Introduction to MANET Routing

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MANET

MANET: Mobile Ad hoc NETwork

- mobile wireless network, capable of autonomous operation
- operates without base station infrastructure
- nodes cooperate to provide connectivity
- operates without centralized administration
- nodes cooperate to provide services

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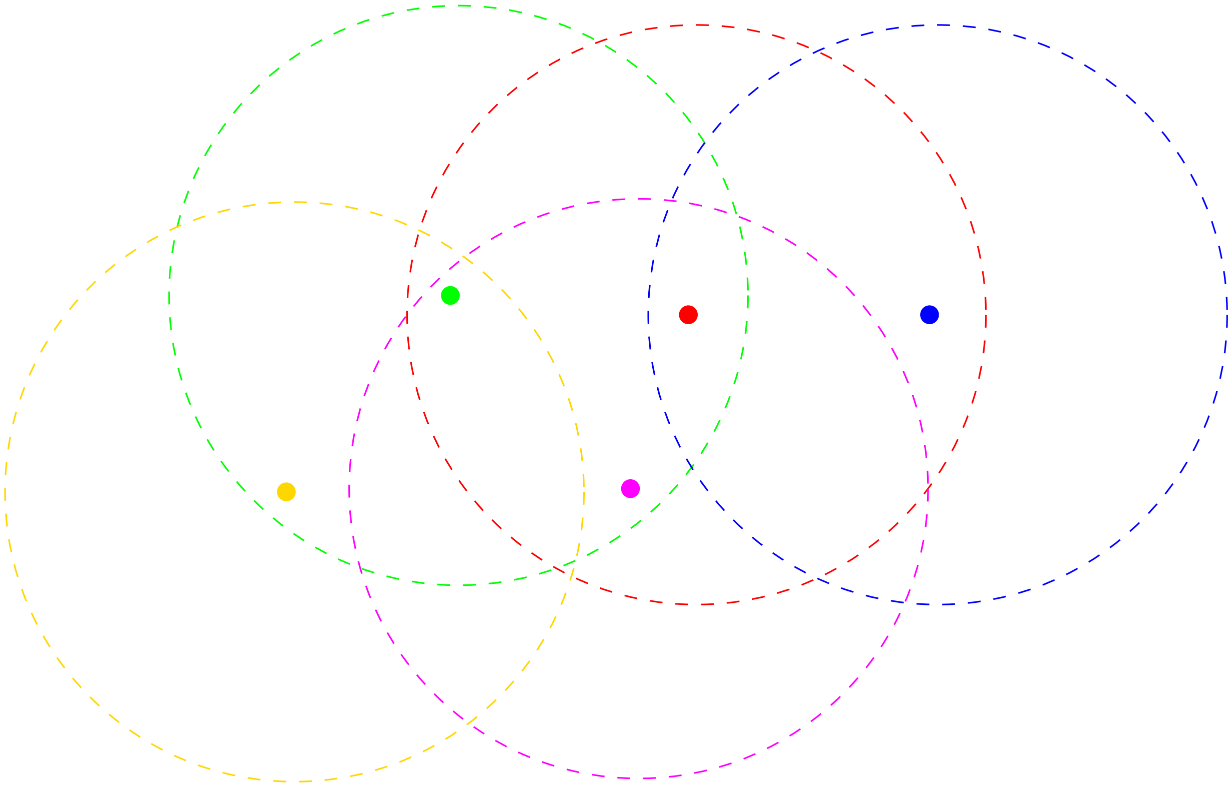
Ad hoc routing



infrastructureless network

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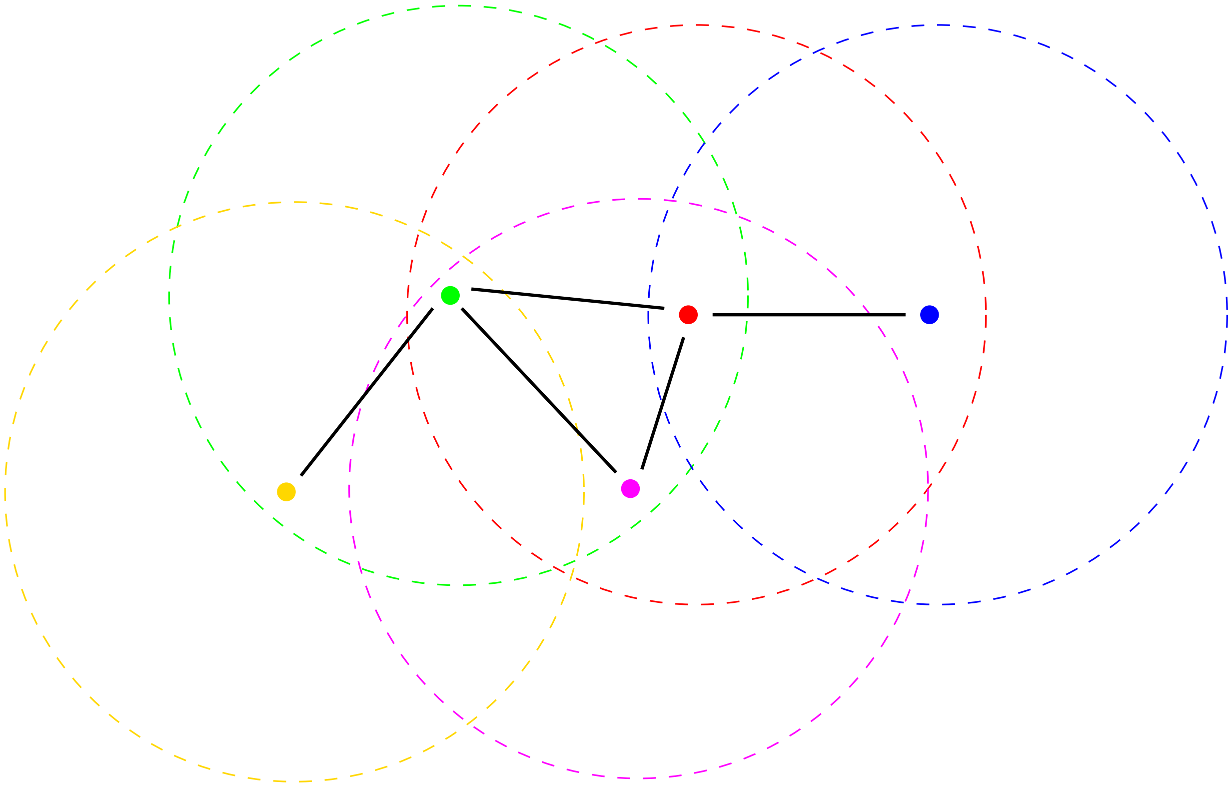
Ad hoc routing



"equivalent" topology

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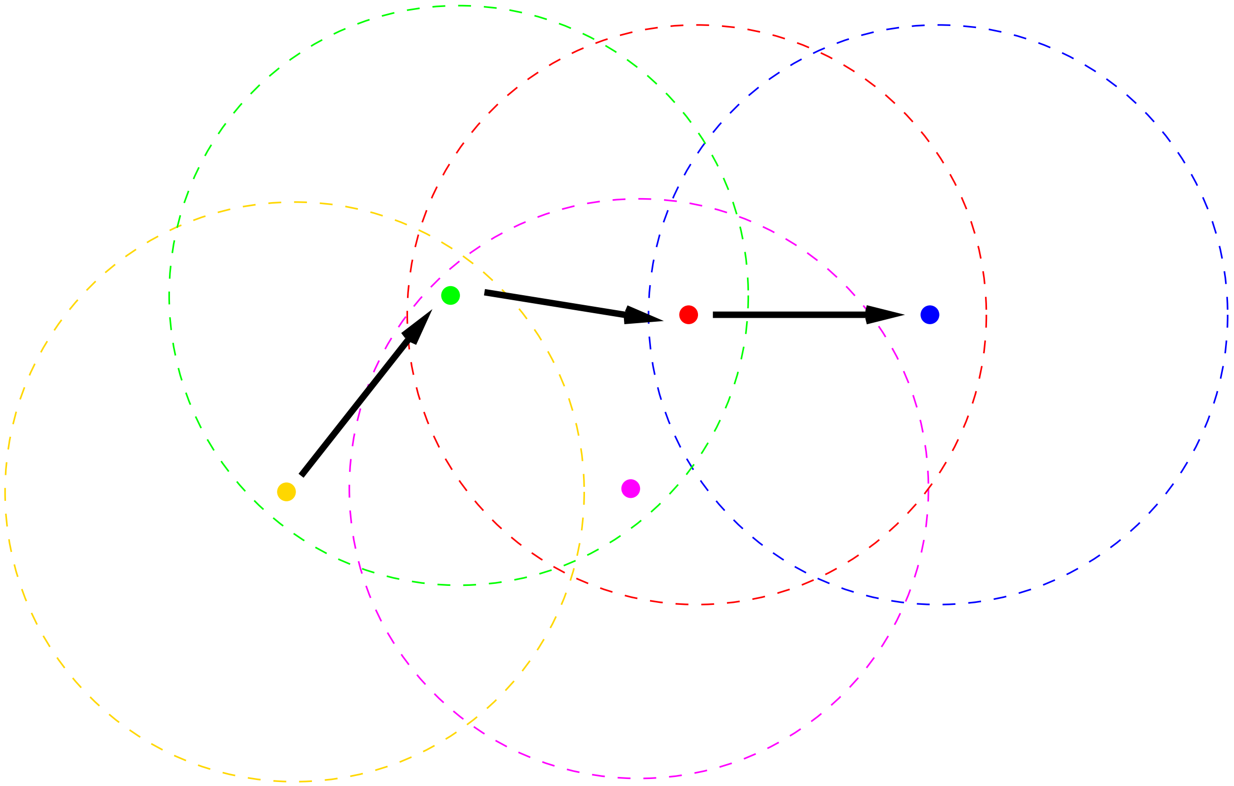
Ad hoc routing



dynamic multihop routing

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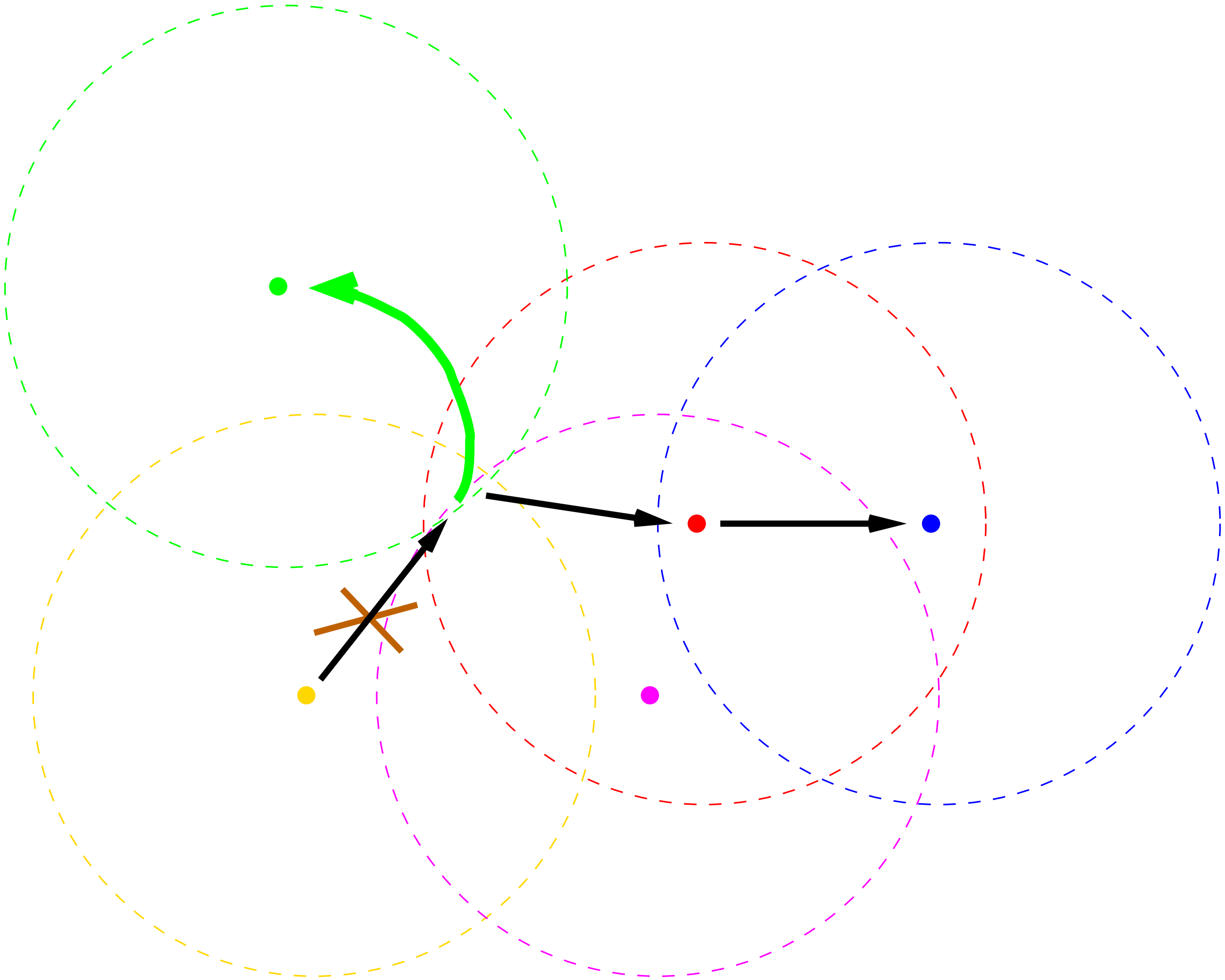
Ad hoc routing



route failure due to mobility

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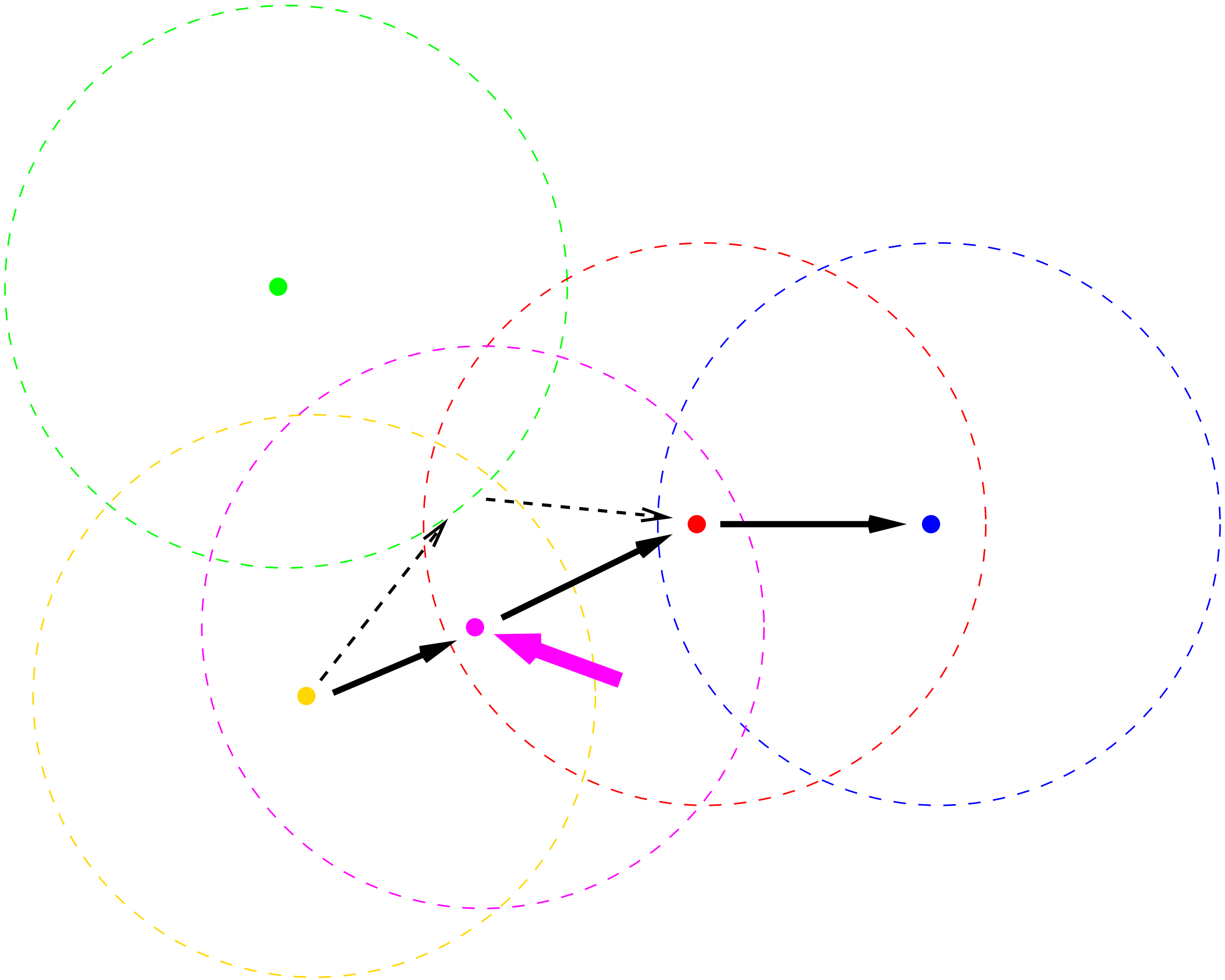
Ad hoc routing



dynamic route repair

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Applications

- tactical (military) networks (FOI)
- disaster recovery services
- metropolitan/campus-area communication networks (UU)
- sensor networks (SICS)
- enhanced cellular networks (KTH)
- delay-tolerant networking (LUTH)

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Definition

How is a MANET different from other networks?

- Internet
- WLAN
- MobileIP

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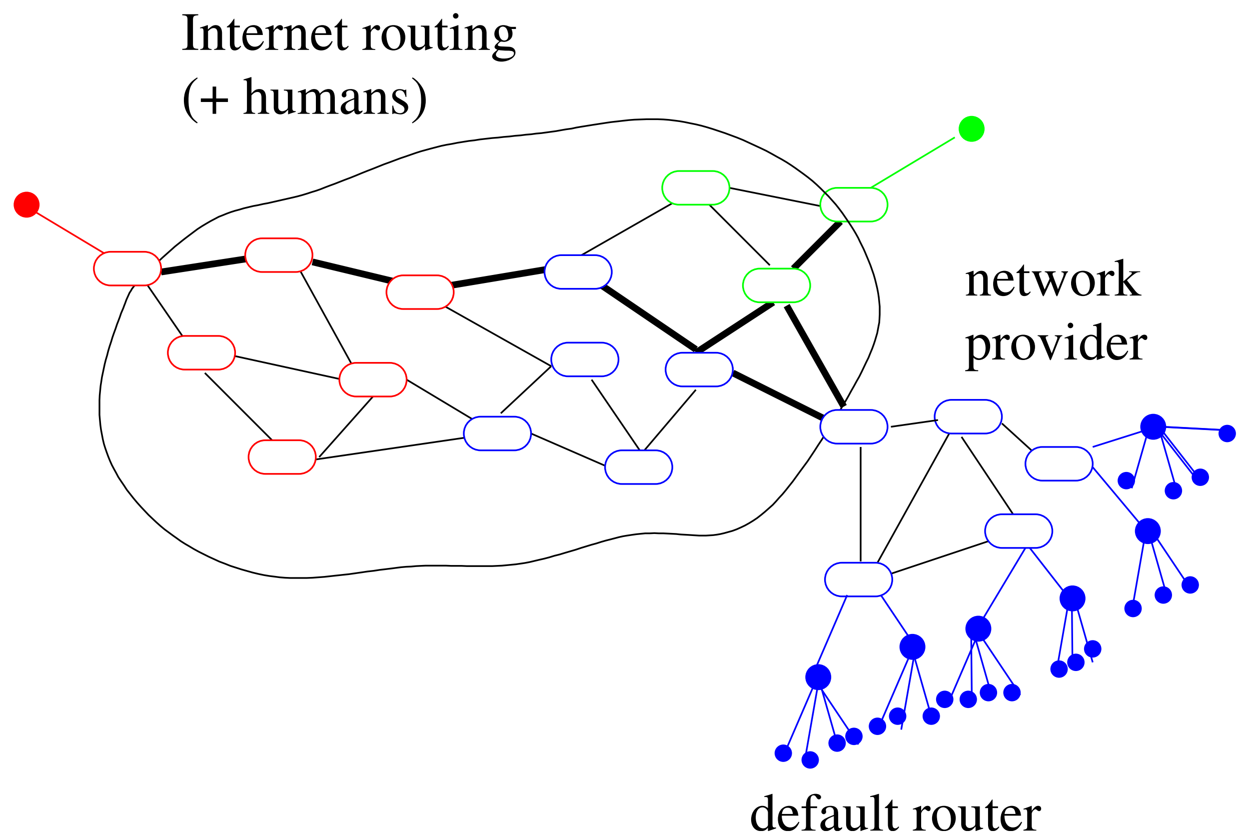
Internet/Intranet



managing infrastructure requires significant expert configuration

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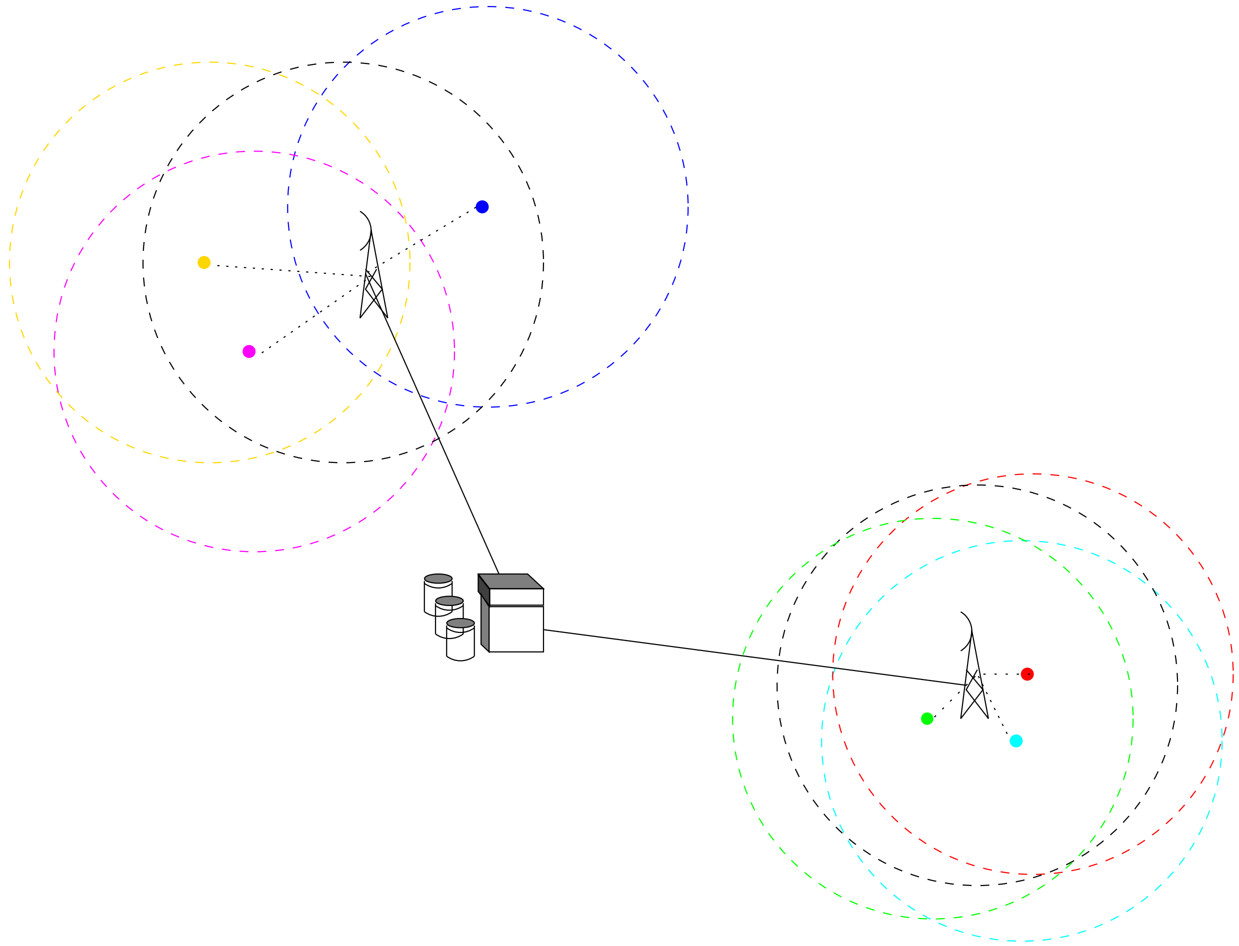
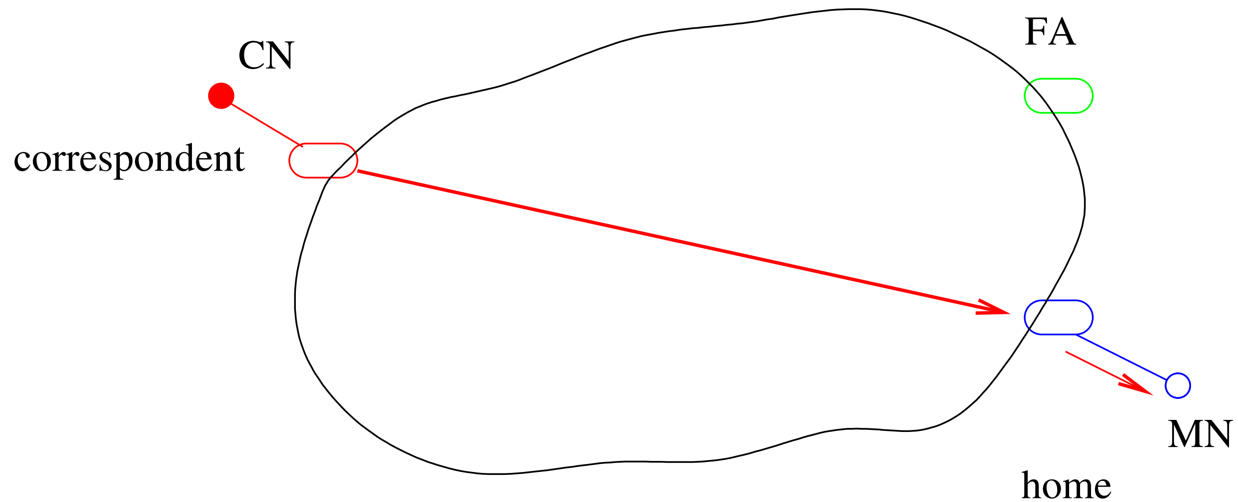
Cellular (WLAN)



mobiles communicate only with base-stations

MobileIP



Mobile-IP allows a node to change its point of attachment to the network

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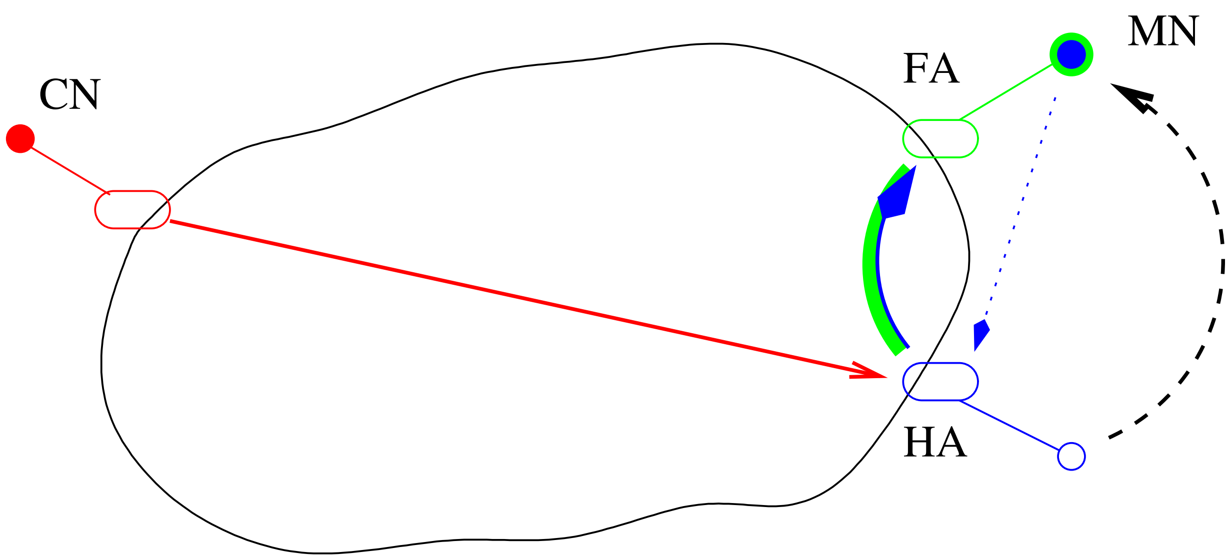
MobileIP



mobiles register location with home agent, which tunnels traffic

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Status

Still largely an R&D activity

- IETF MANET working group
  - two protocols will become "proposed standards"
- IRTF working group
- research community
- small-scale testbeds and simulation experiments

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Overview

- ad hoc routing problem
  - challenges
  - design choices
  - protocol example
- other problems
  - security & cooperation
  - services
  - wireless issues

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Challenges

- distributed state in unreliable environment
- dynamic topology
- limited network capacity
- wireless communication
  - variable link quality
  - interference and collisions
  - energy-constrained nodes

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Criteria

- effectiveness
  - convergence/recovery
  - scalability (number of nodes, density)
- performance
  - data throughput
  - route latency (delay)
  - route optimality (hops/stability/diversity)
  - overhead cost (packets/bandwidth/energy)

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Alphabet Soup

many proposed protocols:

AODV	CEDAR	ABR	FSR
TORA	GSR	OLSR	LANMAR
ZRP	LAR	DSR	OSPF++
RDMAR	CBRP	DSDV	WRP
TBRPF	CGSR	GPSR	

protocols in red are best known

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Design Choices

protocols fall into a few main categories

-
- on-demand (reactive)
- table-driven (pro-active)
- flooding-based
- cluster-based
- geographic
- application specific (cross-layer)

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Design Choices

no pre-assigned backbone
can designate a backbone dynamically
backbone provides structure for the network

- increases (?) scalability
- cost to maintain backbone structure
- disproportionate load on backbone nodes

CEDAR is an example

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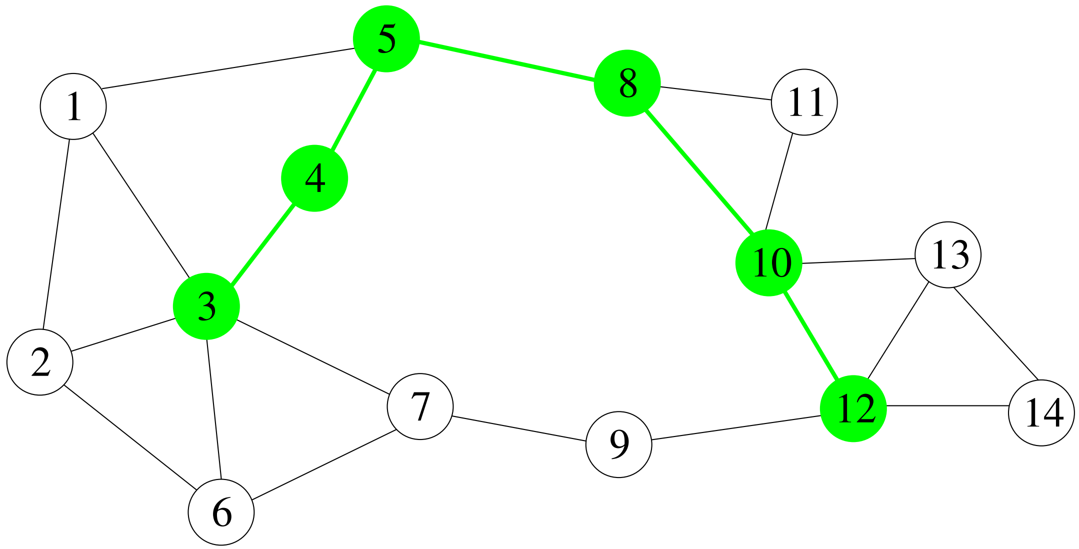
Routing backbone



- connected backbone; each node has a backbone neighbor
- distributed computation of a connected *minimum dominating set* is hard

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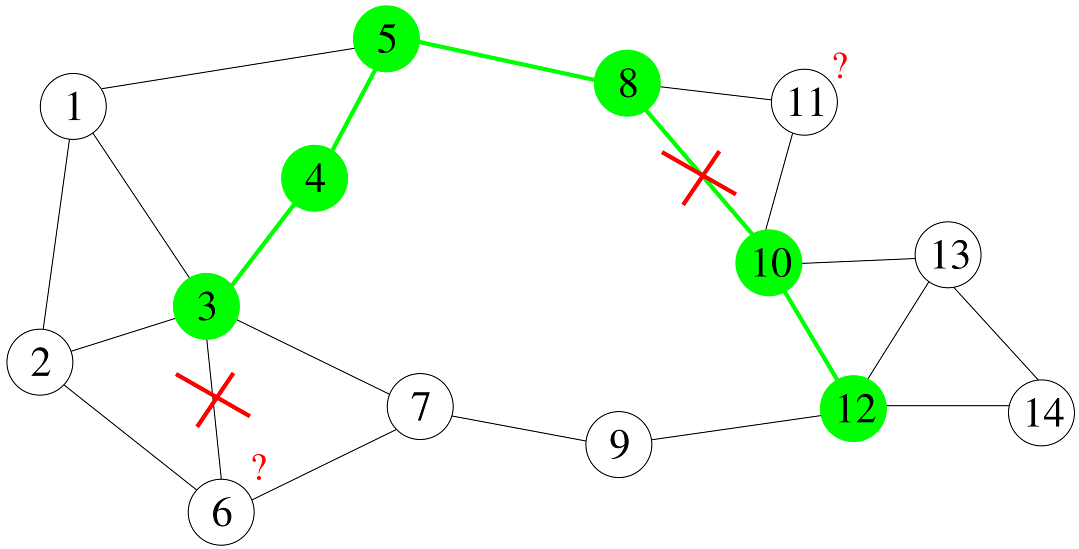
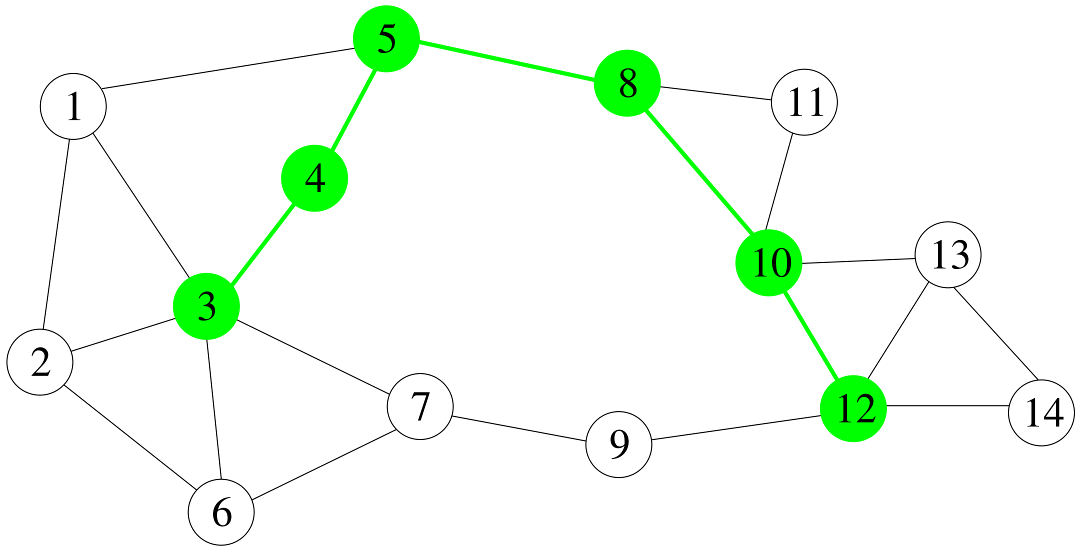
Routing backbone



- maintaining the backbone can be costly
- common strategy
  periodic broadcast of neighbor data, backbone nodes self-nominate via adaptive backoff

Routing backbone



- non-backbone nodes have “default” router
- how to route across the backbone??

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Reactive Routing

- reactive (on-demand) protocol
- only obtain route information when needed
- advantages
  - no overhead from periodic update
- disadvantages
  - high route latency
  - route caching can reduce latency

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Pro-active routing

- pro-active (table-driven) protocol
- more similar to conventional routing
- advantages
  - low route latency
  - state information
- disadvantages
  - high overhead (periodic table updates)
  - route repair depends on update frequency

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AODV (DYMO)

Ad hoc On-demand Distance Vector
(Perkins et.al.)

- conventional distance vector
  - nodes exchange distance tables with their neighbors
  - periodic exchange and immediate update for changes
  - routing table selects shortest path
- exchange a lot of information that is never used

AODV Strategy

- on-demand variant of conventional distance vector
  - route request (RREQ) is flooded through the network
  - route discovery creates (temporary) reverse routes
  - route reply (RREP) activates forward route

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AODV Strategy (cont')

- handling topology change
  - link failure generates route error (RERR)
  - destination managed sequence number ensures loop freedom
- *simplified* presentation follows...

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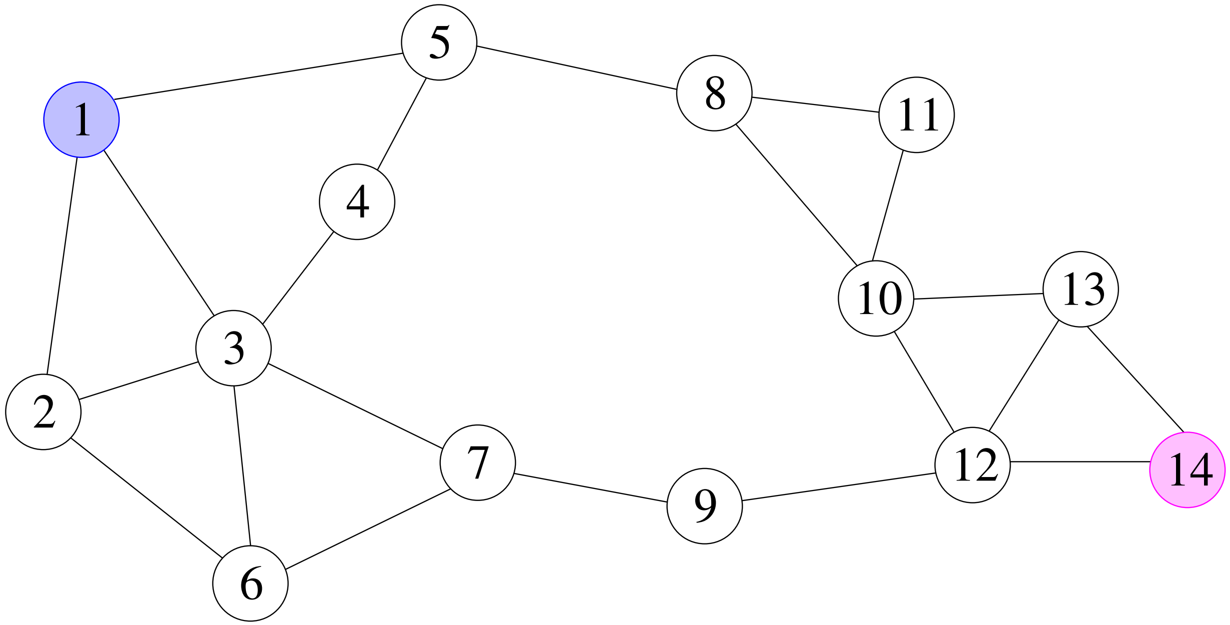
AODV



- on-demand routing protocol
- node 1 $\longrightarrow$ 14

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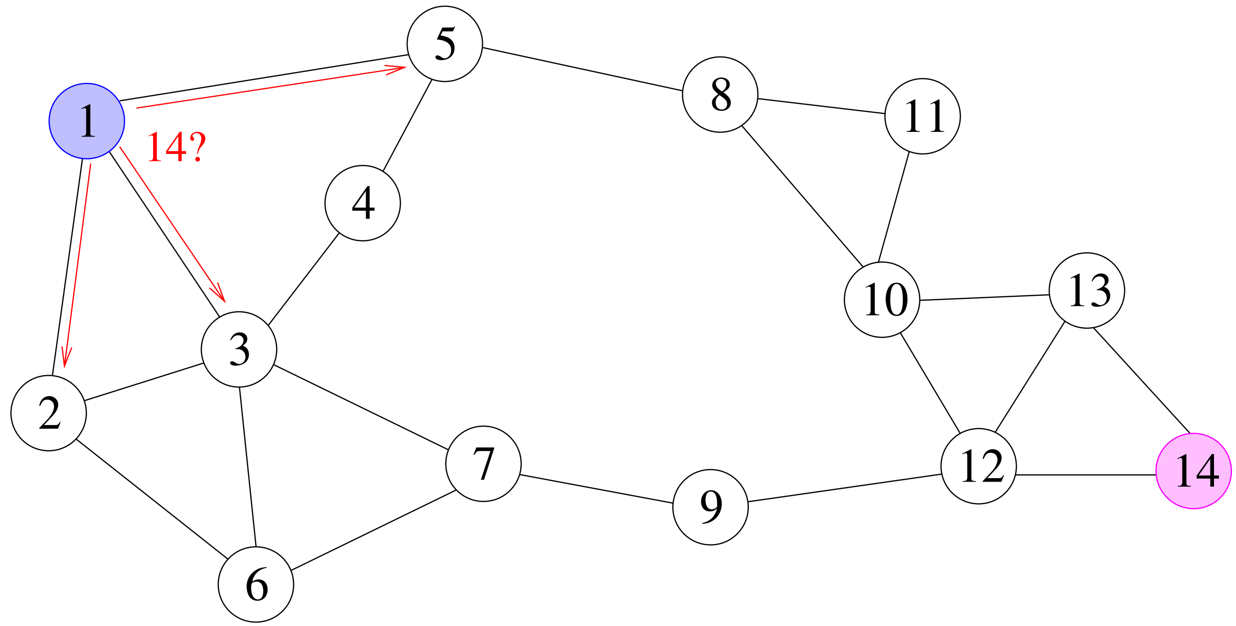
AODV (RREQ)



- broadcast flood route request message
  - (broadcast traffic in red)
- "wireless multicast advantage"

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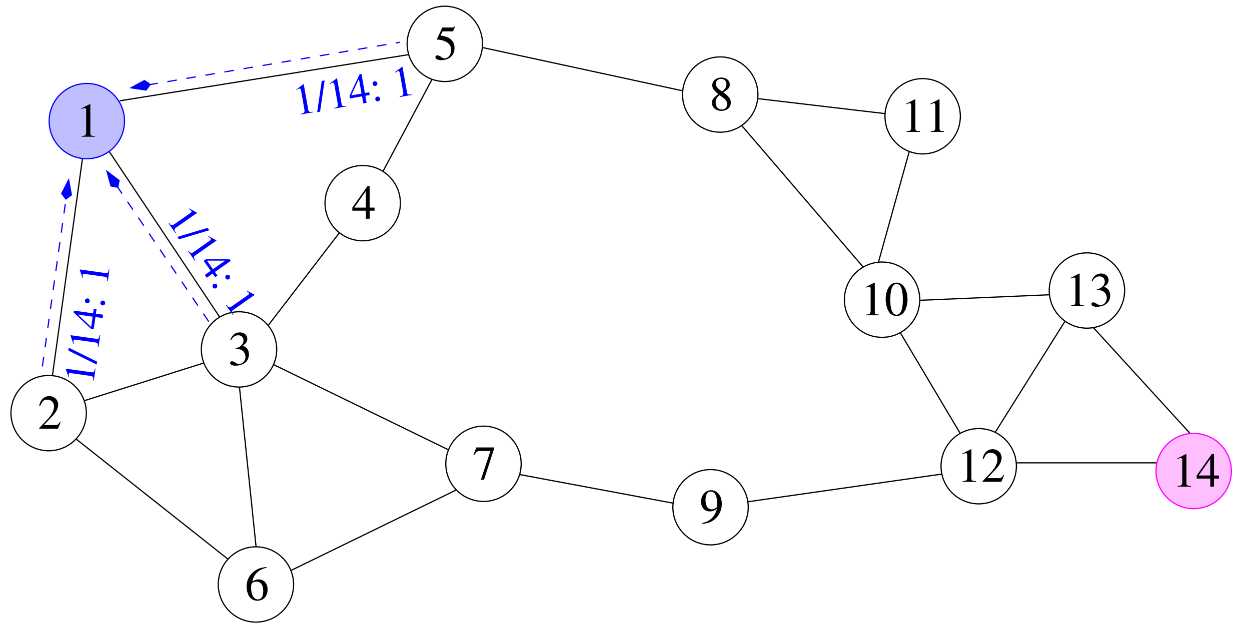
AODV (RREQ)



- node from which RREQ was received defines a reverse route to the source
  - (“reverse routing table entries” blue)

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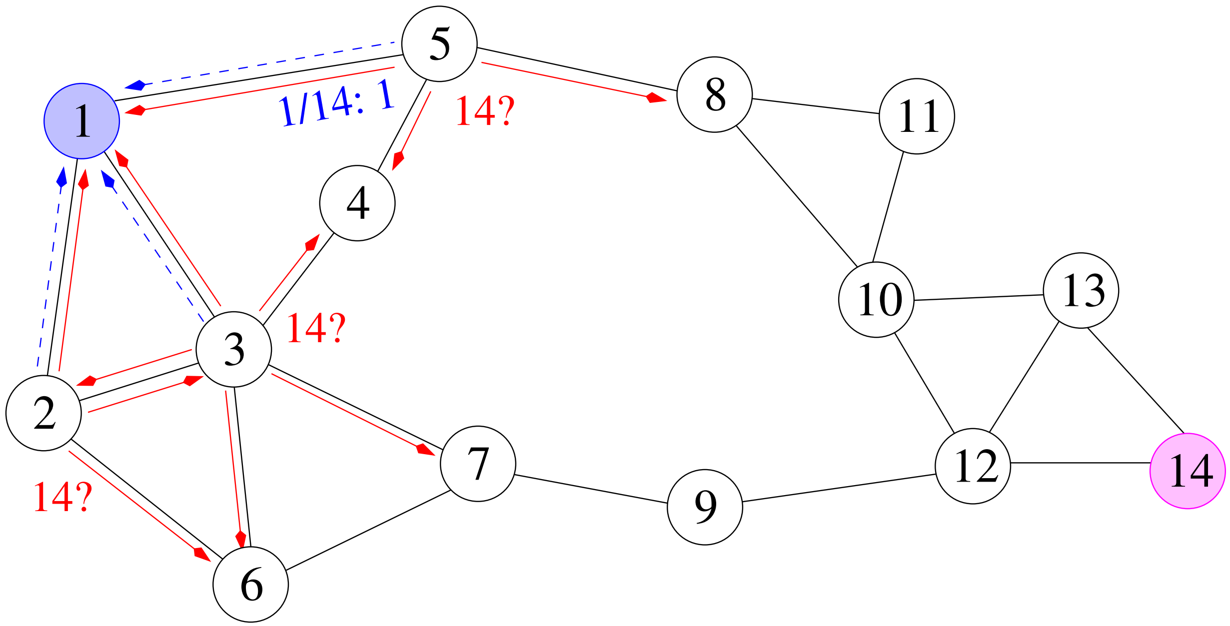
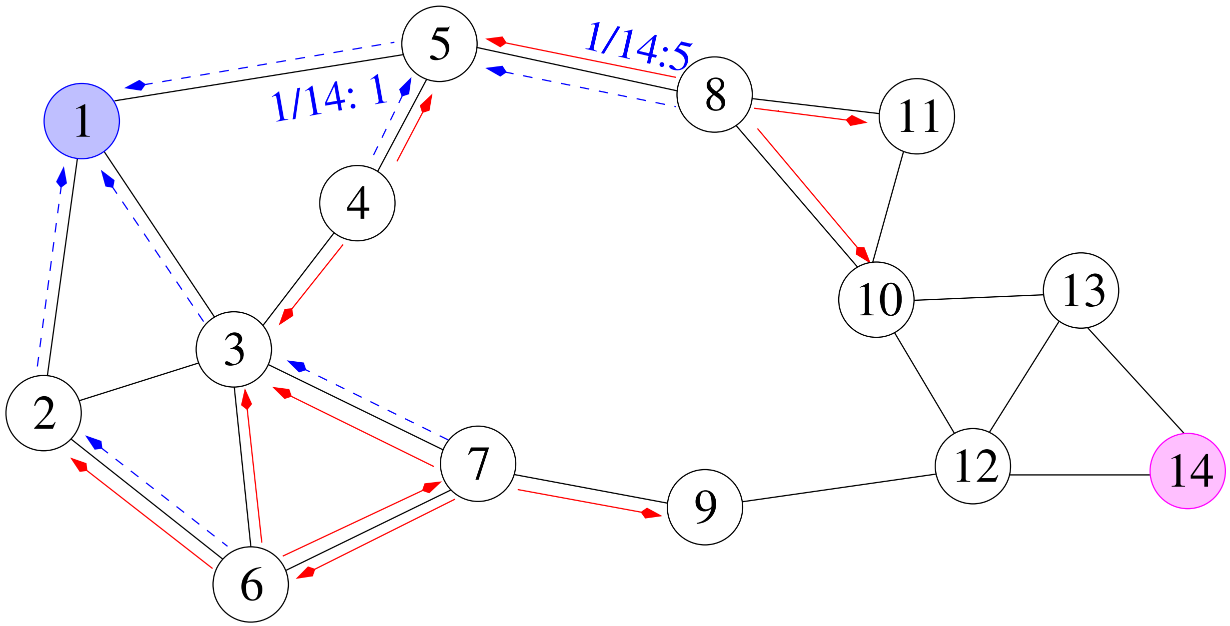
AODV (RREQ)



- route request is flooded through the network
- reverse routing table entries (blue arrows)

AODV (RREQ)



- unreliable communication
- destination managed sequence number, ID prevent looping

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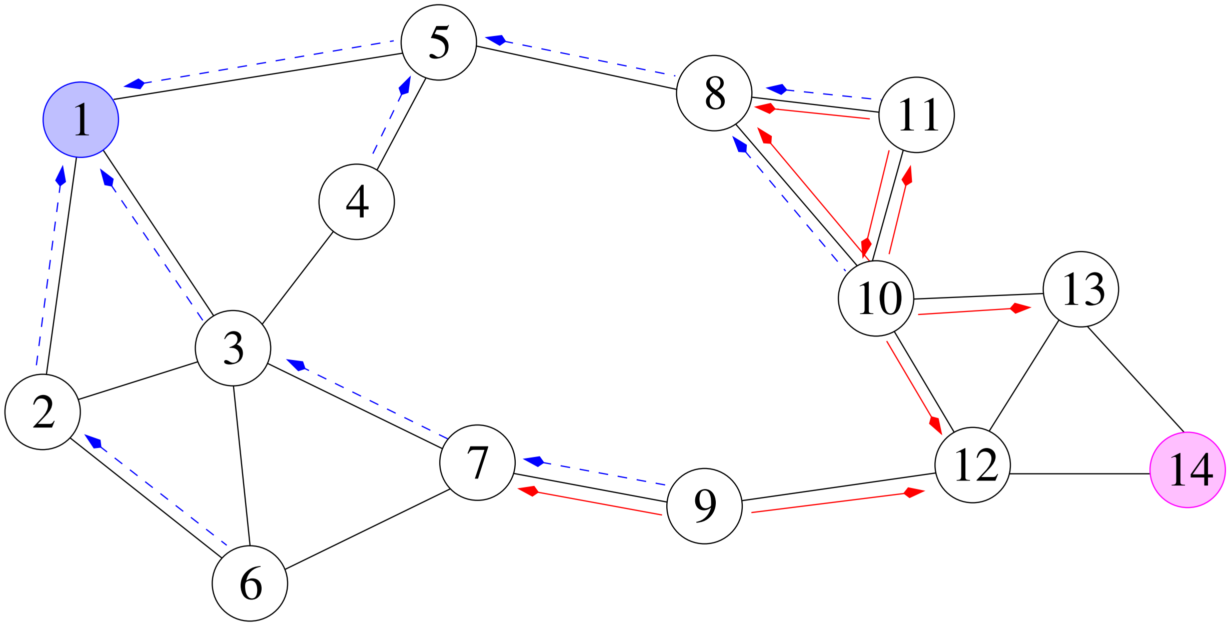
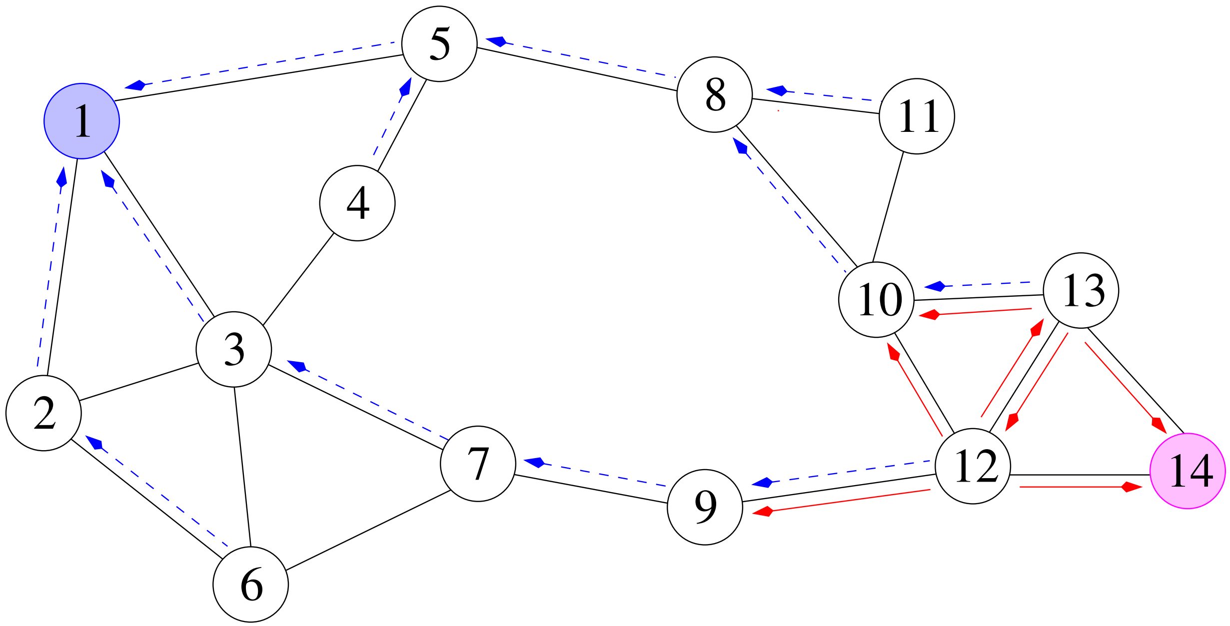
AODV (RREQ)



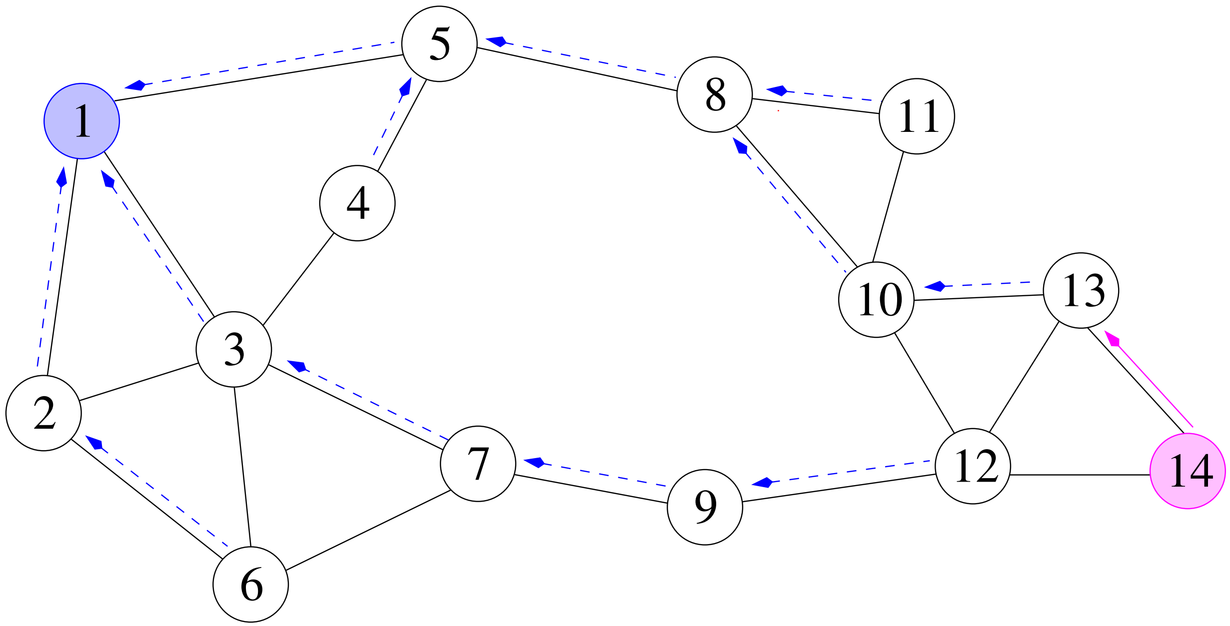
- flooding is expensive
- broadcast collision problem

AODV (RREQ)



- route request arrives at the destination
- two routes are discovered

AODV (RREP)



- destination sends route reply (set sequence number)
  - (unicast reply in magenta)

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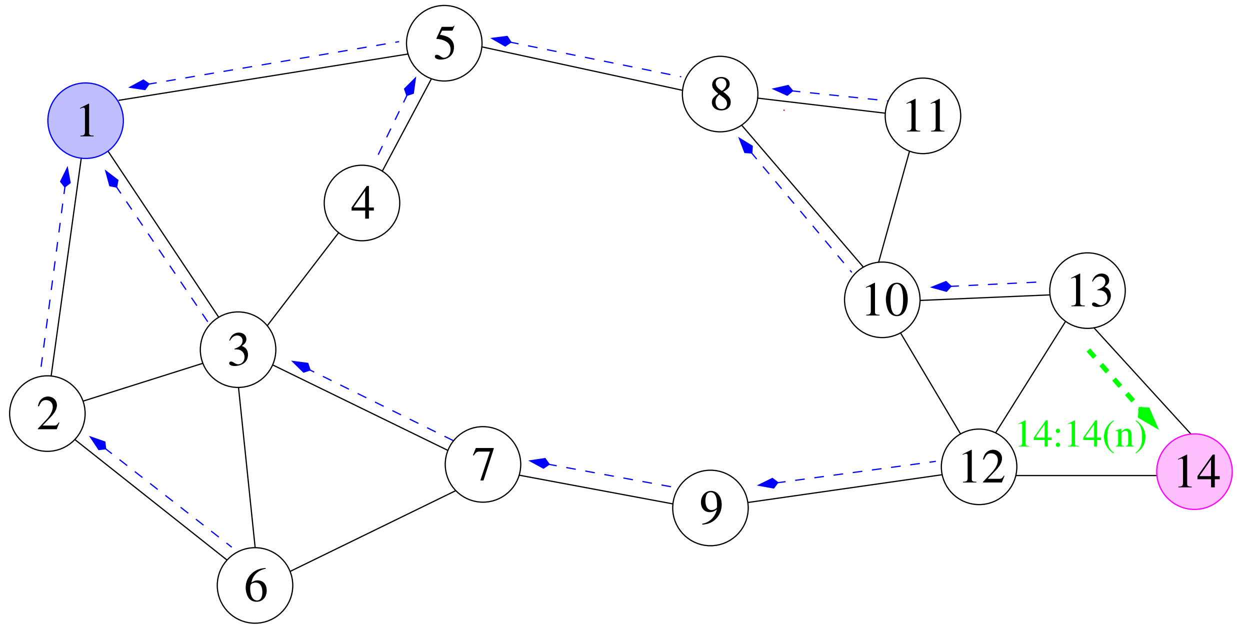
AODV (RREP)



- routing table now contains forward route to the destination
  - ("reverse routing table entries" in blue)

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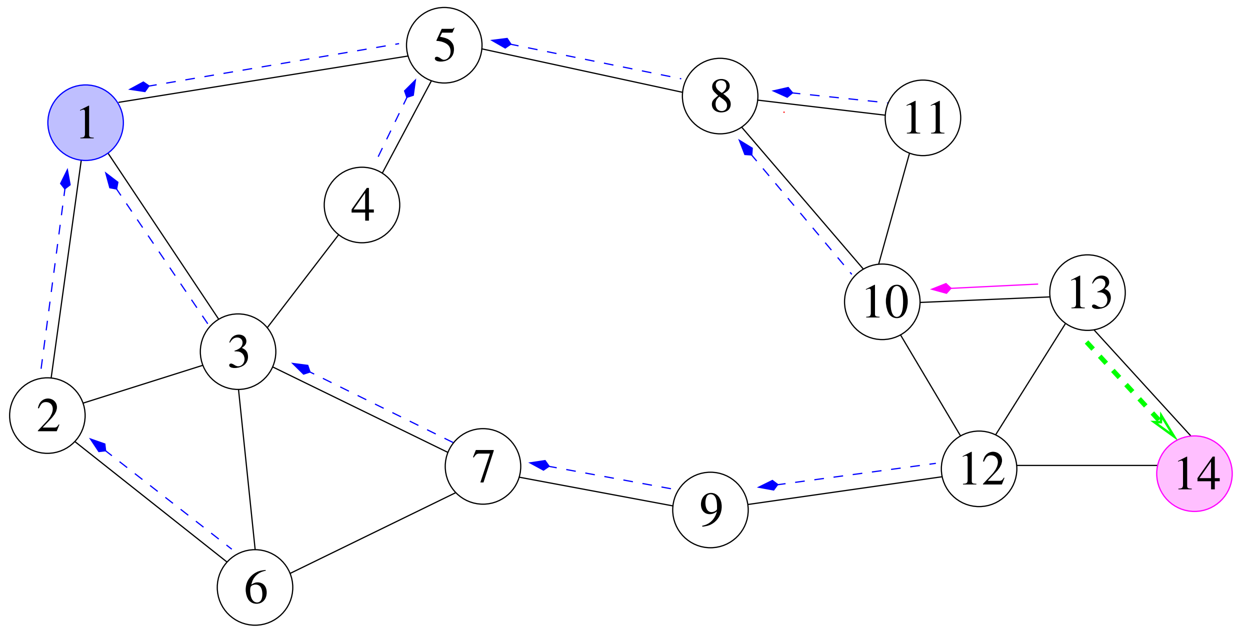
AODV (RREP)



- route reply follows reverse route back to the source

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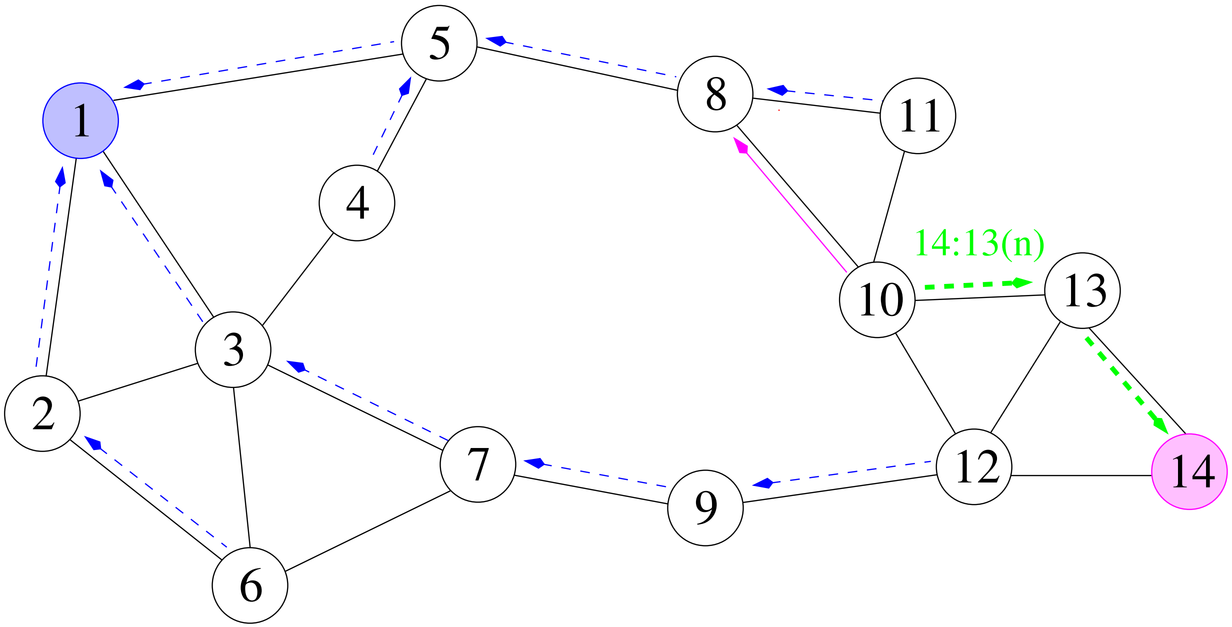
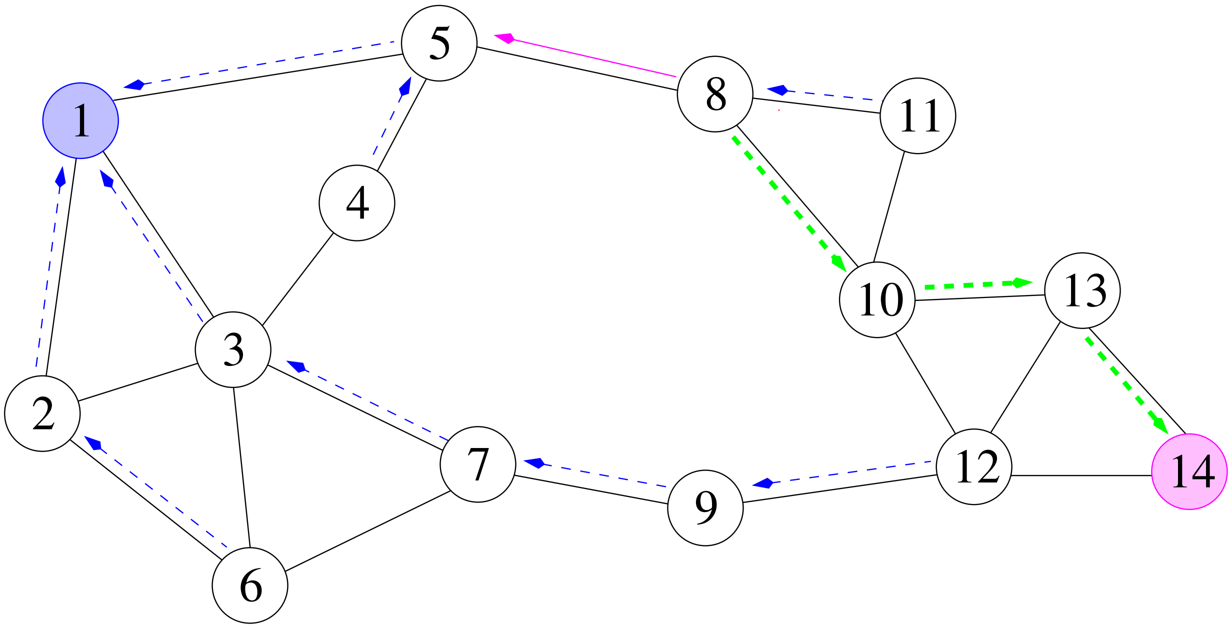
AODV (RREP)



- setting the forward routing table entries along the way

AODV (RREP)



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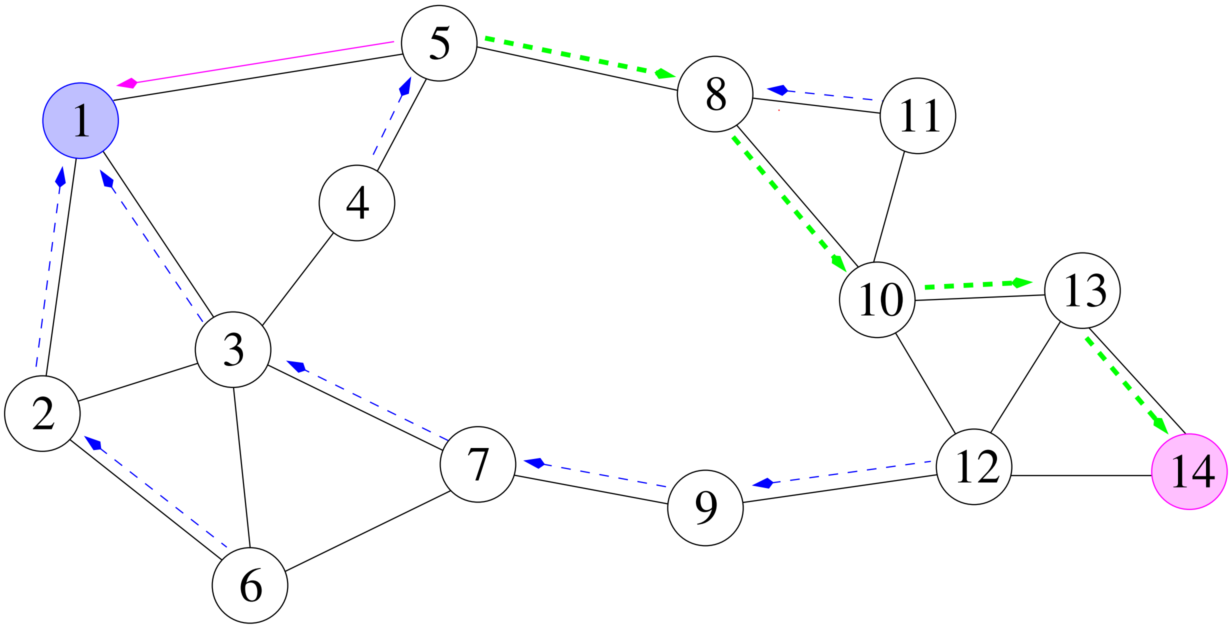
AODV (RREP)



- route reply reaches the source

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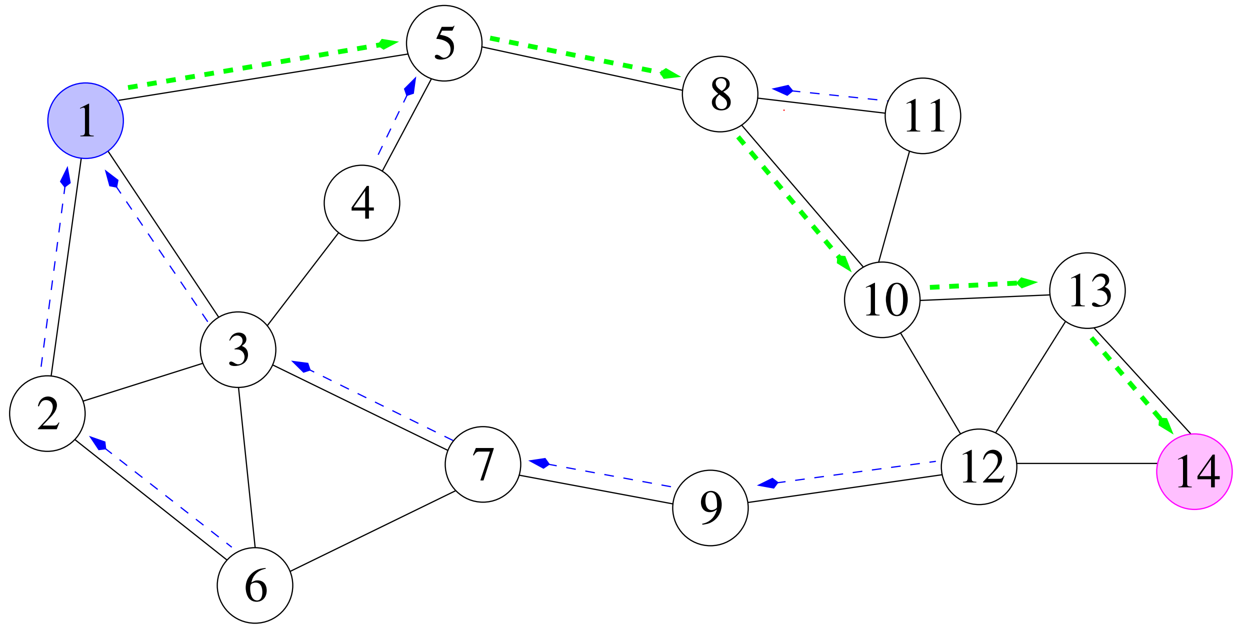
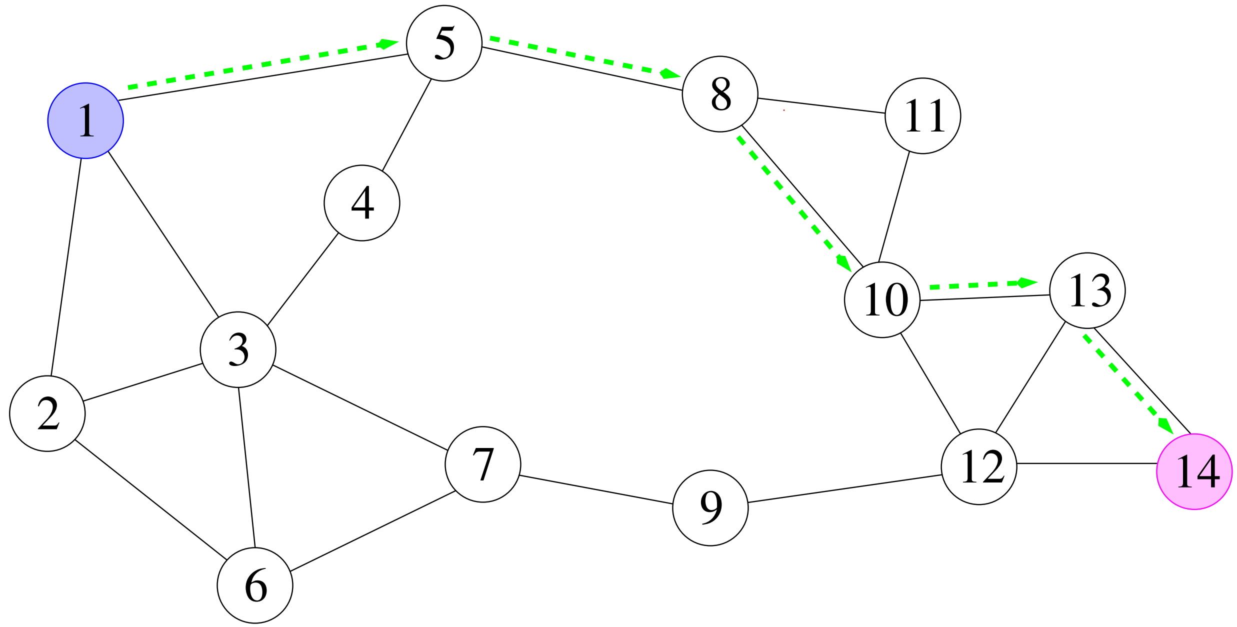
AODV (RREP)



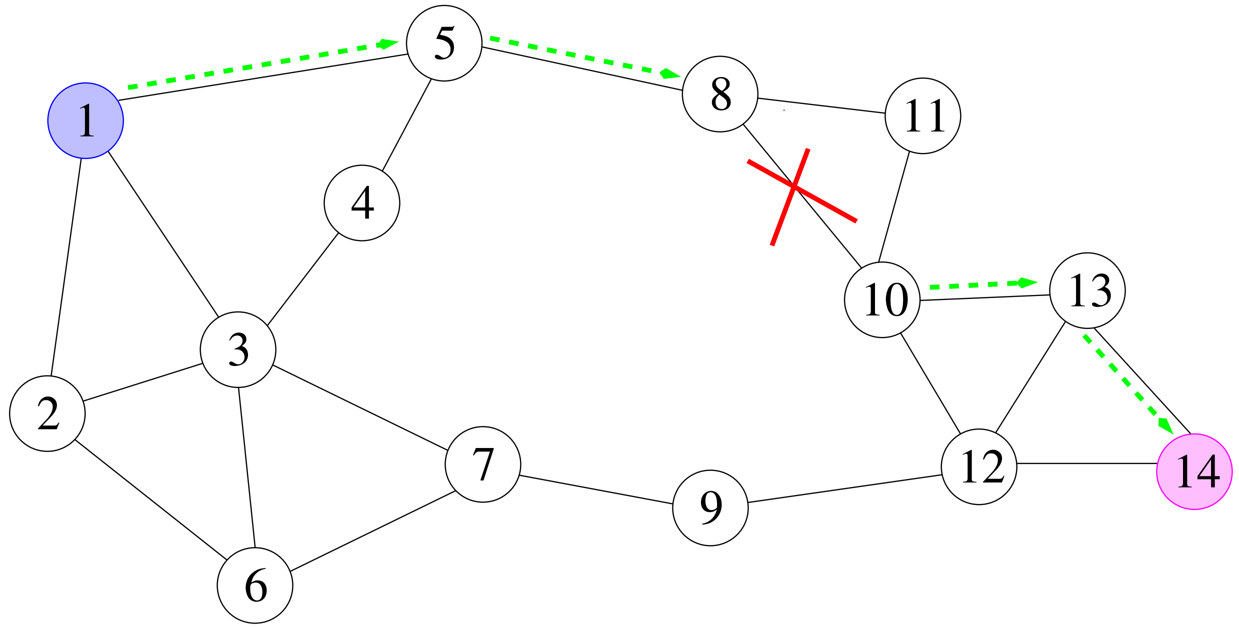
- source adopts destination sequence number

AODV



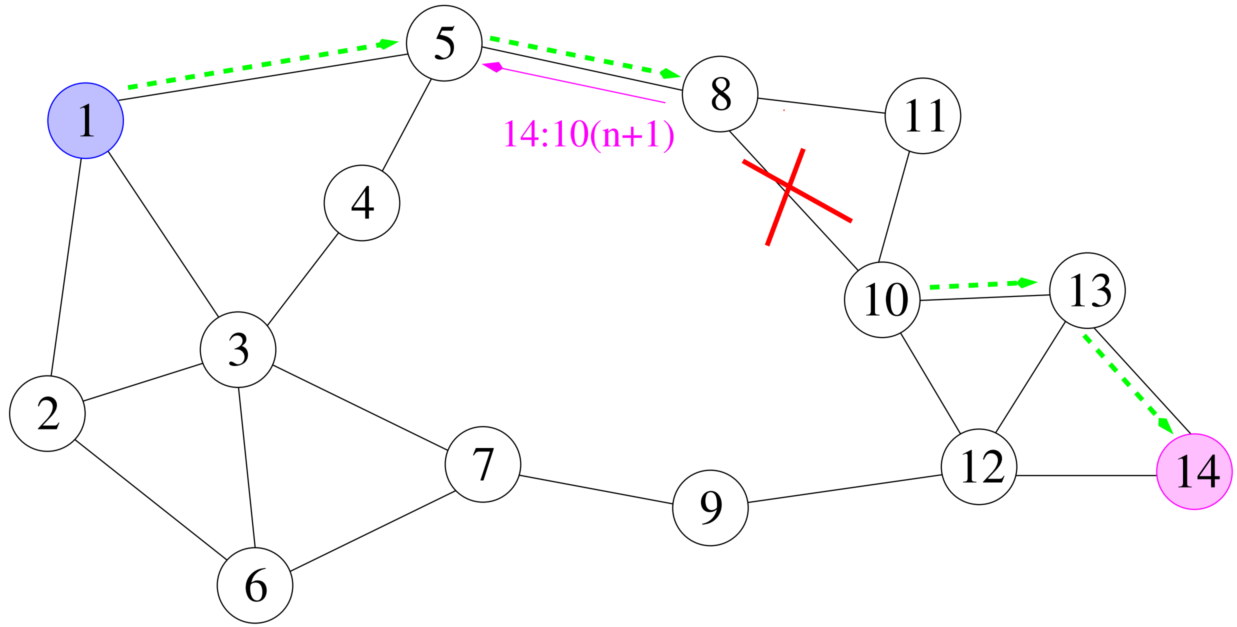
- traffic flows along the forward route
- forward route is refreshed, reverse routes time out

AODV (RERR)



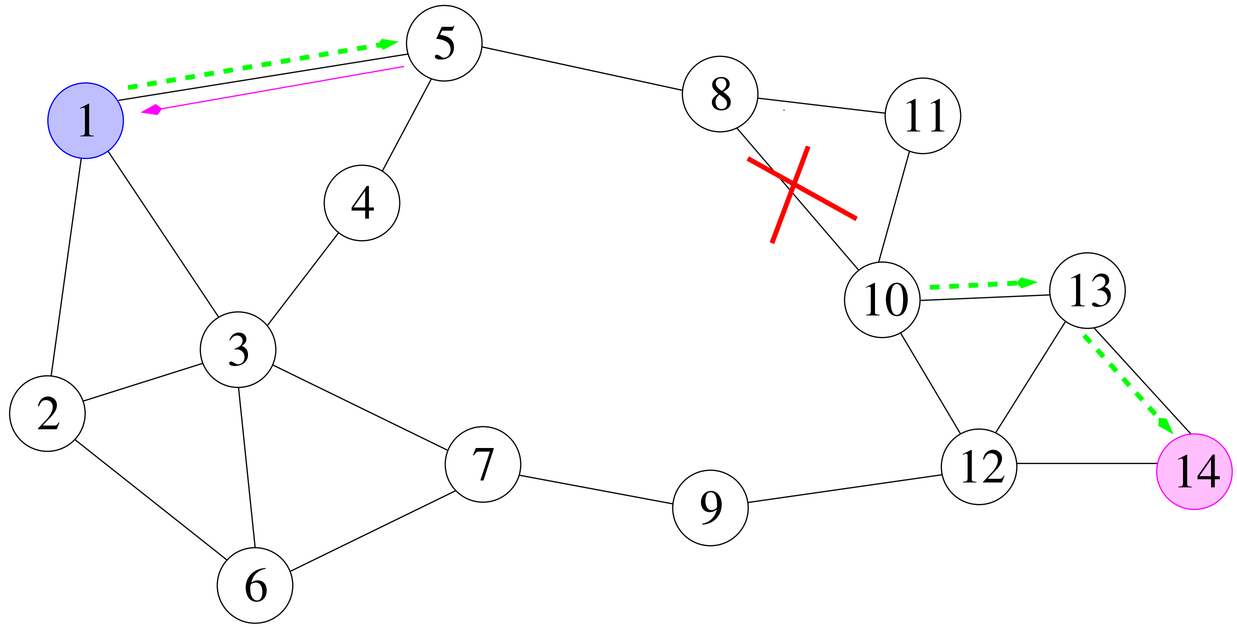
- link failure detection

AODV (RERR)



- return error message to the source (increment sequence number)

AODV (RERR)



- source receives route error

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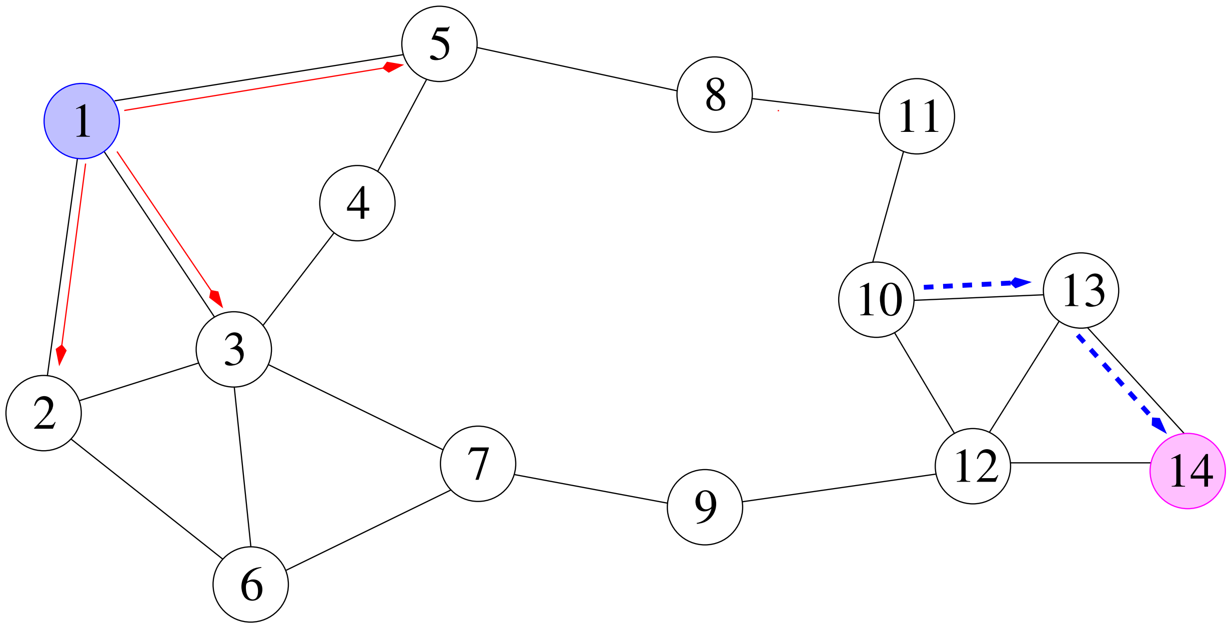
AODV (RREQ)



- re-initiates route discovery process

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Criteria

- effectiveness
  convergence/recovery
  scalability (number of nodes, density)
- performance
  data throughput
  route latency (delay)
  route optimality (hops/stability/diversity)
  overhead cost (packets/bandwidth/energy)

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Design Choices

- reactive (on-demand) protocol
  - high route latency
  - no overhead from periodic update
  - route caching can reduce latency
- pro-active (table-driven) protocol
  - low route latency
  - high overhead (periodic table updates)
  - route repair depends on update frequency

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OLSR

Optimized Link State Routing

Jacquet et. al.

- conventional link-state routing
  - beacon to determine neighbors
  - for each node, disseminate its links to all other nodes
  - use SPF algorithm to generate routing table
- high overhead, exchange information for links that are never used

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OLSR Strategy

- optimized variant of conventional link state routing
  - for each node, disseminate only some of its links
  - for each node, only disseminate information received via some links
  - use SPF algorithm to generate routing table
- "some (carefully selected!) links" = multipoint relay set

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2-hop Neighborhood

- broadcast periodic “hello” messages
  - each message contains a list of neighbors
  - each node discovers its 2-hop neighborhood
  - discovers failed links
  - discovers bi-directional links

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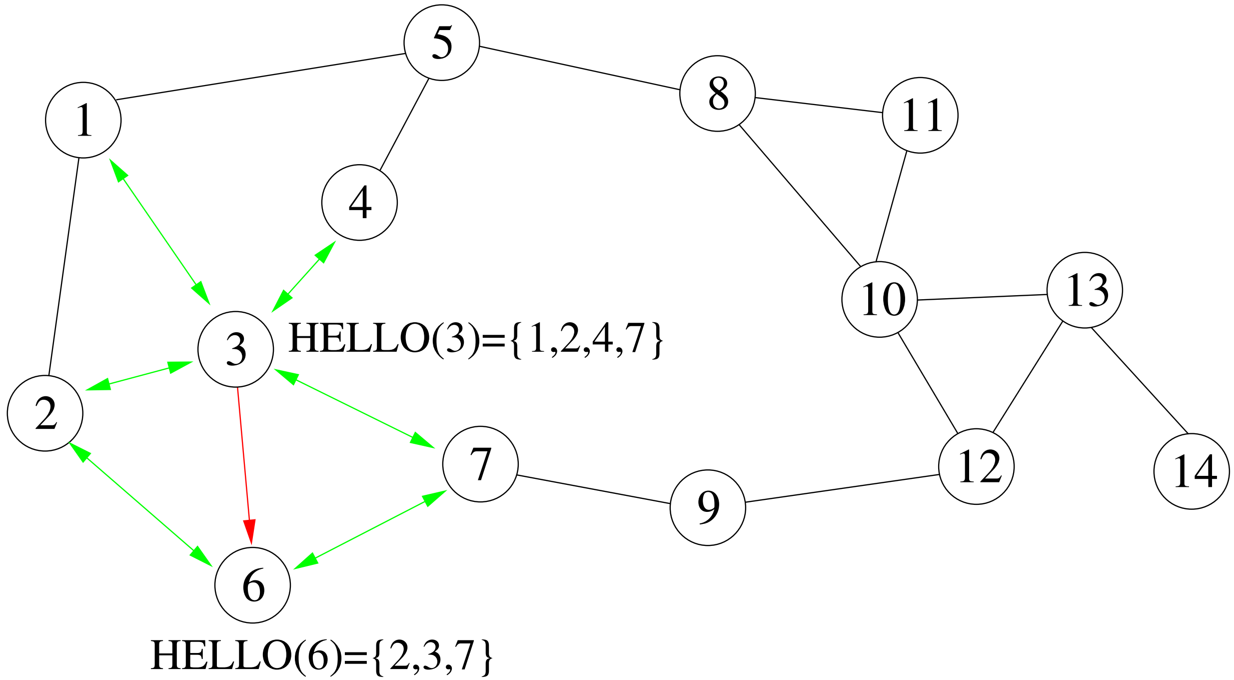
Bi-directional Links



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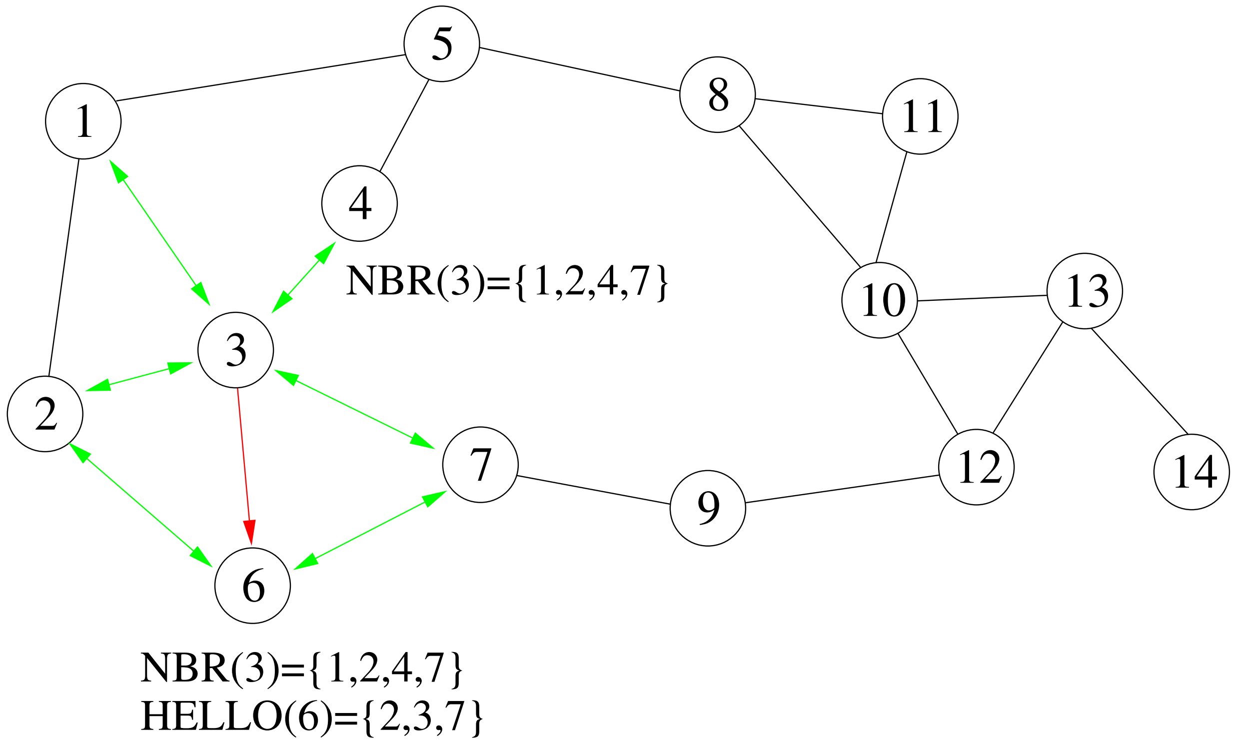
Bi-directional Links



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Multipoint Relay

multipoint relay set (MPR): subset of a node's 1-hop neighbors, such that each of its 2-hop neighbors is a 1-hop neighbor of a node in the MPR set

in practice, approximate optimal MPR set

note that each node independently determines its own MPR set (no global "network MPR set")

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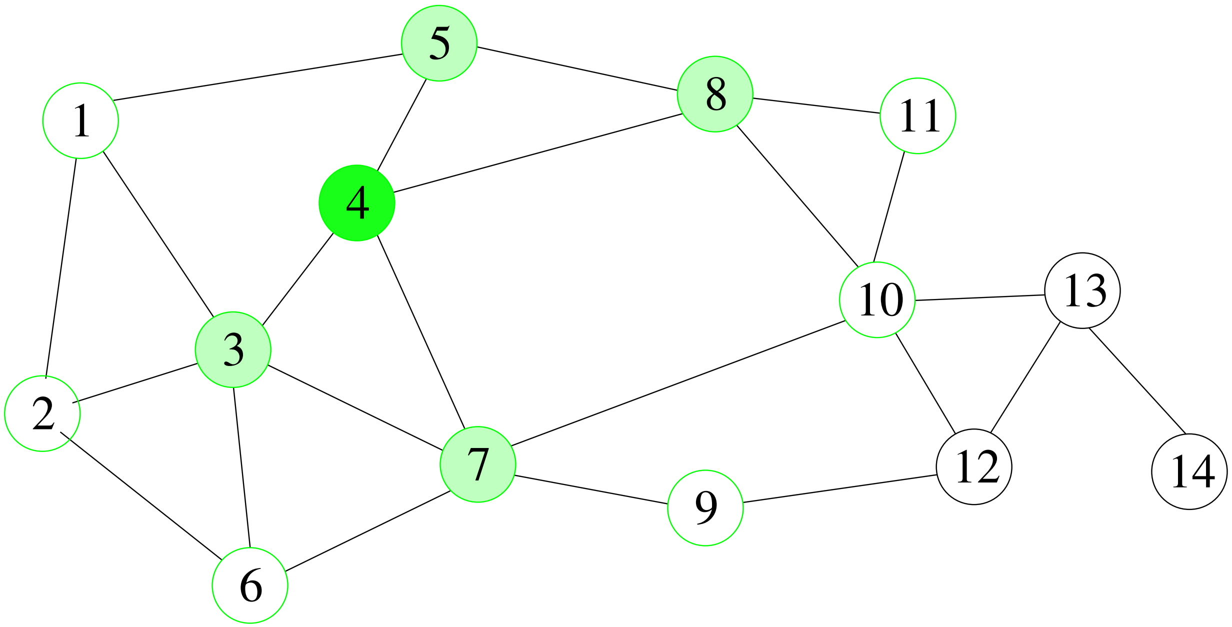
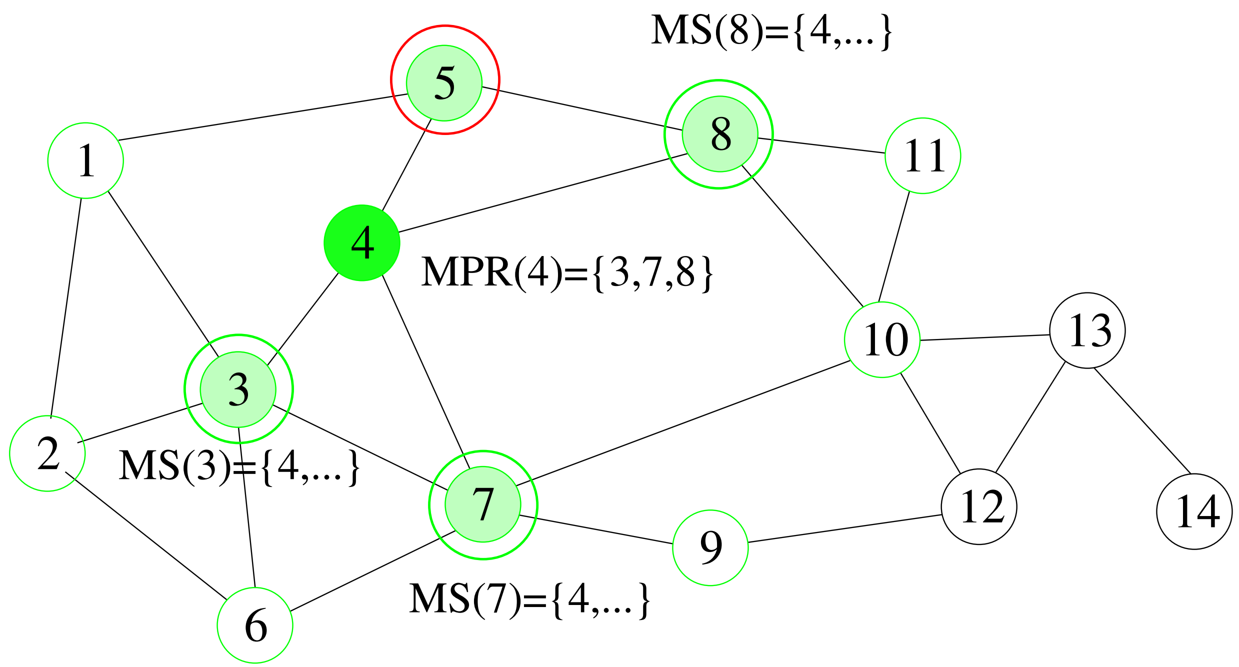
Multipoint Relay



one and two hop neighbors of node 4

Multipoint Relay (MPR set)



node 5 is not needed in the multipoint relay set

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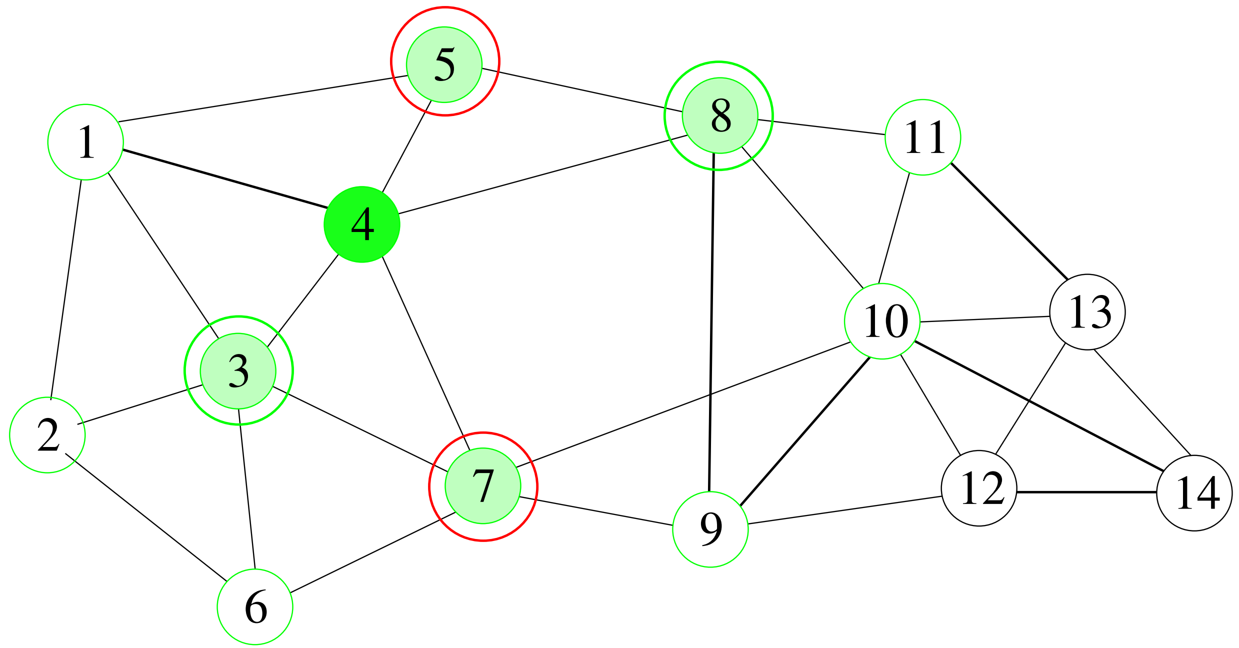
Dense Network



with greater node density, the proportion of relay nodes is smaller

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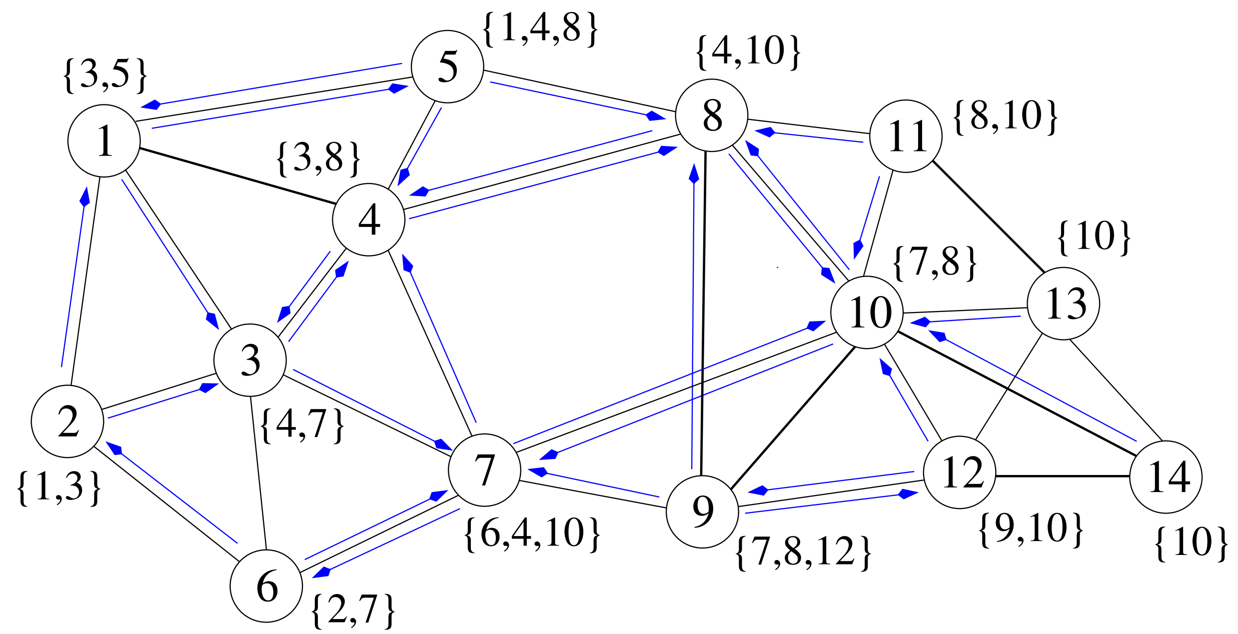
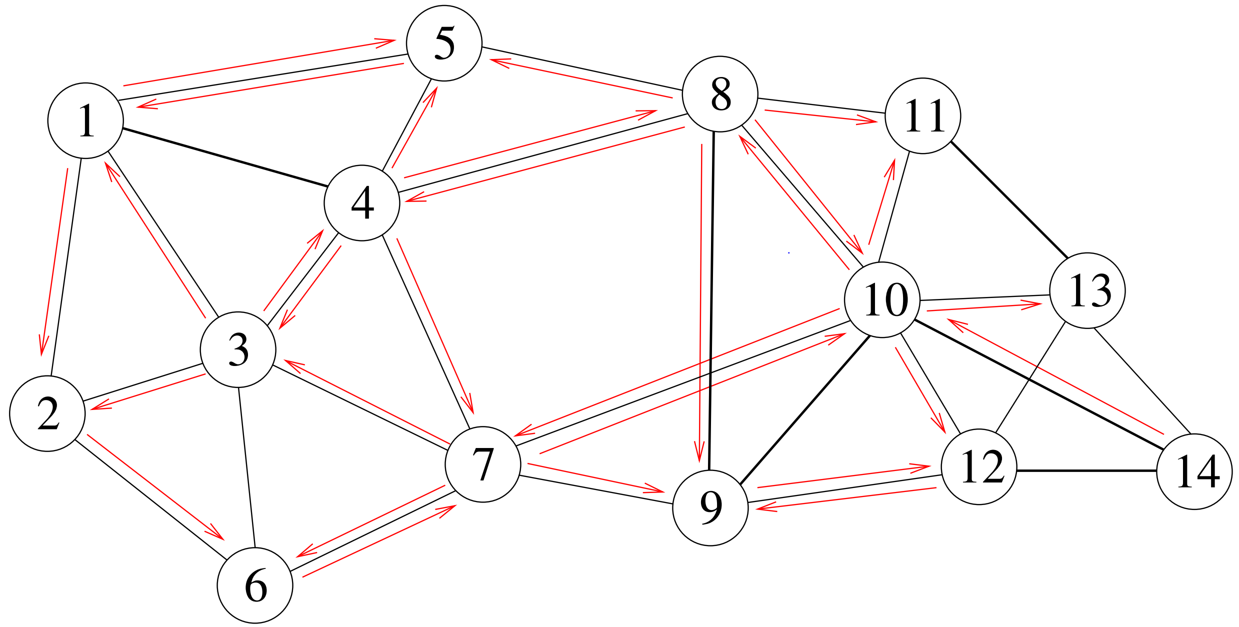
Dense Network (MPR set)



nodes which are not in the MPR set are somehow redundant

Dense Network (MS set)



multipoint selector (MS) set is the inverse of MPR set

OLSR

Operation:

- each node uses HELLO message to calculate and announce its MPR set
- a node sends link state information only for nodes in its MS set (for which it is an MPR)
- each node processes (SPF routes) all link state messages
- a node only rebroadcasts link state messages from nodes in its MS set

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OLSR (Dense Network)

only disseminate link data for green nodes

only rebroadcast data from green

nodes

1: 4 2 3 5	2: 1 3 6	3: 1 2 4 6 7
4: 1 3 5 7 8	5: 1 5 8	6: 2 3 7
7: 3 4 6 9 10	8: 4 5 9 10 11	9: 7 10 12
10: 7 8 9 11 12 13	11: 8 10 13	12: 9 10 13 14
13: 10 11 12 14	14: 10 12 13	