

Self-Organizing Networks: A Choice of Last Resort?

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Overview

- **Background on Mobile Ad hoc Networking**
- **The Promise of MANET**
- **Its Present Limitations**
- **Applicability to Disaster Relief?**
- **Status of IETF MANET Proposals**

MANET (1832-1883) ;-)



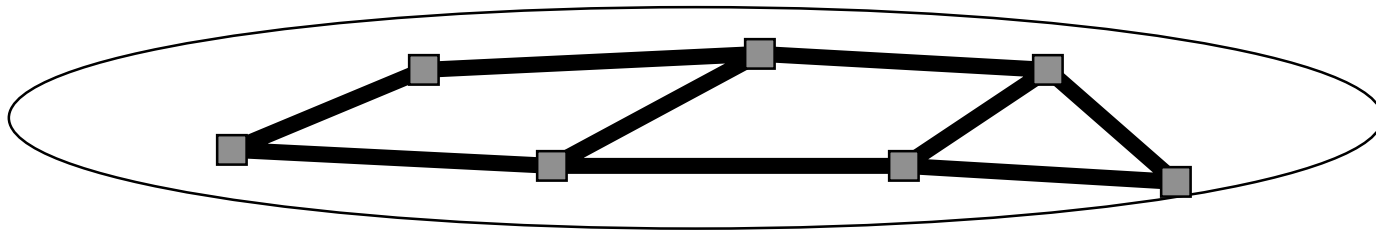
Edouard Manet

“Father of Impressionism”
whose work influenced

- ◆ Edgar Degas
- ◆ Claude Monet
- ◆ Auguste Renoir
- ◆ Alfred Sisley
- ◆ Camille Pissarro
- ◆ Paul Cézanne



The Fixed Internet...

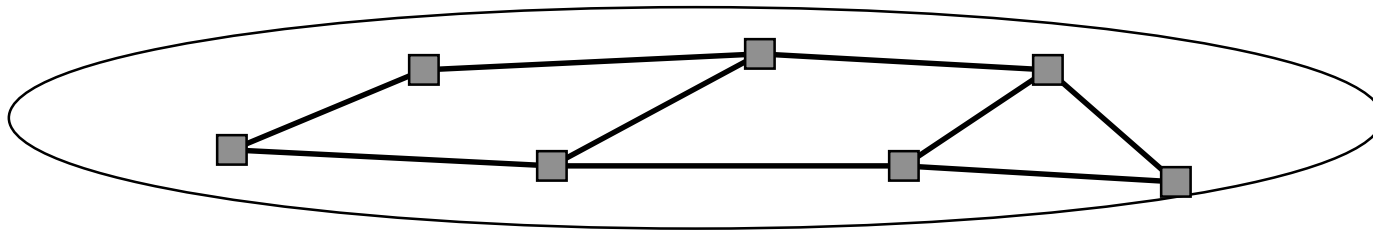


Salient Characteristics:

- ◆ relatively static topology
- ◆ routers are processing/memory-constrained
 - ◆ potentially lots of unfilled bandwidth (fiber)
- ◆ no energy problem

...as compared with MANETs

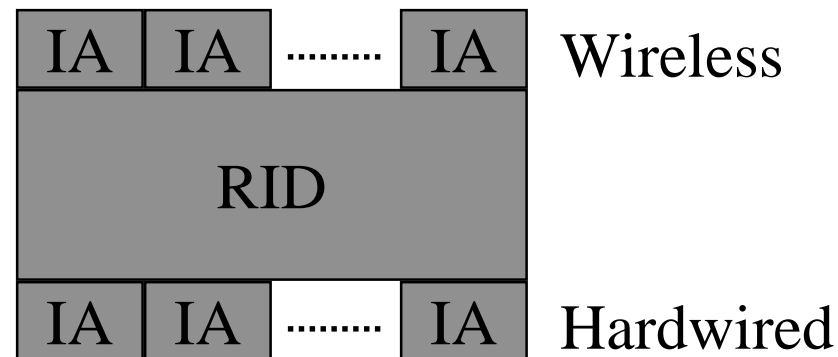
MANETs are mobile, multihop, wireless networks



Salient Characteristics:

- ◆ **potentially dynamic topology**
- ◆ **bandwidth-constrained operation**
 - ◆ **relatively larger amount of available cycles/memory**
- ◆ **possibly energy-constrained as well**
- ◆ **limited physical security**

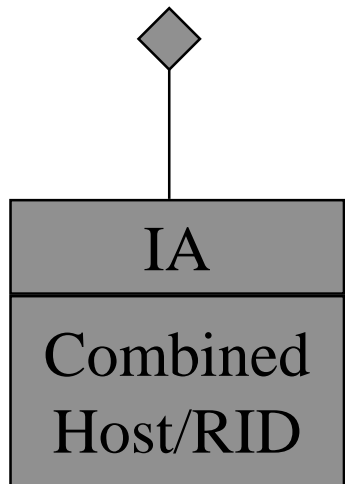
Generic MANET Router



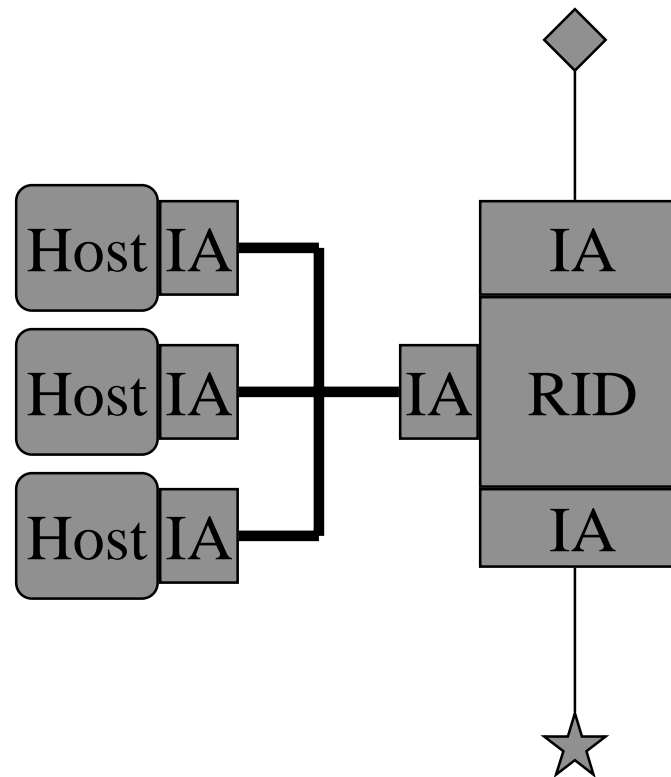
RID: Router Identifier

IA: Interface Address

Two Example MANET Nodes

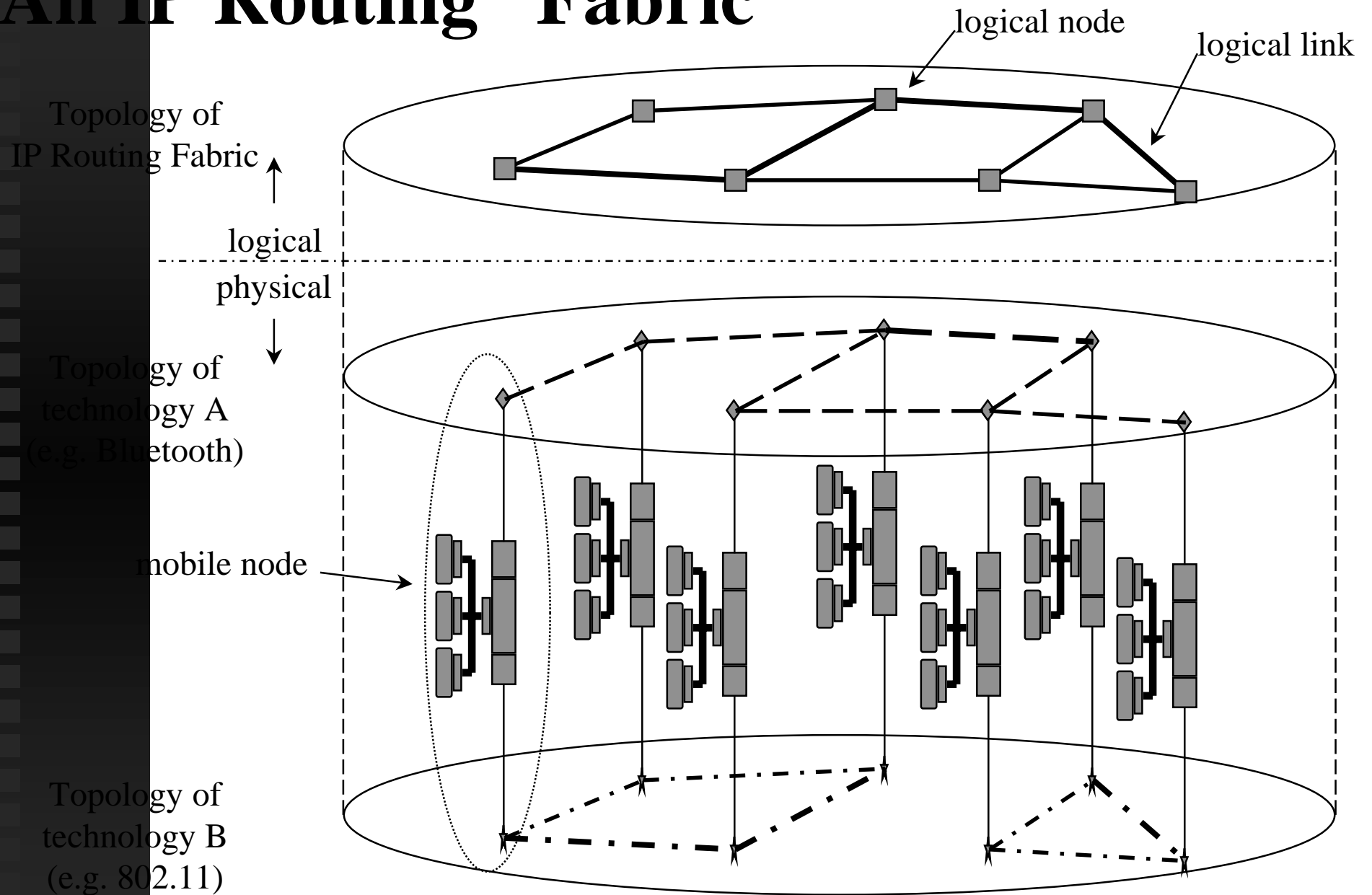


Laptop-based Host
(acting as a router)



Router with two wireless interfaces
and one hardwired interface to a subnet

An IP Routing "Fabric"



Why an “Internet Layer” Solution?

(as opposed to subnet-based, MAC-level addressing and routing?)

- **Same as the original concept of the Internet**

“to develop a homogeneous networking capability over a heterogeneous networking infrastructure”

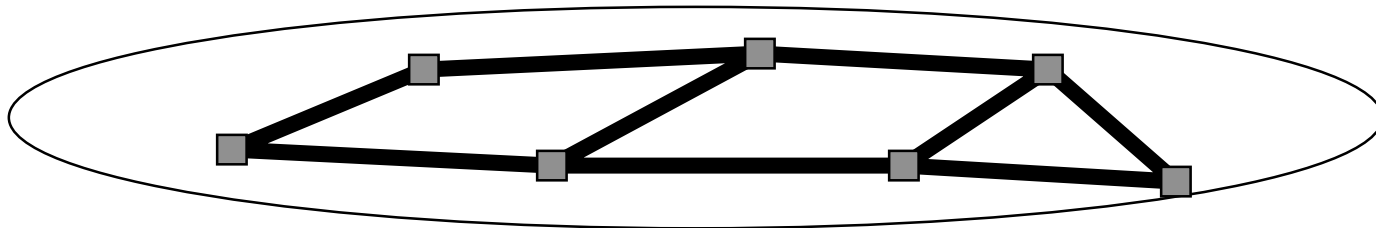
- **Wireless, rather than hardwired**

- ◆ **multiple communications technologies**

- **Cost effectiveness**

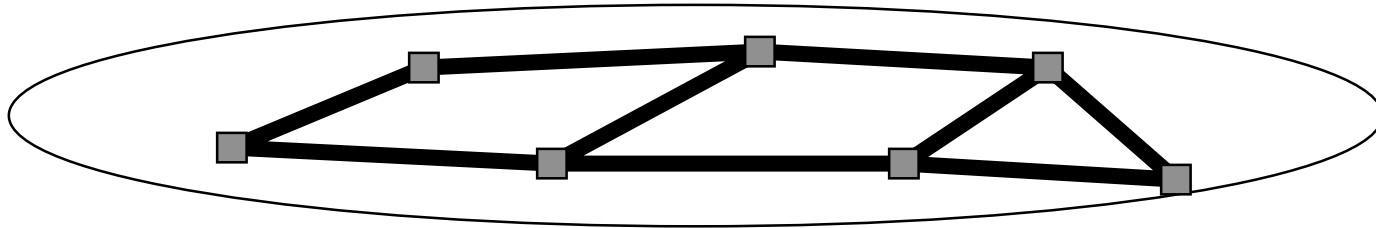
- ◆ **link layer technologies keep changing**

The Promise of MANET...



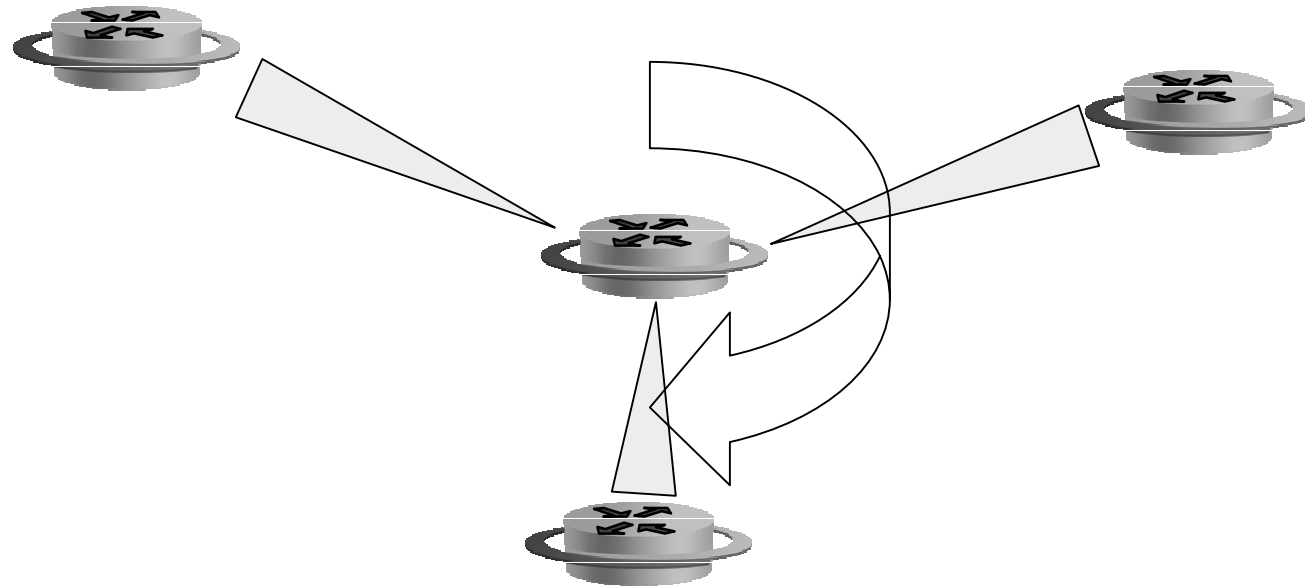
- **Plug n' play Networking**
- **Ubiquitous Computing**
- **Instant Infrastructure**
- **Unregulated Free Communications**
 - ◆ **Like Gnutella, but for wireless networking ;-)**

Its limitations...



- **Routing (difficult)**
- **Address Auto-configuration (worse)**
- **Security (impossible?)**
- **Location Management (Mobile IP makes me cry)**
- **Quality of Service (don't even try! ;-)**
- **Capacity (very sad)**

Omni-Bcast vs. Point-to-point



- **Are steerable beams feasible?**
 - ◆ **Fixed network: probably**
 - ◆ Net increase in capacity
 - ◆ **Mobile: this is seriously being questioned**

Omni-QoS

- **What can be done?**

- ◆ **DiffServ-based**

- ◆ Well-suited for mobility, data traffic dynamics
 - ◆ Relative QoS based on DSCP packet markings
 - ◆ PHBs other than simple priority difficult to enforce in multi-hop broadcast channel

- ◆ **IntServ-based**

- ◆ Well-suited for fixed ad hoc networks, CBR traffic
 - ◆ Effectively circuit-like in operation
 - ◆ Slower to adapt, but QoS predictable under heavier loads

Distributed TDMA Scheduling Protocols (FPRP & E-TDMA)

(joint work with Chenxi Zhu)

- **Objective**

- ◆ **Assign conflict-free TDMA slots in MANET with distributed protocols**

- **Difficulty**

- ◆ **Lack of fixed infrastructure**
- ◆ **Network could be large or dynamic**
- ◆ **Frequent topology change**

Our Approach to Scheduling

- **Generate TDMA schedules quickly**
- **Use contention to generate transmission schedules**
 - ◆ **Contention only involves nearby nodes**
 - ◆ **Many nodes can reserve slots simultaneously**
- **Problems of using contention**
 - ◆ **Lack of central controller**
 - ◆ **Hidden node problem**

Five-Phase Reservation Protocol

- **Objective**

- ◆ **Quickly generate broadcast schedules**

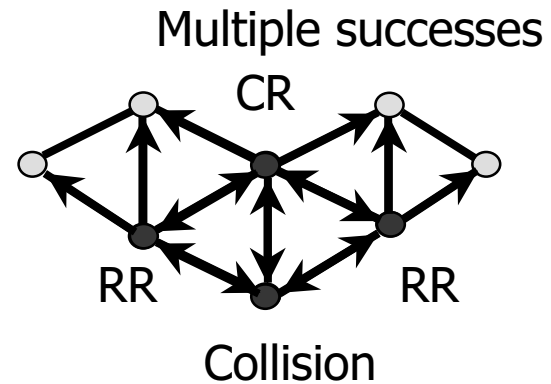
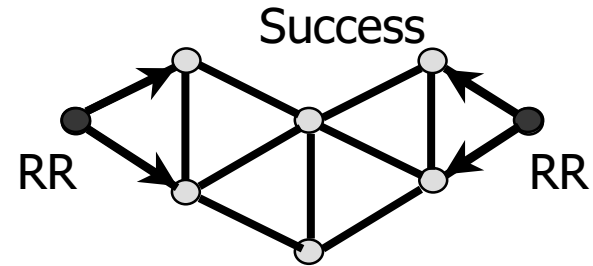
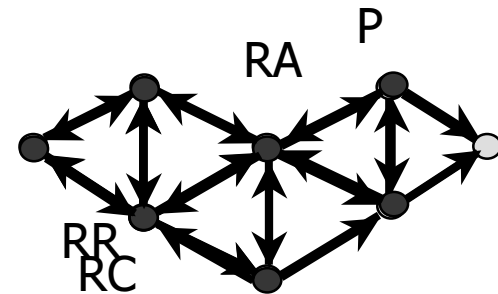
- **Solution**

- ◆ **Nodes contend for slot reservation with a new, five-phase conversation scheme**
- ◆ **Schedule of whole network is generated collectively**

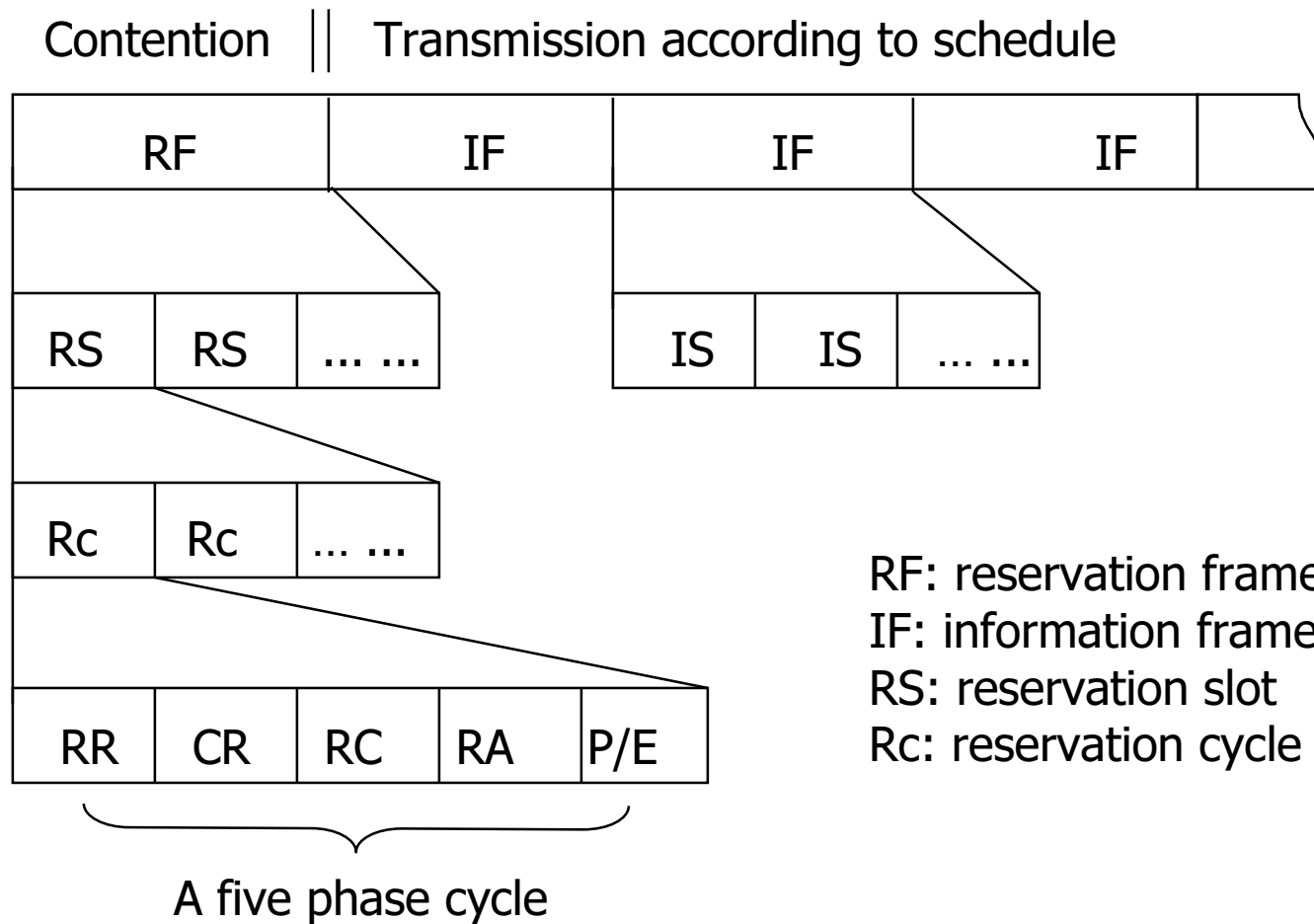
Five Phase Conversation



- **RR: Reservation Request**
- **CR: Collision Report (NACK)**
- **RC: Reservation Confirmation**
- **RA: Reservation Acknowledgment**
- **P/E: Packing/Elimination**

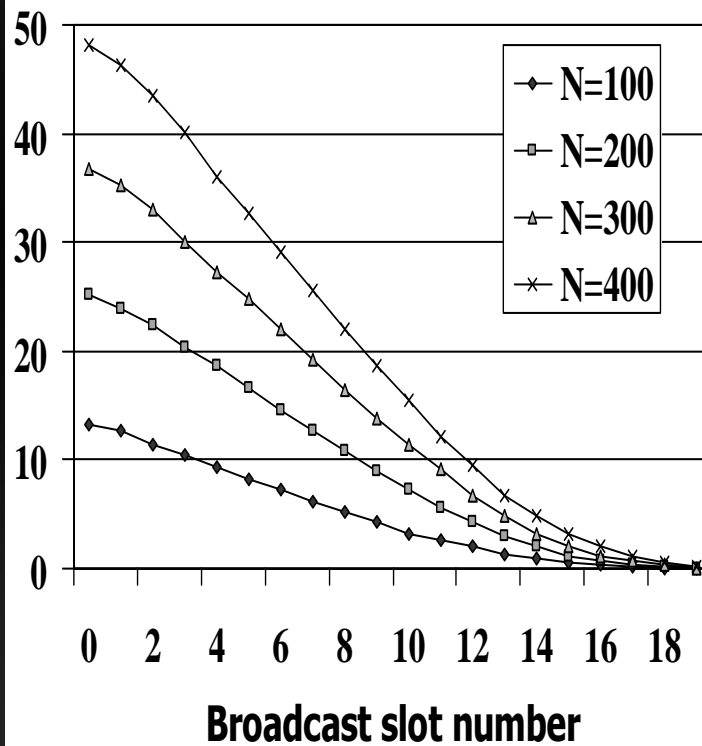


FPRP Frame Structure

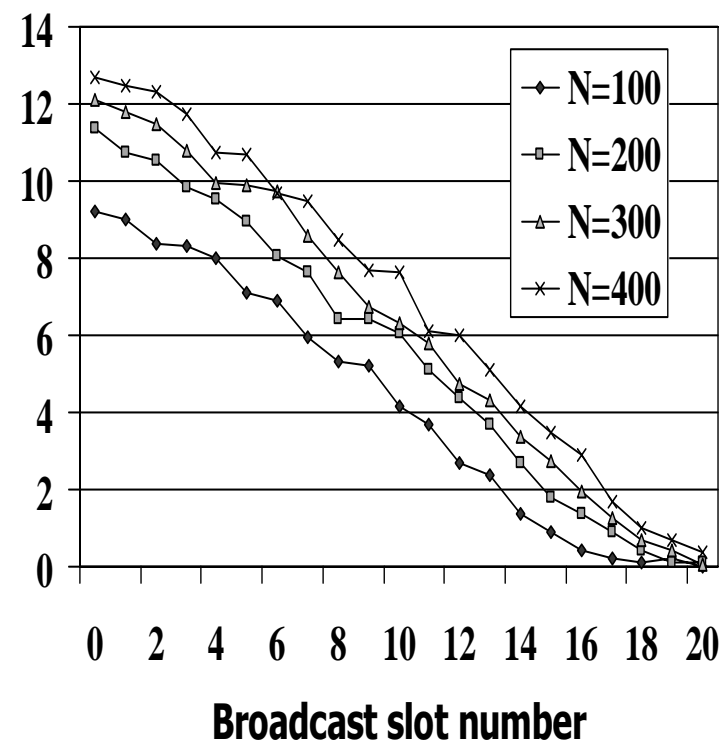


Simulation Results

Assigned node



Number of cycles



E-TDMA protocol

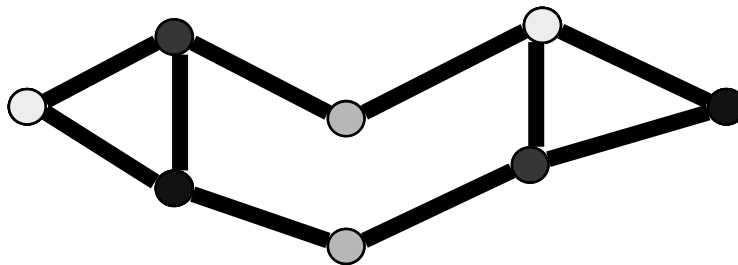
- **Objective**

- ◆ **Generate uni/multi/broadcast transmission schedules under mobility**

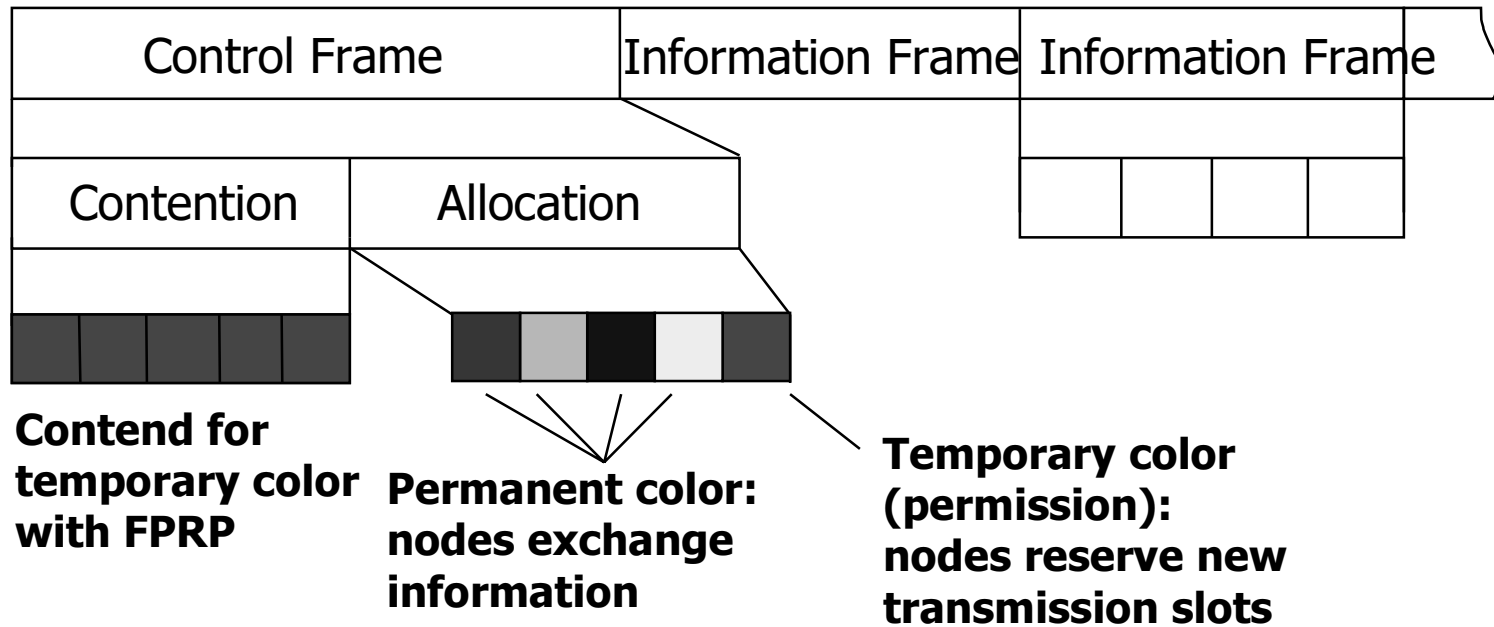
- **Solution**

- ◆ **Update schedules incrementally**
- ◆ **Use FPRP for signaling in order to be scalable**

E-TDMA Frame Structure



- ◆ Spatial reuse
- ◆ Temporal ordering



E-TDMA: an example

Control schedule

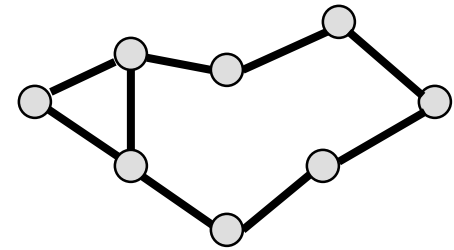
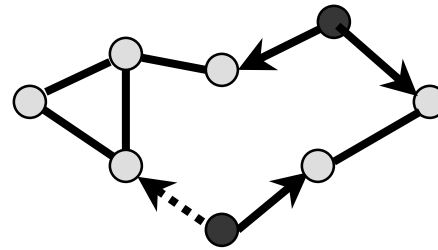
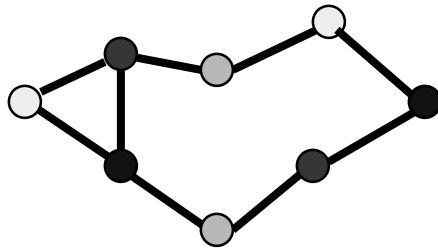


User schedule

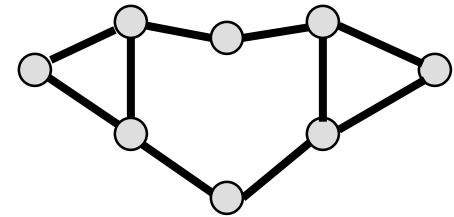
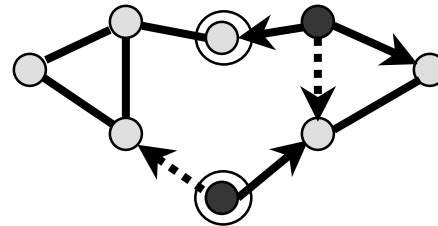
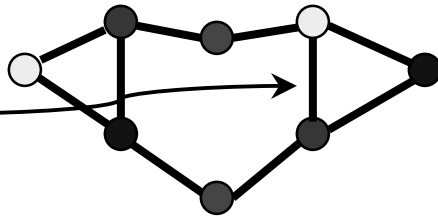
slot1

slot2

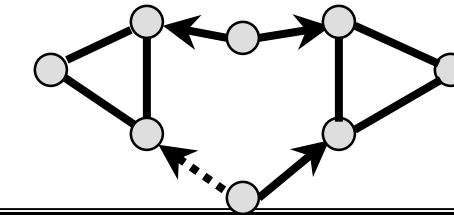
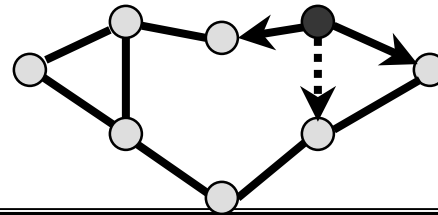
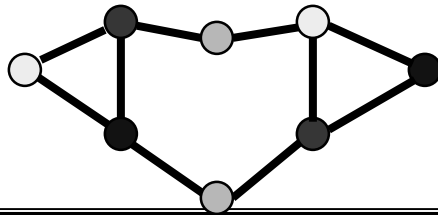
original



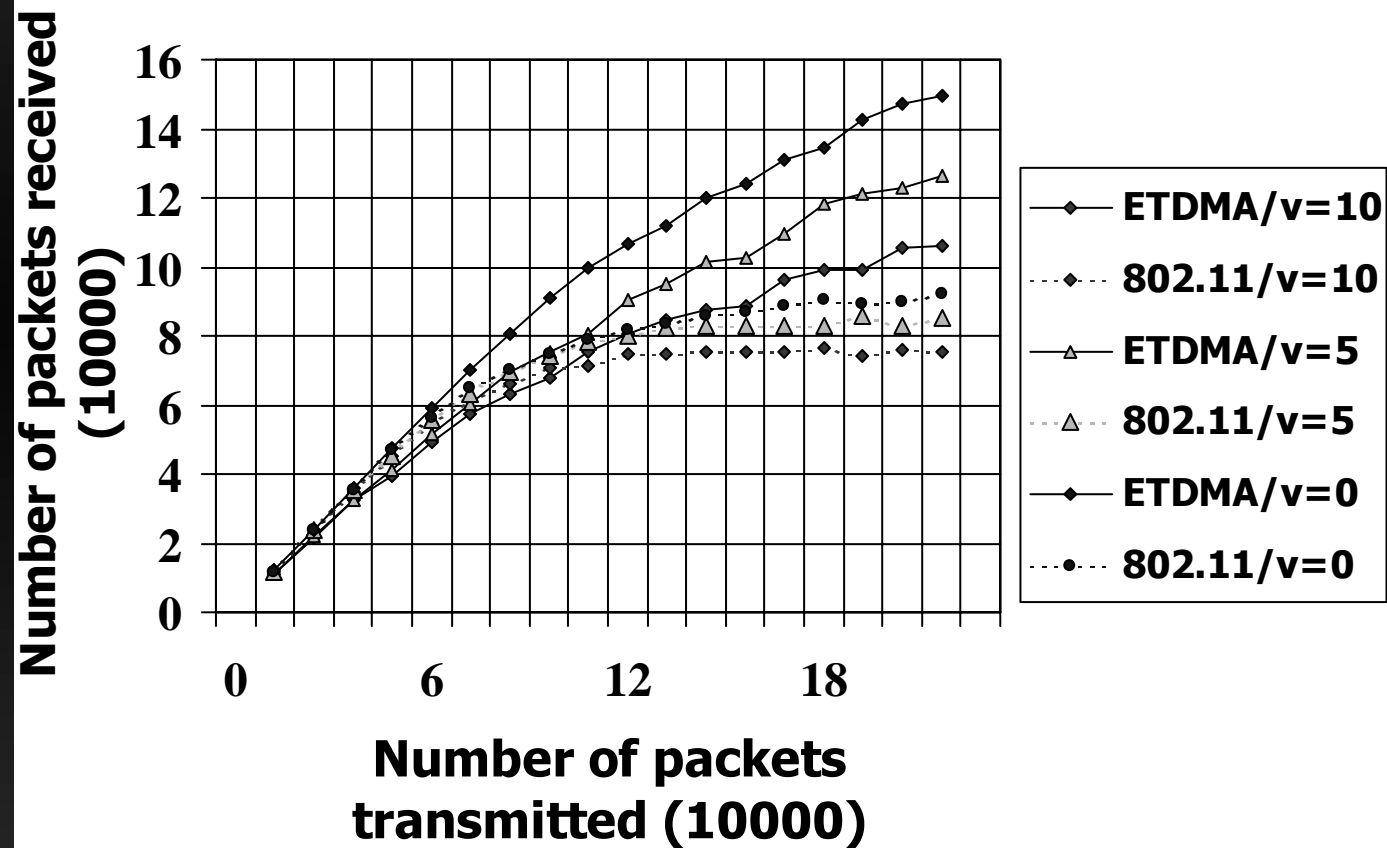
topology change
(new link)



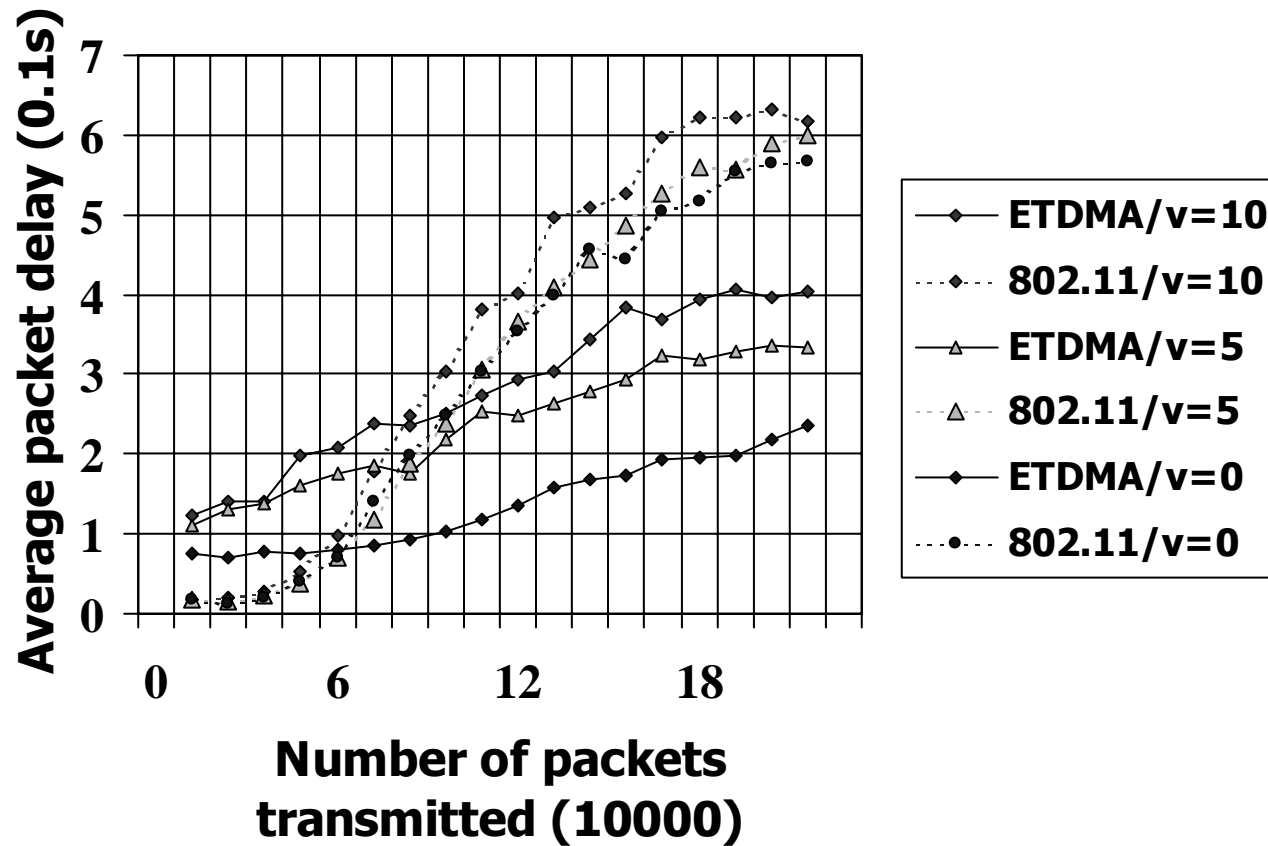
updated



Packet Throughput



Average Packet Delay



Summary of Scheduling Protocols

- **Achievement**

- ◆ **A new approach to schedule TDMA in MANET using contention**
- ◆ **FPRP and E-TDMA adopted by Boeing**

- **Limit**

- ◆ **Contention is non-deterministic**
- ◆ **Parameters not dynamically adjusted**

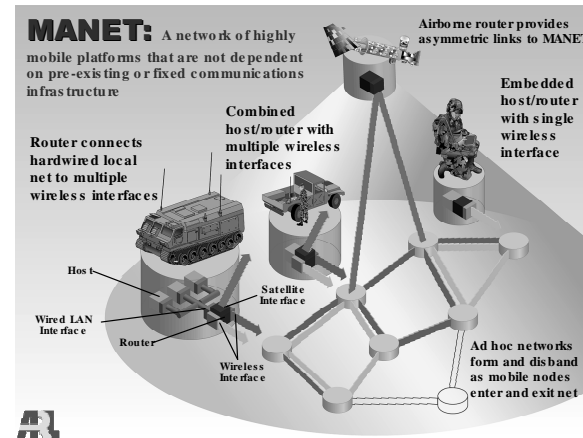
Disaster Recovery: Options?

- **Sensor Networks**
- **Peer-to-peer Ad hoc Networks**
- **Ad hoc Cellular Networks (hybrid)**

Sensor Networks

- **Types**
 - **Chemical**
 - **Biological**
 - **Nuclear**
- **Rapidly deployed at disaster site for safety monitoring**
 - **Deployable via air drop**
- **Practical availability very soon**

Peer-to-peer MANETs



- **The military scenario: “Bring it all with you”**
 - ◆ Generators, spare hard drives, etc. ;-)
 - ◆ Backhaul options (if available)
 - ◆ Microwave? Satellite? Wide-band cellular?
 - ◆ Some options feasible only if immobile

P2P MANETs (cont.)

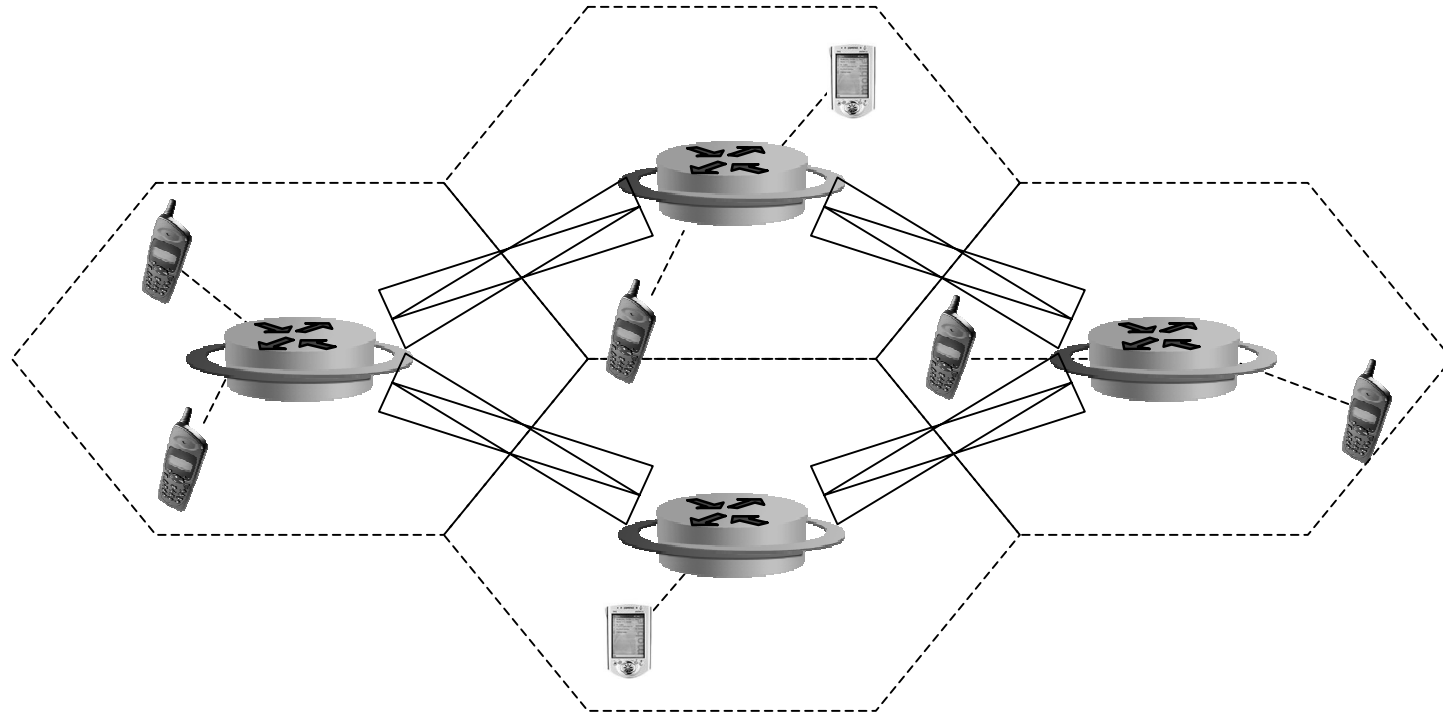
- **Apps**

- ◆ **Push-to-talk communications feasible (half duplex)**
 - ◆ Full duplex interactive voice remains a challenge for anything other than small networks
- ◆ **Instant Messaging rocks (e.g. UDP apps)**
- ◆ **TCP will likely stumble depending on MAC layer**
 - ◆ Another transport protocol required

- **Enables full mobility of all network elements**

- **QoS support variable/unpredictable**

Ad hoc Cellular Networks?



- Ad hoc routers are also cellular-like base stations
- Mobile hosts
- Ad hoc routing/MAC between base stations
 - ◆ Point-to-point or broadcast?

Ad hoc Cellular Networks?

- **QoS more predictable**
 - ◆ **Interactive VoIP can be realized for larger networks, mostly a function of ad hoc MAC and routing**
 - ◆ **All apps now work**
- **Best performance if base stations remain fixed**
 - ◆ **Limited base station mobility is possible, but QoS deteriorates and P2P links may not be feasible**

IETF Standards Snapshot

- **AODV: undergoing second WG last call for comments on promotion to Experimental RFC status**
- **DSR: second last call coming**
- **OLSR and TBRPF: respective proponents are engaged in a debate within the WG for mindshare**
- **Large-scale MANETs: Near-term impracticality and lack of WG interest have put this work into question**
- **Flooding: work beginning on requirements definition**

Questions?

Thanks for listening