5.6 Examples: IP, IPv6, ATM

IP (Internet Protocol)

Protocol of layer 3 in the Internet.

- A datagram protocol (connectionless)
- Implements routing in the internet
- Handles fragmentation of large packets: large service datagrams can be "fragmented" into smaller protocol datagrams.
- Doesn‘t do much more!

Note: If we say "IP" here, we refer to IP version 4. IP version 6 is discussed later.

Format of IP Datagrams (1)

0 4 8 16 19 24 31

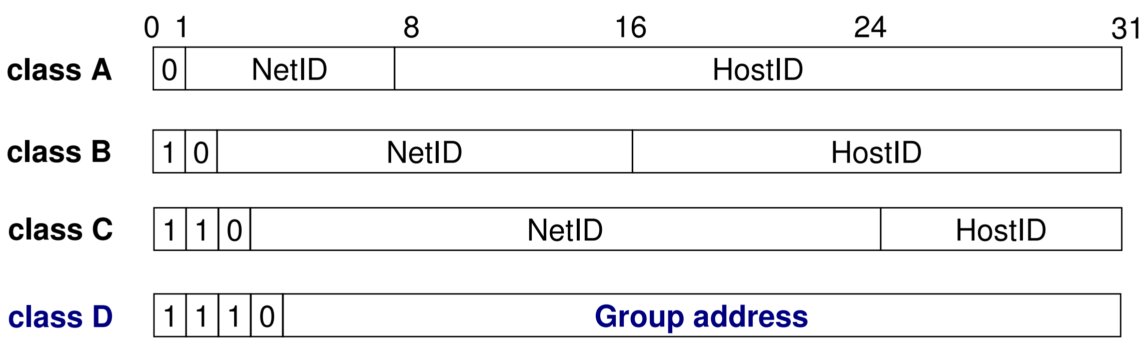
VERS	LEN	TYPE OF SERVICE	TOTAL LENGTH	
IDENT			FLAGS	FRAGMENT OFFSET
TIME		PROTO	HEADER CHECKSUM	
SOURCE IP ADDRESS				
DESTINATION IP ADDRESS				
OPTIONS				PADDING
DATA				
. . .				

Format of IP Datagrams (2)

VERS	Protocol version
LEN	Length of the header (words)
TYPE OF SERVICE	QoS (Priority and D/T/R)
TOTAL LENGTH	Length incl. data in Bytes
IDENT	Identity of the datagram
FLAGS	"don't fragment/ last fragment"
FRAGMENT OFFSET	Offset of this part
TIME	Life span in seconds ("time to live")
PROTO	Type of the higher protocol
HEADER CHECKSUM	EXOR of header words
SOURCE ADDRESS	IP address of source host
DEST ADDRESS	IP address of target host
OPTIONS	Command code for network management datagrams
PADDING	Fill up to word limit
DATA	Use data field

Addressing in the Internet (1)

An IP address is a hierarchical address with net and host identification number (netid and hostid). There are three formats for subnetworks of different sizes as well as one format for multicast:



Addressing in the Internet (2)

Strangely common is a decimal way of writing with one number per byte.
Example:

10.0.0.0	for Arpanet
128.10.0.0	for a large Ethernet LAN
192.5.48.0	for a small ring LAN

(hostid = 0 marks a network of one host)

Address Resolution in the LAN

Problem

How is a computer‘s Internet address (IP address) mapped to its MAC layer address (IEEE 802 address)?

Solution

Address Resolution Protocol (ARP)

Address Resolution Protocol ARP (1)

Protocol in the router

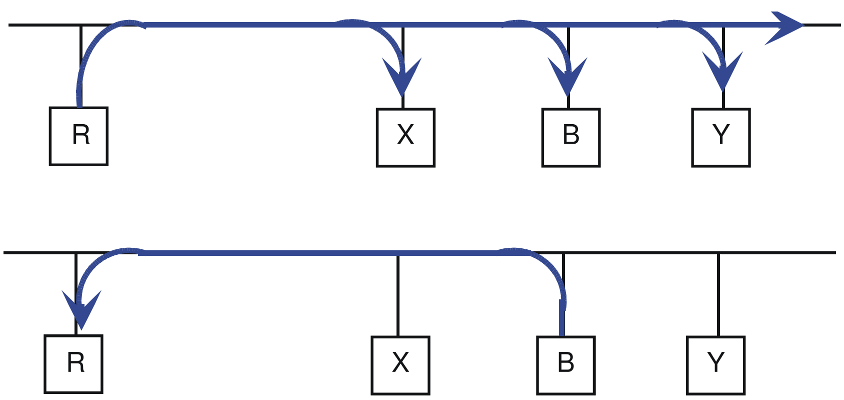
- Send an ARP Request packet by means of broadcast on the LAN, which contains the physical address (802.2) and the IP address of the transmitter and the IP address of the wanted receiver.
- Wait for the ARP Reply packet, which contains its physical address.
- Maintain a cache of (IP, 802.2) address pairs for later inquiries.

Improvement: The receiver of an ARP request also caches the (IP, 802.2) address pair of the transmitter.

Address Resolution Protocol ARP (2)

Flow of the ARP protocol in the LAN

“IP address B, request report“



IP Version 6 (IPv6)

Motivation: Addressing problems

- IP address range will be exhausted soon.
- Class B addresses now are already almost exhausted.
- CIDR (classless inter-domain routing) was introduced as a short-term solution
- Routing tables grow very fast: an addressing hierarchy with additional levels becomes necessary.
- (mobile) Internet devices in cars, households etc..

  $\rightarrow$ 10 billion humans in the year 2020 and 100 IP addresses per person are not unrealistic.

Solution

New IP protocol version 6 (IPv6) with a larger address range is to replace IPv4.

*) I would like to thank Professor Torsten Braun (University of Bern) for letting me use his slides on IPv6.

History of IPv6

1992

IETF publishes Call for Proposals for an “IP next generation“ (IPng) as successor of IPv4

1994

SIPP (simple Internet Protocol plus) is suggested as basis for the new IPng

1995

Internet Draft "Internet Protocol, version 6 (IPv6)" becomes "Proposed standard" (9/95) and RFC1883 (12/95). First prototype implementations.

1996

Establishment of the IPv6 Backbones (6Bone) between research labs, first products in the market.

1998

RFC 2460, Draft Standard

2004

Implemented in many products but not yet widely deployed by ISPs.

Characteristics of IPv6 (1)

Extended addressing capabilities

- 128 bit addresses (one address per atom in the universe, 10^{23} addresses per m^2 of earth's surface)
- Address hierarchy levels for IP (registration instance, provider, subscriber, subnetwork, interface)
- automatic address configuration built into protocol (similar to DHCP)

New IP Header Format

- simplified, minimum IP header
- improved support of new options and extensions: Extension header
- segmenting and reassembling fragments is done in end systems only

Characteristics of IPv6 (2)

Quality of Service Support

- “Flow Labels“ allow marking of application data flows on the IP level
- “Traffic Classes“ for Differentiated Services

Multicast Integration

- pre-defined groups of multicast for control functions
- IGMP (Internet Group Management Protocol) integrated in ICMP (Internet Control Message Protocol)
- special multicast address format
- All routers and final systems support multicast, so that no special measures are necessary for multicast connections (e.g. tunnels) any more.

IP Security

- Authentification and encryption are integrated.

Global Unicast Addresses

Top Level Aggregation (TLA)

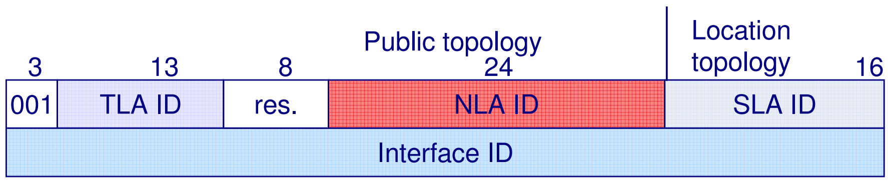
- large internet service provider (ISPs) with transit networks to which other ISPs are attached

Next Level Aggregation (NLA)

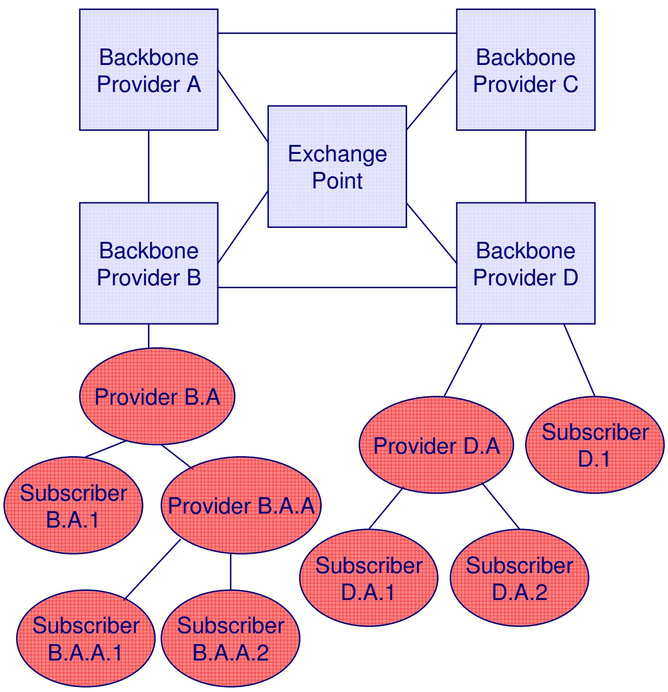
- Organizations on a lower level
- several NLA levels are possible

Site Level Aggregation (SLA)

- individual addressing hierarchy of an individual organization



TLA, NLA and SLA



Special Unicast Addresses (1)

Local Unicast Addresses

- Link local
  - for configuration purposes or IP networks without a router
  - Prefix: 111111101::/64
- Location local
  - for IP networks that are not attached to the Internet
  - when connecting a location to the global Internet only the address prefix (1111111011::/48) must be replaced
  - SLA ID and interface ID remain unchanged

Special Unicast Addresses (2)

Compatible Unicast Addresses

- IPv4 compatible
  - Prefix (96 0-bits) + IPv4 address
- IPv4 mapped
  - Prefix (80 0-bits, 16 1-bits) + IPv4 address
- IPX compatible

IPv4 Header

20 Bytes, 13 fields

cancelled

shifted into the extension header

renamed

- precedence → class
- total length → payload length
- time to live → hop limit
- protocol → next header

Version	Hdr Len	Prece-dence	ToS	Total Length			
Identification				Flags	Fragment Offset		
Time To Live		Protocol		Header Checksum			
Source Address							
Destination Address							

IPv6 Header

40 Bytes, 8 fields

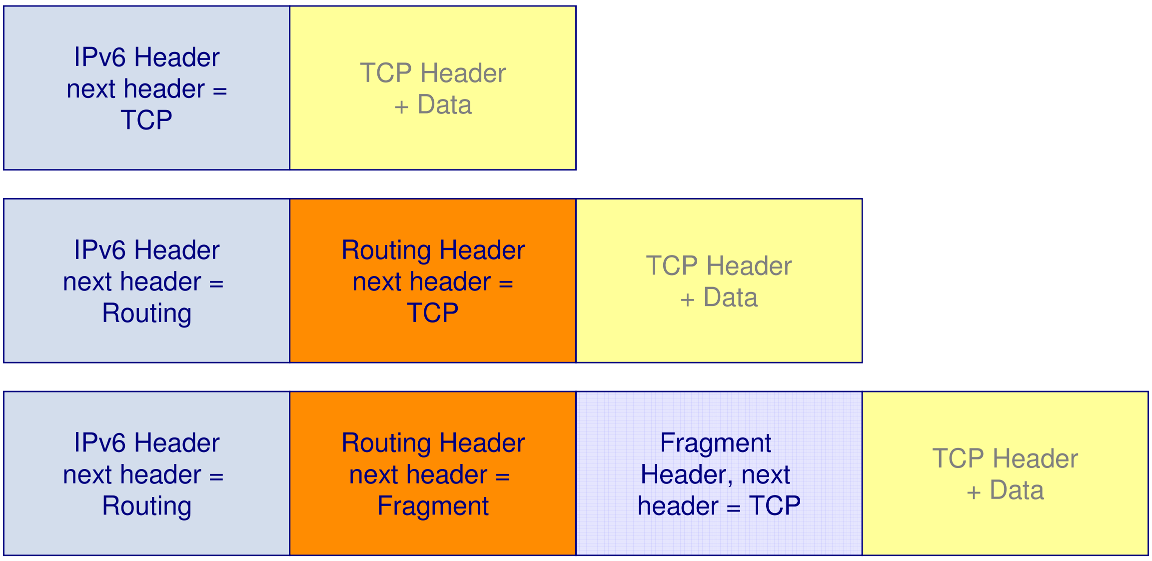
Vers.	Class	Flow Label		
Payload Length			Next Header	Hop Limit
Source Address				
Destination Address				

Concept of Extension Headers

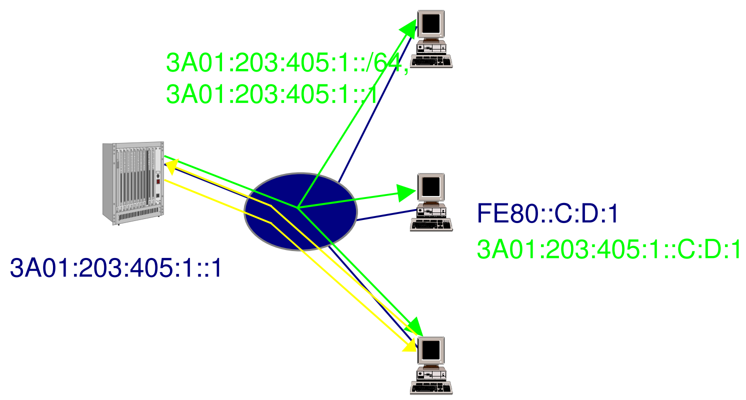
Small Standard Header and Extension Header

- small minimal header of constant size
- additional extension headers, depending on the requirements of the application or the network characteristics
- future extensions and options can be added easily

Examples of Extension Headers



Stateless Automatic Address Configuration



The router periodically broadcasts **IP parameters** to the multicast group of *all* hosts ("Router Advertisement"), e. g. the prefix of the local link.

Each host can send a "Router Solicitation" to the multicast group of all routers, it will be followed by a direct answer of the router.

Transition Strategies

IPv4 and IPv6 systems must be able to communicate with each other. After a transitional phase only a few pure IPv4 systems should remain.

Basis mechanisms

- Dual protocol stacks
- IPv6 over IPv4 Tunneling

The IPv6/IPv4 header translation is necessary only for communication between pure IPv4 nodes and pure IPv6 nodes.

More complex mechanisms

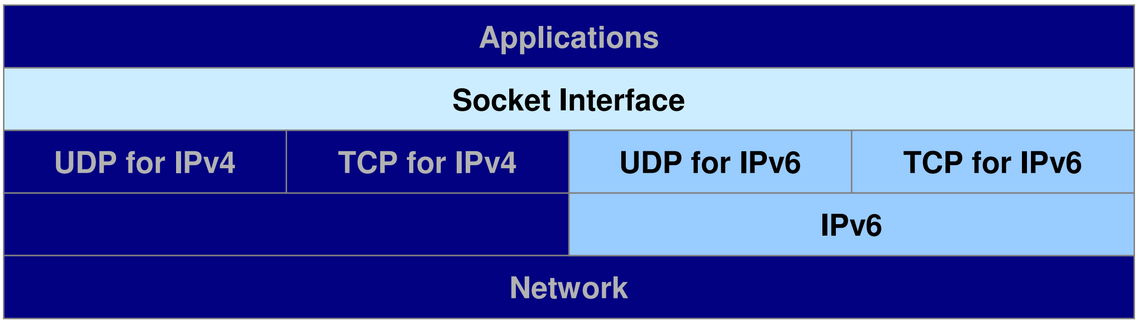
- Stateless IP/ICMP Translation (SIIT)
- No Network Address Translation (NNAT)
- Network Address Translation / Protocol Translation (NAT/PT)

Dual Protocol Stacks

Dual protocol stacks

- UDP/IPv4 and UDP/IPv6
- TCP/IPv4 and TCP/IPv6

All IPv6 systems will also have an IPv4 stack during the transition phase.



IPv4 Compatible Address

An IPv6 address is built on basis of the old IPv4 address.

Used by IPv6 systems for communication with other IPv6 systems via automatic tunnels.

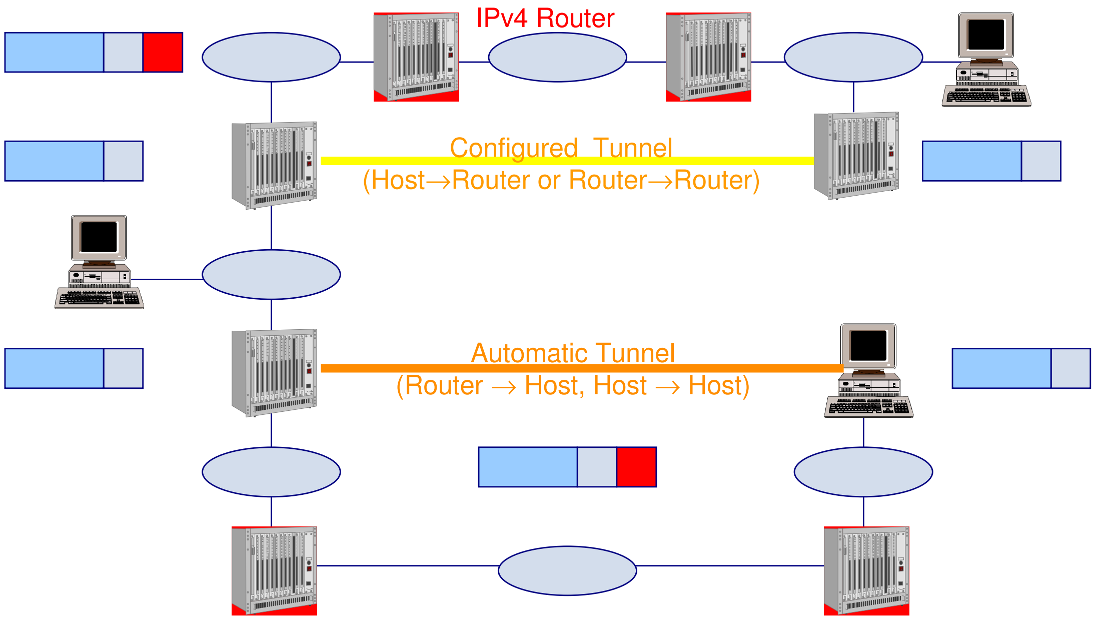
Only useful in the early transition phase; the advantages of IPv6 addressing are lost.

Tunneling

Tunneling is the wrapping of an IP packet into another IP packet with a new destination IP address. At the end of the tunnel, the internal IP packet is unwrapped again. In this way, the original IP packet can "tunnel" subnetwork distances, which it could not pass otherwise.

IP tunnels are usually configured manually.

IPv6 Tunnels



IPv4-Mapped Address

0 ... 0	
00000000 00000000 11111111 11111111	IPv4 Address

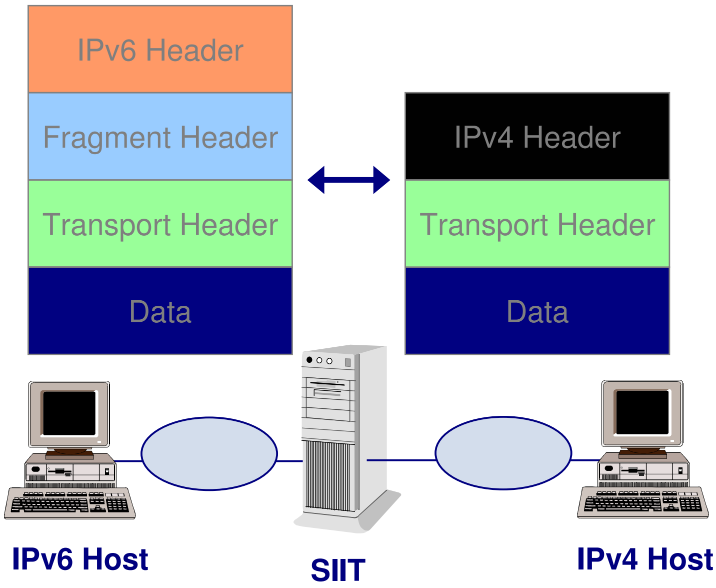
Communication of IPv6 systems with IPv4 systems.

The "IPv4 mapped" address indicates that the IP destination system does not support IPv6. Therefore the IPv4 protocol stack will be selected there.

Stateless IP/ICMP Translation (SIIT)

- Requires dynamic allocation of IPv4 addresses!
- Supports communication between pure IPv6 systems and pure IPv4 systems.
- Stateless translation of IPv4/IPv6 and ICMPv4/ICMPv6 packets
- No translation of Routing Headers, Hop-by-Hop options and destination options.

Illustration of SIIT



Effects of IPv6 on other Protocols

Routing Protocols

- Handling of longer addresses

Transport Protocols

- Reduced maximum user data length because of the larger IP header.
- The fact that there is no checksum in the IPv6 header requires the implementation of the checksum in UDP (now mandatory) and TCP.
- TCP currently does not support an IP address change during an existing TCP connection.

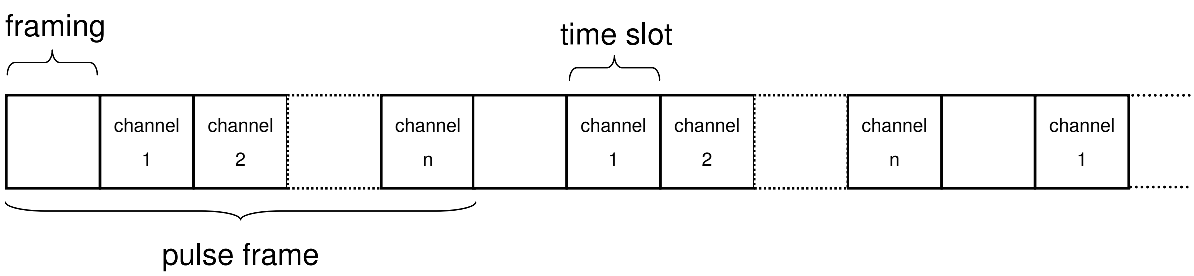
ATM (Asynchronous Transfer Mode)

Basics

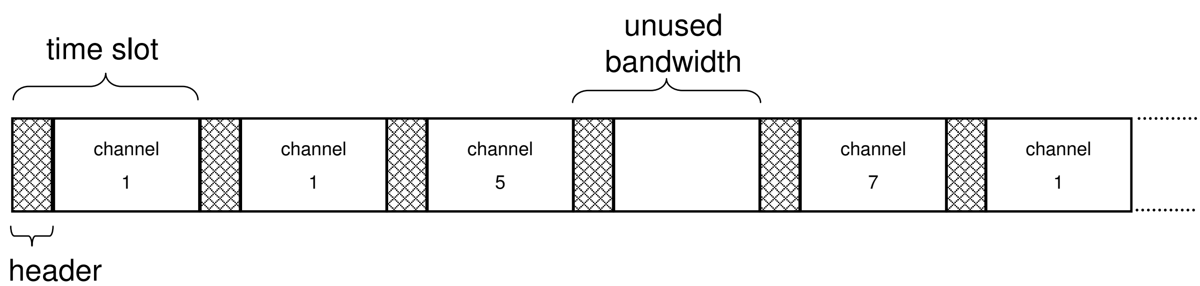
- **Goal:** one network for all kinds of applications
- A fast packet switching technology for **cells** of fixed size (53 bytes).
- Based on asynchronous (statistic) time-division multiplexing; thus the name ATM.
- Connection-oriented. Provides virtual paths and virtual circuits.
- In order to achieve high cell rates, the implementation of ATM switches is largely based on hardware.
- Removal of error detection and correction, flow control, etc. from the cell switching layer, placement in higher adaptation layers if needed
- Offers a broad spectrum of data rates and fulfills a broad spectrum of application requirements.

Synchronous vs. Asynchronous Time Multiplexing

STM

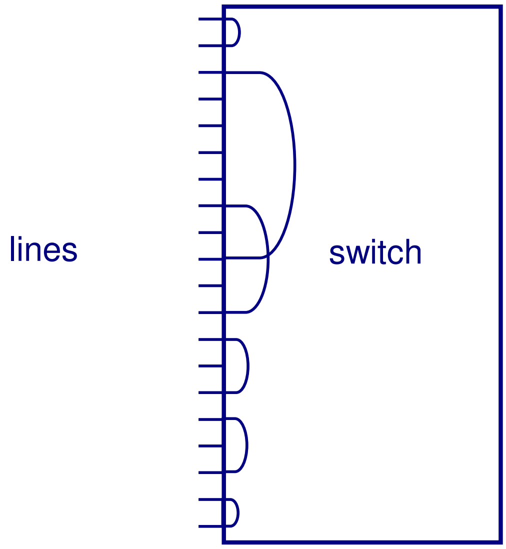


ATM

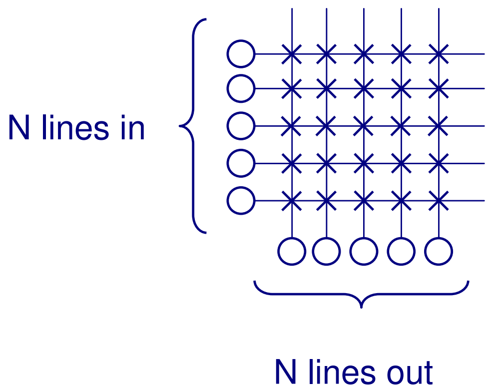


Switching Technology

Function of a switch, abstract



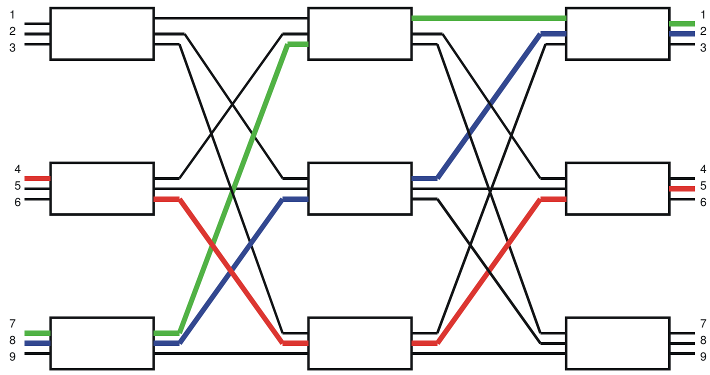
Space Division Switch



Disadvantages of matrix implementation:

- number of crosspoints grows with N^2.
- defective crosspoints makes a certain connection impossible.
- low utilization of the crosspoints (maximum N from N^2 in use).

Multi-stage Space Division Switches



Advantages

- Smaller number of interconnection points
- Several alternative paths for the connection of an input port to an output port; thus higher reliability

Disadvantages

- Congestion can occur: no connection possble between input port and output port. In the example above: cannot connect i_9 with o_4 or o_6.

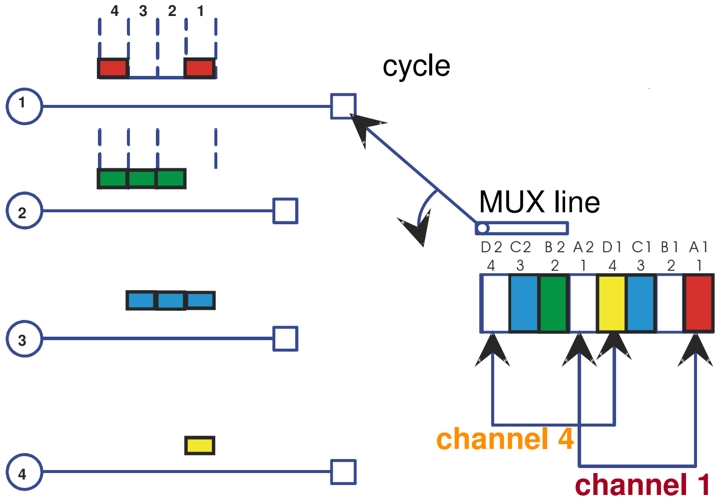
TDM on the Line and Switching Technology

One can differentiate conceptionally:

- Synchronous and asynchronous multiplexing on the transmission line
- Synchronous and asynchronous switching techniques in the switching node

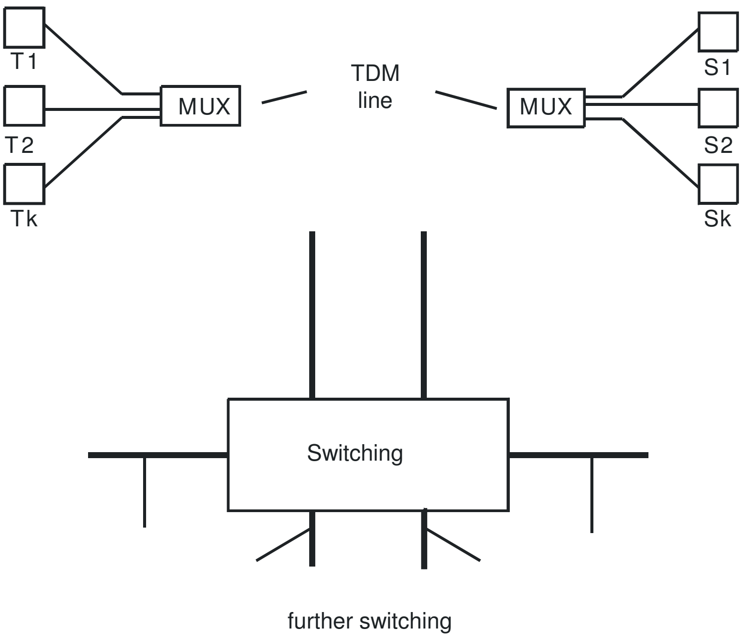
Synchronous Time Multiplexing

Synchronous Time Division Multiplexing (STM)



We observe: For **STM lines,** switching simply means a re-ordering of the time slots!

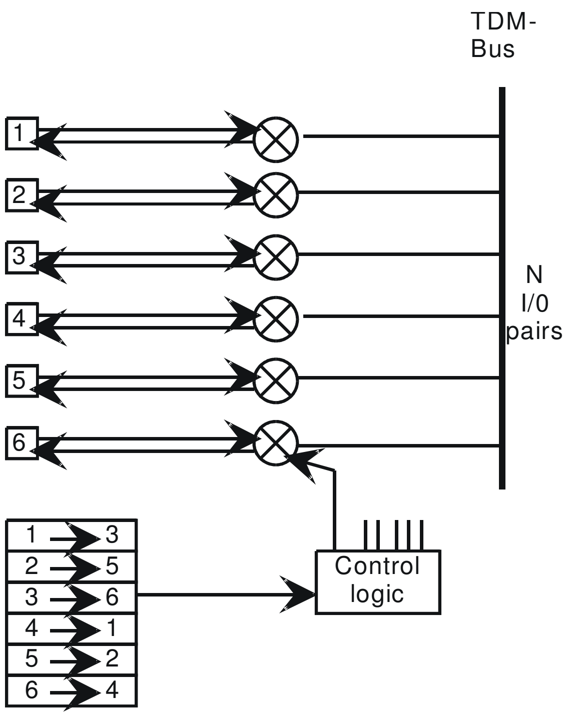
Transmission and Switching for Synchronous TDM



Switch With An Internal TDM Bus (1)

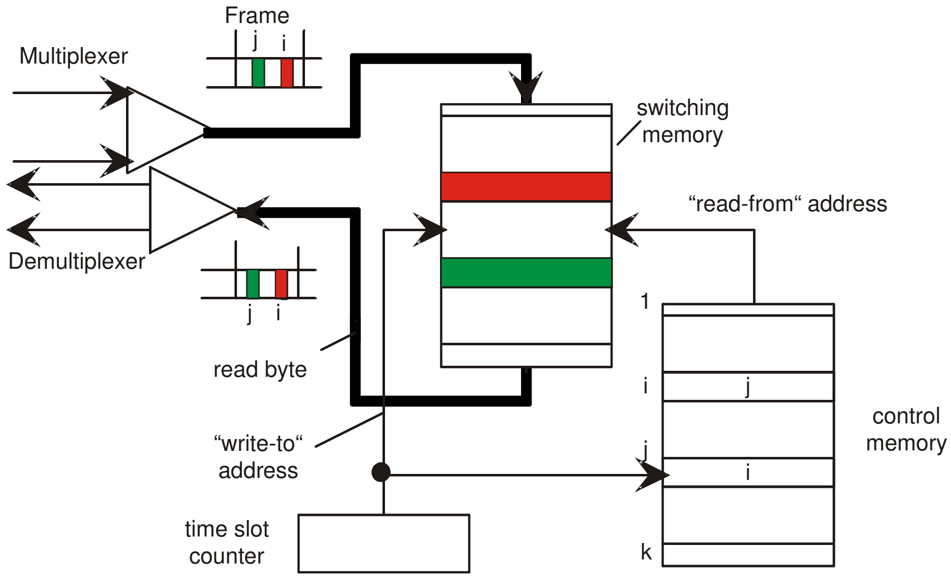
- Use of STM on a fast bus inside the cell switch
- At a given time an input port and an output port are connected to the bus for a short period of time.
- Line buffers are used for speed adjustment between slow external lines and the faster TDM bus.
- Disadvantage: The internal bus must be as fast as the sum of all active connections at a time.

Switch with an Internal TDM Bus (2)



Switching with Internal Switching Memory

"Time Slot Interchange"



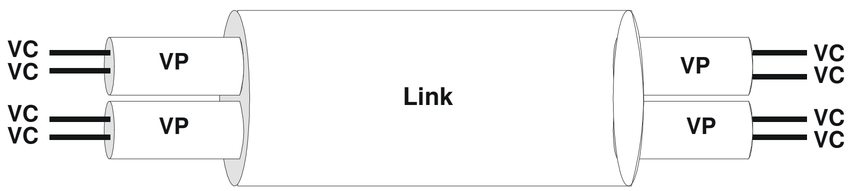
Virtual Circuits and Virtual Paths in ATM

Virtual Circuit (VC):

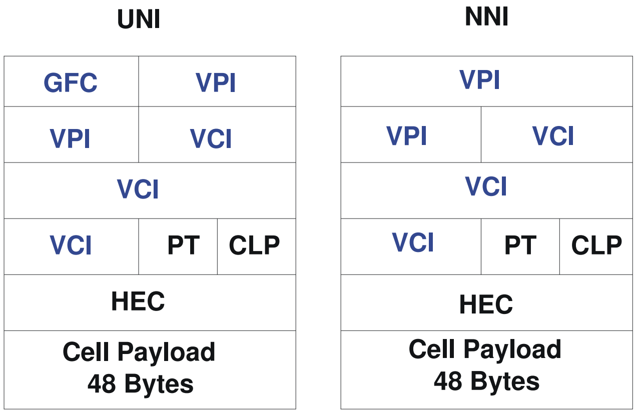
- virtual connection between ATM terminal devices over several hops

Virtual Path (VP):

- VCs bundled on hops

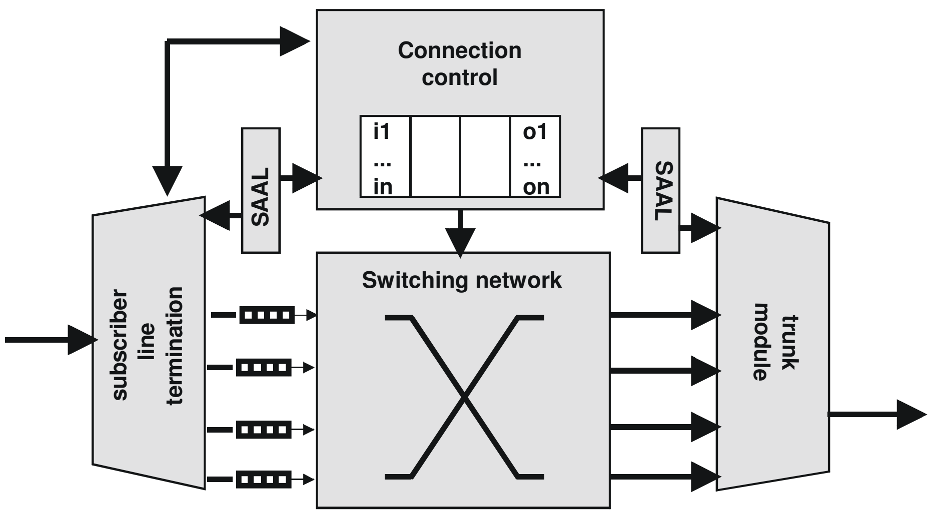


ATM Cell Formats

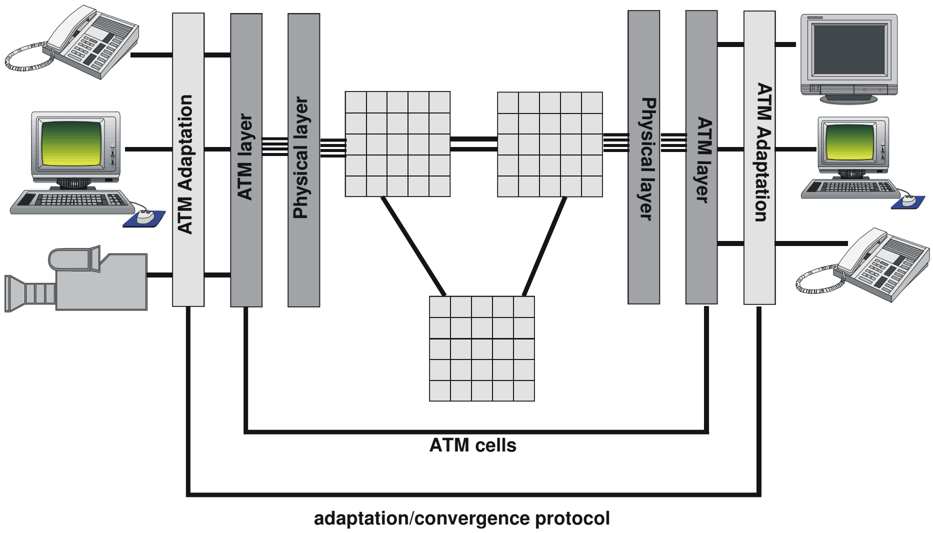


GFC: Generic Flow Control
VPI: Virtual Path Identifier
VCI: Virtual Circuit Identifier
PT: Payload Type
CLP: Cell Loss Priority
HEC: Header Error Check

Schematic Diagram of an ATM Cell Switching Node



ATM Adaptation Layer



ATM Service Classes

	Class A	Class B	Class C	Class D
Synch	isochronous		asynchronous	
Bit rate	constant	variable		
Connection mode	connection-oriented			connection-less
Applications	emulation of synchronous services (ISDN)	variable bitrate video (MPEG, ...)	connection-oriented data communicaion	connection-less data communicaion

ATM Adaptation Layers

- AAL1: Constant Bit Rate (**CBR**) with synchronisation
- AAL2: Variable Bit Rate (**VBR**)
- AAL3/4: for data traffic, predominantly in public networks
- AAL5: standard AAL for data traffic

AALs describe end-to-end protocols. Further AALs can be defined as needed, without changes to the ATM cell switching layer.

ATM Traffic Classes

UBR: Unspecified Bitrate
- For data applications, uses available (remaining) bandwidth
- No "admission control" and on „Policing“
- High cell losses at overload

CBR: Constant Bitrate
- For "Circuit Emulation Services" with fixed PCR, CTD, CDV
- Minimal cell losses

VBR: Variable Bit Rate
- For example for compressed video streams with variable bit rate

ABR: Available Bitrate
- Reliable transmission for data applications
- Implements a flow control in the ATM network

ATM Traffic Contract

- With the establishment of the connection the user and the network close a "traffic contract".
- The user supplies the traffic specified with connection establishment (*traffic description*)
- The user specifies the service qualities desired for this description of traffic (*QoS: Quality of service*)
- The network verifies whether specified traffic with the desired quality can still be transported (*admission control*)
- During the connection the network controls the adherence of the traffic description at the network entrance (*UPC : usage parameters control or source policing*)
- Non-compliant cells are:
  - labeled with CLP=1 at the network entrance
  - Cells with CLP=1 are discarded during overload times, at the network entrance or inside the network.

Traffic Parameter

Traffic Description

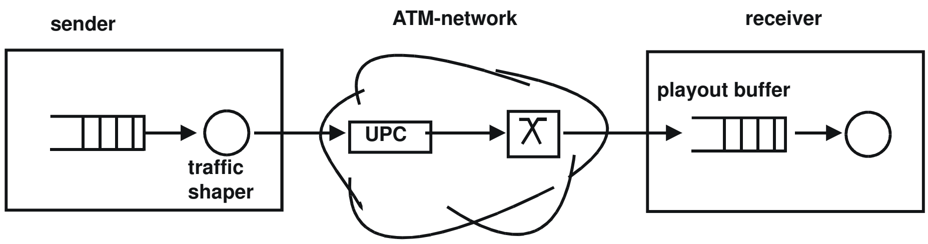
- **PCR**: Peak Cell Rate (cells/s)
- **SCR**: Sustainable Cell Rate (cells/s)
- **MBS**: Maximum Burst Size (cells), also specified as **BT**: Burst Tolerance = (MBS-1)/(1/SCR-1/PCR)
- **MCR**: Minimum Cell Rate (only for ABR)

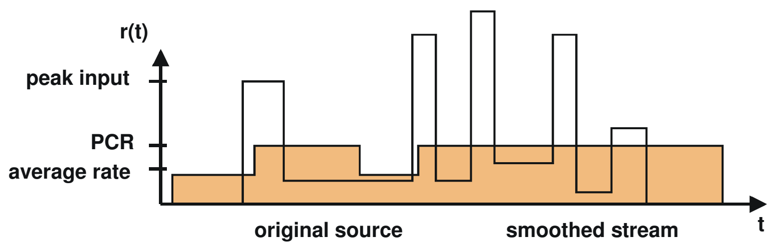
Quality of Service Description (QoS-Parameter)

- **CLR**: Cell Loss Ratio (Number of lost cells/number of sent cells)
- **CTD**: Cell Transfer Delay (from the network entrance to the delivery at the receiver)
- **CDV**: Cell Delay Variation (CTD variance) (Delay Jitter)

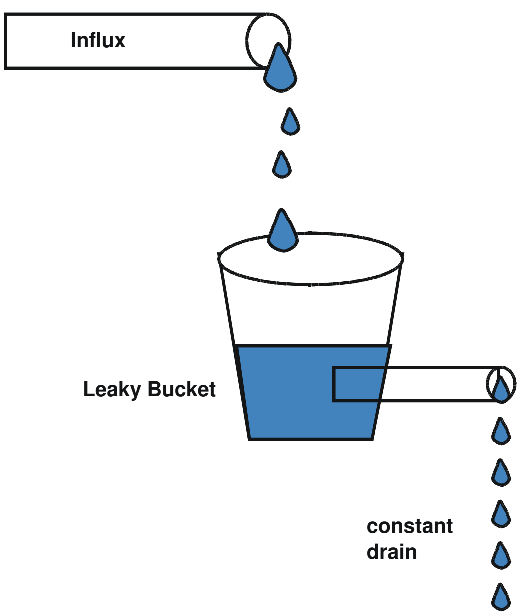
Traffic Shaping

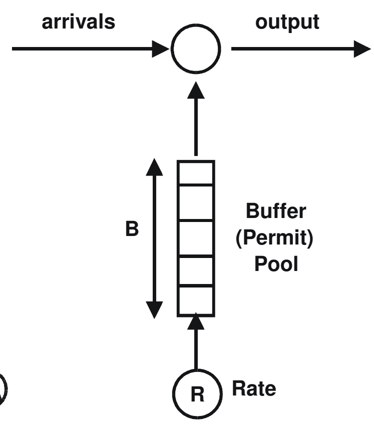
The ATM terminal equipment (end system) shapes the data traffic in order to keep the traffic contract ("**traffic shaping**").





Traffic Shaping: The "Leaky Bucket“ Algorithm





Allocation of Bandwidth for the ATM Traffic Classes