Interactions between Cooperation Strategies in Mobile Ad Hoc Networks

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Abstract - **Cooperation among nodes in an ad hoc network is essential for multi-hop communication. Non-cooperative or selfish nodes reduce (or cease) cooperation by refusing to forward packets for others. In this demo we showcase the interactions between various cooperation strategies and quantify their impact on timely delivery of traffic across multi-hop routes. The cooperation strategies are implemented under the Linux operating system and run on an ad hoc network composed of virtual nodes on multiple physical workstations. The demo includes an interactive component that allows the audience to select the cooperation strategy to run on each individual network node and observe the effects of the selected combination of strategies on network performance. The mobility between nodes is emulated from connectivity traces gathered at the 2007 MANIAC Challenge.**

I. INTRODUCTION

Nodes in a mobile ad hoc network (MANET) are energy constrained and may act selfishly refusing to cooperate in forwarding packets for other nodes. There is growing literature (see [1] and references within) analyzing various cooperation strategies that incentivize nodes to cooperate. This demonstration investigates the effects of different mixes of cooperation strategies adopted by nodes in a MANET on the timely delivery of packets across multi-hop routes.

For increased realism in the selection of cooperation strategies to be adopted and in the modeling of topology changes due to mobility, shadowing, fading, etc., we incorporate into the demo data collected during the first Mobile Ad-hoc Networking Interoperability and Cooperation (MANIAC) Challenge. The MANIAC Challenge [2] is a competition where teams from different academic institutions form a MANET. The competition, its first installment held in November 2007, required participating teams to develop cooperation strategies to optimize the trade-off of forwarding packets for others vis-à-vis conserving their limited energy resources. Using the data collected during that experiment, we characterized the network topology and assessed the feasibility of a MANET in terms of its connectivity and stability. The objective of this demonstration is to extend this research effort to study the interaction between and assess the impact of different cooperation strategies on network performance.

In this demo, we will set-up a 16-node mobile ad hoc network utilizing virtual nodes. In this network each of five physical nodes (laptops) implements one or more virtual machines. This eases network set-up in terms of man-power and space requirements and allows flexibility in scaling the network. We emulate mobility in the network by dynamically changing the topology based on actual connectivity traces collected during the MANIAC Challenge.

The demo will be interactive, insofar as the audience will be able to select which cooperation strategy is adopted by each of 12 nodes in the network (the remaining 4 nodes will be used exclusively as traffic sources). A GUI will then display the effects of that particular mix of strategies on the successful delivery of packets across multi-hop routes.

II. COOPERATION STRATEGIES

We implement three cooperation strategies. Each network node can be programmed to adopt any one of these strategies.

a. Tit-for-tat [3]: A node drops or forwards packets based on the observed behavior of its neighboring nodes. This requires the node to listen in promiscuous mode to capture the actions of its neighbors and mimic them.
b. Live-and-let-live [4]: A node implementing this strategy: (a) minimizes its connectivity to its neighbors by maintaining an active logical connection only to one of its neighbors, selected based on reachability of the remaining network nodes; and (b) adopts a monitoring mechanism to detect misbehaving neighbors and isolate them.
c. Selective drop: A node implementing this strategy drops a fixed percentage of packets (which can be set between 0-100%) that it is asked to forward. A node maintains a list of destination nodes and their respective drop percentages.

The selection of these strategies includes both simple, static strategies (selective drop) and dynamic ones (tit-for-tat and live-and-let-live). These strategies represent a subset of those implemented by teams competing in the 2007 MANIAC Challenge.

We quantify the effect of these strategies on both real-time and non-real-time traffic. The performance is reflected in terms of throughput and packet delivery ratio for non-real-time data and timeliness of packet delivery for real-time data.

III. AD HOC NETWORK EMULATOR

We emulate a mobile ad hoc network by creating virtual nodes using Virtual Network User mode Linux (VNUML) [5]. VNUML is a UML based virtual networking tool that allows one to easily build and configure a virtual network topology of interconnected virtual kernels based on one Linux workstation.

We emulate mobility by integrating the virtual environment with a mobility emulator - Mobiemu [6]. Mobiemu emulates the actual topology changes by generating iptables rules which in turn determine the connectivity of the network. These topology changes are controlled by connectivity traces collected during the 2007 MANIAC Challenge.

As shown in Figure 1, four different instances of UML, each representing a virtual node, are connected through a virtual bridge. The bridge acts as an intermediary to connect the various UML instances to the physical interface. In order to emulate the topology, each virtual node acts as a Mobiemu slave with the master daemon running on a central controller node (see Figure 2). The master daemon synchronizes timing across all slave nodes to accurately emulate the network topology.

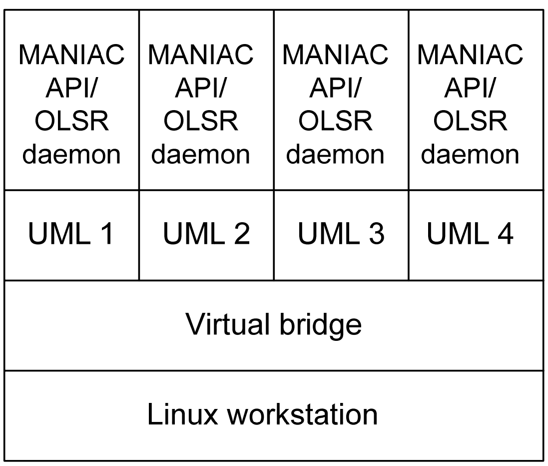

Figure 1. Virtualization of multiple nodes on a single workstation

Once the virtual environment is set, we establish routes using Optimized Link State Routing (OLSR) and implement our cooperation strategies using the MANIAC API [2]. The API provides each node with the ability to select whether to redirect, drop or forward packets to their destination.

IV. DEMONSTRATION SET-UP

The demo network comprises five laptops with four of those implementing four virtual nodes each to form a 16-node mobile ad hoc network, as shown in Figure 2. Four of these virtual nodes act as sources, sending real-time and non-real-time UDP traffic to all the remaining nodes in the network. We pair the destinations into six teams (each node in a team implements the same cooperation strategy). This set-up closely resembles the network observed at the MANIAC Challenge. We further implement a *strategy manager* (along with Mobiemu master and the VNUML controller node) on the fifth laptop, that allows us to remotely select the cooperation strategies to be adopted by the individual nodes.

We demonstrate the interaction between the chosen cooperation strategies for two different mobility scenarios. Each scenario is a three minute snapshot of a 20-minute run at the 2007 MANIAC Challenge. The objective is to assess: (a) the individual node performance by calculating the number of non-real-time packets that arrived at a destination and number of real-time packets that arrived by the playout deadline; and (b) the overall network performance by collecting network-wide metrics such as average throughput, average packet delivery ratio and average timeliness of real-time packet delivery.

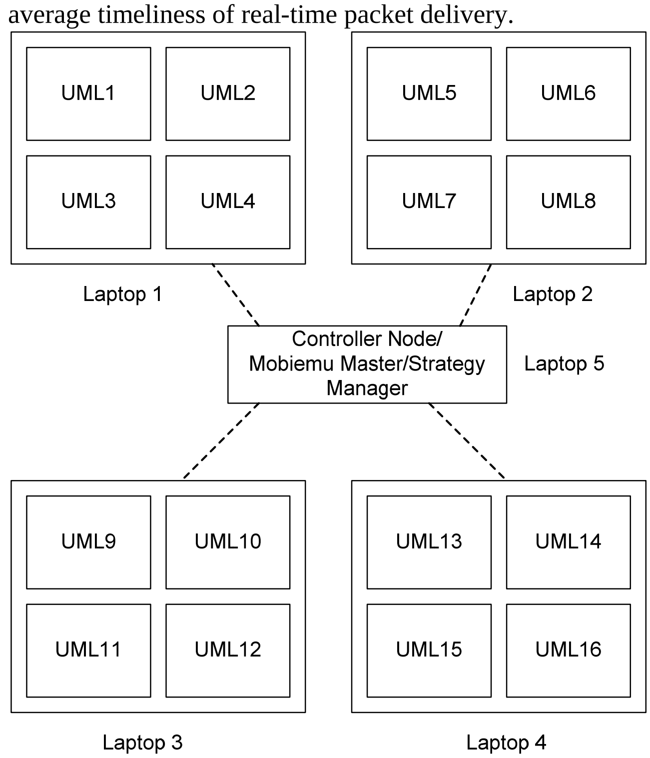

Figure 2. Demo network set-up

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Demo requirements at the workshop:

1. A 20’ x 10’ table (or two smaller tables adding up to similar dimensions) for placing 5 notebooks
2. A power strip (or two smaller ones) with an extension capability to support 7-8 notebooks