IPv6:
The Next Generation Internet Protocol

Tutorial Session: IP over ATM

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Outline

- Addressing problems
- IPng development
- Internet Protocol version 6 (IPv6) characteristics
- Address types
- IPv6 header and extension headers
- Quality-of-Service support (priorities and flows)
- Neighbor Discovery (plug-and-play, address resolution)
- Security (authentication and encryption)
- Transition strategies (dual protocol stacks and tunneling)
- IPv6 over ATM
- Effects of IPv6 on higher layers
- References

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Addressing Problems

- Class B addresses are nearly exhausted.
  - CIDR (classless interdomain routing) provides a short-term solution.
- Routing tables are growing extremely fast.
  - More hierarchical addressing levels are required.
- IP unicast address space will run out between the years 2000 and 2010 for several reasons:
  - Internet euphoria (on-line services, corporate networks over the Internet)
  - new low-end Internet devices (in cars, households etc.)
  - 10 billion people in 2020 and 100 IP addresses per person are not unrealistic.

Solution:

- Larger address space necessary

  -> new IP protocol required to substitute IPv4

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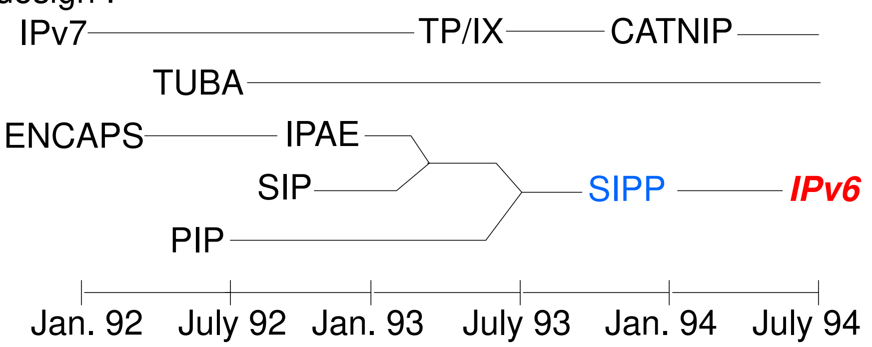
IPng Development

- 1992: IETF issued a call for proposals for a next-generation IP (IPng) to replace the current IP version 4
- Several proposals have been made and evolved to a final design :



- 1994: SIPP (Simple Internet Protocol Plus) was suggested as the new basis of IPng.
- 1995: Internet Draft “Internet Protocol, Version 6 (IPv6)” becomes “proposed standard” (9/95), publication as RFC1883 (12/95)

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IPng/IPv6 Characteristics

- Extended addressing capabilities
  - 128 bit addresses
    ($6.65 \cdot 10^{23}$ addresses per m^2 of earth surface)
  - address hierarchy levels
    (registry, provider, subscriber, subnet, interface)
  - anycast addresses to address one node of a group of nodes (the “nearest” node in terms of the routing metric)
  - address autoconfiguration
  - mobile system support
- New IP header format
  - simplified, minimal IP header
  - improved support for new options and extensions
  - segmentation and reassembly in end systems only

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More IPng/IPv6 Characteristics

- Quality-of-Service support
  - flow labels
  - priorities
- Multicast integration
  - pre-defined groups for control functions
  - IGMP (Internet Group Management Protocol) integrated into ICMP (Internet Control Message Protocol)
  - special address format for multicast addresses
  - all routers and end systems support multicast communication
- Security functions
  - authentication
  - encryption

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Address Types

- Unicast addresses (1:1)
  - provider-based
    (variable length fields, more hierarchy levels are possible)

3 bit	n bit	m bit	o bit	p bit	125-m-n-o-p bit
010	registry ID	provider ID	subscriber ID	subnet ID	interface ID

  - geographically-based
  - link local (for configuration or IP networks without router)
  - site-local (for IP networks not connected to the Internet, only the address prefix must be replaced when the site is connected to the Internet, the subnet and interface ID remain unchanged)
  - IPv4-, IPX-, NSAP- compatible addresses
- Anycast addresses (1: nearest node of a set of addresses, currently only used to address routers)
- Multicast addresses (1:n)

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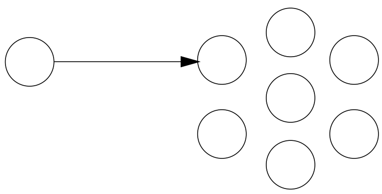
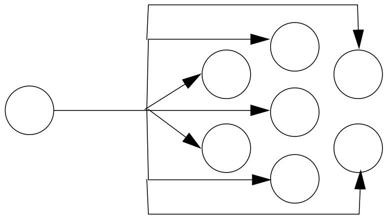
Differences of Address Types

- unicast (1:1)

- anycast (1: nearest)



- multicast (1: n)



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IPv4 Header

version	hdr len	prec	type of service	total length	
identification				flags	fragment offset
time to live		protocol		header checksum	
source address					
destination address					

fields also available in IPv6
fields removed in IPv6
fields moved to IPv6 extension header
fields with new name in IPv6 but with similar meaning

- 20 bytes, 13 fields
- modifications
  - precedence -> priority
  - total length -> payload length
  - time to live -> hop limit
  - protocol -> next header

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IPv6 Header

version	priority	flow label		
payload length			next header	hop limit
source address				
destination address				

- 40 bytes, 8 fields
- less fields, no segmentation and reassembly
  -> simpler and faster router implementations

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Extension Headers

Daisy chain of extension headers

- small minimal header
- flexible headers dependent on application and network requirements
- simple introduction of new extensions and options without IPv4's 40-byte limit on options

IPv6 header next header = TCP	TCP header + data

IPv6 header next header = routing	routing header next header = TCP	TCP header + data

IPv6 header next header = routing	routing header next header = fragment	fragment header next header = TCP	TCP Header + data (fragment)

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IPv6 Packet with Extension Headers

IPv6 header	40	next header field
Hop-by-hop options	variable	
Destination options header	variable	
Routing header	variable	
Fragment header	8	
Authentication header	variable	
Encapsulation security payload header	variable	
Destination options header	variable	
TCP header	20 (optional part variable)	
Application data	variable	

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Routing Header

next header	routing type=0	hdr ext len	segments left
reserved	loose/strict bit mask		
address [0]			
address [1]			
...			

- List of unicast/anycast addresses to be visited (address[i]) (similar to source routing option in IPv4)
- segments left: number of nodes still to be visited
- loose/strict bit mask (1 bit per node):
  1 = strict routing, next address must be a neighbor

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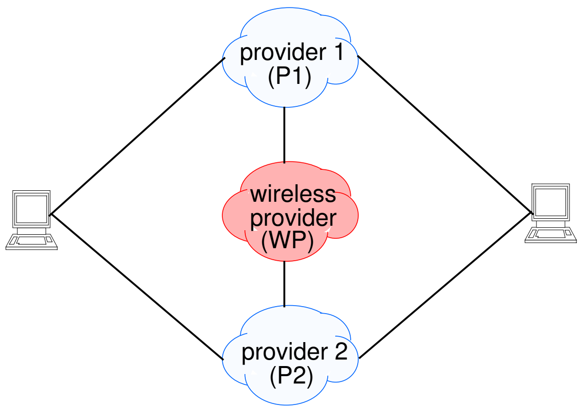
Routing Header Example



- Case 1: no routing header (H1, H2)
  -> either provider can be used
- Case 2: H1enforces traffic to H2 via provider 1 (H1, P1, H2) with strict routing
  -> H2 replies with (H2, P1, H1)
- Case 3: H1 becomes mobile and moves to the wireless provider -> (H1, WP, P1, H2), (H2, P1, WP, H1)

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Priorities

- Priority values allow source to identify packet priority relative to other packets from the same source.
- 2 independent priority classes:
  - congestion-controlled traffic (e.g., TCP traffic): values 0-7
  - non-congestion-controlled traffic (e.g., real-time data): values 8-15 to indicate discard priority
    (8: most willing to discard)

value	traffic type
0	uncharacterized traffic
1	filler traffic (e.g., news)
2	unattended data transfer (z.B. electronic mail)
3	reserved
4	attended bulk transfer (z.B. FTP, HTTP, NFS)
5	reserved
6	interactive traffic (e.g., telnet, X)
7	Internet control traffic (e.g., routing protocols, ICMP, SNMP)

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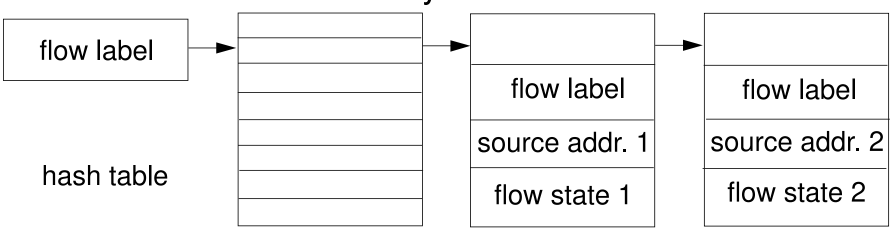
IPv6 Flows

- Sequence of packets for which the source desires non-default or real-time service
- Identification of data flows between end systems
- Identification by source address and random flow label value
  - hash table based on any flow label bits
    --> fast flow state look-up
  - resolution of collisions by source address



- Examples for flow state
  - next hop
  - information about quality-of-service to provide for this flow

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Flow Processing

- Special packet processing
  - quality-of-service support
  - processing information exchanged by
    - packet options (e.g., hop-by-hop options)
    - resource reservation protocols (e.g., RSVP)
- Simplified packet processing
  - Packet processing results are calculated for the first packet of a flow and stored in the hash table.
  - Fast table look-up is performed for the following packets instead of recalculating the results.
  - All packets of a flow must use identical source/destination addresses, priority, hop-by-hop options, and routing header.
  - Flow labels are valid for 6 seconds, packet processing results (flow state) have to be recalculated.

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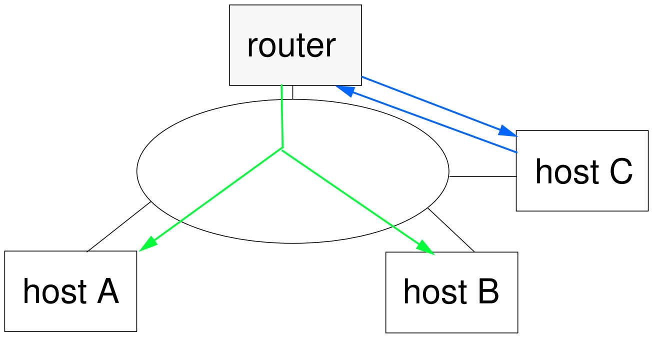
Neighbor Discovery (ND)

- Router discovery
- Prefix discovery
- Next-hop determination
- Parameter discovery (link and Internet parameters)
- Stateless address autoconfiguration
- Duplicate address detection
- Neighbor unreachability detection
- Link-layer address resolution
- Redirects

Plug-and-Play

- IPv4: manual configuration of end system with several IP parameters (IP address, subnet mask, default gateway, ...)
- IPv6: Router advertises parameters periodically (router advertisement to all nodes multicast group) or host solicits advertisements from router (router solicitation to all routers multicast group).
- Hosts use link-local address (pre-defined link-local address prefix + interface ID (MAC address)) during initialization
- IP address = advertised prefix + interface ID



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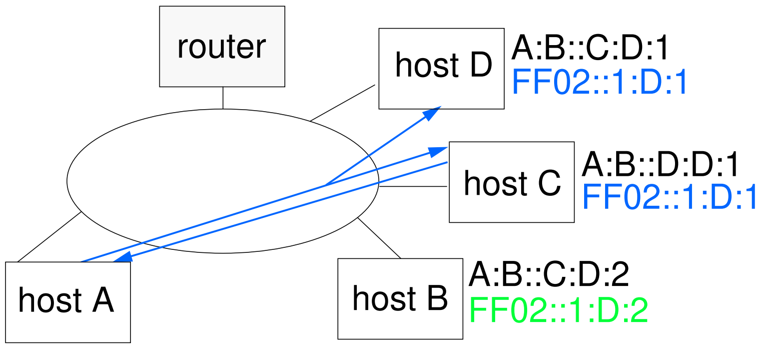
Multicast for Address Resolution

- IPv4: broadcast of ARP_Request, target node responds with ARP_Reply
- IPv6: multicast of a neighbor solicitation to a small local group (solicited nodes multicast address)
- Solicited nodes multicast group: members with identical last 32 bits (e.g., 32 bits of MAC address)
- Target node responds with neighbor advertisement message.



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Authentication

- Check whether the received packet was in fact transmitted by the sender identified as the source of the packet (sender authentication)
- Check whether the data has been manipulated in transit (data integrity)
- Default algorithm: Message Digest 5 (MD5) calculates a 128 bit value over the packet plus a secret key (-> authentication data)

next header	length	reserved
security parameter index (SPI)		
authentication data (n * 32 bit)		

- SPI identifies the pre-established security association and the corresponding parameters.
- Authentication header provides authentication and data integrity for all IPv6 packet fields that do not change en route.

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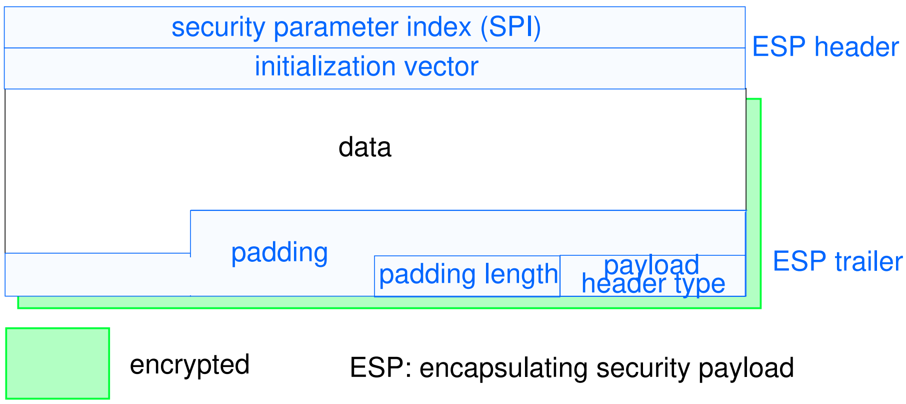
Encryption

- Encryption of the packet for confidential and secure data exchange (privacy)
- DES-CBC as default algorithm
- Initialization vector (n*32 bit) as input for encryption algorithm
- Payload header type: protocol type of the data field (e.g., IP,TCP,UDP)



ESP: encapsulating security payload

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Transition Strategies

- IPv4 addresses do not run out before the year 2000, transition must then be completed.
- Operating systems are replaced in cycles of ca. 3 years
- The first IPv6 implementations are already commercially available, others will be available in 1997.

=> 2 cycles are required for transition

- During the transition phase both IPv4- and IPv6-nodes will be used.
- Both types of nodes shall be able to communicate with each other.
- After the transition phase there will be only very few pure IPv4 nodes.

=> 2 strategies will be necessary:
dual protocol stacks and IPv6-in-IPv4 tunneling

- IPv6/IPv4 header translation is only required, if pure IPv4 nodes want to communicate with pure IPv6 nodes.

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Dual Protocol Stacks

- Dual protocol stacks
  - UDP/IPv4 and UDP/IPv6
  - TCP/IPv4 and TCP/IPv6
- IPv6 as an additional protocol family
- All IPv6-nodes will also have an IPv4 protocol stack during the transition phase.

Application			
Sockets			
UDP for IPv4	TCP for IPv4	UDP for IPv6	TCP for IPv6
IPv4		IPv6	
Network			

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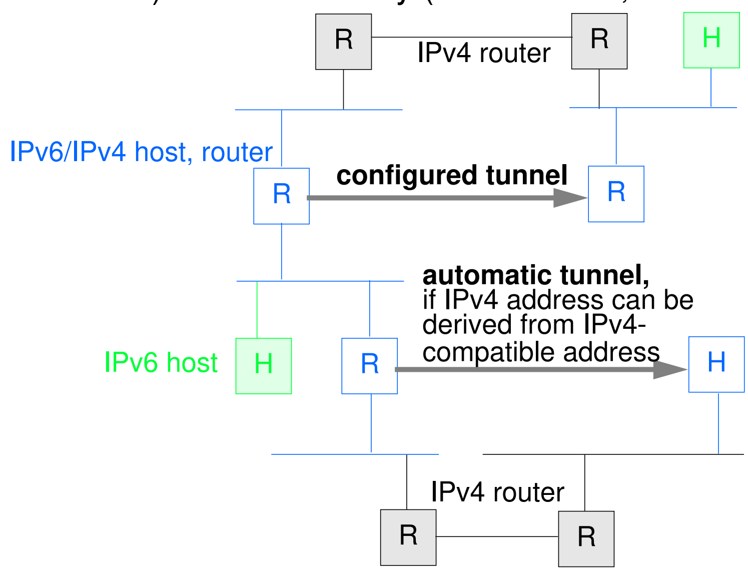
Tunneling

- Tunneling to connect two IPv6 domains over IPv4 islands
  -> encapsulation of IPv6 packet in IPv4 packet
- IPv4 address derived from configuration (host->router, router->router) or automatically (router->host, host->host)



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IPv6 over ATM

- Problem:
  - Control mechanisms are based on multicasting capability of the subnetwork
    (e.g., ND messages to solicited nodes multicast address)
  - IP multicast model (IGMP group management) has been designed for shared medium subnetworks
- Several solutions have been discussed
  - Multicast Address Resolution Server (MARS) as extension of the ATM ARP server (RFC1577) + NHRP in routers
  - hierarchical architecture of neighbor discovery servers (NDS); NDSs exchange and distribute ND messages, hosts send messages to corresponding NDSs
  - NHRP (NBMA Next Hop Resolution Protocol) replace certain ND functions (e.g., address resolution)
- Solutions are under study and will converge.

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Effects of IPv6 on Higher Layers

- Application modifications are required due to modified socket API (new address family, flow label).
- Maximum payload size changed because of bigger IP header.
- New domain name system (DNS) record type (AAAA)
- TCP
  - New IP pseudo header requires modifications of the checksum calculation in UDP and TCP implementations
  - TCP does currently not allow that the IP address changes during a TCP connection (IP address may change due to stateful address autoconfiguration)

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