COMP/ELEC 429/556
Introduction to Computer Networks

Overview
A bit about me...

- Grew up in Hong Kong
- B.S. University of Washington
- Ph.D. Carnegie Mellon University

- Research interests in networked systems
- Teach courses related to computer networks at both undergraduate and graduate levels

- CS Graduate Committee Chair
The BOLD Lab

Researchers Target Network Bottlenecks

Researchers at Rice University will use a three-year National Science Foundation grant to improve network efficiency and speed up science research.

BY COLIN WOOD (HTTP://WWW.GOVTECH.COM/AUTHORS/COLIN-WOOD.HTML) / SEPTEMBER 30, 2013

iPlant delivers free big data tech to the bioscience community

By Paul McDade
Oct 2, 2013

BOLD idea for big data (/news/3740)

Details
Written by Tyler O'Neal
Category: Latest News (News)
Published: 26 September 2013

Rice University creates BOLD system to handle Big Data

One of the problems they're using National Science Foundation funds to solve is creating a network that can carry a lot of data, faster and less expensively, than the Internet.

Get the Full story plus all our news & resources

Your free registration includes: Already Registered?
A bit more about me...

• Love cycling, but don’t have much time for it anymore...

• Besides teaching, research, administrative work, and other professional obligations...
Obviously, networks make these possible...
Network Crucial to Solving Hard Computational and Data Intensive Problems

T. S. Eugene Ng
eugeneng at cs.rice.edu
Rice University
Long before there were computers...

- 1876: Alexander Bell invented telephone
- 1878: Public switches installed at New Haven and San Francisco, public switched telephone network is born
  - People can talk without being on the same wire!
The Advent of Computer Technology

1940s

- Different networking requirements
- Computers to computers communication
  - vs. communication between human beings
- Digital information, discrete messages
  - vs. continuous analog voice
- Circuit switching technique in telephone network hugely inefficient for computer communications
Major Internet Milestones

• 1960-1964 Basic concept of “packet switching” was independently developed by Paul Baran (RAND), Leonard Kleinrock (MIT)
  – AT&T insisted that packet switching would never work!

• 1965 First time two computers talked to each other using packets (Roberts, MIT; Marill, System Development Corp (SDC))

MIT TX-2

SDC Q32
Major Internet Milestones

• 1968 BBN group proposed to use Honeywell 516 mini-computers for the Interface Message Processors (i.e. packet switches)

• 1969 The first ARPANET message transmitted between UCLA (Kleinrock) and SRI (Engelbart)
  – We sent an “L”, did you get the “L”? Yep!
  – We sent an “O”, did you get the “O”? Yep!
  – We sent a “G”, did you get the “G”? Crash!
Major Internet Milestones

- 1971 First packet radio network ALOHANET (Abramson, U Hawaii)
- 1973 Ethernet invented (Metcalf, Xerox PARC)
- 1974 “A protocol for Packet Network Interconnection” published by Cerf and Kahn
  - First internetworking protocol TCP
The 2004 A. M. Turing Award Goes to...

Bob Kahn   Vint Cerf

• "For pioneering work on internetworking, including the design and implementation of the Internet's basic communications protocols, TCP/IP, and for inspired leadership in networking."
Major Internet Milestones

- 1977 First TCP operation over ARPANET, Packet Radio Net, and SATNET
- 1985 NSF commissions NSFNET backbone
- 1991 NSF opens Internet to commercial use
Network Component Examples

Links

Interfaces

Switches/routers

Ethernet

WiFi
Course goals

- Knowledge and skills
  - How stuff work; skills from doing hands-on projects

- Scalability
- Performance
- Coordination
- Robustness
How applications use network to communicate
How to route effectively

<table>
<thead>
<tr>
<th>Step</th>
<th>start S</th>
<th>D(B),p(B)</th>
<th>D(C),p(C)</th>
<th>D(D),p(D)</th>
<th>D(E),p(E)</th>
<th>D(F),p(F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>A</td>
<td>2,A</td>
<td>5,A</td>
<td>1,A</td>
<td>∞</td>
<td>∞</td>
</tr>
<tr>
<td>1</td>
<td>AD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>ADE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>ADEB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ \infty \]

Loop

9 find w not in S s.t. \( D(w) \) is a minimum;
10 add w to S;
1 update \( D(v) \) for all \( v \) adjacent to w and not in S:
12 \( D(v) = \min( D(v), D(w) + c(w,v) ) \);
13 until all nodes in S;

T. S. Eugene Ng
eugeneng at cs.rice.edu
Rice University
How to scale network globally

- You can reach net B via addr1 and the path is “AS3 AS2”
- You can reach net B via addr1 and the path is “AS3”
- E-BGP

AS1

AS2

AS3
How to make communication reliable

- Three-Way Handshake
  - Each side notifies other of starting sequence number it will use for sending
  - Each side acknowledges other’s sequence number
    - SYN-ACK: Acknowledge sequence number + 1
    - Can combine second SYN with first ACK

\[ \text{Client} \quad \text{Server} \]

- SYN: SeqC
- ACK: SeqC+1
- SYN: SeqS
- ACK: SeqS+1
How to share the network effectively

- No congestion $\rightarrow$ rate increases by one packet/RTT every RTT
- Congestion $\rightarrow$ decrease rate by factor 2

Rates equalize $\rightarrow$ fair share

T. S. Eugene Ng
eugeneng at cs.rice.edu
Rice University
How to achieve predictable performance

- Decides how the output link capacity is shared by flows
- A chance to be smart: Transmission of packets held in queues can be *scheduled*
  - Which stored packet goes out next? Which is more “important”? 
  - Impacts quality of service
So whatever happened internally at Verizon caused aggregation for these prefixes to fail which resulted in the introduction of thousands of new /24 routes into the global routing table.
Understand Internet’s insecurity

Hacker redirects traffic from 19 internet providers to steal bitcoins

How Pakistan knocked YouTube offline (and how to make sure it never happens again)

YouTube becoming unreachable isn’t the first time that Internet addresses were hijacked to spur interest in better security, it may be the last.

A high-profile incident this weekend in which Pakistan’s state-owned telecommunications company managed to cut YouTube off the network.

This graph that network.

Talk to us 24/7 Another reason to switch to State: 24/7

Tech Culture
February 25, 2008
4:28 PM PST

by Declan McCullagh
@declanm
New Massive Cloud Data Center Environments
New software defined networking technologies
New optical technologies
Quantum Internet!?

Create

Ok

Ok
Learning from each other

- I try not to spoon feed you the answers
  - Help you discover part of the solution
  - Let you feel smug

- Peer to peer discussions
  - Help to draw out the questions
  - Some like it, some don’t
  - IMHO, it helps most students

- Refrain from non-course related activity in class
I’m Curious: What Motivated You to Take 429/556?

• Introduce yourself to your neighbor
• Interview neighbor on what motivated him/her to take 429/556?
Assignments

• 2 Homeworks (done individually)
• 2 Exams (done individually)
• 3 Projects (done in groups of up to 3 people)
  – Networked Application, Reliable Data Transport, Distributed Routing
  – 4 Flexible Slip Days for each student