SERVICE PROVIDER NETWORK EVOLUTION

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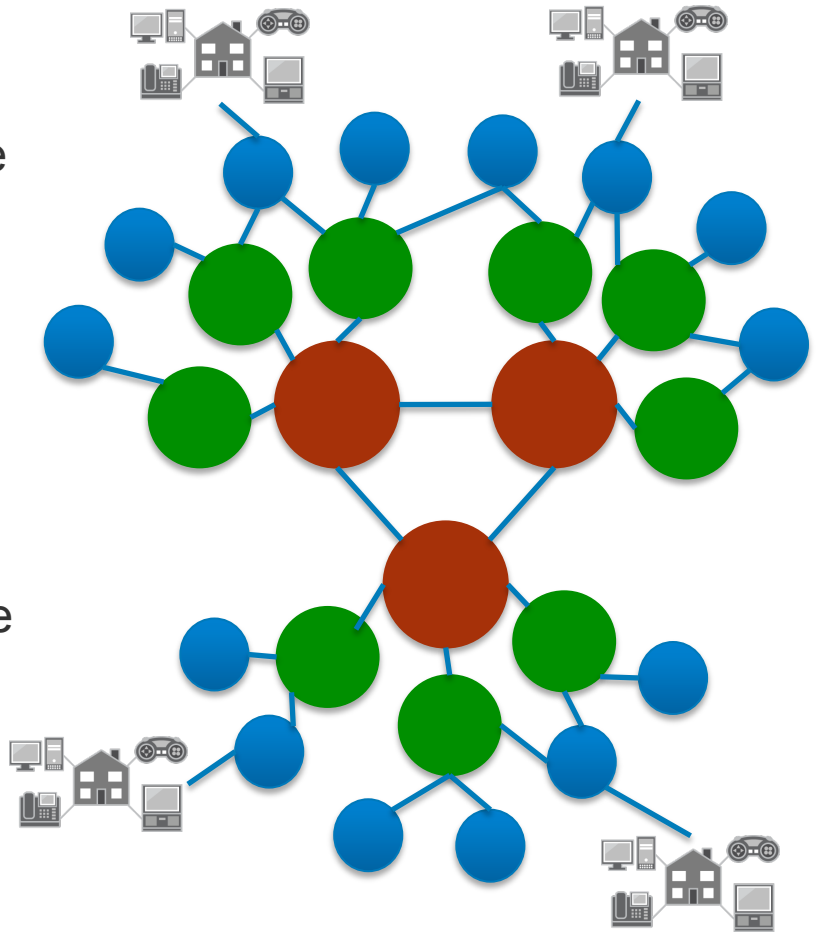
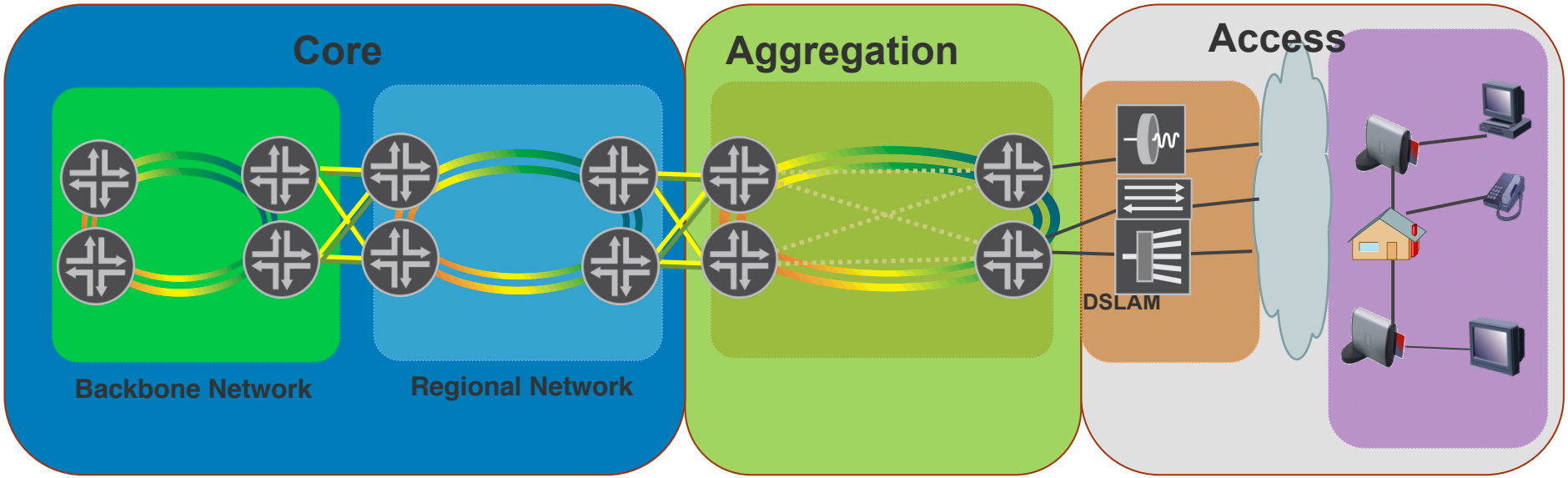
THE HIERARCHY OF NETWORK DESIGN

- **Edge** – the boundary between the service-provider's premises and the customer's location. The concentration point where large numbers of customer connections will be terminated
- **Aggregation** – A concentration point where data from multiple Edge locations will be funneled
- **Core** - the heart of the network. The major switching locations that form the center of the network, where data from multiple Aggregation sites will be funnelled
  - This is typically where one sees the highest volume of data present in the network



REFERENCE ARCHITECTURE WIRELINE SP

- Few core locations
- Larger number of aggregation points
- Much larger number of access points

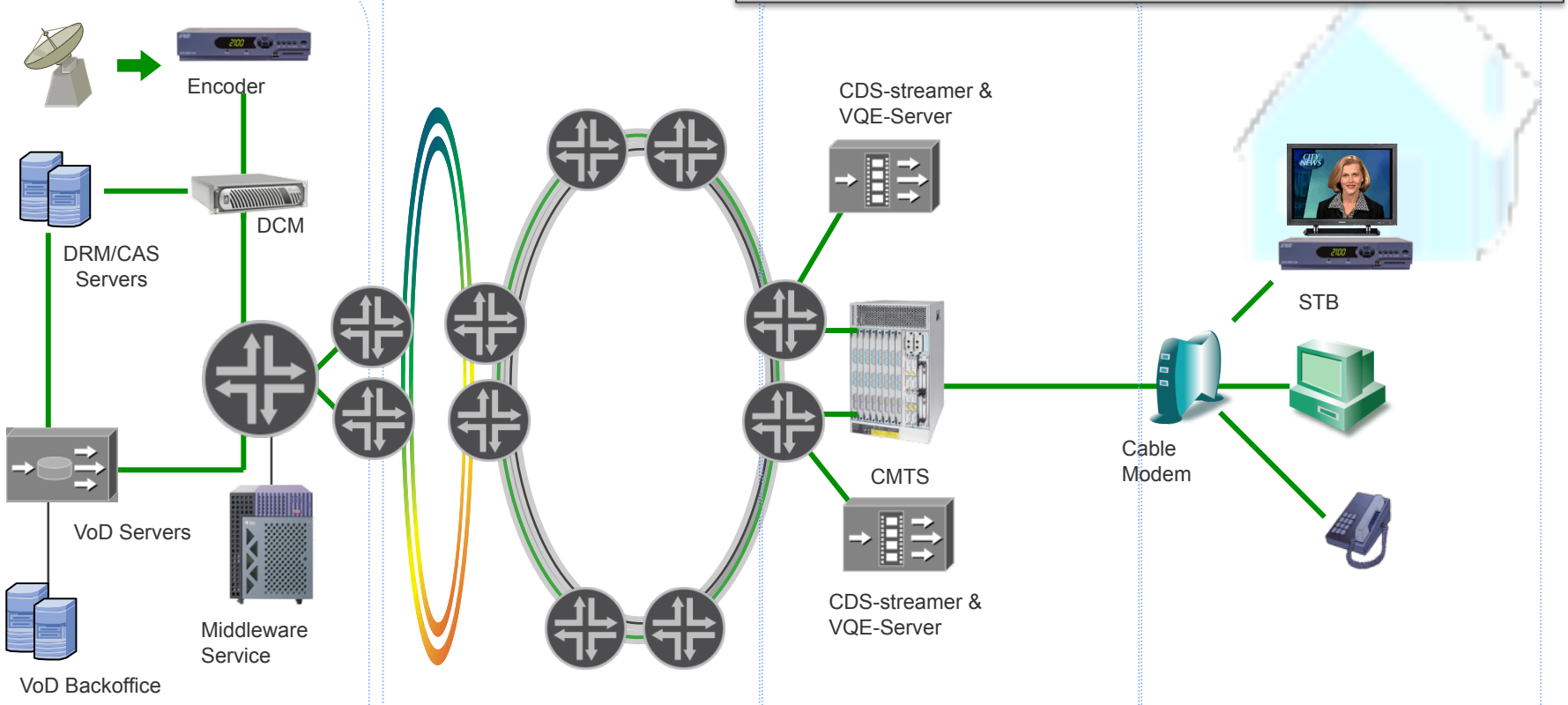


Speeds and feeds:

- Access – 28.8k to 1Gb – 100's to 1000s of subscribers per device
- Aggregation – 155Mb to 10Gb – 1000s to N*10000s of subscribers per device
- Core – 155Mb to N*40Gb – N*1000000s of subscribers per device

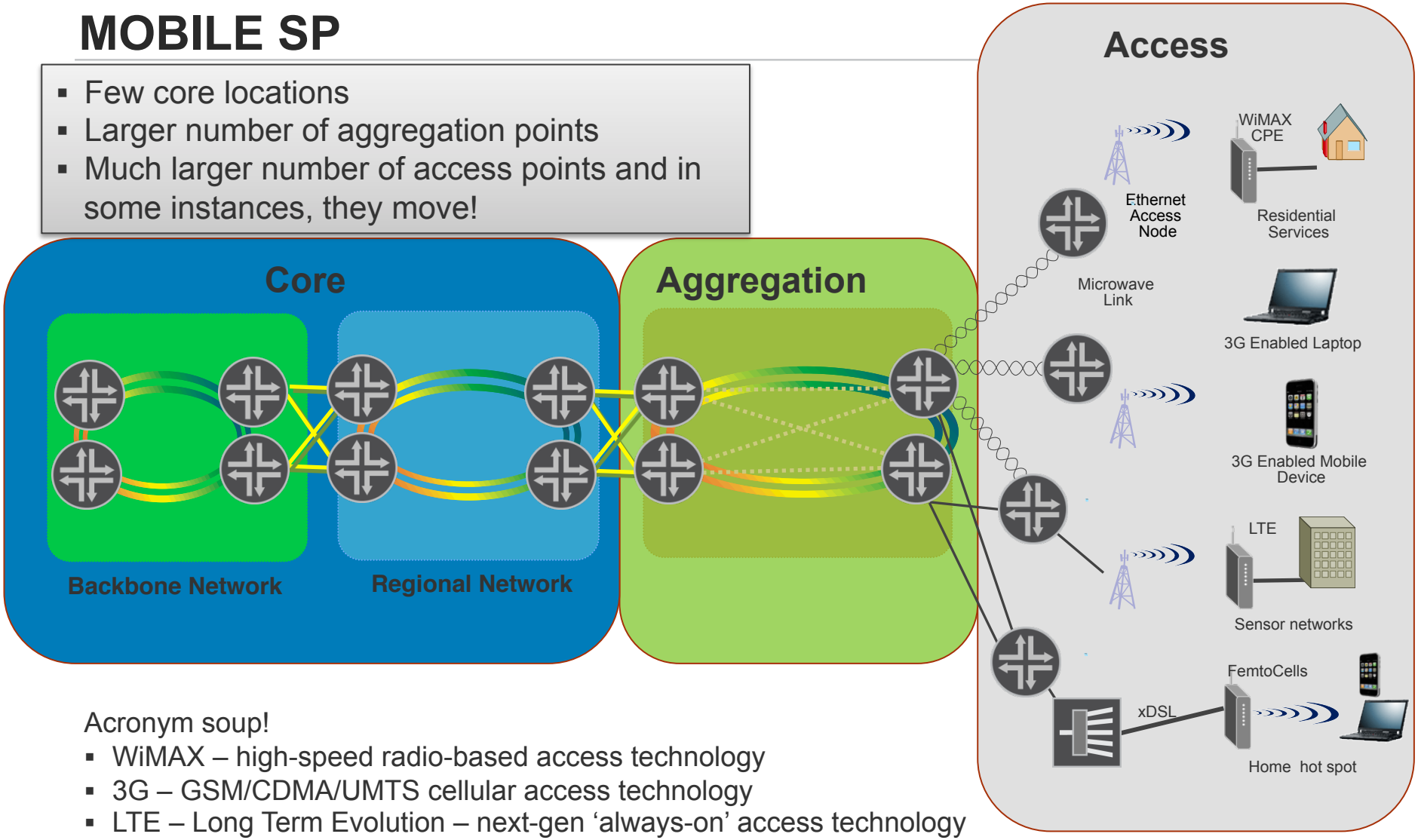
REFERENCE ARCHITECTURE
CABLE SP

- Few core locations
- Larger number of aggregation points
- Much larger number of access points



REFERENCE ARCHITECTURE MOBILE SP

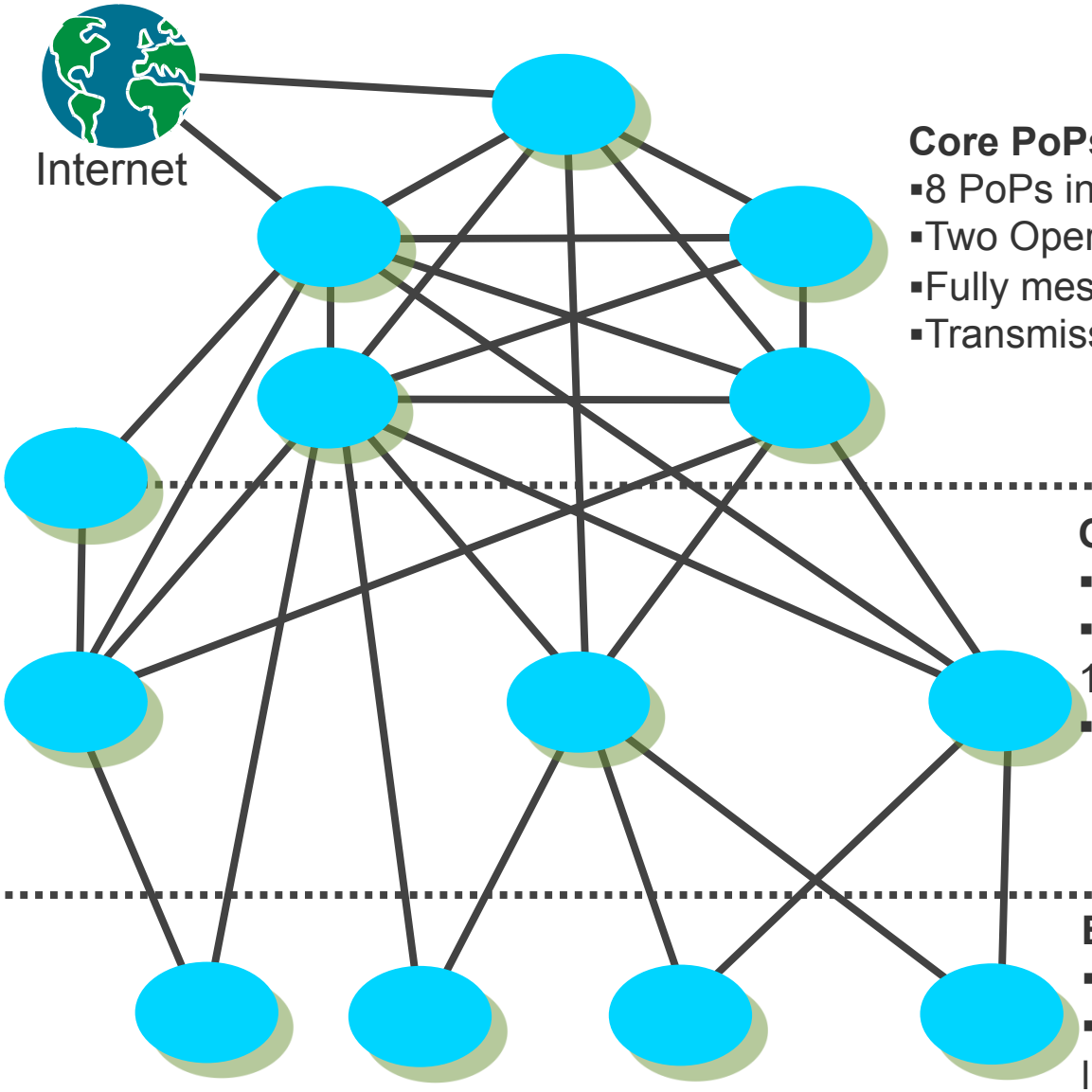
- Few core locations
- Larger number of aggregation points
- Much larger number of access points and in some instances, they move!



Acronym soup!

- WiMAX – high-speed radio-based access technology
- 3G – GSM/CDMA/UMTS cellular access technology
- LTE – Long Term Evolution – next-gen 'always-on' access technology
- FemtoCell – 'In your home' 3G base-station using IP backhaul

REAL WORLD EXAMPLE – UK Service Provider



Core PoPs
- 8 PoPs including 2-4 Internet peering points
- Two Operations Centers
- Fully meshed – multiple parallel 10Gbit/s links
- Transmission layer resilience

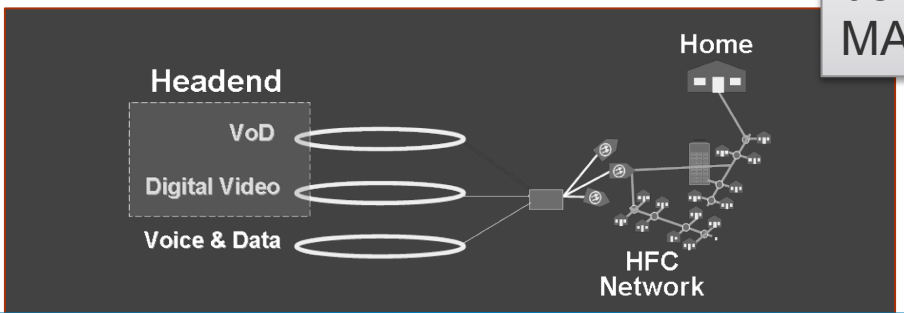
Outer Core/Aggregation PoPs
- 12 PoPs
- At least triple-parented off Inner Core – 10Gbit/s links
- Transmission layer resilience

Edge PoPs
- 86 PoPs
- Dual-parented off Core – 10Gbit/s links

WHERE'S THE EVOLUTION?

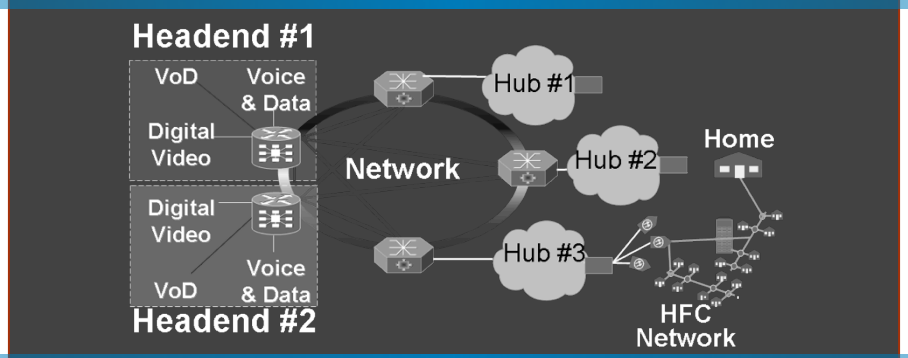
Emerging markets may be 3-4 years behind or MAY leapfrog!

2003



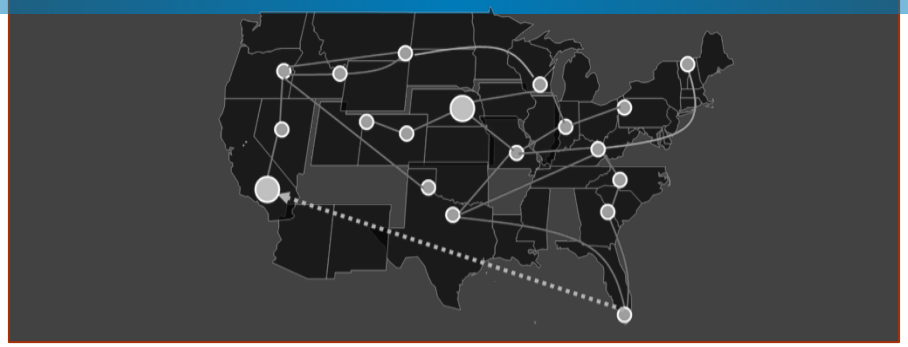
Siloed Network

2006-2008



Network Convergence

2009-2012?



Service Commonality
Full Location &
Device Independence

WHERE'S THE EVOLUTION?

Mobile handset data traffic already outstripping voice traffic

Mobile handset data growth continues to outstrip wireline growth

- Mobile customers not prepared to pay extra for Data!
  - Pricing plan changes for high-data users, a la AT&T

Mobile SPs paid $$$Bn for operating licences

- Mobile market 'saturating' in many countries
- Not seeing ROI
- Need to expand target market -> traditional wireline space?

LTE/Sensor networks starting to appear

WHERE'S THE EVOLUTION?

Growth of 'catch-up' TV and other 'over the top' services like Gaming networks (Xbox live, Playstation, Wii etc)

- More content on 'over the top' service
  - Movies on Demand
  - Games rental

Business customers looking for value-add services

- Still very early days of bandwidth intensive collaboration tools like Hi-Definition Video Conferencing, etc. but seeing significant growth

Massive costs of last-mile technology investments

- Are Wireline customers prepared to pay proportionally for increased BW?
  - Proposed UK Broadband tax!!!
- Are radio-based technologies a more cost-effective solution?

Core / Edge bandwidth dilemma

- New capacity filled in very short period of time
- Oversubscription vs excess capacity
- Content Caching– back in favour?
- Intelligent distribution towards the network edge

Service-level expectations

- Return on investment of CAPEX vs SLA penalties
- OPEX/CAPEX budget reductions

DESIGN EVOLUTION

Converging offerings from Wireline & Mobile service providers

- Need to define service differentiation to maintain and grow market share (content deals for example)

Transmission systems investment choice

- Ethernet (10GE / 100GE) vs SONET (OC192/OC768)

Integrated IPv4/IPv6/MPLS networks

Collapsing Core & Aggregation, Core & SP-2-SP Edge (Transit)

High-density Multi-service edge

- 1 box for Layer 3 and Layer 2 services

Always-on Bandwidth demand

- No quiet-periods of the day!
- Set-top Box evolution
- LTE/Sensor networks

Emerging markets may be 3-4 years behind or MAY leapfrog!

THE CLOUDS ARE BUILDING

"IT resources and services that are abstracted from the underlying infrastructure and provided "on-demand" and "at scale" in a multi-tenant environment."

Software as a Service:
Applications services delivered over the network on a subscription basis

Platform as a Service:
Software development frameworks and components delivered over the network on a pay-as-you-go basis

Infrastructure as a Service:
Compute, network and storage delivered over the network on a pay-as-you-go basis

AND TALKING OF BUILDINGS… SMART GRID / BUILDING / HOME

“A smart grid delivers electricity from suppliers to consumers using digital technology to save energy, reduce cost and increase reliability...Such a modernized electricity network is being promoted by many governments as a way of addressing energy independence, global warming and emergency resilience issues.”

A "home grid" extends some of these capabilities into the home using powerline networking and extensions to DC (power over Ethernet).

Because the communication standards both smart power grids and home grids build on, support more bandwidth than is required for power control, a home grid generally has megabits of additional bandwidth for other services (burglary, fire, medical and environmental sensors and alarms, ULC and CCTV monitoring, access control and keying systems, intercoms and secure phone line services), and accordingly can't be separated from LAN and VoIP networking, nor from TV

Consumer electronics devices now consume over half the power in a typical US home. Accordingly, the ability to shut down or hibernate devices when they are not receiving data could be a major factor in cutting energy use.

http://en.wikipedia.org/wiki/Smart_grid

TRANSMISSION EVOLUTION

TRANSMISSION EVOLUTION – CORE & AGGREGATION

Leased line

- E0/DS0, E1/T1, E3/T3

PDH / SDH/ SONET/ WDM

- OC1 - >OC768
- GE -> 10GE

DWDM

- Multiple Terrabit systems
- IPoDWDM interfaces on routers (10GE/100GE/40G POS)
- OTN interfaces

ATM / Frame-Relay / X.25

- DS0 -> E1 -> OC48

- Some customers leapfrogging older technologies to leading edge systems
- Leading edge does not always mean most costly!
- Legacy systems last – a LONG TIME!

TRANSMISSION EVOLUTION – EDGE

- Some customers leapfrogging older technologies to leading edge systems
- Leading edge does not always mean most costly!
- Legacy systems last – a LONG TIME!

PSTN/ISDN

Leased line

- E0/DS0, E1/T1, E3/T3, xDSL

PDH/SDH

- Ethernet

FTTx

- Multiple Megabit systems some using EPON/GPON transport

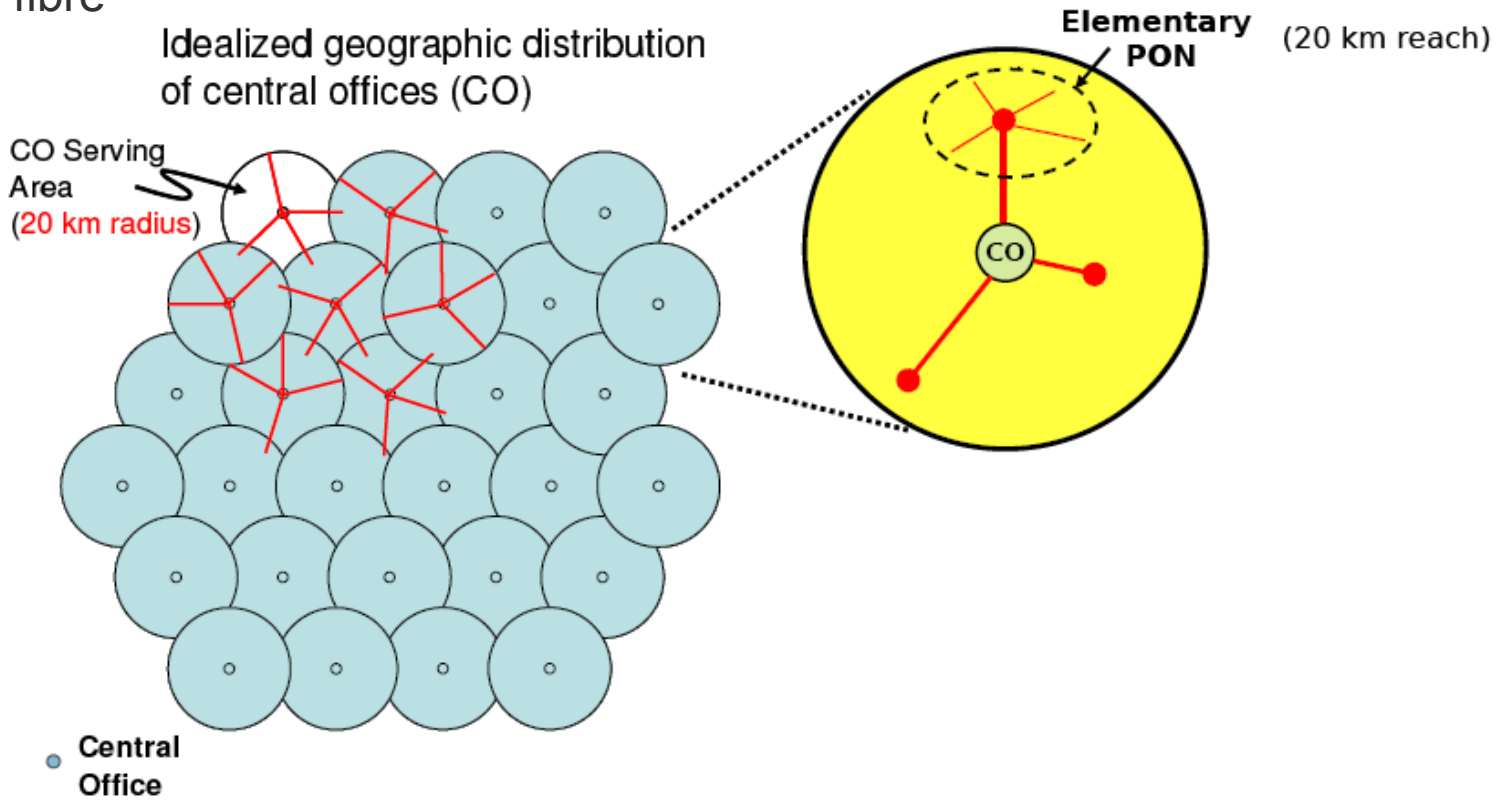
Radio-based access

- 2G,3G,WiMAX, HSDPA, LTE

NEXT GENERATION PON ACCESS

Moving to Next-gen fibre access fundamentally changes residential coverage of a Central Office

- ~8 km on high-quality copper
- 20km on fibre

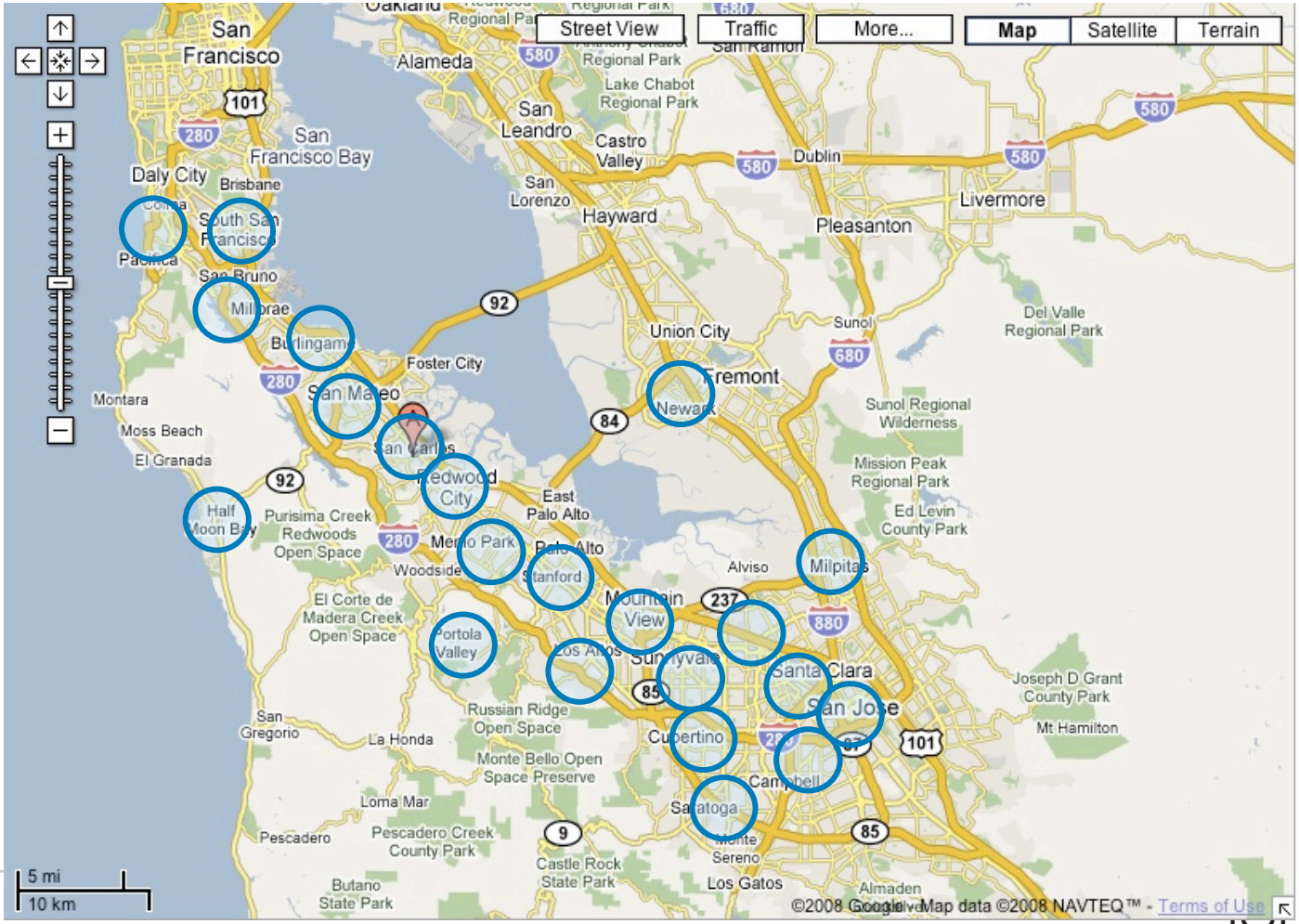


Idealized geographic distribution of central offices

Source: BT, AT&T, 2008

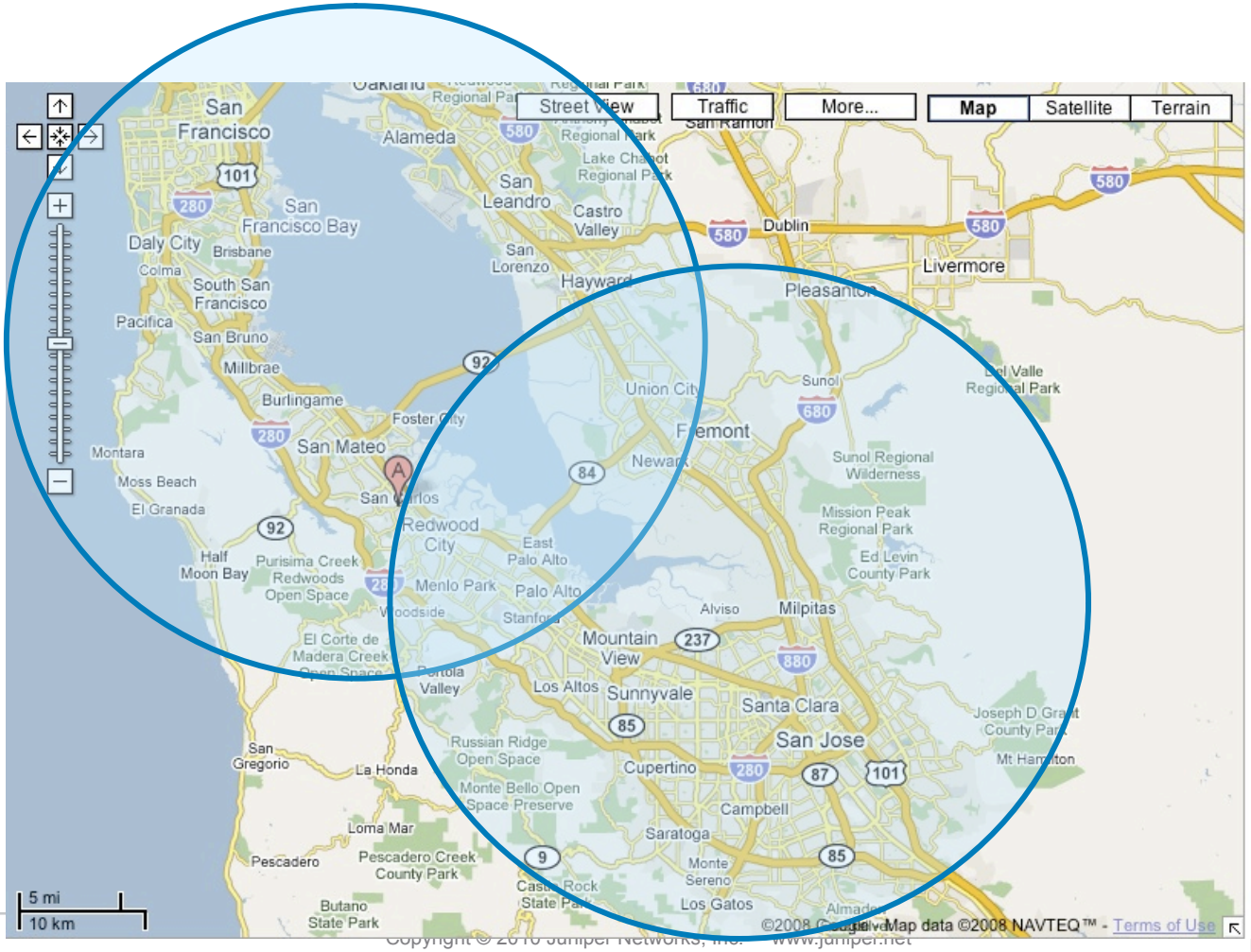
NEXT GENERATION PON – IMPACT OF LONG REACH

As operators cherry pick neighborhoods, selected COs would be decommissioned, others upgraded



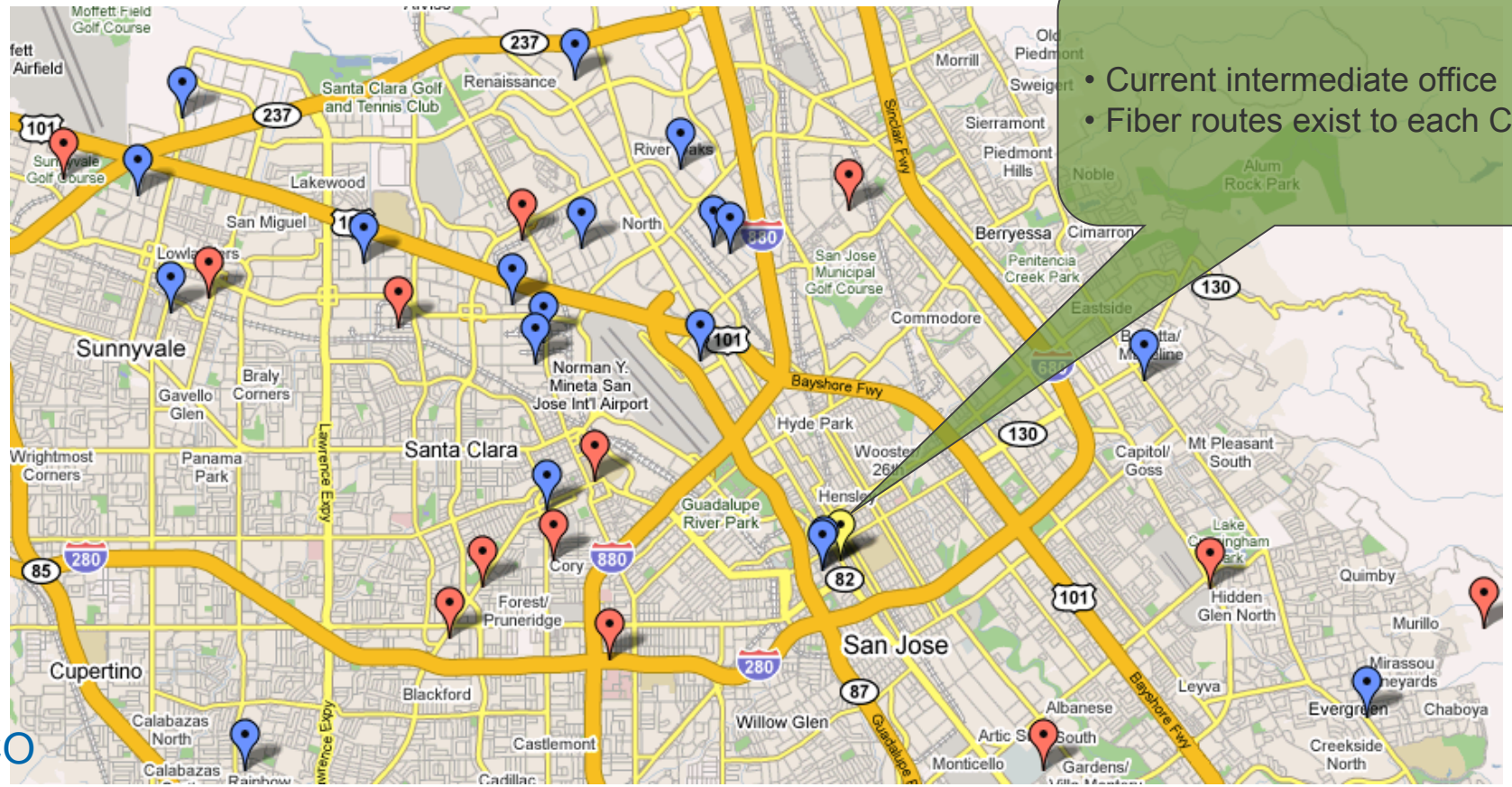
NEXT GENERATION PON: ENABLES NEW CO DESIGN

Two new central offices could replace dozens of CO in the Bay Area



NEXT GENERATION PON – HOW BIG IS THE NEW CO?

There are over 10 COs to serve Sunnyvale, Santa Clara and San Jose.
They could all be consolidated into "1."



CO

Wireless BTS

Source: FCC, American Towers, 2008

IMPACT OF VIDEO AND IP RICH MEDIA ON SP NETWORKS

Worldwide SPs are enhancing their service offering (VoIP, HSD, Video, VPNs, etc…)

- Significant increase in network bandwidth
- Continual increase in per flow bandwidth
- Duration of flows continues to increase

High bandwidth flows reduce the number of active flows that can be supported per 10Gig link

Flow Type	w Bandwidth (Mbps)	#Flows/ 10G Link
Raw HD-TV	1 Gbps	10.00
HD-TV (MPEG-2)	13 Mbps	769.23
HD-TV (MPEG-4)	6 Mbps	1666.67
SD-TV	3 Mbps	3333.33
Video Confrerence	384 kbps	26041.67
VoIP	32 kbps	312500.00

IEEE 40G/100G ETHERNET STANDARDS

802.3 Higher Speed Study Group (HSSG) formed July, 2006

802.3ba Task Force Formed in Jan, 2008

Group is working on development of standards for both 40GE and 100GE, and over distances of up to 40km

- 40GE originally targeted for server interconnect and DC, but likely to proliferate into other areas as well

Standard completed June, 2010

Interface & linecards announced by multiple Router and Transmission vendors

Expect 9-12 month delay in adoption

THAT'S TOMORROW – WHAT ABOUT TODAY?

For some customers, high CAPEX costs of moving to 40G POS make it unattractive – are prepared to wait for the expected lower-cost 100GE solutions

- Many upset by initial prices from vendors for 100GE

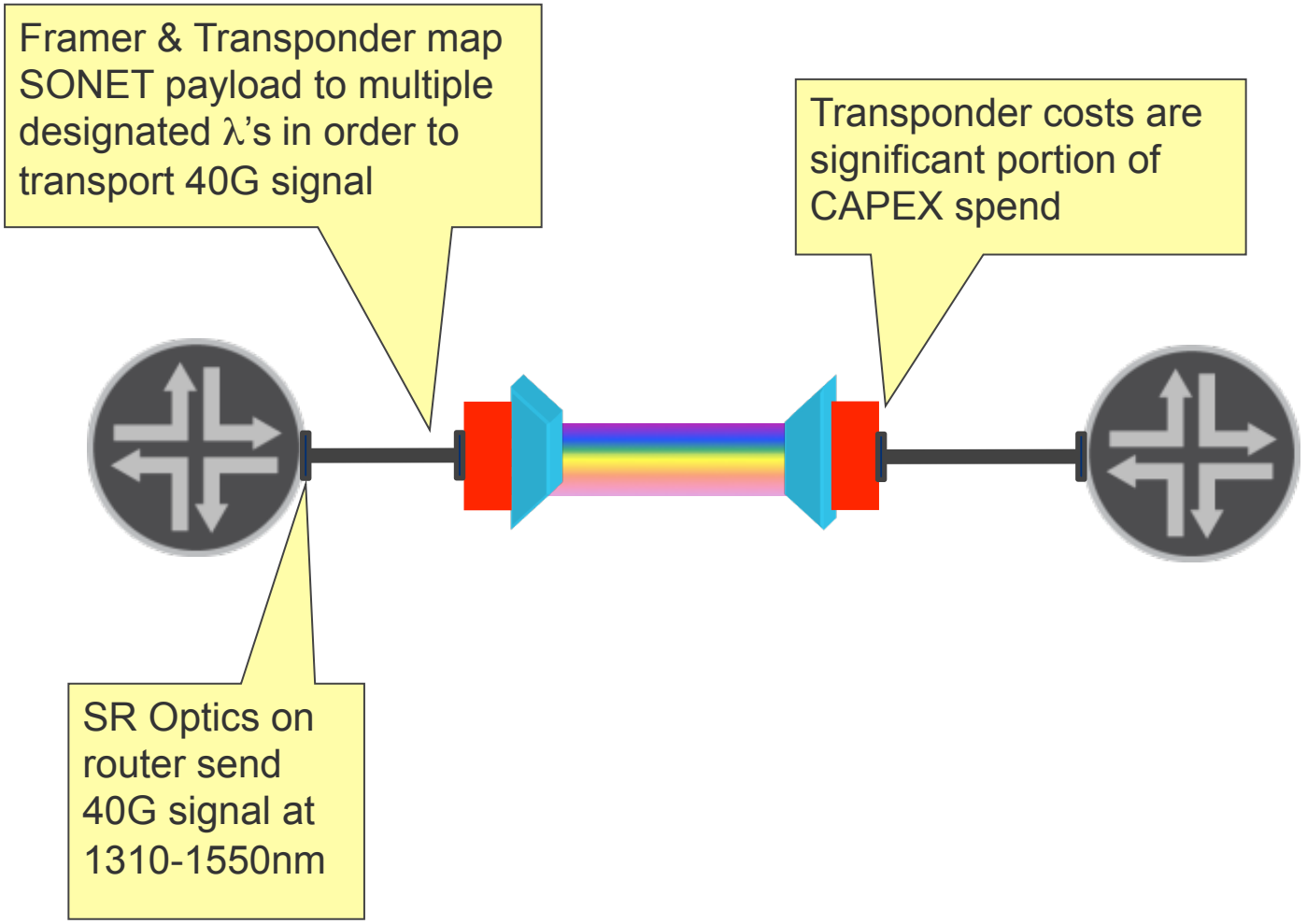
Options for addressing core bandwidth needs?

- Big, fat pipes
  - native 40G POS (SR optics) interface
  - compressed signal 40G interfaces
- Multiple parallel links

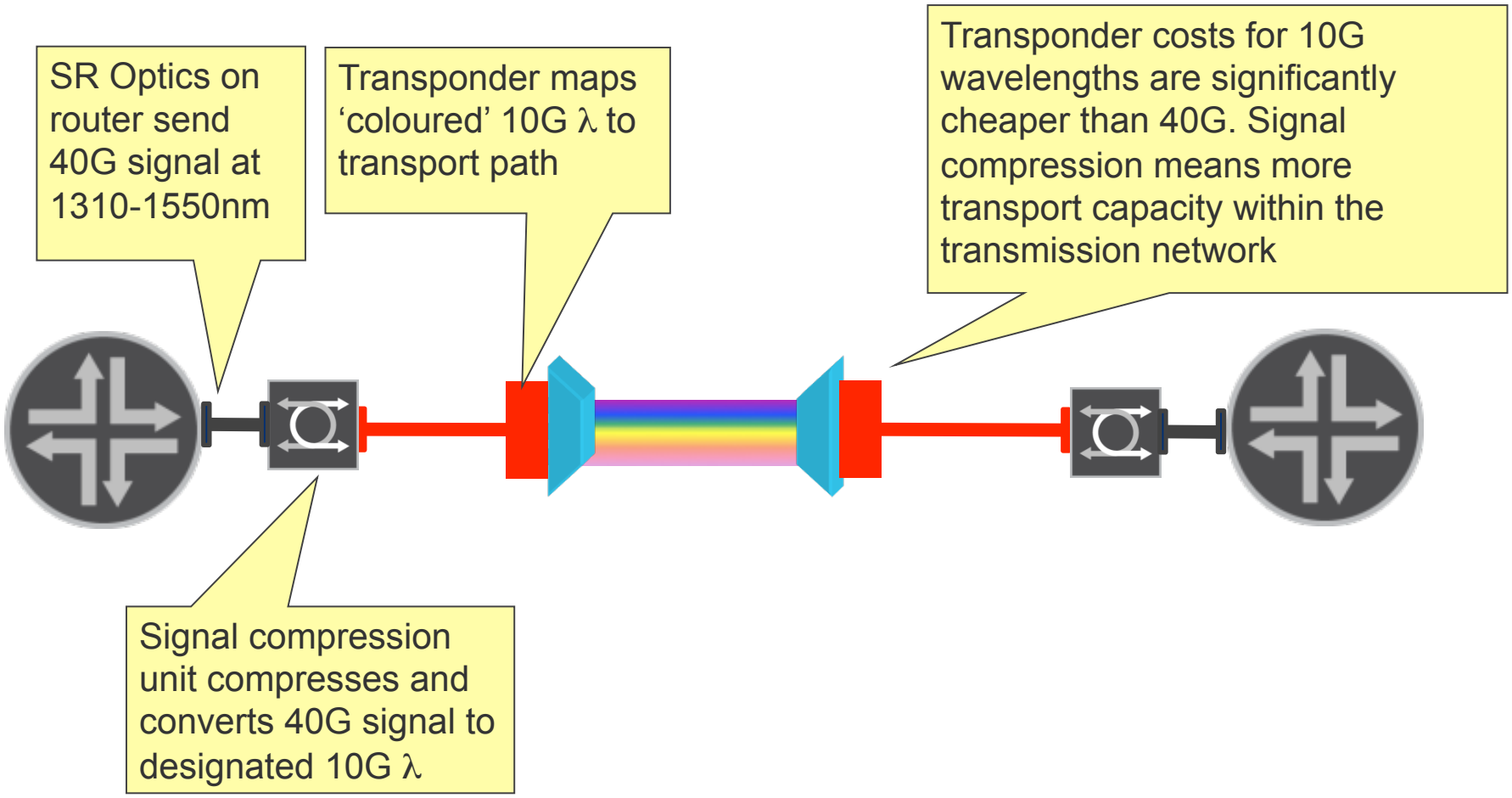
Options are NOT equivalent when considering available bandwidth

- Available bandwidth = maximum bandwidth that can be utilized without any packet drops
- 40Gbps interfaces provide full access to bandwidth
- With nx10Gbps, available bandwidth is non-deterministic

ROUTER OPTICS & THE TRANSPORT NETWORK



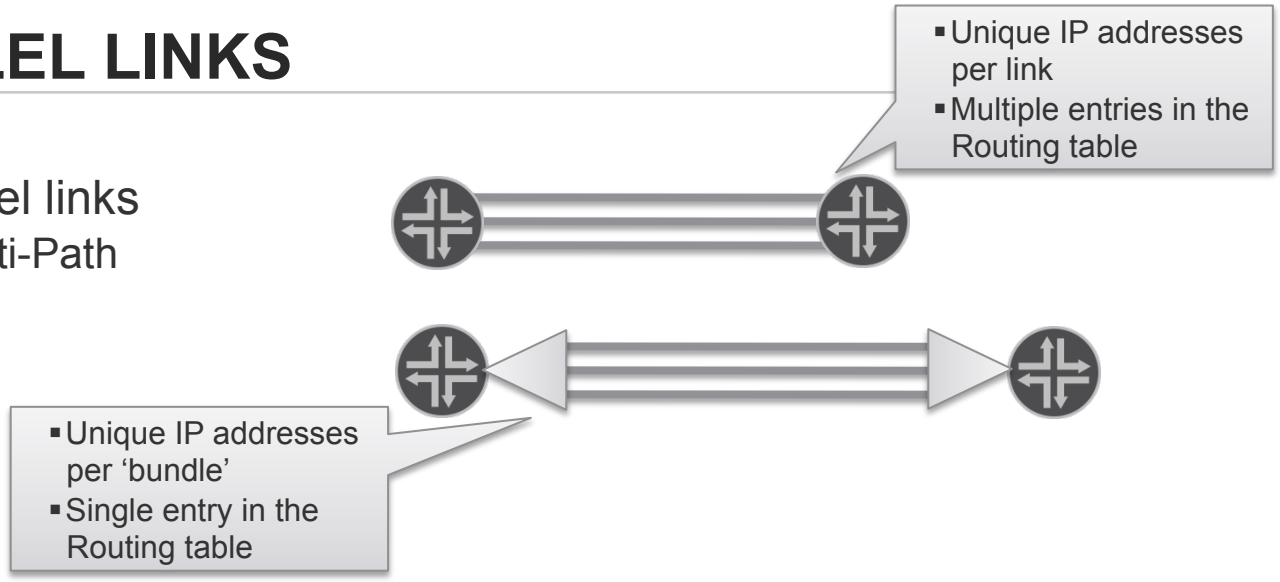
SIGNAL COMPRESSION & THE TRANSPORT NETWORK



USE OF PARALLEL LINKS

Ways to utilize parallel links

- L3 Equal Cost Multi-Path
- L2 Link-bundling



Distribution of traffic over parallel links done via flow-based hash mechanism in both cases

Effectiveness of flow-based Hash distribution determined by traffic characteristics

- Flow diversity - large number of flows
- Average bandwidth per flow - determines number of flows that can be supported on any given link

Flow-based hash mechanism CANNOT guarantee equal distribution of load

- With ideal traffic characteristics it is statistically possible to uniformly distribute load over all links

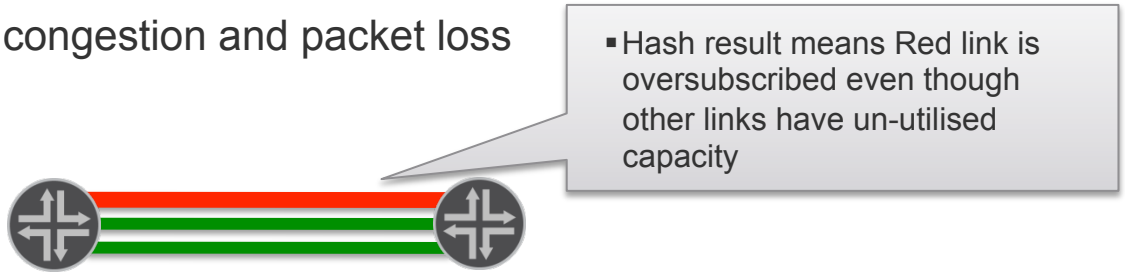
USE OF PARALLEL LINKS

Hash can result in un-equal load distribution

- Caused by Non-ideal traffic characteristics such as:
- Small distribution of src/dest IP addresses
- High per-flow bandwidth

Un-equal load distribution can results in under-utilization of available capacity

- May cause artificial congestion and packet loss

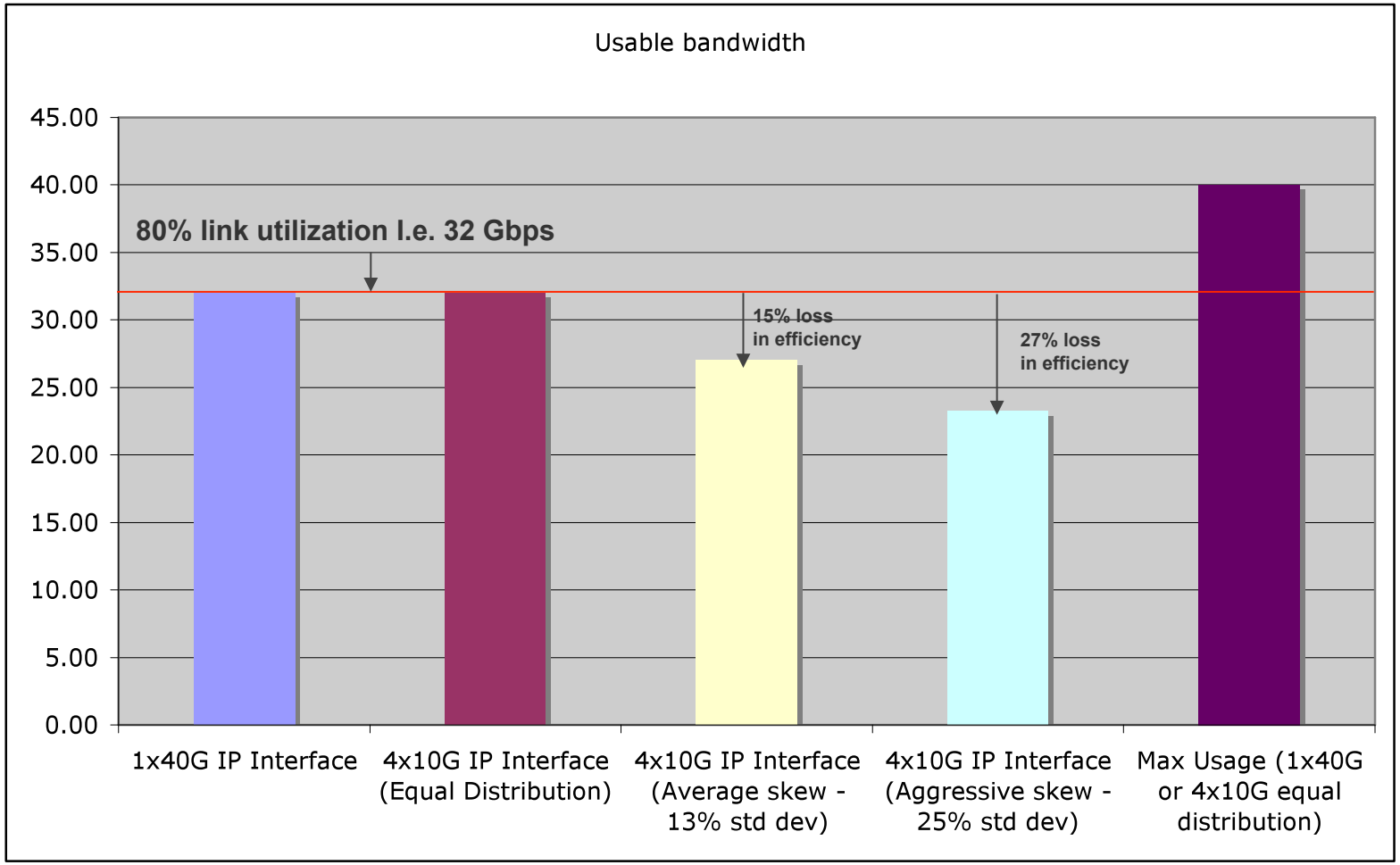


4x10Gbps is not the same as 1x40Gbps from a real throughput perspective

How many parallel 10Gbps links do you need to match usable bandwidth on one 40Gbps link?

- Depends on traffic characteristics… 5 may be 6 !!

ANALYSIS OF IMIX TRAFFIC & HASHING DISTRIBUTION



OPERATIONAL PROS / CONS

Equal Cost Multi-Path

- Ubiquitous & well-understood
- Link instability causes additional load on Routing Protocol (CPU increase)
- More links, more address space required
- NMS overhead for monitoring individual links
- Per-interface QOS policy with full flexibility

OPERATIONAL PROS / CONS

Link-bundles

- Reduced address space consumption vs ECMP
- Easy to add additional link-capacity
- Easy to manage – single interface vs multiple across the router
- Minimum link-member function to shut down bundle if link capacity drops below threshold
- Link instability == ‘black-holing’
  - Can’t readily see link-member loss vs entries in RIB
- QOS functionality can have limitations – not all options may be available
- Can be harder to t-shoot – more complexity in implementation, more ‘layers’ to investigate
- Large bundles != a single large pipe

SUMMARY

Demand for higher bandwidth services driving increased bandwidth requirements on core networks

Adoption of new services changing network traffic characteristics (broadband, video, content, OTT service delivery etc)

Customers can’t wait! Current solutions are already deployed in many large service providers worldwide

- n*OC768 - ECMP and Link bundles
- n*OC192/10GE - ECMP and Link bundles

Q & A


everywhere