Challenged Networking and Flying Ad-hoc Networks

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Outline

- Challenge Networks
  - Infrastructure Reliance
  - Basic Definition
  - Examples

- Flying Ad-Hoc Networks
  - Routing Issues
  - Position-based Routing Protocols
  - Routing in 3D networks
  - IoV Simulation

- FANETs as DTNs
  - Smart Aided routing for FANETs
  - Simulation assessment
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- **Challenge Networks**
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Explosion of computing nodes

- Exponential growth of nodes connected to the Internet
  - Continue on its way beyond world's population
  - Mobile connections (including cellular, IoT, ...): **8.9 billions**
- Scalability becomes more crucial
The mobile revolution

- User-generated content model (e.g., Youtube, Facebook)
- Disconnected, distributed data sources
- Access/distribution through infrastructure mediation
However, current infrastructure networks
○ Suffer from an exponential increase of data traffic
○ Lack of a service connectivity
○ A time, not feasible or cost-effective

**Idea:** interaction without *strict* infrastructure reliance
○ Content produced/consumed locally
○ Data temporal/spatial validity compared to global/always on
○ Exploit *ad hoc* connectivity to exchange data

*Opportunistic communication*

**Scope:** military, transportation, environmental monitoring, crisis and disaster management
“Challenged” according to dictionaries: 
*Having disabilities or impairments - Deficient or lacking*

**Challenged networks**
Networks facing challenges because of “disabilities / impairments / deficiencies” (compared to “normal/conventional/usual” networks)

- **Examples of disabilities / impairments / deficiencies**
  - High error rates
  - Asymmetrical bidirectional data rates
  - Intermittent bidirectional end to end path
Challenged Networks: Examples

Outer space networks

- No continuous end-to-end path
  - Planet orbit and rotation
- High delays and prone to errors
  - Long distances

Wireless Sensor Networks

- Collecting ambient information
- Small scale devices
  - Stationary or mobile
Opportunistic Network Examples

- **Vehicular Ad-hoc Networks**
  - Based on Mobile Ad-hoc Networks
  - Nodes move within the constraints of road
  - Rapid topology Changes
    - Short link life
  - Fragmentation
    - Chunks of the net are unable to reach nodes in nearby regions
  - Limited redundancy
    - Critical providing additional bandwidth

- **Flying Ad-hoc networks**
Challenged Networks: Examples

DTN - Delay Tolerant Networks

- Complexity at special nodes of the system
- Asynchronous (*store-and-forward*)
- On-demand, scheduled communication
- Typically *predictable links*
Opportunistic Forwarding

- Enables seamless communication by **hiding discontinuity** of end-to-end channel
- Caching at Road Side Units (RSUs)
- The challenge is:
  - Maximize delivery
  - Minimize latency
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Flying Devices

**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*
In recent years, drones business employs a tremendous growth, with estimates of over 1.5 billion sold by 2015.
Application of drones

40 Uses for Drones
Practical applications for Unmanned Aerial Vehicles

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

Military
- Surveillance
- Targeting
- Cargo transport

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

Civil
- Infrastructure inspection
- Public safety

Business
- Asset management
- Property assessment

Scientific Research
- Environmental monitoring
- Wildlife tracking

Hobby
- Aerial 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

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

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

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.
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, ...)
  - Connects to the Internet / ground team
Differences between MANET and FANET

FANETs 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
Motivation of FANETs

1. Extend the work coverage and range

2. Reliable UAV system and communication

3. Cooperation, sustainability and distributed working
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
Topography-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..
There are some limitations also using these protocols in FANETs, especially with:
- Limited bandwidth
- Limited energy
- Limited memory

Link failures / node failures

Huge amount of control traffic
- Some topology approaches need to flood the request packets
- Much information have to be frequently updated

Topology-based solution are 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 $\rightarrow$ 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 sends 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

a - b - c - d - b - c - d - .......
Performance results in IoV environment

**Topology vs Position**

- NS-2 simulations
- Urban environment
- Vehicles and UAVs
- Realistic scenario

![Delivery Time Graph]

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Smart DTN aided routing for FANETs

- Shift on *Delay Tolerant Network* environment

- *Use of geographic and mobility waypoint information* to help the packet/bundle routing process in Smart DTN.

- Context example: Search and Rescue operations

Each UAV analyzes the planned path of other UAVs to predict their locations.
The message is sent if a UAV is going to reach the vicinity of message's destination.
Good Results

Advantages in terms of delivery ratio and overhead with respect to the other DTN protocols.

Potential and realistic solution

- Many devices are nowadays equipped with a GPS
- Many applications require the vehicle path to be planned

Open Issue

- Still significant delay

Some References