THE TERASTREAM IPv6 NATIVE NETWORK ARCHITECTURE

How to build a modern service provider using IPv6 and Optics

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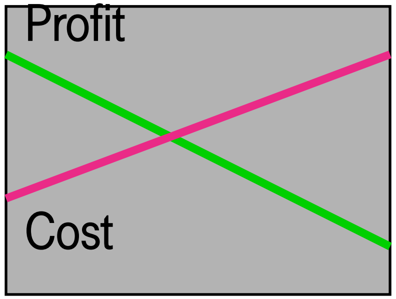
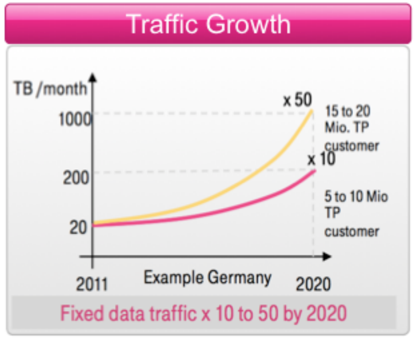
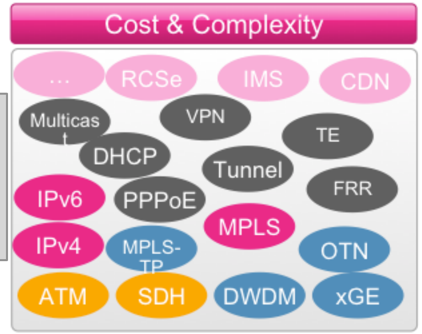
LIFE IS FOR SHARING.

TeraStream Motivations





Must address massive IP traffic growth driven by broadband access and new Internet services and Internet business models



Many networks and technologies, complex systems – long service lead-times, high-cost evolution to converged network architecture

Competitors offer better performance, more service flexibility and more features, faster provisioning, lower price

Multi-layer system complexity results in slow or lack of service innovation, low customer satisfaction, impacting revenue

TeraStream
Packet Cloud Architecture Fundamentals

One truly converged network - de-layered, IP and Optical are one, bits over wavelengths, digital over analog

The same technology for LAN and WAN - for LAN: IP packets in Home, Office, Data Center; for WAN: IP packets in Metro, Country, Continent

Digital services for consumers and businesses - communication, information, cloud-compute and -storage

Real-time OSS - instantaneous service provisioning, guaranteed good user experience

Cloud-era economics - service flexibility, fast-paced innovation, agile implementation, reduced system complexity, lower cost

Stay with the IP Internet Architecture using IPv6 for all functions and services

Have a standardized toolbox, "services in the data center"

Standard computers instead of specialized appliances

Look forward, what can we do**, not backwards** what we used to do

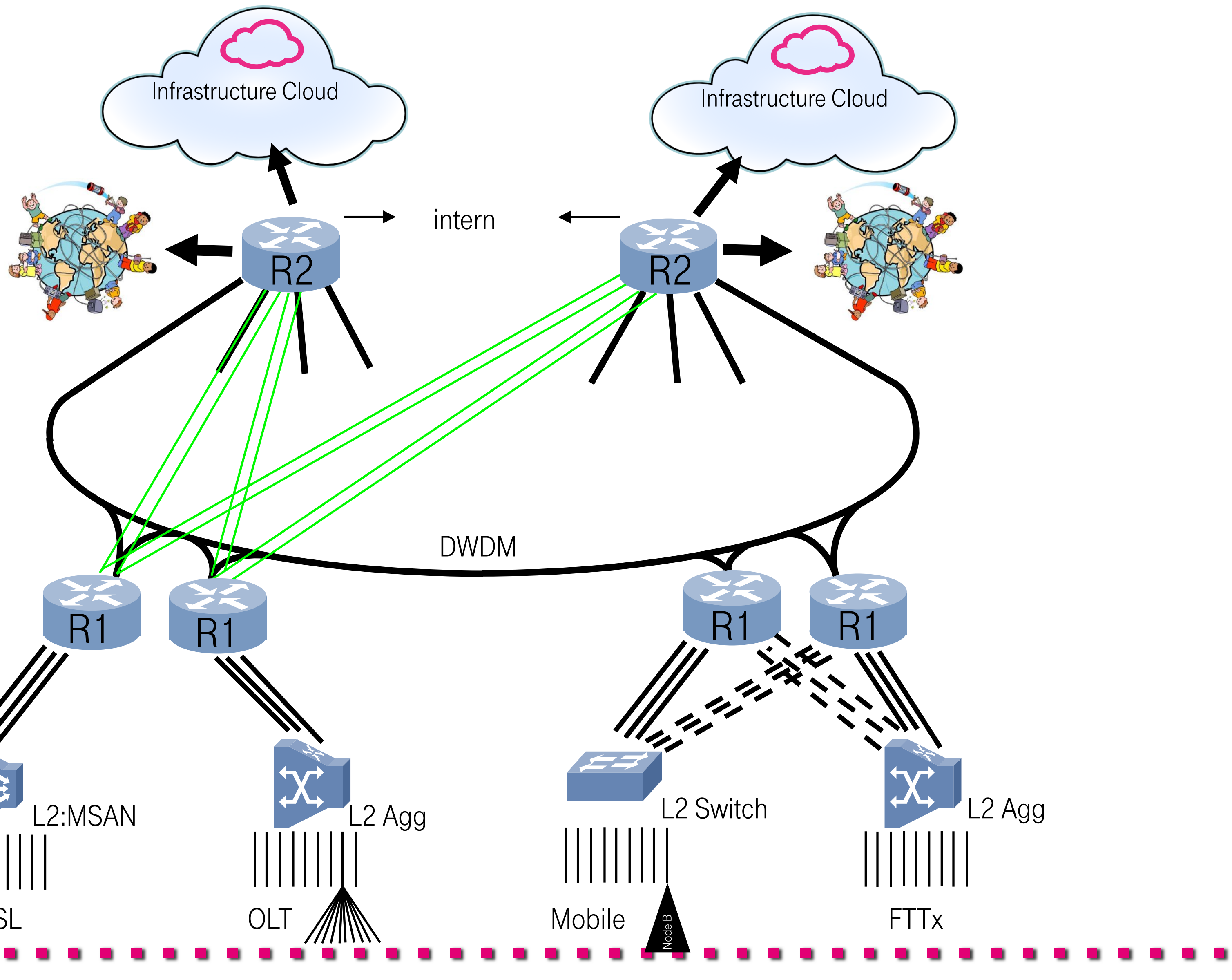
No L1, L2, L3 dependencies

No "best effort" you get what you pay for (Best effort is just a service class..)

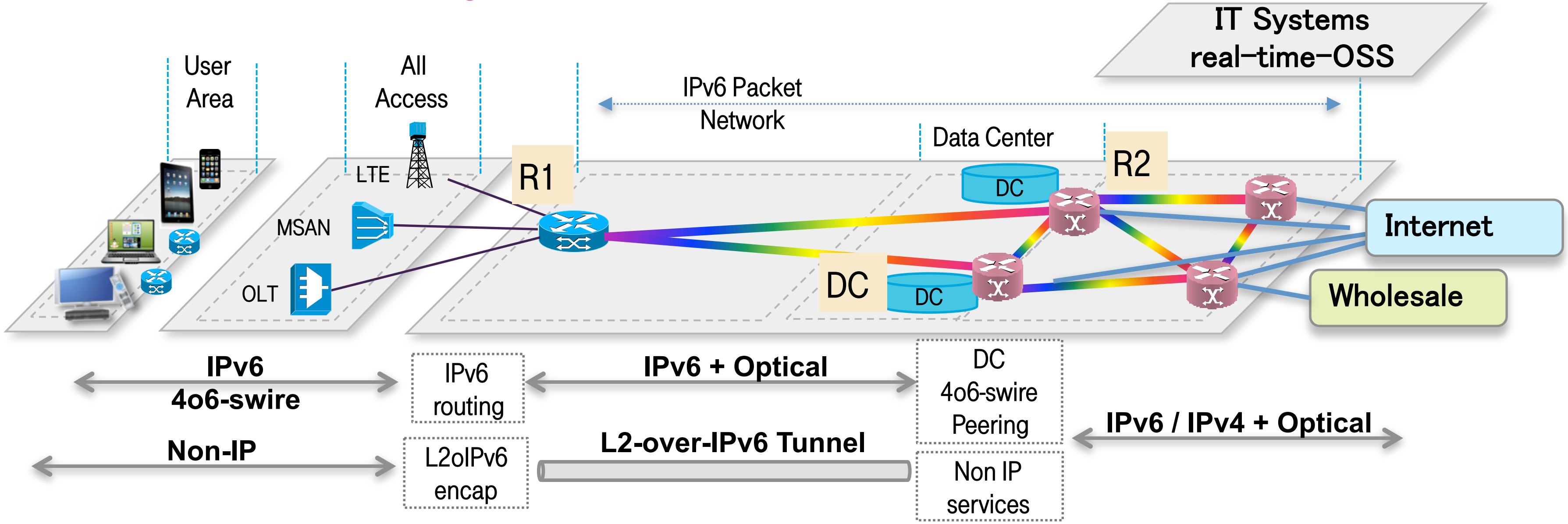
TeraStream Design Principles

Principle	Applied to TeraStream design
Reduce the amount of technologies used	Use IP and optical transmission only No OTN, L2, MPLS switching
Use IPv6 for all internal functions and services	No native IPv4 support in the network IPv4 is a service IPv6 based “carrier Ethernet service”
Avoid internal interfaces	Minimize non-customer, non-peering facing interfaces Distribute Internet peerings, offload external traffic ASAP
Size the network to handle all IP traffic without IP packets losses	Dimension the network for peak hour IP traffic, no oversubscription, packet loss is extreme exception
Integrate optical networks and IP networks as much as possible	Integrate IP and optical layers into routers to simplify the network, avoid redundant mechanisms e.g. failure handling, reduce total cost
Use one network for all services – Internet, IP TV, business, ...	Single converged packet network Note: **Dominant traffic drives the design!**
Deterministic and short routing path for all on-net traffic	Network distance between R1 access routers is at most two R2 backbone routers away and R1 is multi homed to two R2
Service policy for packets are outside the payload	Encode service type, traffic class, direction etc in the IPv6 address
Data Centers are directly connected to backbone routers	DCs connect directly to R2s to avoid building internal IP interfaces for very large amount of traffic

THE TERASTREAM ARCHITECTURE



TeraStream – Design in a Nutshell



TeraStream key functional elements

R1

- Terminate access interfaces
- Runs IPv6 routing only, integrates optical
- Access services
  - IPv6 - dealt with natively
  - IPv4 – IPv4 over IPv6 softwire between HGW / CPE and DC, R1 not involved
  - non-IP - L2-over-IPv6 encapsulation
- User configuration
  - using Netconf / Yang
  - Driven by real-time OSS i.e. self-service portal

R2

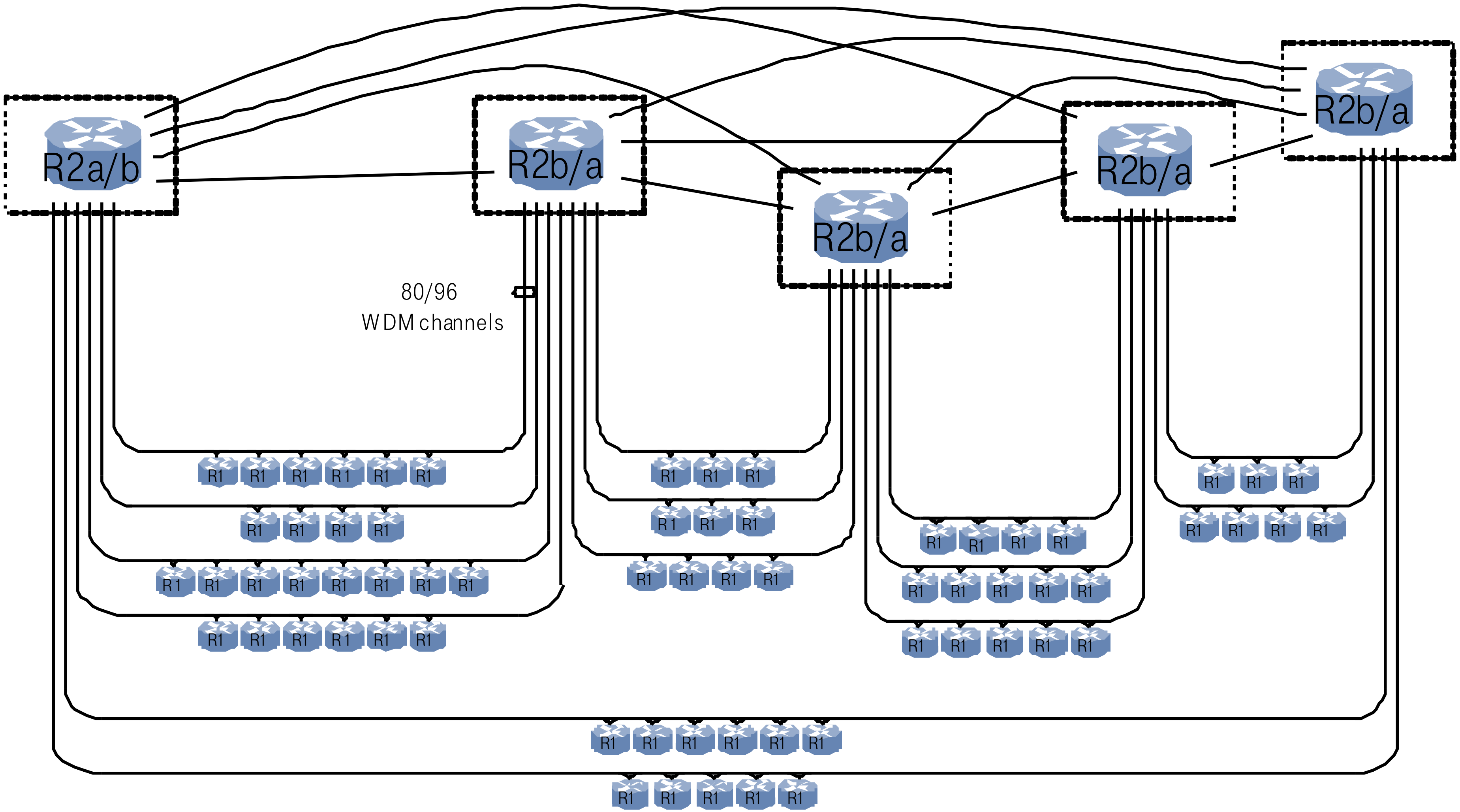
- Connects R1s, Data Centers and Internet peerings
- Runs IPv6 and IPv4 routing, integrates optical
- Closely integrated with Data Centers
  - Optimized handling of locally sourced services
- High scale IP bandwidth

Data Center / Services

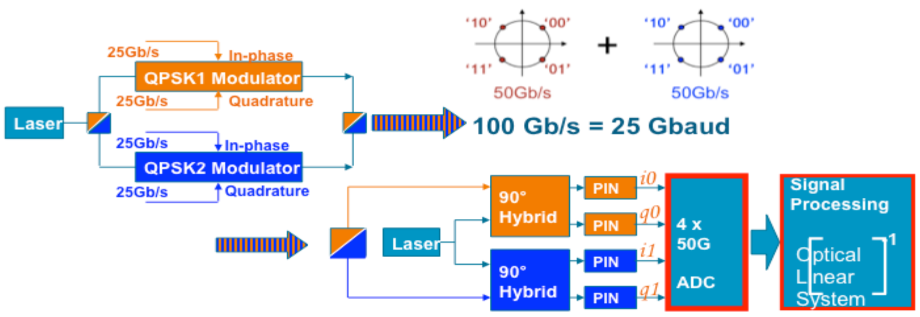
- Distributed design
  - fully virtualized x86 compute and storage environment
- Network support functions - DNS, DHCP, NMS
- Real-time OSS incl. user self-service portal
- Cloud DC applications, XaaS services
- Complex network services e.g. high-touch subscriber handling

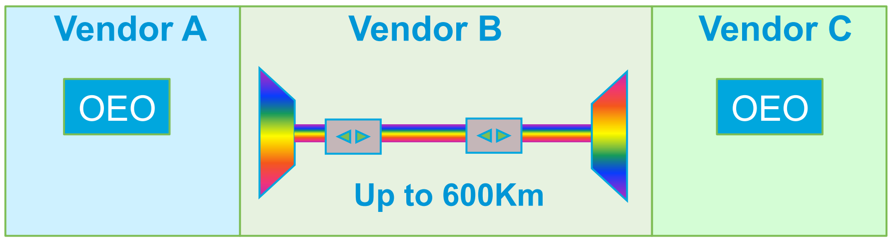
TRANSPORT

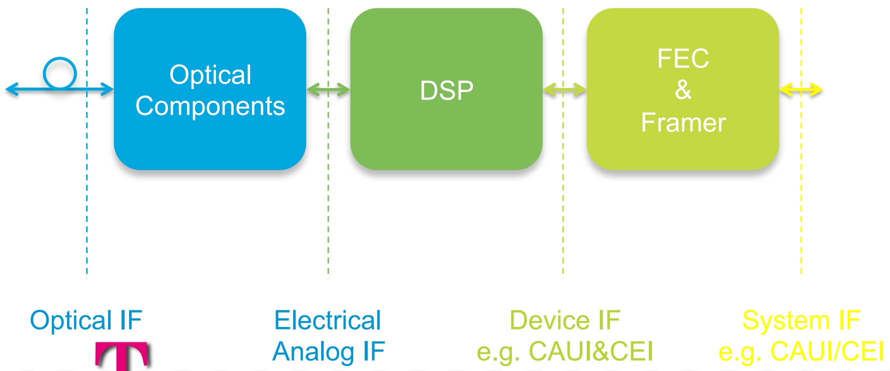
R1 ⇔ R2: OPTICAL FIBER LINKS



100G Coherent DWDM Interop and Pluggable Technology

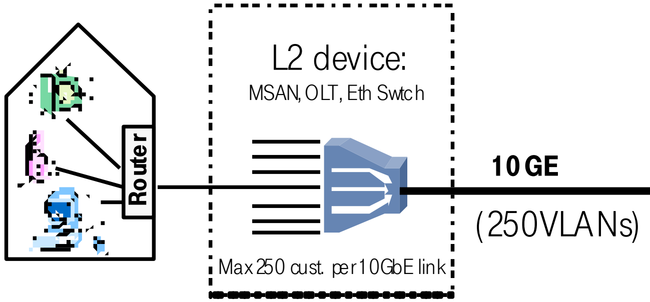


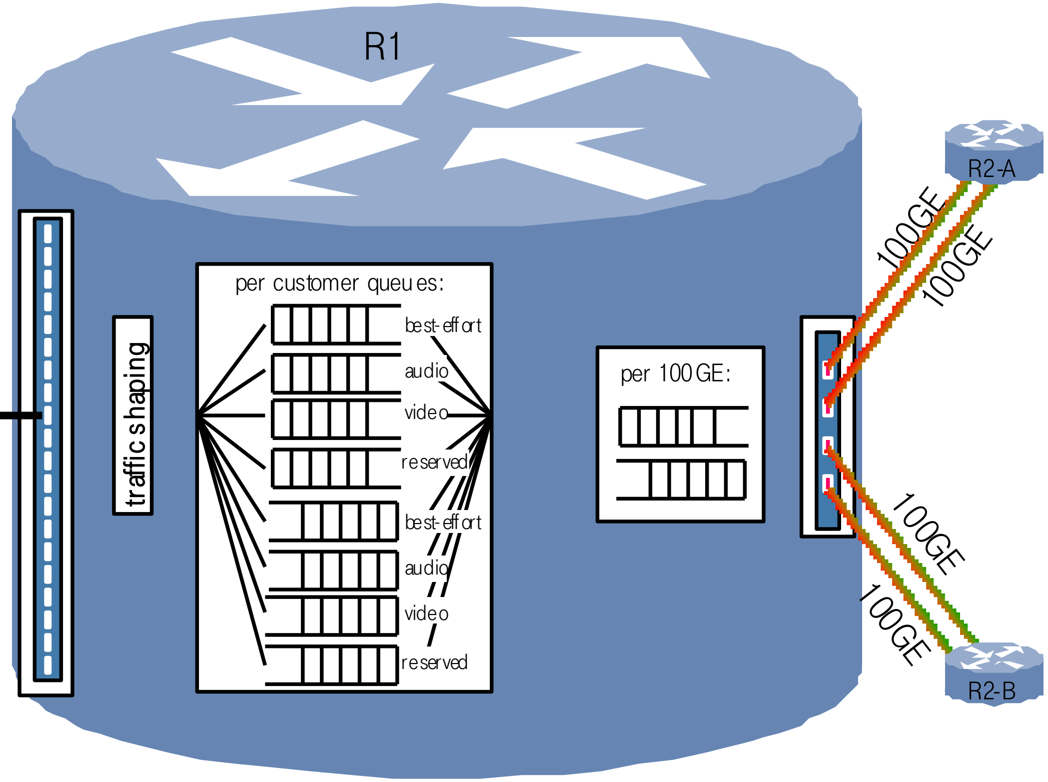




- Agree on a common set of parameters for the 100G line side
- Enable innovation by many players in the silicon optics arena
- Hard FEC, typ 800km
- If price is right, use in data center
- Coding
- Carrier Recovery
- Acquisition (blind)
- Reach
- Framing (works with both OTU4.4 and OTU4.10)
- Forward Error Correction (Hard FEC Staircase)

TeraStream user facing router R1



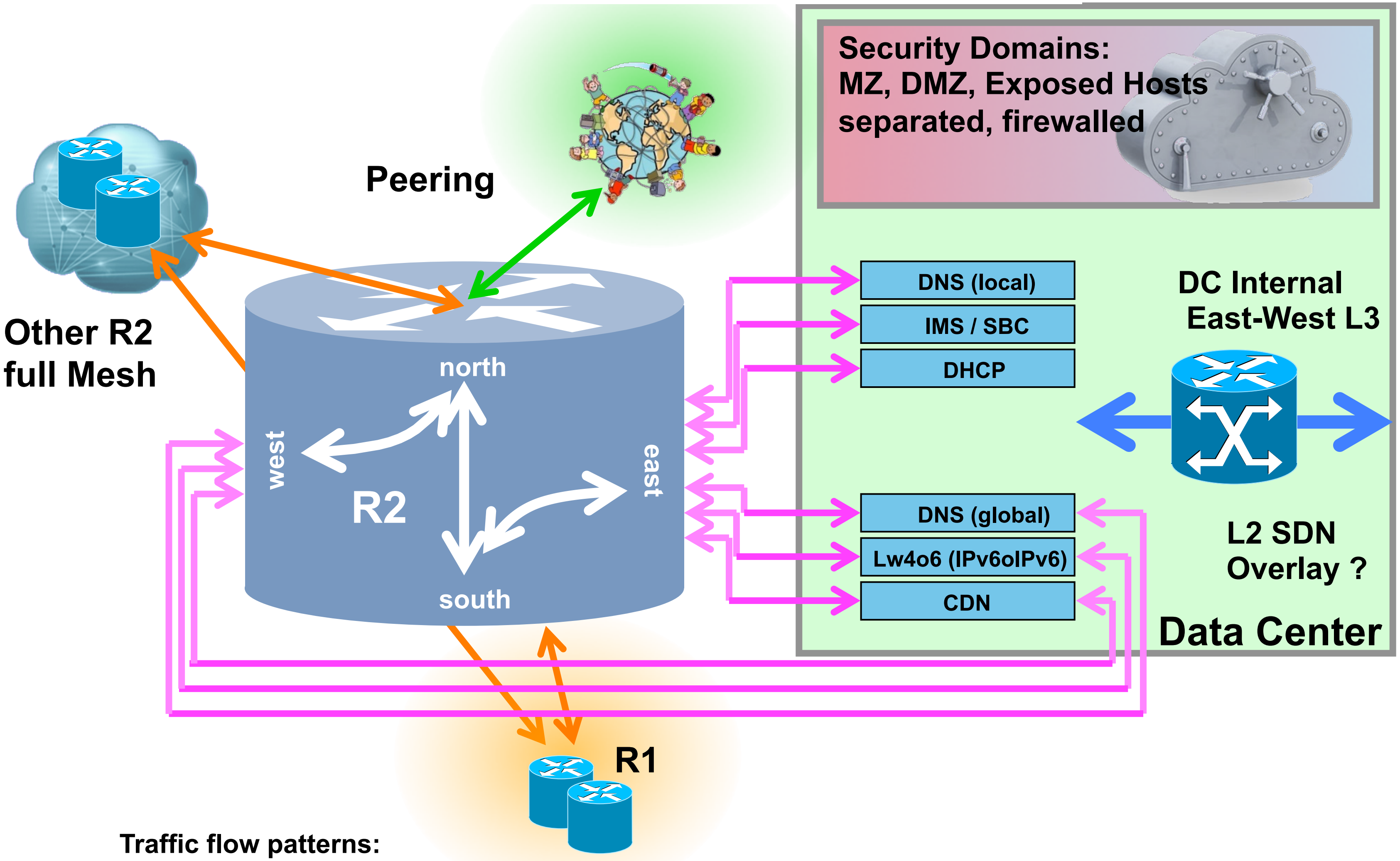


Service Guarantee Architecture

Configure per queue:
- Delay
- Drop
- Bandwidth
- Reorder
- Etc...

- IP traffic shaped to capabilities of L2 device
- 5000 customers connections per R1
- 20 * 10GE port for L2 device
- 4 * 100GE for R2 link

R2 router and traffic patterns



Traffic flow patterns:

- **R1 ⬄ Peers and Other R2 going north ⬄ south (example: IPv6 Internet traffic)**
- **R1 ⬄ Data Center services going south ⬄ east (example: DHCP)**
- **R1 ⬄ Data Center ⬄ Peers going south ⬄ east ⬄ west ⬄ north (example: IPv4 Internet traffic)**

TERASTREAM HOMEGATEWAY PLATFORM

Existing CPE procurement models are far too slow to keep up with the necessary rate of development

The current state of IPv6 support on commercial platforms leaves ... room for improvement!

We believe that we are not the only carrier with this problem

So . . .

DT are currently developing a carrier grade' CPE software platform

Based on OpenWRT, extended with IPv6 and SP functionality

Plan to register this with Linux Foundation

A fully open source initiative

We are looking for other interested carriers to build a development community around the platform

IPv6

IPv6 NATIVE NETWORKING
IPv6 is fundamental, not an Afterthought

A new network - designed from the ground up specifically for IPv6

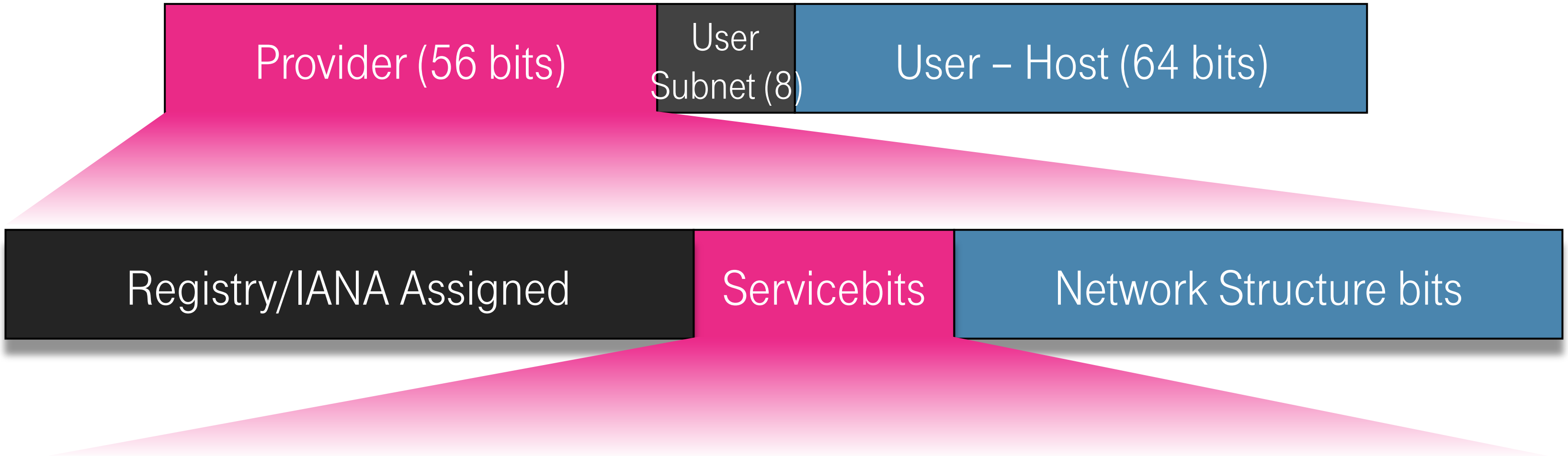
IPv6 for ALL internal interfaces (incl. management, control plane etc) – with just a bit of IS-IS for IGP

Treat IPv6 as a new protocol – It can be much more than just 'IPv4, but bigger'

Don't let native IPv4 into the network

- No Dual-Stack
- Treat IPv4 as a long-tail overlay service – (more on this later)
- Once you let ANY IPv4 into the design, you'll never get rid of it!

SERVICE DIFFERENTIATION BASED ON ADDRESSES
USING IPv6 ADDRESS SPACE AS LABELS




```
P Public            0=SP-intern, 1=extern
I Infrastructure              0=end user, 1=infrastructure packet
E Endpoint/Service0=endpoint, 1=service
SSS Service Type              0=res, 1=internet, 4=video, 5=L2, 6=voice, 7=mgmt
M                             0=fixed, 1=mobile endpoint

Examples:                     Source              Destination
                              PIESSS              PIESSS
--------------------------------------------------------------------------------
User -> IMS                   000110              011110
IMS  -> User                  011110              000110
User -> User (best effort)    X00001              X00001
User -> Internet (best effort)100001              XXXXXX
Internet -> User (best effort)XXXXXX              100001
Lan-Lan service               010101              010101
```

MULTIPLE PREFIXES ON THE CLIENT…

Brings benefits, but also a new (old!) problem

How do you ensure that the client selects the right source address for each different service?

Current source address mechanisms are based on variants of longest source/destination prefix matching policy

- This places constraints on your addressing architecture
- Often require additional policy to be provisioned to the client
- Doesn't give users or applications information about the 'properties' or 'suitability' of a prefix for use

The Solution? - "Prefix Colouring"

- Adds additional metadata to DHCP prefix allocations
- Allows applications and users to select a source prefix based on this metadata
- Source address selection is decoupled from the destination address prefix matching
- Can also help with source address selection in multi-homing deployments
- Described in 'draft-lepape-6man-prefix-metadata'

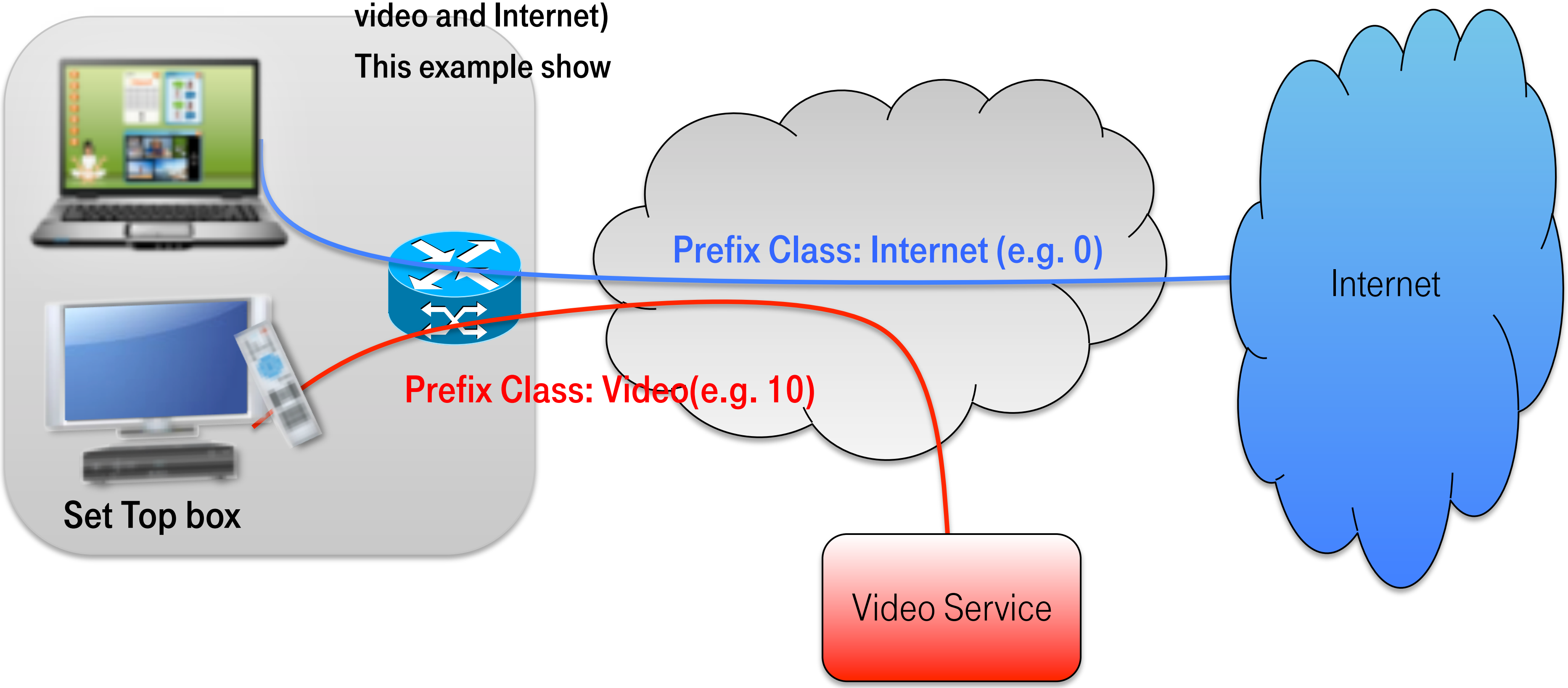
Home network with video class service

In this example, two different services are being run on the same network.

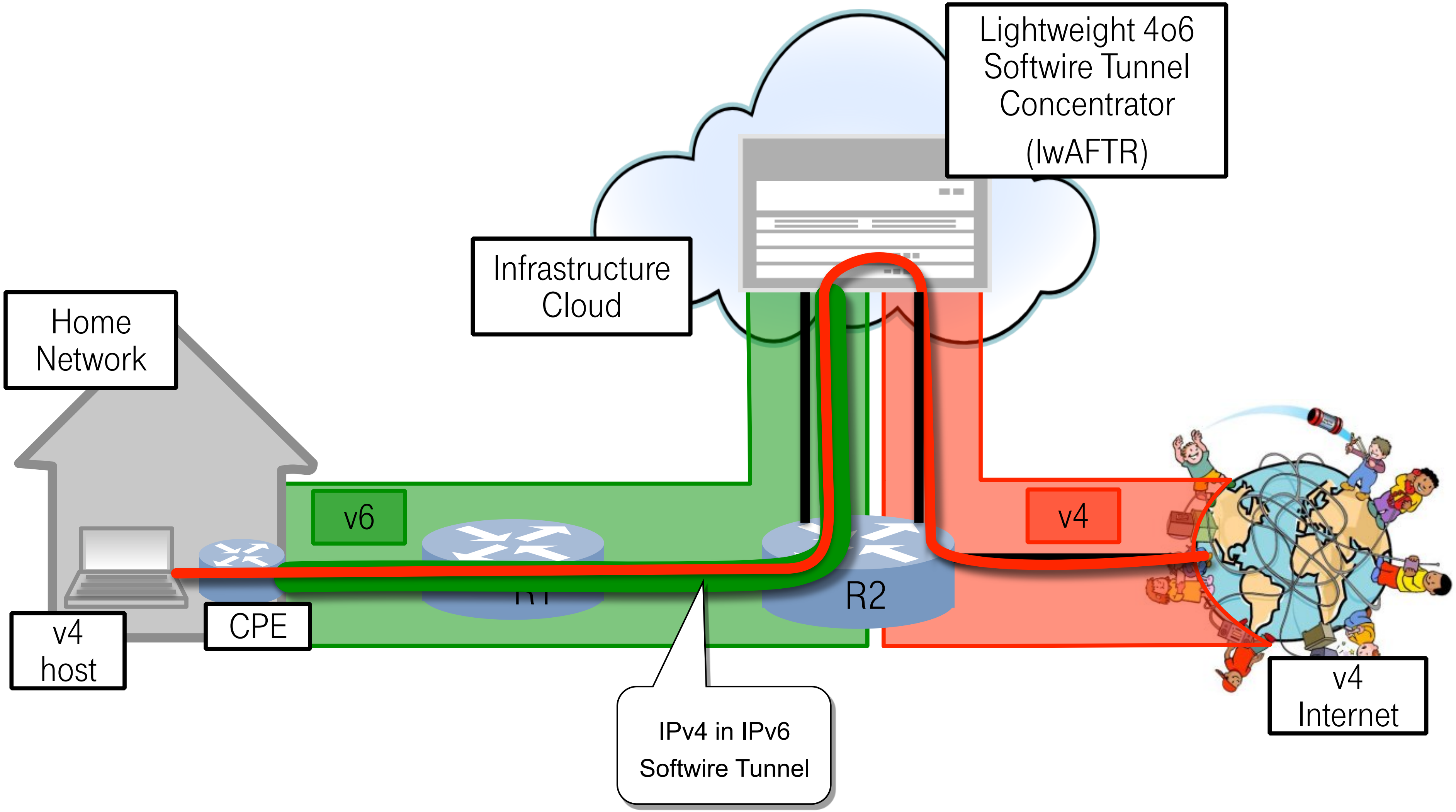
The service provider wishes that traffic is sourced from different prefixes by the home network clients for Video on demand service as against general Internet access

The homenet has several prefixes delegated – (potentially one each for voice, video and Internet)

This example show



IPv4 AS A SERVICE – LIGHTWEIGHT 4o6 SOFTWIRES

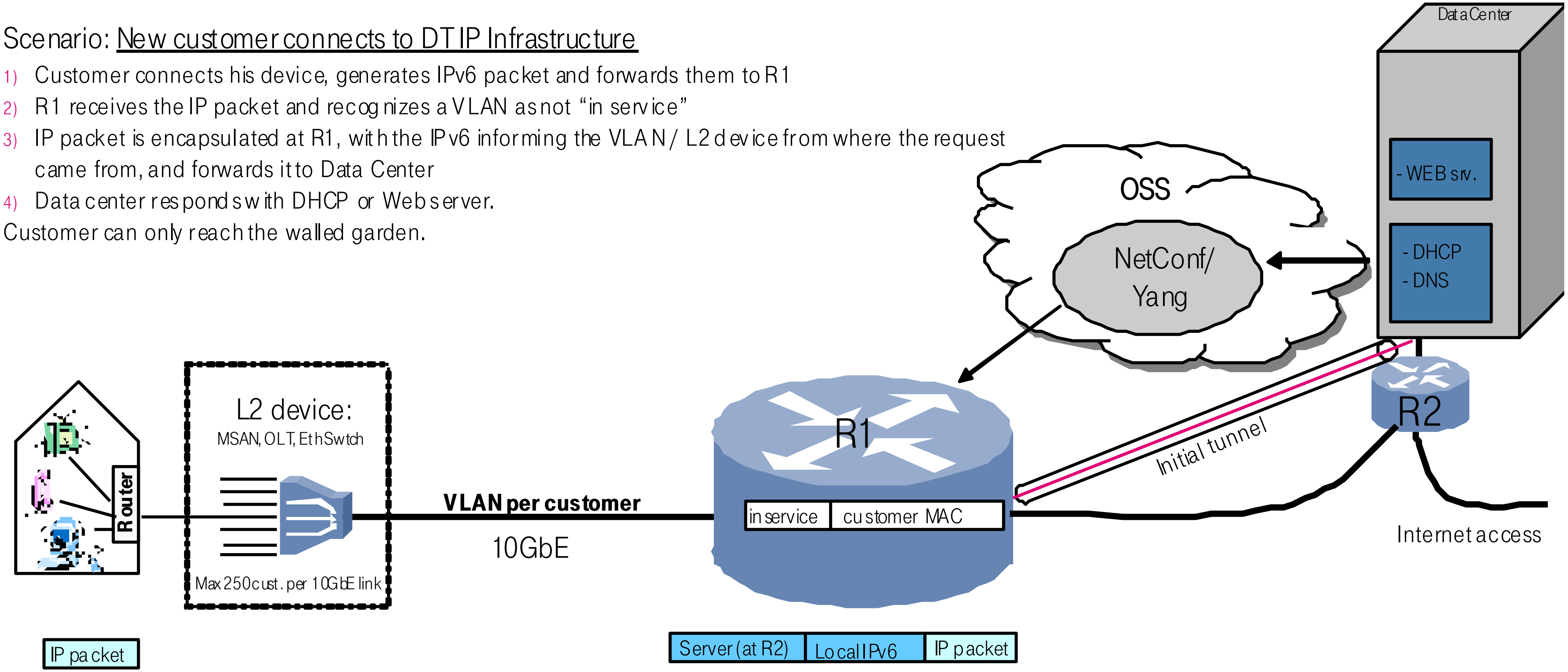


If Not IPv6, use the network as a PTP Ethernet

Scenario: New customer connects to DT IP Infrastructure

1) Customer connects his device, generates IPv6 packet and forwards them to R1
2) R1 receives the IP packet and recognizes a VLAN as not “in service”
3) IP packet is encapsulated at R1, with the IPv6 informing the VLAN / L2 device from where the request came from, and forwards it to Data Center
4) Data center responds with DHCP or Web server.

Customer can only reach the walled garden.



Scenario: customer registers

1) Web server at Data Center generates a request to OSS to configure a new customer via NetConf / Yang at router R1, Line ID.
2) The OSS via NetConf configures the R1 as “in service” for a customer located at a specific interface (IPv6 address).
3) From now on, the customer is outside the walled garden and can reach other Internet addresses.

DEPLOYING v6 ONLY – SOME LESSONS LEARNT SO FAR...

- There are still mainstream products that do not have complete IPv6 implementations:
  - Transport interfaces tend to have more complete implementations
  - Management and control plane functionality may not be so good

- The level of IPv6 testing in shipping products is not on a par with IPv4 – we've found some pretty hairy bugs!

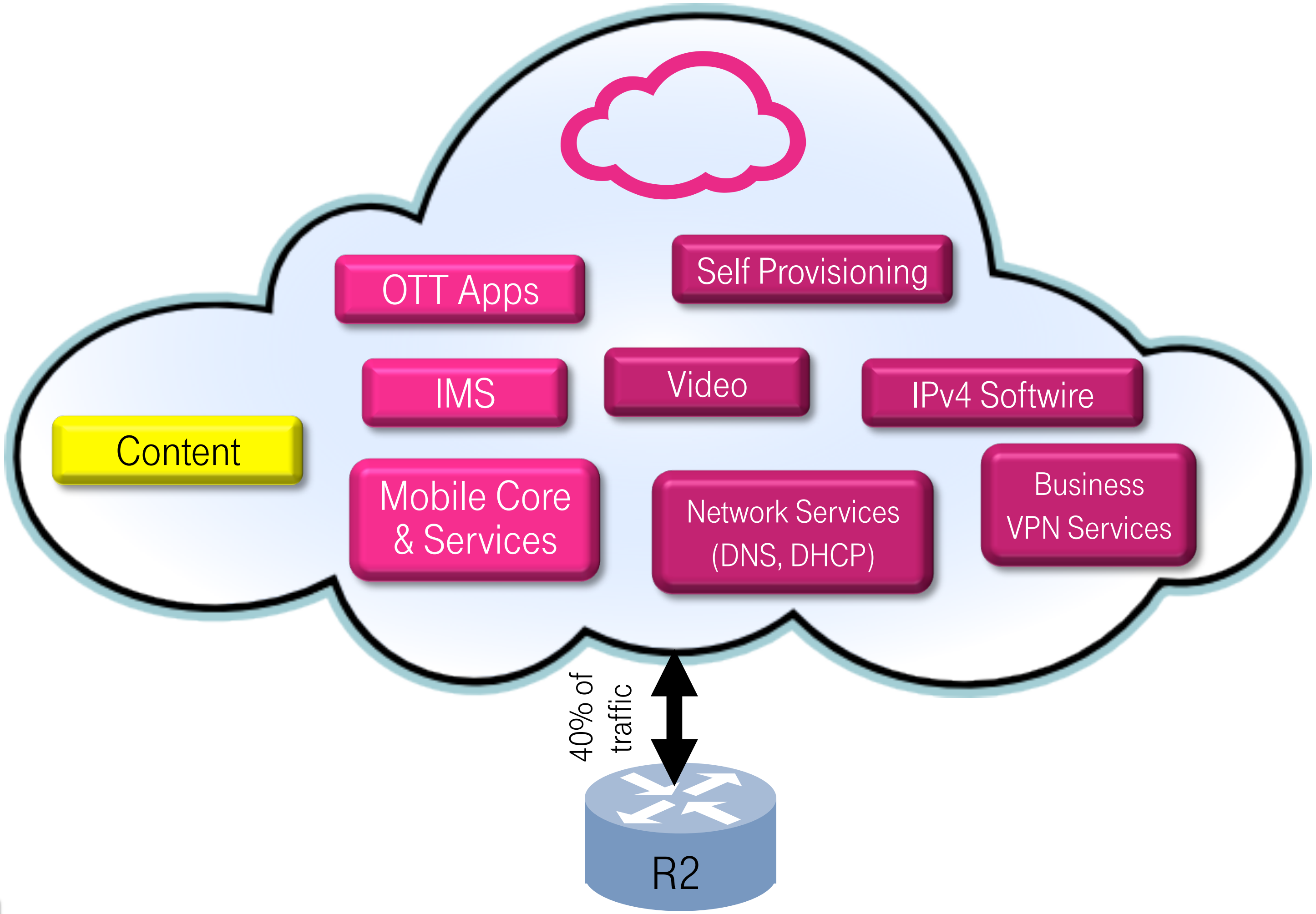
- Vendor's need constant 'encouragement' to resolve these problems

- If you are planning any kind of similar rollout, get your requirements fixed and test well in advance!

NETWORK FUNCTION VIRTUALISATION

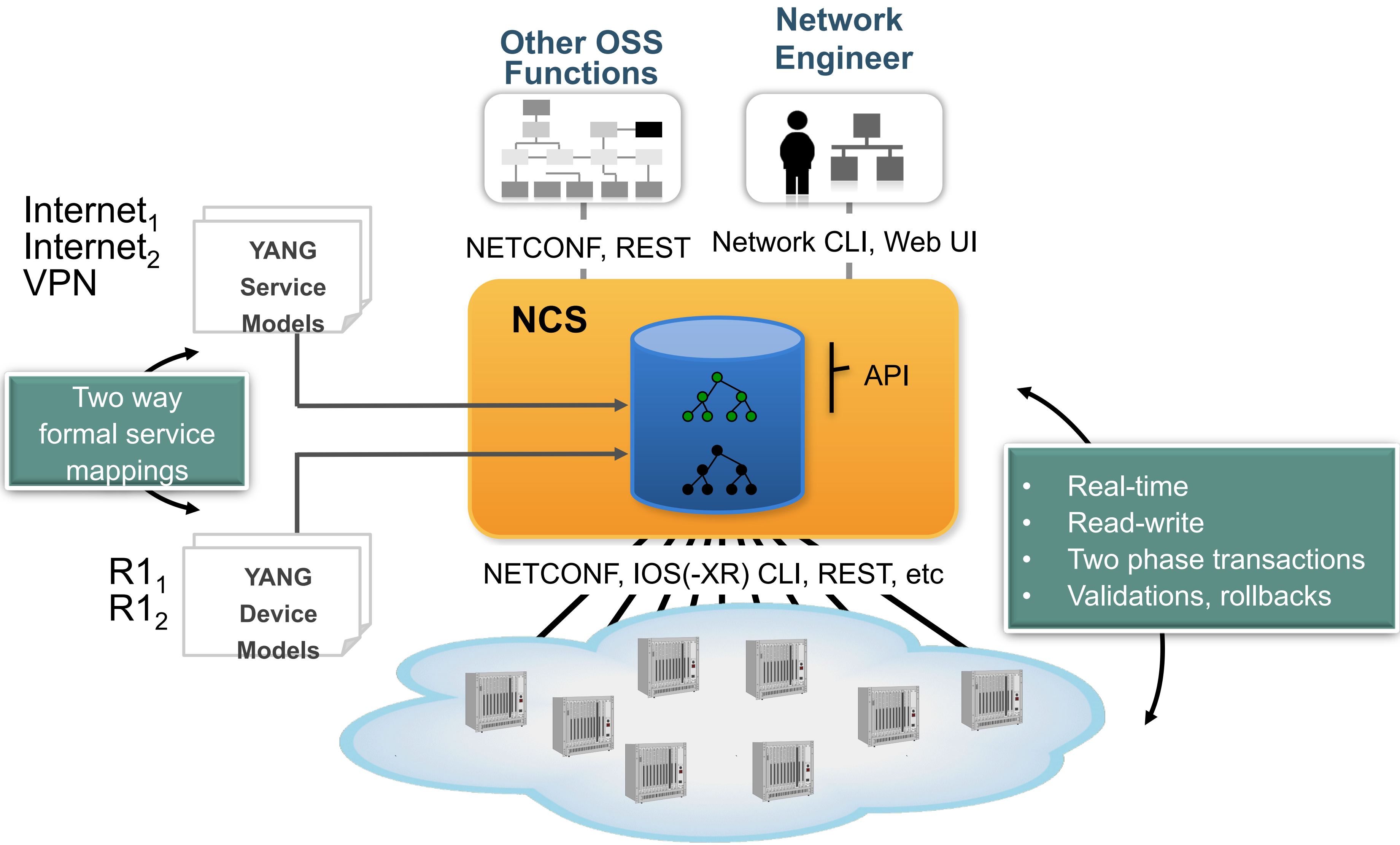
“THE INFASTRUCTURE CLOUD”

INFRASTRUCTURE CLOUD
NETWORK FUNCTION VIRTUALIZATION

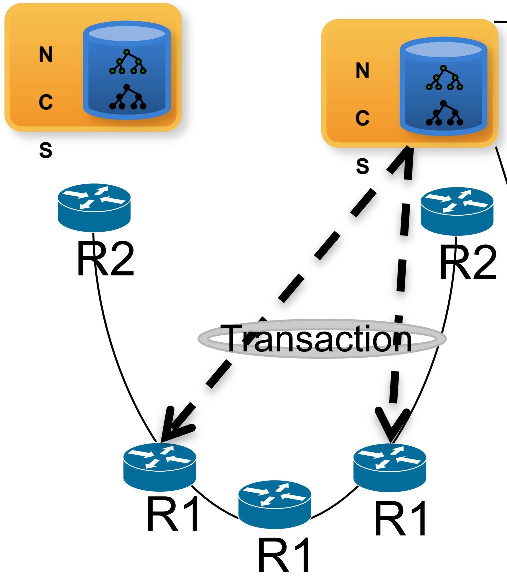


REAL-TIME OSS

Model-Driven Network Abstraction Layer



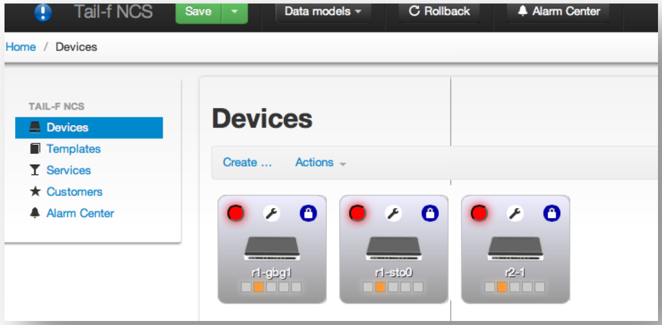
Define “Services” in a data-model language (Yang)



NCS CLI : EVPL Service over R1 and R2

```
ncs# services service evpl2 type evpl bandwidth 100MB qos-template
gold port-1 r1-sto0-ge0/0/1.65 port-2 r1-gbg1-ge0/0/5.65
ncs(config-service-evpl2)# show
ncs(config-service-evpl2)# show conf
services service evpl2
 type evpl qos-template gold
 type evpl bandwidth 100MB
 type evpl port-1 r1-sto0-ge0/0/1.65
 type evpl port-2 r1-gbg1-ge0/0/5.65
!
ncs(config-service-evpl2)# commit
```

NCS WebUI



NCS REST

```
$ curl -v -X POST -T evpl.xml -u admin:admin \
   http://localhost:8080/api/running/services/service
```

NCS NETCONF

```
$ netconf-console --edit-config=evpl.xml
```

TERASTREAM
CROATIA TRIAL

TERASTREAM PILOT SUCCESFULLY LAUNCHED @ HRVATSKI TELEKOM ON DEC 10, 2012

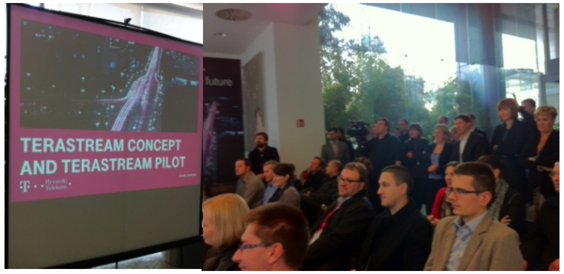
100 Gb/s network using IP and Optical integration	Full integration of Network and Cloud technologies for service production	Native IPv6 network delivering consumer service

- Built in a record time - decision in September, launch on Dec 10th
- 500 customers with up to Gigabit access speeds
- Agile execution – small cross-functional teams (DT, HT, Cisco, Combis)
- Continued development and iterative improvement
  - Technology refinements
  - New vendors being integrated
  - More customers connected


AUSTRIA
Graz
Klagenfurt
HUNGARY
Cakovec
Varazdin
Koprivnica
Ljubljana
Bjelovar
Virovitica
Trieste
Zagreb
SERBIA
Osijek
Umag
Rijeka
Karlovac
Sisak
Vukovar
Porec
Slavonski Brod
Rovinj
Krk
Pula
Cres
Plitvice Lakes
National Park
Losinj
BOSNIA & HERCEGOVINA
Zadar
Sarajevo
Sibenik
Ancona
Trogir
Split
Mostar
Makarska
Brac
Medjugorje
Vis
Hvar
Neum Corridor
MONTENEGRO
Korcula
Dubrovnik
Mljet
ITALY
Pescara
Cavtat

Croatia expansions in 2013:

- Expand TeraStream pilot in Croatia
  - Increase the network
  - Integrate in HT environment
  - Improve data center



Did it again!

13th Dec 2013

TERASTREAM
SUMMARY

TeraStream

- Radical simplification of the IP network architecture
- Removing the legacy from the core (IPv4, MPLS), improving services
- Optical transmission is integrated into the IP routers using 100G coherent technologies
- Combining network and cloud for scalable service production
- Control using a SDN paradigm – Realtime OSS

Benefits

- Improve user experience, real Internet services to more users
- Use just enough complexity to do the job and no more
- Get the revenue and cost balance right

Questions?

Now you can bring out your tar and feathers and start throwing things at me..

THANKS!