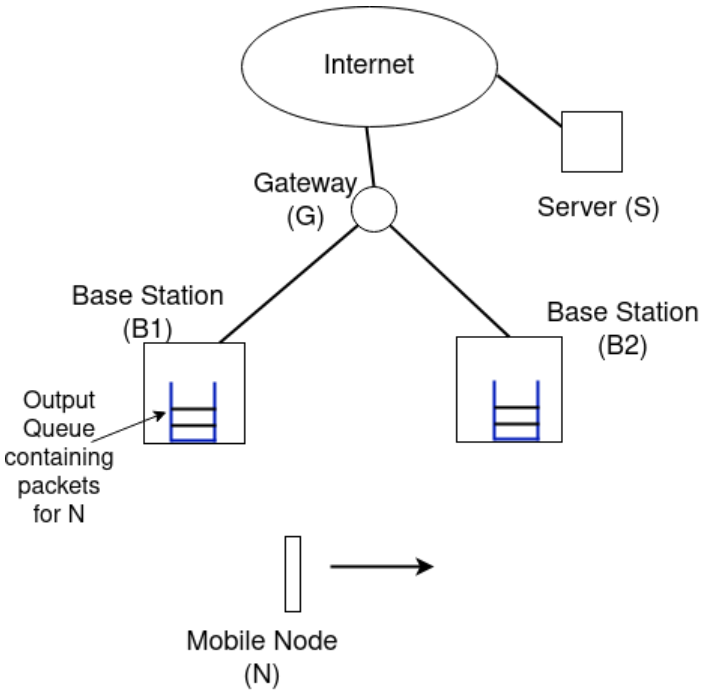
CS348, Assignment 4

Upload a file named <rollno>-cs348-hw4.pdf to Moodle. The final solution must be written entirely by you. Discussions with other classmates is allowed.

Consider the Figure below which depicts a wireless mobile node (N) moving from the coverage of one base-station (B1) to the coverage area of another base-station (B2) in a 4G network. We say that N is in the coverage area of B1 if it is connected to that base-station and receiving data from it.



Suppose that the node N is downloading data via **TCP Reno** from a server (S) located somewhere in the Internet outside this wireless network. Packets from S reach N via G–B1–N when N is in the coverage of B1. The link G–B1 is wired and the link B1–N is wireless. Assume that B1 uses **FIFO output queues with drop-tail mechanism** (recall that "drop-tail" means that arriving packets are dropped if the buffer is full) at every interface. Hence packets (from S to N) arriving on link G-B1 are put into the output queue at B1 (on interface B1-N as shown in the figure) before being sent to N.

As node N moves away from B1 towards B2, the signal strength from B1 to N decreases, which in turn reduces the signal to noise ratio at N. This leads to an increase in bit-error-rate (BER). To improve the BER, B1 uses a lower modulation rate (e.g. changes from QAM-16 to BPSK) to send data to N.

When N finds out that the signal strength from B2 is better than that from B1, it performs a “handover” to B2. At the instant handover takes place (say time t_0), packets reaching G from S, which have destination N, are immediately redirected by

G to B2; that is packets reach N via G–B2–N.

Note that at the instant of handover (t_0), some packets which were destined for N may still be queued at B1 (in output queue at interface B1-N). These packets are then redirected (re-routed) by B1 to B2 via G (on path B1–G–B2). We need not bother about the exact protocol that B1 uses to send these packets to B2, but encapsulation is one possibility.

As N approaches B2, the signal strength at N (for signals from B2) improves, and consequently B2 uses a higher modulation rate to transmit data to N (e.g. changes from BPSK to QAM-16).

For simplicity, assume that N is the only mobile user in the 4G network. Assume that the **same frequency bandwidth** is available for transmission from either base-station (B1 or B2) to N. The following questions are subjective.

(a) (5 marks) First consider the time period before the handover, that is when N is in the coverage of B1. What effect might the reduction in modulation rate (when N is still in the coverage of B1) have on TCP performance (throughput, RTT, packet loss)? You may use diagrams to explain your answer (e.g. cwnd vs. time, RTT vs. time etc.). Assume that all links other than the wireless links have infinite link capacity and that the output queue at B1 can store at most "K" packets.

(b) (5 marks) Recall that at the instant handover takes place (say time t_0), packets reaching G from S, which have destination N, are immediately redirected by G to B2; that is packets reach N via G–B2–N. In addition, some packets which were destined for N may still be queued at B1 (in output queue at interface B1-N) and these packets are then redirected (re-routed) by B1 to B2 via G (on path B1–G–B2). What effect might this have on TCP performance?

(c) (10 marks) Modify the **TCP protocol at the wireless node** (N) in order to mitigate some or all of the negative effects on performance you have mentioned while answering the questions above. You are **not allowed** to modify the TCP implementation at the server (S). This means that S implements the TCP Reno protocol according to the rules discussed in class, without modifications. TCP running at S only expects TCP ACKs from TCP at N. No other special feedback from N to S is allowed. The TCP implementation at N may be a cross-layer solution, that is, TCP (running at N) can ask other protocol layers (running at node N only) for information (e.g. ask the PHY layer for the current modulation rate etc.). State clearly what information TCP asks from lower layers at N and how it uses this information. State any extra assumptions you make.