Department of Computer Science	Computer Networks
Vrije Universiteit	26.05.2003

Always explain your answers concisely and be sure to be to-the-point.

Part I

This part covers the same material as the midterm exam.

1a In the context of computer networks, what is the difference between a service and a protocol? *5pt*

A service is a set of primitives that a layer provides to the layer above it. A protocol is a set of rules that describe the format, meaning, and order of messages that are exchanged between two communicating parties.

1b What does the host-to-network layer prescribe in the TCP/IP reference model? *5pt*

Nothing very specific, except that a host has the responsibility for getting IP packets sent through a low-level network interface (and likewise, to receive such packets). The actual protocol is not defined.

1c The following trace shows the route that a IP packet follows from a local host in the CS department of the Vrije Universiteit, to the Web server of the CS department of the University of Groningen. For example, the fifth line tells that the packet passed through a router named PO1-0.CR2.Amsterdam2.surf.net with IP address 145.145.160.14. What type of networks can you distinguish? Explain your answer! *5pt*

```
 1  192.31.231.1 (192.31.231.1)
 2  hkae16-1-d01.backbone.vu.nl (130.37.5.1)
 3  Gi15-2-27.AR5.Amsterdam1.surf.net (145.145.18.57)
 4  PO6-0.CR1.Amsterdam2.surf.net (145.145.164.1)
 5  PO1-0.CR2.Amsterdam2.surf.net (145.145.160.14)
 6  PO1-0.AR5.Groningen1.surf.net (145.145.165.18)
 7  rug-router.Customer.surf.net (145.145.2.2)
 8  nsa.cs.rug.nl (129.125.5.10)
```

Depending on how you count, there are two or three types of networks. There are small local networks to which the sending and receiving machines are connected; there's a local campus network at the VU (called "backbone.nl"), and there's a wide-area network (called "surf.net") that connects the VU and RuG.

1d Now consider the following excerpts of traces from the same machine at the VU to machines at different universities in Europe. What conclusion can you draw about the organization of networks? *5pt*

```
 1  192.31.231.1 (192.31.231.1)
...
 6  surfnet.nl1.nl.geant.net (62.40.103.97)
 7  nl.uk1.uk.geant.net (62.40.96.114)
 8  janet-gw.uk1.uk.geant.net (62.40.103.150)
 9  146.97.37.81 (146.97.37.81)
```

```
 1  192.31.231.1 (192.31.231.1)
...
 5  P0-0.BR1.Amsterdam1.surf.net (145.145.166.34)
 6  surfnet.nl1.nl.geant.net (62.40.103.97)
 7  nl.be1.be.geant.net (62.40.96.21)
 8  be.fr1.fr.geant.net (62.40.96.18)
 9  renater-gw.fr1.fr.geant.net (62.40.103.54)
10  lyon-pos9-0.cssi.renater.fr (193.51.179.130)
```

```
 1  192.31.231.1 (192.31.231.1)
```

```
...
6  surfnet.nl1.nl.geant.net (62.40.103.97)
7  nl.de1.de.geant.net (62.40.96.53)
8  62.40.103.34 (62.40.103.34)
9  cr-frankfurt1-po8-2.g-win.dfn.de (188.1.80.37)
```

There is a apparently a European network that connects the various national networks, called "geant.net"

2a Explain why bit stuffing is needed, and how it works. *5pt*

Bit stuffing is needed when using frame delimeters such as 01111110. In order to send the delimeter as data in a frame, a zero is inserted after five consecutive 1s have been transmitted. The receiver simply removes the zero following 5 1s in row.

2b Consider an unreliable wireless channel that you need to use for digital-audio broadcasting. What would a data-link layer need to do to provide higher reliability? *5pt*

The protocol should support error correction. Error detection combined with retransmissions is probably not enough because the audio packets keep coming in. Therefore, damaged packets should preferably be be repaired at the receiver.

3a What is function of the logical link control layer? *5pt*

It is a layer on top of the MAC layer and contains additional functionality to handle error- and flow control, just as you would expect from a data-link layer.

3b Ethernet uses a binary exponential backoff algorithm. What does this algorithm do? *5pt*

When a station detects a collision, it stops its transmission and waits a while. If a collision is detected for the i^{th} time in a row, the algorithm prescribes that the station waits somewhere between 0 *and* $2^i - 1$ *slot times. In this way, when it is really busy, the competing stations are spread over a larger interval before they are allowed to make a transmission attempt. The goal is to bring down the chance of collision.*

3c Explain what the hidden and exposed station problems are, and how they can be solved. *5pt*

The problem occurs in wireless communication, and is shown in Figure 4-26. A solution is to use RTS/CTS messages. Be sure to explain how that works.

Part II

5a In wide-area networks that support virtual circuits, a route from *A* to *B* is set up before data packets are sent. What is the main advantage of this approach in wide-area networks? *5pt*

It allows for a much better support of QoS, as it becomes possible to reserve resources at routers so that delay and jitter can be kept within specified bounds.

5b Explain how Multiprotocol Label Switching (MPLS) works. *5pt*

MPLS routers prepend a tag, or label, before the IP header indicating the virtual circuit that has been set up in advance to route labeled packets. The label is used as an index in the routing table to lookup the outgoing network interface. The table also specifies the label that should be prepended when the packet is subsequently forwarded. In other words, a label has only local meaning.

5c Explain how the count-to-infinity problem occurs. *5pt*

See Figure 5-10. Be sure to mention distance vector routing.

6a Consider a home network connected to an ISP through a NAT box (in combination with a modem). The ISP has assigned the owner of the network a permanent IP address, say 213.10.169.34. A process *A* on the host in the home network with IP address 10.0.0.2 sets up a TCP connection from port 23000 to a process *B* on a host having address 192.31.231.80, and which is listening to port 80. Explain

for this situation precisely how the 3-way handshake protocol works, assuming that no messages are lost. Use the notation (10.0.0.2, 23000) to denote the combination of (IP address, port number) that, in this example, process *A* is using. *10pt*

Process A selects an initial sequence number and sends a SYN packet to the NAT box, which associates an arbitrary port number, say Y, with the combination (10.0.0.2, 23000). The NAT box then sends the packet to process B, after having modified the source address to (213.10.169.34, Y). Process B returns an (SYN,ACK) packet, addressed to (213.10.169.34,Y), which is picked up by the NAT box. The NAT box then forwards the packet to process A, changing the source address to (192.31.231.80,80), and the destination address to (10.0.0.2, 23000). Then, process A returns an ACK packet to the NAT box, addressed to (192.31.231.80, 80), which is then subsequently forwarded by the NAT box after modified the source address to (213.10.169.34, Y).

6b Explain how Transactional TCP works. *5pt*

T/TCP combines the 3-way handshake, sending of a request, and disconnecting in a single message, essentially by setting the SYN and FIN bit on. The server can respond with a reply, immediately acknowledging the connection setup (ACK=1), performing its part of the 3-way handshake protocol (SYN=1), and agreeing to close the connection (FIN=1). The client merely needs to respond with its last part of the 3-way handshake (ACK=1) and agreeing to close the connection (FIN=1)

7 The HTTP protocol supports redirection responses by which a requester is instructed to fetch the requested document from another server. Explain how this redirection mechanism is used by Content Delivery Networks to dynamically replicate a Web document to a server close to a requesting client. Be precise. *10pt*

See Figure 7-47. You need to explain steps 9-10 to get the full 10 points.

8 Let K_{CA}^{-} be the private key of a certification authority *CA*, and K_{CA}^{+} the corresponding public key. If Alice's public key is K_A^{+}, what would a certificate for that key, as issued by *CA* look like? *5pt*

$[A, K_A^{+}, CA, K_{CA}^{-}(A, K_A^{+})]$

Final grade: *(1) Add, per part, the total points. (2) Let T denote the total points for the midterm exam (*$0 \leq T \leq 45$*); D1 the total points for part I; D2 the total points for part II. The final number of points E is equal to* $\max\{T, D1\} + D2 + 10$.