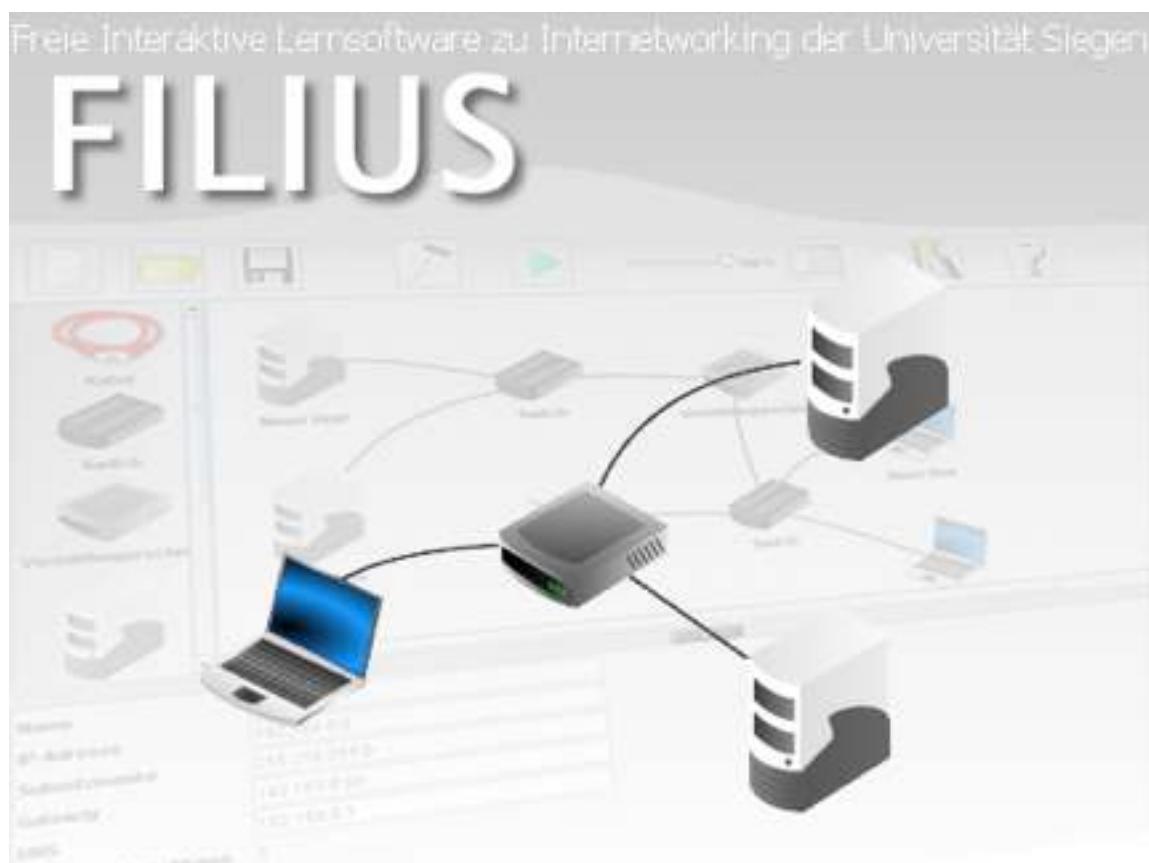


Introduction to the world of **FILIUS**

1



Author: Daniel Garmann (dgarmann@freenet.de), Gymnasium Odenthal (www.gymnasium-odenthal.de)

Translated into English by: Lukas Herbert (herbert.lukas@hotmail.de)

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¹ All pictures are taken from the software Filius. All rights are reserved by it's developers.

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Preliminary Remark

²FILIUS was initially developed by the University Siegen, Germany, to provide a tool for enhancing computer science lessons on networks. The main target group are students of secondary schools but with its wide range of applications it can be interesting for learners of any age. The software especially promotes explorative learning and is very helpful to teach students about the internet and its various applications.

This script is intended to show you as a teacher the possible ways of using FILIUS in the classroom. The different descriptions are always followed by example exercises with corresponding solutions available for download on the FILIUS website.

Design Of FILIUS

After the initial launch of the program (filius.exe or filius.jar) you are prompted with the option to choose the program language, which will be permanently saved³. From now on the program will appear in the following look:



The program decides between three different modes of work, the design mode, the simulation mode and the documentation mode:

To change to design mode, simply click the hammer () symbol in the toolbar on top. This mode is used to construct a network or apply changes to it. After the start of the program, FILIUS will always be in design mode.

² FILIUS stands for Free Interactive Learning Environment for Internetworking of the University Siegen.

³ This preference can be found in the user directory in the folder .filius, which can be deleted for reset.

To start simulation mode, click the green arrow ( in the toolbar. This mode is used for testing the network you built, installing different network applications on the computers and running these.

To reach the documentation mode, select the pencil ( in the toolbar on top. This mode provides the option to add your own annotations to the network and group certain parts of the network for better understanding.

Before starting to build the first network, here is a brief introduction to the essential parts of a network in FILIUS.

The Design Mode

Before building your first network, this chapter will make you familiar with the way the different components work in FILIUS. After that, we will use the various components to build and test networks, starting with some easy examples and increasing the complexity step by step.

Components in FILIUS

Filius provides a range of different components in the toolbar on the left hand side. These can be positioned, connected, modified and deleted in the workspace. To create a new component, use drag and drop to move the component anywhere in the white workspace. To connect two devices with a cable, select the cable in the toolbar and click on the components you want to link. Connections remain even when components are repositioned. Using a right click, you can delete any cable or component again. Now, we will learn about the basic functions of the different components and a deeper explanation will follow in the chapter on designing and testing networks in FILIUS.

Components Computer and Notebook

In the toolbar on the left hand side, FILIUS provides two different types of computers to be used in our virtual networks. Both computers are identical in the way they work and provide the same function but it makes sense to keep a logical distinction between the two. For a computer serving the task of a client, it is advised to use a

Notebook (, whereas for a computer serving the task of a server, we will use a

regular computer (). The components can be added by dragging them to the workspace, using the left mouse button. The configuration of a computer can be seen by using a double-click on the image or right click and select configure. The picture displayed underneath will appear and provide you the option to modify the name of

the computer, its IP address, its net mask and other settings. The standard configuration of a computer is displayed in the following picture.

Name	New Computer
MAC Address	34:8E:32:F6:13:8E
IP address	192.168.0.10
Netmask	255.255.255.0
Gateway	
Domain Name Server	

If you and your students are not familiar with the function of an IP address or subnet mask, please read the appendix A for a short description first.

Component Cable

Two computers can be connected using a cable (). After selecting the cable from the toolbar, you can first click on one and then the other component that you want to connect in your workspace, to establish a link between the two.

Component Switch

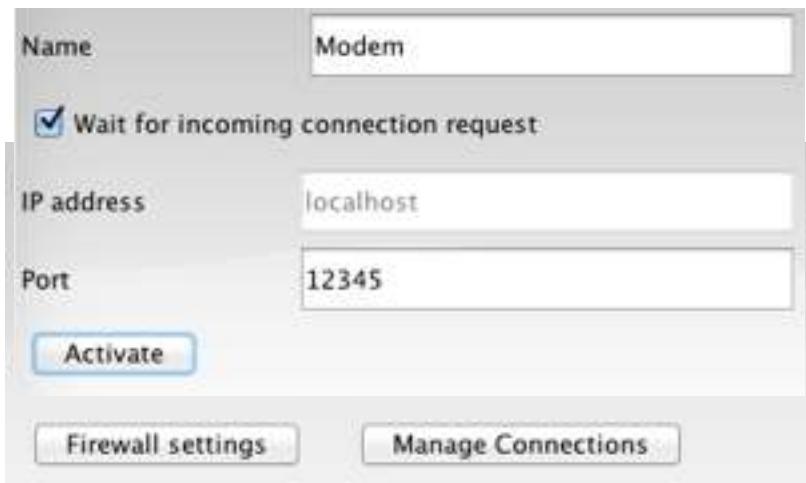
If you want to connect more than two computers with each other, you need a central hub. The easiest way of doing so is using a switch (). For a switch, the configuration can also be modified by double-clicking on the icon.

A switch remembers all connected components after the first request is sent in the network and redirects signals to their recipients. However, a switch can only connect computers of a single network.

Component Router

To send a network signal from one network to another one we need a router () to connect the two. In order for the router to work properly, all connected components have to lie in different networks. This also applies to single computers that may be directly connected to it.

After initialising a router, FILIUS asks how many NICs (Network Internet Card) it should have, that means how many interfaces to networks it should provide. This



configuration can later be changed in the configuration panel of the router, selecting the 'Manage Connections' option.

In the preferences panel you can also find a dedicated tab for each interface with the configuration of the NIC and its network. Modify the IP address according to the connected network, so that a signal can be rerouted correctly (usually the first IP address of the network). In addition, a gateway has to be added for every computer in the network. The exact preferences will be explained in detail in a later example.

Component Modem

FILIUS also provides the option to link several FILIUS-Programs running on different computers in a physically existing network, such as in a classroom. It is important to ensure that your firewall allows such connections. To use this features, all FILIUS-

Programs need to include a modem () in their virtual network. The modem in one of the virtual networks needs to be set as recipient, which can be done by ticking the box that says "Wait for incoming connection request", and then clicking the button "Activate" to start accepting incoming requests.

All modems of the other virtual networks can now establish a physically existing network connection by using the real network IP of the receiving modem. All modems will indicate a successful connection with a small green dot.

The Simulation Mode

Simulation mode is used to install software to the computers, remove it or start it. To change to simulation mode click the green arrow in the top hand toolbar (). FILIUS' main goal is to display network activity on the different layers of the OSI

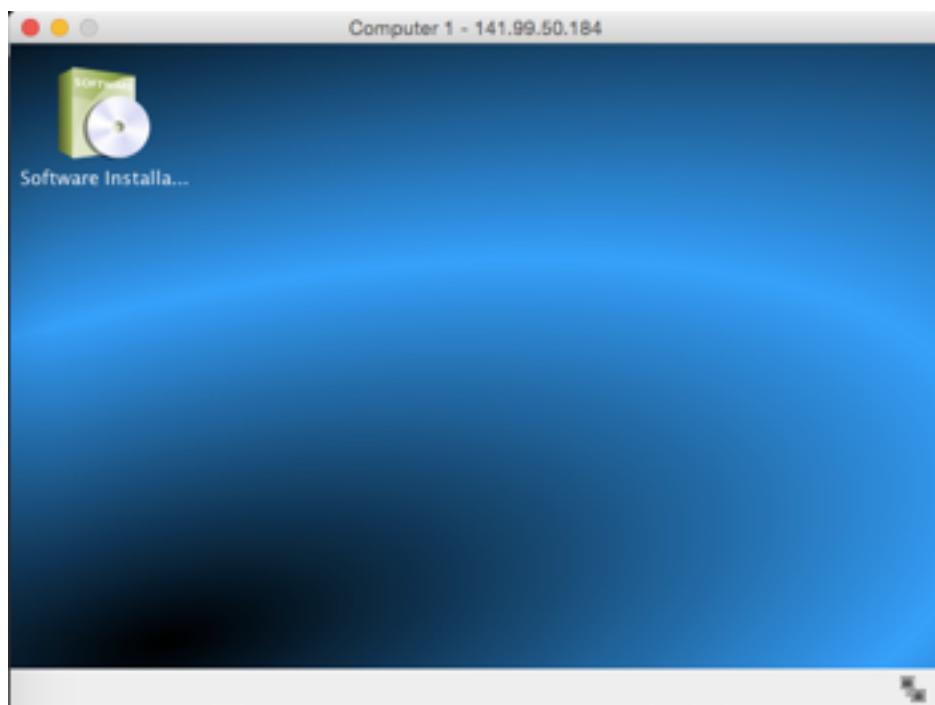
model to the user and thereby enhance the understanding of the functionality of networks.

To modify the speed in which the simulation will be displayed, use the control panel on top . This will adjust the speed of the display of signals in cables as well as in the OSI layers model, which can be seen by right clicking on any computer.

But before you will be able to see any network activity, it is necessary to install

No.	Time	Source	Destination	Protocol	Layer	Comment
1	19:35	181.99.58...181.99.58...	ARP	Internet	Search for MAC 181.99.58.238, 181.99.58...	
2	19:35	181.99.58...181.99.58...	ARP	Internet	Search for MAC 181.99.58.233, 181.99.58...	
3	19:35	181.99.58...181.99.58...	ARP	Internet	181.99.58.233: 181.77.96:CF:32:13	
4	19:35	181.99.58...181.99.58...	TCP	Transport	SYN, SEQ: 4233867973	
5	19:35	181.99.58...181.99.58...	TCP	Transport	SYN, ACK: 4857924646	
6	19:35	181.99.58...181.99.58...	TCP	Transport	ACK: 4857924687	
7	19:35	181.99.58...181.99.58...	Application	GET / HTTP/1.1 Host: www.films.de		
8	19:35	181.99.58...181.99.58...	TCP	Transport	ACK: 4233867973	
9	19:35	181.99.58...181.99.58...	Application	HTTP/1.1 200 OK Content-Type: text/html...		
10	19:35	181.99.58...181.99.58...	TCP	Transport	ACK: 4857924688	
11	19:35	181.99.58...181.99.58...	Application	GET /static/screen-m111.jpg HTTP/1.1 Host: www.films.de		
12	19:35	181.99.58...181.99.58...	TCP	Transport	ACK: 4233867975	
13	19:35	181.99.58...181.99.58...	Application	HTTP/1.1 200 OK Content-Type: image/jpeg...		
14	19:35	181.99.58...181.99.58...	TCP	Transport	ACK: 4857924689	
15	19:35	181.99.58...181.99.58...	Application	GET /index.html HTTP/1.1 Host: www.films.de		
16	19:35	181.99.58...181.99.58...	TCP	Transport	ACK: 4857924698	

software to the computers. Using a double click or right click on a computer will provide you with the desktop the selected device:



By clicking on the symbol for software installation (), you can install () and uninstall () software on that computer. Following is a brief description of the functions of the different pieces of software.

Network Applications in FILIUS

FILIUS has three different types of applications: client applications, server applications and system applications. These will be briefly explained according to their group.

System Applications in FILIUS

File Explorer : This application enables you to copy actual existing files from your computer's hard drive on to a virtual computer in FILIUS.

Command Line : The command line lets you manage the computer by using certain commands that will be displayed on startup of the terminal.

Text Editor : Using the text editor, you can create simple text files, for example HTML, and modify them. You can also modify files that you previously imported using the file explorer.

Firewall : The firewall can be used to open or close certain ports within the network.

Image Viewer : With this program you can open and view images.

Client Applications in FILIUS

Email program : This piece of software lets you virtually send and receive Emails.

Webbrowser : The web browser enables you to view websites. It can handle all basic html commands.

Generic Client : The client is used to connect to a server. It can be used to test whether the network is properly connected.

Gnutella : Gnutella is a peer-to-peer application which allows you to share files within a virtual network.

Server Applications in FILIUS

DNS Server : The DNS server is used to simulate the translation of symbolic URLs into their according IPs.

Email Server : Using an Email server, you can create different Email accounts which can then be used by the Email program on a client computer.

Webserver : This application transforms a computer into a web server, that enables clients to view a website stored on the server, using the web browser. The default website is defined by the file index.html in the virtual directory root/webserver.

Echo server : Once started, the echo server replies to all requests of clients by sending back the received message.

The Documentation Mode

Since version 1.6.0, FILIUS allows the user to document network structures and group them symbolically. To start documentation mode click on the icon displaying a pencil ().

Possible Ways Of Documentation

FILIUS provides two different ways of documentation in this mode, which will be briefly explained. From here on, the script will not focus on using the documentation mode any more but it is up to the user to meaningfully label or group their virtual networks.

Using text fields () , the user can add information regarding the virtual network. Text fields have no influence on the behaviour of the network in design mode or on the network activity in simulation mode.

The same is true for structure fields () . They can be used to symbolically group single components of a network in a meaningful way. The field can be dragged to the right size and will appear in the background upon exiting the documentation mode.

By using the export button () , your virtual network can be saved as a portable network graphic (PNG-file).

Designing and Testing Networks in FILIUS

In the following chapter, we will design and test different networks of, starting with easy examples and rising in complexity. Therefore, a constant switching between

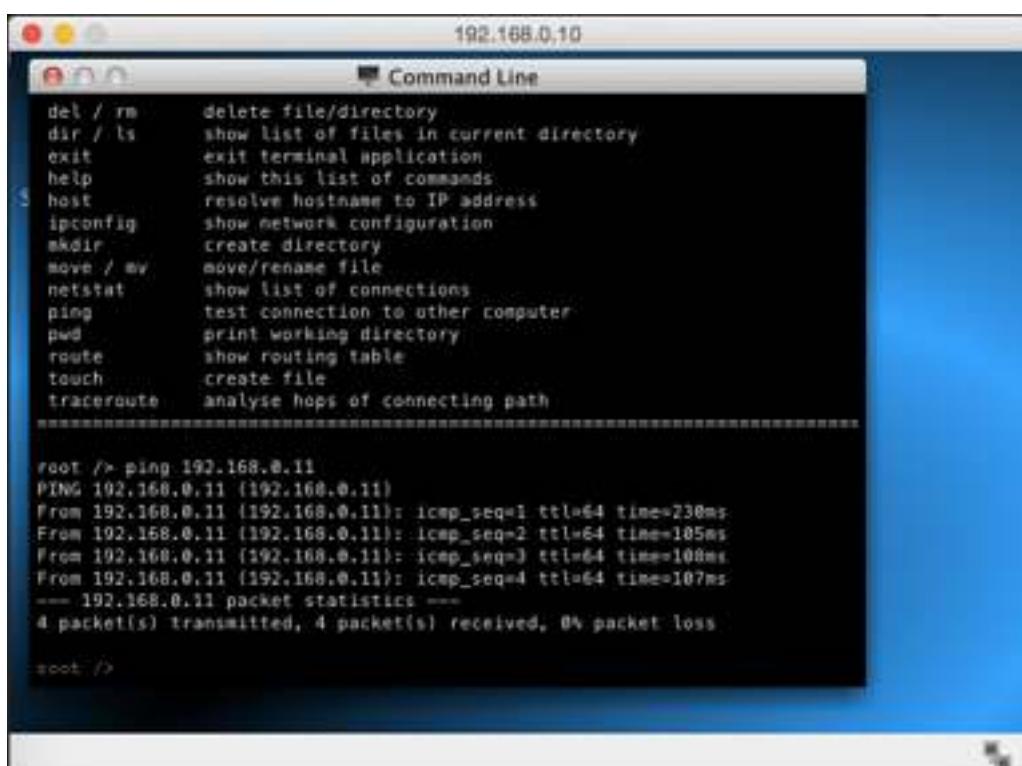
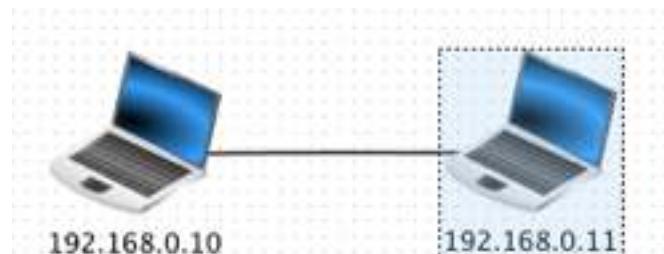
design and simulation mode is necessary. The symbol on the left of each exercise indicates whether it is to be done in design () - or simulation () mode.

Direct Link

The simplest way of connecting to computers is through a direct link using only a network cable. This is called a peer-to-peer connection. With this type of connection, computers can be connected using a twisted pair cable to enable the transfer of data between the two.

Exercise 1: Create a simple network with two linked computers, serving as clients. Configure the computers with the below shown names and the IP addresses 192.168.0.10 and 192.168.0.11. Using the subnet mask 255.255.255.0 ensures that both computers are part of the same network.

Note: If you don't want to manually name each computers, use the option "Use IP address as Name" to let FILIUS automatically set the computer's name as its IP address.



```
192.168.0.10
Command Line
del / rm      delete file/directory
dir / ls      show list of files in current directory
exit          exit terminal application
help          show this list of commands
host          resolve hostname to IP address
ipconfig       show network configuration
mkdir         create directory
move / mv      move/ rename file
netstat        show list of connections
ping          test connection to other computer
pwd           print working directory
route          show routing table
touch          create file
traceroute    analyse hops of connecting path
=====
root /> ping 192.168.0.11
PING 192.168.0.11 (192.168.0.11)
From 192.168.0.11 (192.168.0.11): icmp_seq=1 ttl=64 time=230ms
From 192.168.0.11 (192.168.0.11): icmp_seq=2 ttl=64 time=105ms
From 192.168.0.11 (192.168.0.11): icmp_seq=3 ttl=64 time=100ms
From 192.168.0.11 (192.168.0.11): icmp_seq=4 ttl=64 time=107ms
--- 192.168.0.11 packet statistics ---
4 packet(s) transmitted, 4 packet(s) received, 0% packet loss
root />
```

Exercise 2a: Select the computer with IP address ending with 0.10 and install the command line on it. Start the command line and test the connection to computer 0.11 using the command `ping 192.168.0.11`. Inspect the network activity by displaying the exchanged data of computer 0.10 in the OSI model.

The command line shows that the computer sends four requests (`ping` command) to the other computer and each time, waits for a response (`pong` command). This data exchange can also be displayed in the data exchange window. Here, the first two lines belong to the address resolution protocol, which is used to find out the physical address of the other computer. The following eight lines stand for the exchange of the `ping-pong` commands, where always two lines form a pair. They belong to the internet control message protocol, which is part of the internet protocol IPv4.

Data exchange						
192.168.0.10						
No.	Time	Source	Destination	Proto...	Layer	Comment
1	06:29...	192.168.0.10	192.168.0.11	ARP	Internet	Search for MAC 192.168.0.11, 192.168.0.1...
2	06:29...	192.168.0.11	192.168.0.10	ARP	Internet	192.168.0.11: 75:C8:33:0B:28:55
3	06:29...	192.168.0.10	192.168.0.11	ICMP	Internet	ICMP Echo Request (ping), TTL: 64, Seq.-Nr...
4	06:29...	192.168.0.11	192.168.0.10	ICMP	Internet	ICMP Echo Reply (pong), TTL: 64, Seq.-Nr...
5	06:29...	192.168.0.10	192.168.0.11	ICMP	Internet	ICMP Echo Request (ping), TTL: 64, Seq.-Nr...
6	06:29...	192.168.0.11	192.168.0.10	ICMP	Internet	ICMP Echo Reply (pong), TTL: 64, Seq.-Nr...
7	06:29...	192.168.0.10	192.168.0.11	ICMP	Internet	ICMP Echo Request (ping), TTL: 64, Seq.-Nr...
8	06:29...	192.168.0.11	192.168.0.10	ICMP	Internet	ICMP Echo Reply (pong), TTL: 64, Seq.-Nr...
9	06:29...	192.168.0.10	192.168.0.11	ICMP	Internet	ICMP Echo Request (ping), TTL: 64, Seq.-Nr...
10	06:29...	192.168.0.11	192.168.0.10	ICMP	Internet	ICMP Echo Reply (pong), TTL: 64, Seq.-Nr...

No.: 3 / Time: 06:29:05.402

Network

- Source: 02:A2:58:7C:13:D3
- Destination: 75:C8:33:0B:28:55
- Comment: 0x800

Internet

- Source: 192.168.0.10
- Destination: 192.168.0.11
- Protocol: ICMP
- Comment: ICMP Echo Request (ping), TTL: 64, Seq.-Nr.: 1

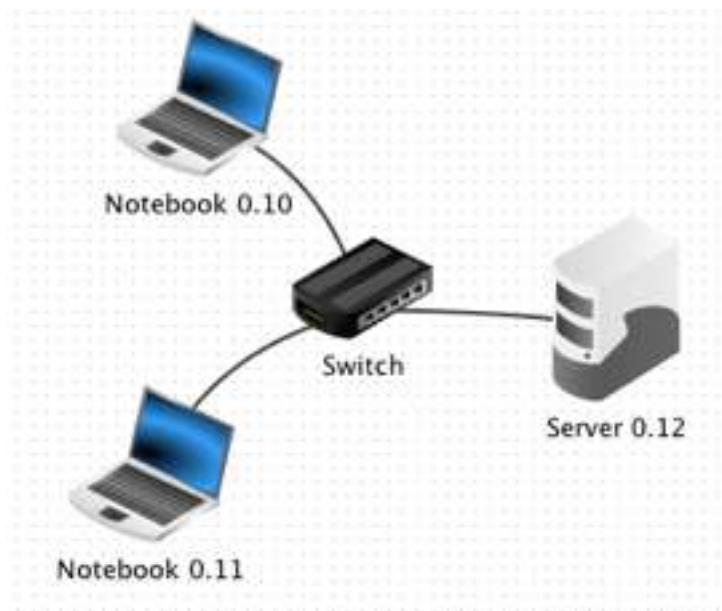
We can also observe that the network activity reaches only to the internet layer. The higher and more complex layers of the OSI model are not yet needed. By selecting one of the lines in the data exchange window, it is possible to view information on the lower layers of the OSI model as well as more detailed information on the layers in use.

Exercise 2b: Also try out other commands using the command line, such as ipconfig, host localhost or dir. The use of the host command will become clear in a later example including a DNS Server.

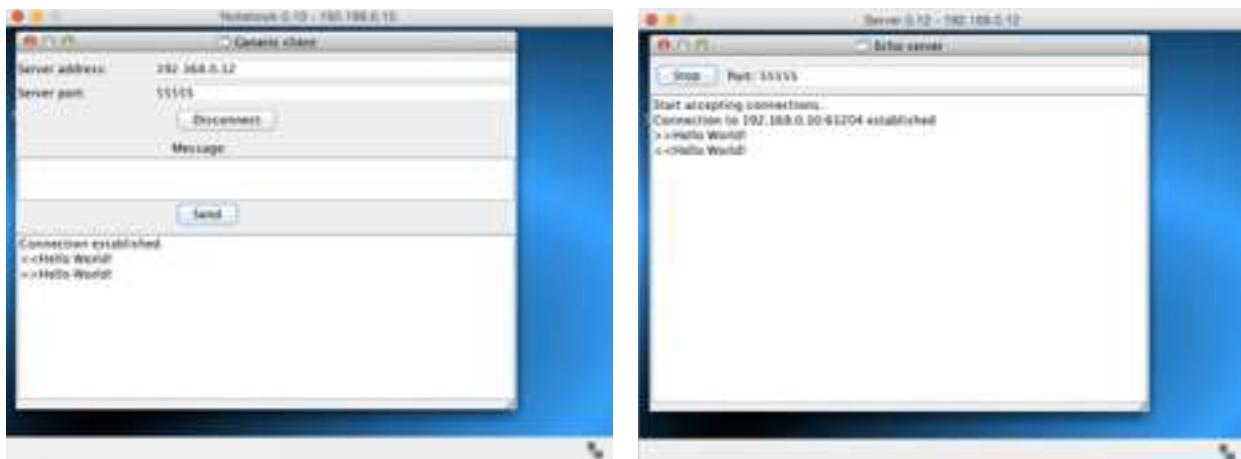
Connecting Computers Using a Switch

If you want to connect more than two computers to a network in FILIUS, it is necessary to use a switch, to which any desired number of computers can be connected. After the first use in simulation mode, a switch remembers the MAC addresses according to the IP addresses of all computers so that it can forward data packages faster. We will now use this component to connect three computers with one another.

Exercise 3: Now, expand your network with a third computer, a server, with the name displayed below and the IP address 192.168.0.12. Remember to use the  symbol for the purpose of a server. Then connect all three computers using a switch.



Exercise 4: Next, open the desktop of server 0.12, install an echo server to it and start it on the preset port 55555. Use one of the notebooks to install a generic client and connect it to the server. Try sending some text messages from the client to the server and observe the outcome. Also take a look at the network activity in the data exchange window of the notebook.



Data exchange						
No.	Time	Source	Destination	Proto...	Layer	Comment
11	12:21...	192.168.0.10	192.168.0.12	ARP	Internet	Search for MAC 192.168.0.12, 192.168.0.1...
12	12:21...	192.168.0.12	192.168.0.10	ARP	Internet	192.168.0.12: A1:07:20:BA:27:AE
13	12:21...	192.168.0...	192.168.0...	TCP	Transport	SYN, SEQ: 1278448526
14	12:21...	192.168.0...	192.168.0...	TCP	Transport	SYN, ACK:1278448527, SEQ: 4064208835
15	12:21...	192.168.0...	192.168.0...	TCP	Transport	ACK: 4064208836
16	12:21...	192.168.0...	192.168.0...		Application	Hello World!
17	12:21...	192.168.0...	192.168.0...	TCP	Transport	ACK: 1278448528
18	12:21...	192.168.0...	192.168.0...		Application	Hello World!
19	12:21...	192.168.0...	192.168.0...	TCP	Transport	ACK: 4064208837

The data exchange window shows that in this example, the transport layer is needed for the first time. Establishing the connection between client and server already uses three layers in the OSI model. The first two lines are again used to determine the MAC address, belonging to the IP of the server.

As soon as you send a message from client to server, the fourth layer, called application layer, comes into play. The application, which is the generic client, first of all uses the application layer, then the transport layer, the internet layer and finally the network layer. All this information will be displayed upon clicking on the first dark blue line in the data exchange model, which will display the image on the right.

In the following exercises, keep in mind to have a look at the data exchange window from time to time to get an idea what kind of information is being transmitted within the network. You will for example notice the huge amount of data that has to be transmitted while sending Emails.

No.:	16	/ Time:	12:21:23.521
	▼ Network		
Source:	76:C4:D1:06:5C:17		
Destination:	A1:07:2D:BA:27:AE		
Comment:	0x800		
	▼ Internet		
Source:	192.168.0.10		
Destination:	192.168.0.12		
Protocol:	IP		
Comment:	Protocol:6, TTL: 64		
	▼ Transport		
Source:	61204		
Destination:	55555		
Protocol:	TCP		
Comment:	SEQ: 1278448527		
	▼ Application		
Comment:	Hello World!		

Connecting two Networks Using a Router

Before installing and testing more software on the computers, we want to expand our existing network with three more computers.

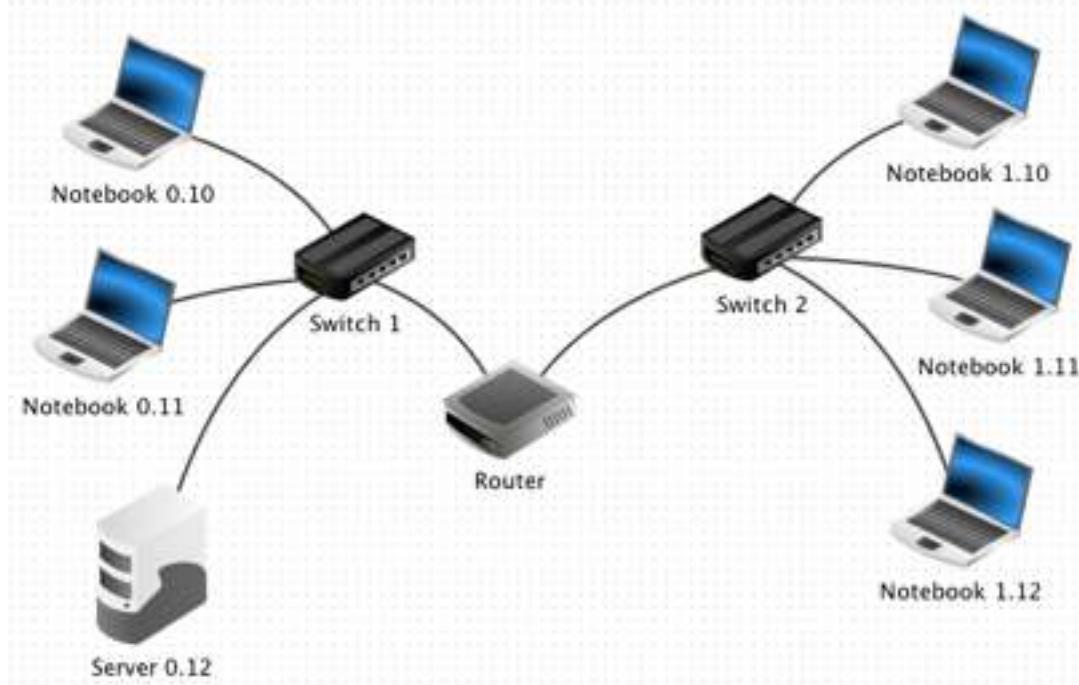
Exercise 5: Create a second network with three new computers as displayed



below. We want the three new computers to be in a logically different network for which we will use IPs 192.168.1.10 to 192.168.1.12. Finally, connect the two networks using a router and configure the two network interface cards with IPs 192.168.0.1 and 192.168.1.1.



Finally, test the connection between computers 0.10 and 1.10 using the ping command.



If you did everything as described above, FILIUS will display the following message in the command prompt:

```
root /> ping 192.168.1.10
Destination not reachable
root />
```

The reason for this response is, that the message would have to leave the local network. However, we haven't yet configured a gateway for the different computers, which would determine where messages that have to leave the network are forwarded to.

Exercise 6: The router has a network interface card with the address 192.168.0.1 which you will configure as a gateway for the three computers on the left hand side. Set the gateway for the three notebooks on the right hand side to 192.168.1.1 accordingly.



Now try the same connection again and it should work properly.



Name	Notebook 0.10
MAC Address	2A:DA:DA:A3:8F:0E
IP address	192.168.0.10
Netmask	255.255.255.0
Gateway	192.168.0.1
Domain Name Server	

When taking a look at the data exchange window, you can observe that the first request takes a lot longer than the following three. This is because the routing table of the two switches is empty at the beginning and is then created after the first request.

Exercise 7: Now try and test your network with a generic client and an echo server. Use Notebook 1.10 to install a generic client and connect it to server 0.12.



Simulation of the World Wide Web

The most important task of the internet today is surely the world wide web. Using FILIUS, you can simulate and analyse the basic processes involved in the communication between a web browser and a remote web server.

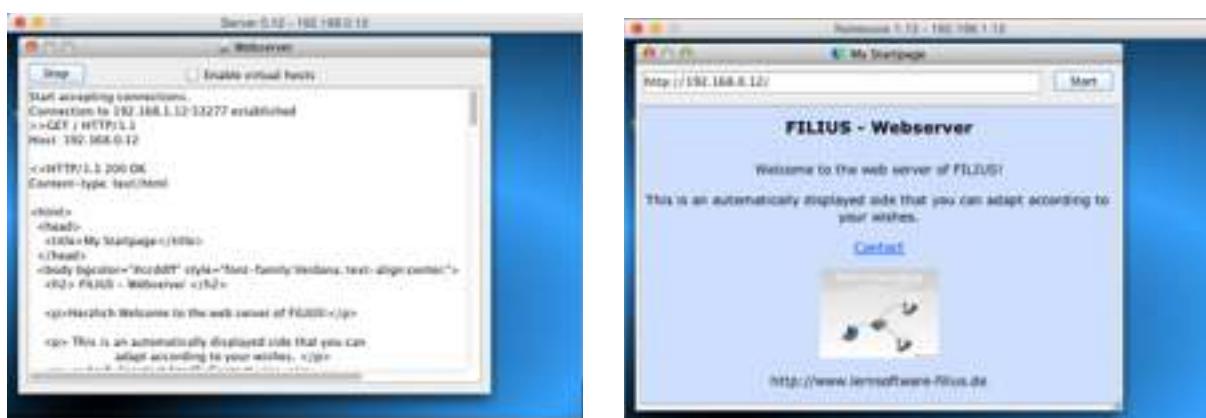
The network we have created in exercise 6 is sufficient for this task. We will use Server 0.12 as our web server and Notebook 1.10 as our client and web browser. But let's first set up our web server.

Exercise 8: Use Server 0.12 to install a web server and a text editor. Take the text editor to open the file index.html which can be found in the virtual directory root/webserver. Now you can modify the file in order to portray the information you like. Also create a new page with the name contact.html which you will link to from the first side.



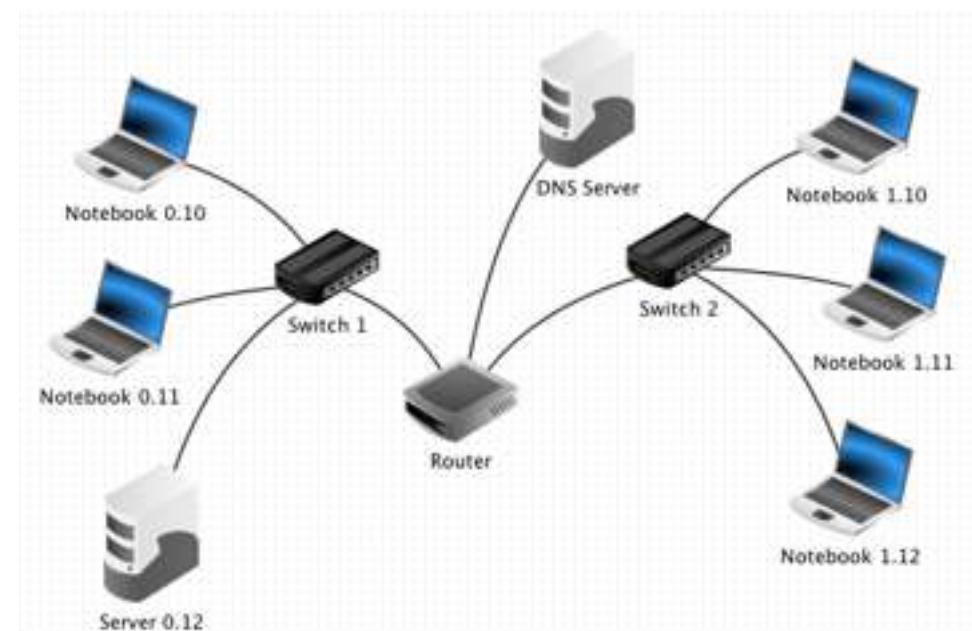
Exercise 9: On the desktop of your web server, start the application "Webserver" using a double click. Then start the virtual web server clicking the button Start. (left picture)

After that, switch to Notebook 1.10 to install a web browser. Start the browser and try to establish a connection to the web server by typing the URL <http://192.168.0.12> into the address field of your web browser. (right picture)



We established a connection but this is not the way we usually communicate with other web servers. Normally, we contact a website by typing its URL and not the IP address of the web server. The resolution between URL and the according IP address is done by a Domain Name Server, also called DNS server, which we will now configure.

Exercise 10: Create a new server with the IP address 192.168.2.10 and the gateway set to 192.168.2.1. Change the number of interfaces of your router to three by navigating to the “General” tab of its configuration and select the button “Manage Connections”. Now move to the tab of the new network interface card and modify the information of the IP address to 192.168.2.1 and the subnet mask to 255.255.255.0. Finally connect the new server to the router with a cable.



To enable all computers to use the service of the DNS server, we need to add the IP address of the DNS server to the configuration of every Notebook.

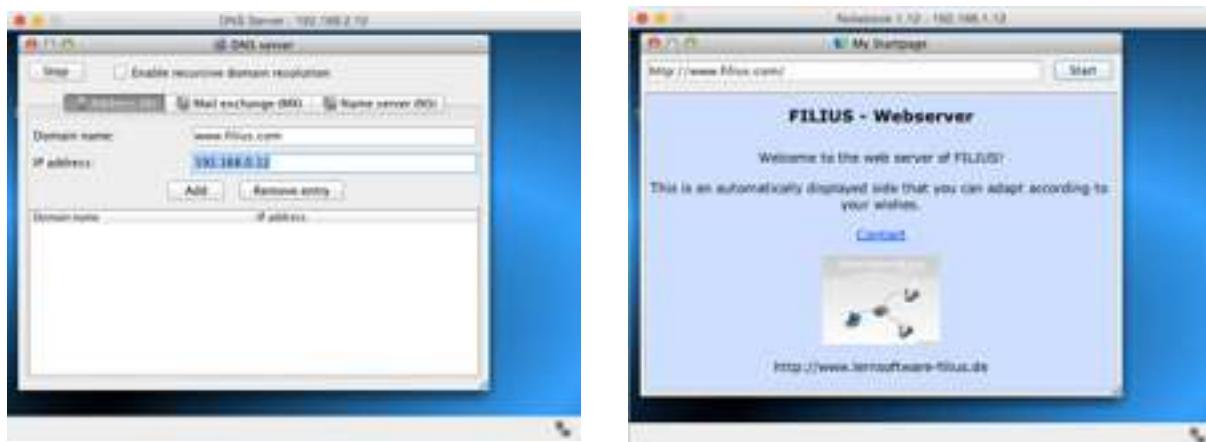
Exercise 11: Add the IP address of the DNS server 192.168.2.10 to the configuration of every Notebook.



Name	Notebook 0.10
MAC Address	98:7D:88:64:78:5D
IP address	192.168.0.10
Netmask	255.255.255.0
Gateway	192.168.0.1
Domain Name Server	192.168.2.10

Lastly, we need to give our web server a suitable URL and add it to the DNS server's reference table so that we can reach it through its name.

Exercise 12a: Select Server 2.10, install the application "DNS server" and start it with a double click. As Domain Name type in www.filius.com and below the IP address 192.168.0.12, belonging to our server. Then click the Add button to add the entry to the DNS server's reference table. Finally start the DNS server by clicking the "Start" button (left picture) and test the connection by using your web browser on a Notebook and searching for the URL <http://www.filius.com> (right picture).



If the web browser returns the message "Server does not exist!", the reason is most likely that you haven't yet started the DNS server or you asked for a URL that you haven't yet added to the reference table of your DNS server.

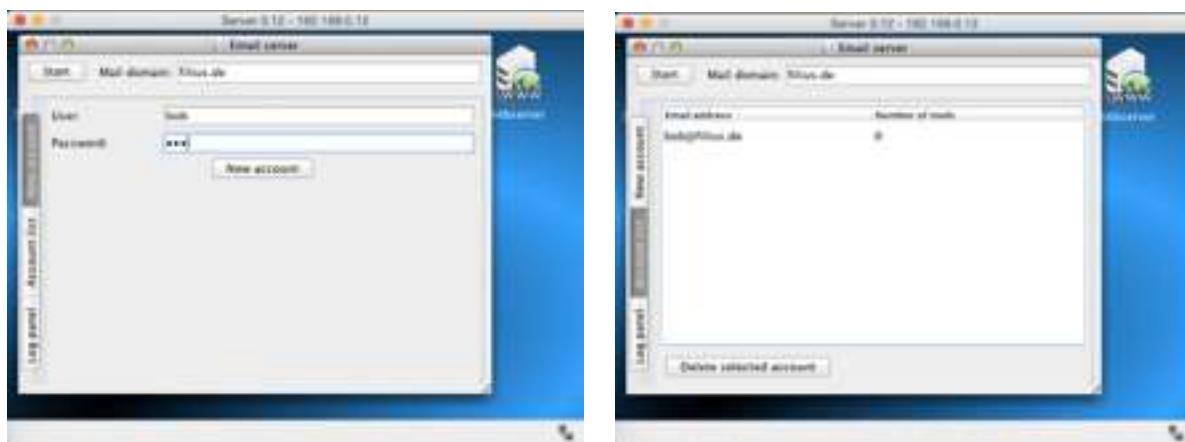
Exercise 12b: At the beginning of our tutorial, we learned about the host command in the terminal. Now try again to use the host command with the URL www.filius.com. Now you will see that the DNS server does its job and returns the IP of the web server.

```
root /> host www.filius.com
www.filius.com has the IP address 192.168.0.12
root /> |
```

Email Service in Your Network

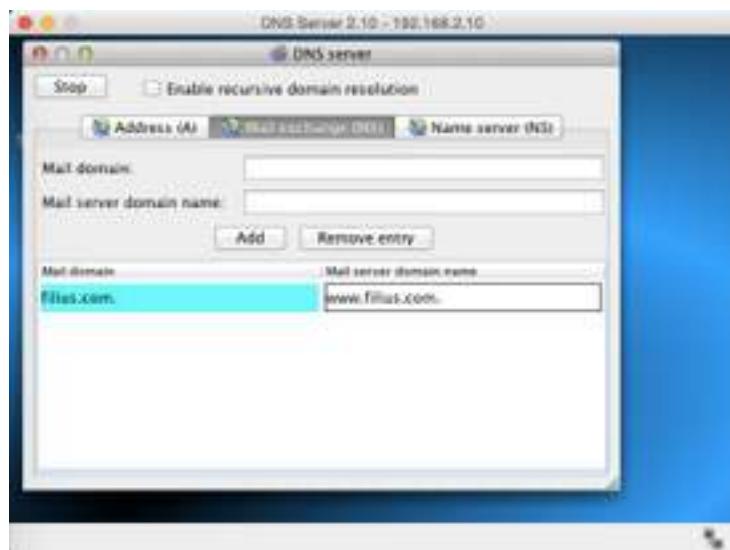
FILIUS provides the feature of simulating the work of different Email servers and the way they interact. At first, we will configure a single Email server and use a Notebook with an Email Programm installed to use the Email service. Later we will install several Email servers that are linked to each other.

Exercise 13: Select Server 0.12 to install the application “Email server” and start it by using a double click. Create a new account with username “bob” and password “bob” (left image). See how your new account appears in the account list. Then start the server using the start button.



Next, we need to set up our DNS server to make it accept the new mail domain.

Exercise 14: Start the application “DNS server” on Server 2.10. Add a new mail exchange with the mail domain filius.com and the mail server domain name www.filius.com. Then restart the server.



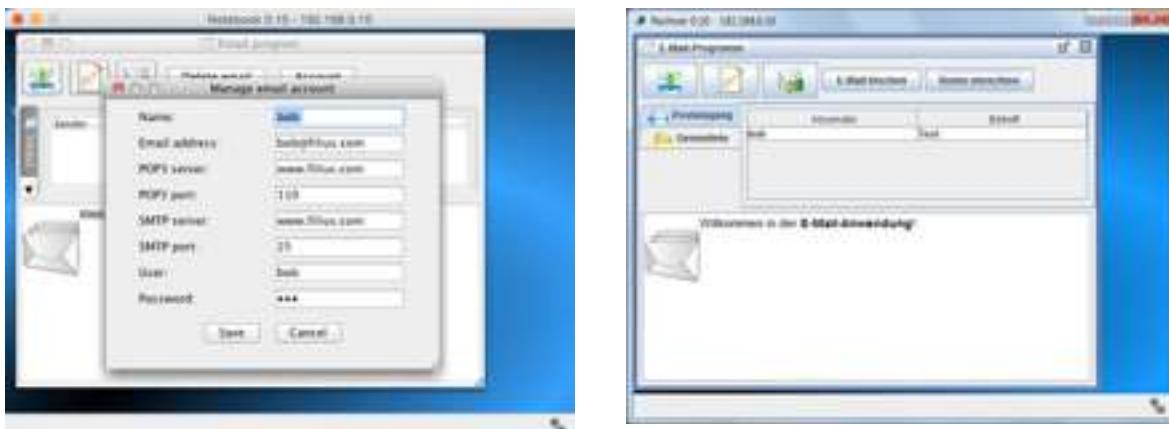
Finally we need to install the Email program to one of our notebooks and configure it.⁴

Exercise 15: Select Notebook 0.10 to install the new application “Email program” and launch it. Click on the button “Account” to create a new account and configure it with the following information of your Email server (left picture):

Name: bob
Email address: bob@filius.com
POP3 server: www.filius.com
POP3 port: 110
SMTP server: www.filius.com
SMTP port: 25
Username: bob
Password: bob

After that, send an Email to bob@filius.com (that means to yourself) and then retrieve your mails (right picture).

⁴ The function for sending a mail did not work on my Mac so there is the picture of the German version running FILIUS on Windows. I hope it works for you and the problem will be solved soon.



Exercise 16: Next, add another Email address to the Email server with the name  bert@filius.com. Also set up an Email programm on Notebook 0.11 so that Bob and Bert can send emails to each other.

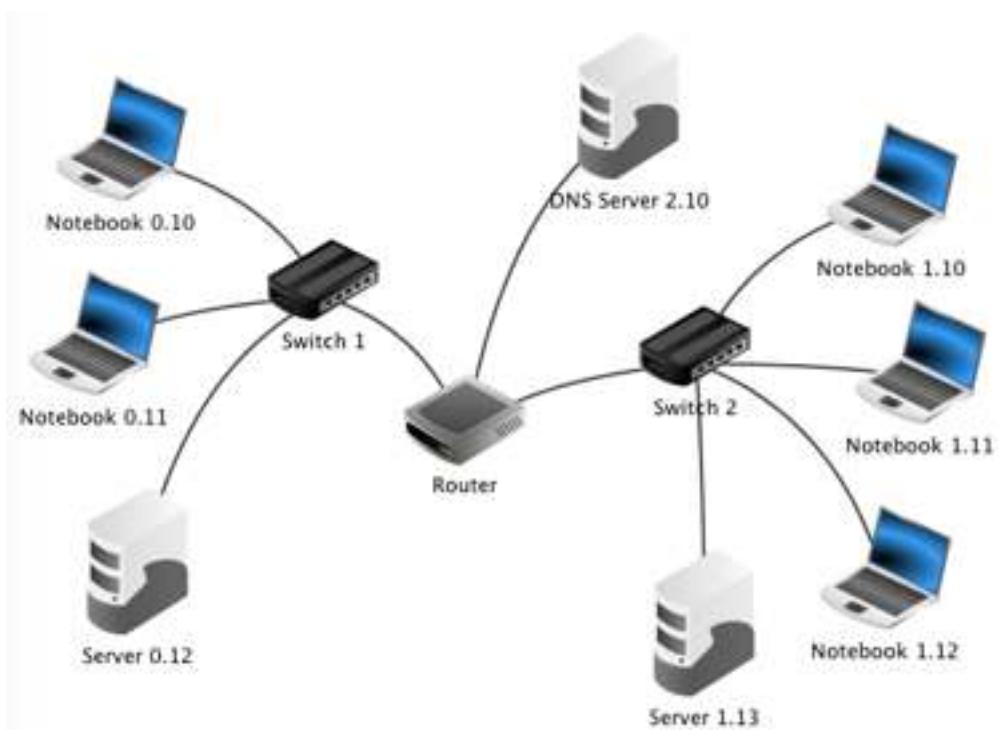
Lastly, we will set up a second Email server, which we want to add to the right side of our network (192.168.1.0).

Exercise 17: Add another server with the name Server 1.13 to the right side of your network and install a mailserver with the mail domain filia.com on it. Finally add an account with the name alice@filia.com to the server.

Also extend the mail exchange table of your DNS server, so that the new mail domain will be excepted.

Take Notebook 1.10 to install an Email programm and configure it for the account alice@filia.com.

Lastly, try sending Email between the two accounts bob@filius.com and alice@filia.com.



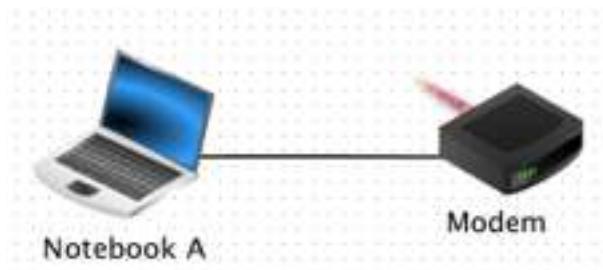
Prospect

If you followed the tutorial up to here, you have mastered all the basic functions of FILIUS. From here on, I will give a little prospect of further possibilities of FILIUS. In how far these can be integrated into your teaching plans depends on the strength of your students and the configuration of your classroom network.

Virtual Networks and Physical Networks

In the chapter on the components of FILIUS we already talked about the modem as providing the possibility to leave the virtual network and send signals over a physically existing network. A premise for this is, of course, a physically existing network of at least two computers running FILIUS, and a local firewall that is configured not to block FILIUS' signals.

You can get an impression of this setup through the following example, where only one Notebook is able to communicate with the physically existing network via a modem.

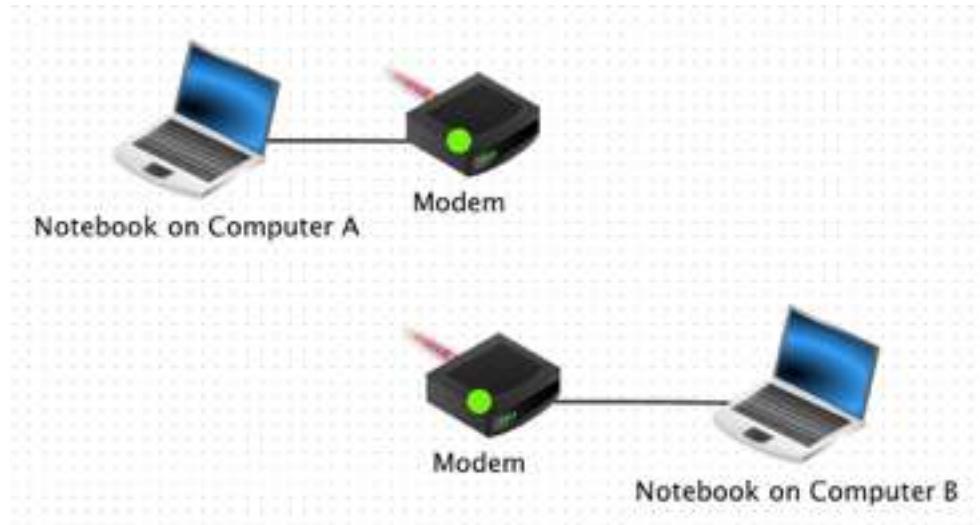


Exercise 18: Create the network structure displayed below on two (physically) different computers (let's call them Computer A and Computer B) with different computer IPs that are part of a physical network. On computer A, set the modem to accept incoming requests, ticking the box "Wait for incoming connection request", and click the button "Activate".



On Computer B, configure the modem so that it connects to Computer A. For this purpose, insert the physical IP of Computer A in the field named IP address and press the button "Connect". (If you want to try this on one computer, simply write 'localhost' as the IP address and choose any port.)

Both modems will show a green light if connected successfully.



If connecting the two modems worked, you can now set up the two virtual notebooks for network communication. You can for example install and echo server on the virtual notebook on Computer A and a generic client on the virtual notebook on Computer B. After starting the echo server, the virtual notebook on Computer B should be able to communicate with it over the physical network.

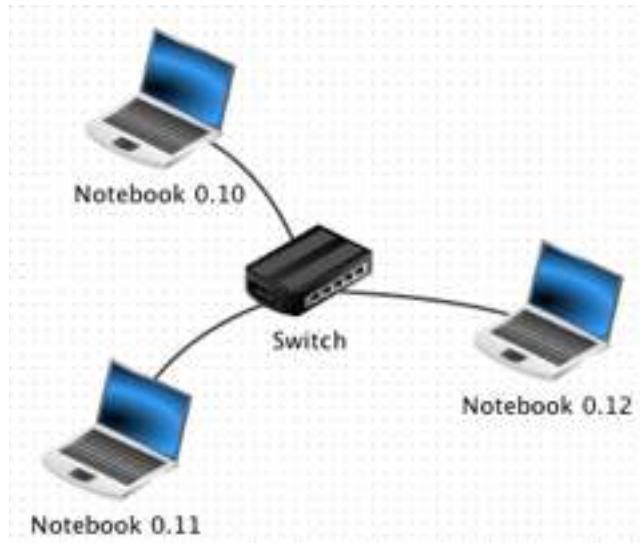
Exercise 19: Install an echo server and a generic client to the virtual notebooks on Computers A and B. Then start the echo server and connect and test the generic client.



Now you can also test other applications on the virtual computers. Also have a look at the data exchange between the both.

Exchanging Files via Peer-To-Peer

FILIUS offers the option to connect several computers to a peer-to-peer network and share files throughout the network using the application Gnutella. All computers in such kind of network serve the function of a client and can connect to all other computers of the network, which is why we use a notebook for this exercise.



Exercise 20: Create the network as displayed above, connecting three laptops using a switch to a peer-to-peer network.



Then, install the application “Gnutella” to all three computers and additionally a “File explorer” to Notebook 0.10.



Start the file explorer and copy the file “index.html” from the directory “webserver” to the directory “peer2peer”, using a right click.

Next, launch the application “Gnutella” on Notebook 0.12 and join the network of Notebook 0.10 (IP address 192.168.0.10). The list of connected neighbours should refresh automatically (left picture).

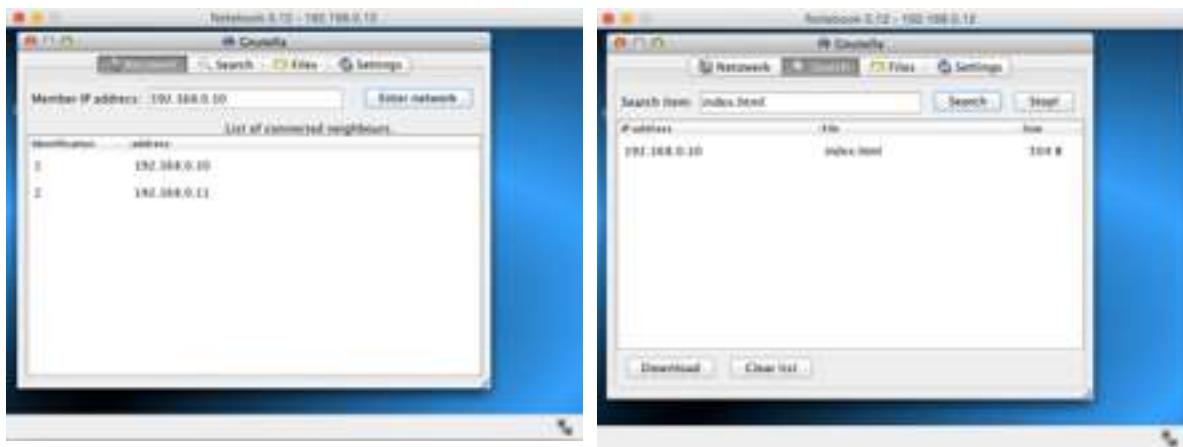
Now you can search the peer-to-peer network for files named “index.html” and download them (right picture).

Name	DHCP Server	<input type="checkbox"/> Use IP address as Name
MAC Address	9A:86:83:FC:01:98	<input type="checkbox"/> Use DHCP for configuration
IP address	10.0.0.10	DHCP server setup
Netmask	255.255.255.0	
Gateway		
Domain Name Server		

Setting Up a DHCP Server

Especially in large networks it is practical to set up a DHCP server which takes over the function of assigning IP addresses to the computers automatically. FILIUS provides the possibility to simulate just that. In the following exercise we will implement a DHCP server to our network of the previous exercise.





Exercise 21a: Implement a DHCP server into your existing network and rename all notebooks in order to suggest that the IP address assignment now works automatically.



Configure the new server with the IP address 10.0.0.10 and then set it up as a DHCP server by clicking the button as shown in the picture below.

Now, a dialogue that asks you to server settings. address range 10.0.0.200 and ticking the box



box will pop up
enter the DHCP
Select the IP
from 10.0.0.100 to
activate DHCP by
“Active DHCP”.

Exercise 21b: Next, for each computer, tick the box “Use DHCP for configuration” to use the DHCP server for IP address assignment. You will notice that you will not be able to manually change the configurations anymore.



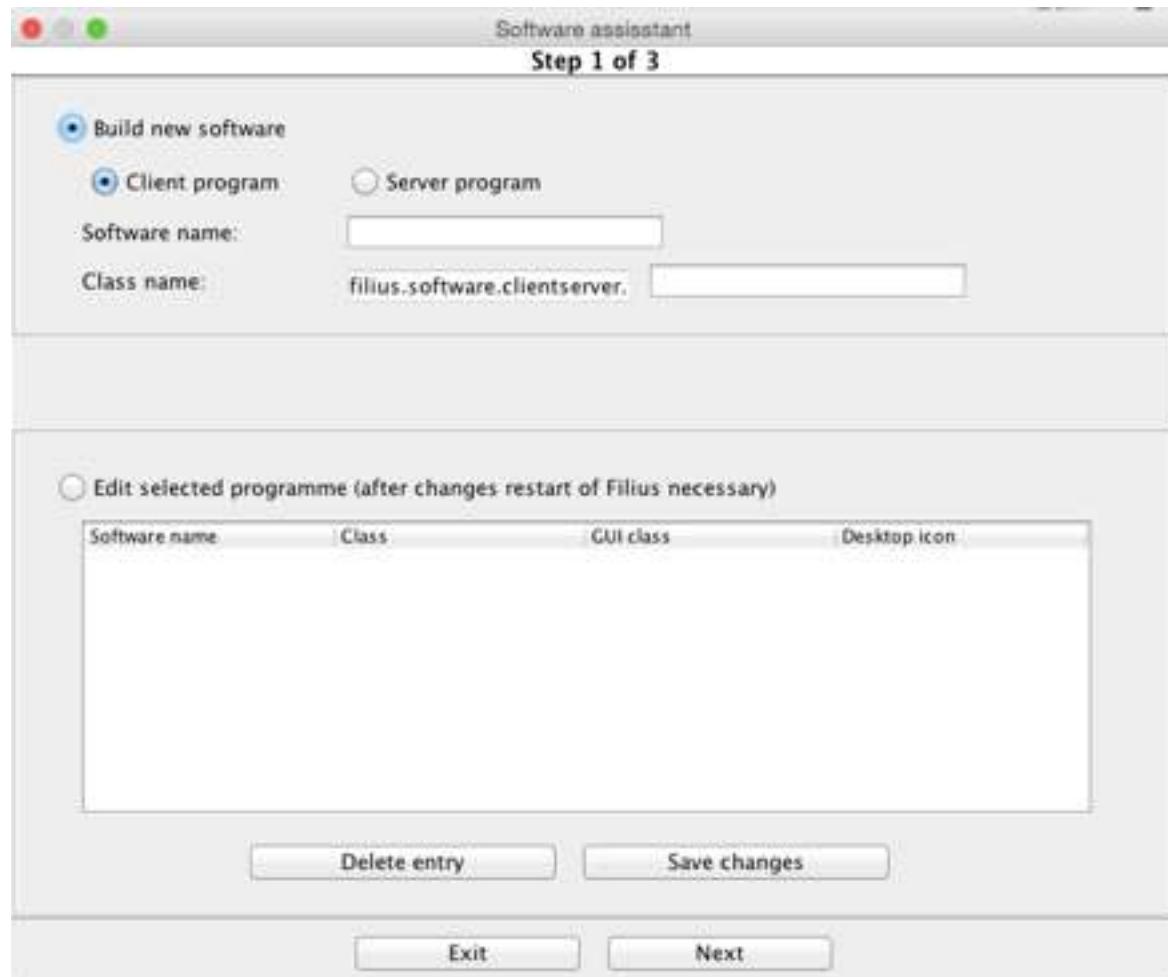


As soon as you switch to simulation mode, the clients will be assigned an IP address by the DHCP server. All wires will blink for a short time to set up the new configurations. (If this does not happen, FILIUS might still have old settings stored to the switch and you will have to restart the application.)

Now start each computer and install a command line to it. Then test which IP address the computers have been assigned by the DHCP server by using the ipconfig command.

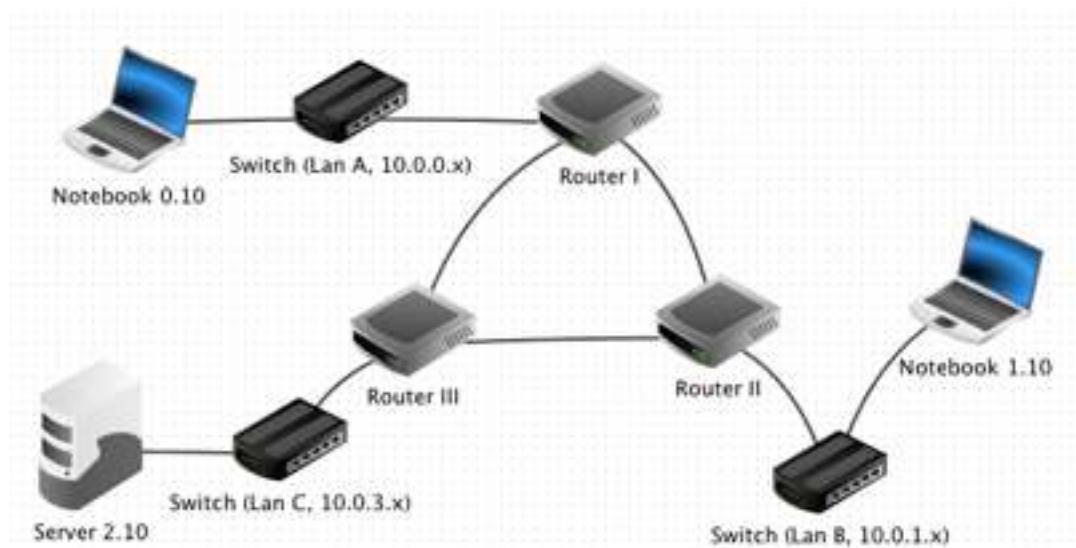
Creating and Implementing Your Own Software

FILIUS even provides the option to create your own software and install it to the virtual computers. With the magic wand symbol () you can reach a 3 step assistant which enables you to integrate your own software, for example a chat server and client application. FILIUS holds some code outlines in Java in the second step, which are unfortunately not yet translated to English. Maybe this feature will follow soon or you can figure out how to write applications within FILIUS by yourself.



Routing Through Several Computers (Manual Routing)

In the chapter on connecting two networks using a router we restricted the traffic to flow through only one router. In reality, things look a little bit different, because the internet is a vast web of uncountable switches and numerous possible ways for a data package to go. It can never be determined which way it will take. Let's have a look at the following, still simple, example:



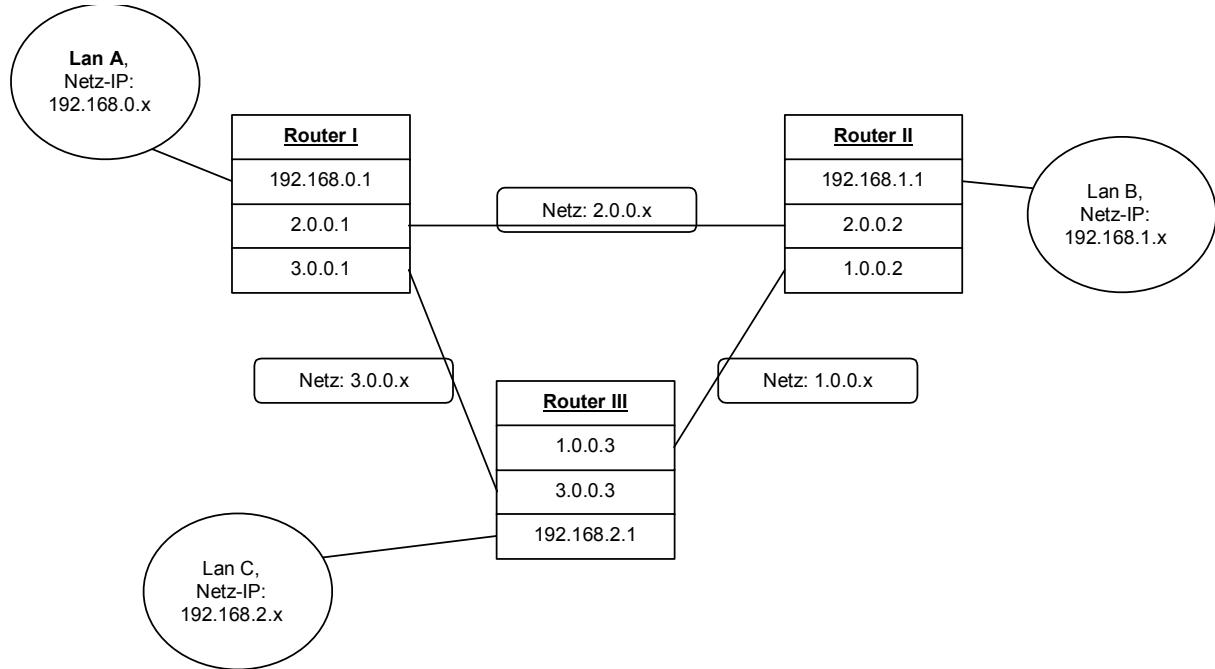
Exercise 22a: Create the network displayed above. Configure Router I so that it is connected to Router II in network 2.0.0.x and to Router III in network 3.0.0.x. Configure Router I with the first addresses of each network.



Then, configure Router II to be connected to Router III in network 1.0.0.x and with the second IP address of each network.

Finally, configure Router III with the third IP of each network.

All together the new network will look like this⁵:



Now we are still missing the settings for packet forwarding. First of all, configure the gateways for the computers of the different networks:

Exercise Set the gateway of Notebook 0.10 in Lan A to 192.168.0.1, so that
22b: Router I will be used as its gateway. Then, set the gateway of
 Notebook 1.10 from Lan B to 192.168.1.1 and the gateway of
 Notebook 2.10 from Lan C to 192.168.2.1 accordingly.

Since version 1.4.5 of FILIUS routers are able to run routing automatically. For using this option simply tick the box “Automatic Routing” in the configuration of each router and the routing information protocol will do the job of finding the shortest way within the network.

⁵ The diagram is taken from the German version of this script, that is why “Netz” should be read as network by speakers of English.

For a better understanding of how routing actually works, it is still possible to manually configure the routing in FILIUS. Every router has its own forwarding table which describes how incoming data packets are to be forwarded. The following three tables are the result of the network shown above:

Router I:	Destination	Netmask	Next gateway	NIC
	192.168.1.0	255.255.255.0	2.0.0.2	2.0.0.1
	192.168.2.0	255.255.255.0	3.0.0.3	3.0.0.1

Router II:	Destination	Netmask	Next gateway	NIC
	192.168.0.0	255.255.255.0	2.0.0.1	2.0.0.2
	192.168.2.0	255.255.255.0	1.0.0.3	1.0.0.2

und Router III:	Destination	Netmask	Next gateway	NIC
	192.168.0.0	255.255.255.0	3.0.0.1	3.0.0.3
	192.168.1.0	255.255.255.0	1.0.0.2	1.0.0.3

Exercise 22c: Configure the forwarding tables of the three routers according to the representations given above. Unselect the box saying “Show all entries” for a clearer view.



Install an Echo server to Server 2.10 and a Generic client to Laptop 0.10. Connect server and client and see how the packages are forwarded. It is easier to observe when you lower the speed down to about 50%.



Now modify the forwarding table so that messages sent from LAN A to LAN B are rerouted to run through LAN C as well. Observe the network activity.

Further Material A: IP Addresses

IP addresses according to the most commonly used IP version 4 (IPv4) are comprised of 32 Bits, split into 4 blocks of 8 Bit each. This gives a total range of IP addresses from 0.0.0.0 to 255.255.255.255. For a better understanding of the process of routing it is helpful to translate the numbers from decimal system to binary system.

Exercise A1: Wiederholen Sie die Umrechnung zwischen dem Binärsystem und dem Dezimalsystem. Wandeln anschließend in das jeweils andere Stellenwertsystem um.

Practice the translation between binary and decimal system.

Translate your result back to the other system to check yourself.

- a) $1101\ 1110_2$
- b) $0011\ 1111_2$
- c) $1111\ 1101_2$
- d) $0101\ 1010_2$
- e) 96_{10}
- f) 254_{10}
- g) 17_{10}
- h) 127_{10}

A *subnet mask* in IPv4 is another 32 bit number that splits the IP address into *network prefix* and the *host identifier*. Through AND operations between IP address and subnet mask, the network prefix can be extracted. Through AND operations between IP address and the inverted subnet mask, the host identifier will show. The smallest address of the network is used to reference the network itself and the highest IP is reserved for *broadcasting*.

Example:

IP address: 192.145.96.201 = 11000000.10010001.01100000.11001001

Subnet mask: 255.255.255.240 = 11111111.11111111.11111111.11110000

AND operation reveals the

network prefix: 192.145.96.192 = 11000000.10010001.01100000.11000000

AND operations with the inverted subnet mask reveals the

host identifier: 0.0.0.9 = 00000000.00000000.00000000.00001001

The highest IP address is reserved for broadcasting.

Broadcast: 192.145.96.207 = 11000000.10010001.01100000.11001111

available range of addresses within the network:

Default Gateway: 192.145.96.193 = 11000000.10010001.01100000.11000001
 to 192.145.96.206 = 11000000.10010001.01100000.11001110

The network prefix is also used as the network address.

Exercise A2: Complete the following table.

IP	Subnet mask	Network address	Host identifier	Broadcast	Default Gateway	max number of IPs in network
192.168.213.15	255.255.255.192					
172.16.5.254	255.255.255.0					
172.254.13.8	255.255.248.0					
10.38.133.5	255.255.0.0					
10.0.0.15	255.0.0.0					

Exercise A3: A message is sent from a computer holding the IP address 192.168.203.15 lying in the network with the subnet mask 255.255.248.0 to a computer with the IP address 192.168.200.65. Does the message remain within the network or does it have to leave it and be sent over the internet?