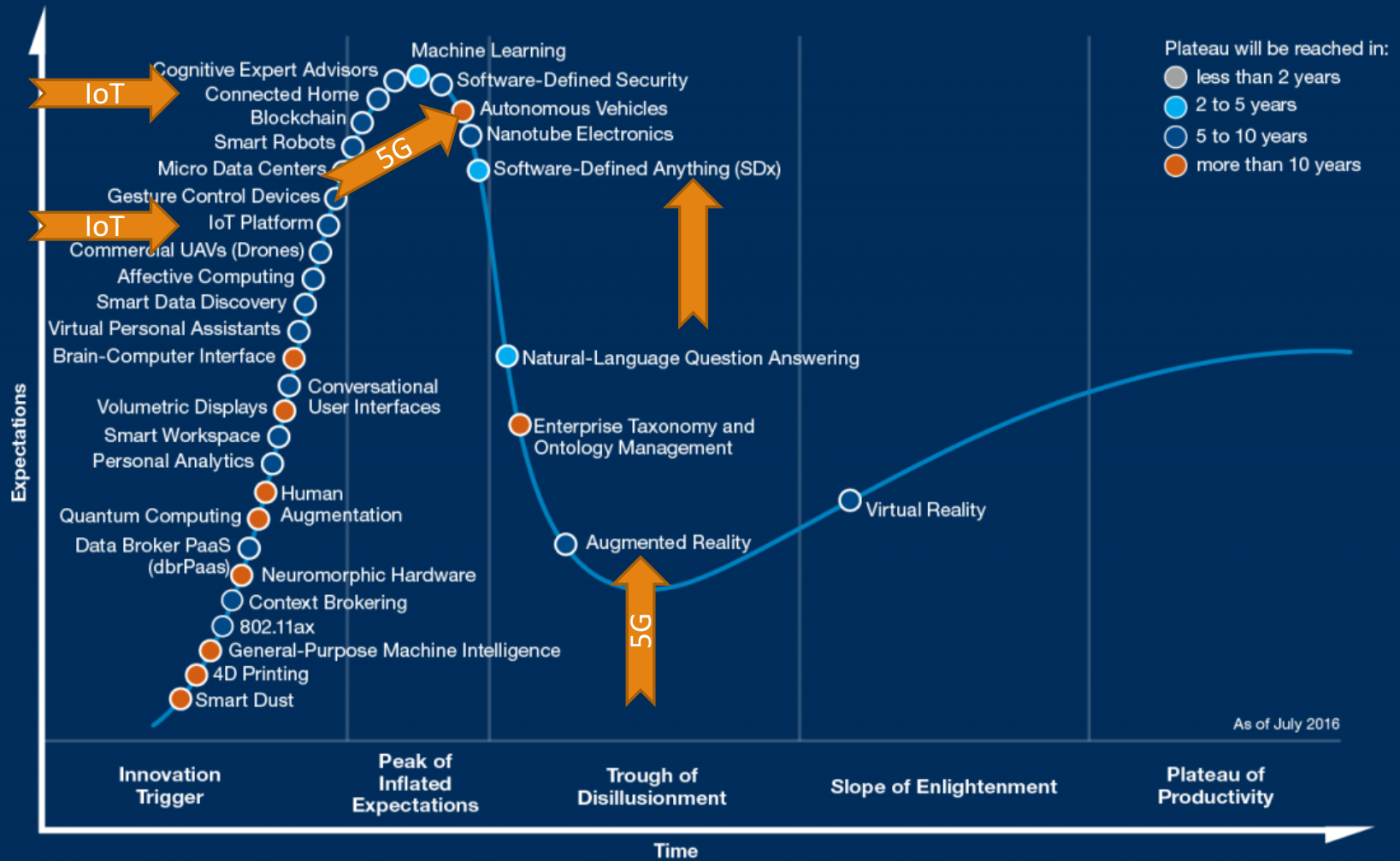# 5G — *Separating Hype from Promise*
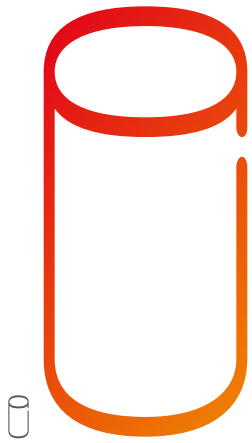
HENNING SCHULZRINNE

The views and opinions expressed in this presentation are those of the author and do not necessarily reflect the official policy or position of any agency of the U.S. government. Any resemblance to actual policies, living or dead, or actual events is purely coincidental.

Gartner Hype Cycle for Emerging Technologies, 2016

Plateau will be reached in:
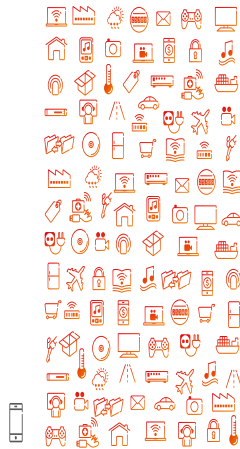- less than 2 years
- 2 to 5 years
- 5 to 10 years
- more than 10 years

Machine Learning
Cognitive Expert Advisors
Software-Defined Security
Connected Home
Autonomous Vehicles
Blockchain
Nanotube Electronics
Smart Robots
Micro Data Centers
Software-Defined Anything (SDx)
Gesture Control Devices
IoT Platform
Commercial UAVs (Drones)
Affective Computing
Smart Data Discovery
Virtual Personal Assistants
Brain-Computer Interface
Natural-Language Question Answering
Conversational User Interfaces
Volumetric Displays
Smart Workspace
Enterprise Taxonomy and Ontology Management
Personal Analytics
Human Augmentation
Quantum Computing
Data Broker PaaS (dbrPaas)
Virtual Reality
Neuromorphic Hardware
Context Brokering
Augmented Reality
802.11ax
General-Purpose Machine Intelligence
4D Printing
Smart Dust

IoT
5G

Expectations

Innovation Trigger | Peak of Inflated Expectations | Trough of Disillusionment | Slope of Enlightenment | Plateau of Productivity

Time

As of July 2016

Gartner

METIS Technical Objectives

1000x data volume	50/500 B devices	Up to 10Gbps	Few ms E2E	10 years

1000x
higher mobile data volumes

10-100x
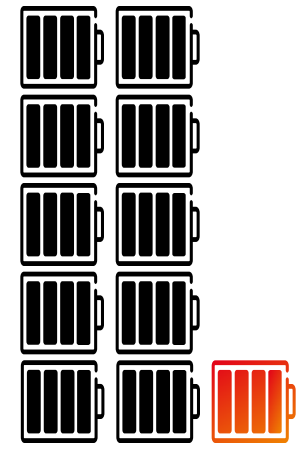higher number of connected devices

10-100x
typical end-user data rates

5x
lower latency

10x
longer battery life for low-power devices

5G = 5 good reasons for hype

- researchers
  - research with real-world impact
  - new opportunity for QoS research!
  - compete with AI for attention

- equipment manufacturers
  - most of the 4G market has been saturated
  - commodization of communications hardware

- carriers
  - need new quality differentiation instead of price-based commodity
  - "4th Wave"
  - motivate getting new spectrum

- governments & regulators
  - restore old industry dominance (Europe)
  - Olympics

- conference organizers & standardization bodies
  - IEEE, ITU, … need excitement

does not encourage critical thinking…

Design for 20 years

Mobile Network Technology Lifecycles (North America)

© Chetan Sharma Consulting, 2014
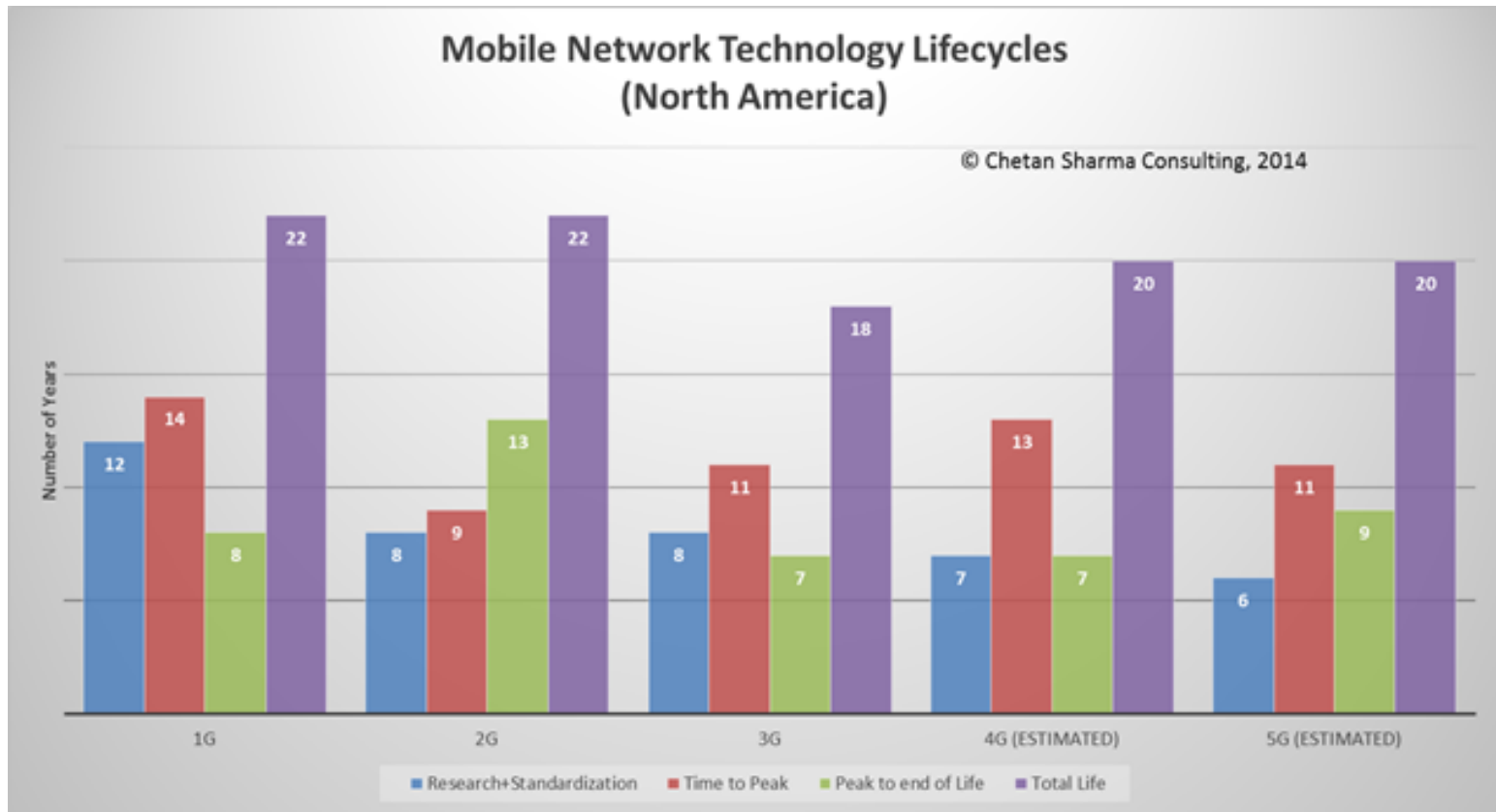
Generational surprises

Generation	Expectation	Surprise	Cost per GB
0G (landline)	voice	fax & modem	
1G	corporate limousine	eavesdropping	
2G	better voice quality ("digital!")	SMS	$1000
3G	WAP	web	$100
4G	IMS	YouTube, WhatsApp, notifications	$10
5G	IoT (low latency)	?	$1?

- underestimated cost and fixed-equivalence as drivers
- are the even generations the successful ones?

IoT requirements

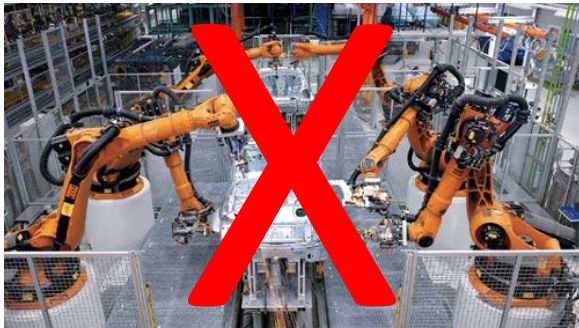| Application	Range	Mo-bility	Device characteristics	Service characteristics	Suitable networks
• Connected car • Fleet management • Remote health monitoring	~1000m	Yes	Rechargeable battery	Managed service, highly secure	• Cellular • Satellite
• Smart metering • Parking meter	~1000m	No	Low rate, low power, low cost	Managed service	• Cellular • Dedicated network
• Hospital asset tracking • Warehouse logistics	~100m	Yes	Low rate, low power, low cost	Enterprise-deployed	• WiFi • RFID
• Industrial automation • Home automation	~10m	No	Low rate, low power, low cost	Subscription-free	• Zwave • Zigbee • Wifi • Powerline
• Personal activity • Local object tracking • Point of sale	~1m	No	Low rate, low power, low cost	Subscription-free	• Bluetooth • NFC

IoT is not a helpful term

o The only common thread is what doesn't matter: absence of a human
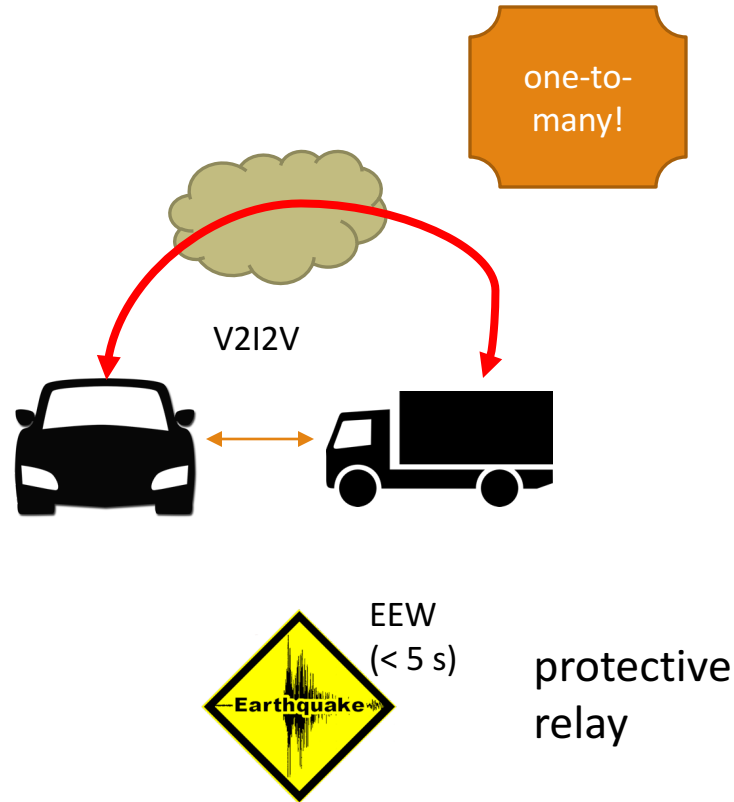
o Otherwise, spans every dimension of networking

fixed infrastructure	**mobility**	high-speed train aeronautical
message/week	**bandwidth**	4K video
minutes or hours	**latency**	10 ms protective relay
indoors or urban	**geography**	remote pipeline
1% of $1B bridge	**cost constraints**	$1/year $5/device

easy

hard

5G low latency

one-to-many!

V2I2V

LAN

EEW
(< 5 s)

protective relay
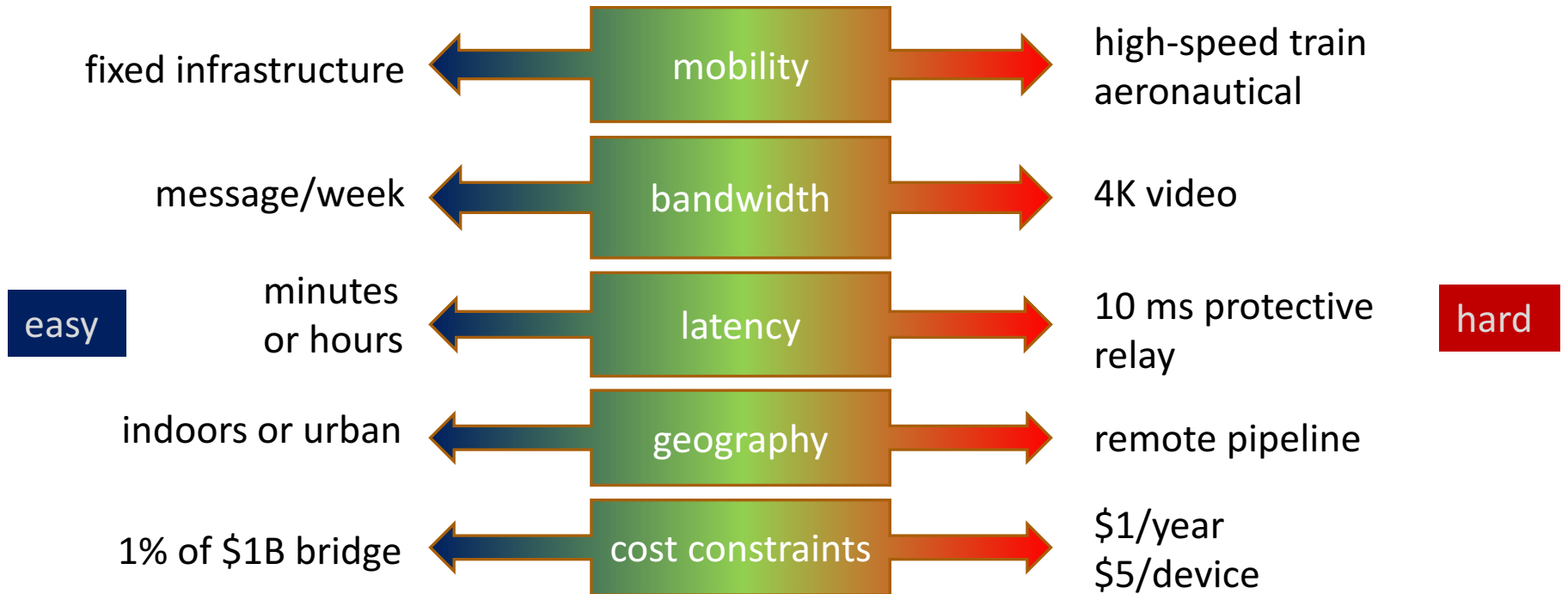
tight control loop → near-100% availability in time & **space**

What's the economic case for 5G?

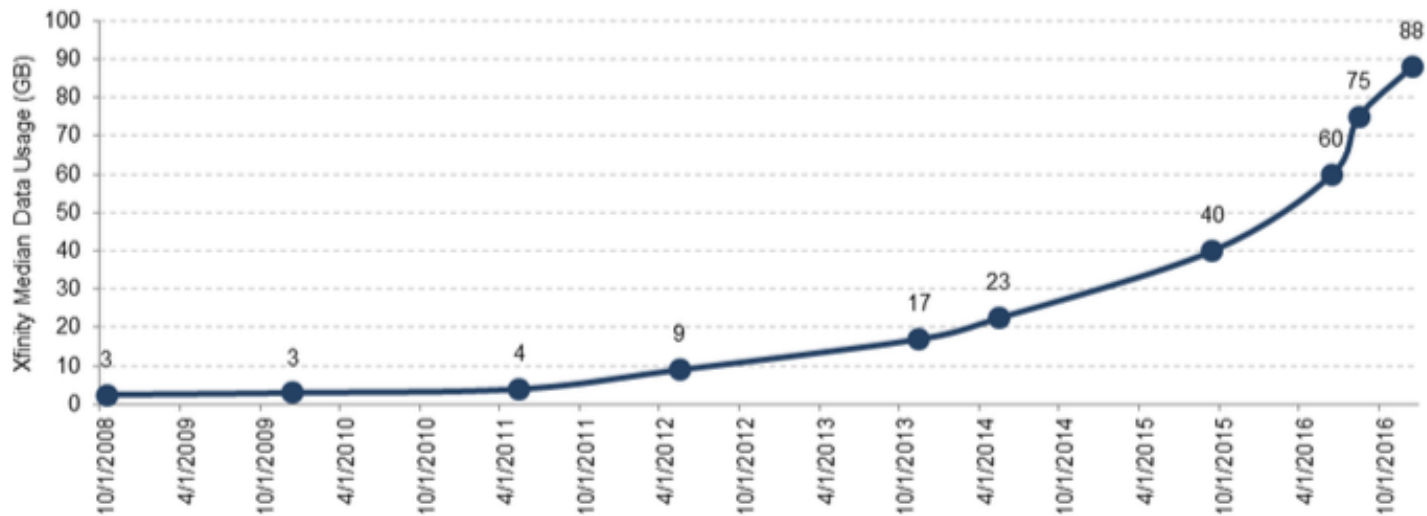**Big 4 Postpaid ARPU**

avg. about 2.1 GB/month
T-Mobile: 10 GB tethering
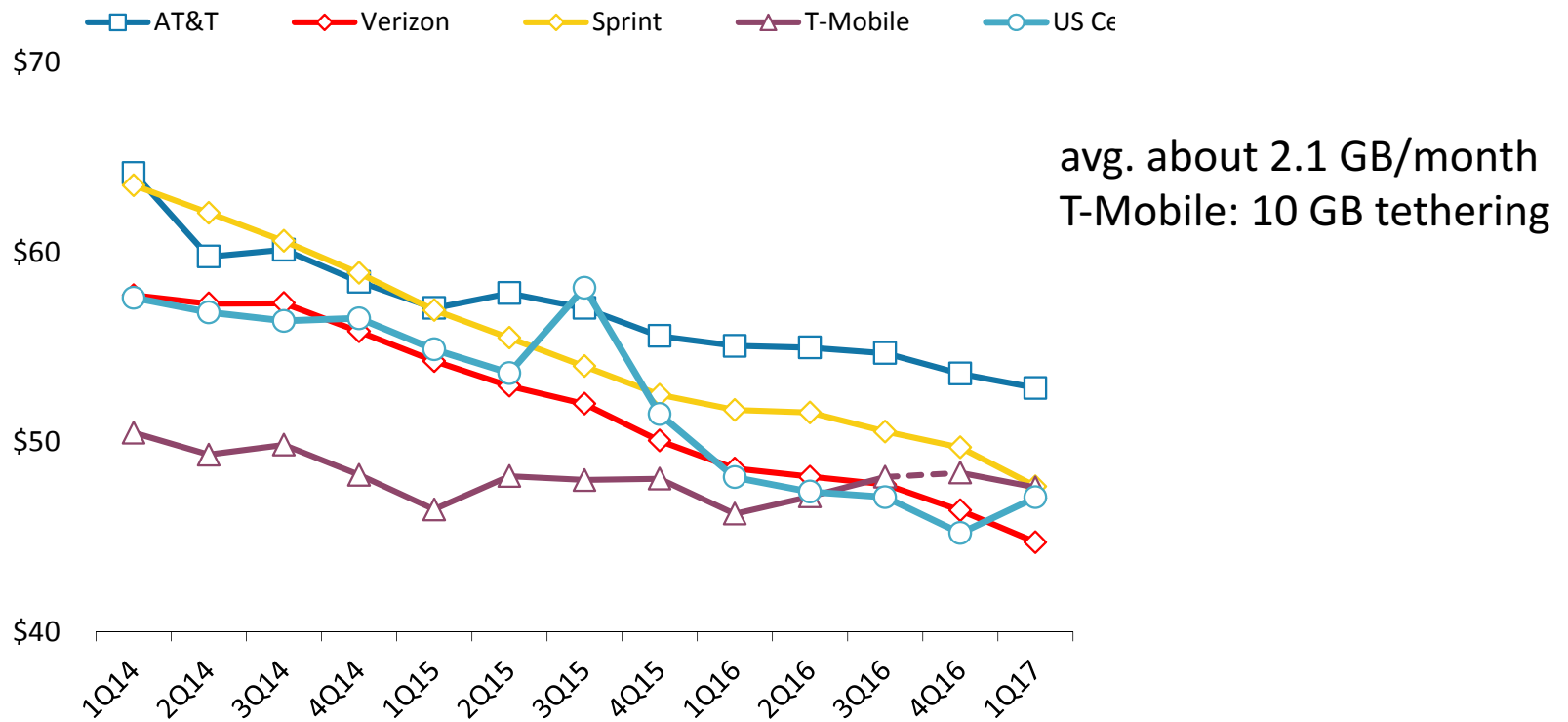
Cord-cutting for broadband?

Exhibit 13

Comcast: Median Bandwidth Usage per Household per Month, 2008 to 2016

Source: Comcast's website, MoffettNathanson estimates and analysis

Metrics: not Gb/s or b/s/Hz, but $/GB and $/year

o Consumer market: $/GB delivered
  - little willingness to pay for speed above 10 Mb/s for now
  - unless $/GB → 0, 1 Gb/s just threatens wallet

o NB-IoT: $/device + $/year cost
  - compete with $0 incremental cost BT/Zigbee/WiFi or LPWAN
  - include amortized
  - typically, << $1/month
  - predictable coverage & international reach
  - alternative for one-way: ATSC 3.0 (50+ miles reach, no incremental cost)

Network economics, (over)simplified

70%

30%

% OF REVENUE

■ Equipment ■ Construction ■ Operations ■

Equipment
4%

Construction
11%
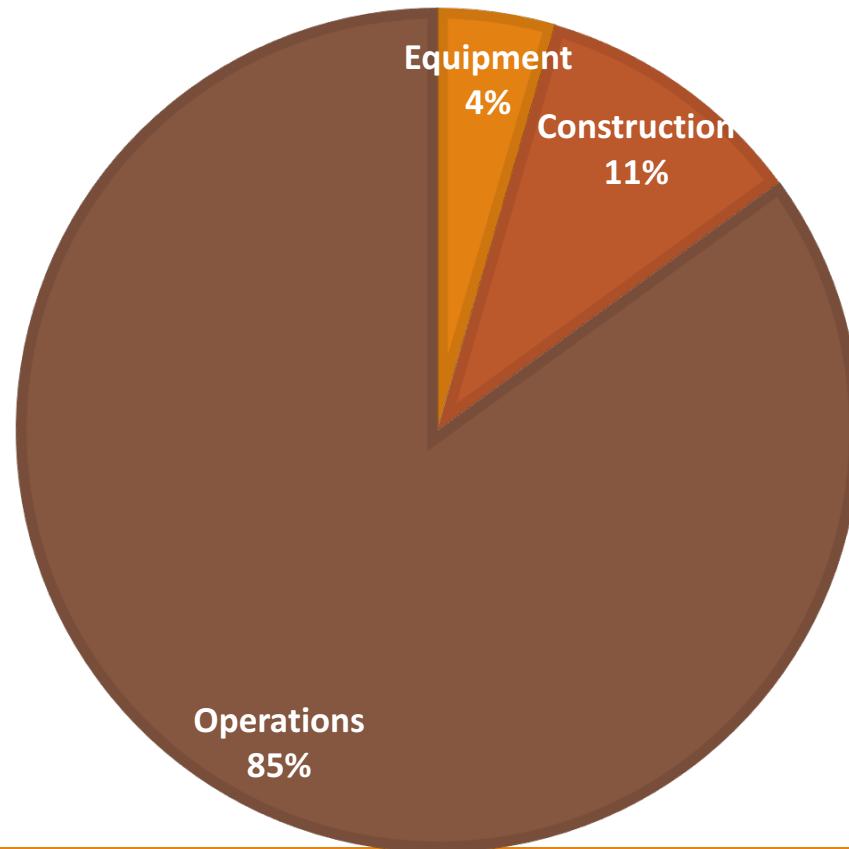
Operations
85%

How can 5G be cheaper by GB?

- Backhaul is major cost factor
  - "Backhaul costs represented over 6% ... of ... total operating expenses (OPEX) and 30% of total network cost..."
- Re-use existing fiber to residential users
  - Requires cooperation of cable/FTTH provider
  - or shared indoor infrastructure (ok for airports & stadiums, unlikely for commercial buildings)

- Reduce license cost for spectrum → unlicensed, mmWave
  - first step: LTE-U

Cost categories	Subcategories	Average Sub-component Breakdown
Network strategy and support		14%
Network infrastructure rent		39%
Core network and transmission	Transmission	7%
	Core Network	8%
Radio operations and maintenance	Radio operations & maintenance	14 %
	Radio deployment	10 %
	Radio design	8 %

Table 5. Wireless Network Cost Breakdown (OPEX and Headcount CAPEX)

| Subcomponents	Carrier A	Carrier B	Carrier C	Carrier D	Average of All Carriers
Strategy and Support	13	8	10	19	14%
Network infrastructure rent	36	45	33	37	39%
Transmission	6	5	13	8	7%
Core Network	10	9	13	3	8%
Radio ops & maintenance	11	15	18	14	14 %
Radio deployment	13	8	8	10	10 %
Radio design	10	9	5	8	8 %

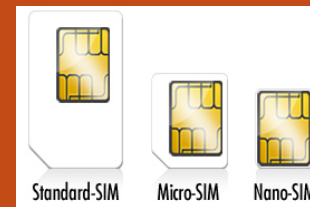*Source: Wireless Carriers Benchmarking Study*

Network architecture

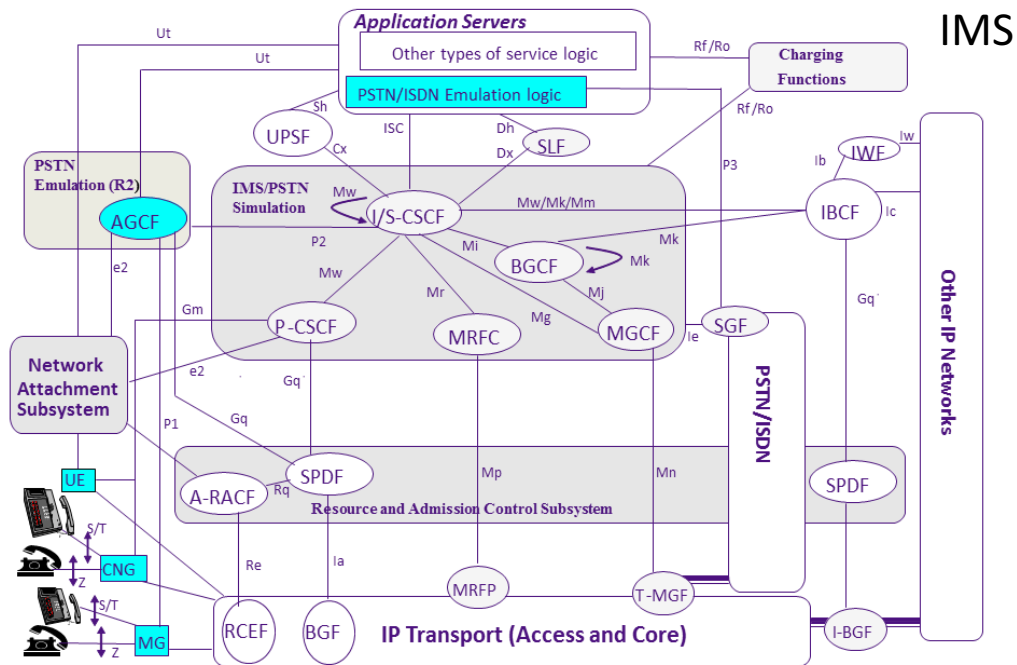# Networks 1G through 4Gish

national carrier
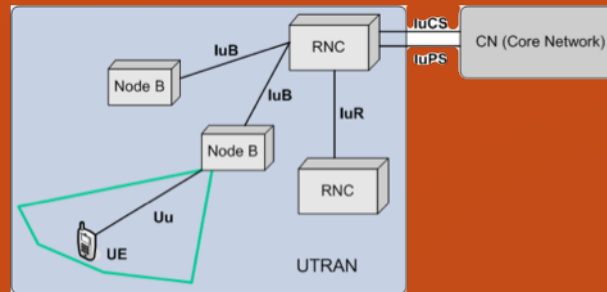
one subscriber,
one phone,
one provider

Complexity kills

IMS

IMS /VoLTE

VoLTE: Taking Carriers Beyond Voice

Mon, 06/06/2011 - 12:43pm

by Maisie Ramsay

✉ Get today's wireless headlines and news - Sign up now!

Project yourself into the future – let's say mid-2012. It's been about a year and a half since Verizon Wireless first launched its LTE network in December 2010, and after a long wait, the company has finally come out with the first smartphone running voice over LTE (VoLTE) technology.

You go out and buy the device, turning it on the second you have it out of the box. One of the first things you notice: The phone's native voice application isn't limited to just voice. It has an option for video calls, and there's also an option to send multimedia messages, along with presence indicators that show when people on your contact list can participate in a video call.

AT&T, Verizon Target VoLTE Interop in 2015, RCS Later

By Doug Mohney / November 04, 2014

AT&T and Verizon have officially declared they are working on Voice over LTE (VoLTE) connections between their respective networks and customers. VoLTE calls between Verizon and AT&T customers "is expected" in 2015, according to a statement from the companies. And, there's also some Rich Communications Services (RCS) news buried in the text.

The announcement comes as three out of four major U.S. carriers promote LTE networks and a number of countries plan to turn up LTE and VoLTE in the next 15 months. "Interoperability among VoLTE service providers in the United States and around the world will create a better and richer mobile experience for customers," declares Verizon's press release.
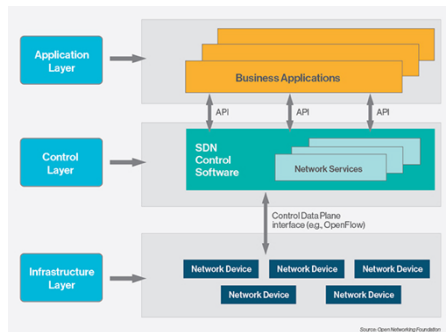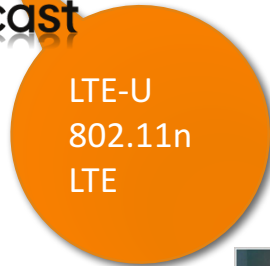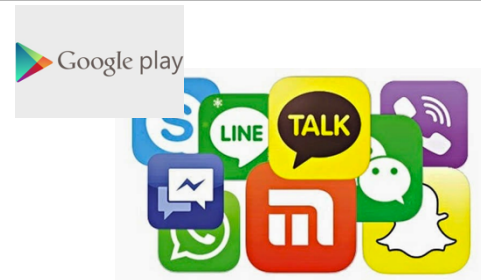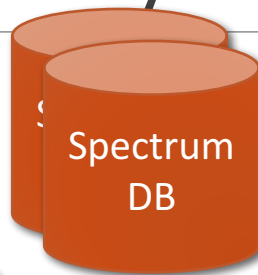
Vodafone Germany announces VoLTE rollout

17 Mar 2015

🇩🇪 Germany

Vodafone Germany claims it has become the first German operator to initiate the rollout of voice-over-LTE (VoLTE), having demonstrated the first live VoLTE call on its network at the CeBIT 2015 technology fair in Hanover. The UK-owned operator says that the technology offers customers an 'unprecedented voice service and telephony experience', ensuring 'crystal clear voice quality, super-fast call set-up and encrypted phone calls' across its LTE network, which currently covers 70% of Germany. Vodafone revealed that it will soon be launching new LTE smartphones for VoLTE, including handsets from manufacturers such as Samsung, Sony and HTC. The announcement follows reports last week that Vodafone plans to introduce both Wi-Fi calling and VoLTE in the UK this summer, following trials of the technologies in laboratory conditions.
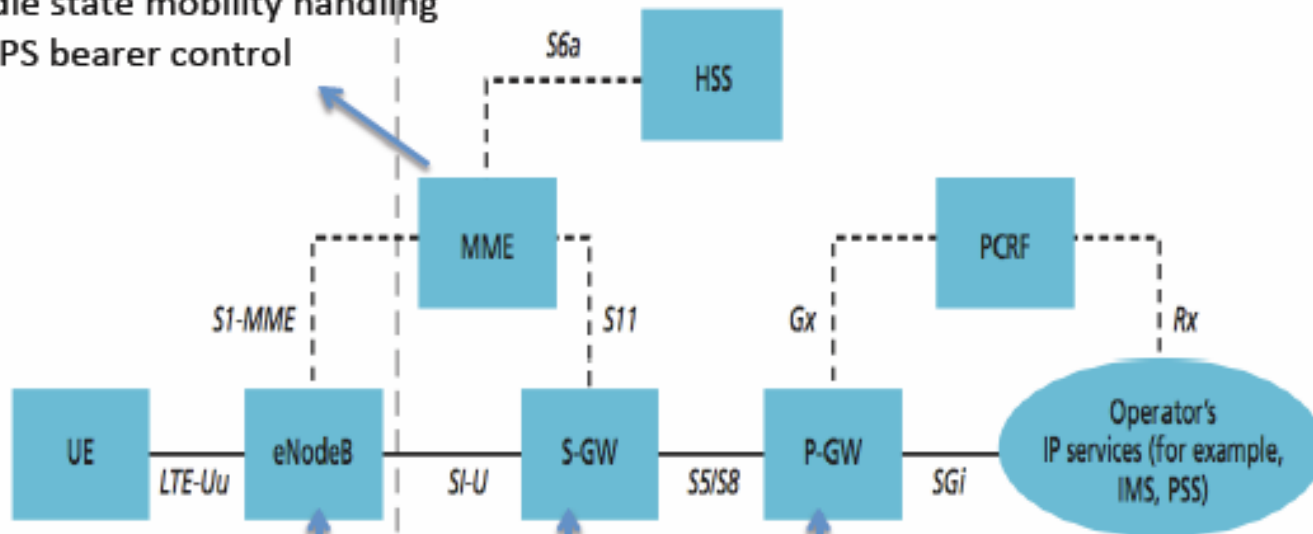
5G – what exactly is a carrier?

AMERICAN TOWER®
40k towers each (US)

CROWN CASTLE

FiberLight

lightower

zayo®

Google play

Spectrum DB

Level3
Cogent

comcast

LTE-U
802.11n
LTE

Application Layer — Business Applications
API   API   API
Control Layer — SDN Control Software — Network Services
Control Data Plane interface (eg., OpenFlow)
Infrastructure Layer — Network Device · Network Device · Network Device · Network Device · Network Device
Source: Open Networking Foundation

ERICSSON

LTE – one carrier, plus roaming

NAS security
Idle state mobility handling
EPS bearer control

S6a — HSS

MME

S1-MME | S11 | Gx | Rx

UE — eNodeB — S-GW — P-GW — Operator's IP services (for example, IMS, PSS)

LTE-Uu | SI-U | S5/S8 | SGi

Radio bearer control
Inter-cell RRM
Connection mobility Control
Radio admission control

Mobility anchoring

UE IP address allocation
Packet filtering

PCRF

5G: Carriers as consumer brand

Outside

Inside

What are carriers good at?

o Research?

o Software development?
  ◦ Who is going to develop those 5G SDN applications?

o OTT applications?

o API-based services?
  ◦ Why did Twilio and Tropo offer voice service APIs and not the ILECs?

o Cost reduction model?
  ◦ Commodity components
  ◦ Simplified provisioning and diagnostics

The law of new networks

- "Any new network technology will be justified on (finally) providing QoS"

- To succeed, they have to provide good-enough QoS for best effort
  ◦ at least with competition

- The business model for QoS is difficult
  ◦ see bypass toll roads

- QoS is usually not accessible to applications
  ◦ or not end-to-end

- Better: virtually-guarantee minimum bandwidth (e.g., 5 Mb/s) + adaptive applications

I-495 Express Lanes Endure Big Losses Early On Way To Potential Profit

By: Martin Di Caro
February 20, 2015

▶ PLAY   comments 2 g+1 f y ✉ 🖨 ➕
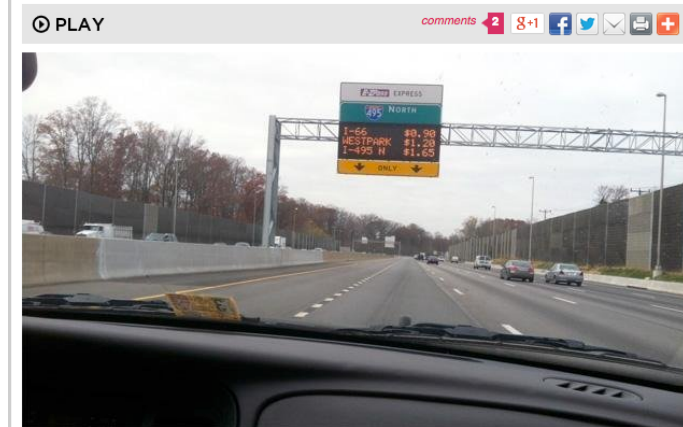
WAMU/Martin Di Caro

The 495 Express Lanes offer a paid respite from the usual Beltway traffic, but fewer drivers than expected are using them.

The private sector firm that operates the 495 Express Lanes along the Beltway in Northern Virginia is down more than $230 million on its investment in the two and a half years since the highway opened, but company officials say toll revenues are beginning to consistently exceed operating costs, a sign the project is winning over commuters in one of the region's most congested corridors.

Transurban, the Australia-based toll road builder that operates high-speed HOT (high-occupancy toll) lanes on I-495 and I-95, has said all along it would take years to turn a profit on its enormous investments in Northern Virginia.

What's the simplest network?

network characteristics (QoS)
IP address
AAA (incl. payment)
discovery
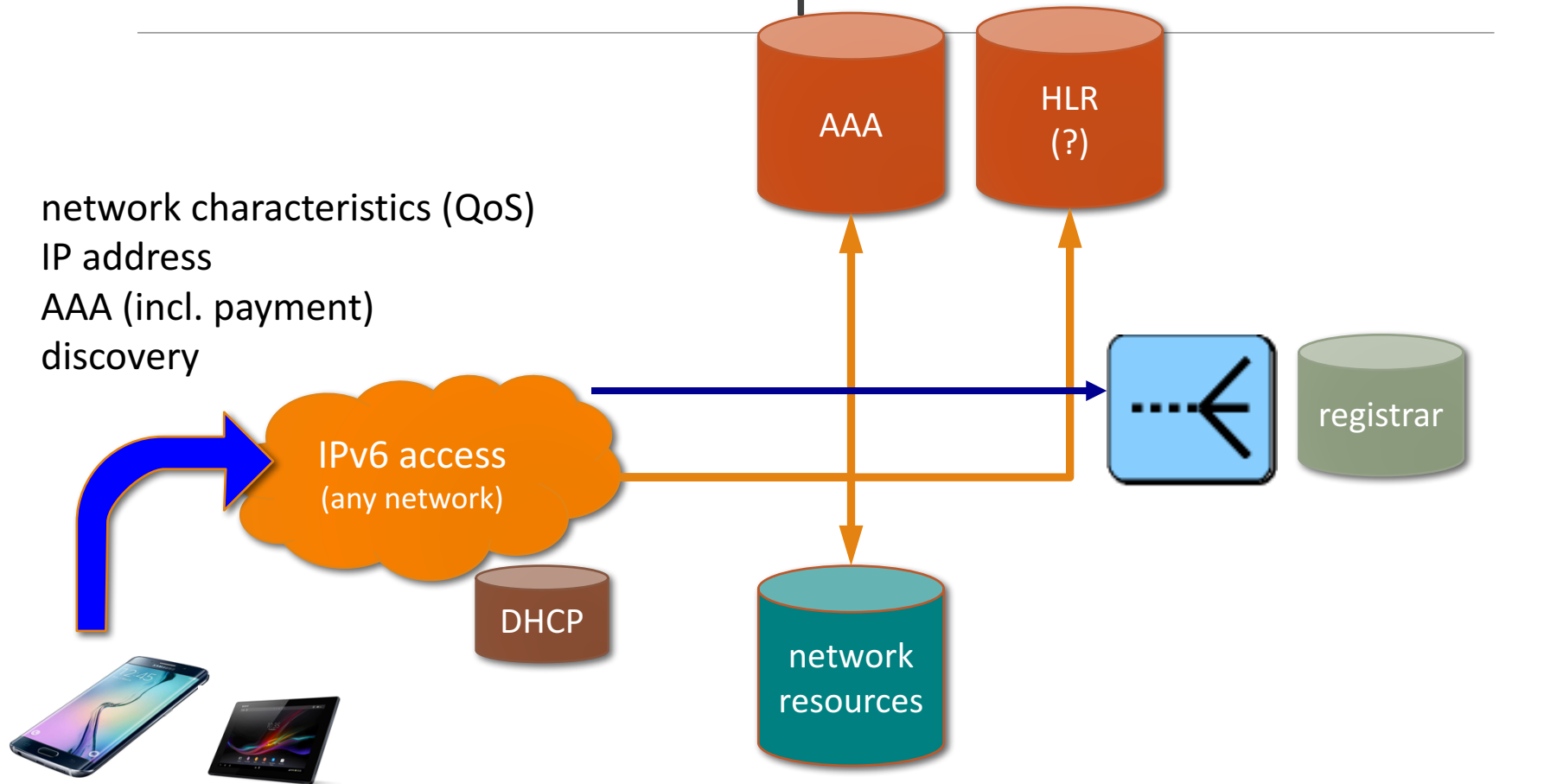
one subscriber, multiple devices, multiple providers

Simplify enrollment

enable access

5G prototype: Eduroam
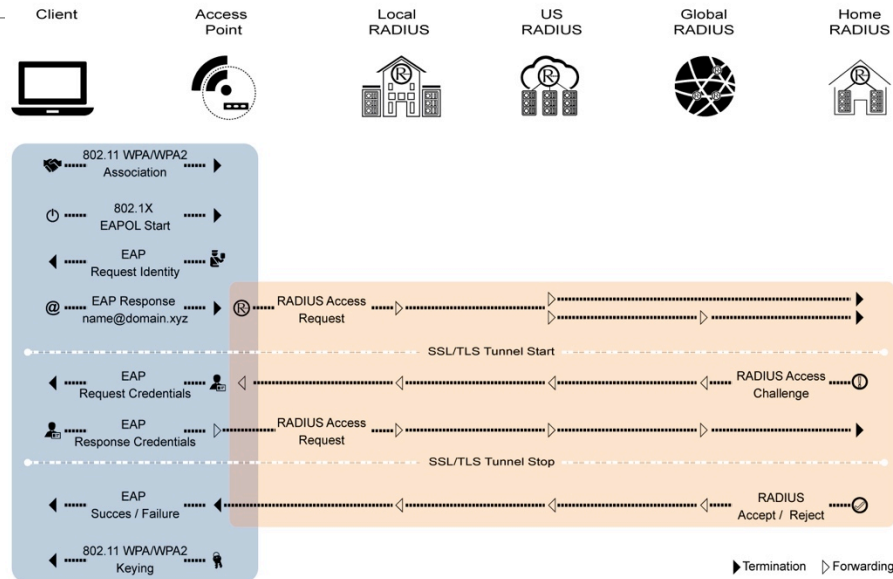
5G opportunities beyond hype

o Applications surprise

o Low cost per GB carried (capex & opex) may beat QoS
   ◦ fixed wireless and predictable motion (trains!) may be initial opportunity

o Complexity kills
   ◦ layering (1984) and information hiding is still a good engineering principle

o 5G: 4G++ or opportunity for re-thinking design assumptions
   ◦ complexity vs. modularity