Problem 1: (21 points) For each any 3 of the following areas, select what you think is a promising solution. Explain, in comparison to another solution what makes it more desirable, clearly identifying the metrics you are using.

- Multicast
- Congestion control in the presence of misbehavior
- QoS
- Searching in P2P networks

Problem 2: (24 points) Comment on any 4 of the following potentially wrong statements

1. CIDR helps with backbone router lookup table size
2. Mobile IP is more efficient than I3 (internet indirection infrastructure) based mobility solution
3. The Chord overlay structure represents a balance between minimizing distances between nodes and the size of the overlay routing table
4. PIM is not scalable because of its dense mode
5. Admission control and policing are control plane functionalities

Problem 3: (25 points) Consider the following solution to allow incremental deployment of router based functionality. Each router discovers if neighboring routers support the functionality (e.g., multicast). If they do, operation proceeds normally. If not, it searches for a nearby neighbor that supports the functionality and tunnels to it.

(a) Discuss how this approach will work for CBT. Clearly identify the performance metrics, and compare it to fully deployed CBT and to Application level multicast.

(b) Discuss how this approach will work for Integrated Services.

Problem 4: (30 points) Portions of an IP backbone network become congested, for example, if some routers are temporarily down, or if a large increase in traffic occurs. One solution to address this problem is “hot-potato” routing. Basically, every router determines if the outgoing link for a packet is congested or not. If a link is congested, the router may then deflect the packet to a direction other than its forwarding direction in the forwarding table.

(a) Suggest a methodology to detect that a link is congested.

(b) Assume that there exists an approach for routers to either be initialized or to discover their approximate geographical location. Come up with a scheme to use hot-potato routing in a way that guarantees loop-freedom.

(c) Is it possible for routing to fail if a packet is deflected from a router A to a router B whose only path to the destination is through A. Discuss a possible solution to this problem?
(d) What are the implications of these mechanisms on the design of the router, and specifically on the IP lookup problem. Discuss an IP lookup approach that can efficiently accommodate your solution and justify the choice.

**Problem 5:** (30 points)
Consider an ATM router that uses weighted round robin to schedule flows. Recall that ATM is cell switched (equal size packets). Flows conform to a leaky bucket model where the size of the bucket is in terms of packets.

(a) If the total number of flows is \( n \), and the weights are equal (basic round robin), derive the maximum delay that a packet belonging to a given flow will suffer.

(b) Consider the problem of supporting Integrated Services over ATM. Give two reasons why this problem simpler than Integrated services over IP and how that may influence the design. Discuss how admission control would work.

(c) If the total size of the buckets (the buffer space promised to the flows) is equal to the available buffer space. A new flow attempts to reserve service. Under what conditions would admission control policy allow the flow to be admitted?

**Problem 6:** (24 points)
Comment on the following ideas:

(a) A TCP optimization scheme that works in the following way. When a TCP connection is established, the server sends a SYN/ACK packet using multiple routes, each with a different sequence number. The first one that gets to the destination is then responded to, resulting in the connection being established over the “best” path.

(b) A layer on top of IP that does loose packet ordering. Specifically, this layer finds an appropriate delay time for which it holds out of order packets before delivering them to the destination. Consider the implications on fast retransmit/recovery.

(c) Adding reliability to Multicast by introducing link-level reliability into a solution such as CBT

**Problem 7:** (20 points)

(a) What is the basic problem brought up by Floyd’s promoting End-to-End congestion control paper?

(b) Does a similar problem arise in QoS enabled networks (e.g., Integrated Services)? Explain.

(c) What is the solution in QoS enabled networks? Is it different from Floyd’s suggested solutions?

**Problem 8:** (30 points)
One of the applications suggested in the Bloom filter paper was using bloom filters for multicast. The idea was that at every interface, if a multicast packet for a certain group has to go out on the interface, the group is added to a bloom filter. When you receive a packet, you check for the group membership on the bloom filter for every interface and send it on the interfaces that match. If necessary, you can assume that the underlying multicast protocol is Core Based Trees.

(a) What are the advantages/disadvantages of this idea?

(b) How can joins/leaves be handled?

(c) Develop an approach for unicast IP lookup based on the use of bloom filters. (Hint: consider the differences between the multicast and unicast lookup problems)

(d) What are the implications of false positives on both the multicast and unicast versions? Roughly, what is the maximum false positive rate that can be tolerated by the network? How can you control that in your design?