Wardrop Routing in Wireless Ad-Hoc Networks
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Abstract---Routing protocols for multihop wireless networks have traditionally used shortest path routing to obtain paths to destinations and do not consider traffic load or delay as an explicit factor in the choice of routes. We focus on static mesh networks and formally establish that if the number of sources is not too large, then it is possible to construct a perfect flow-avoiding routing, which can boost the throughput provided to each user over that of the shortest path routing by a factor of four when carrier sensing can be disabled or a factor of 3.2 otherwise. So motivated, we address the issue of designing a multipath, load adaptive routing protocol that is generally applicable even when there are more sources. We develop a protocol that adaptively equalizes the mean delay along all utilized routes from a source to destination and does not utilize any routes that have greater mean delay. This is the property satisfied by a system in Wardrop equilibrium. We also address the architectural challenges confronted in the software implementation of a multipath, delay-feedback-based, probabilistic routing algorithm. Our routing protocol is Completely distributed, Automatically load balances flows, Uses multiple paths whenever beneficial, Guarantees loop-free paths at every time instant even while the algorithm is suntil converging, Amenable to clean implementation. This protocol is able to automatically route flows to “avoid” each other, consistently out-performing shortest path protocols in a variety of scenarios.

Keywords: load adaptive routing protocol, delay-feedback-based, shortest path protocols.

I. INTRODUCTION
A mobile ad-hoc network (MANET) is a collection of nodes, which have the possibility to connect on a wireless medium and form an arbitrary and dynamic network with wireless links. That means that links that between the nodes can change during time, new nodes can join the network, and other nodes can leave it. A MANET is expected to be of larger size than the radio range of the wireless antennas, because of this fact it could be necessary to route the traffic through a multi-hop path to give two nodes the ability to communicate. There are neither fixed routers nor fixed locations for the routers as in cellular networks - also known as infrastructure networks. Cellular networks consist of a wired backbone which connects the base-stations. The mobile nodes can only communicate over a one-hop wireless link to the base-station; multi-hop wireless links are not possible. By contrast, a MANET has no permanent infrastructure at all. All mobile nodes act as mobile routers. A MANET is depicted in Fig 1.1

Fig. 1: MANET

II. MANET PROTOCOLS

A. Table-Driven (or Proactive)
The nodes maintain a table of routes to every destination in the network, for this reason they periodically exchange messages. At all times the routes to all destinations are ready to use and as a consequence initial delays before sending data are small. Keeping routes to all destinations up-to-date, even if they are not used, is a disadvantage with regard to the usage of bandwidth and of network resources.

B. On-Demand (or Reactive)
These protocols were designed to overcome the wasted effort in maintaining unused routes. Routing information is acquired only when there is a need for it. The needed routes are calculated on demand. This saves the overhead of maintaining unused routes at each node, but on the other hand the latency for sending data packets will considerably increase.

Fig. 2: MANET Protocols
C. Ad Hoc On-Demand Multipath Distance Vector (Aomdv)

The Ad hoc On-Demand multipath Distance Vector (AOMDV) protocol enables dynamic, self-starting, multihop routing between participating mobile nodes wishing to establish and maintain an ad hoc network. AOMDV allows mobile nodes to obtain routes quickly for new destinations, and does not require nodes to maintain routes to destinations that are not in active communication. AOMDV allows mobile nodes to respond to link breakages and changes in network topology in a timely manner. The operation of AOMDV is loop-free, and by avoiding the “counting to infinity” problem offers quick convergence when the ad hoc network topology changes (typically, when a node moves in the network). One distinguishing feature of AOMDV is its use of a destination sequence number for each route entry. The destination sequence number is created by the destination to be included along with any route information it sends to requesting nodes.

III. EXISTING SYSTEM

The routes followed by packets are unrestricted. They can be arbitrarily long. This causes several problems:

1. There are many bad routes (routes with hot spots) that packets can go out on and delays experienced by such packets can be exceedingly long.
2. Since the algorithm requires feedback on all these bad routes before it can adapt, its convergence can be very slow, rendering it impractical.

After the routing probabilities have converged to the correct estimates, the algorithm produces loop-free routes. However, packets can follow loopy paths while the algorithm is converging. The delay measurement in relies on acknowledgments to carry measurements back to sources and intermediate nodes on a per-packet basis. This poses problems in implementation:

1. A scheme relying on transport layer ACKs to solve the network layer routing problem violates layering and does not extend to unreliable transport layers.
2. Further, there is no guarantee that ACKs will follow the reversed path as the data packet.

IV. PROPOSED SYSTEM

In a communication network such equilibrium for load balancing multipath routing:

1. When packets have to be resequenced at the receiver and delivered in-order to the application, equalizing the average delay along utilized paths reduces receiver socket buffer space requirements and receiver socket buffer resequencing delays.
2. Equalizing the average delay along utilized paths mitigates TCP congestion misbehaviour that results from TCP’s adverse reaction to multiple paths and reordered packets.
3. Route adaptation using delay feedback allows rerouting of flows around traffic bottlenecks in wireless environments. This allows flows to automatically “avoid” each other and minimize interference.

A. War drop’s first principle: All utilized paths from a source to a destination have equal mean delays.

B. War drop’s second principle: Any unutilized path from a source to a destination has greater potential mean delay than that along utilized paths.

V. IMPLEMENTATION OF WARDROPEQUILIBRIUM:

AOMDV was specifically designed for use in multi-hop wireless ad hoc networks. AOMDV is a reactive routing protocol which is able to manage a MANET without using periodic table-update messages like table-driven routing protocols. Transmission range is 250 m. Free space propagation models assume that there is only one clear line-of-sight path between the transmitter and receiver. To calculate the received signal power in free space at distance from the transmitter, the network stack for a mobile node consists of a link layer (LL), an ARP module connected to LL, an interface priority queue (IFq), a MAC layer (MAC), a network interface (netIF), all connected to the channel. An Omni-directional antenna having unity gain is used by mobile nodes.

- The network interphase layer serves as a hardware interface which is used by mobile node to access the channel. This interface subject to collisions and the radio propagation model receives packets transmitted by other node interfaces to the channel.
- Cmuqueue which gives priority to routing protocol packets, inserting them at the head of the queue. It supports running a filter over all packets in the queue and removes those with a specified destination address.

The architecture of the implementation is shown in Figure 4.1. The key architectural choice we made was to separate probabilistic packet forwarding from delay estimation. We provide an in-kernel per-packet probabilistic forwarding mechanism consisting of multiple in-kernel forwarding tables. Each table consists of a list of routes to destination. Each route to a destination consists of a vector of two-tuples (next hop, probability of usage). A user-space library provides an API interface to this in-kernel probabilistic forwarding mechanism. This separation of routing policy from forwarding mechanism allows us to cleanly implement different probabilistic route adaptation policies in user space.

The protocol logic is almost completely in user space. The link delay measurement module implements the state machines. The average delay measurement module implements a “distance vector”-like protocol to exchange average delay information with neighbours on a periodic basis. The distance vector routing module uses an implementation of AOMDV to produce hop-count information that is used in P-STARDA to guarantee loop freedom. The probability update policy module implements various War drop route adaptation algorithms, including P-STARDA, M-STARDA, and STARAD. The implementation fully utilizes advanced kernel routing software features like equal cost multipath routing, net filter, iptables, policy routing, and MARK target routing to minimize the need for kernel modifications. Nevertheless, the implementation needed a small amount of in-kernel mechanism.
VI. WARDROP ROUTING ON MOBILE NODES

The routing scheme described above was proposed for static mesh networks which exhibit very low mobility. The application area of these low mobility networks is confined to small range. So the same routing scheme could be extended to dynamic nodes. The inner working of the protocol remains unchanged for dynamic nodes. The dynamic mesh network topology could be implemented on AOMDV protocol seen earlier. This protocol

![Implementation Architecture](image)

Fig. 3: Implementation Architecture

A. Manet Scenario

A pure Manet scenario similar to the simulations was set up in order to gain some experience and to verify the structure of the experiment. The simulation settings were as follows:

- 50 wireless nodes.
- Simulation area of 1500mx300m. A rectangle area is chosen to have longer distances between the nodes than in a quadratic area, i.e. packets are sent over more hops.
- IEEE 802.11 MAC.
- Two ray ground propagation model.
- Node mobility defined by random waypoint movement model.
- Constant bit rate traffic.
- UDP.

VII. REVISED FORMAT FOR WIRELESS TRACES

In an effort to merge wireless trace, using cmu-trace objects, with ns tracing, a new, improved trace format has been introduced. This revised trace support is backwards compatible with the old trace formatting and can be enabled by the following command:

```csh
$ns use-newtrace
```

This command should be called before the universal trace command

```csh
$ns trace-all <trace-fd>
```

Sets up new format for wireless tracing by setting a simulator variable called newTraceFormat. Currently this new trace support is available for wireless simulations only and shall be extended to rest of us in the near future.

An example of the new trace format is shown below:

```
s -t 0.267662078 -Hs 0 -Hd -1 -Ni 0 -Nx 5.00 -Ny 2.00 -Nz 0.00 -Ne
-1.000000 -NI RTR -Nw --- -Ma 0 -Md 0 -Ms 0 -Mt 0 -Is 0.255 -Id 1.255
It message -Il 32 -If 0 -Ii 0 -Iv 32
s -t 1.511681090 -Hs 1 -Hd -1 -Ni 1 -Nx 390.00 -Ny 385.00 -Nz 0.00 -Ne
-1.000000 -NI RTR -Nw --- -Ma 0 -Md 0 -Ms 0 -Mt 0 -Is 1.255 -Id 1.255
It message -Il 32 -If 0 -Ii 1 -Iv 32
s -t 10.000000000 -Hs 0 -Hd -2 -Ni 0 -Nx 5.00 -Ny 2.00 -Nz 0.00 -Ne
-1.000000 -NI AGT -Nw --- -Ma 0 -Md 0 -Ms 0 -Mt 0 -Is 0.0 -Id 1.0 -It tcp -Ps 0 -Pa 0 -Pf 0 -Po 0
r -t 10.000000000 -Hs 0 -Hd -2 -Ni 0 -Nx 5.00 -Ny 2.00 -Nz 0.00 -Ne
```

Fig. 4: WAR drop Routing Protocol
We propose mechanisms to control the lengths of paths and provide loop freedom at all times. A completely distributed delay estimation procedure that eliminates the need for ACK-based delay estimation. Simulations indicate that the protocol appears to be effective in obtaining improved throughput-delay performance gains over shortest path routing in static networks. Encouraged by the results obtained through simulation on static mesh networks, an attempt was made to extend the Wardrop routing principles on dynamic mesh networks using AOMDV. The results showed that the Wardrop Routing holds good even for dynamic mesh topology. We have implemented the protocol in user space on a modified Linux 2.4.20 kernel based on an architecture that separates probabilistic multipath routing from delay estimation. We shows that there is scope for traffic adaptive routing that outperforms minimum hop routing protocols for wireless networks (both static and dynamic) may well benefit from such adaptive routing.

REFERENCES