# POSTER: Comparison of Forwarding Strategies in Internet Connected MANETs


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## ABSTRACT

For efficient Internet Connectivity in MANETs, multiple gateways and potentially multi-homing and hand-over need to be supported. We compare how default routes and tunneling to gateways support this. We find that tunneling is more efficient and flexible compared to default routes. In fact, we show that default routes will not operate correctly in some situations, particularly when there are multiple gateways.


## 1. INTRODUCTION

Mobile ad hoc networks (MANETs) are often envisaged to have flat addressing (no prefixes) and flat routing. Nodes are also mobile and there may be multiple gateways. This makes it challenging to integrate ad hoc networks with the Internet. For Internet connectivity, some proposals exists [2, 1, 5]. However, studies have so far mainly focused on efficient gateway discovery and address configuration [2, 3, 4]. We believe that the choice of strategy for forwarding packets to gateways has been overlooked. Our contribution is to compare the ability of the forwarding strategy to efficiently support multiple gateways, multi-homing and hand-over. We look at default route forwarding and tunneling. We focus on a scenario with Mobile IP and reactive routing.

## 2. FORWARDING USING DEFAULT ROUTES

The idea of a default route as a generic routing table entry is common in LANs, where there is one gateway one hop away with subnet addressing. However, MANETs have flat addressing and multiple

| 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)

**Figure 1: Two different routing table configurations to the same end. The address 66.35.250.151 is a destination on the Internet.**

gateways several hops away. Default route forwarding for MANETs have been proposed in [1] and [5]. To adapt the default route concept to the MANET environment, host route table entries need to be added to avoid repeated route look-ups on source as well as intermediate nodes (figure 1 (a)). Furthermore, multiple gateways are not supported, since there is no way to track gateways in the routing table. In Globalv6 [5], the routing table configuration shown in figure 1 (b) is proposed. The default route is now mapped to a gateway and host routes point to the default route. We note that this increases the required routing table accesses to three for each packet forwarded to a gateway and may be inefficient. Precomputing the host to next hop mapping is not always possible, because most reactive protocols require each accessed entry to be refreshed when a packet is forwarded. Furthermore, we have found two problems with default routes in MANETs:

### *Gateway Tracking Problem*

A default route can be repointed to another gateway on downstream nodes (figure 2). This will break connections when using a gateway running NAT or Mobile IP.

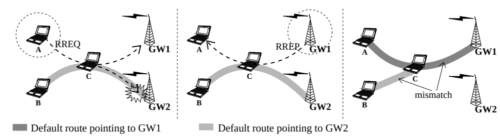


**Figure 2: Problem tracking the gateway. A source node (B) may not be notified of a default gateway change triggered by a reactive routing protocol's route request (RREQ) and route reply (RREP) exchange.**

However, with the routing table in figure 1 (b), a node can tell when a default route is repointed to a new gateway, since there is a default route → gateway mapping. But extra routing logic needs to be added to handle this. For example, to drop route replies conflicting with an existing default route.

### *State Replication Problem*

When a default route is repaired or updated, any new intermediate nodes must gather all the host → default route mappings of upstream nodes. In figure 3, node A is communicating with Internet hosts through gateway (GW). A's host route state $S_A$ is not replicated when node B repairs the route to GW. Node D will not be able to forward packets to host(s) represented by state $S_A$.

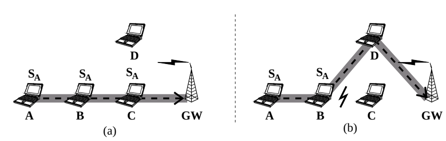


**Figure 3: Example of state replication problem with default routes.**

## 3. FORWARDING USING TUNNELS

In MIPMANET [2] Jönsson et al. propose tunneling as an alternative approach to default routes in ad hoc networks. An encapsulated packet for an Internet destination, originated at an ad hoc node, is sent to the gateway using the gateway's explicit IP address and the IP forwarding mechanism as configured by the ad hoc routing protocol. At the gateway, the packet will exit the tunnel and is decapsulated. In the second step, the initial packet is routed towards the final destination in the global Internet. Return traffic inbound at the gateway does not need to be tunneled, since the return IP address (the ad hoc source node's home address) is routable within the ad hoc network. **Tunneling exhibits the following desirable properties:**

**Protocol transparency.** Tunneling is transparent with existing routing protocols. The minimum required modifications are extra routing table states in the source and gateway nodes which do not affect the protocol. There is no need for new state at intermediate nodes.

**Route aggregation.** Tunneling achieves route aggregation at intermediate nodes since all Internet destinations are encapsulated by gateway addresses.

**Stability.** Once a source node has configured a tunnel to a gateway, that tunnel will not be diverted to another gateway unless connectivity with the gateway is completely lost. In case the source node is running Mobile IP, it is notified and can re-register at a new gateway.

**Multiple gateways.** Nodes can maintain routes to multiple gateways (multi-homing) for fault tolerance and load balancing (see Figure 4). Redundant tunnels can be used as as backup routes if the connectivity to one gateway is lost and to do a soft hand-over between gateways.

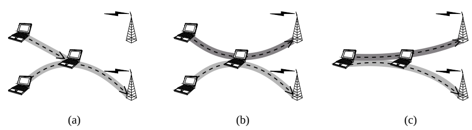


**Figure 4: (a) A default route points to only one gateway at once. (b) With tunneling two nodes can share an intermediate hop while still maintaining tunnels to different gateways, (c) or one node can have tunnels to two gateways at once.**

**Efficient forwarding.** With tunnels, a source node needs to perform two look-ups in the routing table. On intermediate nodes, only one regular look-up is needed, which is a clear advantage over the default route approach.

## 4. EVALUATION

We evaluate the forwarding strategies in simulation. The simulated network has fixed density, two gateways and 10 to 20 mobile nodes. Gateways are MIP agents and two ad hoc nodes communicate with an Internet host. Results are averaged over 50 randomly generated scenarios with random waypoint mobility. We have implemented both Globalv6-style default routes and tunnels for the AODV protocol. For reference we also have a modified default route version that forwards all packets on a default route and that drops route replies that wants to reconfigure an existing default route. This will work in this scenario because we only have traffic to Internet hosts, but delivery to a specific gateway is not guaranteed. A *proxy route reply* solution is used for gateway discovery.

With CBR traffic tunnels have the best performance (figure 5). Default routes have problems and the improved results for the modified default routes indicate that the bad performance is caused mainly by

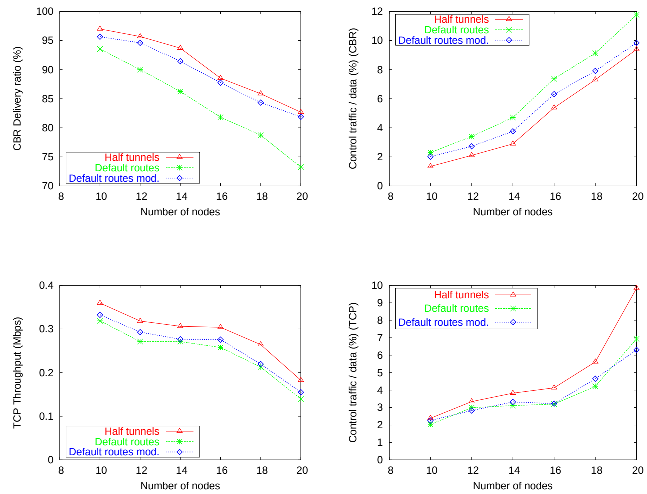


**Figure 5: CBR delivery ratio and TCP throughput with normalized control traffic.**

the state replication problem, since there is no return traffic. Looking at TCP performance the modified default route forwarding is now closer to normal default routes. Gateway tracking is more important for TCP (i.e., two-way traffic) as indicated by the reduced routing overhead (less control traffic when in timeout). *With default routes, nodes may think that they are forwarding packets to a specific gateway, when they are in fact not.* Therefore, they will never re-register with the agent at the new gateway. Further simulations have verified this hypotheses. Tunneling does not suffer from problems tracking gateways and therefore delivers more packets, which in turn increases its overhead.

## 5. CONCLUSION

We have compared the efficiency of two forwarding strategies for Internet connectivity in MANETs. Our conclusion is that tunneling packets to a gateway in ad hoc networks with flat addressing and reactive routing is more efficient and flexible compared to default routes. In fact, we found default route forwarding – as suggested in several proposals – to not operate correctly in some situations, particularly with multiple gateways. This has adverse effects on two-way traffic, for example TCP. We believe that this result is of value to future efforts in the area to build robust Internet connectivity solutions for ad hoc networks.

## 6. REFERENCES


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