Building automated wireless mesh networks

Attila Balogh, Magyar Telekom

about me

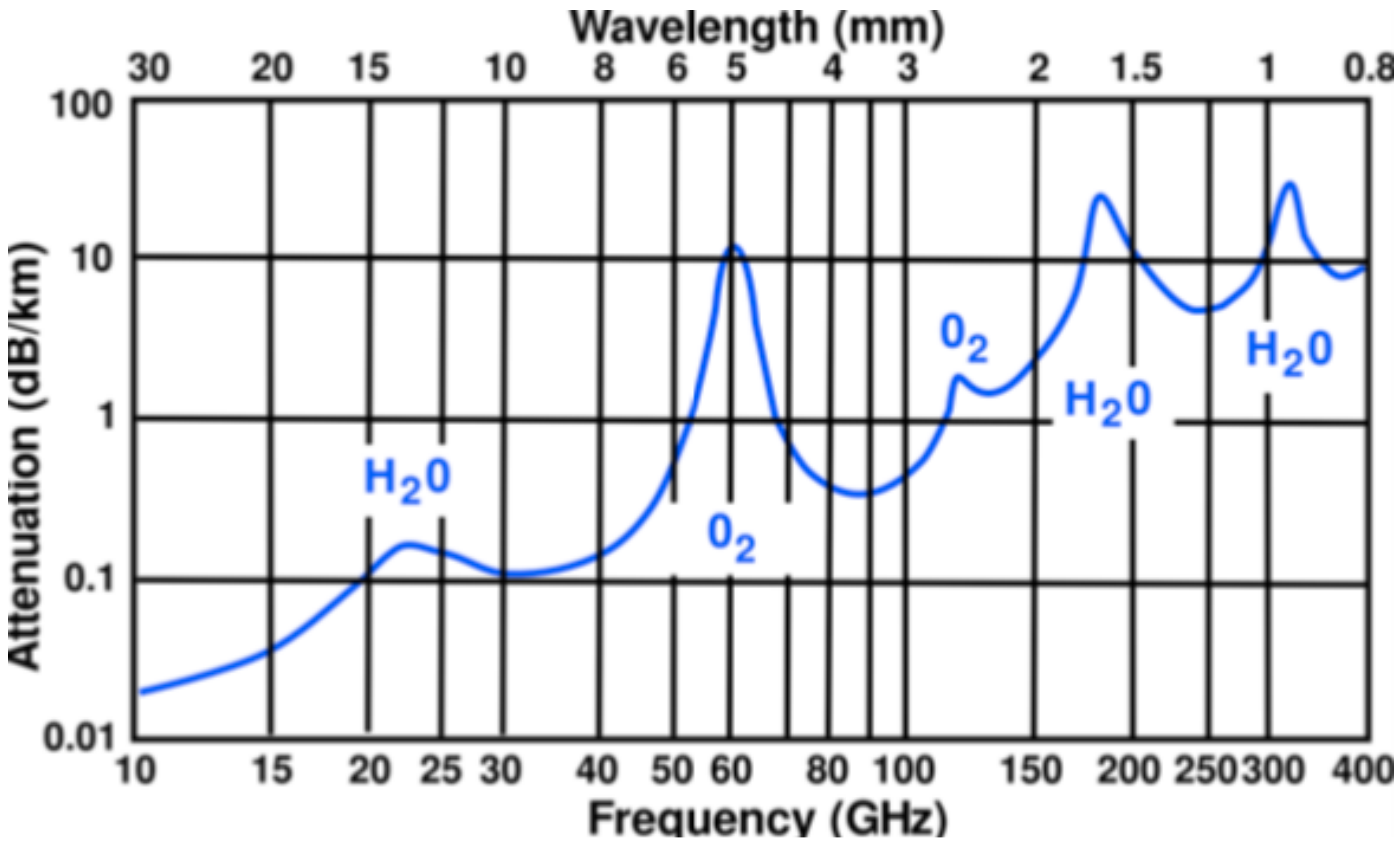
- just a random IP guy
- working for Magyar Telekom
- engineering networks since ’97
- RouterOS user since 2004

how i met ~~your~~ 60 GHz

PART I.

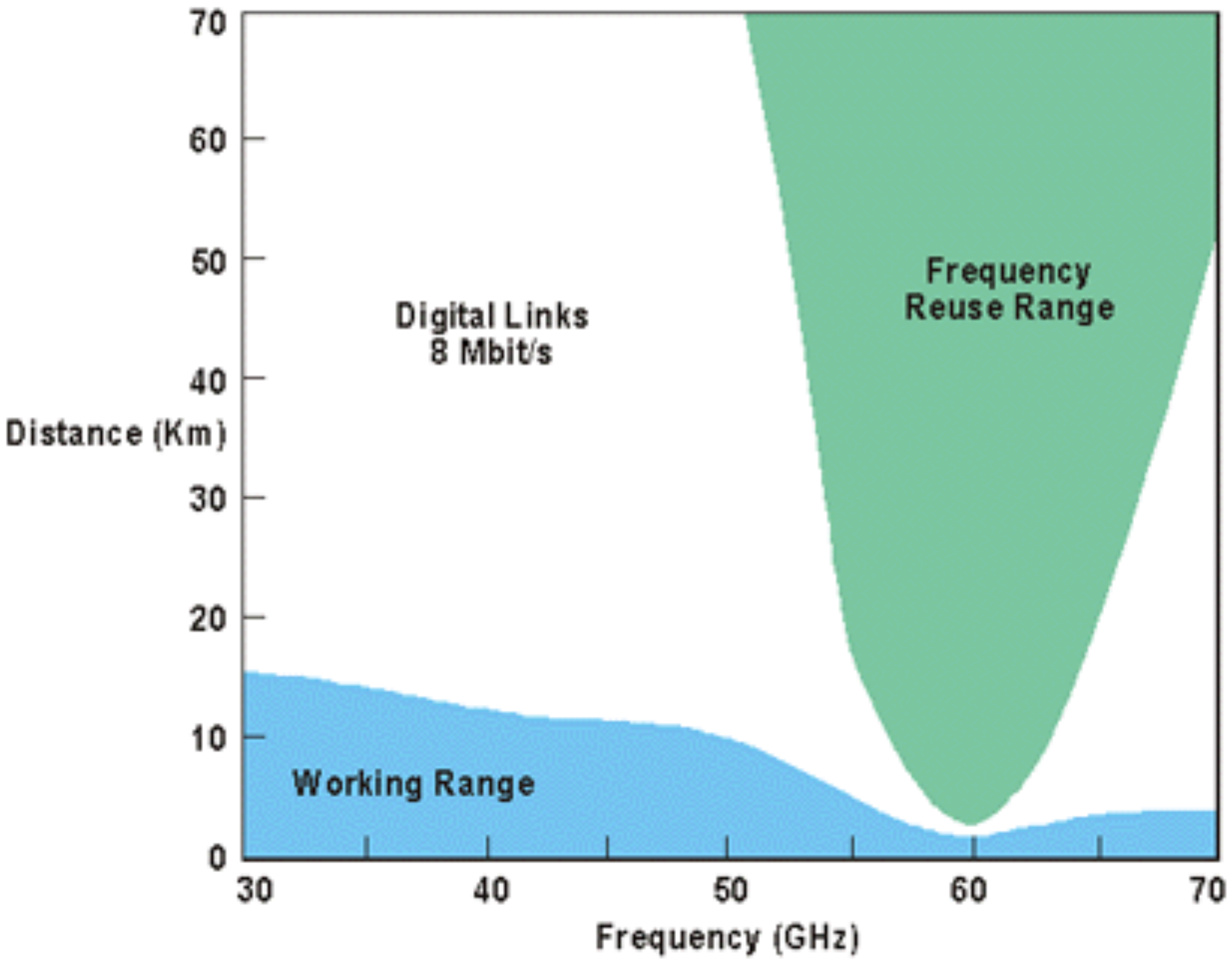
created by Craig Thomas and Carter Bays for CBS

The spectrum (that no one wanted)



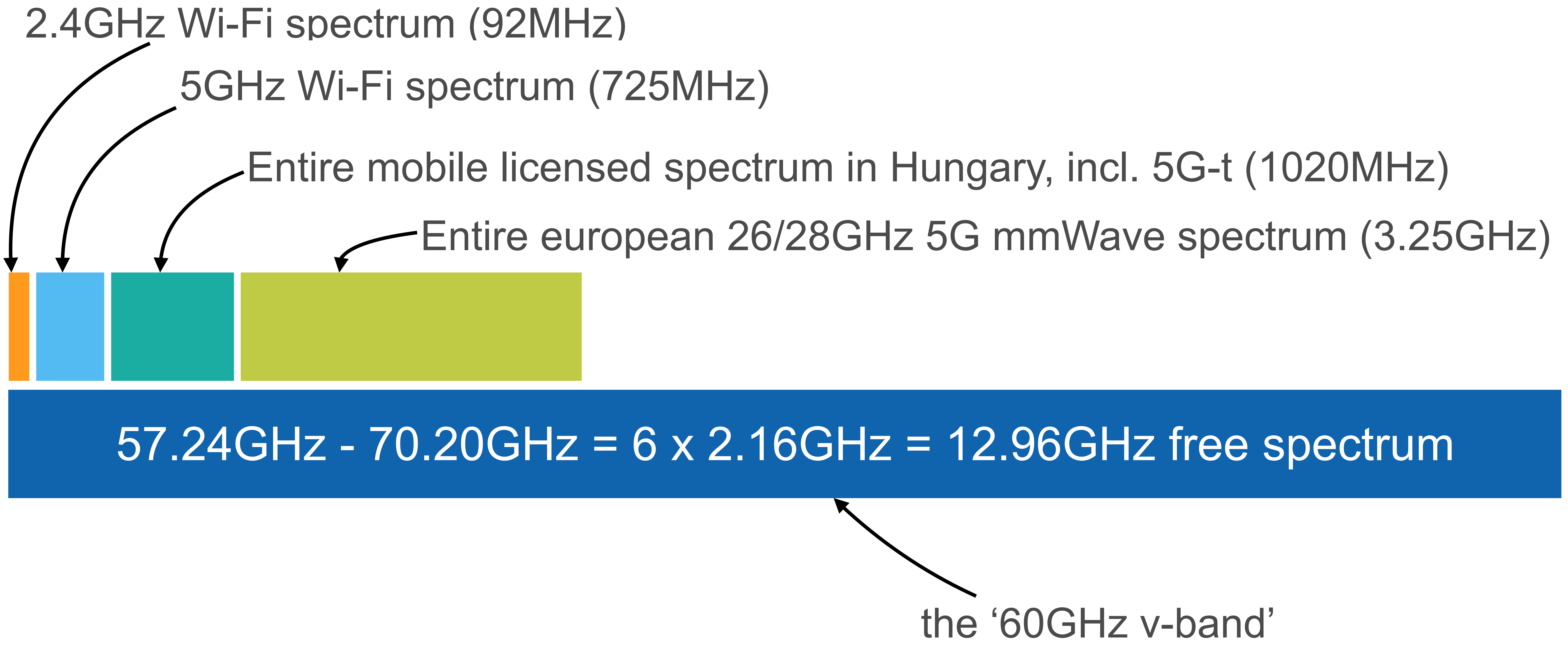
- line of sight
- rain fading
- oxygen absorption
- doppler frequency shift
- unlicensed

The spectrum (that **WE** need)



- minimal interference (high FSL, O_2 absorption)
- beam-like, can be focused
- reflections - to overcome line-of-sight problems
- unlicensed, and big
- upper 2 channels similar to e-band

DEFINE 'BIG'


2.4GHz Wi-Fi spectrum (92MHz)
5GHz Wi-Fi spectrum (725MHz)
Entire mobile licensed spectrum in Hungary, incl. 5G-t (1020MHz)
Entire european 26/28GHz 5G mmWave spectrum (3.25GHz)
57.24GHz - 70.20GHz = 6 x 2.16GHz = 12.96GHz free spectrum
the '60GHz v-band'

BUT WHAT IS IT GOOD FOR?

802.11ad

4.6Gbps / channel

BUT WHAT IS IT GOOD FOR?

802.11ad 4.6Gbps / channel

802.11ay 17.6Gbps / channel

Once upon a time…

TELECOM INFRA PROJECT

Deutsche Telekom

facebook

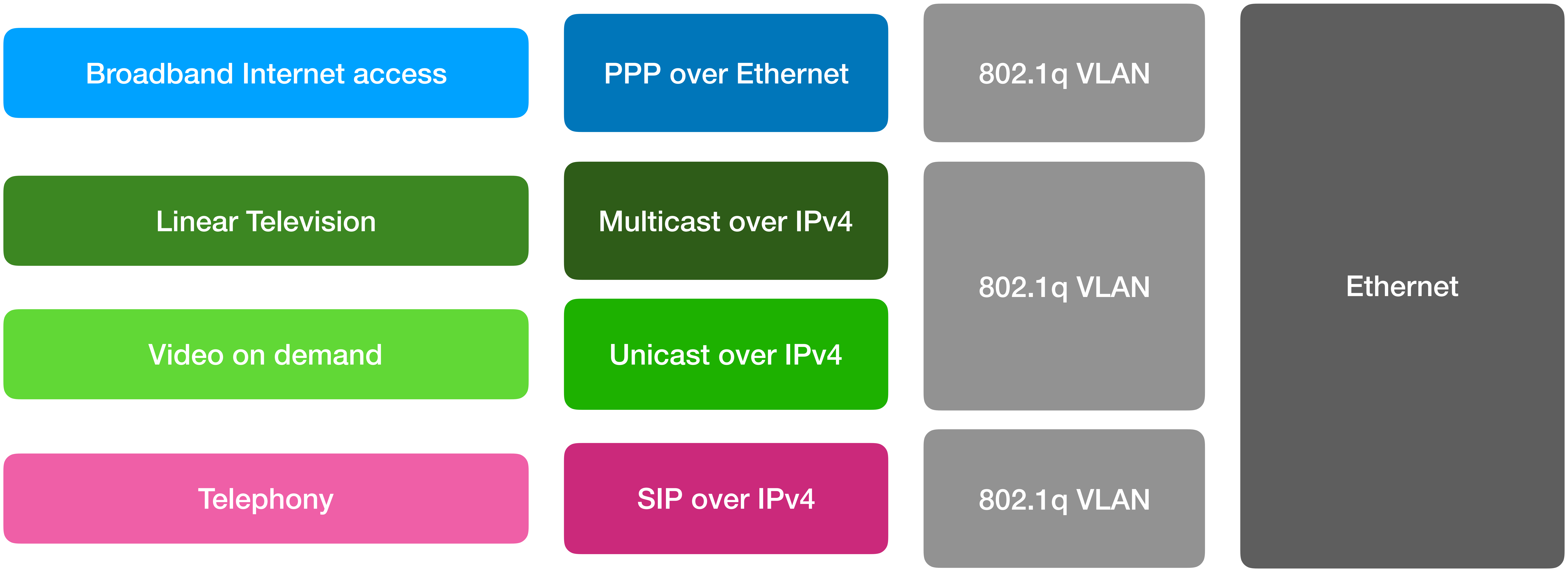
Magyar Telekom

… in a village far, far away

Enter Terragraph

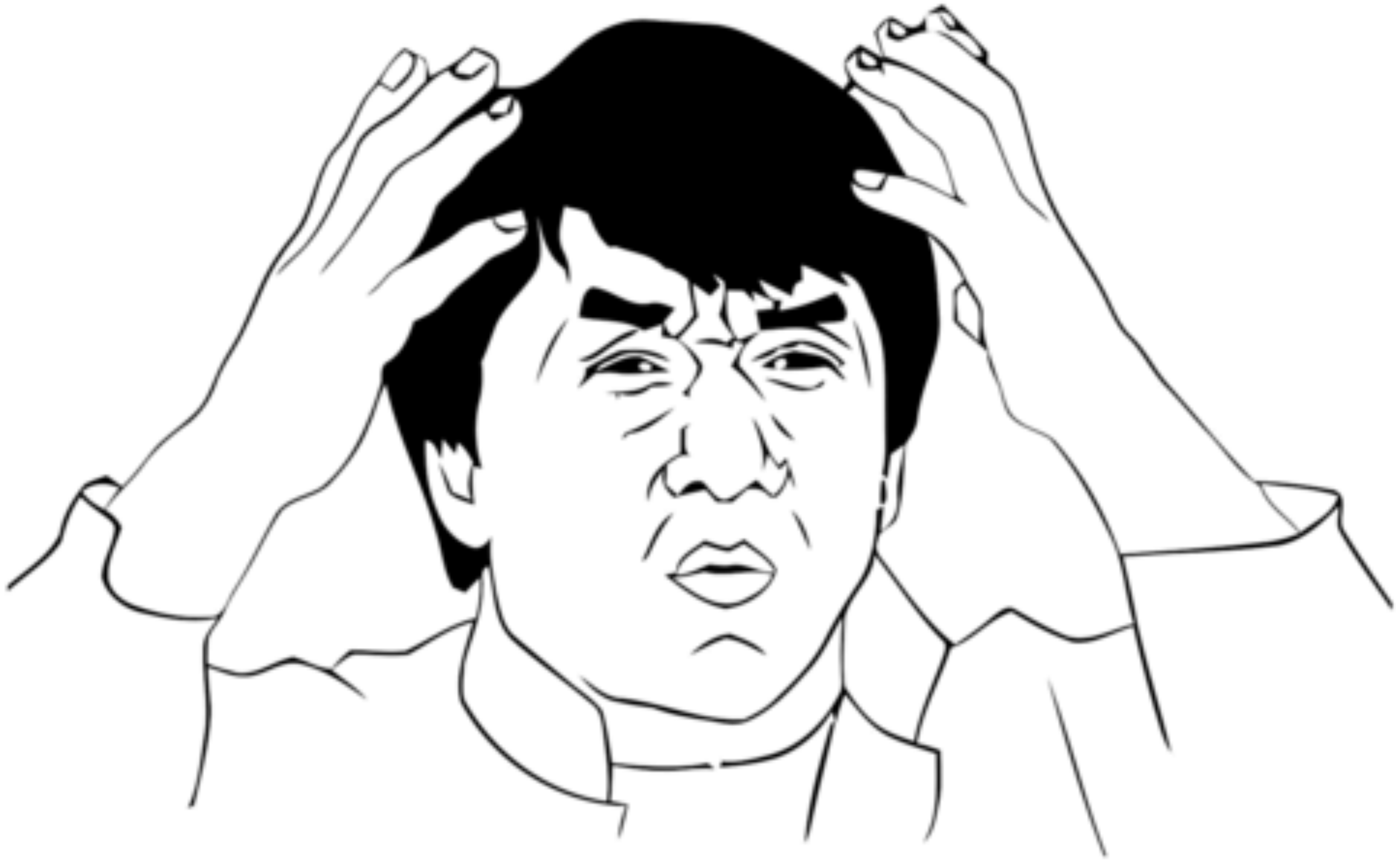
- 60 GHz single frequency mesh network
- bases on 802.11ad + GPS synchronised TDD
- Layer 3 routed mesh with IPv6
- Self organising, Zero touch provisioning
- scales up to 100s of nodes

meanwhile in telecom industry



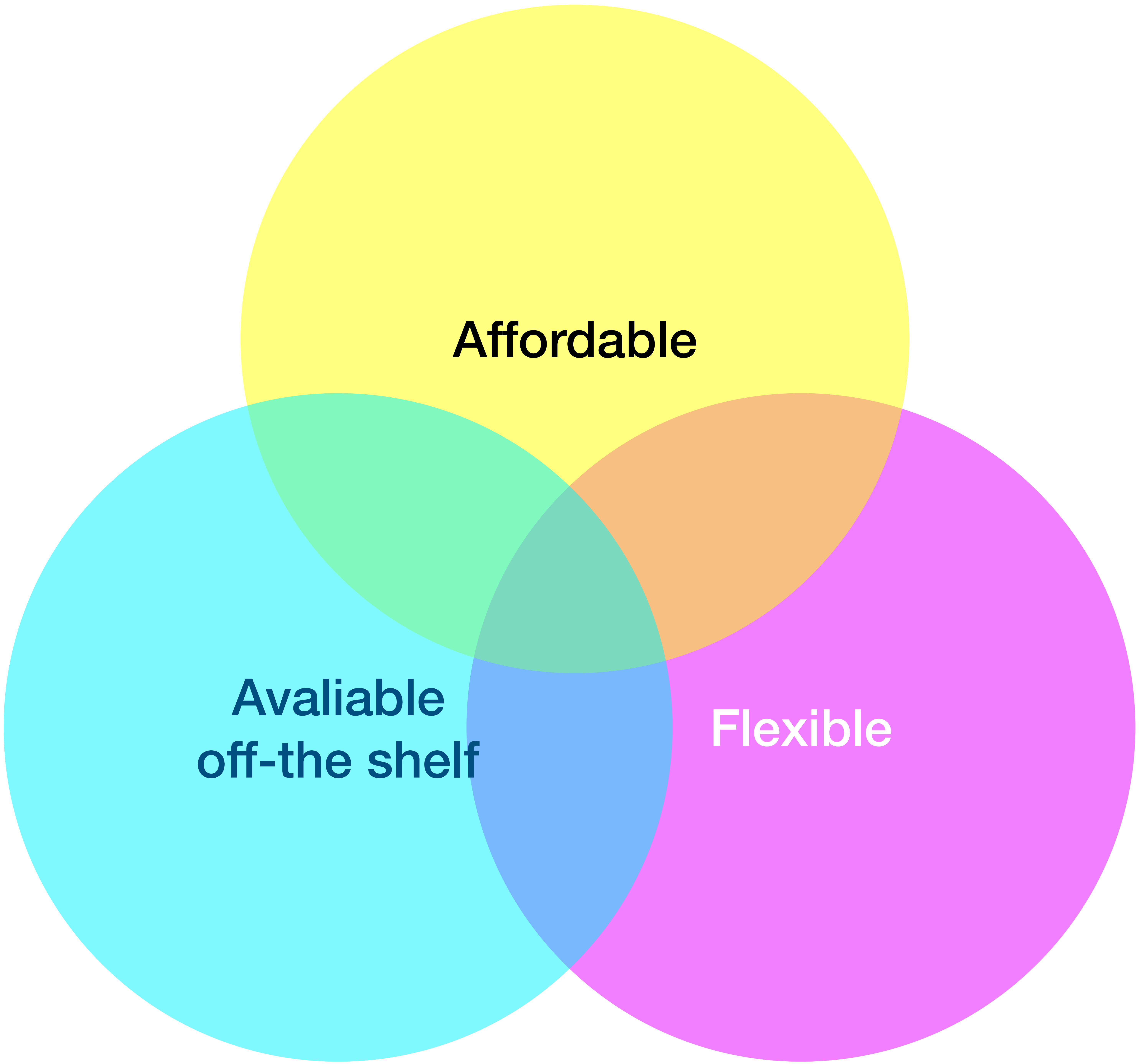
What I need

Ethernet



What I have

IPv6


Affordable
Avaliable
off-the shelf
Flexible

MikroTik

ROUTEROS

idea #1 - L2TP

- Broadband Internet access
  routed L2TP - IPv4 + IPv6 over PPP over L2TP

- Multicast IPTV
  BCP over L2TP - Ethernet bridging over L2TP

- Session negotiation, authentication, keepalive is done by L2TP

- supports MLPPP - PPP fragmentation -> no MTU limits

- No support for ‘client-server’ tunnels over IPv6 in RouterOS

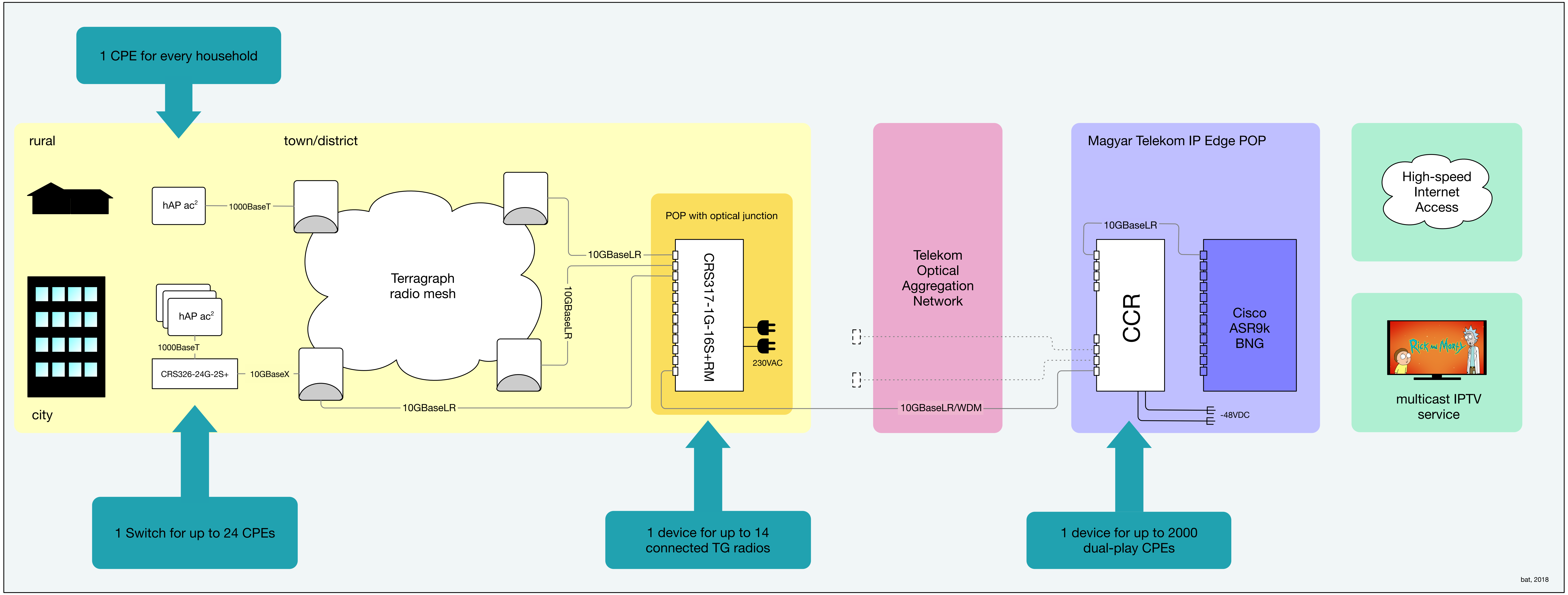
idea #2 - EoIPv6

- Ethernet user plane -> VLANs are possible
- Works over IPv6
- Supports keep-alive and thus some link management
- Supports tunnel IDs: multiple tunnels are possible between the same nodes
- no link negotiation: client and server needs to know each other
- pre-configuration required on both sides

bridging the gaps

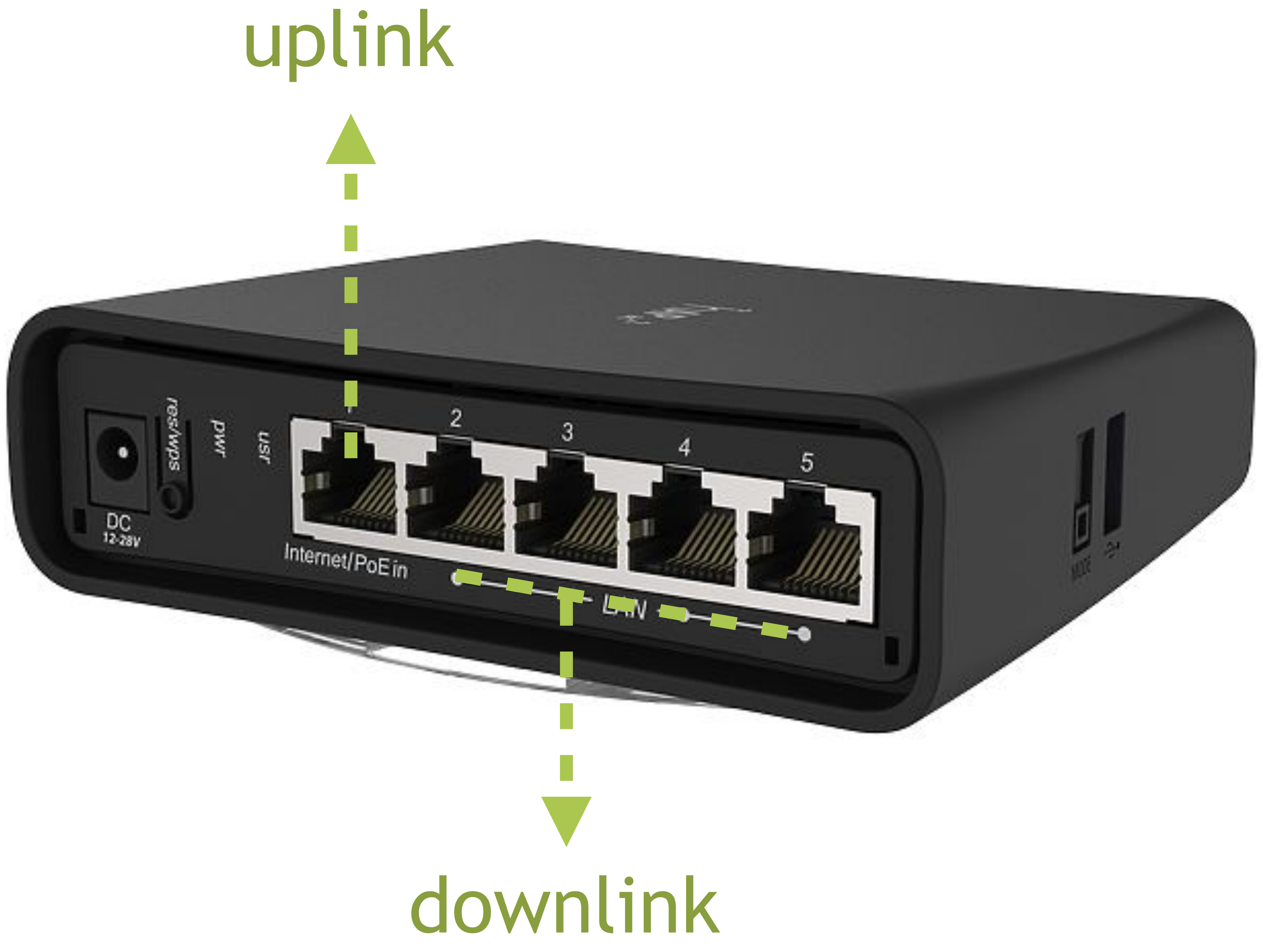
- use FQDNs to establish EoIPv6 tunnels
- use a central controller for tunnel IDs and configuration
- TR-069 is not capable enough for this task
- build a custom system that uses similar concepts
- use scripting on the routers to interact & fix bugs

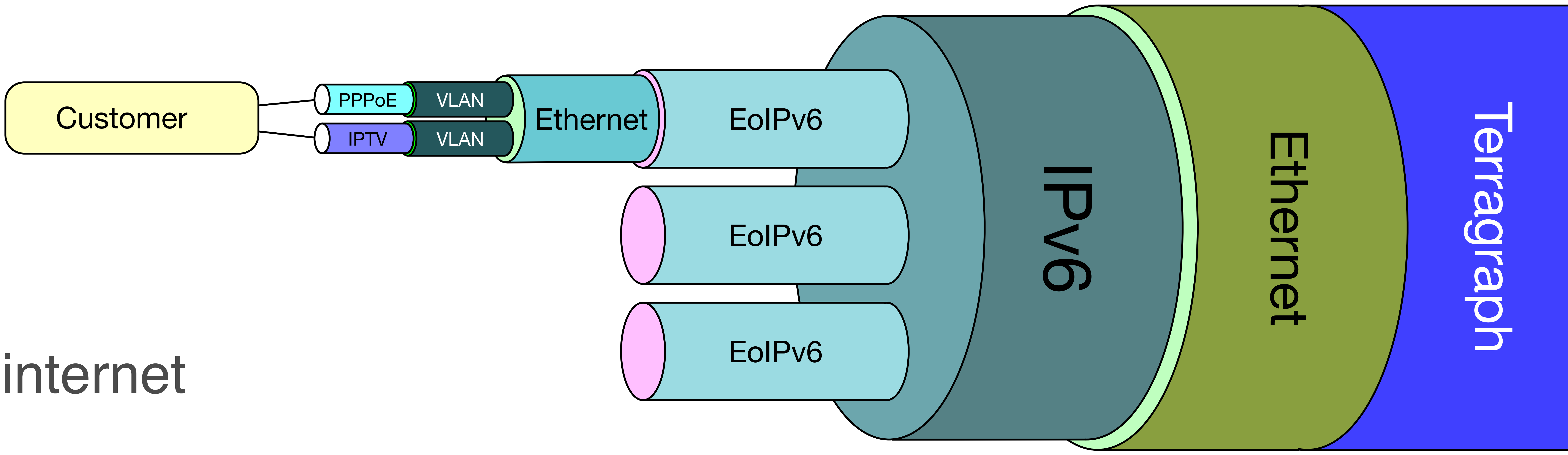
this is how we do it



the current indoor CPE in detail

- 4-core ARMv7 (Qualcomm IPQ4018)
- 5xGE ports
- dual-band 2x2 MIMO WiFi (b/g/n/ac)
- passive POE-in supported
- features/scripting/automation
- up to 700Mbps throughput with complex tunnelling

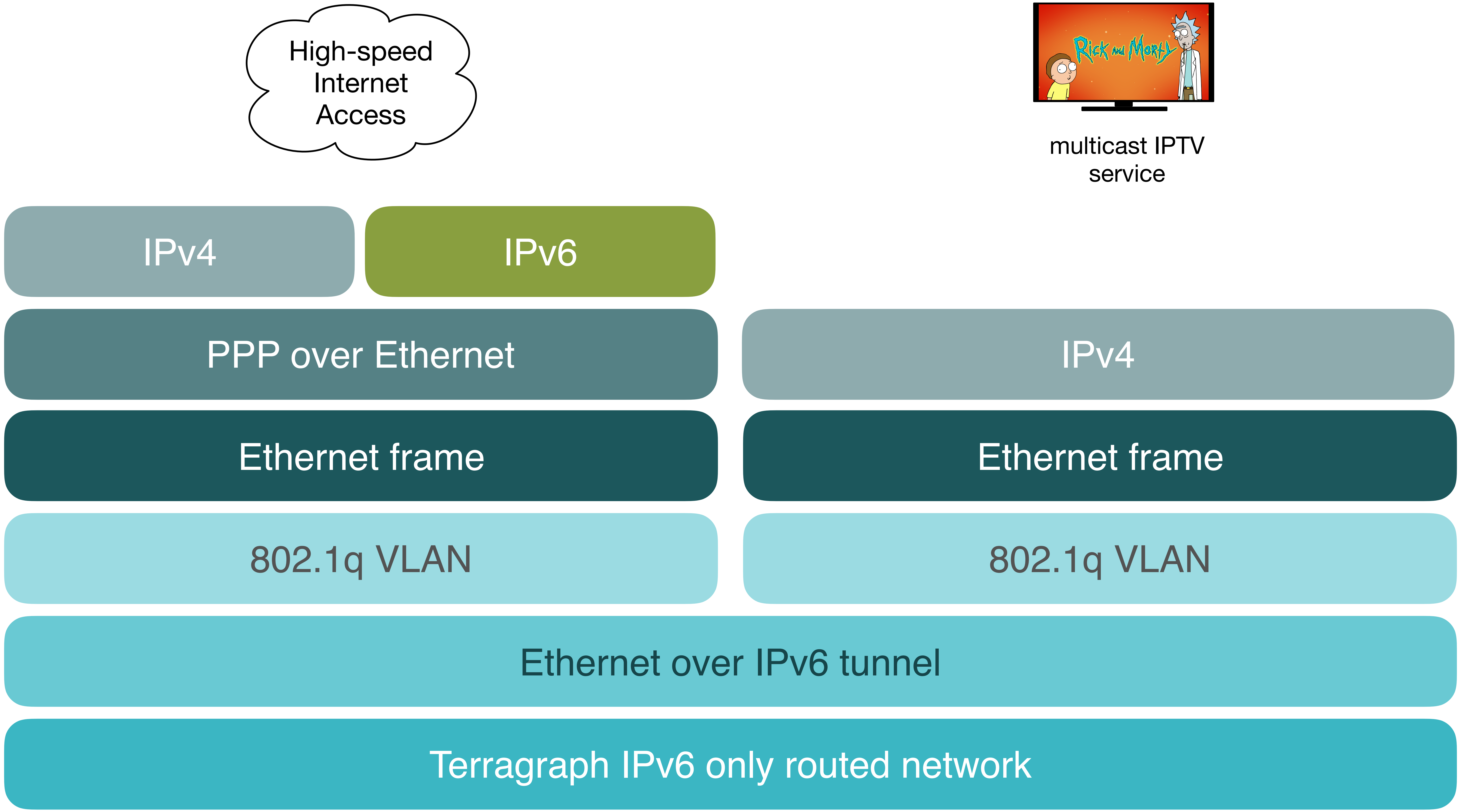




- 500Mbps broadband internet
- SD and HD live TV service with multicast
- Video on Demand service via unicast

RTT: 12ms	**Max DL: 956Mbps**	**Max UL: 965Mbps**	**Simultaneus 35M/35M**	**OSR 1:15**

the service architecture - protocol stacks



how it is done, again?

- CPE serial numbers as identities
- DHCPv6 client to acquire address and to trigger registration
- [fixing EoIPv6 source in case of address change]
- register/update FQDN
- talk to the controller
- 1st time: stand still until new job arrives
- watchdogs, watchdogs and more custom watchdogs

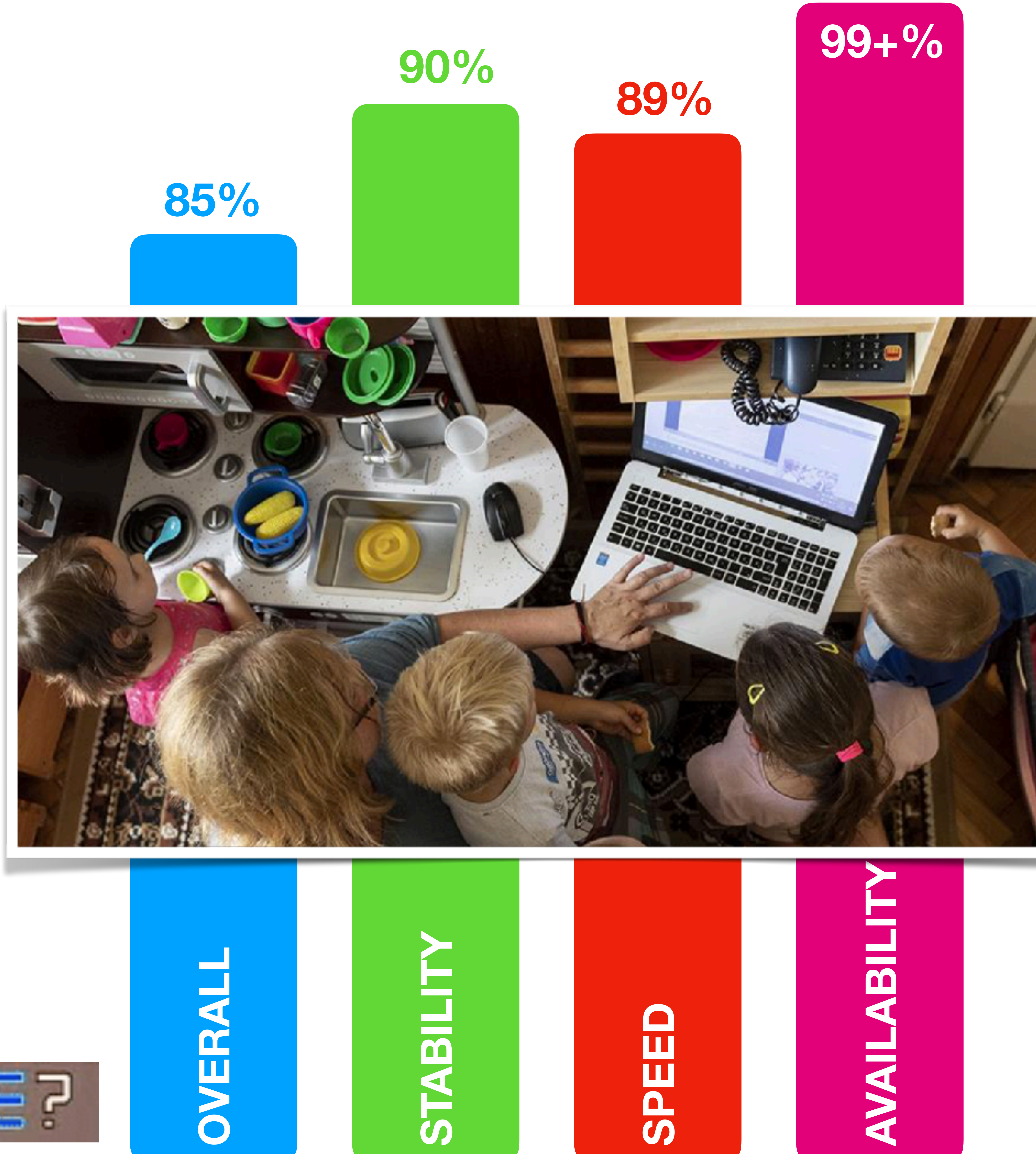
I don't know who you are. What I do have are a very particular set of skills, skills I have acquired over a very long career. I will find you, and I will manage you.

device management (reinvented?)

- ‘Internet of routers’ as in ‘Internet of Things’
- don’t talk, but listen
- CPEs post status, performance data, health data, logs (telemetry)
- CPEs look for jobs to execute:
    - configuration changes
    - command execution
- brought to you by the almighty **`/tool fetch & import`**

RESULTS & OUTLOOK

- Fully automated subscriber provisioning
- network in operation for 9+ months
- 3 month network availability 99.2%
- on-line customer surveys and focus group discussions
- customer satisfaction over 85%



PART II.

MIKROTIK ACCELERATES THE ADOPTION OF 60 GHZ TECHNOLOGIES WITH TERRAGRAPH

24th Feb, 2019 | Announcements

Press Release.
25 February 2019

Riga, Latvia - MikroTik is announcing a collaboration with Facebook to build high-speed connectivity solutions with Terragraph, helping to accelerate the adoption of 60 GHz fixed wireless access technologies to deliver gigabit services and connect more people, faster. The 60 GHz band

Wireless Mesh network

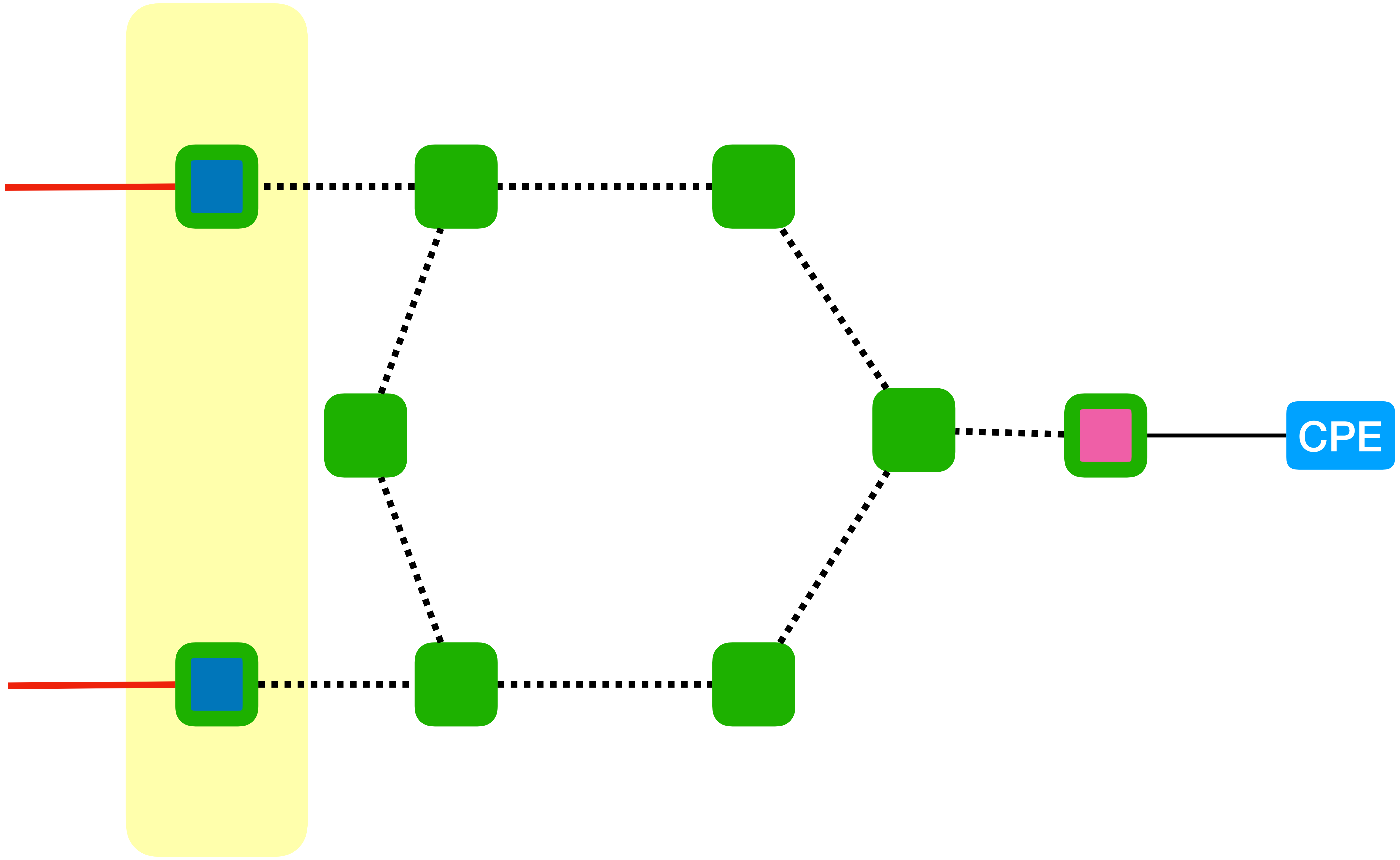
(~100 servings)

- ✓ WiGig support with at least MCS8
- ✓ L3 Routing in radio units
- ✓ Dynamic Routing protocol
- ✓ IPv6 support
- ✗ AP-AP wireless links
- ✗ synchronised network with TDD media access

solving the issues

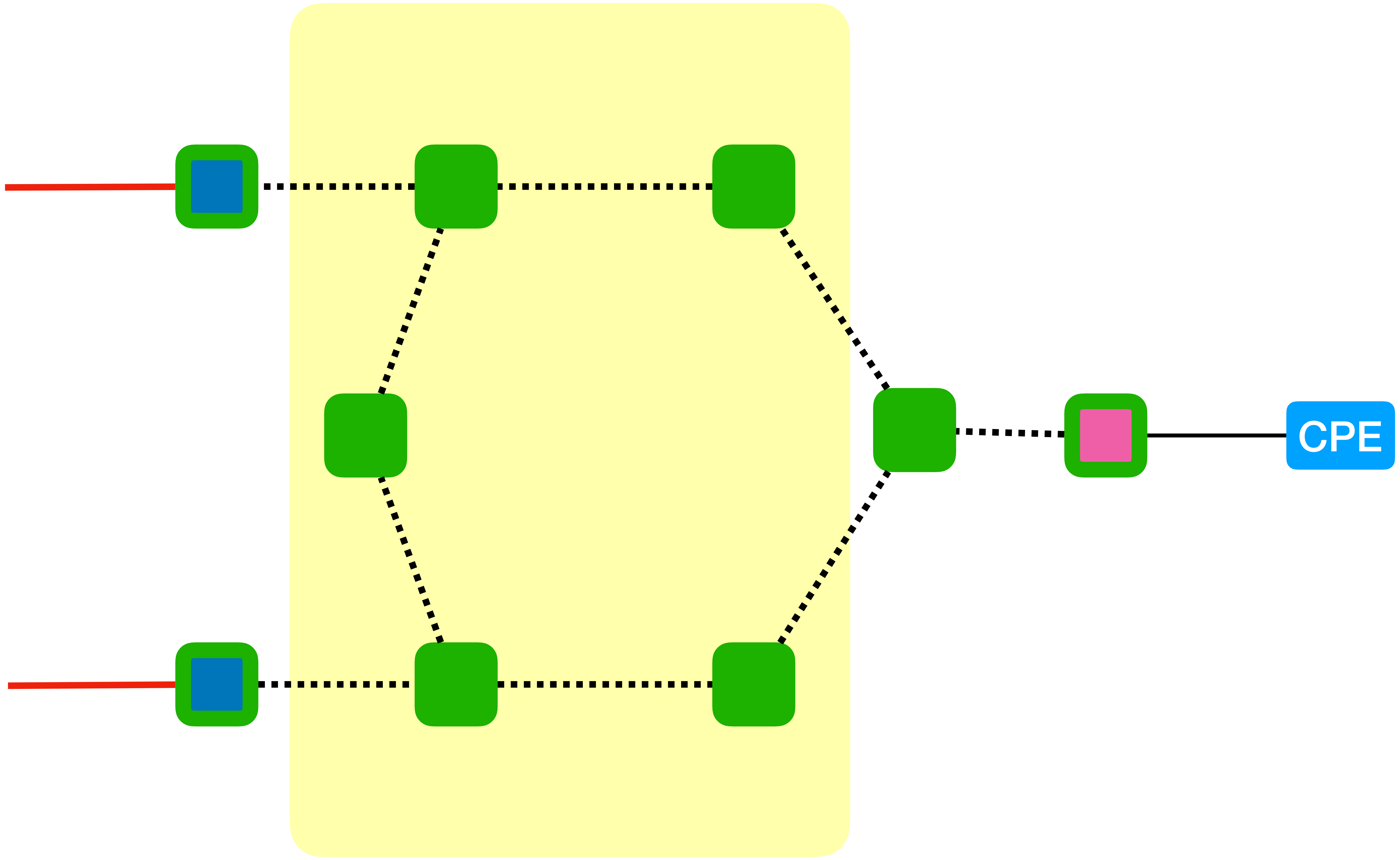
- Open/R >> OSPFv3 (some missing features delivered by HTTP/S)
- no AP-AP links -> dedicated radio for backhaul and for drop
- no TDD/TDMA media access -> relative low number of CPEs / radio
- link coordination -> use multiple SSIDs and ‘w60g station’ entries
- no network management system -> build one!

the network
terminology



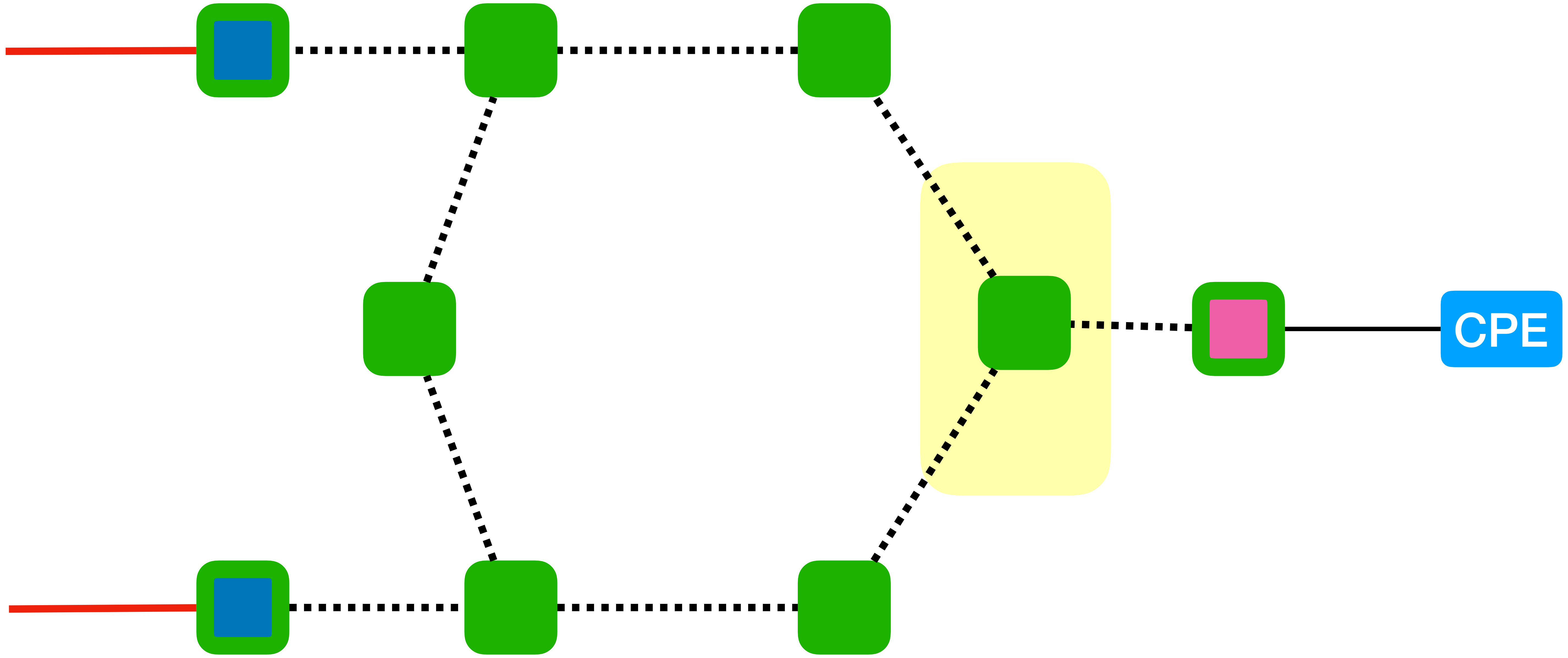
- **Fiber POP**
- connected via 1Gbps SM/MM fiber
- speaks BGP to the outside
- originates default route
- ASBR in OSPFv3
- at least 2 in each mesh

the network
terminology



- **DN BH - backhaul distribution node**
- connected via MCS8+ to neighbouring DNs
- speaks OSPFv3
- wired connection to DN APs

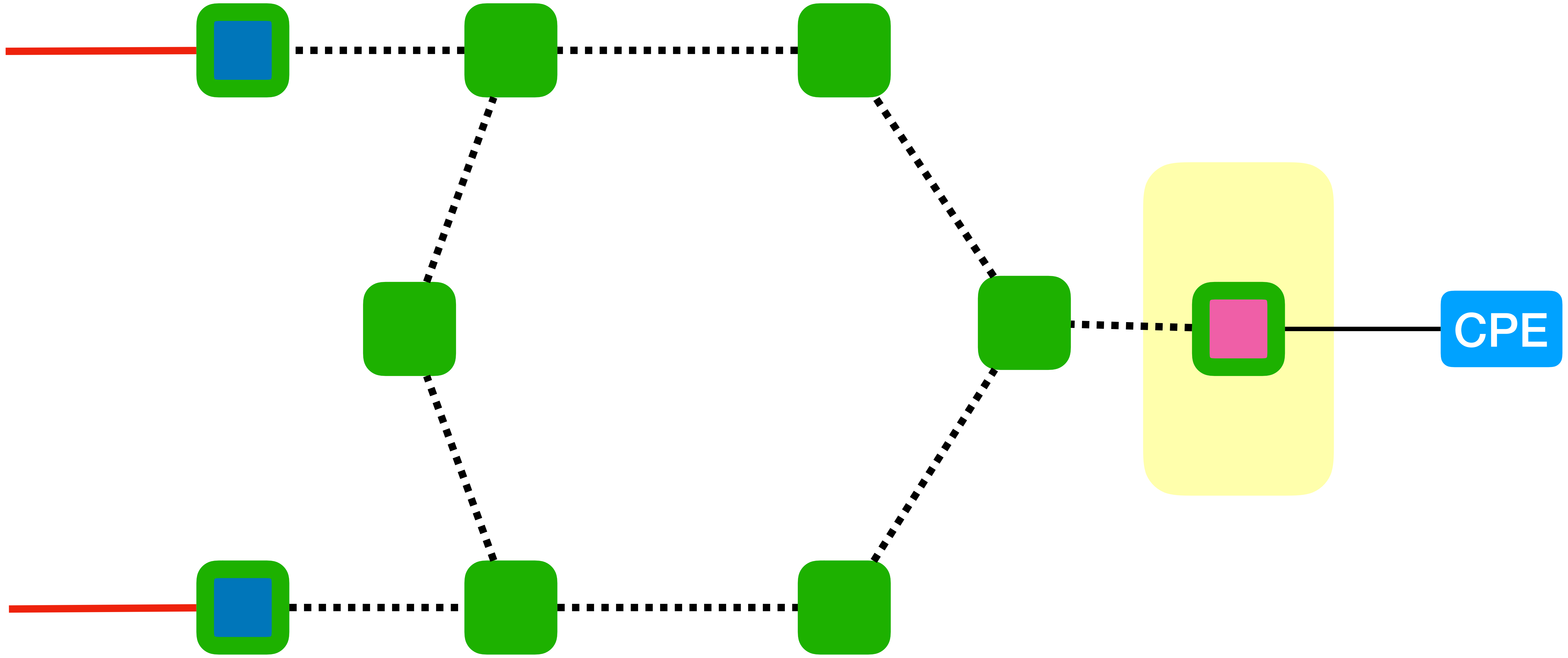
the network
terminology



- **DN AP - drop distribution node**
- CNs connect to it wirelessly
- multiple links / sector
- speaks OSPFv3
- wired connection to DN BHs

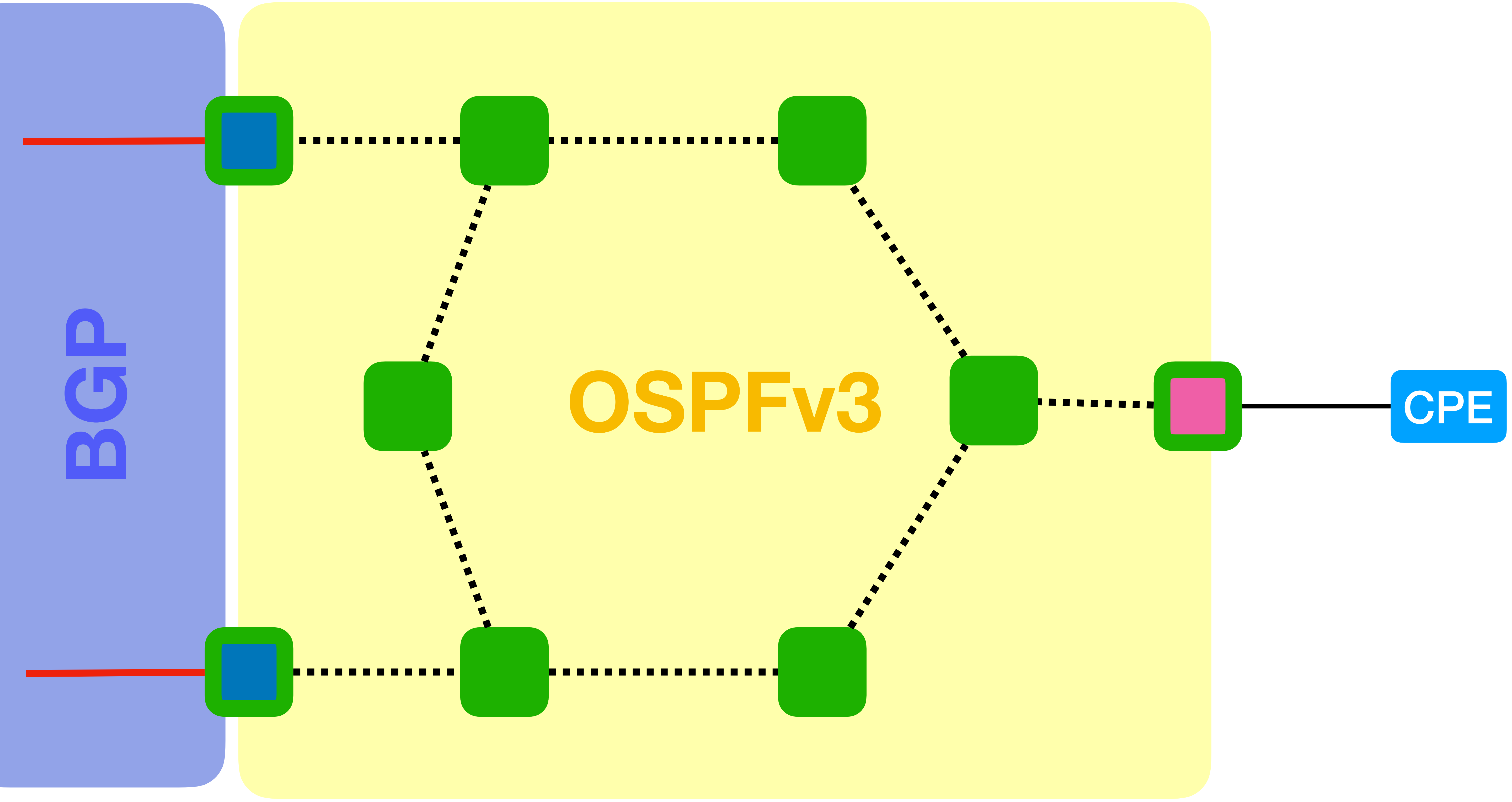
the network

terminology



- **CN - client node**
- connects to DN AP wirelessly
- wired connection to CPE
- starts EoIPv6 tunnels
- speaks OSPFv3
- DHCPv6 PD towards the CPE

the network
routing

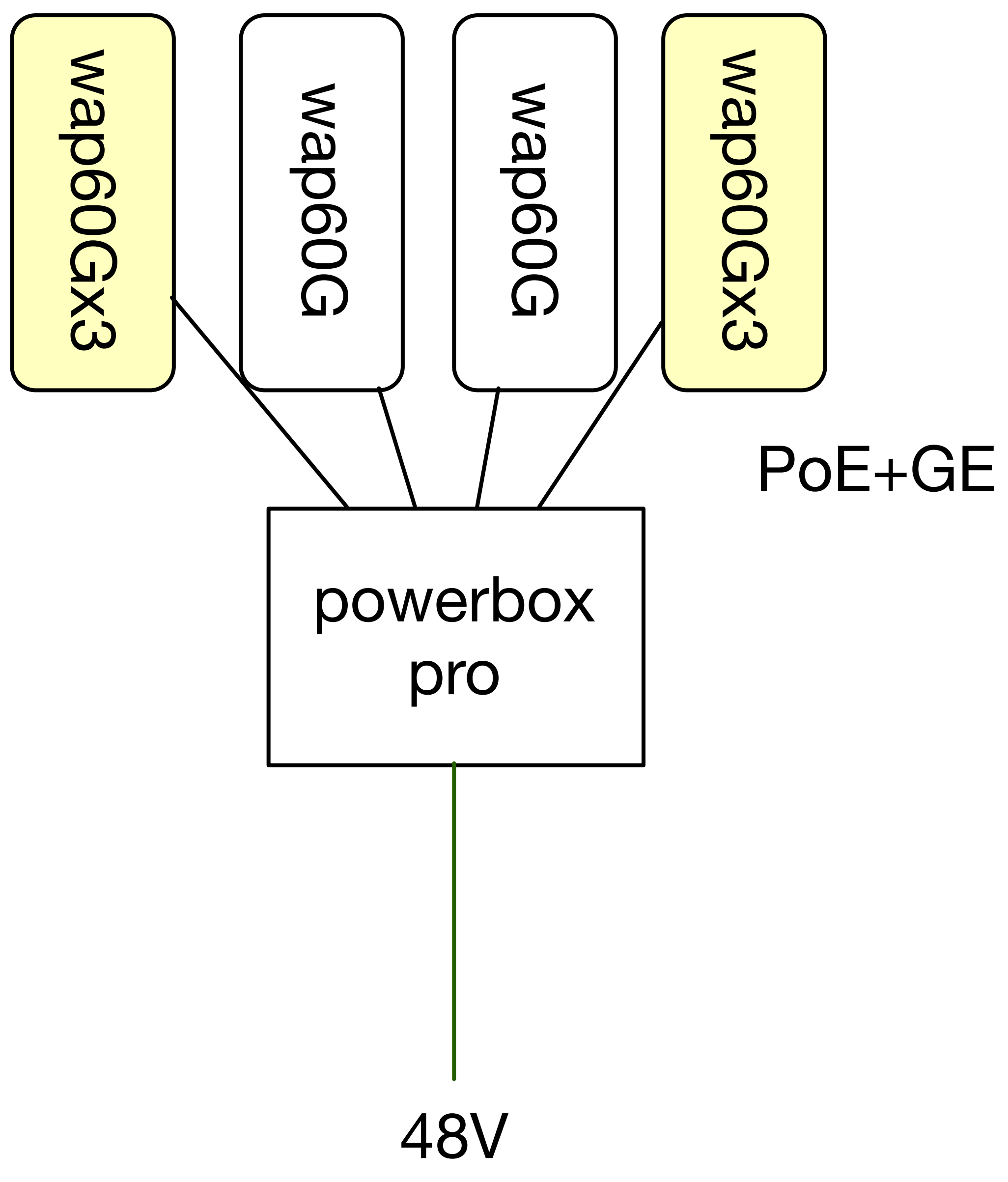


- **Dynamic routing across the entire network**
- node addresses
- subscriber pools

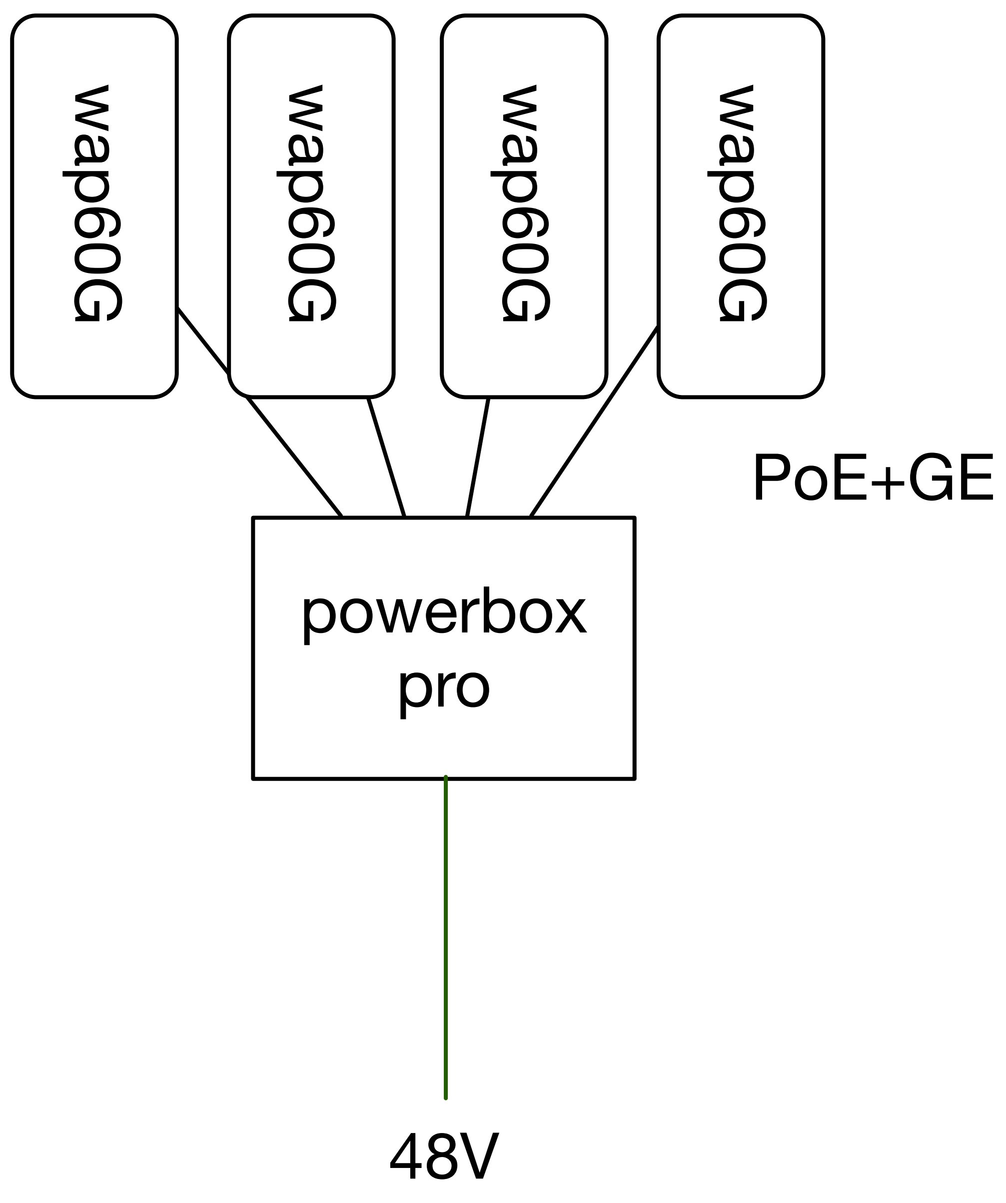
the hardware

- wAP60G (backhaul & CPE)
- PowerBOX Pro (sector interconnect)
- wAP60Gx3 AP (access point)
- SXTsq60 Lite (low end CPE)

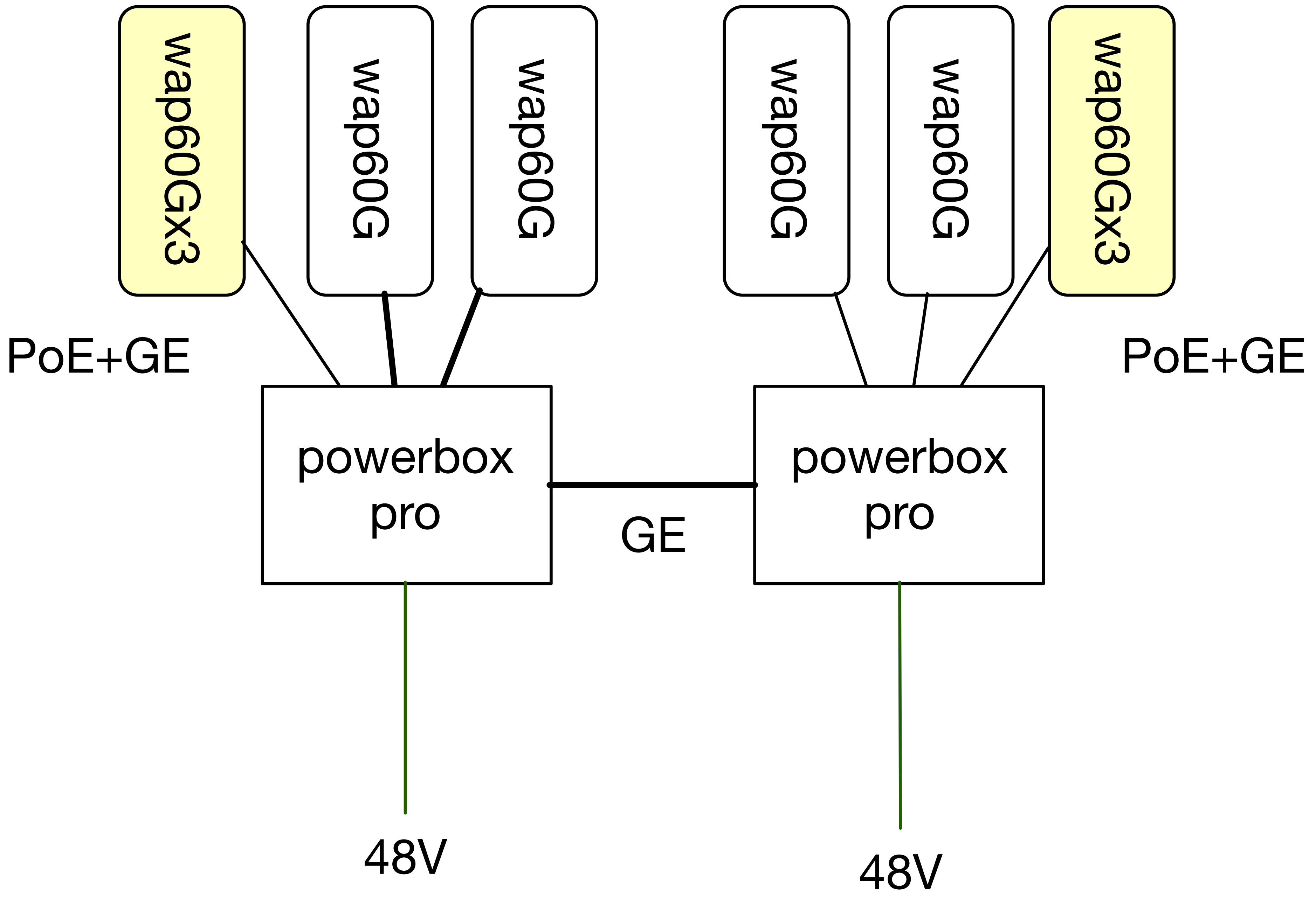
the network
building blocks



mesh node with drop



mesh node



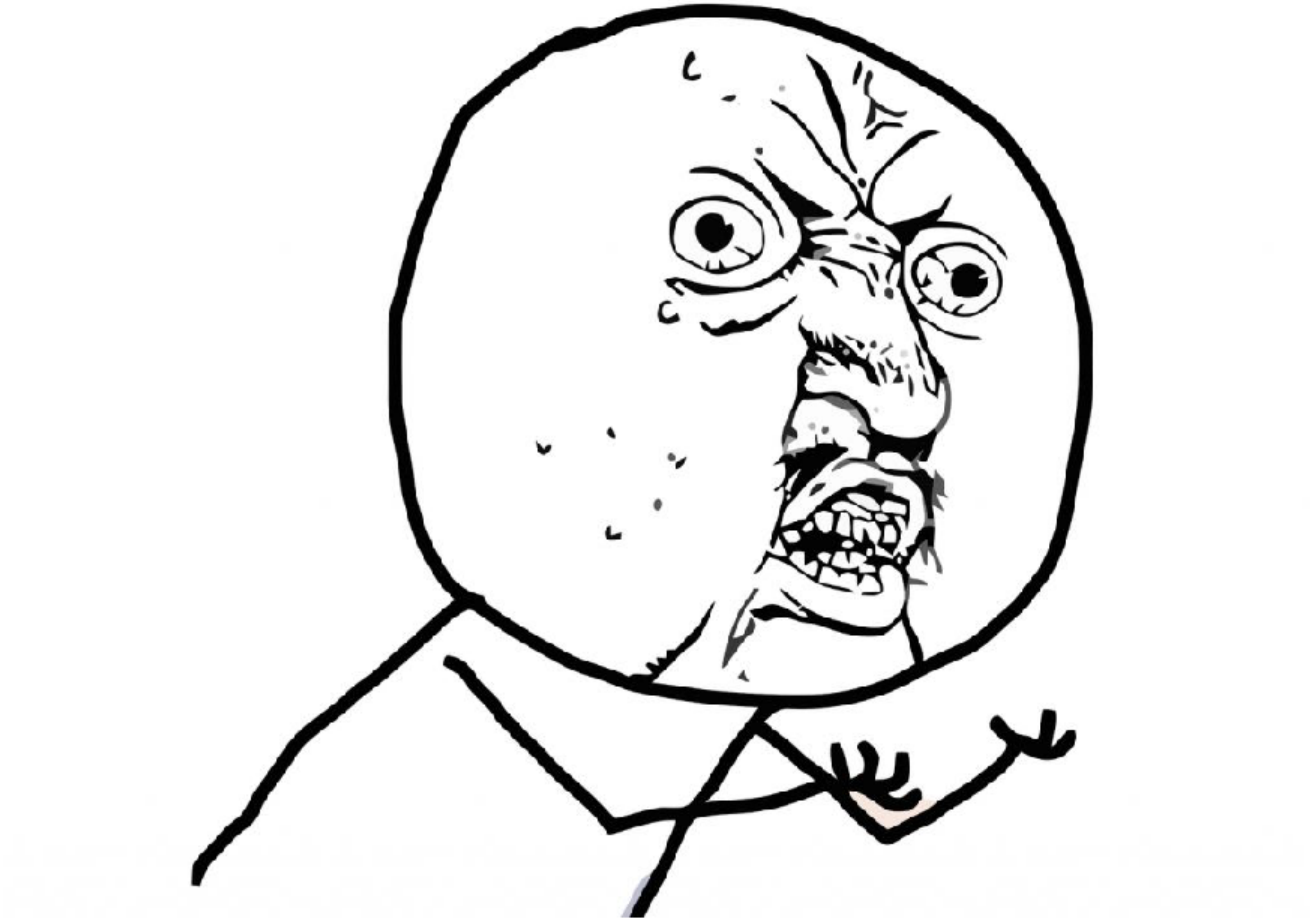
big mesh node with drop

Why IPv6

- plenty of GUA available -> no need to NAT
- Link-local addresses -> link auto addressing with topology hiding
- 64 bits of address range -> flexible unique address generation
- readily supported by routerOS*

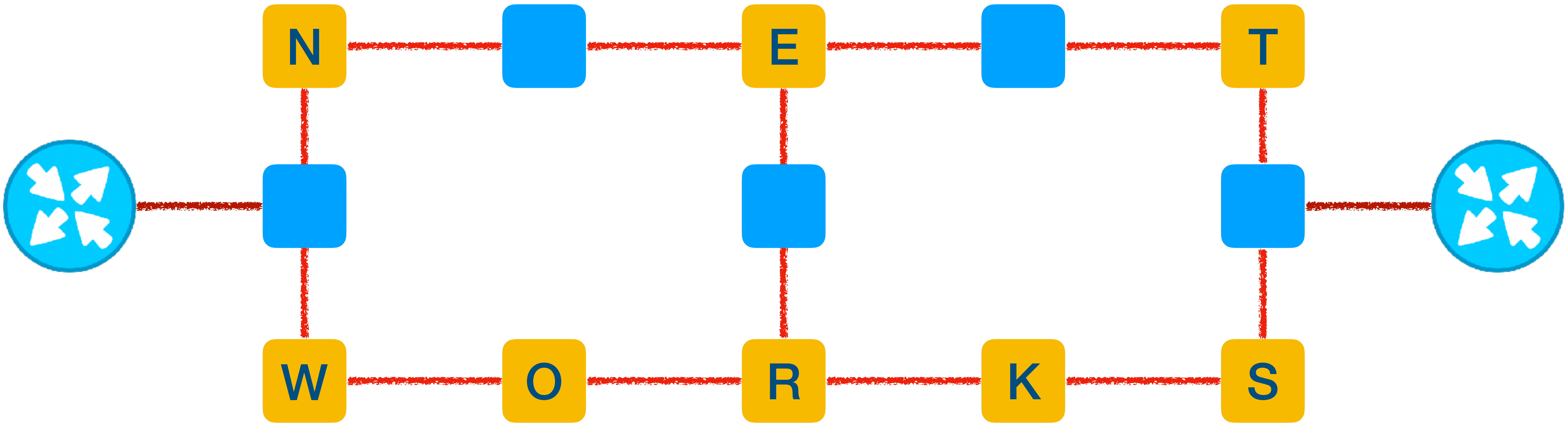
Why OSPFv3

- complex topology, multiple routes, dynamic solution is required
- supports IPv6, works with link local addresses
- faster than RIPng
- point-to-point link support
- BFD support for faster change detection



Why you don’t use just a flat layer-2?

mesh



have loops

I think that I shall never see
A graph more lovely than a tree.
A tree whose crucial property
Is loop-free connectivity.
A tree that must be sure to span
So packets can reach every LAN.

LAYER 2 NETWORKS DON'T MIX PARTICULARLY WELL WITH LOOPS

```
new frame arrived, src: 00:1c:4d:12:34:56 dst: 00:2e:1a:33:44:55, done. new frame arrived, src: 00:1c:4d:
12:34:56 dst: 00:2e:1a:33:44:55, done. new frame arrived, src: 00:1c:4d:12:34:56 dst: 00:2e:1a:33:44:55,
done. new frame arrived, src: 00:1c:4d:12:34:56 dst: 00:2e:1a:33:44:55, done. new frame arrived, src:
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dst: 00:2e:1a:33:44:55, done. new frame arrived, src: 00:1c:4d:12:34:56 dst: 00:2e:1a:33:44:55, done. new
```

Bridge port received packet with own address as source, probably loop

auto addressing

- links with link local addresses just work fine
- to be able to talk to the 'outside', GUA is needed
- let's acquire one from the controller!
- controller is on the outside, so cannot be reached without a GUA

auto addressing, with some help

- what if there could be a hint…
- OSPFv3 can carry routing information of GUA prefixes in a link-local only network
- a special suffix could indicate that this is a ‘hint’
- take the common prefix hint, add something unique -> unique GUA
- routerboard serial numbers are unique by definition

addressing example

:local hint [/ipv6 route get [find where dst-address~"bad:babe/128"] dst-address]

2001:db8:001:603::bad:babe/128

2001:db8:001:603::bad:babe/128 && ffff:ffff:ffff:ffff::

2001:db8:001:603::/128

:local mysn [/sys routerboard get serial-number]

81ED08262E2B

:pick, :pick, :pick, 0000 -> ("0000:" . $part1 . ":" . $part2 . ":" . $part3)

2001:db8:001:603::81ED:0826:2E2B/128

/ipv6 address { remove [find where global and interface="lo0"]; add interface=lo0 address=$loaddr }

addressing rules

- network infrastructure prefix: /64
- node IPv6 address: /128 (loopback)
- network UNI pool: /48
- node UNI address: /64

external connectivity

- BGP advertises mesh aggregate network to the outside (/64-/40)
- OSPFv3 propagetes the BGP provided default into the mesh
- node addresses are not exposed as /128
- all nodes are only reachable via IPv6
- DHCPv6 PD assigned prefixes are redistributed to BGP though OSPF

client connectivity

ethernet emulation

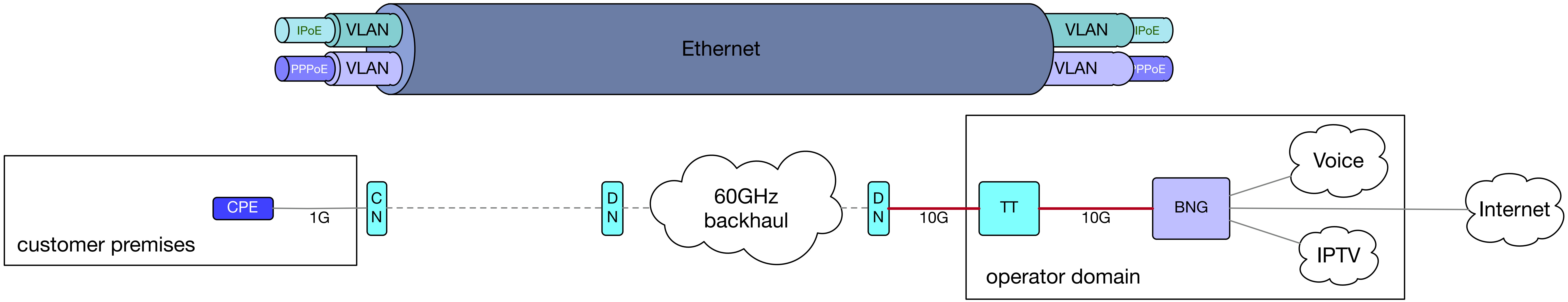
a.k.a legacy

native routed IPv6

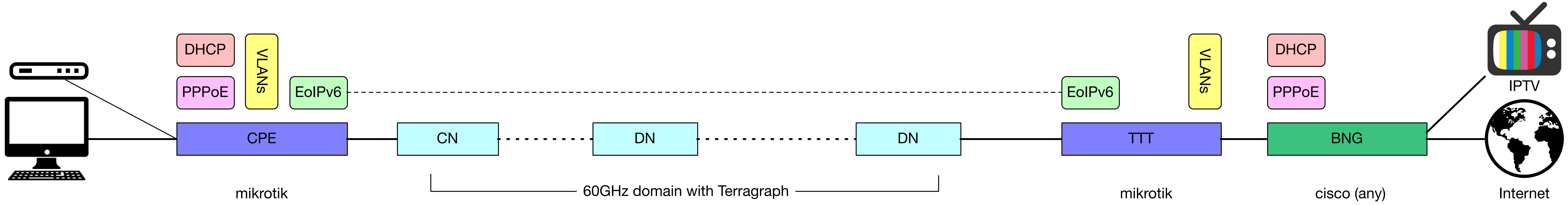
lean and simple

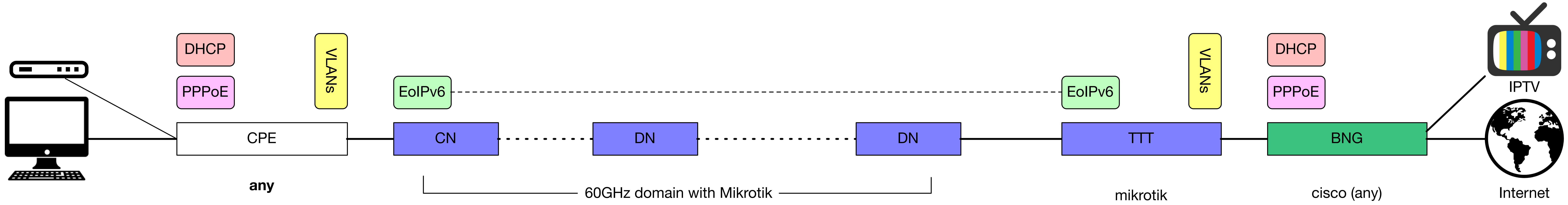
legacy service compatibility

- EoIPv6 tunnels are started in CNs (wAP60G)
- tunnels terminated in CCR (ttt)
- tunnel creation done based on FQDNs and central orchestrator
- 2 VLANs in each tunnel (HSI 1000, IPTV 1001)



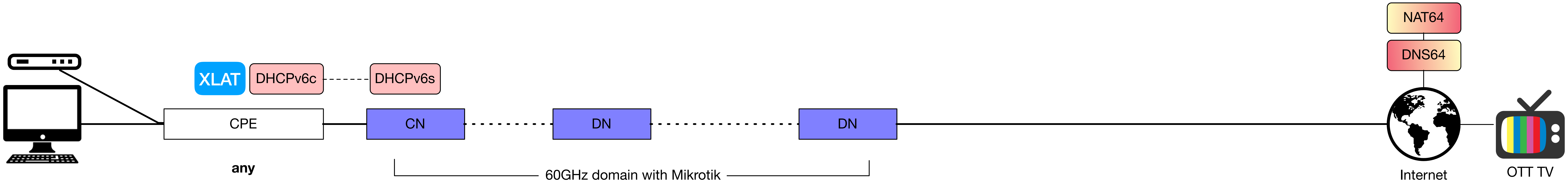
legacy service compatibility





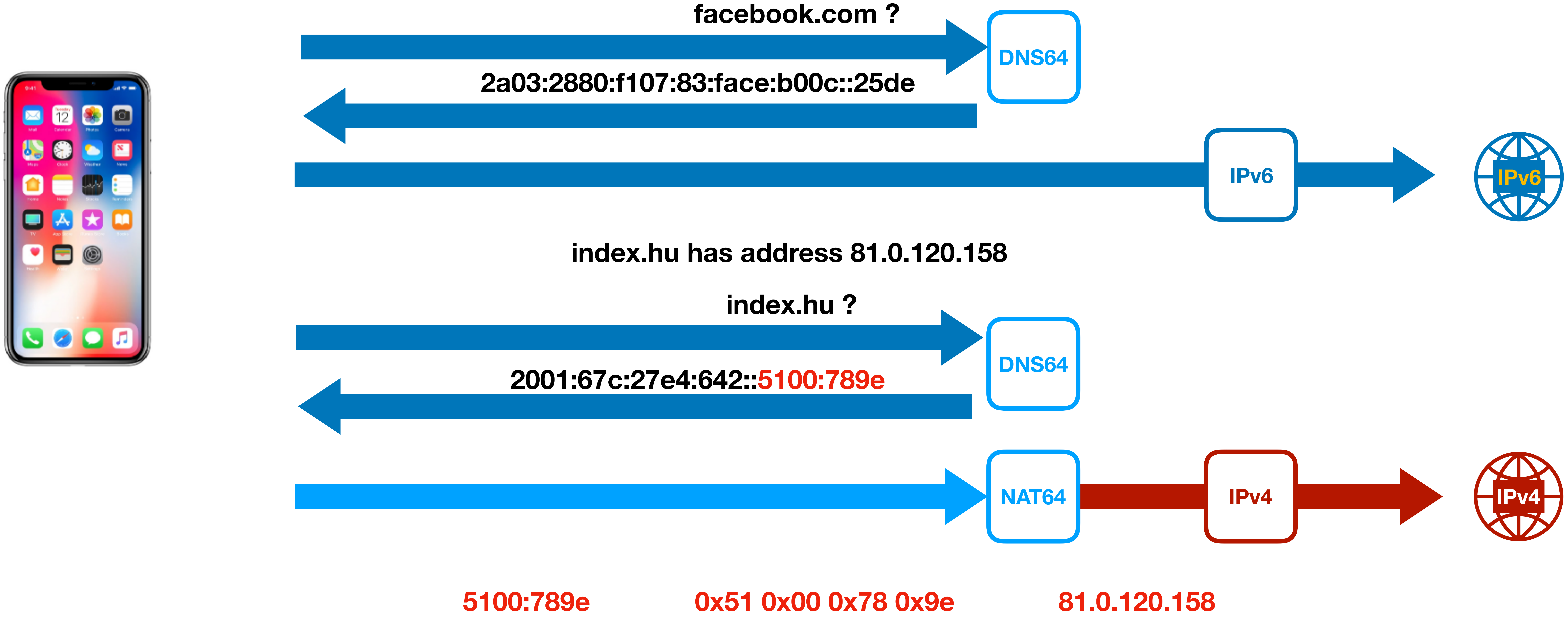
- no crucial difference to existing setup (tunnel initiation changes)
- less functionality in the CPE

modern service delivery



- service creation at the CN, session logging via controller
- end-to-end routed service with IPv6 only access
- NAT64/DNS64 based access to legacy IPv4 resources
- XLAT464* for IPv4 only devices behind the CPE

DNS64/NAT64 crash course



try it here: https://go6lab.si/current-ipv6-tests/nat64dns64-public-test/

automation details

- client initiated communication
- DNs and CNs push and pull data from controller using HTTPS
- node identification based on serial numbers
- non-managed DN nodes show up as TN (trans-node)
- controller to provide final settings (SSID, password, mode, frequency)
- CPE management can be done based on TR-069

toolchain

- nginx (reverse proxy, static content)
- influxDB (time series DB)
- mySQL (config data - so far)
- grafana (data visualisation)
- perl/dancer (web application)
- `/tool fetch` & `/system script` & `/system scheduler` (routeros integration)

room for improvement

- more responsive interaction on automation
  - less complex protocol, like MQTT (pubsub) would be nice
- MCS9+ for backhaul
- support for Terragraph MAC & PHY layer
- Terragraph compatible AP-AP link support
- multi baseband units for more throughput
- N-BaseT for more capacity

thanks for the attention