Lecture 3

HFC Access Plant and DOCSIS Cable Modem

Exercise 1: In the example in the figure below, a city block is 100m long and there are 10 houses on the block. The distribution cable runs down a side street and the along the street being serviced. What total length of distribution cable is required? If each drop is 20m long, how much drop cable is required? what is the ratio of distribution cable to drop cable?

distr. cable length = 100m + 100m = 200m

drop cable length = 10 X 20m = 200m

$$\text{ratio} = \frac{200}{200} = 1:1$$

Exercise 2: A manufacturer specifies that one of their co-ax cables has a loss of 2.5 dB/100m at 100 MHz. What would be the attenuation, at 100 MHz, of 20 m of this cable?

$$2.5 \text{ dB}/100\text{m} \times \frac{20\text{m}}{100\text{m}} = 2.5 \times 0.2 = 0.5 \text{ dB}$$

Exercise 3: What is voltage in mV of a 0 dBmV signal? What is the power in mW if measured across an impedance of 75 ohms? What is this power in dBm?

$$0 \text{ dBmV} = 20 \log (V_{mv})$$

$$V_{mv} = 10^{\frac{0}{20}} = 1 \text{mV}$$

$$P = \frac{V^2}{R} = \frac{(0.001)^2}{75\Omega} = \frac{(10^{-3})^2}{75} = \frac{1 \times 10^{-6}}{75} \approx 10^{-8} \text{W} \approx 10^{-5} \text{mW}$$

$$P_{dBm} = 10 \log (10^{-5}) = -50 \text{ dBm} \quad (-49 \text{ dBm})$$

Exercise 4: A 0 dBmV signal is applied to the input of a distribution amplifier with a gain of 20 dB and a 2 dB noise figure. What are the output signal and noise powers? What is the output C/N (carrier to noise power ratio) measured over a 6 MHz bandwidth?

signal power = 0 dBmV = −49 dBm

after 20 dB gain: −49 + 20 = −29 dBm

noise power = KTBFG (linear units)

log. units:

- $KT = -174$ dBm · Hz
- $B = 6 \times 10^{6}$ Hz $= 60 + 10\log_{10}(6) \approx 68$ dB · Hz
- $F = 2$ dB
- $G = 20$ dB

noise power (in dBm) $= -174 + 68 + 2 + 20 = -84$ dBm

$C/N = -29 - (-84) = 55$ dB

Exercise 5: The signal and noise then travel down a length of co-ax that introduces 20 dB loss and then through another 20 dB amplifier. What is the C/N at the output of the second amplifier?

after 20 dB loss: $C = -29 - 20 = -49$ dBm (0 dBmV)

$N = -84 - 20 = -104$ dBm

after amplifier: $C = -29$ dBm

noise powers from different noise sources add up.
but addition must be in linear units (mW or W)

$$N = 10^{\left(\frac{-104+20}{10}\right)} + 10^{\left(\frac{-84}{10}\right)} \quad (\text{mW})$$

$$= -81 \text{ dBm}$$

$$C/N = -29 - (-81) = 52 \text{ dB}$$

∴ C/N degrades as we get further from head end even if signal power is maintained.

Exercise 6: Assuming the carrier power is the signal power, what is the Shannon capacity of this channel? What is the maximum symbol rate if the symbol period is to be more than 10 times the group delay ripple? What is the maximum area (in km^2) that can be serviced by one DOCSIS CMTS assuming a velocity factor of 0.66?

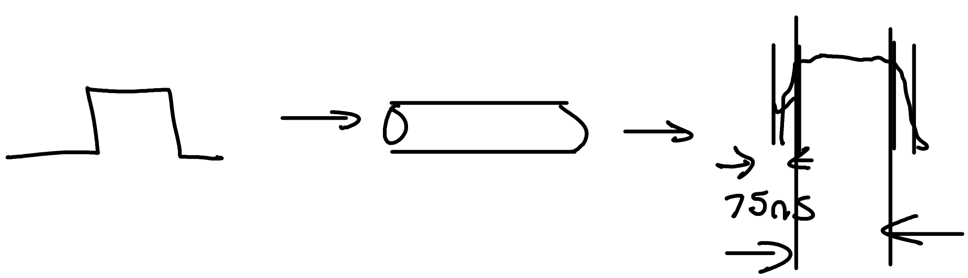
$$C = B \log_2\left(1 + \frac{S}{N}\right)$$

$$B = 6 \text{ MHz} = 6 \times 10^6$$

$$\frac{S}{N} = 35 \text{ dB} = 10^{\frac{35}{10}} = 10^{3.5} \approx 3000$$

$$C = 6 \times 10^6 \log_2(1 + 3000)$$

$$\approx 6 \times 10^6 \times 11.5 = 70 \text{ Mb/s} \quad (69 \text{ Mb/s}).$$

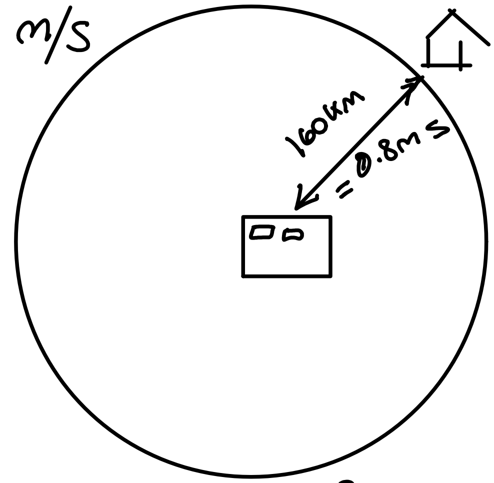


∴ want symbol period > 75 × 10 ns = 750 ns

∴ symbol rate < ≈ 1.3 MS/s.

maximum delay = 0.8 ms

velocity (VF) = $0.66 \cdot 3\times10^{8}$ m/s = 2×10^{8} m/s



maximum distance $= 0.8\times10^{-3} \times 2\times10^{8}$

$= 1.6\times10^{5} = 160\text{km}$

Area $= \pi r^2$

$= 3 \cdot 160^2$ km^2

$= 8.4\times10^{4}$

$\approx 10^{5}$ km^2

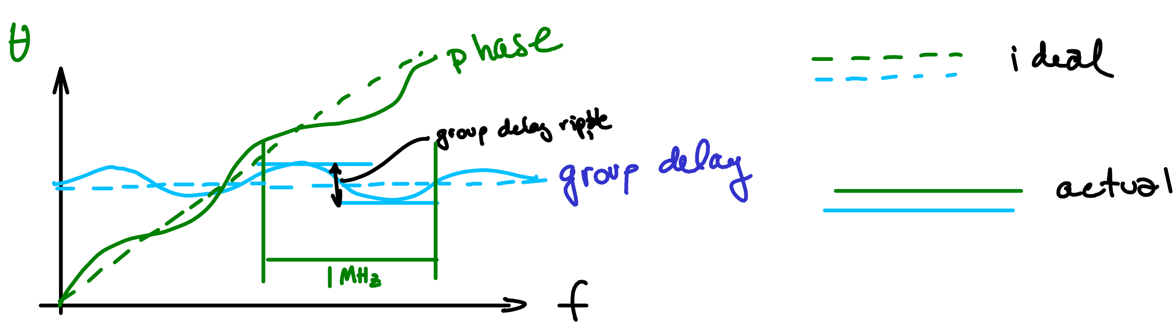
Exercise 7: Again compute the Shannon capacity based on the CNR and the maximum symbol rate based on a period equal to 10 times the group delay ripple.

$$C = B \cdot \log_2(1+S/N)$$

$$= 6\times10^{6} \cdot \log_2\left(1+10^{\frac{25}{10}}\right)$$

$$\approx 6\times10^{6} \cdot \log_2(300)$$

$$= 6\times10^{6} \cdot 8.2 \approx 50 \text{ Mb/s} \qquad (49.8)$$

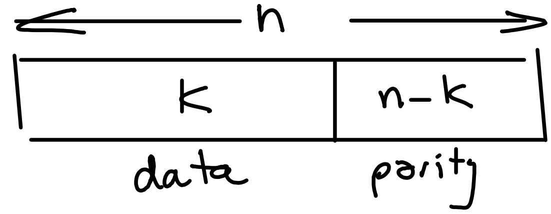


Exercise 8: Assuming 256 bytes per codeword, what is the maximum number of interleaver rows? If an error burst starts with the first byte, what is the longest error burst that will result in 2 or fewer errors per codeword? *t* or fewer errors per codeword? How many errors will appear at the output of the decoder for error burst of this length or shorter?

n = # of bytes / codeword

k = # data bytes / codeword

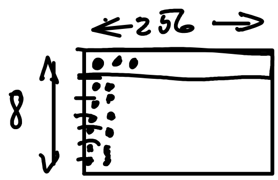
t = # correctable bytes



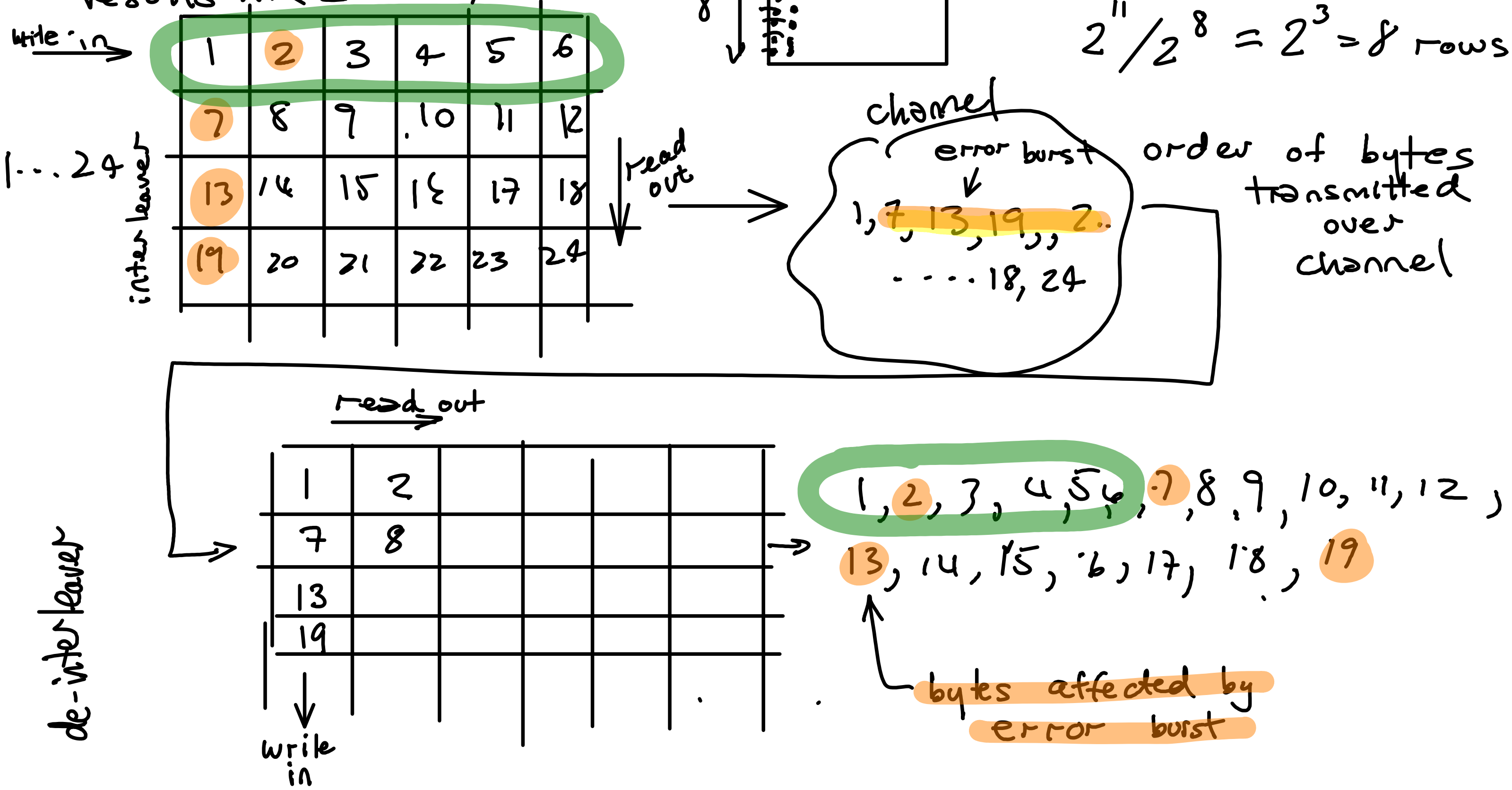
$n = 256$

rows × columns ≤ 2048

→ 16 or fewer errors results in ≤ 2 errors/codeword.



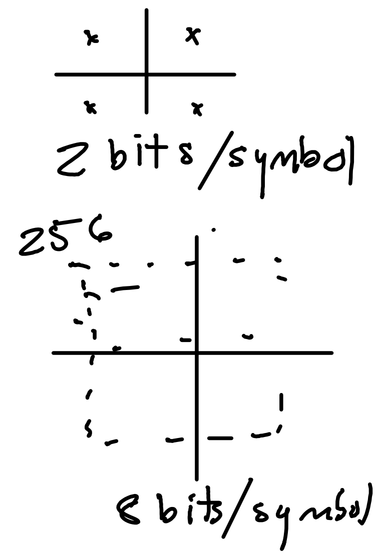
$2^{11}/2^{8} = 2^{3} = 8$ rows



if use 8 rows then error bursts of 8t or fewer errors will result in t or fewer errors per codeword.

& will have 0 error (all are correctable).

Exercise 9: What are the minimum and maximum bit rates for these symbol rates and modulation formats, not including FEC or other overhead?



lowest symbol rate ↓ QPSK ↘

min: $160 \times 10^3 \times 2$ bits/symbol $=$ 320 Kb/s

highest symbol rate ↓ 256-QAM ↘

max: $5120 \times 10^3 \times 8$ bits/symbol $\doteq$ 40.96 Mb/s

Exercise 10: Ignoring guard times, FEC and other overhead, how many bits could be transmitted at the lowest PHY rate during the shortest mini-slot? At the highest PHY rate during the longest min-slot?

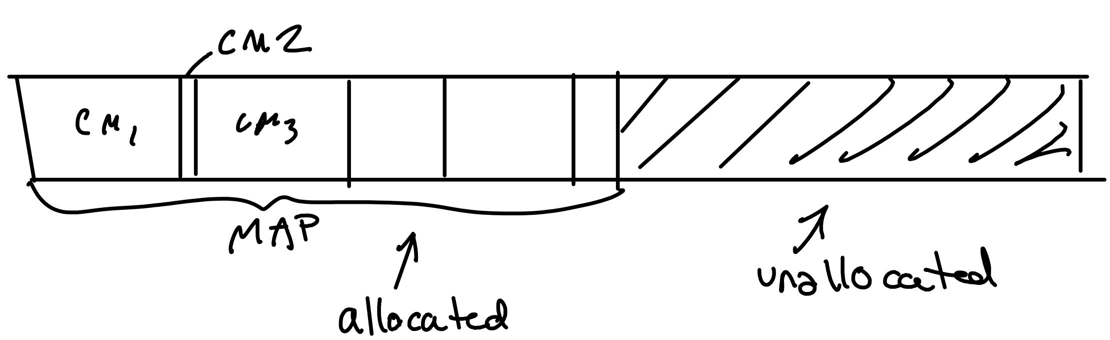
shortest, slowest

$6.25 \times 10^{-6} \times 320 \times 10^3 \approx 2$ bit

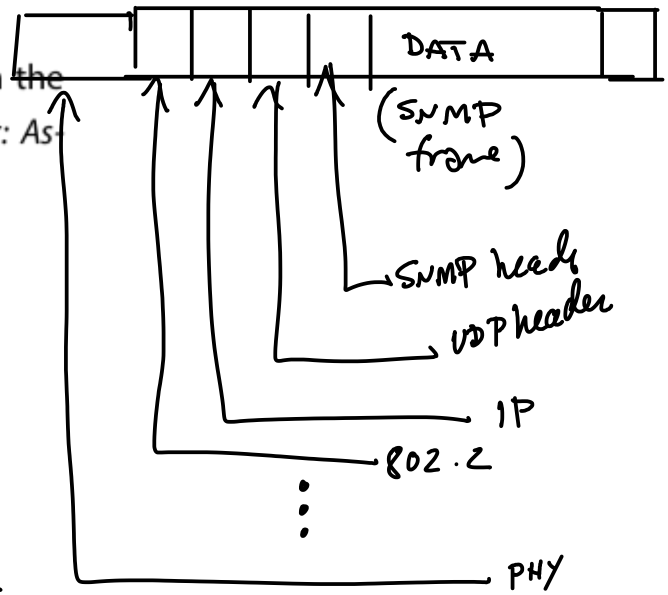
longest, fastest

$800 \times 10^{-6} \times 40.96 \times 10^6 \approx 32$ k bits

US time slots:



Exercise 11: List the protocol layers (headers) between the PHY and the payload of a downstream SNMP frame. *Hint: Assume SNMP uses UDP.*



SNMP - management

UDP - datagrams

IP - internet

802.2 - IEEE 802

DOCSIS - CM-specific

MPEGTS - legacy video transport

PHY - QPSK...

Exercise 12: Assuming the maximum number of CMs per uplink is determined by available SIDs, each CM is allocated two SIDs and only SIDs from 0x0001 to 0x1FFF are available, how many CMs could be supported per uplink channel? What is the longest time offset that can be specified in a MAP frame assuming the length of a mini-slot is 25μs?

$0x1FFF = 8191$

$0x0001 = 1$

\# available SIDs $= 8191 - 1 + 1$

$= \frac{8191}{2}$

\# CM supported $= 4095$

offset is 14 bit value $0 \rightarrow 16383$

longest is $16383 \times 25\mu s \approx 0.4\,s$

[number of values in a range is max − min + 1
eg 1, 2, 3 : 3 − 1 + 1 = 3]