

Experimental Study of Hidden-node Problem in IEEE802.11 Wireless Networks^{*}

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ABSTRACT

The *Hidden-node* problem is a well-known phenomenon in IEEE 802.11 wireless networks. Most previous studies of the hidden-node problem were conducted by simulations, not experiments. In this paper, we set up real-network experiments to investigate the impact of hidden nodes in both infrastructure and multi-hop ad-hoc networks. Our experiments suggest transmission and carrier-sensing channel models different from those in the default settings of the NS2 simulator. We also study the RTS/CTS mode as a solution to the hidden-node problem. We show that using either 2Mbps or 11Mbps to transmit RTS/CTS not only can not solve the problem, but also further degrades the throughput by introducing additional overhead. In addition, our experiments confirm the existence of “re-routing instability” and “optimal offered load” in multi-hop ad-hoc networks which have only been previously “seen” in simulations.

Keywords

Wireless Networks, Ad hoc Networks, IEEE 802.11, Experiments

1. EXPERIMENT SET-UP

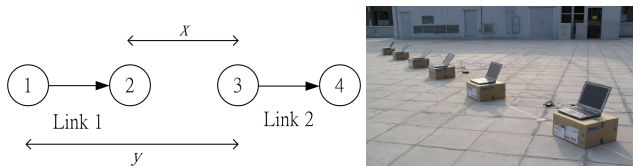


Figure 1. Two 1-hop flows and the real experimental network

We set up a real 6-node multi-hop network with six symmetric DELL Latitude D505 laptop PCs with 1.5GHz Celeron Mobile CPU and 512MB RAM. Each node has a Buffalo WLI2-CF-S11 IEEE 802.11b Wireless LAN card. All nodes run RedHat Linux 9 with HostAP driver. To facilitate experimentation, the transmission power of each WLAN card is fixed to the small value of -38dBm. This has the effect of scaling down the transmission range. The basic and data rates are set at 11Mbps. Unless otherwise indicated, the RTS/CTS mechanism is disabled. The data sources are UDP traffic streams with fixed packet size of 1460bytes.

2. TRANSMISSION CHANNEL MODEL

In the first experiment, we investigate the transmission ranges (TXRange) by varying the distance between node 1 and node 2, for data rates of 2Mbps and 11Mbps. Link 2 is inactive. Figure 2

shows that the 11Mbps-data-rate throughput drops precipitously after distance of 2.2m while that of 2Mbps-data-rate degrades gradually until 10m.

The NS2 simulator’s default setting assumes 2Mbps has a “hard” TXRange (i.e., 250m), below which all transmissions are successful and above which all transmissions are unsuccessful. The experimental results indicate that a more appropriate transmission model will be one in which the probability of successful transmission is a gradual function of distance.

In terms of throughput, we could devise a transmission channel model which includes two operating ranges: 1) full-capacity transmission range and 2) partial-capacity transmission range. With 11Mbps data rate, 1) is around 2.2m while 2) is around 0.4m. With 2Mbps data rate, 1) is around 3m while 2) is around 6m.

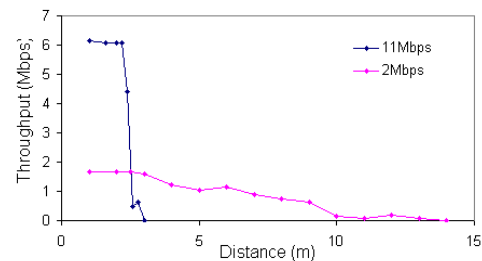


Figure 2. Throughput versus distance y in 1-hop flow

3. CARRIER-SENSING CHANNEL MODEL

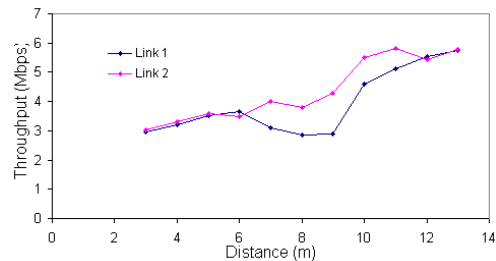


Figure 3. Throughput versus distance y in two 1-hop flows

The next experiment varies the distance between node 1 and node 3 in Fig. 1 with the distances of links 1 and 2 fixed at 2m. The throughput results are shown in Fig. 3. The throughputs as functions of the link separation depend on the carrier-sensing operation. Note that the distance is small in the experiment because we have scaled down the transmission power to facilitate experimentation. Let y be the distance between nodes 1 and 3 and x be the distance between nodes 2 and 3. The particular shapes of the curves suggest a carrier-sensing model which includes four regions: 1) full carrier-sensing region *CSRange* ($y \leq 6m$) where all nodes can hear each other, 2) partial carrier-sensing region ($7m \leq y \leq 9m$) with $y > CSRange$ but $x < InRange$ (Interference

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Range), 3) partial carrier-sensing region ($10m \leq y \leq 12m$) with $y > CSRange$ and $CSRange > x > InRange$, and 4) decoupled region ($y > 12m$) where all nodes can not sense each other. In region 3), the arrival orders of signals determine whether a signal can be received successfully.

Figure 4 shows the simulation results of NS2 with default settings. The nodes of each link are separated by 250m. From Fig. 4, four regions can also be observed. However, all of them have deterministic barriers. These “hard” regions do not exist in real-network experiments as shown by Fig. 3. Thus, we believe a probabilistic model in which the probability of carrier-sensing is a gradual function of distance will be a more accurate model. In addition, the throughputs of link 1 in region 2) ($560m \leq y \leq 690m$) severely degrade to zero which are different from experimental results. Due to space limitation, we defer detailed explanations of our transmission and carrier-sensing channel models to the final poster.

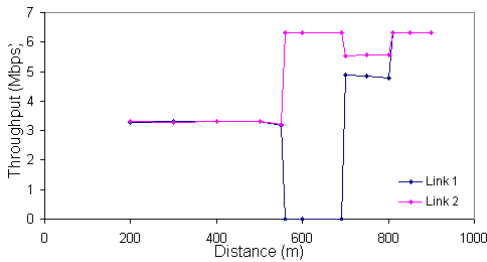


Figure 4. Simulation results of throughput versus distance y in two 1-hop flows

4. RTS/CTS

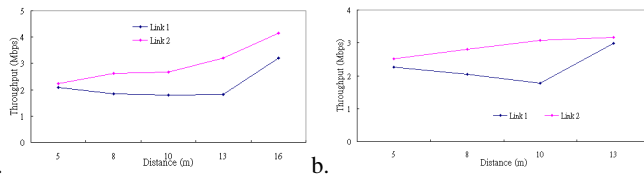
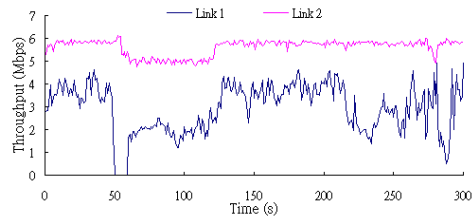


Figure 5. Throughput versus distance y when using a) 2Mbps and b) 11Mbps for transmitting RTS/CTS

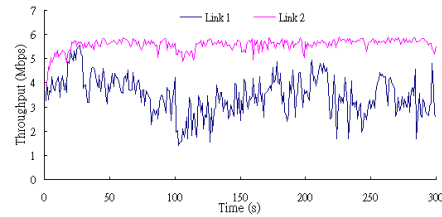
Next, we turn on the RTS/CTS mechanism. Figures 5a and 5b show that using either 2Mbps or 11Mbps to transmit RTS/CTS can not prevent the hidden-terminal problem since RTS from node 1 will collide with DATA from node 3 at node 2. In addition, the RTS/CTS mechanism introduces additional overheads. The throughput of link 1 degrades to less than 2Mbps, which is even worse than that without RTS/CTS.

5. RE-ROUTING INSTABILITY

Reference [1] reported the “re-routing instability” problem in wireless ad-hoc networks observed from simulation. Here we investigate whether such instability occurs in real networks. In this experiment, both links 1 and 2 use AODV as the routing protocol. Figure 6a shows link 2 breaks down for 10 seconds from 50ths to 60ths due to the triggering of the re-routing function in AODV. The associated throughput oscillations are not acceptable for real-time applications such as video conferencing and voice over IP. When AODV is turned off, as shown in Fig. 6b, link 1 has a relatively more stable throughput, although the hidden-node phenomenon still exists.



a.



b.

Figure 6. Throughput versus time a) with and b) without AODV routing protocol

6. OPTIMAL OFFERED LOAD

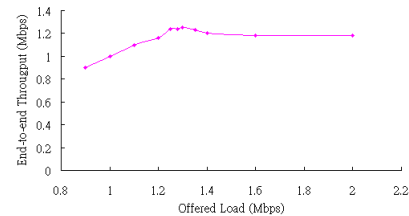


Figure 7. End-to-end throughput versus offered load in a 6-node flow

Reference [2] proposed to control the offered load at the source of a multi-hop traffic flow to eliminate high packet-loss rate and unfairness problems due to self interference. The existence of an “optimal offered load” was derived by simulation and analysis. However, it is not clear whether this exists in real multi-hop networks. Here, we set up a 6-node multi-hop ad-hoc network and our experiment confirms the results of [2]. As shown in Fig. 7, the experimental optimal offered load is obtained at 1.25Mbps. Beyond this value, the offered load is unsustainable – high packet-loss rate is incurred and the throughput obtained is lower than the maximum possible throughput.

7. CONCLUSION

We have performed experiments to verify 1) the existence of throughput degradation and re-routing instability due to the hidden-node problem, 2) the ineffectiveness of RTS/CTS to solve the problem, and 3) the existence of an optimal offered load in a self-interfered multi-hop traffic flow. All these results have only previously been demonstrated in simulations and analyses. Besides confirmation of the above results, additional experiments by us suggest transmission and carrier-sensing models that differ from the default settings in the popular NS2 simulator. Due to space limitation, we defer most details of our work to the final poster.

8. REFERENCE

[1] P. C. Ng, S. C. Liew, “Re-routing Instability in IEEE 802.11 Multi-hop Ad-hoc Networks”, *IEEE WLN'04*, Nov. 2004, Tampa, USA.
 [2] P. C. Ng, S. C. Liew, “Offered Load Control in IEEE 802.11 Multi-hop Ad-hoc Networks”, *IEEE MASS'04*, Nov. 2004, Florida, USA.