IK2217
NS-3 Project – Starving Your Neighbor's Wi-Fi

Due on 12:00 (noon), Tuesday, March 11, 2014

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Rules: Group Formation, Report, Grading, and Bonus Points

Each group of two students will accomplish this NS-3 project. The formation of group will be announced before or shortly after this handout is available to you. Each group will work on their own computers and make one report consisting of answers to the questions in this material. The **report**, that can be either a PDF file or a Microsoft Word file, along with all **NS-3 scripts** used for the project should be zipped into **a single file** and handed in. The length of the report should be between 2 page to 7 pages (font size: no less than 10, paper size: A4 or Letter). Your report and NS-3 scripts will be graded as PASS or FAIL. You can opt to solve the bonus problem to be eligible for the bonus points which will range up to 10% of the total point of the written exam and will mark up your written exam point. Note however that only a few selected groups (which can be either 0, 1, 2 or 3) will be awarded bonus points. The number of selected groups will be decided based on the overall quality of the project reports.

Please bear in mind that you must hand in your report (including NS-3 script) by the deadline, 12:00 (noon) on **March 11**. Since those of you who do not pass NS-3 project will not be eligible for the final exam which is only a few days later than the deadline of the project, your report **shall not and can not** be graded after the deadline. Lastly, please do not forget to write your names on the report.

Underlying Assumptions

To simplify the exposition and to minimize scenarios you have to consider, we make several assumptions:

- All stations (a station refers to either 'node' or 'AP' in this project) are 802.11b-capable. Do not use other versions of 802.11.
- All stations employ CSMA/CA protocol and use the RTS/CTS mechanism based on carrier-sensing capabilities.
- The transmission range of each station is the same as to its sensing range. In other words, station A is able to sense the activities of station B if and only if station A is able to transmit frames to station B.
- The communication channel is error-free. However, there are collisions, that is the main factor to be taken into account.
- All stations are always backloggged, *i.e.*, they always have data in their transmission queues.
- The *Auto Rate Fallback* protocol is disabled, *i.e.*, all stations use a single fixed data rate to transmit the data frames. Though the qualitative outcomes of the project do not depend on a specific data rate, we simply choose to use 11Mbps among three rates of 802.11b.
- The transport protocol adopted by all flows in the project is UDP. The MTU size for the 802.11 protocol is 2272 bytes.
- Each simulation should be run for 100 seconds in simulation time.

Problem 1: Basic Starvation

After moving into a new and cosy apartment, you were leading a happy life there for the time being. Life, however, as is usual, does not treat you well so long. It turns out that your neighbor is not likeable at all. After suffering from insomnia for a few nights due to noisy sounds from your neighbor, you reach a conclusion that your neighbor has been watching movies downloaded from BitTorrent. In revenge for this uncivilized behavior of your neighbor, you make a grim determination to take an effective yet legal measure, *i.e.*, starving your neighbor's Wi-Fi by using your knowledge gained while taking the course 'IK2217: Advanced Internetworking 2'.

As shown in Fig. 1, there are two flows in the two apartments: (i) the flow in your neighbor consists

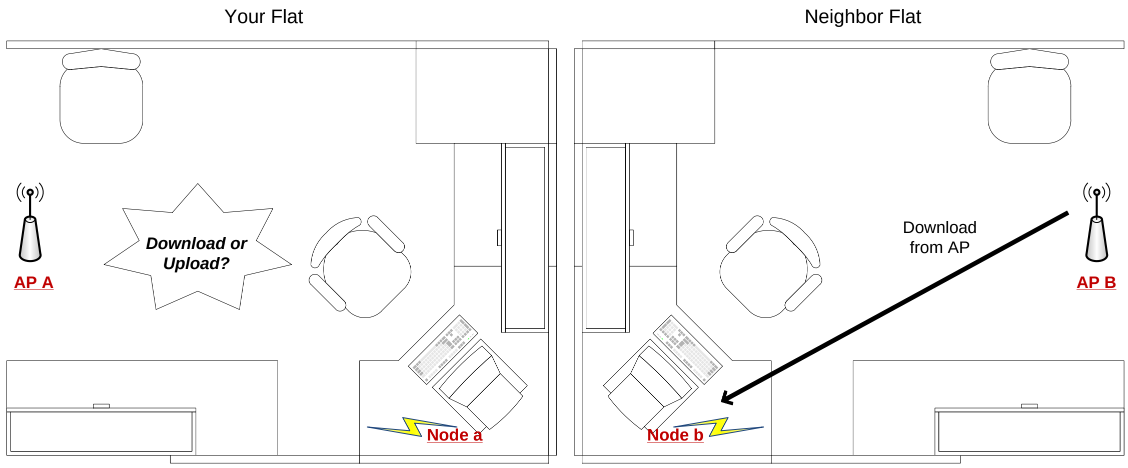

Figure 1: Ground Plan of the Two Apartments

of the source, AP B, and the destination, Node b, on which your neighbor watch movies, and (ii) the flow between your wireless router, AP A, and your computer, Node a. We denote the flows by flow $B - b$ and flow $A - a$, respectively.

We assume that each of the pairs $\{A, a\}$, $\{B, b\}$ are *conflicting pair*. In other words, two components of a pair (*e.g.*, A and a) are within the transmission range of each other (*i.e.*, the received SNR is above the carrier sense threshold). You haven't yet decided how to effectively disturb flow B-b.

Problem 1(a)

To begin with, set up the following topology in NS-3:

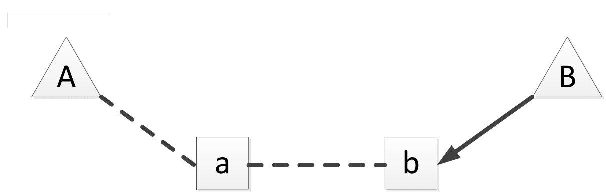

Figure 2: Topology 1

Fig. 2 shows a topological view of Fig. 1 where two stations connected by 'dotted line' are within transmission range of each other. Two stations connected by 'solid arrow' are not only within transmission range of each other but also capable of transmitting data frames into the direction indicated by the arrow.

As it turns out later, it is imperative that B is able to sense only b. Otherwise, you cannot throttle your neighbor's Wi-Fi flow $B - b$. Thus, first of all, we should make sure that a and B cannot sense each other. Since we assume that the sensing capabilities are symmetrical, *i.e.*, a cannot sense B if and only if B cannot sense a, we can ensure that B can sense only b by eavesdropping the activities of B from a.

After setting up the data transmission from B to b in NS-3 (Note that flow $A - a$ is not activated yet), run the script and monitor all frames that can be overheard from a. How many ACK frames are sent by b per each second? Can you infer from this fact how many data frames are sent by B?

Problem 1(b)

As a first step towards starvation of neighbor's Wi-Fi, we activate the data transmission from node A which in turn implies that we investigate the following topology:

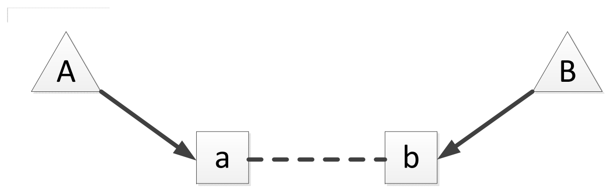

Figure 3: Topology 1 – A transmits

Note that the two flows, $A - a$ and $B - b$, must exhibit the same characteristics due to the symmetry of the topology. Make and run the corresponding NS-3 scripts to answer the following questions. How many data frames B sends per each second? Is it the same to that of A?

Problem 1(c)

After stopping the transmission from A to a, we now activate the data transmission from node a instead of A, which leads to asymmetry in the topology as shown in Fig. 4:

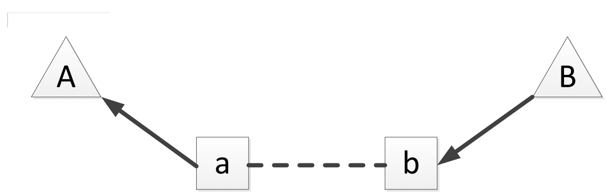

Figure 4: Topology 1 – a transmits

Make and run the corresponding NS-3 scripts to answer the following questions. In this case, how many data frames B sends per each second? Is it the same to that of A? Explain why you can throttle the flow $B - b$ in this topology. What is the main cause of this phenomenon? Compare the average contention windows of the two flows. **Commentate** in detail the NS-3 script used to answer this question and paste the script onto your report.

Problem 2: Cooperative Starvation

In this case, unfortunately, you who live in Flat A get to know that all stations in your flat are within the transmission range of those of the stations in Flat B, where the bad guy resides, implying in turn that you cannot take the topological advantage of Fig. 2. Thrown into despair, you encounters another neighbor by chance, called neighbor C, and happens to find out that he is also very keen about teaching the bad neighbor B a lesson. As shown in Fig. 5, the two guys in flats A and C now cooperate to starve the Wi-Fi flow of neighbor B.

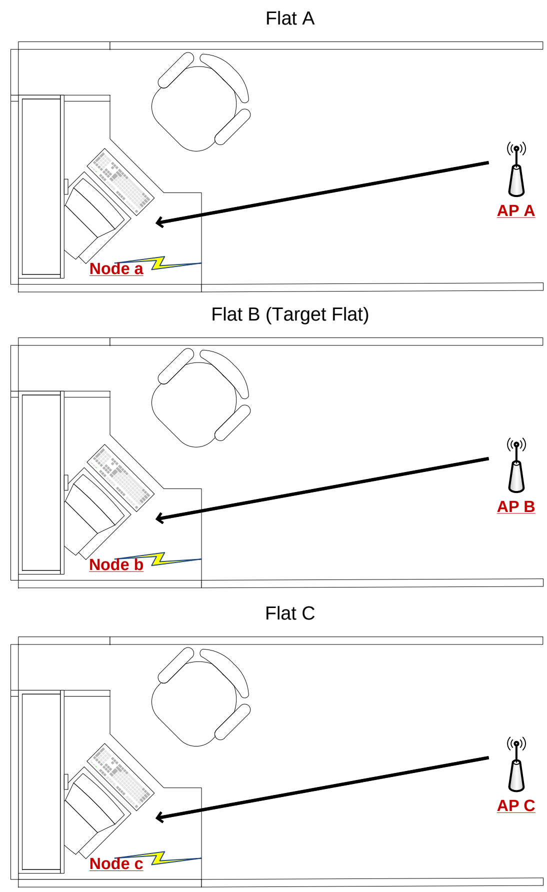

Figure 5: Ground Plan of the Three Apartments

Suppose that the topology of Fig. 5 is given by Fig. 6. Set up this topology in NS-3 and run scripts needed to answer the following questions. How many data frames B sends per each second? How many data frames A and C send per each second? How did you deprive the guy in Flat B of Wi-Fi access? From the viewpoint of flow $B - b$, what is the fundamental difference between the two scenarios in Figs. 4 and 6?

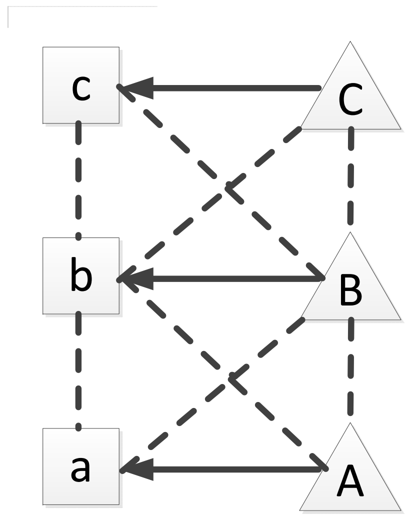

Figure 6: Topology 2

Only a very few groups will be selected and be awarded bonus points for which you will be eligible by solving the following bonus problem. Since merely solving the bonus problem does not warrant the bonus points and all your solutions will be taken into consideration for the rather competitive selection process, you are recommended to devote decent amount of time to this project and would better skip the bonus problem depending on your circumstances.

Problem 3 (Bonus Problem): Performance of Backoff Mechanism

An astute student might have realized that the two problems so far have been centered on *multi-cell Wi-Fi networks* where the synchrony property does not hold. In this bonus problem, we study basic formulae in *single-cell Wi-Fi networks* where all nodes can hear each other and attempt to transmit data to a single destination node, which in turn implies that the entire performance analysis is simplified by harnessing the synchrony property.

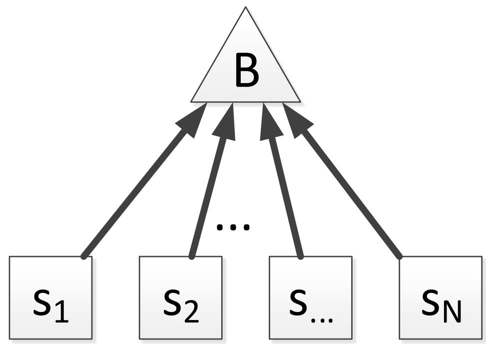

Figure 7: A Single-cell Wi-Fi Network

As shown in Fig. 7, there are N sources, *i.e.*, $s_1, \cdots, s_N$ sending data to the same node B. We investigate how the extent of collision among flows influence the network and its throughput. During lectures, we talked about several equations which offer glimpses of the relation between collision probability, transmission attempt probability, and the number of nodes, which in turn was delineated by the so-called Bianchi's formula. However, the formula, also called as fixed point equation does not explicitly show how the key metrics such as collision probability and transmission attempt probability vary with the number of nodes.

Problem 3(a)

Make and run NS-3 scripts for different values of N (including $N = 1$ and $N = 2$) and plot the average *aggregate* collision probability of all nodes, $s_1, \cdots, s_N$. In order to obtain steady-state results, you will have to run those simulations for a much longer time than 100 seconds. It is left to you to decide what values of N and how long time the simulations should be run for. As a general guideline, N should be large enough that you can be sure about the overall trend of the collision probability with respect to the number of nodes. Plot a graph of the average collision probability with respect to the number of nodes. Formally, the collision probability seen by a node is:

$$\gamma := \text{Prob(an attempt by a node fails to transmit data because of a collision)}$$

There are various ways to extract this metric in NS-3. Describe briefly which output variables in NS-3 you chose to monitor and how you post-processed them to compute the average collision probability. **Commentate** in detail the NS-3 script used to answer this question and paste the script onto your report.

Problem 3(b)

Likewise, make and run NS-3 scripts for different values of N (including $N = 1$ and $N = 2$) and plot the average *total* throughput of all nodes, $s_1, \cdots, s_N$. Once again, it is left to you to decide what values of N

and how long time the simulations should be run for. Plot a graph of the average total throughput with respect to the number of nodes.

Does the total throughput monotonically increase with the number of nodes? How would you like to change the backoff mechanism to better optimize the total throughput provided that you can make use of the information on the number of nodes in the network and reflect this information into the design of the backoff mechanism? Suggest at least one revision method to enhance the throughput performance.

Note that you need to commentate only the NS-3 script used in Problem 1(c) and Problem 3(a) in case you opt to solve the bonus problem.