

L1 Introduction to Comm Networks (Telegraph & Telephone) ^①

1.1 Overview

- Communication networks?

- systems allowing multiple users (people/computers/"entities") to exchange information

- users (obviously) distributed in space

μm : nanonetworks

cm : BAN/PAN

m : LAN

km : cellular, telephone, internet

1000 km : satellite

- and over broad number of users

- getting such systems to work requires the conjunction of many ideas

→ from current levels to protocol architectures

- in this course we look at the key parts

course has 5 main parts

some

1) Network Overview (Ch. 1, 2, 7, 8)

- network examples
- structure/service classification
- means of service implementation
- protocols
- physical calculations

2) Bit-pipe design (Ch. 3)

- how to quickly and accurately send bits over physical connections

3) Error Recovery & Tx Control (Ch. 5)

- how to send a stream of bits across a connection or network

4) Medium Sharing (Ch. 6)

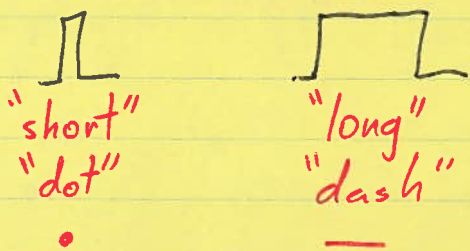
- LANs, small networks multiplexed over a single connection

5) Internetworking (Ch. 7, 8)

- how to get data across big networks (of networks)

1.2 Telegraph

- The first electronic network (~1840s on)
- Send pulses of current over wire



- letters + numbers composed of combinations of • -

- a form of digital communication

• = '0' } each is a bit
 - = '1'

- a little quantification

to send you have ~ 26 letters + 10 digits = 36 chans.

how many bits?

$$n = \lceil \log_2 36 \rceil = \lceil 5.17 \rceil = 6 \text{ bits/chan.}$$

- best telegraphers could send ~ 35 words/min

- what's data rate, R , ???

(4)

• avg. *chars/word* = 5.5

• incl. space had to send ~ 6.5 *chars/word*

$$\therefore R = 35 \times (5.5 + 1) \times 6$$

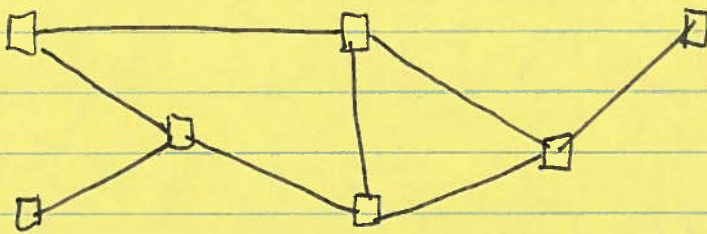
\swarrow *bits/char*

$$= 1365 \text{ bpm}$$

$$R = 22 \text{ bps}$$

1.3 Telegraph Network

• Collection of operating stations (*mesh network*)



• *human operator* : translates letters
transmits bits

• *adjacent station* : receives message
decodes bits

• a *message-switching network* :

↓ that is...

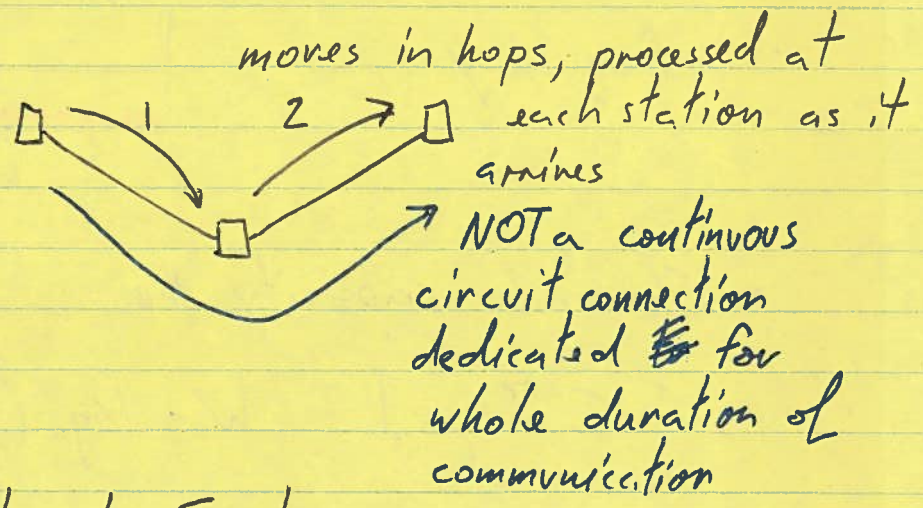
not parts of messages i.e. a continuous link is NOT present

4) messages routed one hop at a time
(instead of right through from source to destination)

2 main features

- 1) store-and-forward switching: decode & accrue whole message before sending on to next hop
- 2) connectionless service: message moved through network before knowing exactly whether destination is willing to take it

message switching in pictures



4 Key Telegraph Network Functions

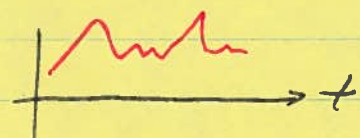
- 1) Digital transmission over wire (physical layer)
- 2) Framing methods (recognizing groups of characters & their boundaries) (data link layer)
- 3) Recognition of destination address & procedure to ROUTE messages there (network layer)

1.5 Telephone

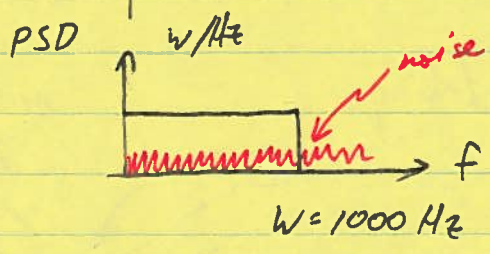
- Analog **plug-and-play** system ~ 1875
- Pick up receiver & start talking
- How many bits are you sending now?

ROUGHLY...

• your signal in time



• in frequency



• Shannon's capacity thm.

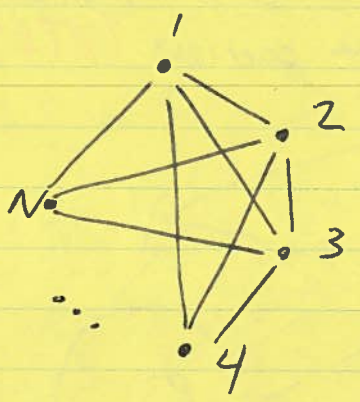
$$\begin{aligned}
 C \text{ [bps]} &= W \cdot \log_2(1 + \text{SNR}) \\
 &= 1000 \cdot \log_2(1 + 10) \\
 &= 3471 \text{ bps}
 \end{aligned}$$

• huge jump over our 22pbs telegraph

1.6 Telephone Network

- originally point-to-point

N units connected to N-1 other units (÷2 for repeats)



$$\frac{N(N-1)}{2} \text{ links}$$

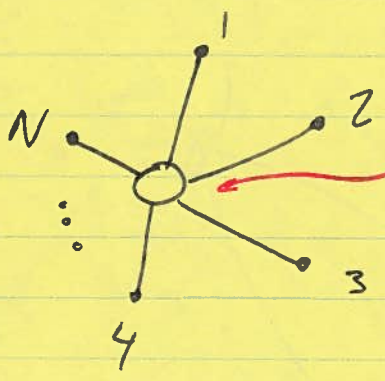
or binomial coefficient

$$= \binom{N}{2} = \frac{N!}{2!(N-2)!}$$

how many different P2P combos

$N = 1000 \sim 500k$ lines needed !!!

- not sustainable/scalable ... hierarchical network constructed

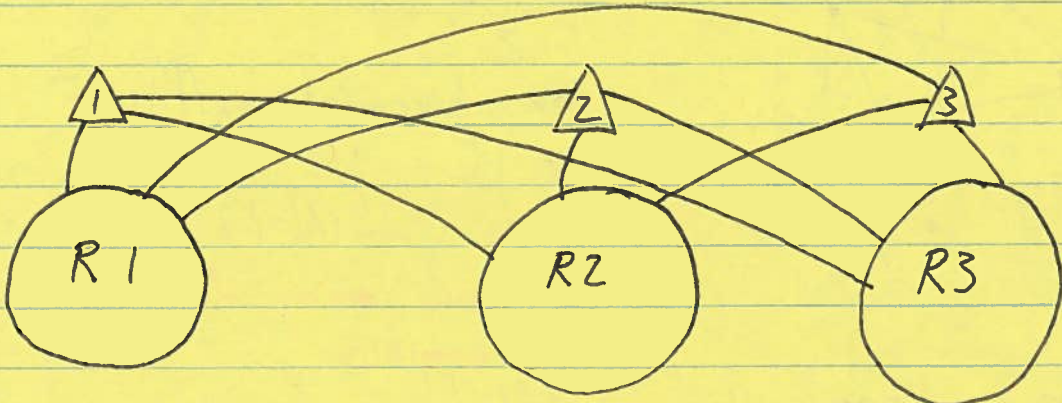


"central office", "end office" CO

- still all networks strive to emulate $\binom{N}{2}$ P2P network as best as possible (with manageable resources)

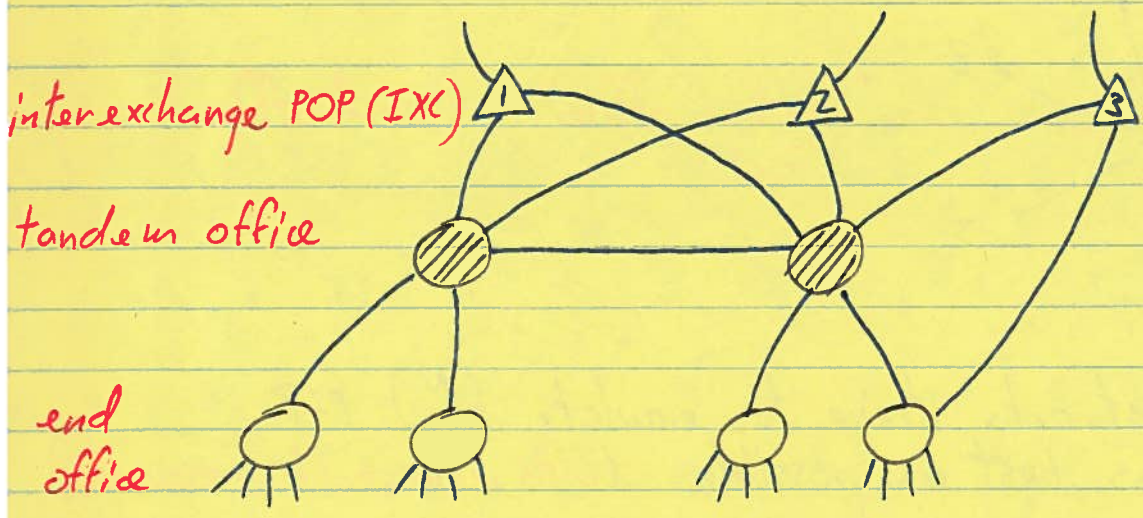
- CO technology
 - human
 - electromechanical (Strowger switch)
 - electronic
 - digital

- Telephone network now a hierarchy of switches
- Country broken down into **REGIONS (LATA)**
 local access & transport area
 - serviced by long distance ~~carriers~~ carriers (**AT&T, Verizon**)



~ 150 regions in USA, ~ 10^6 phones per region (very rough)

- further hierarchy in each region

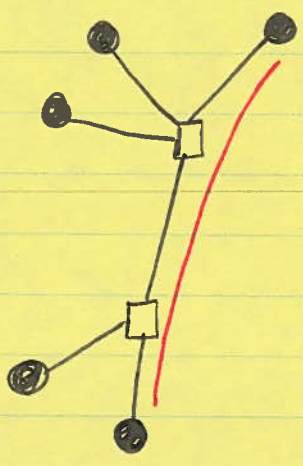


~ 10^4
connections
per end office

~ 150 CO's per region

NYC has 80 for $8 \times 10^6 \sim 10^5$ per CO

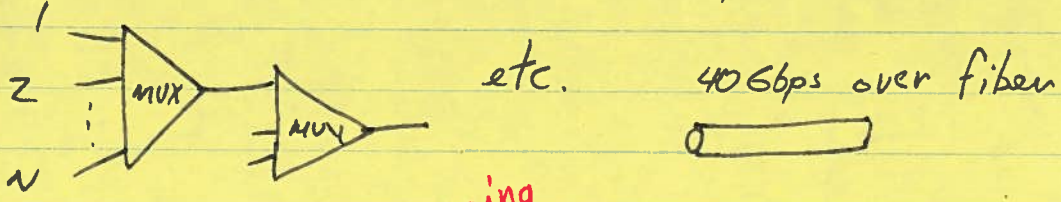
Telephone network vs. telegraph network



- dedicated **physical connection** between end points is made
- "connection-oriented" (vs. "connectionless")
- a link is a **circuit**
 - ↳ switching
- by joining line segments into a circuit we have a **CIRCUIT SWITCHED NETWORK**

1.7 Digital Telephone

- voice sampled at 8-bits every 125µs ... 8 kHz
∴ 64 kbps (cf. 3.5k & 0.02k)
- with digital you can easily store & accrue data



etc. 40 Gbps over fiber

