1. (15) Discuss how you can extend the three ad hoc wireless routing algorithms below to find paths satisfying a “bandwidth” QoS requirement:

(a) DSR

**Answer:** In DSR the RouteRequest Packet is NOT forwarded on links that do not satisfy the QoS requirement. As a result, only paths that satisfy the bandwidth constraint are generated.

(b) AODV

**Answer:** Same answer as for DSR – the RR Packets will not travel on inadequate links.

(c) Distance Vector

**Answer:** Here again, DV advertisements are not forwarded on non compliant links. As a consequence, only the compliant links are used in the distributed shortest path alg. Note that if you have different traffic sources with different constraints, you will need to run a separate instance of DV for each constraint.
2. (15) Consider an ad hoc network scenario where path length is limited (say, at most 5 hops). You have developed a new TCP protocol that can distinguish “random” loss (e.g., loss caused by jamming or microwave oven interference) from the loss due to congestion and buffer overflow, and you want to assess its efficacy. Will the above knowledge (random vs congestion loss) be helpful in adjusting:

(a) TCP congestion window?

**Answer:** the optimal congestion window for the case above is $\text{CongW} = 1$, so the knowledge of loss / congestion has no effect.

(b) TCP retransmission time out?

**Answer:** The knowledge that the loss was error rather than congestion related has MAJOR impact on the choice of timeout. In particular, if the loss is due to random errors, the time out is kept fixed instead of being increased exponentially.

3. (20) Consider the TCP variant called XCP (Explicit Control Protocol). Is this protocol protected from random packet loss? More precisely, are both efficiency and fairness preserved in spite of random packet loss? Please justify your answer

**Answer:** Random packet loss triggers unnecessary congestion window reduction in TCP Reno, leading to inefficient channel utilization. In XCP, channel efficiency relies on the accurate computation of “residual bandwidth” and queue length. Such measurements are only “minimally” affected by random packet loss. Fairness of bandwidth allocation to the various flows is dependent on the per packet feedback delivered to the flows. Recall that each packet in the flow delivers an incremental feedback. So, the loss of an isolated packet has only a marginal impact on the flow increase/decrease. This loss, if it occurs on the bottleneck link, affects all flows equally.

4. (15) TCP Westwood and TCP Vegas share an important property. They both can distinguish a lightly loaded path from a congested path. How is that done?

**Answer:** both TCP W and TCP Vegas compute (from the returning ACKs) the average rate $R$ achieved by the flow. Given $R$, the congestion window $\text{CWIN}_{\text{min}}$ that would yield that value of $R$ in absence of bottleneck backlog is given by:

$$\text{CWIN}_{\text{min}} = \text{RTT}_{\text{min}} \times R,$$

where $\text{RTT}_{\text{min}}$ is the minimum value of RTT measured during the life of this connection.

The difference $(\text{CWIN}_{\text{actual}} - \text{CWIN}_{\text{min}})$ represents the extra packets that have accumulated in various queues along the path, typically, in the bottleneck. Thus, a large backlog means a congested path.
5. (15) According to results reported in class, in a “long range dependent” traffic scenario “Measurement Based” CAC seems to work better than “Quota” or “Parameter” based CAC. Can you explain why?

**Answ:** the long range dependent traffic is traffic with long tails in the distribution, and thus with long intervals of “high rate” followed by long intervals of “low rate”. The measurement approach can detect these fluctuations when they occur, and can allocate new traffic accordingly. The “quota” method uses a fixed allocation for each flow based on “average” or “percentile” flow rate. Whatever the method used to allocate bandwidth, in an LRD situation the quota system is bound to underestimate the traffic during very active periods and thus lead to packet loss.

6. (20) In the “Chord” scheme the ID of a node in the linear identifier space is found by hashing the node IP address.

(a) Show that the Chord directory properties (search, insert, etc) are preserved even if you map the nodes to pre-selected locations instead of using the hash of the IP address.

**Answ:** Assume a node is placed on the virtual linear space in a specifically selected location, as opposed to using the hash of the IP address that will place it in a pseudo random location impossible to control a priori. As part of this placement, the node is inserted in the linked list through the fingers. Once the links are in place, the system will function properly. In fact, key insertions/deletions depend only on the virtual node IDs. They are not dependent of the fact that the node ID on the virtual space is the hash of the node’s IP address, or of any other parameter for that matter.

(b) Discuss the possible advantages of mapping the nodes into predefined sectors of the identifier space. In particular, suppose you subdivide the space into separate sections (each for a different geographical region, e.g. each continent) and assign the nodes to sectors based on their geographic locations. What advantages would you expect from such allocation (Hint: think of geographic proximity)?

**Answ:** the search involves traveling on links that cover progressively smaller and smaller virtual space spans. In the above “geographic sensitive” allocation, the “short” virtual spans are likely to connect nodes geographically near to each other. For example, suppose you partitioned the system into 4 equal geo-partitions. Suppose \( N = 1,000,000 \) and thus \( \log (N) = 20 \). It takes on average 20 hops to get to the key. After the first 3 hops, all the subsequent links of the search are contained within the same partition. This will greatly reduce the propagation/transmission delays, and thus latency, of the key search.