1a Telecommunications companies generally offer various services for data transport across their network. Examples of such services are frame relay and ADSL. Explain in which OSI layer these services belong. *5pt*

Most of these services are offered as data link layer services that allow you to connect to one of the telco's machines that takes care of further data transfer. Of course, the telco's network is implemented using more than just the data link layer, but that normally remains hidden to the service subscriber.

1b Java provides a special interface for sending data across a network. Can we assume that Java also implements its own network protocol? *5pt*

No, by providing a network programming interface, the only thing Java does is give you a standard way to use one of the protocols that is implemented by the underlying operating system.

1c Why do we need a modem for transferring data across a telephone network? Is it not possible for a telephone company to offer a service that allows you to directly connect your computer to their network? *5pt*

We need a modem because sending binary signals across telephone networks is subject to too much attentuation and delay distortion. By using modulation we effectively send an AC signal across the wire that encodes the binary signal by changing the frequency, amplitude, or phase.

2a Explain what bit stuffing is used for and how it works. *5pt*

We need bit stuffing so that we can use selected bit sequences for frame delimiting, but still be able to use such a sequence as part of the data we are sending. How it works is explained on page 181.

2b ATM does not use cell delimiters. How are the beginning and end of a cell detected? *5pt*

Each cell uses an 8-bit header checksum (HEC). We can simply use a 40-bit shift register and see whether the next 8 bits match the 40 bits. If so, we assume we have just detected a cell header and continue reading the next 48 bytes of data without further examination. At that point, the next 40 bits are shifted into the register and checked against the 8 bits that follow them. This procedure is repeated a number of times before the first *batch of 53 bytes is passed to the next layer. (Note: we can, of course, use larger shift registers, but that is not the essential to this algorithm.)*

3a How can a station detect a collision? *5pt*

Simply put a station in continuous receive mode, even when it is sending. This will allow it to check whether what it is sending is the same as what it is receiving. If there is a difference between what is being sent and what is being received, there is most likely some other station sending as well.

3b Ethernet is a popular CSMA/CD protocol. Explain how it works. *5pt*

A station first senses the wire to see whether it is free. If there is currently no other activity, the station will start transmitting its data while it continues to listen. If a collision is detected, transmission stops immediately and a next attempt is made some random period later determined by an exponential backoff algorithm.

3c Originally, Ethernet offered a transmission rate of 10 Mbps, but this rate is much higher now. How is this higher rate possible without changing the frame format, interfaces, and procedural rules? Explain your answer! *10pt*

One of the crucial issues is that we can stick to the minimal frame length but still allow collision detection within the time that it takes to transmit such a frame. The simplest solution is to reduce the maximum cable length. A better solution is try to increase the bandwidth by increasing the number of signal values similar to way modulation techniques are used, and simply encoding several bits at a time. For example, using ternary signals across a single wire instead of binary signals, and using 3 wires at the same time, 27 combinations are possible. These combinations of signals can be used to encode $\lfloor {}^2\log 27 \rfloor = 4$ *bits at a time, effectively increasing the transmission rate by a factor 4. Combining this with an increase of the baud rate (i.e., signaling speed) to 25 MHz, leads to 100 Mbps.*

Grading: *The final grade is calculated by accumulating the scores per question (maximum: 45 points), and adding 5 bonus points. The maximum total* MT *is therefore 50 points. The final exam consists of two parts. Part 1 covers the same material as the midterm. Let* $P1$ *be the number of points for part 1, and* $P2$ *the number of points for part 2 (each being at most 50 points). The final grade* E *is computed as* $E = \max\{MT, P1\} + P2$*. The midterm exam counts only for first full exam.*