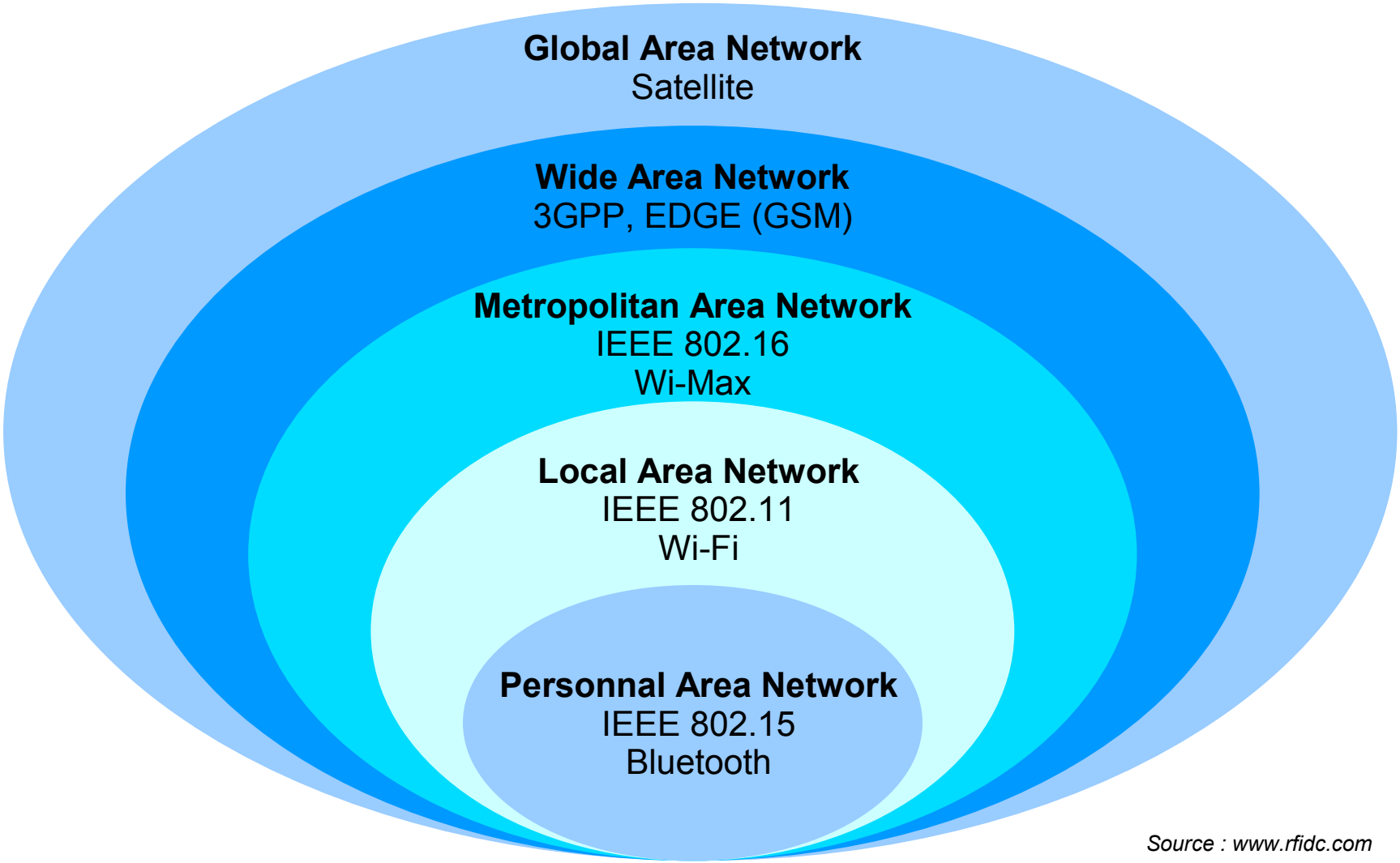
- **Wi-Fi** : LAWN or any other Wi-Fi hotspot to access network resources and the internet

Anywhere else

- **Cellular networks** : IS95, CDMA2000, GSM, GPRS, EDGE, etc. and any standard that is supported by your cell phone.

What have all those networks in common ?

Different standards for different applications



Source : www.rfidc.com

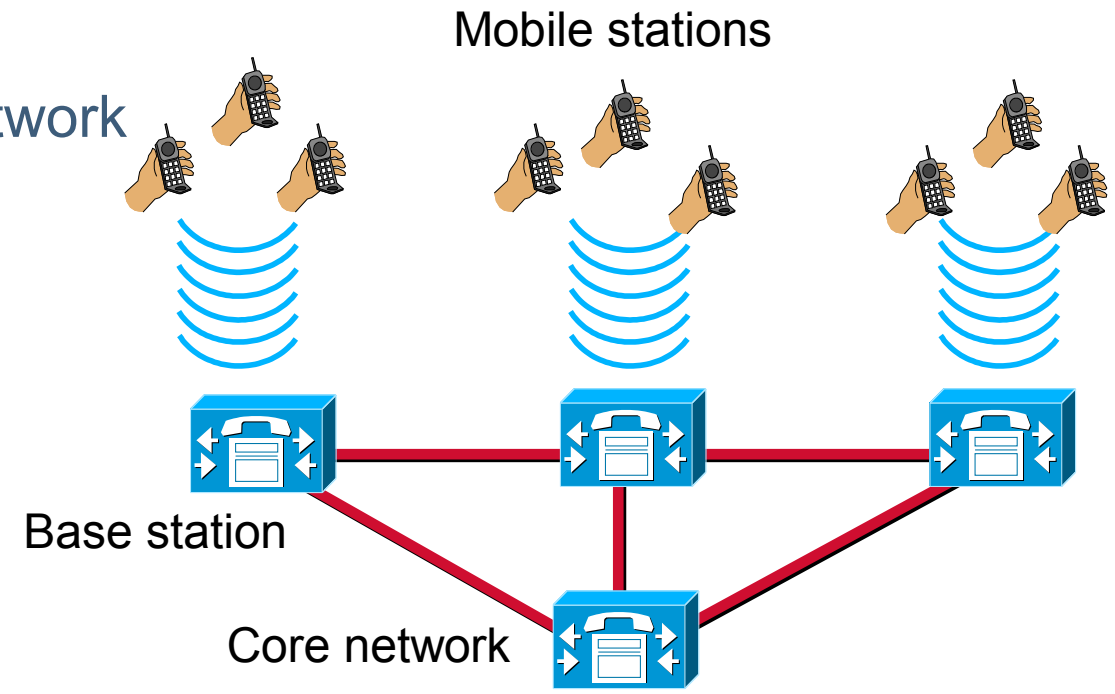
They are all infrastructure networks !

A wired infrastructure is used to interconnect wireless access points (AP)

- Only the **last hop** is wireless and thus mobile
- Users can move within the range of an access point
- They have to change access point when going out of range
  - Handover / Roaming
- **No direct communication between users**

Example of the cellular network

- Also valid for Wi-Fi and WiMax deployments



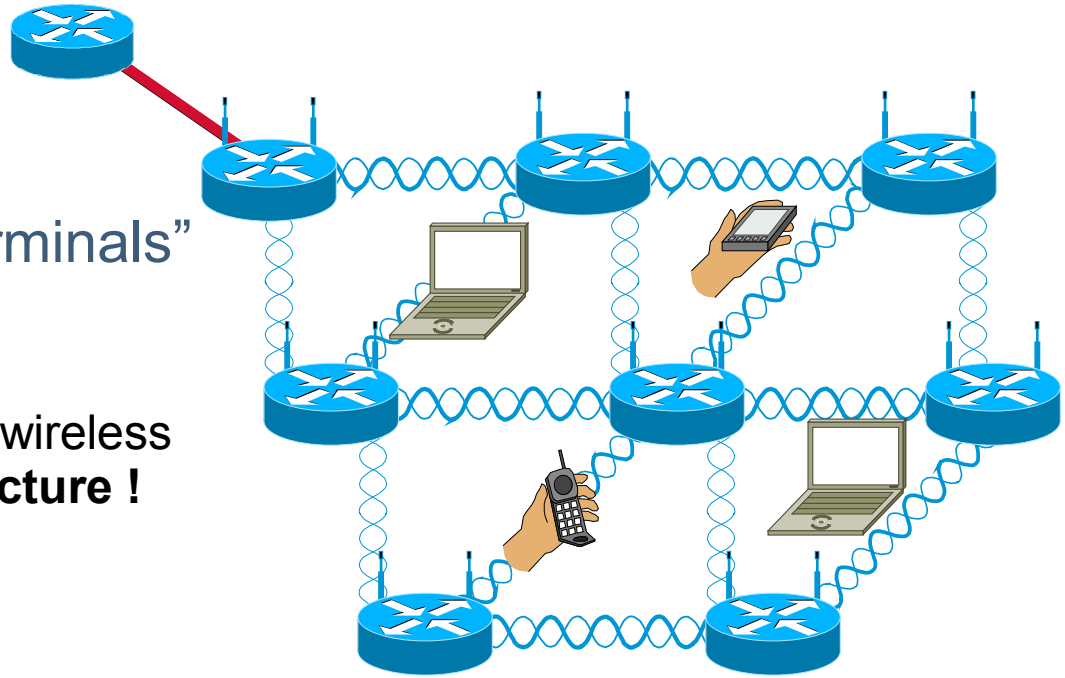
Wireless mesh networks

Wireless access point are interconnected to each other

- Improve wireless coverage w/o additional wired infrastructure
- User can move seamlessly within the area covered by all the AP
- One or several gateways are connected to the wired infrastructure network
- **Access point also act as routers** to relay traffic between users and the infrastructure network

Users still are wireless “terminals”

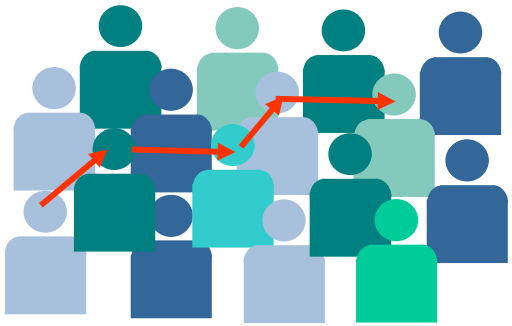
- Communication still only occurs with an AP
- Yes, the infrastructure is wireless but it is **still an infrastructure !**



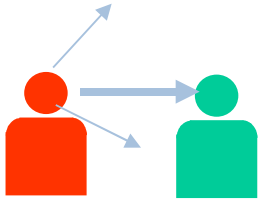
A metaphor for ad hoc networks

Gossiping in a crowded room

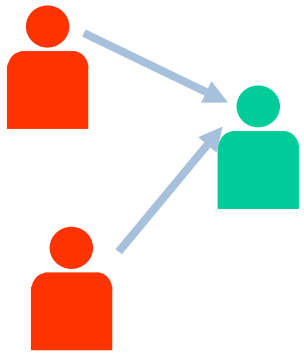
- Need to find a set of persons to propagate the gossip from the initiator to the recipient
- A physicial support for transmission is required (voice)
- Physical support is broadcast (everyone hears what a person says)
- The access to the physical support needs to be organized : only one person talks at a time in a given zone, so it can be understood by its neighbors



Routing



Transmission



Channel access control

Application	
Transport	
Routing (IP)	
MAC (DL)	MAC (DL)
Phy	Phy

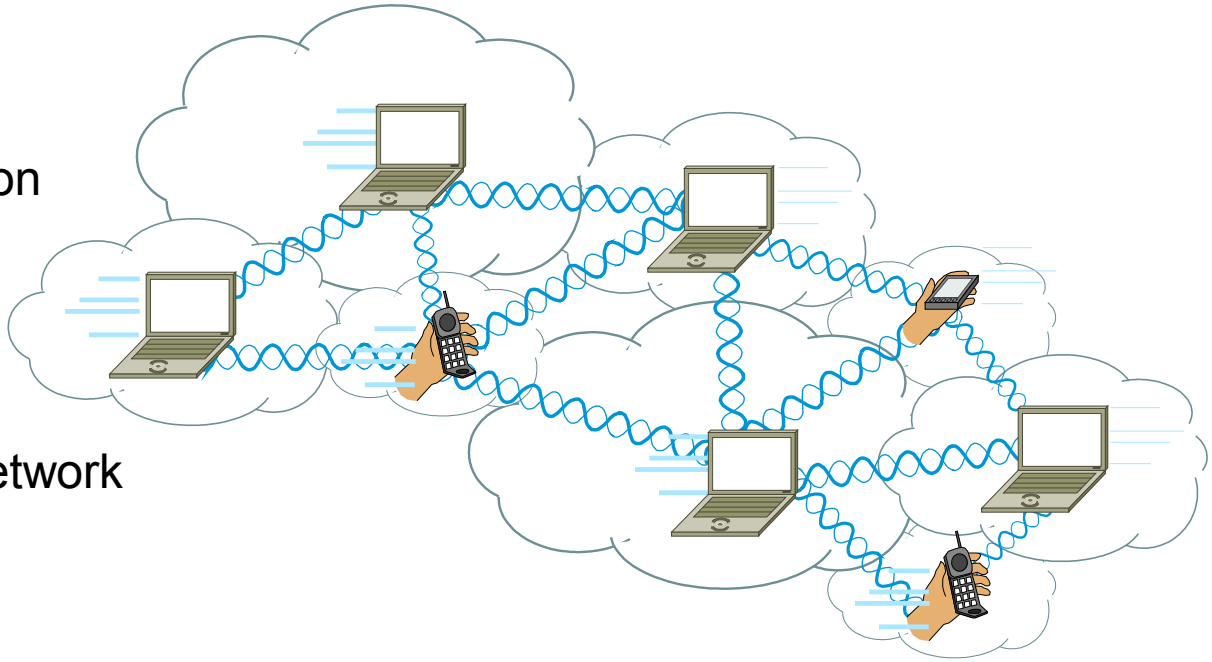
Mobile ad hoc networks (MANETs)

The MANET paradigm

- All nodes are **mobile**
- No infrastructure is required : all nodes **act as routers**
- Information is propagated from node to node using **multihop wireless paths**
- **Self-configuring** and **self-organizing** networks (“anytime, anywhere”)

Each node is a router

- Direct communication between users
- Generates and relays traffic
- All nodes play a similar role in the network



MANET applications

Smart devices / Ubiquitous computing

- Development of handheld communicating devices : tablet PC, UPMC, PDAs, communicating phones, etc.
  → **“anytime, anywhere”**

Disaster relief situations

- How to communicate efficiently when no infrastructure remains
  → **infrastructure-less networks**

Wireless sensor networks

- Dynamic management of a large number of nodes

Digital battlefield

- Easily set up a network, support node failure and movement
  → **self configuring networks, mobility management**

MANET challenges

All decisions should be distributed

- Fair access to the channel
- Routing of information across the multi-hop paths

Mobility management

- Network topology changes dynamically

Limited bandwidth for communication

- Channel usage should be efficiently used
- Volume of signalization (overhead) should be limited

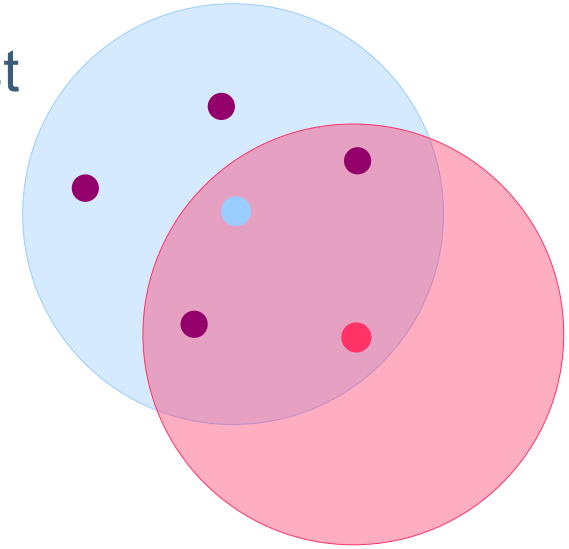
Efficient power management

Security issues

- Any node can enter the network and misbehave

A word about the radio medium

Wireless communication is inherently broadcast



- All nodes in transmission range of a node can receive its messages
- Broadcast is easier to achieve
- But nodes should share access to the medium so they can all transmit their information

What is to be shared ?

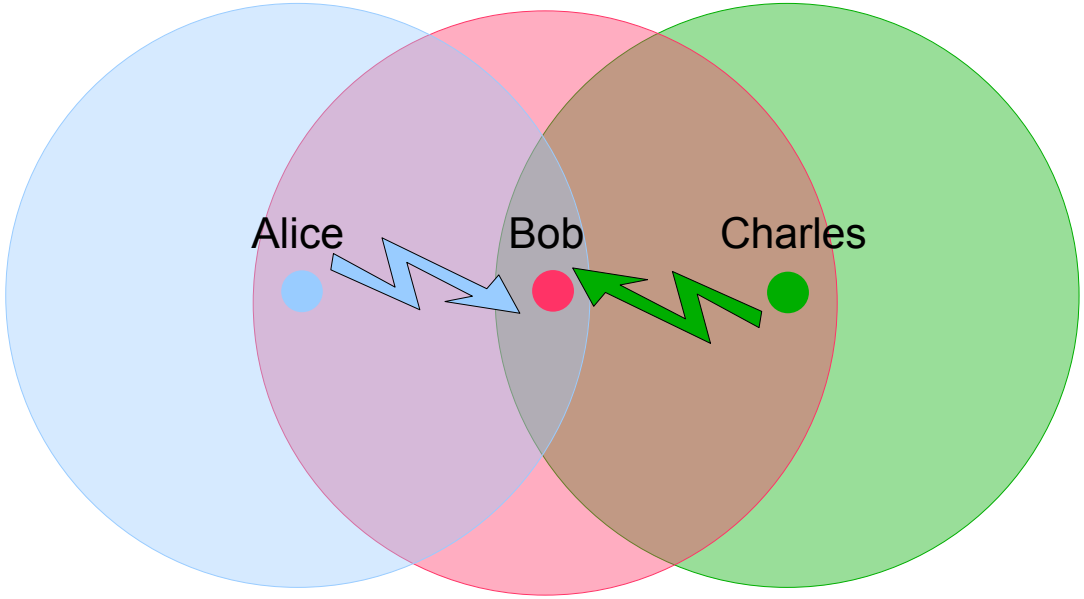
- **Space** : a node can only interfere within a given range
- **Time** : nodes will not interfere if they transmit at different times
- **Frequency** : nodes will not interfere if they transmit at different frequencies
- **Codes** :

→ **One of these (at least) has to be different (orthogonal) for nodes not interfering with each other**

How to efficiently allocate those resources is a key in MANETS

Distributed sharing of the channel is difficult

Famous example : the hidden terminal problem



- Alice hears Bob, but not Charles
- Bob hears both Alice and Charles
- Charles hears Bob, but not Alice

- How to ensure that Alice and Charles won't start transmitting at the same time and cause collision at Bob ?

Approaches for access to channel in MANETS

Contention-less approaches

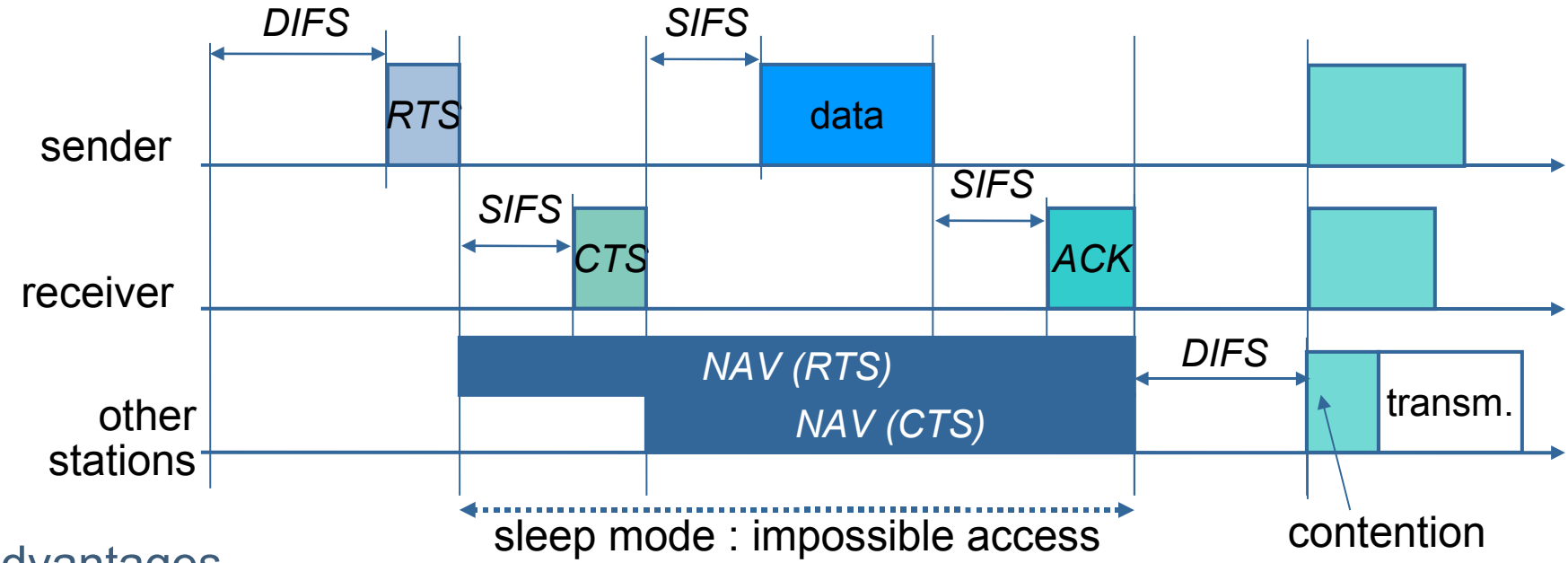
- Allocations in (space,time,freq,codes) are planned before transmission
- No collision should occur
- Problem : requires signaling for distributed planning of resources allocation
- Allocation process may be slow

Example : dynamic TDMA allocation

- Nodes only use different time slices (“slots”) to transmit
- Before series of transmissions, signaling is exchanged by the nodes to agree on a schedule

- This pattern (“frame”) is repeated over time
- Scheduling of allocations can change from frame to frame

Contention-based channel access : CSMA/CA



Advantages

- Relatively simple and fully distributed access control mechanism
- Statistical equity between nodes (Binary Exponential Back-off)

Drawbacks

- High overhead, very low efficiency for small packets (e.g. : VoIP packets)
- Bad interaction with TCP in ad-hoc mode (unfairness)
- Gray zones

Routing in ad hoc networks

How to efficiently determine a path on a dynamically moving network ?

On-Demand or **Reactive** Routing

- Only establish/repair path when necessary
- Limit overhead required but add delay on flow initiation (route discovery)
- Ex : Ad hoc On-demand **Distance Vector** (AODV)

Proactive Routing

- Keep paths ready at any time, always select the best path
- Messaging occurs even when there is no traffic
- Ex: Optimized **Link State** Routing (OLSR)

Hybrid Schemes

Geographical Routing

Hierarchical: One or many levels of hierarchy

Example of reactive routing : AODV

By Perkins and Royer

Sender tries to find destination:

- Broadcasts a Route Request Packet (RREQ).

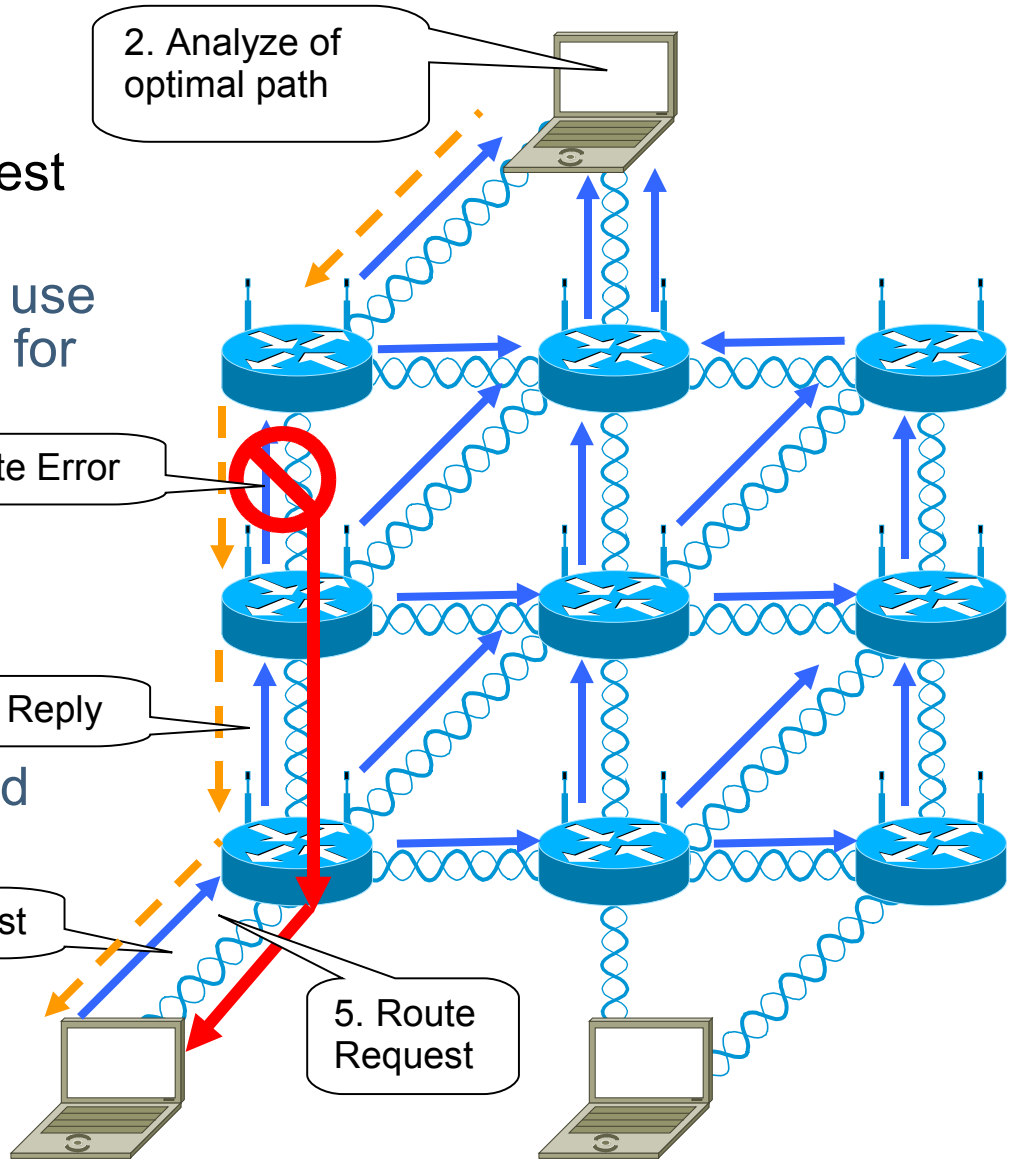
Nodes maintain route cache and use destination sequence number for each route entry

State is installed at nodes per destination

Does nothing when connection between end points is still valid

When route fails

- Local recover
- Sender repeats a Route Discovery



Example of proactive routing : OLSR

From INRIA labs

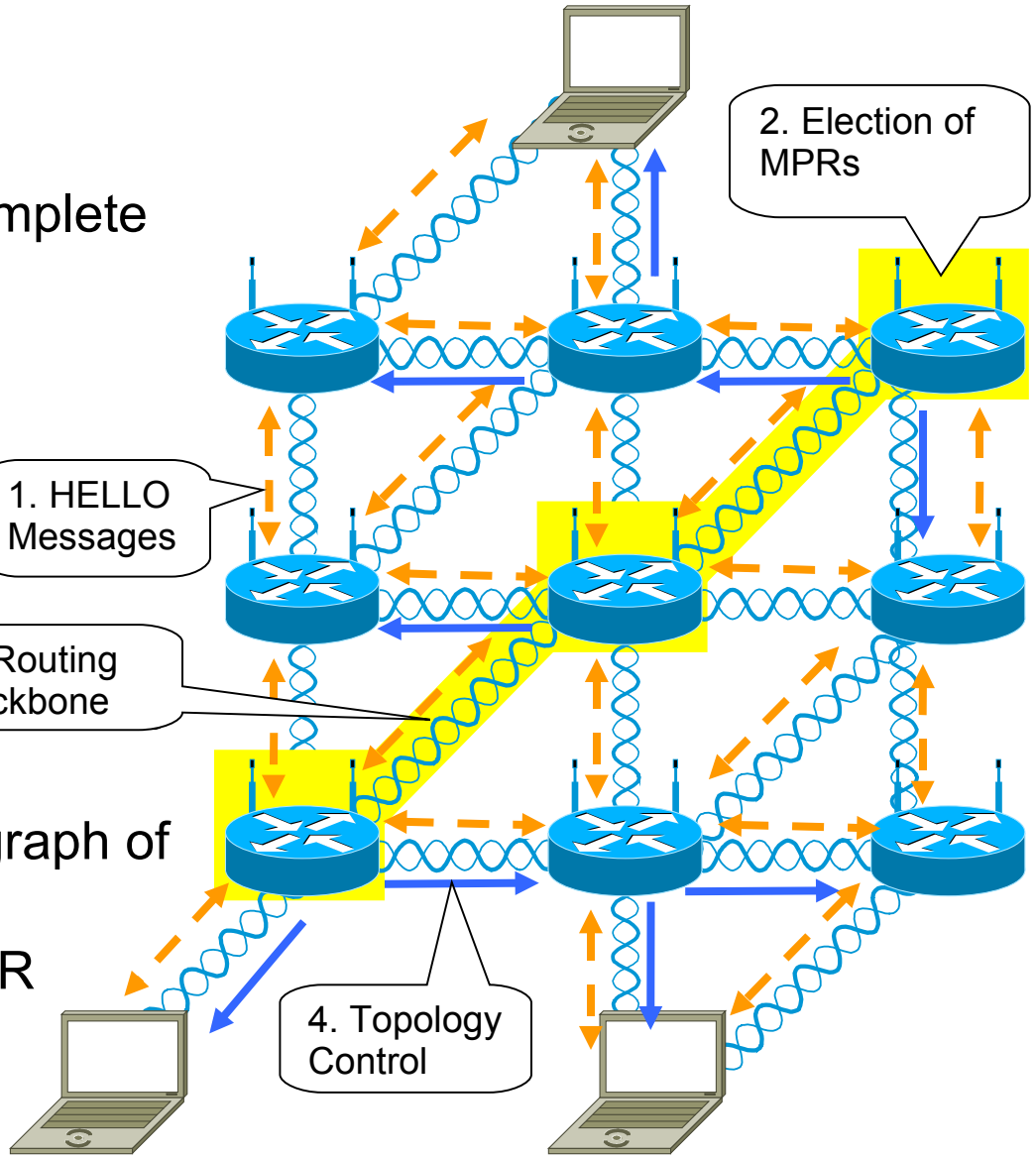
Based on “link sate” paradigm

- Each node knows the complete topology of the network

Shorthest path routing(Dijkstra)

Multipoint-relay (MPR)

- Only nodes relaying tr
  network
- Create a connected subgraph of the network
- Data is routed on the MPR subgraph



Power considerations in ad hoc networks

Power Budget versus Latency

- Most nodes in an ad hoc network are powered by batteries.
- Each node participates in two kinds of activities, sending and receiving messages useful for itself and forwarding messages for other nodes.
- A node may refuse to forward messages if its power level is too low.

Energy-efficient Protocols

- Good routing protocols should be designed to be energy-efficient
- Good routing decisions can only be taken if the nodes have good knowledge of the network topology
- But the nodes need to send more control messages for maintaining topology information...

Open research areas

Scalability

- How to efficiently handle a very large (>10000) number of nodes

Security

- How to transpose traditional security schemes (i.e. IKE-based) to MANETS ?
- Is there other dedicated approaches ?

Support for multicast application

- One-to-many application: video streaming, videoconferencing

Information diffusion/localization

- Apply the P2P paradigms to the ad hoc world

And many more !