ELEX 4550 : Wide Area Networks
2015 Winter Session

Solutions to Assignment 1

Question 1

POTS According to Wikipedia's History of the Telephone article, "*The first commercial telephone exchange in the world was opened at New Haven, Connecticut with 21 subscribers on 28 January 1878*".

ADSL The date depends on the specific technology. Some DSL systems were deployed as early as 1990 as Symmetric DSL (SDSL) to replace T1's. According to Wikipedia's ADSL article the earliest modern DMT-based ADSL standards were published in 1998/99 and mass deployment started around that time.

Cable Modems As with ADSL there were proprietary standards before widespread adoption of the DOCSIS standard. According to Wikipedia's DOCSIS article DOCSIS 1 was released in 1997 although there we earlier trial deployments.

PON According to Wikipedia's PON article the IEEE EPON standard 802.3ah was approved in 2004 while the first version of the ITU GPON standard dates to 2003. A summary of FTTH deployments by country shows that deployments in Asia (Japan and Korea) began in early 2000's while deployments elsewhere began in mid-2000's.

In Vancouver Shaw Communications provides Internet access using DOCSIS Cable Modems while Telus Communications provides POTS, ADSL, VDSL and limited PON service.

Question 2

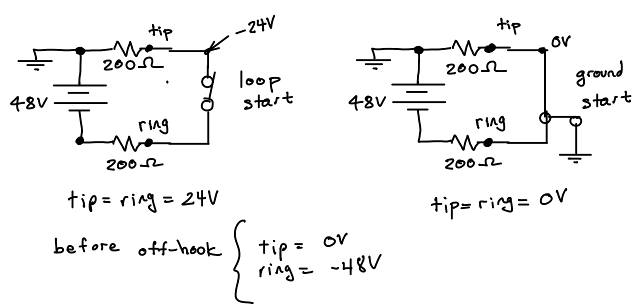
The actions and conditions shown in the flowchart correspond to the following:

1. 620 Hz tone detected: busy tone: condition 3
2. no 480 Hz tone detected for at least 4 seconds: no busy or ringback: condition 4
3. dial the number: action 2
4. go off-hook: start the call: action 1
5. 350 Hz tone detected: dial tone: condition 2
6. go on-hook: terminate the call: action 4
7. play the ad: the purpose of the call: action 3

There is no condition matching condition 1 (it would be "no dialtone detected for T seconds").

Question 3

Assuming the CO has a 48 V battery voltage and 200 ohm current-limiting resistors on each of tip and ring and negligible phone and loop resistance:



- if the subscriber used loop-start the voltage on tip and ring would be the same and half of the battery voltage, -24V with respect to ground.
- if the subscriber used ground-start, the loop would be grounded and the voltage would be zero with respect to ground.

Question 4

The calculation of the power level in dBm corresponding to 0 dBmV at an impedance of 75 ohms is: $P = V^2/R = \frac{(1\times10^{-3})^2}{75} = 13 \times 10^{-9}$ W $= -48.75$ dBm.

The required signal level is 0 dBmV which is -49 dBm. If the signal level is -36 dBm we need to attenuate the signal by: $-36 - (-49) = 13$ dB.

Question 5

A signal at a frequency of 27 MHz would fall in the range of frequencies amplified in the upstream direction. If this signal leaked into a subscribers's cable (e.g. due to faulty wiring) the signal would be detectable at the CMTS where it would interfere with all users who are assigned this upstream frequency.

A signal at 100 MHz would only be amplified in the downstream direction and would only interfere with users downstream of the "ingress."

Question 6

Based on the Arris MB100 Datasheet (E-GaAs model),

(a) there are three downstream frequency ranges (54-1003, 85-100 and 104-1003) and three upstream frequency ranges (5-42, 5-65 and 5-85) MHz.

(b) the maximum forward (DS) and reverse (US) gains are 46 dB and 20 dB respectively

(c) the maximum thermal noise output power contributed by this amplifier on the downstream assuming maximum gain and a 6 MHz bandwidth can be computed from the noise figure of 9 dB and the maximum gain as:

$$-174\text{dBm}+10\log(6\times10^6)+9\text{dB}+46\text{dB} = -102\text{dBm}$$

(d) the datasheet gives the downstream group delay as between between 52 and 12 ns (presumably resulting primarily from the duplexer near the transition between US and DS) but for a 3.58 MHz frequency spacing. The DOCSIS 1.0 channel assumptions are 75 ns within a 6 MHz channel. Thought the two specifications cannot be compared directly, it's likely that the assumptions would be met.

(e) Each amplifier draws 0.92 A at 60 VAC and can pass 15 A. Thus there could be $\frac{15}{0.92} = 16$ amplifiers downstream of the first amplifier (17 total on each side of the power injection point).

Question 7

A data rate of 36 Mb/s is $\frac{36}{8} = 4.5$ MByte/s. An error burst of 10 μs would affect $4.5 \times 10^6 \times 10 \times 10^{-6} = 45$ bytes.

The requirement $t = 1$ means we need to correct one error per codeword (which is one interleaver row) thus the interleaver must have at least 45 rows so that the error burst will be spread out with at most one error per row.

To maximize the code rate, k/n, we would like to make the word size n, as large as possible. For a given interleaver size the maximum width happens when the interleaver has the minimum number of rows (45). Thus the number of columns (and codeword size) is $n = \lfloor 1024/45 \rfloor = 22$.