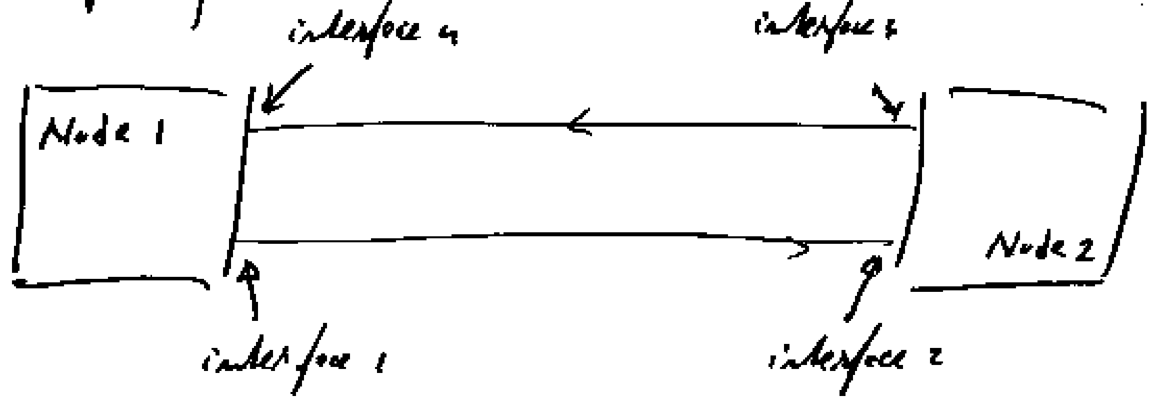
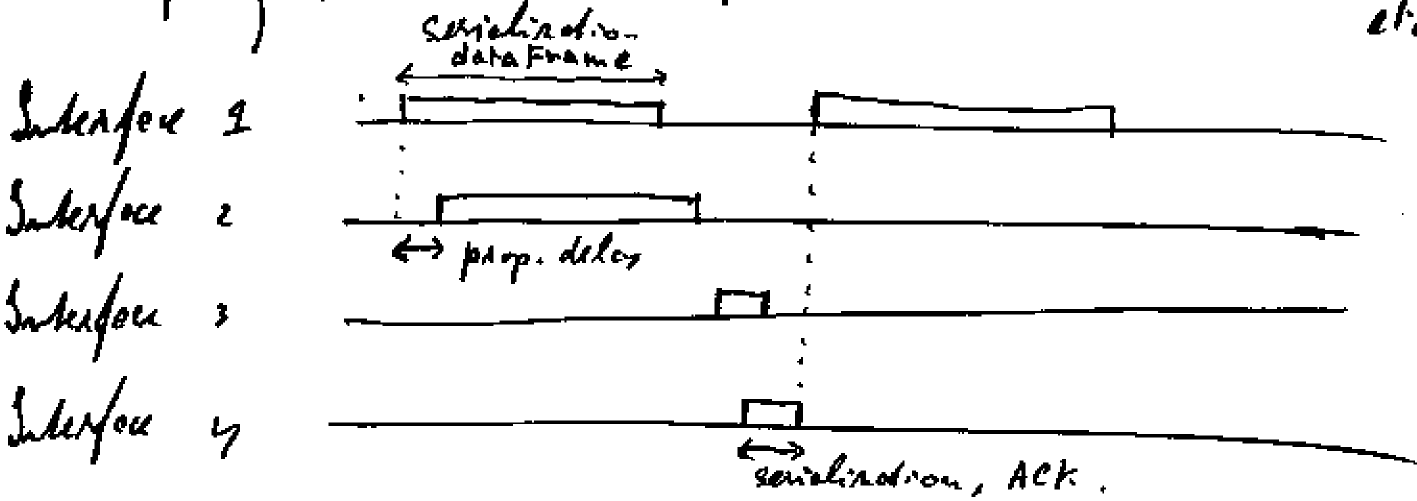
week 12 starts here

Stop & Wait vs Window

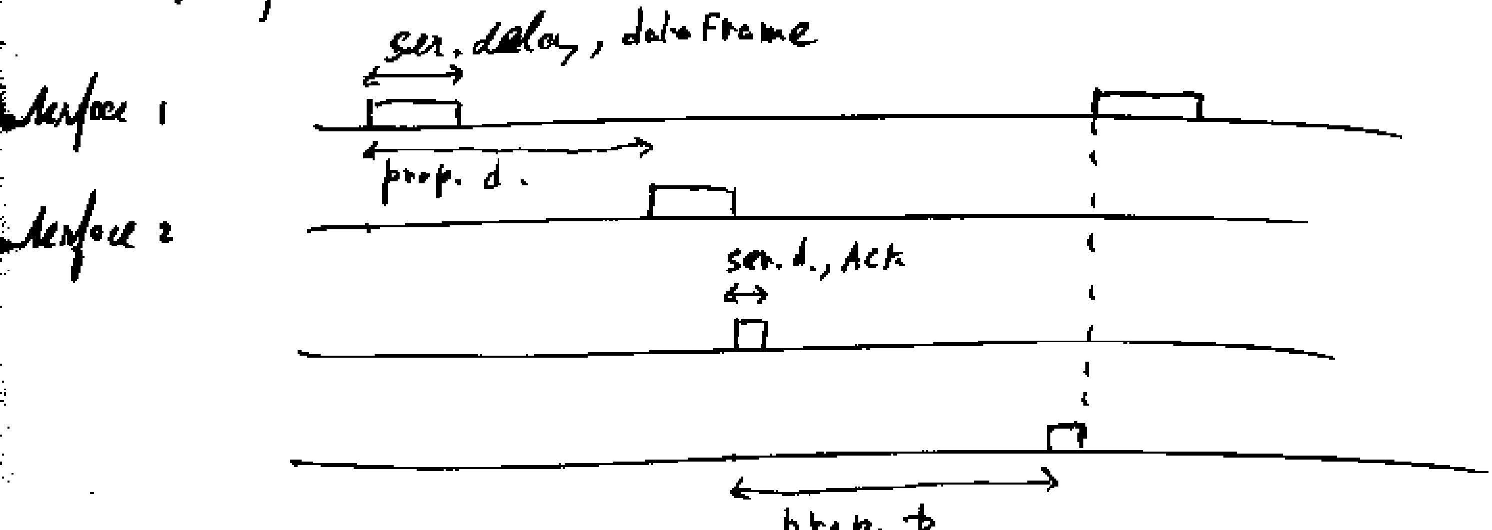


Stop & Wait if prop. delay $\ll$ serialization d.

etc.

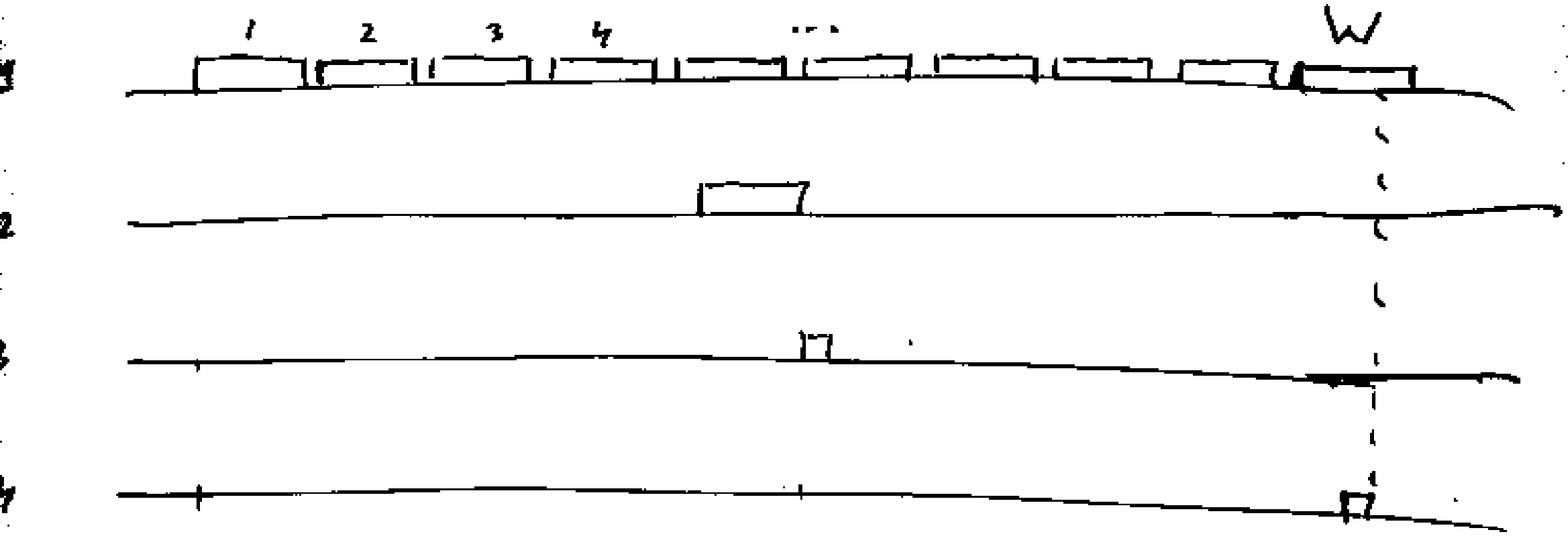


Stop & Wait if serialization delay $\ll$ prop. delay



Inefficient Use of Transmission Channel.

If serialization delay << prop. delay:
Ideally:



Ideally: Ack for 1 arrives at interface 4 "while" frame W is being sent out from interface 1.

W too small: inefficient use of transmission lines.

W too large: all kinds of other problems.

Q: Where do the "extra" frames go?

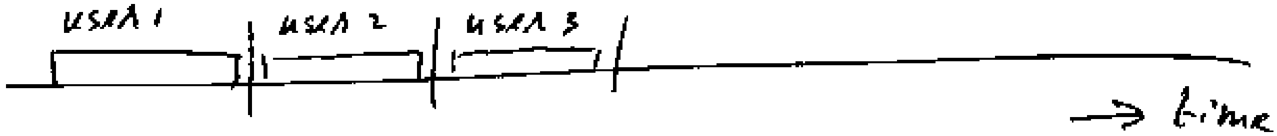
Multiplexing.

(Cable, Radio, and similar).

1. TDM.

Time Division Multiplexing.

Tanenbaum p 137, pp 140 - 141.



Need not be "Round Robin".

Could be

E A B A C A D A B A C A E or so.

Or, "irregular".

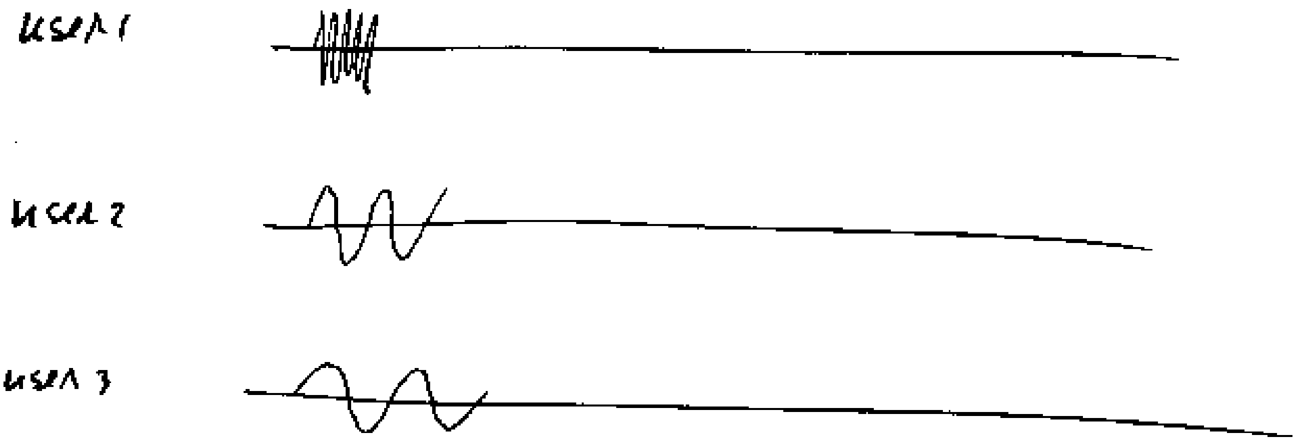
In cable (modems) the head-station assigns timeslots for upstream traffic.

2 FDM, WDM.

Frequency Division Multiplexing.

Wavelength Division Multiplexing.

pp 137 – 140



each user has own frequency band.

Uses QPSK, QAM, Trellis, ...

But stays in own band.

Optical Fibers:

Nowadays ~ 120 (or more?)
wavelengths per fiber.

200 + wavelengths in the lab.

10 Gb/sec per wavelength:

$100 \times 10 \times 10^9 = 10^{12}$ bits/sec = 1 Terabit/sec. per fiber.

(or more).

MPEG2: 3–6 Mb/sec. } 30 90-minute movies is 810×10^9 bits.
Say 5 Mb/sec: } < 1 Terabit.

3 CDMA Tanenbaum pp 162 – 166.

Code-Division Multiple Access.

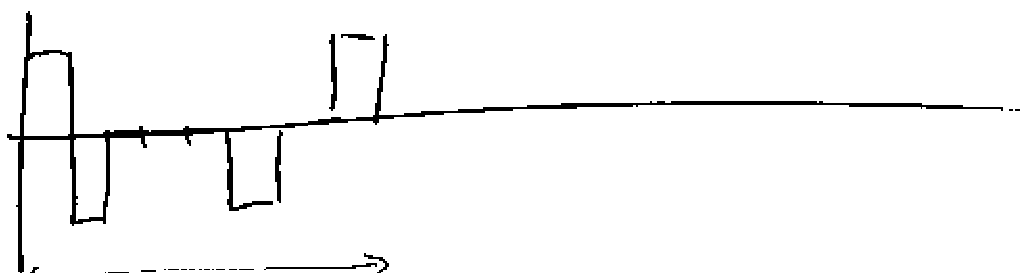
Let's do it on <u>Baseband</u>.

Direct Sequence CDMA.

Each user has <u>two</u> "chip sequences".

one for 1, one for 0.

Assume synchronized.



Sequence k: $(\delta_{1,k}, \delta_{2,k}, \cdots, \delta_{N,k})$.

$k \neq l$: $\sum_{j=1}^{N} \delta_{j,k}\, \delta_{j,l} = 0$ (contribution zero for each contributor)

$k = k$: $\sum_{j=1}^{N} (\delta_{j,k})^2 = P$.

CDMA:

(Assume synchronized)

If you know sequence k,

and you hear signal S ($S_j, j=1,\dots,N$)

(superposition of many)

$$\sum_{j=1}^{N} \delta_{j,k} \cdot S_j = \begin{cases} 0 & \text{if k-th sequence there} \\ P & \text{not.} \end{cases}$$

Complications:

Not synchronized,

Not Baseband.

But "the same idea" still works.

CDMA

Qualcomm

<u>Mixtures</u> of

TDM, FDM, CDMA.

E.g. Frequency hopping.

Coding

We talked about coding several time.

1. How to put binary signals on analog links.
(Baseband, Manchester,
QAM, ~~PS~~ QPSK, Trellis, ...)

2. How to ~~xxx~~ put an analog ~~s~~ signal like voice on a digital channel
(PCM, Delta Modulation, ...)
And lower data rates:
"lossy compression":
Information is lost, but the user will not notice.
(will hardly notice. Can live with it).
"Does not mind".

3 Loss less Compression.
You have a file. Say 1 M Bytes.
You want to "describe" it in fewer bytes, then send it over.
E.g. "This ~~b file~~ File is FFF...FF".

Huffman 1952.

~~Variable~~
Variable length encoding.

Suppose our message (file) is organized in Bytes.

There are $2^8 = 256$ different possible Bytes. "Alphabet of $2^8 = 256$ different characters".

In advance, find the frequencies of each of these 256 bytes:

by $p_1, p_2, \ldots, p_{256}$.

Re-order: $1 > p_1 \geq p_2 \geq \cdots \geq p_{256}$.

Now encode the bytes,

$Byte_1$: short # bits $Byte_2$: l more ⋮ $Byte_{256}$: longest.	Complication: "Short code word" must not be pre-fix for any longer code word.

Now send. If there are a few bytes with $p_i \gg \frac{1}{256}$:

It is worth first sending the map

... stands for ..., then the transformed bytes -

~~M~~ practically

$$p_i \sim \frac{1}{256} \quad \text{for } \underline{\text{all}}\ i$$

(all Bytes)

this scheme does not work.

(does not compress).

But then, maybe it works with a different "alphabet" of

1024 10-bit "letters" ~~words~~, or

65536 16-bit "letters" ~~words~~, (etc.)

Coding Schemes (lossless).

(1) Huffman (1952).

Go to Unix/Solaris/Linux system,

do man pack .

(2) Lempel - Ziv

Go to Unix/Solaris/Linux system,

do ~~co~~ man compress .

If you have to store or transmit a large file, it may be worth compressing it.

I assume log tapes are usually compressed.

SONET

Synchronous Optical Network

Tanenbaum, pp 144-146.

Please Read.

But: I will ask only from what I cover in class.

Bellcore standard.

(I was not involved).

Specialized for ATM

(Asynchronous Transfer Mode).

A "SONET Frame" is

$9 * 90 =$ ~~[illegible]~~ 810 Bytes large

$9 * 3 =$ 27 Bytes for control

$9 * 87 =$ 783 Bytes payload.

At OC-1 (STS-1) a SONET frame takes 125 μ sec: 8000 frames/sec

OC-1 or STS-1 :

Total $8000 * 9 * 90 * 8 = 51.84$ Mbit/sec.

Payload $8000 * 9 * 87 * 8 = 50.112$ Mbit/sec.

OC-3 : 3 times. ~ 150 Mb/s.

OC-6

OC-12

⋮

OC-48 ~ $48 * 50 =$ 2.4 Gb/sec.
(used to be <u>one</u> wavelength!)

OC-96 ~ 4.8 Gb/sec.

OC-192 ~ ~~192 * 5 0~~ $192 * 50$ = 9.6 Gb/sec
(actually a bit more).

Raw: $192 * 51.84 = 9.95328$ Gb/sec.

Payload: $192 * 50.112 = 9.621504$ Gb/sec.

At higher bandwidths, overhead changes.
(Minor)

SONET:

"Synchronous":

Frames are sent ~~st~~ even if there is no data. (Back to back).

° Frames can be "partially full". (partially empty).

pointer to "real data" part.

The "Real Data" can start anywhere in the frame.

Can span frames.

ATM over SONET

ATM over SONET over light.

IP over ATM over SONET over light.

AAL 3/4

Tanenbaum p 65.

(And somewhere in these notes).

Later added:

ATM over twisted wire.

Now in labs:

IP over SONET over light

IP over light.

Mobile phones.

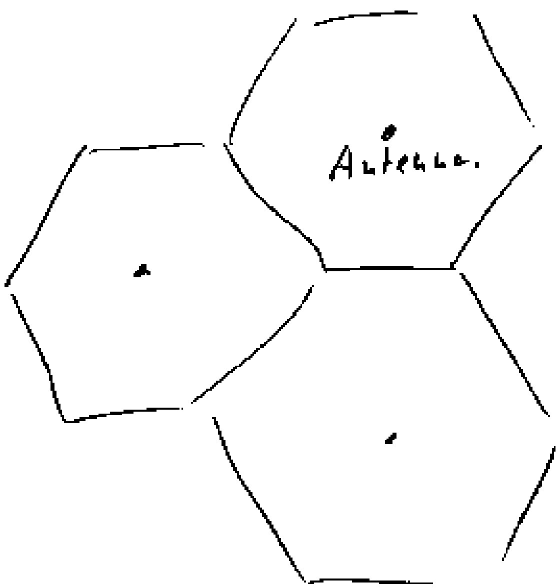
Tanenbaum pp 152 - 169.

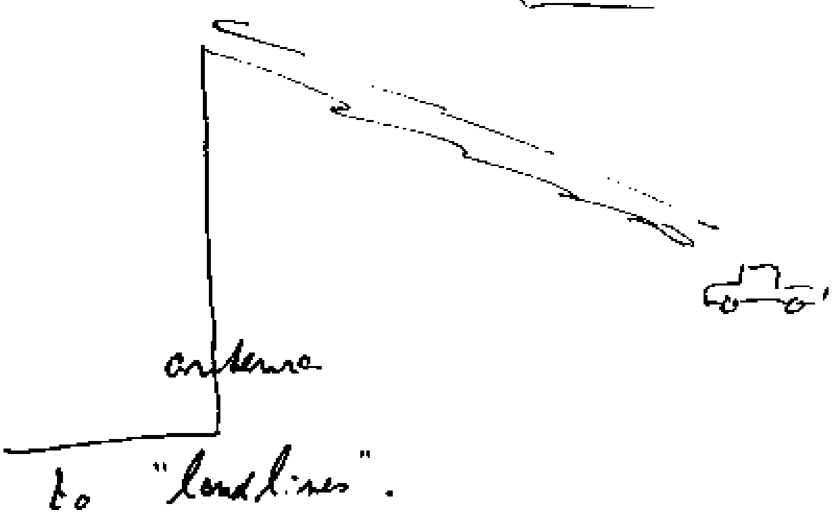
Read.

CDMA: only what I did in class.

Rest: you are supposed to know book and class.

Basic idea: areas (now called cells)





Old:

Large "cells" (diameter ~ 100 km or more)

1 channel (wavelength) per "cell")

~~for all the up- or down)~~

Analog, "push to talk".

~ 1960 (sixties) IMTS (Improved Mobile Telephone System)

23 channels.

each two parts: up / down.

Still analog Still large cells.

~ 1982. AMPS Advanced Mobile Phone Systems

cells. 10-20 km across. (smaller than before)

~~AMPS: a few bands: 824-849 MHz, 869-894 MHz.~~

AMPS:

832 channels. (

each channel: duplex, actually 2 simplex.

each simplex channel: 30 kHz wide.

FDM separates channels

832 :

21 for control.

811 for voice, pagers, etc.

21 Control channels: Use FSK

(digital: Frequency Shift Keying,

Two frequencies (?)

0, 1.)

811 ~~Those~~ "voice" channels use FM.

(Analog : Frequency Modulation).

If two companies share:

each might have 21 control channels.

395 "voice" channels.

416

Handset: 32 bit serial number

10 digit (?) phone number

When turned on: scans 21 control channels.

finds "strongest signal". Announces itself to

Base-Station.