UCL

Université
catholique
de Louvain

Infrastructures des réseaux du Système d'information (SRI)
Service Général du Système d'Information (SGSI)

Case study : UCL's computer network

Quentin Hunin
Network engineer

About myself

Graduated from UCL in 2011

Network engineer at ING Belgium between 2011 and 2013

Network engineer at UCL since 2013

Agenda

Some design considerations

Some figures

IP plan

Core network

External connections

Data-centers

Campus

DHCP / DNS

Monitoring and management tools

Design considerations

Applications give sense to IT infrastructures

but IT infrastructures make it possible.

Computer networks belong to the foundations.

Design considerations

- Optimal technical solution
- Cost and time
- History
- Existing agreements
- Management
- Compliancy and legal constraints
- Public tender rules
- Maintenance cost

…

Some figures

6 000 staff members

30 000 students

6 geographical sites (LLN, Woluwe, Saint-Gilles, Mons, Tournai, Charleroi)

100+ buildings

Tens of partners depending on our IT (non-profits organizations, hospitals, schools,…)

Some IT figures

3 main data-centers / 500 servers / 150 TB of storage

10 Gigabit connectivity towards research networks

5 Gigabit commercial bandwidth

7 core L3 switches

500 Ethernet access and distribution switches

25.000 network outlets

900 WiFi access points supporting up to 12.000 clients

30 kms of fiber cables

How we connect

What we connect and power









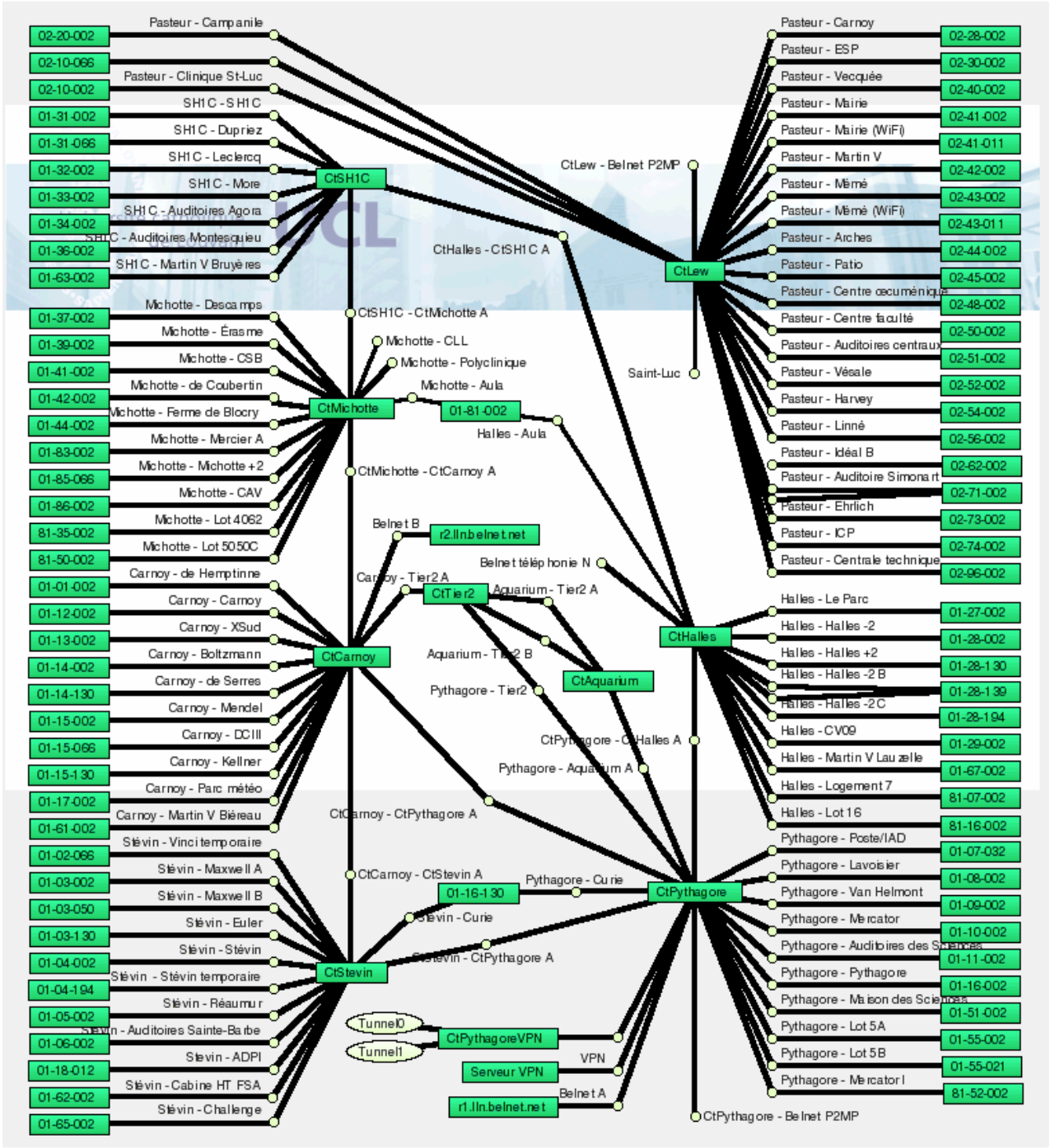








The big picture


Pasteur - Campanile
02-20-002
02-10-066
Pasteur - Clinique St-Luc
02-10-002
SH1C - SH1C
01-31-002
SH1C - Dupriez
01-31-066
SH1C - Leclercq
01-32-002
SH1C - More
01-33-002
SH1C - Auditoires Agora
01-34-002
SH1C - Auditoires Montesquieu
01-36-002
SH1C - Martin V Bruyères
01-63-002
CtSH1C
CtLew - Belnet P2MP
CtHalles - CtSH1C A
CtLew
Pasteur - Carnoy
02-28-002
Pasteur - ESP
02-30-002
Pasteur - Vecquée
02-40-002
Pasteur - Mairie
02-41-002
Pasteur - Mairie (WiFi)
02-41-011
Pasteur - Martin V
02-42-002
Pasteur - Mérné
02-43-002
Pasteur - Mérné (WiFi)
02-43-011
Pasteur - Arches
02-44-002
Pasteur - Patio
02-45-002
Pasteur - Centre oecuménique
02-48-002
Pasteur - Centre faculté
02-50-002
Pasteur - Auditoires centraux
02-51-002
Pasteur - Vésale
02-52-002
Pasteur - Harvey
02-54-002
Pasteur - Linné
02-56-002
Pasteur - Idéal B
02-62-002
Pasteur - Auditoire Simonart
02-71-002
Pasteur - Ehrlich
02-73-002
Pasteur - ICP
02-74-002
Pasteur - Centrale technique
02-96-002
Saint-Luc
Michotte - Descamps
01-37-002
Michotte - Érasme
01-39-002
Michotte - CSB
01-41-002
Michotte - de Coubertin
01-42-002
Michotte - Ferme de Blocry
01-44-002
Michotte - Mercier A
01-83-002
Michotte - Michotte +2
01-85-066
Michotte - CAV
01-86-002
Michotte - Lot 4062
81-35-002
Michotte - Lot 5050C
81-50-002
CtMichotte
CtSH1C - CtMichotte A
Michotte - CLL
Michotte - Polyclinique
Michotte - Aula
01-81-002
Halles - Aula
CtMichotte - CtCarnoy A
Belnet B
r2.lln.belnet.net
Belnet téléphonie N
Carnoy - de Hemptinne
01-01-002
Carnoy - Carnoy
01-12-002
Carnoy - XSud
01-13-002
Carnoy - Boltzmann
01-14-002
Carnoy - de Serres
01-14-130
Carnoy - Mendel
01-15-002
Carnoy - DCIII
01-15-066
Carnoy - Kellner
01-15-130
Carnoy - Parc météo
01-17-002
Carnoy - Martin V Biéreau
01-61-002
CtCarnoy
Carnoy - Tier2 A
CtTier2
Aquarium - Tier2 A
Aquarium - Tier2 B
Pythagore - Tier2
CtAquarium
CtPythagore - CtHalles A
Pythagore - Aquarium A
CtCarnoy - CtPythagore A
CtHalles
Halles - Le Parc
01-27-002
Halles - Halles -2
01-28-002
Halles - Halles +2
01-28-130
Halles - Halles -2 B
01-28-139
Halles - Halles -2 C
01-28-194
Halles - CV09
01-29-002
Halles - Martin V Lauzelle
01-67-002
Halles - Logement 7
81-07-002
Halles - Lot 16
81-16-002
Stévin - Vinci temporaire
01-02-066
Stévin - Maxwell A
01-03-002
Stévin - Maxwell B
01-03-050
Stévin - Euler
01-03-130
Stévin - Stévin
01-04-002
Stévin - Stévin temporaire
01-04-194
Stévin - Réaumur
01-05-002
Stévin - Auditoires Sainte-Barbe
01-06-002
Stévin - ADPI
01-18-012
Stévin - Cabine HT FSA
01-62-002
Stévin - Challenge
01-65-002
CtStevin
CtCarnoy - CtStevin A
01-16-130
Stévin - Curie
CtStevin - CtPythagore A
Pythagore - Curie
CtPythagore
Pythagore - Poste/IAD
01-07-032
Pythagore - Lavoisier
01-08-002
Pythagore - Van Helmont
01-09-002
Pythagore - Mercator
01-10-002
Pythagore - Auditoires des Sciences
01-11-002
Pythagore - Pythagore
01-16-002
Pythagore - Maison des Sciences
01-51-002
Pythagore - Lot 5A
01-55-002
Pythagore - Lot 5B
01-55-021
Pythagore - Mercator I
81-52-002
Tunnel0
Tunnel1
CtPythagoreVPN
VPN
Serveur VPN
Belnet A
r1.lln.belnet.net
CtPythagore - Belnet P2MP

IP prefixes

130.104.0.0/16

192.135.167.0/23

193.191.171.0/24

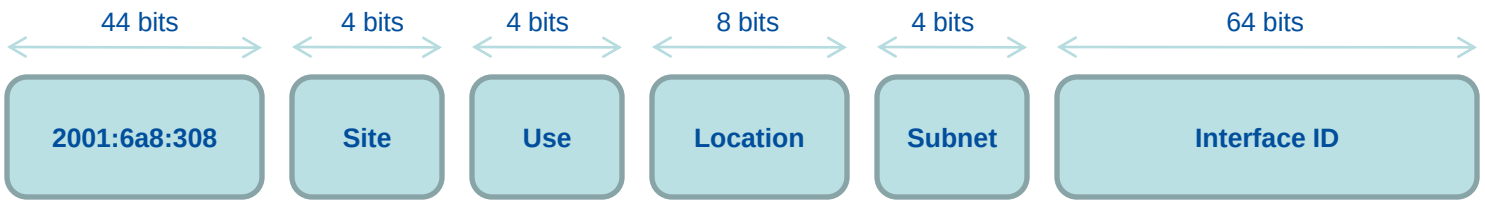
→ no NAT needed

2001:6a8:3080::/44

IPv4 addressing plan

- No addressing plan at that time
- Started with a first asked first served assignment

IPv6 addressing plan



Encode information inside the prefix to:

have smaller routing tables.

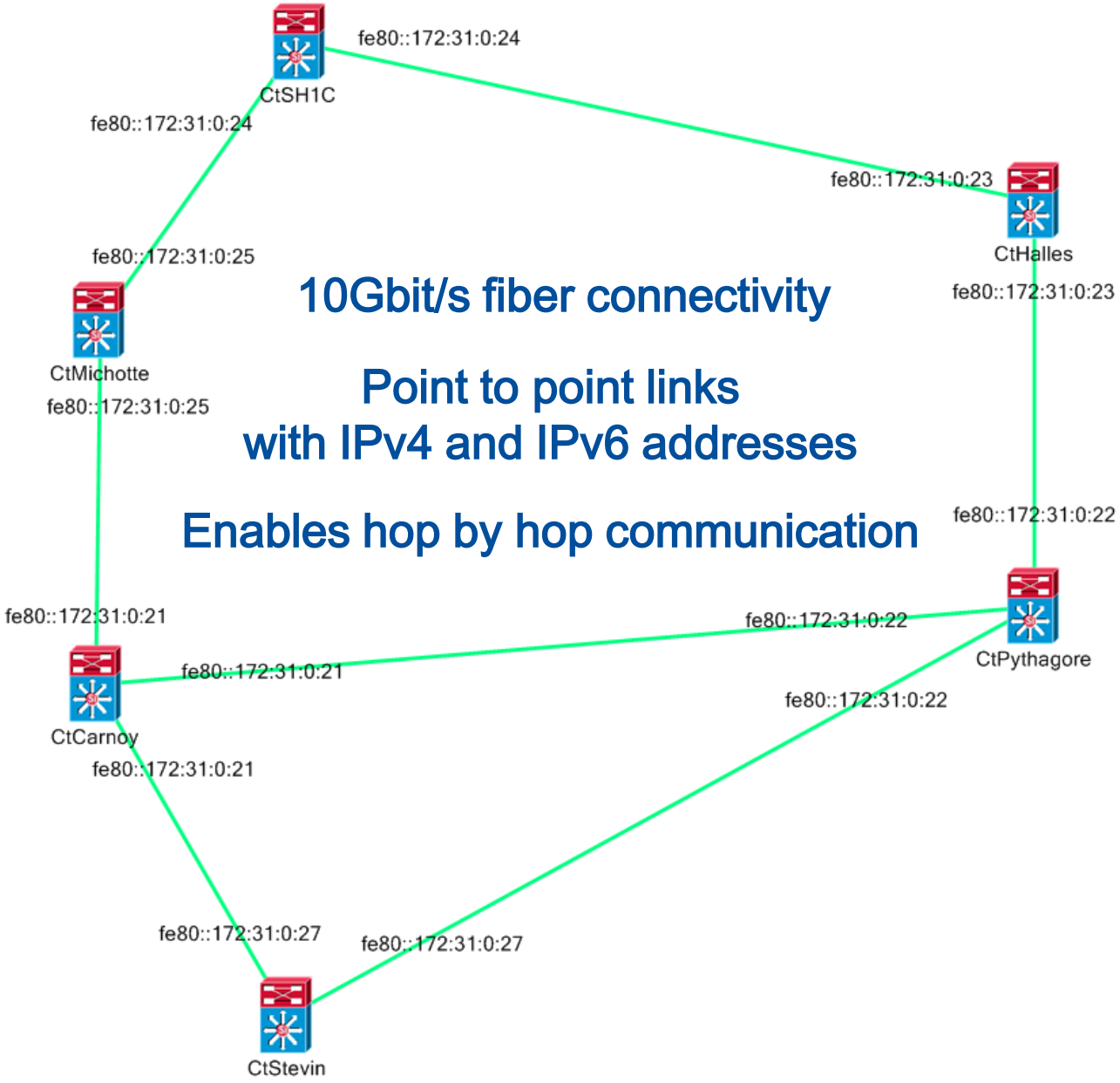
make filtering rules easier and more readable

Core network

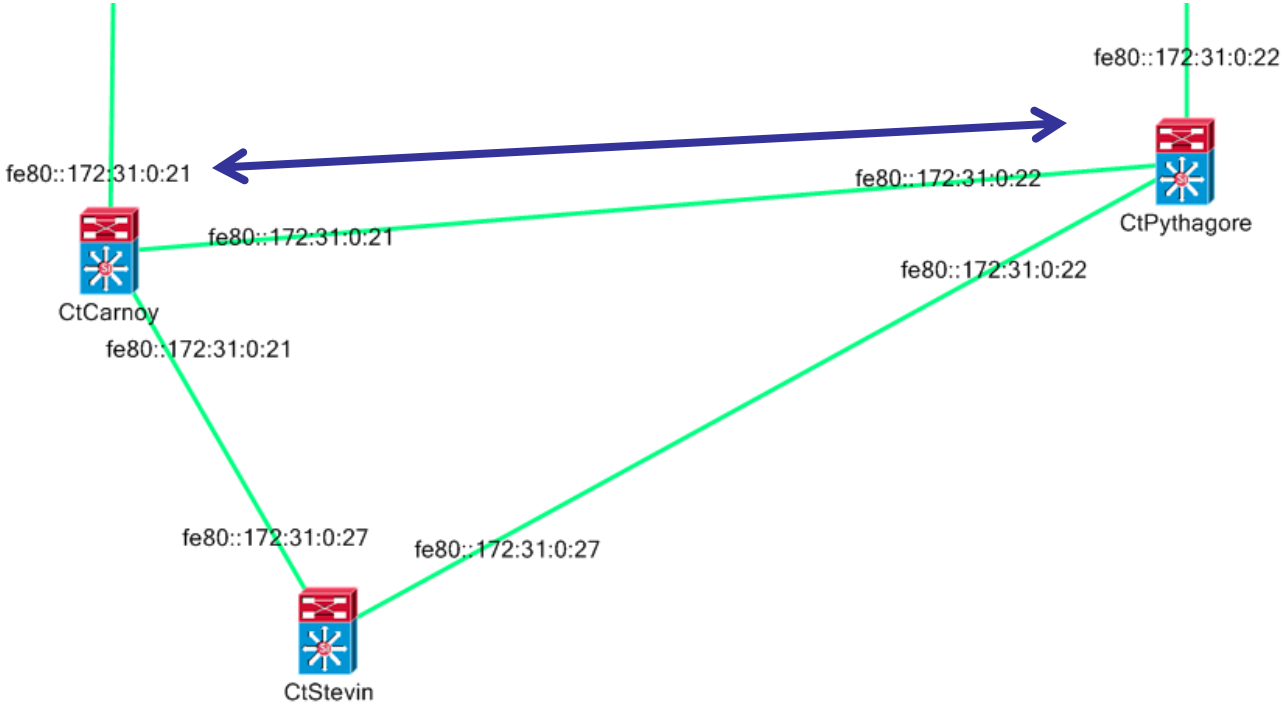
- 10 Gbit/s inter router links
- Dual stack IPv4 / IPv6.
- Supports unicast and multicast traffic forwarding

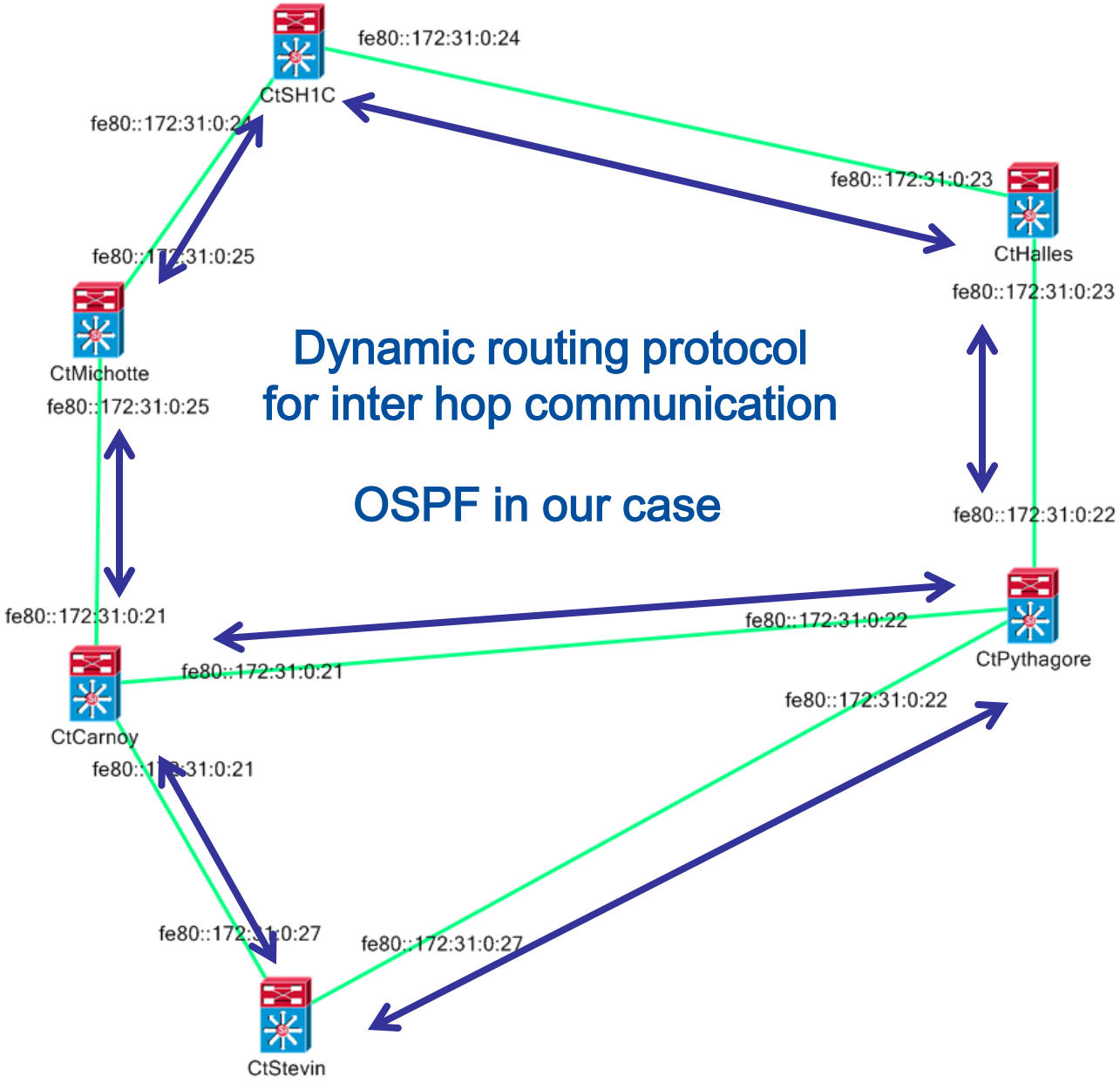
Core network

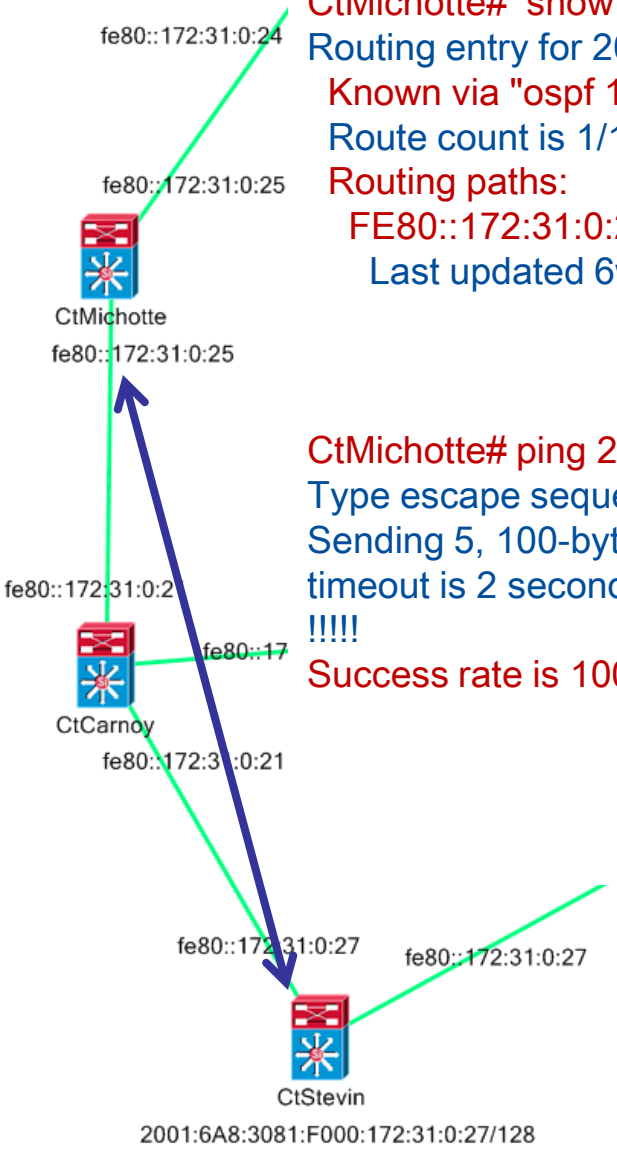
Cisco 6509-E


fe80::172:31:0:24
CtSH1C
fe80::172:31:0:24
fe80::172:31:0:23
CtHalles
fe80::172:31:0:25
fe80::172:31:0:23
CtMichotte
fe80::172:31:0:25
10Gbit/s fiber connectivity
Point to point links
with IPv4 and IPv6 addresses
Enables hop by hop communication
fe80::172:31:0:22
fe80::172:31:0:21
fe80::172:31:0:22
CtPythagore
fe80::172:31:0:21
fe80::172:31:0:22
CtCarnoy
fe80::172:31:0:21
fe80::172:31:0:27
fe80::172:31:0:27
CtStevin

```
CtPythagore# ping FE80::172:31:0:21
Output Interface: Vlan981
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FE80::172:31:0:21, timeout is 2 seconds:
Packet sent with a source address of FE80::172:31:0:22%Vlan981
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 0/0/0 ms
```




fe80::172:31:0:24
CtSH1C
fe80::172:31:0:24
fe80::172:31:0:23
CtHalles
fe80::172:31:0:25
CtMichotte
fe80::172:31:0:25
fe80::172:31:0:23
Dynamic routing protocol
for inter hop communication
OSPF in our case
fe80::172:31:0:22
fe80::172:31:0:21
fe80::172:31:0:22
fe80::172:31:0:21
CtPythagore
fe80::172:31:0:22
CtCarnoy
fe80::172:31:0:21
fe80::172:31:0:27
fe80::172:31:0:27
CtStevin



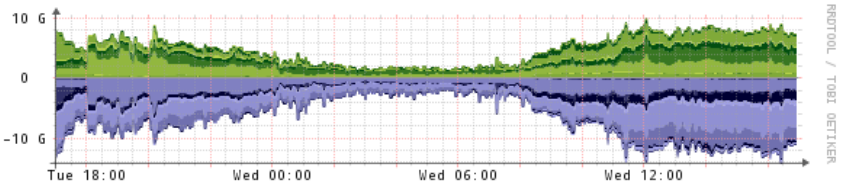

```
CtMichotte#  show ipv6 route 2001:6A8:3081:F000:172:31:0:27
Routing entry for 2001:6A8:3081:F000:172:31:0:27/128
  Known via "ospf 1", distance 110, metric 3, type intra area
  Route count is 1/1, share count 0
  Routing paths:
    FE80::172:31:0:21, Vlan985
      Last updated 6w2d ago
```

```
CtMichotte# ping 2001:6A8:3081:F000:172:31:0:27
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:6A8:3081:F000:172:31:0:27,
timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 0/0/4 ms
```

Cisco IOS Software, s2t54 Software (s2t54-IPSERVICESK9-M), Version 15.1(2)SY7, RELEASE SOFTWARE (fc4) Technical Support: http://www.cisco.com/techsupport Copyright (c) 1986-2016 by Cisco Systems, Inc. Compiled Sun 13-Mar-16 07:14 by prod_rel_team

Hardware	Cisco 6509 (WS-C6509-E)
Operating system	Cisco IOS 15.1(2)SY7 (IPSERVICESK9)
System name	ctpythagore.sri.ucl.ac.be
Contact	UCL/SRI, +32 (10) 47 2611, sri@sri.ucl.ac.be
Serial	SMC09210001
Uptime	313 days, 52m 17s

Ports



238 | 221 | 2 | 15

Te2/1, Te2/2, Te2/3, Te2/4, Te2/5, Te2/6, Te2/7, Te2/8, Te2/9, Te2/10, Te2/11, Te2/12, Te2/13, Te2/14, Te2/15, Te2/16, Te5/4, Te5/5, NDE_0, Gi1/1, Gi1/2, Gi1/3, Gi1/4, Gi1/5, Gi1/6, Gi1/7, Gi1/8, Gi1/9, Gi1/10, Gi1/11, Gi1/12, Gi1/13, Gi1/14, Gi1/15, Gi1/16, Gi1/17, Gi1/18, Gi1/19, Gi1/20, Gi1/21, Gi1/22, Gi1/23, Gi1/24, Gi5/1, Gi5/2, Gi5/3, Gi8/1, Gi8/2, Gi8/3, Gi8/4, Gi8/5, Gi8/6, Po24, Vlan1, Vlan134, Vlan196, Vlan200, Vlan201, Vlan203, Vlan207, Vlan208, Vlan209, Vlan211, Vlan212, Vlan213, Vlan214, Vlan216, Vlan217, Vlan218, Vlan219, Vlan220, Vlan221, Vlan222, Vlan223, Vlan224, Vlan225, Vlan226, Vlan227, Vlan230, Vlan231, Vlan232, Vlan233, Vlan234, Vlan235, Vlan236, Vlan237, Vlan238, Vlan239, Vlan240, Vlan241, Vlan242, Vlan243, Vlan244, Vlan245, Vlan246, Vlan247, Vlan248, Vlan249, Vlan250, Vlan252, Vlan253, Vlan254, Vlan255, Vlan256, Vlan257, Vlan258, Vlan259, Vlan260, Vlan261, Vlan262, Vlan264, Vlan265, Vlan266, Vlan267, Vlan268, Vlan269, Vlan270, Vlan271, Vlan272, Vlan273, Vlan274, Vlan275, Vlan276, Vlan277, Vlan298, Vlan299, Vlan303, Vlan307, Vlan308, Vlan309, Vlan310, Vlan449, Vlan484, Vlan814, Vlan815, Vlan816, Vlan817, Vlan818, Vlan819, Vlan820, Vlan821, Vlan822, Vlan824, Vlan826. Vlan828. Vlan829. Vlan830. Vlan831. Vlan833. Vlan836. Vlan837. Vlan838. Vlan839. Vlan842. Vlan843. Vlan844.

Processors

Routing Processor 5	18%
Module 1	11%
Module 2	45%

Memory

Module 1 (Processor)	58.5MB/181MB (32%) 122MB (68%)
Module 2 (Processor)	212MB/949MB (22%) 736MB (78%)
Routing Processor 5 (Processor)	315MB/1.41GB (22%) 1.11GB (78%)
Routing Processor 5 (I/O)	124MB/256MB (49%) 131MB (51%)

Storage

Boot Disk	282MB/977MB (29%) 694MB (71%)
CFC's Boot Flash	634kB/15.2MB (4%) 14.6MB (96%)

c6500/7600 Crossbar

Physical Slot 1				Crossbar	
Fabric 0	ok	20Gbps		Ingress 5%	Egress 2%
Physical Slot 2				DCEF	
Fabric 0	ok	20Gbps		Ingress 3%	Egress 15%
Fabric 1	ok	20Gbps		Ingress 8%	Egress 7%
Physical Slot 5					
Fabric 0	ok	20Gbps		Ingress 7%	Egress 8%
Fabric 1	ok	20Gbps		Ingress 0%	Egress 0%
Physical Slot 8					

External connections

- Connects the internal network to the Internet through a ISP

  → BGP is used for this.

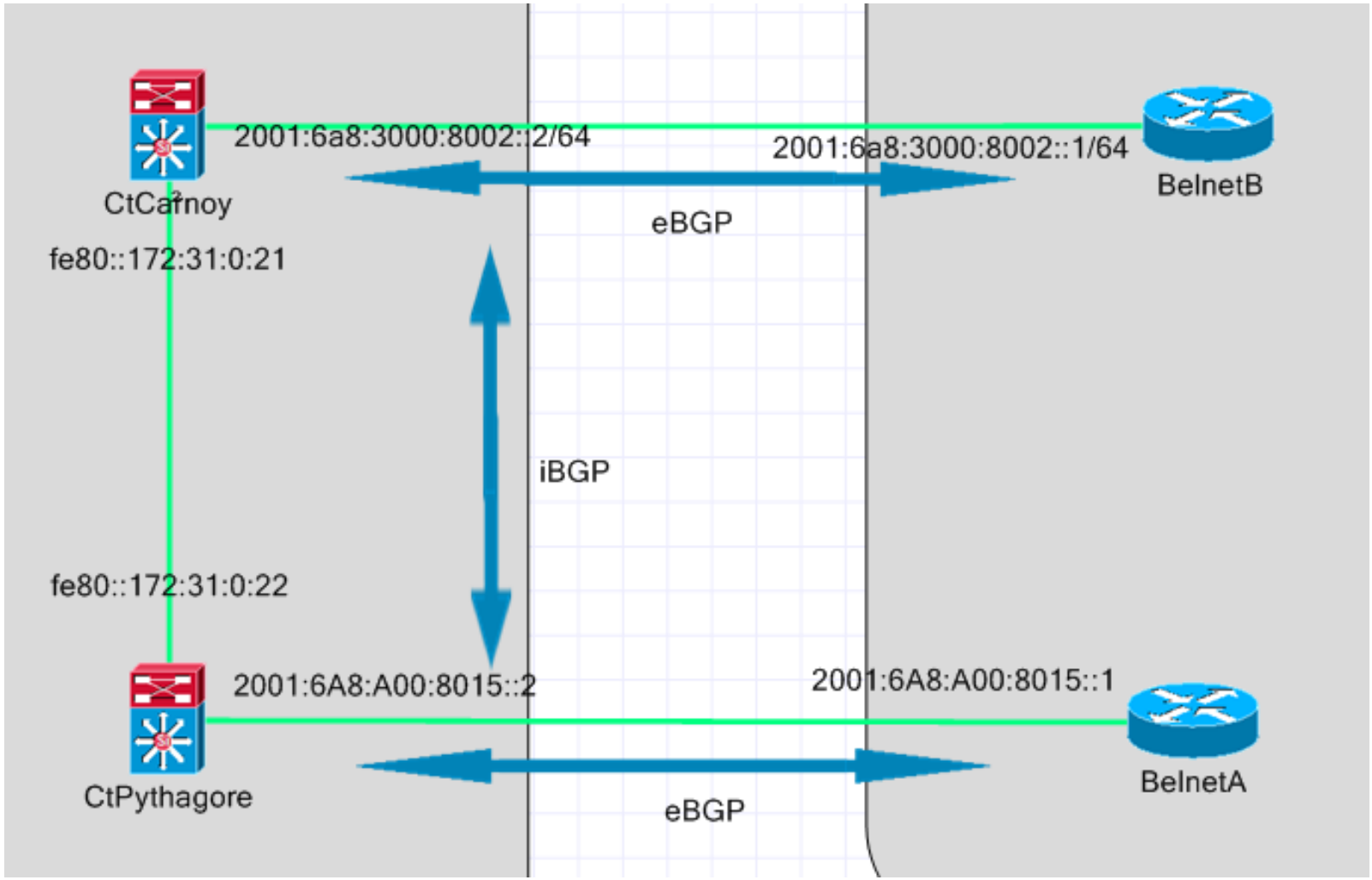
- Connects remote sites

  → L2 and L3 VPNs provided by ISP

  or directly over the Internet

- No DMZ in our case

Internet connectivity


2001:6a8:3000:8002::2/64
2001:6a8:3000:8002::1/64
CtCarnoy
BelnetB
eBGP
fe80::172:31:0:21
iBGP
fe80::172:31:0:22
2001:6A8:A00:8015::2
2001:6A8:A00:8015::1
CtPythagore
BelnetA
eBGP

Internet connectivity

- Default route ::/0 announced by ISP on both BGP sessions
- UCL’s prefix announced on both BGP session to ISP
- Local pref on both side decide which link is active
- Filters on both side protects from incorrect announcements

```
CtCarnoy# show ip bgp ipv6 unicast
BGP table version is 3, local router ID is 193.191.X.Y
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? – incomplete

   Network          Next Hop            Metric LocPrf Weight Path
r  ::/0             2001:6A8:3000:8002::1
                                         100      0 2611 i
r>i ::/0            2001:6A8:A00:8015::1
                                           0    200      0 2611 i
```

```
CtPythagore# show ipv6 route
IPv6 Routing Table - default - 82 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, I1 - ISIS L1, I2 - ISIS L2
       IA - ISIS interarea, IS - ISIS summary, D - EIGRP, EX - EIGRP external
       ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
B   ::/0 [20/0]
    via FE80::327C:5EFF:FE9F:3428, TenGigabitEthernet2/13
```

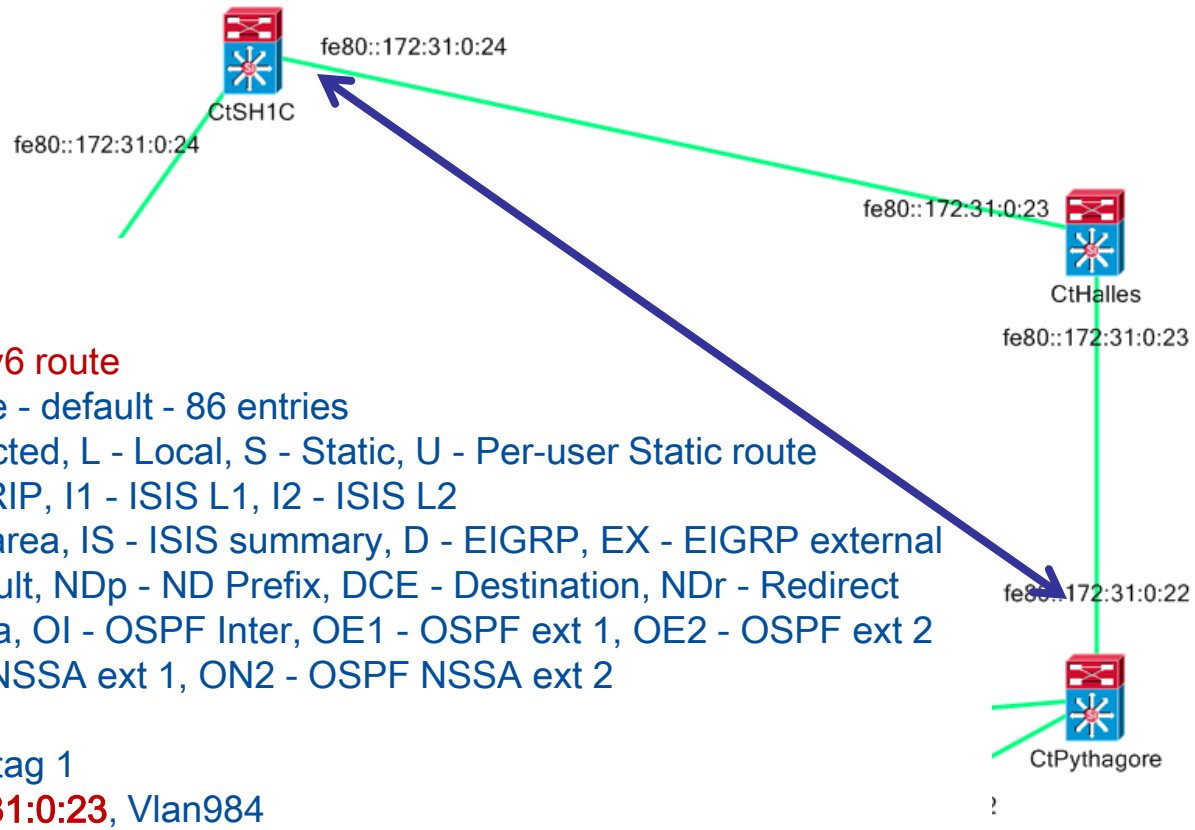
```
CtPythagore# ping 2001:4860:4860::8888 source Loopback 0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:4860:4860::8888, timeout is 2 seconds:
Packet sent with a source address of 2001:6A8:3081:F000:172:31:0:22
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/7/8 ms
```

Internet connectivity

- Other routers need to learn the default route
- Can be achieved by configuring BGP on each router

or

ask OSPF to generate and announce a default route



CtSH1C# show ipv6 route
IPv6 Routing Table - default - 86 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
B - BGP, R - RIP, I1 - ISIS L1, I2 - ISIS L2
IA - ISIS interarea, IS - ISIS summary, D - EIGRP, EX - EIGRP external
ND - ND Default, NDp - ND Prefix, DCE - Destination, NDr - Redirect
O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2

OE2 ::/0 [110/50], tag 1
via FE80::172:31:0:23, Vlan984

Security considerations

Make it robust by inserting static routes to null 0 on each router

ipv6 route 100::/8 null 0

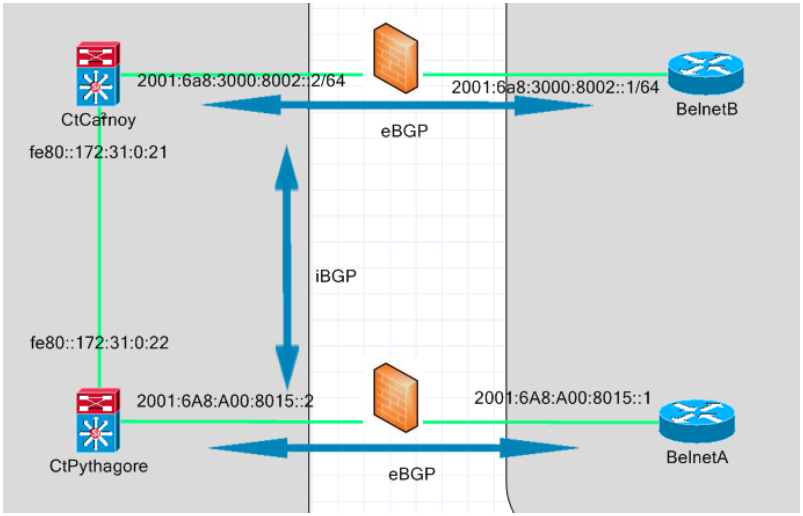
ipv6 route 2001:db8::/32 null 0

ipv6 route 2001:6a8:3080::/44 null 0

(…)

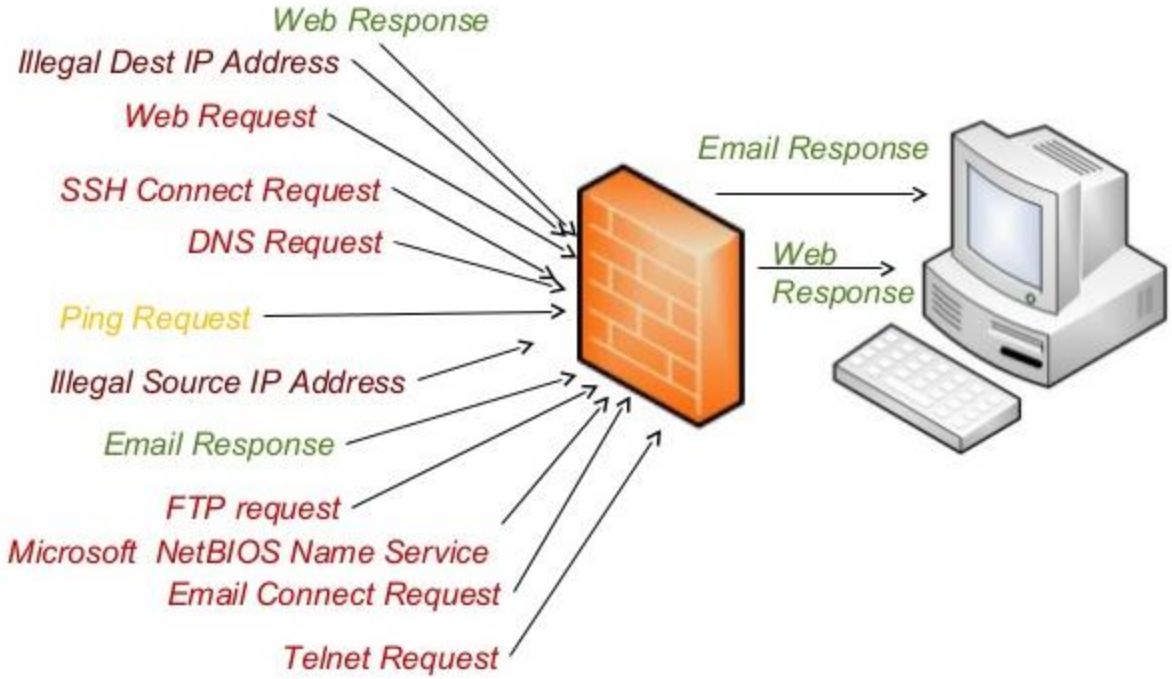
Security considerations (2)

- A big part of the IT threats come from the Internet
- ACLs are currently protecting the edge of the network
  - mainly L3 and L4 filtering rules
  - stateless filtering



Security considerations (3)

Packet Filter Firewall



Security considerations (4)

IPv6 access list belnet-in-ipv6-acl (snapshot)

deny ipv6 2001:6A8:3080::/44 any (24 matches)

permit udp any host 2001:6A8:3081:1::53 eq domain (1 match)

permit udp any host 2001:6A8:3081:2::53 eq domain

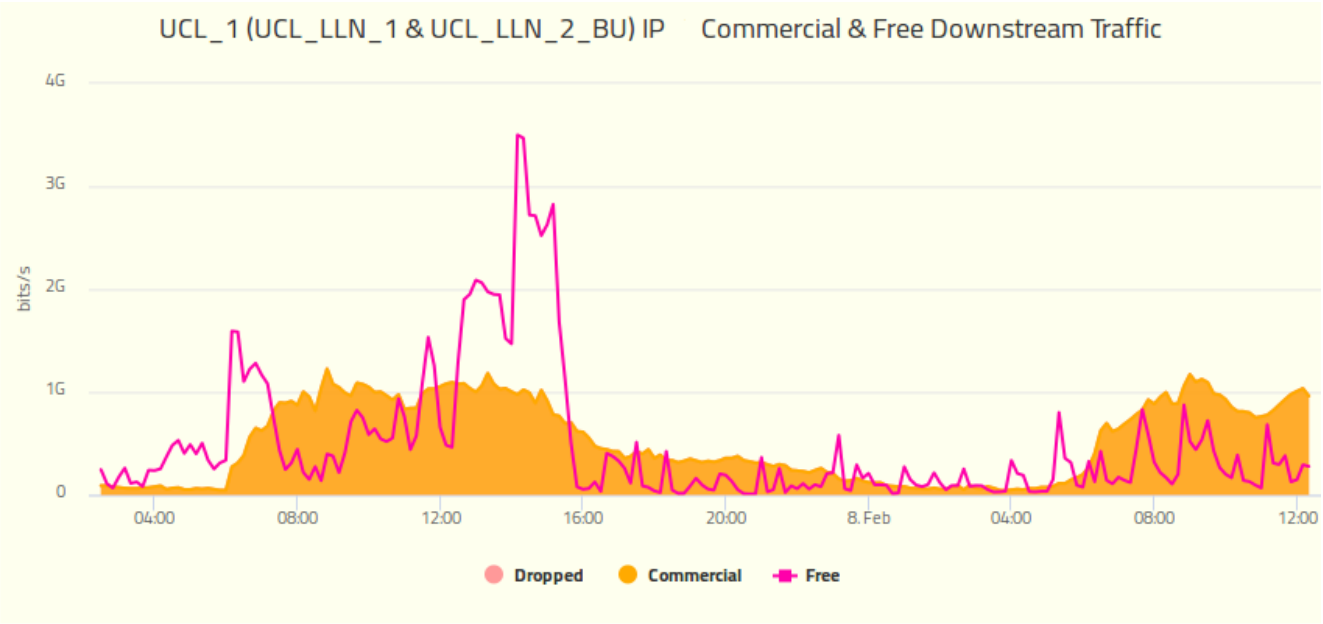
permit udp any host 2001:6A8:3082:1::53 eq domain (2 matches)

deny udp any any eq domain (111 matches)

Security considerations (4)

Project ongoing to install next generation firewalls at the edge

Monitoring



	Max	Avg	Last
Dropped	0.00 B	0.00 B	0.00 B
Commercial	1.23 GB	489.85 MB	0.00 B
Free	3.50 GB	455.46 MB	0.00 B

Data-centers

- Hosts business critical applications and data
- Security and high availability are very important
- Virtualization is a key component for efficiency, scalability and elasticity but imposes constraints to the network


PORTAIL / HEBERGEMENT
PORTAIL UCL
REDDOT CMS
HÉBERGEMENT UCL
ALFRESCO
TRANSVOL
FTP
SHAREPOINT
OWAPP
WORKFLOW
E-LEARNING
ICAMPUS
MOODLE
EPORTFOLIO
PODCAST
MAIL
POP EXCHG
IMAP EXCHG
OWA EXCHG
SMTP
SMTP-LISTES
MAILING LISTS
LISTES UCL
LISTES AUTRES
LISTES ETD
FILEMAKER
FMS
FMS2
FMS3
FMS4
FMS5
FMS6
FMS12
FMS13-0
FMS13-1
AUTHENTIFICATION
IDGLOBAL
ACTIVE DIRECTORY
SHIBBOLETH
ANNUAIRE
PROXY
PROXYSGSI
PROXY BIB
PROXY DIDAC
SIPS
EPC
OSIS
STUDIES
INSCRIPTION
HORAIRE
REAL
SRV FICHIERS
ALFRESCO
FS01A
FS02A
FS02B
FS03A
FS03B
FS03C
FS04A
FS04B
FS04C
FS05B
FS05C
FS06B
FS06C
FS08A
FS08B
FS08C
FS09A
SRV IMPRESSIONS
ANTENOR
PRN01
PRN02
PRN03
DIDACPRN
DPRN02
SAP
BIBLIOTHEQUES
PORTAIL BIB
VIRTUA
DIAL
HANDLE
SAP
PORTAIL ECPT
PORTAIL SAP
BWPGUI
HRPGUI
SAPGUI
PIP
SOLMAN
BUSINESS OBJECTS
ARCHIVAGE
DNS
NS1
NS2
NS3
DHCP
DHCP-1
DHCP-2
DHCPTEL-1
DHCPTEL-2
WIFI/VPN UCL
RADIUS1 PRS
RADIUS2 PRS
RADIUS1 LOGE
RADIUS2 LOGE
RADIUS1 EXT
RADIUS2 EXT
RADIUS1 EDUROAM
RADIUS2 EDUROAM
RADIUS1 VPN
RADIUS2 VPN

```
Device Status
       Name: PORTAIL UCL
   DNS Name: uclouvain.be.
    Address: 130.104.5.100
     Status: UP (Reachable since 04 Feb, 19:50:52)
      Probe: Probe Group
Recent Outages:
  04/02 19:49:52: DOWN for 1 minute, 0 seconds
  20/12 13:25:07: DOWN for 9 minutes, 0 seconds
  09/12 05:01:05: DOWN for 2 hours, 19 minutes
  08/12 10:36:54: DOWN for 7 minutes, 2 seconds
  07/12 22:36:45: DOWN for 10 hours, 5 minutes
  05/12 06:52:03: DOWN for 1 minute, 0 seconds
  03/12 11:44:19: DOWN for 1 minute, 0 seconds
  01/12 13:09:33: DOWN for 9 minutes, 0 seconds
  01/12 08:57:29: DOWN for 11 minutes, 0 seconds
  10/11 16:37:21: DOWN for 1 minute, 0 seconds
Last updated 08 Feb, 13:42:09

Member Probes
   OK: HTTP   PORTAIL UCL
Device Status
     Status: UP (Reachable since 01 Dec, 09:02:36)
      Probe: HTTP (port 80)
    Up Time: n/a
  Availability:            100 % (of 518 days, 5 hours, 58 minutes)
  TCP Failures:           0.01 % (of 745933 total attempts)
  Short-term Packet Loss:  0.0 % (of 100 last attempts)
  Recent Failure: 1 attempts at 01 Dec, 09:02:06
  Response time:  75 msec
```

Data-centers

- Redundant connection to electrical grid
- UPS / diesel power generator
- Redundant servers / switches / connections
- Redundant power supplies
- Strict access-control
- Advanced fire protections
- Strict temperature and humidity conditions
- Dust control
- Disaster recovery plan

Data-centers layers

- Security layer (ACLs, network firewall, server firewall, application firewall)
- Load-balancing
- Application servers
- Load-balancing
- Database servers

Data-centers: load-balancer

- Shares the load between a pool of servers
- Servers can be removed or added to the pool on the fly
  - for maintenance purposes
  - due to an outage
  - to increase or decrease capacity
- Can provide SSL offloading

Data-centers: load-balancer

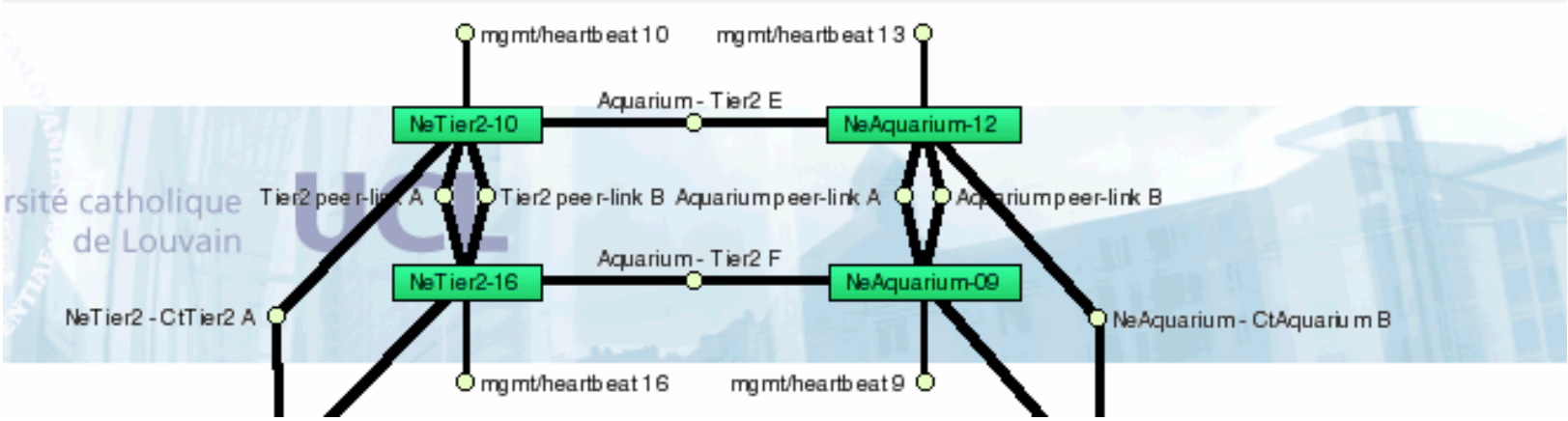
-Different load-spread techniques:

- round robin
- number of active connections
- response time

- Servers inside pool are monitored using probes

- ping
- tcp connection
- application call

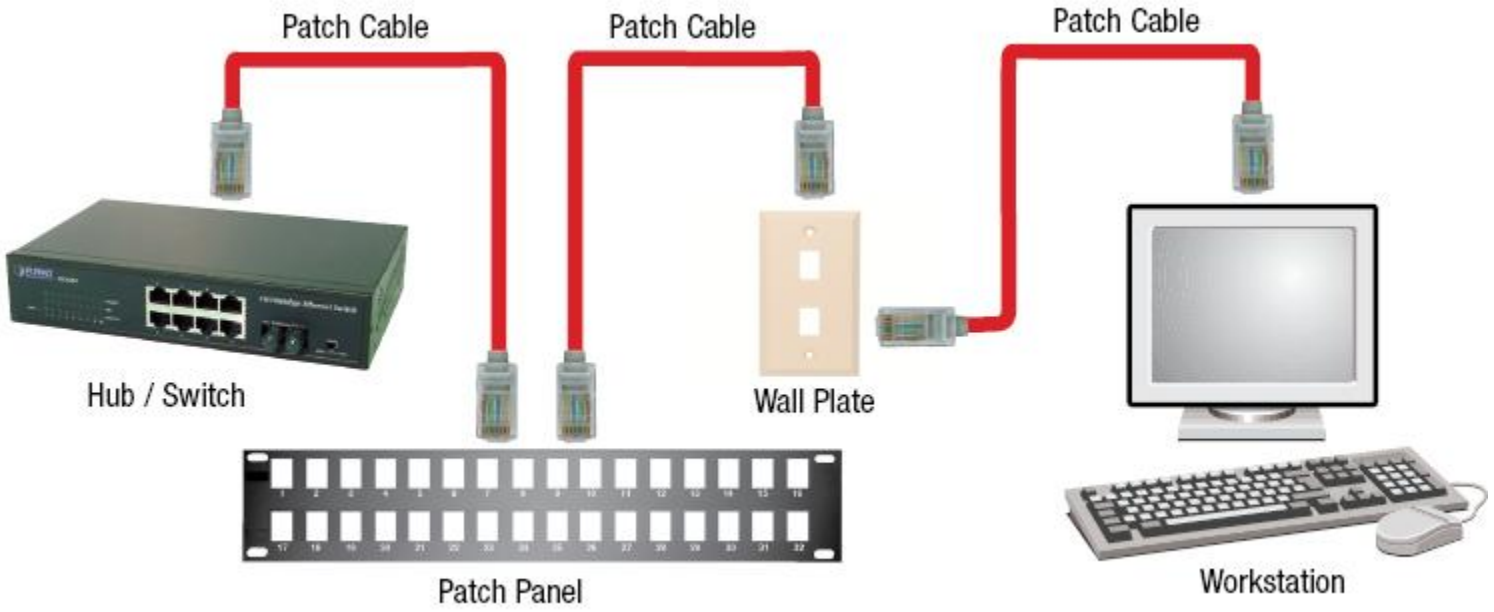
Data-centers



Campus

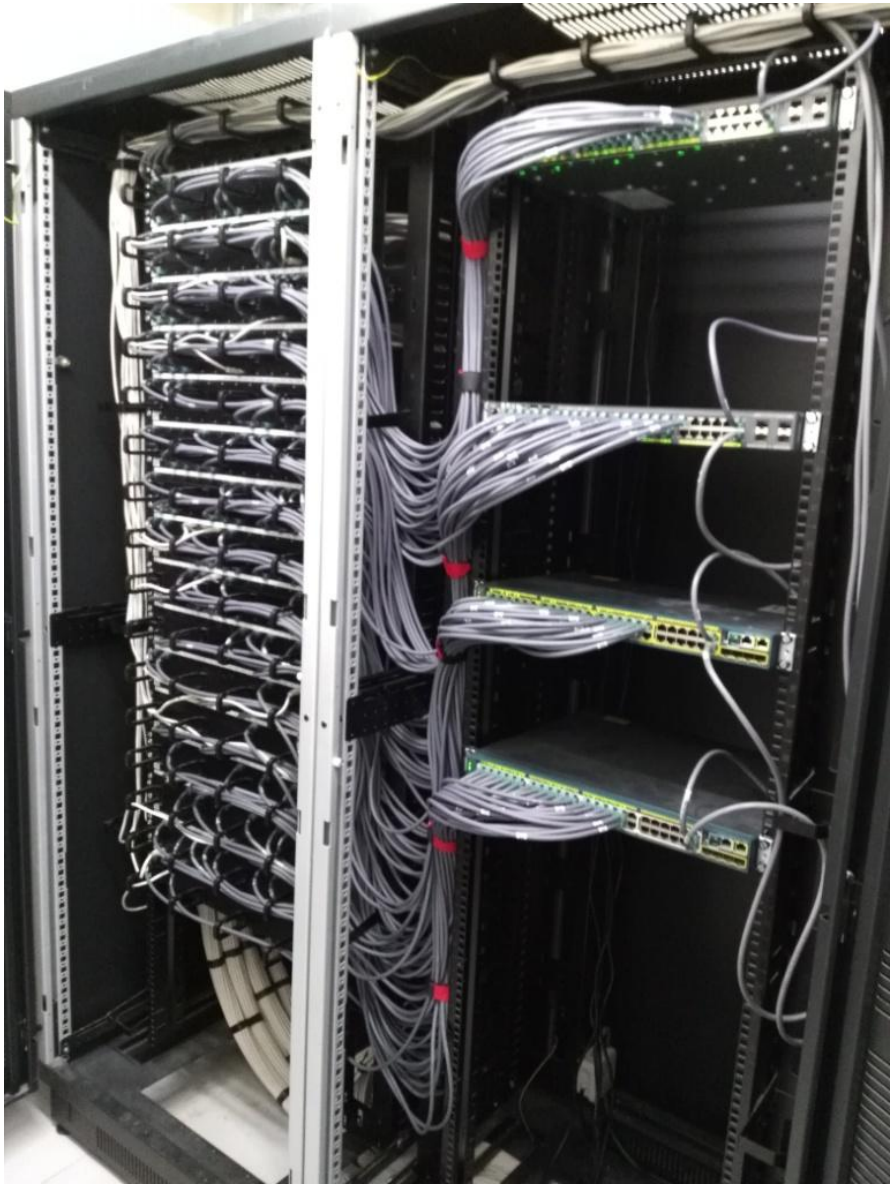
The wide part of UCL's network

Switches are located in patchrooms



How patching is done

Example of a badly managed patchroom



properly managed patchroom

properly managed patchroom

Distribution and access layer

Each building is based on the same design

- 1 building switch:

  connected using fiber to the core network

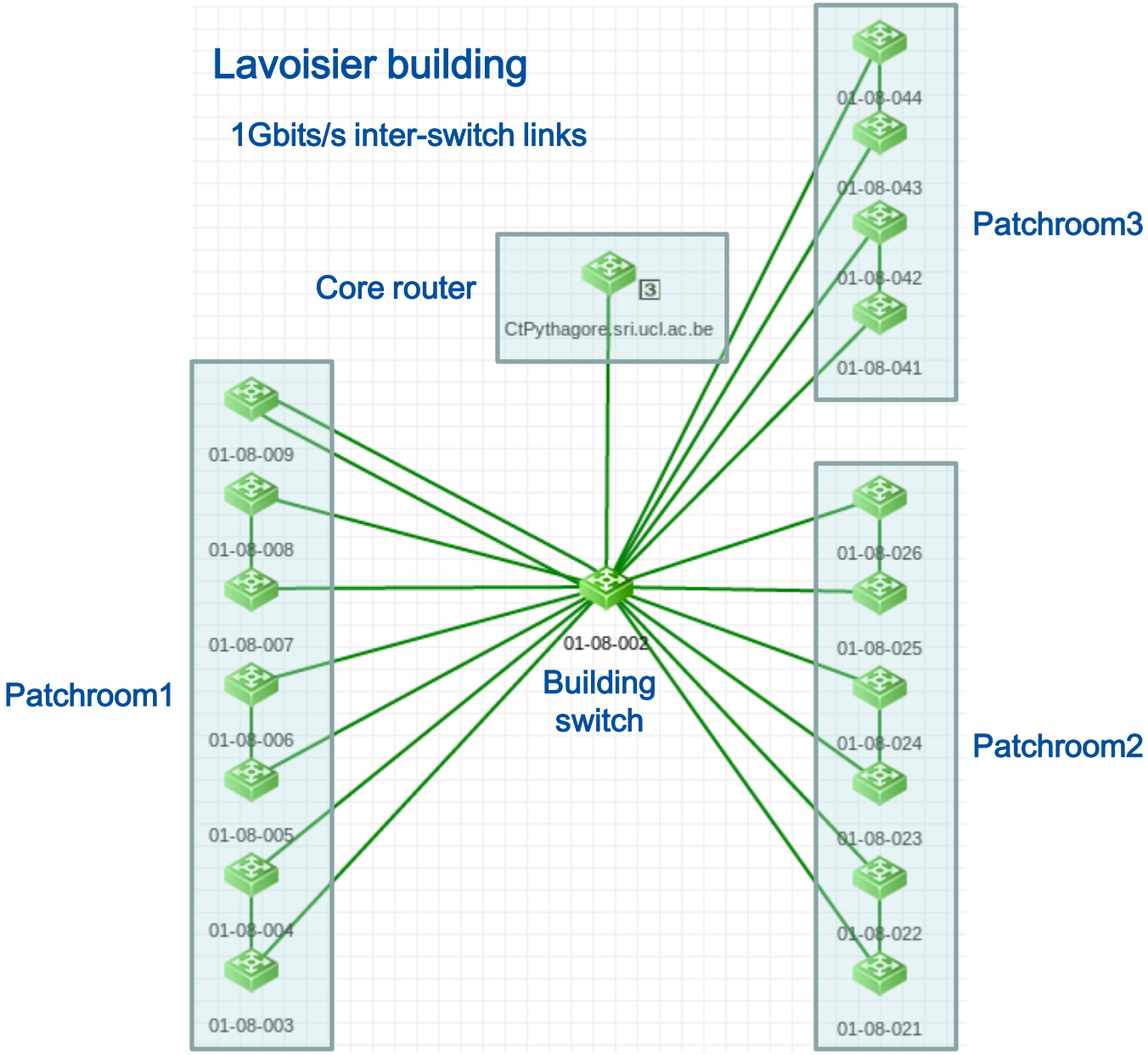
  connected using copper to access layer switches

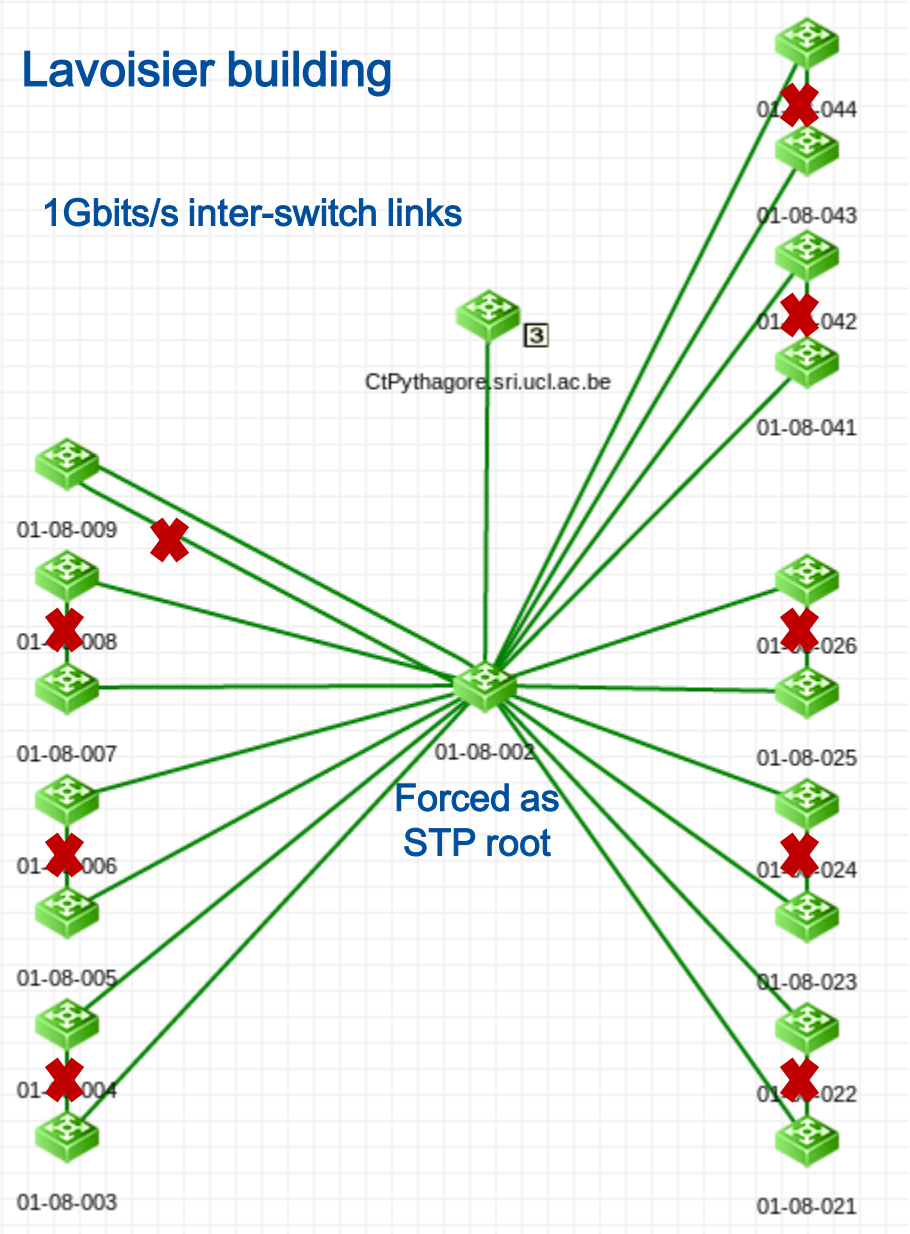
- Several access switches:

  hold device connections

- STP used to avoid loops at L2

- L3 routing done on core switch

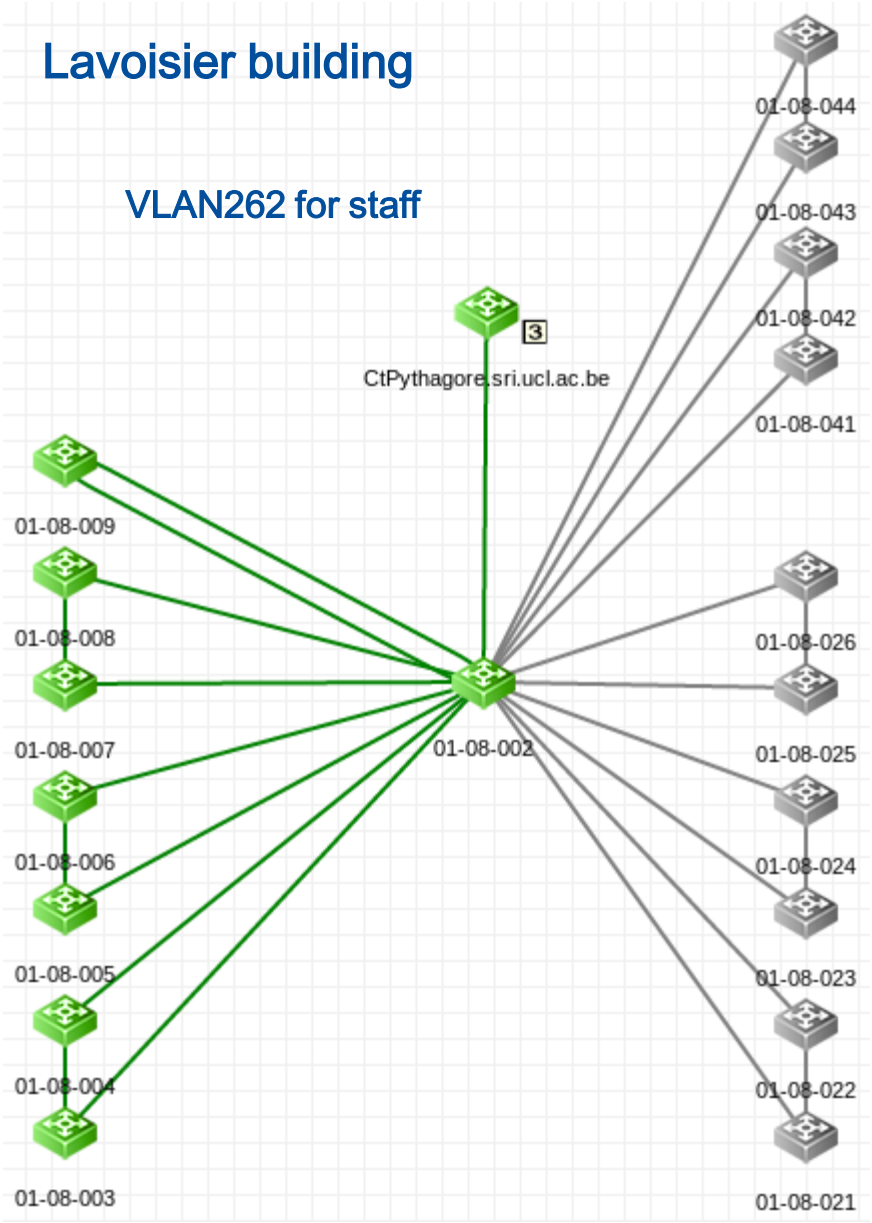

Lavoisier building
1Gbits/s inter-switch links
Core router
CtPythagore.sri.ucl.ac.be
3
Patchroom3
01-08-044
01-08-043
01-08-042
01-08-041
Patchroom1
01-08-009
01-08-008
01-08-007
01-08-006
01-08-005
01-08-004
01-08-003
01-08-002
Building switch
Patchroom2
01-08-026
01-08-025
01-08-024
01-08-023
01-08-022
01-08-021

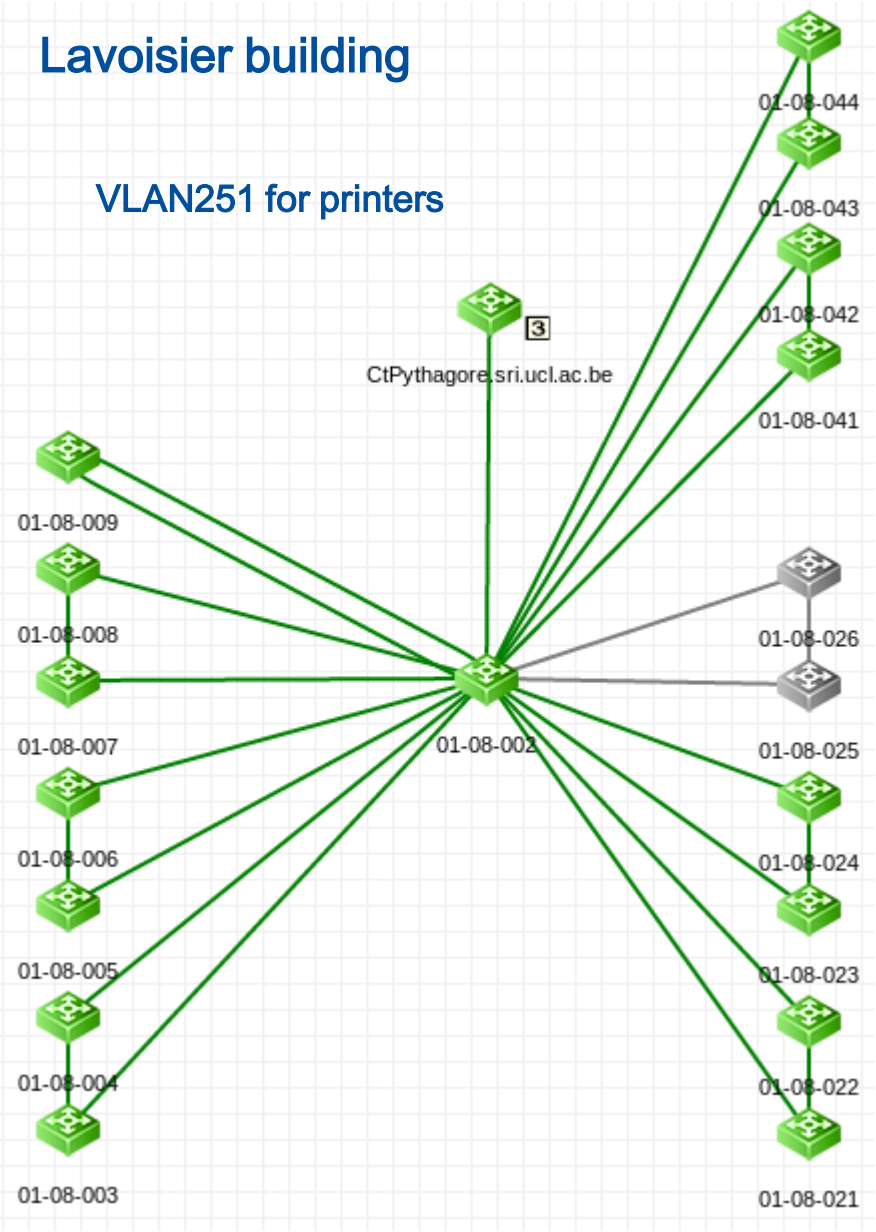

Lavoisier building
1Gbits/s inter-switch links
3
CtPythagore.sri.ucl.ac.be
01-08-044
01-08-043
01-08-042
01-08-041
01-08-009
01-08-008
01-08-007
01-08-006
01-08-005
01-08-004
01-08-003
01-08-002
Forced as
STP root
01-08-026
01-08-025
01-08-024
01-08-023
01-08-022
01-08-021

Distribution and access layer

VLANs used to separate traffic from different groups at L2

- Desktops used by students
- Desktops used by staff members
- Printers
- IP phones
- …


Lavoisier building
VLAN262 for staff
3
CtPythagore.sri.ucl.ac.be
01-08-002
01-08-044
01-08-043
01-08-042
01-08-041
01-08-009
01-08-008
01-08-007
01-08-006
01-08-005
01-08-004
01-08-003
01-08-026
01-08-025
01-08-024
01-08-023
01-08-022
01-08-021


Lavoisier building
VLAN251 for printers
3
CtPythagore.sri.ucl.ac.be
01-08-002
01-08-044
01-08-043
01-08-042
01-08-041
01-08-009
01-08-008
01-08-007
01-08-006
01-08-005
01-08-004
01-08-003
01-08-026
01-08-025
01-08-024
01-08-023
01-08-022
01-08-021

QoS

- Prioritization needed because of the wide range of devices and applications using the network
- Different RTT, jitter and bandwidth constraints
- Kicks in only when congestion occurs
- Packets are tagged with a priority
- Voice calls get the highest priority but at low bandwidth
- Security cameras flows get higher priority
- Other flows get normal priority
- Access ports with more than 50Mbits/s traffic get low priority

Security considerations

- Enforce security rules as close as possible to the source.
- Switches inspect user traffic to:
  - drop unauthorized router advertisements (RA)
  - deny unauthorized DHCP servers
  - allow traffic only if DHCP transaction completed
  - avoid address spoofing
- Routers check if source IP correspond to the defined network
- ACLs are applied on specific networks

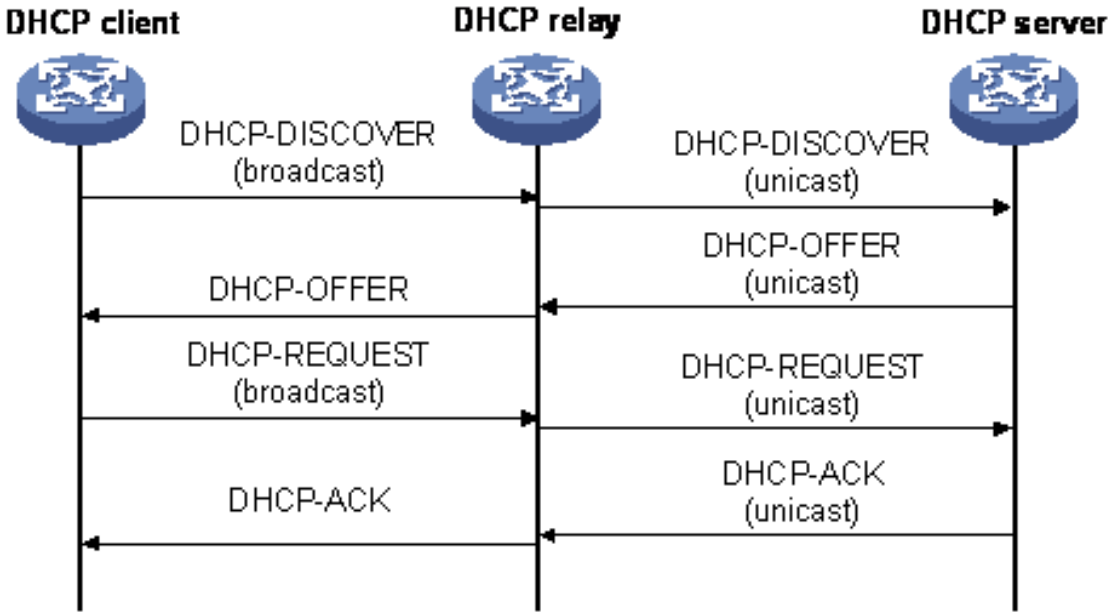
```
01-16-012#sh ipv6 neighbors binding
Binding Table has 79 entries, 79 dynamic
Codes: L - Local, S - Static, ND - Neighbor Discovery, DH - DHCP, PKT - Other Packet, API - API created

    IPv6 address                      Link-Layer addr Interface vlan prlvl  age   state    Time left
ND  FE80::FAB1:56FF:FECB:10A5         F8B1.56CB.10A5  Gi1/0/2    238  0005    4mn REACHABLE  24 s try 0
ND  2001:6A8:3081:4160:F803:99A6:37CA:53DF  E8EA.6A00.159B  Gi1/0/38   225  0005  237mn STALE      73544 s
```

Address assignment

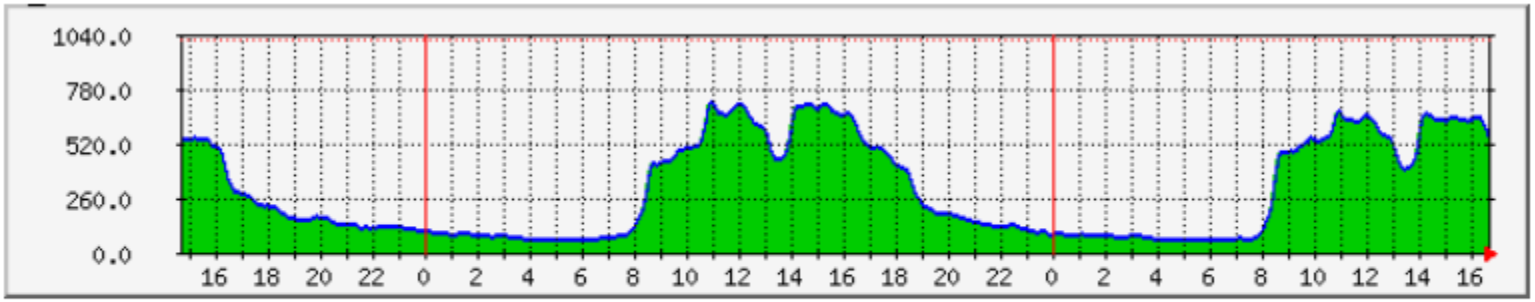
- Avoid manually assigned addresses:
  - generates a lot of configuration burden
  - prone to human error
- Unable to dynamically renumber a network
- Exceptions exist for network devices and specific servers

DHCP

- One global redundant DHCP infrastructure hosted in the DC
- Routers act as a DHCP relay agent



DHCP monitoring



	Max	Moyenne	Actuel
Adr. IP utilises:	712 adresse(s)	291 adresse(s)	538 adresse(s)

Number of distributed IPs on a DHCP pool used for WiFi

DNS

LLN DC1

NS1

LLN DC2

NS2

Woluwe

NS3

Belnet

NS1

NS2

```
-qhunin@vps73519:~$ dig @130.104.1.1 uclouvain.be NS
-(…)
-;; QUESTION SECTION:
-;uclouvain.be.                          IN      NS

-;; ANSWER SECTION:
-uclouvain.be.          604800  IN      NS      ns3.sri.ucl.ac.be.
-uclouvain.be.          604800  IN      NS      ns2.belnet.be.
-uclouvain.be.          604800  IN      NS      ns1.sri.ucl.ac.be.
-uclouvain.be.          604800  IN      NS      ns2.sri.ucl.ac.be.
-uclouvain.be.          604800  IN      NS      ns1.belnet.be.
-;; ADDITIONAL SECTION:
-ns1.sri.ucl.ac.be.     604800  IN      A       130.104.1.1
-ns2.sri.ucl.ac.be.     604800  IN      A       130.104.1.2
-ns3.sri.ucl.ac.be.     604800  IN      A       130.104.254.1
-ns1.sri.ucl.ac.be.     604800  IN      AAAA    2001:6a8:3081:1::53
-ns2.sri.ucl.ac.be.     604800  IN      AAAA    2001:6a8:3081:2::53
-ns3.sri.ucl.ac.be.     604800  IN      AAAA    2001:6a8:3082:1::53
```

DNS

- Two different views:

one for the external world

DNS servers respond only for UCL's domains

one for the internal network

DNS servers respond for all domains

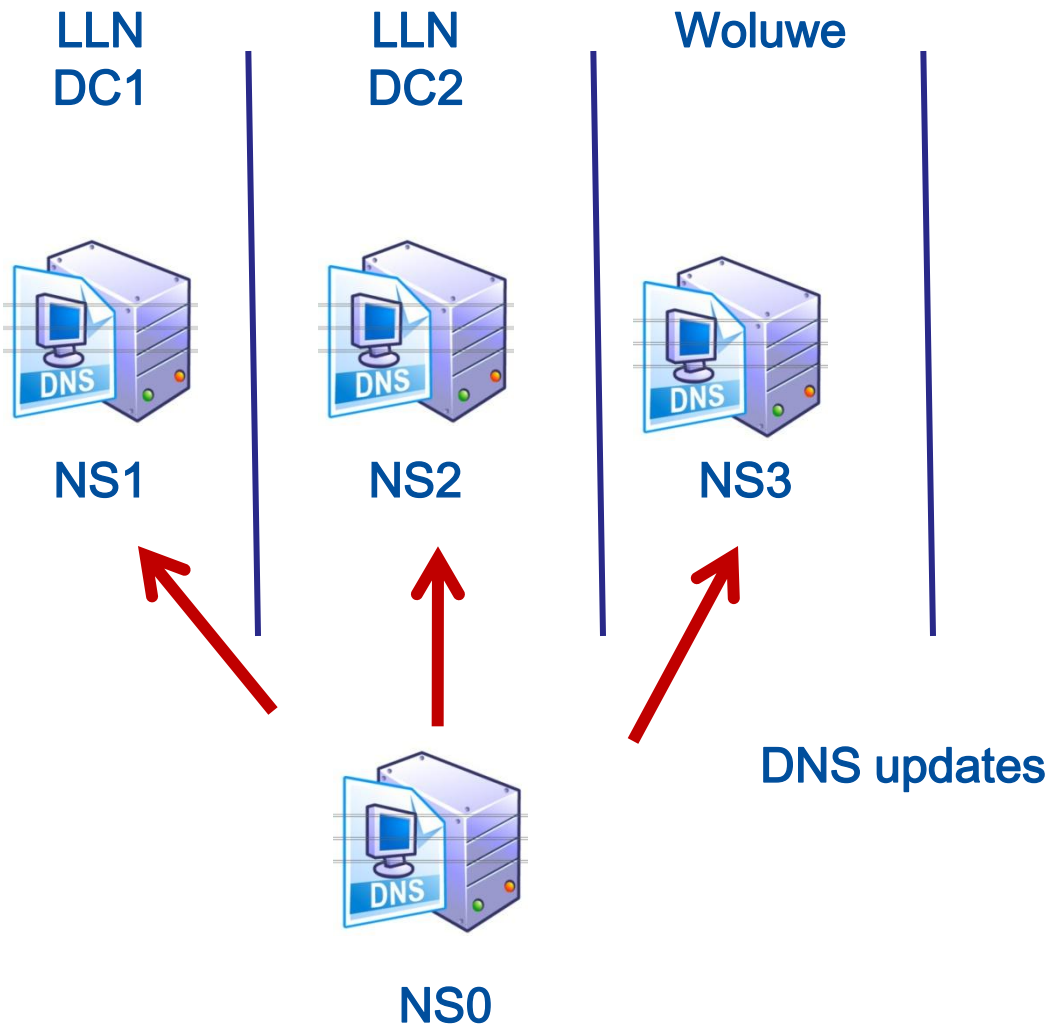
recursive DNS

DNS - security

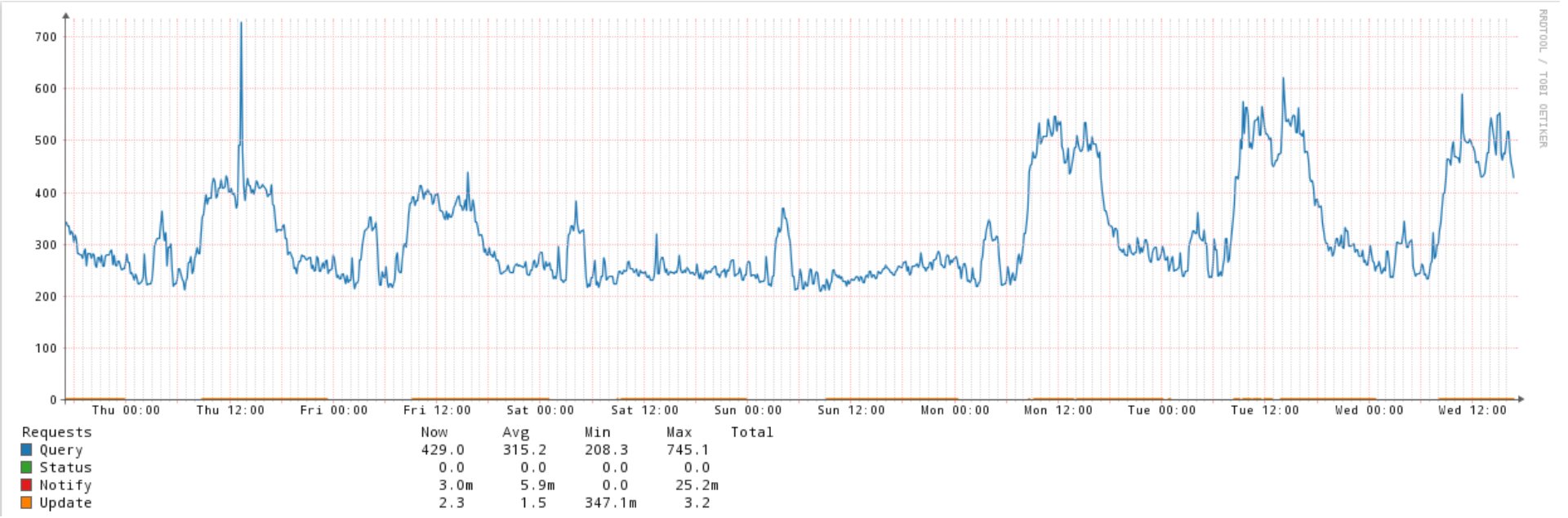
- DNSSec: DNS responses are signed using cryptography

- Hidden master: holds the authoritative DB

  does not serve client queries


LLN
DC1
LLN
DC2
Woluwe
DNS
DNS
DNS
NS1
NS2
NS3
DNS
NS0
DNS updates

DNS monitoring



Nbr of incoming DNS requests per second on NS1

Monitoring tools

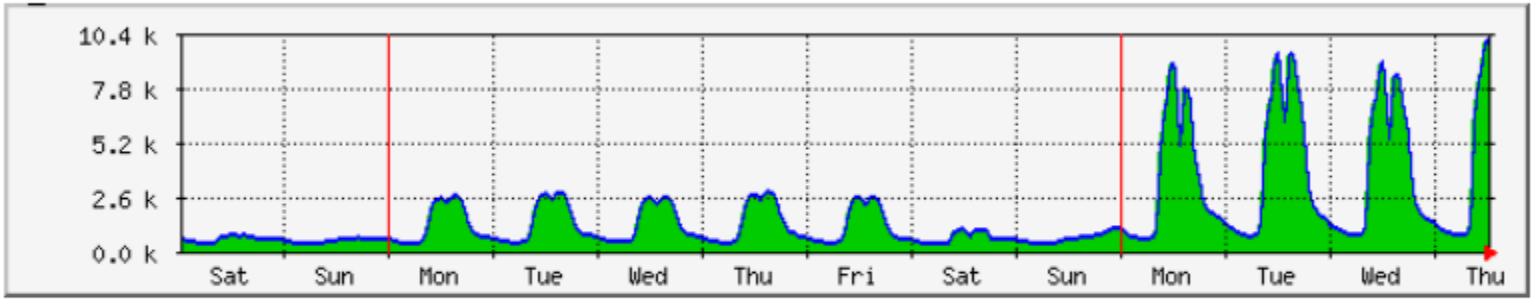
- Essential to see, detect and understand
  - what happened
  - what's happening
  - what will happen
- Used for proactive and reactive action during:
  - incidents
  - capacity planning
  - design
- Uses SNMP, netflows, syslog and/or CLI to collect data

Management tools

- Essential to be able to scale
- Examples:
  - configuration backup automation
  - software update automation
  - automated configuration deployment
  - …

Monitoring

Graphique hebdomadaire (sur 30 minutes : Moyenne)

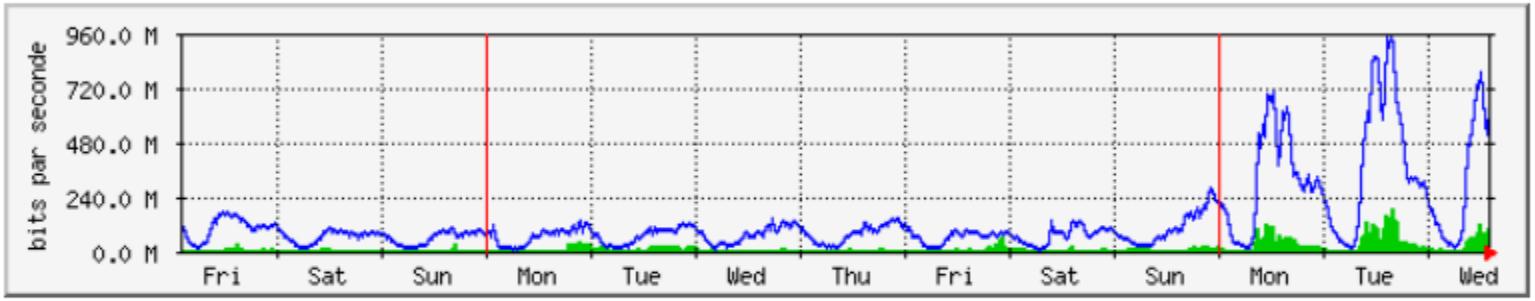


	Max	Moyenne	Actuel
Clients:	10 kClients	1715 Clients	9652 Clients
Sortie	10 kClients	1715 Clients	9652 Clients

Total number of simultaneous WiFi clients

Monitoring

Graphique hebdomadaire (sur 30 minutes : Moyenne)

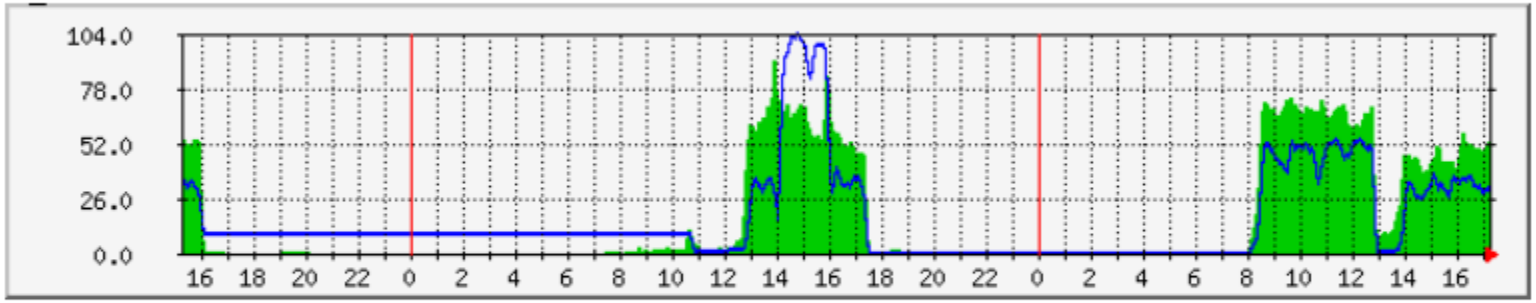


	Max	Moyenne	Actuel
Entrée	185.8 Mb/s (1.9%)	14.3 Mb/s (0.1%)	105.5 Mb/s (1.1%)
Sortie	949.8 Mb/s (9.5%)	126.0 Mb/s (1.3%)	627.7 Mb/s (6.3%)

Student's bandwidth usage on WiFi

Monitoring

Graphique quotidien (sur 5 minutes : Moyenne)

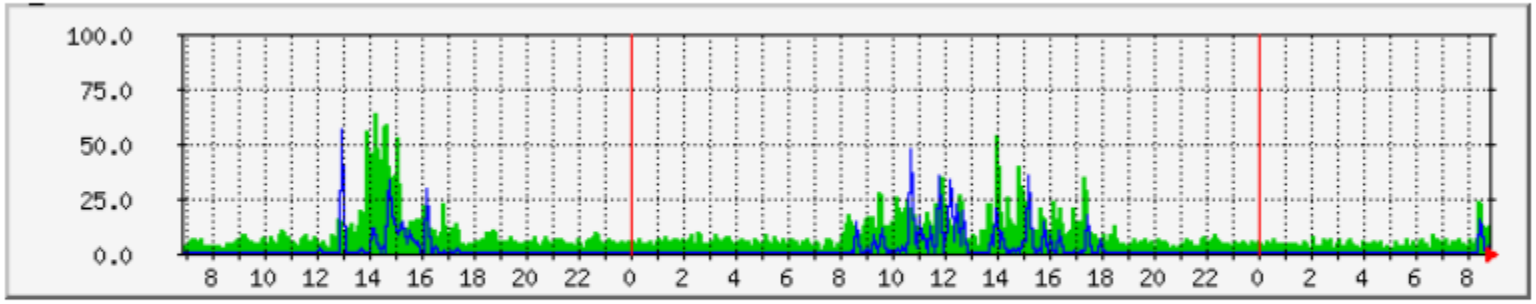


	Max	Moyenne	Actuel
2.4Ghz:	91 Clients	20 Clients	53 Clients
5Ghz:	104 Clients	19 Clients	32 Clients

Number of connected clients on one of the WiFi access points in the SC10 auditorium

Monitoring

Graphique quotidien (sur 5 minutes : Moyenne)



	Max	Moyenne	Actuel
2.4Ghz:	64 %	9 %	13 %
5Ghz:	55 %	2 %	1 %

Medium usage on one of the WiFi access points
in the SC10 auditorium

WiFi is slow

-Is it due to:

- user's computer
- a coverage issue
- interference issue
- saturated WiFi access point
- saturated uplink on the wired part
- WiFi controller issue
- Limit of available commercial bandwidth reached
- Service provider issue
- Destination website issue
- …

UCL Université catholique de Louvain

Infrastructures des réseaux du Système d'information (SRI)
Service Général du Système d'Information (SGSI)

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