Computer Sciences Department
Networking Qualifying Exam
Fall 2008
All six questions must be answered.

Q1. Network Architecture and Protocols

The End-to-End principle is widely realized in the network architecture and protocols today. Driven in part by this principle, many crucial services are implemented purely on end-hosts for correctness and completeness. Yet, arguments can be made that a fraction of these services are better off with a purely network-based or a network-assisted implementation. At the same time, there are other crucial services that are solely implemented within the network because they apply generally to all (or most) end-to-end transfers. Yet, a case can be made for an end-host-only or a end-hosted-assisted implementation.

Listed below are a few services which are implemented predominantly in end-hosts (or close to network-edges, perhaps using special devices) or predominantly in the network (i.e. within all or most network elements) today. For each service, your goal is: (1) To briefly sketch how a network-only implementation can be achieved for services which are implemented in end-hosts today, and how an end-host-only implementation can be achieved for services which are implemented in the network today; And, (2) To identify the pros and cons of the alternative implementations relative to the current implementations.

a) Congestion control
b) Quality of Service
c) Caching and compression

Q2. TCP and Congestion Control

a) Van Jacobson's paper on Congestion Avoidance and Control argues that if TCP connections obeyed the "packet conservation principle" then congestion collapses become highly unlikely and the network operates at optimal efficiency. Name three ways in which a network transfer can violate the packet conservation principle. Briefly outline the mechanisms incorporated in TCP to ensure that these conditions do not arise in the common case.

b) TCP's congestion control and avoidance mechanisms ensure fair and efficient use of network bandwidth. How can a TCP sender exploit the fair sharing property to obtain a significantly higher share of network bandwidth? Your answer to this question must not require to the sender or receiver's TCP/IP stack.

c) How do packet losses impact TCP's ACK clocking mechanism? Describe the mechanism used in TCP to recover (or maintain) ACK clocking after a single packet loss occurs within a congestion window.

Q3. Network Traffic Characterization

As the Internet has grown and diversified, understanding its empirical characteristics and behavior has been critical to the design, implementation, deployment and use of new systems. At a high level, empirical study of the Internet can be divided into several categories including, 1) topology, 2) general packet dynamics and 3) protocol and application specific behavior.

a) Provide a brief overview of the methods that are used to gather empirical data on Internet topology and include the challenges and limitations of these methods. Also provide a brief overview of the current understanding of Internet topology and how this understanding could be improved in the future.

b) Provide an overview of the current understanding of general traffic dynamics in the Internet. How does this perspective influence the design and implantation of new systems and protocols?

c) Provide an overview of the current understanding of TCP in the form of a model of its behavior (hint - more than one are possible). Have these models helped inform new versions of TCP and if so, how?

Q4. Multi-hop Wireless Communication

Mobile Ad-hoc Networks (MANETs) consist of mobile, power-constrained devices that require end-to-end communication services in the absence of any infrastructure-based support. A significant focus of protocol design for MANETs was in energy efficiency. For example, popular routing mechanisms, such as OSPF or RIP, were considered inadequate, and a new class of routing protocols, such as DSR, AODV, and TORA, emerged.

a) Explain the common theme among all routing strategies popular in MANETs and how these routing protocols differed from prior approaches.

b) In the recent years, multi-hop wireless networks have re-emerged in a new environment — metro-scale wireless mesh networks. Even though such metro meshes and MANETs are both multi-hop wireless environments, routing protocol design for metro meshes is quite different. Explain three ways in which routing in metro meshes differs from routing in MANETs, and how these differences manifest themselves in routing protocol design within metro meshes.

Q5. Peer-to-peer Internet Applications

A resilient overlay network utilizes a set of distributed peers to achieve high end-to-end reliability and resilience. This is an example of a scenario where an application layer mechanism outperforms existing mechanisms solely implemented in the network layer.

a) Use an example to explain why end-to-end Internet connectivity can exist through the application layer, when it does not exist at the network layer.

b) Going beyond just end-to-end connectivity, it is also possible that a lower latency end-to-end path can be found by techniques, such as the one proposed in Resilient Overlay Networks, than found by the network layer. Provide a practically-motivated example why that can happen.

Q6. Revisiting Packet Sizes

Communication between endhosts can happen using small packets (tens or hundreds of bytes) or large packets (thousands of bytes or larger). Briefly discuss whether the following trends (some of these trends do not apply to the current Internet) impact the relative appeal of using small packets versus using large packets and if they do whether they favor the use of small or large packets.

a) The speed of the links is increasing.

b) Processors are getting faster.

c) The error rate on the links is going down.

d) The error rates are going up because we use more unreliable wireless links.

e) The cost of buffers is going down.

f) End to end latencies are going up for the nodes on spacecraft far away in the solar system.

g) The cost of per packet processing (e.g. forwarding table lookup) is going up while the per bit cost of transmission is going down.

h) Due to deep pipelining within processors, the overhead of handling an interrupt is increasing.

i) Bulk transfers (downloading large movies) are becoming more common.

j) Voice traffic is becomming more common.