Communications Network Design

lecture 01

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Introduction

What, When, Where, How, Who, Why

Note that not everything said in the lectures is included in the notes provided. You must listen, and take notes. These spaces in your handout notes are provided to allow you to take notes in lectures. You may be examined on material that is discussed in lectures, even if it does not appear explicitly in your notes!

Why do we need design

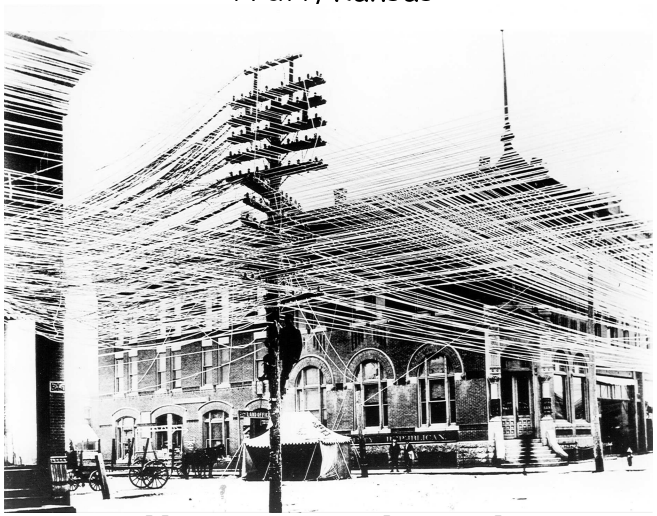
?

I don't know how any of the stuff works that is involved with telephone networks, let alone what works in any computer network.

former Chief Executive of a major Australian Telco

… Without Design

Pratt, Kansas



http://www.bellsystemmemorial.com/oldphotos_6.html

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The picture shows an example of what can happen when you don't design a network carefully! A not particularly large network resulted in many, many wires, and a large cost.

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Motivation

- Telecommunications industry in the US in 1997
  $256 billion industry [1]
- Compare to other US industries [1]
  - Motion picture industry: $63 billion
  - TV: $37 billion
  - Newspapers: $55 billion
  - Radio: $14 billion
- Telstra 2005, [2]
  - property, plant, equipment >$22 billion
- National Broadband Network, 2009
  - $4.7 billion public investment (+ private)

What if you could save 1%?

Wider Motivation

More than just telephone networks ...

"Close roads to clear traffic gridlock"
Bernard Lane, The Australian, 17-02-2005

- postal network
- more sinister networks
  - al-Qaeda
  - Mafia
- transportation network
  - road
  - rail
  - truck

http://www.dbcde.gov.au/communications_for_business/funding_programs__and__support/national_broadband_network

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Focus

- data networks
- main example: the Internet
  - made up of lots of components
  - we'll look at specific design problems within this context
- many techniques have MUCH wider applicability

Course objectives

Objectives: At the end of this subject the students should be able to:

- analyse the features of a network design problem:
  - objectives (e.g. cost minimization)
  - constraints (e.g. technological limits)
  - properties of each
- understand what data is needed/available
- choose suitable algorithm for solving the problem
- understand the limits of methods, and inputs, and therefore critically interpret the output

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Not covered

- **Stochastic modelling**: see "Modelling Telecommunication Traffic (APP MTH 4012)", or "System Modelling and Simulation (APP MTH 4004)"
- **Pricing**: Lots of work on this (e.g. Paris Metro pricing, and Frank Kelly's proportional fairness)
- **Protocol design**: e.g. framing and encapsulation, TCP congestion control design, or Ethernet details.
- **Network Administration**: e.g. how to configure Cisco routers (this is not a CCNA course).
- **Physical Networks**: e.g. RF, error correction, Shannon and Nyquist limits, compression, ...
- **Multimedia or Design of Web Pages**: application layer, client-server, ...
- **Security**: encryption, ...

A Brief History of Networking

"Those who do not study history are doomed to repeat it."

Georges Santayana

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Why bother?

- ideas have their time
  - most things are invented for a need
  - this gives insight into network design
- most things in networking are reinvented again and again
  - can save a lot of time if you already know the answer
- gentle introduction to some concepts

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A brief history of networking

An outline:

1. pre-industrial
2. 19th century
3. early 20th century
4. computer networks
5. early 21st century (now)

More detailed telephony timelines can be found at
`http://www.telephonetribute.com/timeline.html`
`http://www2.fht-esslingen.de/telehistory/`

Histories of computing and computer networks
`http://en.wikipedia.org/wiki/Computing_timeline`
`http://www.isoc.org/internet/history/`

Australian telecoms history
`http://www.caslon.com.au/timeline.htm`
`http://www.anu.edu.au/people/Roger.Clarke/II/OzIHist.html`

Pre-industrial

- Jungle drums
- Signal fires
  1184 BC, fall of Troy [3]
  1588 AD, Arrival of Spanish Armada
- Carrier pigeons
  700 BC, Olympic games
- Smoke signals
  150 AD, Romans
- Semaphore
  1791 AD, Chappe brothers
  later used by Napoleon

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Marathon: One of the more famous events in early telecommunications occurred in September 490 BC. The Greeks defeated a much larger Persian army (numbering in the hundreds of thousands as compared to the Greeks who had more like 10,000 soldiers). An Athenian herald, Pheidippides, ran from Marathon to Athens to deliver the message "We were victorious!", following which he immediately died.

Most telecommunications providers would prefer not to die :-)

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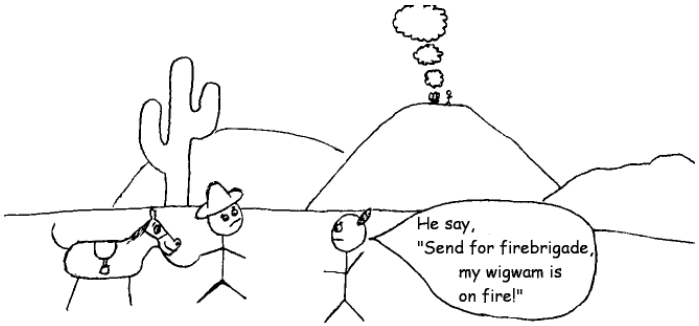
Pre-industrial

These had limitations

- Carrier pigeons: `1 short message per pigeon`
- Signal fires: `one bit per fire`
- Semaphore: `15 characters per minute.`



19th century

Post office:

- British post office founded 1635.
- modern postoffice 1840 (1st "penny black" in UK)
- send **content** as letter or parcel
- encapsulate package with address on the front
- send to local postoffice
- each postoffice determines next postoffice
- final postoffice delivers to the address

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`http://www.bbc.co.uk/history/timelines/britain/vic_penny_black.shtml`

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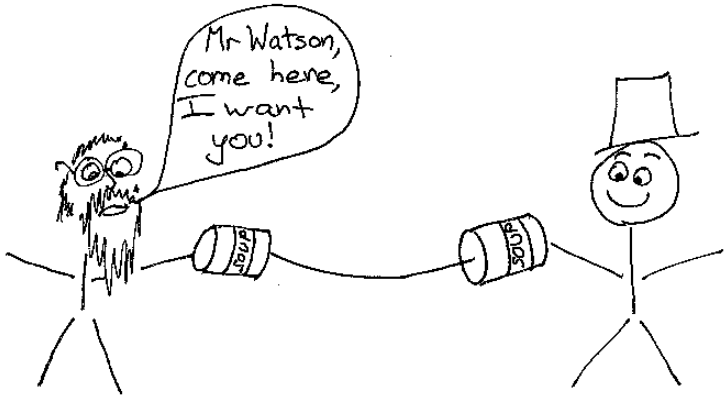
19th century

Electronic communication:

- telegraph
  - invented 1753
  - Morse code 1835
  - take off 1838
  - 1st transatlantic line 1866
- radio (Marconi, 1896)
- telephone
  - A.G. Bell
  - filed patent Feb. 14, 1876, 3 hours before Elisha Gray

19th century

Simple telephone: connects two points with a wire



Reportedly, the first words over the telephone came when Bell spilled some acid on his pants, whereupon he call "Mr. Watson, come here, I want you!"

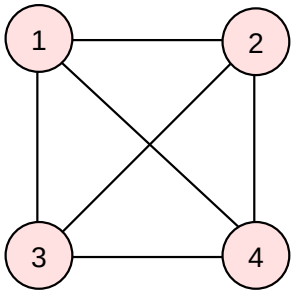
In 1876, Bell and his financial backer, G.G. Hubbard, offered Bell's patent to the ancestor of Western Union. Their committee to investigate the patent reads in part:

> "The Telephone purports to transmit the speaking voice over telegraph wires. We found that the voice is very weak and indistinct, and grows even weaker when long wires are used between the transmitter and receiver. Technically, we do not see that this device will be ever capable of sending recognizable speech over a distance of several miles.
> "Messer Hubbard and Bell want to install one of their "telephone devices" in every city. The idea is idiotic on the face of it. Furthermore, why would any person want to use this ungainly and impractical device when he can send a messenger to the telegraph office and have a clear written message sent to any large city in the United States?
> "The electricians of our company have developed all the significant improvements in the telegraph art to date, and we see no reason why a group of outsiders, with extravagant and impractical ideas, should be entertained, when they have not the slightest idea of the true problems involved. Mr. G.G. Hubbard's fanciful predictions, while they sound rosy, are based on wild-eyed imagination and lack of understanding of the technical and economic facts of the situation, and a posture of ignoring the obvious limitations of his device, which is hardly more than a toy... .
> "In view of these facts, we feel that Mr. G.G. Hubbard's request for $100,000 of the sale of this patent is utterly unreasonable, since this device is inherently of no use to us. We do not recommend its purchase."

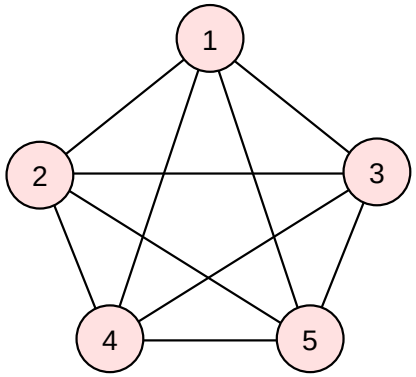
The amusing thing about this letter, in retrospect, is that Bell obtained controlling interest in Western Union by 1882!

Dumb network design

One link between every pair who wish to speak



N=4
L=6

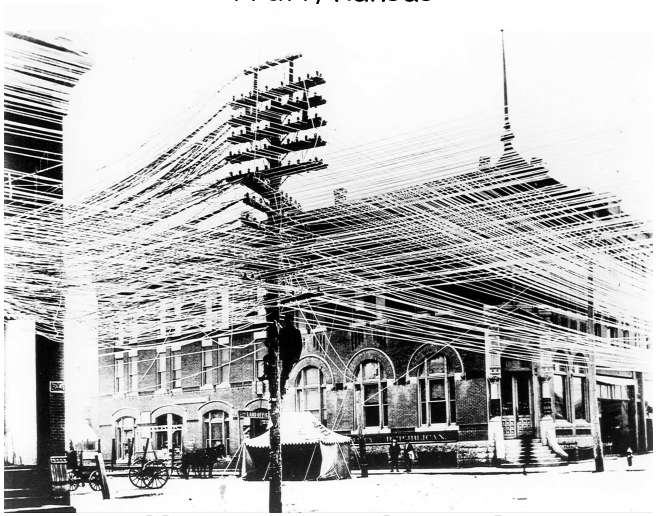


N=5
L=9

N nodes, then we have L=N(N-1)/2 links

Dumb network design

Pratt, Kansas



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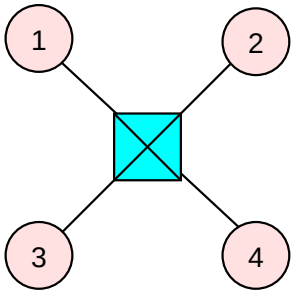
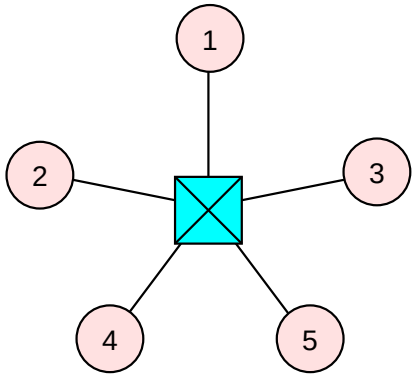
A switch

What if each person has one wire to a **switch**.



N=4
L=4



N=5
L=5

N nodes, then we have L=N links

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Switchboards

So switches are great, but what is a switch?

http://www.bellsystemmemorial.com/oldphotos_6.html

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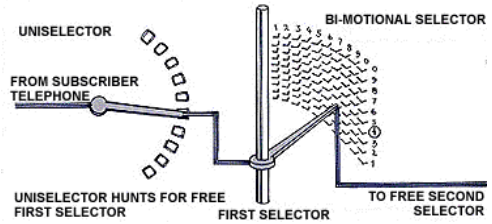
Electromechanical switch

Almon Strowger was an undertaker in Kansas City in the late 1800's

- http://www.strowger.com/history.html
- Company 'Strowger Automatic Telephone Exchange' in October 1891
- step-by-step electromechanical switch [4]



http://www.sigtel.com/tel_tech_sxs.html

Towards modern telephony

- switches get more complicated and sophisticated
  - electronic switch (instead of electromechanical)
  - 4ESS (like a building)
    http://www.att.com/history/nethistory/switching.html
- networks become hierachical
  - long distance versus local
- reliability and redundancy become important
  - alternate routing
- billing systems
  - harder than you think!

More pictures with commentary
http://www.technology.niagarac.on.ca/people/mcsele/TelephoneSwitch.html

More history
http://www.telephonetribute.com/switches_survey_intro_chapter_1.html
http://www.strowger.com/history.html

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Some additional links

More detailed telephony timelines can be found at
http://www.telephonetribute.com/timeline.html
http://www2.fht-esslingen.de/telehistory/
http://www.webbconsult.com/hist-time.html
http://www.ieee.org/organizations/history_center/comsoc/timelines.html
http://williamstallings.com/Extras/Telecom.html
http://aronsson.se/hist.html

Histories of computing and computer networks
http://en.wikipedia.org/wiki/Computing_timeline
http://www.isoc.org/internet/history/
http://www.isoc.org/internet/history/brief.shtml
http://www.dei.isep.ipp.pt/docs/arpa.html
http://www.zakon.org/robert/internet/timeline/
http://en.wikipedia.org/wiki/History_of_the_Internet
http://goldenink.com/computersandnetworks.shtml
http://www.davesite.com/webstation/net-history.shtml
http://www.computerhistory.org/exhibits/internet_history/
http://www.tranquileye.com/cyber/
http://www.onlineitdegree.net/

Australian telecoms history
http://www.caslon.com.au/timeline.htm
http://www.anu.edu.au/people/Roger.Clarke/II/OzIHist.html

References

[1] A. M. Odlyzko, "The history of communications and its implications for the Internet." http://www.dtc.umn.edu/~odlyzko/doc/networks.html.

[2] "Telstra corporation limited — half-year report," 2005.

[3] Aeschylus, Agamemnon. http://classics.mit.edu/Aeschylus/agamemnon.html, 458 B.C.E.

[4] A. B. Strowger, "Automatic telephone exchange." United States Patent Office, patent no. 447,918, March 10th, 1891.