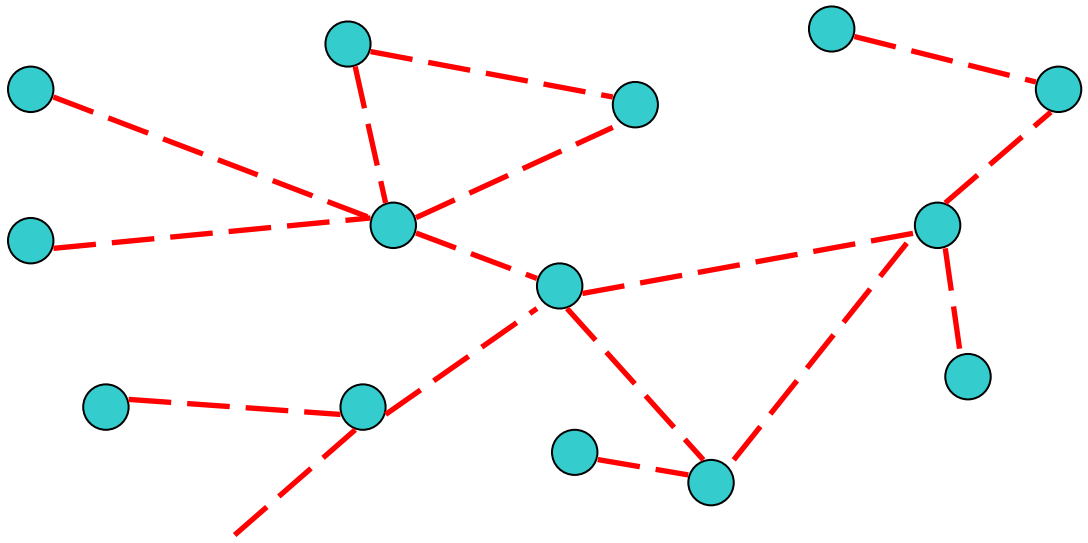
Wireless Ad-Hoc Networks



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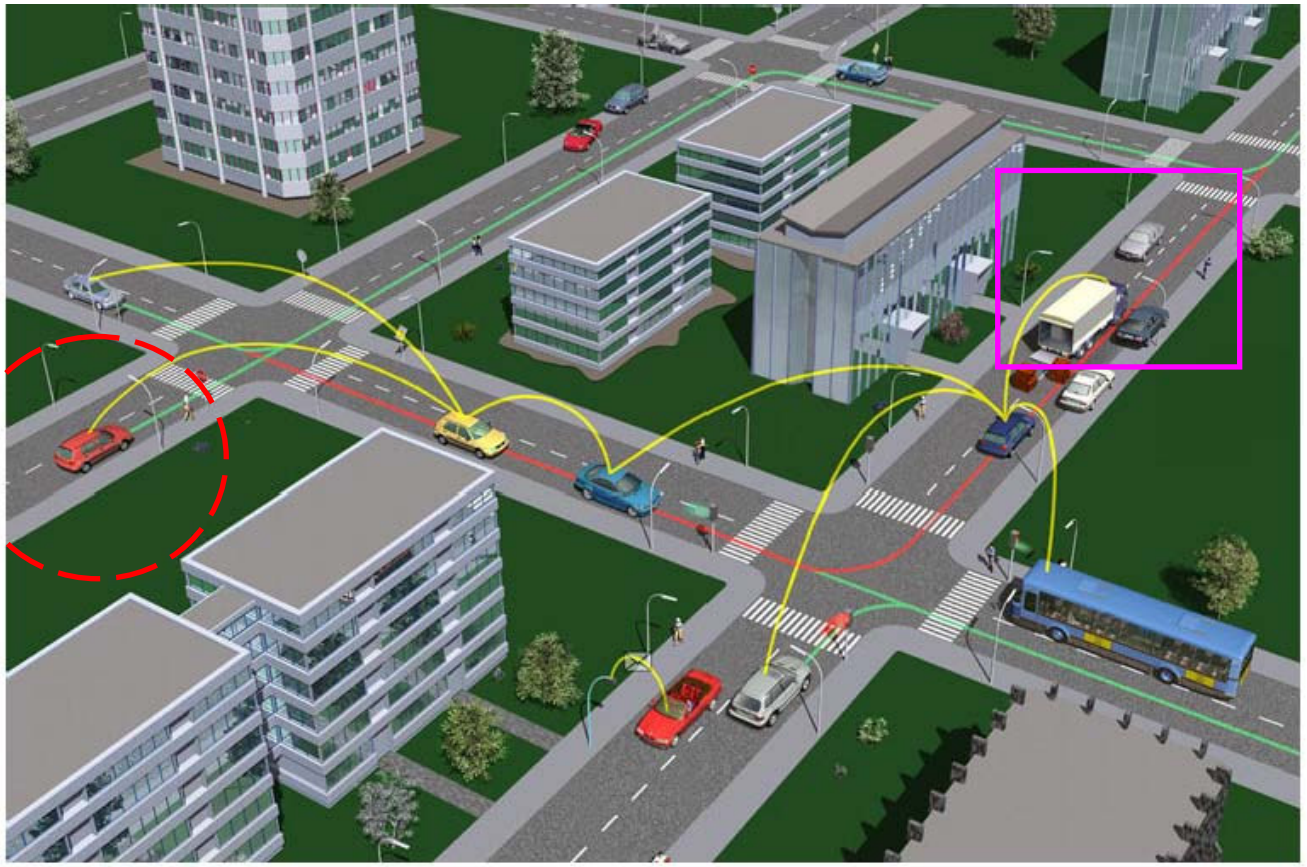
Outline – Part 1

- Motivation
- Wireless Ad hoc networks
  - Comparison with infrastructured networks
  - Benefits
  - Evolution
  - Topologies
  - Types
- Class exercise

Knowledge is life!



Traffic accident

original route

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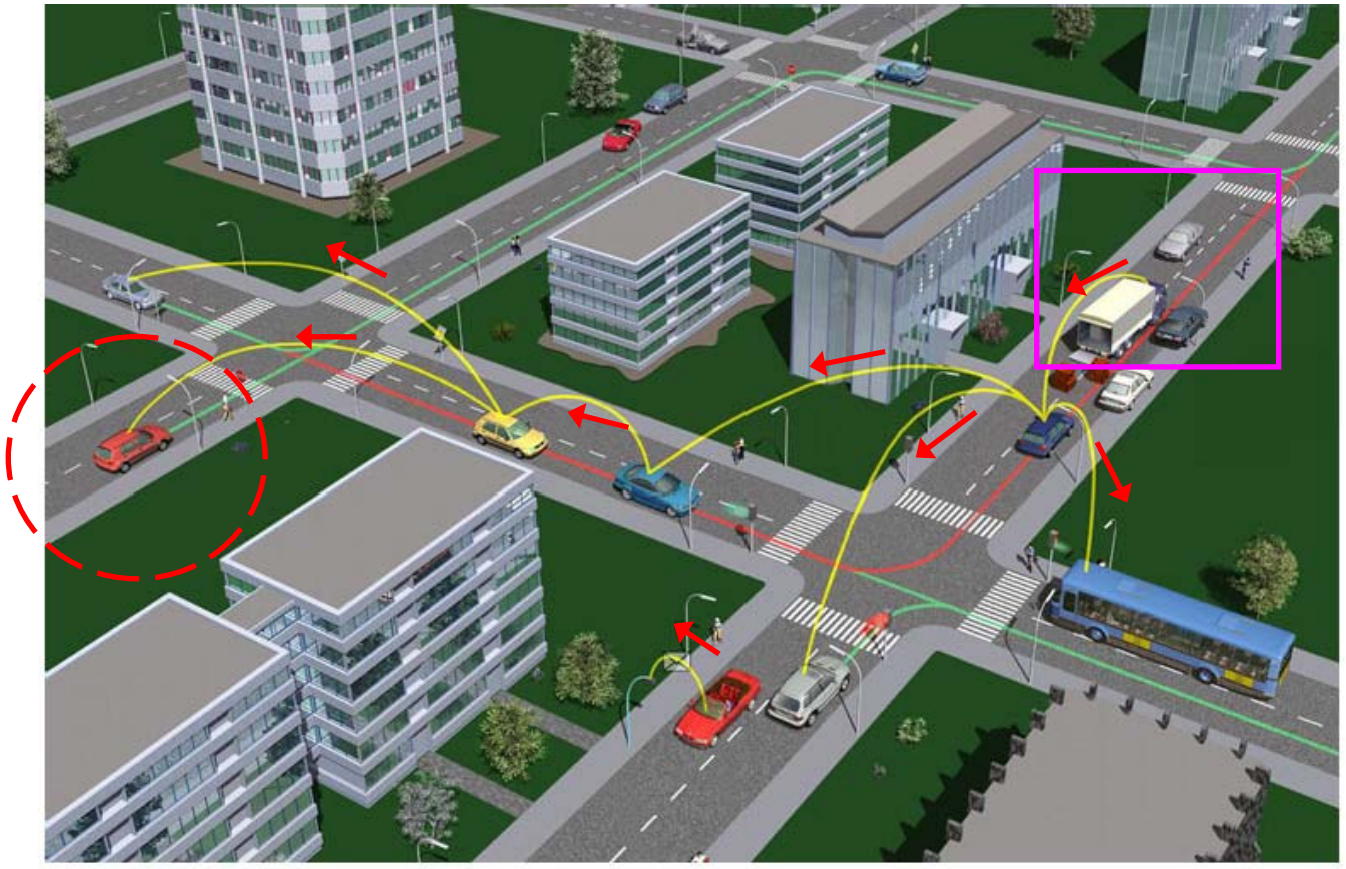
Car-to-car communication



Traffic accident

original route **new route**

Source: www.car-2-car.org

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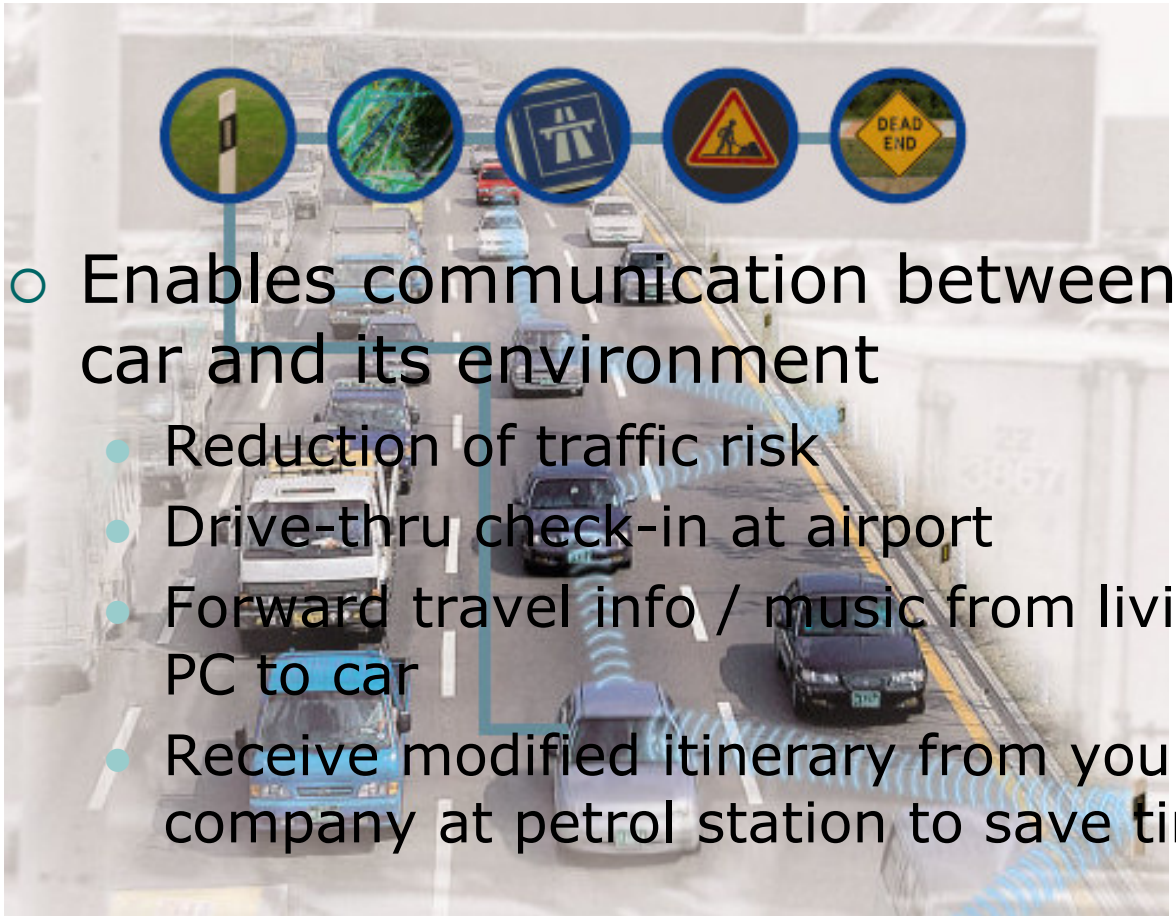
Car-to-car communication



- Enables communication between each car and its environment
  - Reduction of traffic risk
  - Drive-thru check-in at airport
  - Forward travel info / music from living room PC to car
  - Receive modified itinerary from your company at petrol station to save time

Source: www.car-2-car.org

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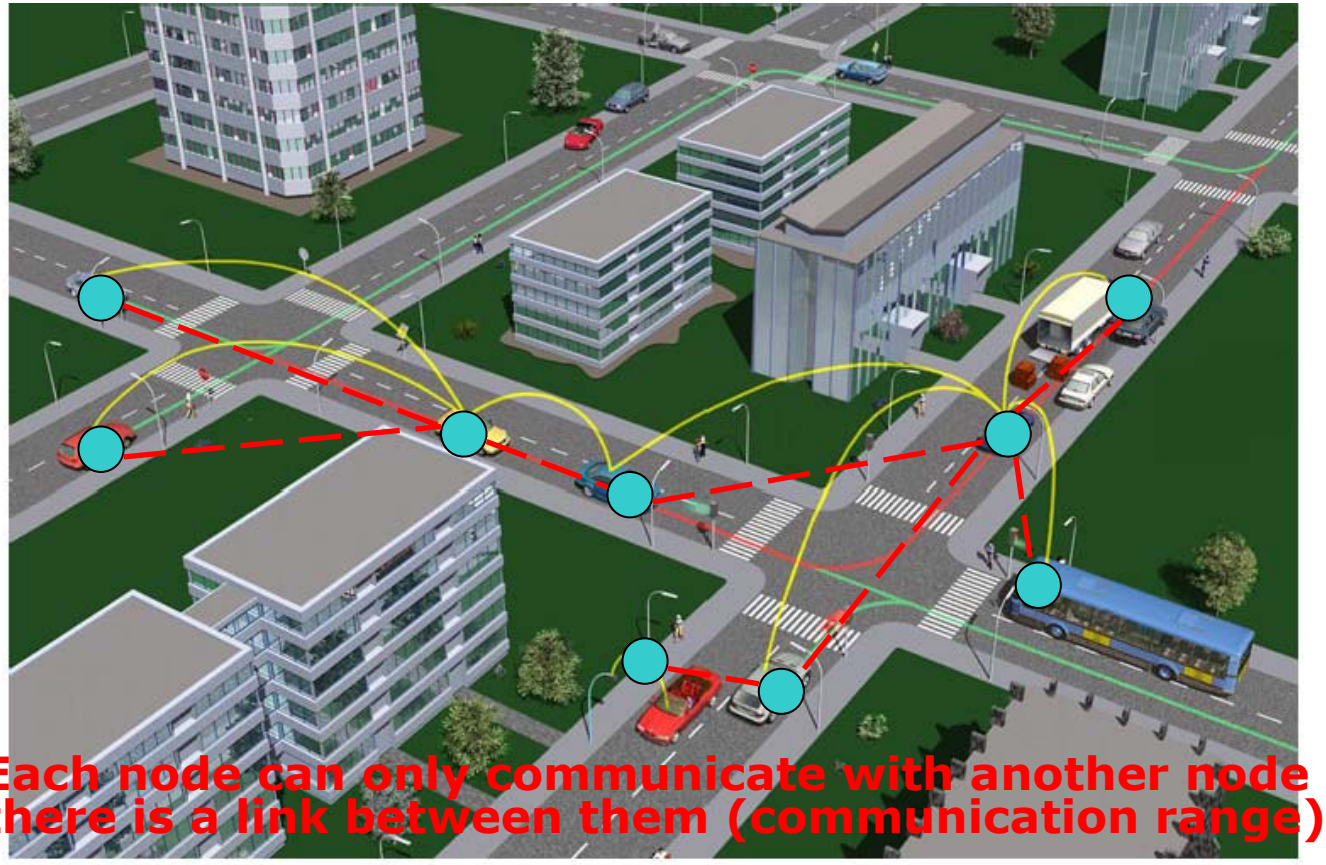
Wireless Ad Hoc Network (WAHN)



- **Each node can only communicate with another node if there is a link between them (communication range)**

Source: www.car-2-car.org

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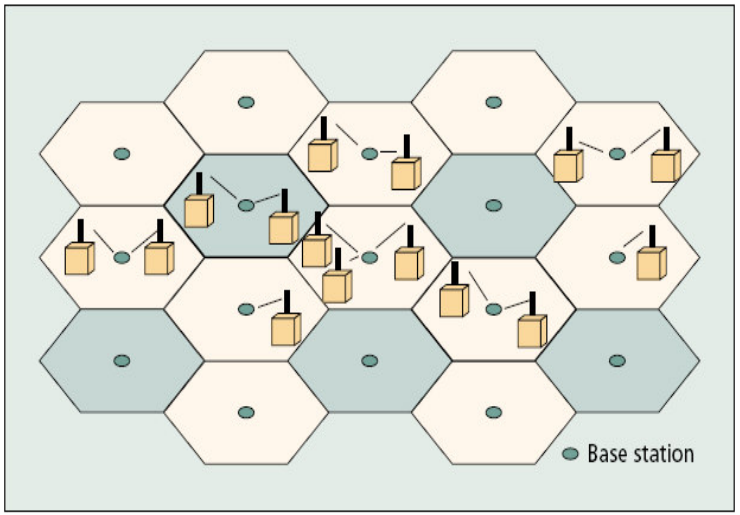
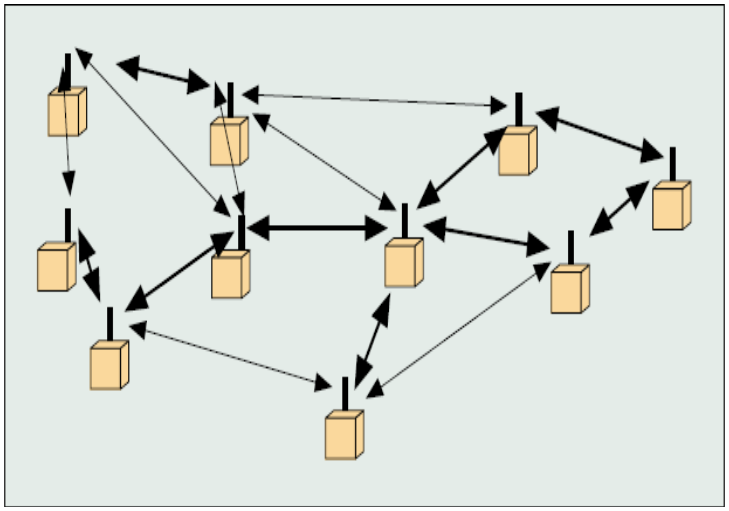
Wireless Ad Hoc Network (WAHN)





- Infrastructured networks
  - Comm. through base station (BS)
  - *Single-hop*
  - *Centralized* management at BS
  - Long-term comm. needs
  - Homogeneous devices

- WAHN
  - Peer-to-peer communication
  - *Multi-hop, relay*
  - *Distributed* management
  - Short-term, on-the-fly
  - Heterogeneous devices

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Characteristics of WAHN

- Advantages
  - Quick and inexpensive to setup
  - Extends range and reduces power consumption through multihop comm.
- Disadvantages
  - Traditionally viewed for military use
  - Difficult to build business model for profit generation for operators
  - Difficult to guarantee quality of service
  - Requires node cooperation

Evolution of WAHN

Packet radio networks (DARPA, 73)

- To enable comm. in mobile environment
  - Packet-switched
  - Store-and-forward
- Broadcast radios
  - Heavy and expensive
  - High power
  - Low processing capability
- Not scalable and robust!

Evolution of WAHN

Packet radio networks (DARPA, 73)

Survivable radio networks (DARPA, 83)

- Comm. in mobile environment
  - Scalable
  - Robust in hostile environment
- Radios
  - Small and low cost
  - Low power
  - High processing capability

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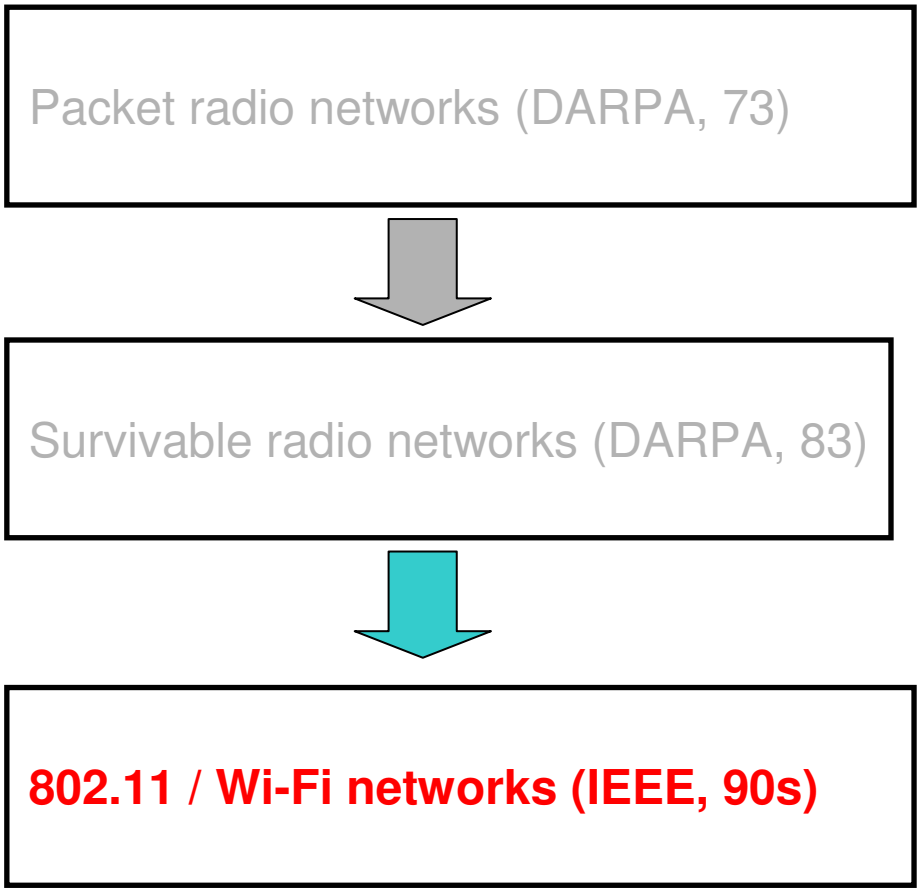
Evolution of WAHN



- Portable devices (e.g., laptops, PDAs)
  - Peer-to-peer connectivity
  - Consumer electronics and gaming applications
- Radio cards
  - Small and low cost
  - Low energy consumption
  - High processing capability

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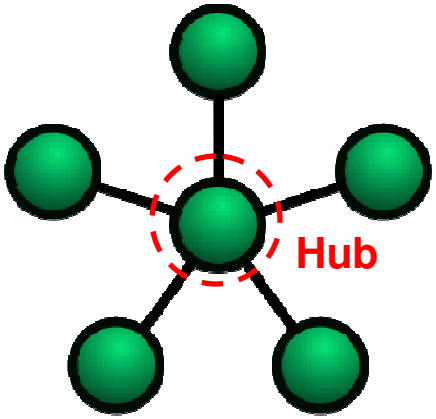
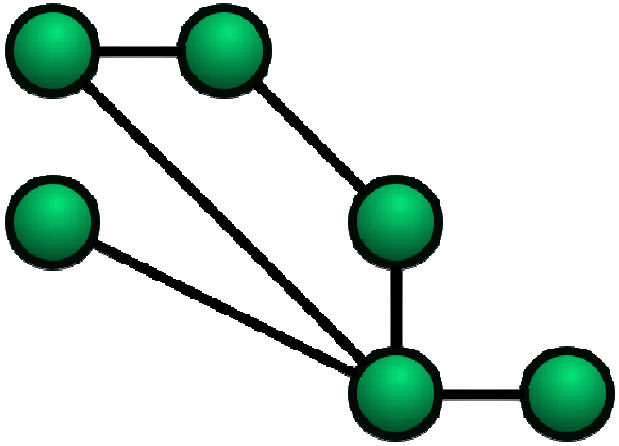
WAHN topologies





- Star-topology
  - Good performance
  - Easy to setup and scalable
  - Bottleneck at hub
- Examples
  - Bluetooth piconets
  - Cellular networks

- Mesh-topology
  - Highly Reliable
  - Difficult to setup
  - Non-scalable
- Examples
  - Community networks

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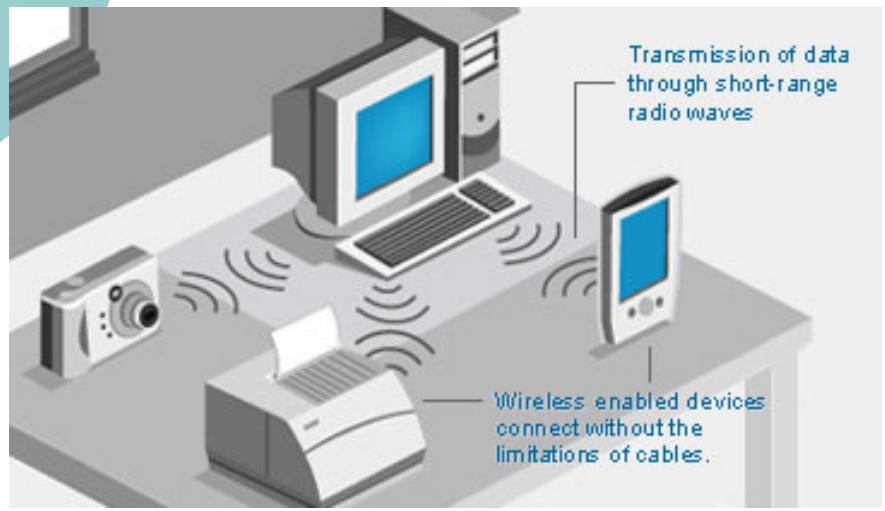
Types of WAHN

- Wireless Personal Area Networks (WPAN)
  - Interconnects devices centered around an *individual*'s workspace
- *Mobile* Ad-Hoc NETworks (MANET)
  - Network of *mobile routers* (relay)
- Wireless *Sensor* Networks (WSN)
  - *Remote* network of *sensing* devices for monitoring / detection of phenomena
- Wireless *Mesh* Networks (WMN)
  - *Highly-reliable* mesh of *cooperative* nodes to *extend* network reach

WPAN [IEEE 802.15.x]



- Salient features
  - Direct (Single-hop) comm.
  - Standalone network
  - Supported devices
    - Fixed (printer, desktop)
    - Portable (cellphone, PDA, mp3 player etc)
- Example technologies
  - Bluetooth
  - IrDA
  - ZigBee

Comparison of WPAN technologies

Technology	Bluetooth	IrDA	Zigbee
Appn focus	Cable replacement		Remote, large scale control
Comm. Medium	RF, ISM	Infra Red	RF, ISM
Data rate	1 Mbps	4 Mbps	250 kbps
Range	<10m	1m	<70m
Power consumption	Low	Very low	Very low
Cost	Low	Very low	Very low
Mobility support	Good	Poor	Good

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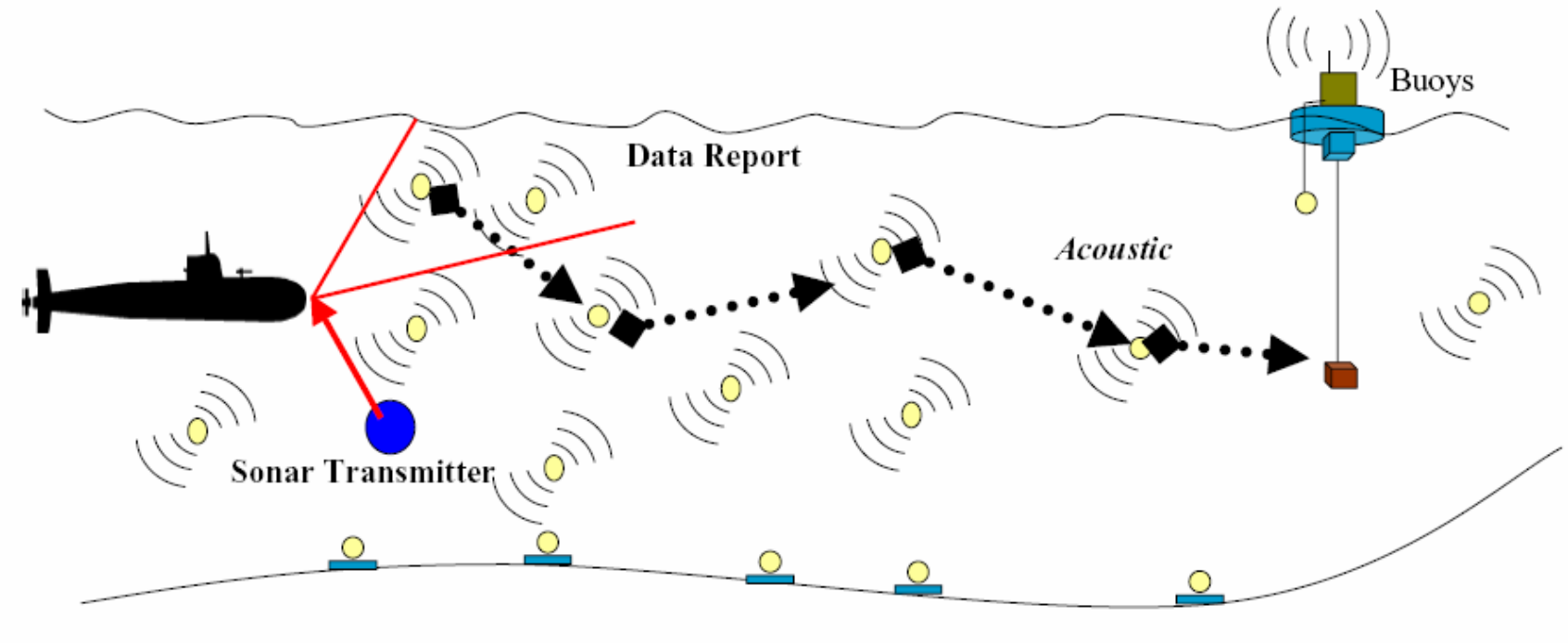
MANETs

- Salient features
  - Dynamic topology (due to high mobility)
  - Energy-constrained operation
  - Standalone or extension of fixed network
- Example technologies
  - Vehicular Ad-hoc NEtworks (VANET)
    - Car-2-car communications
  - Wireless broadband emergency / public safety network

WSN [Underwater Sensor Networks]

- Submarine detection for Naval / Maritime patrol



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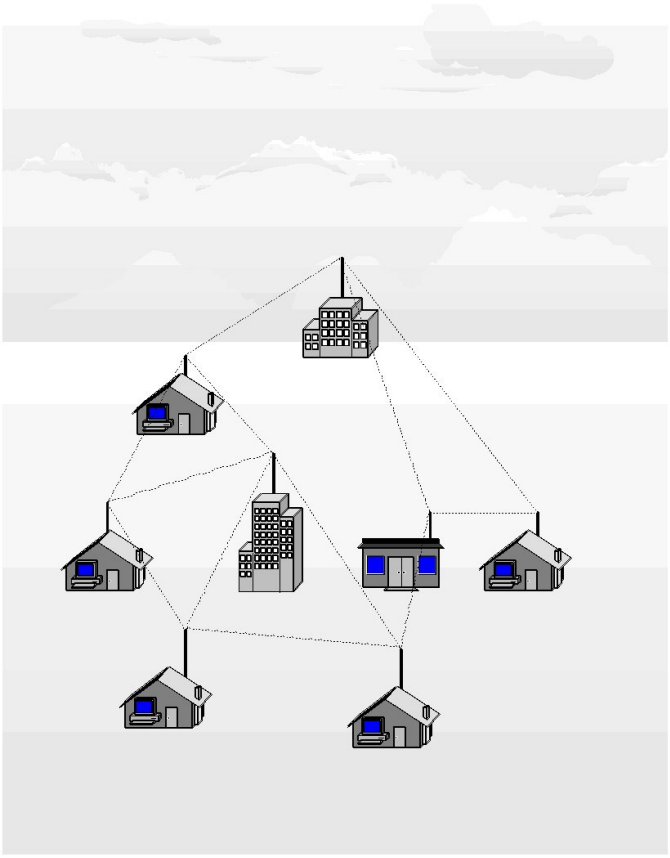
Wireless Sensor Networks

- Salient features
  - Remote, large scale deployment
  - RF / Sonar communications
  - Harsh environment
  - Size- and energy-constrained sensors
  - Failure-prone sensors

- Example applications
  - Environment and habitat monitoring
  - Underwater sensing (seismic / oil-spills)
  - Battlefield surveillance
  - Wireless Sensors Enterprise led Networks [WiSEN]
    - www.tyndall.ie/projects/wisen

Wireless Mesh Networks



- Salient features
  - Highly reliable (mesh structure)
  - Based on 802.11
  - Cooperative relay nodes (international postal agreement)
  - Extend network reach (e.g., Internet)
- Example
  - Wireless community networks

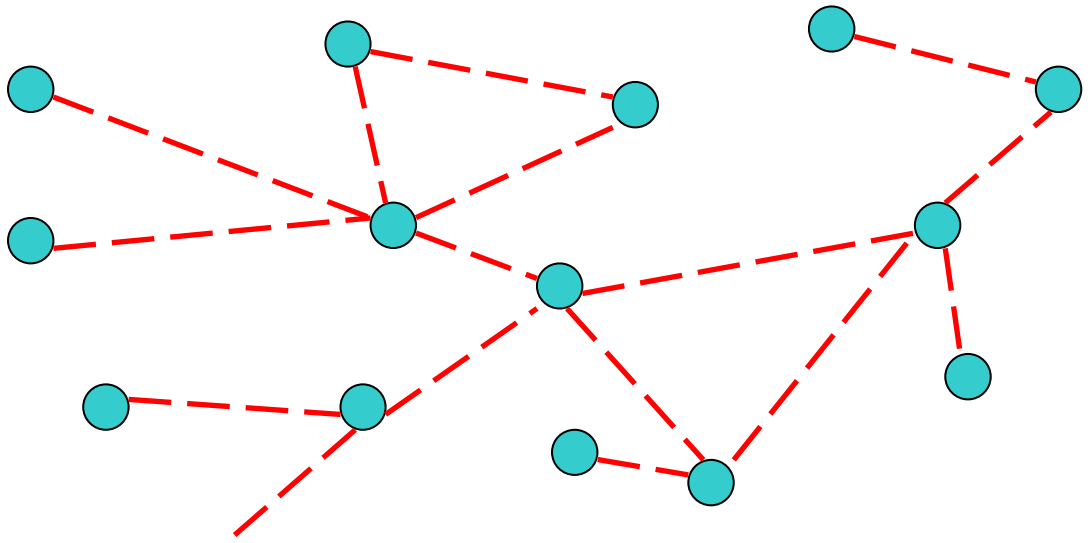
Wireless Community Networks

- Development of interlinked citywide or city-rural networks to extend Internet reach
  - Based on 802.11
  - Hobbyist (voluntary)-led and non-profit
  - Managed by community using the network
    - School, neighborhood, small businesses
- Examples
  - IrishWAN [Clare, Limerick, Galway and SE region]
    - http://www.irishwan.com
  - CorkWAN [Cork]
    - http://www.corkwan.org/

Time for some brainstorming..

- Think of a application scenario for wireless ad-hoc networking
- Bear in mind the following:
  - Salient features
  - Advantages / disadvantages
  - Why not infrastructured?

Wireless Ad-Hoc Networks



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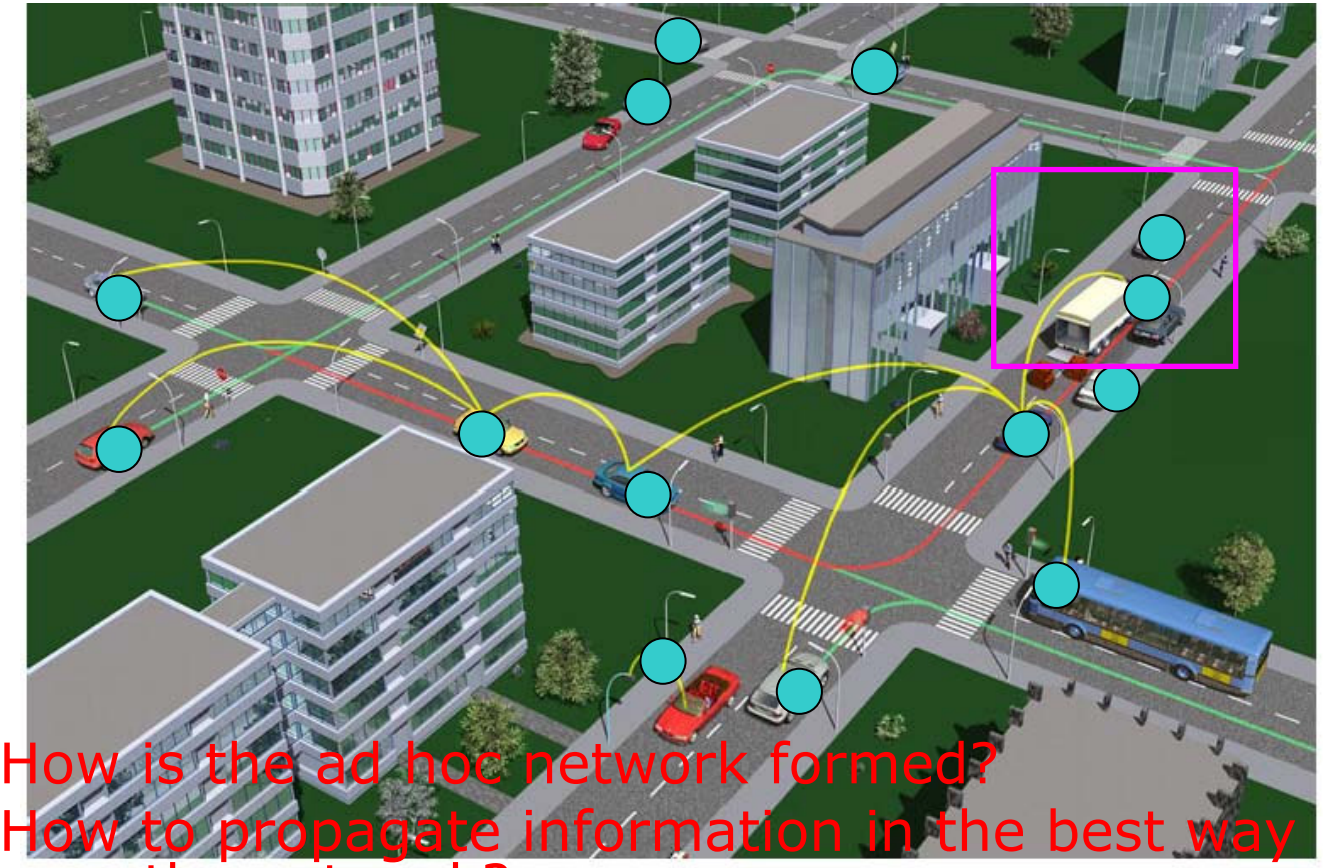
How does it work?



Traffic accident

- How is the ad hoc network formed?
- How to propagate information in the best way over the network?

Source: www.car-2-car.org

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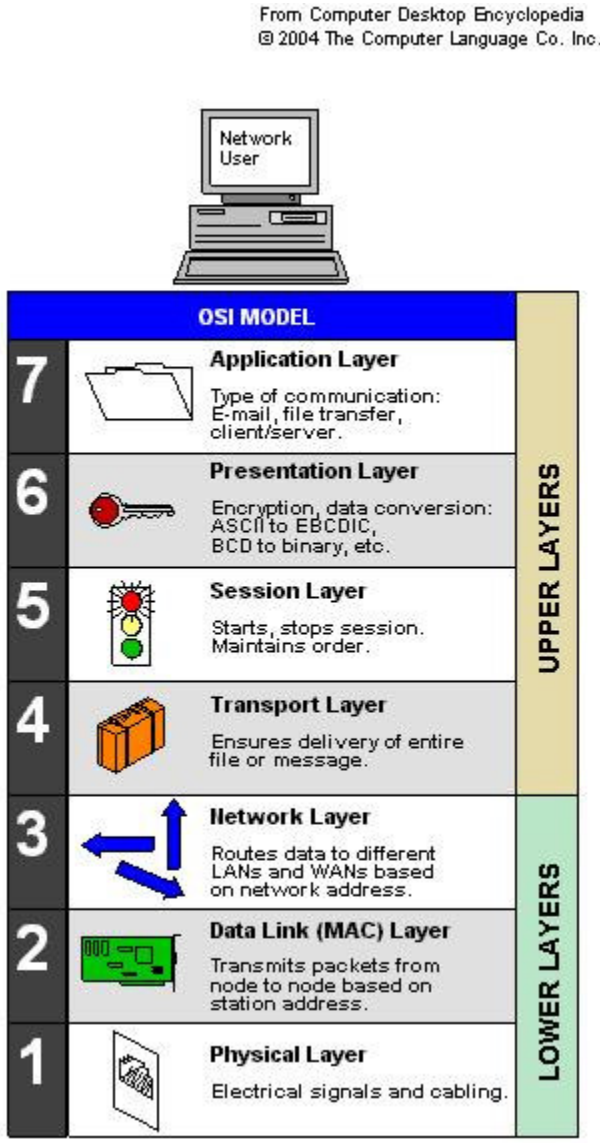
Outline – Part 2

- How do ad-hoc networks function?
  - Routing
  - Medium Access Control
  - Power control
- Performance metrics



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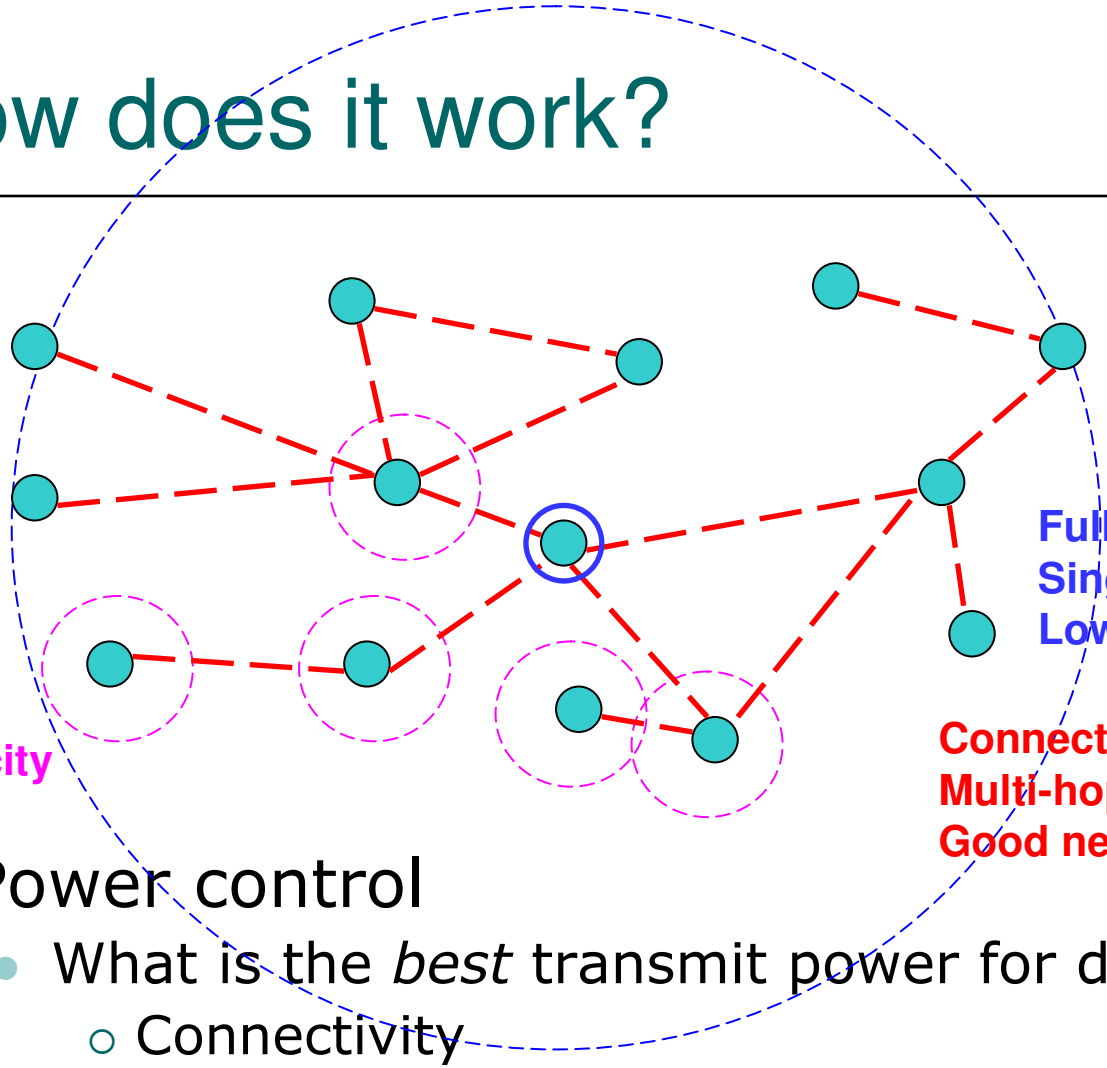
How does it work?



Fully connected
Single hop
Low network capacity

Disconnected
High network capacity

Connected
Multi-hop
Good network capacity

- Power control
  - What is the *best* transmit power for desired
    - Connectivity
    - Topology
    - Network capacity

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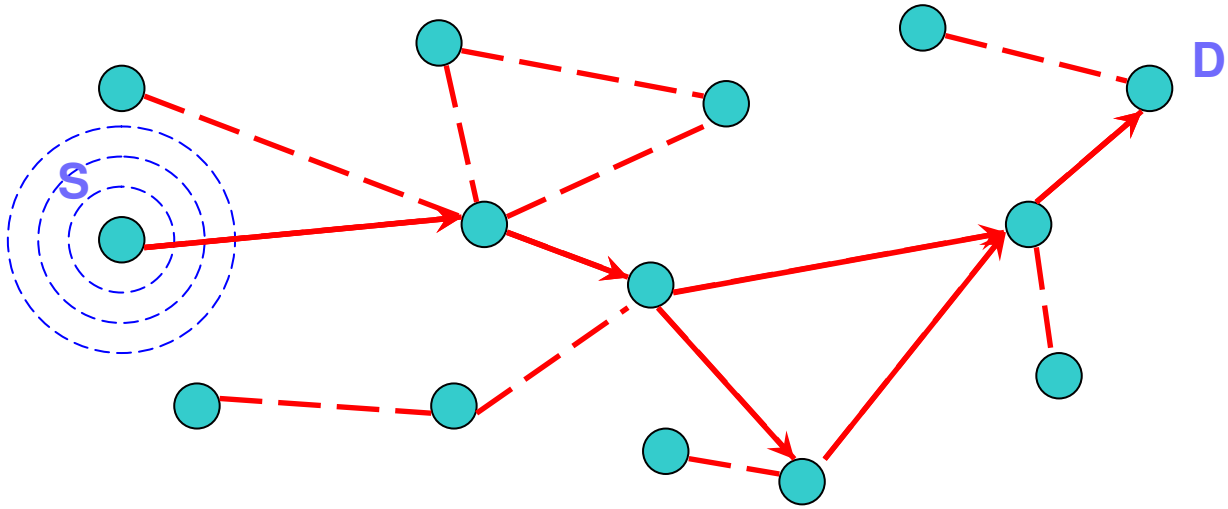
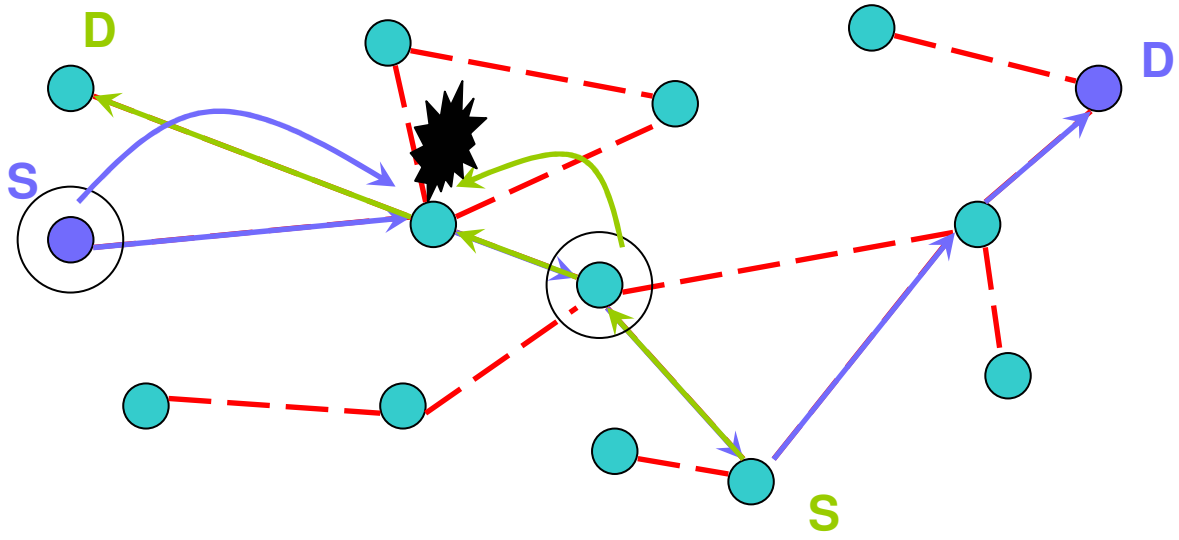
How does it work?



- Routing
  - What is (are) the *best* path(s) from source (S) to destination (D)?
  - Depends on design criteria, e.g., delay, energy, throughput etc

How does it work?



- Another source-destination pair
- Medium Access Control (MAC)
  - Who transmits when?

Classification of routing protocols

- Table-driven routing [DSDV]
  - Each node maintains consistent, up-to-date routes
    - periodic updates in response to topology changes
  - Useful for datagram (bursty) traffic
  - High signalling traffic and power consumption
  - Wastage in maintaining routes never used
- On-demand routing [DSR]
  - Creates route(s) only when source needs
  - High latency
  - Low signalling traffic

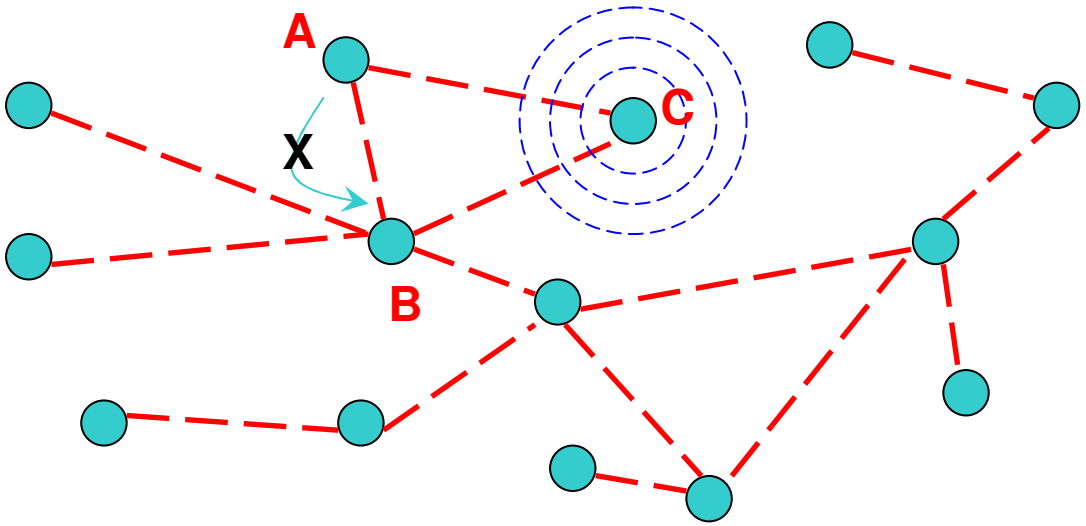
Ad Hoc Routing protocols

- Hybrid table-driven / on-demand routing
  - Zone Routing Protocol [ZRP]
- Hierarchical routing
  - Nodes clustered according to relative proximity
  - Inter-/intra-cluster routing
  - Suitable for large networks
- Geographic routing
  - Node geographically closer to destination chosen as next hop
- Power-aware routing
  - Transmit over shorter distance / more hops to save energy

Desirable characteristics

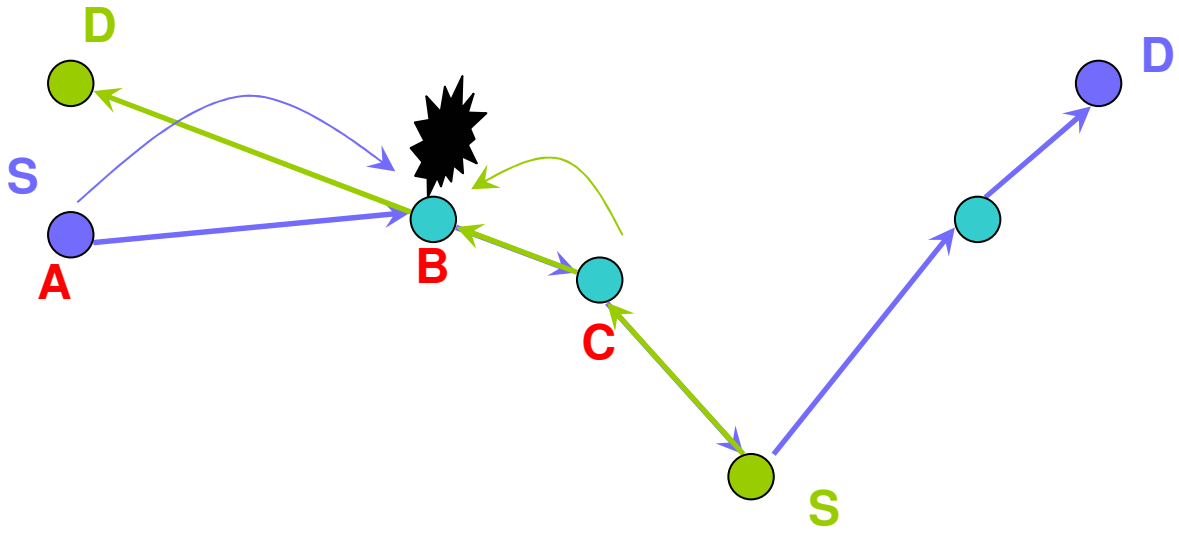
- Distributed operation
- Loop-free
- Driven by bottleneck
  - Bandwidth/energy -> on-demand
  - Delay -> table-driven
- Security
- Sleep-period operation
- Supports uni-directional (assymmetric) links

Carrier Sense Multiple Access (CSMA)



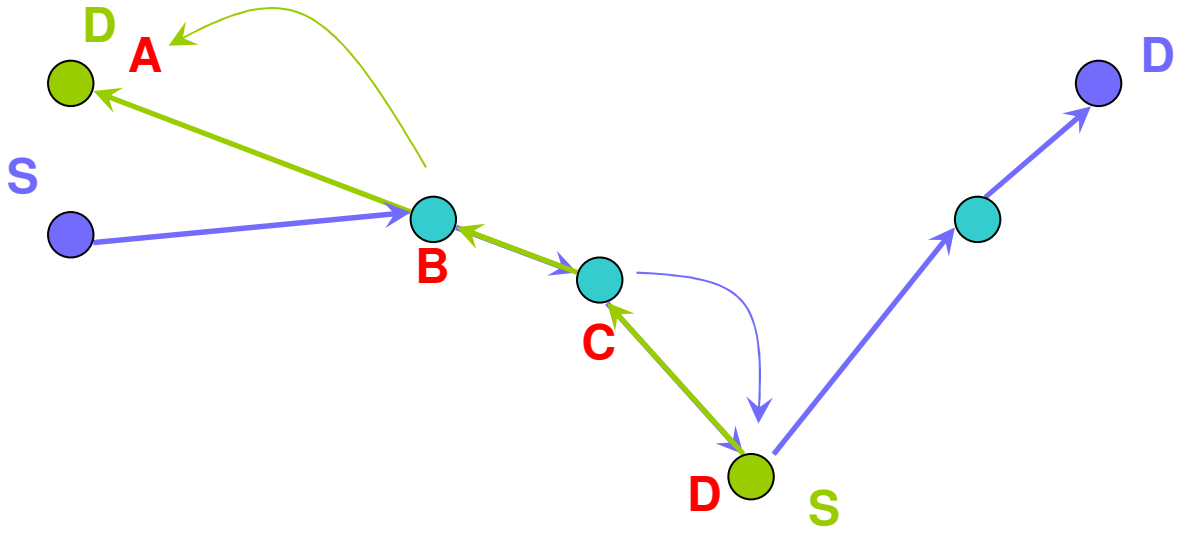
- Node A wants to communicate with node B
- Node A *physically senses* the channel and *defers* transmission if channel already in use
  - Node A won't transmit since it detects Node C's transmission
- ALOHA, *n*-persistent algorithms

Hidden-node problem



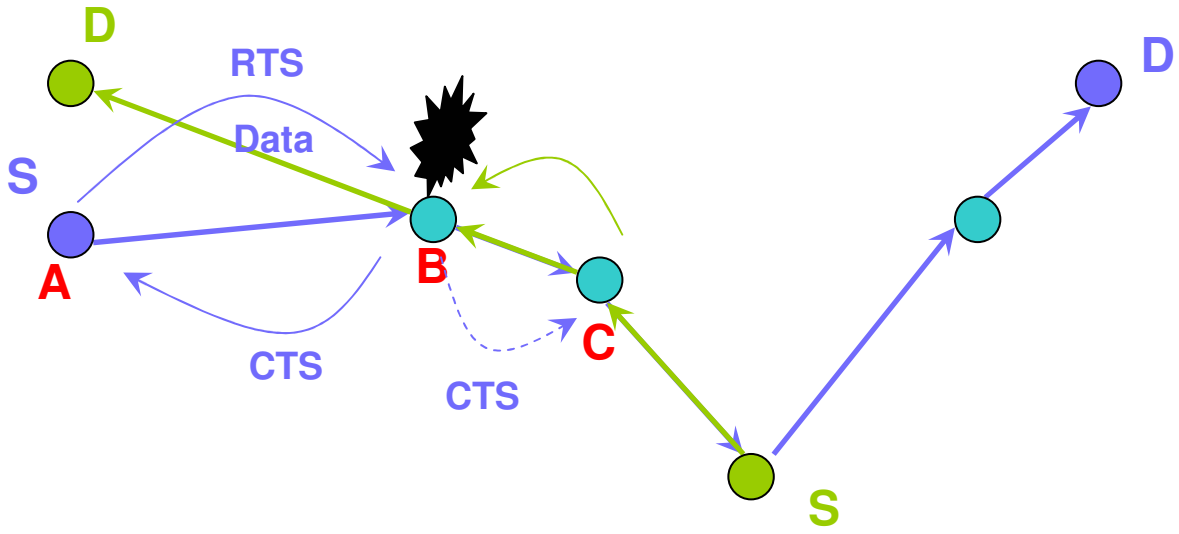
- Node A is communicating with node B
- Node C also wants to comm. with node B
  - Node C senses that channel is available
  - Collision at node B because node A is *hidden* from node C!

Exposed-node problem



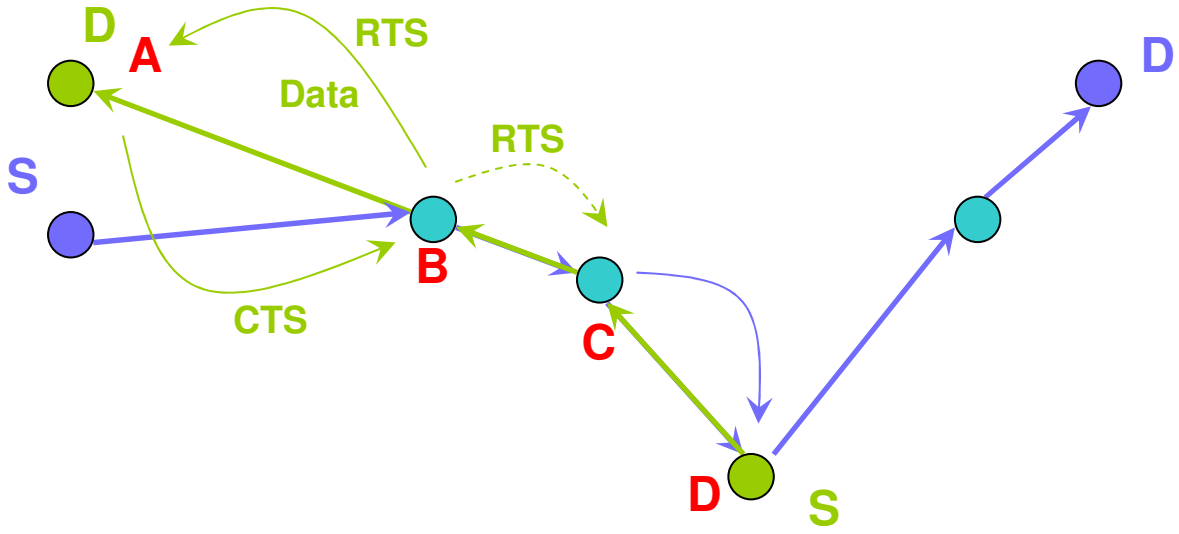
- Node B is communicating with node A
- Node C wants to communicate with node D
  - Node C refrains from transmitting since it senses node B's transmission even though *NO* collision will occur otherwise!

Medium Access Collision Avoidance (MACA)



- *Virtual sensing* via Request-to-send (RTS) / Clear-to-send (CTS) handshake
  - Nodes that overhear CTS not in response to its RTS (*RTS not from its intended recipient*) refrain from transmitting (*will transmit*)

Medium Access Collision Avoidance (MACA)



- *Virtual sensing* via Request-to-send (RTS) / Clear-to-send (CTS) handshake
  - Nodes that overhear CTS not in response to its RTS (*RTS not from its intended recipient*) refrain from transmitting (*will transmit*)

Classification of MAC protocols

- Contention-based vs scheduled
- Single vs multi-channel system
- Flat vs clustered structure
- Omnidirectional vs directional antenna
- Solution to hidden / exposed node problem?

Source:
www.utdallas.edu/~mxw013200/MAC_ADHOC.html

Power control protocols

- Optimal transmit power to control connectivity properties
- Power-aware routing
- Power-aware MAC
- Joint power-aware routing/MAC

Performance metrics

- End-to-end throughput / delay
- Route acquisition time
- % out-of-order delivery
- Efficiency (overhead)
- Fairness
- Energy efficiency

Summary

- What is a wireless ad hoc network? (WAHN)
  - Features
  - Benefits
- Types of WAHN
  - Personal area networks
  - Mobile ad hoc networks
  - Sensor networks
  - Mesh networks
- How does a WAHN work?
  - Power control
  - Routing
  - Medium access control
  - Performance metrics

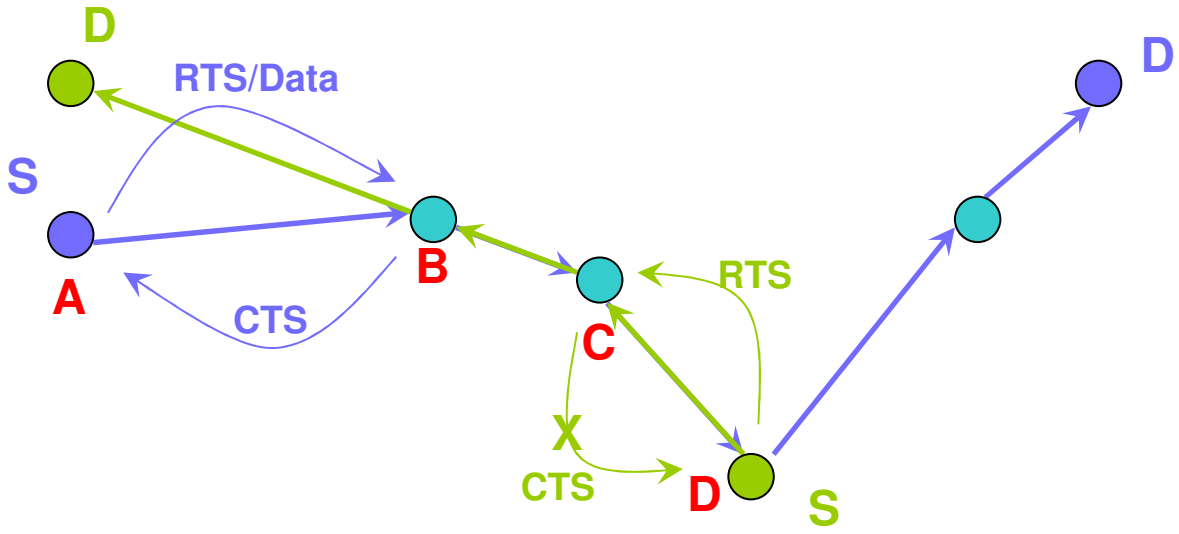
Useful links

- Wikipedia
  - en.wikipedia.org/wiki/Ad_hoc
- Routing
  - www.cs.ucsb.edu/~ebelding/txt/**review**.ps
- Medium access control
  - www.utdallas.edu/~mxw013200/MAC_ADHOC.html
- Power control
  - black.csl.uiuc.edu/~prkumar/ps_files/compow_ewc_2002.pdf

Time for some brainstorming..

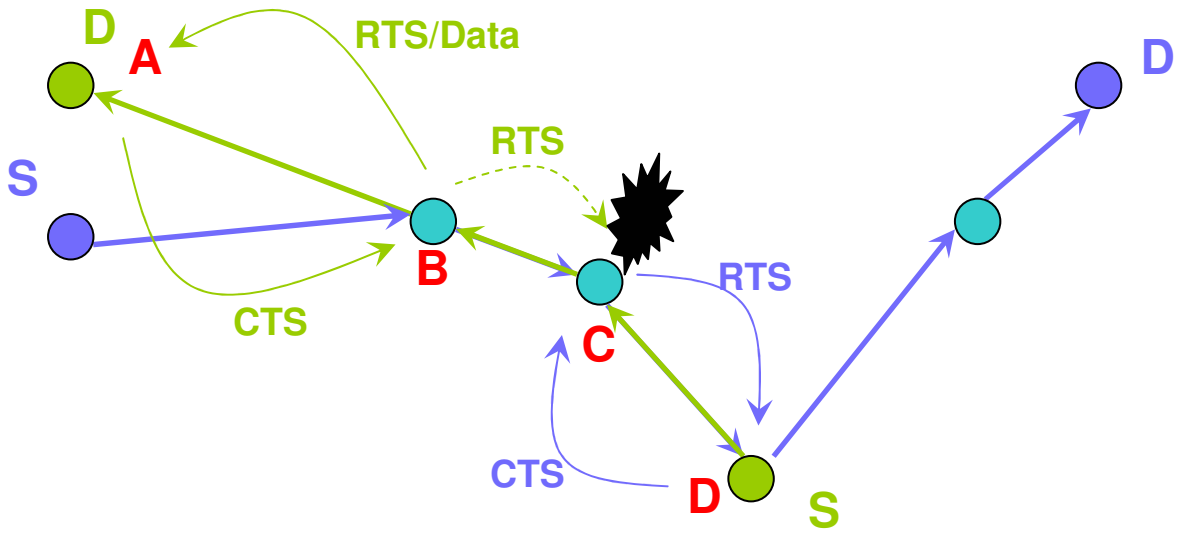
- Are the hidden / exposed node problems solved *completely* with MACA??
- Ans: No!
- Think of scenario(s) where MACA fails to prevent
  - Collision
  - Inefficiency

Inefficiency



- Node A is communicating with node B
- Node D wants to communicate with node C
  - Node C refrains from transmitting CTS since it hears node B's CTS even though *NO* collision will occur otherwise!

Collision



- Node B is communicating with node A
- Node C wants to communicate with node D
  - Node D's CTS may collide with RTS from node B at node C
  - Node C may not get to transmit to node D