Gateway Forwarding Strategies in Ad hoc Networks

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Erik Nordström, Per Gunningberg

IT department, Uppsala University

Christian Tschudin

CS Department, University of Basel

The story so far. . .

Ad hoc $\approx$ Mobile Multi-hop Wireless Networking

IETF started MANET (Mobile Ad hoc NETworks) working group on ad hoc routing in 1995/96. Since then:

- Four routing protocols going for RFC status (**AODV**, **OLSR**, **DSR**, TBRPF)
- AODV implementations $\approx$ 10
- Zero deployment

One explanation: **No Internet integration**

Common MANET Internet connectivity scenarios

- Extending the reach of wireless LANs
- Disaster area rescue drones with connection to rescue central
- Military units communicating with headquarters

– Uppsala students are building rescue robots with ad hoc routing for participation in Robocup.

So what has gone wrong?

Internet and ad hoc networks are very different:

- Hierarchical vs. Flat addressing and routing
- Fixed vs. Mobile (macro and micro mobility)

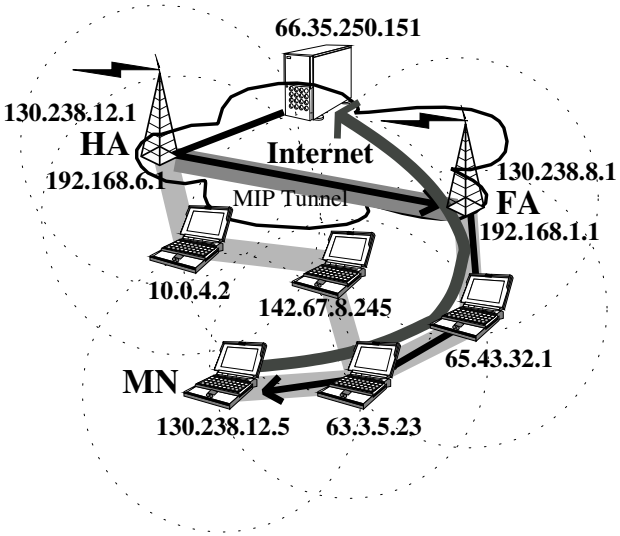
For Internet connectivity many suggest Mobile IP (MIP).

- It is only half the solution (solves macro mobility)
- Provides topologically correct (care-of) addresses
- Operates (mainly) at gateways towards the Internet (i.e., MIP does not really matter until packets reach the gateway)

Example of an Internet connected ad hoc network

Combining Ad hoc Networking with MIP connectivity:

- Computers are mobile and use their home addresses
- Multiple gateways (MIP agents, FA, HA) to the Internet
- Multi-hop paths to gateways



How do we stitch all this together?

Challenges

- Gateways have to be discovered and self-configured at nodes
- Gateway changes have to be trackable so that MIP can re-register (otherwise return traffic is lost)
- For smooth operation, hand-over and multi-homing might be beneficial (i.e., we must support connectivity to more than one gateway at once)
- Efficient integration with the routing protocol is important (for example, mixing *proactive* gateway discovery with *reactive* routing does not make sense)

Our contribution

A lot of Previous Work on:

- Address configuration
- Gateway discovery (efficiency in gateway advertisements)

Our complementary work is a comparison of different gateway forwarding strategies:

- Default routes – one generic path to a gateway for all external (Internet) destinations.
- Tunneling – temporary replace the destination address with the gateway address

Default Routes – Routing Tables

Destination	Next Hop	Hop Cnt
63.3.5.23	63.3.5.23	1
66.35.250.151	default	–
default	63.3.5.23	3

(a)

Destination	Next Hop	Hop Cnt
192.168.1.1	63.3.5.23	3
63.3.5.23	63.3.5.23	1
66.35.250.151	default	–
default	192.168.1.1	3

(b)

a) we need host state (to avoid subsequent route lookups on source and intermediate nodes)...

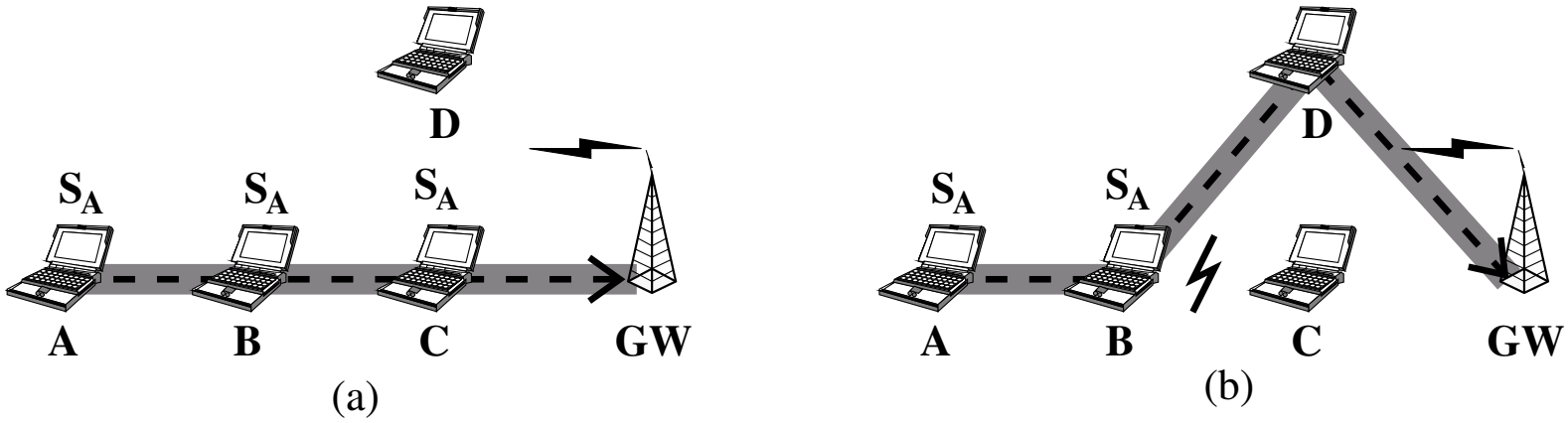
b) but also a gateway route to track gateways (GlobalV6 proposal)

- as much as three routing table lookups might be necessary (host→default→gateway/next hop)

Default Routes – State Replication Problem

Extra routing table state (host, gateway, default route) introduces problems:

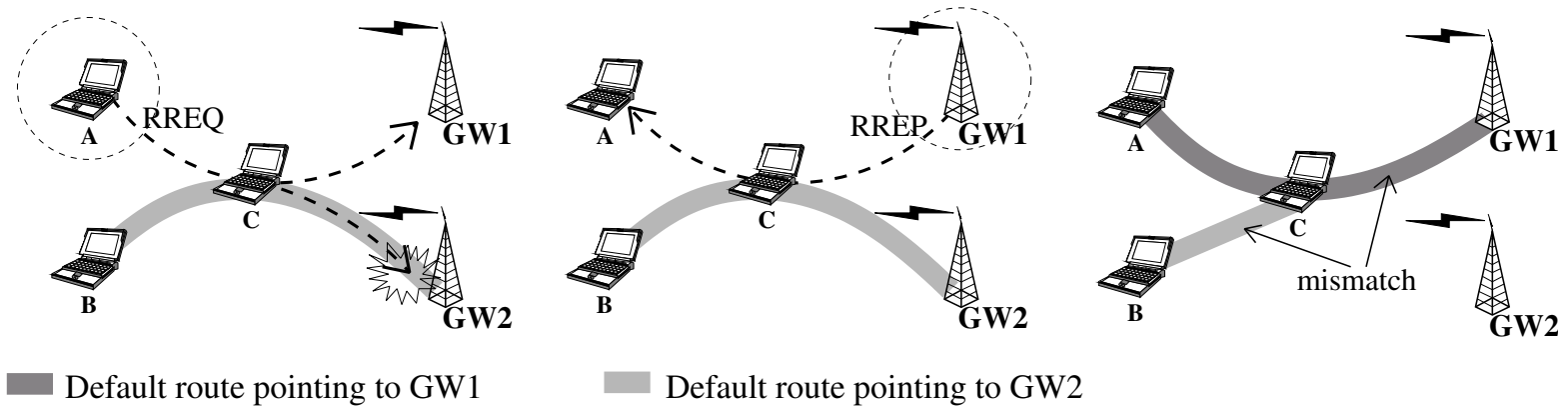
- states (e.g., S_A) must be replicated on intermediate nodes
- how do we handle repairs or route optimizations?



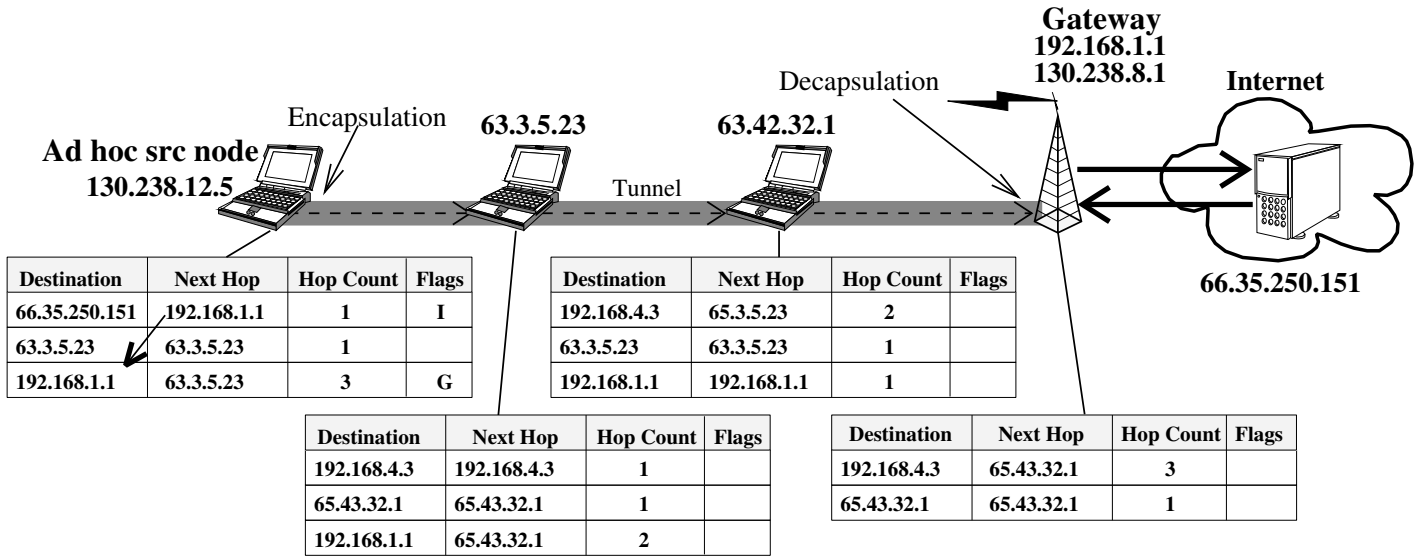
Default Routes – Gateway Tracking Problem

A default route might not stay consistent along a hop by hop path when there are multiple gateways

- Breaks two-way communication (e.g., TCP)



Tunneling – Routing Tables



Destination	Next Hop	Hop Count	Flags
66.35.250.151	192.168.1.1	1	I
63.3.5.23	63.3.5.23	1	
192.168.1.1	63.3.5.23	3	G

Destination	Next Hop	Hop Count	Flags
192.168.4.3	65.3.5.23	2	
63.3.5.23	63.3.5.23	1	
192.168.1.1	192.168.1.1	1	

Destination	Next Hop	Hop Count	Flags
192.168.4.3	192.168.4.3	1	
65.43.32.1	65.43.32.1	1	
192.168.1.1	65.43.32.1	2	

Destination	Next Hop	Hop Count	Flags
192.168.4.3	65.43.32.1	3	
65.43.32.1	65.43.32.1	1	

- Gateways addressed in packets – not in nodes (some overhead)
- No extra state at intermediate nodes – only a gateway route
- Can be done one-way to gateway only

Tunneling – Benefits

- Protocol transparency
- Route aggregation
- Stability (no gateway tracking problem)
- Multiple gateways (multi-homing, load-balancing, hand-over)

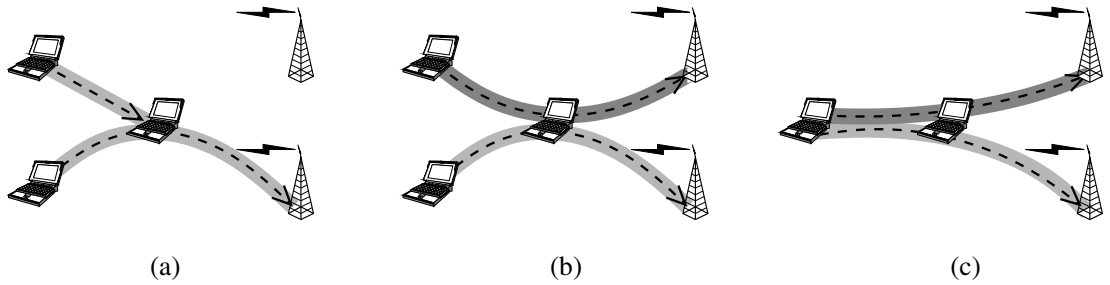


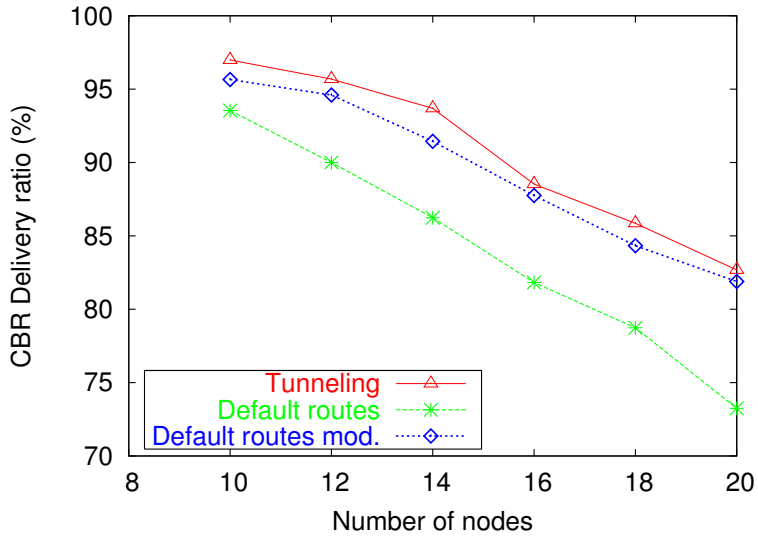
Figure 1: (a) Default route. (b) & (c) Tunnel configurations.

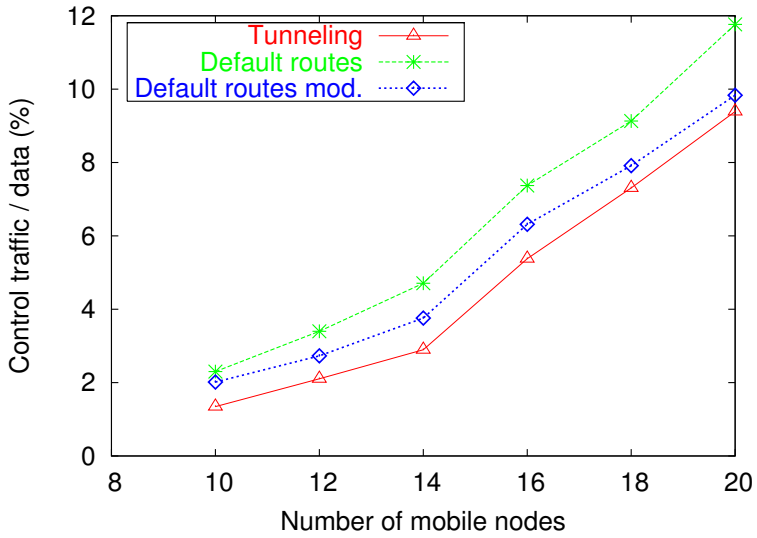
Comparison

ns-2 simulations with:

- Two gateways, 10 - 20 mobile nodes, fixed density
- Tunneling to gateways
- Globalv6-draft style default routes
- Modified default routes – A reference implementation that forwards all traffic on a default route, ignoring host route state (we have no traffic among ad hoc nodes)

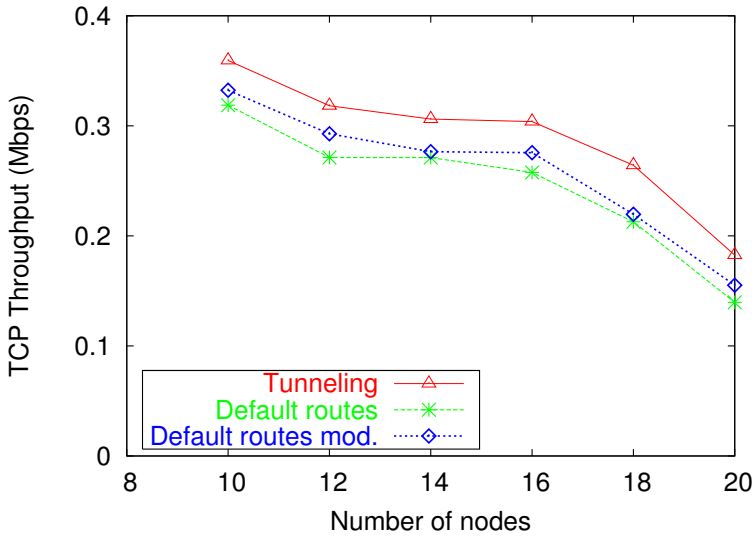
Some simulation results – CBR Traffic (UDP)

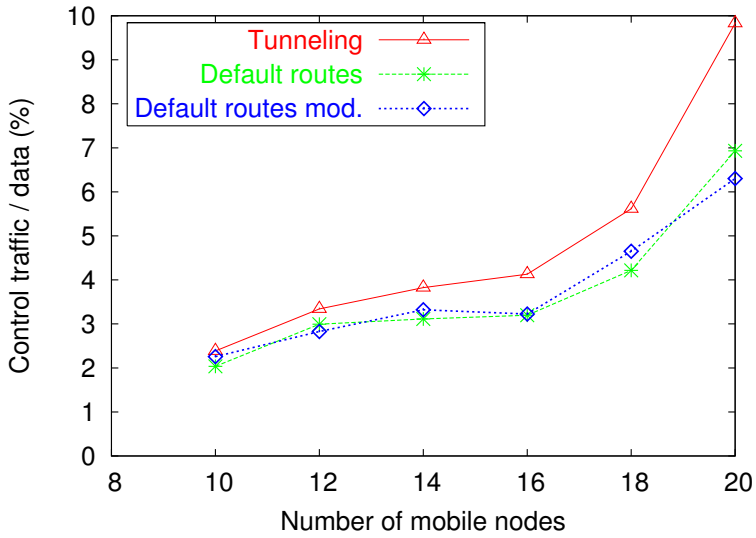




- Default routes have state replication problems – ignoring state helps

Some simulation results – TCP Traffic (FTP)





- With TCP we also need to track gateways – ignoring state does not help as much here

Conclusions

Internet connectivity is critical for MANET deployment. Our comparison shows:

- The default route concept does not transfer well to MANETs
- Default routes operate incorrectly with multiple gateways
- Tunneling is efficient, simple, transparent and works with multiple gateways at the cost of a small overhead

We will demo ad hoc network Internet connectivity today!