Communication Networks

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Solution: Exercise 6 – Internet Protocol (IP) and Forwarding

Internet Protocol (IP)

6.1 IPv4 vs. IPv6

a) In the lecture you heard about IPv4 and IPv6. Why was IPv6 introduced? What is the main difference?

Solution: The main motivation for IPv6 is the IPv4 address exhaustion. Even though Network Address Translation (NAT) could temporarily solve the problem, there are no longer enough IPv4 addresses / subnets for all the devices connected to the Internet. The main difference is the higher number of bits for each IP address (128 instead of 32). Furthermore, IPv6 also handles e.g. fragmentation or header options in a different way.

b) How many IPv4 and IPv6 addresses exist? Is it possible to use all the addresses for hosts in the Internet?

Solution: IPv4: $2^{32} \approx 4.3 * 10^9$

IPv6: $2^{128} \approx 3.4 * 10^{38}$

No, it is not possible to use all the addresses. Some address spaces are reserved e.g. for private addresses. Other addresses are used to identify the network/router or as broadcast addresses.

c) Assuming there are 7.8 billion people in the world, how many IPv4/IPv6 addresses are theoretically available per person?

Solution: IPv4: $2^{32}/(7.8 * 10^9) \approx 0.55$

IPv6: $2^{128}/(7.8 * 10^9) \approx 4.36 * 10^{28}$

d) Even though IPv6 has been standardized more than 10 years ago, it still has very limited coverage. What are the reasons why the deployment of IPv6 is so slow?

Solution: Every network device, which has to interact with the network layer, needs to be able to understand the new IPv6 addresses and the corresponding header. It is therefore not possible to switch from IPv4 to IPv6 on one specific day. Upgrading the hardware is costly and especially for end-users there is no real motivation. At the moment, everything seems to work well with IPv4 addresses.

6.2 IPv4 Calculations

Each row in the following table describes an IP network. Fill in the missing values.

Solution:

Slash-notation	Netmask-notation	First usable address	Last usable address	Broadcast address
10.0.0.0/24	10.0.0.0/255.255.255.0	10.0.0.1	10.0.0.254	10.0.0.255
126.127.128.0/17	126.127.128.0/255.255.128.0	126.127.128.1	126.127.255.254	126.127.255.255
12.34.32.0/19	12.34.32.0/255.255.224.0	12.34.32.1	12.34.63.254	12.34.63.255
222.208.0.0/12	222.208.0.0/255.240.0.0	222.208.0.1	222.223.255.254	222.223.255.255
123.45.67.224/27	123.45.67.224/255.255.255.224	123.45.67.225	123.45.67.254	123.45.67.255

6.3 IPv6 Computations

Answer the following questions to IPv6.

a) Currently, all global unicast IPv6 addresses are inside 2000::/3. Assume that every network in the Internet gets an entire /64 prefix. How many different /64 prefixes can you distribute? How many hosts can be inside one of these /64 prefixes? Compare these numbers with the total amount of IPv4 addresses.

Solution: If every network gets a /64 prefix within 2000::/3. Then, there are $64 - 3 = 61$ bits to use. This allows for $2^{61} = 2.30 * 10^{18}$ /64 prefixes. In each prefix, you can allocate a total of $2^{64} = 1.84 * 10^{19}$ hosts. There are only $2^{32} = 4.29 * 10^{9}$ IPv4 addresses.

b) Simplify the notation of the following IPv6 addresses:

Solution:

Full IPv6 address	Simplified IPv6 address
000a:1234:abda:0000:0000:0140:0000:0001	a:1234:abda::140:0:1
0000:0000:0000:0000:0000:0003:0000:0010	::3:0:10
000a:0031:003f:0000:0000:0000:0000:0000	a:31:3f::
0000:0000:0000:0000:0000:0000:0000:000b	::b

c) For the following pairs of IPv6 addresses, find the longest prefix that contains both addresses.

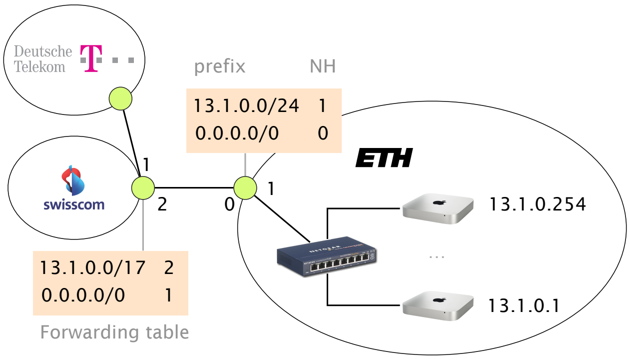
Solution:

Address 1	Address 2	Prefix
2000::a35a	2000::ac3f	2000::a000/116
2005::2e90:12fa:1	2005::2eb0:0:1	2005::2e80:0:0/90
200a::789:3	200a:5c::	200a::/25

Forwarding

6.4 The Art of Defaulting Properly (Exam Style Question)

Consider this simple network configuration between ETH and Swisscom. Assume that ETH owns a large IP prefix 13.1.0.0/17, but only uses 13.1.0.0/24 to address its internal hosts. For simplicity, we assume that ETH and Swisscom operators configure their forwarding table statically and rely on the use of a default route (0.0.0.0/0).



Where are my IP packets going?

a) How many IP addressable addresses does ETH "own" in total?

Solution: $2^{(32-17)} - 2$

b) Give the first and last IP address that ETH can use for addressing a host.

Solution: 13.1.0.1 and 13.1.127.254

c) Suppose Swisscom receives a packet for 13.1.0.66 from Deutsche Telekom. What is the path taken by this IP packet?

Solution: Swisscom/1 → Swisscom/2 → ETH/0 → ETH/1

d) Suppose Swisscom receives a packet for 13.1.66.1 from Deutsche Telekom. What is the path taken by this IP packet?

Solution: Swisscom/1 → Swisscom/2 → ETH/0 → Swisscom/2 → ETH/0 → ...

e) What eventually happens to the packet for 13.1.66.1? As an attacker observing this, could you use this observation to congest the ETH-Swisscom link more easily? Explain why (or why not).

Solution: It will eventually be dropped as the TTL reaches 0. Permanent forwarding loops can be used to perform a Denial of Service (DoS) attack with few resources. Here an attacker can simply start sending fake traffic to 13.1.66.1 which will start "pilling up" on the Swisscom ↔ ETH link. The actual damages will depend on: *i)* the rate at which the attacker can send; *ii)* the TTL of the packets; as well as *iii)* the actual capacity of the link. Observe that the induced congestion negatively impact *all* traffic, including traffic destined to 13.1.0.0/24.

6.5 Summer Pruning (Exam Question 2018)

Consider an IP router with a forwarding table composed of the 9 entries depicted on the left. Write down (on the right) an equivalent forwarding table by combining entries together into shorter ones such that the resulting table has the least number of entries. Your reduced forwarding table should be such that the forwarding decision made by the router for any IP packet is equivalent to the initial one.

Solution:

prefix	next-hop
82.130.32.0/20	1
82.130.64.0/20	1
82.130.80.0/20	2
82.130.96.0/20	1
82.130.112.0/21	1
82.130.120.0/21	1
82.130.122.0/24	1
82.130.123.0/24	1
82.130.124.0/24	2

prefix	next-hop
82.130.32.0/20	1
82.130.64.0/18	1
82.130.80.0/20	2
82.130.124.0/24	2

Answer to the same question as above considering the forwarding table below instead (left) in which an extra default route is defined.

Solution:

prefix	next-hop
0.0.0.0/0	1
82.130.32.0/20	1
82.130.64.0/20	1
82.130.80.0/20	2
82.130.96.0/20	1
82.130.112.0/21	1
82.130.120.0/21	1
82.130.122.0/24	1
82.130.123.0/24	1
82.130.124.0/24	2

prefix	next-hop
0.0.0.0/0	1
82.130.80.0/20	2
82.130.124.0/24	2