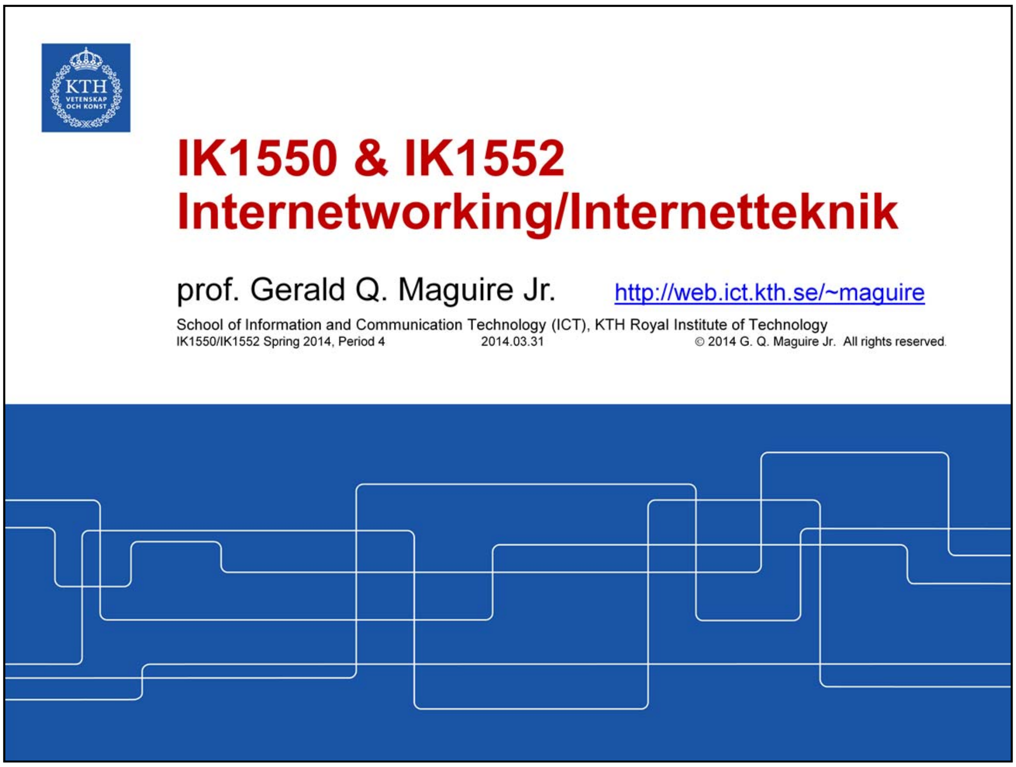
IK1550 & IK1552
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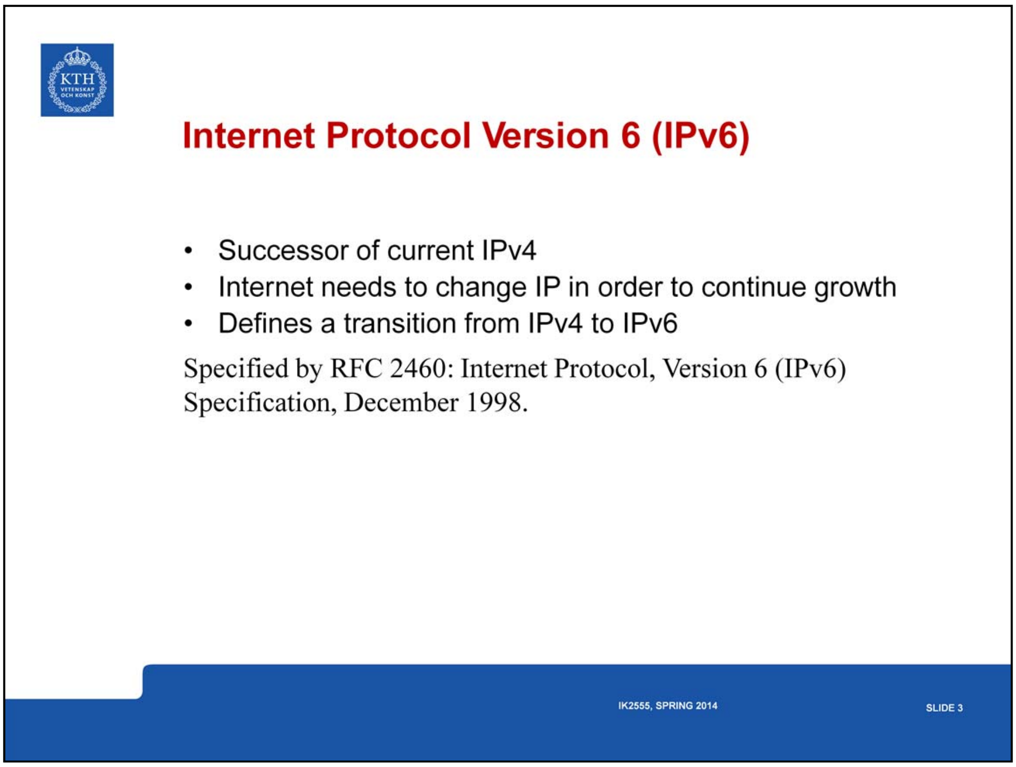
Module 10: IPv6

Lecture notes of G. Q. Maguire Jr.

For use in conjunction with James F. Kurose and Keith W. Ross, *Computer Networking: A Top-Down Approach*, Fifth Edition, Pearson, 2010.



S. Deering and R. Hinden, ‘Internet Protocol, Version 6 (IPv6) Specification’, *Internet Request for Comments*, vol. RFC 1883 (Proposed Standard), December 1995, Available at http://www.rfc-editor.org/rfc/rfc1883.txt.

S. Deering and R. Hinden, ‘Internet Protocol, Version 6 (IPv6) Specification’, *Internet Request for Comments*, vol. RFC 2460, December 1998, Available at http://www.rfc-editor.org/rfc/rfc2460.txt.

Growth

- IPv4 serves a market doubling every ~12 months
- In addition, new and very large markets are developing rapidly:
  - Nomadic Computing
  - Networked Entertainment
  - Device Control

Nomadic Computing

Wireless computers
- supporting multimedia
- replacing pagers, cellular telephones, …

IPv6 includes support for mobility
- low overhead (?)
- auto configuration
- mobility

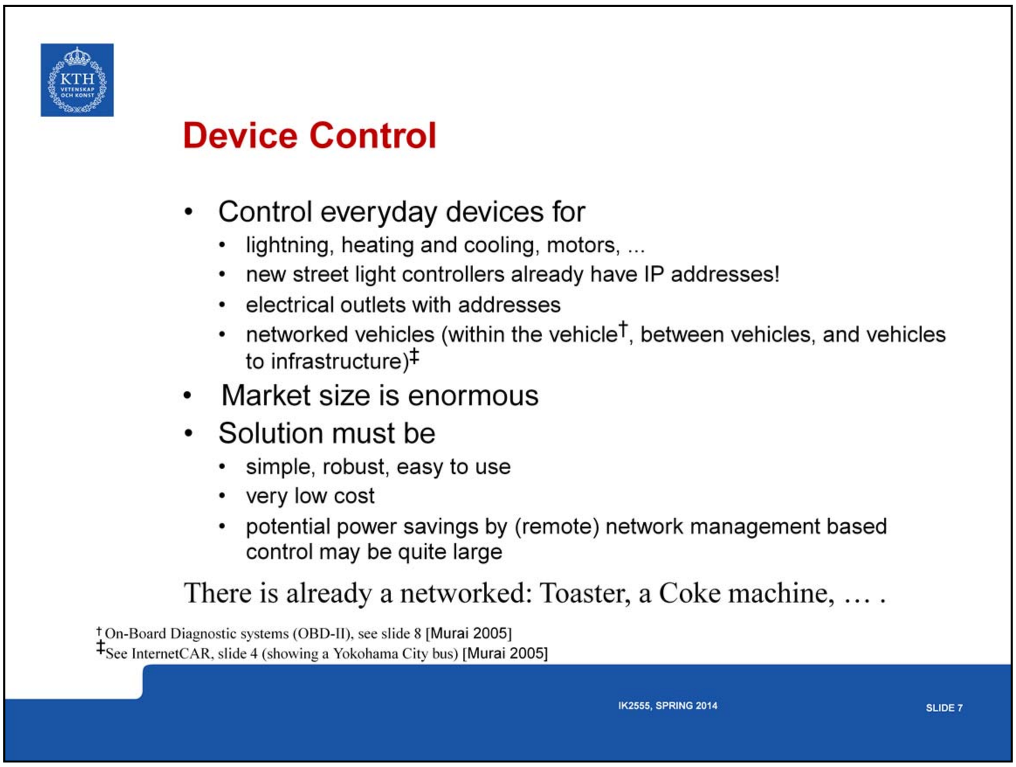
Networked Entertainment

Your TV will be an Internet Host!
[consider the network attached Personal Video Recorders (PVR), such as TiVo's DVR, SONICblue's ReplayTV, Sony's SVR-2000, Philips' PTR, …)]

- 500 channels of television
- large scale routing and addressing
- auto-configuration
- requires support for real-time data

SonicBlues's ReplayTV 4000 a networked Digital Video Recorder (DVR) {i.e., coder/decoder + very big disk) that takes advantage of your broadband Internet connection - enables you to capture and transfer videos.

Providing "narrowcast" content via broadband ⇒ all the time is "primetime".



Jun Murai, “WIDE report”, 5th CAIDA-WIDE Workshop, Information Sciences Institute, Marina del Rey, CA, 15 March 2005 *http://www.caida.org/projects/wide/0503/slides/murai.pdf*

IPv6 features

- Expanded Addressing Capabilities
  - 128 bit address length
  - supports more levels of hierarchy
  - improved multicast routing by using a scope field
  - new cluster addresses to identify topological regions
- Header Format Simplification
  - some IPv4 fields have been dropped, some made optional
  - header is easier to compute
- Improved Support for Extensions and Options
  - more efficient for forwarding of packets
  - less stringent limits to length of options
  - greater flexibility for introduction of future options
- Flow Labeling Capability
  - labeling of packets belonging to a particular “flow”
  - allows special handling of, e.g., real-time, packets
- Authentication and Privacy Capabilities

  Extensions to support authentication, data integrity, and (optional) data confidentiality

IPv6 header format

version 4 bits	Class 8 bits	flow label 20-bits		
"payload" length (in octets) 16 bits			next header 8 bits	hop limit 8 bits
Source Address 128 bits				
Destination Address 128 bits				

IPv6 header (total length = 40 bytes)

IPv6: 6 fields + 2 addresses versus

IPv4: 10 fixed fields + 2 addresses + options

Demultiplexing

Initially, it was assumed that by keeping the version field the same that IPv4 and IPv6 could be mixed over the same links with the same link drivers.

However, now IPv6 will be demultiplexed at the link layer: hence, IPv6 been assigned the Ethernet type 0x86DD (instead of IPv4's 0x8000)

Simplifications

IPv6 builds on 20 years of internetworking experience - which lead to the following simplifications and benefits:

Simplification	Benefits
Use fixed format headers	Use extension headers instead, thus no need for a header length field, simpler to process
Eliminate header checksum	Eliminate need for recomputation of checksum at each hop (relies on link layer or higher layers to check the integrity of what is delivered)
Avoid hop-by-hop segmentation	No segmentation, thus you must do **Path MTU discovery** or only send small packets (1996: 536 octets, 1997: proposed 1500 octets) (for observed PMTUs see [Cho 2005]) • This is because we should have units of **control** based on the units of **transmitted** data.
Eliminate Type of Service (ToS) field	Instead use (labeled) flows

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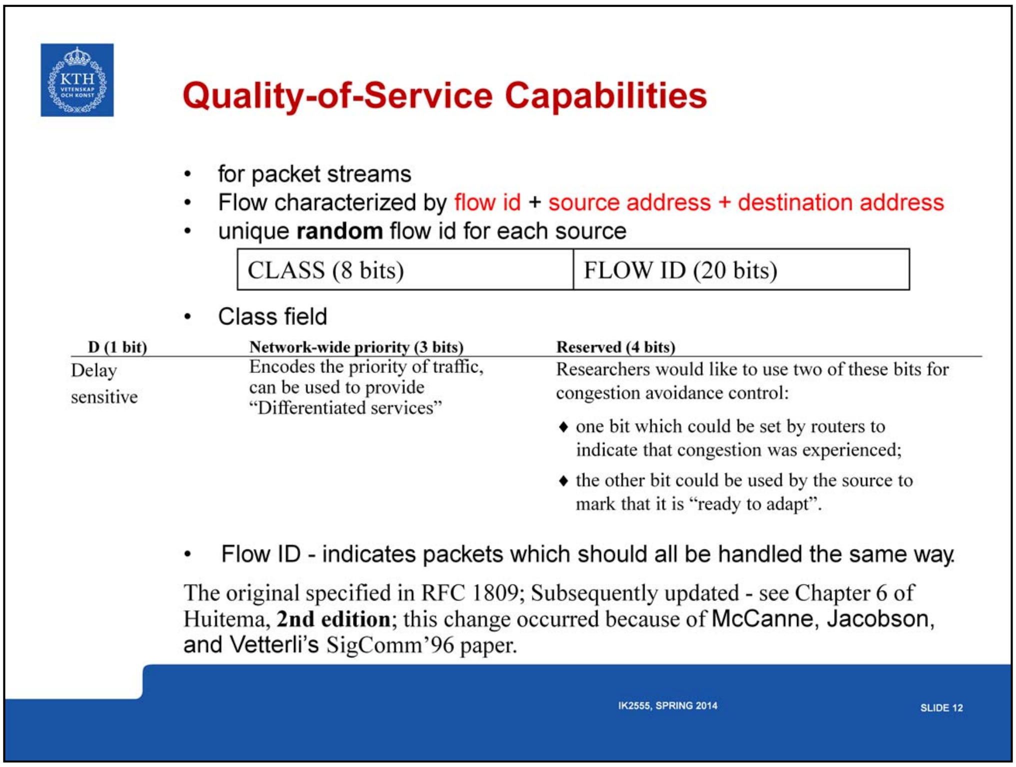
Kenjiro Cho, “Measuting IPv6 Network Quality” (part 2), *Internet Iniative Japan (IIJ)* / WIDE, 5th CAIDA-WIDE Workshop, Information Sciences Institute, Marina del Rey, CA, 15 March 2005 *http://www.caida.org/projects/wide/0503/slides/kenjiro-2.pdf*



C. Partridge, 'Using the Flow Label Field in IPv6', *Internet Request for Comments*, vol. RFC 1809 (Informational), June 1995, Available at http://www.rfc-editor.org/rfc/rfc1809.txt.

S. McCanne, V. Jacobson, M. and Vetterli, "Receiver-driven Layered Multicast", ACM SIGCOMM, August 1996, Stanford, CA, pp. 117-130. *ftp://ftp.ee.lbl.gov/papers/mccanne-sigcomm96.ps.gz*

Payload length

Payload length is the length of the data carried after the header.

As the length field is 16 bits ⇒ maximum packet size of 64 kilobytes; but there is a provision for "jumbograms" [via the Hop-by-Hop option header with option type 194]. See RFC 2675.

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D. Borman, ‘TCP and UDP over IPv6 Jumbograms’, *Internet Request for Comments*, vol. RFC 2147 (Proposed Standard), May 1997, Available at http://www.rfc-editor.org/rfc/rfc2147.txt.

D. Borman, S. Deering, and R. Hinden, ‘IPv6 Jumbograms’, *Internet Request for Comments*, vol. RFC 2675 (Proposed Standard), August 1999, Available at http://www.rfc-editor.org/rfc/rfc2675.txt.

IPv4 Protocol type ⇒ IPv6 Next Header type

Tells how to interpret the next header which follows, it is either the payload type or the type of the next header. [Payload types use the IPv4 protocol type values]

Decimal	Keyword	Header type
0	HBH	Hop-by-hop options
2	ICMP	IPv6 ICMP
3	GGP	Gateway-to-Gateway Protocol
5	ST	Stream
6	TCP	Transmission Control Protocol
17	UDP	User Datagram Protocol
43	RH	IPv6 Routing Header
44	FH	IPv6 Fragmentation Header
45	IDRP	Inter-domain Routing Protocol
51	AH	Authentication Header
52	ESP	Encrypted Security Payload
59	Null	No next Header (IPv6)
60		IPv6 Destination Options Header
88	IGRP	IGRP
89	OSPF	Open Shortest Path First
255		Reserved

Extension headers

- Each header is a multiple of 8 octets long
- order (after IPv6 header):
  - Hop-by-hop option,
  - Destination options header (1)
  - Routing header,
  - Fragment header,
  - Authentication header,
  - Encapsulating security payload header,
  - Destination options header (2)
  - Followed by the upper layer header (e.g., TCP, UDP, …)

So a TCP packet looks like:

IPv6 header Next Header = **TCP**	TCP header + data

If we wanted to explicitly route the above packet, we simply add a routing header:

IPv6 header Next Header = **Routing**	Routing header Next Header = **TCP**	TCP header + data

Addressing

- 128 bits long
- three types: unicast, multicast, anycast

Unicast	identifies exactly one interface
Multicast	identifies a group of interfaces; a packet sent to a multicast address will be delivered to all members of the group
Anycast	delivered to the nearest member of the group

- 2^{96} times more addresses than IPv4 are available !!!

IPv6 addresses per m^2

Earth: 511,263,971,197,990 m^2

$\Rightarrow$ 665,570,793,348,866,943,898,599 / m^2

- pessimistic estimate with hierarchies: ~1,564 addresses / m^2
- optimistic: 3,911,873,538,269,506,102 /m^2

Writing an IPv6 address

The 128 bit IPv6 address is written as eight 16 bit integers using hexadecimal digits.

The integers are separated by colons, for example:
2001:0DB8:7654:3210:FEDC:BA98:7654:3210

A number of abbreviations are allowed:

- leading zeros in integers can be suppressed
- a single set of consecutive 16 bit integers with the value null, can be replaced by double colon, i.e., 2001:DB8:0:0:0:0:7654:3210 becomes 2001:DB8::7654:3210
- When an IPv4 address is turned into an IPv6 address we prepend 96 bits of zeros; but we can write it as:
  ::10.0.0.1 - hence combining dotted-decimal and IPv6 forms
- Prefixes can be denoted in the same manner as for IPv4, i.e., CIDR:
  2001:DB8::/32 - for a 32 bit long prefix

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Address Allocation [RFC 3513] and [Hosaka 2004]

Binary prefix	Hex. prefix	Fraction of address space	Assignment
0000 0000	::/8	1/256	Reserved
0000 0001	100::/8	1/256	Unassigned
~~0000 001~~	~~200::/7~~	~~1/128~~	~~Network Service Access Point (NSAP) Allocation RFC 1888~~ (Obsolete - RFC 4048)
0000 01	400::/6	1/64	Unassigned (first half was formerly Novell's IPX)
0000 1	800::/5	1/32	Unassigned
0001	1000::/4	1/16	Unassigned
001	**2000::/3**	**1/8**	**Global Unicast - RFC 2374, see RFC 3587**
010	4000::/3	1/8	Unassigned (formerly provider based unicast addresses)
011	6000::/3	1/8	Unassigned
100	8000::/3	1/8	Unassigned (formerly Geographic-based Unicast Addresses)
101	A000::/3	1/8	Unassigned
110	C000::/3	1/8	Unassigned
1110	E000::/4	1/16	Unassigned
1111 0	F000::/5	1/32	Unassigned
1111 10	F800::/6	1/64	Unassigned
1111 110	FC00::/7	1/128	unique local address (ULA) - RFC 4193
1111 1110 0	FE00::/9	1/512	Unassigned
1111 1110 10	**FE80::/10**	**1/1024**	**Link Local Use Addresses**

R. Hinden and S. Deering, 'IP Version 6 Addressing Architecture', *Internet Request for Comments*, vol. RFC 2373 (Proposed Standard), July 1998, Available at http://www.rfc-editor.org/rfc/rfc2373.txt.

R. Hinden and S. Deering, 'Internet Protocol Version 6 (IPv6) Addressing Architecture', *Internet Request for Comments*, vol. RFC 3513 (Proposed Standard), April 2003, Available at http://www.rfc-editor.org/rfc/rfc3513.txt.

R. Hinden and S. Deering, 'IP Version 6 Addressing Architecture', *Internet Request for Comments*, vol. RFC 4291 (Draft Standard), February 2006, Available at http://www.rfc-editor.org/rfc/rfc4291.txt.

J. Bound, B. Carpenter, D. Harrington, J. Houldsworth, and A. Lloyd, 'OSI NSAPs and IPv6', *Internet Request for Comments*, vol. RFC 1888 (Historic), August 1996, Available at http://www.rfc-editor.org/rfc/rfc1888.txt.

B. Carpenter, 'RFC 1888 Is Obsolete', *Internet Request for Comments*, vol. RFC 4048 (Informational), April 2005, Available at http://www.rfc-editor.org/rfc/rfc4048.txt.

R. Hinden and B. Haberman, 'Unique Local IPv6 Unicast Addresses', *Internet Request for Comments*, vol. RFC 4193 (Proposed Standard), October 2005, Available at http://www.rfc-editor.org/rfc/rfc4193.txt.

R. Hinden, M. O’Dell, and S. Deering, ‘An IPv6 Aggregatable Global Unicast Address Format’, *Internet Request for Comments*, vol. RFC 2374 (Historic), July 1998, Available at http://www.rfc-editor.org/rfc/rfc2374.txt.

R. Hinden, S. Deering, and E. Nordmark, ‘IPv6 Global Unicast Address Format’, *Internet Request for Comments*, vol. RFC 3587 (Informational), August 2003, Available at http://www.rfc-editor.org/rfc/rfc3587.txt.

Toshiyuki Hosaka, “IPv6 Address Allocation and Policy: PART1 IPv6 Address Basics”, Tech Tutorials, IPv6Style, NTT Communications, 18 November 2004 *http://www.ipv6style.jp/en/tech/20041117/index.shtml*

Global Unicast Addresses

RFC 2374 defined an IPv6 address allocation structure that which featured Top Level Aggregator (TLAs) and Next Level Aggregator (NLAs) - this has been replaced (see RFC 3587) by a coordinated allocation policy defined by the Regional Internet Registries (RIRs) [ripe-267]

The Subnet Local Aggregator (SLAs) of RFC 2374 ⇒ now called the "subnet ID"

001 (3 bits)	global routing prefix (45 bits)	subnet ID (16 bits)	Interface ID (64 bits)

Thus the Regional Internet Registries are allocating addresses from 2000:/3 For a table of IPv6 unicast assignment see

http://www.iana.org/assignments/ipv6-unicast-address-assignments

For an analysis of use from the point of view of RIPE see [Döring 2005]

R. Hinden, M. O'Dell, and S. Deering, 'An IPv6 Aggregatable Global Unicast Address Format', *Internet Request for Comments*, vol. RFC 2374 (Historic), July 1998, Available at http://www.rfc-editor.org/rfc/rfc2374.txt.

R. Hinden, S. Deering, and E. Nordmark, 'IPv6 Global Unicast Address Format', *Internet Request for Comments*, vol. RFC 3587 (Informational), August 2003, Available at http://www.rfc-editor.org/rfc/rfc3587.txt.

Gert Döring, "Impressions:An overview of the global IPv6 routing table", RIPE 50, Stockholm, SE, 3 May 2005, *http://www.space.net/~gert/RIPE/R50-v6-table.pdf*

APNIC, ARIN, and RIPE NCC, "IPv6 Address Allocation and Assignment Policy", Document ID: ripe-267, January 22, 2003 *http://www.ripe.net/ripe/docs/ipv6policy.html*

IPv6 unicast assignments (as of 2014-03-19)

Prefix	Status	Note
2001:0000::/23	ALLOCATED	2001:0000::/23 is reserved for IETF Protocol Assignments [RFC2928]. 2001:0000::/32 is reserved for TEREDO [RFC4380]. 2001:0002::/48 is reserved for Benchmarking [RFC5180]. 2001:10::/28 is reserved for Overlay Routable Cryptographic Hash Identifiers (ORCHID) [RFC4843].
2001:0200::/23	ALLOCATED	
2001:0400::/23	ALLOCATED	
2001:0600::/23	ALLOCATED	
2001:0800::/23	ALLOCATED	
2001:0a00::/23	ALLOCATED	
2001:0c00::/23	ALLOCATED	2001:db8::/32 reserved for Documentation [RFC3849]
2001:0e00::/23	ALLOCATED	
2001:1200::/23	ALLOCATED	
2001:1400::/23	ALLOCATED	
2001:1600::/23	ALLOCATED	
2001:1800::/23	ALLOCATED	
2001:1a00::/23	ALLOCATED	
2001:1c00::/22	ALLOCATED	
2001:2000::/20	ALLOCATED	
2001:3000::/21	ALLOCATED	
2001:3800::/22	ALLOCATED	
2001:3c00::/22	RESERVED	2001:3c00::/22 is reserved for possible future allocation to the RIPE NCC.

KTH has a /48 allocation from SUNET: 2001:6b0:1::/48

from this CoS has: 2001:6b0:1:10f0::/64

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http://www.iana.org/assignments/ipv6-unicast-address-assignments

R. Hinden, S. Deering, R. Fink, and T. Hain, ‘Initial IPv6 Sub-TLA ID Assignments’, *Internet Request for Comments*, vol. RFC 2928 (Informational), September 2000, Available at http://www.rfc-editor.org/rfc/rfc2928.txt.

C. Huitema, ‘Teredo: Tunneling IPv6 over UDP through Network Address Translations (NATs)’, *Internet Request for Comments*, vol. RFC 4380 (Proposed Standard), February 2006, Available at http://www.rfc-editor.org/rfc/rfc4380.txt.

C. Popoviciu, A. Hamza, G. V. de Velde, and D. Dugatkin, ‘IPv6 Benchmarking Methodology for Network Interconnect Devices’, *Internet Request for Comments*, vol. RFC 5180 (Informational), May 2008, Available at http://www.rfc-editor.org/rfc/rfc5180.txt.

P. Nikander, J. Laganier, and F. Dupont, ‘An IPv6 Prefix for Overlay Routable Cryptographic Hash Identifiers (ORCHID)’, *Internet Request for Comments*, vol. RFC 4843 (Experimental), April 2007, Available at http://www.rfc-editor.org/rfc/rfc4843.txt.

G. Huston, A. Lord, and P. Smith, ‘IPv6 Address Prefix Reserved for Documentation’, *Internet Request for Comments*, vol. RFC 3849 (Informational), July 2004, Available at http://www.rfc-editor.org/rfc/rfc3849.txt.

http://www.lan.kth.se/ipv6/

IPv6 unicast assignments (continued)

Prefix	Status	Note
2001:4000::/23	ALLOCATED	
2001:4200::/23	ALLOCATED	
2001:4400::/23	ALLOCATED	
2001:4600::/23	ALLOCATED	
2001:4800::/23	ALLOCATED	
2001:4a00::/23	ALLOCATED	
2001:4c00::/23	ALLOCATED	
2001:5000::/20	ALLOCATED	
2001:8000::/19	ALLOCATED	
2001:a000::/20	ALLOCATED	
2001:b000::/20	ALLOCATED	
2002:0000::/16	ALLOCATED	2002::/16 is reserved for 6to4 [RFC3056].
2003:0000::/18	ALLOCATED	
2400:0000::/12	ALLOCATED	
2600:0000::/12	ALLOCATED	
2610:0000::/23	ALLOCATED	
2620:0000::/23	ALLOCATED	
2800:0000::/12	ALLOCATED	
2a00:0000::/12	ALLOCATED	
2c00:0000::/12	ALLOCATED	
2d00:0000::/8	RESERVED	
2e00:0000::/7	RESERVED	
3000:0000::/4	RESERVED	
3ffe::/16	RESERVED	3ffe:831f::/32 was used for Teredo in some old but widely distributed networking stacks. This usage is deprecated in favor of 2001::/32, which was allocated for the purpose in [RFC4380]. 3ffe::/16 and 5f00::/8 were used for the 6bone but were returned. [RFC5156]
5f00::/8	RESERVED	3ffe::/16 and 5f00::/8 were used for the 6bone but were returned. [RFC5156]

http://www.iana.org/assignments/ipv6-unicast-address-assignments

Interface ID

Must be unique to the link, but there are some advantages of making it more globally unique.

Hence, most will be based on the IEEE EUI-64 format, but with the “u” (unique) bit inverted.

- The “u” bit is the 7th most significant bit of a 64 bit EUI.
- The inversion was necessary because 0:0:0:0 is a valid EUI, but this would collide with one of the IPv6 special addresses.
- u=1, when the address comes from a valid EUI, and is 0 otherwise.

To go from a 48 bit IEEE 802, you insert 0xFFFE in between the 3rd and 4th octets of an IEEE 802 address, i.e., 123456789abc becomes 123456FFFE789abc.

Special Address Formats

Unspecified address

"::" == "0:0:0:0:0:0:0:0 (::/128) - can only be used as a source address by a station which does not yet have an address

Loop-back address

0:0:0:0:0:0:0:1 (::1/128) - used to send an IPv6 datagram to yourself

IPv4-based address

prefix the 32 bit IPv4 address with 96 zero bits

Link local addresses

Link local address are simply unique to a given link - they can be used by stations that have not yet been assigned a provider-based address.

1111 1110 10 (10 bits)	0 (54 bits)	Interface ID (64 bits)

Site local addresses

Site local address (FEC0:/:/10) can not be routed on the global internet, but they can be used by sites that are not connected to the internet or for communication within the site.

1111 1110 11 (10 bits)	0 (38 bits)	Subnet (16 bits)	Interface ID (64 bits)

Due to lack of a clear definition for a site, these were replaced by Unique local addresses.

Unique local address (ULA) [RFC 4193]

IPv6 block fc00::/7 – for private networks (similar to IPv4 private network addresses)

The block is split into:

- fc00::/8 the purpose is not yet defined
- fd00::/8 + 40 bit (pseudo) random string – generates a /48 prefix.

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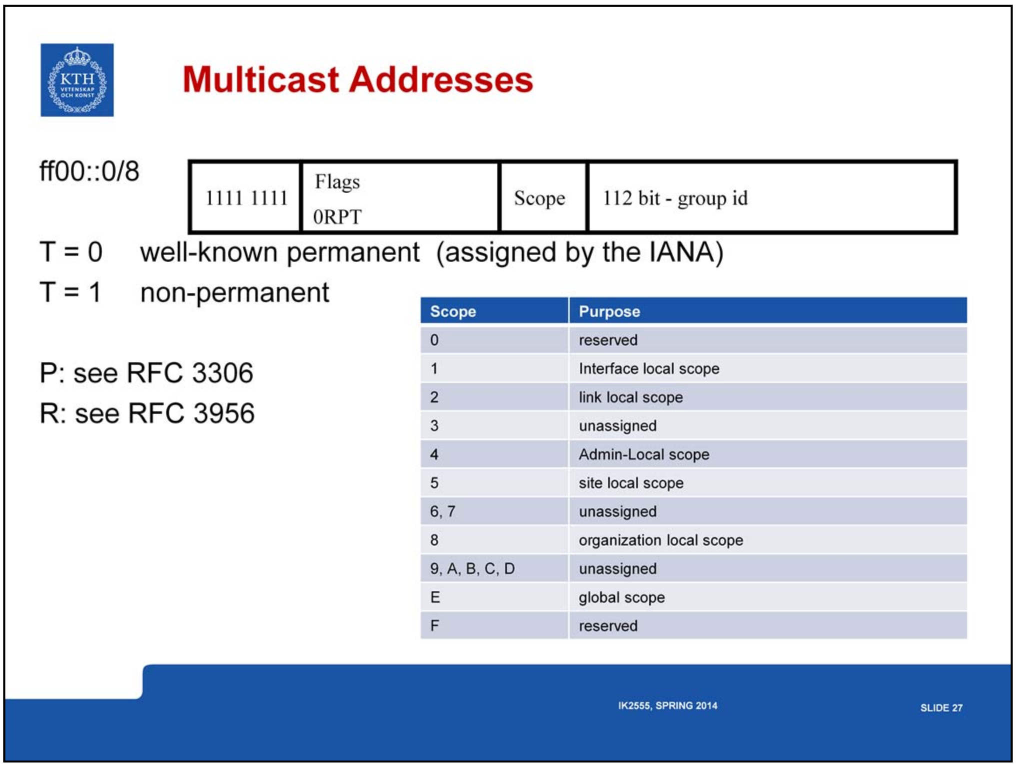
R. Hinden and B. Haberman, ‘Unique Local IPv6 Unicast Addresses’, *Internet Request for Comments*, vol. RFC 4193 (Proposed Standard), October 2005, Available at http://www.rfc-editor.org/rfc/rfc4193.txt.



http://www.iana.org/assignments/ipv6-multicast-addresses/ipv6-multicast-addresses.xhtml

B. Haberman and D. Thaler, 'Unicast-Prefix-based IPv6 Multicast Addresses', *Internet Request for Comments*, vol. RFC 3306 (Proposed Standard), August 2002, Available at http://www.rfc-editor.org/rfc/rfc3306.txt.

P. Savola and B. Haberman, 'Embedding the Rendezvous Point (RP) Address in an IPv6 Multicast Address', *Internet Request for Comments*, vol. RFC 3956 (Proposed Standard), November 2004, Available at http://www.rfc-editor.org/rfc/rfc3956.txt.

Permanently assigned groups

For example, group 0x43 has been assigned to the Network Time Protocol (NTP), hence:

FF01::43	represents all NTP servers on the same node as the sender
FF02::43	represents all NTP servers on the same link as the sender
FF05::43	represents all NTP servers on the same site as the sender
FF08::43	represents all NTP servers within the same organization as the sender
FF0E::43	represents all NTP servers in the Internet

IANA has assigned a whole series of group identifiers, including:

FF0X:0:0:0:0:0:0	Reserved multicast address - this can not be used within any scope
FF01:0:0:0:0:0:1	All Nodes on this node address
FF02:0:0:0:0:0:1	All Nodes on this link address
FF01:0:0:0:0:0:2	All Routers on this node address
FF02:0:0:0:0:0:2	All Router address on this link

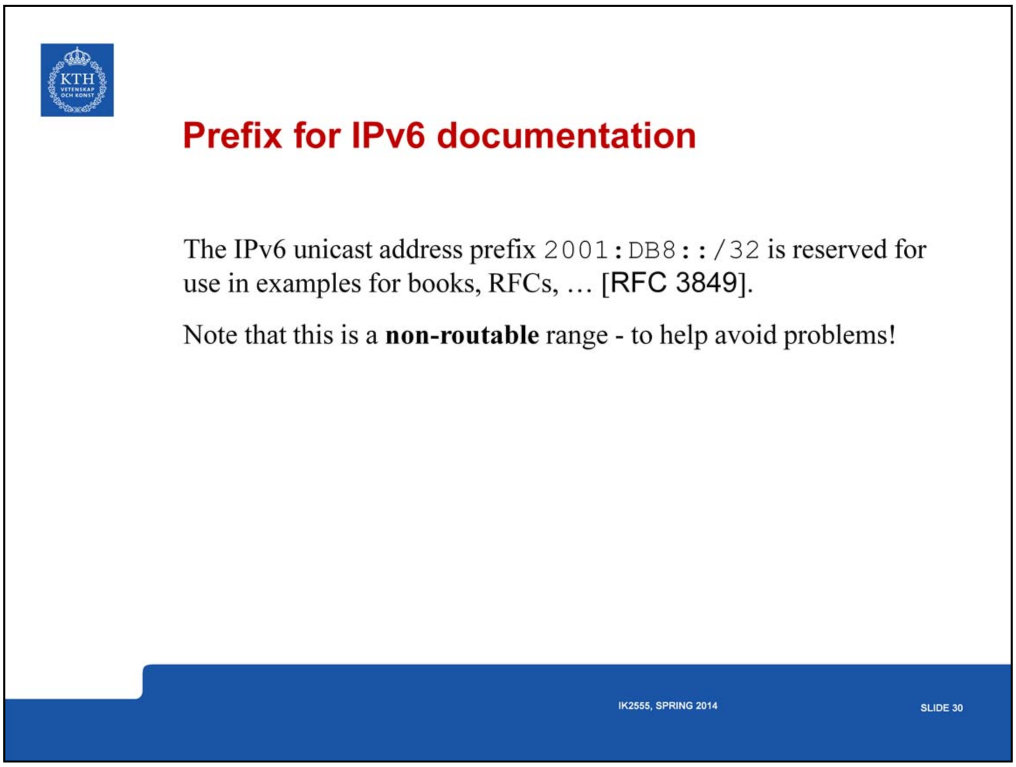
Multicast Multimedia conferences

FF0X:0:0:0:0:2:8000 .. FF0X:0:0:0:0:2:FFFF multimedia conferences

X=2 -- this link

X=5 -- this site

Use SAP to announce the conference - repeatedly until the end of the conference.



G. Huston, A. Lord, and P. Smith, 'IPv6 Address Prefix Reserved for Documentation', *Internet Request for Comments*, vol. RFC 3849 (Informational), July 2004, Available at http://www.rfc-editor.org/rfc/rfc3849.txt.

Anycast

Sending a packet to a generic address to get a specific service from the “nearest” instance. This puts the burden of determining which instance to deliver it to on the routing system.

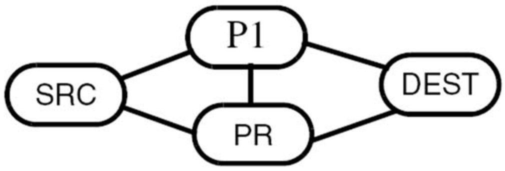
Requires defining a router entry for each anycast address.
Subnet Anycast Address:

Subnet prefix (n bits)	0 (128-n bits)

Thus the host ID of zero is treated as the subnet.

IPv6 Routing

- all standard routing protocols
- routing extensions
  - Provider Selection
  - Host Mobility (route to current location)
  - Auto-Readdressing (route to new address)



IPv6 Routing Option:
provider specifies: SRC, PR, P1, Dest
reply: Dest, PR, P1, SRC

Routing header

Next Header (8 bits)	Header Ext Length (8 bits)	Routing Type=0 (8 bits)	Segments Left (8 bits)
reserved (32 bits)			
address[1] (128 bits)			
address[2]			
...			
address[n]			

Next Header identifies the next header in the chain of headers.

Header Ext. Length. - number of 64 bit words (not including the first 64 bits).

Routing type=0, is the generic routing header which all IPv6 implementations must support.

Number of Segments is the number of segments left in the list (between 0 and 23).

Fragment header

Next Header (8 bits)	Reserved (8 bits)	Fragment offset (13 bits)	RESERVED (2 bits)	M (1 bit)
Identification				

Fragment offset - in units of 64 bit words, the field is the most significant 13 bits of a 16 bit words.

M == More fragment bit, set in all but the last fragment Identification - a 32 bit number

Destination Options header

Next Header (8 bits)	Header Ext. Length (8 bits)	
Options		

Each options field is encoded as:

Option Type (8 bits)	Option Data Length (8 bits)	Option Data (n octets)

The option type:

Action (2 bits)	C (1 bit)	Number (6 bits)

Action tells what action must be taken if the processing nodes does **not** recognize the option.

Bits	Action
00	Skip over this option
01	Discard packet silently (i.e., without sending an ICMP report)
10	Discard packet and send an ICMP report - even if destination is multicast
11	Discard packet and send an ICMP report - only if destination is **not** multicast

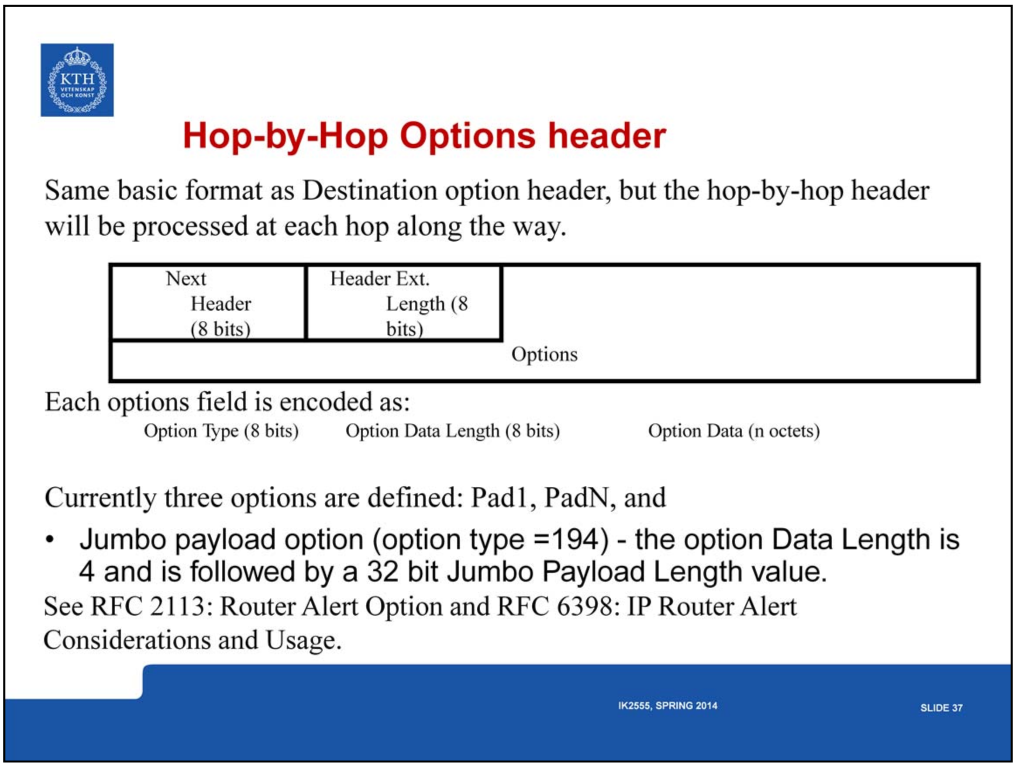
Destination Options header (continued)

C == change en route bit -- indicates that this option may be changed by intermediate relays on the way to the destination

Currently only two options are defined:

Pad1 == a null byte - for use in padding to a 64-bit boundary; note it does not have a null option length field after it - as it is the whole field

PadN - the length field says how many null bytes are needed to file to a 64-bit boundary.



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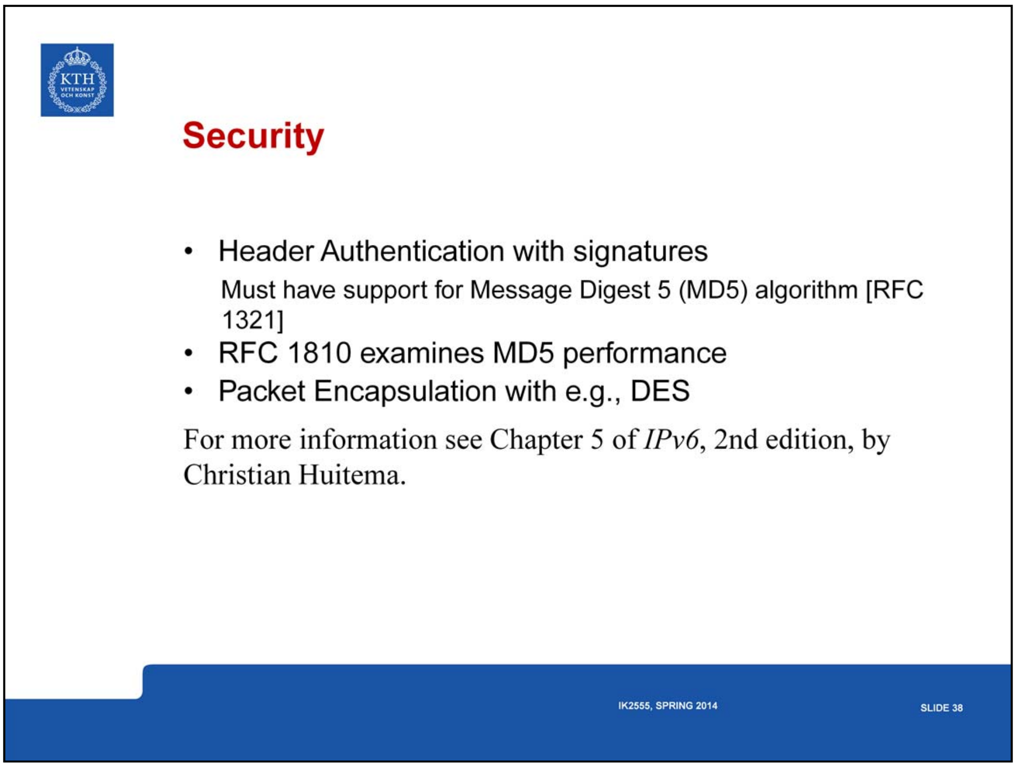

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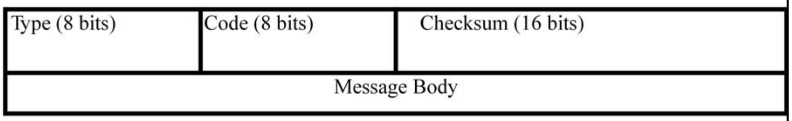
IPSEC IPv6 implementation

The US Naval Research Lab (NRL) IPv6/IPsec Software Distribution

- a reference implementation of IPv6 and IP Security for the 4.4BSD-Lite networking software.
- Freely distributable (subject to U.S. export controls) and usable for commercial and non-commercial purposes (you must adhere to the NRL and UC Berkeley license terms) see also: *http://web.mit.edu/network/isakmp*

IPv6 ICMP [RFC 2463]



Currently defined ICMP Types

Type	Purpose
1	Destination Unreachable
2	Packet too big
3	Time exceeded
4	Parameter problem
128	Echo Request
129	Echo Reply

Type	Purpose
130	Group Membership Query
131	Group Membership Report
132	Group Membership Reduction
133	Router Solicitation
134	Router Advertisement
135	Neighbor Solicitation
136	Neighbor Advertisement
137	Redirect

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A. Conta and S. Deering, ‘Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification’, *Internet Request for Comments*, vol. RFC 2463 (Draft Standard), December 1998, Available at http://www.rfc-editor.org/rfc/rfc2463.txt.

IPv6 ICMP Error Messages

Type: 1, 2, 3, or 4:

Type	Code	Checksum
Parameter		
As much of invoking packet as will fit - without the overall ICMP packet exceeding 576 octets		

For type 1 the code reveals the reason for discarding the datagram

IPv6 ICMP Echo Request/Reply (PING)

Type: Echo Request = 128, Echo Reply = 129

Type	Code	Checksum	
Identifier		Sequence number	
Data			

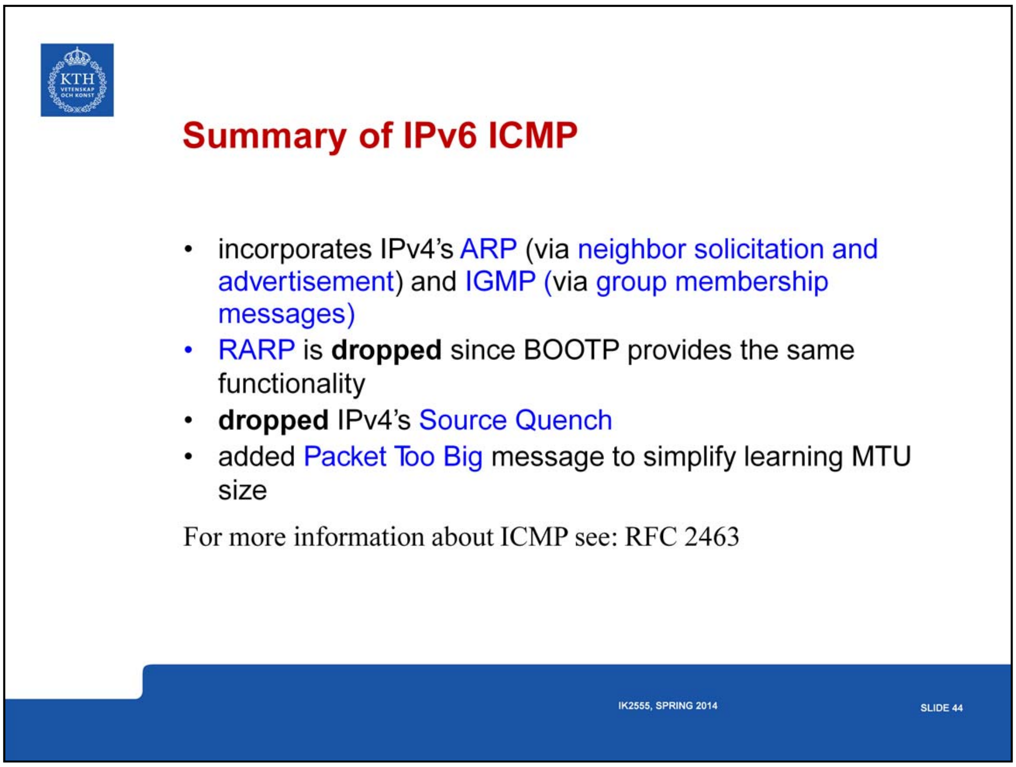
IPv6 ICMP and groups

Three group membership messages (type 130, 131, and 132):

Type	Code	Checksum
Maximum Response Delay		Unused
Multicast Address		

The Group Membership Reduction is used when a node leaves group. Reports are always sent to the same group address that is reported.

Maximum response delay is the time in milliseconds that the responding report messages can be delayed. Responding stations are supposed to spread their responses uniformly over this range of delays (to prevent everyone from responding at once).



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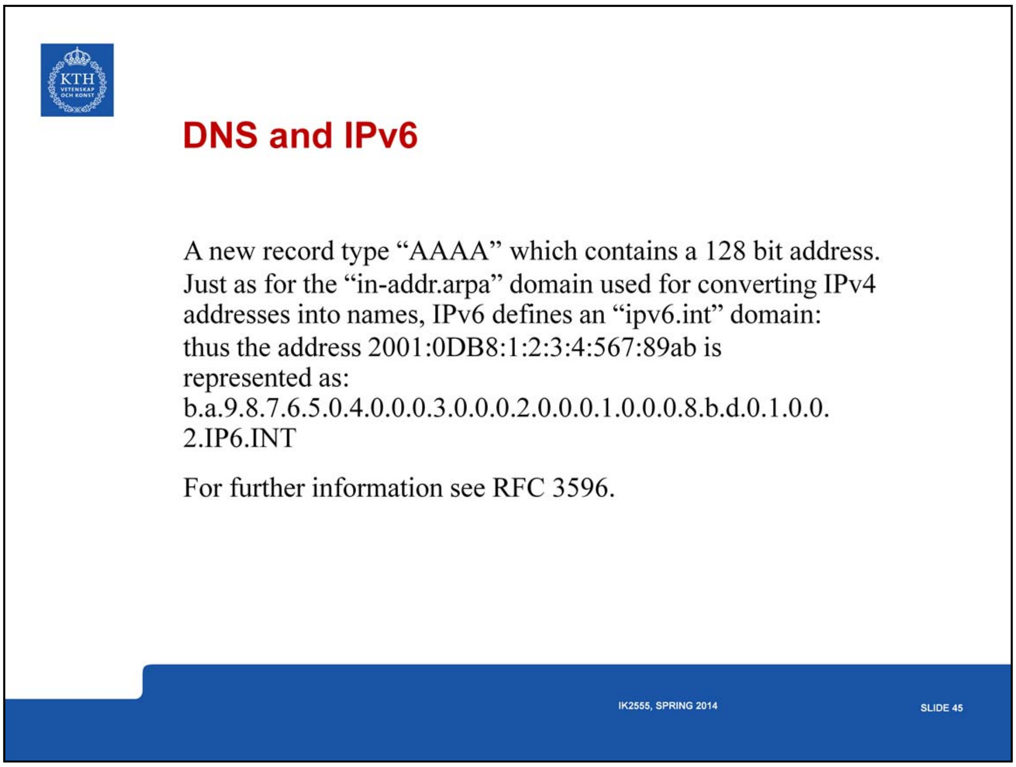

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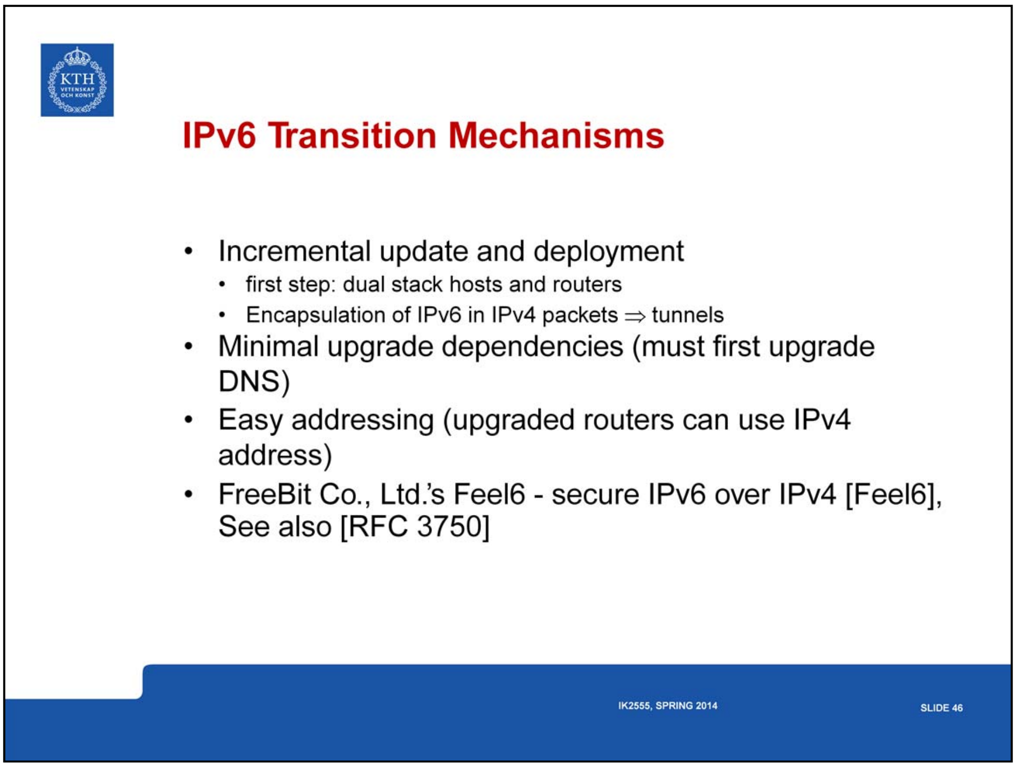
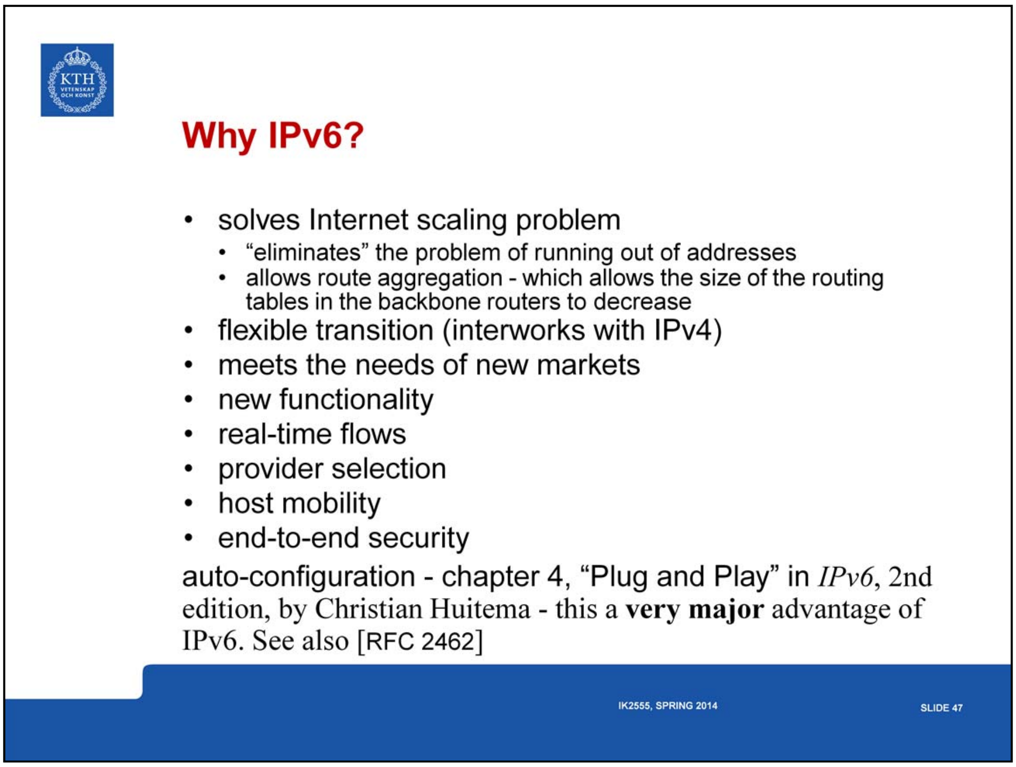
S. Thomson, C. Huitema, V. Ksinant, and M. Souissi, ‘DNS Extensions to Support IP Version 6’, *Internet Request for Comments*, vol. RFC 3596 (Draft Standard), October 2003, Available at http://www.rfc-editor.org/rfc/rfc3596.txt.



“Trying Out for Yourself: Smooth use of IPv6 from IPv4 by Feel6 Farm”, IPv6Style, NTT Communications, 7 March 2003 http://ww

C. Huitema, R. Austein, S. Satapati, and R. van der Pol, ‘Unmanaged Networks IPv6 Transition Scenarios’, *Internet Request for Comments*, vol. RFC 3750 (Informational), April 2004, Available at http://www.rfc-editor.org/rfc/rfc3750.txt.

w.ipv6style.jp/en/tryout/20030307/index.shtml



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N. Moore, ‘Optimistic Duplicate Address Detection (DAD) for IPv6’, *Internet Request for Comments*, vol. RFC 4429 (Proposed Standard), April 2006, Available at http://www.rfc-editor.org/rfc/rfc4429.txt.

IPv6 networks

6Bone - http://www.gogo6.com/page/6bone a testbed for deployment of IPv6

- Note the phase out of the 3FFE::/16 prefix

prefix will be returned to the unassigned address pool on 6 June 2006 [RFC 3701].

6NET http://www.6net.org/ - project co-funded by European Commission (concluded 30 June 2005), followed by http://www.6diss.org/

Internet Society Deploy 360 programme: http://www.internetsociety.org/deploy360/ipv6/

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R. Fink and R. Hinden, ‘6bone (IPv6 Testing Address Allocation) Phaseout’, *Internet Request for Comments*, vol. RFC 3701 (Informational), March 2004, Available at http://www.rfc-editor.org/rfc/rfc3701.txt.

RIR assignments of IPv6 addresses

Total number of allocated IPv6 prefixes per RIR on 13/05/2005:

RIR	Size in /48s	Count
APNIC	416,579,590	376
ARIN	9,699,375	195
LACNIC	1,048,577	17
RIPE NCC	1,091,723,264	635
Total:	1,519,050,806	1,223

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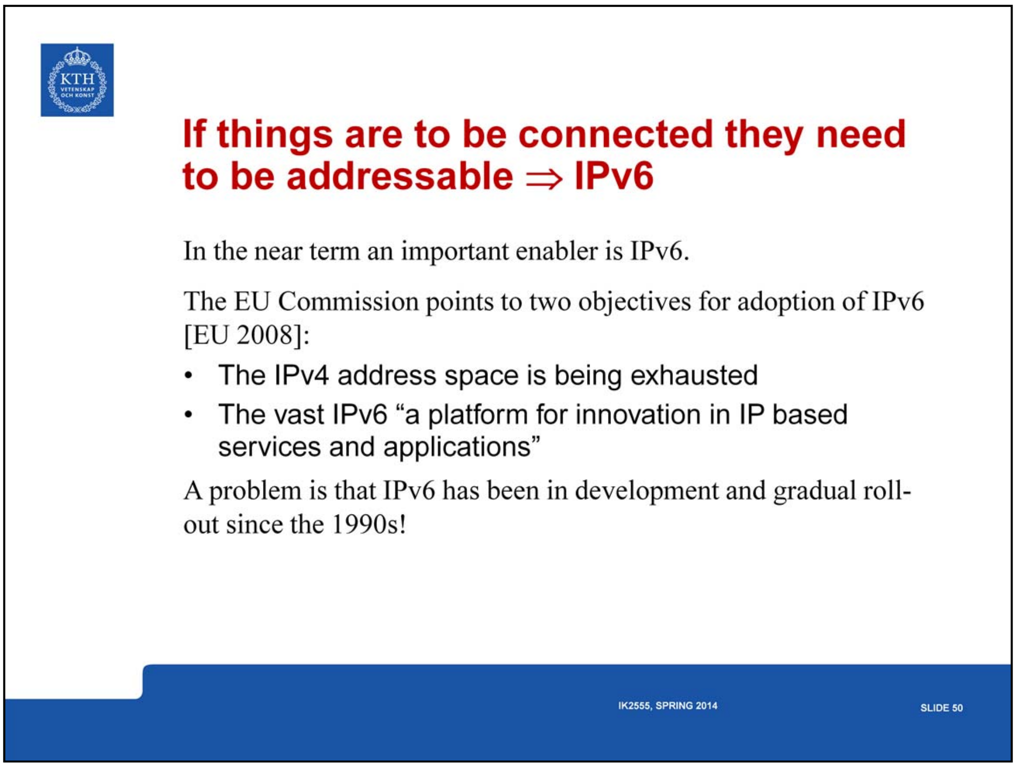
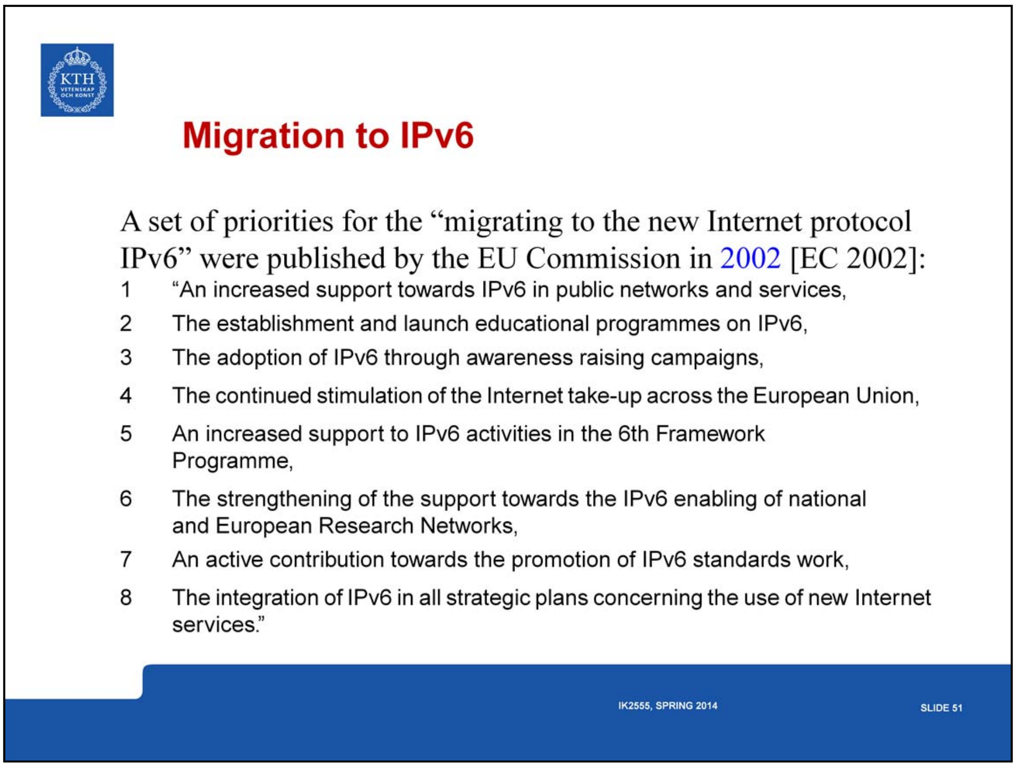
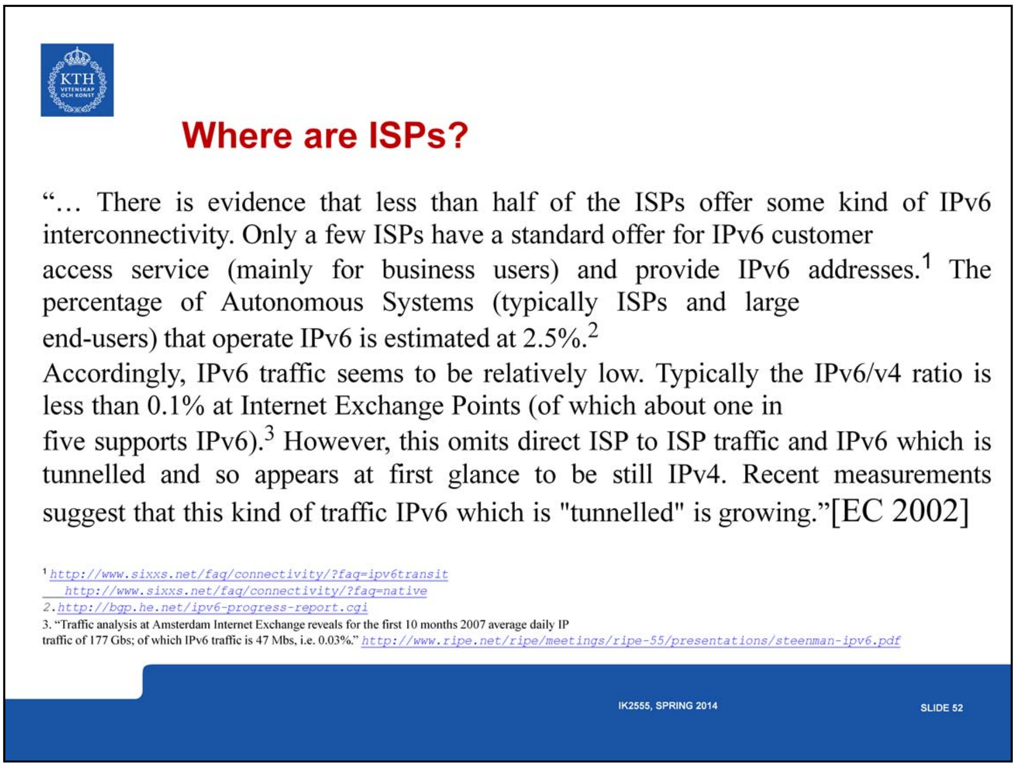
RIPE, “Total number of allocated IPv6 prefixes per RIR on 13/05/2005”, web page accessed 2005.05.14 *http://www.ripe.net/rs/ipv6/stats/index.html*



[EU 2008]: Advancing the Internet, Action Plan for the Deployment of Internet Protocol version 6 (Ipv6) In Europe, Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee and the Committee of the Regions, Brussels, 27 May 2008 *http://ec.europa.eu/information_society/policy/ipv6/docs/european_day/communication_final_27052008_en.pdf*



[EC 2002]: European Commission, Next Generation Internet priorities for action in migrating to the new Internet protocol IPv6, Communication from the Commission to the Council and the European Parliament, 21 February 2002



http://www.sixxs.net/faq/connectivity/?faq=ipv6transit

http://www.sixxs.net/faq/connectivity/?faq=native

European Commission, Next Generation Internet priorities for action in migrating to the new Internet protocol IPv6, Communication from the Commission to the Council and the European Parliament, 21 February 2002

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Further information

See:

- http://www.ipv6.org/
- http://www.ipv6forum.com/
- Measurements of dual stack IPv6 implementations: http://mawi.wide.ad.jp/mawi/dualstack/

See also: [Cho 2005 parts 1 and 2].

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Kenjiro Cho, “Measuring IPv6 Network Quality” (part 1), 5th CAIDA-WIDE Workshop, Information Sciences Institute, Marina del Rey, CA, 15 March 2005 *http://www.caida.org/projects/wide/0503/slides/kenjiro-1.pdf*

Kenjiro Cho, “Measuting IPv6 Network Quality” (part 2), *Internet Iniative Japan (IIJ)* / WIDE, 5th CAIDA-WIDE Workshop, Information Sciences Institute, Marina del Rey, CA, 15 March 2005 *http://www.caida.org/projects/wide/0503/slides/kenjiro-2.pdf*

Summary

This module we have discussed: IPv6


¿Questions?
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