1. **(25 points)** State whether the following statements are true or false. No justification is necessary.

   (a) (5 points) The goal of TCP congestion control is to achieve high throughput with no packet loss.

   (b) (5 points) As the propagation delay decreases, the performance of the selective-repeat ARQ protocol will approach that of the Go-Back-N protocol.

   (c) (5 points) For stable G/G/1/N systems with one server and buffer size N, the probability that an arrival is blocked is equal to the fraction of time that the system is full.

   (d) (5 points) Consider an M/M/K/(K+1) system with K servers and one additional buffer space. Let N(t) be the number of servers that are busy at time t.

   **Statement:** N(t) is a continuous-time Markov chain.

   (e) (5 points) Packets arrive to a network node A according to a Poisson process with rate λ. Every packet that arrives is transmitted independently to station 1 with probability 2/3 and to station 2 with probability 1/3. Station 1 and 2 are connected only to node A.

   **Statement:** Given the above configuration,

   \[
   \lim_{t \to \infty} \frac{|N_1(t) - N_2(t)|}{t} \to \frac{1}{3} \lambda.
   \]

   where \( N_i(t), i = 1, 2, \) is the number of packets that arrive at station i in the time interval (0, t).

2. **(30 points)**

   (a) (10 points) Carefully describe Dijkstra's algorithm.

   (b) (20 points) Using Dijkstra's algorithm, find the shortest path between Node B and all other nodes in the network shown below. (Note: the source node is Node B.)
3. (45 points) A service provider (e.g., one that serves web requests) can use one or more servers to handle service requests. Assume that service requests arrive according to a Poisson process. Currently, the service provider has only one server that can serve each request in an exponentially distributed amount of time with mean $1/\mu$. However, as the demand increases, the service provider needs to increase the capacity. There are two options available. One option is to buy an additional server with identical capacity. The other option is to upgrade the existing server to a faster server with $c$ times the current capacity. In other words, each request will then take on average $1/(c\mu)$ time to be served. Let $\lambda$ be the arrival rate that the service provider expects to handle. Assume that with either options, the service request that finds the server(s) busy will wait in an infinite-buffer queue. The service requests are always served on a first-come-first-serve basis. You are asked to compare the two options in the following questions.

(a) (10 points) Suppose the service provider chooses option 1 (buying an additional server). Draw a state-transition diagram of the system.

(b) (10 points) Find the probability $p_n$ that there are $n$ service requests in the system.

(c) (10 points) Find the expected delay from the time that a service request arrives, to the time that the service request is completed.

(d) (15 points) Now, suppose that the service provider chooses option 2 (upgrading the capacity to $c\mu$). Find the value of $c$ that would lead to the same expected delay as the one you obtained in part (c).