Flying Ad-hoc Networks and Position-based routing

Wireless Networks, aa. 2017/2018

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UNIVERSITÀ DEGLI STUDI DI PADOVA

Introduction

Drone - Flying Device

- Unmanned Aerial Vehicle (UAV)
- Unmanned Aircraft System (UAS)
- Remotely Piloted Aircraft (RPA)

Flying controllable/independent device without a human pilot aboard.

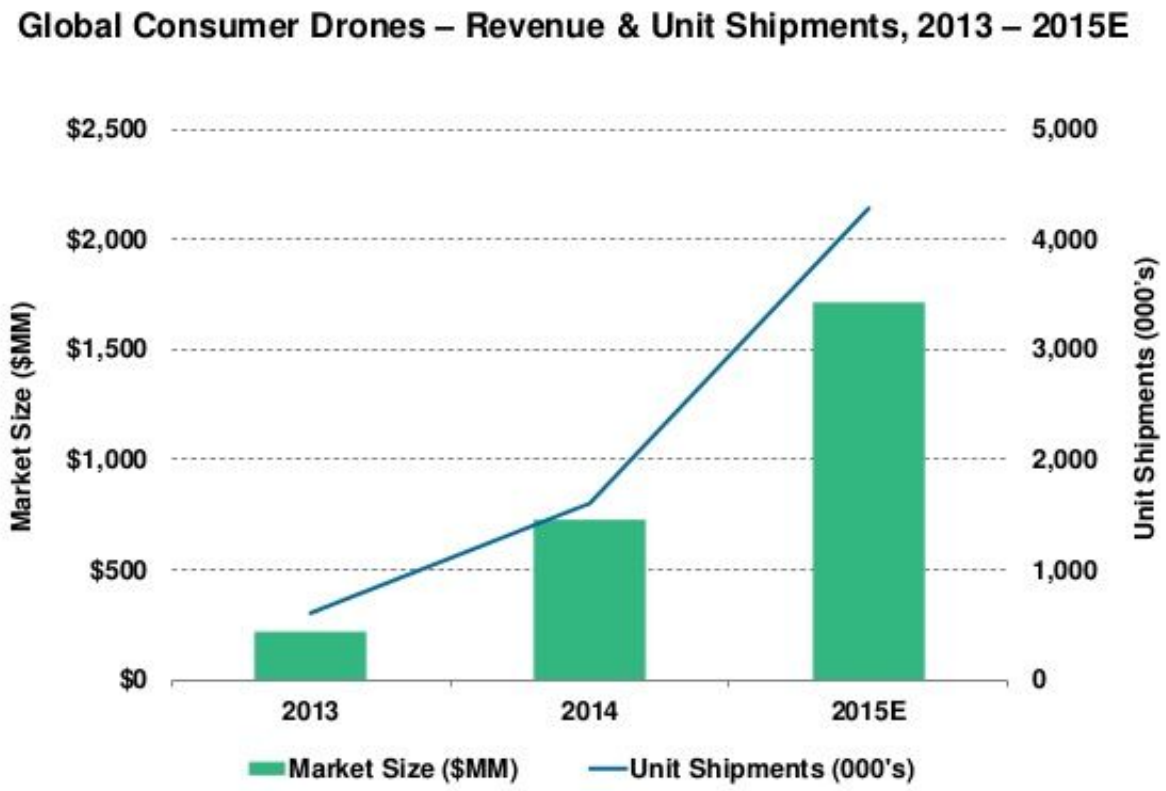
- Several application scenarios
  - Originated for military applications
  - Expanded in commercial, scientific, civil, ...

- Characteristics of UAVs
  - Typically use Wi-Fi technology (802.11) to communicate
  - Equipped with GPS, camera, sensors
  - Energy consumption recovery
  - Can be part of a **network**

Introduction

In recent years, drones business employs a tremendous growth, with estimates of over 1,5 billion sold by 2015.

Consumer Drone Shipments = Rising Rapidly...
@ 4.3MM Units in 2015E, + 167% Y/Y, Revenue to $1.7B



@KPCB Source: KPCB estimates.

Parrot

dji

3D Robotics
UAV TECHNOLOGY

Application of drones

40 Uses for Drones

Practical applications for Unmanned Aerial Vehicles

DJI Spreading Wings S800 Evo

Emergency Services & Disaster Recovery

1. Disaster & hazmat monitoring
2. Emergency delivery (medicine, equipment, supplies...)
3. Emergency response coordination (situational awareness)
4. Disaster relief & post-disaster assessment
5. Search & rescue

Security Services

6. Crime scene investigation
7. Criminal surveillance & tracking
8. Police response coordination
9. Security surveillance
10. Training & evaluation

Urban Planning, Real Estate, Architecture & Engineering

21. Construction management
22. Environmental design (architecture, engineering, landscape architecture, urban design)
23. Mapping (archaeology, resource, topography...)
24. Marketing
25. Site analysis, planning & design

Media & Communications

26. Advertising & marketing
27. Art (commercial design, fine art, social practice...)
28. Entertainment (film, television, Internet...)
29. Investigative journalism
30. News photography & videography

Agriculture, Aquaculture, Silviculture, Viticulture

11. Chemical & biological monitoring (irrigation, pesticides, treatments...)
12. Flood & fire detection & monitoring
13. Inventory & records
14. Pest & disease detection & treatment
15. Precision operations & management

Environmental Management

16. Environmental hazard assessment
17. Environmental impact assessment & compliance
18. Invasive species & pest control
19. Scientific research
20. Wildlife & habitat monitoring & protection

Business & Commerce

31. Aero-technology / robotics research & development
32. Documentation (accident reporting, building verification, site status...)
33. Exploration (water, oil, gas, mineral...)
34. Inspection (infrastructure, structural, industrial...)
35. Pick-up & delivery services

Recreation & Entertainment

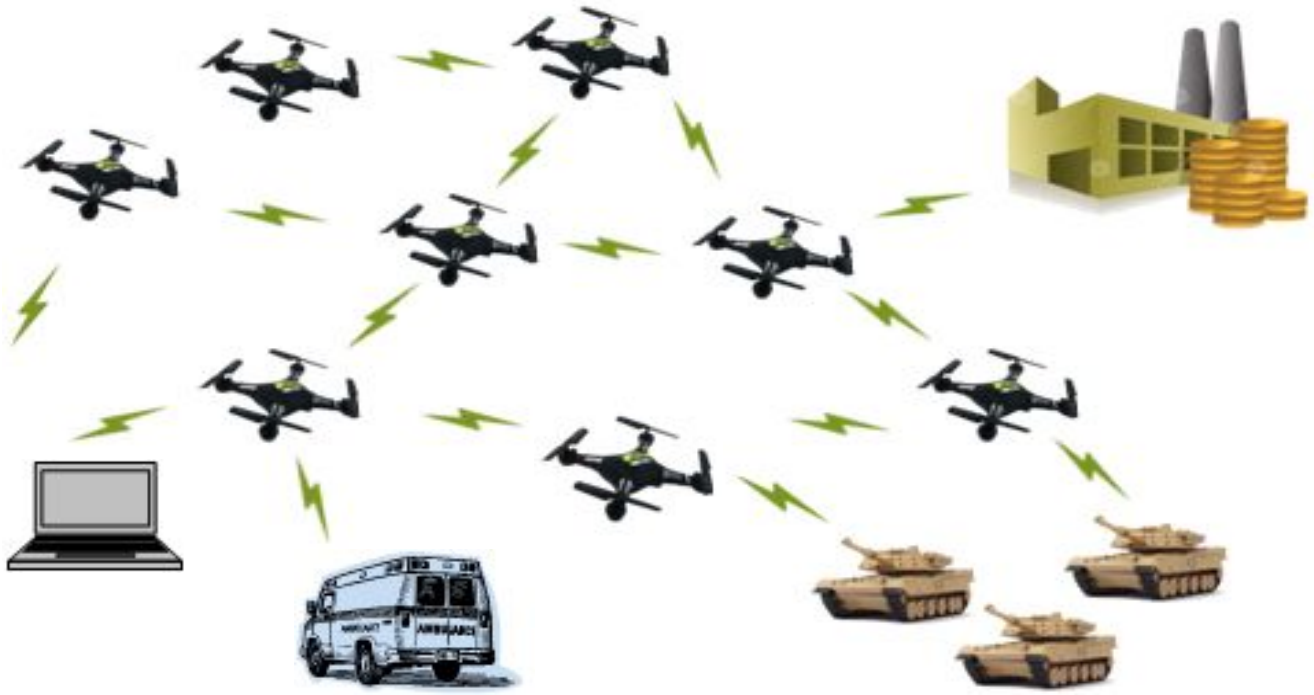
36. Exploration
37. Group activities & events
38. Hobby (do-it-yourself & kit building)
39. Personal photography & videography
40. Remote control flying

The potential value of unmanned aerial vehicles (UAVs) is extraordinary. Privacy and safety issues must be addressed rationally and within the larger context of these public and private benefits.

Stephens Planning & Design LLC
July 19, 2014

Flying Ad-Hoc Networks (FANETs)

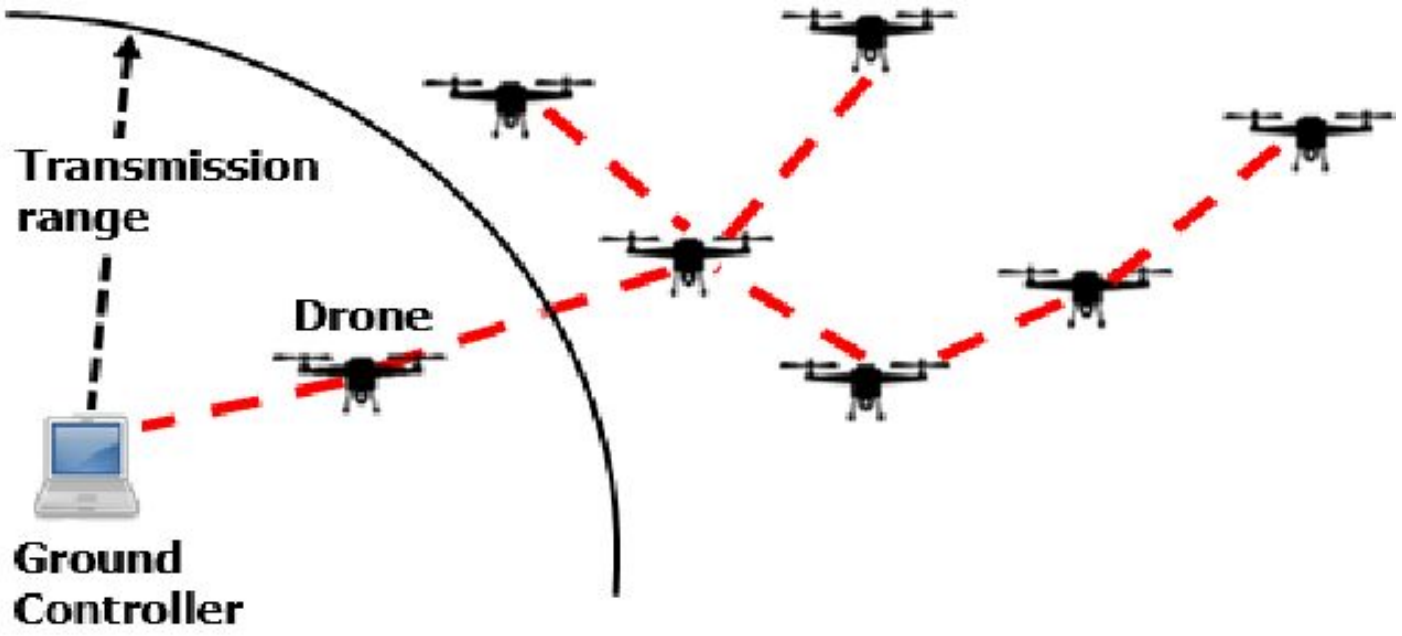
- Other terminologies
  - Drone ad-hoc Networks (DANETs)
  - Unmanned Aerial ad-hoc Networks (UAANETS)



Flying Ad-Hoc Networks (FANETs)

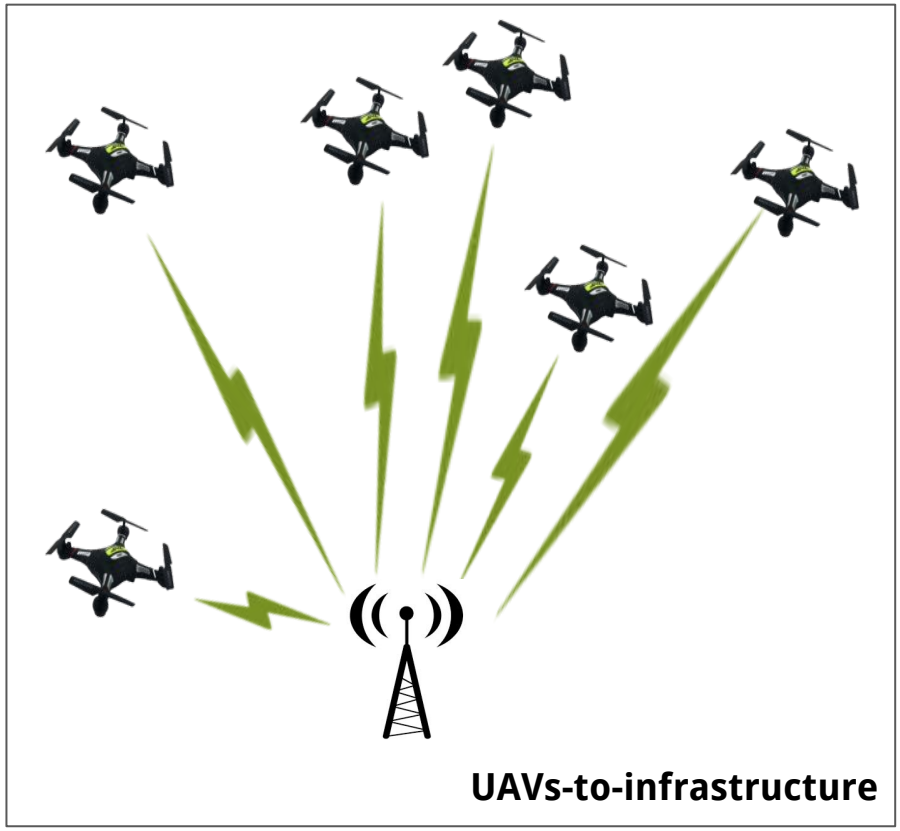
Two parts:

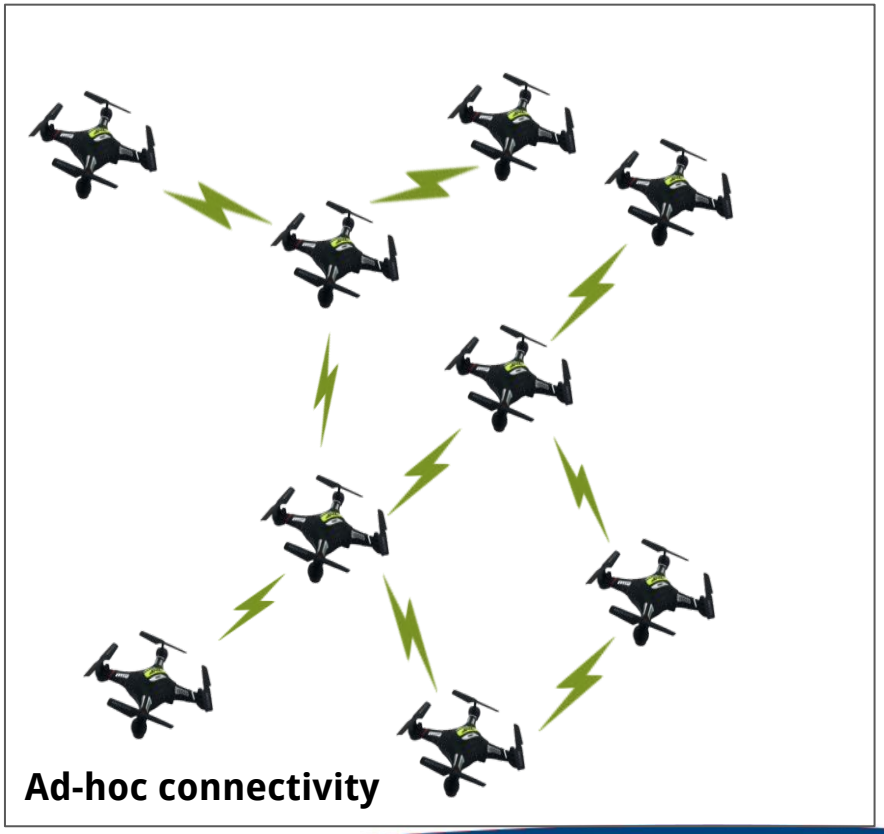
- Ad-hoc network
- Access point (satellite, ground base, laptop, ...)



Flying Ad-Hoc Networks (FANETs)

Multi-UAV system directly connected to infrastructure (UAV-to-Infrastructure) is NOT a FANET





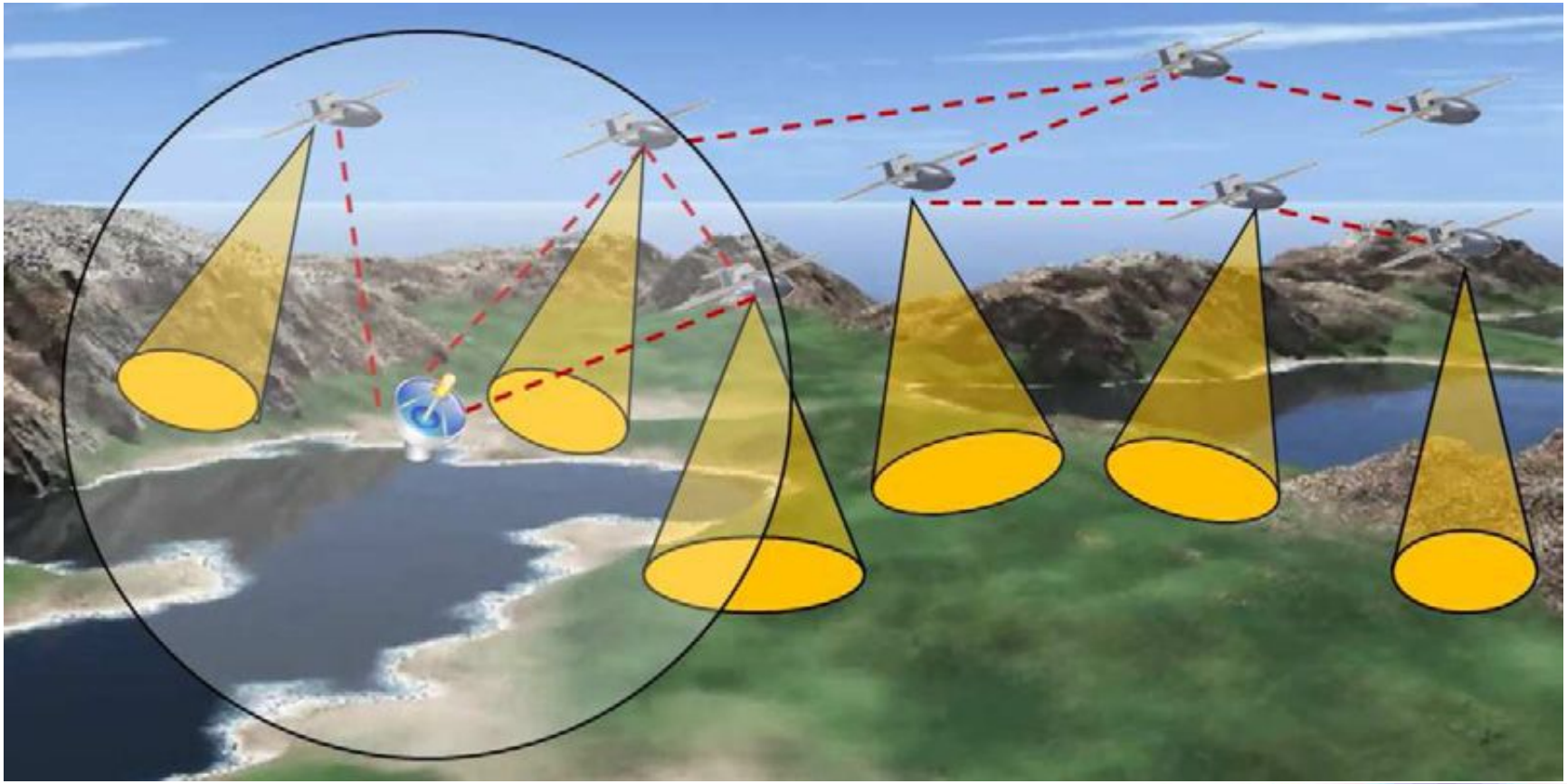
Differences between MANET and DANET

FANET are a special case of mobile ad hoc networks (MANETs)

- Mobility model
  - Different speed
  - Different topology
  - Different movement
- Topology changes
  - More frequently link failures
  - Link quality changes
- Peer-to-peer communication
  - P2P for coordination and collaboration
- Distances
- Equipments

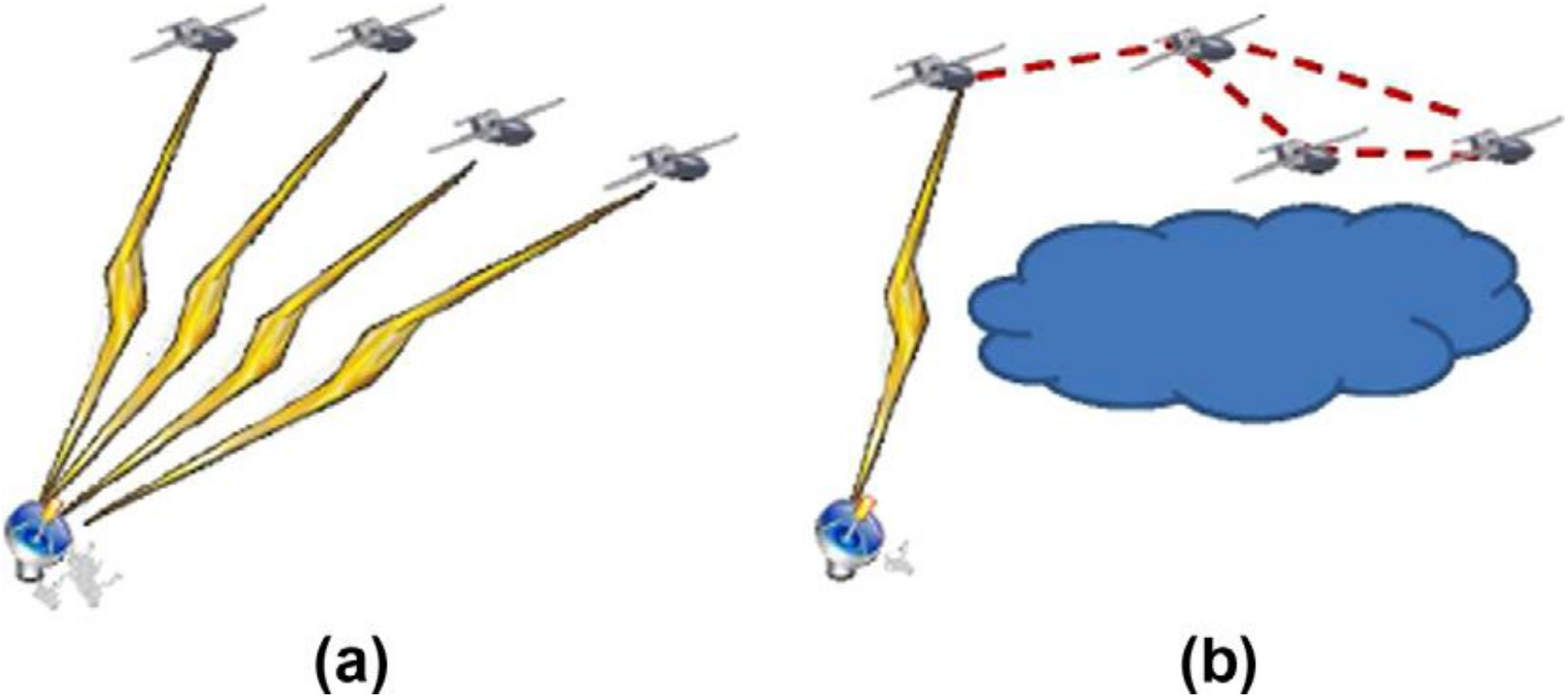
Motivation of FANETs

- Extend the work coverage and range
  - Chain of UAVs
  - Larger operation area



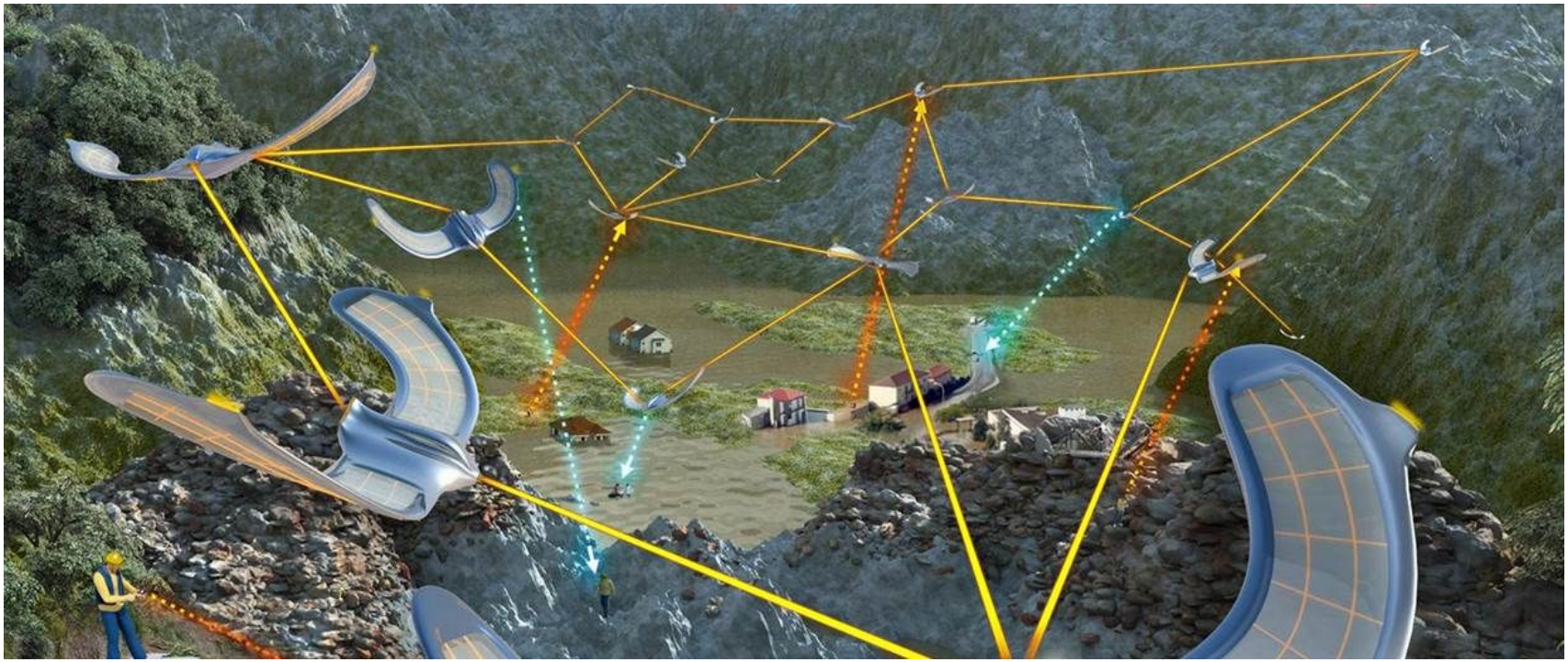
Motivation of DANETs

- Reliable UAV system and communication
  - Loss/broken link substitution
  - Obstacle bypass

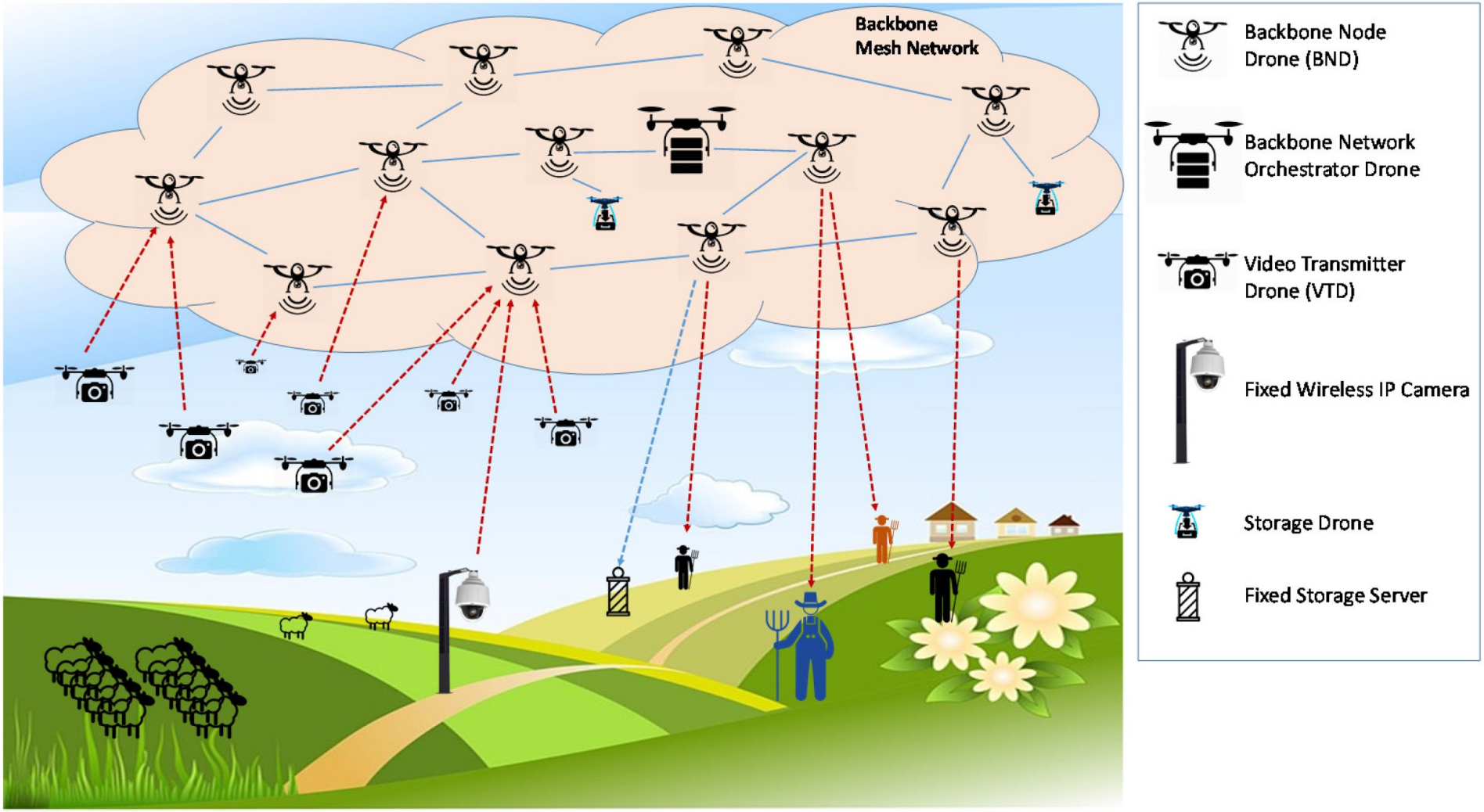


Motivation of DANETs

- Cooperation, sustainability and distributed working
  - Completing missions in short time
  - Maximization of the operations by adding more UAVs



A FANET in a IoT scenario



Communication in FANETs

Communication protocols in FANETs have still open research challenges

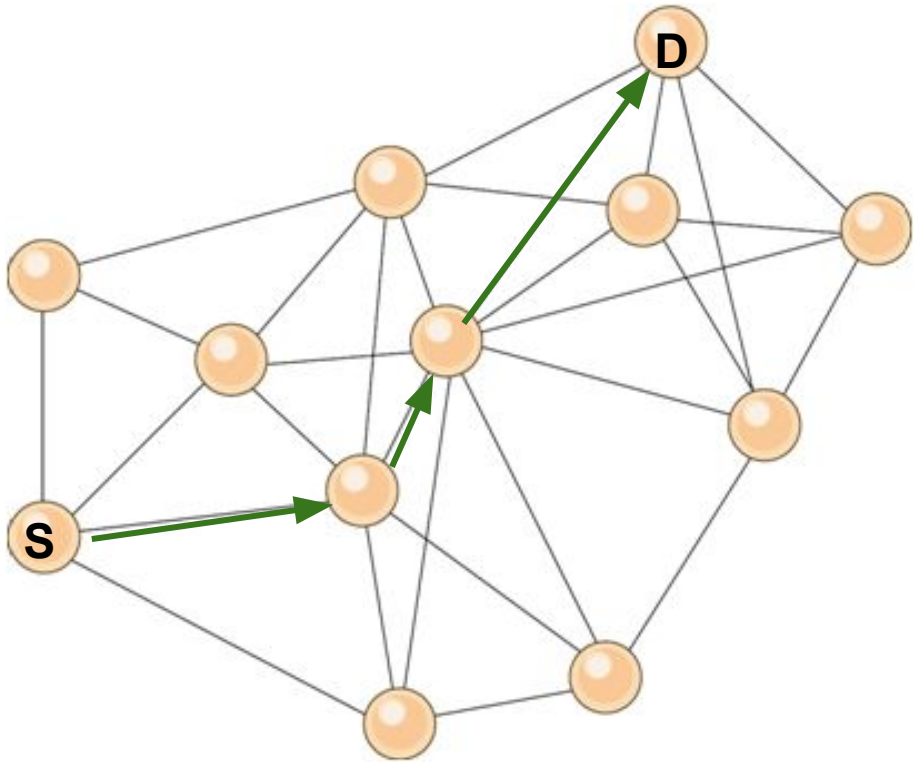
- Physical layer
  - Radio propagation
  - Antenna structure
- MAC layer
  - Link quality degradation
  - Adaptive MAC Protocol Scheme for UAVs (AMUAV)
- Network layer
  - Packet forwarding decision is more difficult
  - Maintaining of routing tables
- Transport layer
  - Reliability
  - Disconnections

Routing in FANETs

- Routing is a mechanism to send a packet from a source to a destination
- Routing in a MANET needs a multi-hop forwarding of packets
  - Difficult due to the continuous change of topology
- Routing in a FANET is even more difficult …
  - More speed
  - Different density
  - 3D topology
  - Different radio propagation
  - Power consumption

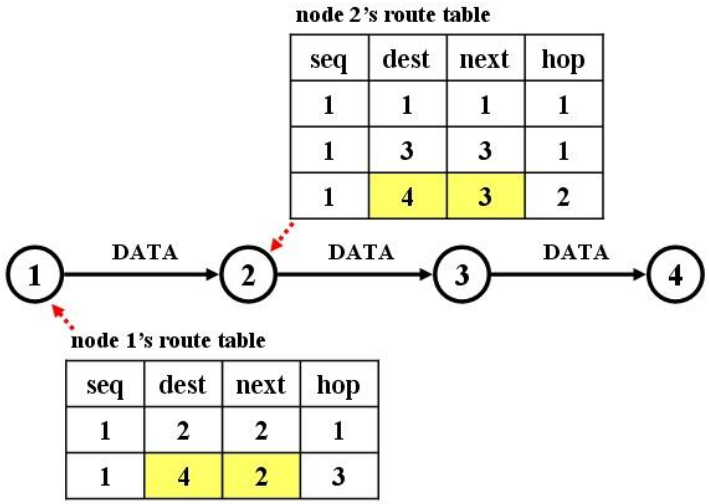
Routing in FANETs

- Main routing challenges
  - Link failures
  - Limited bandwidth
  - Limited energy
- Two main approaches
  - Topology-based
  - Position-based



Topology-based

- Use information about links
- Routing table
- Proactive, reactive and hybrid approaches
- Reactive approach is more suitable for MANETs
  - Need route only when required
  - There are not continuous table updates
  - AODV, DSR, etc ..



Topology-based

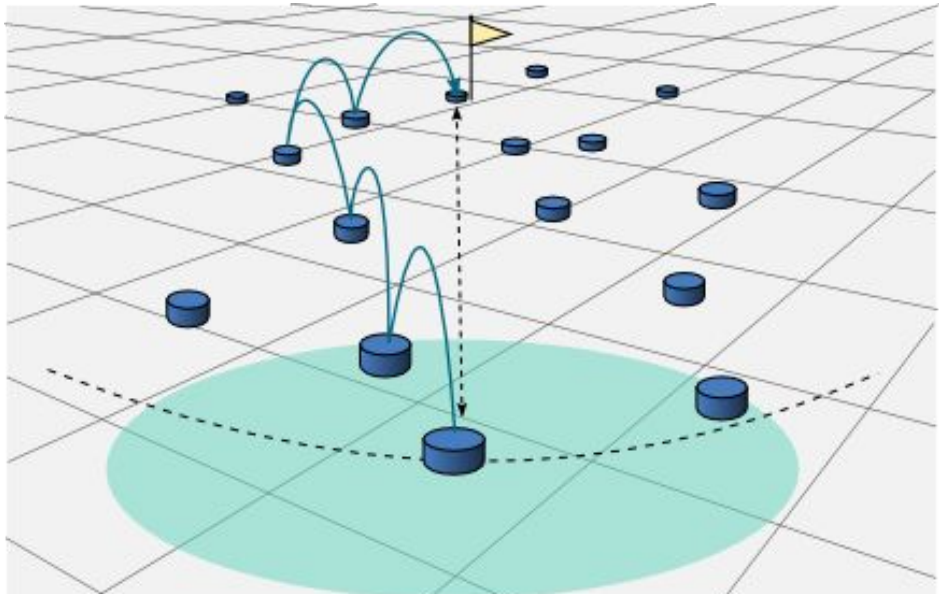
- There are some limitations also using these protocols in FANETs, especially with
  - Limited bandwidth
  - Limited energy
  - Limited memory
- Huge amount of control traffic
  - Reactive approaches need to flood the request packets
  - Many information have to be frequently updated
- Huge amount of nodes' memory
  - Need information about entire network

NOT SCALABLE!

Position-based

- Use geographic position information for packet forwarding decision
  - Location service (GPS)
- No need for a routing table
  - Only neighbors' information
  - Limited control overhead

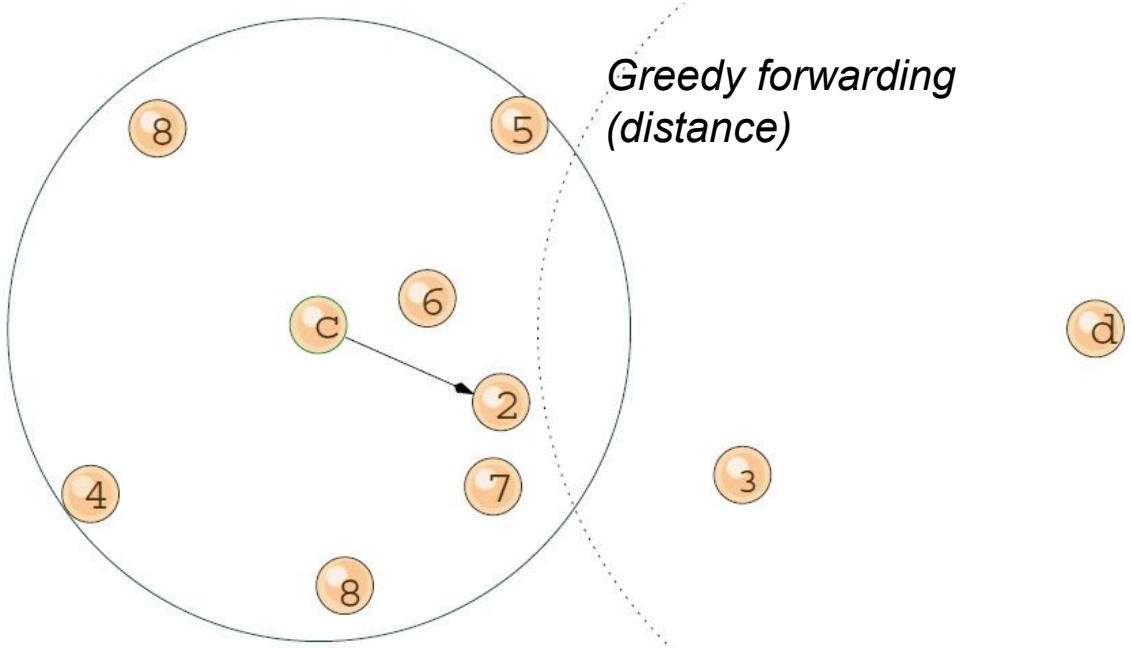
MORE SCALABLE



- Current node chooses the best next-hop node toward the destination node
- But.. the **Hello messages**? --> constant control overhead
  - Adaptive Hello timer

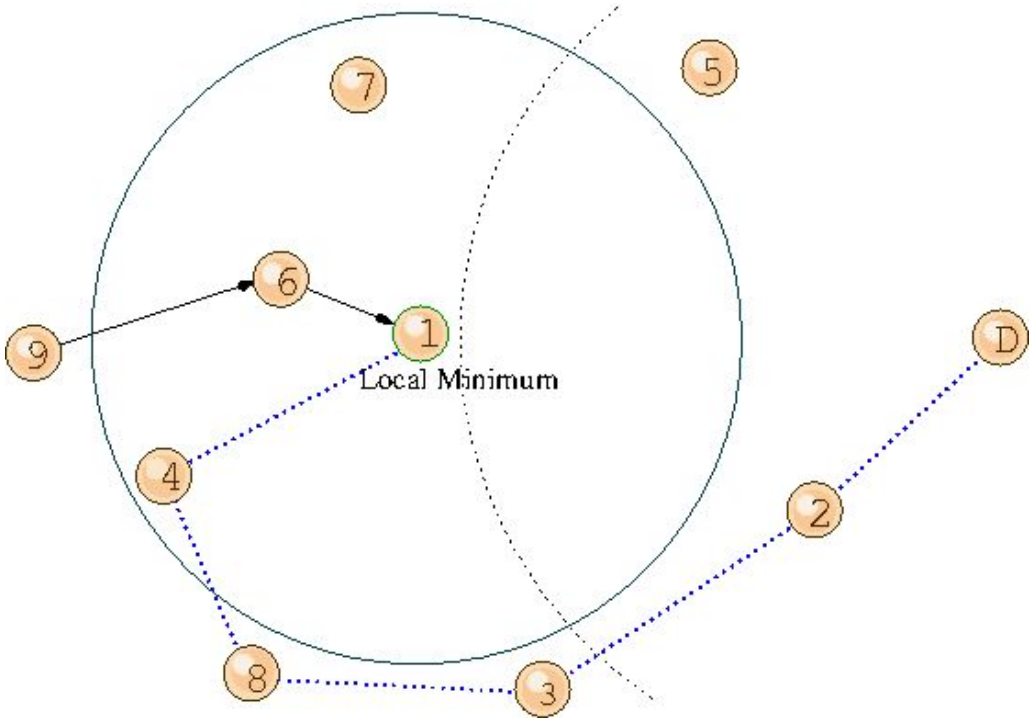
A trivial approach

- A node forwards the packet to one of its neighbors that make **progress** toward the destination (Greedy)
  - Distance
  - Projected distance
  - Angle
  - …



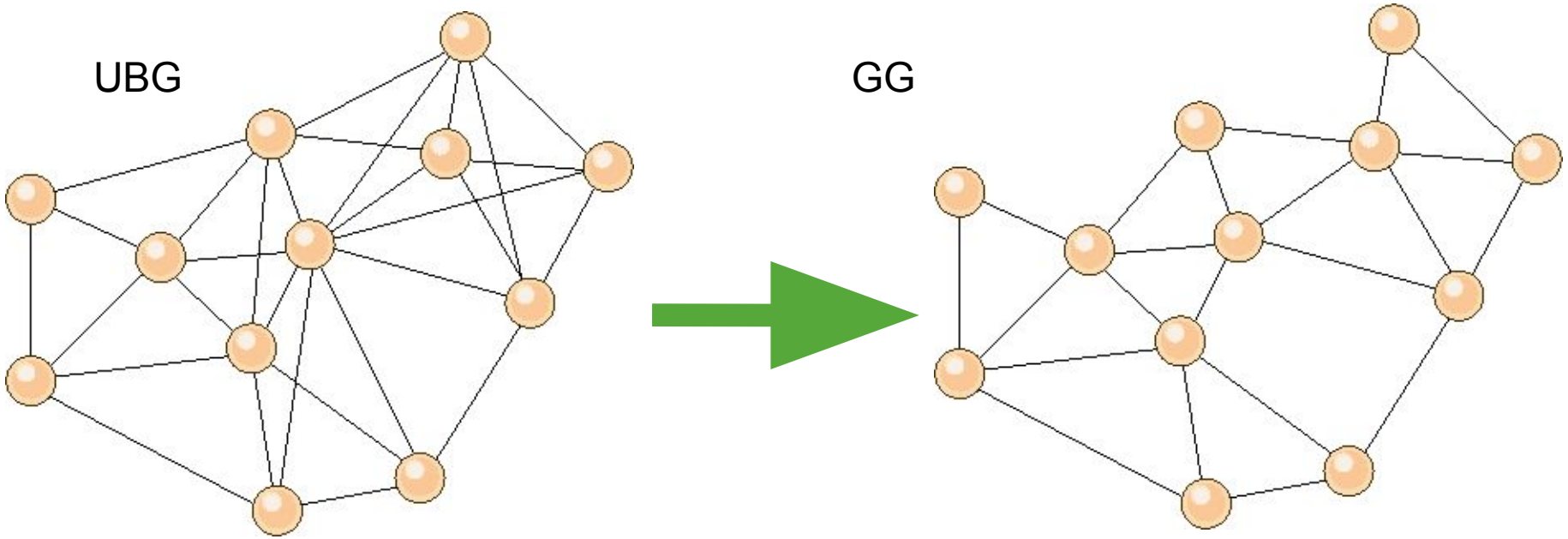
A trivial approach

- Greedy approaches suffer of the problem of **local minimum**
  - The packet gets stuck in a node
  - Sometimes the packet does not arrive at destination



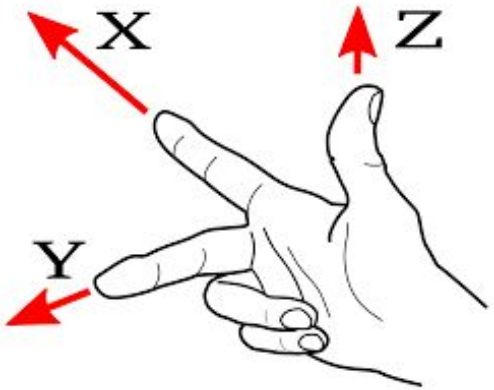
A recovery strategy

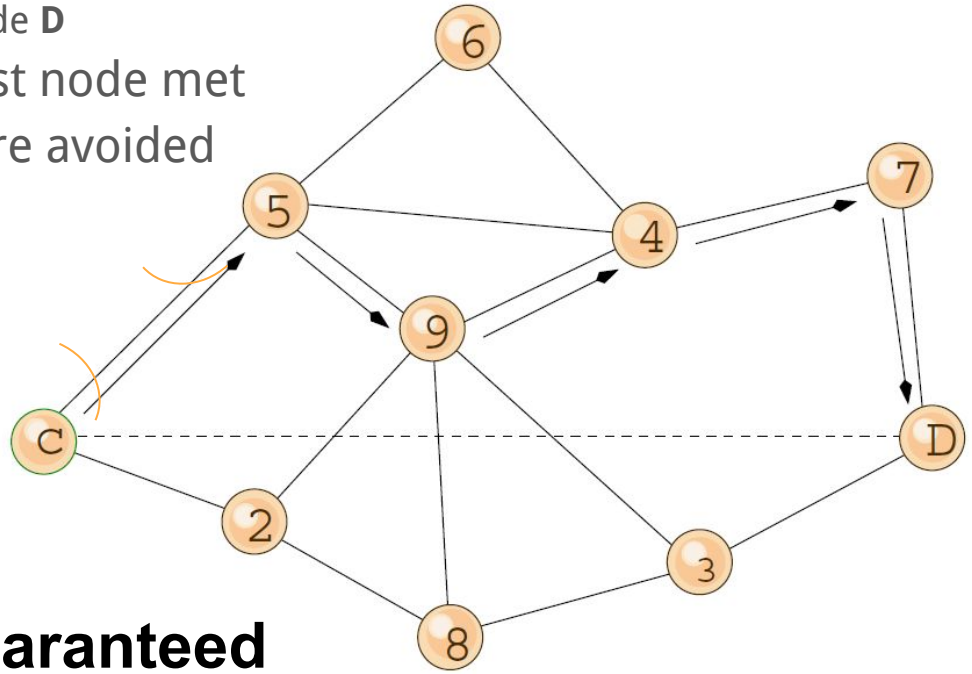
- **Face** routing algorithm
  - The packet walks adjacent faces to reach the destination
  - Graph planarization → planar sub-graph
  - Remove cross-links



Face algorithm

- Right-hand rule (or left-hand rule)
- Looking for the first node at the right (left)
  - Starting from the line represented by the link from where the packet arrived
    - Only the **first iteration** starts from line starting from the local minimum **c** (or source node) and the destination node **D**
  - The packet is sent to the first node met
  - Links crossing the line **cD** are avoided

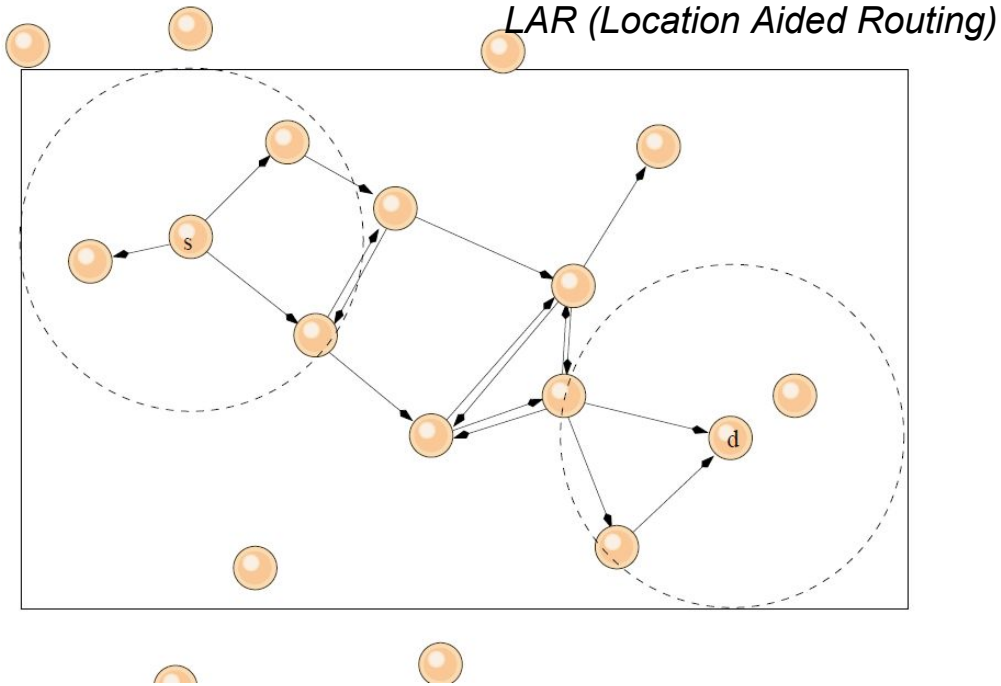




Delivery of packet is guaranteed

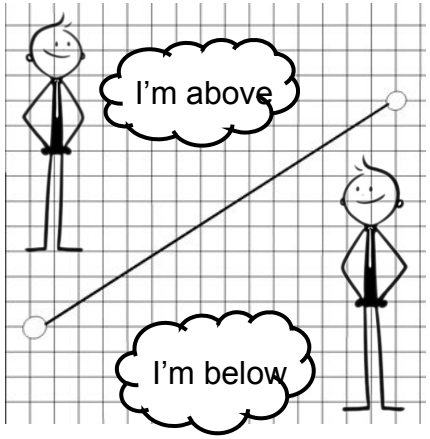
Multi-path forwarding

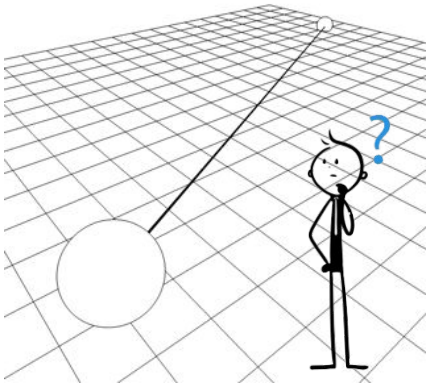
- A node send the same packet to multiple neighbors
- **Location Aided Routing** algorithm: uses a rectangle that includes transmission ranges of source and destination
- Limited flooding

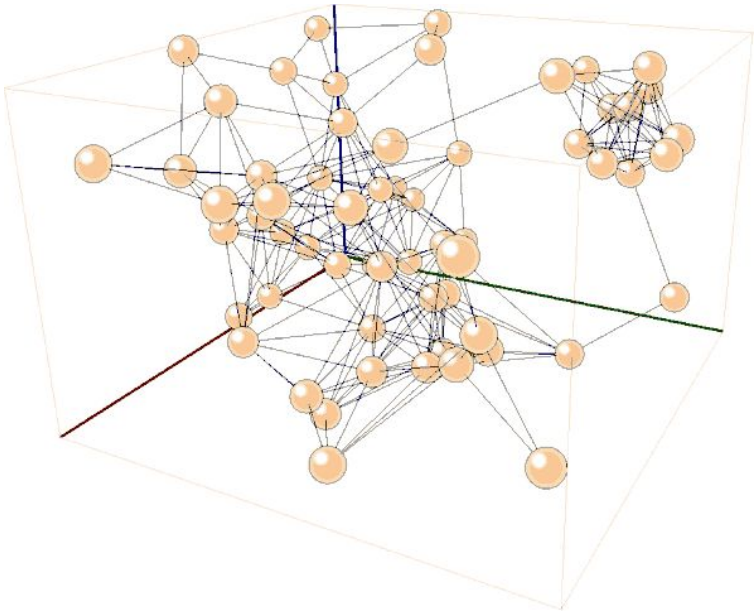


What if 3D networks?

- Many researches on position-based routing focused on 2D networks models
  - E.g., Vehicular Ad-hoc Networks (VANETs)
- FANETs are intrinsically 3D
- Difficult to extend 2D concepts to 3D space
  - NO planarization
  - NO above and below a line

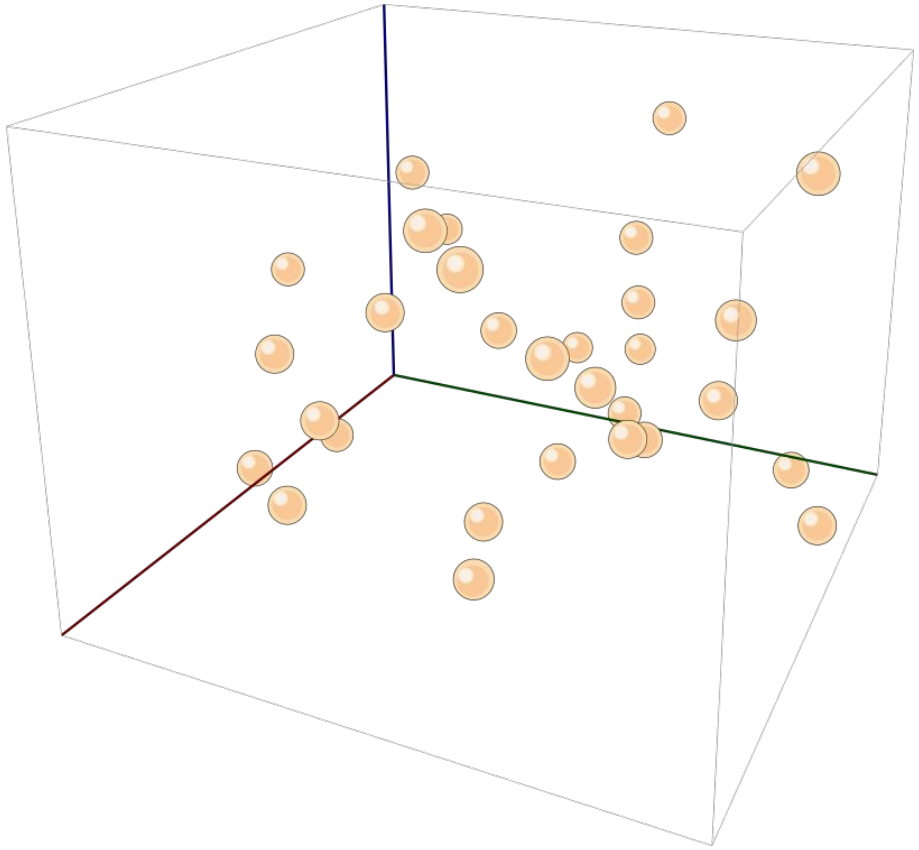






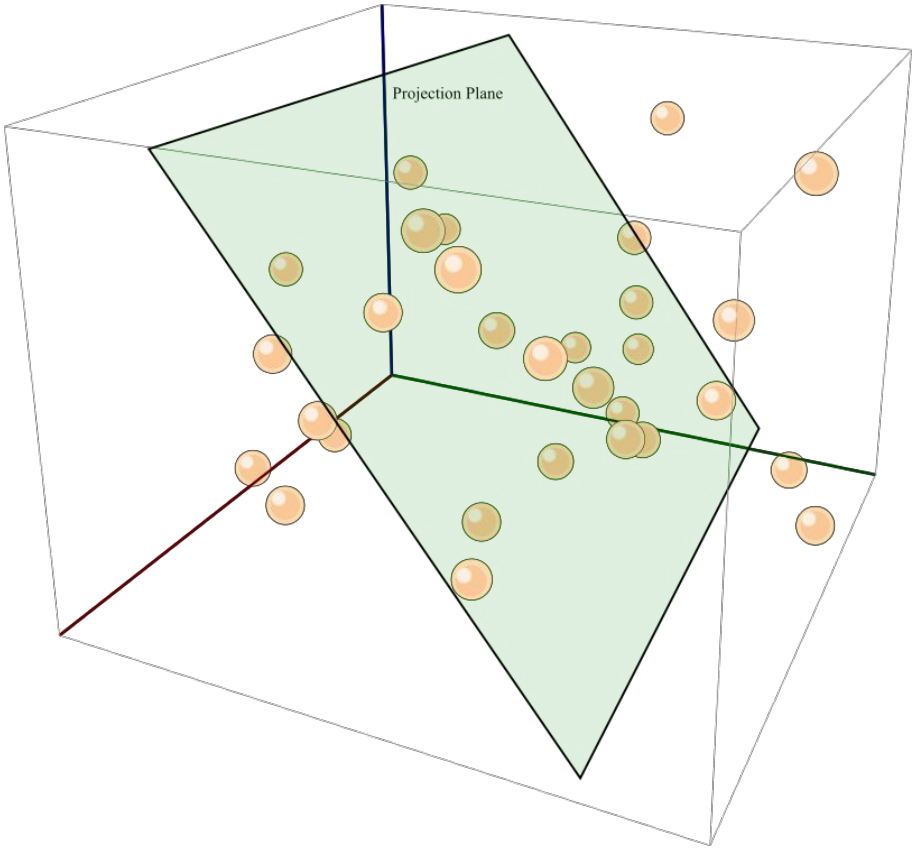
3D version of Face algorithm

- 2D Face cannot be used directly in 3D



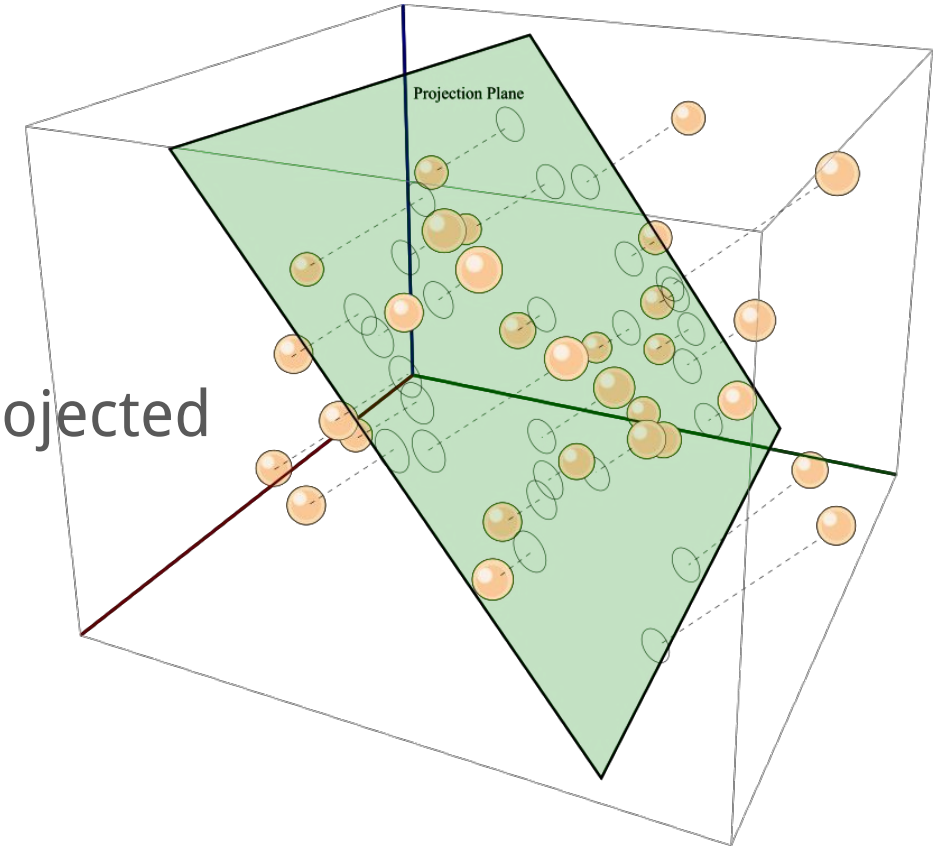
3D version of Face algorithm

- 2D Face cannot be used directly in 3D
- A 3D plane is created
  - Random plane
  - Source-dest-random point
  - ALSP



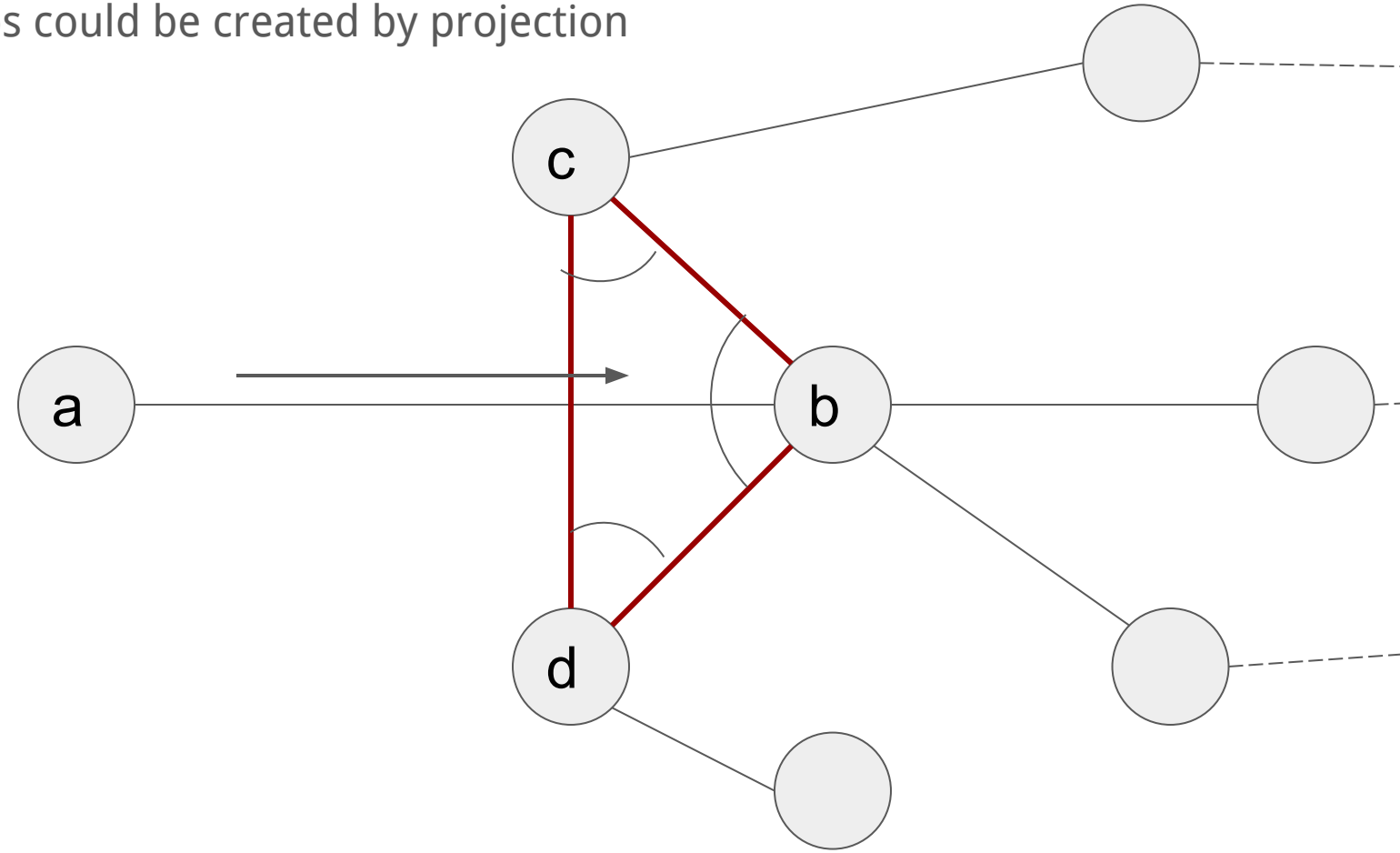
3D version of Face algorithm

- 2D Face cannot be used directly in 3D
- A 3D plane is created
  - Random plane
  - Source-dest-random point
  - ALSP
- Project nodes on a plane
- Start face routing on this projected graph



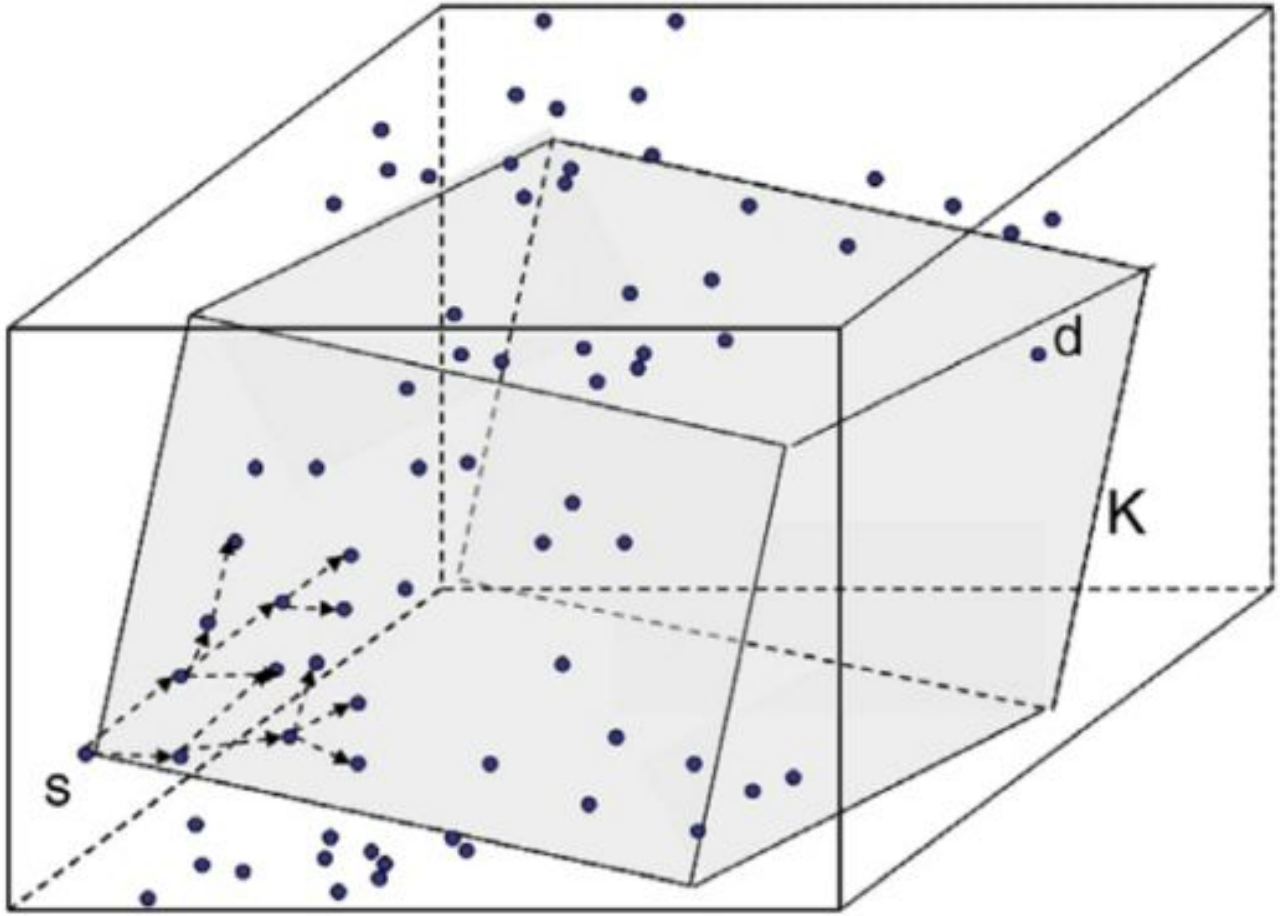
3D version of Face algorithm

- Packet delivery is not guaranteed!!
  - Loops could be created by projection

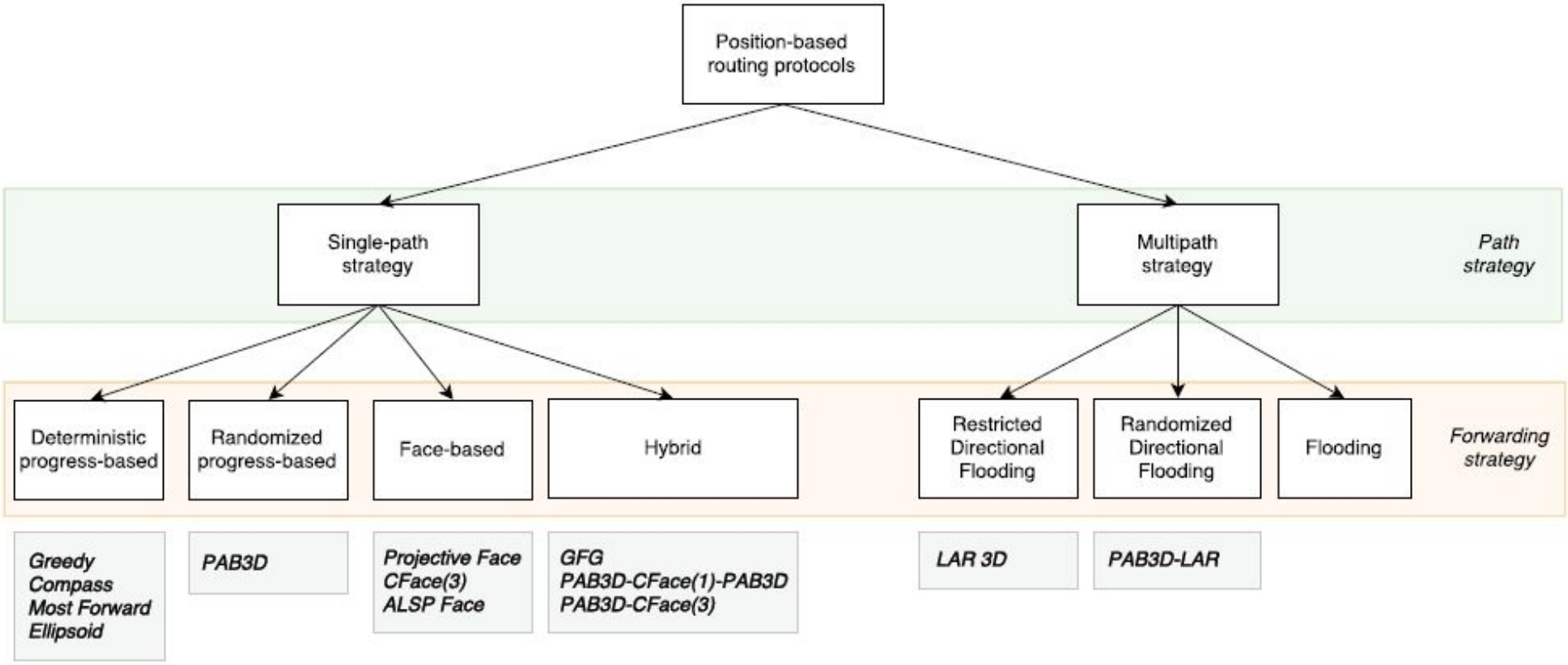


3D LAR

- 3D version of LAR



A taxonomy of position-based approaches

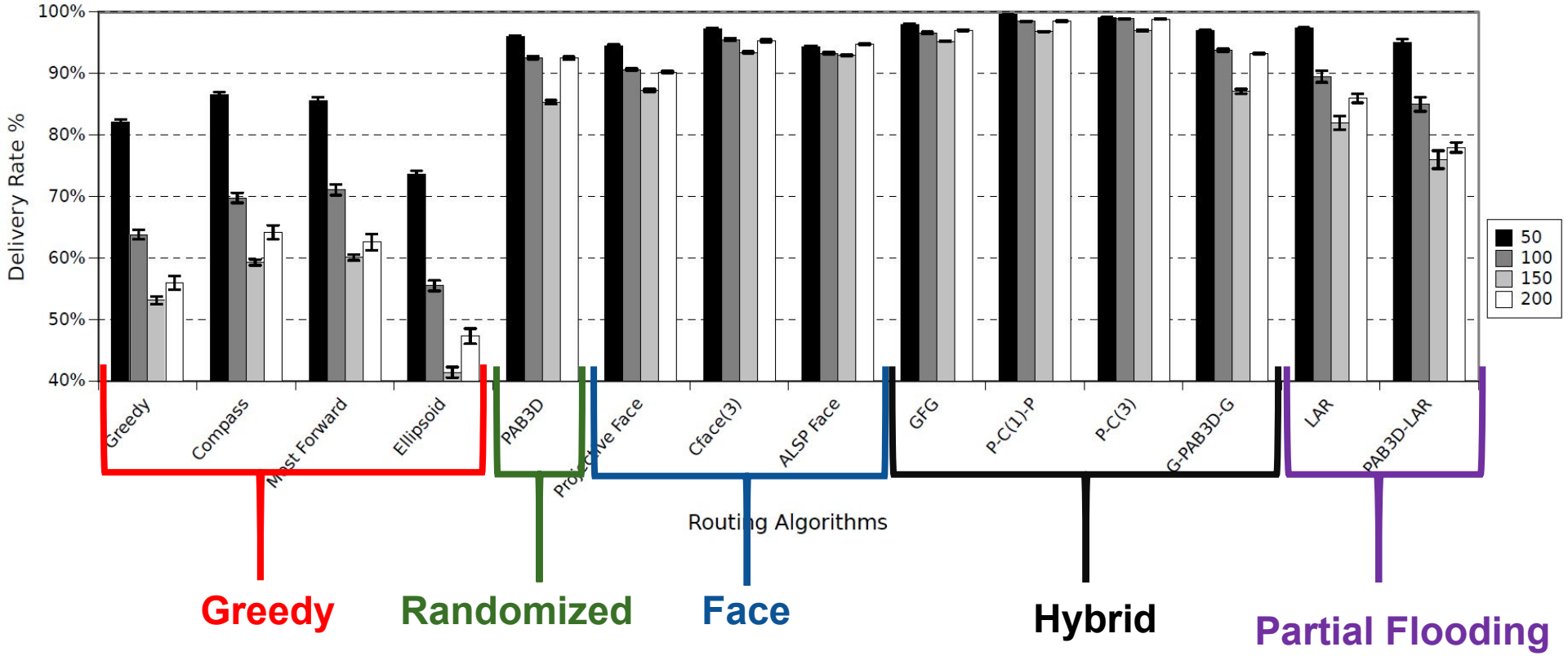


Performance simulation

- NS-2 simulation environment
- Cube of 500 meters of side length
- Transmission range of 100 meters
- Network sizes: 50, 100, 150, 200 nodes
- Performance metrics
  - Delivery Rate
    - Percentage of delivered packets at the recipient
  - Path Dilation
    - Average ratio of the number of hops traveled to the minimum path length

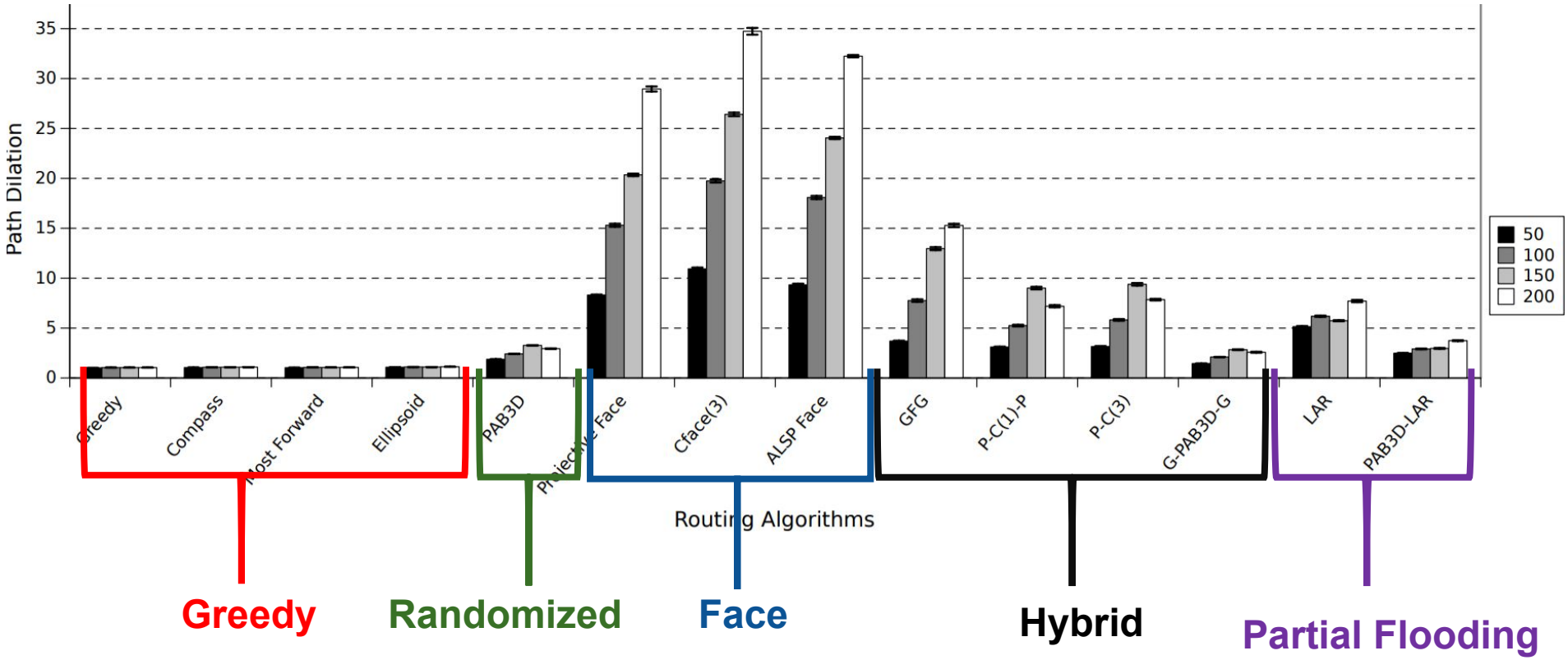
Performance results

- Single Packet – 50, 100, 150, 200 nodes
- Delivery Rate

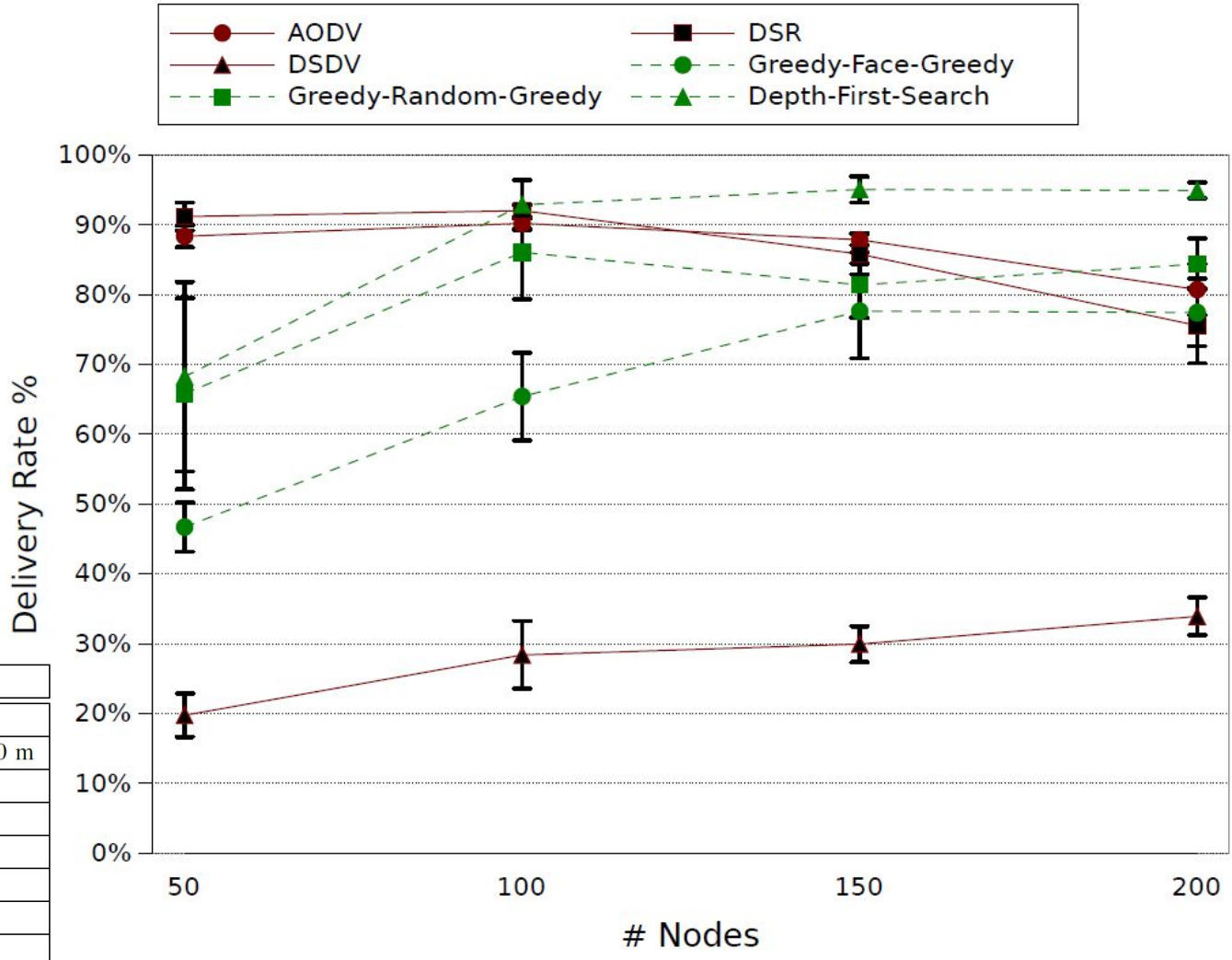


Performance results

- Single Packet - 50, 100, 150, 200 nodes
- Path dilation



Comparison with topology-based



Parameter	Value
MAC type	IEEE 802.11g
Simulation area	1000 m x 1000 m x 1000 m
Transmission range	250 m
Node max speed	10 m/s
Traffic type	CBR
Number of data flows	10
Data packet size	64 bytes
Packet rate	2 pckt/s
Queue type	Drop Tail
Number of nodes	50, 100, 150, 200
Pause times (sec)	5, 20, 40, 100 (static)

Conclusions

- Position-based protocols perform better than topology-based ones (in some situations)
  - Require less resources (memory, energy, bandwidth)
  - Scalable under certain conditions
- Several forwarding algorithms in 3D graphs
  - 2D geometric concepts not adaptable to 3D space
  - Delivery not guaranteed with local knowledge strategies
- Promising approaches could be improved to achieve better results
  - Hybrid solutions (Hybrid greedy-AODV??)
  - Reduce search space
  - Information regarding past decision
    - Depth first search

Some References

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