The Internet

- Domain Name System: translates betweens names and IP addresses
- Properties of the Internet
  - Heterogeneity
  - Redundancy
  - Packet-switched
  - 604 million online (CIA World Factbook 2002)
- What country has the highest percentage of people online?

1. Aruba
2. Australia
3. Denmark
4. Hong Kong
5. Iceland
6. South Africa
7. South Korea
8. Sweden
9. UK
10. USA

Tim Berners-Lee

I want you to realize that, if you can imagine a computer doing something, you can program a computer to do that.

Unbounded opportunity... limited only by your imagination. And a couple of laws of physics.

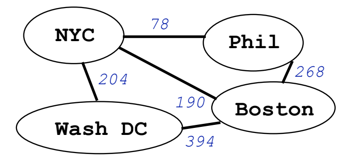
- TCP/IP, HTTP
  - How, Why, What, When?

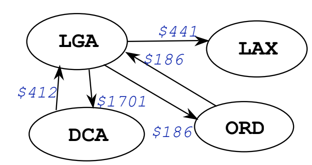
Graphs: Structures and Algorithms

- How do packets of bits/information get routed on the internet
  - Message divided into packets on client (your) machine
  - Packets sent out using routing tables toward destination
    - Packets may take different routes to destination
    - What happens if packets lost or arrive out-of-order?
  - Routing tables store local information, not global (why?)
- What about The Oracle of Bacon, Erdos Numbers, and Word Ladders?
  - All can be modeled using graphs
  - What kind of connectivity does each concept model?
- Graphs are everywhere in the world of algorithms (world?)

Vocabulary

- Graphs are collections of *vertices* and *edges* (vertex also called node)
  - Edge connects two *vertices*
    - Direction can be important, *directed edge, directed graph*
    - Edge may have associated weight/cost
- A vertex sequence $v_0, v_1, \ldots, v_{n-1}$ is a *path* where v_k and v_{k+1} are connected by an edge.
  - If some vertex is repeated, the path is a *cycle*
  - A graph is *connected* if there is a path between any pair of vertices





Network/Graph questions/algorithms

- What vertices are reachable from a given vertex?
  - Two standard traversals: depth-first, breadth-first
  - Find *connected components*, groups of connected vertices
- Shortest path between any two vertices (weighted graphs?)!
- Longest path in a graph
  - No known efficient algorithm
  - Longest shortest path: Diameter of graph
- Visit all vertices without repeating? Visit all edges?
  - With minimal cost? Hard!
- What are the properties of the network?
  - Structural: Is it connected?
  - Statistical: What is the average number of neighbors?

Network Nature of Society

- Slides from Michael Kearns - Univ. of Pennsylvania

Emerging science of networks

- Examining apparent similarities between many ***human*** and ***technological*** systems & organizations
- Importance of ***network effects*** in such systems
- How things are ***connected*** matters greatly
- ***Structure, asymmetry*** and ***heterogeneity***
- Details of ***interaction*** matter greatly
- The metaphor of ***viral spread***
- Dynamics of ***economic and strategic*** interaction
- Qualitative and quantitative; can be very subtle
- A revolution of
  - measurement
  - theory
  - breadth of vision

"Real World" Social Networks

- Example: Acquaintanceship networks
  - vertices: people in the world
  - links: have met in person and know last names
  - hard to measure
- Example: scientific collaboration
  - vertices: math and computer science researchers
  - links: between coauthors on a published paper
  - *Erdos numbers* : distance to Paul Erdos
  - Erdos was definitely a ***hub*** or ***connector;*** had 507 coauthors
  - how do we ***navigate*** in such networks?

Online Social Networks

- A very recent example: Friendster
  - vertices: subscribers to www.friendster.com
  - links: created via deliberate ***invitation***
- More recent and interesting: thefacebook
  - Join the Computer Science 1 group!
- Older example: social interaction in LambdaMOO
  - LambdaMOO: chat environment with "emotes" or verbs
  - vertices: LambdaMOO users
  - links: defined by chat and verb exchange
  - could also examine "friend" and "foe" sub-networks

Content Networks

- Example: document similarity
  - vertices: documents on the web
  - links: defined by document similarity (e.g. Google)
  - here's a very nice visualization
  - not the ***web graph***, but an ***overlay*** content network
- Of course, every good scandal needs a network
  - vertices: CEOs, spies, stock brokers, other shifty characters
  - links: co-occurrence in the same article
- Then there are ***conceptual networks***
  - a thesaurus defines a network
  - so do the interactions in a mailing list

Business and Economic Networks

- Example: eBay bidding
  - vertices: eBay users
  - links: represent bidder-seller or buyer-seller
  - fraud detection: bidding ***rings***
- Example: corporate boards
  - vertices: corporations
  - links: between companies that share a board member
- Example: corporate partnerships
  - vertices: corporations
  - links: represent formal joint ventures
- Example: goods exchange networks
  - vertices: buyers and sellers of commodities
  - links: represent "permissible" transactions

Physical Networks

- Example: the Internet
  - vertices: Internet routers
  - links: physical connections
  - vertices: Autonomous Systems (e.g. ISPs)
  - links: represent peering agreements
  - latter example is both physical and business network
- Compare to more traditional data networks
- Example: the U.S. power grid
  - vertices: control stations on the power grid
  - links: high-voltage transmission lines
  - August 2003 blackout: classic example of interdependence