

THE FUTURE **X** NETWORK A BELL LABS PERSPECTIVE



<http://bit.ly/blbook-order>

(...or building the digital fabric for the next technological revolution)

Marcus Weldon

President of Bell Labs & CTO of Nokia

Future X By The Numbers

66x

Increase in wireless
traffic 2015-2025

720%

Increase in
video traffic
2012-2017

2000x

Increase in public cloud
objects
2015-2025

400%

Increase in ROI for high
customer satisfaction
companies

700Bn

Things connected
to the Internet
in the future

13x

Increase in core
network traffic
2015-2025

620x

Increase data
analyzed in the cloud
2015-2025



Technological Revolution

=

*Interconnectedness and Interdependence of
participating systems and technologies*

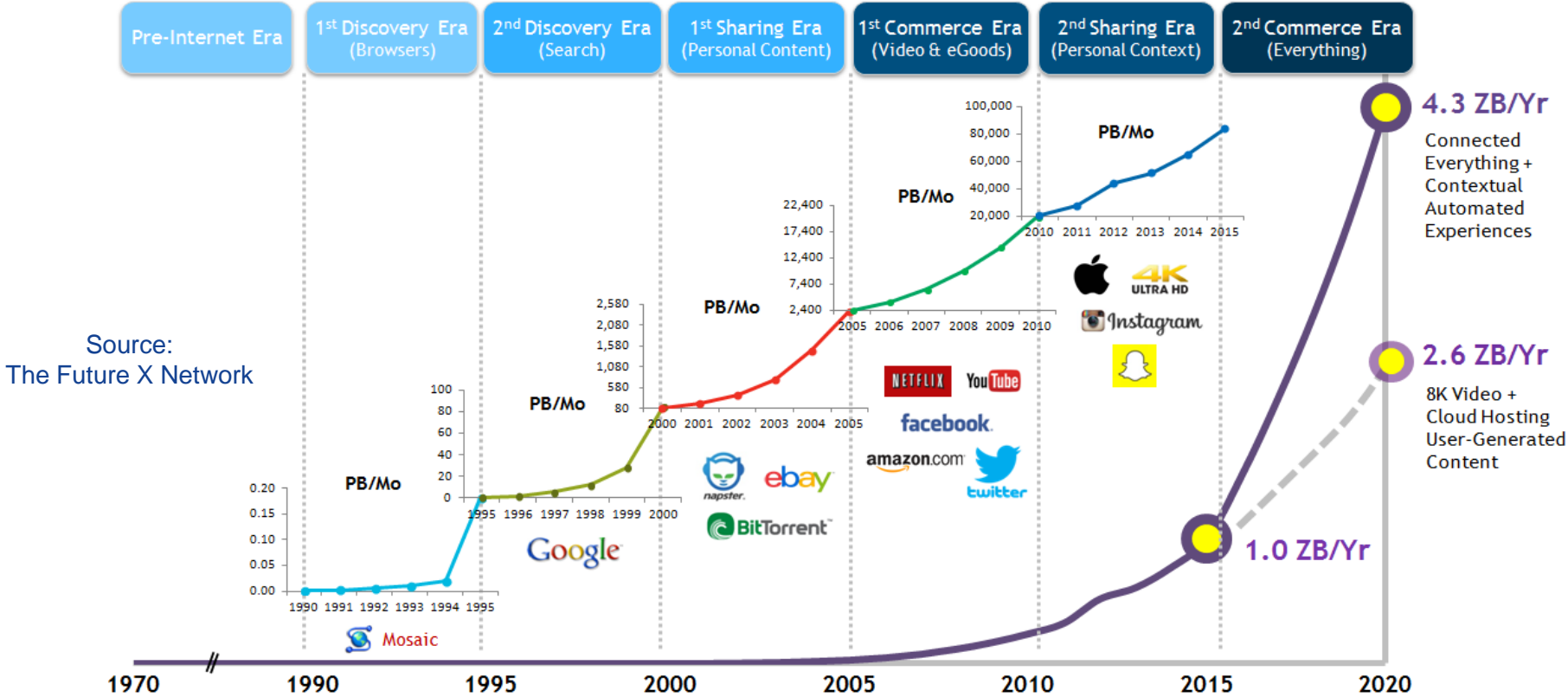
+

*The capacity to profoundly transform the
economy and eventually society*

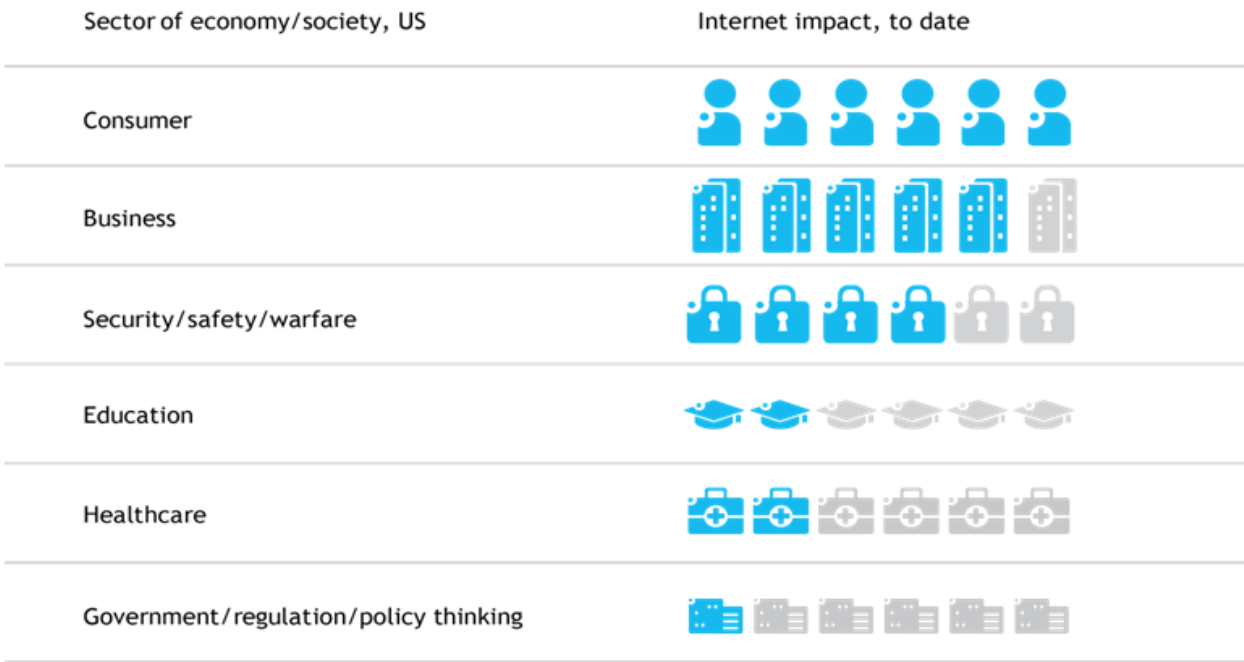
Future X Network: The Past, Present & Future

Tech. Revolution	Enabling Technology	Connectivity
Financial (1600 – 1740)	Stocks & Bonds	Banking & Stock Market Infrastructure
1 st Industrial (1780 – 1840)	Steam Engine & Iron Production	Rail and Shipping Networks
2 nd Industrial (1880 – 1920)	Steel & Chemicals	Extended transportation Networks Electricity & Telecom Networks
Scientific-Technical (1940 – 1970)	Analog & digital signal processing	Digital communications networks
Information (1985 – 2015)	The Web, Cloud computing & Mobile devices	Internet & Broadband Access
Automation of Everything (2015 –)	Digital interfaces & Data analysis	Cloud Integrated Network

Future X Network: A New Networking & Connectivity Era

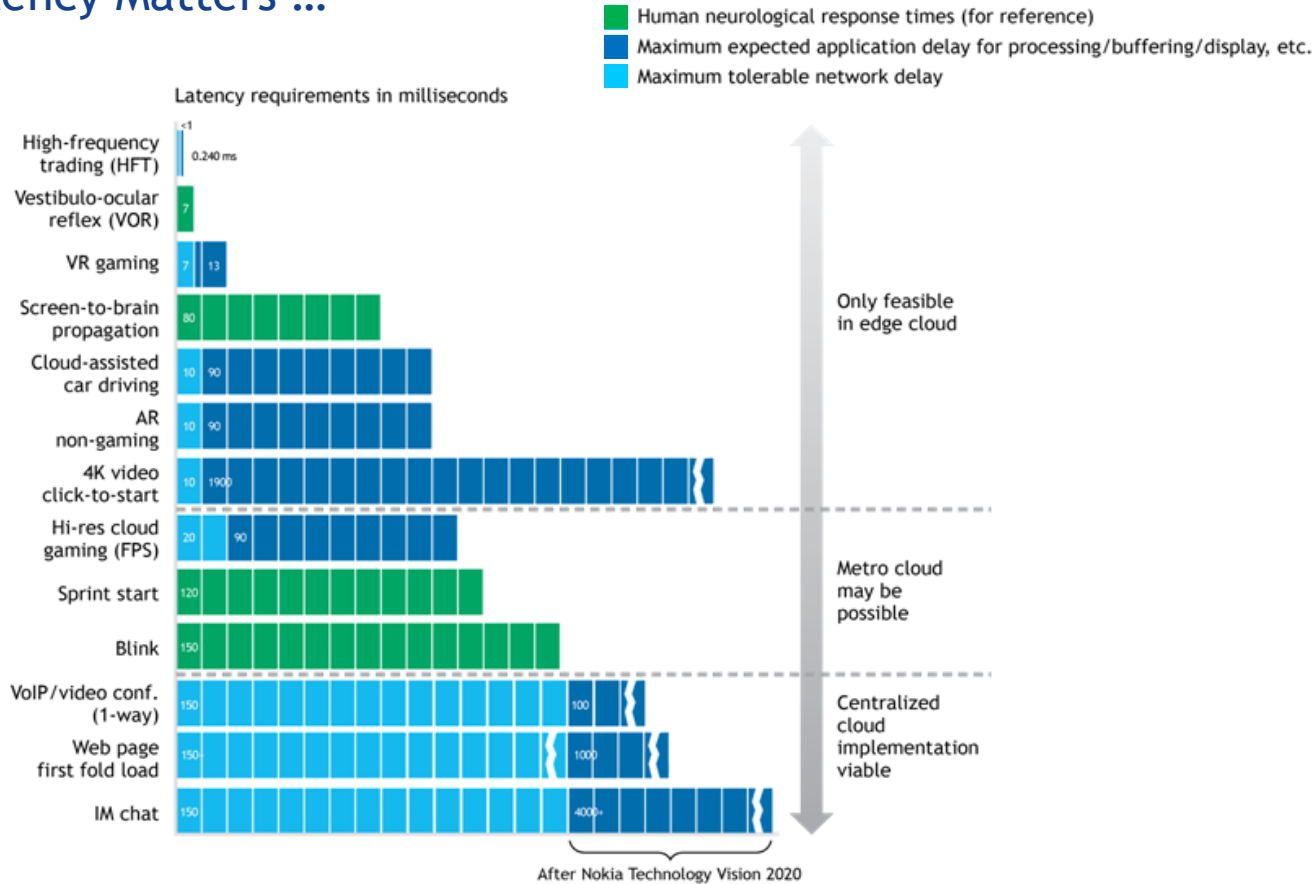


Future X Network: Driven by an Enterprise Revolution



After Mary Meeker, Internet Trends 2015

Future X Network: Latency Matters ...



Future X Network: Latency and Throughput Matters

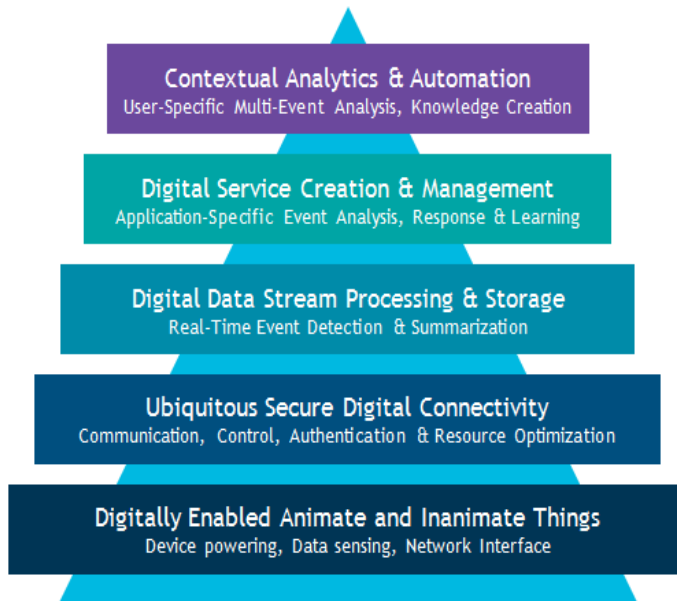
$$\text{Maximum TCP Throughput (bits/second)} = \frac{\text{TCP window size (bits)}}{\text{Round-trip latency (seconds)}}$$

Future X Network: The Automation of Everything & the New Digital Currencies



Analog Needs

Create Time ...with Trust
(by Prediction & Automation) (in Privacy & Security)



Digital Needs

Future X Network: Global-Local is the New Opportunity/Reality

Local Forces

Low Latency & High Bandwidth

Trusted Brand Relationship

Personalization & Contextualization (& **Privacy**)

Economies of (**Secure**) Delivery



Global Forces

Ubiquitous Access to Digital Content

Brand Power

Omniscient Perspective & Analytics

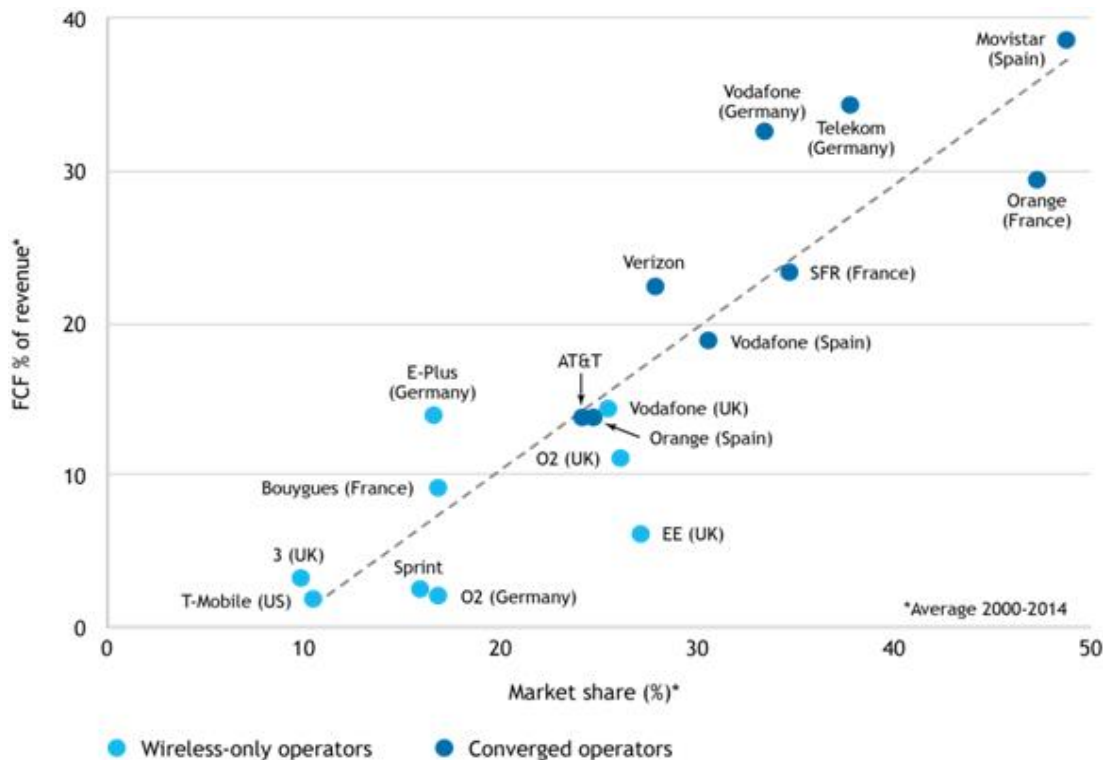
Economies of Scale

THINK GLOBALLY
ACT LOCALLY



Peace Resource Project 888-622-7075 www.peaceproject.com (MS#10)

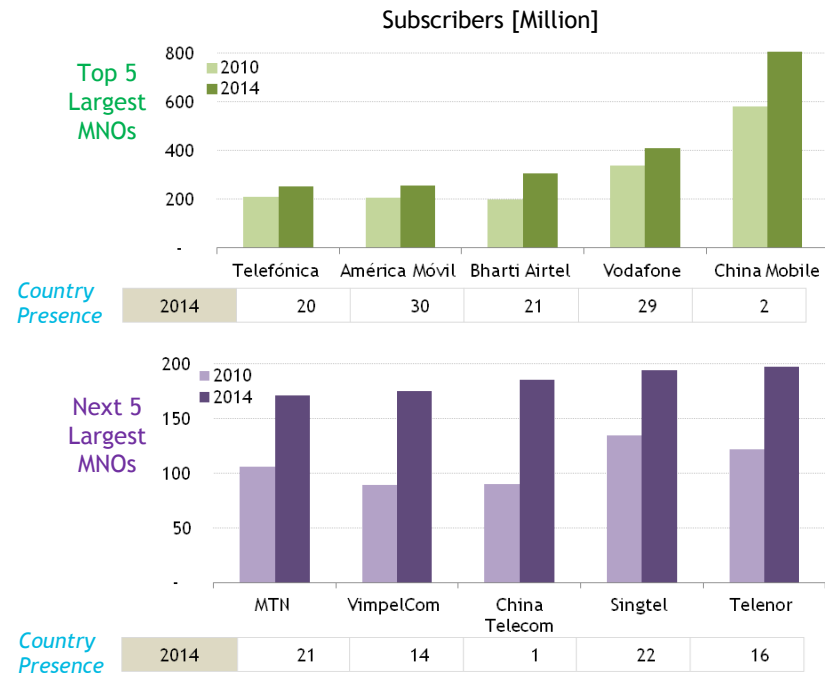
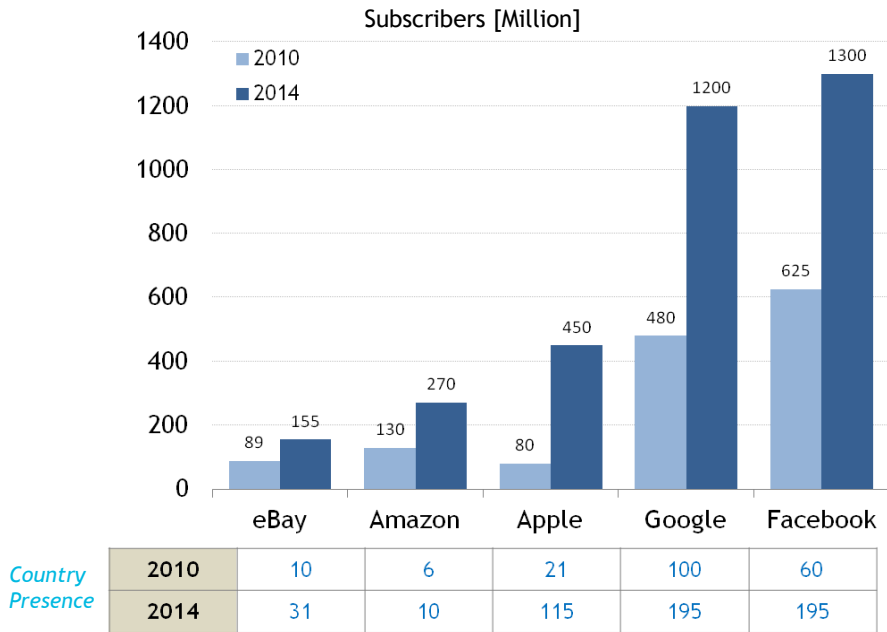
Future X Network: Convergence and Consolidation Drives New Local



Recent M&A Activity

Mobile Network Operator	Consolidation / Convergence
O2 Telefónica (Germany)	E-Plus
VF (Germany)	KDG
VF (Spain)	Ono
EE (UK)	BT
3 (UK)	O2 UK
Orange (Spain)	Jazztel
Liberty Global	Base
Charter	Time Warner
Altice	Suddenlink
Altice	Cablevision T-Mobile ?

Future X Network: The Service Scale Challenge Drives New Global

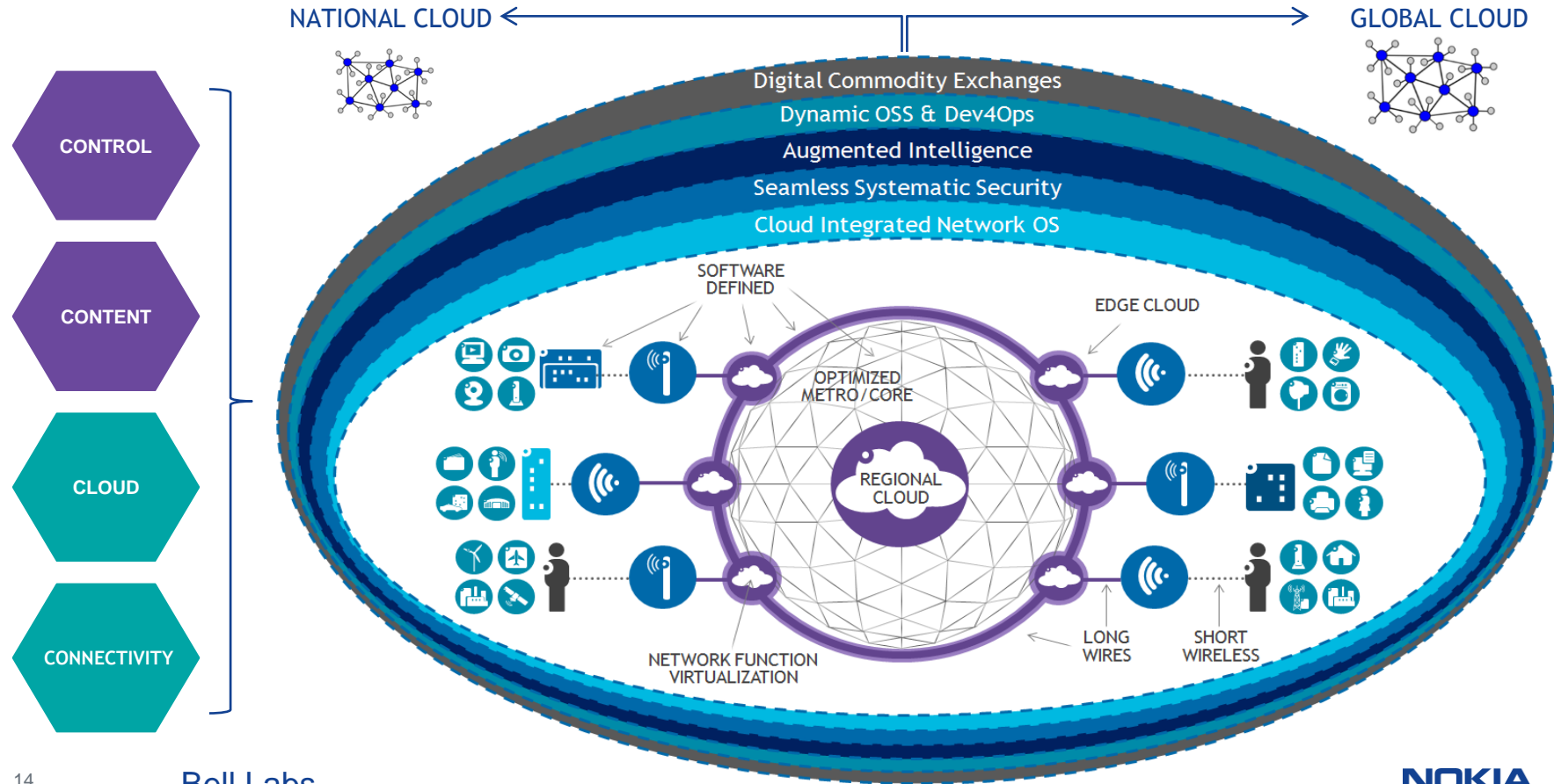


*Average properties per group: 11 (2004) → 18 (2014)

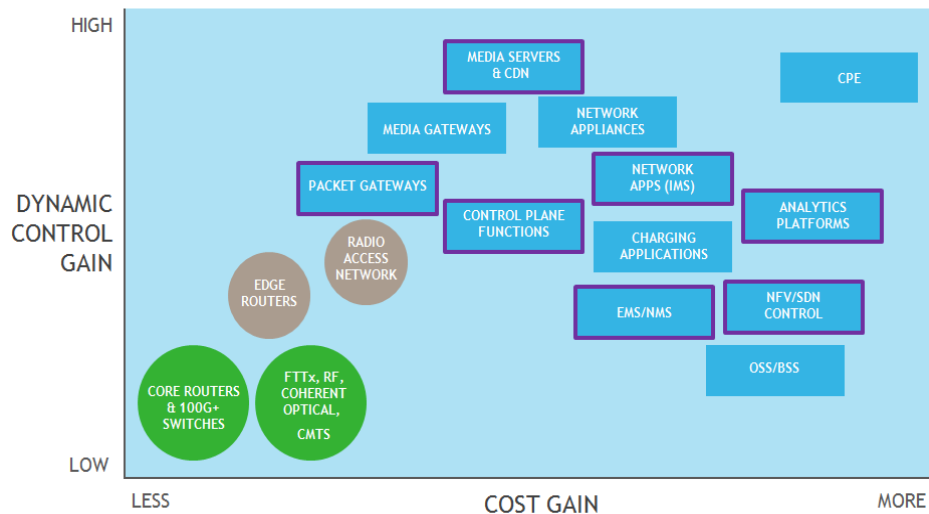
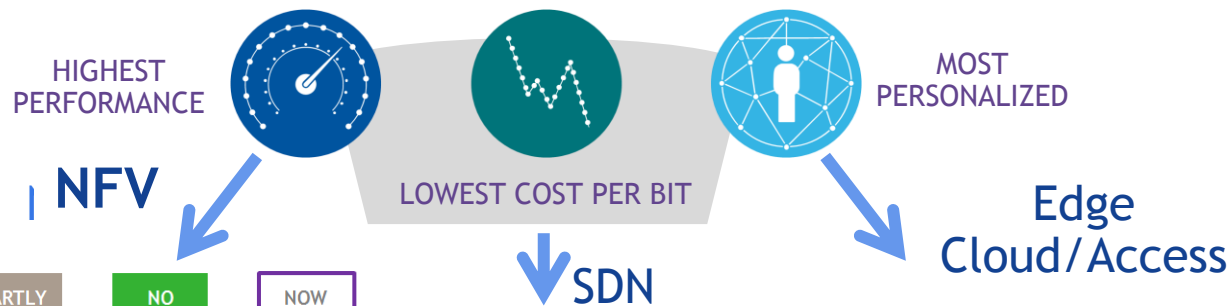
Future X Network: A New Value Paradigm



Future X Network: The Target Architecture and Value Vectors

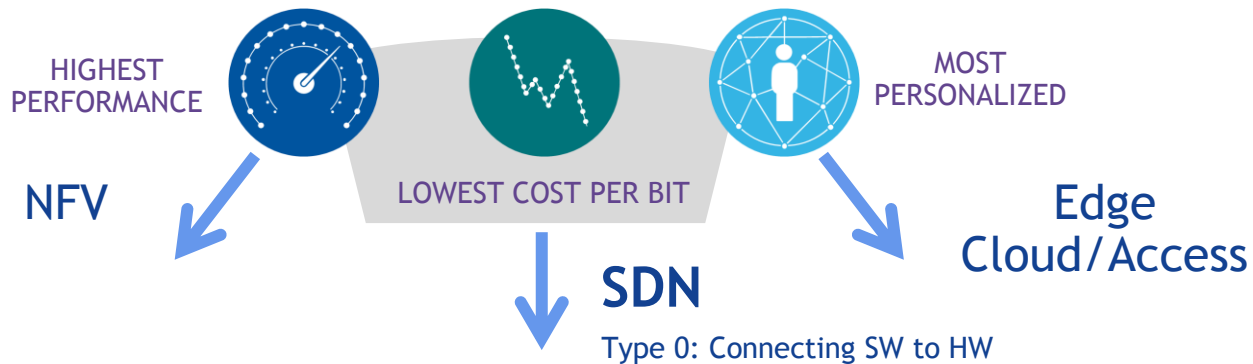


Future X Network: Virtualizing the Network



~40 %
CapEx & OpEx
Savings

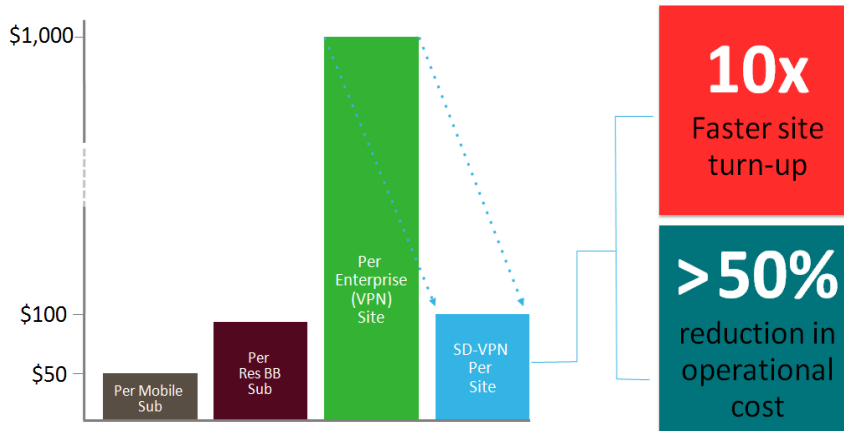
Future X Network: Software-Defining the Network



Type 2: Software-define a Network Path

40 %
IP + Optical
CapEx Savings

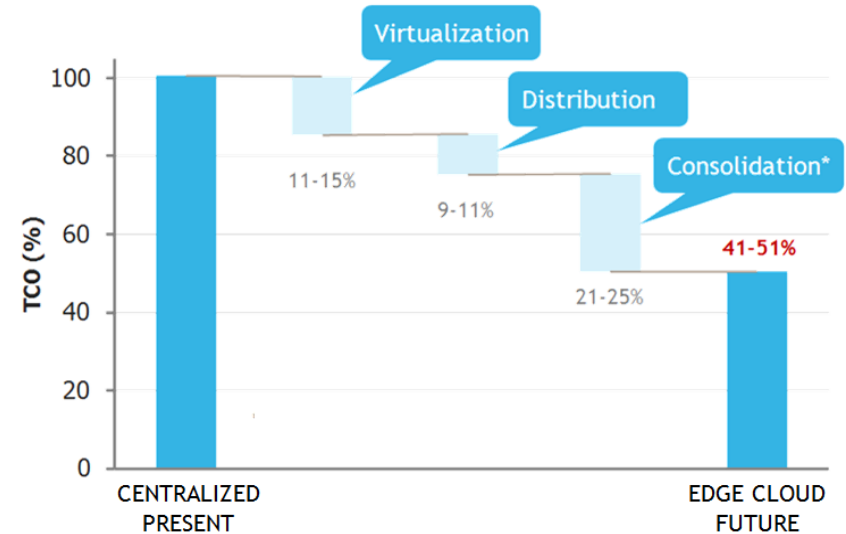
Type 1: Software-define a Service



Future X Network: Distributing the Cloud...in the Network



~40 %
CapEx & OpEx
Savings

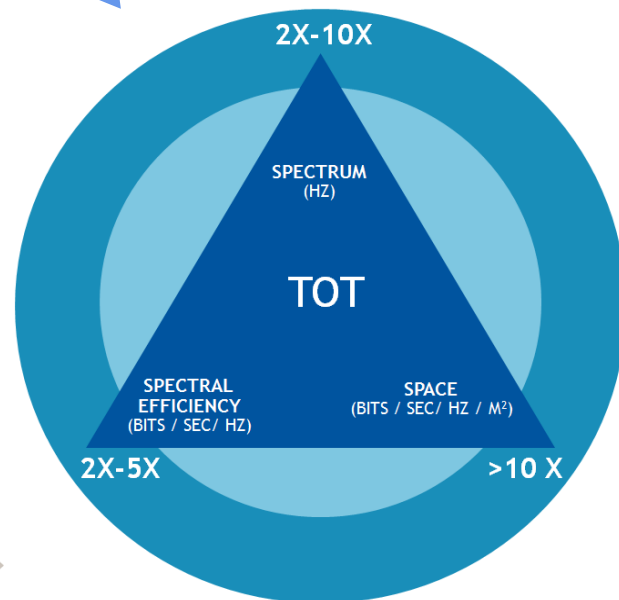
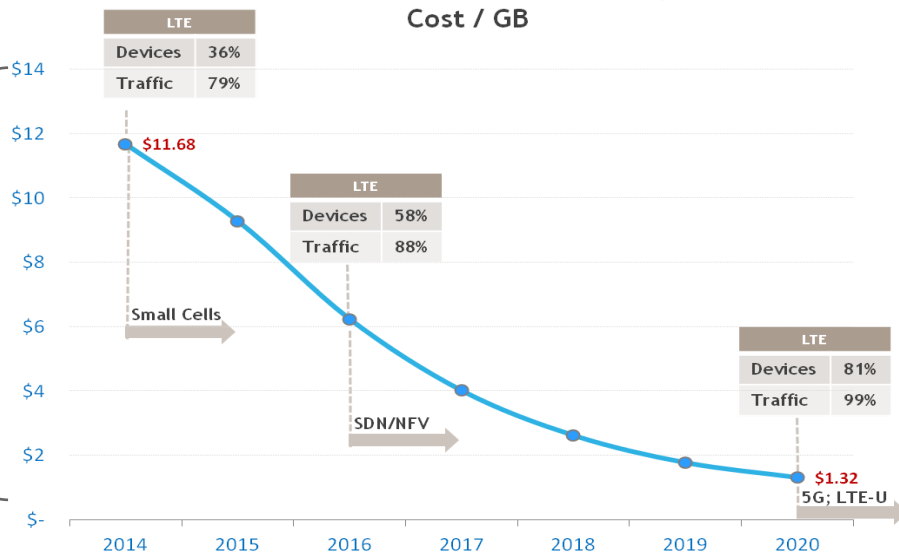


Future X Network: Distributing the Network

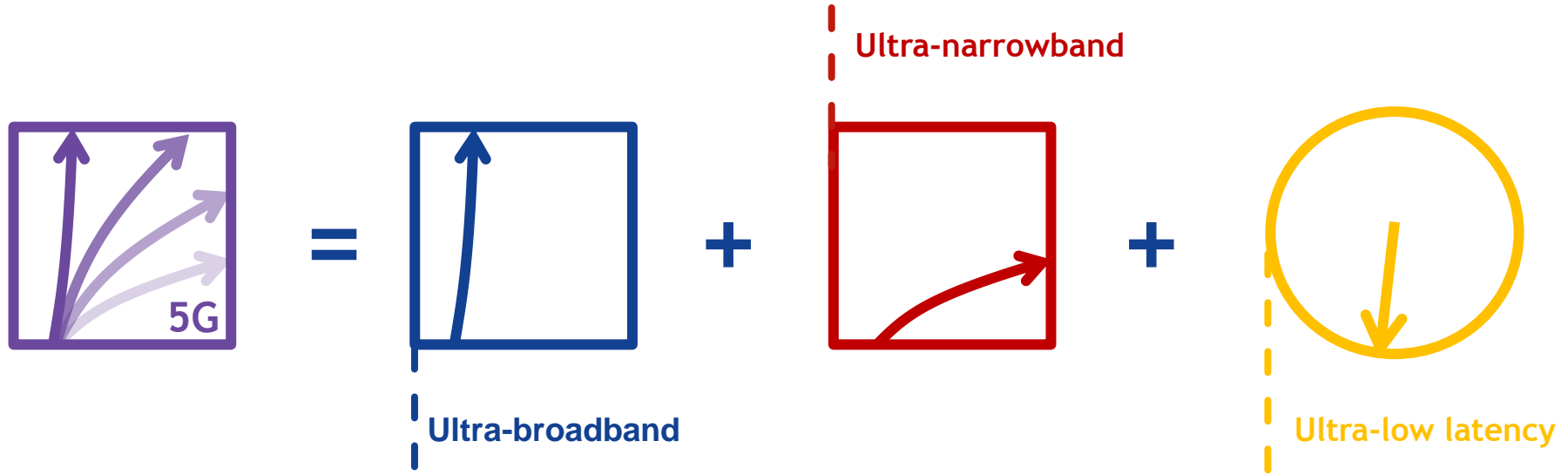


90 %

CapEx
savings by
Small Cells
& vRAN



Future X Network: The new local connectivity = 5G



5G : a **unified wireless 'ether'** for a new digital existence, supporting traditional 'human' applications and new 'machine' applications enabling 'AoE' - the Access to Everything and the Automation of Everything

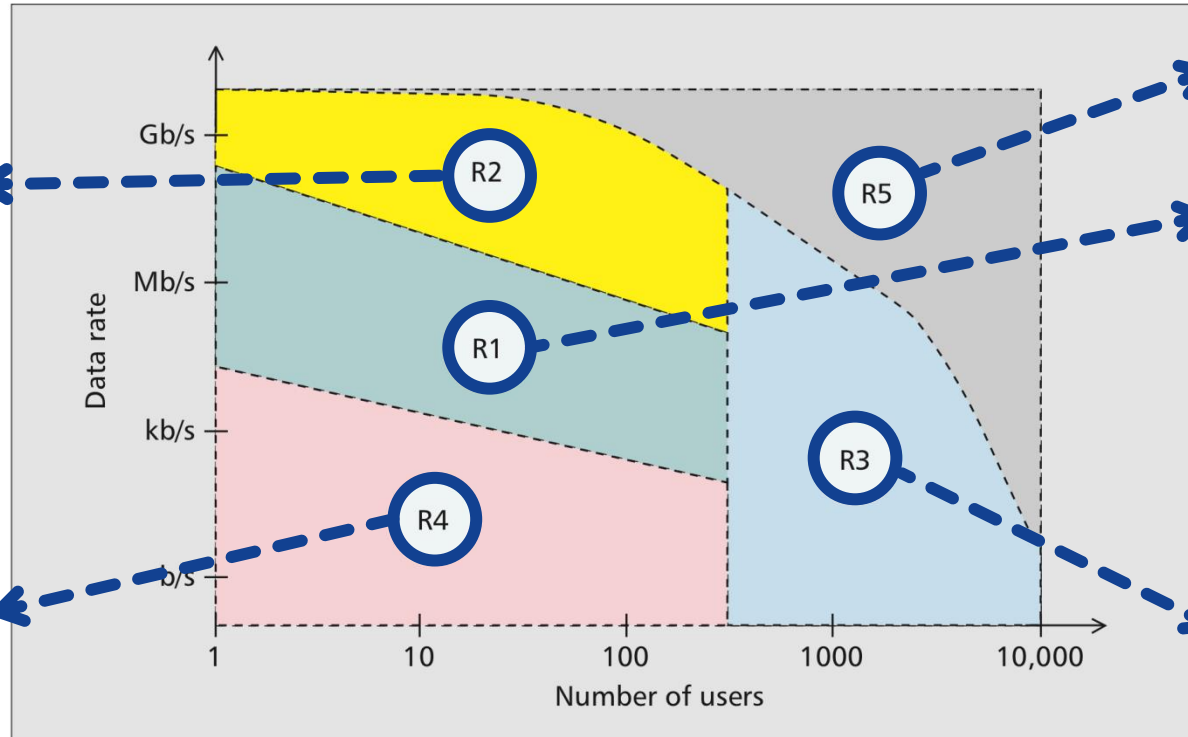
The Simple Formula: $5G = R1+R2+R3+R4$

Ultra-broadband:

Massively increased data rate per user (using new spectrum, spectral efficiency, spatial efficiency)

Ultra-low latency:

Massively increased responsiveness at same user density (using new control & connectivity & air interface paradigms)



Forbidden region:
Shannon Limit

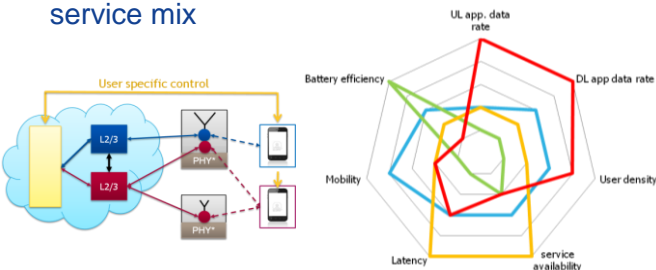
Today: As number of users increases, data rate per user decreases

Ultra-narrowband:
Massively increased number of users @ same data rate (using new control & connectivity & air interface paradigms)

F. Boccardi, Bell Labs, IEEE Comms. Magazine, 201402

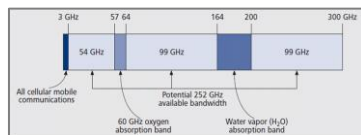
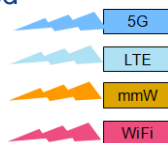
5G: The Six Essential Technology Elements

New Virtualized + Software-Defined Core for flexible routing through centralized, distributed, gateways optimized for any service mix

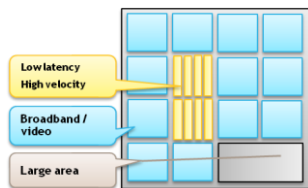


Multi-RAT with network controlled traffic steering and cell-less architecture

- ~2X increase data rate
- Guaranteed user/service experience

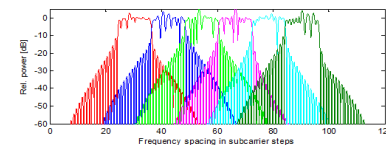
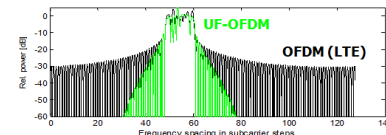


Modular Framing Structure for ultra-broadband, ultra-narrowband and ultra-low latency support



New Air Interface: New Waveform and control for flexible multi-service interface

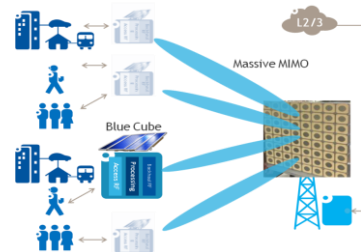
- ~2X battery life
- ~5X lower latency



Massive MIMO

Higher spectral efficiency through spatial multiplexing (beamforming)

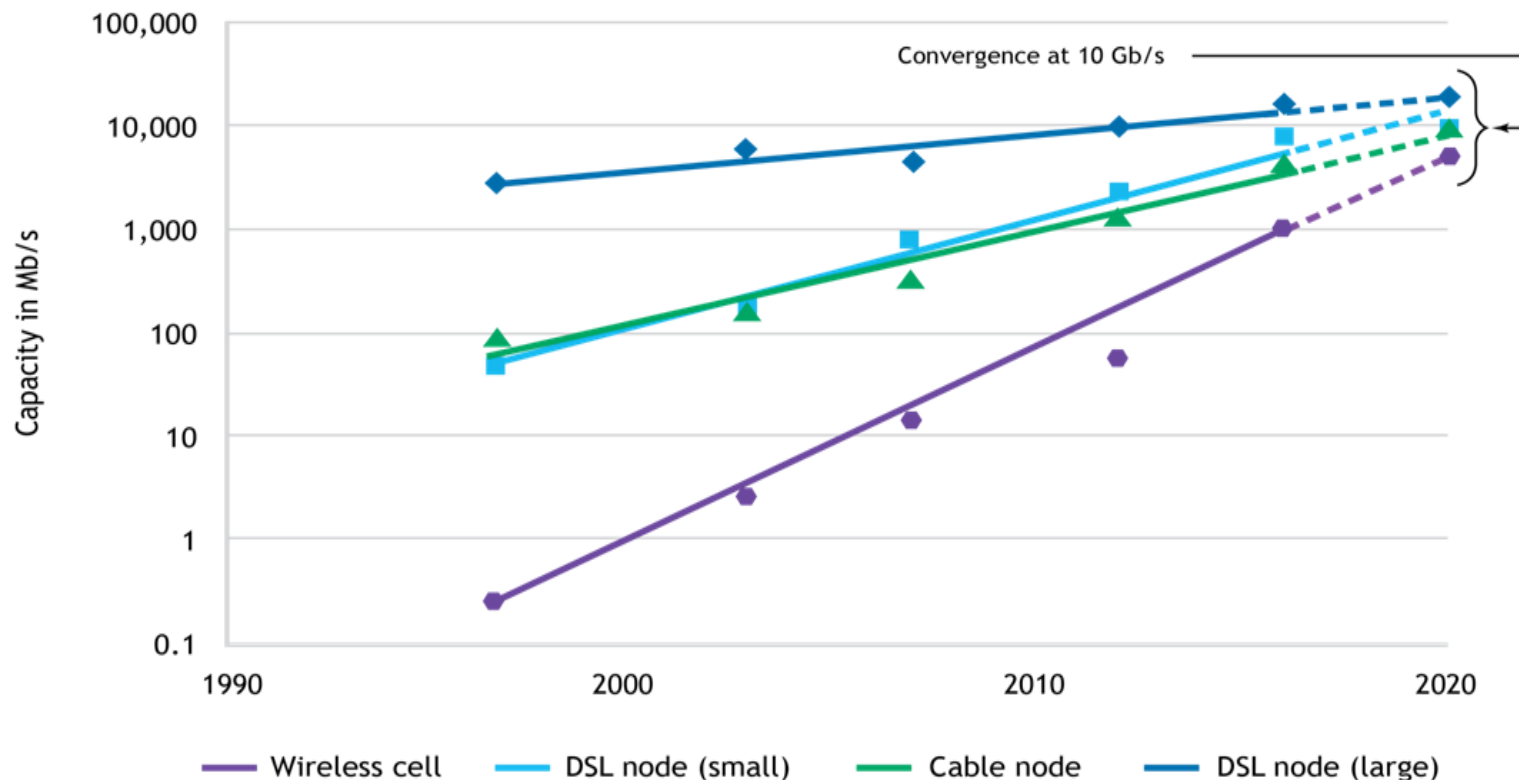
- ~5X increase in spectral efficiency



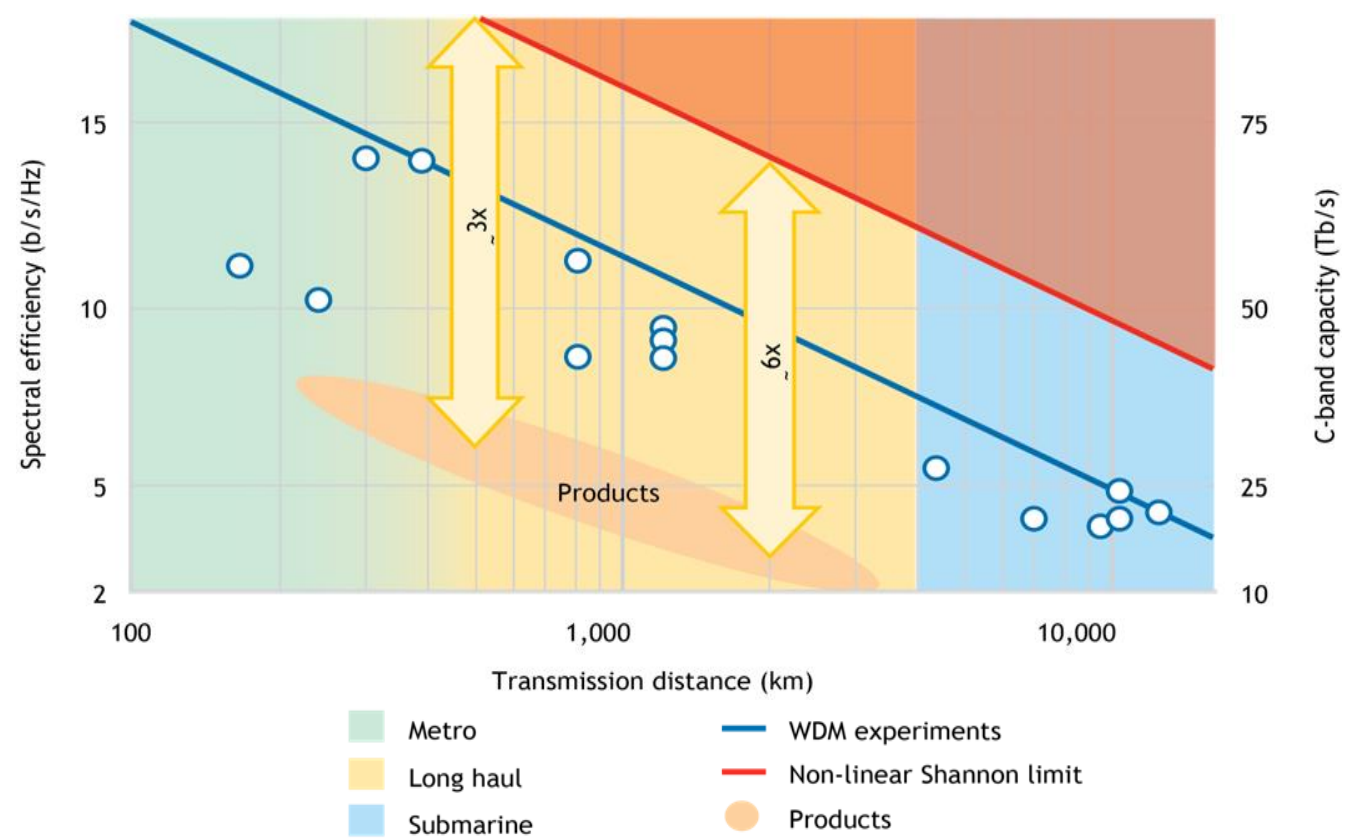
New "mmWave" spectrum small cells

- ~10X bandwidth

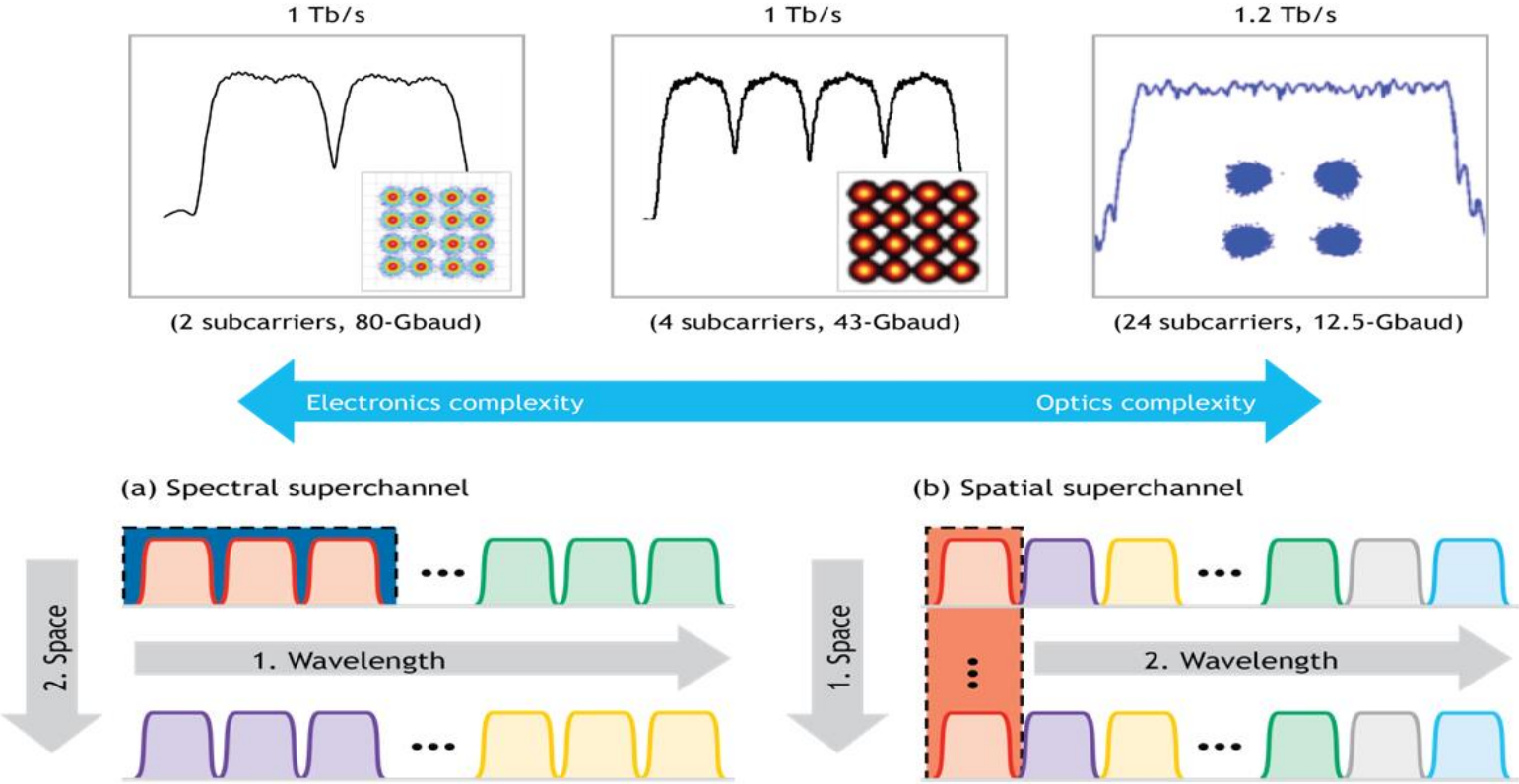
Future X Network: Converging the Distributed Access Network



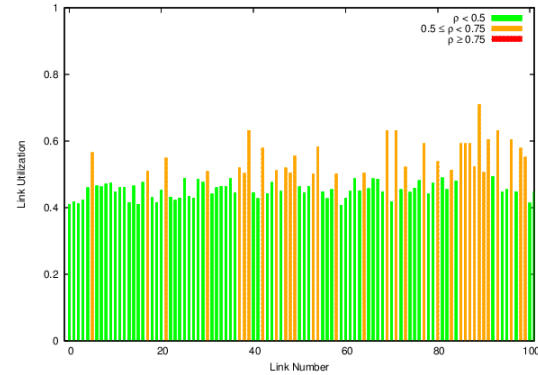
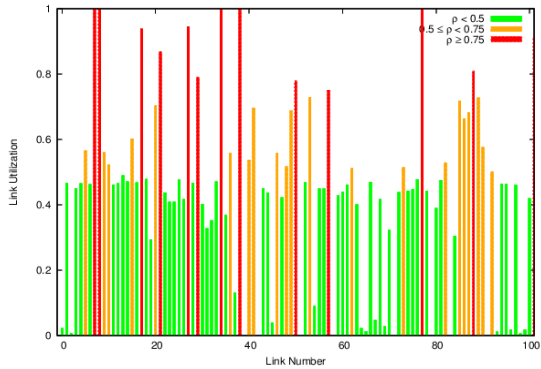
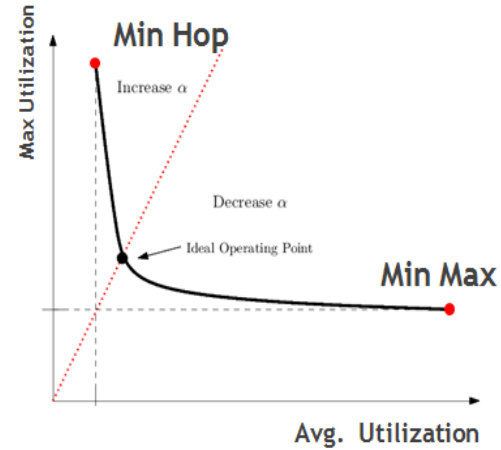
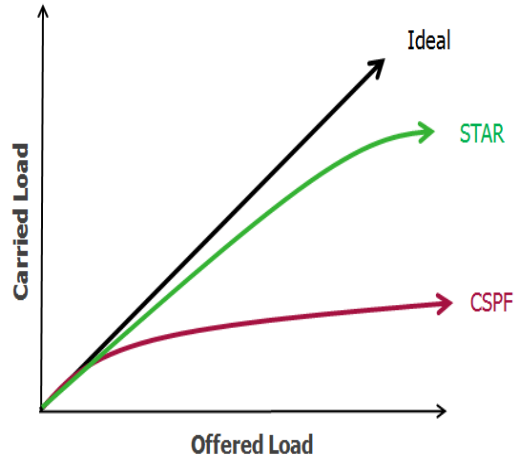
Future X Network: Scaling the Metro & Core Network



Future X Network: Scaling the Metro & Core Network - Optics

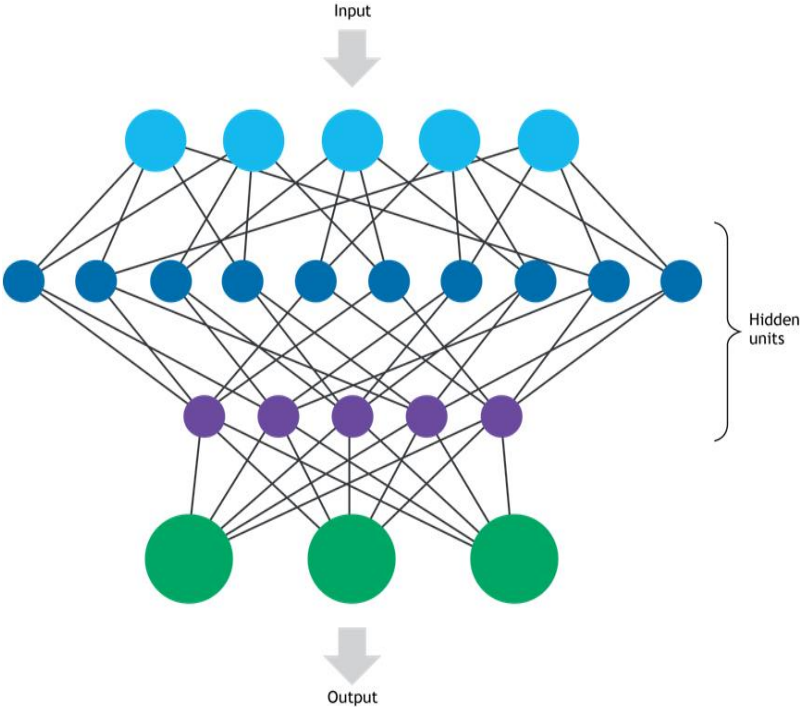


Future X Network: Scaling the Metro & Core Network - IP

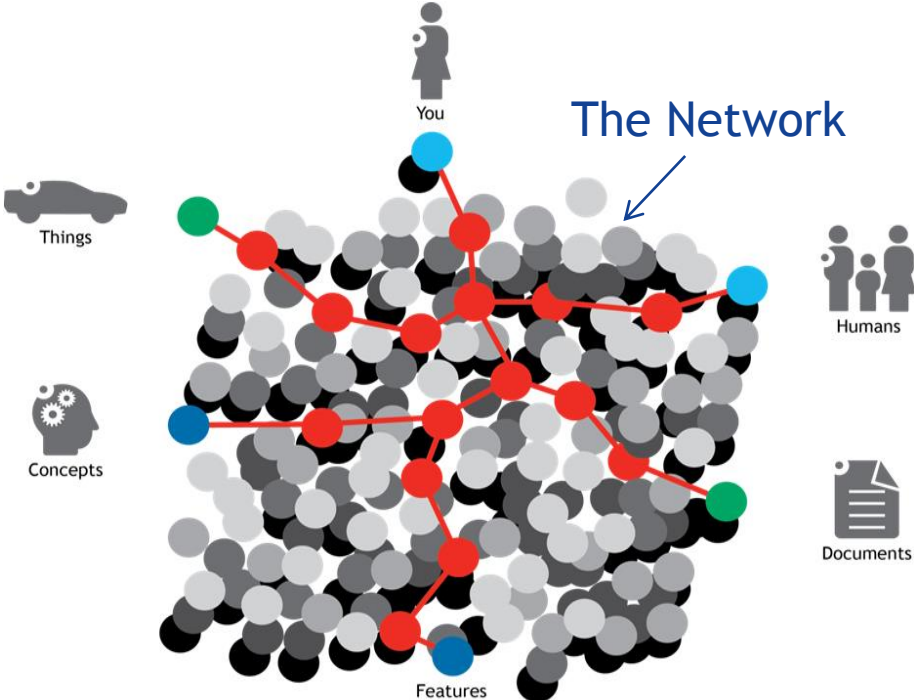


Future X Network: Automating Knowledge Creation

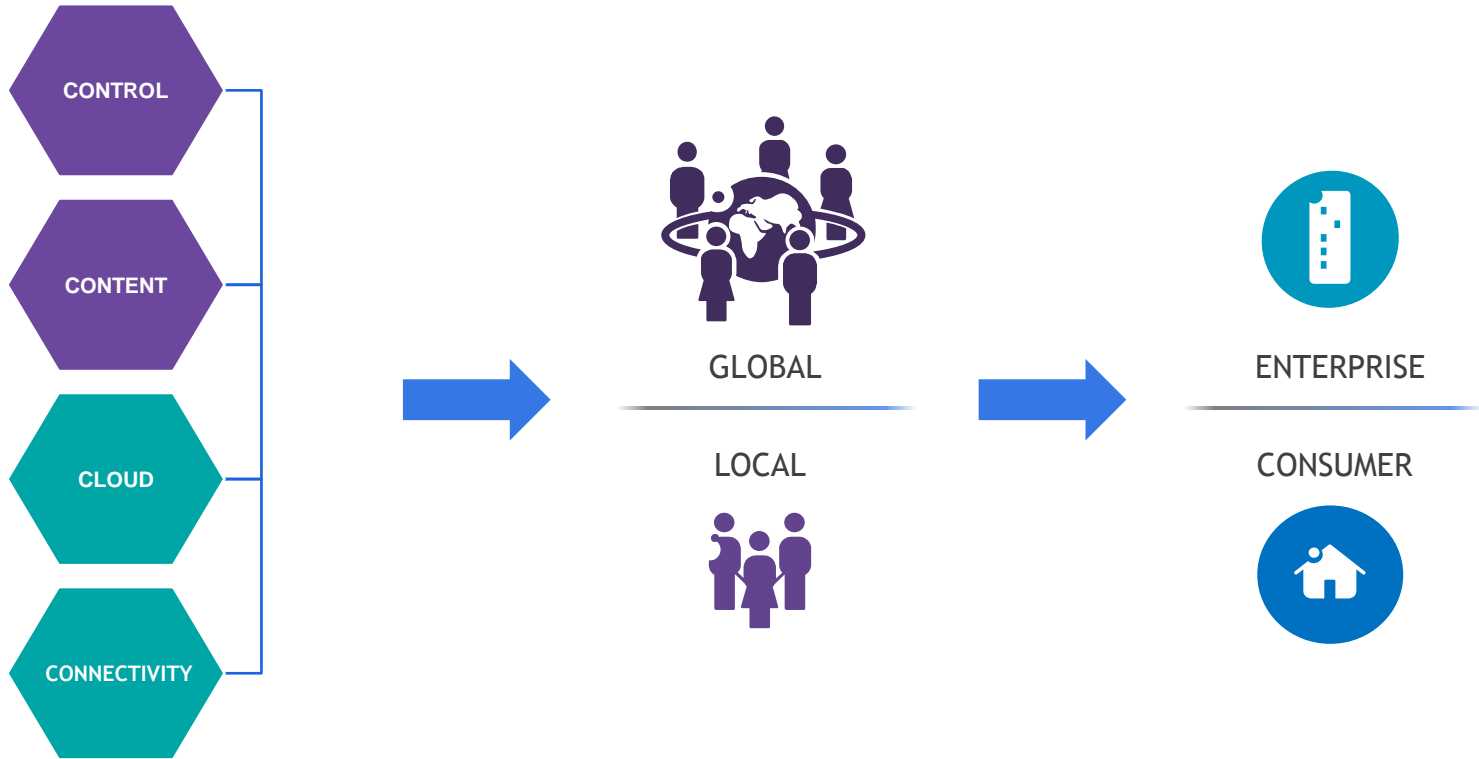
Artificial Intelligence



Augmented Intelligence



Future X Network: The Competitive Dimensions



Future X Network: A New Business Era

amazon



.....

↑ Time

.....

↓ Cost

.....

↑ Knowledge

.....

