Industrial Automation – Spring 2025

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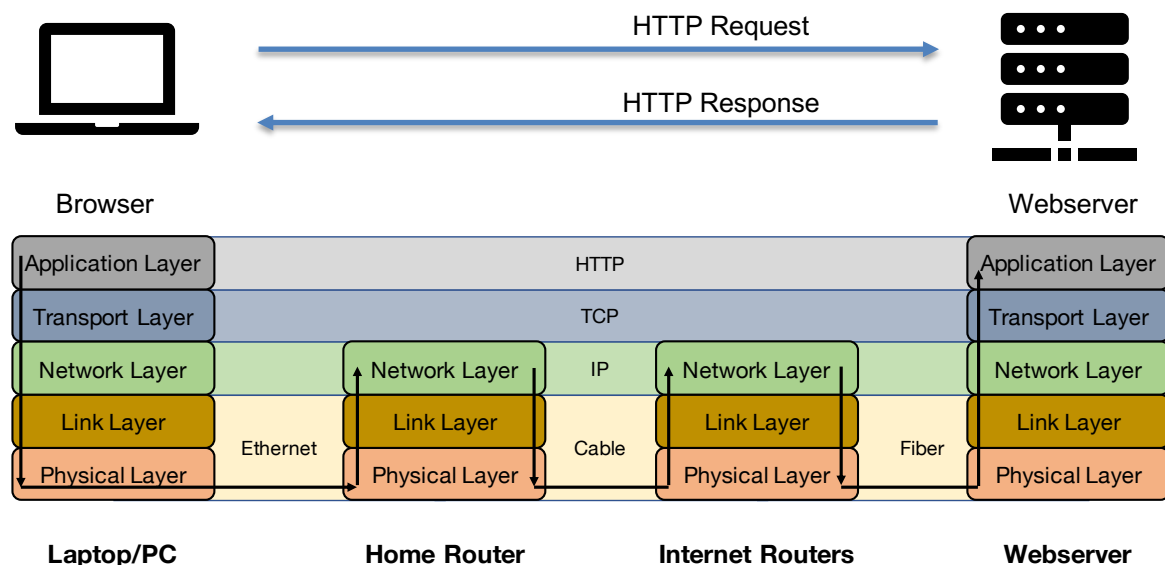Dr. Jean-Charles Tournier
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Exercise Sheet: Week 6 (Solution)

Question 1

Explain which protocols are involved when downloading this exercise sheet as a PDF file from the EPFL course website to your computer or laptop. If you change the way your computer is connected to the Internet from a wired to a wireless connection, which layers in the OSI model will be affected and how? Which layers/protocols will stay the same?

When downloading a file from a website, your browser (client) will connect to the web server using the Hypertext Transfer Protocol (HTTP), which is an application layer protocol (OSI Layer 7). The browser will send a HTTP GET request to the web server, which will respond with the content of the PDF file.

The HTTP protocol itself relies on a reliable transport protocol underneath. On the Internet, the Transmission Control Protocol (TCP) is often used as the transport protocol (OSI Layer 4). TCP operates on top of the Internet Protocol (IP) (OSI Layer 3), which is used to relay data packets through the various sub networks that build the Internet. So called Routers provide forwarding of packets from the source to the destination node based on IP addresses. Below the Network Layer, the Link Layer (OSI Layer 2) and Physical Layer (OSI Layer 1) protocols provide the physical connection between the different nodes in a sub-network. Depending on the type of the physical infrastructure deployed, various technologies (cable, fiber, Ethernet) and protocols are used at the link and physical layers.
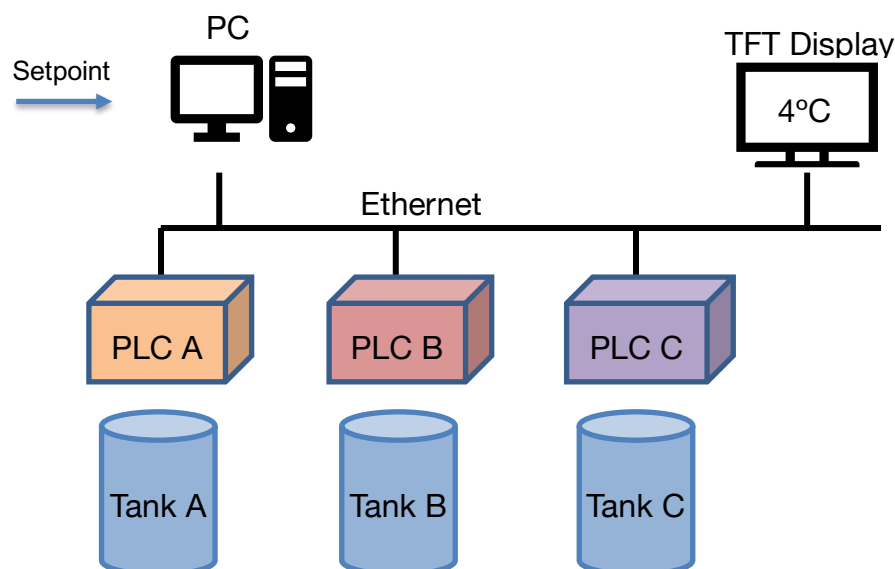
In the figure above, we show which layers of the OSI model are involved at the devices between your laptop/PC and the webserver. Please note that in the Internet Protocol suite, the OSI Layers 5,6 and 7 (Session, Presentation and Application) are often combined into the Application layer. The laptop/PC and the webserver require an implementation of the transport and application layers, while the intermediate routers will only forward IP packets without modifying the content of the higher layers (e.g. transport and application layer payload).

If the Laptop/PC is connected with the Home Router using a wired connection, then typically the Ethernet protocol (IEEE 802.3) is used for the Physical and Link layers in your home network. In contrast, connecting wirelessly to your Home Router will make use of a protocol of the WiFi protocol family (IEEE 802.11). However, the other layers above the link layer will remain the same.

Question 2

It's your first day as an automation engineer in a beverages factory and you are given the task of upgrading the control system for the factory's refrigerated liquid storage tanks. There are three tanks with built-in cooling systems and each tank is controlled by a separate PLC. Since the cooling systems have been purchased from different manufacturers, each PLC is from a different vendor. Each PLC provides a temperature setpoint variable as well as a variable holding the current temperature of the tank. Up to now, three different proprietary software tools on the PC have been used to configure the temperature setpoints of each tank.

Your task is to design the system architecture to control the temperature setpoint for all three tanks simultaneously from within a single software application running on the PC.

a) Which communication protocol from the lecture would you use for this task? Explain why you have chosen this protocol.

The OPC UA protocol is a viable choice for this scenario, as it is supported by many different PLC vendors. Using OPC UA will allow to implement a single software application on the PC that can access the sensor readings from multiple PLCs.

b) What will be the role of the PLCs? What will be the role of the PC?

The PLCs will act as the OPC UA server to provide the temperature sensor readings as variables. The PC will act as the client and will connect to the three OPC UA servers at the PLCs to fetch the temperature values.

c) What is the communication pattern between the different devices (PLCs, PC)?

There are two different communication patterns possible:

1. *Client polls the temperature values:*
   In the first scenario, the OPC UA client on the PC will periodically connect to each of the three OPC UA servers running on the PLCs and read the most recent temperature value for each tank.

2. *Client subscribes to data change events:*
   In the second scenario, the OPC UA client creates a subscription at each OPC UA server for the corresponding temperature sensor variable. Then, each OPC UA server will notify the client upon any change of the temperature variable's value.

d) Now you are also asked to provide a visualization of the current temperature of each tank using a large TFT display with embedded PC. How will you integrate the display into your existing setup?

One possible approach is to install an OPC UA server on the embedded PC inside the TFT display. The OPC UA server exposes a "temperature setpoint" variable, which can be used to update the setpoint temperature shown on the display. The standard PC can then write to this variable each time the user has changed the setpoint.

Alternatively, it would also be possible to configure an OPC UA server on the standard PC, which exposes the temperature setpoint as a variable, which can then be read by an OPC UA client running on the embedded PC inside the TFT display. Of course, the polling interval has to be chosen so that the display is updated frequently, or one has to use a subscription for a data change event to notify the display's embedded PC on any changes to the setpoint temperature.