Week 11 Starts here.

"Above" PPP: (In the sense of carried inside PPP).

(1) LCP Link Control Protocol.

If the ~~Data~~ PPP data is an LCP packet, the protocol is $C021_{16}$

(12-0-2-1.
1100-0000-0010-0001).

(2) Authentication Protocols.

One of these is PAP
Password Authentication Protocol

Protocol (PAP): $C023_{16}$.

Also CHAP
Challenge Handshake Auth P

(3) Network Control Protocols (NCP)
plural.

One of these is IPCP
Internetwork Protocol Control Protocol.

Protocol: 8021

1000 0000 0010 0001

To "set up etc". IP ~~[illegible]~~ connections

(4) Actually, carrying IP Packets.

Protocol: ~~00~~ 0021_{16}

0000 0000 0010 0001.

PPP:

IP oriented.

But can also carry

IPX, Appletalk, OSI, and more I do not know.

(CLNP, XNS)?

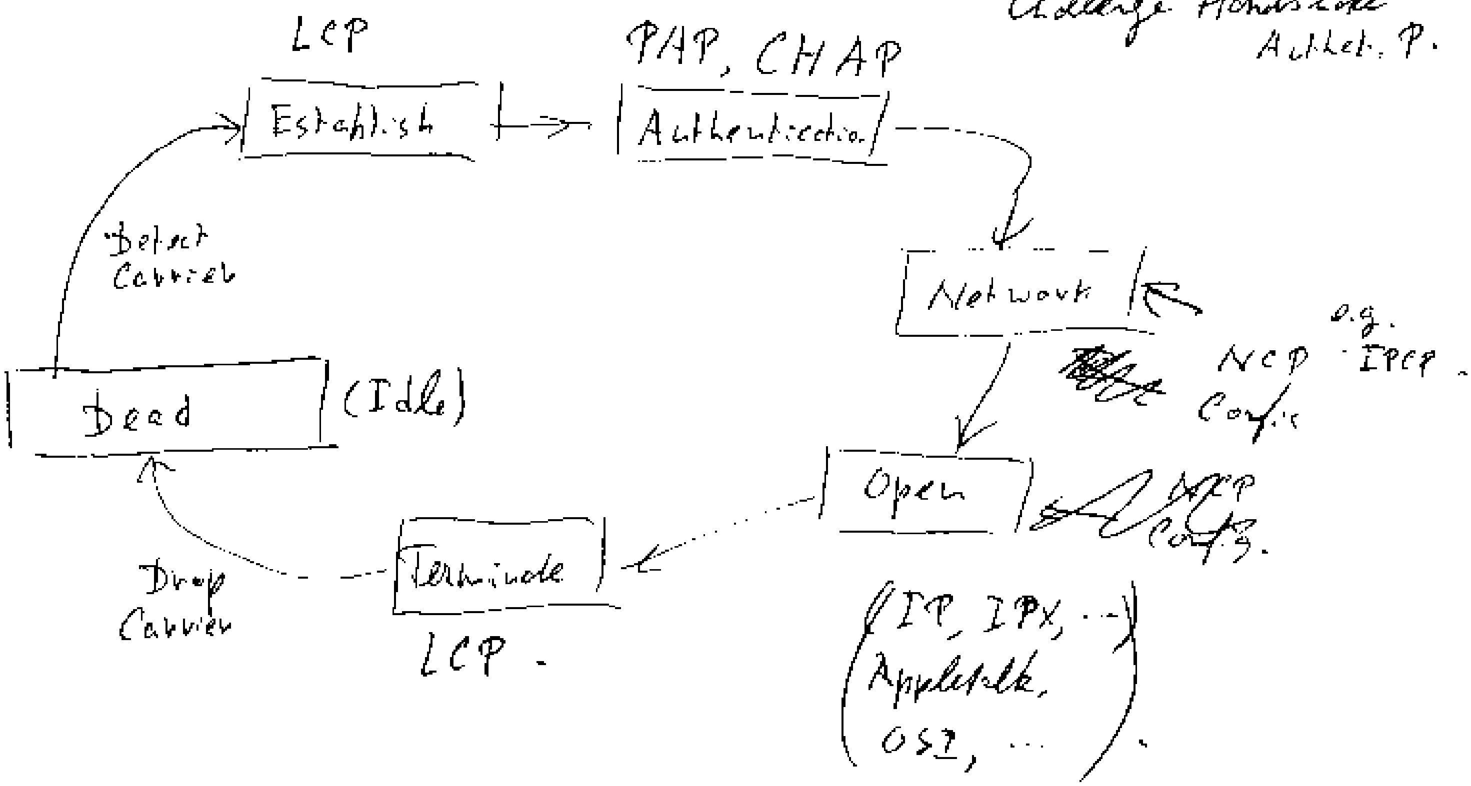
PPP "State Diagram".

Tanenbaum

Link Control Protocol

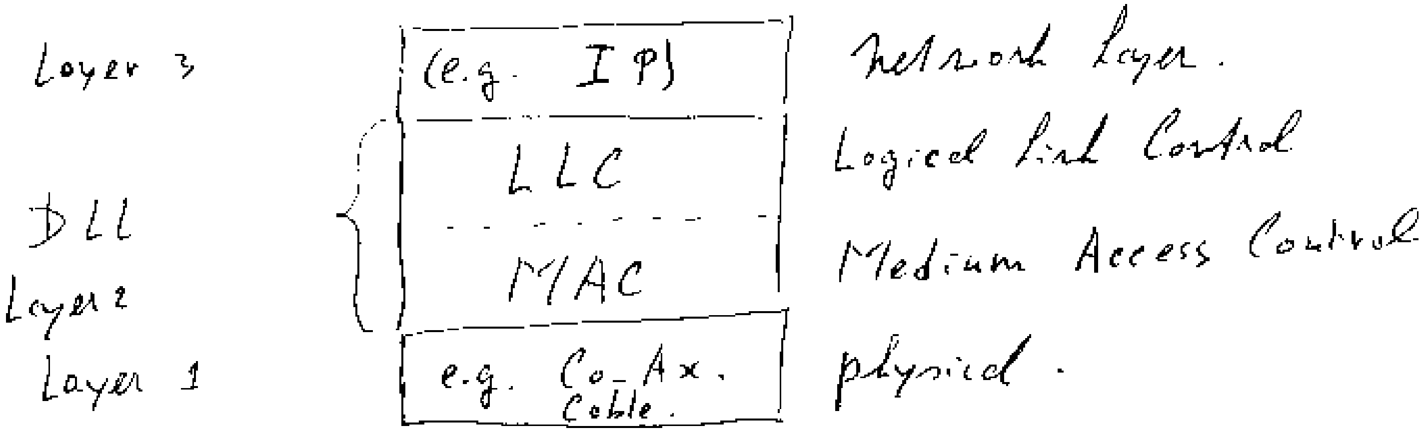
PAP: Password Authentication P

CHAP: Challenge Handshake Authent. P.



IPX: Stuff that in Novell (?)

Data Link Layer   DLL   (layer 2)



Tanenbaum, p 291

This is a distinction IEEE makes
(in the 802.X series).

IETF does not (in PPP).

Though, you could say
LCP is "more like MAC".
Link Control Protocol.
NCP is "more like LLC"
Network Control Protocol.

Data Link Layer Protocols:

(1) ~~PPP~~ PPP. IETF. (done)
For point-to-point connections

(2) Rest: IEEE:

(2) 802.3 "ethernet". (done)
(multiple access, also point to point).
these two are most important.

(3) 802.11 Wireless LAN. (next)
(like the one in this classroom).

(4) 802.16 Broadband Wireless.

(5) 802.15 (≈) Bluetooth.
IETF (?)

Satelite. (not DLL)

IEEE 802.11.

Tanenbaum pp 68-71

pp 292-302

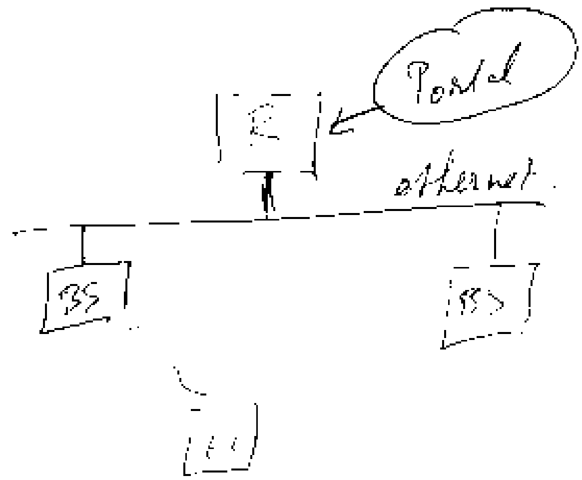
pp 267-270

WiFi

Two situations:

(1) Base Station
(Access point).
"Like Cable modem, headstation".

(2) Without Base Station.
"Ad Hoc Networking".



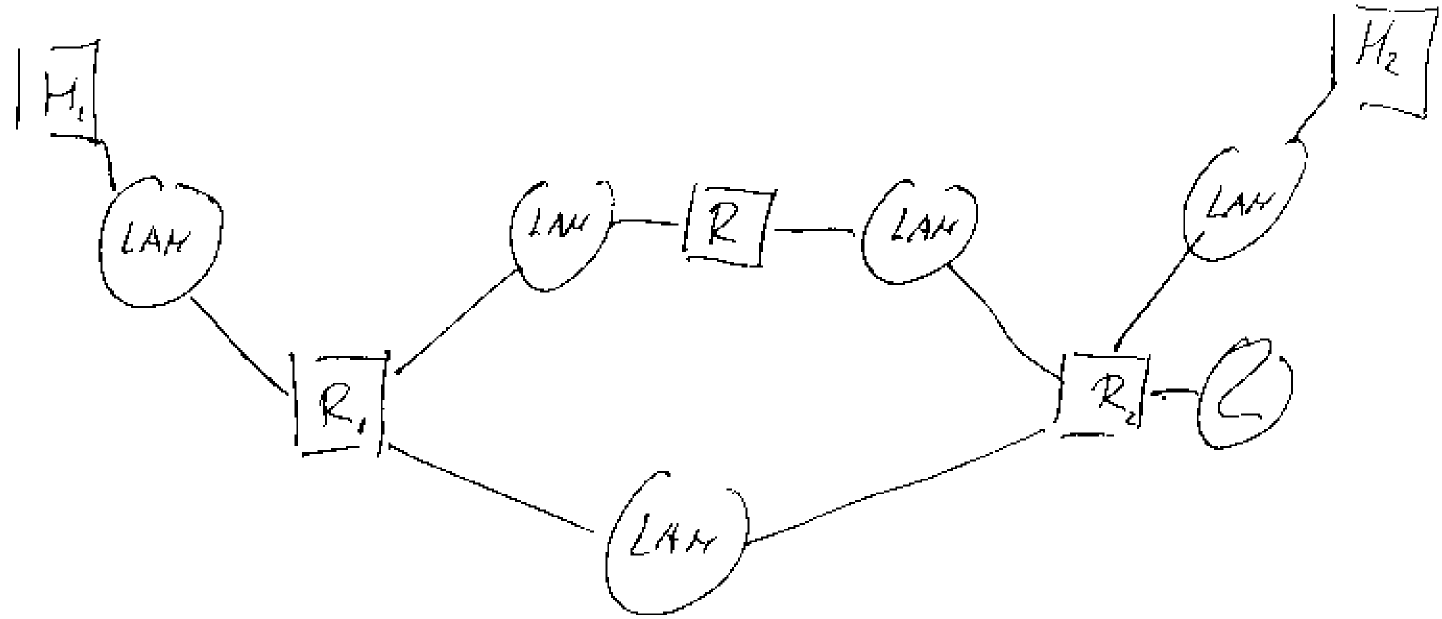
Base Station: "is" the router.
(Access to Router).

Ad Hoc Networking: There is no "designated" router. ("designated": used loosely).

The computers (hosts) involved must share the routing function.

(One more reason to study IP routing first).

IP Routing



What is the __best__ route $H_1 \to H_2$?

H_1 does not know.
It only knows R_1 is the "next router".

Routers know "more"
(depends on actual routing scheme used. RIP, OSPF, IS-IS, ...).

Routers ~~dynamically~~ exchange information, dynamically adjust "routes".

Change: moderately slowly.

Routers, hosts, are __stationary__.
(links may come & go).

Ad-Hoc Networks:

(1) Nodes may be moving.

(2) Nodes need to share routing function.

Typical^(?) example:

An infantry squadron,
couple of tanks,
one or two helicopters,
planes
with hilly terrain that masks
stations.
(And multipath problems?)

HandoFF. (in situation with multiple
base-stations).

MAC. Medium Access Control.

in <u>old</u> ethernet : CSMA-CD.

in <u>new</u> ethernet (no collisions) : simple.

in Wireless : ?

MAC on wireless.
Complications.

(General, not specific to 802.11).

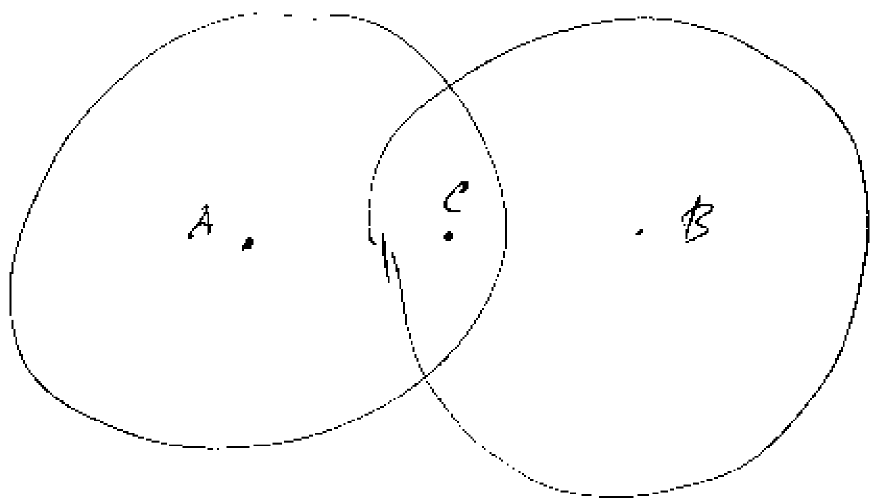
(1) Maybe the "destination" is too far away (in shadow of hill, of building): can not hear you.

destination: in DLL sense!
not (necessarily) in IP sense.
"Next Hop" in IP sense

A wants to send to C.
C too far away.

In this case: no MAC solution!
Get help. (Find "Router").

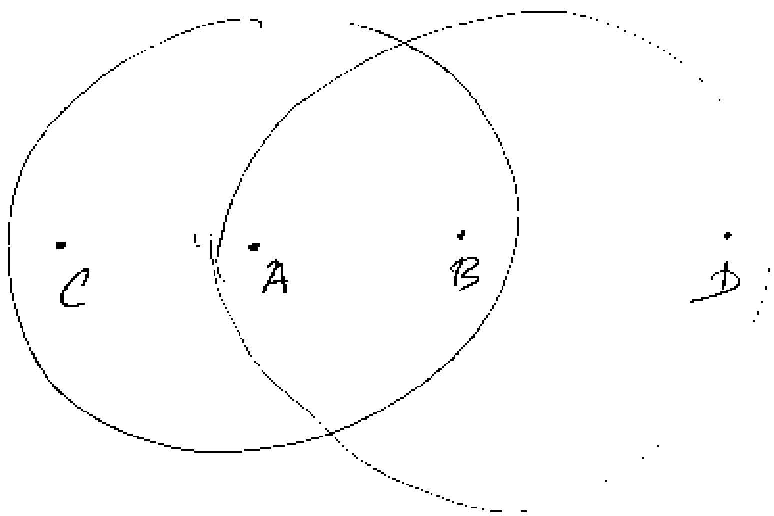
(2) Maybe the dest could hear you, but there is interference you can not hear.



A wants to send to C
C already hears B.
A does not hear B: ~~CS ...~~
CS (Carrier Sense) does not work..

Hidden Station Problem

(3) Maybe the (potential) sender <u>thinks</u> there is interference but there is not.



B sending to D
A wants to send to C.
listens (CS). hears B.
waits.

Exposed Station Problem.

Solutions. (2 and 3 only).

MACA Multiple Access with Collision Avoidance.
Karn, 1990.

A wants to send to B.

(1) ~~Send~~ A sends RTS "Request to Send".
Short (30 Bytes).
Contains length of <u>Data frame</u> it wants to send.

(2) B sends CTS "Clear to Send".
Short (... ?)
Contains length of frame.

(3) "Everybody listens".
If you hear RTS or CTS: compute length (duration), shut up.
If you hear RTS, not CTS: you <u>could</u> send. (?)
~~If you hear CTS, not RTS: you could~~ listen. ~~(send~~
Assuming Symmetry.

MACA:

exponential backoff after collision
(or failure?).
Could be "send RTS, and not get CTS".

MACAW 1994
MACA for Wireless.

Ack and re-transmission at
<u>link-layer</u>.

Does that make sense?

Also, some ~~Carrier~~ Carrier Sense
added back in.

Left over: hand-off.

Now 802.11.

Tanenbaum, pp 292 - 302.

Physical layer:

Infrared, (1-2 Mb/sec

Short Range Radio (FHSS, DSSS) (?)

Unlicensed part of spectrum. (1-2 Mb/sec)

Short Range Radio (OFDM, HR-DSSS) (?)

OFDM ↑ 54 Mb/s; HR-DSSS ↑ 11 Mb/s

Short Range Radio (OFDM)

OFDM ↑ 54 Mb/s, different frequency.

Infrared: "Gray Code". See Tanenbaum p 294.
(will not be asked)

FHSS Frequency Hopping Spread Spectrum.
"Quickly switches frequency".
Protection against multipath.
Security! (Random Number Generator).

DSSS Direct-Sequence Spread Spectrum.

I'll get back to DSSS when we discuss CDMA.

OFDM Orthogonal Frequency Division Multiplexing.

~~f...~~

(Minor aside:
FDM = Frequency Division Multiplexing.
~~OFDM~~ Many Bands.
Different sources can use different bands: sharing.

OFDM: "Orthogonal" (?)
1 ~~Stat~~ Source (at a time) has all bands.
like ADSL.
)

HR-DSSS High-Rate DSSS
Similar to DSSS,
different coding.

Not to be asked.

IEEE 802.11 MAC.

With Base Station: PCF
Point Coordination Function.

Without (Ad Hoc Networks) DCF
Distributed Coordination Function.

~~DCF~~ PCF (in this class room).

1 Base-Station.

CSMA/CA
CSMA with Collision Avoidance.

Sense,
wait,
send frame,
wait for ack. (retransmit)
if Time-out; ~~incr~~ increase wait.

DCF : Based on MACAW.

DCF

Distributed Coordination Function.

Tanenbaum pp 296 - 299.

(1) Send RTS Request to Send.

(2) Receive ~~CTF~~ CTS Clear to Send

(3) Send.

(4) Wait for ACK.

If necessary. Re-transmit.

NAV : Network Allocation Vector.

"personalized ~~la~~ back-off period".

802.11 allows <u>link-level fragmentation.</u>

(1) Whole Frame,
n pieces
prob p of defect each,
Frame-level error detect.

(2) Piece-level
Error ~~bad~~
Detection

(1) "One step."
One Giant Frame

π = prob. no success
$1-\pi$: prob. success
$= (1-p)^n$.

$$\frac{1}{1-\pi} = \frac{1}{(1-p)^n}$$
expected # frames.

$\frac{n}{(1-p)^n}$ expected # pieces

(2) "n steps".
n separate pieces.

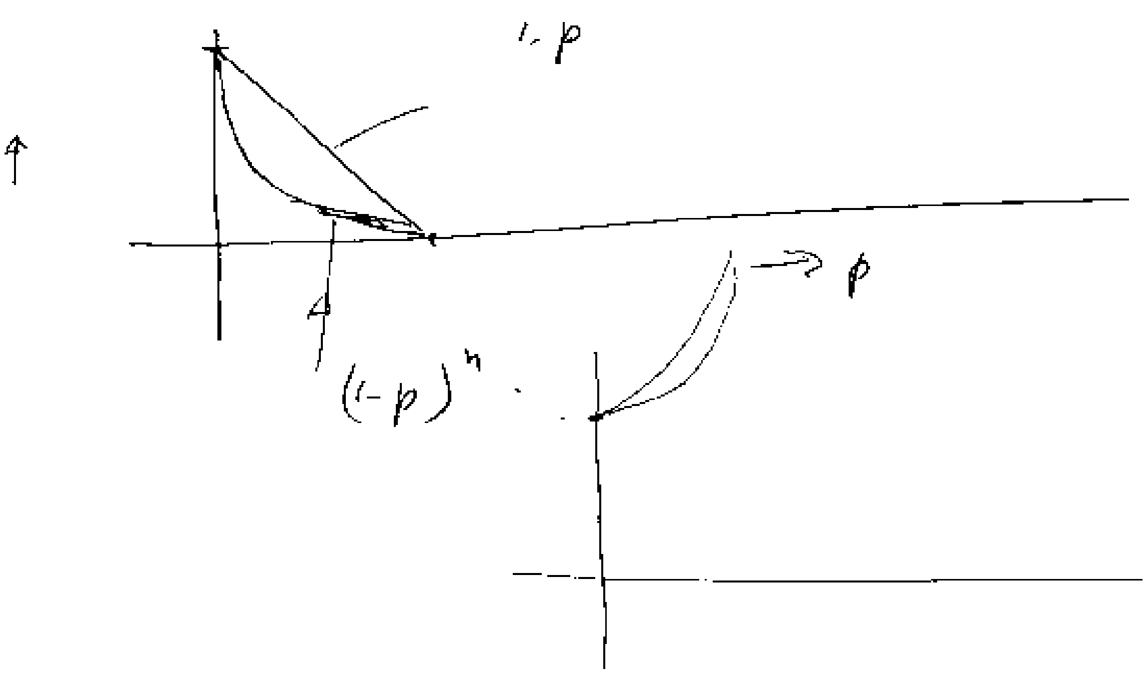
$\frac{1}{1-p}$ per piece

$\frac{n}{1-p}$ Total.

$$\frac{1}{(1-p)^n} \overset{?}{>} \frac{1}{1-p}$$

$(1-p)^n < (1-p)$
$0 < 1-p < 1$ OK.

$p = 0$: $1 = 1$. OK.



Per fragment: "stop & wait".

Is this reasonable? yes:

close by.

Serialization D >> Propagation D.

SIFS

PIFS

DIFS

EIFS

Tanenbaum p 294.

Will not be asked.

(Various types of
Interframe Spacing,
to provide priorities,
"message continuity", etc.)

802.11, MAC Layer Frame.

2B	2B	6B	6B	6B	2B	6B	0-2312B	4B
FC	D	Addr1	Addr2	Addr3	SC	Addr4	Frame Body.	FCS

FC: Frame Control   Complicated. See Tanenbaum p.

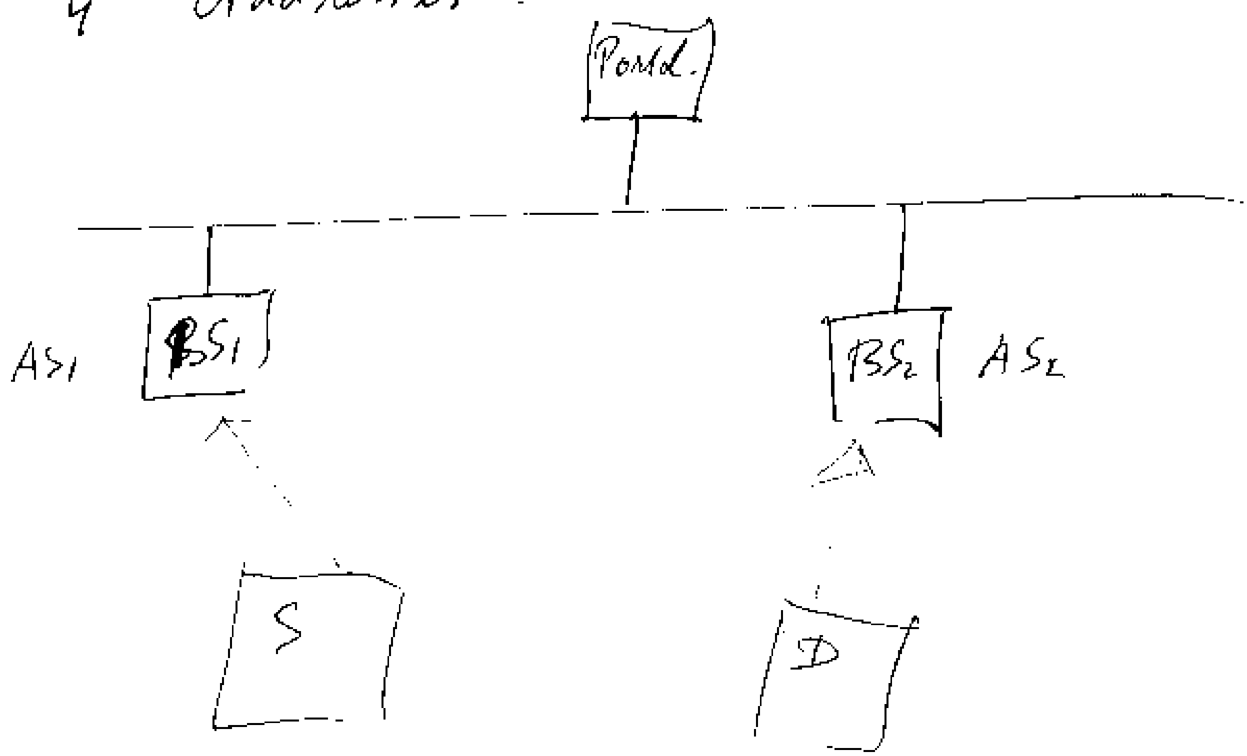
D: Duration. (listener: computes NAV)

Addresses: four of them!

SC: Sequence Control.
(Sequence number).

FCS: CRC-32 error detection

4 Addresses!



Bluetooth

Tanenbaum pp 310 – 317.

Please read.

Will not be asked.

(You must be aware of it!).

802.16 Wireless WAN. Not mobile.

~~"Circuit oriented"~~. "connection oriented".

Tanenbaum pp 302 – 316

Please Read.

May be in class end semester.

You must be aware of it!

Bridges etc.

Tanenbaum pp 317 – 328.

Please Read.

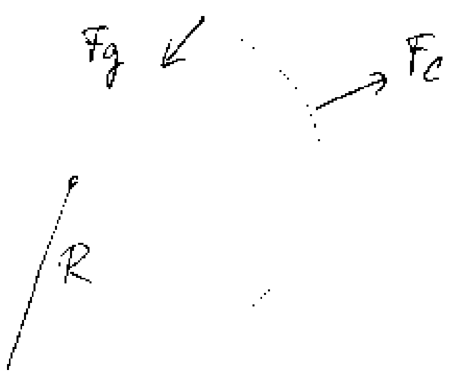
In class notes: pp 142 – 144

Switches: pp ~~[illegible]~~ 145 – 146

Routers: CIS 456

Satellite Communication.

Tanenbaum, pp 109 - 118.



ω:

Rotations/sec = $\frac{\omega}{2\pi}$

ω: Rad/sec.

v: km/sec.

$Fg = \frac{c_1}{R^2}$ $\qquad$ $Fc = \omega^2 R = \frac{v^2}{R}$

Gravity $\qquad$ Centrifugal.

Fg = Fc: $\frac{c_1}{R^2} = \omega^2 R$ $\qquad$ $\omega^2 = \frac{c_1}{R^3}$

$\omega = \frac{c_2}{R^{3/2}} = $ ~~$c_2 \sqrt{R^3}$~~ $\frac{c_2}{\sqrt{R^3}}$.

NOT asked!

Rotations/sec = $\frac{c_2}{2\pi}$ ~~$\sqrt{R^3}$~~ $\frac{c_2}{2\pi} \cdot \frac{1}{\sqrt{R^3}}$

Rotation time = $\frac{2\pi}{c_2} \sqrt{R^3}$.

For the moon: ~ 29 days (~ 450,000 km)

For geostationary satellite: 24 hours (35,000 km).

~~Satellites~~:

Confounding Factor: Van Allen Belts.

(~~ap~~ lower and upper).

Satellites:

LEO Low - Earth Orbit.

~~[illegible]~~

~~Both~~ Below lower Van Allen Belt.
circle earth in ~ 1.5 hours

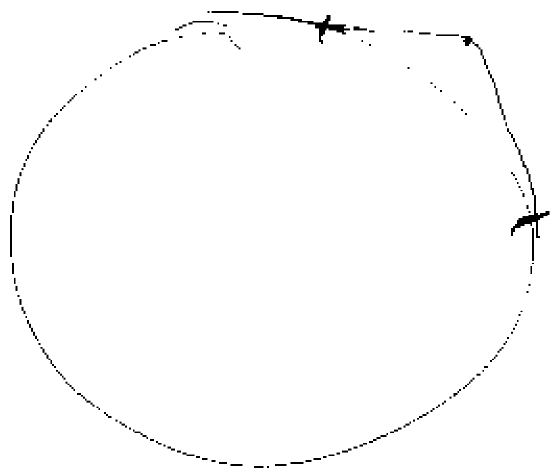
MEO Medium - Earth Orbit

Between Van Allen Belts.
circle earth in ~6 hours.

GEO ~~Static~~ Geostationary
(24 hours!)

LEO: Low delay.

Footprint.
of Satellite.



Small for LEO,
Larger for MEO
~ $\frac{1}{3}$ earth for GEO

earth Radius
~ ~~6000 km~~.
6300 km.

GEO : $\int$ above equator
(custom)
looks stationary

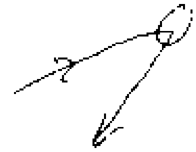
Many GEO ~~Sat~~ Satellites above equator.
cover earth from ? North to ? South.

GEOs require about 2 degrees of separation (!)
So, at most ~ 180

GEO . you need ~~about~~ only 3,
but you want as many as possible.
(~ 180).
High Delay: not for real time interactive.
Good for NRT, ~~AB~~
Good for Broadcast

Delay: ~ 270 msec. (two-way).
over $\frac{1}{4}$ sec
Conversation impossible

GEO: "Bent Pipe"
using Transponders.



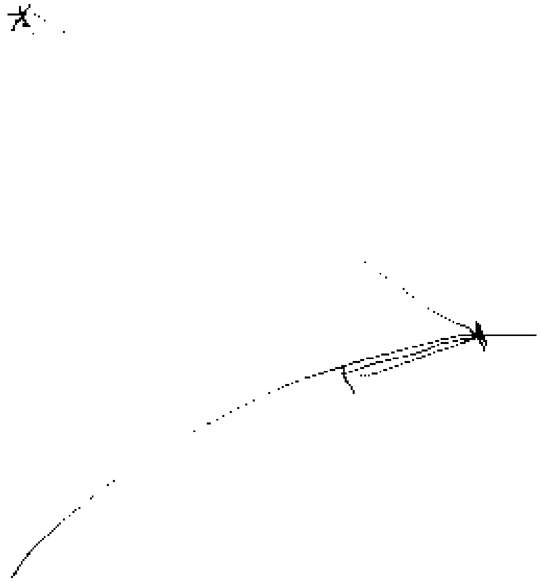
MEO. 10 Satellites needed to cover whole earth. Delay: $\frac{10{,}000}{300{,}000} = \frac{1}{30} \sim$ 30 msec. even: 6 msec.
(polar or semi-polar orbits). ~6 hours.
GPS: 24 Satellites. all MEO.

LEO: 50 needed. ~ 1.5 hours. orbit.
delay: $\sim \frac{2000}{300{,}000} = \frac{1}{150}$ two way: ~ 8 msec.

Telstar. 1962 ATT and NASA.
Eisenhower had supported ATT.
Kennedy did not want a monopoly in space.
ATT was blocked from Satellite Comm.

Originally: Transponder.
(Intelligent Amplifier),
Also changes Frequency.
"Bent Pipe".

Footprint of Transponder
(of Antenna, Beam)



~~Smaller~~
more Transponders with smaller footprint:
more efficient use of spectrum.

Systems:

Telstar (1961) ATT.

Irridium ~ 1990

Motorola.

First planned 77 LEO satellites

later, 66.

Service started 1998.

Voice quality.

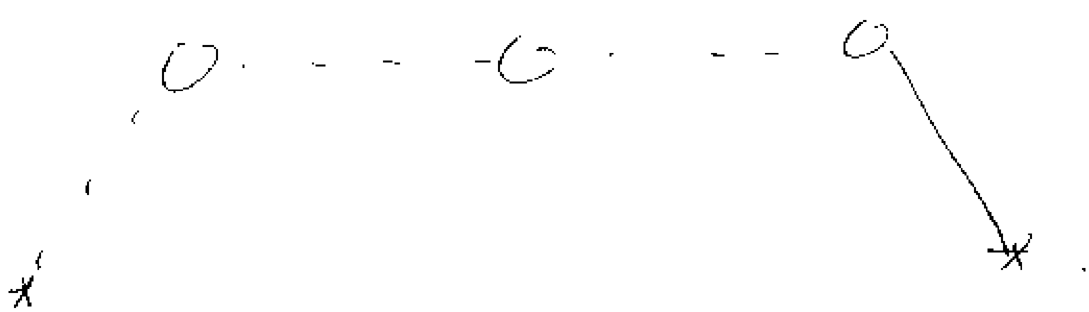
Big Phones!

1999: Closed (but see further).

Irridium Satellites: 750 km high.

Voice, data, paging, FAX, ...

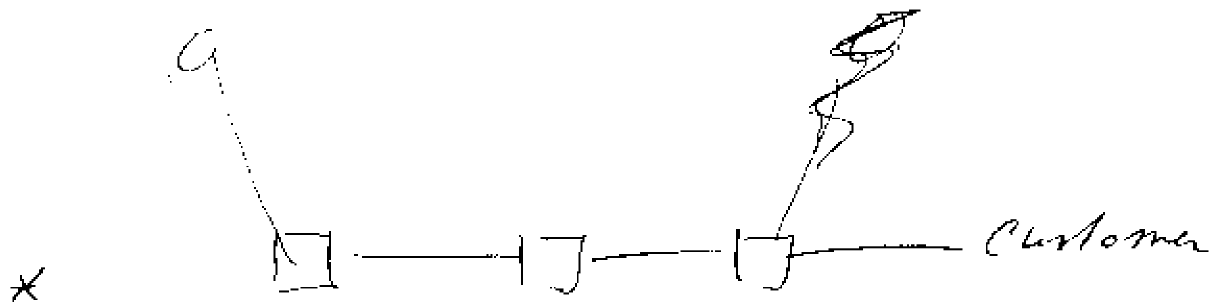
Irridium: "Bridging" is satellite-satellite



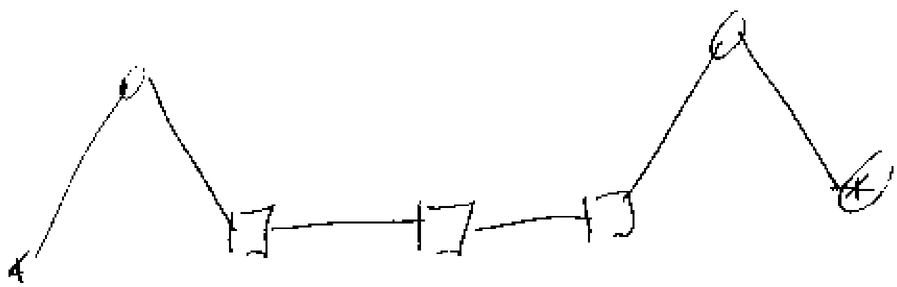
<u>Routing</u> function in 8 Satellites!

No mere Transponders!

Globalstar.
48 LEOs
"Bent Pipe".



or



(First is more likely)

Globalstar exists (again)?

Further "similar to Iridium"

See

Teledesic.

Bill Gates
Craig McCaw.

Company ~~exists~~ (still? again?)

[illegible] Aimed at Internet Access.

~~[illegible]~~:
Originally: 288 small-foot print satellites.
1350 km hgt.

Later: 30 Satellites
Larger Foot print.

Service Starts 2005 ?

Up: 128 kb/s to 100 Mb/s
Down: up to 720 Mb/sec.

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see www.teledesic.com

Globalcom. (not in Tanenbaum).

See www.global-com.com

At some point I had the impression
Globalcom bought
Irridium
as well as
Globalstar.

After my last visit to the websites:
Not so sure.

Satellite vs "Terrestrial".

(1) Mobile.

(2) less dependent on "terrestrial infrastructure" (fiber, politics, hostile terrain).

(3) Quickly installed.

Next : cell phones