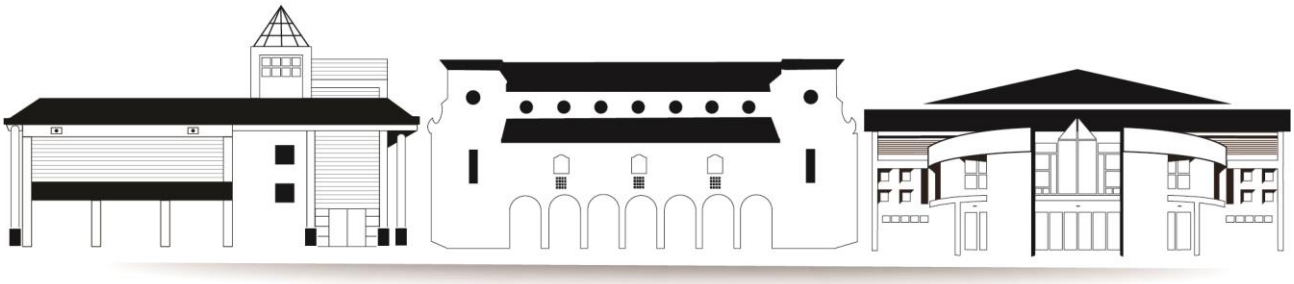


ITRW 322 VBC

COMPUTER NETWORKS
REKENAARNETWERKE

Name of Faculty

Study guide compiled by: Mr JP Jooste

North-West University

MODULE CONTENTS

Module information

Module code	ITRW 322 VBC		
Module Credits	16		
Module name	Computer networks / Rekenaarnetwerke		
Name of lecturer(s)			
Office telephone			
Email address		**NWU-level:**	3
Building and Office nr		**National level:**	7
Consulting hours		**Contact time:**	2 theory + 2 practical periods

Welcome

Welcome to the Computer Networks module. I hope and trust that you will find this module very interesting and useful. Computer Networks is one of the fastest growing technologies today and one of the effects is the dramatic increase in careers relating to computer networks. To be successful in these careers it is important to understand the technologies involved as well as the underlying principles. In this module we study the connection of a group of computers.

Rationale

This module is about network architectures and protocols which allow information to be shared.

When people share their e-mail addresses it gives an indication of the increased levels of interconnection defined by the way that we communicate with other people and institutions. The Internet and World Wide Web shows the real possibility of collaboration on a global scale. Networks are changing the way we do business and make decisions. Business decisions have to be taken at an increasing pace and decision makers require immediate access to accurate information. Before we ask the questions of how we can join these networks, we should know how they function and what range of technologies are available.

Module outcomes

After successfully completing this module, you should:

- be acquainted with the operation of the OSI, TCP/IP and IEEE (local area network) protocols, as well as protocol independent topics such as congestion control and routing.

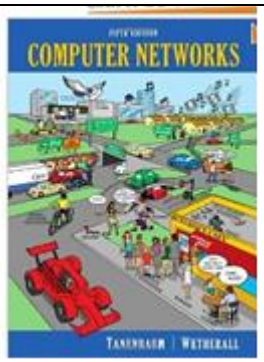
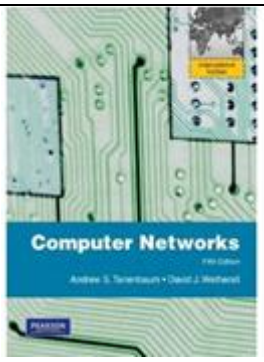
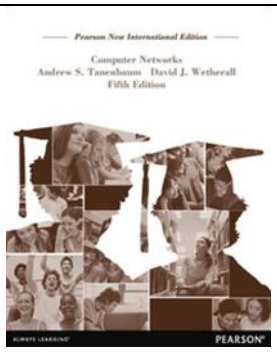
- master OSI, TCP/IP and IEEE (local area network) protocols further by means of a simulated low level implementation of the IEEE protocols in a high level programming language.
- have knowledge about the Internet, it's operation, services and properties and will be able to do practical assignments on the Internet.
- be able to use your knowledge of the basic concepts of computer networks in all forms of communication, in context and accurately.
- know computer network architecture in detail and be able to apply it to problems.
- understand the basic techniques used in the field and be able to apply them to problems.
- be able to implement basic protocols in a suitable high level programming language.
- be able to select problem solving techniques and apply them to case studies.
- be able to operationalise your knowledge from an acknowledged and ethical framework.
- be able to operate successfully in a group and even act as leader.
- be able to use initiative and operate with creative thinking and an entrepreneurial attitude.
- be able to communicate effectively with both expert and lay audiences on topics of computer networks while using IT tools.

Study material

Prescribed textbook

Computer Networks. Prentice Hall, 5th edition. - Tanenbaum, A.S. & Wetherall, D.J.

Several versions of the 5th edition have been printed. They all have the same content.

[Hardcover] 2010 ISBN-13: 978-0132126953 Publisher: Prentice Hall	International Version 2011 ISBN-13: 978-0132553179 Publisher: Pearson Education	New International Version 2013 ISBN-13: 978-1292024226 Publisher: Pearson Education
		

Additional sources

- Networking Chapter of The Java Tutorial.
- Additional study material has been included in this study guide.

Time allocation

Activity	Weeks	Hours/Week	Total
Class work and tests	13	2	26
Practical assignments	8	5	40
Self study	12	6	72
Examination	1	22	22
TOTAL			**160**

Web page / E-learning environment

A web page for the module can be found at: http://efundi.nwu.ac.za During the course of the module material and marks may be placed on the web page.

How to study

When you study ITRW322, you should:

- Study the outcomes of each study unit or study section to see what you ought to achieve;
- Study the study unit or study section according to the guidelines provided in the study guide and in accordance with the study outcomes;
- Make sure that you understand the definitions, methods and techniques;
- Work through the examples to see whether you can apply the technique practically;
- Complete all exercises and assignments;
- Complete all self-evaluation exercises and monitor your own progress.

It is important in this module that you can practically apply every method and technique that you acquire. The final test to see whether you understand a technique or method is therefore not whether you can write down the technique or method verbatim, but whether you can use it to solve a problem successfully.

The exercises serve as a test to see whether you understand the work in the study unit/study section and whether you can practically apply it to problems. The exercises are not submitted or marked, but it is very important that you do work through the exercises, since it gives you an indication of what typical questions will look like in the semester test and examination.

Evaluation

In this module the following forms of evaluation will be used. (Weights for calculation of the participation mark is also given):

Continuous evaluation (for calculation of participation mark)

- theory evaluation (at least 3 tests) 60%
- practical evaluation (at least 2 tests) 40%

Exam

You will only be granted exam entrance if your participation mark is 40% or higher.

The examination consists of one three-hour paper for which you have to get a minimum of 40%.

Final module mark

Your final module mark is compiled from your participation mark and the examination mark in a 1:1 ratio. You need a sub-minimum of 50% to pass the module.

Icons

Time allocation

Learning outcomes

Study material

Assessment / Assignments

Individual exercise

Group Activity

Example

Reflection

Warning against plagiarism

ASSIGNMENTS ARE INDIVIDUAL TASKS AND NOT GROUP ACTIVITIES. (UNLESS EXPLICITLY INDICATED AS GROUP ACTIVITIES)

Copying of text from other learners or from other sources (for instance the study guide, prescribed material or directly from the internet) is **not allowed** – only brief quotations are allowed and then only if indicated as such.

You should **reformulate** existing text and use your **own words** to explain what you have read. It is not acceptable to retype existing text and just acknowledge the source in a footnote – you should be able to relate the idea or concept, without repeating the original author to the letter.

The aim of the assignments is not the reproduction of existing material, but to ascertain whether you have the ability to integrate existing texts, add your own interpretation and/or critique of the texts and offer a creative solution to existing problems.

Be warned: students who submit copied text will obtain a mark of zero for the assignment and disciplinary steps may be taken by the Faculty and/or University. It is also unacceptable to do somebody else's work, to lend your work to them or to make your work available to them to copy – be careful and do not make your work available to anyone!

For the NWU link for plagiarism, go to http://www.nwu.ac.za/webfm_send/25355

Study unit 1

AN INTRODUCTION TO COMPUTER NETWORKS

Study section 1.1

Practical exploration of concepts

Study hours

The time scheduled for this section is 4 hours

Learning outcomes

At the end of this study unit you should:

- be able to describe the interaction between two computers on a network as a protocol;
- understand that there is a link between an ip-address and a symbolic address of a computer;
- be able to use basic network utility programs such as ping, nslookup, traceroute, putty/ssh
- be able to use the basic functions of ifconfig (on Linux) and ipconfig (on Windows)

Study material

1. **Tanenbaum sections**:
   1.1 Uses of Computer Networks, 1.2 Network Hardware, 1.7 Metric Units
2. The DESCRIPTION parts in the relevant Linux manual pages. Read it with the commands: Man **ping** man **ssh** man **ifconfig** man **nslookup**

Assessment

LAN _____	Ethernet _____
MAN _____	IP _____
WAN _____	TCP/IP _____
PAN _____	_____
VPN _____	VoIP _____
VLAN _____	IPTV _____
ISO _____	micro _____
OSI _____	nano _____
IEEE _____	pico _____
ISP _____	Mega _____
WiFi _____	Tera _____
WiMAX _____	Exa _____
3G _____	Giga _____

Individual PC assignment

Exploring an existing TCP/IP network

1. Do the PacketTracer exercise given on eFundi
2. Do "**Cisco Lab 6.7.1: Ping and Traceroute**" applied to the local environment

Use ifconfig / ipconfig to inspect the ip configuration of the local machine.
Use **ping** from the computer in the lab. Also log in to the Linux server and use **ping** from there. **Compare your results.** Which connection is the fastest on average? How much does it vary.

Note that the ping program cannot reach computers outside the university firewall. From the campus labs you may use as destinations the following computers ...

- efundi, www.nwu.ac.za, vdk-cache1.v.nwu.ac.za, 143.160.52.200, 143.160.48.100
- Log on to the Linux server and then ping back to your local machine

Explain the output of the command: gethostip -f `hostname`

Study section 1.2
Introduction to computer networks

Study time

The time scheduled for this section is 15 hours.

Study outcomes

At the end of this study unit you should:

- be able to describe the classification and different uses of computer networks.
- be able to describe the layered architecture of computer networks.
- be able to explain and compare the components of the OSI and TCP/IP reference models.
- be able to describe the Internet as example of a computer network.
- be able to divide a computer network into different components.
- be able to build (in theory) a computer network layers from different basic components.
- be able to give an opinion of a specified computer network in terms of your acquired knowledge and be able to communicate it (also in a group) to others.

Study material

Tanenbaum sections: 1.3 Network Software, 1.4 Reference Models
1.5.1 The Internet, 1.5.2 Third-Generation Mobile Phone Networks,
1.5.3 Wireless LANs (IEEE 802.11), 1.5.4 RFID and Sensor Networks,
1.6 Network Standardization, 1.7 Metric Units

Individual activity

Test your knowledge and insight with the following questions:

1. What is the definition of a computer network?
2. Name and describe two uses of computer networks.
3. There are two types of transmission technologies used in computer networking, broadcast and point-to-point connections. Explain the difference between the two.
4. Describe the functioning of a local area network.
5. What is the purpose of the protocol hierarchy?
6. What is the difference between a connection oriented and a connectionless service?
7. Describe the functions of each of the layers of the OSI reference model.
8. Describe the functions of each of the layers of the TCP/IP model.

Individual activity

Do the following exercises in writing and bring it along to the next class.

- Problems at the end of chapter 1 of Tanenbaum: **1, 2, 3 and 4** **(shown below)**

1. Imagine that you have trained your St. Bernard, Bernie, to carry a box of three 8-mm tapes instead of a flask of brandy. (When your disk fills up, you consider that an emergency.) These tapes each contain 7 gigabytes. The dog can travel to your side, wherever you may be, at 18 km/hour. For what range of distances does Bernie have a higher data rate than a transmission line whose data rate (excluding overhead) is 150 Mbps? How does your answer change if (i) Bernie's speed is doubled; (ii) each tape capacity is doubled; (iii) the data rate of the transmission line is doubled.

- Hint for question 1 above: Create a spreadsheet to do the calculations, draw a simple graph

2. An alternative to a LAN is simply a big timesharing system with terminals for all users. Give two advantages of a client-server system using a LAN.

3. The performance of a client-server system is strongly influenced by two major network characteristics: the bandwidth of the network (that is, how many bits/sec it can transport) and the latency (that is, how many seconds it takes for the first bit to get from the client to the server). Give an example of a network that exhibits high bandwidth but also high latency. Then give an example of one that has both low bandwidth and low latency.

4. Besides bandwidth and latency, what other parameter is needed to give a good characterization of the quality of service offered by a network used for (i) digitized voice traffic? (ii) video traffic? (iii) financial transaction traffic?

and so that you can change values to find out the results in alternative situations

Assessment

Reflect on your own progress and ensure that you have achieved the outcomes before continuing

Study unit 2
THE PHYSICAL LAYER

Study time

The time scheduled for this study unit is 10 hours.

Study outcomes

At the end of this study unit you should be able to:

- explain the implications of the results / expressions of Nyquist and Shannon for the maximum data rate of a channel;
- calculate the upper limit of bits/second for a channel with certain characteristics.
- describe and compare **guided** transmission media with different characteristics and apply this knowledge to a given problem or choice of transmission media.
- be able to make CAT-5 UTP Ethernet cables: **patch** (straight-through) and **crossover**.
- establish communication between two computers over Ethernet (CAT-5 UTP) by programming in a high level language (e.g. Java) using (a) a cross-over cable (b) patch cables connected to a switch;
- describe the communication and give an opinion of selected transmission components in terms of your acquired knowledge and communicate it in scientific terms (also as a group).

Study section 2.1
Transmission media

Study material

Study Tanenbaum sections:

2.1.3 The Maximum Data Rate of a Channel,
2.2 Guided Transmission media,
2.3 Wireless Transmission

Individual activity

Test your knowledge and insight with the following questions:

1. What are the practical implications of the results / expressions of Nyquist and Shannon?
2. Describe the operation and construction of magnetic media, twisted pair, coaxial cable and optical fibre cables.
3. Explain the operation of a fibre optic network.
4. Compare fibre optic with copper wire in terms of bandwidth, amplification of signals, weight, security and skills needed by technician to install it.

Individual activity

Do chapter 2 **exercises 2, 3 and 4** in writing and bring it to the next class.

Assessment

Reflect and ensure that you have achieved the outcomes before continuing

Study section 2.2
Building a small network

Example

1.Ethernet cables UTP

Practical exploration

1. Identify cables: cat3 and cat5, cat5e, cat6, fiber, coax
2. Identify connector wiring: T568A vs. T568B
3. Make Ethernet cables: CROSSOVER for PC-to-PC using T568A and T568B
4. Test cables: cat 3 vs. cat5; and crossover vs. straight-through.

Individual PC assignment

2. Cisco Lab 2.6.1: Topology Orientation and Building a Small Network

Individual activity

Answer the following questions about programs above.

- The programs implement some protocol. Is it a high level or low level protocol? Motivate.
- Which network services are used by your programs? Are they high level or low level services?
- With which layers of the OSI reference model as well as the TCP/IP model does your programs have similarities?

Study unit 3

THE PHYSICAL LAYER – TELEPHONE AND MOBILE NETWORKS

Note: This study unit may be postponed until later in the semester

Study time

The time scheduled for this study unit is 15 hours.

Study outcomes

At the end of this study unit you should be able to:

- describe the public telephone network.
- explain the operation of a modem, codec and describe digital subscriber lines.
- explain the process of multiplexing.
- discuss the different forms of switching
- describe the structure of the mobile telephone system.
- give an opinion in terms of your acquired knowledge of the public and mobile telephone systems and communicate it is scientific terms (also in a group).

Study section 3.1

Digital Modulation and Multiplexing

Study material

Study Tanenbaum sections:

2.5.1 Baseband Transmission
2.5.2 Passband Transmission
2.5.3 Frequency Division Multiplexing
2.5.4 Time Division Multiplexing
2.5.5 Code Division Multiplexing

Study section 3.2
Telephone networks

Study material

Study Tanenbaum sections:
2.6 THE PUBLIC SWITCHED TELEPHONE NETWORK
You can omit the following parts: 2.6.2 The Politics of Telephones; "SONET/SDH" (inside 2.6.4)
2.7 THE MOBILE TELEPHONE SYSTEM
2.9 SUMMARY

Individual activity

Test your knowledge and insight with the following questions:

1. Describe the different ways of multiplexing signals.
2. Explain the different forms of modulation which can be used by modems.
3. Describe the three components of the telephone system.
4. Explain the different ways of switching telephone calls.
5. Explain the first generation mobile phone system in terms of structure, channel allocation and call management.

Individual activity

Do chapter 2 **exercises 16, 22 and 28** in writing and bring it to the next class.

Indiviual PC assignment

1. PacketTracer®:

- "Lab 2.6.1: Topology Orientation and Building a Small Network"
- "Lab 11.5.3: Configure Host Computers for IP Networking"

Alternative assignment: Simulation with Java

Assignment 2 – multiplexing

Extend the client-server programs of a previous study unit. Simulate a physical layer protocol using time division multiplexing with **n channels per second**, where n is chosen by the user on the sending-side. In this example n=3 is used

Client side (sender)

The program asks the user to enter 3 strings of characters. The client then sends a synchronisation sequence 3 times in three seconds. The sequences should be 1 2 3 1 2 3 1 2 3. The client immediately starts sending the 3 strings together, one character at a time using the 3 channels. Use the underscore character _ to fill a channel when the letters are used up for that channel. When all channels have been empty for 3 seconds then the transmission should stop.

Server side (receiver)

The server determines the number of channels from the synchronisation sequence and then receives the data. It then displays every second the updated content of the channels until all channels are empty.

Example session (client side)	Example session (server side)
User 1: abcde User 2: XYZ User 3: 98765	
ready to send ! sec 1: "123" sec 2: "123" sec 3: "123" sec 4: "aX9" sec 5: "bY8" sec 6: "cZ 7" sec 7: "d_6" sec 8: "e_5" sec 9: "_ _ _" sec 10: "_ _ _" sec 11: "_ _ _"	listening . . . getting channel sequence Channel 1: **a** Channel 2: **X** Channel 3: **9** Channel 1: a**b** Channel 2: X**Y** Channel 3: 9**8** Channel 1: ab**c** Channel 2: XY**Z** Channel 3: 98**7** Channel 1: abc**d** Channel 2: XYZ_ Channel 3: 987**6** etc.

Assessment

Reflect and ensure that you have achieved the outcomes before continuing

Study unit 4

THE DATA LINK LAYER – FRAMING AND ERROR HANDLING

Study time

The time scheduled for this study unit is 11 hours

Study outcomes

At the end of this study unit you should be able to:

- explain the different types of services offered by the data link layer to the network layer.
- describe different framing techniques
- discuss error-correcting codes and error-detecting codes
- explain and program Hamming's algorithm to detect and correct a single error.
- explain the polynomial code checksum technique and calculate the resulting frame for a given string and generator polynomial.
- give an opinion about framing and error handling in terms of your acquired knowledge and communicate it (also in a group) in scientific language.

Study material

Study Tanenbaum chapter 3, as well as the explanation below:

Hamming's correction algorithm

This work is revision and self study. Work through this example carefully and ensure that your understand each step.

Suppose there are m data bits. We then add r extra bits to give an $n = m + r$ bit frame for transmission. The smallest value for r which make the following expression true, is chosen:

$$m + r + 1 \leq 2^r \qquad (1)$$

Consider an example in which the data to be sent is 1 1 0 0 1 1 1. In this case m is equal to 7 and the minimum r which makes expression (1) true is 4. Thus n is equal to 11.

The steps to create the Hamming code are the following:

1. Number the bits of the error correcting code from the most significant bit to the least significant bit, starting from 1. The error correcting code contains two types of bits: data bits and test bits. Place the test bits in the positions of the error correcting code numbered with powers of two. The data bits use the remaining positions and is taken from the original data in the same sequence. In our example we get:

T	T	1	T	1	0	0	T	1	1	1
1	2	3	4	5	6	7	8	9	10	11

   Note that positions marked with a T represent test bits.
2. Each test bit calculates the parity (even or odd) of a particular combination of data bits. To determine which data bits are used for each test bit, we write the position of each data bit as a sum of the positions of test bits.

```
3  = 1 + 2
5  = 1 +     4
6  =     2 + 4
7  = 1 + 2 + 4
9  = 1 +         8
10 =     2 +     8
11 = 1 + 2 +     8
```

A test bit, X, tests or creates the correct parity of all the data bits in which it is used to build the sum. In our example test bit 1 is used in the calculation of 3, 5, 7, 9 and 11. If we choose the parity as even, then bits 1, 3, 5, 7, 9 and 11 should together have even parity. (The choice of even parity or odd parity does not affect the process, but should be used throughout and by both sender and receiver). In this case the test bit is number 1 which means it should be manipulated to produce even parity.

In our example the test bits are as follows:

```
T1: tests 1, 3, 5, 7, 9 and 11

T2: tests 2, 3, 6, 7, 10 and 11

T4: tests 4, 5, 6, and 7

T8: tests 8, 9, 10 and 11
```

The following frame should be sent:

0	1	1	1	1	0	0	1	1	1	1
1	2	3	4	5	6	7	8	9	10	11

When the receiver gets the frame each test bit is checked for correct parity. For each test bit, *k*, with wrong parity, the value of *k* is added to a counter (initially the counter is 0). Is the counter is still 0 after all test bits have been checked, then there were no errors in transmission. If the counter is not zero, then it contains the position of the bit which is wrong and should be inverted.

Suppose the receiver gets 0 1 1 1 1 1 0 1 1 1 1 (bit 6 is wrong) then the parity for bits 2 and 4 will be wrong. The sum of 2 + 4 is 6 and thus bit 6 is shown to contain the error. We can then correct the code by inverting bit 6.

Individual activity

Test your knowledge and insight with the following questions:

1. Describe 3 types of services offered by the data link layer to the network layer.
2. Explain how a frame can be built by:
    - using a character count
    - using flag bytes with byte stuffing
    - using begin and end flags with bit-stuffing
    - abusing the coding scheme of the physical layer.
3. Discuss **Hamming's algorithm** to detect and repair a single error. Hint: You will understand the algorithm better when implementing it as indicated in the **practical work of this study unit**.
4. Describe the **polynomial checksum technique** to detect errors. Hint: You will understand the algorithm better when implementing it as indicated in the **practical work of the following study unit**.

Individual activity

Do chapter 3 **exercises 2, 3, 9 and 14** in writing and bring it to the next class.

Individual PC assignment

Practical assignment:

1. Use the software **PacketTracer** in Linux or Windows for:
Cisco Lab 11.5.3: Configure Host Computers for IP Networking

2. Assignment 3 – DLL framing and error handling (simulation with Java)

Extend the client-server programs to simulate 3 protocols with 3 program pairs:

1. a data link layer (DLL) protocol working with character framing;
2. a DLL protocol working with bit framing and bit stuffing;
3. a DLL protocol working with Hamming error correction.
4. a DLL protocol working with CRC error detection.

Client side

The program asks the user to enter a string. The program then frames the string sending it one character at a time and wait for the acknowledgement frame "**ACK**". If the acknowledgement frame does not arrive in 3 seconds then the clients starts sending the framed string again. When the acknowledgement arrives, the client should display a message to say that the frame has been received by the server.

With protocol 3 the client program should randomly decide to artificially introduce errors from time to time.

Server side

The server receives the frame and deals with it according to the appropriate protocol. An acknowledgement frame "**ACK**" should be sent back to the client to let the client know that the frame was received.

Protocol 1 – framing and character stuffing

Suppose the user enters:

```
hello friend
```

The program then constructs a frame from the string by adding a flag (f character) to the front and back of the string, e.g.:

fhello friend**f**

If there is a character in the string which resembles the flag, then an escape character "e" is inserted before that character in the frame, e.g.:

fhello **e**friendf

If there is a character in the string which resembles the escape character "e", then an extra escape character is inserted before that character in the frame, e.g.:

fh**e**ello efri**e**endf

Hint: Do not prepare the whole frame at once from the given string, but build it up character by character just before sending each character.

Example session (client side)	Example session (server side)
User types the phrase "ref"	
ready to send: "ref"	listening ...
sending "f"	received "f"
sending "r"	received "r"
sending "e"	received "e"
sending "e"	received "e"
sending "e"	received "e"
sending "f"	received "f"
sending "f"	received "f"
listening ...	sending "ACK"
received "ACK"	Frame received = "freeeff"
sent successfully.	Content extracted = "ref"

Protocol 2 – binary framing and bit stuffing

Suppose the user enters the following: 011011111111111111110010

The program then forms a frame from the string by adding the special bit pattern (01111110) at the front and back of the string, e.g.:

01111110011011111111111111110010**01111110**

To guard against the possibility of the special bit pattern occurring as normal data and being mistaken for a flag, the following should be done. If there are five consecutive ones in the string, then an extra zero is inserted after the fifth, e.g.:

01111100110111110111110111110**0**1001001111110

The original string (`01101111111111111110010`)
and the frame (`01111110`**`01101111101111101111010010`**`01111110`) should be displayed on the screen of the server.

Protocol 3 – Hamming error correction

Suppose the user enters the following: `01101111111111111110010`

The program then uses the Hamming algorithm to generate the code to be transmitted; attach it to the data to create a frame and sends the frame. (Unlike protocol 1 and 2, the frame is first fully created before any part of it is sent.)

The server receives the frame and test it with the Hamming algorithm. If the server detects an error it should print out the erroneous frame as well as the corrected data.

Protocol 4 – CRC error detection (polynomial checksum technique)

Client side

The program asks the user to enter a frame (message) of bits, e.g. 1101011011. The generator polynomial, e.g. 10011, is fixed by prior agreement between client and server. The polynomial checksum technique should be applied to the frame to calculate the frame to be transmitted. In this case it will be 11010110111110. Build in an option to create an artificial error in the frame. The client program should randomly decide to artificially introduce errors from time to time. Display the (possibly erroneous) frame at the client and send it to the server. If an error was introduced the client must say so.

Hints

- Represent the frame as a string of zeros and ones.
- Do not convert the generator polynomial and frame to decimal values and then attempt normal division. This is not the way that modulo 2 calculations are done.
- Use the example in the textbook to test your program.

After sending the frame the program waits for the acknowledgement frame "**ACK**". If the acknowledgement frame does not arrive in 3 seconds or the client receives a "**NACK**" then the clients starts sending the frame again.

Server side

The server receives the frame and performs the modulo 2 division. If the remainder is not 0, then an error message is displayed. If there are no errors, then the original data should be displayed.

The server should send back a "NACK" if an error was detected in the frame and then wait for the frame to be sent again. It should also display a message such as "Error detected. NACK sent"

Study unit 5

THE DATA LINK LAYER – PROTOCOLS

Study time

The time scheduled for this study unit is 12 hours.

Study outcomes

At the end of this study unit you should:

- be able to describe the operation of the different data link layer protocols and write them down as algorithms.
- be able to address and explain problems of each protocol
- be able to give an opinion about protocols in terms of your acquired knowledge and communicate it (also in groups) using scientific language.

Study material

Study from Tanenbaum:

3.1 DATA LINK LAYER DESIGN ISSUES (all sections)
3.2 ERROR DETECTION AND CORRECTION
3.3 ELEMENTARY DATA LINK PROTOCOLS
3.4 SLIDING WINDOW PROTOCOLS
3.5.2 ADSL (Asymmetric Digital Subscriber Loop/Line)
3.6 SUMMARY

Individual activity

Test your knowledge and insight with the following questions:

1. Explain the operation of the following protocols:
    - The simplex stop-and-wait protocol.
    - The simplex protocol for a channel with noise.
    - The one-bit sliding window protocol.
    - A protocol which uses go-back-*N*.
    - A protocol which uses selective repeat.
2. Which assumptions are made for each of these 6 protocols?
3. Write down the protocols of question 1 as algorithms.
4. Describe the problems addressed by the last two protocols of question 1.

Individual activity

Do chapter 3 **exercises 19** in writing and bring it to the next class.

Individual PC assignment

1. Cisco Lab 7.5.2: Frame Examination (with WireShark)

2. Assignment 4a – simplex

Implement the simplex protocol for noisy channel. (The time-out should be configurable.)

3. Assignment 4b – duplex

Write one of the duplex protocol programs as allocated by the lecturer:

1. Duplex one-bit sliding window protocol. (The time-out should be configurable.)
2. Duplex protocol with go-back-*N*. (Configurable: window size; 3 or 4-bit seq. numbers)
3. Duplex protocol with selective repeat. (Configurable: window size; 3/4-bit seq. numbers)

Client side (sender) – All protocols

The program asks the user to enter a sentence. This sentence is then sent word-for-word to the server. Each word represents a frame. Depending on the protocol, the client should first wait for the required acknowledgement(s) from the server before continuing. If a certain time has elapsed and no acknowledgement is received, then the word / frame should be considered lost and sent again.

Server side (receiver) – All protocols

The receiver should simulate transmission errors. The user specifies an error likelihood between 0 and 1 (e.g. 0.4). When the server receives a word, it generates a random number between 0 and 1.
If the number is less than 0.4 then a NACK is sent to the client, else an ACK is sent.

Duplex protocols

Combine client and server into one program which will be run on both computers. The user should enter a sentence on both sides. The sending must start when the first word is received from the other party or when Enter is pressed (send button).

Simplex protocol for a noisy channel	
(client side) The user types: **"Fear not! Java's networking is easy."**	Example session (server side)
sending "1:Fear received "**ACK**" sending "2:not!" received "**NACK**" sending "2:not!" received "**NACK**" sending "2:not!" received "**ACK**" sending "3:Java's" received "**ACK**" sending "4:networking" received "**ACK**" sending "5:is" "**Timeout**" sending "5:is" received "**ACK**" sending "6:easy." received "**ACK**"	receiving "1:Fear sending "**ACK**" receiving "*" (simulated error) sending "**NACK**" receiving "*" sending "**NACK**" receiving "2:not!" sending "**ACK**" receiving "3:Java's" sending "**ACK**" receiving "4:networking" sending "**ACK**" receiving "5:is" sending "**ACK**" receiving "5:is" (ignore because of duplicate sequence number.) receiving "6:easy." sending "**ACK**"

ACKs with duplicate sequence numbers are ignored. Use a graphical representation of the sliding window over the buffer (aka sequence number range), and display the change as sending continues e.g.:

0	1	2	3	4	5	6	7
ACK	ACK					ACK	ACK

0	1	2	3	4	5	6	7
	ACK	ACK	ACK				

Study unit 6

THE MEDIUM ACCESS CONTROL SUB-LAYER AND DLL SWITCHING

Study section 6.1
Channel allocation and Ethernet

Study time

The time scheduled for this section is 5 hours.

Study outcomes

At the end of this study unit you should be able to:

- describe the static way of channel allocation;
- explain the five key assumptions of dynamic channel allocation;
- describe the carrier sense multiple access protocols (including CSMA/CD);
- explain the development from Ethernet to Gigabit Ethernet;
- distinguish the cabling requirements and technical limits of different Ethernet types;
- give a retrospective on Ethernet and compare the advantages and disadvantages.

Study material

Study from Tanenbaum:

- 4.0 Channel allocation; 4.1.1 Static Channel Allocation; 4.1.2 Assumptions for Dynamic Channel Allocation
- 4.2 MULTIPLE ACCESS PROTOCOLS; 4.2.2 CSMA; 4.2.5 Wireless LAN Protocols
- 4.3 ETHERNET (all sections)

Individual activity

Test your knowledge and insight with the following questions:

1. Explain the static channel allocation method used in LANs and MANs.
2. Discuss the five assumptions of all dynamic channel allocation protocols.
3. Discuss the different persistent and not-persistent CSMA protocols.
4. Describe the operation of the carrier sense multiple access protocol with collision detection (CSMA/CD).

Individual activity

Do chapter 4 **exercises 8(a)** in writing and bring it to the next class.

Individual PC assignment

1. Lab 9.8.2: Cisco Switch MAC Table Examination

Study section 6.2
Wireless LAN and Bluetooth

Study time

The time scheduled for this section is 5 hours.

Study outcomes

At the end of this study section you should be able to:

- show the relationship between the 802.11 Protocol stack, Physical layer and MAC sub-layer
- describe the 5 distribution services and 4 station services of wireless LAN
- compare wireless LAN (802.11) with “broadband” wireless MAN (802.16)
- discuss the 4 service classes of the 802.16 MAC sub-layer
- discuss the need for personal area networks (PANs) leading to Bluetooth (802.15)
- explain the Bluetooth protocol architecture
- give an opinion about the medium access control sub-layers of different systems in terms of your acquired knowledge, and to communicate it in scientific language.

Study material

Study from Tanenbaum:

- 4.4 WIRELESS LANS (all sections)
- 4.5 BROADBAND WIRELESS; 4.5.1 Comparison of 802.16 with 802.11 and 3G; 4.5.2 The 802.16 Architecture and Protocol Stack
- 4.6 BLUETOOTH; 4.6.1 Bluetooth Architecture; 4.6.2 Bluetooth Applications; 4.6.3 The Bluetooth Protocol Stack

Individual activity

Test your knowledge and insight with the following questions:

1. Why can the 802.11 standard not be used for broadband wireless?
2. Explain the CSMA/CA (CSMA with Collision Avoidance) protocol.
3. In which protocol(s) or layer(s) of the wireless networks is Hamming code used? Why?
4. Describe the different Bluetooth profiles.

Study section 6.3
Data Link Layer switching

Study time

The time scheduled for this section is 2 hours.

Study outcomes

At the end of this study section you should be able to:

- explain the need for, possibilities of and obstacles for internetworking;
- describe the differences between and use of:
  repeaters, hubs, bridges, switches, routers and gateways;
- explain the concept and implementation of Virtual LANs.

Study material

Study from Tanenbaum:

- 4.8 DATA LINK LAYER SWITCHING;
  4.8.1 Uses of Bridges;
  4.8.2 Learning Bridges;
  4.8.3 Spanning Tree Bridges;
  4.8.4 Repeaters, Hubs, Bridges, Switches, Routers, and Gateways;
  4.8.5 Virtual LANs;
- 4.9 SUMMARY

Individual activity

Test your knowledge and insight with the following questions:

1. Draw a diagram to show on which layers the following devices belong: repeaters, hubs, bridges, switches, routers and gateways
2. Discuss the methods used by bridges and switches to know the VLAN colour of an incoming frame.
3. Describe the following channel allocation methods:
    - FDM
    - TDM
    - CSMA/CD
    - MACA
    - MACW
    - Ethernet
    - CSMA/CA

Study unit 7
THE NETWORK LAYER – ROUTING

Study section 7.1
Network layer design and algorithms

Study time

The time scheduled for this section is 7 hours

Study outcomes

At the end of this study unit you should:

- be able to describe the store and forward of packets by a network.
- be able to explain the services offered by the Network layer to the Transport layer.
- be able to describe the implementation of the connectionless service
- be able to describe the implementation of the connection oriented service.
- be able to compare a virtual circuit subnet and a datagram subnet.
- be able to explain specific routing techniques and apply it to a given network problem.
- be able to represent the optimality principle
- be able to give an opinion about routing in terms of your acquired knowledge and communicate it (also in a group) in scientific language.

Study material

Study from Tanenbaum:

- 5.1 NETWORK LAYER DESIGN ISSUES (all sections)
- 5.2 ROUTING ALGORITHMS;
  5.2.1 The Optimality Principle;
  5.2.2 Shortest Path Algorithm
- 5.2.4 Distance Vector Routing
  Notes: A distributed version of Distance Vector Routing is used in RIP. (Routing Information Protocol. RIPv2 includes the ability to carry subnet information - supporting Classless Inter-Domain Routing (CIDR))
- 5.2.5 Link State Routing (e.g. OSPF).

Individual activity

Test your knowledge and insight with the following questions:

1. What are the 3 goals for the design of network layer services?
2. Explain the implementation of a connectionless service and a connection oriented service with the aid of a diagram.
3. Name five differences between a datagram subnet and a virtual circuit subnet.
4. What are the differences between a non-adaptive and adaptive routing algorithm?
5. Describe the optimality principle.

Individual activity

Do chapter 5 **exercises 1, 2 and 3** in writing and bring it to the next class

Study section 7.2
Routing tables in hosts and routers

Study time

The time scheduled for this section is 7 hours.

Study outcomes

At the end of this study unit you should be able to:

- Use the route command to modify a Windows and Linux computer routing table.
- Use a Telnet client to connect to a Cisco router.
- Examine router routes using basic Cisco IOS commands.

Individual PC assignment

Practical assignment:

Do Cisco "**Lab 5.5.2: Examining a Route**" as well as additions given on eFundi.

Study unit 8
THE NETWORK LAYER – INTERNET

Study section 8.1
Internet Protocol (IP)

Study time

The time scheduled for this study section is 5 hours

Study outcomes

At the end of this study section you should be able to:

- describe the ten principles to design a network layer.
- explain the different components of the Internet Protocol (IP)
- describe the structure of IP-packet headers (both IPv4 and IPv6)
- describe the structure of IP-addresses (both IPv4 and IPv6)
- explain the way routing is done in the Internet.
- give an opinion about the Internet Protocol in terms of your acquired knowledge and communicate it (also in a group) in scientific language.

Study material

Study from Tanenbaum:

- 5.6 THE NETWORK LAYER IN THE INTERNET; 5.6.1 The IP Version 4 Protocol;
  5.6.2 IP Addresses; 5.6.3 IP Version 6; 5.6.4 Internet Control Protocols
- 5.6.6 OSPF--An Interior Gateway Routing Protocol
- 5.7 SUMMARY

Individual activity

Test your knowledge and insight with the following questions:

1. Name and describe 10 principles for the design of a network layer.
2. Name and describe the different components of the IP header
3. How are IP addresses assigned to subnets of a network?

Individual activity

Do chapter 5 **exercises 37, 38 and 39** in writing and bring it to the next class

Individual PC assignment

Practical assignment:

Use use the Zenmap (nmap) software to examine a “honeyd” simulated network services (ports)

Study section 8.2
Routing – set up and troubleshooting

Study outcomes

At the end of this section you should be able to:

- Design a logical network with subnets.
- Configure the network topology physically in the laboratory.
- Configure the logical LAN topology.
- Verify LAN connectivity.

Individual PC assignment

1. Cisco Lab 10.6.1: Creating a Small Lab Topology (Planning and implementing subnets)
2. Cisco Lab 11.5.4: Network Testing
3. PacketTracer assignment**.**

Study unit 9
THE TRANSPORT LAYER

Study time

The time scheduled for this study unit is 9 hours

Study outcomes

At the end of this study unit you should be able to:

- explain why the transport layer is the key to understanding layered protocols;
- explain the need for transport layer services to higher layers and describe these services;
- describe the transport layer service primitives;
- distinguish the two main transport protocols of the Internet: UDP and TCP;
- fit the characteristics of UDP and TCP respectively to proposed applications;
- understand that network performance is typically dominated by protocol and TPDU processing overhead;
- give an opinion about the transport layer in terms of your acquired knowledge and communicate it (also in a group) in scientific language.

Study material

Study Tanenbaum:

- 6.1 THE TRANSPORT SERVICE;
  6.1.1 Services Provided to the Upper Layers;
  6.1.2 Transport Service Primitives
- 6.2 Elements of Transport Protocols (You can omit 6.2.1 – 6.2.6)
- 6.4 THE INTERNET TRANSPORT PROTOCOLS: UDP;
  6.4.1 Introduction to UDP;
  6.4.2 Remote Procedure Call;
  6.4.3 The Real-Time Transport Protocol
- 6.5 THE INTERNET TRANSPORT PROTOCOLS: TCP;
  6.5.1 Introduction to TCP;
  6.5.2 The TCP Service Model;
  6.5.3 The TCP Protocol; 6.5.4 The TCP Segment Header;
  6.5.5 TCP Connection Establishment; 6.5.6 TCP Connection Release
- 6.5.10 TCP Congestion Control; 6.5.11 The Future of TCP
- 6.6.1 Performance Problems in Computer Networks
- 6.8 SUMMARY

Individual activity

Test your knowledge and insight with the following questions:

1. Explain the statement “the transport protocol is end-to-end and not chained like the lower layers.”
2. A client sends a 128-byte request to a server located 100 km away over a 1-gigabit optical fiber. What is the efficiency of the line during the remote procedure call?
3. Consider the situation of the previous problem again. Compute the minimum possible response time both for the given 1-Gbps line and for a 1-Mbps line. What conclusion can you draw?
4. Both UDP and TCP use port numbers to identify the destination entity when delivering a message. Give two reasons for why these protocols invented a new abstract ID (port numbers), instead of using process IDs, which already existed when these protocols were designed.
5. Datagram fragmentation and reassembly are handled by IP and are invisible to TCP. Does this mean that TCP does not have to worry about data arriving in the wrong order? Explain your answer.

Practical Assignment to apply knowledge of several network layers together

Study outcomes

At the end of this assignment unit you should be able to demonstrate

- how a TCP segment is constructed, and explain the segment fields;
- how an IP packet is constructed, and explain the packet fields;
- how an Ethernet II frame is constructed, and explain the frame fields;
- what the contents is respectively of an ARP REQUEST and ARP REPLY.

Individual PC assignment

Lab 11.5.6: Final Case Study - Datagram Analysis with Wireshark

Study unit 10
THE APPLICATION LAYER

Study time

The time scheduled for this study unit is 7 hours

Study outcomes

At the end of this study unit you should be able to:

- have a basic overview of high level protocols in the TCP/IP model;
- describe the operation of the Domain Name System;
- explain the operation of e-mail;
- demonstrate your understanding of the SMTP protocol by directly interacting with a mail server using a terminal emulation program such as telnet to issue SMTP commands and receive feedback;
- write and understand a program operating op die application layer of a network;
- give an opinion about the application layer in terms of your acquired knowledge and communicate it (also in a group) in scientific language.

Study material

Study Tanenbaum:

- 7.1 DNS--THE DOMAIN NAME SYSTEM (all sub sections)
- 7.2 ELECTRONIC MAIL (all sub sections)

Individual activity

Test your knowledge and insight with the following questions:

1. How does an address such as *adele@art.ucsb.edu* get converted to the IP address format *adele@128.111.24.41 by* the Domain Name System?
2. Explain how domain names are organised by the DNS name space.
3. What is the purpose of resource records?
4. Describe the five basic functions of an e-mail system.
5. E-mail systems have two basic parts, namely the user agents and the message transfer agents. Discuss the purpose of the two parts respectively.
6. Name and discuss 10 MIME types/subtypes that exist.

Individual activity

Do chapter 7 exercises 1, 7 and 8

Individual PC assignment

Assignment 6

Revisit the Java Networking tutorial

Extend the program given in subsection “Reading from a URLConnection”.

Find out from internet sources or books in the library how to send e-mail with a Java program.

Purpose with this assignment:
To use 1 or more protocols on the application layer in a custom program. The program will have to interact with other software on the application layer and will be using services of lower layers in the process of doing so.

Assignment:

Write a Java program which monitors web pages at regular intervals and notify a user via e-mail when a page has changed.

Hints:
Maintain a file with URLs, dates, checksums and e-mail addresses.
Do not hard-code parameters such as the mail server address, but use a separate configuration file.