GlomoSim Platform Validation – Analytical and Experimental

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Number of Hops	CSMA	FAMA	802.11
1	1819817	1741646	1500633
2	908637	869645	750262
3	600982	579484	500140
4	450648	434494	375199
5	360447	347573	300125

Table 1 : Throughput (bps), Single TCP Connection, Variable Number of Hops, W=1460B

Simulation models can be verified against analytical models. We start by examining the performance of TCP with window size equal to one packet (1460B) on top of CSMA, FAMA and IEEE 802.11 (with virtual carrier sense) by varying the number of hops of a TCP session between the source and destination. In such environment, no contention exists and therefore, intuitively, we expect CSMA to exhibit better throughput compared to that of FAMA and 802.11 since the latter two are unnecessarily hindered by control frame overheads. Table 1 confirms our insight. The send-and-wait model also supports the throughput behavior shown in Table 1. Assuming that propagation delay is negligible, the expected utilization of a one-hop connection for a send-and-wait protocol is given by:

$$\frac{tx}{tx + ta}$$

where tx and ta are the transmission delay of TCP data packet and ACK, respectively. With the size of TCP data packets being 1500 bytes (includes 40 byte header) and TCP ACKs being 40 bytes each, the expected utilization of a one-hop connection is 0.97. Thus, the expected throughput for a 2Mbps channel is 1940Kbps. For a two-hop connection, we have:

$$\frac{tx}{2tx + 2ta}$$

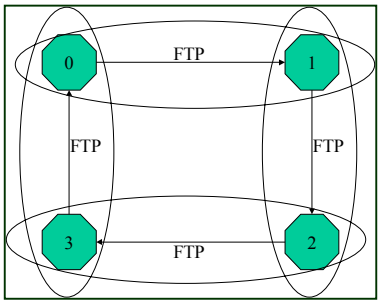
Here, the expected link utilization is 0.48 and thus the expected throughput is 960Kbps. Finally, for three-hop connection, we obtain:

$$\frac{tx}{3tx + 3ta}$$

The link utilization is thus 0.32 and the expected throughput for a three-hop connection is therefore 640Kbps. From Table 1, we observe that the performances of CSMA, FAMA and 802.11 are extremely close to that of the expected throughput. The results are slightly lower than theory since propagation, processing, and carrier sensing delays are not taken into consideration in theoretical analysis. Similar analysis applies to the four-hop and five-hop connections.

TCP capture GlomoSim Validation

Two sets of experiments are presented that both show the 'capture' phenomenon that is noticed when TCP connections are deployed over known wireless MAC CSMA based protocols. The first set of experiment is performed in a real multihop testbed and the second in simulation using the GlomoSim platform.



The topology used in both experiment sets is shown. We, first, notice the 'capture' effect in the real testbed experiment. The testbed consists of 4 laptops equipped with WaveLan I network interfaces delivering 2Mbps at 915Mhz and using a CSMA/CA MAC protocol. The routing is static i.e. using manually entered routing tables. The 4 nodes are placed to the 4 corners of Boelter Hall building and the ftp connections are attempting to transfer a 12MB file to the next-hop station. The next table shows the unbalanced bandwidth distribution caused by the capture effect. In the following figure, packet traces -as seen by node 1 at experiment number 4- are graphed, in order to clearly notice 'capture' effect.

TCP Connections (Kbps)	0-1	1-2	2-3	3-0
Trial 1	328.08	54.55	329.46	137.06
Trial 2	94.72	67.88	428.59	318.90
Trial 3	578.51	24.96	130.40	42.91
Trial 4	574.34	7.22	102.75	1.03

Table 2 : Real testbed bandwidth distribution

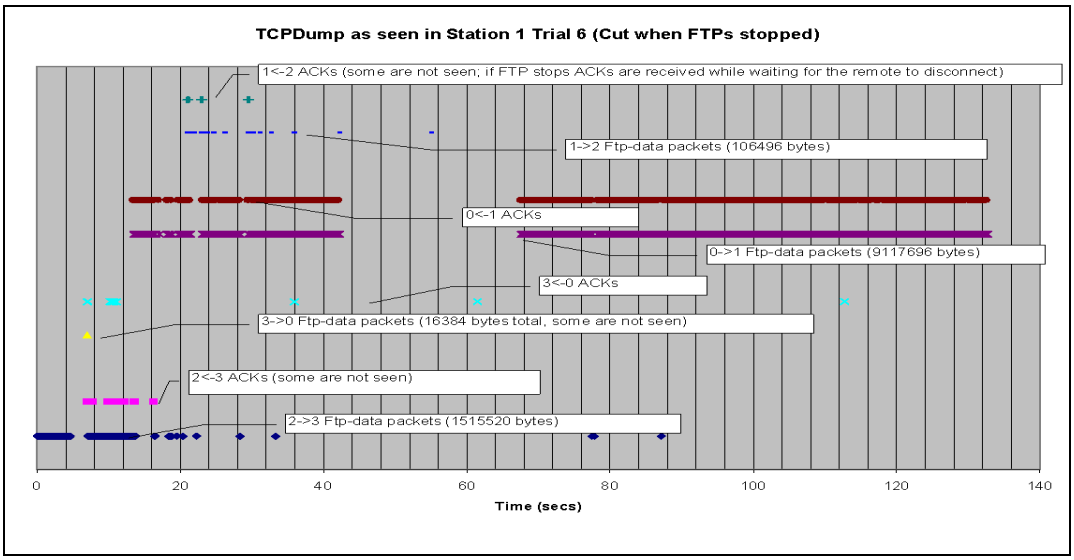


Figure 1: Real testbed packet trace graph as seen from node 1 in trial 4

A similar set of experiments, using CSMA, has been performed in the GlomoSim platform. The 'capture' effect is clear in this case too. Small differences are attributed to not exact matching of the

environment (for example the real ftp connections need to login in presence of interference, a step not necessary in simulations).

TCP Connections (Kbps)	0-1	1-2	2-3	3-0
Trial 1	133.46	24.58	175.52	17.64
Trial 2	293.09	4.17	336.05	2.52
Trial 3	29	247.46	95.8	237.39
Trial 4	3.52	1.40	134.14	242.65

Table 3 : Simulation bandwidth distribution

Trial 1 packet traces have been graphed in order to clearly notice the 'capture' effect.

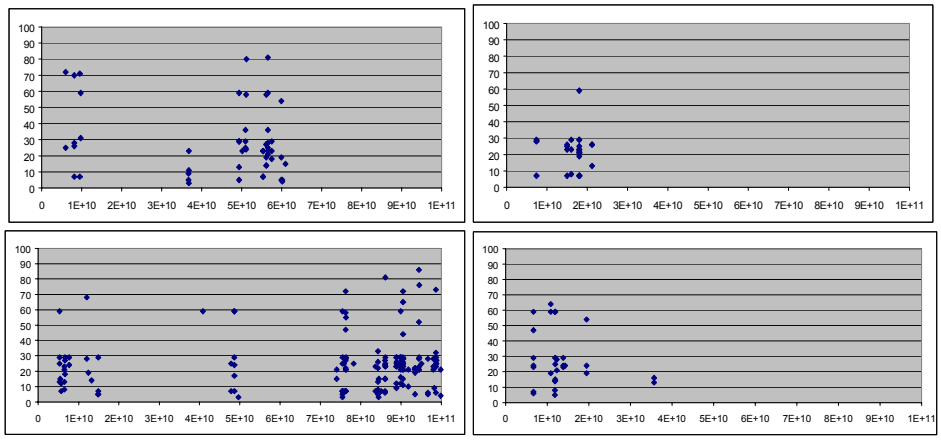


Figure 2 : Packet Sizes of packets sent vs Time for connections 0-1, 1-2, 2-3, and 3-0 in that order.

These clearly show the 'capture' phenomenon in both real and simulated environment when using the GlomoSim platform.

Audio Experiment Validation

Two sets of experiments have been performed using the same platform as above. One real testbed consisting of laptops equipped with Wavelan I network interface cards and one using simulation and the GlomoSim platform. The metric used in these experiments is an application layer metric which combines the effects of all the layers below. Namely it is the loss rate of a real-time connection.

The loss rate, as seen from the application, has two components. One for packets actually lost (UDP is used for the real-time connection) and the packets that were received after their playback points. It calculated as the number of packets received in an interval of 1 second versus the number of packets expected to be received (as the real-time rate defines)

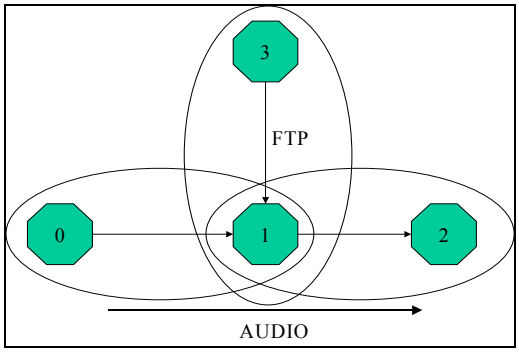


Figure 3: Topology used in audio experiments

The topology used is shown in figure 3. The audio connection is 184Kbps and its packets are sent off at constant rate. An ftp connection interferes with the audio packet forwarding at the gateway node 1.

The experiment was run for 200 seconds in both the platforms, real and simulation. Loss rates appeared oscillatory and of similar magnitude to both platforms. Figure 4 shows the real and the simulation results.

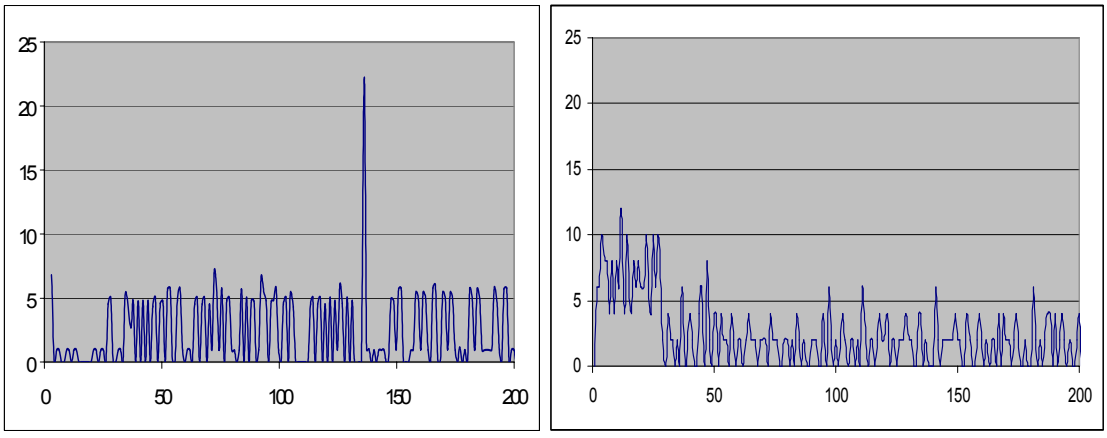


Figure 4: Real experiment (left) and simulation (right) loss rates (%) vs time (sec)