# Course on Evolving Internet

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## Homework 2 – Due on Wednesday 6, 2024 (23:59 CET)

**Problem 1: Shortest paths in Fully Predicted Delay-Tolerant Networks**

Assume a Delay Tolerant Network composed of five nodes A, B, C, D and E. Nodes get in contact with each other from time to time. The schedule of contacts between any two nodes is given next in the form of a couple ($t_{start}$ ; $t_{finish}$), which implies that from time $t_{start}$ to time $t_{finish}$ data between the two nodes can be transferred:

- (A;B) = (1; 3); (7; 10); (15; 16); (25; 30)
- (A;C) = (3; 4); (6; 8); (11; 14); (21; 23)
- (A;E) = (9; 12); (20; 23)
- (B;C) = (4; 6); (12; 15); (18; 20); (27; 28)
- (B;D) = (1; 2); (10; 13); (19; 23)
- (C;D) = (7; 8); (15; 17); (25; 26)
- (D;E) = (2; 4); (8; 10); (15; 17); (27; 30)
- (C;E) = (3; 4); (9; 12); (20; 22); (26; 28)

a) Find shortest paths (minimum delay paths) from A to all other nodes, starting at time 0, using the modified Dijkstra's algorithm. Show all the intermediate steps of the algorithm. We assume bandwidth to be infinite and propagation delay of links to be zero. Give for each destination the path to follow and the total delay.

b) What if A has to transmit a message at time 5 to node D for example ? do the previous calculated paths still hold ? What would be then the path to follow from A to D at time t = 5 ?

**Problem 5: Performance of long TCP transfers**

A client downloads a large file with TCP on an ADSL access with 10 Mbps in the downlink and 1 Mbps in the uplink. *We assume that the client acknowledges every TCP packet*. The total size of a data packet is 1500 bytes. This size includes 1440 data bytes, the 20 bytes of the TCP header, the IP header of 20 bytes and the 20 bytes of the Ethernet header. The total size of an acknowledgement is 60 bytes: 20 bytes of TCP header, 20 bytes of IP header and 20 bytes of Ethernet header. The round-trip delay between the client and the server is 200 ms.

1) Assume first that there is no packet loss in the network. What should be the size of the window advertized by the TCP client to be able to use 100% of the downlink bandwidth? *We recall that the TCP window is measured in bytes and that the client downloads a window worth of bytes ever round trip.* Is the current window field in the TCP header enough to announce to the server such required window?

2) When using the downlink at 100%, what would be the utilization of the uplink caused by the TCP acknowledgments?

3) We now assume that the network loses a packet every 5 seconds. *The client window is set to the value calculated in step 1).*

   a. Put yourself in the Congestion Avoidance phase where the TCP congestion window increases by 1 packet every round trip and ignore the slow start phase. *The window is always measured in bytes*. By how much can the congestion window increase between two successive losses? Call this quantity W. Find its value.

   b. The window is divided by two upon each packet loss. Consider a periodic evolution of the congestion window, where it decreases from 2W to W when a loss occurs, then increases by W bytes until the next loss, where it is decreased again from 2W to W, and so on. What would the long-run TCP throughput? The time between packet losses is always set to 5 seconds.

4) Now, the time between packet losses is no longer 5 seconds. Let's consider it to be constant during the entire TCP connection and equal to T (T > 0).

   a. According to you, how TCP throughput varies as a function of T when T is "less" than 5 seconds? Give the expression of the throughput as a function of T.

   b. What happens when T gets above 5 seconds? Starting from which value of T > 5 the window size (i.e., the 2W) starts hitting the maximum network capacity?

   c. Denote the value calculated in b) by T0. According to you what can happen to the TCP throughput when T becomes larger than T0?