Week 1 Calculation Examples

1. 78.24 Mbps = _____ Kbps

   Solution:

$$78.24\ Mbps * \left(\frac{1{,}000\ Kbps}{1\ Mbps}\right) = 78{,}240\ Kbps$$

   Note: Answers like this should be entered in the Canvas learning system (for the weekly homework exercises and quizzes/exams) as 78240 without the comma and without the units.

2. 17 MiB = _____ bytes

   Solution:

$$17\ MiB * \left(\frac{1{,}024\ KiB}{1\ MiB}\right) * \left(\frac{1{,}024\ bytes}{1\ KiB}\right) = 17{,}825{,}792\ bytes$$

3. Suppose there are 45 packets entering a queue at the same time. Each packet is size 3 MiB. The link transmission rate is 1.3 Gbps. What is the queueing delay of packet number 19 (in milliseconds rounded to one decimal point)?

   Solution:

The queueing delay of a given packet N is calculated using the formula $(N-1) * \left(\frac{L}{R}\right)$ since packet N waits in the queue for precisely the amount of time that it takes for all the packets before it to be pushed onto the link.

$$(19-1) * \left(\frac{3\ MiB * \left(\frac{1{,}024\ KiB}{1\ MiB}\right) * \left(\frac{1{,}024\ bytes}{1\ KiB}\right) * \left(\frac{8\ bits}{1\ byte}\right)}{1.3\ Gbps * \left(\frac{1{,}000{,}000{,}000\ bps}{1\ Gbps}\right)}\right)$$

$$= 18 * \left(\frac{25{,}165{,}824\ bits}{1{,}300{,}000{,}000\ bps}\right) = 0.34844987\ s$$

Since the answer must be in milliseconds with one decimal point precision, we must convert:

$$0.34844987\ s * \left(\frac{1{,}000\ ms}{1\ s}\right) = 348.4\ ms$$

Note: The conversion from Gbps to bps in the denominator can also be done in multiple steps by first converting Gbps to Mbps, then converting Mbps to Kbps, and finally Kbps to bps, as follows.

$$1.3\ Gbps * \left(\frac{1{,}000\ Mbps}{1\ Gbps}\right) * \left(\frac{1{,}000\ Kbps}{1\ Mbps}\right) * \left(\frac{1{,}000\ bps}{1\ Kbps}\right) = 1{,}300{,}000{,}000\ bps$$

4. Voice over IP (VoIP)

Given the attached image, and:

Host A converts analog to digital at a = 65 Kbps

Link transmission rate R = 1.8 Mbps

Host A groups data into packets of length L = 65 bytes

Distance to travel d = 712.7 km

Propagation speed s = 2.5 x 10^8 m/s

Host A sends each packet to Host B as soon as it gathers a whole packet.

Host B converts back from digital to analog as soon as it receives a whole packet.

How much time elapses from when the first bit starts to be created until the conversion back to analog begins? Give answer in milliseconds to two decimal places.

Solution:

The packet length is converted from bytes to bits in order to align the units with the conversion rate and transmission rate provided in the question.

$$(65\ bytes) * \left(\frac{8\ bits}{1\ byte}\right) = 520\ bits$$

Calculating the amount of time elapsed is done by adding together the following durations:

- The time elapsed in converting analog to digital
- The transmission delay
- The propagation delay

$$\left(\frac{1{,}000\ ms}{1\ s}\right) * \left(\left(\frac{520\ bits}{65{,}000\ bps}\right) + \left(\frac{520\ bits}{1{,}800{,}000\ bps}\right) + \left(\frac{712{,}700\ m}{250{,}000{,}000\frac{m}{s}}\right)\right)$$

$$= 8\ ms + 0.2888\ ms + 2.8508\ ms = 11.14\ ms$$

Note: The sum of the three terms (or each individual term) must be multiplied by 1,000 so that the final answer is in milliseconds instead of seconds.

5. How long does it take to send a 5 MiB file from Host A to Host B over a circuit-switched network, assuming:

   Total link transmission rate = 56.7 Gbps

   Network is TDM, with 17 permitted users, each with an equal time slot size.

   A link connection requires a setup time of 87.2 ms.

   Your answer should be in milliseconds with one decimal place.

   Solution:

Divide the total link transmission rate by the number of permitted users to get the bandwidth reserved for each user. Convert the total link transmission rate from Gbps to bps.

$$\frac{56.7\ Gbps}{17\ users} * \left(\frac{1{,}000{,}000{,}000\ bps}{1\ Gbps}\right) = 3{,}335{,}294{,}118\ bps$$

Note: Loss of precision in this answer (such as approximating it as 3.3 Gbps) may lead to imprecision in the final answer.

The packet length is converted from MiB to bits to align the units with the transmission rate.

$$5\ MiB * \left(\frac{1{,}024\ KiB}{1\ MiB}\right) * \left(\frac{1{,}024\ bytes}{1\ KiB}\right) * \left(\frac{8\ bits}{1\ byte}\right) = 41{,}943{,}040\ bits$$

Then calculate the transmission delay and add that to the setup time to get the final answer.

$$\left(\left(\frac{41{,}943{,}040\ bits}{3{,}335{,}294{,}118\ bps}\right) * \left(\frac{1{,}000\ ms}{1\ s}\right)\right) + 87.2ms = 12.6\ ms + 87.2\ ms = 99.8\ ms$$

Note: (If you had approximated the per-user transmission rate as 3.3 Gbps, the resulting final answer would be 99.9ms. While this is within +/- 0.1ms, this may not always be the case.

6. Suppose there are 7 routers in sequence between Host A and Host B, all of which user store-and-forward routing. What is the total end-to-end delay for a packet originating from Host A with destination Host B, under the following conditions.

   Each of the link transmission rates are 3 Mbps

   The total distance from Host A to Host B along its path of transmission is 152 km

   The speed of propagation through the transmission medium is 2.7 x 10^8 m/s

   The packet size is 12 KiB

Remember that you must also uplink from Host A to the first router. Give answer in milliseconds, to one decimal place.

Solution:

Since there are 7 routers in sequence between Host A and Host B, we know the packet will need to travel on 8 links.

Convert the packet size from KiB to bits.

$$12\ KiB * \left(\frac{1{,}024\ bytes}{1\ KiB}\right) * \left(\frac{8\ bits}{1\ byte}\right) = 98{,}304\ bits$$

Convert the transmission rate from Mbps to bps.

$$3\ Mbps * \left(\frac{1{,}000{,}000\ bps}{1\ Mbps}\right) = 3{,}000{,}000\ bps$$

Calculate the transmission delay for all 8 links and add that to the propagation delay to get the total end-to-end delay in seconds, multiply by 1,000 to convert to milliseconds.

$$\left(\frac{1{,}000\ ms}{1\ s}\right) * \left(\left(8 * \left(\frac{98{,}304\ bits}{3{,}000{,}000\ bps}\right)\right) + \left(\frac{152{,}000\ m}{270{,}000{,}000\frac{m}{s}}\right)\right) = 262.7\ ms$$

7. What is the total utilization of a circuit-switched network, accommodating eight users with equal bandwidth share, and the following properties:

   Four users each using 65% of their bandwidth share

   Three users each using 52% of their bandwidth share

   One user using 15% of their bandwidth share

   Give answer in percent to one decimal place.

   Solution:

The utilization is based on the number of users permitted to share the network and the percentage of bandwidth share that each of those users is utilizing. This is calculated as follows:

$$(4 * 0.65 * 0.125) + (3 * 0.52 * 0.125) + (1 * 0.15 * 0.125) = 0.53875 = 53.9\%$$

Note: The value 0.125 is used in the calculation since the network is accommodating eight users with equal bandwidth share, meaning each user gets 1/8 (or 12.5%) of the bandwidth.