

Debian/GNU Linux Networking

Basics of the Networking

Károly Erdei

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Agenda

- 1 Networks
- 2 Ethernet
- 3 Internet Protocol
- 4 TCP
- 5 DHCP
- 6 Check Network
- 7 Connecting PCs

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Network of Networks

Internet

Internetwork:

- Connects multiple WANs/LANs across the globe
- LANs/WANs connected to Internetworks by **routers** or **gateways**
- Each attached network may have different **protocol**
 - Protocol = language spoken by computers on network
- Any computer in any network can communicate with any other computer in any other network independently of physical network technologies
 - Communication based on higher level protocols

The Internet

- A worldwide internetwork that uses the **TCP/IP** protocol suite
- It is a packet switching network (data will be splitted in packets)

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Ethernet

MAC addresses

MAC / physical / hardware Address

- each Ethernet station is given a single 48-bit unique MAC address
- is used both to specify the destination and the source of each data packet
- is six groups of two hexadecimal digits, separated by - or :
 - first three octets identify the organization
 - arbitrary but unique next three octets assigned by the organisation
- is used/valid only in LAN (network segment)

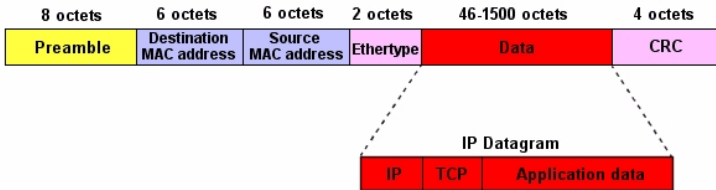
technologies which use MAC address

- Ethernet, 802.11 wireless networks, Bluetooth

ARP - Address Resolution Protocol

- convert IP addresses to MAC addresses

Ethernet Frame



Ethernet - MAC address

How to find a local MAC addresses

Linux - command line with `/sbin/ifconfig`

```
uhu:~> /sbin/ifconfig eth0
eth0      Link encap:Ethernet  HWaddr 00:16:41:16:6D:5D
          inet addr:192.168.1.115  Bcast:192.168.1.255  Mask:255.255.255
          ....
uhu:~> /sbin/ifconfig eth1
eth1      Link encap:Ethernet  HWaddr 00:16:6F:BA:3E:01
          UP BROADCAST MULTICAST  MTU:1500  Metric:1
          ....
```

MS Windows - fastest way

- in DOS Window by means of `ipconfig /all`

Linux - all units in the network segment

- `arp -a` (only one line listed as example):
 - `crutch.risc.uni-linz.ac.at (193.170.37.76) at 00:16:35:37:5C:EC [ether] on eth0`

Ethernet - MAC address

How to find a local MAC addresses - Linux with gnome-nettool

The screenshot shows the 'Network Tools - Devices' window in gnome-nettool. The 'Network device' is set to 'Ethernet Interface (eth0)'. The 'IP Information' section contains a table with the following data:

Protocol	IP Address	Netmask / Prefix	Broadcast	Scope
IPv4	193.170.37.80	255.255.255.0	193.170.37.255	
IPv6	fe80::213:20ff:fe75:4402 64			Link

Below the IP information, there are two sections: 'Interface Information' and 'Interface Statistics'.

Interface Information

- Hardware address: 00:13:20:75:44:02
- Multicast: Enabled
- MTU: 1500
- Link speed: not available
- State: Active

Interface Statistics

- Transmitted bytes: 1.5 GiB
- Transmitted packets: 2187400
- Transmission errors: 0
- Received bytes: 893.2 MiB
- Received packets: 2569788
- Reception errors: 0
- Collisions: 0

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IP - The Internet Protocol

Features of IP

- No delivery guarantees
 - **Connection-less**
 - **Unreliable**: packets may be lost, duplicated, reordered
 - packets oriented
- **defines IP addresses and routing in the network**

RFC - Request for Comments

- description of some feature, object, protocol, etc. in the Internet
- each RFC is the base to implement some feature
 - https://en.wikipedia.org/wiki/List_of_RFCs
 - <https://tools.ietf.org/html/rfc15>

IP Addressing

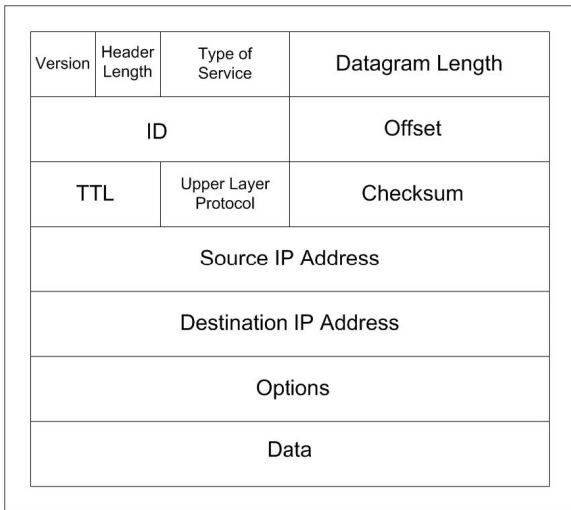
RFC 1166: Internet Numbers

- An IP address is a 32 bit unsigned integer
 - There exist $2^{32} \approx 4$ billion IP addresses
- Representation in dotted decimal notation
 - $X.X.X.X$; Each X is a decimal number, a byte of the address
- Example: 128.10.2.30: 10000000 00001010 00000010 00111110
- Network classes (net.hosts): A(1:3), B(2:2) and C-class (3:1)

Some addresses are reserved for special purposes

- **net.0**: the “network” address (not a particular host) 193.170.37.0
- **default gateway**: an address in this network: 193.170.37.1
- **broadcast address**: **net.255**
- 0.0.0.0: “this” host
- 127.0.0.1: **loopback, localhost, lo** (not sent across network, for testing local IP setup)

IP Datagram Structure



Routers and Gateways

Features

Router: a networking device

- a computer whose software and hardware are usually tailored to the tasks of routing and forwarding packets
- transfers packets only across networks using similar protocols
- contains a specialized operating system (e.g. Cisco's IOS)
- has multiple network connections
- Types of routers
 - small units (DSL router) - ISPs big multiprocessor unit

Private Networks - Private IP Addresses

The addresses, which can be used by **everyone**

Private Internet Addresses

- May be used **internally** in any organization
- routers have to discard any packets with a private IP address in the IP header
- gives security for private networks they are not available from the Internet
- Networks
 - Home network: 192.168.0.0 - 192.168.255.255 (Cable/DSL router: 192.168.1.1)
 - Company network: 172.16.0.0 - 172.31.255.255
 - Big Company network: 10.0.0.0 - 10.255.255.255

Checking connections

- ping
- traceroute

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TCP - Transmission Control Protocol

Transport layer services

- Connection oriented
 - for data delivery first a connection must be established
- Same Order Delivery
 - data will arrive in the same order it has been sent
- Reliable data transmission
 - retransmit corrupted packages; error detection code, packet acknowledgement
- Byte orientation: not packages, but **stream** of byte sent
- Introducing the term **port**
 - port addresses multiple entities on the same location

TCP - Ports

The problem of the applications on a host to communicate

- more programs run on a computer
 - sendmail, webserver, name server, ftp-, pop server, etc.
- the computer has one unique IP address
- how to deal with the application, how to differ them
- introducing **ports** is the solution
 - analogy: postal address as IP address; appartement number or name is the port number

Ports

- to each services in the Internet/Computer a port is assigned
 - ports are identified by the port number
 - see in Linux the `/etc/services` file for numbers/services allocation
 - port number is a part of TCP packets header
- a program implement a service
 - the program **LISTEN** on the port for a communication

TCP - Ports

Unix port in /etc/services

```

ftp-data      20/tcp
ftp           21/tcp
ssh           22/tcp      # SSH Remote Login Prot
telnet        23/tcp
smtp          25/tcp      mail
whois         43/tcp      nicname
domain        53/tcp      # name-domain server
domain        53/udp
finger        79/tcp
www           80/tcp      http
www           80/udp      # WorldWideWeb HTTP
              # HyperText Transfer Pr
pop3          110/tcp     pop-3      # POP version 3
imap2         143/tcp     imap       # Interim Mail Access P
https         443/tcp     # http protocol over TL
https         443/udp
ftps          990/tcp
telnets      992/tcp     # Telnet over SSL
imaps         993/tcp     # IMAP over SSL
pop3s         995/tcp     # POP-3 over SSL

```

TCP - Transmission Control Protocol

Example: Sending email per smtp port (1)

```
hu:~> telnet bullfinch 25
Trying 193.170.37.222...
Connected to bullfinch.risc.uni-linz.ac.at.
Escape character is '^]'.
220 bullfinch.risc.uni-linz.ac.at ESMTP Sendmail 8.13.8/8.13.8/Debian-3
Mon, 3 Nov 2008 15:19:26 +0100; (No UCE/UBE) logging access from: i
uhu37.risc.uni-linz.ac.at(OK)-ke@uhu37.risc.uni-linz.ac.at [193.170.37.
helo ich-bin-s
250 bullfinch.risc.uni-linz.ac.at Hello ke@uhu37.risc.uni-linz.ac.at
[193.170.37.115], pleased to meet you
mail from: k.erdei@risc.uni-linz.ac.at
250 2.1.0 k.erdei@risc.uni-linz.ac.at... Sender ok
rcpt to: karoly.erdei@jku.at
250 2.1.5 karoly.erdei@jku.at... Recipient ok
```

TCP - Transmission Control Protocol

Example: Sending email per smtp port (2)

```
data
354 Enter mail, end with "." on a line by itself
this is an email sent by telnet 25 command from the laptop to the mail
server bullfinch.risc... demonstrating how smtp works
.
250 2.0.0 mA3EJQr4014077 Message accepted for delivery
quit
221 2.0.0 bullfinch.risc.uni-linz.ac.at closing connection
Connection closed by foreign host.
uhu:~>
```

TCP - Transmission Control Protocol

Example: Downloading file from the WWW server

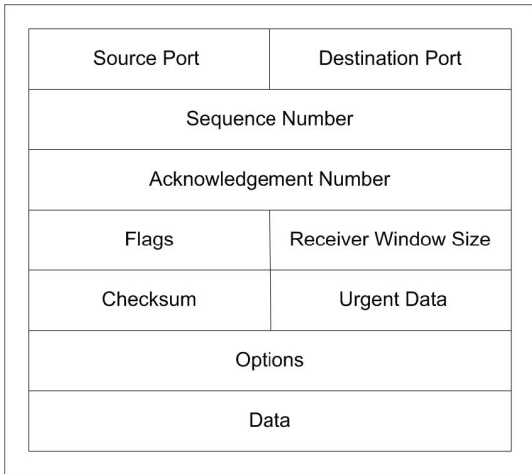
Telnet to port 80 on the Web server

```
hades:www!11> telnet www 80
Trying 193.170.37.138...
Connected to crow.risc.uni-linz.ac.at.
Escape character is '^]'.
GET http://www.risc.jku.at/proba.txt
```

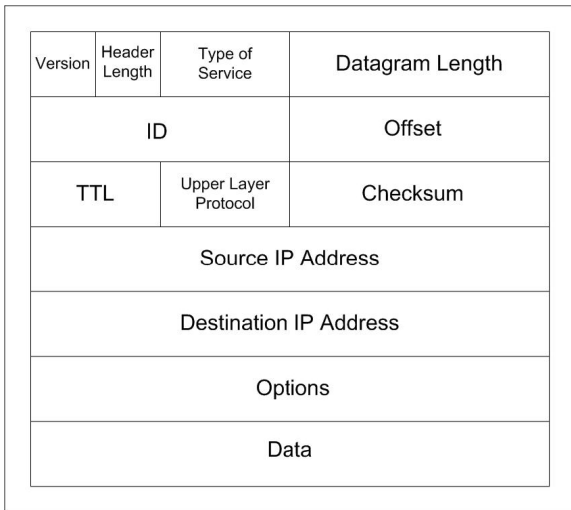
```
Hello! This is a test file. To get it per port access with telnet.
It succeeded to get this file per port access from the web server.
Great!
```

```
Connection closed by foreign host.
hades:www!12>
```

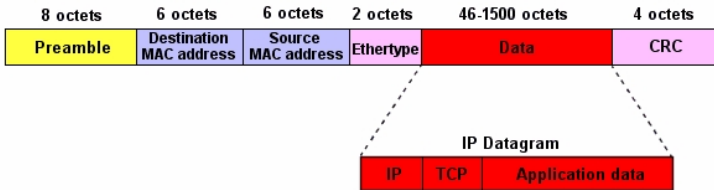
TCP Datagram Structure



IP Datagram Structure



Ethernet Frame



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DHCP - Dynamic Host Control Protocol

Client - Server application

DHCP Client - Server communication flow

- DHCP is used to obtain parameters necessary for IP networking
- **client**: broadcasts a DHCPDISCOVER request
 - Asks for a DHCP server on the network segment
 - Asks for a lease and for an IP address
 - Lease: the length of time for the allocation is valid
- **server**: sends a DHCPOFFER message
 - Checks if the MAC of client is registered
 - Marks an IP from the spool
- **client**: broadcasts a DHCPREQUEST on the network
 - The IP of the server is in the packet
- **server**: sends the client the data DHCPDATA
 - Reservers the IP for the time of the lease
 - Other servers delete the mark for the IP

DHCP - Dynamic Host Control Protocol

DHCP server

- has a pool of IP addresses
- manages other network parameters for networking by client
 - options are widely configurable
- checks the MAC of the client, if configured
- lease time is configurable (max;min)

Client requests periodically

- Client has to request again before lease time is over
 - a new IP or request the same IP
- By booting must suspend other processes
 - without IP no network connection

DHCP server is implemented in Home/DSL/Cable routers

DHCP - Dynamic Host Control Protocol

DHCP Server data table

Assigned data by DHCP server at RISC

- Network configurations parameter at RISC
 - IP Address
 - Lease
 - Domain Name (risc.uni-linz.ac.at)
 - Default Gateway address (193.170.38.1)
 - Name server IP address (193.170.37.225)
 - Name server IP address (193.170.37.224)
 - WINS servers (phoebe.risc.uni-linz.ac.at)
 - WINS servers (samba-dc1.risc.uni-linz.ac.at)
 - NTP servers (time.risc.uni-linz.ac.at)
 - SMTP server (mail.risc.uni-linz.ac.at)
 - POP server (pop.risc.uni-linz.ac.at)

NAT - Network Address Translation

How NAT works

- general definition
 - a technique that hides an entire address space, usually consisting of private network addresses (RFC 1918), behind a single IP address in another, (often) public address space.
- implemented in a router - connected to private/public network
 - uses translation tables to map/remap the addresses
 - translation table are created by the outgoing requests
 - rewrites the outgoing IP packets as sent from the router
 - Assigns to each connection a different source **port**
- NAT introduces complications in communication, performance
 - it has to rewrite checksum, reassemble packets, fragment them again, etc.
- The NAT box - the Internet router
 - Cable/DSL router: a firewall is always integrated

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Checking Network Connections

gnome-nettool, ping, remote

The screenshot shows the 'Network Tools - Ping' window. The 'Network address' field contains 'www.univie.ac.at'. The 'Send' options are set to 'Only 5 requests'. A 'Ping' button is visible. Below the input fields is a table showing the results of the ping test.

Bytes	Source	Seq	Time	Units
64	131.130.1.78	1	4.16 ms	
64	131.130.1.78	2	4.13 ms	
64	131.130.1.78	3	4.18 ms	
64	131.130.1.78	4	4.12 ms	
64	131.130.1.78	5	4.09 ms	

Below the table, there are two sections of statistics:

- Round Trip Time Statistics**
 - Minimum: 4.09 ms
 - Average: 4.14 ms
 - Maximum: 4.18 ms
- Transmission Statistics**
 - Packets transmitted: 5
 - Packets received: 5
 - Packets loss: 0%

Checking Network Connections

gnome-nettool, traceroute

The screenshot shows the 'Network Tools - Traceroute' application window. The title bar indicates the window is titled 'Network Tools - Traceroute <@prometheus>'. The menu bar includes 'Tool', 'Edit', and 'Help'. Below the menu bar, there are several tabs: 'Devices', 'Ping', 'Netstat', 'Traceroute', 'Port Scan', 'Lookup', 'Finger', and 'Whois'. The 'Traceroute' tab is currently selected. A text input field labeled 'Network address:' contains the value 'www.bme.hu'. To the right of this field is a 'Trace' button with a green arrow icon. Below the input field is a table displaying the results of the traceroute.

Hop	Hostname	IP	Time 1	Time 2
1	net37-gtw	193.170.37.1	0.453	0.429
2	jkuc3hb1.edvz.uni-linz.ac.at	140.78.222.1	0.498	0.503
3	jkuc6bb1.edvz.uni-linz.ac.at	140.78.200.140	0.632	0.575
4	Linz.ACO.net	193.171.22.25	0.586	0.575
5	linz2.aco.net	193.171.15.10	1.064	1.005
6	wien21.aco.net	193.171.15.5	4.477	4.430
7	aconet.rt1.vie.at.geant2.net	62.40.124.1	4.446	5.584
8	so-3-0-0.rt1.bud.hu.geant2.net	62.40.112.14	41.474	9.231
9	hungarnet-gw.rt1.bud.hu.geant2.net	62.40.124.102	9.410	9.422
10	c6513-tengbeth13-3.vh.hbone.hu	195.111.97.242	9.468	9.454
11	sup720-tengbeth2-1.bme.hbone.hu	195.111.97.102	9.501	9.439
12	tge8-1.taz.bme.hu	152.66.0.125	9.441	9.417
13	torpapa.eik.bme.hu	152.66.115.35	9.348	9.303

Network Connections - Active Services

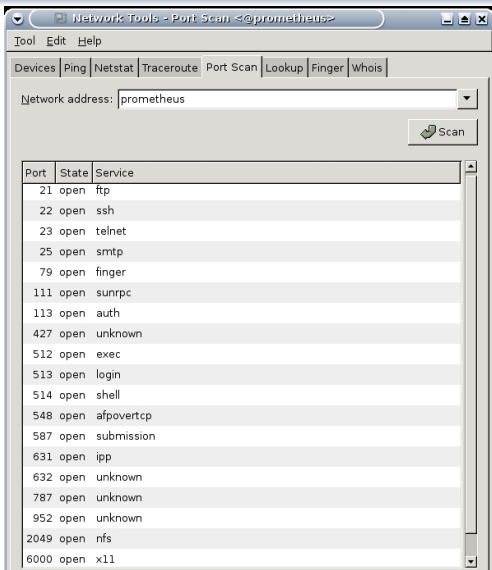
gnome-nettool, netstat

The screenshot shows the 'Network Tools - Netstat' window. The 'Netstat' tab is selected. Under the 'Display' section, 'Active Network Services' is selected. A table below displays the following data:

Protocol	IP Source	Port/Service	State
tcp	0.0.0.0	512	LISTEN
tcp	127.0.0.1	2208	LISTEN
tcp	0.0.0.0	513	LISTEN
tcp	0.0.0.0	2049	LISTEN
tcp	0.0.0.0	514	LISTEN
tcp	0.0.0.0	548	LISTEN
tcp	0.0.0.0	57253	LISTEN
tcp	0.0.0.0	587	LISTEN
tcp	193.170.37.80	427	LISTEN
tcp	127.0.0.1	427	LISTEN

Network Connections - nmap

gnome-nettool, local



The screenshot shows a window titled "Network Tools - Port Scan <@prometheus>". The menu bar includes "Tool", "Edit", and "Help". Below the menu is a toolbar with buttons for "Devices", "Ping", "Netstat", "Traceroute", "Port Scan", "Lookup", "Finger", and "Whois". The "Port Scan" button is active. A text field labeled "Network address:" contains the value "prometheus". To the right of this field is a "Scan" button with a magnifying glass icon. Below the text field is a table displaying the scan results.

Port	State	Service
21	open	ftp
22	open	ssh
23	open	telnet
25	open	smtp
79	open	finger
111	open	sunrpc
113	open	auth
427	open	unknown
512	open	exec
513	open	login
514	open	shell
548	open	afpovertcp
587	open	submission
631	open	ipp
632	open	unknown
787	open	unknown
952	open	unknown
2049	open	nfs
6000	open	x11

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Connecting Computers to the Network

General remarks

Connecting automatically by DHCP

- the most comfortable solution
 - if DHCP server is available for the domain, for the LAN segment
 - if the DHCP server is not restricted to known hosts
 - the hardware address (MAC address) of ethernet/wireless interface needed for access

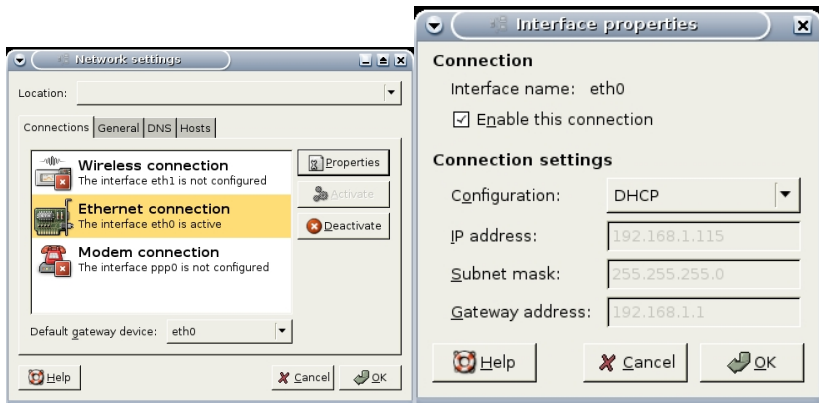
Connecting manually with fixed IP address

- this solution always works (local help (IP) needed)
- needs more knowledge about the OS, configuration files, etc.
- the only possibility if no DHCP server available

Connecting Computers to the Network

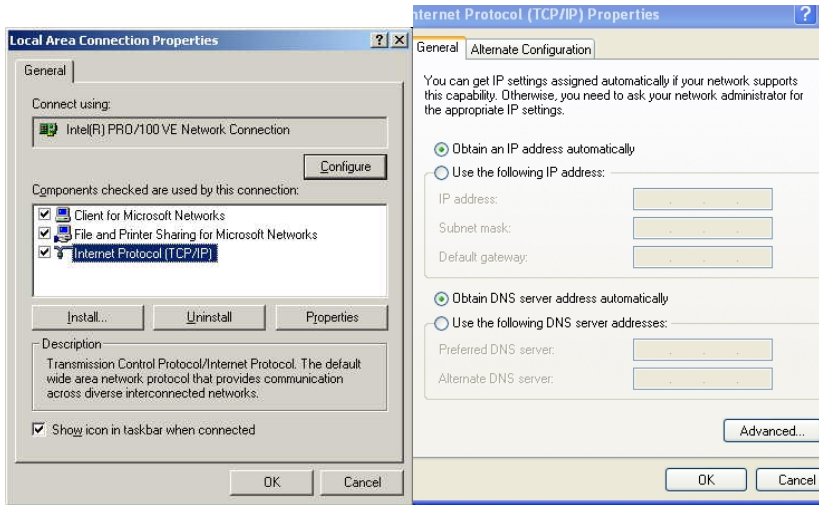
Using DHCP

Linux Configuration with `network-admin` - root access necessary



Connecting Computers to the Network

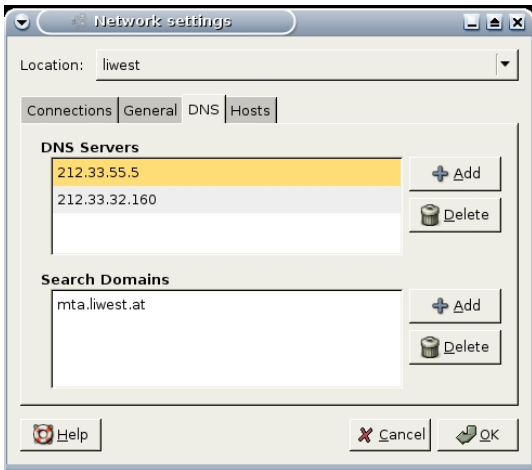
by DHCP for MS Windows



Connecting Computers to the Network

The Name Server

Configuration in Linux with network-admin



End of Network Basics

Thanks for your attention !