TECHNISCHE UNIVERSITÄT BERLIN
Fakultät IV – Elektrotechnik und Informatik
Fachgebiet Internet Network Architectures

WirelessLab WS 2016/17
Homework 6: Medium Utilization

This homework focuses on how the 802.11 channel (the medium) is used in terms of air time.

- What data throughput can we achieve with and without RTS/CTS in theory?
- How much throughput do we get in practice? Is RTS/CTS efficient?
- How can we measure and analyze the utilization of the medium?

Question 1: (40 Points) *Data throughput with and without RTS/CTS*

(a) First, let's try to see on paper why it is not possible to achieve the PHY layer rate in IEEE 802.11 and understand the effect of RTS/CTS regarding throughput.
Assume the following:

- IEEE 802.11g, PHY layer transmission rate = 54 Mbps
- OFDM symbol duration = 4 μs
- MAC layer data payload = 1452 B
- MAC header size = 28 B
- ACK size = 14 B
- RTS size = 20 B
- CTS size = 14 B
- Propagation delay = 1 μs
- Slot time = 9 μs
- SIFS time = 16 μs
- DIFS time = 34 μs
- PHY layer overhead = 20 μs
- Random backoff: Between 1 and 15 slots. Use the Expected value.

Calculate the MAC layer throughput, i.e., the number of bits sent as payload within the MAC layer in a given period of time, for the following:

- A station is sending to an AP without using RTS/CTS.
- Same as above but RTS/CTS is enabled.

Compare and interpret your results.

(b) Now, you will analyze the impact of RTS/CTS in the testbed.
Set up your nodes, one as Access Point, one as client, so they can ping each other.
Enable RTS/CTS on the client for all packets that exceed 100 bytes. You can use the following command:

```
> iw phy <phyname> set rts <threshold|off>
```

Alternatively, you can configure it in `/etc/config/wireless`, setting `rts`. Setting the threshold to 2346 or simply ,,off" disables RTS/CTS.
Fix the data rate on both interfaces at 54 Mbps.
Setup an iperf experiment between the nodes, sending 1400 Bytes within each UDP datagram at 54 Mbps for 30 seconds per run. Repeat this ten times for both (a) RTS/CTS enabled, with a threshold of 100 Bytes, and (b) RTS/CTS off.
Afterwards, repeat the experiment with sending 200 Bytes within each UDP datagram.
Draw a boxplot comparing the median throughput and 95% confidence for the median for all four cases.
Explain your results. How does the throughput compare to the theoretical values from (a)?

Question 2: (60 Points) *Measuring the medium utilization*

The goal of this exercise is to compute the utilization of the medium, i.e., the percentage of time during which the medium is busy, for instance due to an 802.11 frame being detected.

You will try three different ways of computing the medium utilization, so read the whole question first before starting your experiment. Also, record the date and time at which you do your experiment.

(a) Configure the node with one wireless interface to be the sender and the node with two interfaces to be the receiver on its ath5k card and the monitor on its ath9k card. Do not set a fixed data rate, and turn RTS/CTS off.

Start a packet capture on the monitor interface. At the same time, do a `iw dev $INTERFACE survey dump` on the receiving interface periodically (about every 100 ms) and record the output. Note: Before doing this, please reset the counters, e.g.:
`echo '1' > /sys/kernel/debug/ieee80211/phy0/ath5k/reset`

About 5 seconds after starting the packet capture and the survey dump, run an iperf experiment with only UDP traffic at 54 Mbps for 15 seconds. Stop the capture and the survey dump after the iperf has finished.

(b) Compute the medium utilization over time (one value for every 1 second) in these three ways:

- Write a script that gets your packet trace as input and that computes the sum of packet durations for every second. You can use a formula similar to what you used in 1 (a).
  Note: You need to take into account the announced rate in the frame, and information about the preamble within the radiotap header, and the length of the payload in bytes. You can assume a propagation delay of 0 μs.
- From the packet trace, read the Channel Utilization from the BSS Load information elements of the beacon frames on the channel, and compute its mean for every second.
  Note: Your own Access Points do not insert BSS Load elements, since their implementation in hostapd seems to be broken. Please use the BSS Load elements from the beacons sent by other APs on the same channel, such as eduroam.
- From the surveydump output, read the duration during which the interface sensed the medium busy, was in sending mode (tx) or in receiving mode (rx) during every second.

(c) Make a plot with the medium utilization (percentage of time that the medium was busy for every 1 second) over time for all three ways of computation and compare them. Are they similar? If not, describe and explain the differences.

(d) For the time period between the first UDP packet and the last UDP packet in the trace, make a barplot that shows how many percent of the time there was what type of frame on the air (data frame of the UDP traffic, other traffic such as beacon frames/probe requests, or no frame). What do you observe?

Submission
`https://www.isis.tu-berlin.de/2.0/course/view.php?id=8501`

Please submit a PDF document containing *a cover page* with your names and group ID, and *having your group number in its file name.*
The PDF should contain:

- Question 1: Your calculation (i.e., the formulas you use and the result) for the first part, and all your scripts and plots for the second part. Elaborate on your results in text.
- Question 2: All scripts and plots, as well as some written evaluation.

Please also include your scripts in a format in which we could run them ourselves.
All code must be properly documented using inline comments in English.
Make an archive (.tar.gz, .zip) containing *a directory* with all of your files and *having your group number in its file name.* All files that belong to a specific question must have the question/subquestion in their filenames. Please try not to clutter your submission with temporary files.
Due Date: Wednesday, 7. December, 23:55.