Supporting Hierarchy and Heterogeneous Interfaces in Multi-Hop Wireless Ad Hoc Networks

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IETF MANET Working Group
Oslo, Norway
July 14, 1999

(an extended version of the talk given in Oslo)

Carnegie Mellon

Goals

Design an addressing architecture for ad hoc networks that supports:

- routing across heterogeneous network interfaces
- connecting ad hoc networks to the Internet
- integrating ad hoc network routing with Mobile IP
- increasing scalability in the presence of hierarchy

Addressing in Ad Hoc Networks

Addressing can be ***flat*** or ***hierarchical***

Flat addressing provides flexibility

- a node's address is independent of its location
- may reduce scalability

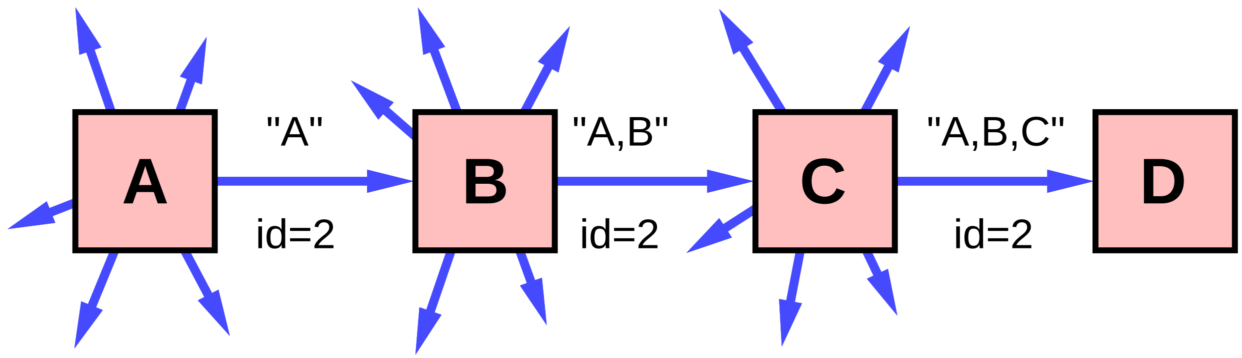
Hierarchical addressing provides scalability

- constrains nodes to move with their branch of hierarchy, OR
- requires the hierarchy to be updated as nodes move

Our approach:

- use a ***flat*** addressing scheme
- take advantage of hierarchy where it exists

Dynamic Source Routing Protocol (DSR)



Divide the traditional routing problem into two pieces:

- ***Route discovery*** : only try to find a route to some destination when you don't have one and need to send something there
- ***Route maintenance*** : while you're actually using a route, try to keep it working or fix it in spite of changes

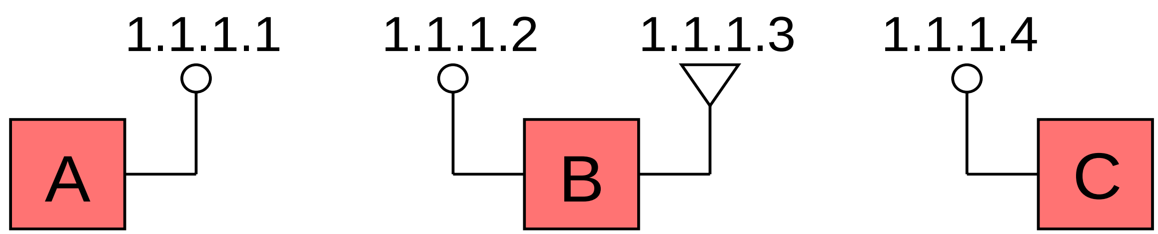
Purely on-demand: ***No*** periodic routing or link status messages

Source route in each packet controls its routing through network

Cost of route discovery reduced by aggressive use of route caches and optimizations

Problems?

Assigning an IP address to each ***interface*** can be problematic...



Node **A** communicates with **C** using source route

$1.1.1.1 \rightarrow 1.1.1.2 \rightarrow 1.1.1.4$

If **A** wants to communicate with 1.1.1.3 (node **B**):

- **A** must perform Route Discovery for 1.1.1.3
- results in ***very inefficient*** use of network resources
- **A** does not know that 1.1.1.2 and 1.1.1.3 both identify **B**

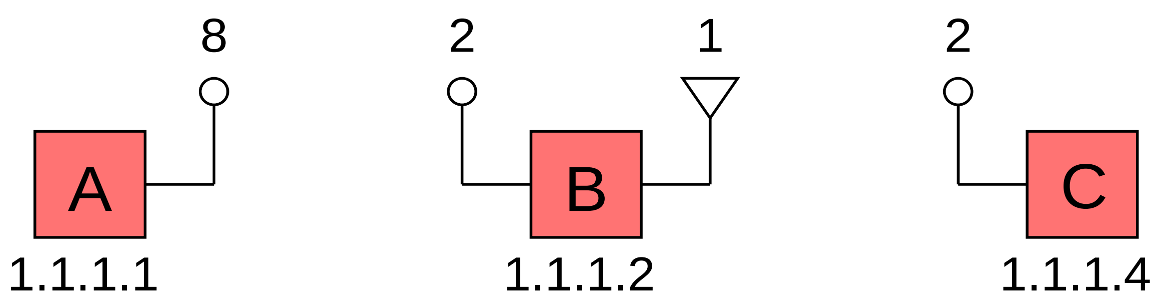
Our Addressing Architecture

Addresses:

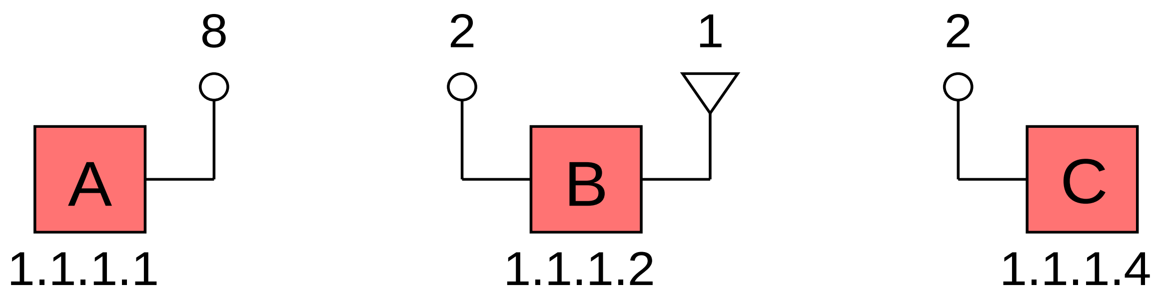
- each node selects and uses one IP address
- similar to the notion of a Mobile IP ***home address***

Interfaces:

- identified by an ***interface index***
- interface indices are opaque identifiers
- each node chooses its interface indices independently



Our Addressing Architecture (2)



Node **A** communicates with **C** using source route

$1.1.1.1/8 \rightarrow 1.1.1.2/2 \rightarrow 1.1.1.4$

If **A** wants to communicate with node **B**:

- **A** can use its existing route to 1.1.1.2
- results in ***efficient*** use of network resources
- **A** always uses 1.1.1.2 to identify node **B**

Supporting Heterogeneous Interfaces

Performing Route Discovery across multiple interface types:

Route Request for D

forward route	reverse route
A/1	A

Route Request for D

forward route	reverse route
A/1	A
B/1	B/2

Route Request for D

forward route	reverse route
A/1	A
B/1	B/2
C/4	C/4

The ***forward route*** identifies a route from **A** to **D**

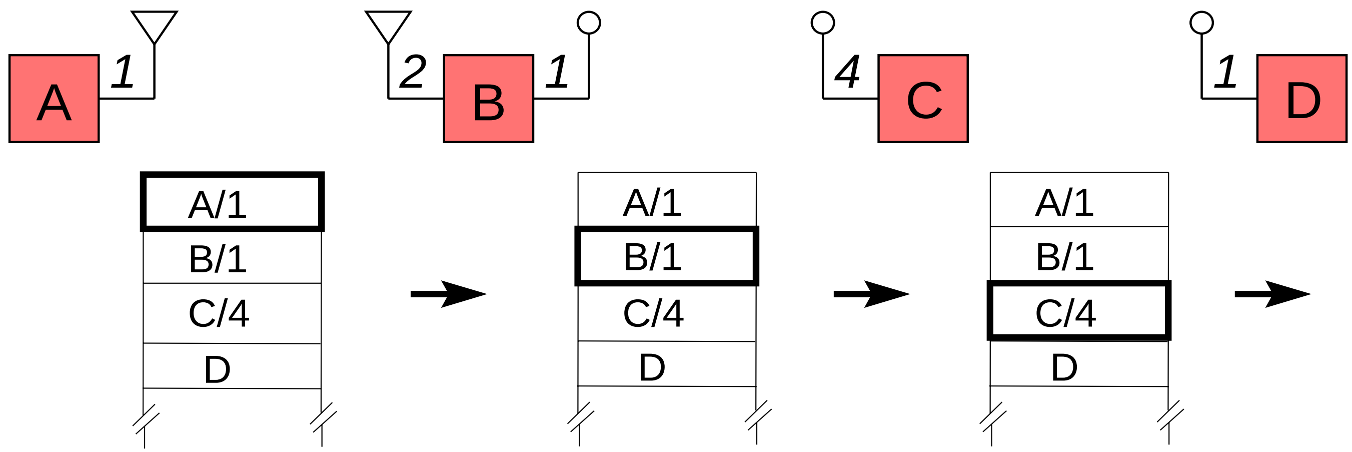
A/1 $\rightarrow$ **B**/1 $\rightarrow$ **C**/4 $\rightarrow$ **D**

The ***reverse route*** identifies a route from **D** to **A**

D/1 $\rightarrow$ **C**/4 $\rightarrow$ **B**/2 $\rightarrow$ **A**

Supporting Heterogeneous Interfaces (2)

Routing a packet across multiple interface types:



The interfaces indices are critical for correct routing:

- they prevent **B** from forwarding on its interface 2
- they force **B** to forward on its interface 1

Source routing works as it did with homogeneous interfaces...

Benefits of this Architecture

This architecture

- allows efficient use of network resources
- provides support for heterogeneous interfaces

It can also support:

- integrating ad hoc networks with the Internet
- integrating ad hoc networks with Mobile IP
- increased scalability in the presence of hierarchy

Assumptions

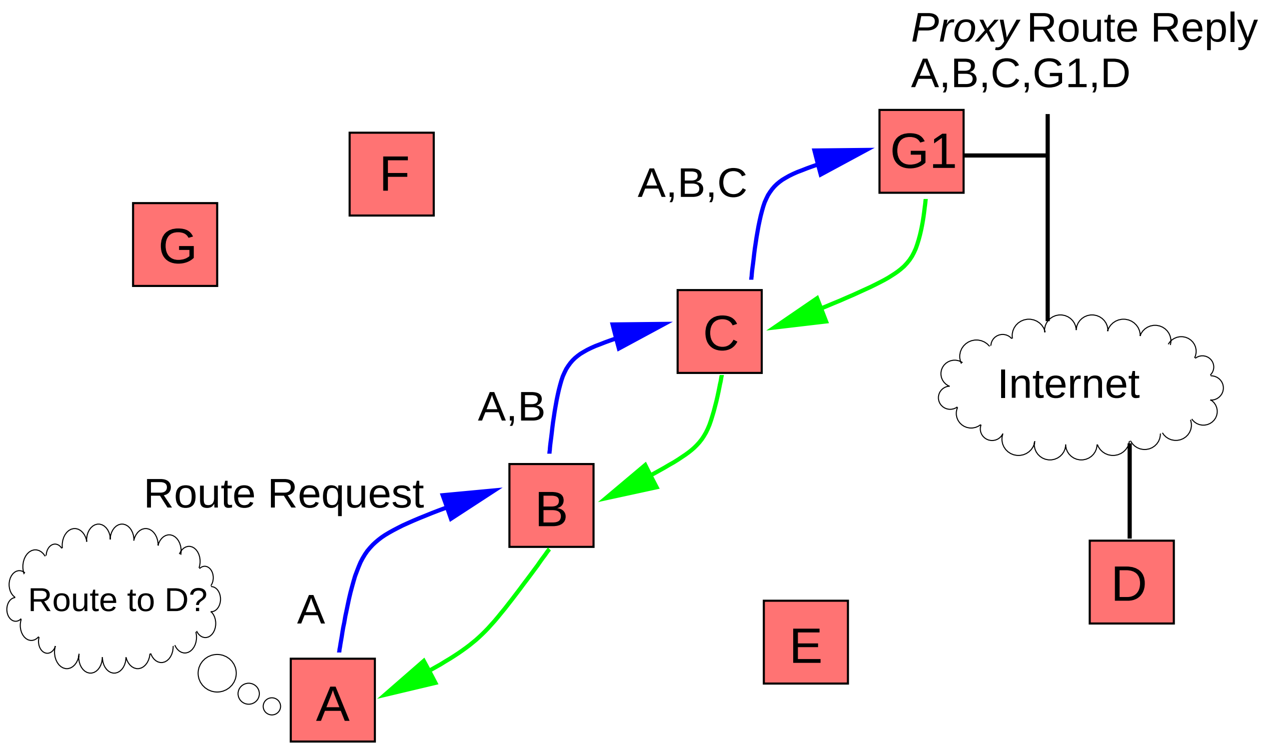
Example ad hoc network scenarios:

- military units (companies, etc.)
- disaster relief teams
- construction projects

Many organizations that will deploy ad hoc networks:

- are comprised of individual groups that will tend to work together in close physical proximity
- can have their IP addresses assigned from a single administrative source
- can effectively utilize ***configured hierarchy*** as they carry out their tasks

Integration with Internet Routing



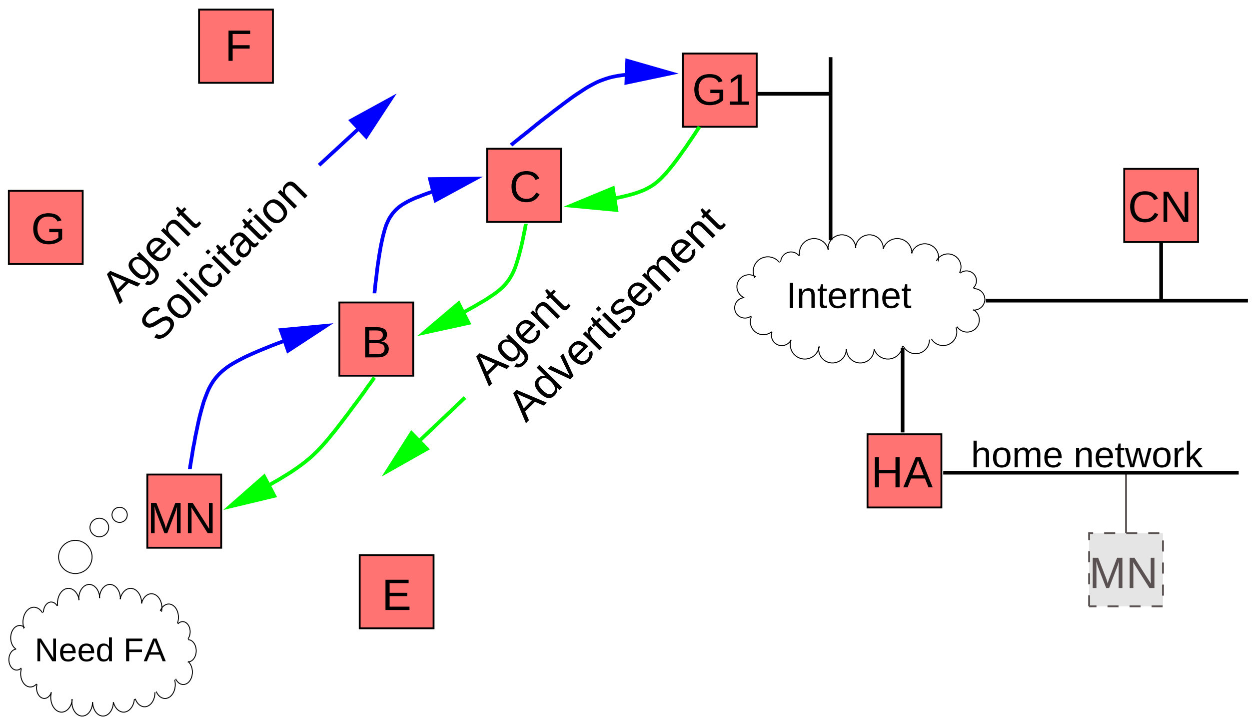
A can send packets to **D** located elsewhere in the Internet

- **G1** sends a ***proxy*** ROUTE REPLY for **D**

D can send packet to **A** located in the ad hoc network

- **G1** performs local delivery to **A** using DSR

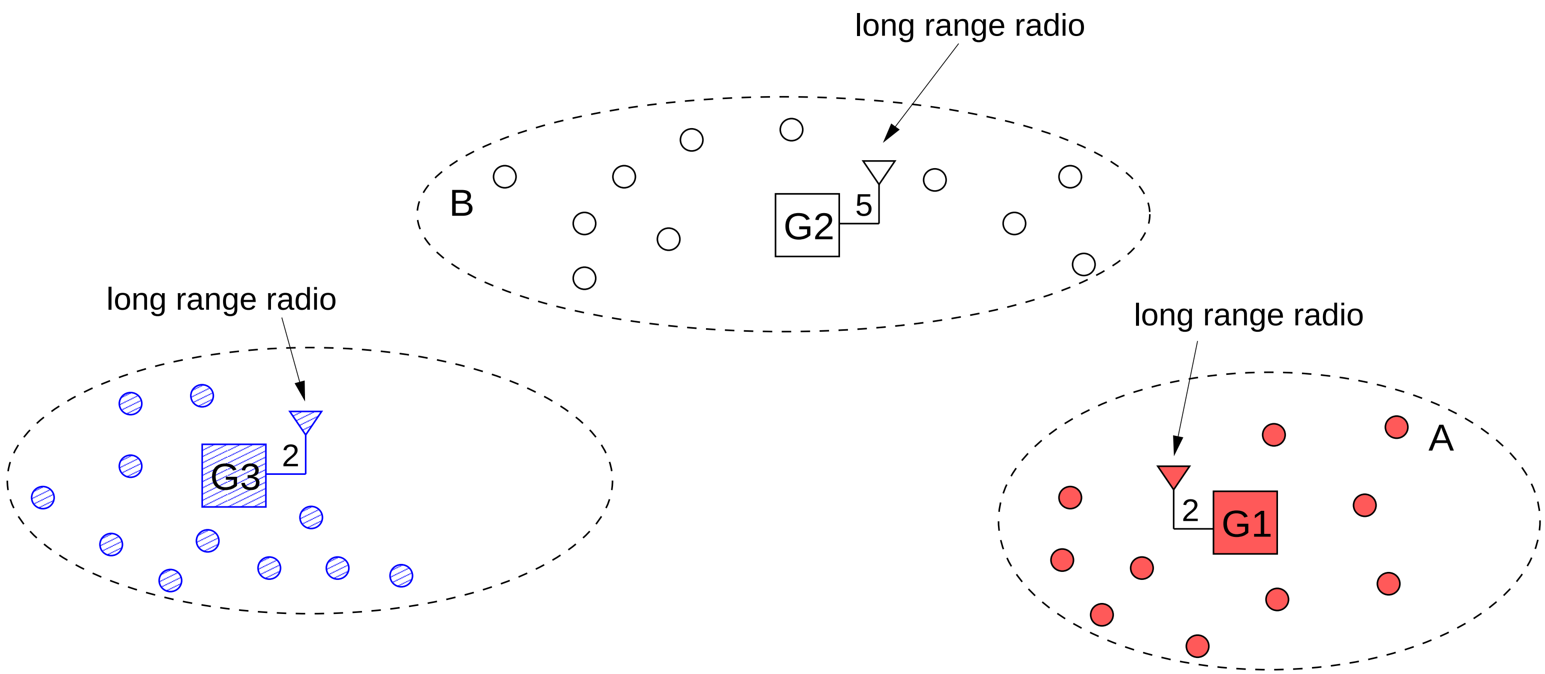
Integration with Mobile IP



Gateway **G1** acts as a router ***and*** as a Mobile IP foreign agent

If **MN** joins the ad hoc network, it can use **G1**'s Mobile IP foreign agent services over ***multiple*** hops

Increasing Scalability



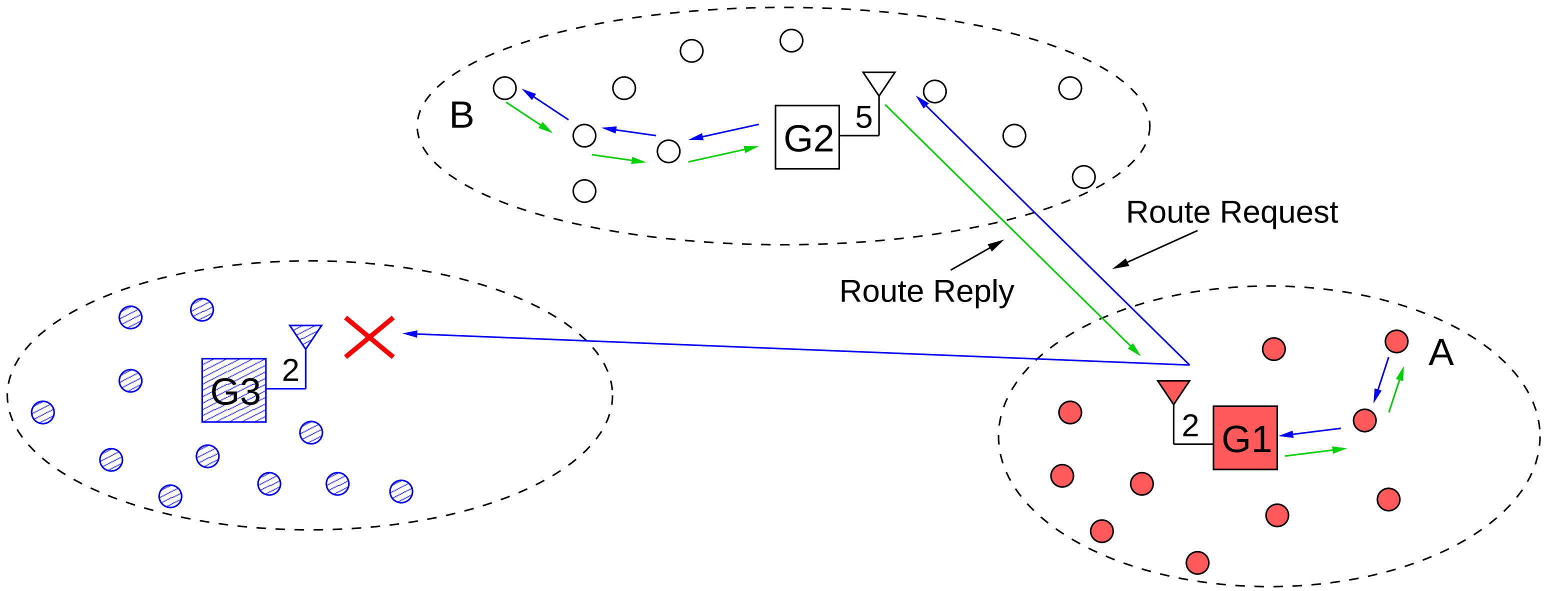
G1, **G2**, and **G3** are ***gateways*** with 2 network interfaces

Three different multi-hop ad hoc ***clouds***

- each ad hoc cloud is an IP subnet
- connected via the long-range radios of the gateways

Increasing Scalability (2)

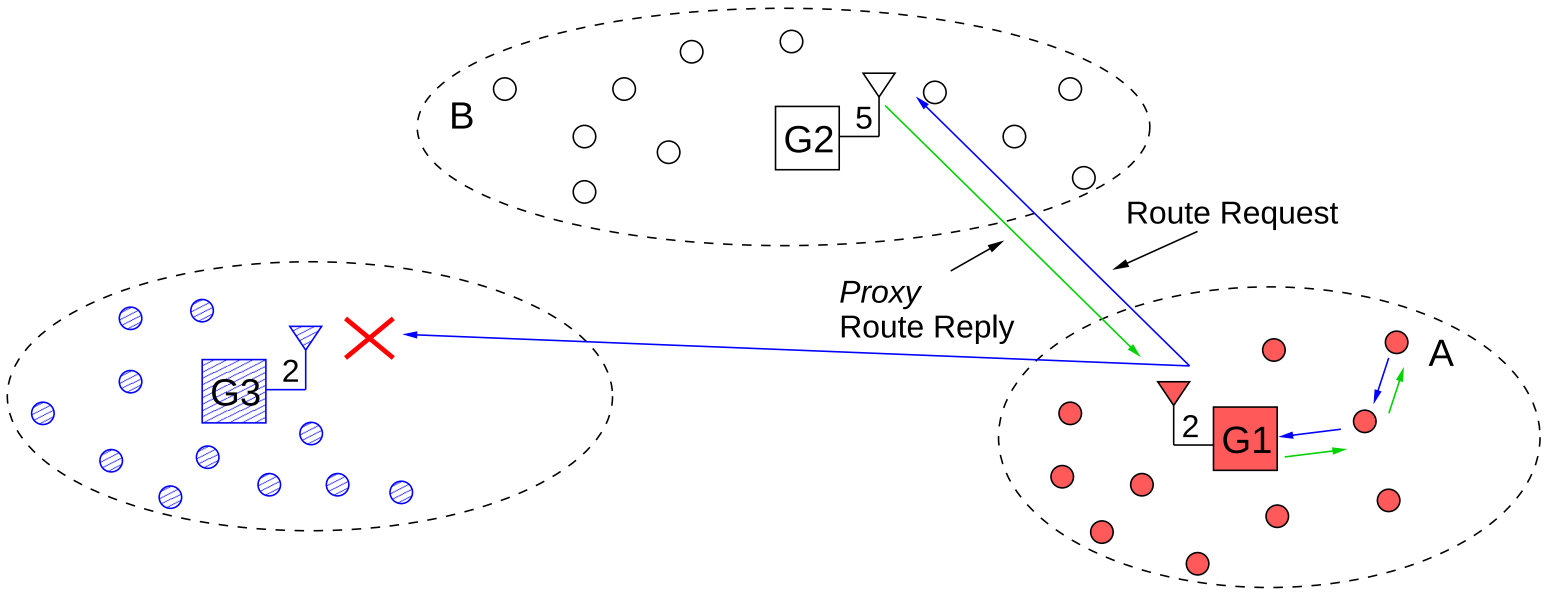
Without hierarchy, **A**'s ROUTE REQUEST for **B** can flood the entire ad hoc network...



Hierarchy can increase the ***containment*** of Route Discovery

- **G3** knows that **B** is ***not*** in its cloud
- **G3** will not forward the REQUEST for **B** into the striped cloud

Increasing Scalability (3)



Proxy reply mechanism can localize topological change

Gateway **G2** sends a ***Proxy*** ROUTE REPLY for **B**:

- **A** uses source route **A**/1 → **G1**/2 → **G2**/253 → **B**
- **G2** uses source route **G2**/1 → ... **B**

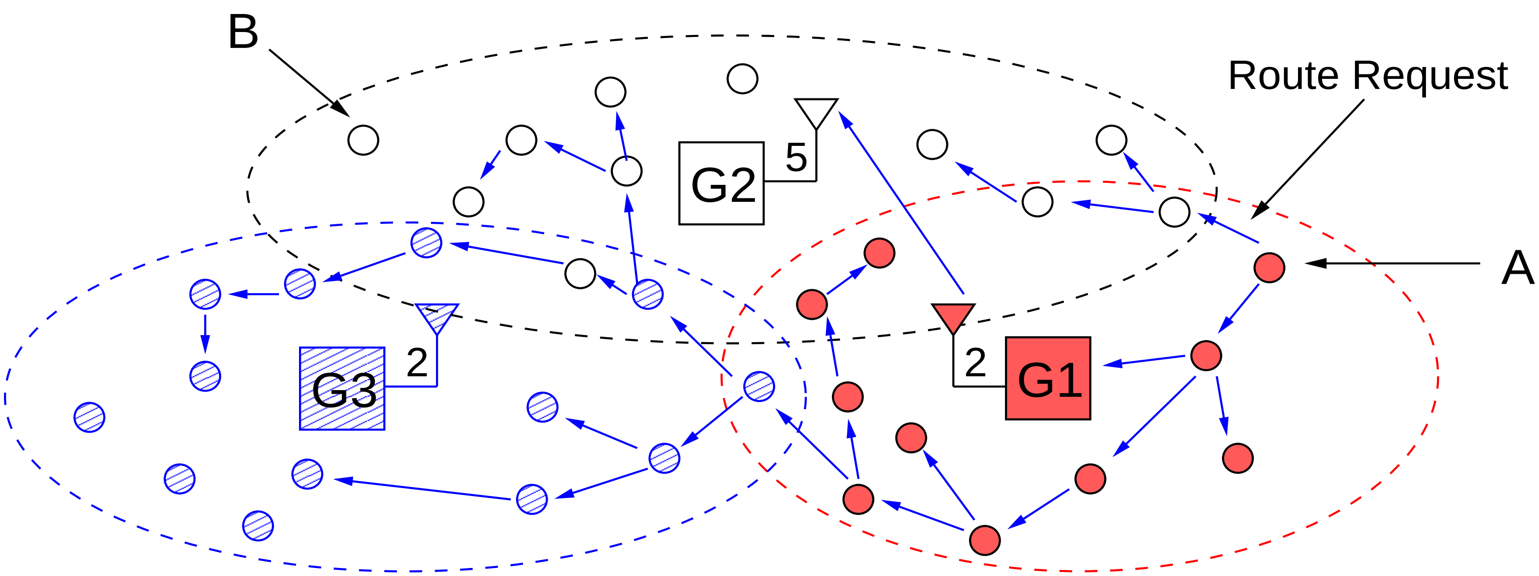
A needs only to maintain its route to **G2**

- topological change within the white cloud won't affect **A**

Overlapping Ad Hoc Clouds

When ad hoc clouds overlap, the benefits of hierarchy are lost:

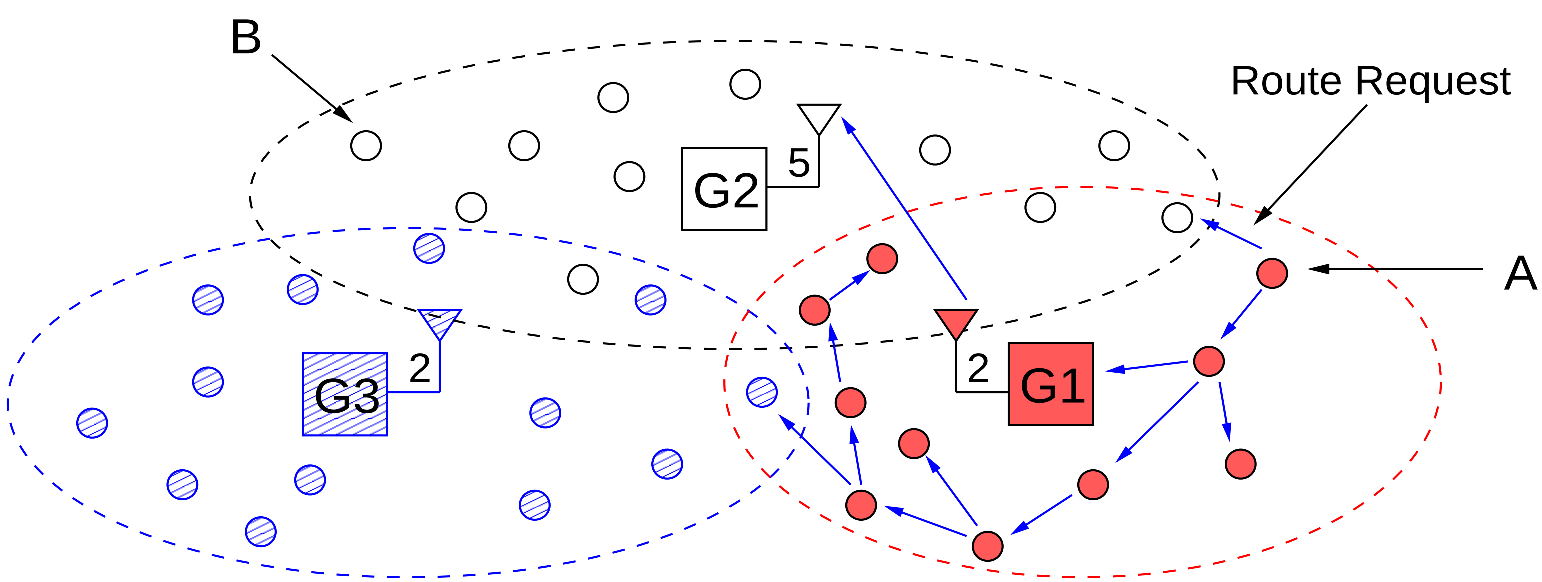
- **A**'s ROUTE REQUEST for **B** can flood the entire network



Overlapping Ad Hoc Clouds (2)

Scalability can be reclaimed by

- preventing nodes from forwarding ROUTE REQUEST packets last processed by a node in a different cloud, and
- using the “I” (Introduce) bit to enable selective forwarding



Conclusions

Flat addressing provides the flexibility needed in ad hoc networks:

- each node uses only one IP address
- each interface on a node is identified with an ***index***

This addressing architecture supports:

- heterogeneous network interfaces
- integration of ad hoc networks with the Internet
- integration of ad hoc networks with Mobile IP
- increased scalability in the presence of hierarchy