Homework 1

This assignment is due in class on **Tuesday, September 25**. It covers readings and lectures through Thursday, September 20. Late homeworks will not be accepted.

Write your name, your e-mail address, and the date on the paper that you hand in.

1. INTERNET ARCHITECTURE (30 points)

For 5 points each, match each item in the left-hand column with the item in the right-hand column with which it is most closely associated.

Browsers	UDP
Flexibility and empowerment	IP layer
Packet routing	Increased core-network functionality
Reliable byte streams	Application layer
Low prices and ease of use	End-to-end arguments
Nonreliable byte streams	TCP

2. INFORMATION ECONOMY (20 points)

a. (5 points) The basic technology for fax machines was patented in 1843, but fax machines remained rare until the mid-1980's. During the period from 1982 to 1987, fax usage experienced explosive growth because of *positive feedback*: As the number of fax owners increased, the usefulness of a fax machine grew; the more useful fax machines were, the more people bought them. What well-known property of communication technologies does this illustrate?

b. (5 points) True or false: The vendor of a product that exhibits the phenomenon described in 2(a) can definitely maintain a large market share; once adoption reaches critical mass, the product is so useful that customers cannot bear the switching costs of abandoning it, even for something better.

c. (5 points) Production of an information good exhibits *high fixed costs* and *low marginal costs*. Because creators of information goods can reproduce them cheaply, potential competitors can copy or imitate them cheaply. Nonetheless, some information businesses are long-lived and profitable. Give an example of a technique that allows information producers to succeed in spite of this inherent property of information goods.

d. (5 points) Cable-TV subscription packages, Microsoft Office, and a discounted subscription to the online *Wall Street Journal* for subscribers to the printed version are all examples of a common strategy for pricing information goods that we discussed in class. What is the name of this strategy?

3. DIGITAL CONTENT DISTRIBUTION (20 points)

a. (5 points) What do the following businesses have in common?

- Traditional broadcast television
- Training and support services for free software
- Certain pairs of complementary software products, e.g., Adobe Acrobat Reader and the Adobe document-preparation software.

b. (5 points) Technical protection measures:

1. Can help rights holders prevent unauthorized copying.
2. Can help verify legitimate provenance of digital documents.
3. Will probably be more effective against professional content pirates when implemented in special-purpose hardware for single-purpose devices than they are when implemented in software for general-purpose, networked PCs.
4. All of the above.

c. (5 points) In the physical realm, the question of *access* to copyrighted works is cleanly separable from the question of *reproduction* of such works. For example, a single copy of a book can be read, a single copy of a music CD played, or a painting viewed by many people without any additional copies' being made. By contrast, in the digital realm, access usually entails reproduction. For example, software programs are copied from disk into RAM (random access memory) so that they can be run, and Web pages are copied from remote machines onto local machines so that they can be viewed. This fundamental difference between physically embodied copyrighted works and digitally embodied copyrighted works calls into question the continued applicability of one of the central elements of existing copyright law listed below. Which one?

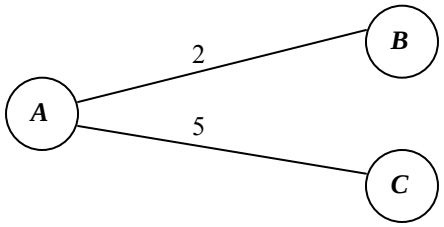
1. The long duration of copyright ownership (e.g., the fact that copyrights last much longer than patents)
2. The copyright owner's exclusive right to reproduce the copyrighted work in copies or phonorecords (number 1 of Section 106 of U.S. Copyright Law)
3. The copyright owner's exclusive right to prepare derivative works based upon the copyrighted work (number 2 of Section 106 of U.S. Copyright Law)
4. "Fair use" limitations on exclusive rights of copyright owners (Section 107 of U.S. Copyright Law)

d. (5 points) The widely held belief that virtually all non-commercial, private-use copying is lawful is wrong. However, in the physical realm, copyright owners do not suffer much from non-commercial, private-use copying, because it does not destroy their markets and because its private nature usually means that it is limited in scope. Is this true in the digital realm? (Answer yes or no.)

4. ROUTING (30 points)

I. OSPF Routing

Recall that, in OSPF routing, each node broadcasts the state of links physically connected to it, and nodes use this information to calculate shortest paths and forwarding tables. For example, consider a node ***A*** that has two neighbors:



A would then broadcast the following *link-state packet* (LSP):

Link	Weight
A→B	2
A→C	5

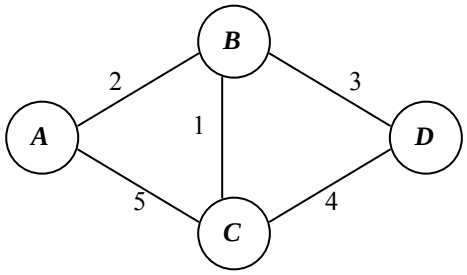
Suppose ***A*** receives the following LSPs from other nodes:

Link	Weight
B→A	2
B→C	1
B→D	3

Link	Weight
C→A	5
C→B	1
C→D	4

Link	Weight
D→B	3
D→C	4

From this information, we can deduce the topology of the network, calculate the shortest paths to the other nodes, and construct the forwarding table. Here is what the whole network looks like, based on the above:



The shortest paths (paths of minimum total weight) from ***A*** to the other nodes are:

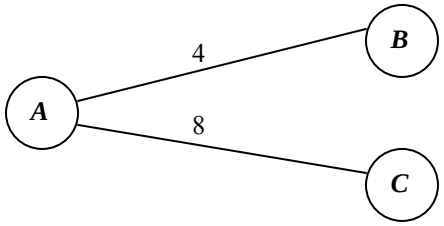
Destination	Path	Total Cost
A→B	***A→B***	2
A→C	***A→B→C***	3
A→D	***A→B→D***	5

Then the forwarding table for ***A***, which indicates where next to send packets for a given destination, is:

Destination	Next Hop
B	***B***
C	***B***
D	***B***

When ***A*** receives updated LSPs from new or existing nodes on the network, it recalculates its forwarding table to reflect the new shortest paths.

Now consider a new network in which node ***A*** has two neighbors:



and ***A*** receives the following LSPs:

Link	Weight
B→A	4
B→D	11

Link	Weight
C→A	8
C→D	5

Link	Weight
D→B	11
D→C	5

a. (5 points) Give the forwarding table for ***A***.

b. (6 points) Suppose a new node on the network, ***E***, powers up, and ***A*** receives the following new and updated LSPs:

Link	Weight
B→A	4
B→D	11
B→E	1

Link	Weight
D→B	11
D→C	5
D→E	3

Link	Weight
E→B	1
E→D	3

Give the new forwarding table for ***A*** (including the new entry for destination ***E***).

c. (4 points). Suppose node ***B*** suddenly gets misconfigured and resets all its neighboring link costs to zero. It would send out the following LSP:

Link	Weight
B→A	0
B→D	0
B→E	0

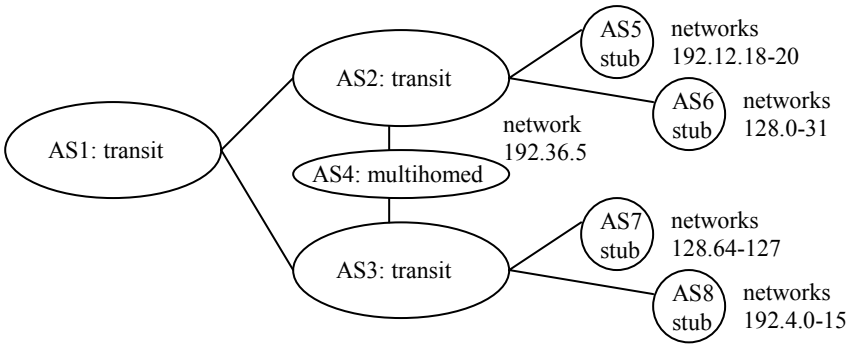
What happens to the network traffic when these link costs are set to zero?

II. BGP Routing

BGP directs traffic between three types of *autonomous systems* (AS) connected arbitrarily:

1. *stub* AS: connected to only one other AS; only accepts local traffic
2. *multihomed* AS: connected to more than one AS but only accepts local traffic
3. *transit* AS: will pass traffic through it along to another AS

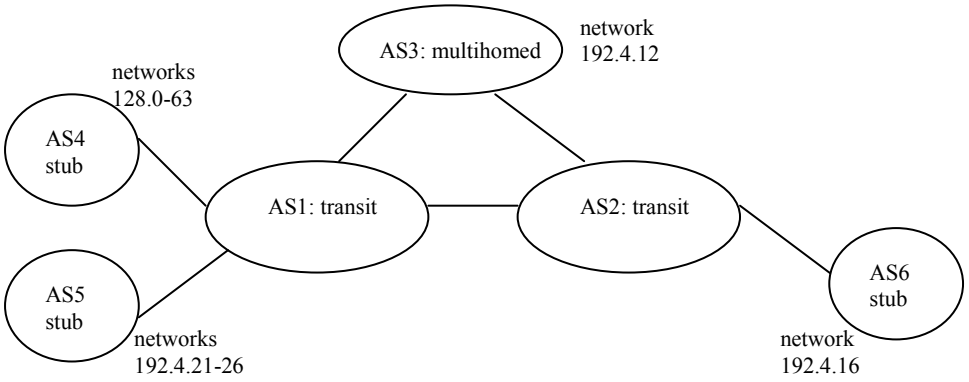
The *BGP speaker* for an AS advertises which other networks can be reached from it depending on the type of AS it represents. Consider the following example AS map:



Here, AS4 would advertise that it contains network 192.36.5, but nothing else, because it is multihomed. AS1 would advertise the following paths:

- networks 128.0 through 128.31 are reachable through the path <AS1, AS2, AS6>;
- networks 192.12.18 through 192.12.20 are reachable through the path <AS1, AS2, AS5>;
- networks 128.64 through 128.127 are reachable through the path <AS1, AS3, AS7>;
- networks 192.4.0 through 192.4.15 are reachable through the path <AS1, AS3, AS8>; and
- network 192.36.5 is reachable through the path <AS1, AS2, AS4>. (Because AS4 can be reached through AS2 or AS3, the speaker for AS1 simply chooses one.)

Now consider the following AS map:



d. (5 points) What does AS1 advertise?

e. (5 points) What does AS3 advertise?

f. (5 points) Suppose the link between AS1 and AS3 failed. What would AS1 then advertise?