POGIl-CSP: Internet I: What is the Structure?
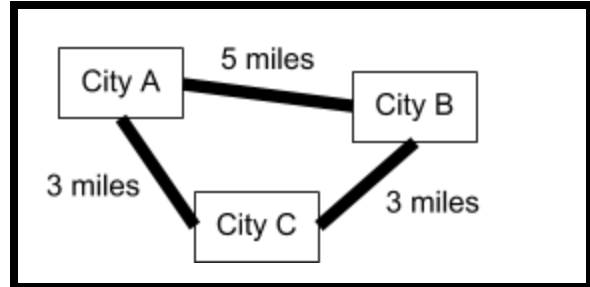
(10 min) A. Routes	start time:

To understand the Internet, we will use the road system as a model. Consider this map of **3 cities** (A,B,C) connected by roads. Each road has one lane in each direction, and a **speed limit** of 30 miles/hour (mph).

1. Many people live in City A and work in City B.

a.	What are the two routes from A to B?	
b.	What is the length of each route (in miles)?	
c.	If everyone travels at the same speed and there are no delays in cities, which route will be faster?	
d.	How many minutes are in an hour?	
e.	What is the speed limit in miles per minute?	

2. Show a calculation to explain why it should take 10 minutes to drive from A to B.

3. A driver who follows the **two-second rule** should stay (at least) 2 seconds behind the car in front of them (at any speed). (A **three-second rule** is safer!)
In the questions below, assume that all drivers follow the two-second rule.
What should be the distance between cars at:

a.	35 miles/hour (50 feet/sec)?	
b.	70 miles/hour?	

4. Explain why at most 30 cars/minute can enter City B on the road from A to B.
(Assume that all drivers follow the two-second rule.)

5. What is the maximum number of cars that can enter City B per minute?
(Recall that two roads connect to City B.)

(10 min) B. Bandwidth & Latency	start time:

Latency measures **time** - how long it takes to get from one place to another by a given connection. High latency is slower (**later**), low latency is faster.
Bandwidth measure **capacity** - how many items can use a given connection.

1. Consider the cities and roads described in Model 1 above, and your previous answers.

a.	What is the **latency** (in minutes) of the shortest route from A to B?	
b.	What is the **bandwidth** (in cars/minute) of the shortest route from A to B?	

2. Suppose that the **speed limit** on the road from A to B is raised from 30 to 60 MPH. Explain why this **decreases latency** but has **no effect on bandwidth**. (Assume that there are no changes in driver behavior.)

3. Instead, suppose that the road from A to B is **widened** from one to two lanes in each direction, so that twice as many cars can use the road. How does this affect the road's **bandwidth** and **latency**? (Assume that there are no changes in the speed limit or driver behavior.)

4. Suppose that the road from A to B is **under construction** and the speed limit is **lowered** to 10 MPH. What is now the **latency** of each route from A to B? Explain which is faster, and state any assumptions.

5. When an **emergency vehicle** (ambulance, fire truck, police car) uses its siren, other vehicles should move out of the way to allow the emergency vehicle to pass.
In complete sentences, use the terms **bandwidth** and **latency** to describe the effect on:
      a. other traffic   b. the emergency vehicle

6. We could measure bandwidth in **people/minute** instead of **cars/minute**.
Explain why this would be a good idea if we want to encourage people
to use carpools and public transportation.

(10 min) C. The Internet	start time:
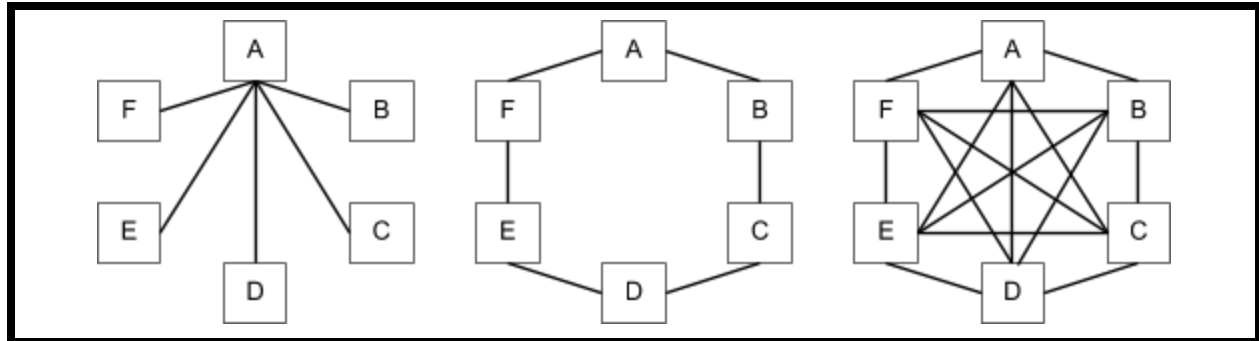
The Internet is a (worldwide) network of **connections** between **sites**,
like a network of **roads** between **cities**. Latency and bandwidth are still important.
The diagrams above show 3 ways that a set of sites (or cities) could be connected.

1. In the first (left) figure, there is a **connection** between site A and each other site,
and there is exactly one **route** between any two sites.

a.	How many **connections** are shown?	
b.	What is the **route** from C to E?	
c.	How many **connections** must be broken to isolate a site from the rest of the network?	

2. In the second (middle) figure:

a.	How many **connections** are shown?	
b.	How many **routes** connect any two sites?	
c.	How many **connections** must be broken to isolate a site?	

3. In the third (right) figure:

a.	How many **connections** are shown?	
b.	How many **connections** must be broken to isolate a site?	

4. In one or two grammatically correct sentences, describe two advantages
of having **multiple (redundant) possible routes** between sites.

5. If multiple routes are better, why not provide **all possible connections,**
as show in the third (right) figure? (Hint: Consider the cost for each connection.)

6. Roads can be ranked in a **hierarchy**, although the details vary by country.
For each dimension below, rank each road type as **Low**, **Medium**, or **High**.
    a. speed limit (provided below)
    b. bandwidth (e.g. maximum number of cars per minute)
    c. cost per mile (to build and maintain a road)
    d. % of the total road miles (which categories are most and least common)
(Hint: Do not assume that the same pattern holds for all 4 dimensions.)

	a.	b.	c.	d.
Road Type	**Speed Limit (mph)**	**Bandwidth (cars/min)**	**Cost (per mile)**	**% of Total Road Miles**
limited access highways, freeways, toll roads	High (60 mph)			
arterial and connector roads	Medium (40 mph)			
local streets and roads	Low (20 mph)			

7. In complete sentences, describe the relationships between these four factors.

For the Internet, we usually measure the **bandwidth** (capacity) of a connection
in **bits per second (bps or baud)**. For example, early modems were
300 to 1200 bps, current wifi connections are 2 to 50 Mbps (mega = 1,000,000),
ethernet connections within a building are 10 or 100 Mbps,
and some high bandwidth connections are measured in Gbps (giga = 1,000,000,000).

8. The **Internet backbone** is a set of high bandwidth (e.g. 10 Gbps) connections.
Use the terms **bandwidth** and **latency** to explain why companies like
Amazon or Walmart should locate warehouses near major highways,
and their web servers near the Internet backbone.

(10 min) D. Conclusions	start time:

INFORMATION

At any moment, many computers are turned off, idle, or not accessing the Internet. During web browsing, there is a burst of Internet traffic when we load a new page, and then little or no traffic while we read the page. When we watch streaming videos, the web server splits the video into many small segments and sends a few at a time, so the client computer usually has the next few seconds of video ready to play.

9. An **Internet Service Provider (ISP)** provides a 1 Mbps connection to each subscriber. If all 10,000 subscribers use their full bandwidth at one time, what bandwidth would the ISP need to connect to the Internet backbone?

10. Explain why an **ISP** with a 1000 Mbps connection to the Internet backbone can claim to provide 1 Mbps of bandwidth to 10,000 subscribers.

11. In complete sentences, describe the general structure of the Internet and how it is hierarchical, redundant, and fault tolerant.