Ad Hoc Networks: Introduction
Module A.int.1

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Ad Hoc networks: introduction

- Ad Hoc network overview
- Ad Hoc network types
  - Sensor networks
  - Mesh networks
  - MANETs
- Design issues
  - Link layer and MACs
  - Spectrum reuse
  - Routing
  - Crosslayer design
- End of Module A.int.1
Ad-Hoc networks: overview

- Peer-to-peer communications.
- Virtually fully connected
  - Since media is wireless anyway
  - Quality of link varies a lot!
  - Diagram never can be done accurately
Ad Hoc networks: overview

**Characteristics**
- Without using a pre-existing infrastructure
- Wireless
- Mobile (partial)
- Multi-hop
- Ad hoc deployment

**Benefits**
- Easy and fast deployment
- Eliminating dependency on infrastructure
Ad Hoc networks: overview

Applications

- **PAN**
  - Personal area networking, connecting with cell phones, laptop, wrist watch, etc

- **Military environments**
  - Tanks, soldiers, planes, battlefield communications

- **Emergency operations**
  - Rescue, fire fighting
  - Surveillance

- **Civilian environments**
  - Town hall meeting
  - Gathering, convention
**Multi-hop**

- From source to destination
  - May need to traverse multiple hops
  - Every node capable of forwarding
  - Require routing algorithms

- Impacts on **MAC**
  - Multi-hop aware **MAC**
Assumptions and variations

Symmetric or asymmetric?

- All nodes have identical capabilities & responsibilities
- Or capacity variations in
  - Transmission ranges & bandwidth
  - Battery life
  - Mobility & its speed
  - Processing capacity
- Or capacity variation in
  - Elected as a leader
  - Routing and forwarding packets
  - Co-exist or co-operate with an infrastructure-based network
Assumptions and variations

- Variation with infrastructures
  - Coexistence with an infrastructure if any

- Variations in traffic characteristics
  - Bit rate
  - Realtime or data oriented
  - Unicast/multicast/geocast
  - Addressing (host, content, capability)

- Variation in mobility
  - Link failure/repair due to mobility may have different characteristics than those due to other causes
  - Rate of link failure/repair may be high when nodes move fast
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Ad hoc special: sensor networks

- Ad hoc → sensor networks
  - Node equipped with sensing capability
  - Node are severely power constrained
  - Applications are most likely data driven
    → a large collection of tiny sensor devices

- Limited resource with sensors
  - Power, processing, storage, communication

- Deployment in harsh environments
  - Self-organize, self-healing
Ad hoc special: mesh networks

- Ad hoc $\rightarrow$ mesh networks
  - Rapidly deployable wireless infrastructure
  - Largely immobile nodes or stationary nodes
Ad hoc special: MANETs

- Ad hoc → MANET
  - Highly mobile nodes
  - Mobility causes route changes
Ad hoc special: MANETs

IEFT MANET Working Group

- to standardize an interdomain unicast routing protocol which provides one or more modes of operation, each mode specialized for efficient operation in a given mobile networking “context”, where a context is a predefined set of network characteristics.
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Design issues

- Link layer design
- Channel access and frequency reuse
- Reliability
- Routing
- Network issues
- Power/energy management
Link layer design

- Modulation and Coding
  - Robustness
  - Rate requirements
  - Performance
  - Adaptive techniques: rate, power, BER, code, framing, etc.

- Power control

- Multiuser Detection

- Antenna design
  - Smart antennas and MIMO.
MAC design

- Nodes need a decentralized channel access method
  - Minimize packet collisions while increasing channel utilization
    - Collisions cause significant delay
- Aloha w/ CSMA/CD have hidden/exposed terminals

- 802.11 uses four-way handshake
  - Creates inefficiencies, especially in multihop setting
Design issues

- Scalability issues
- Tradeoff
  - energy consumption vs. latency
- Standard issues
  - protocol deployment and incompatibility standards
- Security issues
Spectrum reuse

- Static channel allocation, multiple channels
  - Poor connectivity

![Diagram of network with nodes and connections](image)
Spectrum reuse

- Static channel allocation, single channel
  - Poor interference
Spectrum reuse

- Dynamic channel allocation, single interface
  - Good Connectivity and Controlled Interference
Spectrum reuse

- Dynamic channel allocation, multiple interfaces
- Complicated control
Ad hoc routing

AD-HOC MOBILE ROUTING PROTOCOLS

TABLE DRIVEN/PROACTIVE
- DSDV
- CGSR

ON-DEMAND-DRIVEN REACTIVE
- HYBRID
- DSR
- AODV
- ZRP
Ad hoc routing

- **Flooding, broadcast-based**
  - Inefficient
  - Robust for fast changing topologies.
  - Little explicit overhead

- **Point-to-point routing**
  - Routes follow a sequence of links
  - Connection-oriented
    - Explicit end-to-end connection
    - Less overhead/less randomness
    - Hard to maintain under rapid dynamics.
  - Connectionless
    - Packets forwarded towards destination
    - Local adaptation
Ad hoc routing

Table-driven
- Destination-sequenced distance-vector
- Clusterhead gateway switch routing
- Wireless routing protocol

On-Demand Routing
- On-demand distance vector routing
- Dynamic source routing
- Temporally ordered routing
- Associativity-based routing
- Signal stability routing
Ad hoc routing

Proactive Routing Protocol:
- continuously evaluate the routes
- attempt to maintain consistent, up-to-date routing information
  - when a route is needed, one may be ready immediately
- when the network topology changes
  - the protocol responds by propagating updates throughout the network to maintain a consistent view

Reactive Routing Protocol:
- on-demand
- Ex: DSR, AODV
Ad hoc route dissemination

Route computed at centralized node
- Most efficient route computation.
- Can’t adapt to fast topology changes.
- BW required to collect and disseminate information

Distributed route computation
- Nodes send connectivity information to local nodes.
- Nodes determine routes based on this local information.
- Adapts locally but not globally.

Nodes exchange local routing tables
- Node determines next hop based on some metric.
- Deals well with connectivity dynamics.
- Routing loops common.
Reliability

- Packet acknowledgements needed
  - May be lost on reverse link
  - Need negative ACKs?

- Combined ARQ and coding
  - Retransmissions cause delay
  - Coding may reduce data rate

- Hop-by-hop acknowledgements
  - Explicit ACKs
  - Echo ACKs
    - Transmitter listens for forwarded packet
    - More likely to experience collisions than a short ACK.
  - Hop-by-hop or end-to-end or both.
Crosslayer design

- Application
- Network
- Access
- Link/MAC
- Hardware

Delay Constraints
Rate Requirements
Energy Constraints
Mobility

Optimize and adapt across design layers
Provide robustness to uncertainty
Crosslayer design?

The technical challenges of future mobile networks cannot be met with a layered design approach.

QoS cannot be provided unless it is supported across all layers of the network.

- The application must adapt to the underlying channel and network characteristics.
- The network and link must be application aware.

Interactions across network layers must be understood and exploited.
Summary

- Ad-hoc networks provide a flexible network infrastructure for many emerging applications.
- Advances in communication techniques should be incorporated into ad-hoc network design.
- Design issues traverse all layers of the protocol stack, and cross-layer designs are needed.
  - Protocol design in one layer can have unexpected interactions with protocols at other layers.
- Many new issues to be addressed.
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