Problem 1:
For this problem you should familiarize yourself with Figure 1 first. Now assume that in the network shown in Figure 1 two parallel TCP transmissions are performed. TCP1 is a transmission between Source A and Sink A that uses TCP Tahoe. TCP2 is a transmission between Source B and Sink B that uses TCP Reno. Initial ssthresh for both TCP transmissions is set to 32. In this specific scenario no additional delay through forwarding is introduced. Thus, the RTT is only composed of the sums of the delay indicated on each link, times two.

a. For the TCP 1 transmission, draw the resulting congestion window, assuming that a packet loss (triple duplicate ACKs) is detected at time t=900ms.
b. For the TCP 2 transmission, draw the resulting congestion window, assuming that a packet loss (triple duplicate ACKs) is detected at time t=650ms.
c. Describe the benefit of TCP Reno over TCP Tahoe.

![Network layout](image)

Figure 1 Network layout for problem 5.
Solution:
Problem 2:
Consider the network shown below, and assume that each node initially knows the cost to each of its neighbors. Consider the distance-vector algorithm and show the distance table entries at node \( z \).
Cost to
\[ u \quad v \quad x \quad y \quad z \]
\[ v \]
From \[ x \]  
\[ z \]

Cost to
\[ u \quad v \quad x \quad y \quad z \]
\[ v \]
From \[ x \]  
\[ z \]

Cost to
\[ u \quad v \quad x \quad y \quad z \]
\[ v \]
From \[ x \]  
\[ z \]

Solution:
Cost to
\[ u \quad v \quad x \quad y \quad z \]
\[ v \quad \infty \quad \infty \quad \infty \quad \infty \quad \infty \]
From \[ x \quad \infty \quad \infty \quad \infty \quad \infty \quad \infty \]
\[ z \quad \infty \quad 7 \quad 3 \quad \infty \quad 0 \]
Problem 3:
Consider four LANs interconnected by two routers, as shown in the figure below.
   a. Assign IP addresses to all of the interfaces. For Subnet 1 use addresses of the form 192.168.1.xxx; for Subnet 2 use addresses of the form 192.168.2.xxx; for Subnet 3 use addresses of the form 192.168.3.xxx; for Subnet 4 use addresses of the form 192.169.4.xxx; and for Subnet 5 use addresses 192.168.5.xxx.
   b. Assign MAC addresses to all of the adapters.
   c. Consider sending an IP datagram from Host E to Host B. Suppose all of the ARP tables are up to date. Enumerate all five steps required. (1. What interface should packet be routed to? 2. What are destination and source addresses of Ethernet frame created at E? 3. What happens at router 2? 4. What are destination and source addresses of Ethernet frame created at Router 2? 5. Repeat steps 1-4 for the remainder of the path!
   d. Repeat (c), now assuming that the ARP table in the sending host is empty (and the other tables are up to date).
Solution:

a), b) See figure below.

c) d) ARP in E must now determine the MAC address of 198.162.3.002. Host E sends out an ARP query packet within a broadcast Ethernet frame. Router 2 receives the query packet and sends to Host E an ARP response packet. This ARP response packet is carried by an Ethernet frame with Ethernet destination address 77-77-77-77-77.

Problem 4:
Suppose nodes A and B are on the same 10 Mbps Ethernet bus, and the propagation delay between the two nodes is 245 bit times. Suppose A and B send frames at the same time, the frames collide, and then A and B choose different values of $K$ in the CSMA/CD algorithm. Assuming no other nodes are active, can the retransmission from A and B collide? For our purposes, it suffices to work out the following example. Suppose A and B begin transmission at $t=0$ bit times. They both detect collisions at $t=245$ bit times. They finish transmitting a jam signal at $t=245+48=293$ bit times. Suppose $K_A=0$ and $K_B=1$. At what time does B schedule its retransmission? At what time does A begin transmission? (Note: The nodes must wait for an idle channel after returning to Step 2.) At what time does A’s signal reach B? Does B refrain from transmitting at its scheduled time?

To answer these questions complete the table below! (Idle bit time is 92)

<table>
<thead>
<tr>
<th>Time, $t$</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$A$ and $B$ begin transmission</td>
</tr>
<tr>
<td>245</td>
<td>$A$ and $B$ detect collision</td>
</tr>
<tr>
<td>293</td>
<td>$A$ and $B$ finish transmitting jam signal</td>
</tr>
<tr>
<td>293+245=538</td>
<td>$B$’s last bit arrives at $A$; $A$ detects an idle channel</td>
</tr>
<tr>
<td>538+96=634</td>
<td>$A$ starts transmitting</td>
</tr>
<tr>
<td>293+512=805</td>
<td>$B$ returns to Step2</td>
</tr>
<tr>
<td>634+245=879</td>
<td>$A$’s transmission reaches B</td>
</tr>
</tbody>
</table>

Solution

Because $A$’s retransmission reaches $B$ before $B$’s scheduled retransmission time ($805+96$), $B$ refrains from transmitting while $A$ retransmits. Thus $A$ and $B$ do not collide. Thus the factor 512 appearing in the exponential backoff algorithm is sufficiently large.

**Problem 5: (Modify)**

Suppose within your Web browser you click on a link to obtain a Web page. The IP address for the associated URL is not cached in your local host, so a DNS lookup is necessary to obtain the IP address. Suppose that $n$ DNS servers are visited before
your host receives the IP address from DNS; the successive visits incur an RTT of $RTT_1$, ..., $RTT_n$. Further suppose that the Web page associated with the link contains exactly one object, consisting of a small amount of HTML text. Let $RTT_0$ denote the RTT between the local host and the server containing the object.

a. Assuming zero transmission time of the object, how much time elapses from when the client clicks on the link until the client receives the object?

Now suppose the HTML file references six very small objects on the same server. Neglecting transmission times, how much time elapses with

b. Non-persistent HTTP with no parallel TCP connections?

c. Non-persistent HTTP with browser configured for 2 parallel connections?

d. Persistent HTTP?

Solution:

a. The total amount of time to get the IP address is $RTT_1 + RTT_2 + \cdots + RTT_n$.

Once the IP address is known, $RTT_0$ elapses to set up the TCP connection and another $RTT_0$ elapses to request and receive the small object. The total response time is $2RTT_0 + RTT_1 + RTT_2 + \cdots + RTT_n$.

b. $RTT_1 + \cdots + RTT_n + 2RTT_0 + 6*2RTT_0 = 14RTT_0 + RTT_1 + \cdots + RTT_n$

c. $RTT_1 + \cdots + RTT_n + 2RTT_0 + 3\cdot2RTT_0 = 8RTT_0 + RTT_1 + \cdots + RTT_n$

d. $RTT_1 + \cdots + RTT_n + 2RTT_0 + RTT_0 = 3RTT_0 + RTT_1 + \cdots + RTT_n$.

Problem 6:
The figure below shows three wireless nodes and their transmission ranges.

a. Use Figure 3 to explain the “hidden node” problem. What happens when nodes A and C start sending a message simultaneously?

b. Use Figure 4 to explain how CSMA/CA is realized in the case of the IEEE 802.11 protocol. For your explanation, assume that A wants to send a frame to the destination.

![Figure 3](image-url)
Figure 4