Answer all parts of all questions. There are four multi-part questions, each of equal weight. Turn in your answers by Friday, December 17, at the same time you picked up your exam, to Jennifer Streubel at MCS-140G.

Brevity is the soul of wit. Be brief and to the point. This is a depth exam. So, your answers should show research maturity and depth. Do not pad your answers and do not write for the sake of writing.

You are free to consult any notes, books and papers during the examination, but make sure to include your references. You must develop your own solutions, which might use existing ideas and techniques, as long as you cite them and clearly explain how these existing ideas/techniques fit within your own solution.

You are not allowed to consult with any person during the examination.

If you have any doubt as to the interpretation of a question, make a reasonable assumption and explain your interpretation in your answer. No explanations will be given during the exam.
1. **Part I: Loc / id split**

A fundamental problem with the current Internet architecture is that of naming and addressing. For example, some studies attribute difficulties with supporting mobility and multihoming to the flaw that the “IP address semantics are overloaded”.

(a) What is meant by this flaw?

(b) A so-called “Loc / id split” approach has been proposed to try to eliminate such semantics overloading. Describe how this approach achieve such objective.

(c) Comment on the pros and/or cons of loc / id split architecturally and in terms of impact on both the data and control planes. Specifically assess whether it follows Jerry Saltzer’s naming and addressing principles (J.H. Saltzer, Naming and Binding of Objects, Lecture Notes in Computer Science, 1978, Volume 60/1978, 99-208).

(d) Imagine you are writing a paper on naming and addressing. Write a related work section (about 1 page) that lists and classifies different loc / id split approaches.

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2. **Part II: New Architecture**

A researcher proposes to solve the Internet’s naming and addressing problem using a “clean-slate” architecture. The architecture is claimed to be recursive and divides the Internet into nested regions. Regions (and ultimately nodes) are assigned unique ids according to such nesting. For example, for a two-level Internet, a region (Autonomous System) is assigned a unique AS-id and a node is assigned a local-id unique within its region. Thus, a node’s address is given by AS-id+local-id. Routing is first done based on the destination AS-id, then routing is done within the destination region using the local-id of the destination node.

(e) Comment on the novelty of this proposal by contrasting it to related work. Discuss how addressing nodes this way may or may not deal with the “semantics overloading” of addresses?

(f) Do you agree that such proposal is “recursive” in some sense? Explain.

(g) Comment on how effective this proposed architecture is in dealing with mobility and multihoming.

(h) How does this proposed solution compare to a loc / id solution?

(i) Do you agree that this proposal is “clean-slate”? If it is, comment on its generality and how the Internet may transition to it. If you think it is not, explain how the current architecture can be extended to adopt it.

(j) You often hear nowadays that networking should go beyond devices and deal with data / content. Comment on efforts in this data centric direction and how the naming and addressing problem is relevant in such settings / architectures.
2. Consider an overlay network such as a p2p network, end-system multicast, or a CDN serving a set of customers. There are \( N \) overlay endpoints in the network and for each pair \((i, j)\) (where \(i \in 1..N\) and \(j \in 1..N\) and \(i \neq j\)) there is data flowing at some rate from \(i\) to \(j\).

The overlay network is flowing over some physical topology of endsystems, routers, and links. There are \( R \) routers and \( L \) links.

Imagine that you want to observe the traffic flowing in the overlay, but you can only make observations at \( k < R \) routers.

(a) Describe a strategy for observing as much overlay traffic as possible for a fixed \( k \).

(b) Under what circumstances can one observe all of the overlay traffic?

(c) Describe a strategy for observing all of the overlay traffic while minimizing the value of \( k \). Discuss the computational efficiency of the strategy.

(d) If the algorithm you propose in (3) is intractable (exponential complexity), propose and justify a heuristic to approximately minimize \( k \) via a non-exponential algorithm.
3. Consider the following content delivery problem facing an ISP for mobile networking: A large number $N$ of mobile users (think about spectators in a large football stadium) are interested in downloading the same content of size $F$ (e.g., a video stream following a scoring drive). The ISP has a total bandwidth of $B$ which can be used to communicate content to the mobile nodes. If this bandwidth $B$ is split across all $N$ users, the download delay would be around $F \times N/B$. For large $N$, this delay was deemed unacceptable. As a solution, the ISP is contemplating the use of a hybrid protocol, whereby it pushes the content to some of the mobile nodes (seeders) while also allowing these nodes to relay that content to other nodes, until the content reaches all nodes in the network. In particular, it is assumed that each mobile device has two modes of communication – using a direct link to the provider (through a cellular connection to the ISP) and using peer-to-peer communication with neighboring mobile devices (through an 802.11 channel). Moreover, each mobile device is able to measure and report back to the ISP the set of other mobile devices within communication range and the bandwidth to each such device.

(a) How might the ISP decide on the appropriate number of “seeders” to use?

(b) Assuming that the ISP wants to use $K$ seeders, how might it choose these seeders?

Rather than sending the entire content to a set of nodes (seeders), the ISP may view the set of mobile nodes as a swarm, and thus send different “pieces” of the content to different “leechers”.

(c) What is different about a swarming solution in this setting, compared to one in a wired networking setting?

(d) How might the ISP go about distributing pieces of the content to specific leechers under such setting?
4. This question relates to the paper: “Taming the Torrent: A practical approach to reducing cross-ISP traffic in P2P systems”, D. Choffnes and F. Bustamante, Proc. of ACM SIGCOMM 2008. We recommend that you read the paper carefully before attempting the questions.

(a) On pp. 3-4, the authors describe a structure they call a *ratio map*, a vector of frequencies that a given DNS redirection is witnessed. To compare these maps, they “… would like a metric that, given two peers, produces a continuum of values describing the similarity between the peers’ redirection behaviors.” Based on this, they choose cosine similarity as an appropriate metric. Give three alternative measures that also meet this criterion. Argue why each of these are more suitable, less suitable, or equivalent, to cosine similarity.

(b) Consider Figure 11 on p. 9 of this paper. Communicate the main ideas of this plot in a one-page writeup to someone who is familiar with BitTorrent, but has never read the Ono paper, i.e. has a CS 655 level of understanding of networking. You will have to first convey the main thrust of the Ono work, and then drill down to the specific details of what this particular plot shows. You may include and refer to the figure itself in your writeup, but not any other portion of the paper.