Autonomous Networking

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Today's plan

- Drones
- Networks of drones

Unmanned Aerial Vehicle (UAV)

- UAV, commonly known as a **Drone**, is an **aircraft without a human pilot aboard** (*unmanned* or *uncrewed*).
- May operate with various degrees of autonomy: either under remote control by a human operator or autonomously by on board computers.

UAV or drone Characteristics

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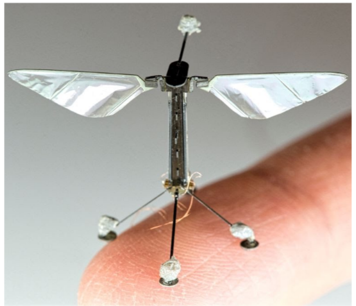
Weight: from 0.5 g (RoboBee) up to 15000 kg (Northrop Grumman RQ-4 Global Hawk).

Maximum speed: up to 11265 Kph (X-43A an unmanned hypersonic aircraft), commercial drones from 50 to 150 kph.

Propellant:
- Fossil Fuel: gasoline, methane, and hydrogen.
- Battery: Ni-Cd, Ni-Mh, Li-PO and Li-S.
- Solar cells.





UAV or drone Characteristics

Autonomy: commercial drones approximately 30 minutes.

Various shapes and flight modes:

Single-rotor helicopter

Multi-rotor helicopter

Aeroplane

Airship




Why UAVs?

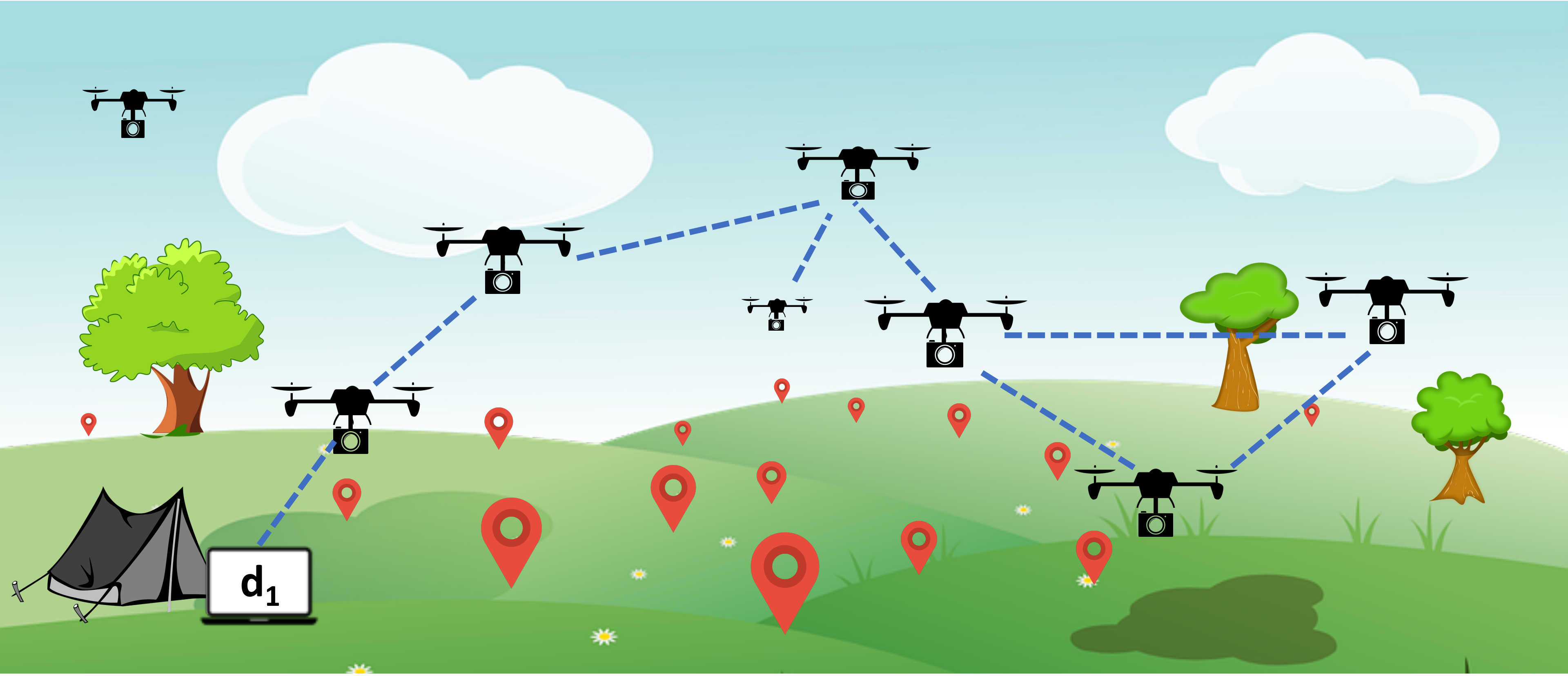
- Can provide timely disaster warnings and assist in speeding up rescue and recovery operations.
- Can carry medical supplies to areas rendered inaccessible.
- Can be used in dangerous situations.
- Can be used in common applications as traffic monitoring, wind estimation and remote sensing.
- And so on…




UAVNET or DRONET

- In general, drones are used to search, identify and monitor interesting events **over massive and/or inaccessible areas**.
- **Multiple UAVs** are deployed in a certain area and are expected to **coordinate actions in an autonomous fashion** or execute direct instructions from a control centre.
- **DRONET** – network of drones that fly over a zone and cooperate to accomplish a mission
- In many scenarios, the UAVs need to **exchange a relatively large amount of data** among themselves and/or with the control station (depot) to support a given service

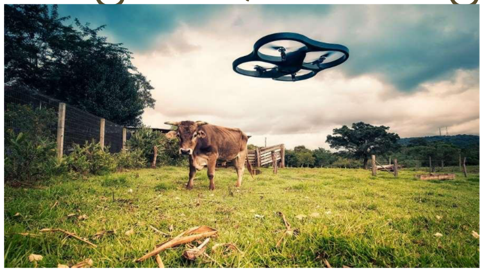
Dronet



Applications

- Search and rescue

- Sensing, reconnaissance, search, detecting fires, tracking, …

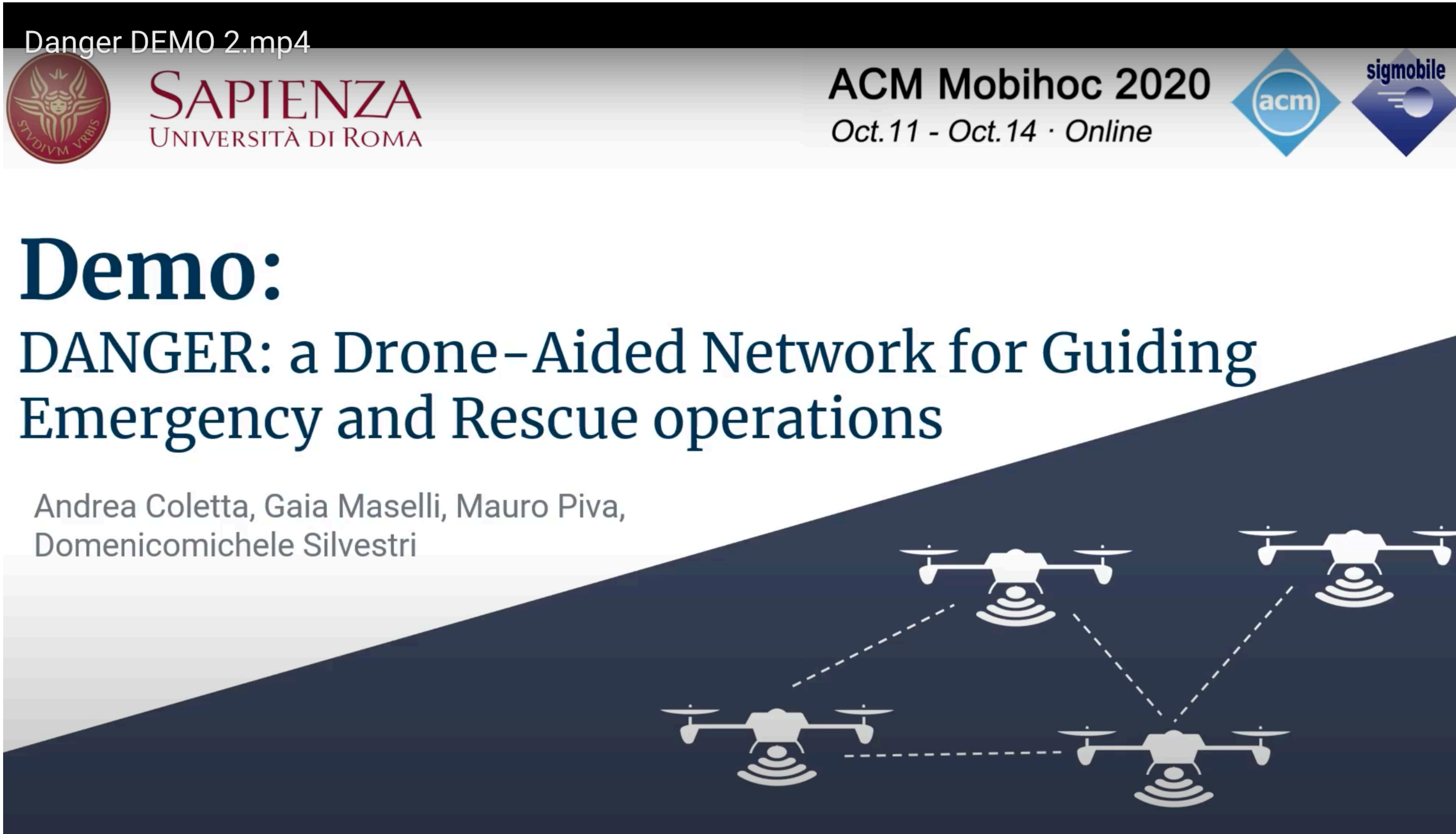


- Attack , war and active defence

Applications: Providing network connectivity

- Drones can act as flying BSs or relay nodes and support the connectivity of existing terrestrial communication networks

Implementation



DANGER demonstration

UAVNET Issues and Challenges

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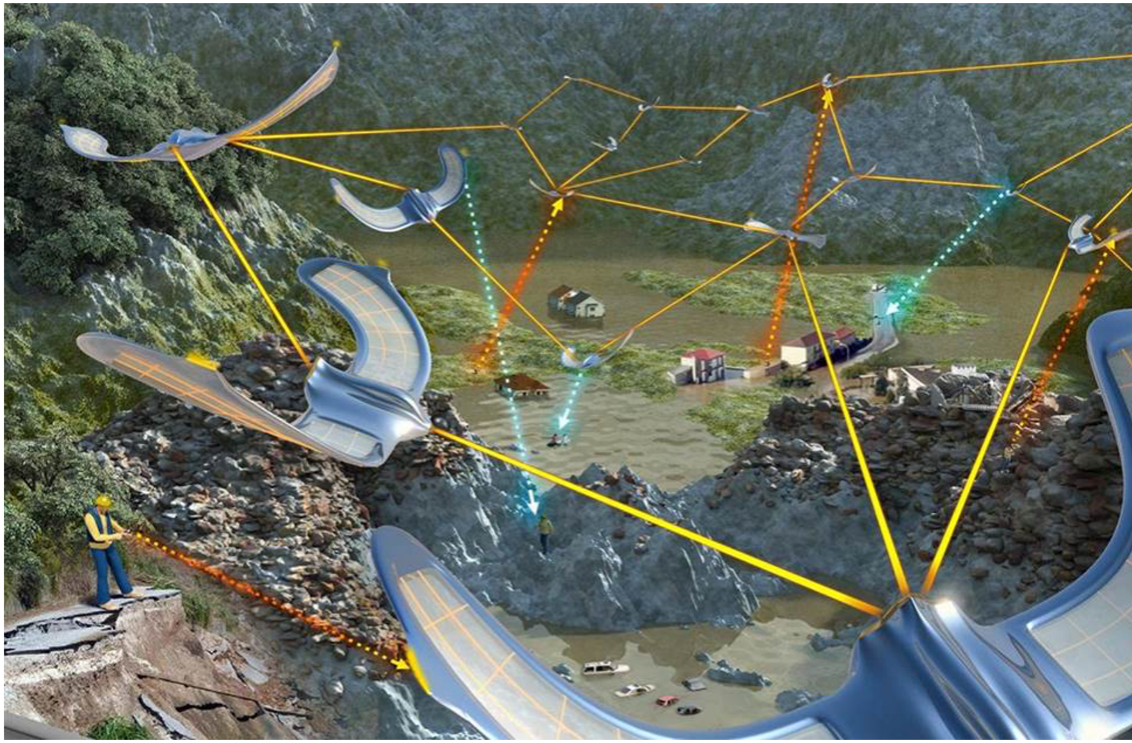
- Medium to high mobility
- Fluid Topology
- Node Failure
- Routing
- Energy constraints



MAC in UAVNET

- Drones can be equipped with several **standard radio modules**
- Wi-Fi
- Cellular
- LPWAN - Low Power Wide Area Network (e.g. LoRa - Long Range)

Routing

- Distributed area monitoring/patrolling applications often require the drones to stream high definition video or thermal camera recordings to the depot, which demands wideband communication technologies (limited coverage range)
- Providing video monitoring over wide areas may require **multi-hop** data connections, where the drones themselves can act as relays for other nodes in the network
- Which routing protocol?

Comparison

	WSN	IoT	Dronet
Mobility	None	None or Low	**High (even 3D)**
Topology	Random, ad-hoc Node failure	Star or ad hoc	Mesh **Jeopardized**
Infrastructure	Absent (sink)	Partial (central point)	**Absent (depot)**
Energy source	battery	Wired, battery, backscattering	**battery**
Typical use	Environmental monitoring	Smart environments	Rescue, monitoring, Surveillance

Routing in UAVNET (3)

Goals of Routing protocol:

Routing Protocols

- DRONETS are similar to Mobile Ad-Hoc Networks (MANETs) and WSN, but typically have much **higher mobility**
- **Proactive protocols**: use tables in their nodes to store all the routing information, they are updated when topology changes.
- **Reactive protocols**: a route is stored when there is need of communication between nodes (on-demand).
- **Hybrid protocols**: try to reduce overhead of protocol mixing proactive and reactive approaches.
- **Geographic protocols**: a routing scheme based on the geographical position of the nodes.

Proactive Protocols

- Characteristics:
  - routing tables saved on nodes to store all the routing information of other nodes
  - tables need to be updated when topology changes
- **Suitable for UAV network?**
  - bandwidth constraints
  - slow reaction to topology changes causing delays
- Protocols:

OLSR - Optimized Link State Routing

DSDV - Destination-Sequenced Distance Vector

B.A.T.M.A.N. – Better Approach to Mobile Ad Hoc Networ

Reactive Protocols

- Characteristics:
  - On demand
  - No periodic messages
  - Source or hop by hop routing
  - Route acquisition latency

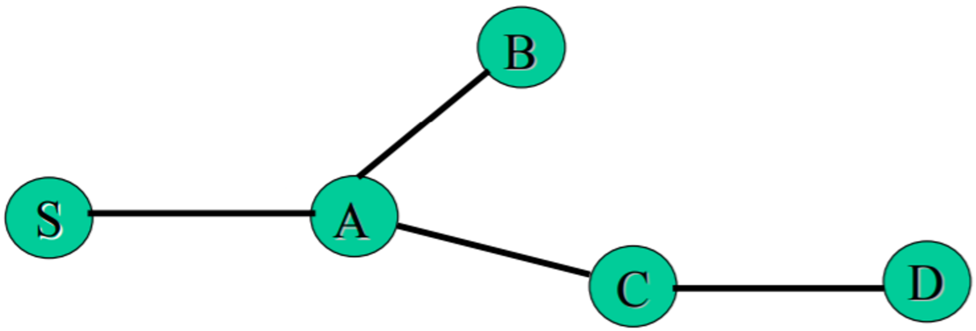
- **Suitable for UAV network?**
  - **Scalability?**
  - **Latency ?**

- Protocols:
  - **DSR** – Dynamic Source Routing
  - **AODV** – Ad hoc On Demand Distance Vector

Reactive Protocols: AODV – Ad Hoc On demand Distance Vector (2)

How it works – A brief Recap:

- **Node S wants to communicate with D**



Reactive Protocols: AODV – Ad Hoc On demand Distance Vector (2)

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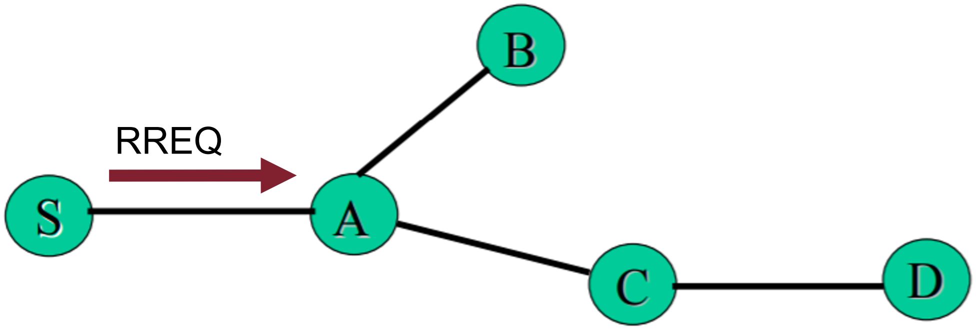

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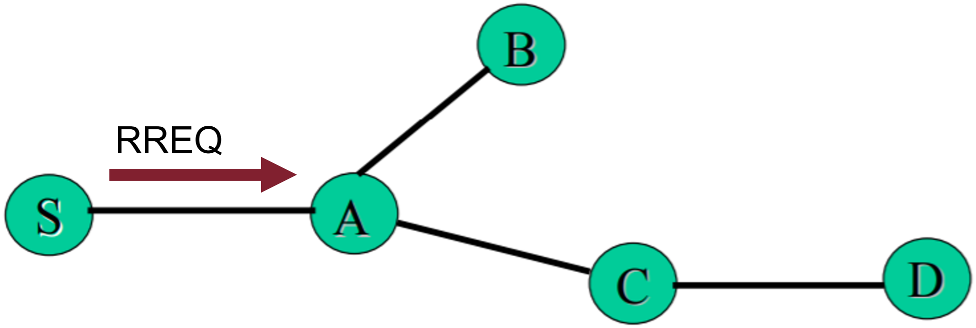

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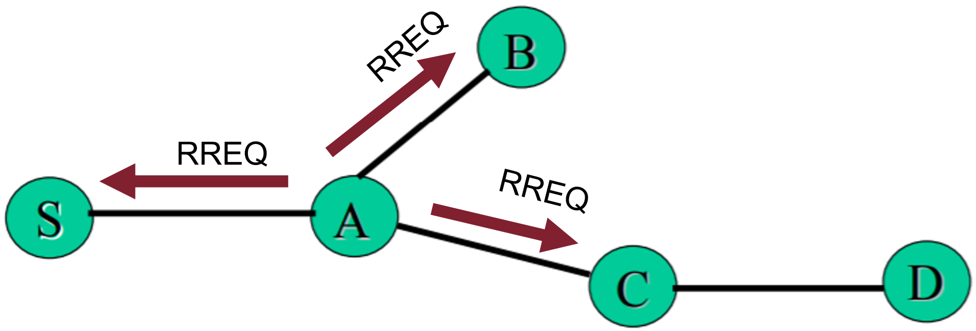
- **A rebroadcasts RREQ**



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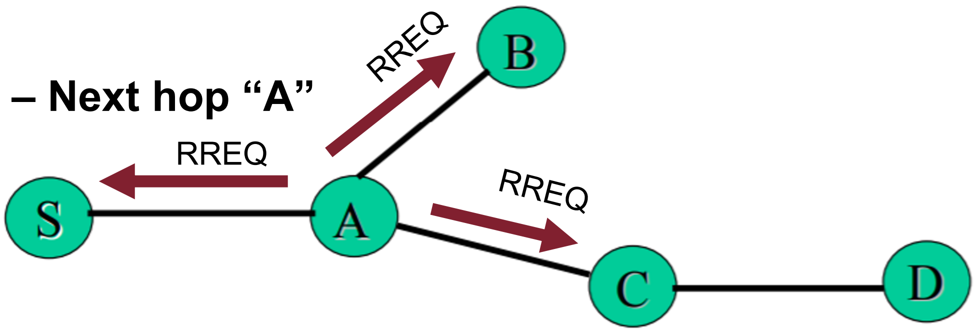
- **C stores reversal route: Dest “S” – Next hop “A”**



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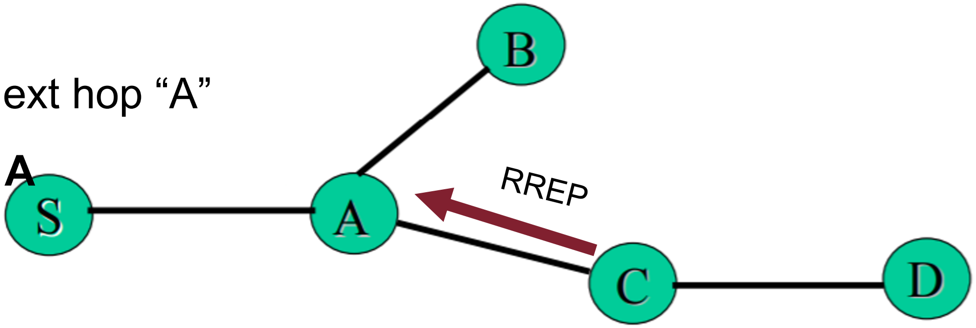
- **C creates RREP and unicast it to A**



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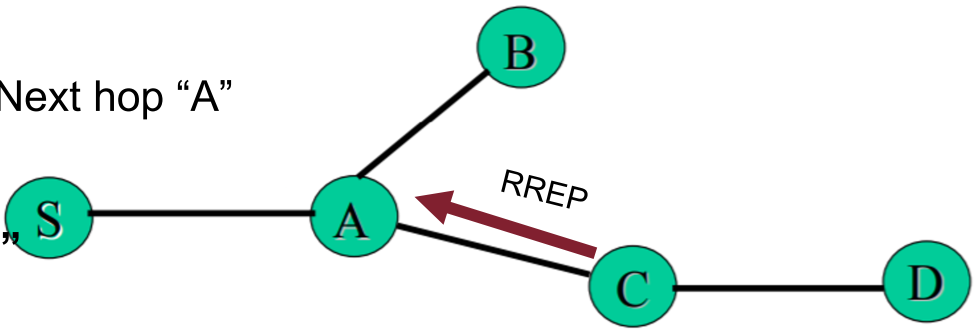

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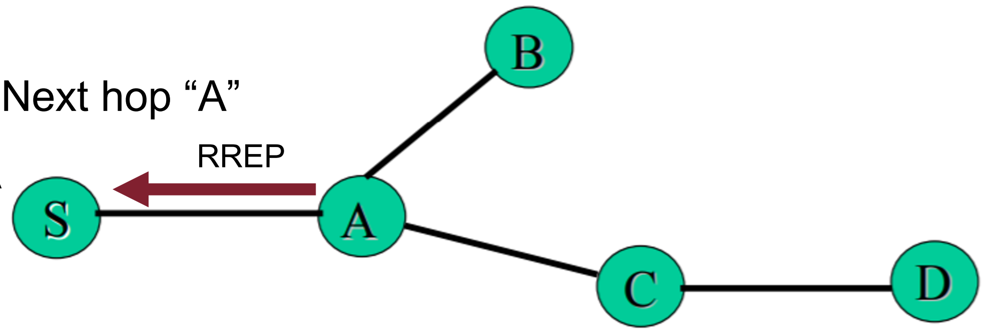
- **A sends RREP in unicast to S**



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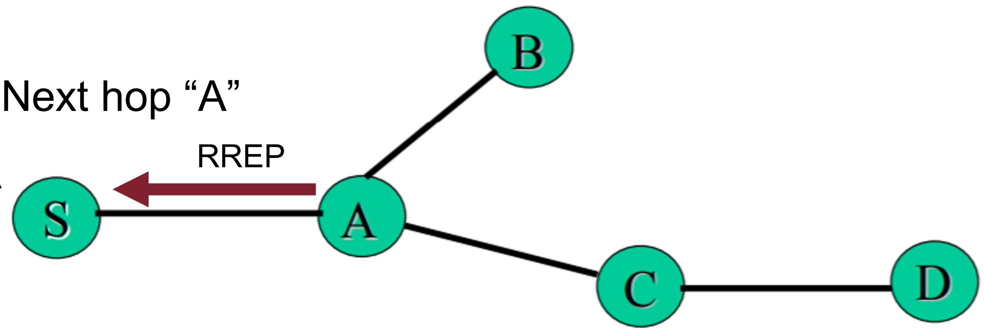


Reactive Protocols: AODV – Ad Hoc On demand Distance Vector (3)

AODV in UAVNET:

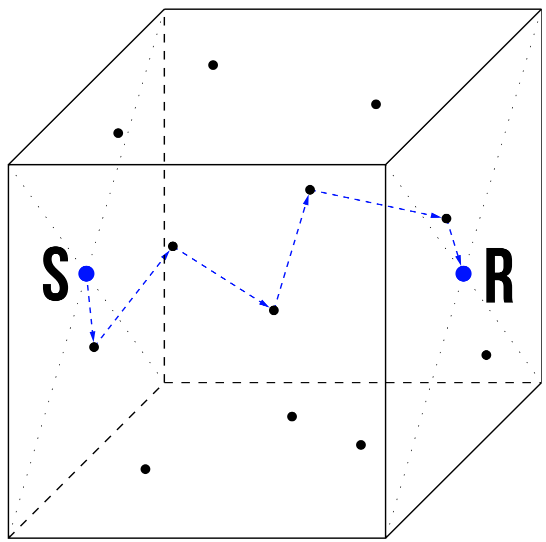
Pros:

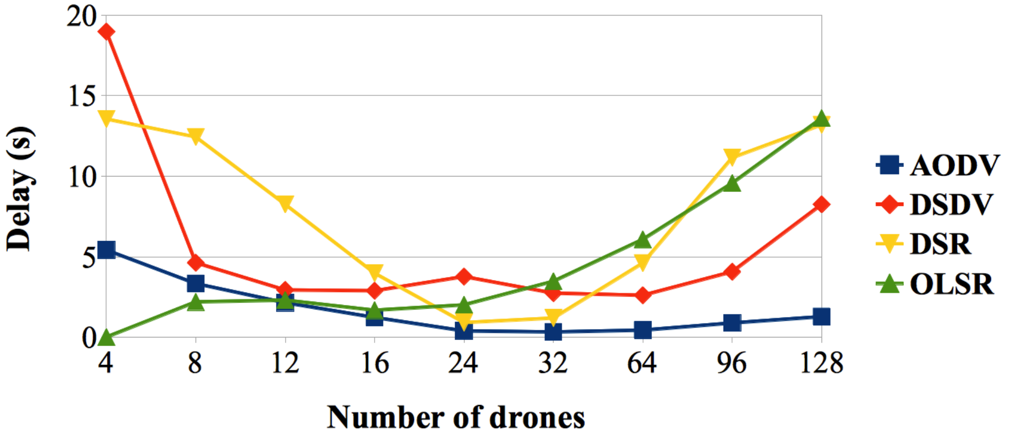
- On demand
- Hop by hop routing
- No loop
- Minimal routing traffic

Cons:

- "Hello" messages timing and overhead
- High latency in route finding (flooding)
- Intermittent links affect the throughput
- No load balancing

Performance evaluation





"*Benchmarking of Routing Algorithms in 3D MANETs*", ACM DroNet'18,

Hybrid Protocols

Characteristics/Goals:

- Mix reactive and proactive approach
- Reduce reactive delay of discovery process
- Reduce proactive overhead of control messages
- Scale well on large network
- Hard to implement

Protocols:

- **ZRP** – Zone Routing Protocol
- **TORA** – Temporarily Ordered Routing Algorithm

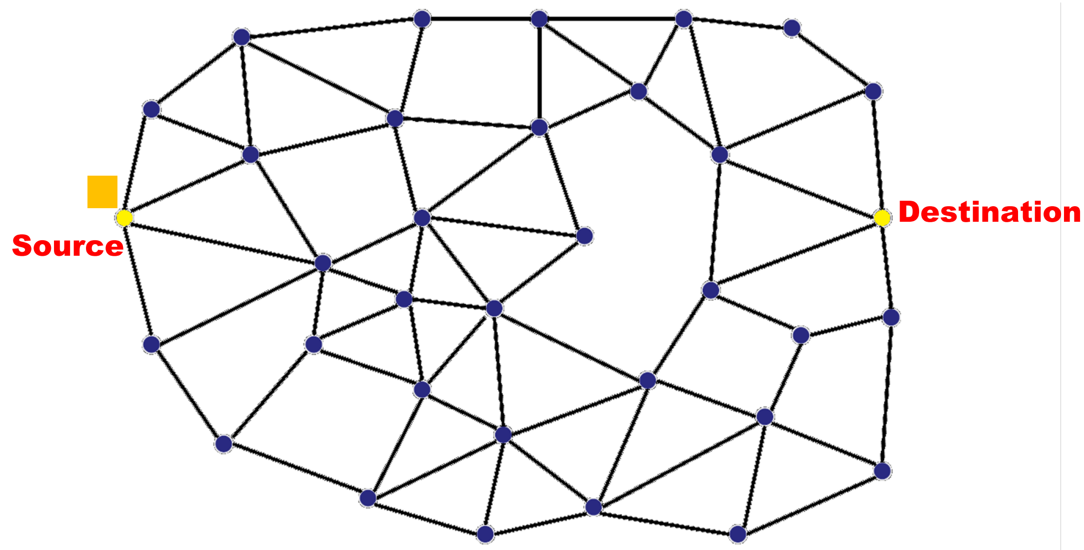
Geographic routing

Geographic Protocols

- The geographical position information of the nodes is utilized for data packet forwarding decisions
- Each UAV knows its own location using the GPS device embedded on board or any other means of positioning system
- Geographic routing schemes **do not need** the **entire network information**
- No Route discovery
- No routing tables
- Use local information to forward the data packets
- Routing overhead, bandwidth, and energy consumption are reduced
- For routing decisions, only the neighbor UAVs and destination UAV position information are required.

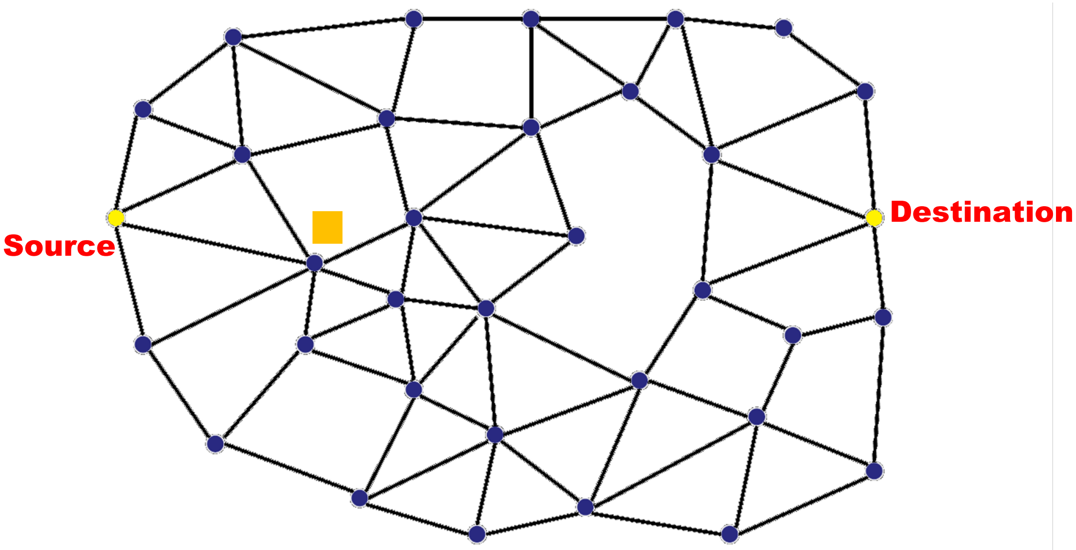
Geographic routing

- Nodes have coordinates of neighbors



GDSTR-3D

- Nodes have coordinates of neighbors
- Node closest to the destination is chosen



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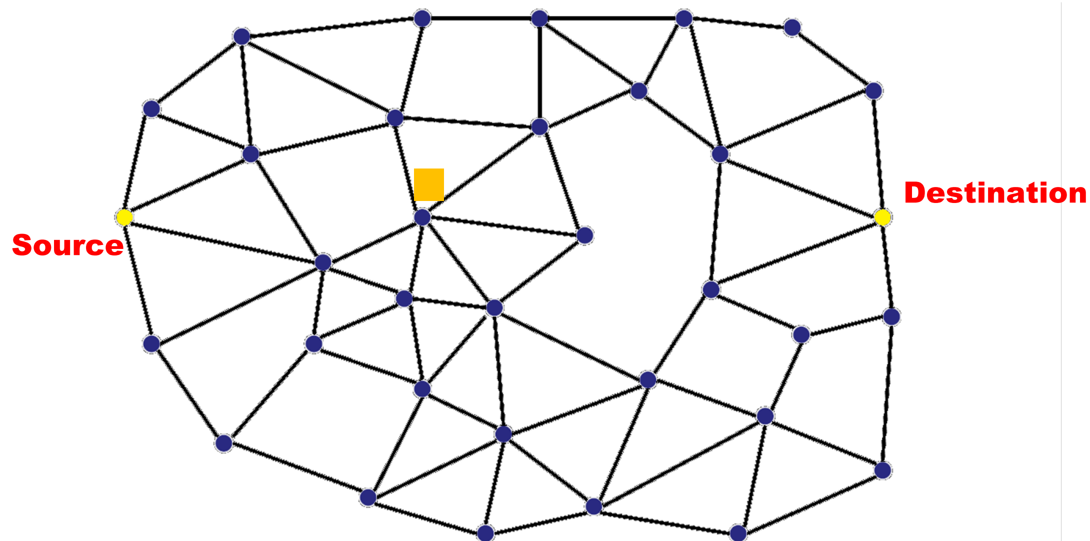

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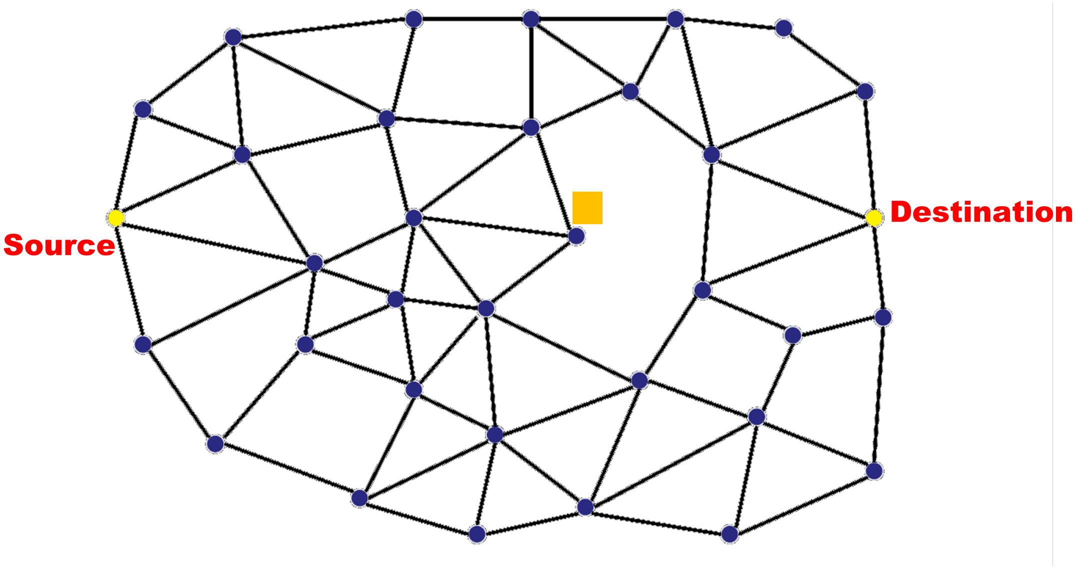


Dead end

- The packet can arrive to a dead end, i.e., a node that does not have any neighbor closest to the destination
- Several techniques have been defined to recover from a dead end but they are often not applicable to dronet
- The topology can change fast

Geographic approach in dronets

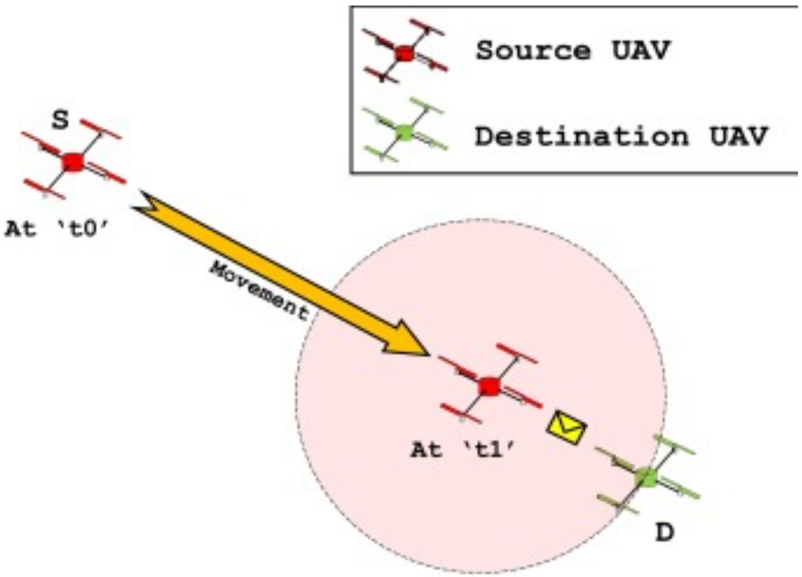
Assume that each **UAV knows its own location** using the GPS device embedded on board or any other means of positioning system

Are based on three main approaches

Store-carry and forward	*Greedy forwarding*	*Prediction*

Store-carry and forward

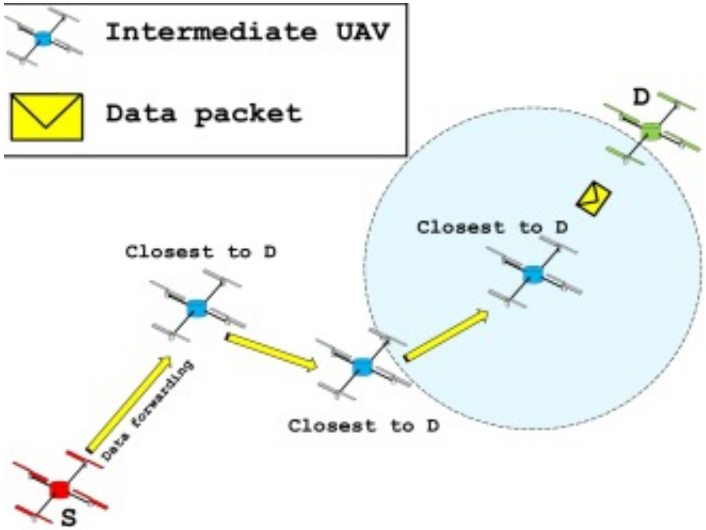
- When the network is intermittently connected, the forwarder nodes do not have any solution to find a relay node
- It is not possible to forward any data packet to a predefined node which does not exist in the trans- mission range
- In this case, the current node tends to **carry the packet until meeting another node or the target destination it- self**



(A) Store-Carry and Forward technique

Greedy forwarding

- The principle is to select the **geographically closest node to the target destination** as a relay node and so on until the packet reaches its destination.
- Drawback: local optimum problem, in which the process is blocked at a node which is considered as the closest to the destination and cannot find any relay nodes to reach it
- a combination of other techniques should be used to en-sure the reliability of this technique

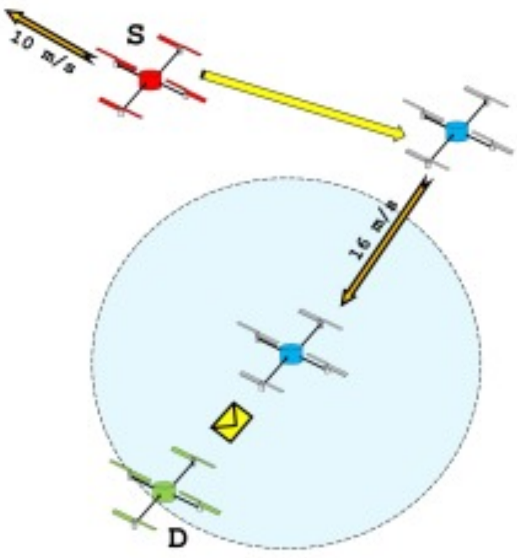


(B) Greedy Forwarding technique

Prediction

- prediction based on the geographical location, direction, and speed, to predict the future position of a given node

- Prediction technique based on **the future geographical location of a next relay node**.



(F) Prediction technique

Conclusions

- Try to think to a routing protocol feasible for dronets

- Our travel through wireless technology is completed
- Next step: make networks intellgent