Mobile Wireless Networking
The University of Kansas EECS 882
Mobile Ad Hoc Networks

James P.G. Sterbenz
Department of Electrical Engineering & Computer Science
Information Technology & Telecommunications Research Center
The University of Kansas

jgps@eeecs.ku.edu

http://www.ittc.ku.edu/~jgps/courses/mwnets
Mobile Wireless Networking
Mobile Ad Hoc Networks

AH.1  Motivation and application
AH.2  Architecture, challenges and issues
AH.3  Self-organisation
AH.4  Routing overview
AH.5  Autonomic control and self-management
Mobile Ad Hoc Networks
AH.1 Motivation and Application

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AH.2 Architecture, challenges and issues
AH.3 Self-organisation
AH.4 Routing overview
AH.5 Autonomic control and self-management
Mobile Ad Hoc Networks

Introduction

- **Mobile ad hoc network** (MANET)
  - mobile: node and groups of nodes move
  - wireless: mobility implies mostly wireless links
  - ad hoc: little or no reliance on network infrastructure
    - from Latin: *for this* (purpose)

- Ad hoc network
  - generalisation of mobile ad hoc network
    - nodes need not be mobile
    - but are typically wireless: e.g. fixed wireless mesh network
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Introduction: MANET

- **MANET**: mobile ad hoc network
  - rhymes with “planet” but accent on 2nd syllable
  - many people pronounce as French painter Édouard Manet

- **MANET** can be used in two senses
  - mobile ad hoc network, in general
  - IETF MANET working group protocols

  - AODV ad hoc on demand distance vector [RFC 3651]
  - DSR dynamic source routing [RFC 4728]
  - OLSR optimized link state routing [RFC 3626]
  - TBRPF topology broadcast based on RPF [RFC 3684]
  - and other work in progress (NHDP, DYMO, SMF)
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Motivation

- Untethered operation
  - requires mobile and wireless
  - same motivation as for WLANs and mobile cellular telephony

- Ubiquitous communication
  - precludes dependence on infrastructure
    - physical infrastructure, e.g. base stations
    - protocol infrastructure, e.g. name servers, topology databases
  - infrastructure may be used when available
    - e.g. gateway from MANET to Internet or PSTN
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Applications

Applications for MANETs?
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Applications

• Local communication when infrastructure unavailable
  – shielded environments
    • caves, faraday cages in corporate and defense facilities
  – remote environments; infrastructure economically infeasible
    • research and rescue in mountains, Arctic and Antarctic
  – disaster and emergency network (re)deployment
  – military operations in hostile environments
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Applications

• Local communication when infrastructure unavailable
  – shielded environments
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• Highly mobile groups
  – communication among vehicles
    • VANETS: vehicle ad hoc nets
  – tactical military networks
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AH.2 Architecture, Challenges and Issues

AH.1 Motivation and application
AH.2 Architecture, challenges and issues
AH.3 Self-organisation
AH.4 Routing overview
AH.5 Autonomic control and self-management
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Background: Review of Wireless Network Types

- Wireless Internet: WLANs, WANs, and mobile IP
- Mobile cellular telephony
- MANETs: mobile ad hoc networks
MANET Background

Wireless Internet

- **Wireless Internet**
  - *wireless nodes* use
  - *base station* or *access point*
  - connected to wired Internet perhaps *multihop wireless mesh*

*Relationship to MANETs?*
**MANET Background**

**Wireless Internet**

- wireless nodes use
- base station or access point
- connected to wired Internet perhaps multihop wireless mesh

**Relationship to MANETs**

+ support untethered communication: wireless access links
+ limited mobility possible if mobile IP deployed

*problems?*
MANET Background

Wireless Internet

- **Wireless Internet**
  - wireless nodes use
  - base station or access point
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- **Relationship to MANETs**
  + support untethered communication: wireless access links
  + limited mobility possible if mobile IP deployed
  - *infrastructure required*: APs or BSs
  - *no peer-to-peer communication*
MANET Background
Mobile Cellular Telephone Network

- Mobile cellular telephone network
  - network divided into cells
  - covered by *base stations*
  - cells interconnected to PSTN by *mobile switching centers*
  - *mobile terminals* move among cells

*Relationship to MANETs?*
MANET Background
Mobile Cellular Telephone Network

• Mobile cellular telephone network
  – network divided into cells
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• Relationship to MANETs?
  + support for mobility and roaming among providers

problems?
MANET Background
Mobile Cellular Telephone Network

- Mobile cellular telephone network
  - network divided into cells
  - covered by base stations
  - cells interconnected to PSTN by mobile switching centers
  - mobile terminals move among cells

- Relationship to MANETs?
  + support for mobility and roaming among providers
    - *infrastructure required*: BSs and MSCs
    - *no peer-to-peer communication*
    - *not originally designed for data*
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Requirements

- Untethered operation
  - *wireless* links
  - provided by Wireless Internet and mobile telephony
Mobile Ad Hoc Networks

Requirements

- Untethered operation
  - *wireless* links
  - provided by Wireless Internet and mobile telephony

- Nomadic operation
  - *mobility* support
  - provided by mobile telephony
  - limited support provided by mobile IP
    - but rarely deployed

*What else?*
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Requirements

- Untethered operation
- Nomadic operation
- Non-dependence on infrastructure
  - may use when available to improve service
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Requirements

- Untethered operation
- Nomadic operation
- Non-dependence on infrastructure
- Arbitrary data communication
  - peer-to-peer
  - group communication (multicast, broadcast)
  - multihop: nodes are both ES and IS
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Requirements

• Untethered operation
• Nomadic operation
• Non-dependence on infrastructure
• Arbitrary data communication
• Management of constrained resources Lecture EM
  – energy, bandwidth, processing, memory
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Requirements

- Untethered operation
- Nomadic operation
- Non-dependence on infrastructure
- Arbitrary data communication
- Management of constrained resources  Lecture EM
- Resilience and security  Lecture RS
  - unreliable open channel
Mobile Ad Hoc Networks
MANET Architecture

- Mobile ad hoc networks
  - *mobile nodes* communicate with one another
  - PDAs, laptops, vehicles
Mobile Ad Hoc Networks

MANET Architecture

- Mobile ad hoc networks
  - mobile nodes communicate with one another
    - PDAs, laptops, vehicles
  - MNs relay *multihop* when necessary
Mobile Ad Hoc Networks

MANET Architecture

- Mobile ad hoc networks
  - mobile nodes communicate with one another
    - PDAs, laptops, vehicles
  - MNs relay multihop when necessary
  - without the need for infrastructure
Mobile Ad Hoc Networks
MANET Architecture

- Mobile ad hoc networks
  - mobile nodes communicate with one another
    - PDAs, laptops, vehicles
  - MNs relay multihop when necessary
  - without the need for infrastructure
    - infrastructure used when available
      - *access gateway* to Global Internet
      - directory and security servers
Mobile Wireless Networking
AH.3 Self-Organisation

AH.1 Motivation and application
AH.2 Architecture, challenges and issues
AH.3 Self-organisation
  AH.3.1 Auto-configuration
  AH.3.2 Self-organisation
AH.4 Routing overview
AH.5 Autonomic control and self-management
Mobile Ad Hoc Networks

Implications of No Infrastructure

- MANETs need to operate without infrastructure 
  \textit{implication}?
Mobile Ad Hoc Networks
Implications of No Infrastructure

- MANETs need to operate without infrastructure
  - nodes must configure themselves
  - nodes must organise themselves into networks

Challenges?
Mobile Ad Hoc Networks

Challenges

- MANETs need to operate without infrastructure
  - nodes must configure themselves
  - nodes must organise themselves into networks

- Challenges
  - fully distributed system with inconsistent information
  - weak and episodic connectivity: stale information
  - mobility: dynamically changing information
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AH.3 Self-Organisation

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  AH.3.1 Auto-configuration
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Auto-Configuration

- Nodes must be configured for a particular network
  - physical layer: frequency, coding, bandwidth, ...
  - MAC layer: type and parameters
  - link layer: protocol, error control, ...
Mobile Ad Hoc Networks
Auto-Configuration

• Nodes must be configured for a particular network
  – physical layer: frequency, coding, bandwidth, ...
  – MAC layer: type and parameters
  – link layer: protocol, error control, ...
  – network layer: (preliminary) addresses

• Auto-configuration: nodes configure themselves
  – without human interaction
  – without depending on infrastructure
    how?
Mobile Ad Hoc Networks
Auto-Configuration Techniques

• Auto-configuration: nodes configure themselves
  – reasonable defaults
  – context-based
    • sensing environment
    • may use infrastructure if available
  – policy driven
    • may be guided by human
Mobile Ad Hoc Networks
Auto-Configuration Techniques

• Auto-configuration: nodes configure themselves
  – reasonable defaults
  – context-based
    • sensing environment
    • may use infrastructure if available
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    • may be guided by human

• Configured nodes do not a network make

*what’s next?*
Mobile Wireless Networking
AH.3  Self-Organisation

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   AH.3.1  Auto-configuration
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Mobile Ad Hoc Networks
Self-Organisation

- Configured nodes must be organised into a network
  - pairwise link agreement to form L2 structures
    - may modify auto-configuration of L1 – L2 parameters
  - network topology and federation to form L3 structures
    - will likely modify any preliminary node addresses
Mobile Ad Hoc Networks
Self-Organisation

- Configured nodes must be organised into a network
  - pairwise link agreement to form L2 structures
    - may modify auto-configuration of L1 – L2 parameters
  - network topology and federation to form L3 structures
    - will likely modify any preliminary node addresses

- **Self-organisation**: nodes organise themselves
  - without human interaction
  - without depending on infrastructure such as DHCP and DNS
    *how?*
Ad Hoc Self-Organisation

Steps

- Neighbour discovery
- Link formation
- Self-organisation
- Topology optimisation and maintenance
Ad Hoc Self-Organisation

Set of Nodes

• Set of nodes to self-organise
Ad Hoc Self-Organisation

Neighbour Discovery

• Nodes emit beacons to announce their presence
  – known frequencies and codes used for announcements
  – part of auto-configuration

• Establishes set of directly reachable nodes

*should all pairs form links?*
Ad Hoc Self-Organisation
Link Formation

- Pairwise negotiation of link formation
  - constrained by maximum degree
  - interested nodes answer beacons
Ad Hoc Self-Organisation

Link Formation

• Pairwise negotiation of link formation
  – constrained by maximum degree
  – interested nodes answer beacons
  – exchange identification, node and link characteristics
  – agree on variable physical, MAC, and link parameters

• Forms layer 2 connectivity structure
Ad Hoc Self-Organisation
Link Formation

- Maintain link adjacencies
  - e.g. keepalive messages
  - discard links to unreachable nodes
  - add links to new nodes in range
- Maintains layer 2 connectivity structure
Ad Hoc Self-Organisation
Link Formation

• Layer 2 connectivity structure built and maintained

*what’s next?*
Ad Hoc Self-Organisation

Link Formation

- Layer 2 connectivity structure built and maintained
  - but we need a network with the ability to route and forward
  - we may need hierarchy to manage scalability
Ad Hoc Self-Organisation
Self-Organisation and Federation

• Communicating nodes self-organise into federations
  – network-layer address acquisition and agreement
  – bootstrap routing topology

unlimited size of federations?
Ad Hoc Self-Organisation
Self-Organisation and Federation

- Communicating nodes self-organise into federations
  - network structure
    - small networks can be flat (10s to perhaps 1000s of nodes)
    - large networks need hierarchical structure of clusters

how formed?
Ad Hoc Self-Organisation

Self-Organisation and Federation

- Clustering algorithm requirements
  - efficiency measured in message complexity
  - efficiency measured in time to form cluster
Ad Hoc Self-Organisation

Self-Organisation and Federation

• Clustering algorithm objectives
  – cluster size (number of nodes), e.g. expanding ring search
  – cluster diameter (maximum length of shortest path)
  – policy-driven constraints
    • e.g. don’t cluster with a bad guy
Ad Hoc Self-Organisation
Self-Organisation and Federation

• Hierarchical network structure
  – lowest level: clusters of physical nodes
  – higher levels: clusters of clusters

*how?*
Ad Hoc Self-Organisation

Self-Organisation and Federation

• Hierarchical network structure
  – each cluster may have a leader or cluster head
  – leader is abstraction for entire cluster to higher level
Ad Hoc Self-Organisation
Self-Organisation and Federation

- Hierarchical network structure
  - each cluster may have a leader or cluster head
  - leader is abstraction for entire cluster to higher level
  - level $n$ clusters are virtual nodes in level $n+1$ cluster
Ad Hoc Self-Organisation

Self-Organisation and Federation

- Hierarchical network structure: cluster selection
  - determined by role (e.g. personal node in a PAN)
  - leader election by distributed algorithm (most common)
  - leaderless clustering: fully distributed operation
Ad Hoc Self-Organisation
Self-Organisation and Federation

- Layer 3 connectivity structure self-organised

*what about mobility and dynamic behaviour*?
Ad Hoc Self-Organisation

Topology Optimisation and Maintenance

- Topology maintenance of federations
  - merge/split
    - group mobility, dynamic coalitions
  - heal partition
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Topology Optimisation and Maintenance

- Topology maintenance of nodes
  - leave/join from/to federation
    - node mobility
  - resolution to identifier vs. topological address reassignment
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AH.4 Routing Overview

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Mobile Ad Hoc Networking
Routing Challenges

- Routing algorithm discovers path
  - between source(s) and destination(s)
Mobile Ad Hoc Networking
Routing Challenges

- Routing algorithm discovers path
  - between source(s) and destination(s)
- Routing algorithm classes
  - distance vector (e.g. RIP)
  - link state (e.g. OSPF, ISIS)
  - source routing

**Challenges in MANETs?**
Mobile Ad Hoc Networking
Routing Challenges

- Routing algorithm discovers path
  - between source(s) and destination(s)
- Routing algorithm classes
  - distance vector (e.g. RIP)
  - link state (e.g. OSPF, ISIS)
  - source routing
- Challenges in MANETs
  - episodic connectivity and mobility
  - routes and link state keeps changing
  - difficult or impossible to maintain consistent information
- Conventional DV and LS algorithms do not work well
Mobile Ad Hoc Networking
Routing Algorithm Examples

• Many proposals *Lecture MR*
  – many within the IETF MANET working group
  – specialised domains: e.g. supersonic military aircraft

• Examples:
  – DSDV: destination-sequenced distance vector
  – AODV: ad hoc on-demand distance vector
  – OLSR: optimized link state routing protocol
  – DSR: dynamic source routing
Mobile Ad Hoc Networking
Routing Algorithm Examples

• Many proposals *Lecture MR*
  – many within the IETF MANET working group
  – specialised domains: e.g. supersonic military aircraft

• Examples:
  – AODV: ad hoc on-demand distance vector
  – DSR: dynamic source routing

• Problem:
  – no one protocol can possibly be right for all scenarios
  – adaptive framework needed to negotiate protocols
    • part of self-organisation and federation
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AH.5  Autonomic Control and Self-Management

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Introduction

• In the current Internet:
  – network control is poorly understood
  – network management is a dark art
  – already exceeding the ability for humans to understand
Ad Hoc Control & Management

Introduction

• In the current Internet:
  – network control is poorly understood
  – network management is a dark art
  – already exceeding the ability for humans to understand

• In large-scale MANETs:
  – problem is significantly worse
  – dynamic behaviour
  – distributed ownership and management of resources
Autonomic Control & Management

Motivation

• Large-scale MANET control and management
  – seems to require autonomic mechanisms

• Autonomic network management and control: self-*
  – auto-configuration
  – self-organisation
  – self-management
  – self-diagnosis and repair
  – ...

• Significant extension to self-organisation
  – very hard research problem
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Further Reading

Mobile Ad Hoc Networks

Acknowledgements

Some material in these foils is based on the textbook

- Murthy and Manoj,

  *Ad Hoc Wireless Networks: Architectures and Protocols*

Some material in these foils enhanced from EECS 780 foils