COMP9332 Network Routing and Switching
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Geographic Routing

Lecture overview

This lecture examines the concept of using location (geography) to route packets in wireless adhoc (multi-hop) networks.

Topics to be covered

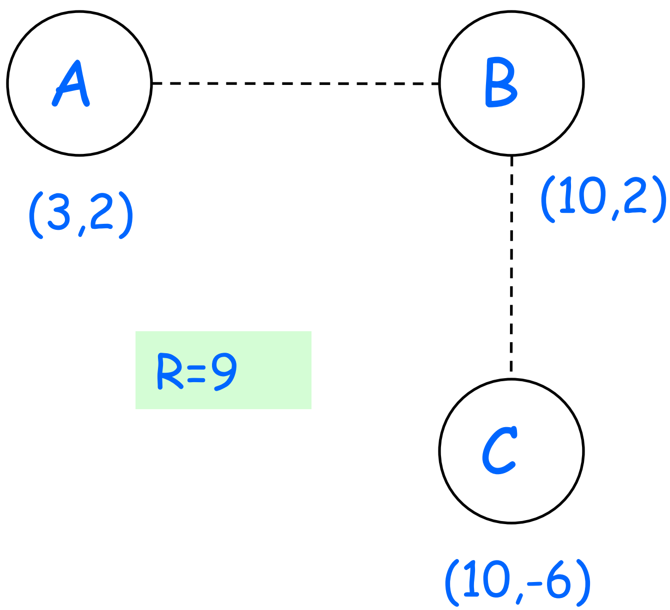
- Graph representation of multi-hop wireless networks
- Position beaconing and neighbourhood discovery
- Progress-based next-hop selection
- Greedy Perimeter Stateless Routing
  - Voids
  - Void traversal using right hand rule

Routing Options for Adhoc Networks

- Table-driven (high overhead)
- No precomputing of routing tables
  - On-demand route computation (e.g. AODV protocol later)
  - Geographic or position-based routing (this lecture)

Graph representation for multi-hop wireless networks – unit graphs

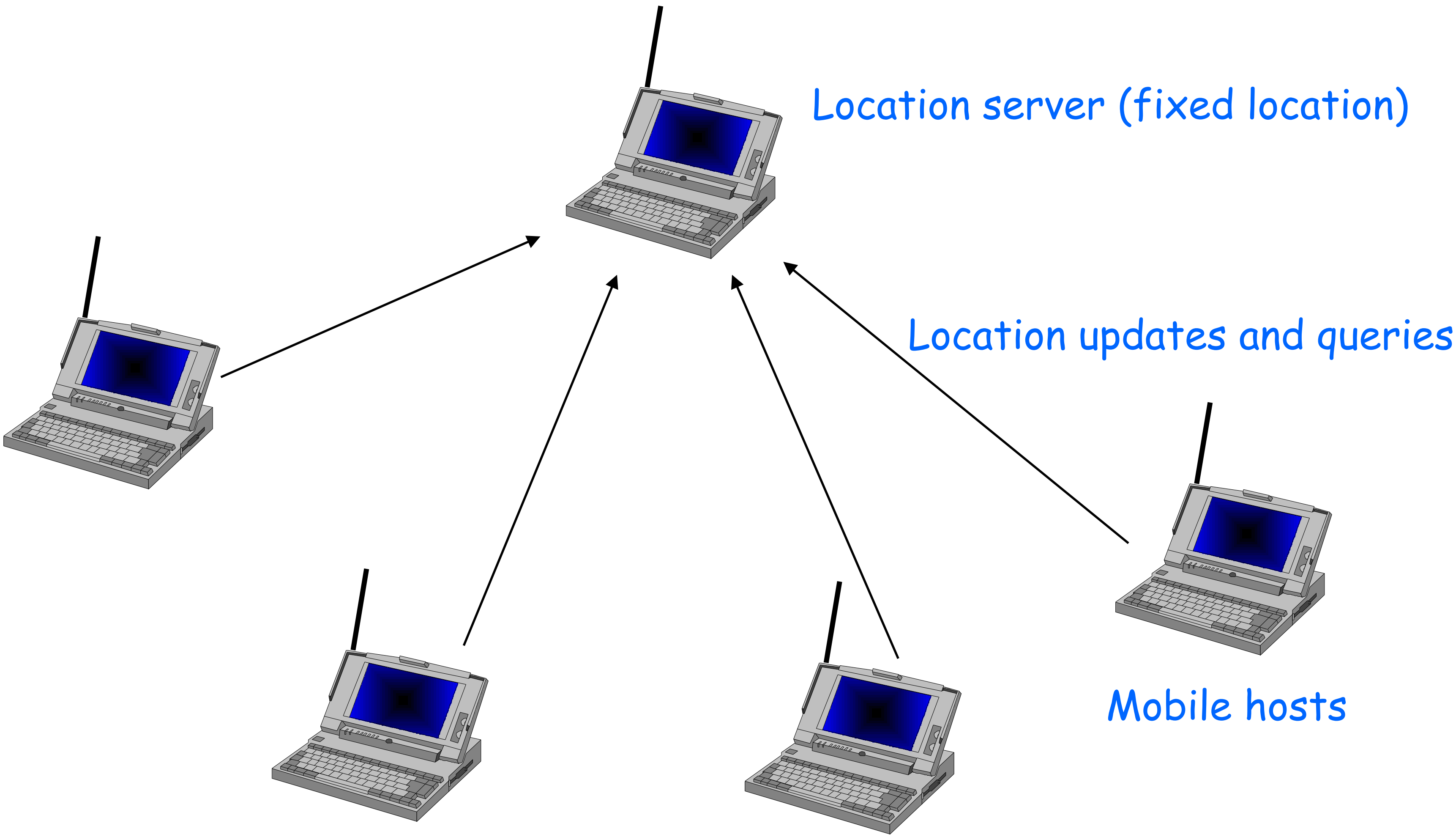
- All nodes have identical wireless communication range of R
- An edge exists between two nodes iff Euclidean distance <= R



Geographic routing

- Nodes know their location (e.g. using GPS)
- Nodes know location of one-hop neighbours
  - neighbours within radio range are one-hop away
  - every node periodically broadcast their positions
- Nodes know the location of the destination
  - using some location service, or
  - publicly known fixed servers
  - when they receive a packet from that node
- Packet header contains location information
- Routing is based on location, not IP address
  - next hop is decided based on nodes own position, position of one-hop neighbours, and position of the destination

Location Service



Geographic routing
selecting next hop

- S wants to send to D
- S must select a next hop from A,B,C,E,F
- Which one should node S select as next hop?

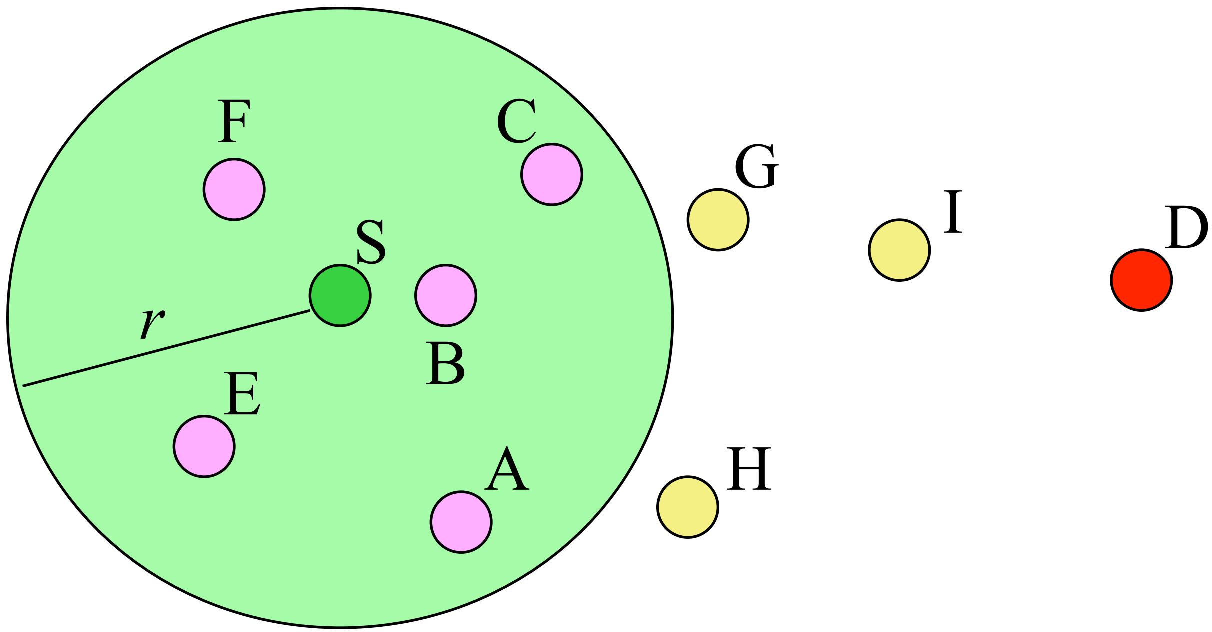


Fig 1: S (source) has a radio range of *r*. A, B, C, E and F are within radio range of S

Concept of Progress

- S selects neighbour *A* as next hop to send a packet to D
- Progress = d(S,D) - d(*A*,D)
- Progress can be *positive* or *negative*

Progress-based next-hop selection

- Three approaches
  - Random progress
  - Most forward within radius
  - Greedy forwarding

Progress-based next-hop selection

random progress

- Equal probability for all positive-progress neighbours
- K neighbours that would make positive progress
- Probability of any of these k neighbours to be selected as the next hop = 1/k
- Exercise: In Fig 1, what are the probabilities of nodes A,B,C,E, and F to be selected as next hop?
- Packet is dropped if no neighbour with positive progress, even if a route exists!

Progress-based next-hop selection

most forward within radius

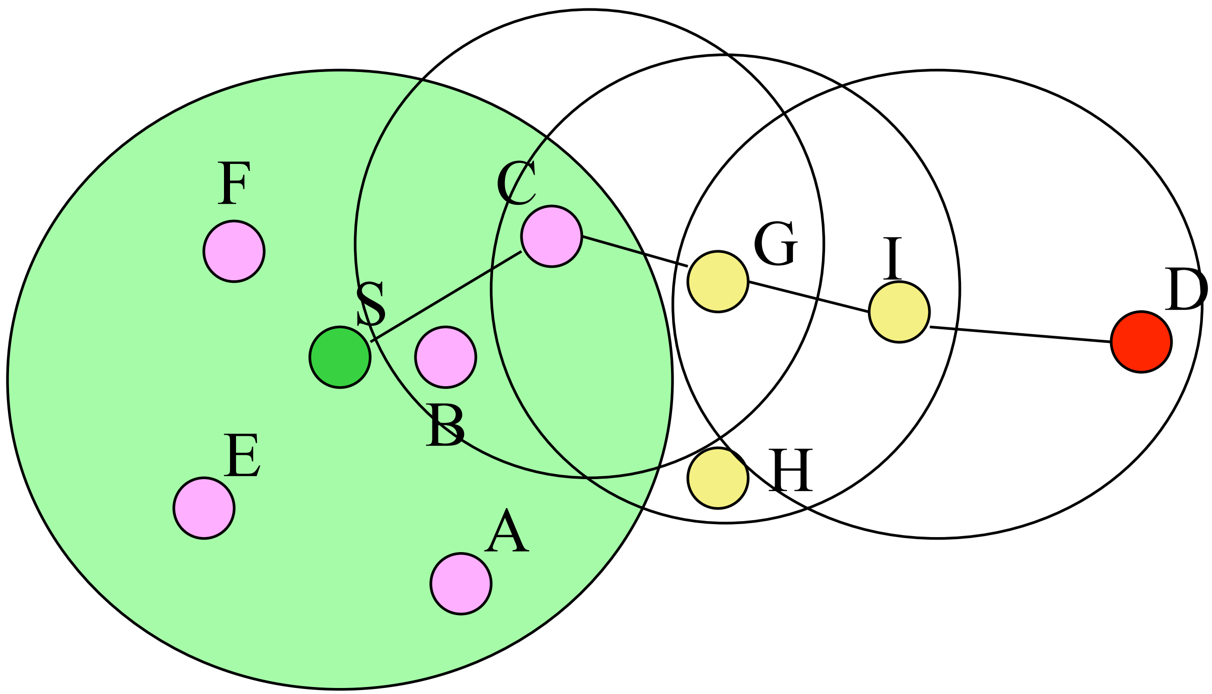
- Pick the neighbour with maximum progress
  - Don't worry about positive or negative progress
- Exercise: In Fig 1, what are the probabilities of nodes A,B,C,E, and F to be selected as next hop?
- Packet is not necessarily dropped if no neighbour with positive progress (improves chances of reaching the destination at the risk of creating loops)

Progress-based next-hop selection
greedy forwarding

- Pick the neighbour with maximum positive progress
- Exercise: In Fig 1, what are the probabilities of nodes A,B,C,E, and F to be selected as next hop?
- Packet would be dropped if no neighbour with positive progress
- Greedy because it wants to reach the destination as quickly as possible (contrast it with *random progress*)

Greedy Forwarding

try to minimise number of hops



- **S computes distance from each neighbour to the destination** (Note: S knows its position, position of D, and position of its neighbours, A,B,C,E,F)
- **Chooses the neighbour which is closest to the destination as the next hop (next hop must make positive *geographic progress* towards destination to avoid loop)**
- **S forwards to C. C forwards to G. G forwards to I.**
- **Finally I forwards to destination D.**

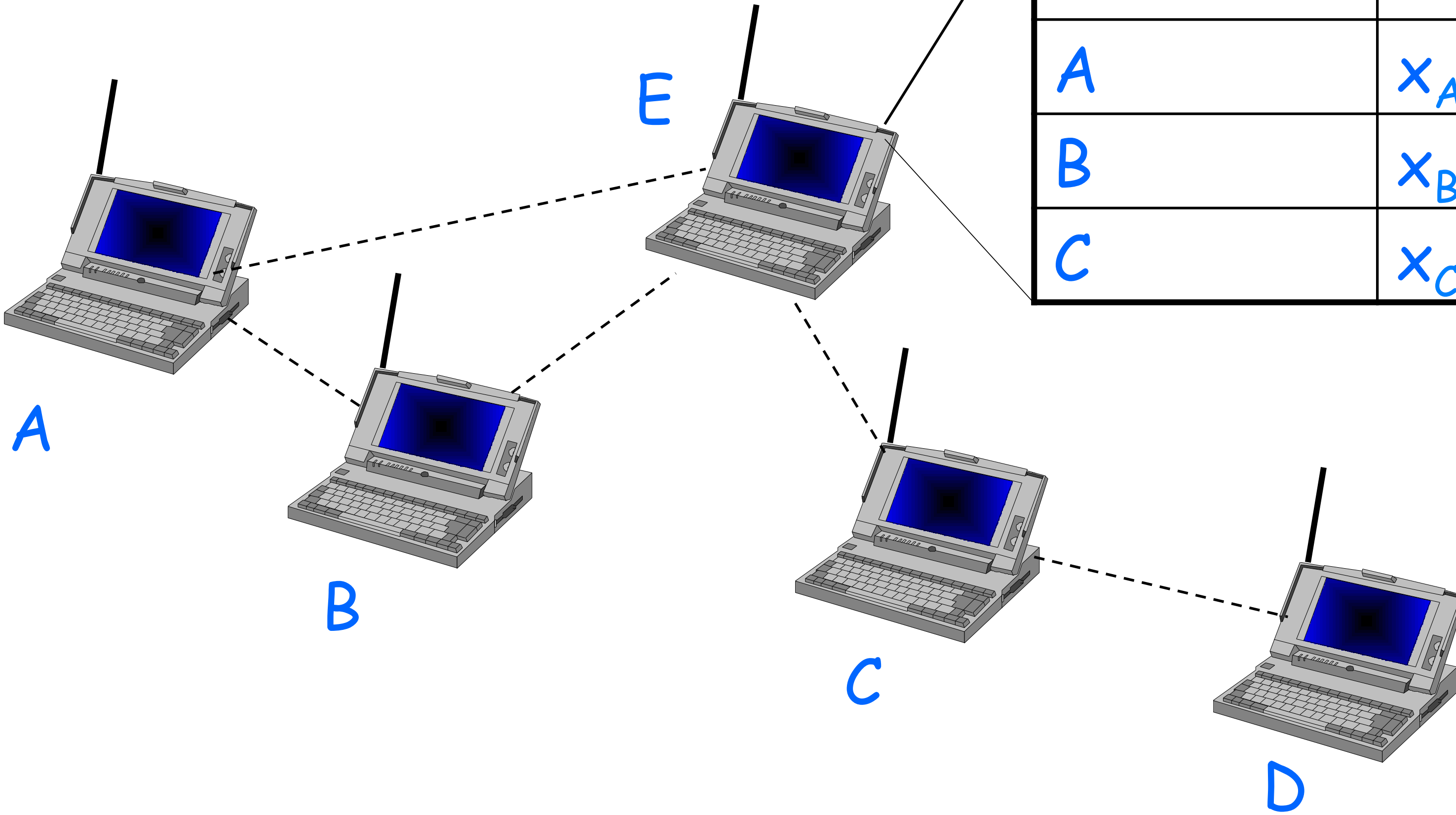
Benefits of Geography

- Self-describing
- As node density increases, shortest path tends toward Euclidean straight line between source and destination
- Node's state concerns only one-hop neighbors:
  - Low per-node state: O(density)
  - Low routing protocol overhead: state (location) pushed only one hop

Position beaconing

- Control packet: Nodes periodically broadcast (single-hop) their positions in special beacon (*control*) packets
- Piggybacking: Nodes piggyback position information in usual *data* packets
  - Other nodes hearing the data packet learns the position of the sender

Neighbour table

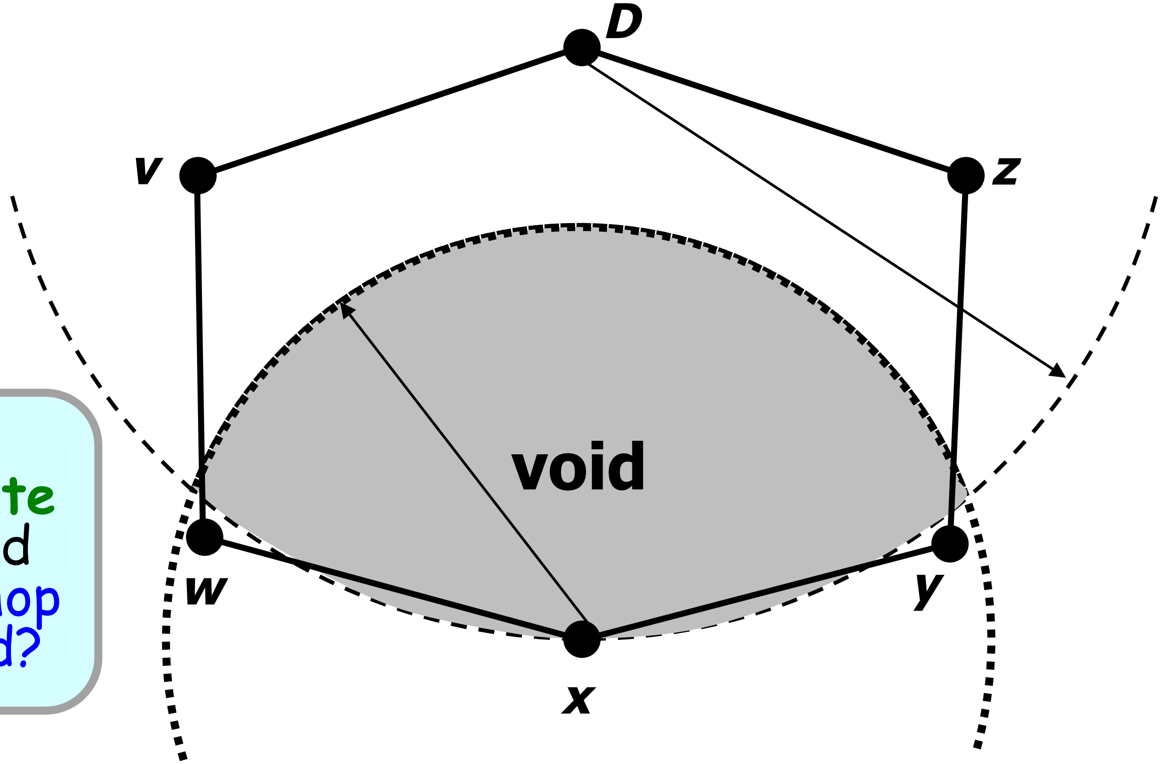


neighbour	location
A	x_A, y_A
B	x_B, y_B
C	x_C, y_C

Voids

Failure of Greedy Forwarding

Greedy forwarding not always possible! Consider:



How can we **circumnavigate** voids? ...based only on one-hop neighborhood?

x is not allowed to forward to *y* or *w*, because it would not make geographic progress towards D

Greedy Perimeter Stateless Routing (GPSR)

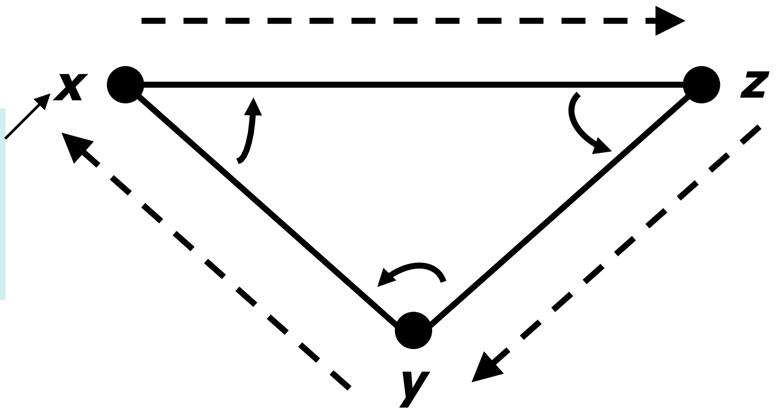
GPSR

- A greedy-forwarding-based routing protocol
- Ability to traverse voids when possible (perimeter routing mode)
- Switches between two modes
  - Greedy mode (when greedy forwarding is possible)
  - Perimeter mode (when faced with a void)

Void Traversal
The Right-hand Rule

- Well-known graph traversal: *right-hand rule*
- Requires only neighbors' positions

X receives a packet from y, and forwards it to *z*

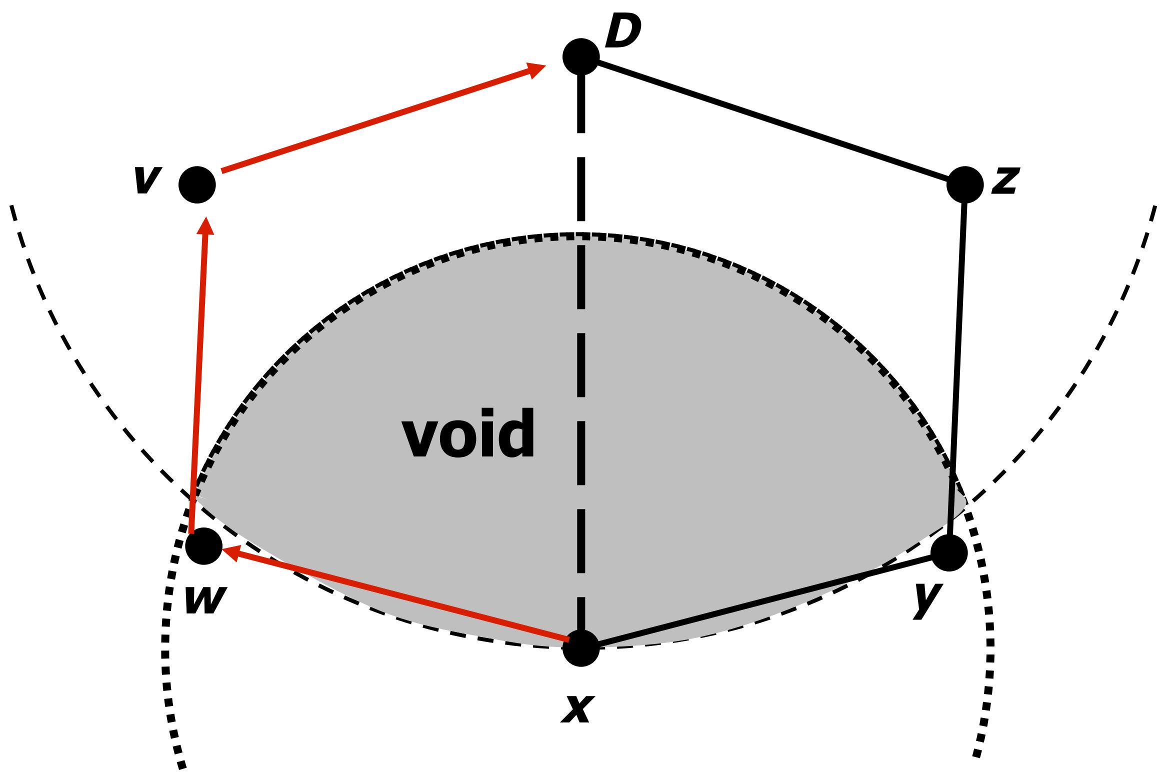


Right-hand rule: when arriving at *x* from *y*, the next edge traversed is the next one *sequentially counterclockwise* about *x* from edge *x*-*y*.

More on Right-hand Rule

- Traverses a closed polygon in clock-wise order
- If the void is an interior of a polygon, the packet will move through the perimeter of the void to the nodes that are closer to the destination

Traversing void using right-hand-rule

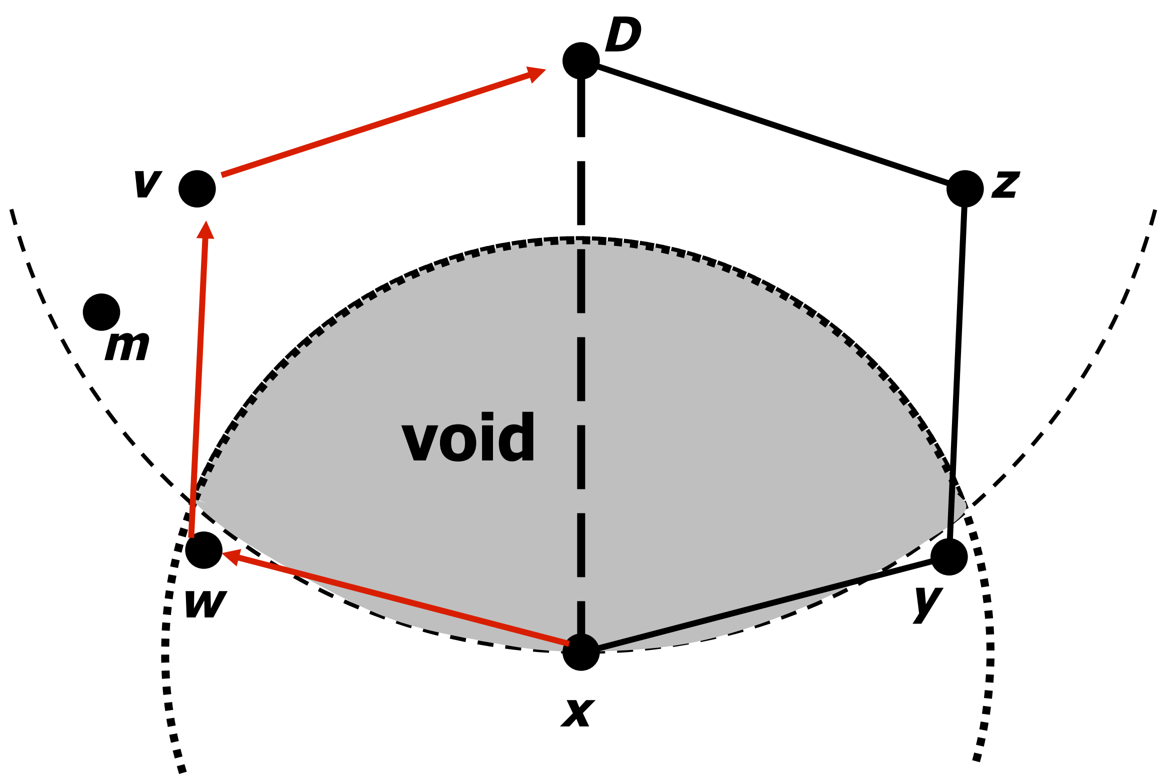


- First step: forward to first edge counterclockwise about *x* from line *xD* (*x* forwards to *w*)
- Then after apply right-hand-rule (*w* -->*v* -->*D*)

GPSR Packet Header

Field	Function
D	Destination Location
Lp	Location packet entered perimeter mode
Lf	Point on xV packet entered current face
e0	First edge traversed on current face
M	Packet Mode: Greedy or Perimeter

Traversing void using right-hand-rule



- Q. Could *w* forward to *m*?
- A. No.

Which mode to select? Perimeter or Greedy?

- Default is *greedy*
- Select *perimeter* when no positive progress towards destination is possible
  - Stay in perimeter mode until positive progress is possible again
- Switch back to greedy if positive progress is possible again

Bibliography

- Karp and Kung, "GPSR: Greedy perimeter stateless routing for wireless networks," ACM MOBICOM 2000
- Position Based Routing Algorithms For Ad Hoc Networks: A Taxonomy (2001)by Silvia Giordano , Ivan Stojmenovic , Ljubica Blazevic, Ad Hoc Wireless Networking