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Homework 1

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Question 1

a) Layer is the idea in which a system is divided into smaller and simpler portions which in turn simplified a problem into a simpler set of problems. Each layer will perform some sort of processing to the original data and pass it on to lower layers. After the data has been processed by the lowest layer, it is passed to the receiving device where the data is unpacked from the lowest to highest layers in order. Using layered architecture will also allow changes to the design or operation of a single layer without impacting other layers.

b) The network protocol was designed in seven layers for a variety of reasons. While more layers would allow for lower complexity in each layer, layers needs to interface with their direct siblings above and below. The creation of these interfaces is not trivial and therefore the number of layers should be kept to a reasonable count. When choosing the functionality of each layer, similar functional steps in the communication process are grouped up abstract the process. Additionally, as previously mentioned, by abstracting each step into layers, changes can be made to the operation of a single layer while not affecting other ones.

Question 2

RRC (Radio Resource Control)

The radio resource control later of the LTE architecture is the most difficult layer to classify in terms of the OSI model. It has a wide range of functionality mostly pertaining to that of the session layer. The key management for encryption as well as mobility and QoS functionality are not explicitly defined by the OSI model, however, they are related to session management.

PDCP (Packet Data Convergence Protocol)

The PDCP layer will provide a protocol to send and receiving acknowledgment units as well as provide data integrity checks on these units. It is mostly draws from aspects described in the data link layer of the OSI model.

RLC (Radio Link Control)

The RLC layer will segment the data into packets and verify in-sequence delivery of these packets. The OSI model would group together some of the functionality of the PDCP and RLC layers to formulate the data link layer.

MAC (Medium Access Control)

Manages the physical connection by scheduling the sending and receiving of packets. Incorporates parts of the data link and physical layers in the OSI model.

Wireless mobile connections

Wireless mobile connections are especially vulnerable to cyber attacks because their data is being transmitted through a public medium at long range. This means a potential attacker may "listen in" on messages transmitted through mobile protocols. Security and encryption has a much stronger emphasis in the mobile network architecture that previously noted in the OSI model. While data integrity is something that both the wired and mobile links need to take into account, ciphering to verify packet integrity is not explicitly defined in the OSI model. The LTE PDCP layer will request re-transmission of a packet if it cannot be verified against its cipher.

Question 3

Part 1

In the worst case scenario of the described problem, the packet would need to wait for the transmission delay of two other 10 kbit at each of the three routers.

There are four physical lines connecting the sender and receivers via the three intermediate routers. The total transmission time can then be calculated between the start of the message being sent until the message has been fully received by the receiver.

We start with the basic equations and definitions of nodal delay:

$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop} \tag{1}$$

$$d_{proc} \approx 0 \tag{2}$$

$$d_{queue} = d_{trans} * n_{packets\_in\_queue} \tag{3}$$

$$d_{trans} = L_{packet\_length} / R_{link\_bandwidth} \tag{4}$$

$$d_{prop} = d_{line\_length} / s_{prop\_speed} \tag{5}$$

Equation 2 shows a negligible time delay for the processing of each packet. This is due to the sub-millisecond delay seen during this step. Equation 3 was derived with this question in mind. The message in question needs to wait for the transmission delay of two other 10k messages at each of the three intermediate routers.

We can therefore arrive at an expression for the entire packet transmission:

$$\begin{aligned} d_{total} &= d_{trans\_sender} + d_{physical\_line} + 3d_{router} \\ &= d_{trans} + 1000\,\text{km}/0.3\,\text{km}\,\mu\text{s}^{-1} + 3d_{queue} + 3d_{trans} \\ d_{trans} &= 10\,000\,\text{bits}/10\,\text{Mpbs} = 1\,\text{ms} \\ d_{queue} &= 1\,\text{ms} * 2\,\text{packets} = 2\,\text{ms} \\ d_{total} &= 1\,\text{ms} + 3.33\,\text{ms} + 3\cdot 2\,\text{ms} + 3\cdot 1\,\text{ms} = \mathbf{13.33\,ms} \end{aligned}$$

Part 2

Question 4

To calculate the minimum link capacity we start with the transmission delay at each intermediate node as well as their definitions based on the question:

$$\begin{aligned} d_{nodal} &= d_{proc} + d_{queue} + d_{trans} + d_{prop} \\ d_{proc} &= 0 \\ d_{trans} &= L_{packet\_length}/R_{link\_bandwidth} = \frac{1\,\text{Mbytes}}{R}\left(\frac{8\,\text{bits}}{1\,\text{byte}}\right) = \frac{8\,\text{Mbits}}{R} \\ d_{queue} &= d_{trans} * n_{packets\_in\_queue} = d_{trans} * 4 \\ d_{prop} &= d_{line\_length}/s_{prop\_speed} = \frac{200\times 10^3\,\text{m}}{2\times 10^8\,\text{m/s}} = 1\,\text{ms} \end{aligned}$$

With the expression for the delay at each node described in terms of the link bandwidth, R, an expression is derived in terms of a single node d_{nodal}.

$$\begin{aligned} 1\,\text{s} = d_{total} &= d_{trans} + d_{prop} + 2\cdot d_{nodal} \\ &= \frac{8\,\text{Mbits}}{R} + 1\,\text{ms} + 2\left(0 + 4\frac{8\,\text{Mbits}}{R} + \frac{8\,\text{Mbits}}{R} + 1\,\text{ms}\right) \\ 1\,\text{s} &= 11\frac{8\,\text{Mbits}}{\text{R Mbps}} + 0.003\,\text{s} \\ R &= \mathbf{88.265\,Mbps} \end{aligned}$$