Computer Networks

Lecture on

Review of Today's Network Technologies

Plan of This Lecture

- Word Wide Web
- Internet
- Other WAN technologies
- Access networks
- Passive networks
- Wavelength-Division Multiplexing
- Special purpose networks

Word Wide Web

- Is an information space where documents and services – called resources
  - are identified by Uniform Resource Locators (URLs)
  - are interlinked by hypertext links
- Works over the Internet – precisely over the Hypertext Transfer Protocol (HTTP)
  - for security HTTPS – i.e. HTTP over Transport Layer Security (TLS) protocol
- Is standardised by Word Wide Web Consortium (W3C)

The W3C standards define a collection of technologies for application development

- Web Design and Applications – for building and Rendering Web pages
- Web of Devices – to enable Web access anywhere, anytime, using any device
  - e.g. mobile phones, interactive television, automobiles
- Web Architecture
- Semantic Web
- Web of Services
- Browsers and Authoring Tools

Internet

Interconnected networks or internetwork – origin of the term “internet”

Next the Internet protocol was standardised (1982)

The Internet – a global public network where devices communicate over the Internet protocol (IP)

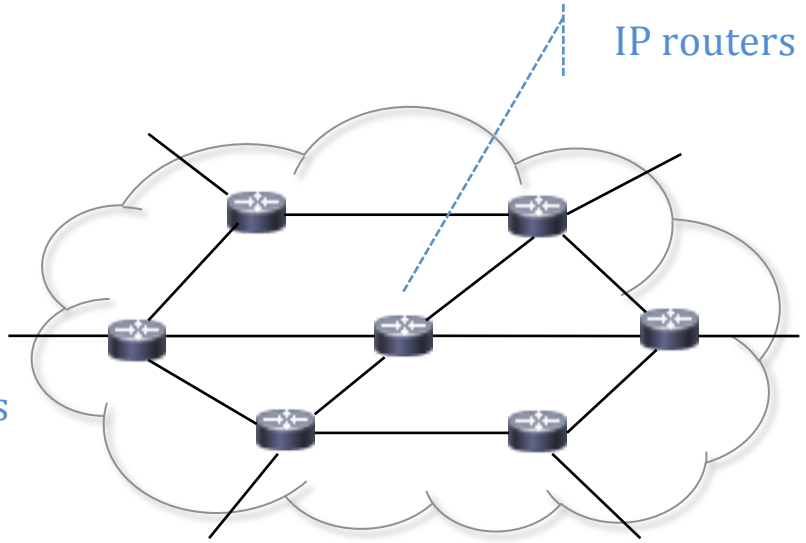
- A proper noun – to distinguish it from other public WANs
- An internet – a common noun as a computer communication medium, like radio, television
- See: en.wikipedia.org/wiki/Capitalization_of_Internet

An intranet – a private network where devices communicate over IP

All over the Internet

- digital documents
- remote processing
- telephone calls VoIP – Voice over IP
- TV programs IPTV
- commercial and financial services

IP header contains destination address
Router use it to select output interface



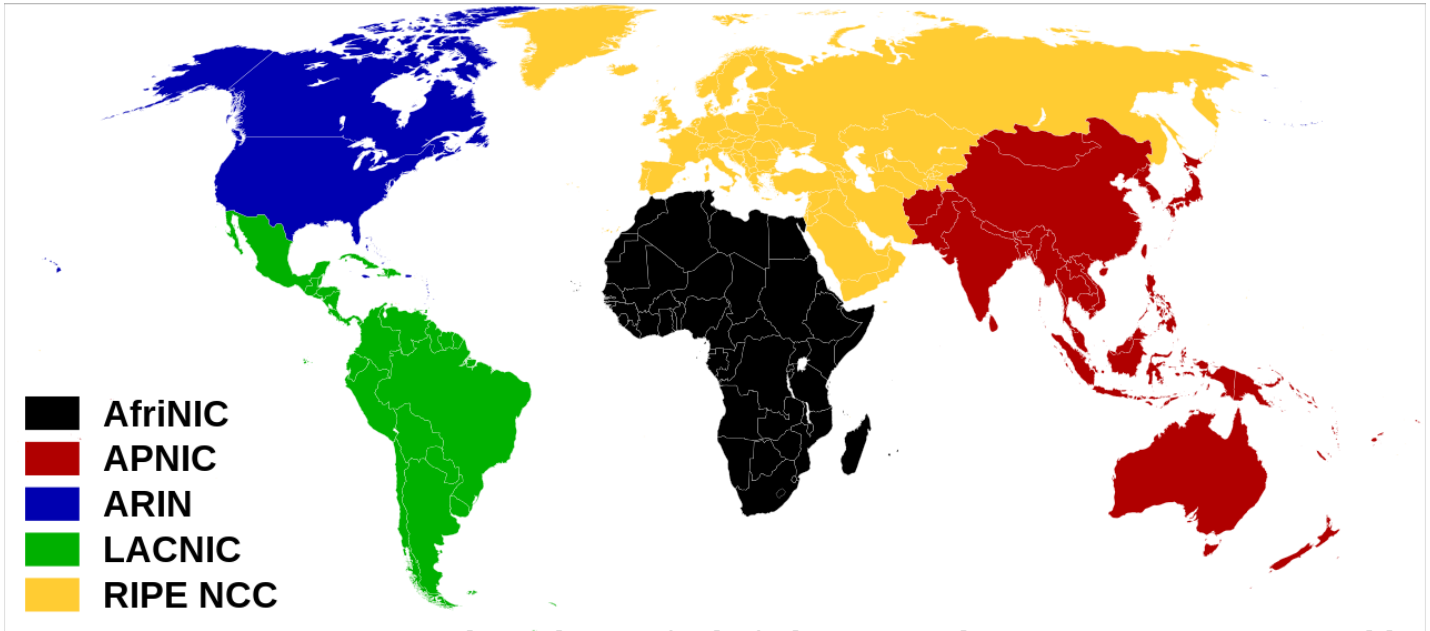
Institutions related to the Internet

IRTF Internet Research Task Force

IETF Internet Engineering Task Force – publishes RFCs *Request For Comments*

IANA Internet Assigned Numbers Authority – e.g. IP addresses

- RIPE Réseaux IP Européens
- ARIN American Registry for Internet Numbers
- APNIC Asia-Pacific Network Information Centre
- LACNIC Latin American and Caribbean Internet Addresses Registry
- AfriNIC African Network Information Centre



Source: commons.wikimedia.org/wiki/File:Regional_Internet_Registries_world_map.svg

Brief Internet History

1962 first memos about packet switching
from Bolt Beranek and Newman - a high-technology company

1966 Advanced Research Projects Agency of USA DoD started the ARPANET project

1968 BBN started its deployment

1969 public distribution of RFC - *Request For Comments* !!!
nic.ddn.mil ftp telnet (guest anonymous)
www.rfc-editor.org/rfcsearch.html – today
datatracker.ietf.org
tools.ietf.org/html/ See RFC 2549 – have some fun

1971 ARPANET opened to the public use NCP – *Network Control Protocol*

- remote login
- file transfer
- email

1981 TCP/IP – It is a shortcut for a bunch of related protocols
National Transport Control Protocol / Internet Protocol, Version 4 Specification

1983 UNIX 4.2 BSD with TCP / IP - public domain !!!

rise of DNS !!!

1984 MILNET - separation of the military portion of ARPANET

1985 Creation of NSFNET *National Science Foundation Network*

1989 100 000 computers in the Internet

1990 Dismantling of ARPANET

First web server !!! – non qualified people can use the Internet

1992 1 000 000 computers in the Internet

1994 Creation of W3C *World Wide Web Consortium*

1994 NAT *The IP Network Address Translator* – connects to Internet nodes with private addresses

1996 IPv6 *Internet Protocol, Version 6 Specification* – huge IP address space

1998 CIDR *Classless Inter-Domain Routing* – more efficient IP address assignments

2002 200 000 000 computers in the Internet

2004 Root DNS servers support both IPv6 and IPv4

2008 DNS support IPv4 & IPv6 in IANA IP core – users mustn't deal with IP addresses

Other WAN Technologies

	X.25	Frame Relay (FR)	Asynchronous Transfer Mode (ATM)	Multiprotocol Label Switching (MPLS)
Massive deployments from	1980	1990	1995	2000
In use	no	yes	yes	still new deployments
Max. speed	64 kb/s – access 2 Mb/s – net.	45 Mb/s	1,54 ... 622 Mb/s, 2.5, 10 Gb/s	100 Gb/s
Packets	variable length	variable length	53 bytes length	variable length

Quality of services	Basic, i.e.:
	• delay
	• delivery ratio availability
	• time to repair
		Basic +
		CIR – Committed Information Rate
		EIR – Excess Information Rate
			Basic +
			traffic categories:
			• **C**onstant **B**it **R**ate
			• Real-Time
			  • **V**ariable **B**it **R**ate
			• Non-Real-Time
			  • **V**ariable **B**it **R**ate
			• Unspecified Bit Rate
			• Available Bit Rate
				Basic +
				a few forwarding classes (class of services)

- X.25, FR, ATM switches are layer 3 devices
  - Addressing – International numbering plan for public data networks ITU-T X.121
  - Path identifier is used to switch data packets
- ATM QoS parameters

	CBR	nrt-VBR	rt-VBR	ABR	UBR
Cell Loss Ratio	+	+	+	+	
Cell Transfer Delay	+		+		
Cell Delay Variation	+	+	+		
Peak Cell Rate	+	+	+		+
Sustained Cell Rate		+	+		
Burst Tolerance @ PCR		+	+		
flow control				+	

  - ATM connection can manage some QoS parameters
- MPLS switches are considered layer 2.5 devices
  - Path identifier is used to switch data packets
  - Packet flows are bound to forwarding classes – Class of Services
    - Bandwidth is statically allocated to the classes

Telephony Technologies

All of them can carry data, so IP packets too

Analog telephony networks via modems

Digital

- ISDN – Integrated Services Digital Network
  - N x 64 kb/s
- SONET / SDH – Synchronous Optical Networking / Synchronous Digital Hierarchy in USA / in Europe
  - reliable transmission channels of fixed bit rate – TDM
  - STM-1 – 155.52 Mb/s … STM-256 – 39.813120 Gb/s
- Cellular Networks
  - GSM
  - IS-95
  - UMTS
  - CDMA2000
  - LTE
- Satellite phone networks

Access networks

DSL – Digital Subscriber Line

- family of technologies used to transmit digital data over copper telephone lines
- different down- and up-link speeds, e.g. 24 Mbit/s and 3.5 Mbit/s
- speed strongly depends on distance and cable quality

DOCSIS – Data Over Cable Service Interface Specification

- data transfer over existing cable television systems (hybrid fiber-coaxial)
- speeds from 10 Mb/s to 10 Gb/s

Ethernet

- wired network
- big variety of interfaces
- speeds: 10, 100 Mb/s, 1, 10, 40, 100, 400 Gb/s

Wi-Fi

- wireless network
- numerous versions
- speed strongly depends on distance and radio noise

Generation	Supported version	Max. link rate
Wi-Fi 6	802.11ax	600–9608 Mbit/s
Wi-Fi 5	802.11ac	433–6933 Mbit/s
Wi-Fi 4	802.11n	72–600 Mbit/s

Passive Networks

Passive network infrastructure

- telecommunication pipes
- telecommunication cables

Laid by

- telephone and cable-TV companies
- energy (electro- and heat), water, gas, oil distribution companies
- railway and highway companies
- municipalities
- building developers

for

- their own purposes
- lease

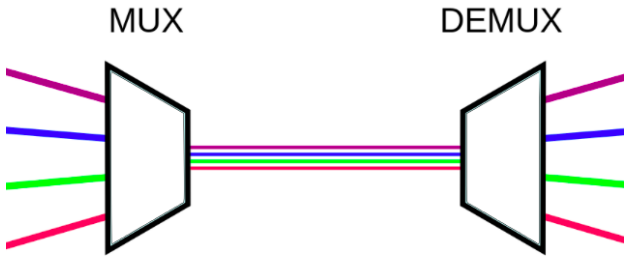
Optical cables replace copper cables

Wavelength-Division Multiplexing

Multiplexes a number of optical carrier signals onto a single optical fiber

Wavelengths are colors of laser light

- Coarse WDM
  - 60 km span
  - up to 16 colors
- Dense WDM
  - 100-140 km span
  - 40, 80 and more colors



Overlay Networks

- VPN – Virtual Private Network
  - e.g. enterprise intranet connecting remote departments and workers

- Content addressable
  - to unbind resources from their locations
  - e.g. for distributed data storage

- Anonymous Internet – TOR (The Onion Routing)
  - intended to protect the personal privacy – e.g. visits to Web sites, instant messages
  - does not hide the fact that someone is using TOR

Special Purpose Networks

- Delay tolerant (disruption tolerant)
  - lack of continuous connectivity due to
    - limits of wireless radio range
    - sparsity of mobile nodes
    - energy resources
    - attack
    - noise
  - mobile or extreme terrestrial environments
  - planned networks in space
- Ad hoc networks
  - e.g. between moving vehicles
- Sensor networks
  - for energy and computation constrained devices
  - can be connected to the Internet via gate devices

Bandwidth

Offered by interfaces

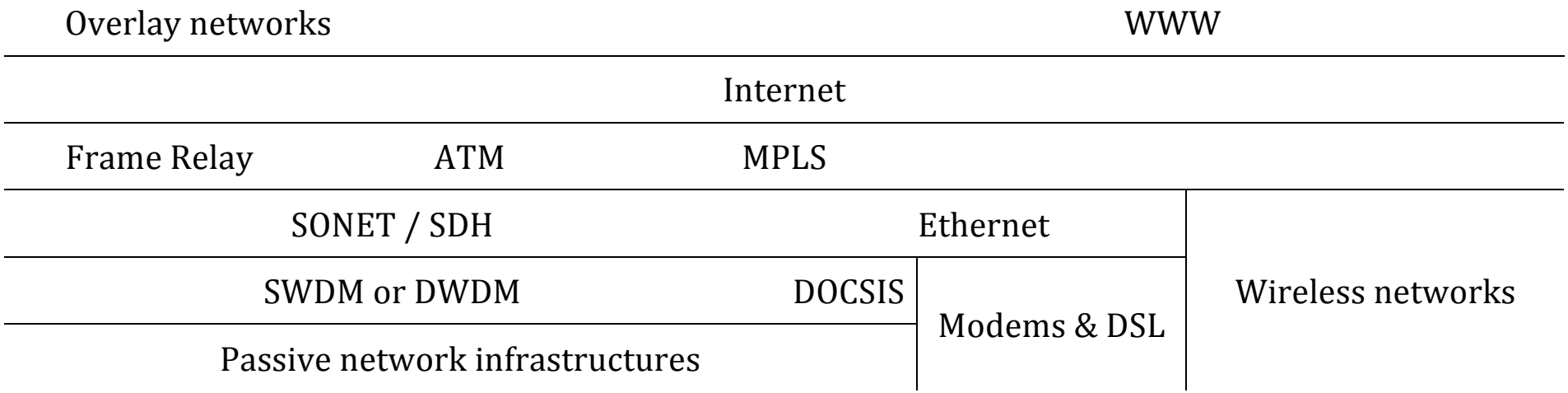
- analog modem 28.8 ÷ 56 kb/s
- ISDN 64 kb/s ÷ 2 Mb/s
- DSL 115 kb/s ÷ 1 Gb/s – distance and cable quality dependent
- Ethernet 10 Mb/s ÷ 100 Gb/s
- optical fiber 34 Mb/s ÷ 40 Gb/s
- DWDM 800 Gb/s ÷ 10 Tb/s (!)
- radio link 128 kb/s ÷ 1 Gb/s

Needed by applications

- voice channel 64 kb/s
- SDTV (MPEG-2) 3 ÷ 8 Mb/s
- SDTV (MPEG-4) 1.4 ÷ 2 Mb/s
- HDTV (MPEG-2) 14 ÷ 20 Mb/s
- HDTV (MPEG-4) 4 ÷ 18 Mb/s

Summary

Data transmission services or infrastructure for lease:



Owners of passive network infrastructures:

- municipal companies that distribute: electricity, water, heat, gas
- country wide distributors of: electricity, gas, oil
- rail roads and highway companies

- Word Wide Web
- Internet
  - Institutions related to the Internet
  - Brief internet history
- Other WAN technologies
- Access networks
- Passive networks
- Wavelength-Division Multiplexing
- Overlay networks
  - Virtual private network
  - Content addressable
  - Anonymous Internet
- Special purpose networks
  - Delay tolerant
  - Ad hoc & sensor networks
- Offered and needed bandwidth

Questions

1. What is WWW (World Wide Web)?
2. What are the aims of IETF, IANA and APNIC?
3. Describe the history of Internet evolution.
4. What were the most important reasons for Internet grow and be world widely used?
5. What was the reason for introduction of NAT (Network Address Translation) into Internet?
6. What was the main reason for IPv6 construction?
7. What was the reason for introduction of CIDR (Classless Inter-Domain Routing)?
8. Compare Frame Relay, ATM and MPLS technologies.
9. What are the telephony technologies used for data transmission?
10. What are today's network access technologies?
11. Who builds passive network infrastructures?
12. What for do we use wavelength-division multiplexing devices?
13. What is the difference between SWDM and DWDM?
14. Give 2 examples of overlay networks.
15. Give 2 examples of special purpose networks.