

Wireless Ad Hoc and Sensor Networks

Ad Hoc Networks: History and Open Problems

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What is an ad hoc network?

- **Definitions:**

- An ad-hoc network is one that comes together as needed, not necessarily with any assistance from the existing Internet infrastructure [Perkins01]
- Instant infrastructure [Bagrodia96]
- A MANET is a collection of mobile platforms or nodes where each node is free to move about arbitrarily [Macker98a]
- A MANET: distributed, possibly mobile, wireless, multihop network that operates without the benefit of any existing infrastructure (infrastructure-less), except the nodes themselves [Freebersyser01]

History

- In 1972, DoD-sponsored Packet Radio Network (PRNet)
 - Initial network used centralized control station
 - Evolved into a distributed architecture
 - A network of broadcast radios
 - Minimal central control
 - Use multi-hop store-and-forward routing
 - (used Aloha/CSMA, spread-spectrum, etc throughout 80s)
 - Demonstrated the technologies needed to create a MANET

- In 1983, Survivable Radio Network (SURAN) program. Motivations:

- Move towards smaller size, low-cost, low power radio
- Support more sophisticated radio protocols
- Develop and demonstrate scalable algorithms, up to 10ks of nodes.
- Develop and demonstrate robustness and survivability against sophisticated attacks
- (spread spectrum improvements, hierarchical network topology, dynamic clustering, and even cross-layer design)

- Army (Army Research Office-ARO)

- The army did not embrace the new MANET technology until it was demonstrated experimentally in mid-1980s [Freebersyser01]
- Used it for primarily land-based applications
- Utilized mainly as overlays to existing networks

- **Navy (Office of Naval Research-ONR)**

- Primarily for use by ships at sea [Ephremides87]
- Network is not as dense as a ground network
- Required integration with satellite links
- Now includes a host of well known apps[Baker97]

- **Air Force**

- Explored utilizing aircrafts to provide communications between ground stations

Commercialization

- The community started to adopt the term “Ad-Hoc Networks”
 - commercial applications started to appear
- (Arguably) two conference papers, both addressing the routing problem, helped spur the ad-hoc networks research
 - [Perkins-Bhagwat94, Johnson94]
- A number of standards activities evolved in the mid90s—
- Notably, the MANET working group (within the IETF) to standardize routing protocols for ad hoc networks
 - Reactive and proactive routing
- The 802.11 subcommittee standardized an ad-hoc mode MAC layer
 - Made it possible to build ad-hoc networks using laptops
- Several standards emerged such as HIPERLAN and Bluetooth

Note: check this NIST webpage

<http://www.antd.nist.gov/wctg/manet/adhoclinks.html#ASSOCIATIONS>

Fundamental Challenges

*It is better to know some of the questions
than all of the answers.*

*— James Thurber
(1835-1910)*

1. Scalability

- Whether the network is able to maintain an acceptable level of service even as the number of nodes in the network is increased
- This typically translates to how fast the network protocol control overhead increases as N increases
- Solution approaches:
 - Introducing hierarchy
 - Utilizing location information
 - Limiting reactions to changes
 - Fixing things (e.g. paths) locally

2. Energy Efficiency

- No infrastructure means must rely on batteries (or, in general, limited energy resources)
- Solution approaches:
 - Selectively sending nodes into a sleep mode
 - Using transmitters with variable power (the Power Control problem)
 - Using energy-efficient paths
 - Using co-operative techniques (still relatively new)

3.QoS

- Providing QoS even in wired networks (e.g. the Internet) is a challenging problem
- Wireless RF channels further complicate the problem
 - Unpredictability
 - Medium access
- **Solution approaches:**
 - Cross-layer (vertical-layer) integration (debates): deliberately violate the traditional layering approach to allow different layers to adapt depending on available information at other layers (debates)

4. Robots/Mobility

■ Mobility

■ Controlled e.g. Robots

- Offers opportunities for improving the network functions e.g. connectivity
- But the robot functions are typically tightly coupled
 - Movement and motion planning
 - Decision-making
 - Networking

■ Uncontrolled e.g. Nomadic users

- Offers challenges to network design
- But also offers opportunities for improvement, e.g.
 - Users “carry” delay-tolerant data closer to destination

5.Utilizing new technologies

- What are the gains that could be achieved by using newly available technologies such as
 - Smart directional (beamforming) antennas
 - increases the spatial reuse in cellular, but how about ad-hoc?
 - Can several nodes together act as an antenna array? Practical issues?
 - Software Radio
 - The ability to quickly switch the operating frequency may provide opportunities, but also challenging
 - GPS
 - Location information may help (debate)

6.Security

- From crypto point of view, lack of a trusted authority is one of the main challenges
 - How to generate/share keys reliably Harder to track or even detect attackers in a wireless environment, given that:
 - Network relies on in-situ connections to other nodes which may be malicious
- Malicious nodes may be especially harmful by injecting bogus control packets
- DoS attacks that deplete a node's battery

7.Lack of reference

- Lack of sufficient experimental data to confirm models
 - What does a multi-hop path really mean? What is a link?
- Simplistic models that do not capture the complexities, or complex models that do not lead to insights?
 - We will discuss notable recent success stories later in the course
- Are the protocols good enough, have they reached closed to the best possible?
- Mathematical and Experimental work
 - "A hypothesis or theory is clear, decisive, and positive, but it is believed by no one but the man who created it. Experimental findings, on the other hand, are messy, inexact things, which are believed by everyone except the man who did that work." — *Harlow Shapley (1885—1972)*.
- Debates
 - "Good research generates more questions than answers"

Future

- **Check Start-ups ;-)**
 - Rooftop Communications (now part of Nokia)
 - Mesh Networks
 - Radiant Networks
- **Multi-hop makes more sense than single “long” hop bcoz of:**
 - spatial reuse
 - high bandwidth (high freq & short propagation)
 - Lower energy consumption favors multihop
- **Abundance of comm. Devices**
 - Smaller, cheaper, ubiquitous
 - Makes sense to network them (smart buildings, vehicular traffic, etc.)
- **Unpredictable killer app**
 - W W W appeared after the Internet by 20 years!

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