Various Aspects of Network Modeling

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“Network” (1755)

“Network: Any thing reticulated or decussated, at equal distances, with interstices between the intersections.”

*Dictionary of the English Language, 1755*
“Network” (1996)

“When I took office, only high energy physicists had ever heard of what is called the World Wide Web. Now even my cat has its own page.”

Bill Clinton, announcement of Next Generation Internet Initiative, 1996
Invention of the telephone

“The method of, and apparatus for, transmitting vocal or other sounds telegraphically by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sound.”

US Patent #174465 issued to Alexander Graham Bell on March 7, 1876
“This ‘telephone’ has too many shortcomings to be seriously considered as a means of communication.”

*Western Union internal memo, 1876*
Telephone network dimensioning

• How to measure telephone traffic?
• Given traffic $A$ offered from source $S$ to destination $D$, what’s the capacity of the link between $S$ and $D$ to meet GOS requirements?
• Erlang loss formula
Basic works by Agner Krarup Erlang

- “The Theory of Probabilities and Telephone Conversations” (1919)

- “Solution of some Problems in the Theory of Probabilities of Significance in Automatic Telephone Exchanges” (1917)
“I think there is a world market for maybe five computers.”
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_Thomas Watson, Chairman of IBM, 1943_
# Growth of the Internet

<table>
<thead>
<tr>
<th>Date</th>
<th>Number of hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969</td>
<td>4</td>
</tr>
<tr>
<td>1971</td>
<td>23</td>
</tr>
<tr>
<td>1984</td>
<td>1,000</td>
</tr>
<tr>
<td>1987</td>
<td>10,000</td>
</tr>
<tr>
<td>1989</td>
<td>100,000</td>
</tr>
<tr>
<td>1992</td>
<td>1,000,000</td>
</tr>
<tr>
<td>1996</td>
<td>10,000,000</td>
</tr>
<tr>
<td>July 2000</td>
<td>93,050,000</td>
</tr>
<tr>
<td>July 2010</td>
<td>770,000,000</td>
</tr>
</tbody>
</table>
“There is no reason for any individual to have a computer in his home.”
“There is no reason for any individual to have a computer in his home.”

Ken Olson, president and founder of Digital Equipment Corp., World Future Society Convention, 1977
## Growth of the Internet (cont'ed)

<table>
<thead>
<tr>
<th>Date</th>
<th>Number of users</th>
<th>% of world population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 1995</td>
<td>16 million</td>
<td>0.4%</td>
</tr>
<tr>
<td>Dec. 2000</td>
<td>361 million</td>
<td>5.8%</td>
</tr>
<tr>
<td>Dec. 2005</td>
<td>1,018 million</td>
<td>15.7%</td>
</tr>
<tr>
<td>June 2011</td>
<td>2,110 million</td>
<td>30.4%</td>
</tr>
</tbody>
</table>
# Email statistics (2010)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of email messages per day</td>
<td>294 billion</td>
</tr>
<tr>
<td>Number of email accounts worldwide</td>
<td>2.9 billion</td>
</tr>
<tr>
<td>New email users since the year before</td>
<td>480 million</td>
</tr>
<tr>
<td>Share of emails that were spam</td>
<td>89.1%</td>
</tr>
</tbody>
</table>
# Website statistics (2010)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of websites in Dec. 2010</td>
<td>255 million</td>
</tr>
<tr>
<td>Added websites in 2010</td>
<td>21.4 million</td>
</tr>
</tbody>
</table>
Do they have anything to do with Internet research?

- Isaac Newton (1643-1727)
  *The universal law of gravitation*

- Siméon Denis Poisson (1781-1840)
  *The probability distribution applied to the deliberations of juries (1838)*

- Vilfredo Pareto (1848-1923)
  *Probability distribution of wealth, the 80-20 rule*

- George Kingsley Zipf (1902-1950)
  *Statistical occurrences in different languages*

- D. Lavalette
  *Statistical analysis of numerical values of the Journal Impact Factor*
New applications for old laws

• Gravity models used to model the volume of $S->D$ traffic in a network (PSTN, Internet)

• Poisson distribution: telephone call arrivals, packet arrivals, web transaction arrivals

• Zipf’s law, Pareto distribution: file size distribution, Internet topology, file access requests, website visitors

• Modified Lavalette’s law: wireless Internet access
Network modeling and teletraffic analysis

- Nondeterministic models
- Do we need a crystal ball?
- Probability distributions
- Measurement data
Sample projects

- Analysis of wireless Internet access sessions
- Synthesis of Internet traffic matrices
- Profiling various categories of Wi-Fi hotspot network users by applying clustering techniques
- Generation of cell dwell time residuum
Sample projects (cont’d)

• Website visitor traffic analysis

• Video on demand and time shifted TV traffic analysis
Teaching

- CS-455 Data Communications (Fall 2011, Spring 2012)
- CS-542 Computer Networks I (Fall 2011)
- CS-544 Computer Networks II (Spring 2012)
“There are three kinds of death in this world. There's heart death, there's brain death, and there's being off the network.”

Guy T. Almes, former Chief Engineer for the Internet2 Initiative
Enjoy studying at our CS Department!