Networks - Physical Layer Cheat Sheet

by Bayan (Bayan.A) via cheatography.com/122738/cs/22931/

Nyquist Theorem

Equation expressing maximum data rate for a finite bandwidth noiseless channel

If signal is run through a low-pass filter of bandwidth B	The filtered signal can be completely reconstructed by making only 2B samples per second
Sampling faster than 2B x per second is pointless	Higher frequency components have already been filtered out.

B = channel bandwidth
V = discrete levels the signal consists of
Max data rate = $2B \log_2 V$ bits/sec

Twisted Pair

A form of transmission media

Two insulated copper wires (1mm thick)	Twisted in helical form (like DNA)

Wires are twisted so the waves cancel out

Used for transmitting analog or digital information

Bandwidth depends on wire thickness and distance traveled	Several megabits/sec for a few kilometers
Widely used	Adequate performance and cheaper
UTP	Unshielded Twisted Pair
Cat 5 UTP cable, mostly in office buildings:	4 pairs of twisted insulated wires in a single plastic sheath.

Twisted Pair (cont)

Full-D-uplex	Links can be used in both directions at the same time, like a two-way road
Half-D-uplex	Link can be used in either direction, only one way at a time
Simplex	Links that allow traffic in only one direction.

Digital Modulation

Process of converting between bits and signals

To send digital information, we must devise analog signals to represent bits

Baseband Transmission

Signals occupies frequency from zero up to a maximum

The maximum frequency depends on the signaling rate.

Clock recovery

The process of extracting timing information from a data stream for the receiver to decode

To encode bits into symbols, receiver must know when one symbol ends and the next begins

Receiver needs to reference a clock of the same frequency

Accurate clocks are expensive	Another strategy must be used

Overhead Definition

Overhead is any combination of excess or indirect computation time, memory, bandwidth, or other resources that are required to perform a specific task.

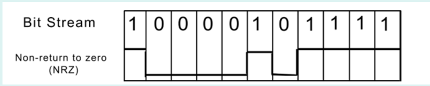
NRZ

Non-return to zero

Simplest, literal line code

-V for 0	+V for 1
A long run of 0's or 1's leaves the signal unchanged	Differentiating between bits become difficult. A long line of 15 0's looks like 16 without a very accurate clock

NRZ



Bandwidth Efficiency

For NRZ, it moves between + and - levels every 2 bits	Requires bandwidth of at least *B/2* when the bit rate is *B* bits/sec

This limits the speed, as more bandwidth is required to run faster.

Using more than two signalling levels, the limited bandwidth can be used for efficiently

e.g. using 4 voltages, 2 bits can be sent at once, as a single symbol	Effective only if the receiver can distinguish the 4 levels

The signal change rate is now half the bit rate, thus reducing the required bandwidth.

Bandwidth Efficiency (cont)

The rate the signal changes is the **symbol rate**

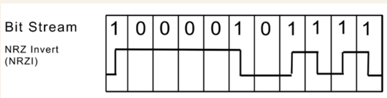
the **bit rate** is the *symbol rate multiplied by the number of bits per symbol*

NRZI

The inverted vesion of NRZ

transition for 1	no transition for 0
Used by USB	Universal Serial Bus

NRZI Image



Manchester

Used for classic Ethernet

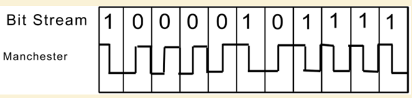
low to high = 0	high to low = 1

Requires twice as much bandwidth as NRZ because of the clock

Adds 100% overhead

Guarantees clock recovery and balanced signal because:	-Each bit is modulated in a balanced signal

Manchester Image



Bipolar Encoding (AKA Alternate Mark Inversion)

0 = logical zero	Encodes 0's with a zero-signal
1 = + or -	Encodes 1 with positive or negative level

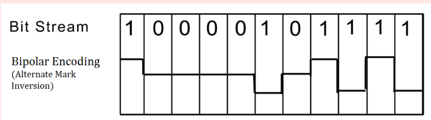
In telephone networks, it is know as Alternate Mark Inversion(AMI), where "mar-k" is 1 and "space" is 0.

Bipolar Encoding (AKA Alternate Mark Inversion) (cont)

Guarantees a balanced signal because:	-1's are encoded in alternating +V, - V signal levels

If -V is a logical zero, and the two voltages +1V and -1V represents a logical zero, to send "1", the transmitter **alternates** between +1V and -1V.

Bipolar Encoding Image



Balanced Signal

Base-band signal averages zero	As much + voltage as -, even after short period of time
No DC electrical components	Advantangeous, as some channels (coaxial or lines with transformers) attenuate a DC component due to their physical properties
DC component filtered out	Avoids energy waste
Provides better clock recovery	Through transitions, due to mix of + and - volatages.
Allows measuring the signal average	For error detection and receiver calibration. Impossible with an unbalanced signal

Link Failure

Instances for possible link failure:

Sequence used for scrambling could be the same as the signal	Transmitting all 0's, constituting a link failure

With unbalanced signals, the average may drift from the true decision level due to a density of 1s, for example, which would cause more symbols to be decoded with errors.

Capacity Coupling

Method of **connecting the reciever to the channel.**

Passes only the AC portion of the signal.

4B/5B

A form of **line code**

Maps groups of 4 bits of data onto groups of 5 bits for transmission

Used to **prevent more than 3 consecutive 0's**

Every data (4B) has a fixed codeword(5) that it is translated to

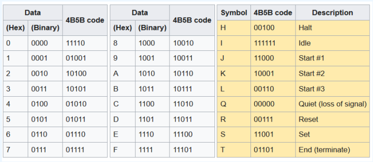
This scheme adds 25% overhead	Better than the 100% overhead of Manchester encoding

Non-data codes can represent physical layer control signals

e.g: "11111" - idle line	"11000" = start of a frame

Produces at least two transitions per 5 bits of output code, regardless of input data.

4B/5B Encoding Table



Data		4B5B code	Data		4B5B code	Symbol	4B5B code	Description
(Hex)	(Binary)		(Hex)	(Binary)		H	00100	Halt
0	0000	11110	8	1000	10010	I	111111	Idle
1	0001	01001	9	1001	10011	J	11000	Start #1
2	0010	10100	A	1010	10110	K	10001	Start #2
3	0011	10101	B	1011	10111	L	00110	Start #3
4	0100	01010	C	1100	11010	Q	00000	Quiet (loss of signal)
5	0101	01011	D	1101	11011	R	00111	Reset
6	0110	01110	E	1110	11100	S	11001	Set
7	0111	01111	F	1111	11101	T	01101	End (terminate)

8B/10B

Maps 8 bits input onto 10 bits output	80% efficient
Achieves DC signal balance, never far from balanced	At most 2 bit disparity

8 bits of data are transmitted as a 10-bit entity called a **symbol**

Low 5 bits are encoded into a 6 bit group	5b/6b portion
Top 3 bits encoded into a 4-bit group	3b/4b portion

These groups are concatenated together to form a 10-bit symbol that is transmitted.

Standards also define up to 12 symbols that can be sent in place of a data symbol	These indicate start-of-frame, end-of-frame, link idle, etc.

Helps clock recovery, never more than 5 consecuive 1s or 0s

Passband Transmission

Signals that are shifted to **occupy a higher range of frequencies**, (all wireless transmissions)

Scheme that regulates the **amplitude**, **phase** or **frequency** of a carrier signal to convey bits.

Occupies a band of frequencies around the frequency of the carrier signal.

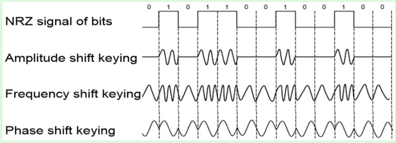
Passband Transmission (cont)

Common for wireless and optical channels.

Regulatory constraints and intereference prevention dictates choice of frequencies.

Modulating the amplitude, frequency/phase of a carrier signal sends bits in a (non-zero) frequency range

Passband Transmission Image



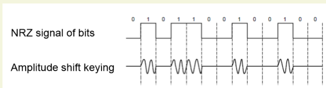
ASK, FSK, PSK

Regulating/modulating a carrier

Amplitude Shift Keying (**ASK**)	-Two different amplitudes represent 0 and 1
	-More levels can represent more sumbols
Frequency Shift Keying (**FSK**)	-Two or more tones used
Phase Shift Keying(**PSK**)	- Carrier wave systematicaly shifted 0 or 180 dgrees at each symbol period.

Schemes can be combined and more levels used to transmit more bits per symbol. However, only one of frequency and phase can be modulated as they are related.

ASK

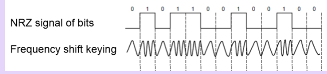


Frequency Shift Keying (FSK)

Two frequencies used

one symbol for 0, another for 1

FSK Image



Phase Shift Keying - PSK

Only Phase is modulated through time	to identify points on the plane

Amplitude stays constant, **not** modulated

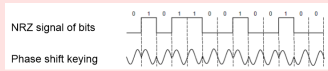
Each point corresponds to one of four symbols.

2 bits per symbol transmitted

Example:

To indentify 4 vertices("quadrature") of a square centered plane. Each point corresponds to 4 symbols.
As there are 4 symbols, 2 bits per symbol are transmitted.

PSK



Constellation Diagrams

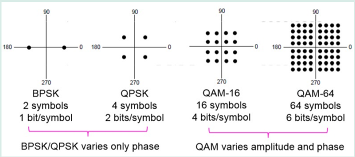
Shorthand to capture the amplitude and phase modulations symbols

The points give the **legal amplitude and phase combinations** of each symbol.

The **phase** of a dot is indicated by the *angle a line from it to the origin makes with the positive x-axis*

The **amplitude** of a dot is the *distance from the origin*

Constellation Diagram Image



QAM-16

QAM	Quadrature Amplitude Modulation
16 combinations of amplitudes and phase used	Can transmit 4 bits per symbol

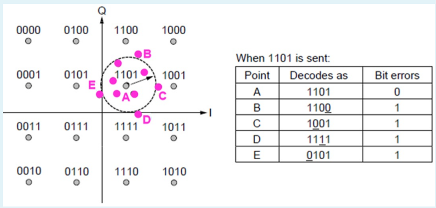
A denser modulation scheme with 64 different combinations is called QAM-64. There are even higher-order QAMs used.

Gray-Coding

Assigns(maps) bits to symbols so that adjacent symbols differ in only 1 bit position

If a receiver decodes the symbol in error	It will make only a single bit in error

Gray-coding Image



Gray-coded QAM-16 constellation

Multiplexing

Channels shared by multiple signals

More convenient than using a single wire to carry several signals than to install a wire for every signal.

Frequency Division Multiplexing(FDM)

Divides the spectrum into frequency bands. e.g. AM radio

Shares the channel by placing users on different frequencies

Frequencies are allocated different logical channels, with interchannel separation great enough to prevent interference

Subcarriers are coordinated to be tightly packed

Filters limit the useable bandwidth to 3100hz p/voice-grade channel.

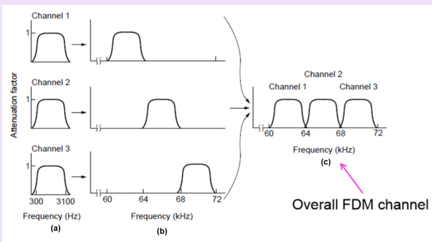
Many channels multiplexed together, 4000hz allocated per channel

Different frequencies encode different values, while phase and amplitude remain constant.

Higher frequency is associated to 1 bit, and a lower to 0

Separations(the excess) are called **guard bands**. Even though there is a large gap, some adjacent channels do overlap because filters do not have ideal 'sharp edges', therefore a strong spike at the edge of one channel will be felt in jacanet as *nonthermal noise*

Frequency Division Multiplexing Image



(a) The original bandwidths
(b) The bandwidths raised in frequency
(c) The Multiplexed channel

Orthogonal FDM (OFDM)

OFDM (Orthogonal FDM) is an efficient FDM technique used for 802.11, 4G cellular and other communications that does not use guard bands.

The channel is divided into many subcarriers that independently send data.

Subcarriers are tightly packed in the frequency domain.

Frequency response of each subcarrieris zero at the center of adjacent subcarriers, therefore subcarriersbe sampled at their center frequencies without interference from neighbours

Guard time required to repeat ports of symbol signals so that they have the desired frequency

Time Division Multiplexing

Shares a channel over time

Users take turns on a fixed schedule	**Not packet switching**

Each gets the entire badwidth for a little burst of time

Bits from each input stream are taken in a fixed **time slot** and output to the aggregate stream.

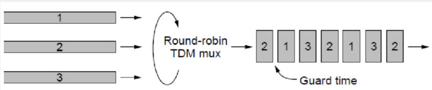
This stream runs the *sum rate* of individual streams.

Streams must be *synchronized* in time.

Widely used in telephone/cellular systems

Small intervals of **guard time** analoguous to a requency guard band may be added to accomodate small timing variations

Time Division Multiplexing Image



Three streams being multiplexed with TDM.

Code Divison Multiple Access

Shares the channel by giving users a code

Codes are orthogonal	Can be sent at the same time

Widely used as part of 3G networks

Scalar Product (example):	$A \bullet B = (a_1, a_2, a_3) \bullet (b_1, b_2, b_3) = a_1b_1 + a_2b_2 + a_3b_3$

Walsh Codes (example):
$\mathbf{A} = (a_1, a_2, a_3)$ $\overline{\mathbf{A}} = (-a_1, -a_2, -a_3)$
$\mathbf{B} = (b_1, b_2, b_3)$ $\overline{\mathbf{B}} = (-b_1, -b_2, -b_3)$

Properties of CDMA codes:
For all **A**, **B** with **A** ≠ **B**
$\mathbf{A} \bullet \mathbf{A} = +1$
$\mathbf{A} \bullet \overline{\mathbf{A}} = -1$
$\mathbf{A} \bullet \mathbf{B} = \mathbf{A}\,\mathbf{B} = 0$

Transmission:
A, B and C transmit 1, 1 and 0 respectively
A, B and C send codes **A**, **B** and $\overline{\mathbf{C}}$ respectively
The receiver sees $\mathbf{A} + \mathbf{B} + \overline{\mathbf{C}}$

Code Division Multiple Access(CDMA)

A form of **spread spectrum** communication	Narrowband signal spread out over a wider frequency band

Tolerant of interference.

Allows multiple signals from different users to share the same frequency band.

CDMA shares the channel by giving users a code

Codes are orthogonal;	Can be sent at the same time

Widely used as part of 3G networks

Code Division Multiple Access(CDMA) (cont)

Each station can transmit over the entire frequency spectrum all the time

Can also be called "Code Division Multiplexing", but because it is used mostly to allow the same frequency band to be shared by different users by multiple signals, it was commonly called Code Division Multiple *Access*