EIT5 – Fall 2022
Final Exam - Solutions

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Problem 1: Bellman-Ford Algorithm

1. The maximum number of iterations = num. of nodes - 1 = 5 - 1 = 4.

2. Construct the shortest path tree

   Initial

Node	A	B	C	D	E
Cost	0	∞	∞	∞	∞
Pre-Node	-	-	-	-	-

   Iteration 1

Node	A	B	C	D	E
Cost	0	3	1	7	9
Pre-Node	-	C	A	B	D

   Iteration 2

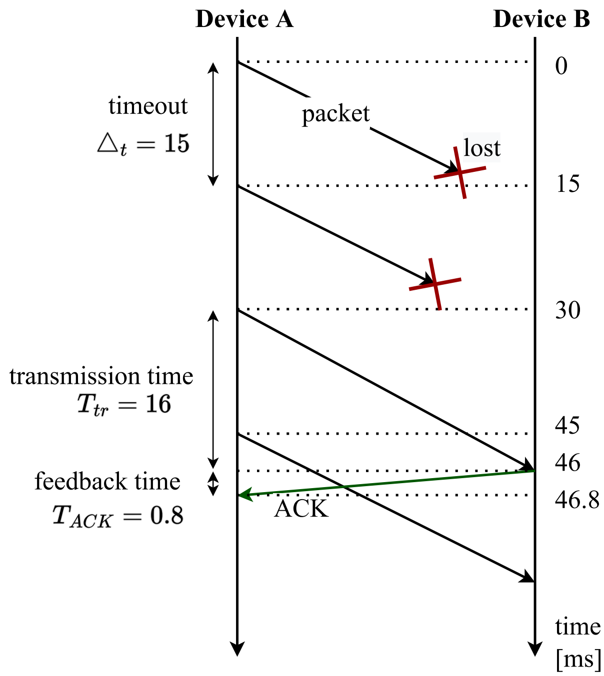
Node	A	B	C	D	E
Cost	0	3	1	6	8
Pre-Node	-	C	A	B	D

   Iteration 3

Node	A	B	C	D	E
Cost	0	3	1	6	8
Pre-Node	-	C	A	B	D

Then the shorstest path tree: A - C -B - D - E

Problem 2: Link-Layer Procedure



Transmission time for one frame from A to B: $T_{tr} = \frac{200\times 8}{0.1\times 10^6} = 0.016$ [s] $= 16$ [ms]. Transmission time of the ACK frame from B to A: $T_{ACK} = \frac{10\times 8}{0.1\times 10^6} = 0.0008$ [s] $= 0.8$ [ms]
The timeout $\Delta_t = 15$ [ms]
From the above figure, we can see timestamps for events that occurred during the communication between A and B.

1. It takes 46.8 ms for device A to receive the ACK signal from the decive B.

2. Device A sent the first frame 4 times before receiving the ACK.

3. The timeout should be designed so that there is enough time for device A to receive the ACK signal from B before determining whether to retransmit the frame. Therefore, the timeout in this case should be
$\Delta_t > T_{tr} + T_{ACK} = 16 + 0.8 = 16.8$ [ms]

Problem 3: Slotted ALOHA

1. The efficiency: $S = Ge^{-G} = 0.2e^{-0.2}$, leading to the actual throughput $= 20 * S = 4e^{-0.2} = 3.28$ kbps.

2. The transmission time $T = 20\text{bits}/20\text{kbps} = 1\text{ms}$. As Bandwidth is 20 Kbps to number of bits can be transfered in 1 ms = 20 bits. This means one packet can be transmitted in one transmission time, i.e., $G = 1$.

   So the efficiency will be $S = Ge^{-G} = 1e^{-1} = 0.368$.

   The maximum possible throughput is then equal to $20 * S = 20 * 0.368 = 7.36$ [bps].

Problem 4: Modulation techniques

1. You have a receiver and transmitter with a link between them. The transmitter is sending 1 symbol every 1 microsecond, find the throughput of the system if:

   (a) 16 QAM is used for modulation.
   The system transmits 4 bits per symbol, leading to the throughput $= \frac{4\times1}{1\times10^{-6}} = 4 \times 10^6$ [bps].

   (b) QPSK is used for modulation.
   The system transmits 2 bits per symbol, leading to the throughput $= \frac{2\times1}{1\times10^{-6}} = 2 \times 10^6$ [bps]

2. Are the following questions false or true:

   (a) False
   (b) True
   (c) False
   (d) True

Problem 8: Modulation techniques

1. The modulated signal (a) comes from a frequency modulation, whereas modulated signal (b) is the result of amplitude modulation.

2. **Amplitude modulation (AM):** uses the amplitude of the carrier frequency signal to convey the information of the message signal. The main advantage is that since a coherent reference is not required for demodulation, the demodulator becomes simple and inexpensive. The main disadvantage of this modulation is the wastage of carrier power.
   Frequency modulation (FM): convey the information of the message signal by changing the instantaneous frequency of the carrier signal. The pros of frequency modulation are: Less interference and noise (higher signal-to-noise ratio) and the power

consumption is less as compared to AM. The cons of frequency modulation are the higher cost of the equipment due to the larger bandwidth, and the more complicated receiver and transmitter.
In general, an equivalent FM signal covers less area than the corresponding AM signal.

3. First, we need to compute the modulated signal as follows:

$$
\begin{aligned}
a(t) &= m(t)c(t) && (1)\\
&= (\mathrm{sinc}(t) + \mathrm{sinc}(2t))A\cos(2\pi f_c t) && (2)\\
&= A\cos(2\pi f_c t)\mathrm{sinc}(t) + A\cos(2\pi f_c t)\mathrm{sinc}(2t) && (3)
\end{aligned}
$$

Lets denote the Fourier transform as $\mathcal{F}$. Our goal is to find $\mathcal{F}\{a(t)\}$, which characterizes the spectrum of the modulated signal. Then, we have:

$$
\begin{aligned}
\mathcal{F}\{a(t)\} &= \mathcal{F}\{A\cos(2\pi f_c t)\mathrm{sinc}(t) + A\cos(2\pi f_c t)\mathrm{sinc}(2t)\} && (4)\\
&= \frac{1}{4}\pi A\{\Pi(1/4(2\pi f_c - \omega)) + \Pi(1/4(2\pi f_c + \omega)) && (5)\\
&+ 2\Pi(\pi f_c - \omega/2) + 2\Pi(\pi f_c + \omega/2)\}, && (6)
\end{aligned}
$$

where $\omega = 2\pi f$ and Π is the rectangular function. Then, the bandwidth can be found by finding the highest frequency components of the spectrum. By analyzing the above expression, we find that the spectral components from $\mathrm{sinc}(2t)$ yields the highest frequency components of the spectrum given by the pair related to $2\Pi(\pi f_c \pm \omega/2)$. Then, the bandwidth would be $\mathrm{BW} = 2\omega_c$ with $\omega_c = 2\pi f_c$.