

Welcome to

1. TCP/IP and Security in TCP/IP protocol suite

Communication and Network Security 2023

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Slides are available as PDF, kramse@Github 

1-TCP/IP-and-Security-in-TCP/IP-protocol-suite.tex in the repo security-courses

Goals for today



- Show how some problems in networks, and especially LAN are common security problems
- TCP/IP is everywhere and some problems categories have existed for centuries
- Even switching from IPv4 to IPv6 will not solve all

Photo by Thomas Galler on Unsplash

Plan for today

Subjects

- TCP/IP
- Some security problems in the TCP/IP protocol suite
- Understand basic IP protocols and inherent security problems
- Make sure we have a common vocabulary in this course, like CIDR

Exercises

- Wireshark and Tcpdump 15 min
- Capturing TCP Session packets 10 min
- Whois databases 15 min
- Using ping and traceroute 10 min
- DNS and Name Lookups 10 min

Reading Summary

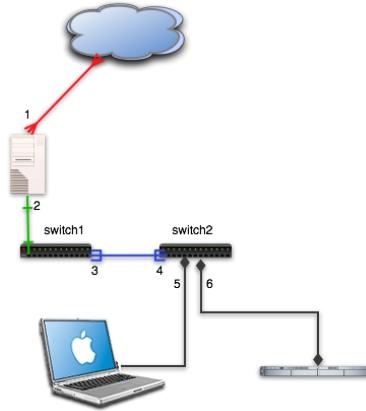
Read

- PPA chapters 1,2,3
- Chapter 1: Packet Analysis and Network Basics
- Chapter 2: Tapping into the Wire
- Chapter 3: Introduction to Wireshark
- ANSM chapter 13: Packet Analysis

Skim:

- *Security problems in the TCP/IP protocol suite*, S. M. Bellovin <https://www.cs.columbia.edu/~smb/papers/ipext.pdf>
- *A Look Back at “Security Problems in the TCP/IP Protocol Suite”* <https://www.cs.columbia.edu/~smb/papers/acsac-ipext.pdf>

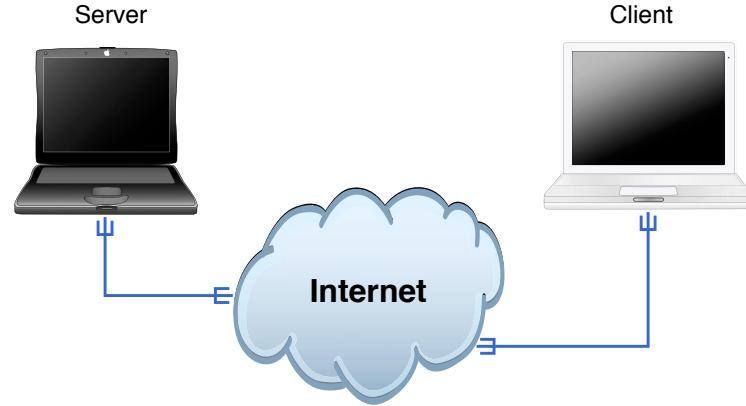
Course Network



Our network will be similar to regular networks, as found in enterprises

We have an isolated network, allowing us to sniff and mess with hacking tools.

Internet Today



Clients and servers, roots in the academic world

Protocols are old, some more than 20 years

Very little is encrypted, mostly HTTPS

Internet is Open Standards!

We reject kings, presidents, and voting.
We believe in rough consensus and running code.
– The IETF credo Dave Clark, 1992.

Request for comments - RFC - er en serie af dokumenter

RFC, BCP, FYI, informational

de første stammer tilbage fra 1969

Ændres ikke, men får status Obsoleted når der udkommer en nyere version af en standard

Standards track:

Proposed Standard → Draft Standard → Standard

Åbne standarder = åbenhed, ikke garanti for sikkerhed

Hvad er Internet

Kommunikation mellem mennesker!

Baseret på TCP/IP

- best effort
- packet switching (IPv6 kalder det packets, ikke datagram)
- forbindelsesorienteret, *connection-oriented*
- forbindelsesløs, *connection-less*

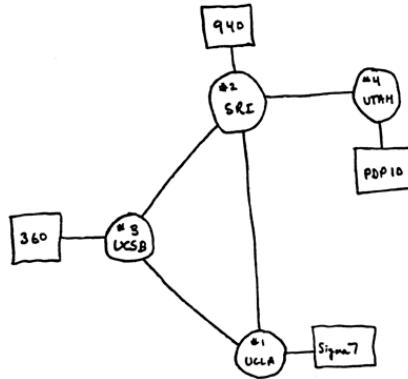
RFC-1958:

A good analogy for the development of the Internet is that of constantly renewing the individual streets and buildings of a city, rather than razing the city and rebuilding it. The architectural principles therefore aim to provide a framework for creating cooperation and standards, as a small "spanning set" of rules that generates a large, varied and evolving space of technology.

IP netværk: Internettet historisk set

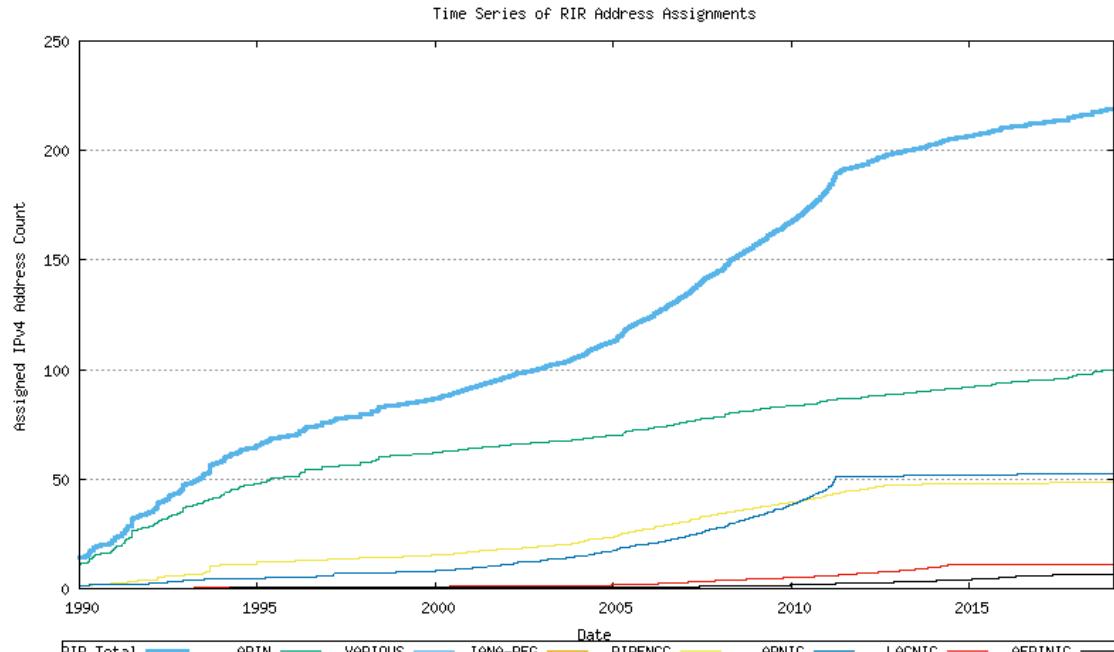
- 1961 L. Kleinrock, MIT packet-switching teori
- 1962 J. C. R. Licklider, MIT - notes
- 1964 Paul Baran: On Distributed Communications
- 1969 ARPANET startes 4 noder
- 1971 14 noder
- 1973 Arbejde med IP startes
- 1973 Email er ca. 75% af ARPANET traffik
- 1974 TCP/IP: Cerf/Kahn: A protocol for Packet Network Interconnection
- 1983 EUUG → DKUUG/DIKU forbindelse
- 1988 ca. 60.000 systemer på Internettet The Morris Worm rammer ca. 10%
- 2000 Maj I LOVE YOU ormen rammer
- 2002 Ialt ca. 130 millioner på Internet

Internet historisk set - anno 1969



- Node 1: University of California Los Angeles
- Node 2: Stanford Research Institute
- Node 3: University of California Santa Barbara
- Node 4: University of Utah

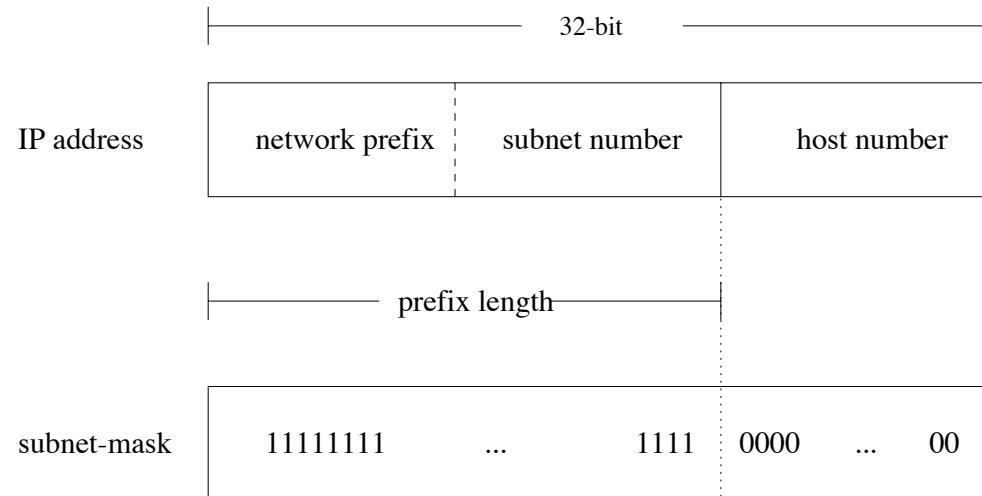
Hvad er Internet hosts



Cumulative RIR address assignments, per RIR

Source: IPv4 Address Report - 28-Jan-2019 <http://www.potaroo.net/tools/ipv4/>

Fælles adresserum



Hvad kendetegner internet idag

Der er et fælles adresserum baseret på 32-bit adresser, example 10.0.0.1

IPv4 addresser og skrivemåde

```
hlk@bigfoot:hlk$ ipconvert.pl 127.0.0.1
Adressen er: 127.0.0.1
Adressen er: 2130706433
hlk@bigfoot:hlk$ ping 2130706433
PING 2130706433 (127.0.0.1): 56 data bytes
64 bytes from 127.0.0.1: icmp_seq=0 ttl=64 time=0.135 ms
64 bytes from 127.0.0.1: icmp_seq=1 ttl=64 time=0.144 ms
```

IP-adresser skrives typisk som decimaltal adskilt af punktum

Kaldes **dot notation**: 10.1.2.3

Kan også skrive som oktal eller heksadecimale tal

Tidligere benyttede man klasseinddelingen af IP-adresser: A, B, C, D og E

Desværre var denne opdeling ufleksibel:

- A-klasse kunne potentielt indeholde 16 millioner hosts
- B-klasse kunne potentielt indeholder omkring 65.000 hosts
- C-klasse kunne indeholde omkring 250 hosts

Derfor bad de fleste om adresser i B-klasser - så de var ved at løbe tør!

D-klasse benyttes til multicast

E-klasse er blot reserveret

Se evt. http://en.wikipedia.org/wiki/Classful_network

Stop saying C, say /24

CIDR Classless Inter-Domain Routing

Classful routing		Classless routing CIDR	
4 class C networks	Inherent subnet mask	Supernet	Subnet mask
192.0.8.0	255.255.255.0	192.0.8.0	255.255.252.0
192.0.9.0	255.255.255.0		252d=11111100b
192.0.10.0	255.255.255.0		
192.0.11.0	255.255.255.0	Base network/prefix	
			192.10.8.0/22

Subnetmasker var oprindeligt indforstået

Man tildelte flere C-klasser - spare de resterende B-klasser - men det betød en routing table explosion

Idag er subnetmaske en sammenhængende række 1-bit der angiver størrelse på nettet

10.0.0.0/24 betyder netværket 10.0.0.0 med subnetmaske 255.255.255.0

CIDR Classless Inter-Domain Routing RFC-1519

IPv4 addresser opsummering

- Altid 32-bit adresser
- Skrives typisk med 4 decimaltal dot notation 10.1.2.3
- CIDR notation 10.0.0.0/8 - fremfor 10.0.0.0 med subnet maske 255.0.0.0
- Specielle adresser
 - 127.0.0.1 localhost/loopback
 - 0.0.0.0 default route
- RFC-1918 angiver private adresser som alle kan bruge

RFC-1918 Private Networks

Der findes et antal adresserum som alle må benytte frit:

- 10.0.0.0 - 10.255.255.255 (10/8 prefix)
- 172.16.0.0 - 172.31.255.255 (172.16/12 prefix)
- 192.168.0.0 - 192.168.255.255 (192.168/16 prefix)

Address Allocation for Private Internets RFC-1918 adresserne!

NB: man må ikke sende pakker ud på internet med disse som afsender, giver ikke mening

Documentation Prefix, IPv6 updates etc.

Even documentation has its own prefix, RFC5737:

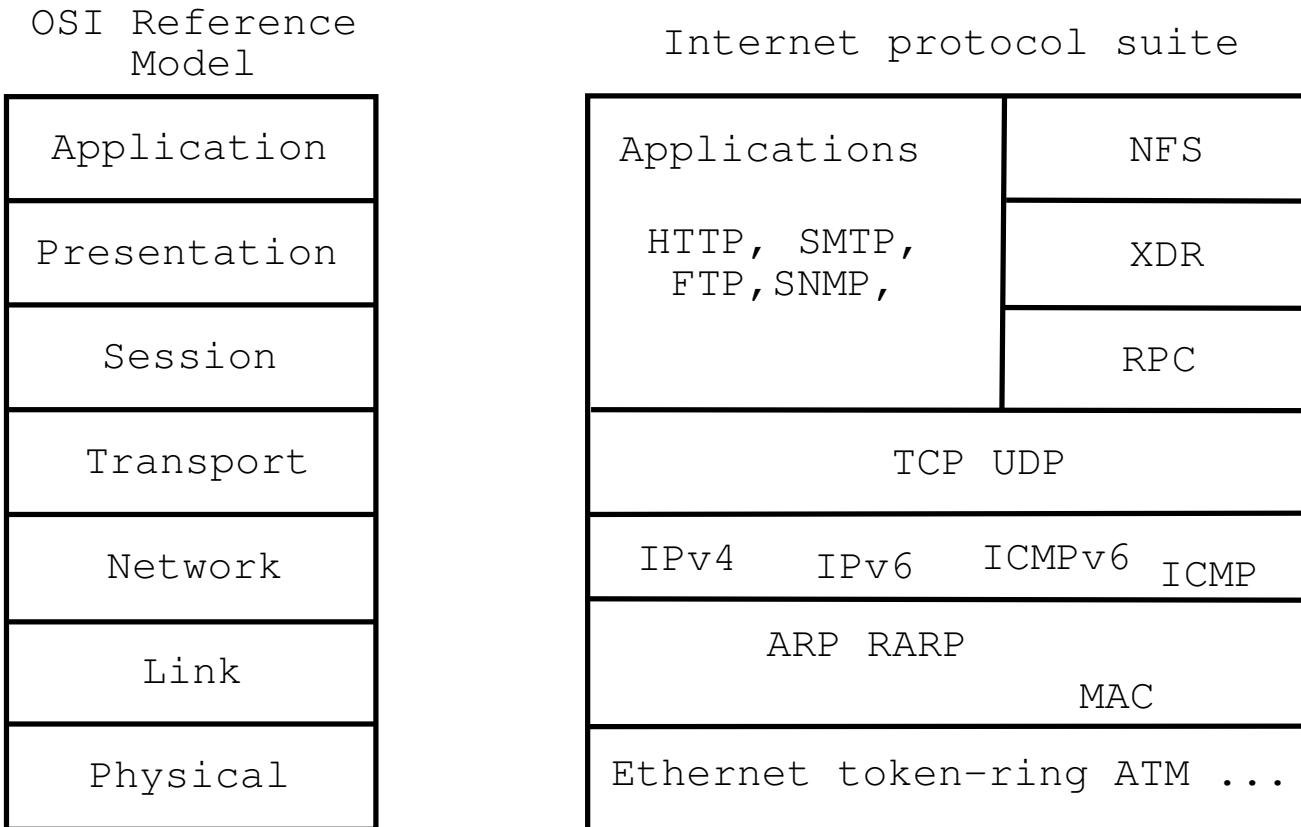
The blocks 192.0.2.0/24 (TEST-NET-1), 198.51.100.0/24 (TEST-NET-2),
and 203.0.113.0/24 (TEST-NET-3) are provided for use in
documentation.

IPv6 listed in RFC3849 2001:DB8::/32

See RFC3330 *Special-Use IPv4 Addresses* which is updated by RFC6890 *Special-Purpose IP Address Registries* which in turn is updated by RFC8190

Use the web version of RFCs to surf back and forth <https://www.rfc-editor.org/rfc/rfc8190>

OSI og Internet modellerne



Der er mange muligheder med IP netværk, IP kræver meget lidt

Ofte benyttede idag er:

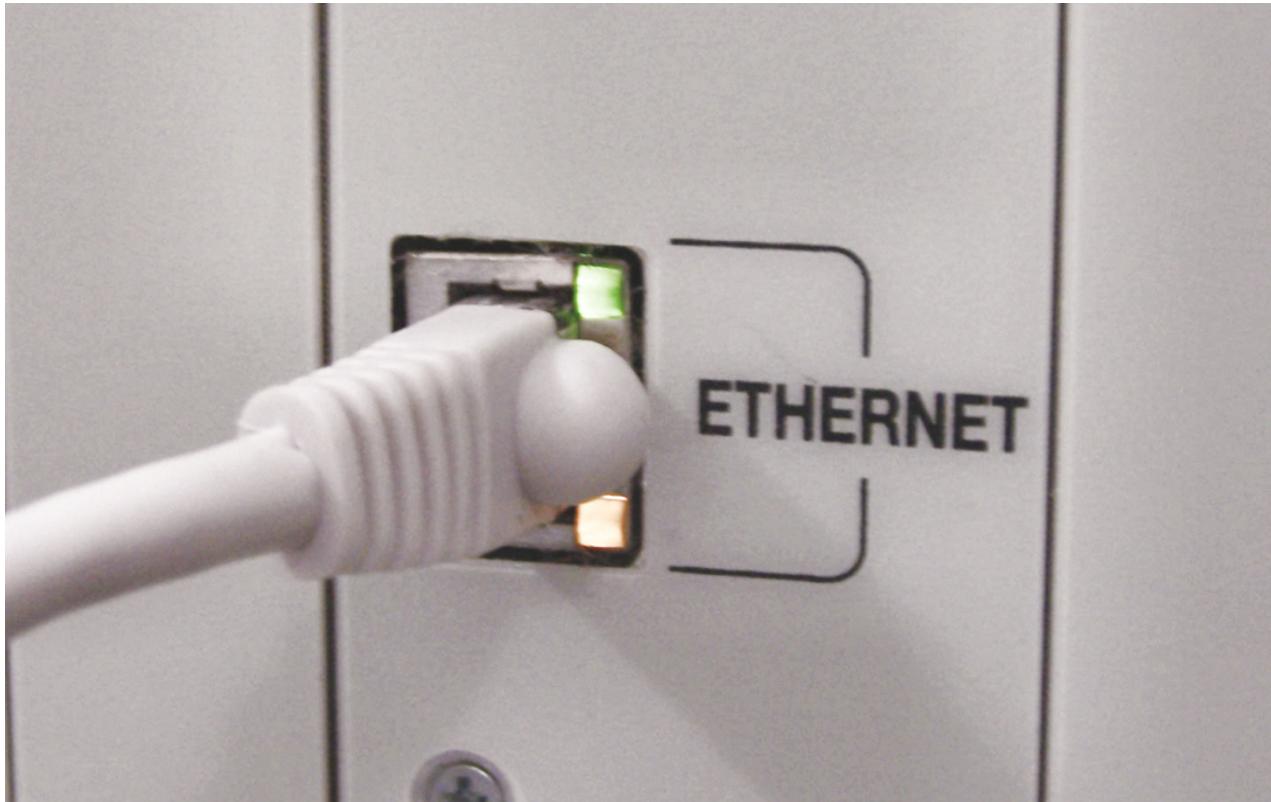
- Ethernet - varianter 10mbit, 100mbit, gigabit, 10G, 100G, 200G, 400G, ...
- Wireless 802.11 teknologier
- ADSL/ATM teknologier til WAN forbindelser
- MPLS ligeledes til WAN forbindelser

Ethernet kan bruge kobberledninger eller fiber

WAN forbindelser er typisk fiber på grund af afstanden mellem routere

Tidligere benyttede inkluderer: X.25, modem, FDDI, ATM, Token-Ring

Ethernet stik, kabler og dioder



Dioder viser typisk om der er link, hastighed samt aktivitet

Trådløse teknologier



Et typisk 802.11 Access-Point (AP) der har Wireless og Ethernet stik/switch

MAC adresser

00-03-93	(hex)	Apple Computer, Inc.
000393	(base 16)	Apple Computer, Inc.
		20650 Valley Green Dr.
		Cupertino CA 95014
		UNITED STATES

Netværksteknologierne benytter adresser på lag 2

Typisk svarende til 48-bit MAC adresser som kendes fra Ethernet MAC-48/EUI-48

Første halvdel af adresserne er Organizationally Unique Identifier (OUI)

Ved hjælp af OUI kan man udlede hvilken producent der har produceret netkortet

<http://standards.ieee.org/regauth/oui/index.shtml>

Ethernet er broadcast teknologi, hvor data sendes ud på et delt medie - Æteren
Broadcast giver en grænse for udbredningen vs hastighed

Ved hjælp af en bro kan man forbinde to netværkssegmenter på layer-2

Broen kopierer data mellem de to segmenter

Virker som en forstærker på signalet, men mere intelligent

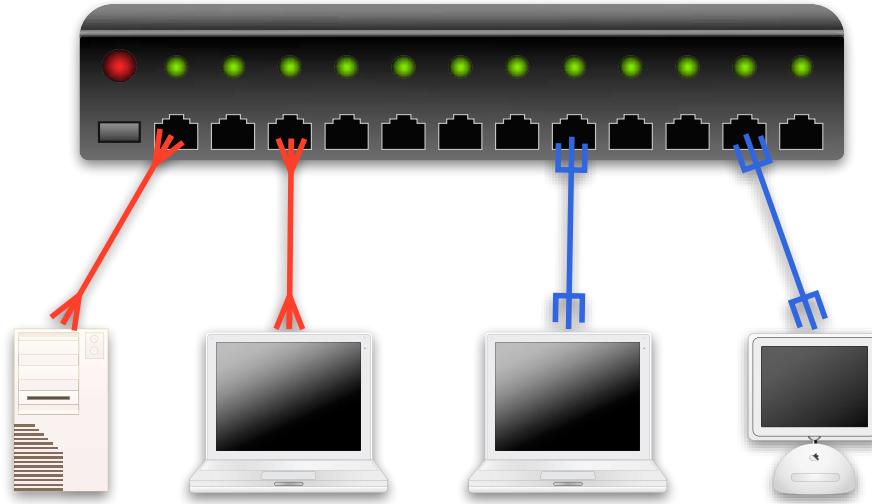
Den intelligente bro kender MAC adresserne på hver side

Broen kopierer kun hvis afsender og modtager er på hver sin side

Kilde: For mere information søger efter Aloha-net

<http://en.wikipedia.org/wiki/ALOHA>

En switch

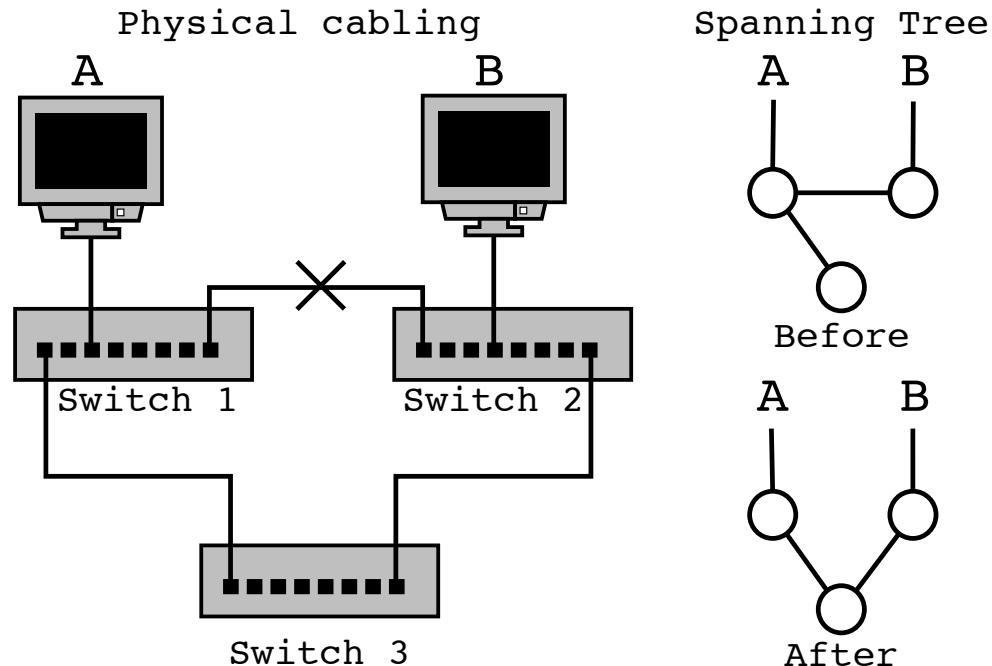


Ved at fortsætte udviklingen kunne man samle broer til en switch

En switch idag kan sende og modtage på flere porte samtidig, og med full-duplex

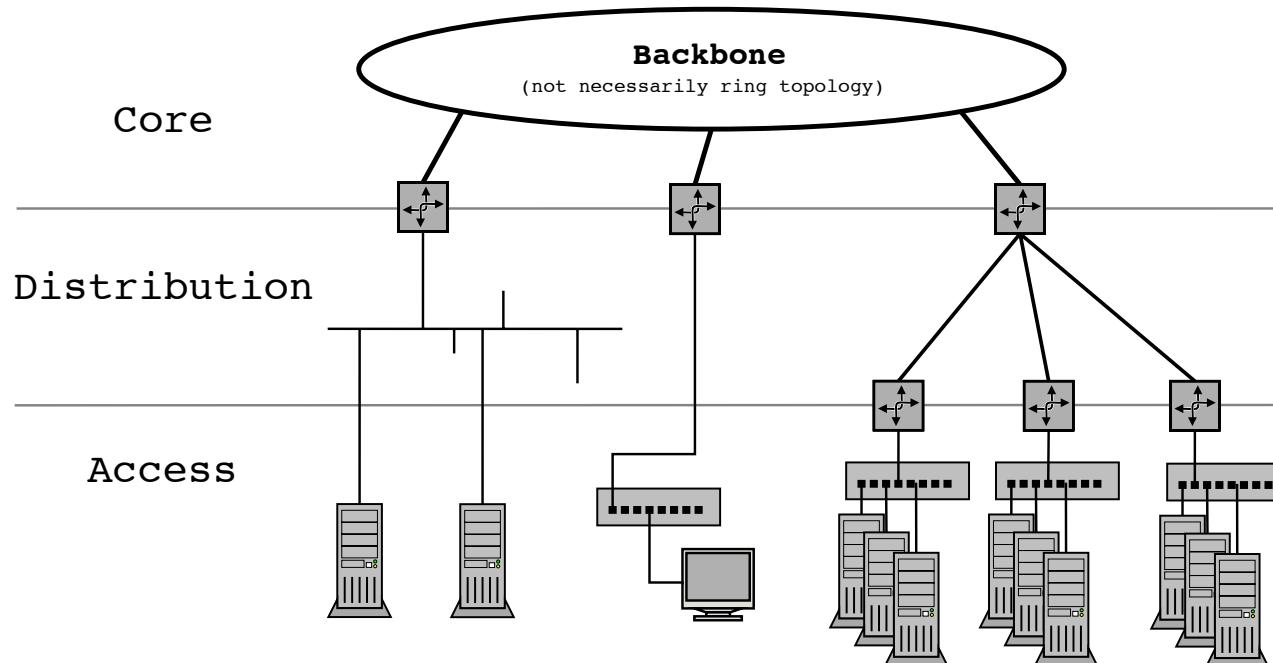
Bemærk performance begrænses af backplane i switchen

Topologier og Spanning Tree Protocol



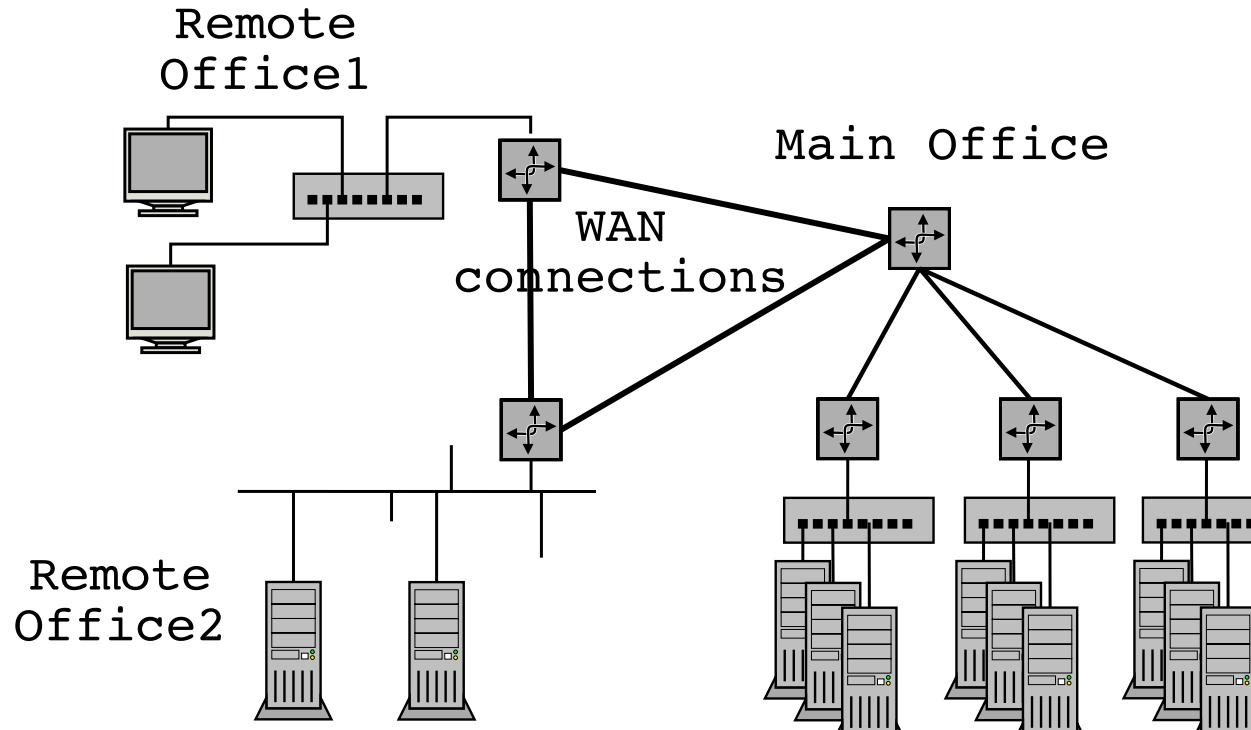
Se mere i bogen af Radia Perlman, *Interconnections: Bridges, Routers, Switches, and Internetworking Protocols*

Core, Distribution og Access net



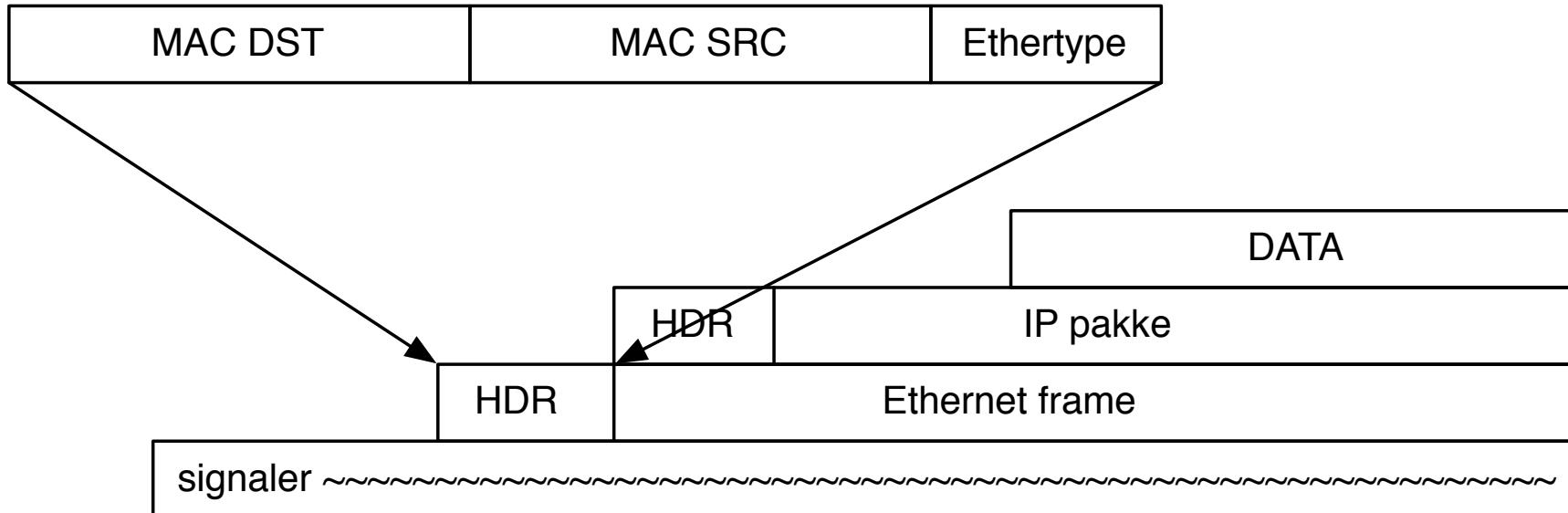
Det er ikke altid man har præcis denne opdeling, men den er ofte brugt

Broer og routere



Fysisk er der en begrænsning for hvor lange ledningerne må være

Pakker i en datastrøm

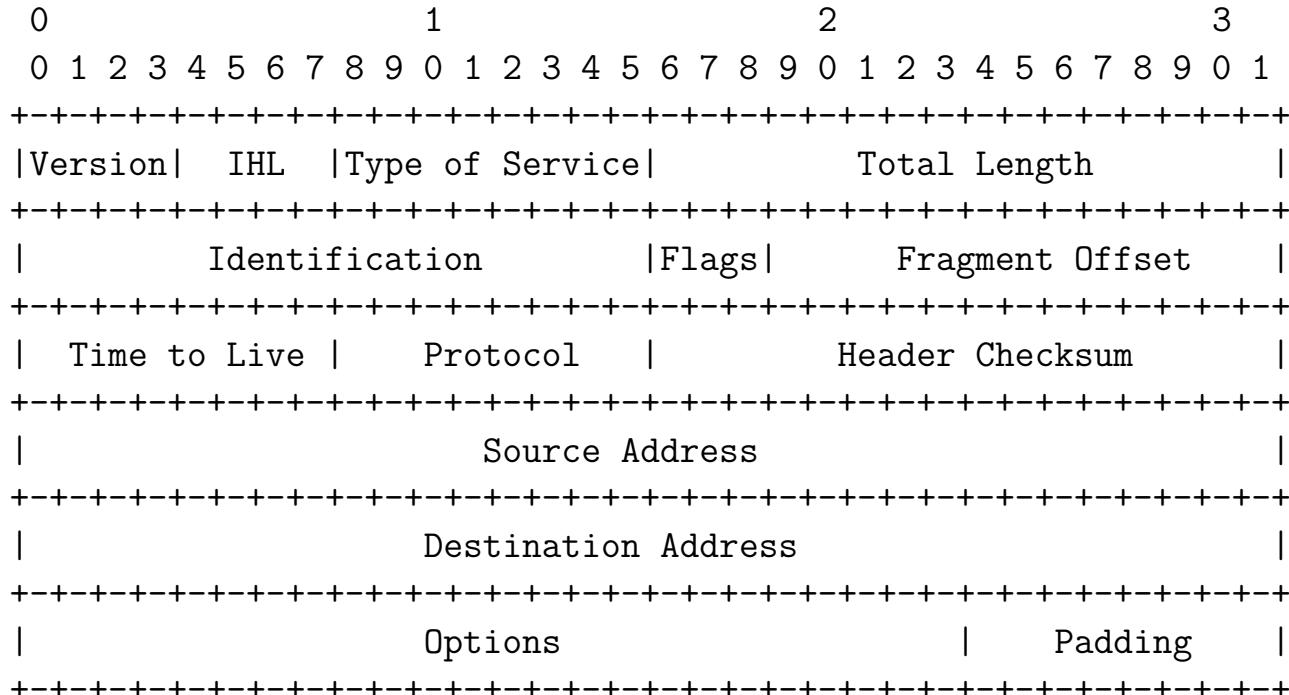


Ser vi data som en datastrøm er pakkerne blot et mønster lagt henover data

Netværksteknologien definerer start og slut på en frame

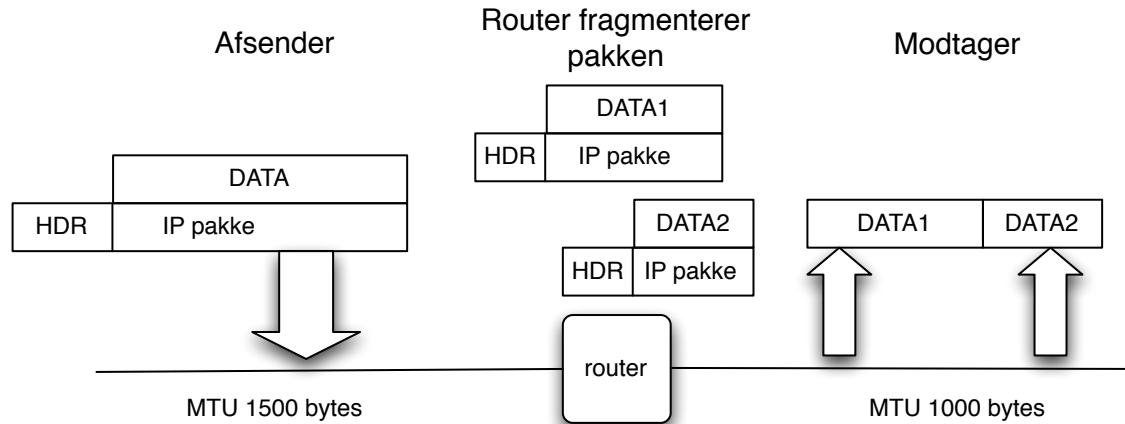
Fra et lavere niveau modtager vi en pakke, eksempelvis 1500-bytes fra Ethernet driver

IPv4 pakken - header - RFC-791



Example Internet Datagram Header

Fragmentering og PMTU



Hidtil har vi antaget at der blev brugt Ethernet med pakkestørrelse på 1500 bytes
Pakkestørrelsen kaldes MTU Maximum Transmission Unit
Skal der sendes mere data opdeles i pakker af denne størrelse, fra afsender
Men hvad hvis en router på vejen ikke bruger 1500 bytes, men kun 1000

ICMP Internet Control Message Protocol

Kontrolprotokol og fejlmeldinger

Nogle af de mest almindelige beskedtyper

- echo
- netmask
- info

Bruges generelt til *signaling*

Defineret i RFC-792

NB: nogle firewall-administratorer blokerer alt ICMP - det er forkert!

ICMP beskedtyper

Type

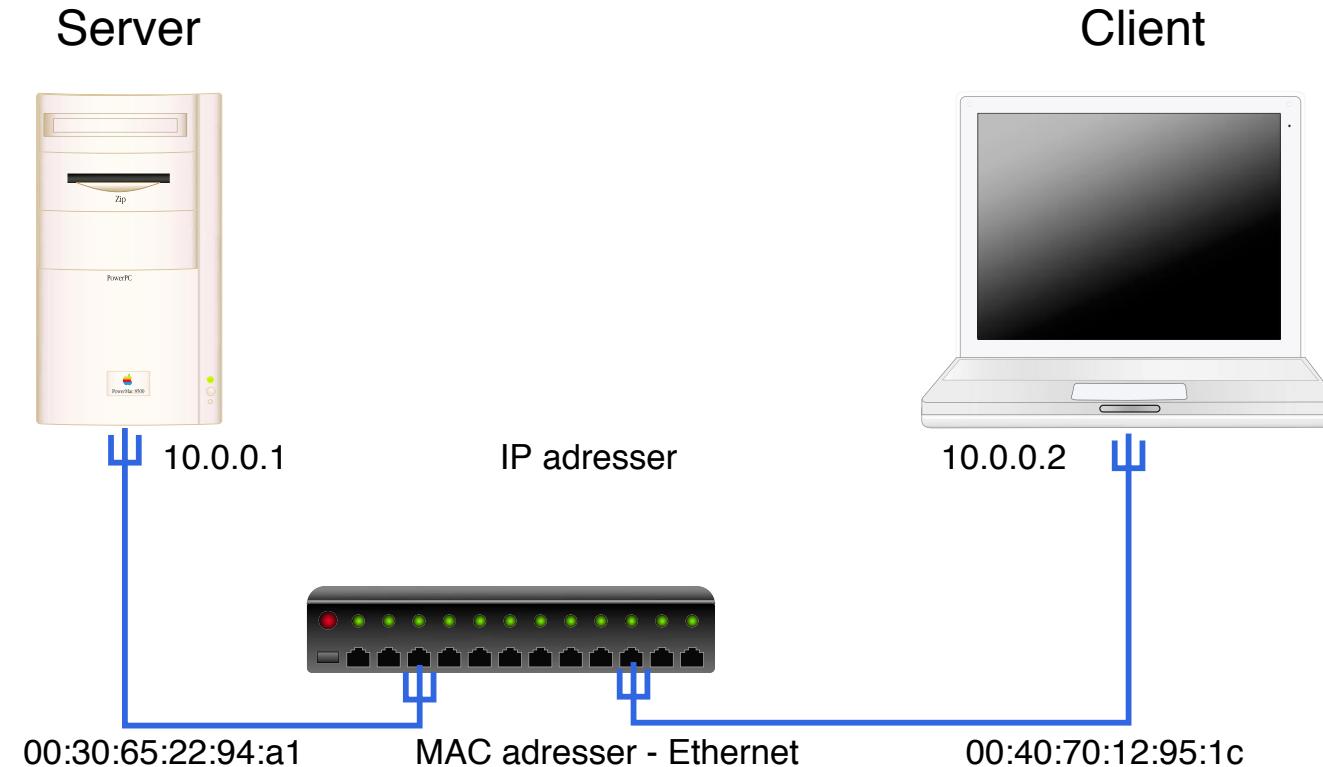
- 0 = net unreachable;
- 1 = host unreachable;
- 2 = protocol unreachable;
- 3 = port unreachable;
- 4 = fragmentation needed and DF set;
- 5 = source route failed.

Ved at fjerne ALT ICMP fra et net fjerner man nødvendig funktionalitet!

Tillad ICMP types:

- 3 Destination Unreachable
- 4 Source Quench Message
- 11 Time Exceeded
- 12 Parameter Problem Message

Hvordan virker ARP?



Hvordan virker ARP? - 2

ping 10.0.0.2 udført på server medfører

ARP Address Resolution Protocol request/reply:

- ARP request i broadcast - Who has 10.0.0.2 Tell 10.0.0.1
- ARP reply (fra 10.0.0.2) 10.0.0.2 is at 00:40:70:12:95:1c

IP ICMP request/reply:

- Echo (ping) request fra 10.0.0.1 til 10.0.0.2
- Echo (ping) reply fra 10.0.0.2 til 10.0.0.1
- ...

ARP udføres altid på Ethernet før der kan sendes IP trafik

(kan være RARP til udstyr der henter en adresse ved boot)

ARP cache

```
hlk@bigfoot:hlk$ arp -an
? (10.0.42.1) at 0:0:24:c8:b2:4c on en1 [ethernet]
? (10.0.42.2) at 0:c0:b7:6c:19:b on en1 [ethernet]
```

ARP cache kan vises med kommandoen `arp -an`

`-a` viser alle

`-n` viser kun adresserne, prøver ikke at slå navne op - typisk hurtigere

ARP cache er dynamisk og adresser fjernes automatisk efter 5-20 minutter hvis de ikke bruges mere

Læs mere med `man 4 arp`

Basale testværktøjer TCP - Telnet og OpenSSL

Telnet blev tidligere brugt til login og er en klartekst forbindelse over TCP

Telnet kan bruges til at teste forbindelsen til mange ældre serverprotokoller som benytter ASCII kommandoer

- telnet mail.kramse.dk 25 laver en forbindelse til port 25/tcp
- telnet www.kramse.dk 80 laver en forbindelse til port 80/tcp

Til krypterede forbindelser anbefales det at teste med openssl

- openssl s_client -host www.kramse.dk -port 443
laver en forbindelse til port 443/tcp med SSL
- openssl s_client -host mail.kramse.dk -port 993
laver en forbindelse til port 993/tcp med SSL

Med OpenSSL i client-mode kan services tilgås med samme tekstkommandoer som med telnet

Wireshark - grafisk pakkesniffer

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News And Events

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SHARKFEST '15 will be held from June 22 – 25 at the Computer History Museum in Mountain View, CA.
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Troubleshooting with Wireshark
By Laura Chappell
Foreword by Gerald Combs
Edited by Jim Aragon

This book focuses on the tips and techniques used to identify

Wireshark Blog

Cool New Stuff
Dec 17 | By Evan Huus

Wireshark 1.12 Officially Released!
Jul 31 | By Evan Huus

To Infinity and Beyond! Capturing Forever with Tshark
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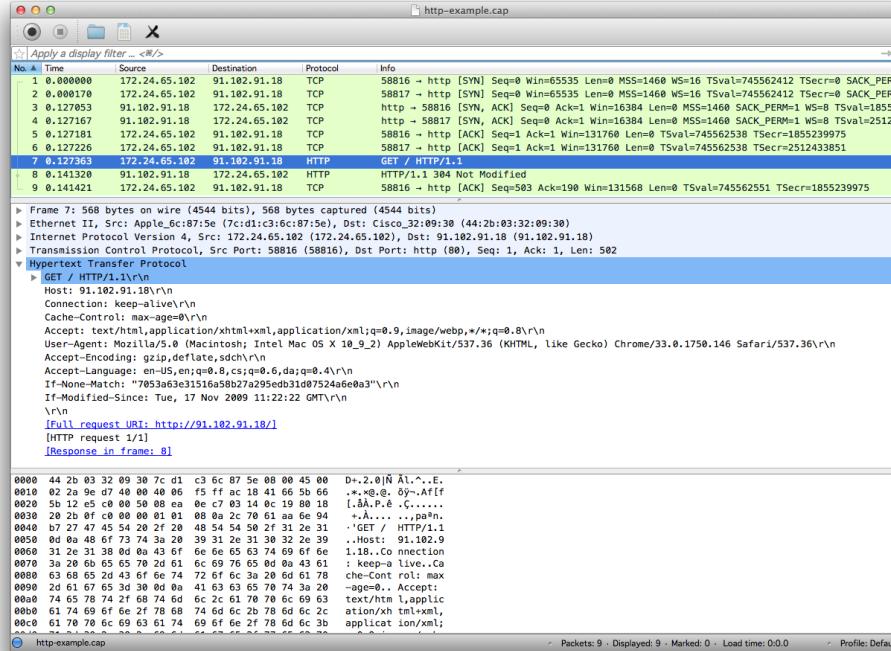
802.11 Packet Capture

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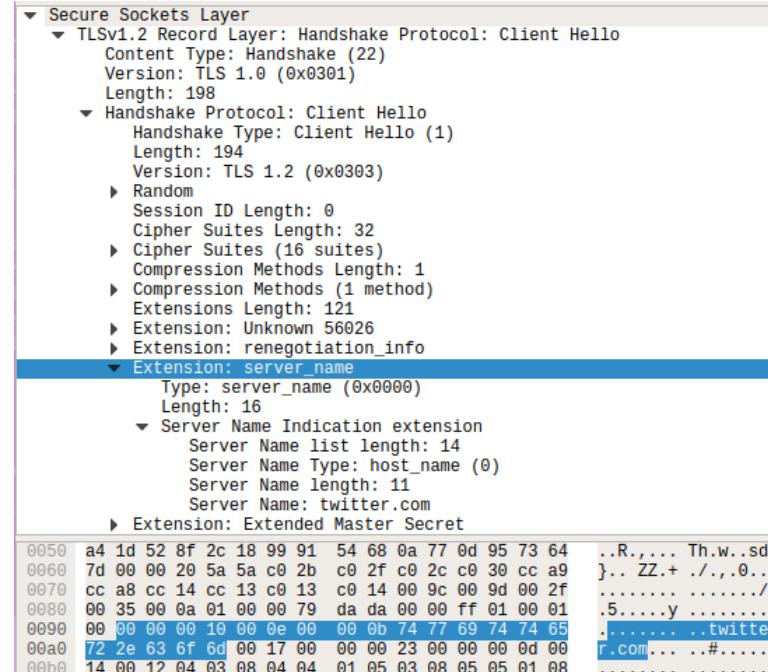
<http://www.wireshark.org>
både til Windows og UNIX

Brug af Wireshark



Man starter med Capture - Options

Brug af Wireshark



The screenshot shows the Wireshark interface with a selected TLS Client Hello message. The tree view on the left details the message structure:

- Secure Sockets Layer
- TLSv1.2 Record Layer: Handshake Protocol: Client Hello
 - Content Type: Handshake (22)
 - Version: TLS 1.0 (0x0301)
 - Length: 198
- Handshake Protocol: Client Hello
 - Handshake Type: Client Hello (1)
 - Length: 194
 - Version: TLS 1.2 (0x0303)
 - Random
 - Session ID Length: 0
 - Cipher Suites Length: 32
 - Cipher Suites (16 suites)
 - Compression Methods Length: 1
 - Compression Methods (1 method)
 - Extensions Length: 121
 - Extension: Unknown 56026
 - Extension: renegotiation_info
 - Extension: server_name
 - Type: server_name (0x0000)
 - Length: 16
 - Server Name Indication extension
 - Server Name list length: 14
 - Server Name Type: host_name (0)
 - Server Name length: 11
 - Server Name: twitter.com
 - Extension: Extended Master Secret

The 'Extension: server_name' section is highlighted with a blue background. Below the tree view, the hex and ASCII panes show the raw bytes and characters of the selected message.

Hex	ASCII
0050 a4 1d 52 8f 2c 18 99 91 54 68 0a 77 0d 95 73 64	.R.,.... Th.w..sd
0060 7d 00 00 20 5a 5a c0 2b c0 2f c0 2c c0 30 cc a9	}.. ZZ.+ ./.,.0..
0070 cc a8 cc 14 cc 13 c0 13 c0 14 00 9c 00 9d 00 2f/
0080 00 35 00 0a 01 00 00 79 da da 00 00 ff 01 00 01	.5.....y
0090 00 00 00 10 00 0e 00 00 0b 74 77 69 74 74 65twitte
00a0 72 2e 63 6f 6d 00 17 00 00 00 23 00 00 00 0d 00	r.con... .#....
00b0 14 00 12 04 03 08 04 04 01 05 03 08 05 05 01 08

Læg også mærke til filtermulighederne

Hardware IPv4 checksum offloading

IPv4 checksum skal beregnes hvergang man modtager en pakke

IPv4 checksum skal beregnes hvergang man sender en pakke

Lad en ASIC gøre arbejdet!

De fleste servernetkort tilbyder at foretage denne beregning på IPv4

IPv6 benytter ikke header checksum, det er unødvendigt

NB: kan resultere i at værktøjer siger checksum er forkert!

Exercise



Now lets do the exercise

Wireshark and Tcpdump 15 min

which is number **10** in the exercise PDF.

TCP/IP basiskonfiguration

```
ip address add 10.0.42.123/254dev eth0  
ip route add default via 10.0.42.1
```

konfiguration af interfaces og netværk på UNIX foregår med:

ip fra iproute2 <https://en.wikipedia.org/wiki/Iproute2>

Tidligere brugte vi ifconfig, route og netstat

- ofte pakket ind i konfigurationsmenuer m.v.

fejlsøgning foregår typisk med ping og traceroute

På Microsoft Windows benyttes ikke ifconfig

men kommandoerne ipconfig og ipv6

Netværkskonfiguration på OpenBSD:

```
# cat /etc/hostname.em0
inet 10.0.0.23 0xffffffff00 NONE
# cat /etc/mygate
10.0.0.1
# cat /etc/resolv.conf
domain zecurity.com
lookup file bind
nameserver 91.239.100.100
```

Vigtigste protokoller

ARP Address Resolution Protocol

IP og ICMP Internet Control Message Protocol

UDP User Datagram Protocol

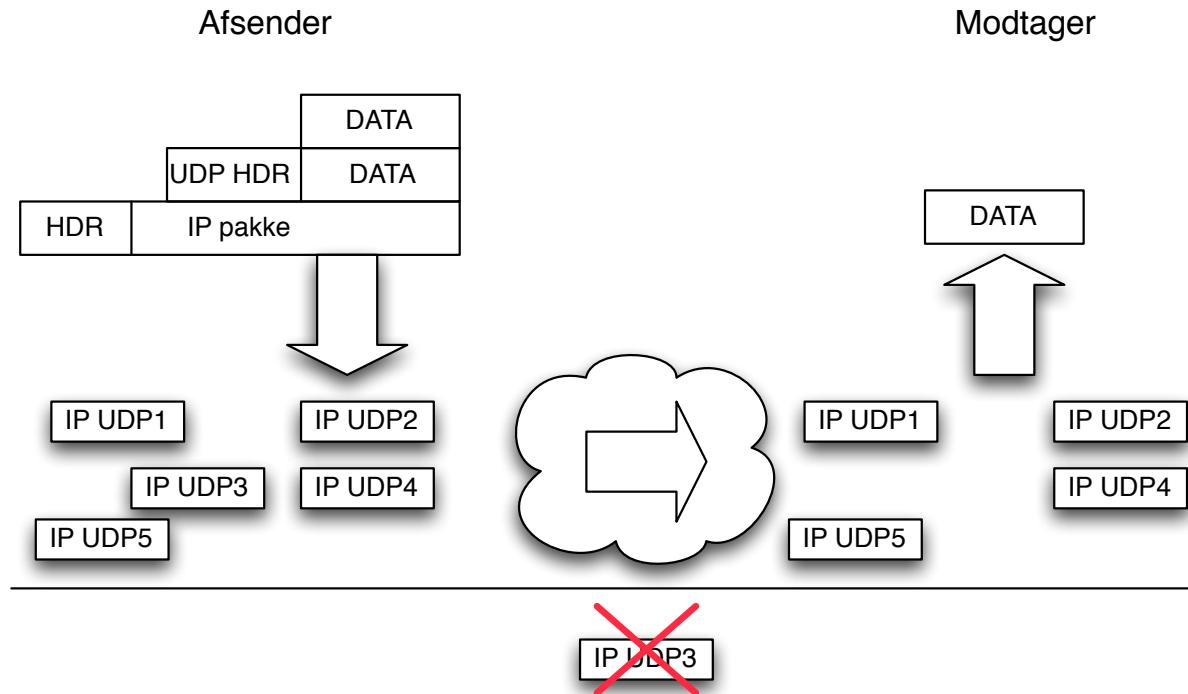
TCP Transmission Control Protocol

DHCP Dynamic Host Configuration Protocol

DNS Domain Name System

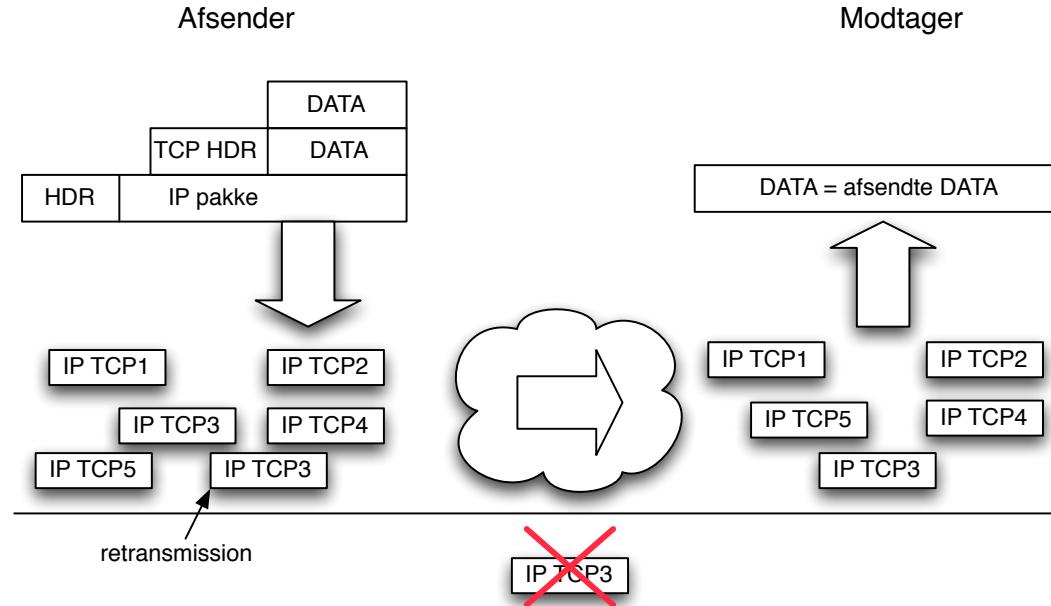
Ovenstående er omrent minimumskrav for at komme på internet

UDP User Datagram Protocol



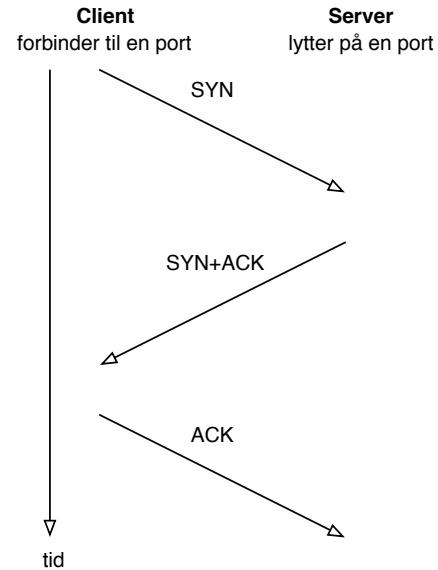
Forbindelsesløs RFC-768, *connection-less*

TCP Transmission Control Protocol



Forbindelsesorienteret RFC-791 September 1981, *connection-oriented*
Enten overføres data eller man får fejlmeddeelse

TCP three way handshake



- **TCP SYN half-open** scans
- Tidligere loggede systemer kun når der var etableret en fuld TCP forbindelse
 - dette kan/kunne udnyttes til *stealth*-scans



Now lets do the exercise

Capturing TCP Session packets 10 min

which is number **11** in the exercise PDF.

Well-known port numbers



IANA vedligeholder en liste over magiske konstanter i IP

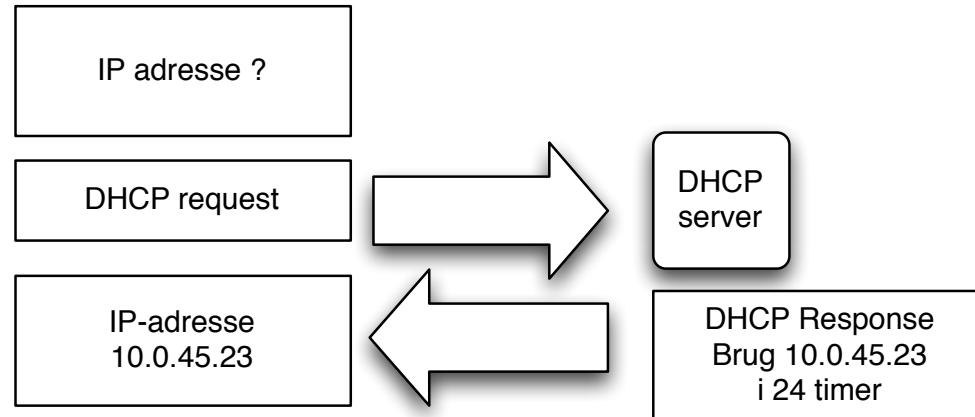
De har lister med hvilke protokoller har hvilke protokol ID m.v.

En liste af interesse er port numre, hvor et par eksempler er:

- Port 25 SMTP Simple Mail Transfer Protocol
- Port 53 DNS Domain Name System
- Port 80 HTTP Hyper Text Transfer Protocol over TLS/SSL
- Port 443 HTTP over TLS/SSL

Se flere på <http://www.iana.org>

DHCP Dynamic Host Configuration Protocol



Hvordan får man information om default gateway

Man sender et DHCP request og modtager et svar fra en DHCP server

Dynamisk konfiguration af klienter fra en centralt konfigureret server

Bruges til IP adresser og meget mere

IP adresserne administreres i dagligdagen af et antal Internet registries, hvor de største er:

- RIPE (Réseaux IP Européens) <http://ripe.net>
- ARIN American Registry for Internet Numbers <http://www.arin.net>
- Asia Pacific Network Information Center <http://www.apnic.net>
- LACNIC (Regional Latin-American and Caribbean IP Address Registry) - Latin America and some Caribbean Islands
disse fire kaldes for Regional Internet Registries (RIRs) i modsætning til Local Internet Registries (LIRs) og National Internet Registry (NIR)

ansvaret for Internet IP adresser ligger hos ICANN The Internet Corporation for Assigned Names and Numbers

<http://www.icann.org>

NB: ICANN må ikke forveksles med IANA Internet Assigned Numbers Authority <http://www.iana.org/> som bestyrer portnumre m.v.

ICMP - Internet Control Message Protocol

Benyttes til fejlbeskeder og til diagnosticering af forbindelser

ping programmet virker ved hjælp af ICMP ECHO request og forventer ICMP ECHO reply

```
$ ping 192.168.1.1
PING 192.168.1.1 (192.168.1.1): 56 data bytes
64 bytes from 192.168.1.1: icmp_seq=0 ttl=150 time=8.849 ms
64 bytes from 192.168.1.1: icmp_seq=1 ttl=150 time=0.588 ms
64 bytes from 192.168.1.1: icmp_seq=2 ttl=150 time=0.553 ms
```

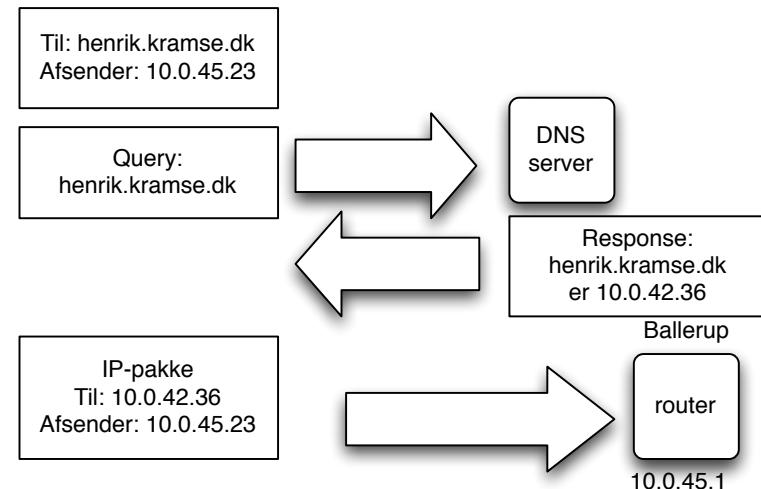
traceroute programmet virker ved hjælp af TTL

levetiden for en pakke tælles ned i hver router på vejen og ved at sætte denne lavt opnår man at pakken *timer ud* - besked fra hver router på vejen

default er UDP pakker, men på UNIX systemer er der ofte mulighed for at bruge ICMP

```
$ traceroute 185.129.60.129
traceroute to 185.129.60.129 (185.129.60.129),
30 hops max, 40 byte packets
 1  safri (10.0.0.11)  3.577 ms  0.565 ms  0.323 ms
 2  router (185.129.60.129)  1.481 ms  1.374 ms  1.261 ms
```

Domain Name System



Gennem DHCP får man typisk også information om DNS servere

En DNS server kan slå navne, domæner og adresser op

Foregår via query og response med datatyper kaldet resource records

DNS er en distribueret database, så opslag kan resultere i flere opslag

DNS systemet

navneopslag på Internet

tidligere brugte man en **hosts** fil

hosts filer bruges stadig lokalt til serveren - IP-adresser

UNIX: /etc/hosts

Windows c:\windows\system32\drivers\etc\hosts

Eksempel: www.zencurity.com har adressen 185.129.60.130

skrives i database filer, zone filer

www	IN	A	185.129.60.130
	IN	AAAA	2a06:d380:0:101::80

More than name lookups

Lots of resource records and types:

- addresser A-records
- IPv6 addresser AAAA-records
- authoritative nameservers NS-records
- post, mail-exchanger MX-records
- flere andre: md , mf , cname , soa , mb , mg , mr , null , wks , ptr , hinfo , minfo , mx ...

IN	MX	10	mail.zecurity.com.
IN	MX	20	mail2.zecurity.com.

Configuration via: /etc/resolv.conf

```
domain zecurity.com
nameserver 91.239.100.100
```

DNS root servers



As of 2019-01-29, the root server system consists of 933 instances operated by the 12 independent root server operators.

<http://root-servers.org/>

bestyrer .dk TLD - top level domain

man registrerer ikke .dk-domæner hos DK-hostmaster, men hos en registrator

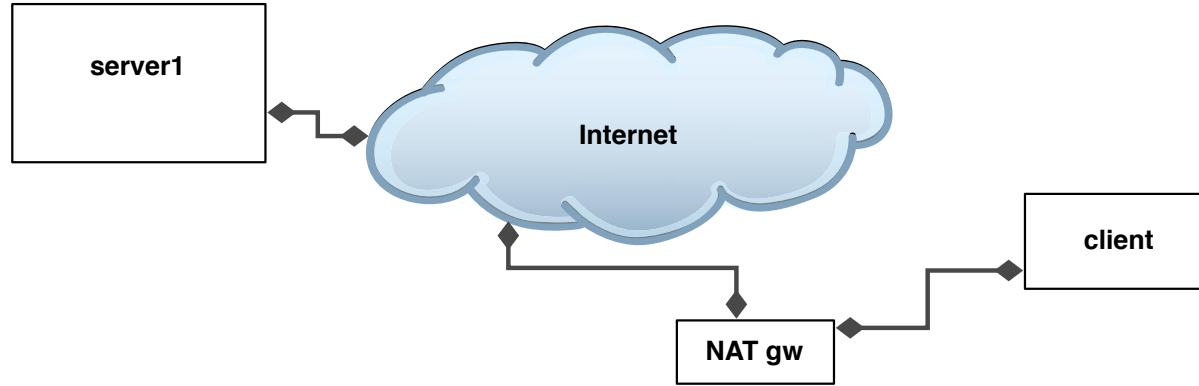
Et domæne bør have flere navneservere og flere postservere

autoritativ navneserver - ved autoritativt om IP-adresse for maskine.domæne.dk findes

ikke-autoritativ - har på vegne af en klient fået en adresse op

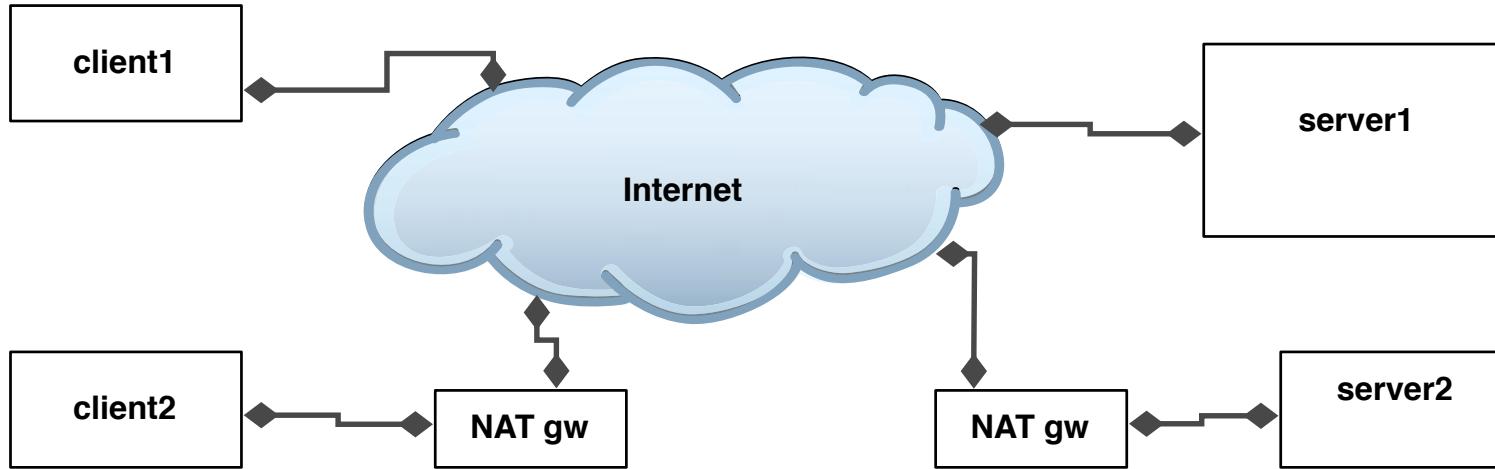
Det anbefales at overveje en service som har flere navneservere distribueret over stor geografisk afstand

NAT Network Address Translation



- NAT bruges til at forbinde et privat net (RFC-1918 adresser) med internet
- NAT gateway udskifter afsender adressen med sin egen
- En quick and dirty fix der vil forfølge os for resten af vores liv
- Lægger state i netværket - ødelægger fate sharing

NAT is BAD



- NAT ødelægger end-to-end transparency!
- Problemer med servere bagved NAT
- "løser" problemet "godt nok"(tm) for mange
- Men idag ser vi multilevel NAT! - eeeeeeewwwwww!
- Se RFC-2775 Internet Transparency for mere om dette emne

Exercise



Now lets do the exercise

Whois databases 15 min

which is number **12** in the exercise PDF.



Now lets do the exercise

Using ping and traceroute 10 min

which is number **13** in the exercise PDF.

Exercise



Now lets do the exercise

DNS and Name Lookups 10 min

which is number **14** in the exercise PDF.

Short IPv6 introduction

IPv4 running out

32-bit - der ikke kan udnyttes fuldt ud

Husk at idag benyttes Classless Inter-Domain Routing CIDR

http://en.wikipedia.org/wiki/Classless_Inter-Domain_Routing

IPv6 was developed in the 1990s

Tidslinie for IPv6 (forkortet)

- 1990 Vancouver IETF meeting det estimeres at klasse B vil løbe ud ca. marts 1994
- 1990 ultimo initiativer til at finde en afløser for IPv4
- 1995 januar RFC-1752 Recommendation for the IP NG Protocol
- 1995 september RFC-1883, RFC-1884, RFC-1885, RFC-1886 1. generation
- 1998 10. august "core"IPv6 dokumenter bliver Draft Standard
- Kilde: RFC-2460, RFC-2461, RFC-2463, RFC-1981 - m.fl.

IPv6: Internet redesigned? - nej!

Målet var at bevare de gode egenskaber

- basalt set Internet i gamle dage
- back to basics!
- fate sharing
- kommunikationen afhænger ikke af state i netværket
- end-to-end transparency

Idag er Internet blevet en nødvendighed for mange!

IP er en forretningskritisk ressource

IPv6 basis i RFC-1752 The Recommendation for the IP Next Generation Protocol

KAME - en IPv6 reference implementation



<http://www.kame.net>

- Er idag at betragte som en reference implementation
 - i stil med BSD fra Berkeley var det
- KAME har været på forkant med implementation af draft dokumenter
- KAME er inkluderet i OpenBSD, NetBSD, FreeBSD og BSD/OS - har været det siden version 2.7, 1.5, 4.0 og 4.2
- Projektet er afsluttet, men nye projekter fortsætter i WIDE regi <http://www.wide.ad.jp/>
- Der er udkommet to bøger som i detaljer gennemgår IPv6 protokollerne i KAME

Hvordan bruger man IPv6

www.zecurity.com

hlk@zecurity.com

DNS AAAA record tilføjes

```
www      IN A      185.129.60.130
          IN AAAA  2a06:d380:0:101::80
mail     IN A      185.129.60.131
          IN AAAA  2a06:d380:0:101::25
```

IPv6 addresser og skrivemåde

subnet prefix	interface identifier
---------------	----------------------

2001:16d8:ff00:012f:0000:0000:0000:0002

2001:16d8:ff00:12f::2

- 128-bit adresser, subnet prefix næsten altid 64-bit
- skrives i grupper af 4 hexcifre ad gangen adskilt af kolon :
- foranstillede 0 i en gruppe kan udelades, en række 0 kan erstattes med ::
- dvs 0:0:0:0:0:0 er det samme som
0000:0000:0000:0000:0000:0000:0000:0000
- Dvs min webservers IPv6 adresse kan skrives som: 2001:16d8:ff00:12f::2
- Specielle adresser: ::1 localhost/loopback og :: default route
- Læs mere i RFCerne

IPv6 addresser - prefix notation

Aggregatable Global Unicast

2001::/16 RIR subTLA space

- 2001:200::/23 APNIC
- 2001:400::/23 ARIN
- 2001:600::/23 RIPE

2002::/16 6to4 prefix

3ffe::/16 6bone allocation – nu udgået

link-local unicast addresses

fe80::/10 genereres udfra interface MAC addresserne EUI-64

Nu også privacy enhanced adresser

Se mere på <https://www.iana.org/assignments/iana-ipv6-special-registry/iana-ipv6-special-registry.xhtml>

IPv6 addresser - multicast

Unicast - identifierer ét interface pakker sendes til en modtager

Multicast - identifierer flere interfaces pakker sendes til flere modtagere

Anycast - identifierer en "gruppe"en pakke sendes til et vilkårligt interface med denne adresse typisk det nærmeste

Broadcast? er væk, udeladt, finito, gone!

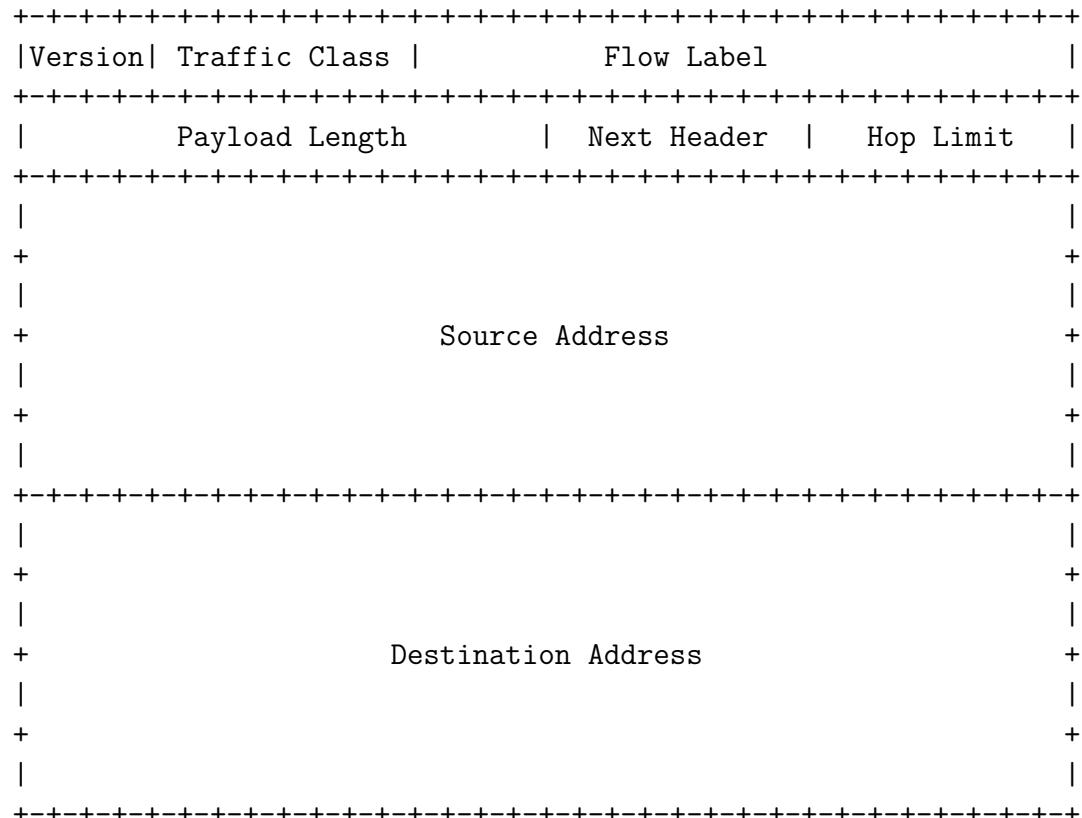
Husk også at site-local er deprecated, se RFC-3879

IPv6 pakken - header - RFC-2460

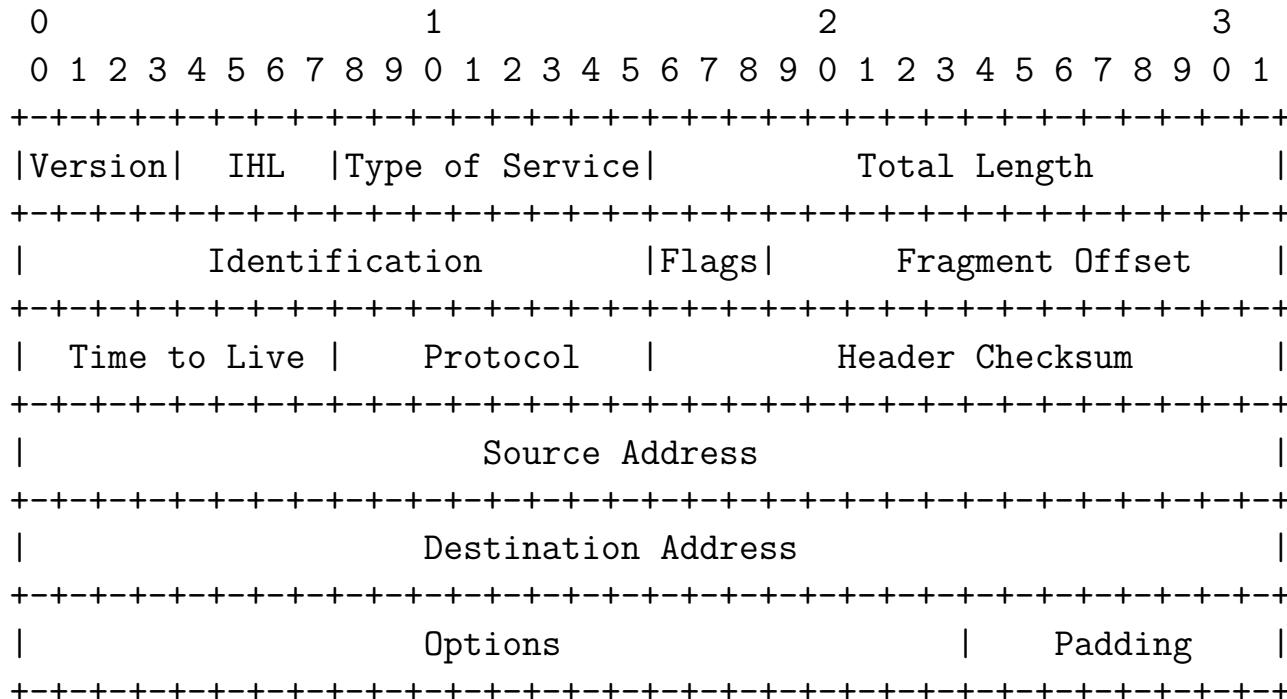
- Simplere - fixed size - 40 bytes
- Sjældent brugte felter (fra v4) udeladt (kun 6 vs 10 i IPv4)
- Ingen checksum!
- Adresser 128-bit
- 64-bit aligned, alle 6 felter med indenfor første 64

Mindre kompleksitet for routere på vejen medfører mulighed for flere pakker på en given router

IPv6 pakken - header - RFC-2460



IPv4 pakken - header - RFC-791



Example Internet Datagram Header

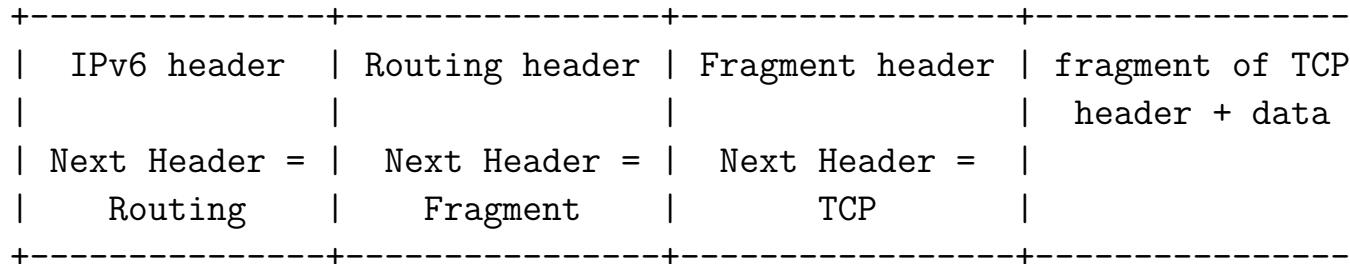
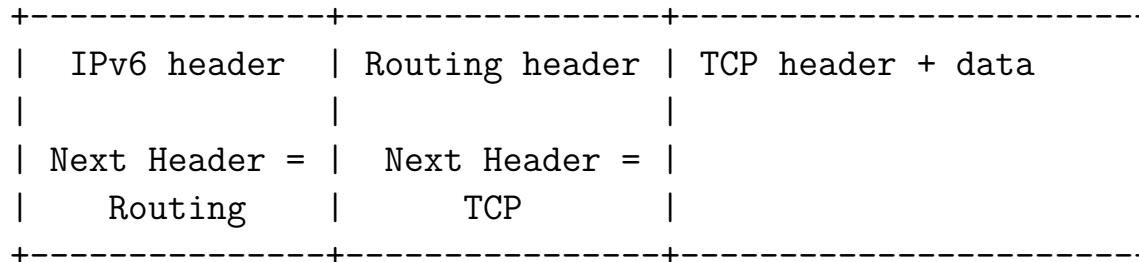
IPv6 pakken - extension headers RFC-2460

Fuld IPv6 implementation indeholder:

- Hop-by-Hop Options
- Routing (Type 0) - deprecated
- Fragment - fragmentering KUN i end-points!
- Destination Options
- Authentication
- Encapsulating Security Payload

Ja, IPsec er en del af IPv6!

Placering af extension headers



ping til IPv6 adresser

```
root# ping6 ::1
PING6(56=40+8+8 bytes) ::1 --> ::1
16 bytes from ::1, icmp_seq=0 hlim=64 time=0.312 ms
16 bytes from ::1, icmp_seq=1 hlim=64 time=0.319 ms
^C
--- localhost ping6 statistics ---
2 packets transmitted, 2 packets received, 0% packet loss
round-trip min/avg/max = 0.312/0.316/0.319 ms
```

Nogle operativsystemer kalder kommandoen ping6, andre bruger blot ping

ping6 til global unicast adresse

```
root# ping6 2001:1448:81:beef:20a:95ff:fef5:34df
PING6(56=40+8+8 bytes) 2001:1448:81:beef::1 --> 2001:1448:81:beef:20a:95ff:fef5:34df
16 bytes from 2001:1448:81:beef:20a:95ff:fef5:34df, icmp_seq=0 hlim=64 time=10.639 ms
16 bytes from 2001:1448:81:beef:20a:95ff:fef5:34df, icmp_seq=1 hlim=64 time=1.615 ms
16 bytes from 2001:1448:81:beef:20a:95ff:fef5:34df, icmp_seq=2 hlim=64 time=2.074 ms
^C
--- 2001:1448:81:beef:20a:95ff:fef5:34df ping6 statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max = 1.615/4.776/10.639 ms
```

ping6 til specielle adresser

```
root# ping6 -I en1 ff02::1
PING6(56=40+8+8 bytes) fe80::230:65ff:fe17:94d1 --> ff02::1
16 bytes from fe80::230:65ff:fe17:94d1, icmp_seq=0 hlim=64 time=0.483 ms
16 bytes from fe80::20a:95ff:fef5:34df, icmp_seq=0 hlim=64 time=982.932 ms
16 bytes from fe80::230:65ff:fe17:94d1, icmp_seq=1 hlim=64 time=0.582 ms
^C
--- ff02::1 ping6 statistics ---
4 packets transmitted, 4 packets received, +4 duplicates, 0% packet loss
round-trip min/avg/max = 0.483/126.236/982.932 ms
```

- ff02::1 ipv6-allnodes
- ff02::2 ipv6-allrouters
- ff02::3 ipv6-allhosts

Tilsvarende IPv4 er der special use adresser, se links til RFC tidligere for detaljer

Stop - tid til leg

Der findes et trådløst netværk med IPv6

Join med en laptop og prøv at pinge lidt

1. Virker ping6 ::1 eller ping ::1, fortsæt
2. Virker kommando svarende til: ping6 -I en1 ff02::1
- burde vise flere maskiner
3. Kig på dine egne adresser med: ipv6 (Windows) eller ifconfig (Unix)
4. Prøv at trace i netværket

Hvordan fik I IPv6 adresser?

Prøv at sætte jeres Debian eller Kali i bridge mode på netværkskortet, hvis muligt – wifi kort kan drille her

router advertisement daemon

```
/etc/rtadvd.conf:  
en0:  
    :addrs#1:addr="2001:1448:81:b00f::":prefixlen#64:  
en1:  
    :addrs#1:addr="2001:1448:81:beef::":prefixlen#64:
```

```
root# /usr/sbin/rtadvd -Df en0 en1  
root# sysctl -w net.inet6.ip6.forwarding=1  
net.inet6.ip6.forwarding: 0 -> 1
```

Stateless autoconfiguration er en stor ting i IPv6

Kommandoen starter den i debug-mode og i forgrunden

- normalt vil man starte den fra et script

Typisk skal forwarding aktiveres, som vist med BSD sysctl kommando

IPv6 og andre services

```
root# netstat -an | grep -i listen
```

tcp46	0	0	*.80	*.*	LISTEN
tcp4	0	0	*.6000	*.*	LISTEN
tcp4	0	0	127.0.0.1.631	*.*	LISTEN
tcp4	0	0	*.25	*.*	LISTEN
tcp4	0	0	*.20123	*.*	LISTEN
tcp46	0	0	*.20123	*.*	LISTEN
tcp4	0	0	127.0.0.1.1033	*.*	LISTEN

ovenstående er udført på Mac OS X

IPv6 output fra kommandoer - inet6 family

```
root# netstat -an -f inet6
```

Active Internet connections (including servers)

Proto	Recv	Send	Local	Foreign	(state)
tcp46	0	0	*.80	*.*	LISTEN
tcp46	0	0	*.22780	*.*	LISTEN
udp6	0	0	*.5353	*.*	
udp6	0	0	*.5353	*.*	
udp6	0	0	*.514	*.*	
icm6	0	0	*.*	*.*	
icm6	0	0	*.*	*.*	
icm6	0	0	*.*	*.*	

ovenstående er udført på Mac OS X og tilrettet lidt

IPv6 er default for mange services

```
root# telnet localhost 80
```

```
Trying ::1...
Connected to localhost.
Escape character is '^]'.
GET / HTTP/1.0
```

```
HTTP/1.1 200 OK
Date: Thu, 19 Feb 2004 09:22:34 GMT
Server: Apache/2.0.43 (Unix)
Content-Location: index.html.en
Vary: negotiate,accept-language,accept-charset
...
```

IPv6 er default i OpenSSH

```
hlk$ ssh -v localhost -p 20123
OpenSSH_3.6.1p1+CAN-2003-0693, SSH protocols 1.5/2.0, OpenSSL 0x0090702f
debug1: Reading configuration data /Users/hlk/.ssh/config
debug1: Applying options for *
debug1: Reading configuration data /etc/ssh_config
debug1: Rhosts Authentication disabled, originating port will not be trusted.
debug1: Connecting to localhost [::1] port 20123.
debug1: Connection established.
debug1: identity file /Users/hlk/.ssh/id_rsa type -1
debug1: identity file /Users/hlk/.ssh/id_dsa type 2
debug1: Remote protocol version 2.0, remote software version OpenSSH_3.6.1p1+CAN-2003-0693
debug1: match: OpenSSH_3.6.1p1+CAN-2003-0693 pat OpenSSH*
debug1: Enabling compatibility mode for protocol 2.0
debug1: Local version string SSH-2.0-OpenSSH_3.6.1p1+CAN-2003-0693
```

Routing forståelse - IPv6

```
$ netstat -f inet6 -rn
Routing tables
Internet6:
Destination          Gateway          Flags    Netif
default              fe80::200:24ff:fed1:58ac  UGc      en0
::1                  ::1               UH       lo0
2001:1448:81:cf0f::/64 link#4          UC       en0
2001:1448:81:cf0f::1  0:0:24:c1:58:ac  UHLW     en0
fe80::/64            fe80::1          Uc       lo0
fe80::1              link#1          UHL      lo0
fe80::/64            link#4          UC       en0
fe80::20d:93ff:fe28:2812 0:d:93:28:28:12  UHL      lo0
fe80::/64            link#5          UC       en1
fe80::20d:93ff:fe86:7c3f 0:d:93:86:7c:3f  UHL      lo0
ff01::/32            ::1               U       lo0
ff02::/32            ::1               UC      lo0
ff02::/32            link#4          UC       en0
ff02::/32            link#5          UC       en1
```

IPv6 neighbor discovery protocol (NDP)

OSI	IPv4	IPv6
Network	IP / ICMP	IPv6 / ICMPv6
Link	ARP	
Physical	Physical	Physical

ARP er væk

NDP erstatter og udvider ARP, Sammenlign arp -an med ndp -an

Til dels erstatter ICMPv6 således DHCP i IPv6, DHCPv6 findes dog

NB: bemærk at dette har stor betydning for firewallregler!

ARP vs NDP

```
hlk@bigfoot:basic-ipv6-new$ arp -an
? (10.0.42.1) at 0:0:24:c8:b2:4c on en1 [ethernet]
? (10.0.42.2) at 0:c0:b7:6c:19:b on en1 [ethernet]
hlk@bigfoot:basic-ipv6-new$ ndp -an
Neighbor                      Linklayer Address  Netif Expire      St Flgs Prbs
::1                           (incomplete)        lo0 permanent R
2001:16d8:ffd2:cf0f:21c:b3ff:fec4:e1b6 0:1c:b3:c4:e1:b6 en1 permanent R
fe80::1%lo0                   (incomplete)        lo0 permanent R
fe80::200:24ff:fec8:b24c%en1 0:0:24:c8:b2:4c       en1 8h54m51s S R
fe80::21c:b3ff:fec4:e1b6%en1 0:1c:b3:c4:e1:b6       en1 permanent R
```

Ovenstående udført på Mac OS X, BSD unix – på Linux ville man ofte bruge ip neighbor show

Hvorfor implementere IPv6 i jeres netværk?

Addresserummet

- end-to-end transparency
- nemmere administration

Autoconfiguration

- stateless autoconfiguration
- automatisk routerconfiguration! (router renumbering)

Performance

- simplere format
- kortere behandlingstid i routere

Fleksibilitet - generelt

Sikkerhed

- IPsec er et krav!
- Afsender IP-adressen ændres ikke igennem NAT!

I resten af kurset vil vi ikke betragte IPv6 eller IPv4 som noget specielt

Vi vil indimellem bruge det ene, indimellem det andet

Alle subnets er konfigureret ens på IPv4 og IPv6

Subnets som i IPv4 hedder prefix.45 vil således i IPv6 hedde noget med prefix:45:

At have ens routing på IPv4 og IPv6 vil typisk IKKE være tilfældet i praksis

Man kan jo lige så godt forbedre netværket mens man går over til IPv6 :-)

Security problems in the TCP/IP Suite

The title of a nice paper, and the rest of today

The paper “Security Problems in the TCP/IP Protocol Suite” was originally published in Computer Communication Review, Vol. 19, No. 2, in April, 1989

Problems described in the original:

- sequence number spoofing
- routing attacks,
- source address spoofing
- authentication attacks

TCP sequence number prediction

TCP SEQUENCE NUMBER PREDICTION One of the more fascinating security holes was first described by Morris [7] . Briefly, he used TCP sequence number prediction to construct a TCP packet sequence without ever receiving any responses from the server. This allowed him to spoof a trusted host on a local network.

tidligere baserede man login/adgange på source IP adresser, address based authentication
Er ikke en pålidelig autentifikationsmekanisme

Mest kendt er nok Shimomura der blev hacket på den måde,
måske af Kevin D Mitnick eller en kompagnon

I praksis vil det være svært at udføre på moderne operativsystemer

Se evt. <http://www.takedown.com/> (filmen er ikke så god ;-)

Det er naturligvis fint med filtre så man kun kan tilgå services FRA bestemte IP

Routing attacks

Problems described in the original from 1989:

- IP Source routing attacks - angiv en rute for pakkerne
Knapt så brugbar idag
- Routing Information Protocol Attacks
The Routing Information Protocol [15] (RIP) - denne bruges ikke mere, outdated
- BGPv4 som bruges idag har kæmpe problemer, kludetæppe af kludges

Vi kommer til at snakke om <https://github.com/tomac/yersinia>

Solutions to TCP/IP security problems

Solutions:

- Use RANDOM TCP sequence numbers, Win/Mac/Linux - DO, but IoT?
- Filtering, ingress / egress:
"reject external packets that claim to be from the local net"
- Routers and routing protocols must be more skeptical
Routing filter everywhere, auth på OSPF/BGP etc.

Has been recommended for some years, but not done in all organisations

BGP routing Resource Public Key Infrastructure RPKI

DNS problems

The Domain Name System (DNS) [32][33] provides for a distributed database mapping host names to IP addresses. An intruder who interferes with the proper operation of the DNS can mount a variety of attacks, including denial of service and password collection. There are a number of vulnerabilities.

We have a lot of the same problems in DNS today

Plus some more caused by middle-boxes, NAT, DNS size, DNS inspection

- DNS must allow both UDP and TCP port 53
- Your DNS servers must have updated software, see DNS flag day
<https://dnsflagday.net/> after which kludges will be REMOVED!

SNMP problems

5.5 Simple Network Management Protocol The Simple Network Management Protocol (SNMP) [37] has recently been defined to aid in network management. Clearly, access to such a resource must be heavily protected. The RFC states this, but also allows for a null authentication service; this is a bad idea. Even a “read-only” mode is dangerous; it may expose the target host to netstat-type attacks if the particular Management Information Base (MIB) [38] used includes sequence numbers. (T

True, and we will talk more about SNMP later in this course.

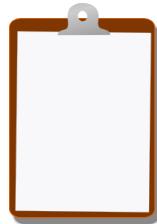
local networks

6.1 Vulnerability of the Local Network Some local-area networks, notably the Ethernet networks, are extremely vulnerable to eavesdropping and host-spoofing. If such networks are used, physical access must be strictly controlled. It is also unwise to trust any hosts on such networks if any machine on the network is accessible to untrusted personnel, unless authentication servers are used. If the local network uses the Address Resolution Protocol (ARP) [42] more subtle forms of host-spoofing are possible. In particular, it becomes trivial to intercept, modify, and forward packets, rather than just taking over the host's role or simply spying on all traffic.

Today we can send VXLAN spoofed packets across the internet layer 3 and inject ARP behind firewalls, in some cloud infrastructure cases ...

A Look Back at “Security Problems in the TCP/IP Protocol Suite” about 1989 + 15 years = 2004

For Next Time



Think about the subjects from this time, write down questions

Check the plan for chapters to read in the books

Visit web sites and download papers if needed

Retry the exercises to get more confident using the tools