Mobile and Sensor Systems

Lecture 3: Infrastructure, Ad-hoc and Delay Tolerant Mobile Networks

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In this lecture

- In this lecture we will describe the difference in infrastructure and ad hoc networks and we will introduce ad hoc routing protocols.
- We will also introduce disconnected ad hoc networks and delay tolerant routing protocols.

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Infrastucture-based sv Ad-hoc

- Wireless communication can be organized in two different fashions :
  - This might depend on the application and on the network set up.

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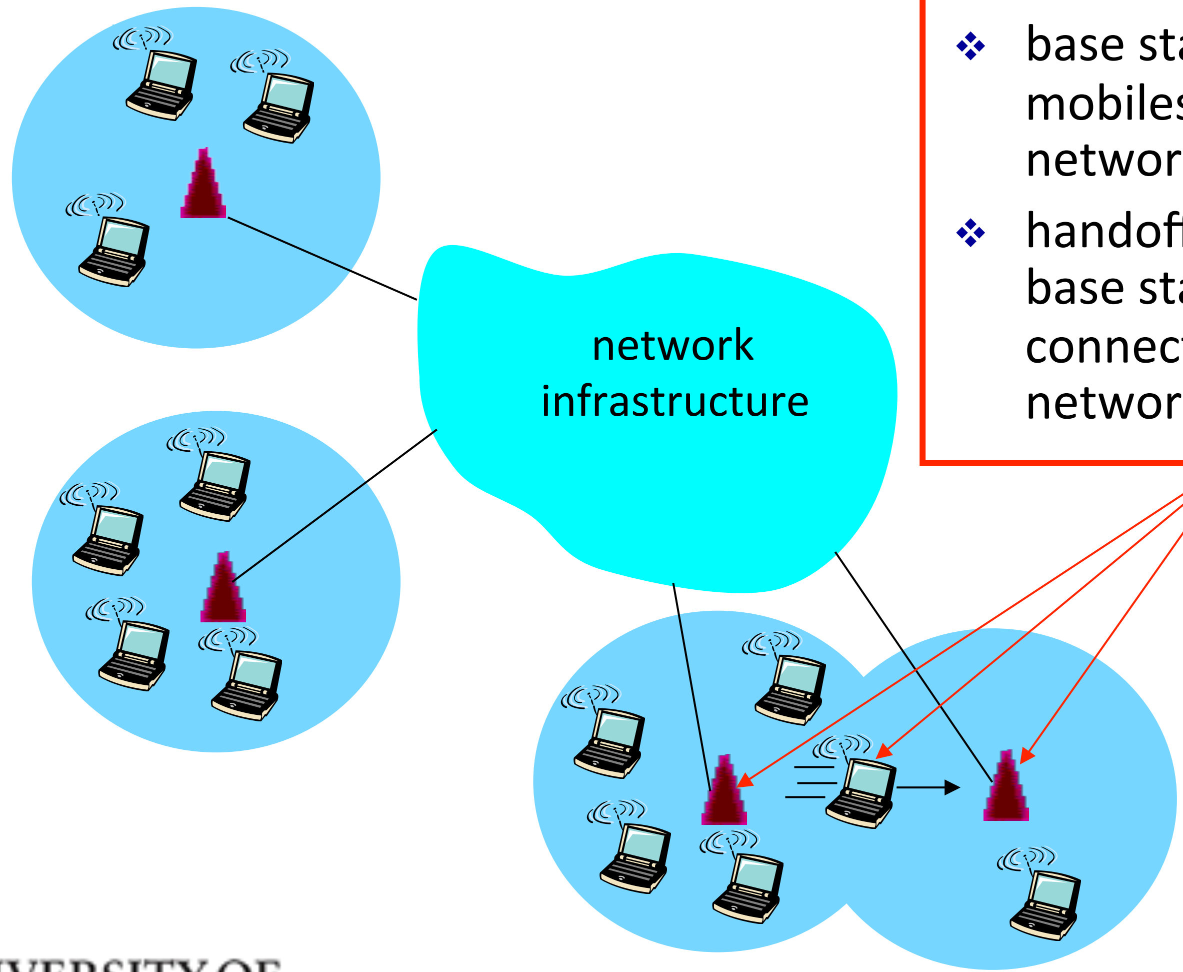
Infrastructure-based



infrastructure mode

- base station connects mobiles into wired network
- handoff: mobile changes base station providing connection into wired network

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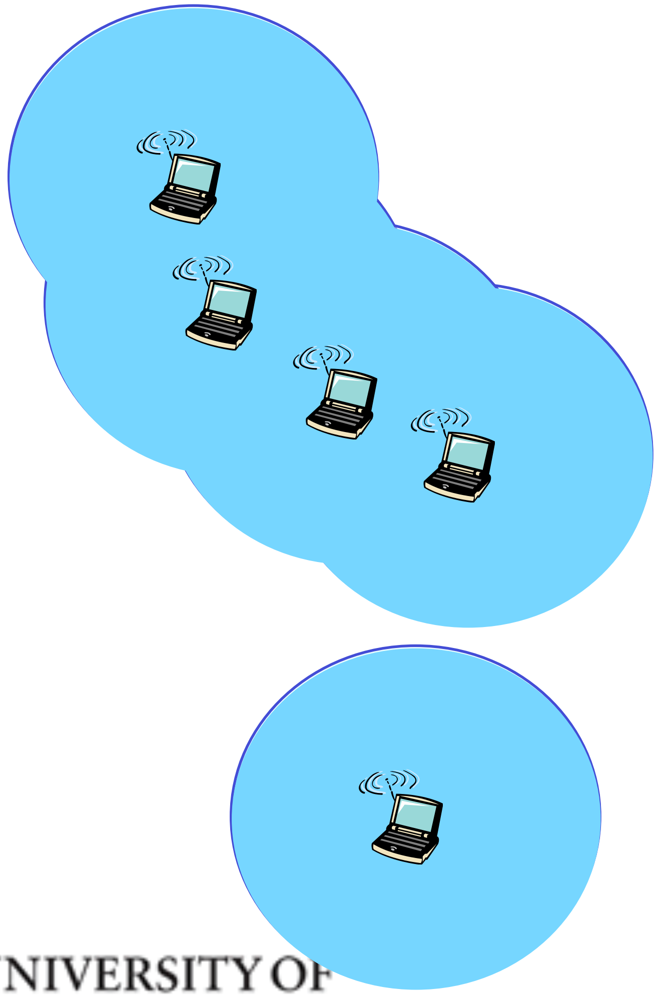
Ad-hoc



ad hoc mode

- no base stations
- nodes can only transmit to other nodes within link coverage
- nodes organize themselves into a network: route among themselves

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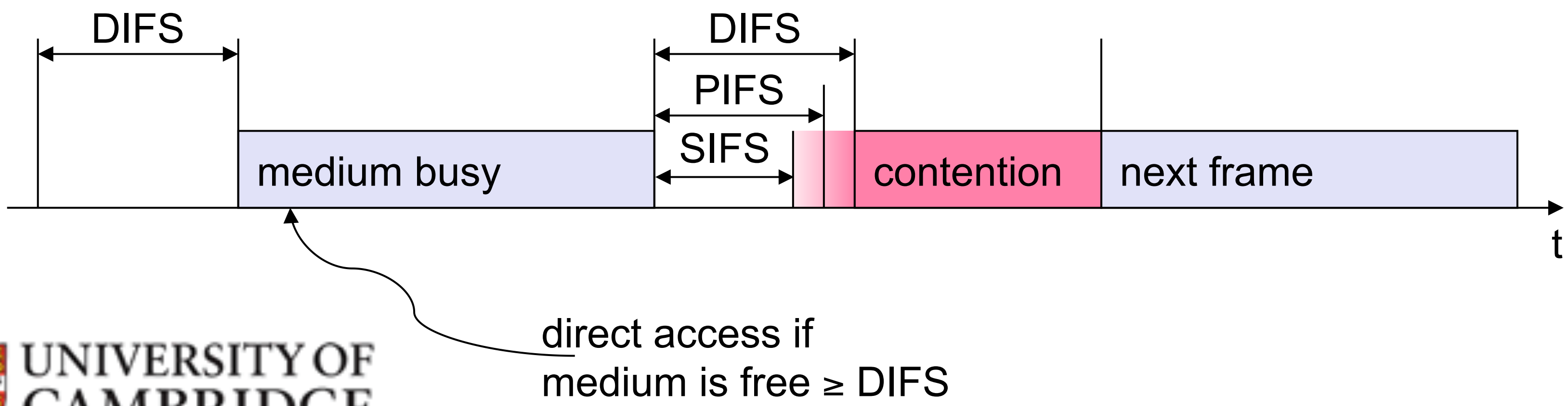
802.11 - MAC layer (recap)

- Priorities
  - defined through different inter frame spaces
  - no guaranteed, hard priorities
  - SIFS (Short Inter Frame Spacing)
    - highest priority, for ACK, CTS, polling response
  - PIFS (PCF IFS)
    - medium priority, for time-bounded service using PCF
  - DIFS (DCF, Distributed Coordination Function IFS)
    - lowest priority, for asynchronous data service



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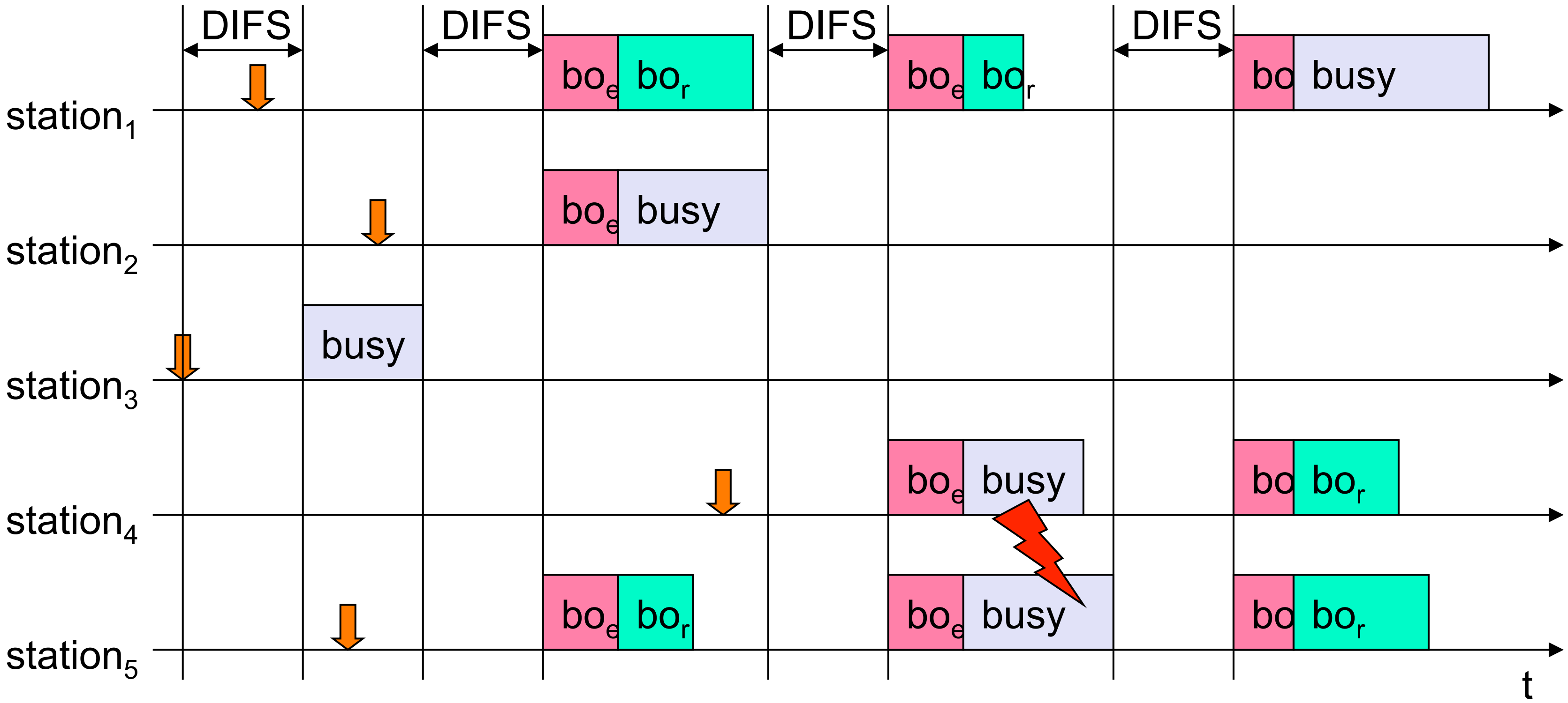
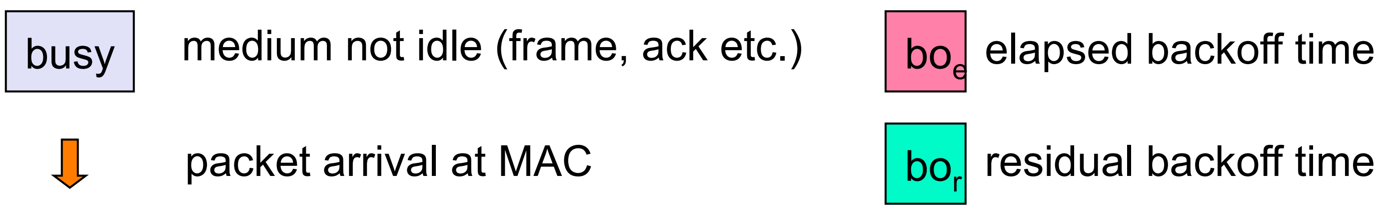
802.11 – competing stations





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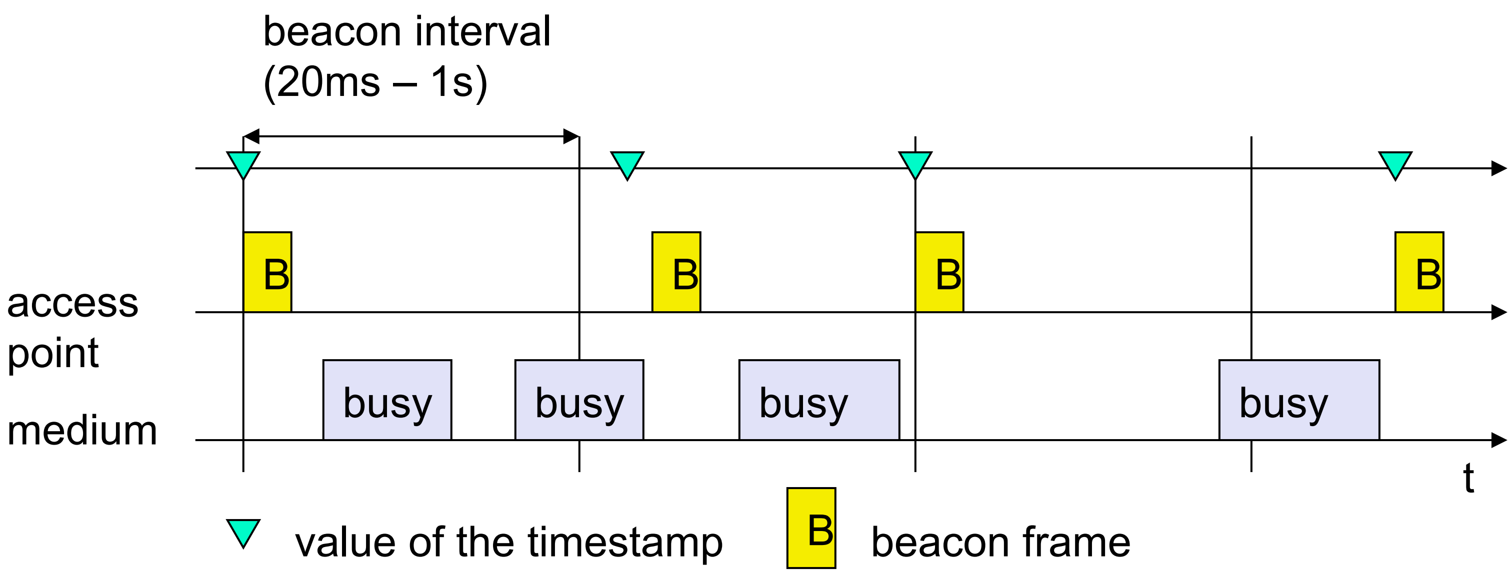
Synchronization using a Beacon (infrastructure)



•Nodes need to keep a tight synchronized clock with the access point: this is useful for power management and coordination of frequency hopping or contention slots.

•Beacons are sent semi-periodically [ei when the medium is not busy]

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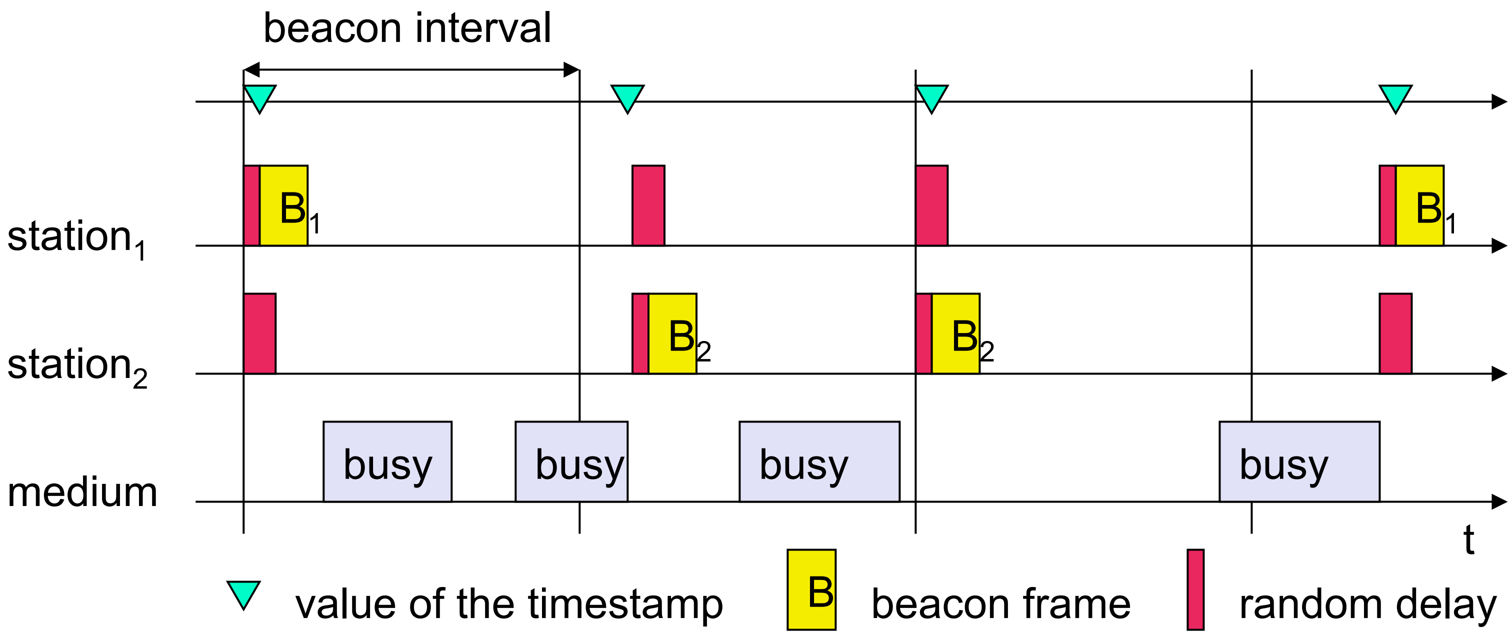
Synchronization using a Beacon (ad-hoc)



•In ad hoc mode each station transmits a beacon after the beacon interval [semi periodic again]

•Random backoffs are applied to beacons too: all station adjust clock to beacons received and suppress their beacon for the beacon interval

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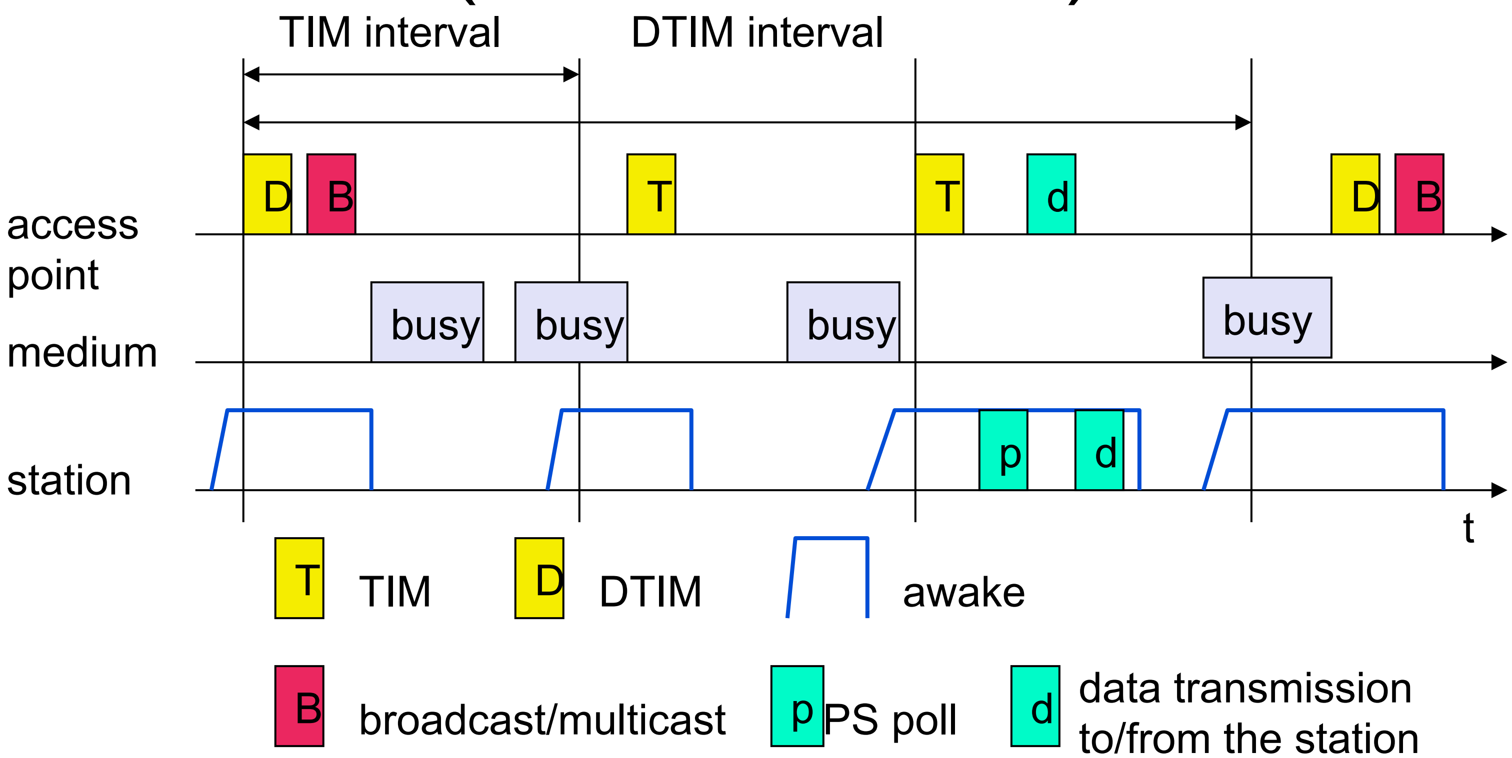
Power saving with wake-up patterns (infrastructure)



TIM: list of stations for which there will be data in the slot
DTIM Interval indicates the delivery traffic indication map: for broadcast and multicast frames. It’s a multiple of TIM

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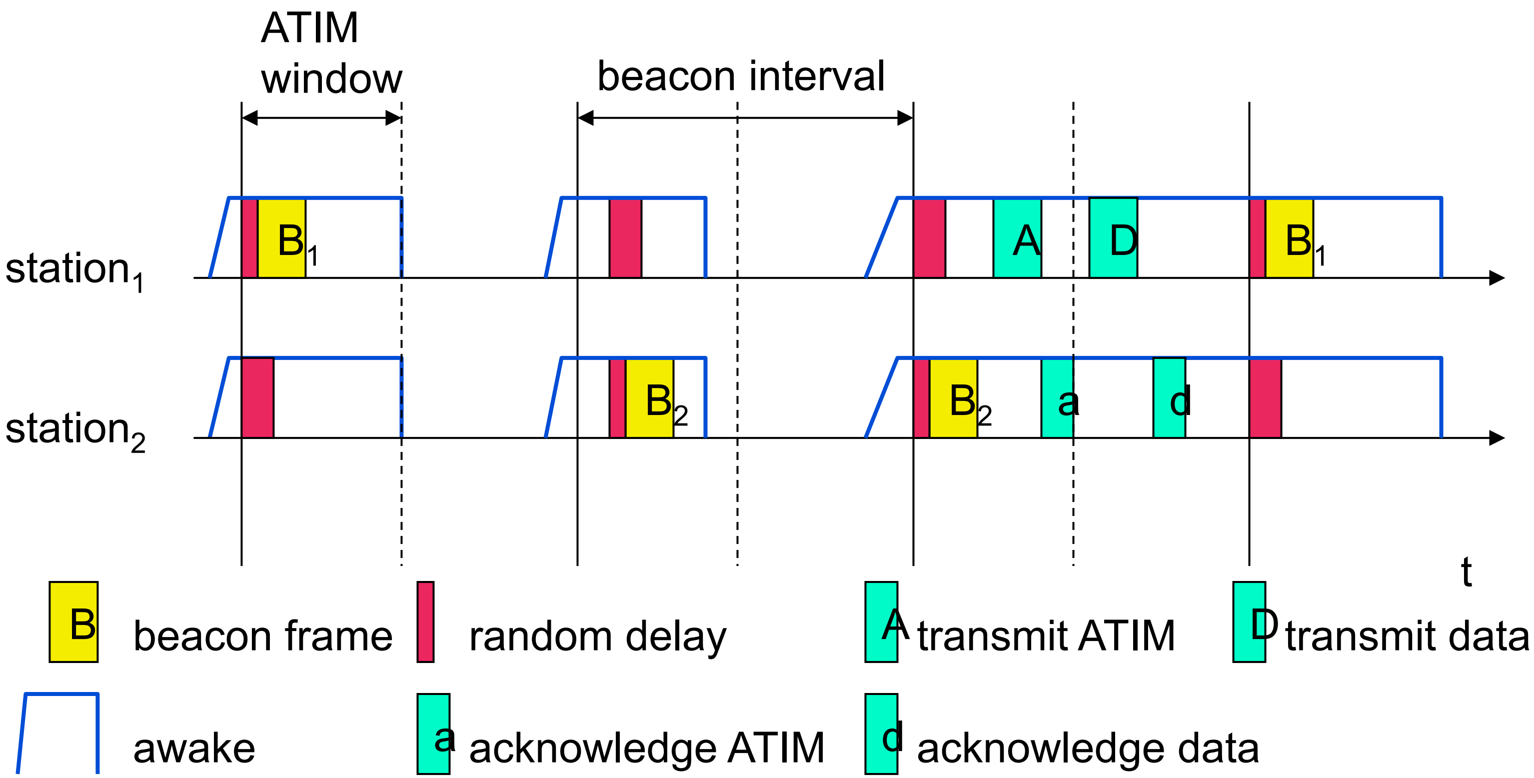
Power saving with wake-up patterns (ad-hoc)



ATIM is the transmission map for ad hoc traffic: all stations stay awake for this slot

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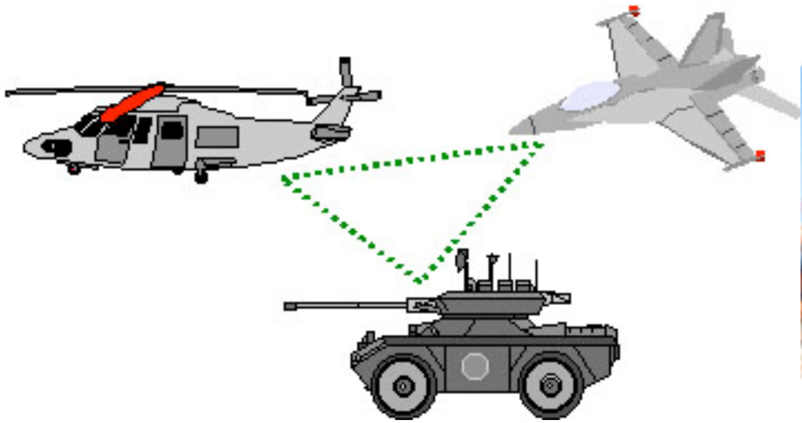
Examples of Multi-hop Ad hoc Networks



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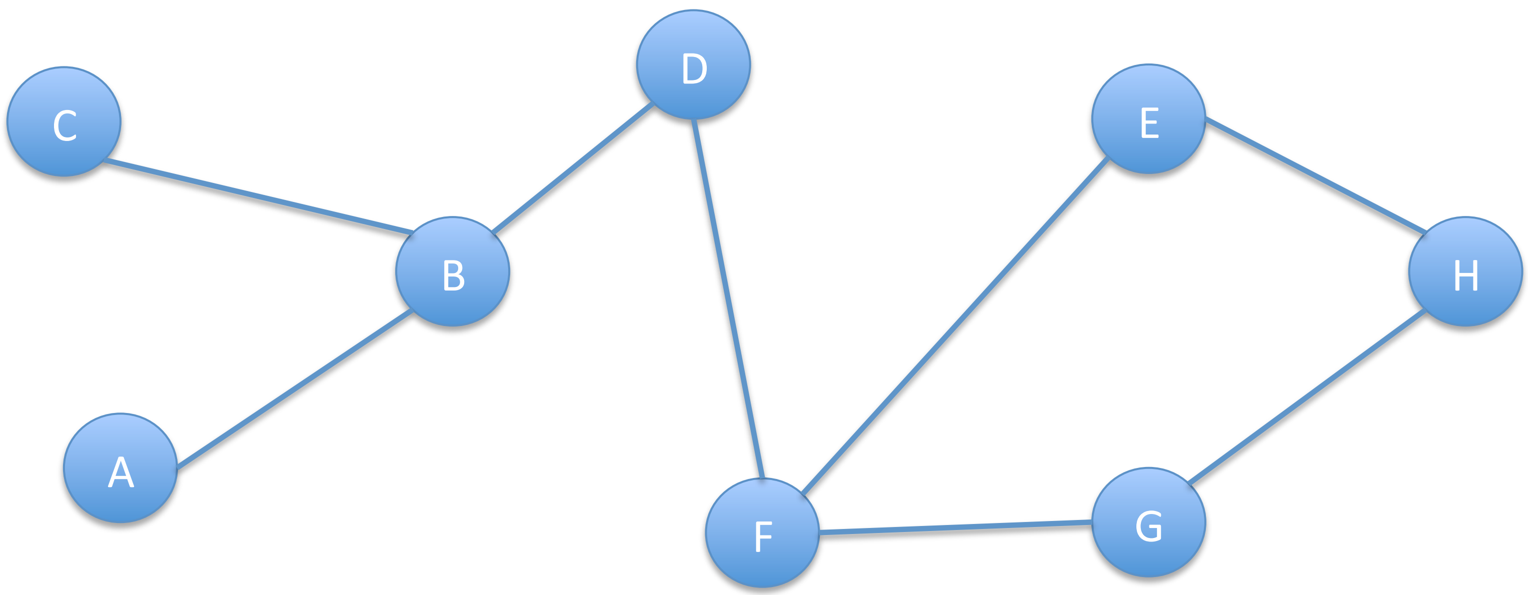
A schematic of an ad hoc network



Note that this is a static snapshot: the network will be reconfiguring when nodes move.

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Examples of Ad-hoc Networking

- Destination Sequenced Distance Vector (**DSDV**) Routing.
- Proactive: routes are maintained also when not needed. Each node maintains a table with a route to every node.
- Each entry of the table has a sequence number assigned by the destination.

Dest. Next Hop, Hops Required, Dest. Seq. number.

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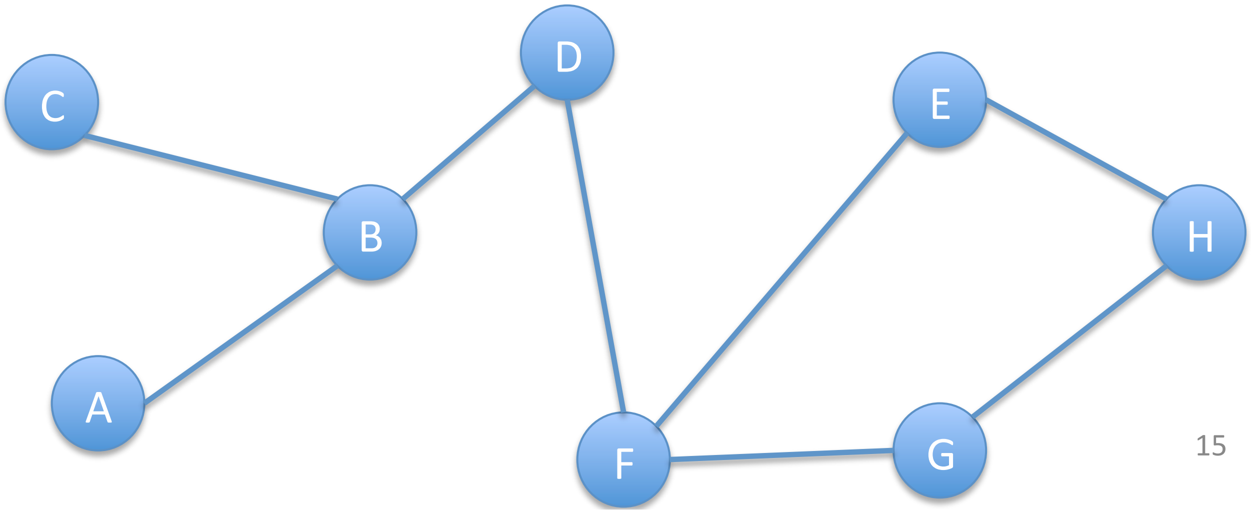
DSDV: Routing Table for Node D

Dest	Nexthop	Hops	SequenceN
A	B	2	406
B	B	1	128
C	B	2	564
D	D	0	710
E	F	2	392
F	F	1	076
G	F	2	128
H	F	3	050



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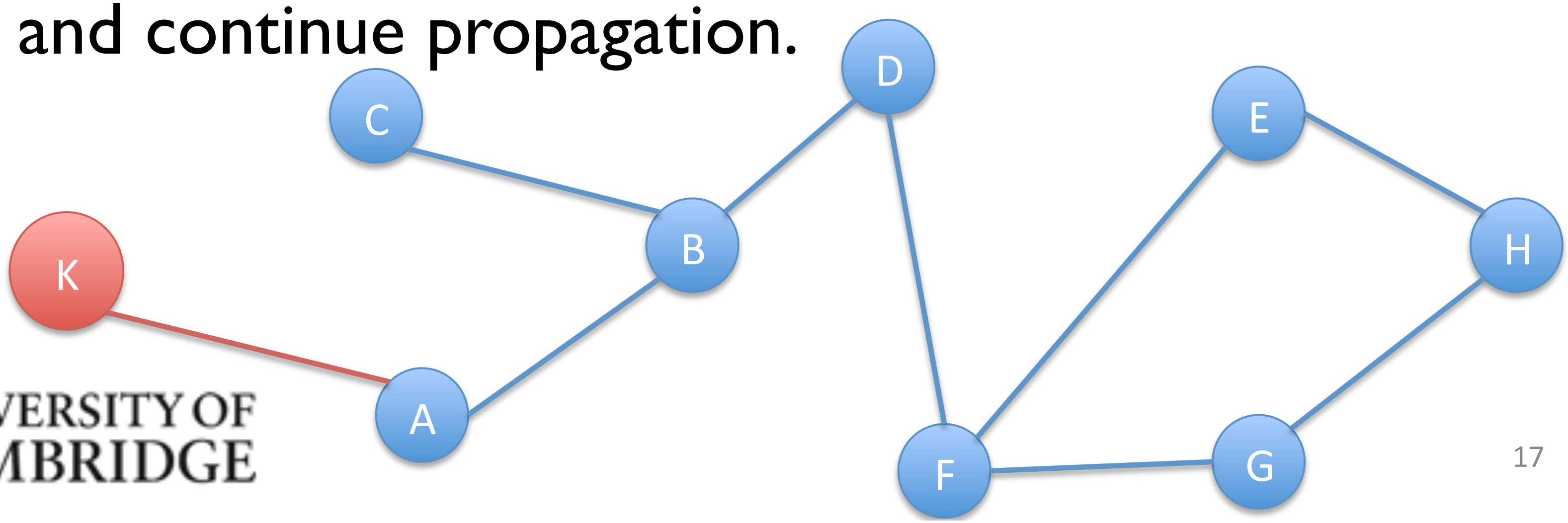
DSDV Routing Updates

- Each node periodically transmits updates.
- Includes its own sequences number, routing table updates.
- Nodes also send routing table updates for some incremental link changes.
- When two routes to a destination received from two different neighbors, choose the one with *greatest* destination sequence number.
- If equal (when would they be equal?), choose the smaller metric (hop count).

DSDV: When a new link appears (ie a node moved closer)

- When K joins it
  - Transmits routing table <K,K,0,101>
  - Node A receives it and inserts in routing table: <K,K,1,101>
  - Node A propagates the new route to neighbours.
  - Neighbours of A update table with <K,A,2,101> and continue propagation.



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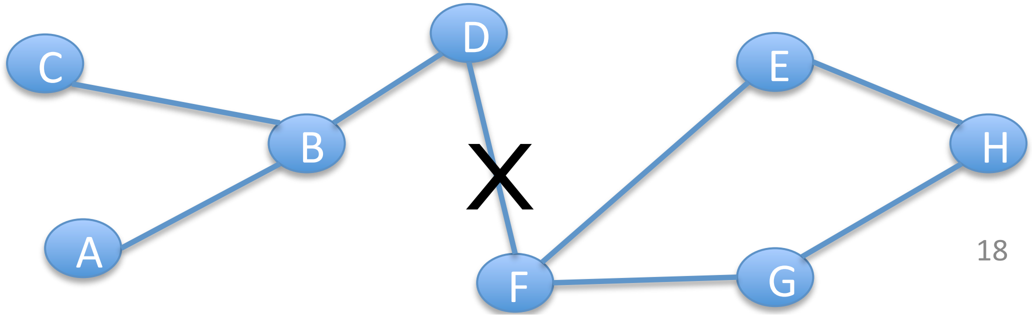
DSDV: When a link breaks (ie a node moves away)

- The link between D and F breaks (the two nodes move apart or the wireless link has no connection for other reasons).
- Node D notices the break (eg lack of table update from F):
  - Updates hop count to F to infinity.
  - Increments the sequence number for F,E,G,H
  - Then:



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DSDV: When a link breaks (ie a node moves away)

– Then Node D sends updates with new route information:

- <F, -,∞, 077>
- <E, -,∞, 393>
- <G,-,∞, 129>
- <H,-,∞, 051>

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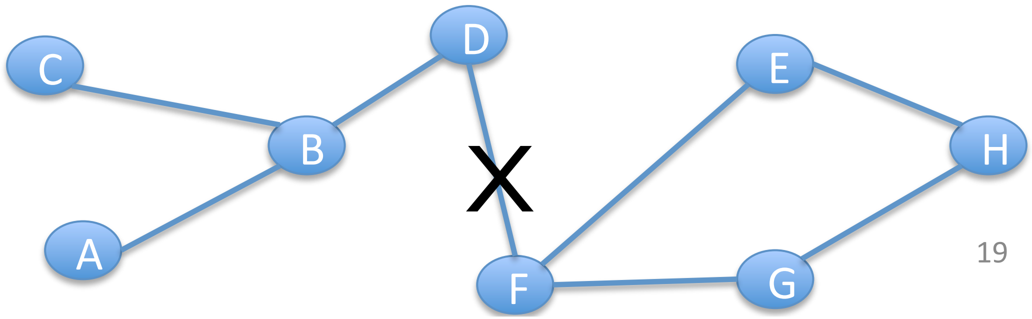

DSDV: Limitations

- Circulating and maintaining table updates is expensive for the network.
  - Especially if this is battery powered.
- If the network changes a lot then these updates might be worthwhile but only if all nodes need to communicate to all others
  - Why would a node need to keep updates of routes to nodes it does not need to communicate with?

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Another Ad-hoc routing example Dynamic Source Routing (DSR)

- DSR is a reactive protocol: routes are searched only when communication with a node is needed.
- When a node needs to communicate it sends a route request packet.
- Nodes receive it and add themselves to the path and propagate the request to their neighbours.
- Eventually the destination node is found and the path is sent back to the source (how?).

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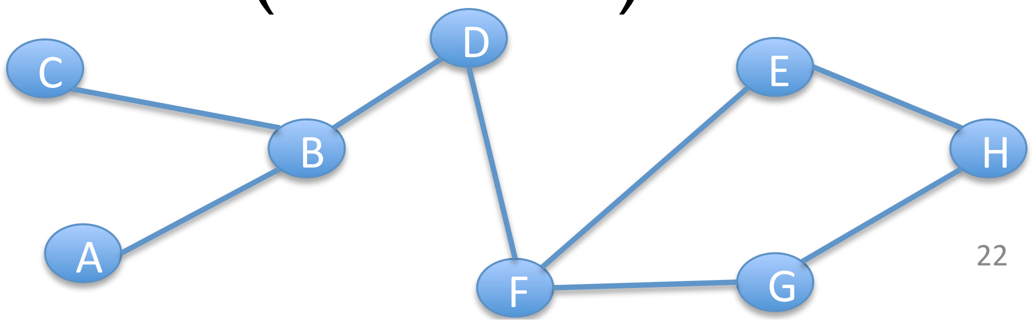
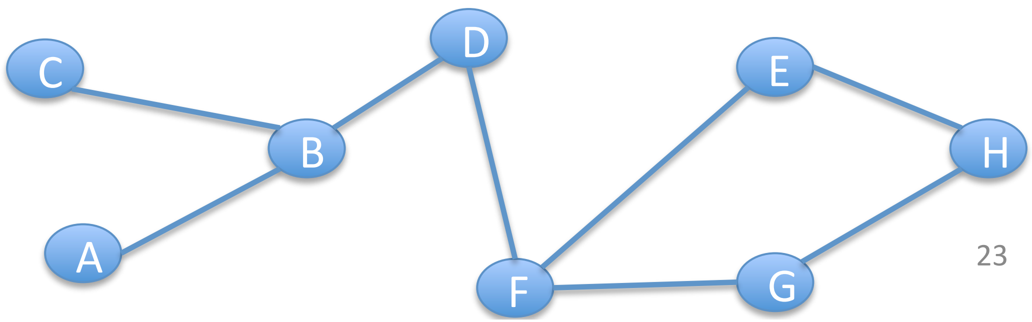
DSR example

- Node A needs to communicate with F. Sends request <A,F, [-],101>.
- Node B receives the request and forwards:
  - <A,F,[B],101>.
- Node D receives it and forwards:
  - <A,F,[B,D],101>.
- Node F receives it and ? (continued).



DSR example (continued)

- Node F receives it and:
  - If links are symmetric sends the path back following the indicated inverse route.
  - Or, if it has cached a path to A uses it.
  - Otherwise it sends a route request for A.



DSR Comments

- Sequence numbers are used to avoid routing loops.
- Routes are cached for some time to avoid frequent route requests by intermediate nodes.
- Low mobility and low traffic are the best scenarios for this protocol.

Hybrid Solutions
Zone Routing Protocol (ZRP)

- Zone routing is a hybrid protocol which combines proactive with reactive approaches.
- A zone around node N is maintained where routes are collected proactively.
- Beyond the zone an inter zone protocol is responsible to determine the routes in a reactive way.

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Disconnected Ad-hoc Networks

- The protocols we have seen until now only work when there is a "connected path" among the communicating nodes
- I.e. no storage on intermediate nodes is allowed.
- The protocols do not work when this is not the case.

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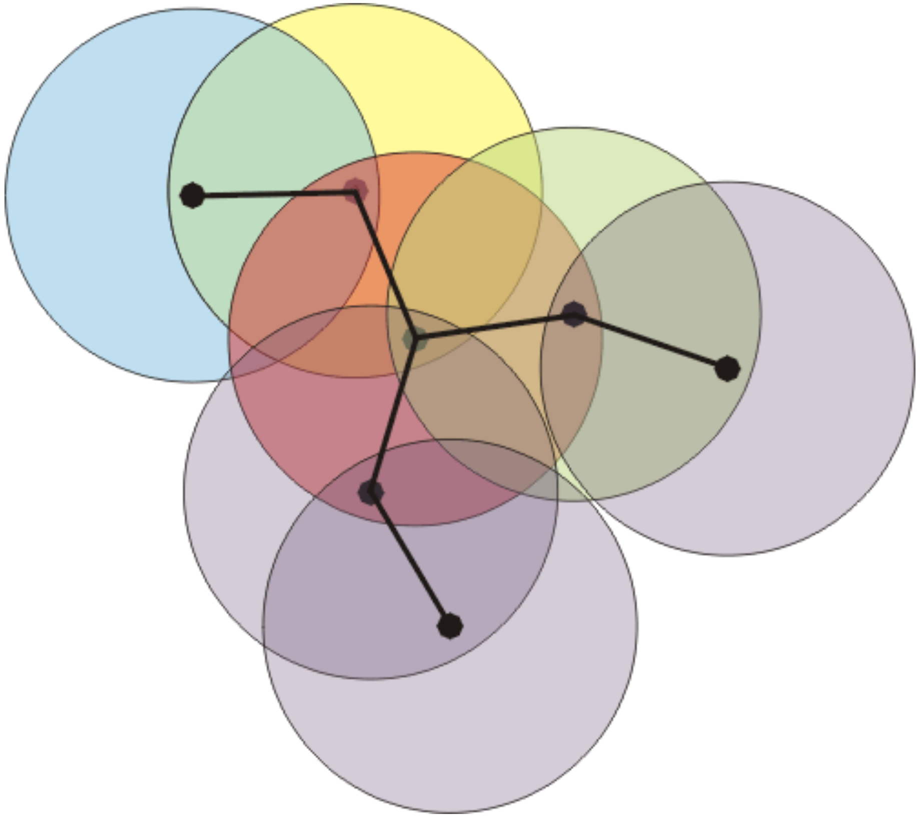
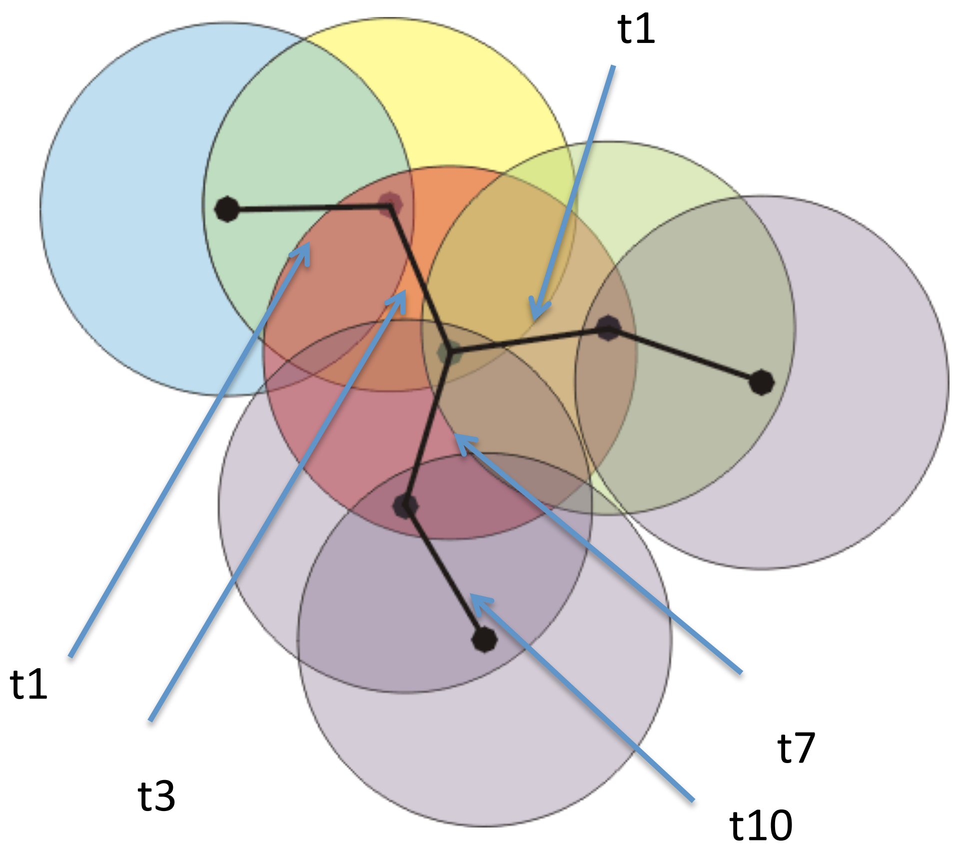
Connected vs Disconnected Ad-hoc Networks

Connected: there is a connected path among each couple



Disconnected: not all links are present at the same time



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Delay Tolerant Networks and Protocols

- These protocols do not assume a temporally connected path among the nodes.
- Nodes can accept a packet and deliver it later, after some time storing it.

Example: Epidemic Routing

- A flooding protocol which allows nodes to store packets before forwarding.
- A node accepts a packet, moves while carrying the packet and then forwards at a different time to a different neighbourhood.
- Flooding is always expensive (many transmissions, large buffers needed)

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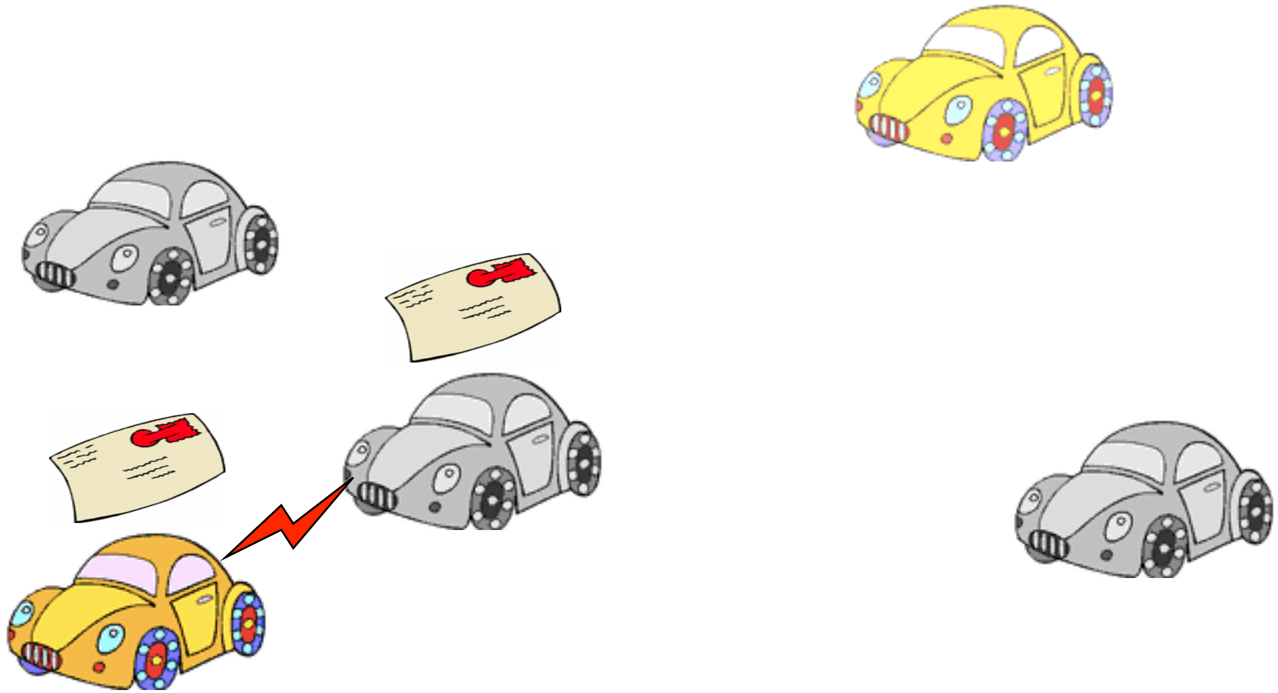
Example



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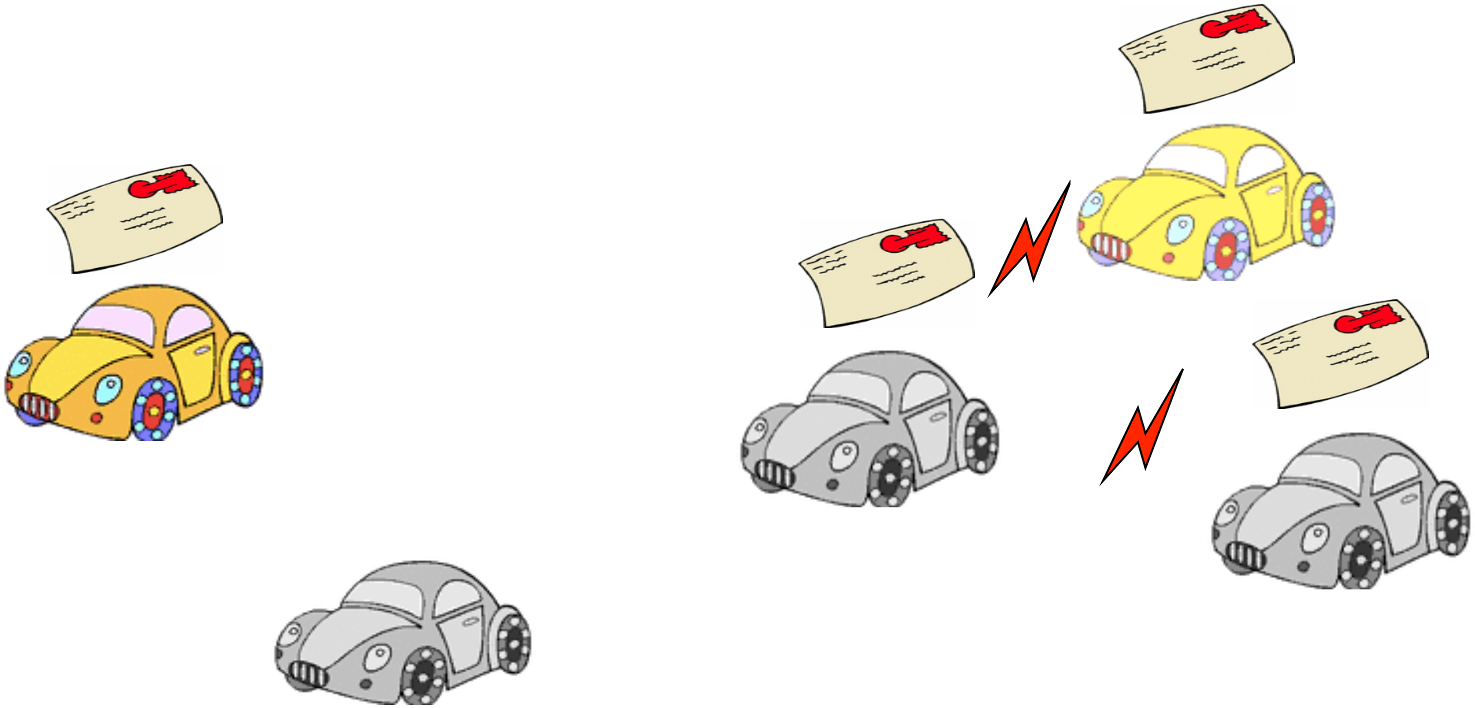
Example continued



Can we do better?

- Exploit the knowledge on the mobility of the nodes
- Is the mobility deterministic (ie. Always on the same path at same times like busses)? Maybe we can even control the mobility of some of the nodes!
- If not fixed, is it at least predictable?
- If not predictable, random…

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When mobility is predictable

- Prediction of mobility techniques need to be applied unless you want to use "epidemic".
- Instead of blindly forwarding packets to all or some neighbors, intermediate nodes estimate the chance, for each outgoing link, of eventually reaching the destination.
- Based on this estimation, the intermediate nodes decide whether to store the packet and wait for a better chance, or decide to which nodes (and the time) to forward.

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Context Aware Routing (CAR)

- A node chooses the best carrier to reach a specific node. How is the best carrier neighbour chosen?
  - Host mobility, host colocation with destination node, battery.
  - A utility function which weights these aspects
  - Kalman Filter is used to predict future host colocation with destination based on previous history.
- The approach is based on local knowledge only.

Reference

- Agrawal, D. & Zheng, Q. (2006). Introduction to wireless and mobile systems. Thomson.
- A. Vahdat and D. Becker, Epidemic routing for partially-connected ad hoc networks, 2000.
- M. Musolesi and C. Mascolo. CAR: Context-aware Adaptive Routing for Delay Tolerant Mobile Networks. In IEEE Transactions on Mobile Computing. Vol. 8(2). pp. 246-260. February 2009.