Blobs and Graphs

Prof. Noah Snavely

CS1114

http://cs1114.cs.cornell.edu

Cornell University
Computer Science

Administrivia

- Assignment 2 is out
  - First part due on Friday by 5pm
  - Second part due next Friday by 5pm

- Quiz 2 on Thursday
  - Coverage through today
    (topics include running time, sorting, graphs)
  - Closed book / closed note

Administrivia

- Webcams in lab not yet working, please load in static images for now

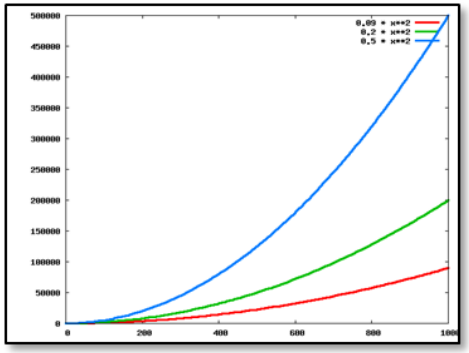
♦ What is the running time of:

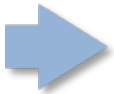
- Finding the median using repeating "find biggest"?
  - Answer: $O(n^2)$
- Finding the median using quickselect (on average)
  - Answer: O(n) (expected)
- Finding the 2^{nd} biggest element (>all but 1) using repeated "find biggest"? The 3^{rd} biggest (> all but 2)? The $50{,}000^{th}$ biggest element?
  - Answer: All are O(n)
- Finding the element bigger than all but 5%?
  - Suppose we use repeated "find biggest"; Answer: $O(n^2)$
  - What if we use quickselect? Answer: O(n)

- Finding the biggest element in the first 50,000 entries of an array?
  - O(1) !

Big-O notation

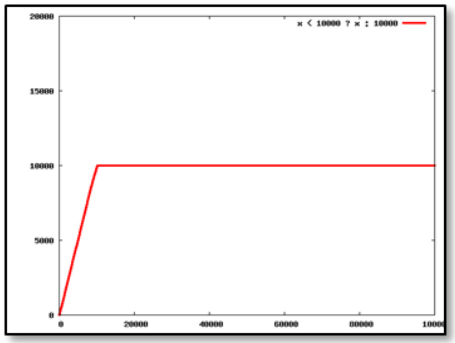
- "Constant of proportionality" doesn't matter



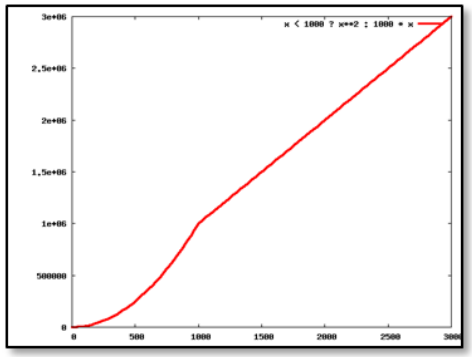


$O(n^2)$

- We only care about how the function grows for "large" values of *n*



$O(1)$



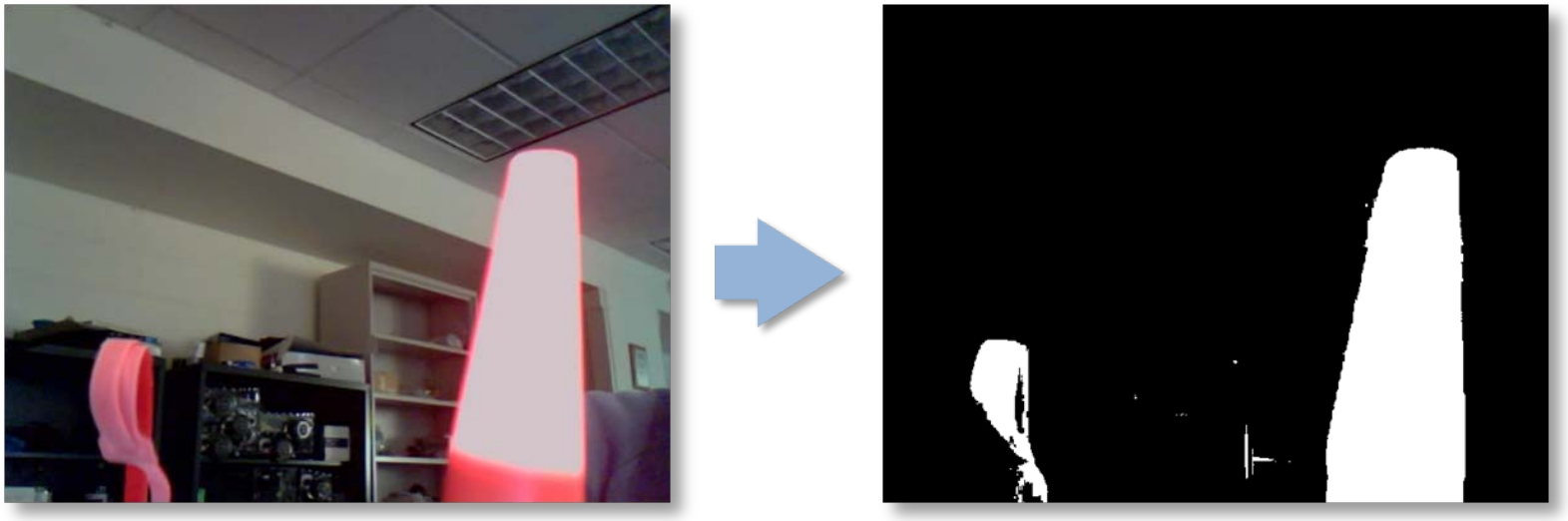
$O(n)$

Problems, algorithms, programs

- A central distinction in CS
- Problem: what you want to compute
  - "Find the median"
  - Sometimes called a specification
- Algorithm: how to do it, in general
  - "Repeated find biggest"
  - "Quickselect"
- Program: how to do it, in a particular programming language

```
function [med] = find_median[A]
...
```

Back to the lightstick



- The lightstick forms a large “blob” in the thresholded image (among other blobs)

What is a blob?

1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	0	0	0	0	0	0

Finding blobs

1. Pick a 1 to start with, where you don't know which blob it is in
   - When there aren't any, you're done
2. Give it a new blob color
3. Assign the same blob color to each pixel that is part of the same blob

Finding blobs

1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	1	0	0	0	0	0	0	0

Finding blobs

1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	1	0	0	0	0	0	0	0

Finding blobs

1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	1	0	0	0	0	0	0	0

Finding blobs

1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	1	0	0	0	0	0	0	0

Finding blobs

1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	1	0	0	0	0	0	0	0

Finding blobs

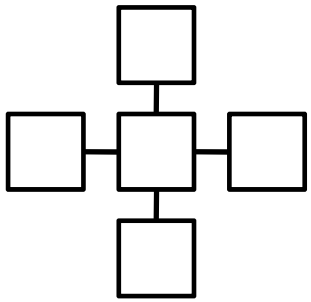
1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0
0	0	1	0	0	0	0	0	0	0

Finding blobs

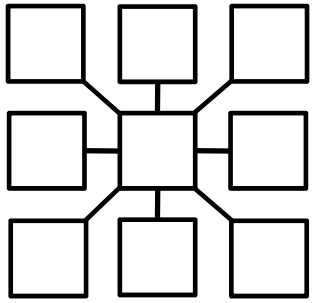
1. Pick a 1 to start with, where you don't know which blob it is in
   - When there aren't any, you're done
2. Give it a new blob color
3. Assign the same blob color to each pixel that is part of the same blob
   - How do we figure this out?
   - You are part of the blob if you are next to someone who is part of the blob
   - But what does "next to" mean?

What is a neighbor?

- We need a notion of neighborhood
  - Sometimes called a neighborhood system
- Standard system: use vertical and horizontal neighbors
  - Called “NEWS”: north, east, west, south
  - 4-connected, since you have 4 neighbors



- Another possibility includes diagonals
  - 8-connected neighborhood system



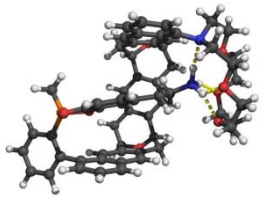
The long winding road to blobs

- We actually need to cover a surprising amount of material to get to blob finding
  - Some of which is not obviously relevant
  - But (trust me) it will all hang together!

A single idea can be used to think about:

– Assigning frequencies to radio stations

– Scheduling your classes so they don't conflict



– Figuring out if a chemical is already known

– Finding groups in Facebook

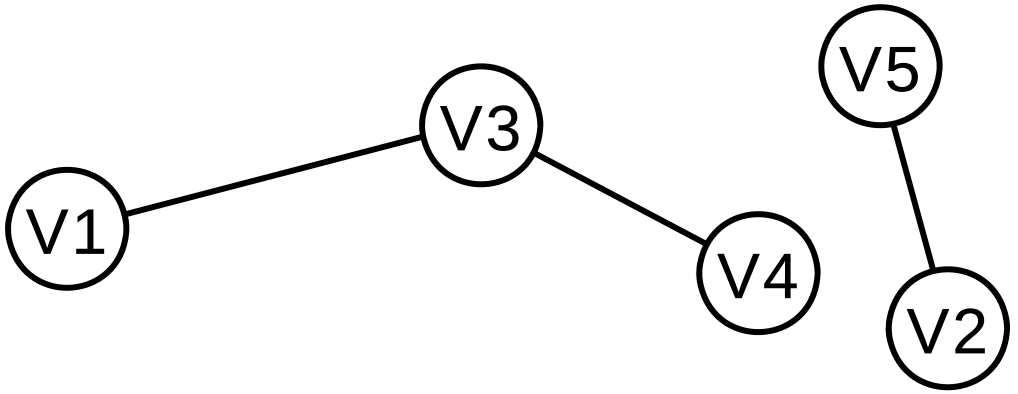
– Ranking web search results

Graphs: always the answer

- We are going to look at an incredibly important concept called a graph
  - Note: not the same as a plot
- Most problems can be thought of in terms of graphs
  - But it may not be obvious, as with blobs

What is a graph?

- Loosely speaking, a set of things that are paired up in some way
- Precisely, a set of vertices **V** and edges **E**
  - Vertices sometimes called nodes
  - An edge (or link) connects a pair of vertices

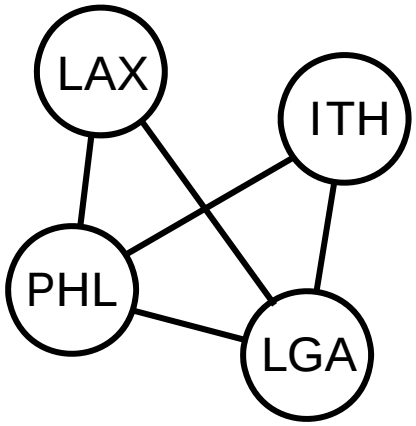


V = { V1, V2, V3, V4, V5 }

E = { (V1,V3), (V2,V5), (V3,V4) }

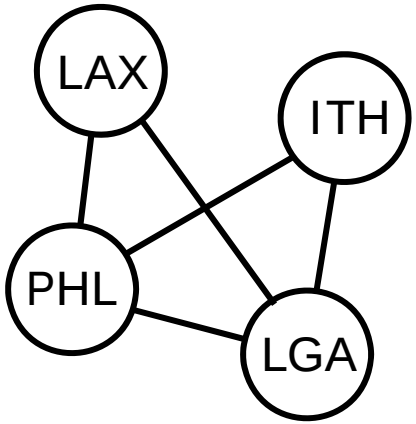
Notes on graphs

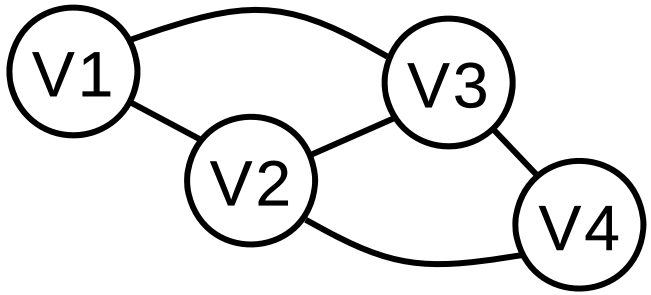
- What can a graph represent?
  - Cities and direct flights
  - People and friendships
  - Web pages and hyperlinks
  - Rooms and doorways
  - IMAGES!!!



Notes on graphs

- A graph isn't changed by:
  - Drawing the edges differently
    - While preserving endpoints
  - Renaming the vertices





Some major graph problems

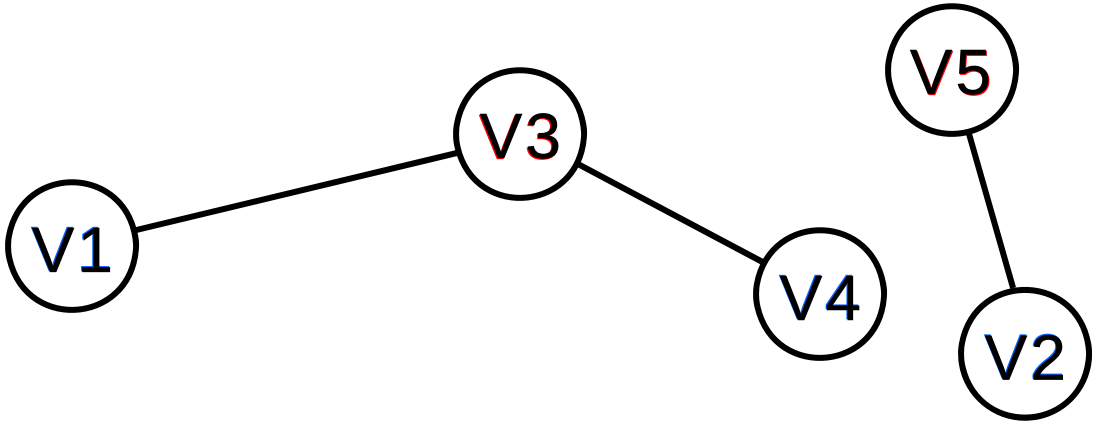
- Graph coloring
  - Ensuring that radio stations don't clash
- Graph connectivity
  - How fragile is the internet?
- Graph cycles
  - Helping FedEx/UPS/DHL plan a route
- Planarity testing
  - Connecting computer chips on a motherboard
- Graph isomorphism
  - Is a chemical structure already known?

Some major graph problems

- Graph coloring
  - Ensuring that radio stations don't clash
- **Graph connectivity**
  - How fragile is the internet?
- Graph cycles
  - Helping FedEx/UPS/DHL plan a route
- Planarity testing
  - Connecting computer chips on a motherboard
- Graph isomorphism
  - Is a chemical structure already known?

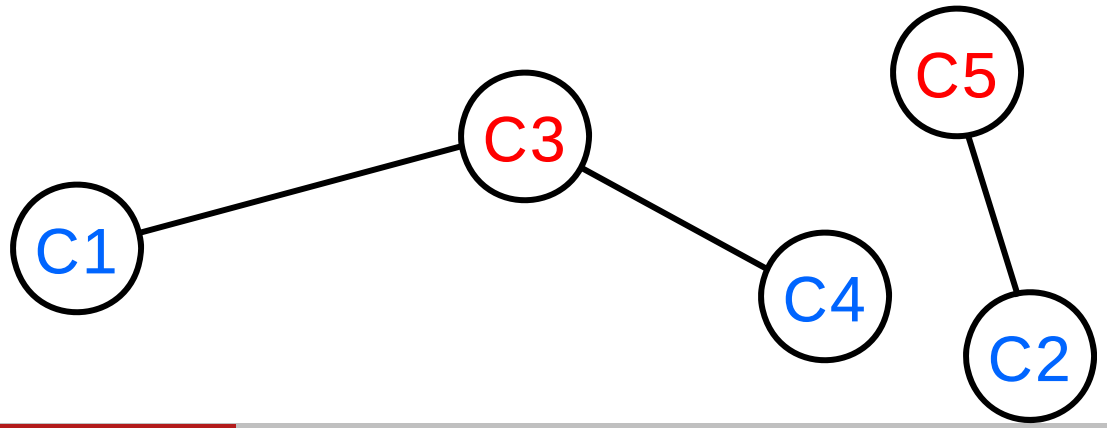
Graph coloring problem

- Given a graph and a set of colors {1,…,k}, assign each vertex a color
- Adjacent vertices have different colors

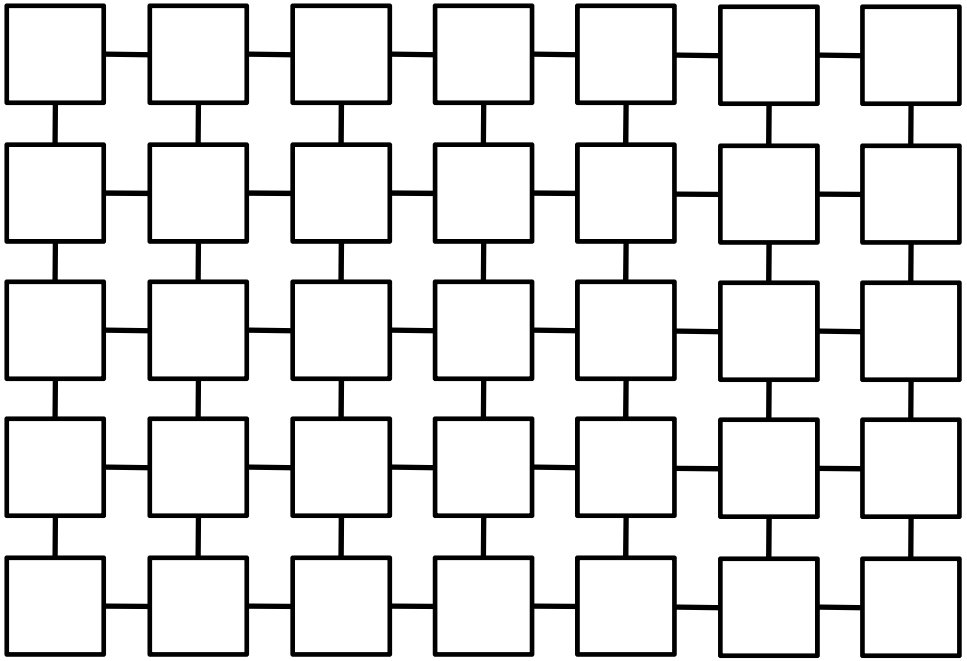


Radio frequencies via coloring

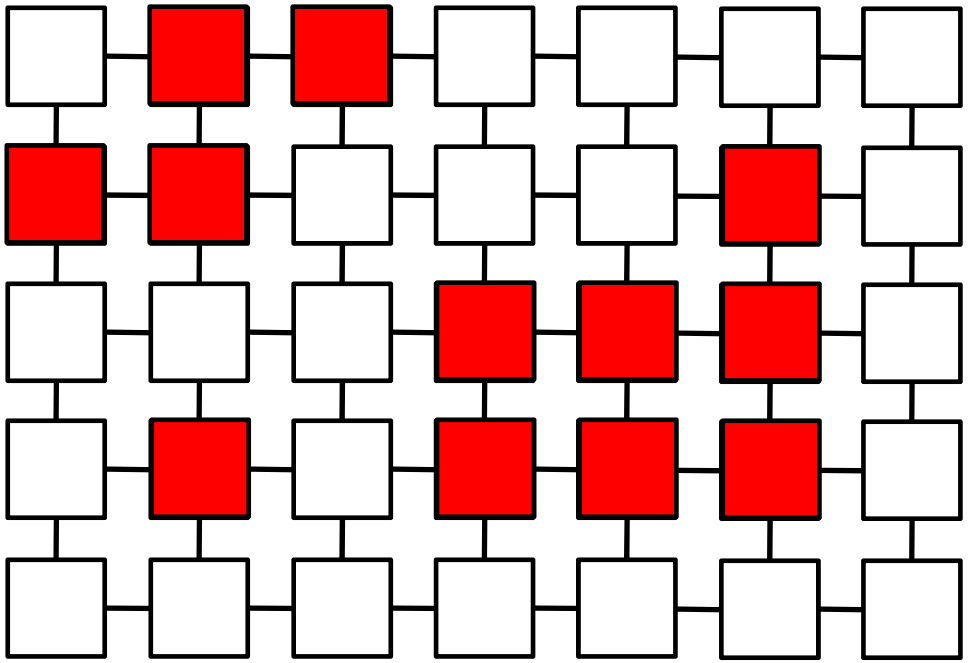
- How can we assign frequencies to a set of radio stations so that there are no clashes?
- Make a graph where each station is a vertex
  - Put an edge between two stations that clash
    - I.e., if their signal areas overlap
  - Any coloring is a non-clashing assignment of frequencies
    - Can you prove this? What about vice-versa?



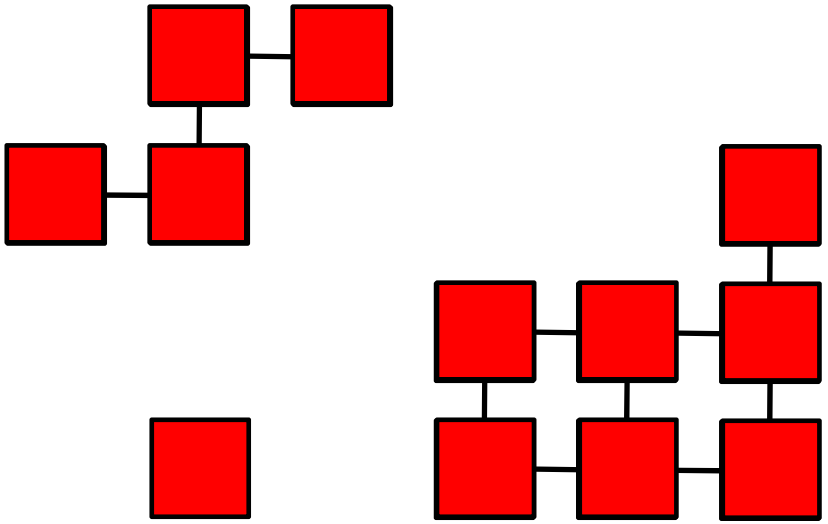
Images as graphs



Images as graphs



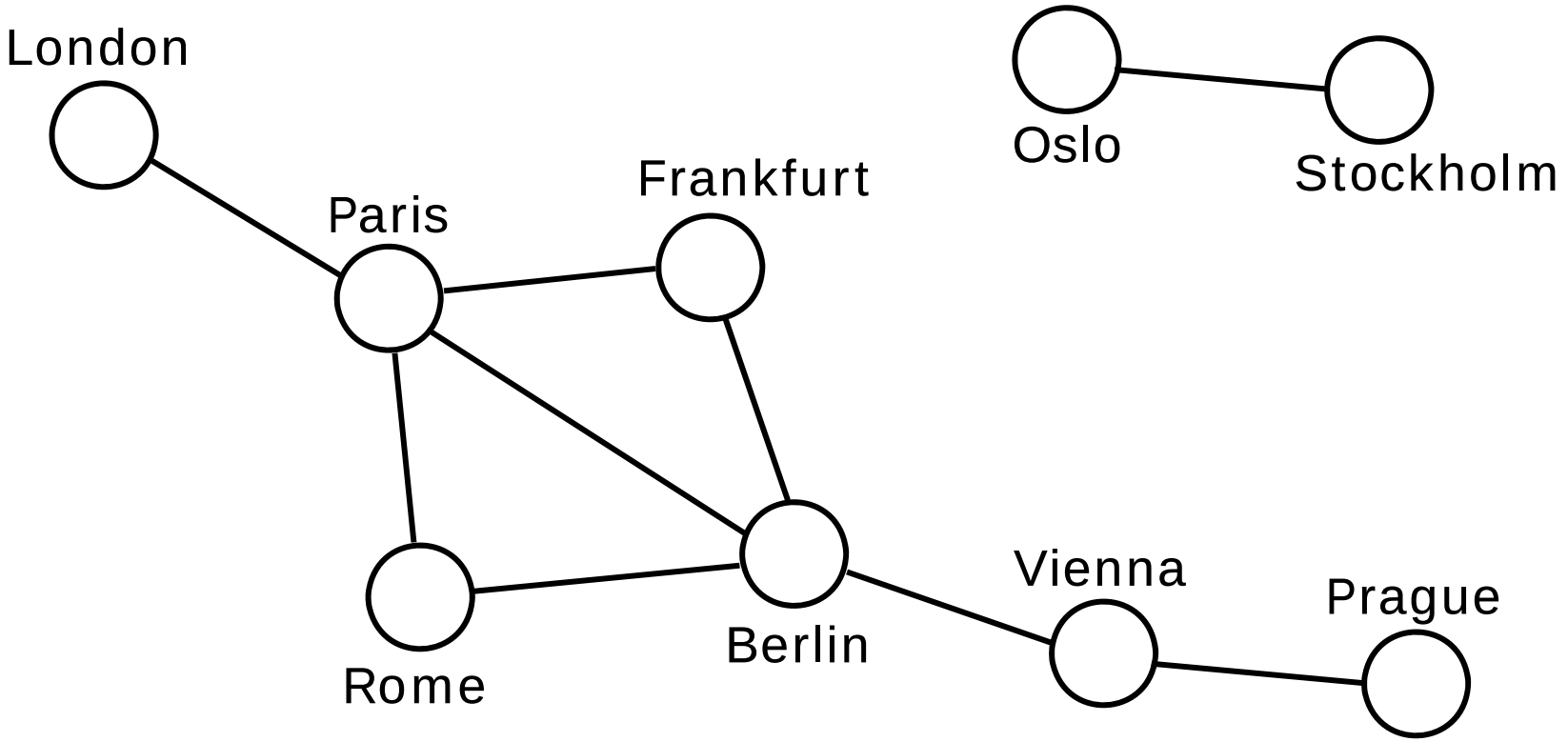
Images as graphs



Graphs and paths

- Can you get from vertex V to vertex W?
  - Is there a route from one city to another?
- More precisely, is there a sequence of vertices $V, V_1, V_2, \ldots, V_k, W$ such that every adjacent pair has an edge between them?
  - This is called a **path**
  - A **cycle** is a path from V to V
  - A path is **simple** if no vertex appears twice

European rail links (simplified)

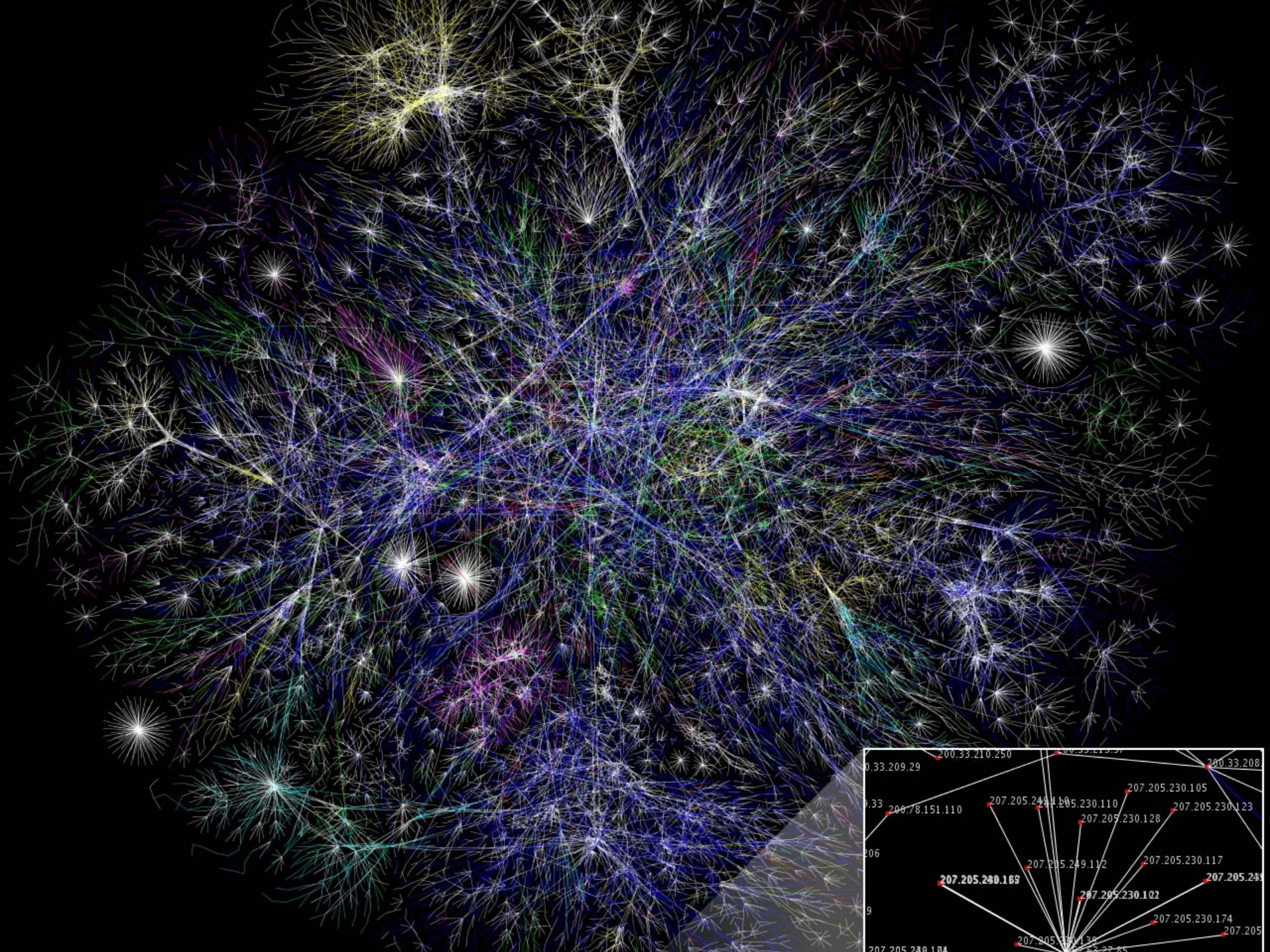


- Can we get from London to Prague on the train?
- How about London to Stockholm?

Graph connectivity

- For any pair of nodes, is there a path between them?
  - Basic idea of the Internet: you can get from any computer to any other computer
  - This pair of nodes is called *connected*
  - A graph is connected if all nodes are connected

- Related question: if I remove an arbitrary node, is the graph still connected?
  - Is the Internet intact if any 1 computer fails?
  - Or any 1 edge between computers?


200.33.210.250
0.33.209.29
207.205.230.105
208.78.151.110
207.205.230.110
207.205.230.123
207.205.230.128
207.205.249.112
207.205.230.117
207.205.230.102
207.205.230.174

Map

ections

updated 6:18 p.m. EST, Fri February 1, 2008

Third undersea Internet cable cut in Mideast

STORY HIGHLIGHTS

- Repairs to one Mediterranean cable expected by February 12
- Cable reported cut Friday off Dubai in Persian Gulf
- Extensive Internet failure has affected much of Asia, the Middle East, north Africa
- Analysts say no chance of similar Internet loss in United States

Next Article in World »

READ | VIDEO | MAP

TEXT SIZE

(CNN) -- An undersea cable carrying Internet traffic was cut off the Persian Gulf emirate of Dubai, officials said Friday, the third loss of a line carrying Internet and telephone traffic in three days.

Dubai has been hit hard by an Internet outage apparently caused by a cut undersea cable.

Ships have been dispatched to repair two undersea cables damaged on Wednesday off Egypt.

FLAG Telecom, which owns one of the cables, said repairs were expected to be completed by February 12. France Telecom, part owner of the other cable, said it was uncertain when repairs on it would be repaired.

Stephan Beckert, an analyst with TeleGeography, a research company that consults on global Internet issues, said the cables off Egypt were likely damaged by ships' anchors.

The loss of the two Mediterranean cables -- FLAG Telecom's FLAG Europe-Asia cable and SeaMeWe-4, a cable owned by a consortium of more than a dozen telecommunications companies -- has snarled Internet and phone traffic from Egypt to India.

Officials said Friday it was unclear what caused the damage to FLAG's FALCON cable about 50 kilometers off Dubai. A repair ship was en route, FLAG said.

When it comes to reducing CO_2, we say

YES WE CAN

FOLLOW THE PROGRESS

CLEAN COAL.
AMERICASPOWER.ORG

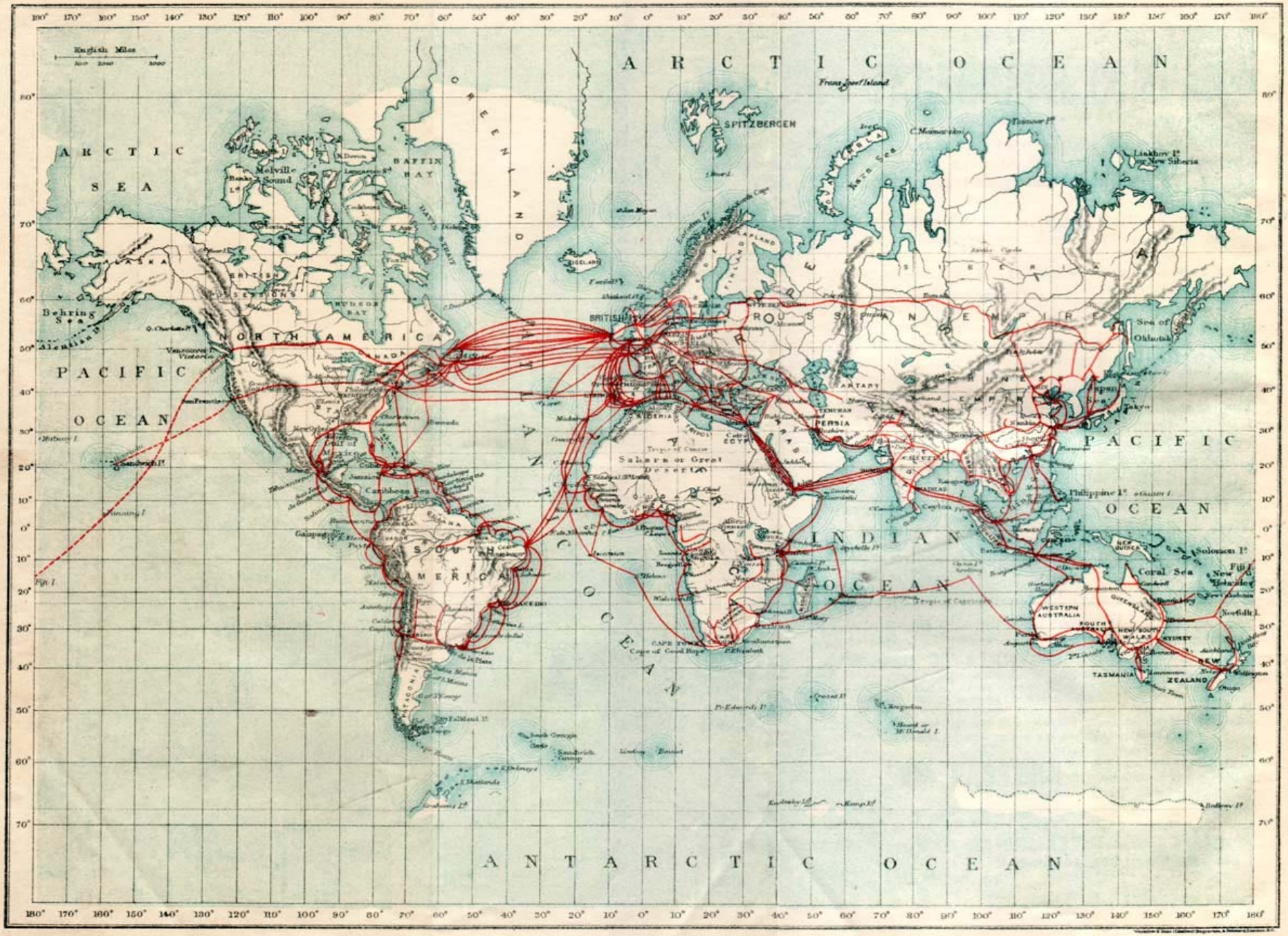
Most Popular on CNN

STORIES

Most Viewed | Most Emailed | Top Searches

1 Muslim identity in America

EASTERN TELEGRAPH Co.'s SYSTEM AND ITS GENERAL CONNECTIONS.



Next time:

- Quiz 2

- How can we find connected components?