Routing In (Mobile) Ad-Hoc Networks

Outline

- Flooding
- Topology-based Routing Protocols
  - Proactive Algorithms [DSDV – Destination Sequenced Distance-Vector Routing]
  - Reactive (on demand) Algorithms [AODV – Ad-hoc On-Demand Distance Vector Routing], [DSR – Dynamic Source Routing]
- Geographic Routing Protocols
  - [FR – Face Routing], [GPSR – Greedy Perimeter Stateless Routing]

Communication by flooding

- Pros
  - Simple
  - Work also in highly dynamic networks
- Cons
  - Lots of messages duplicate
  - All nodes always involved
  - Scalability

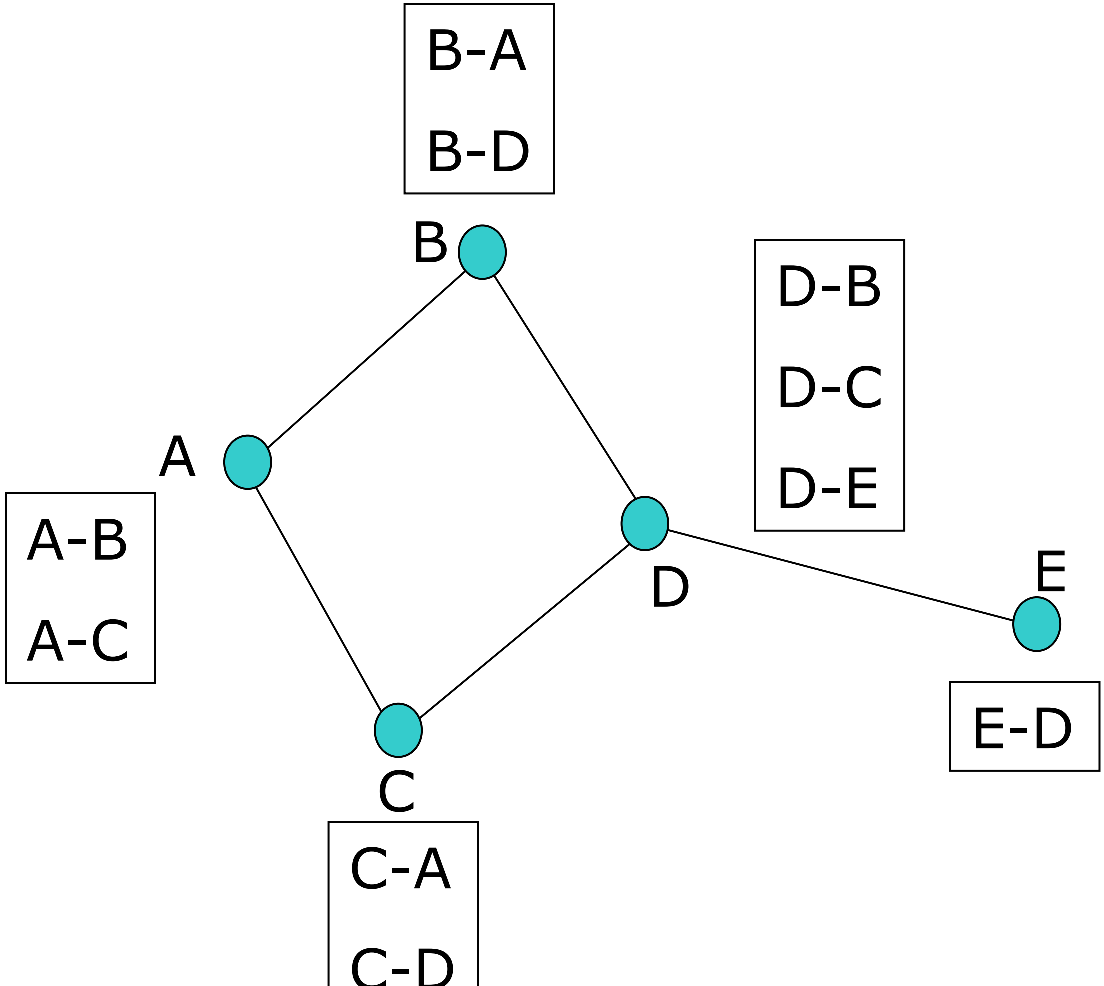
Routing In (Mobile) Ad-Hoc Networks

Proactive, table-driven algorithms

Proactive Routing

- Each node floods the network with its own local topology information
- On the basis all this information each node computes the global topology of the network.
- Each node can calculate complete routes.

DSDV – Destination Sequenced Distance-Vector Routing



DSDV – Destination Sequenced Distance-Vector Routing

A-B
A-C

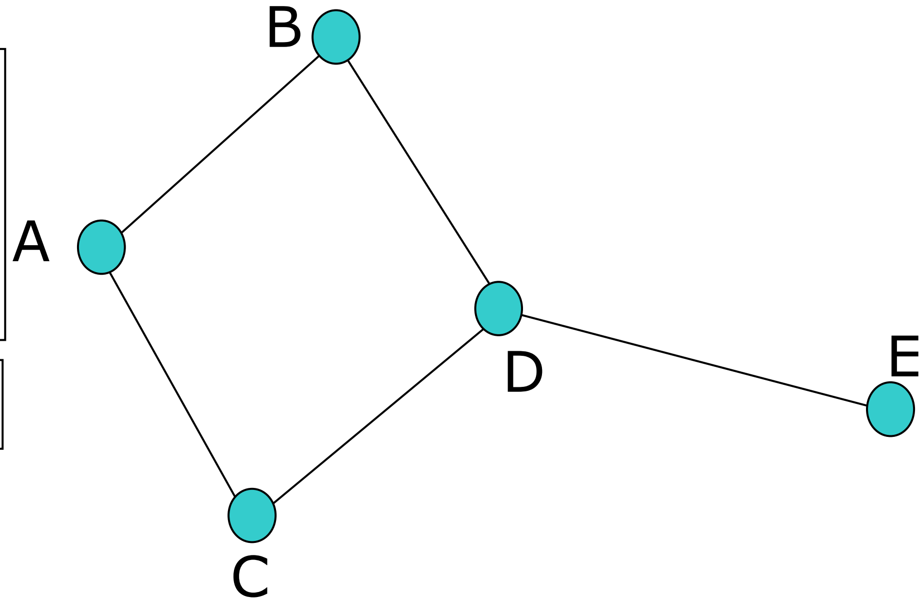
B-A
B-D

C-A
C-D

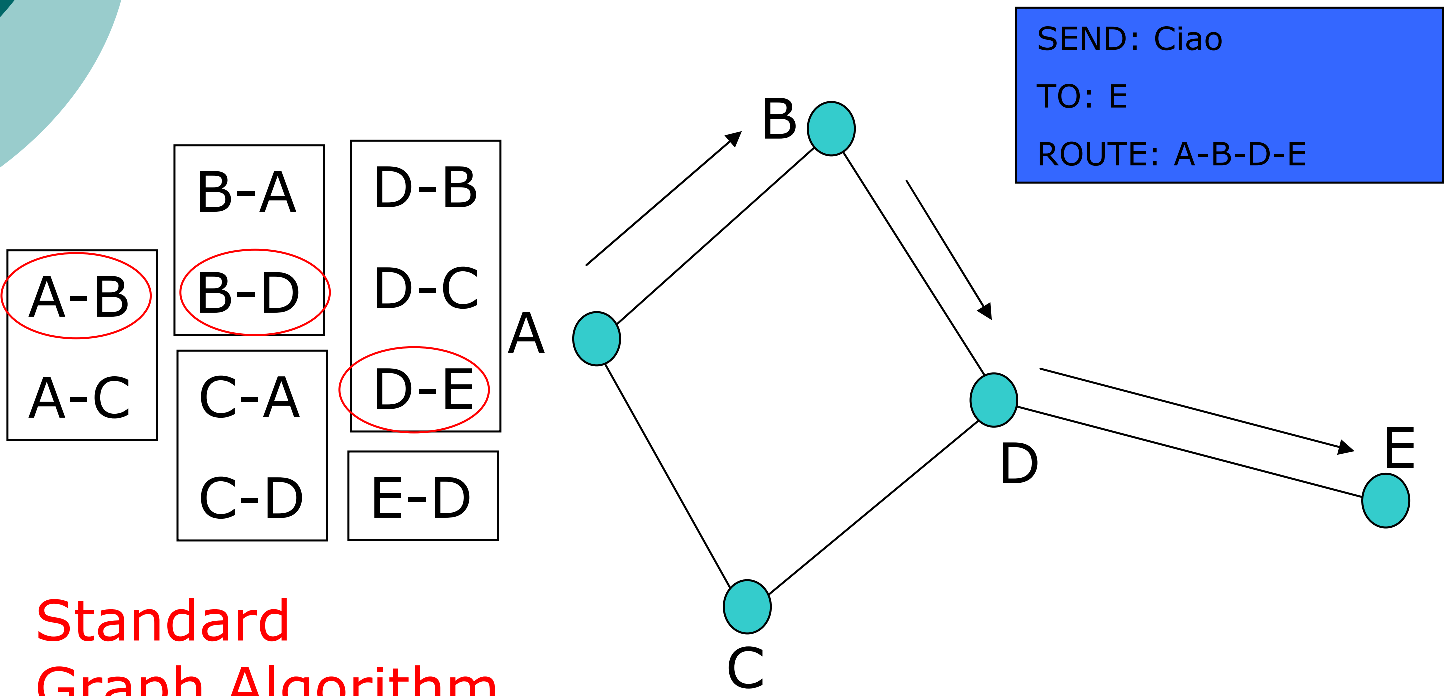
D-B
D-C
D-E

E-D

Graph Algorithm



DSDV – Destination Sequenced Distance-Vector Routing



Standard
Graph Algorithm

Routing In (Mobile) Ad-Hoc Networks

Reactive, on-demand algorithms

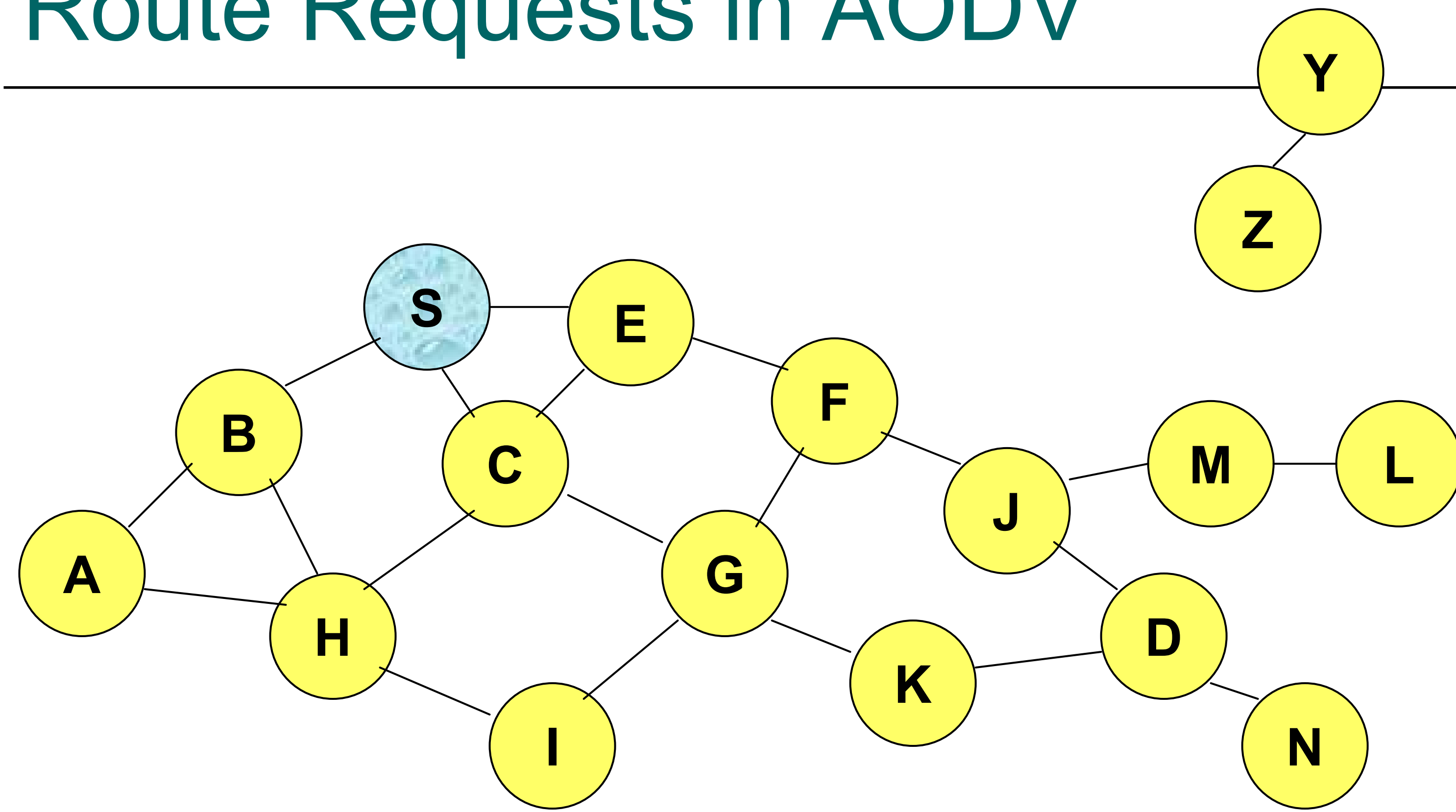
Ad Hoc On-Demand Distance Vector Routing (AODV) 1/2

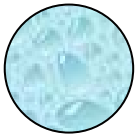
- Routes are created on demand, only when actually needed.
- A node S wishing to communicate with node D starts a discovery process to find where is D
- D replies creating a communication channel between S and D
- Communication travels through the established channel

Ad Hoc On-Demand Distance Vector Routing (AODV) 2/2

- Route Requests (RREQ) are flooded across the network, implementing a breadth-first, expanding-ring algorithm.
- When a node re-broadcasts a Route Request, it sets up a reverse path pointing towards the source
  - AODV assumes symmetric (bi-directional) links
- When the intended destination receives a Route Request, it replies by sending a Route Reply (RREP)
- Route Reply travels along the reverse path set-up when Route Request is forwarded

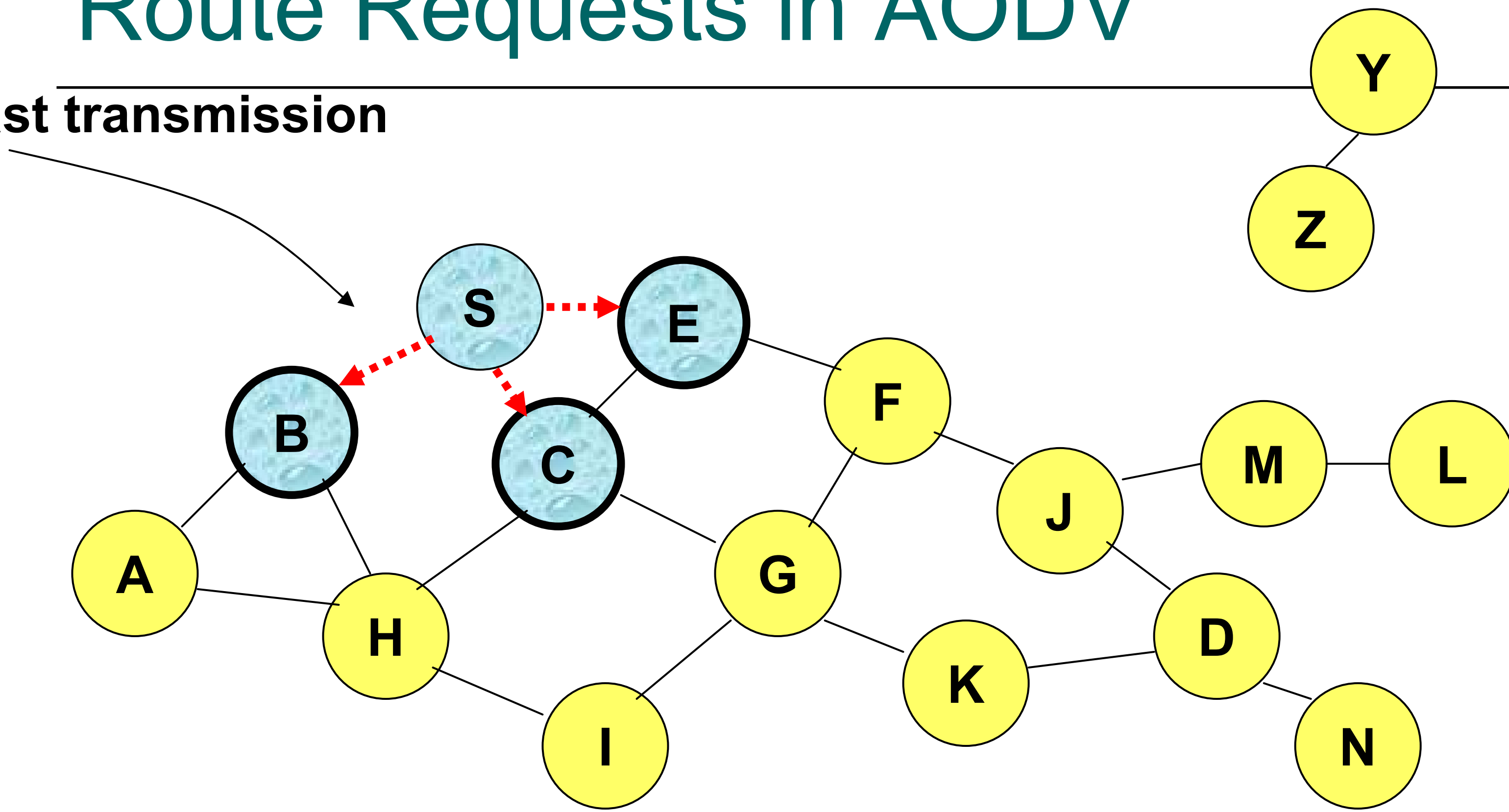
Route Requests in AODV





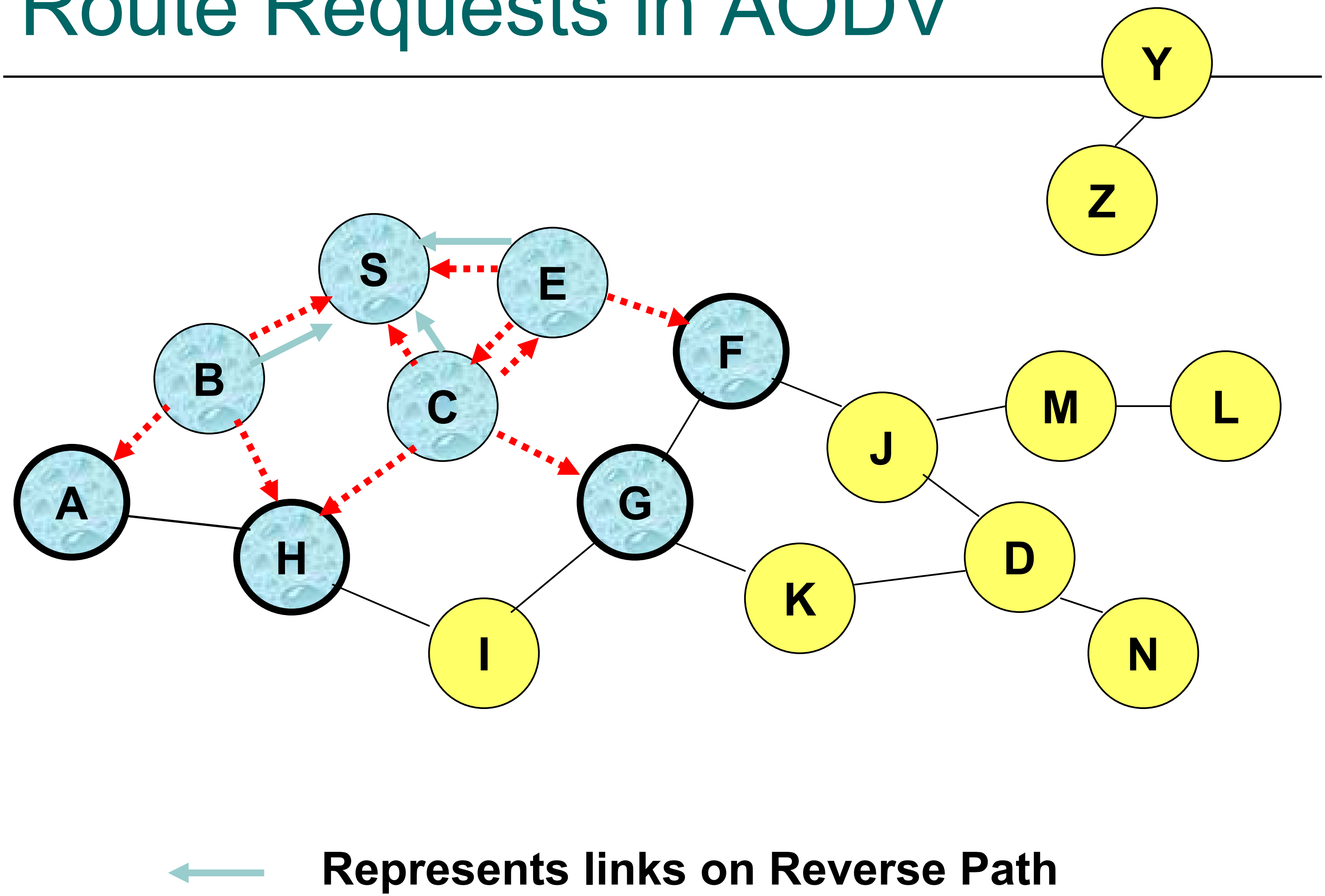
Represents a node that has received RREQ for D from S

Route Requests in AODV

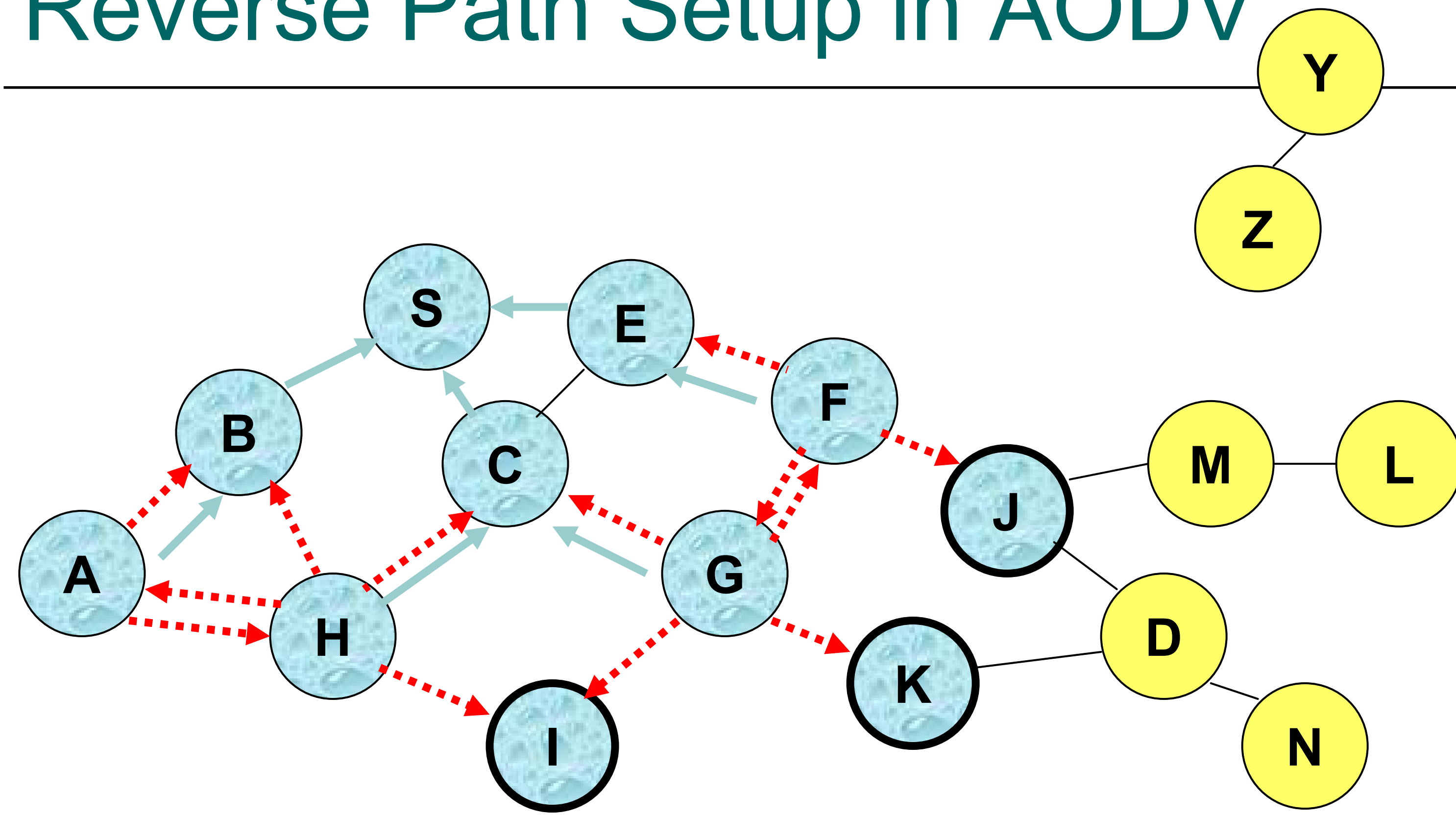


Represents transmission of RREQ

Route Requests in AODV

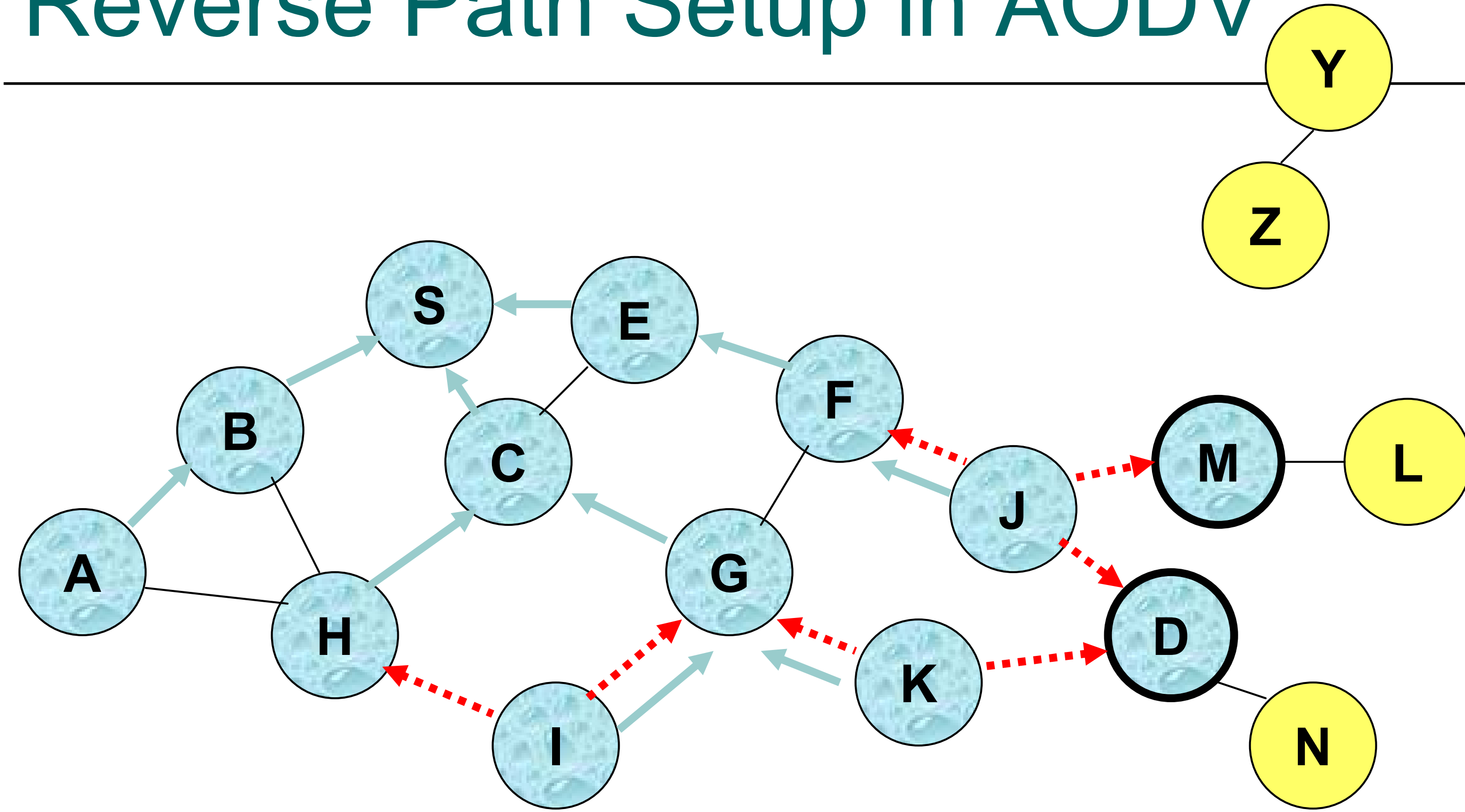


Reverse Path Setup in AODV

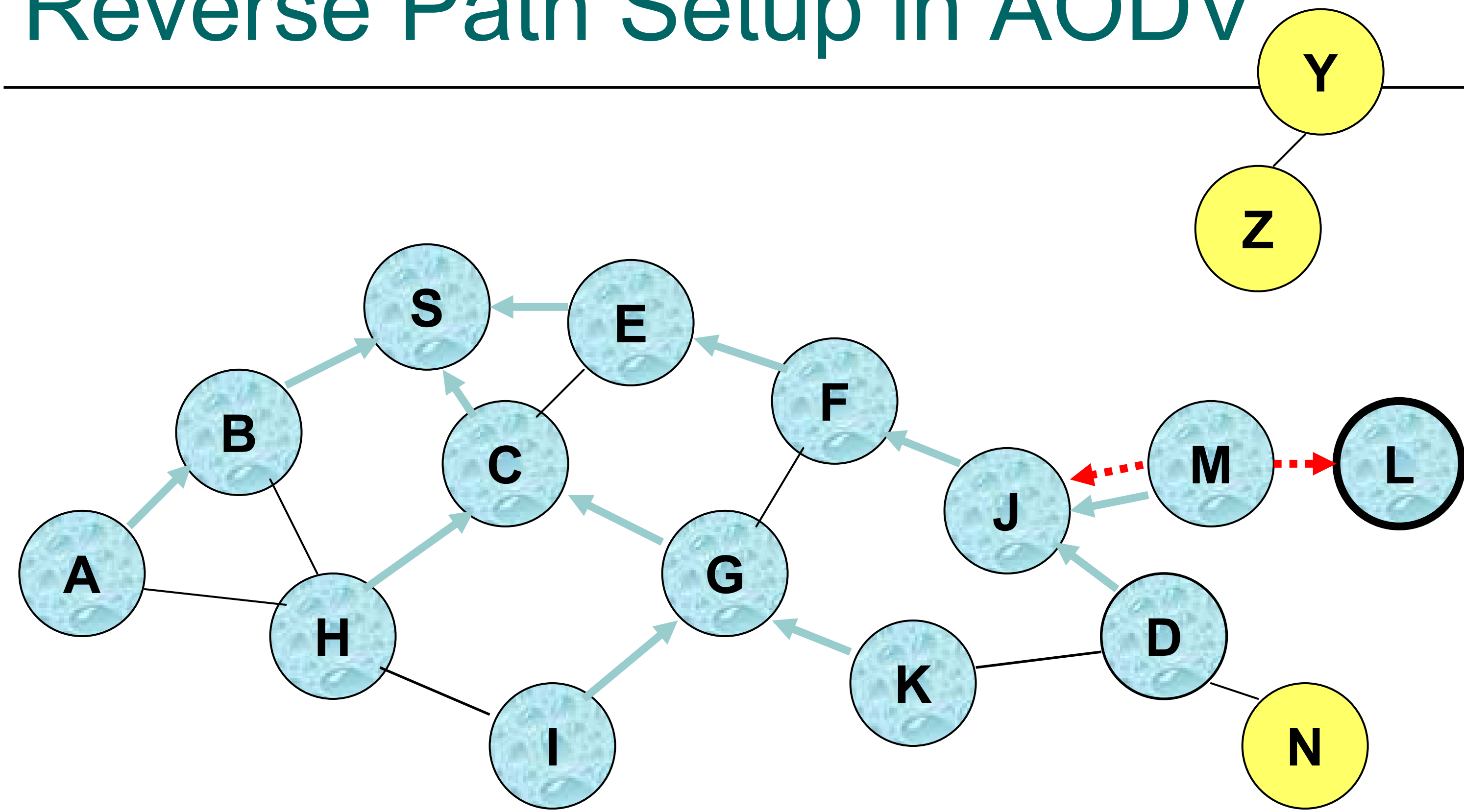


- Node C receives RREQ from G and H, but does not forward it again, because node C has already forwarded RREQ once

Reverse Path Setup in AODV

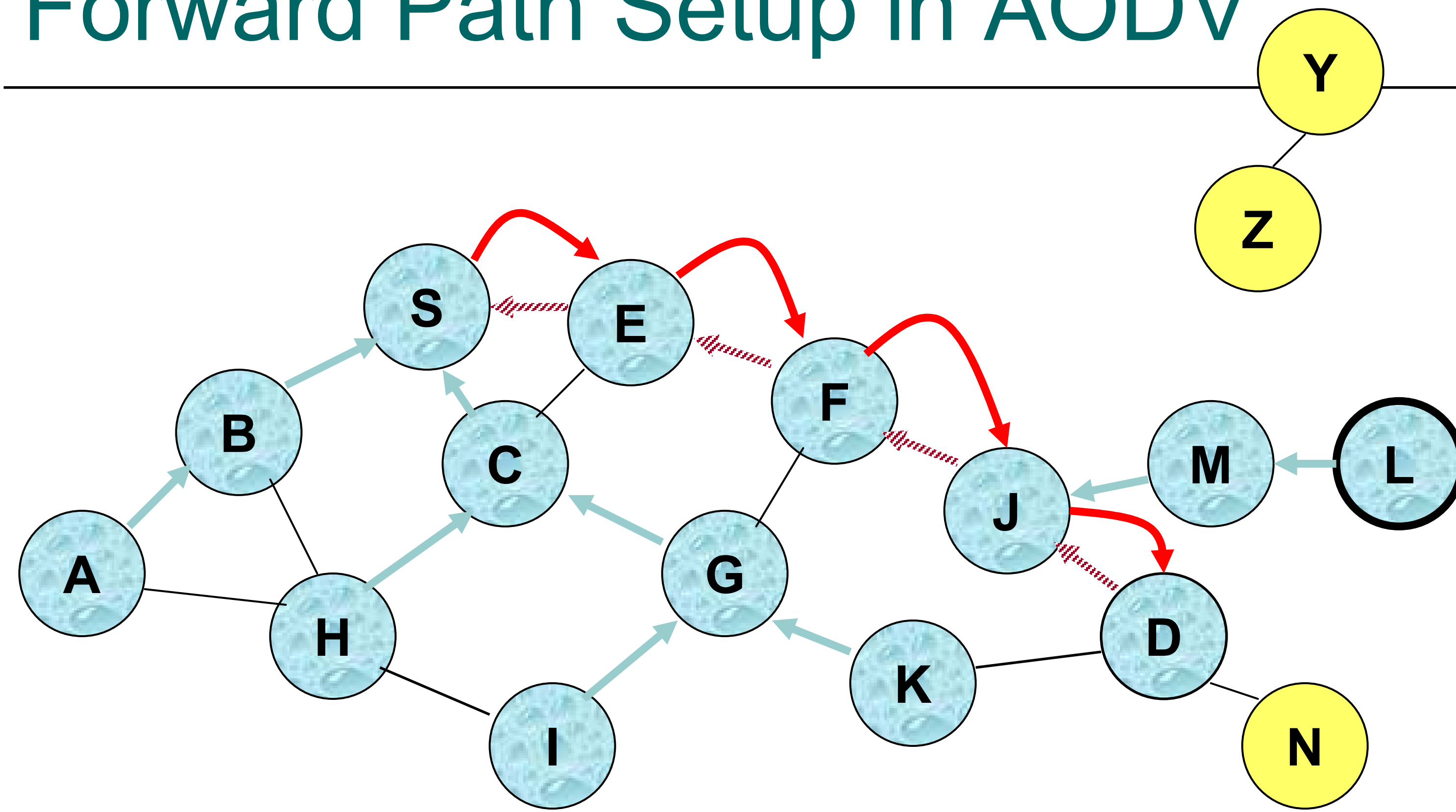


Reverse Path Setup in AODV

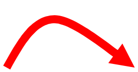


- Node D **does not forward** RREQ, because node D is the **intended target** of the RREQ

Forward Path Setup in AODV



Forward links are setup when RREP travels along the reverse path

 **Represents a link on the forward path**

Communication and Link Failure

- Communication
  - Once forward and backward routes have been established S and D can communicate without flooding the network.
  - Moreover, subsequent discovery of routes toward S and D can take advantage of the established route constraining flooding.
- Link Failure
  - When node X is unable to forward packet P (from node S to node D) on link (X,Y), it generates a RERR message to S.
  - When node S receives the RERR, it initiates a new route discovery for D
  - The routing structure is adjusted on-demand

Routing In (Mobile) Ad-Hoc Networks

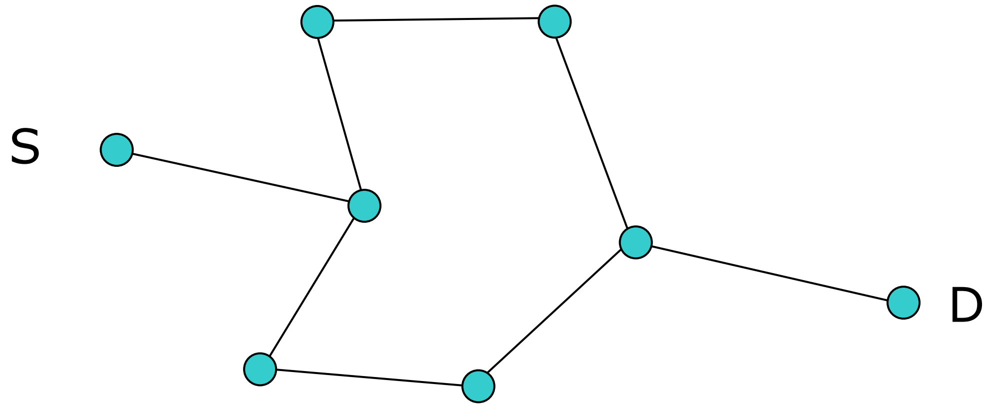
Geographic algorithms

What is Geographic Routing?

- A.k.a. location-based, position-based, geometric, etc.
- Each node knows its own position and position of neighbors
- Source knows the position of the destination. No routing tables stored in nodes!
- Geometric routing is important:
  - GPS/Galileo, local positioning algorithm, overlay P2P network, Geo-casting
- The Problem with Greedy Routing

Greedy Routing…. Problems

- Forward to the node closer to the destination…..

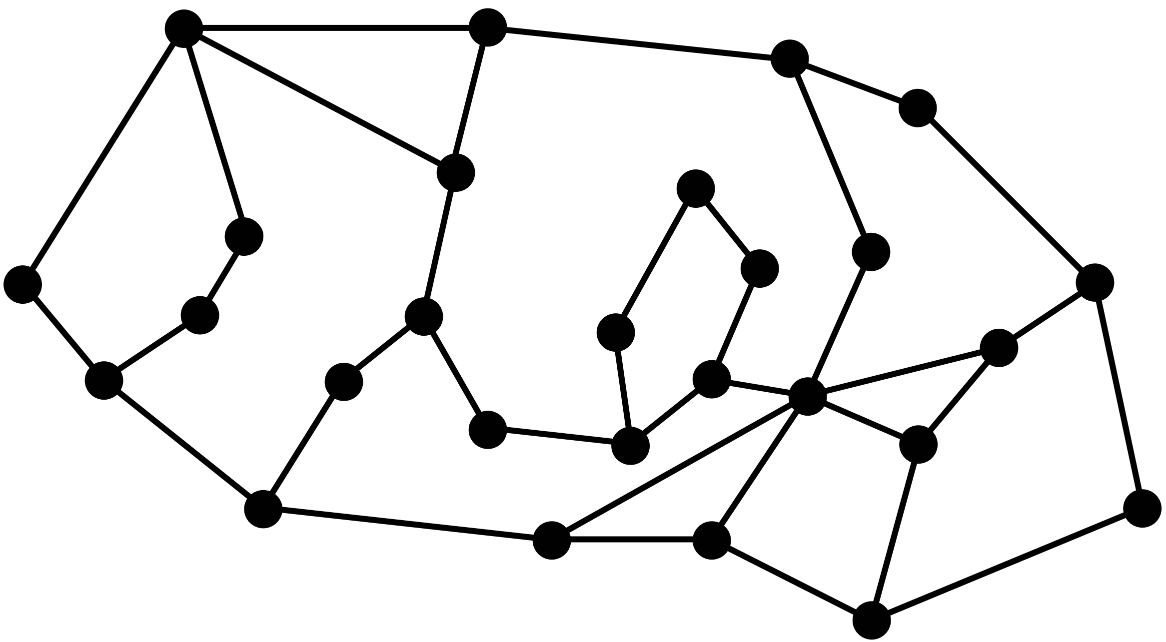


Related Work in Geometric Routing

Kleinrock et al.	Various 1975ff	MFR et al.	Geometric Routing proposed
Kranakis, Singh, Urrutia	CCCG 1999	Face Routing	First correct algorithm
Bose, Morin, Stojmenovic, Urrutia	DialM 1999	GFG	First average-case efficient algorithm (simulation but no proof)
Karp, Kung	MobiCom 2000	GPSR	A new name for GFG
Kuhn, Wattenhofer, Zollinger	DialM 2002	AFR	First worst-case analysis. Tight $\Omega(c^2)$ bound.
Kuhn, Wattenhofer, Zollinger	MobiHoc 2003	GOAFR	Worst-case optimal and average-case efficient, percolation theory
Kuhn, Wattenhofer, Zhang, Zollinger	PODC 2003	GOAFR+	Improved GOAFR for average case, analysis of cost metrics

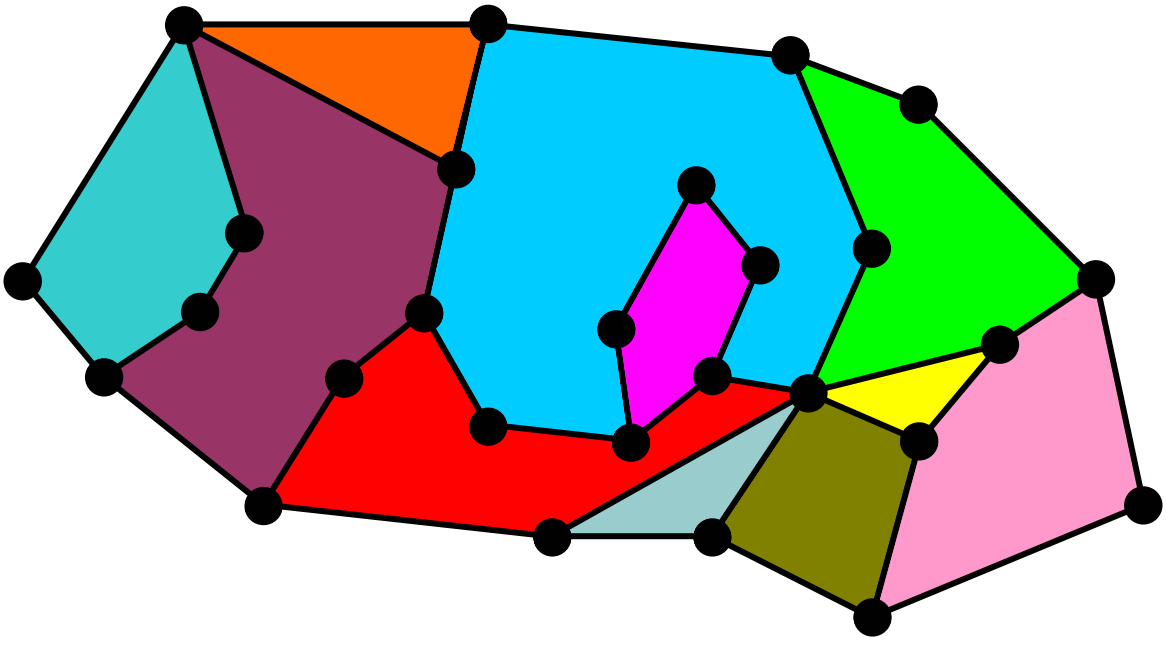
Face Routing

- Based on ideas by [Kranakis, Singh, Urrutia CCCG 1999]
- Here simplified (and actually improved)



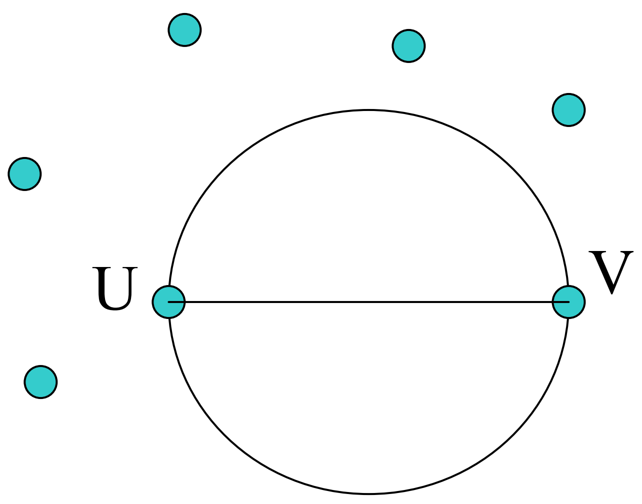
Face Routing

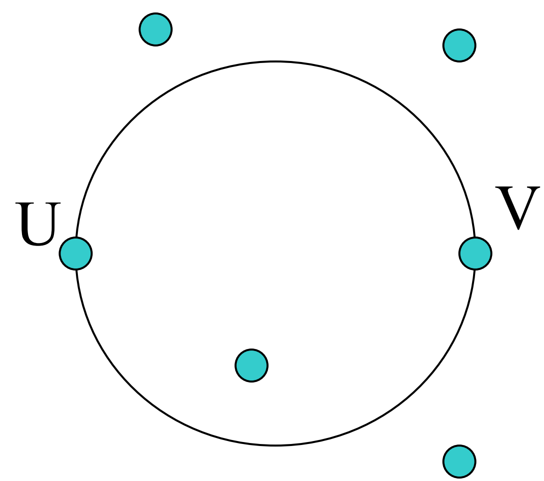
- It applies to planar graph only.
- Remark: Planar graph can easily (and LOCALLY!) be computed with the Gabriel Graph, for example



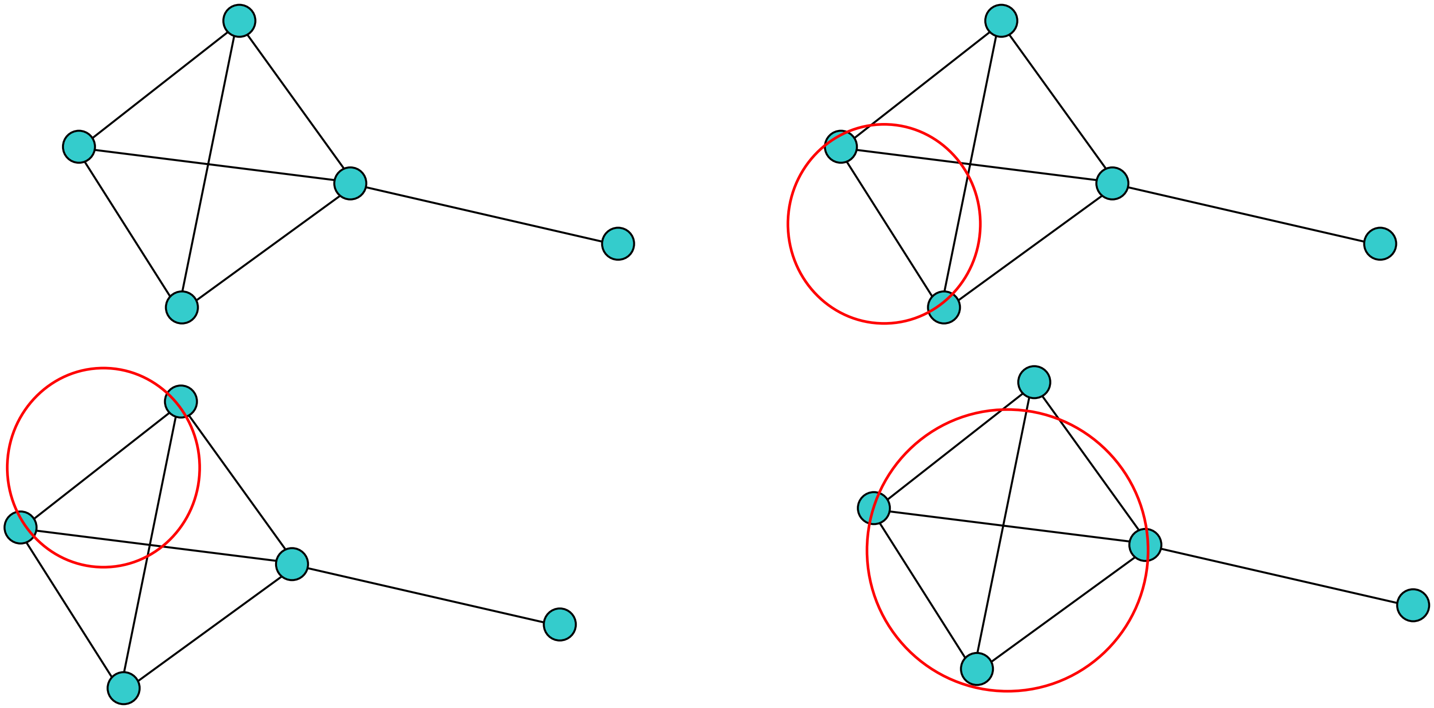
Gabriel Graph

- A planar (Gabriel) graph is computed from an ad-hoc network by dropping crossing-links
- The Gabriel Graph GG(*V*) is defined as an undirected graph (with *E* being a set of undirected edges). There is an edge between two nodes *u*,*v* iff the disk(*u*,*v*) inclusive boundary contains no other points. disk(*u*,*v*)

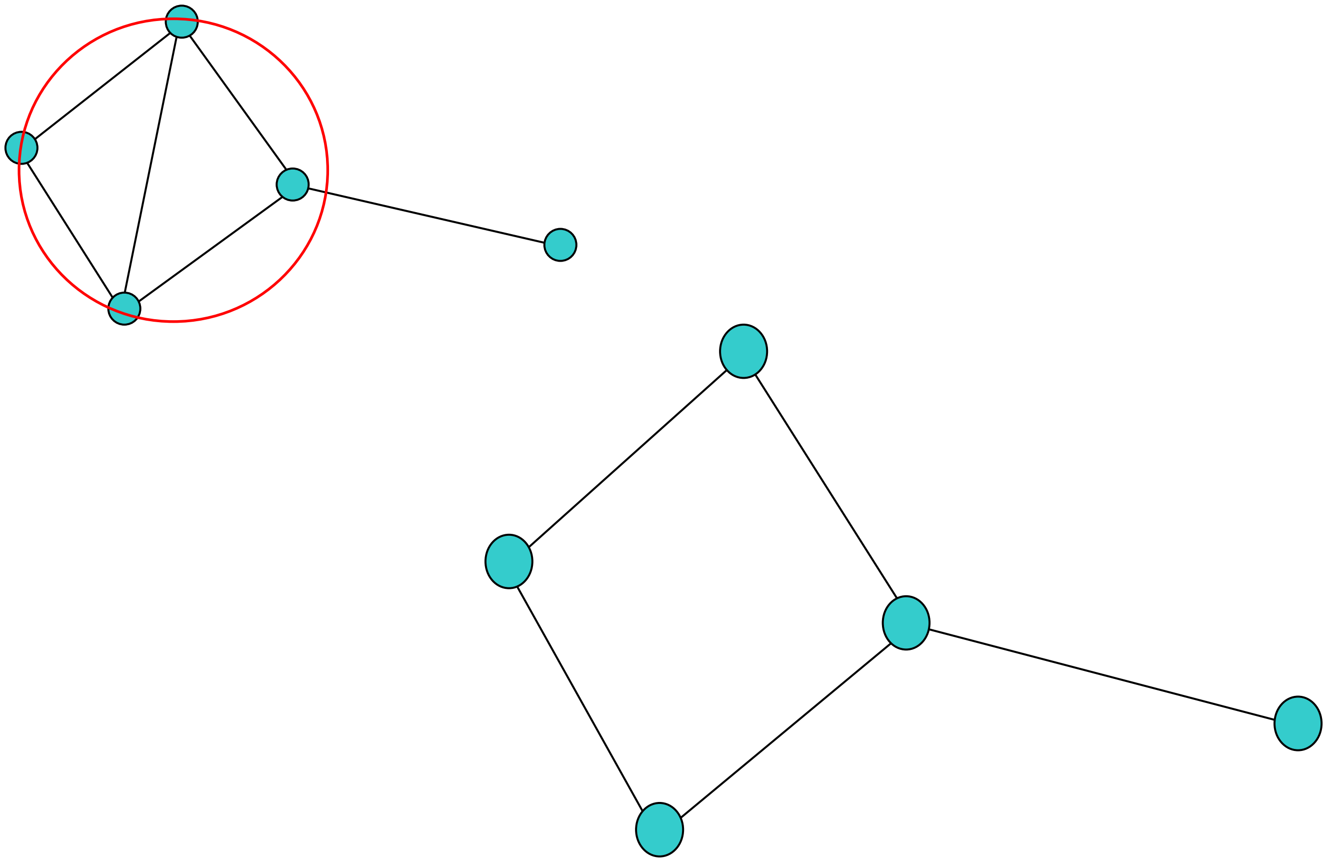




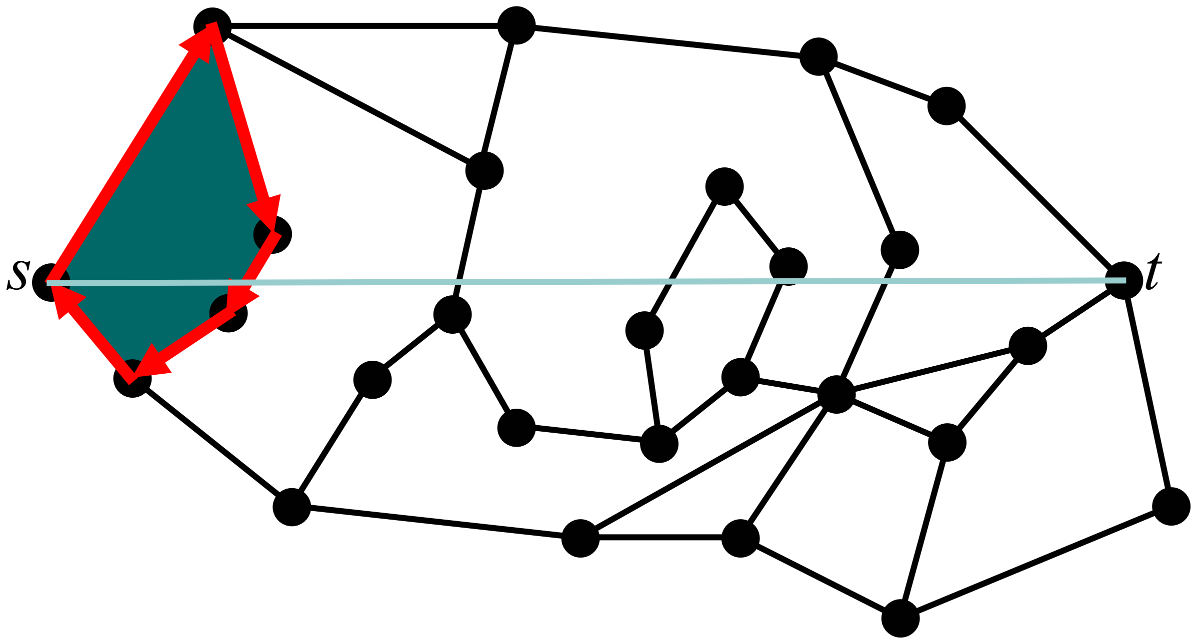
Gabriel Graph Example 1/2



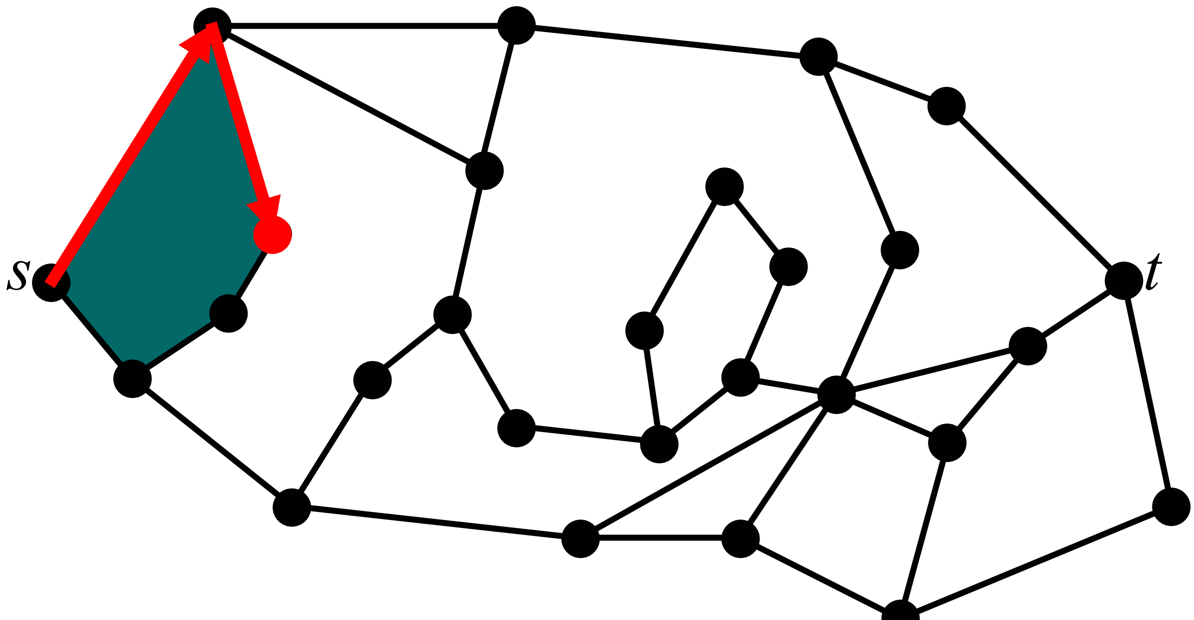
Gabriel Graph Example 2/2



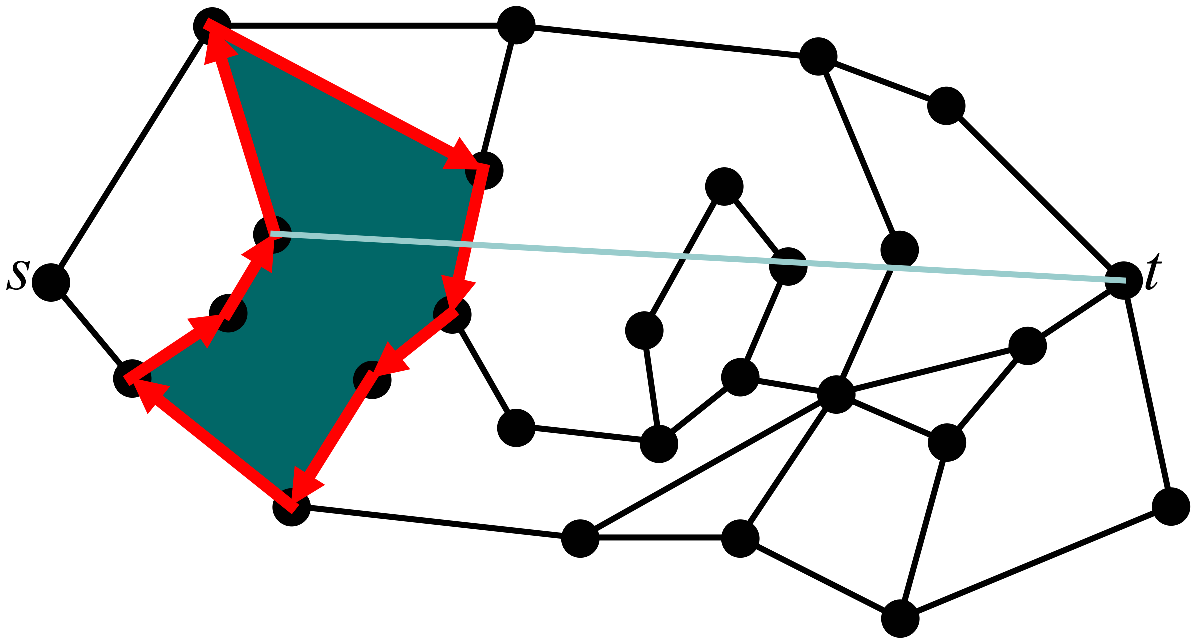
Face Routing



Face Routing



Face Routing



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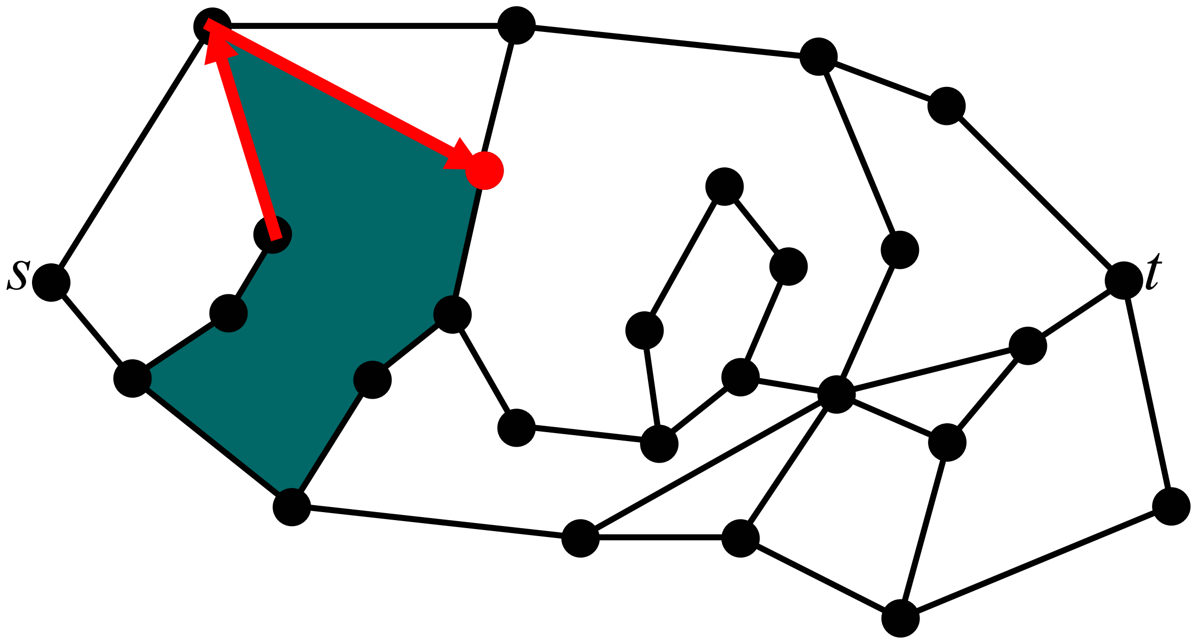

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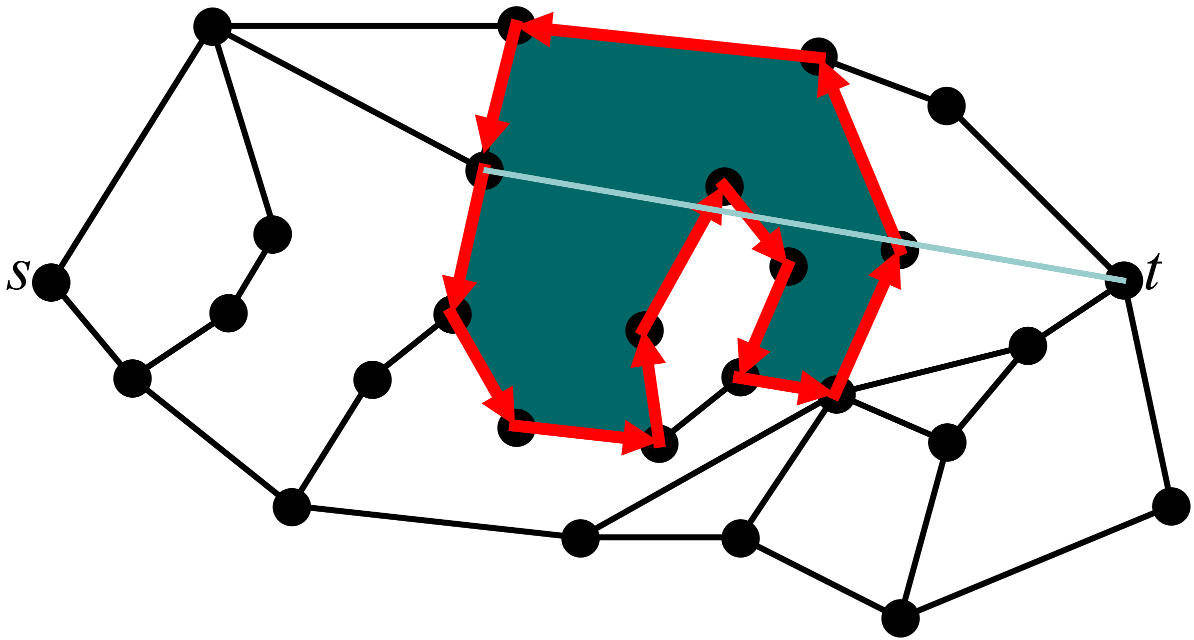

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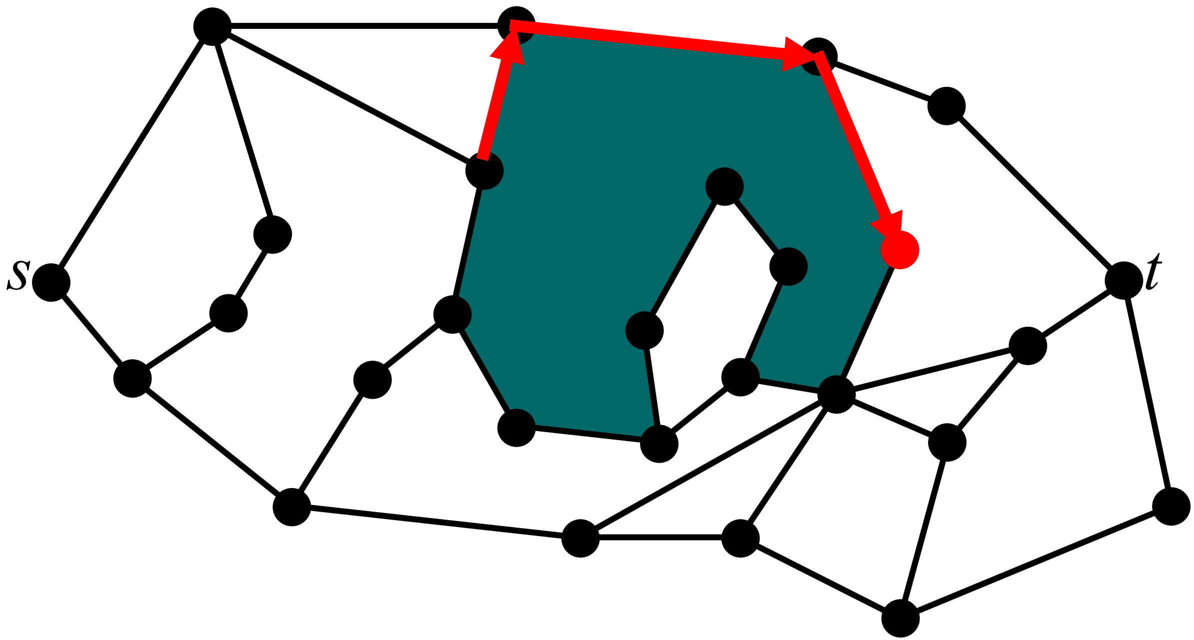
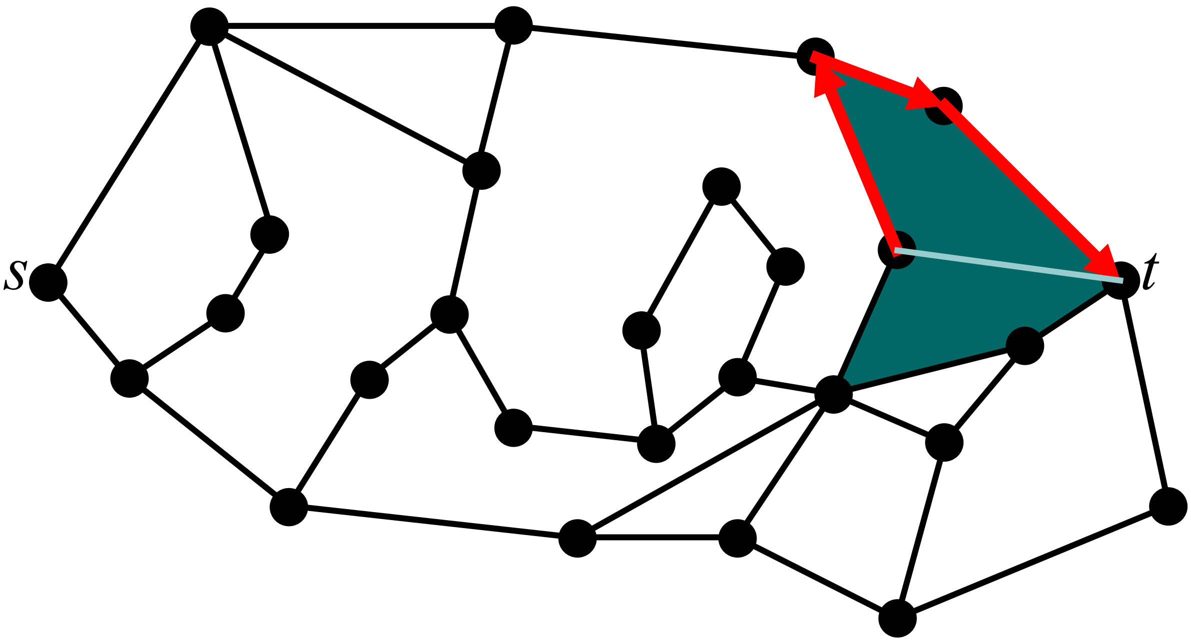
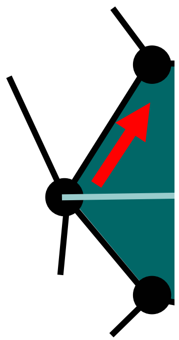


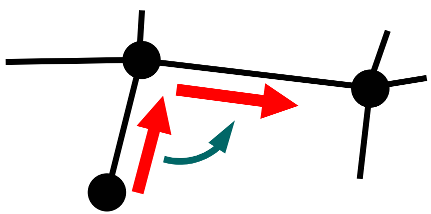
Face Routing



Face Routing Properties

- All necessary information is stored in the message
  - Source and destination positions
  - Point of transition to next face
- Completely local:
  - Knowledge about direct neighbors‛ positions sufficient
  - Faces are implicit





"Right Hand Rule"

- Planarity of graph is computed locally (not an assumption)
  - Computation for instance with Gabriel Graph

Conclusions

- Proactive
  - Suitable for only relatively static networks.
- Reactive
  - Suitable for highly mobile networks, with mainly 1-1 communication
- Geographic
  - Require localization. Opens new scenarios (decoupling).