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5G and IoT – Cousins, not Siblings

Henning Schulzrinne

Columbia University

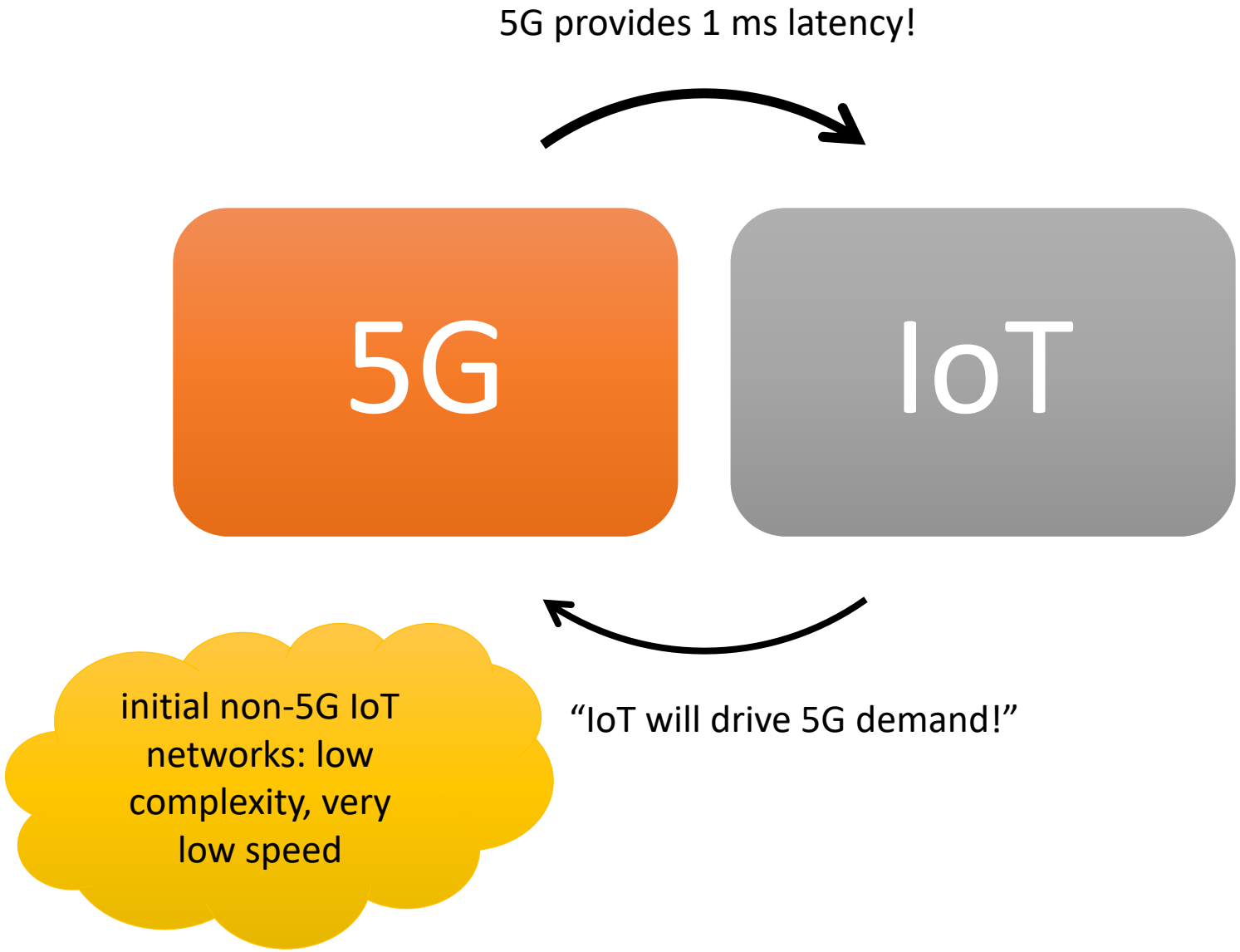
typical keynote

closer to this one

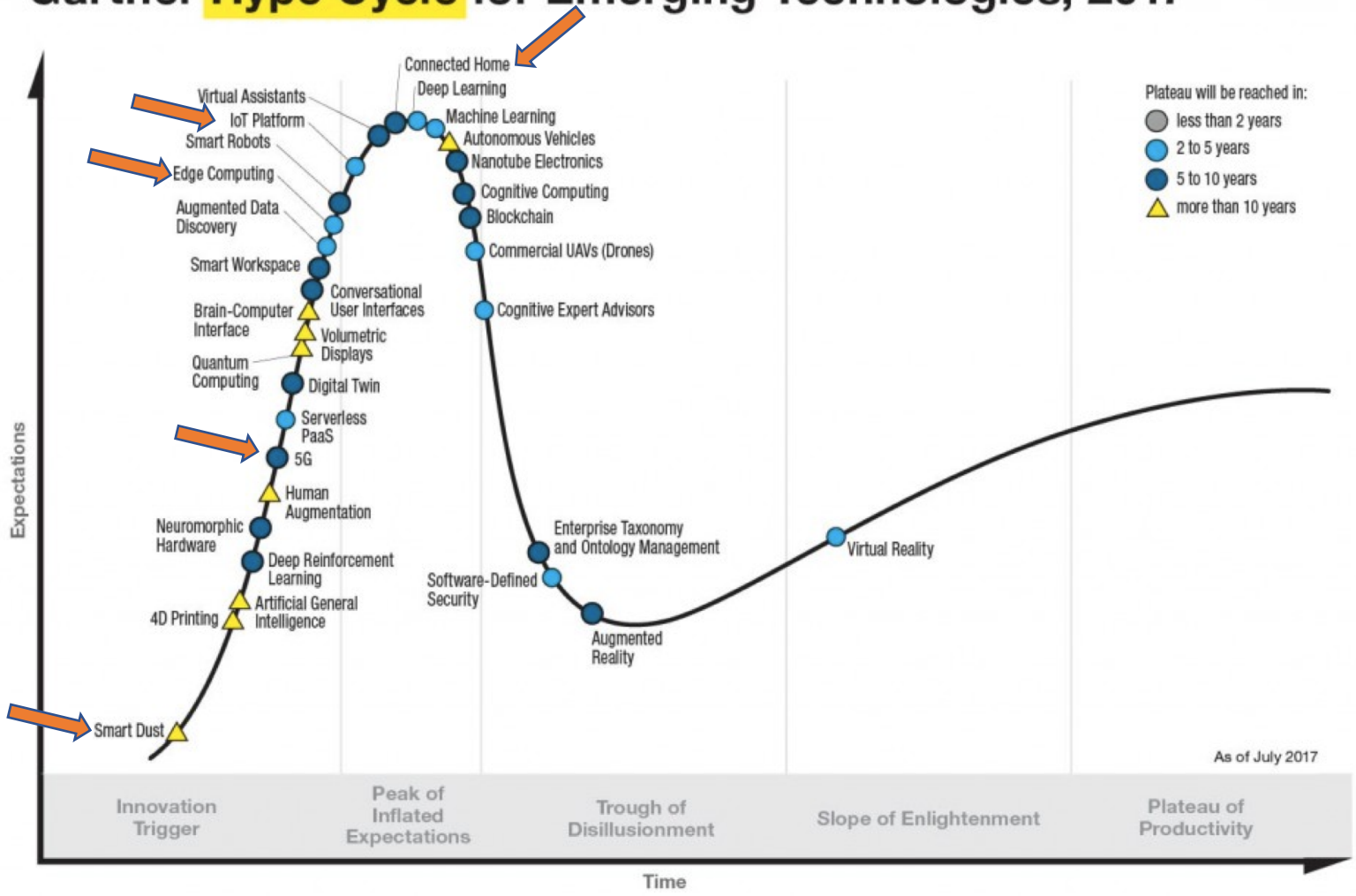
5G and IoT – buzzword cousins

- Looking back: IoT is old
- Billions and billions of IoT devices justify 5G investment and hype
  - rather than 5G as minor efficiency tune-up for 4G
- There is no single IoT network technology
- Economics of edge/fog/dew/… computing

Hype feedback loop



Gartner Hype Cycle for Emerging Technologies, 2017

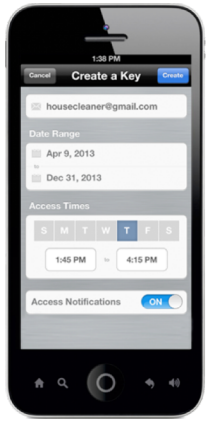


gartner.com/SmarterWithGartner

Source: Gartner (July 2017)

Gartner

Natural evolution



Billions and billions of devices

Table 1: IoT Units Installed Base by Category (Millions of Units)

Category	2016	2017	2018	2020
Consumer	3,963.0	5,244.3	7,036.3	12,863.0
Business: Cross-Industry	1,102.1	1,501.0	2,132.6	4,381.4
Business: Vertical-Specific	1,316.6	1,635.4	2,027.7	3,171.0
Grand Total	**6,381.8**	**8,380.6**	**11,196.6**	**20,415.4**

Source: Gartner (January 2017)

roughly 3 devices per human

https://www.gartner.com/newsroom/id/3598917

Pick your number

high expectations for potential IoT growth and profits. Remarkably, thos projections weren't even close to the highest of the time—in 2012, IBM forecasted 1 trillion connected devices by 2015. "The numbers were getti

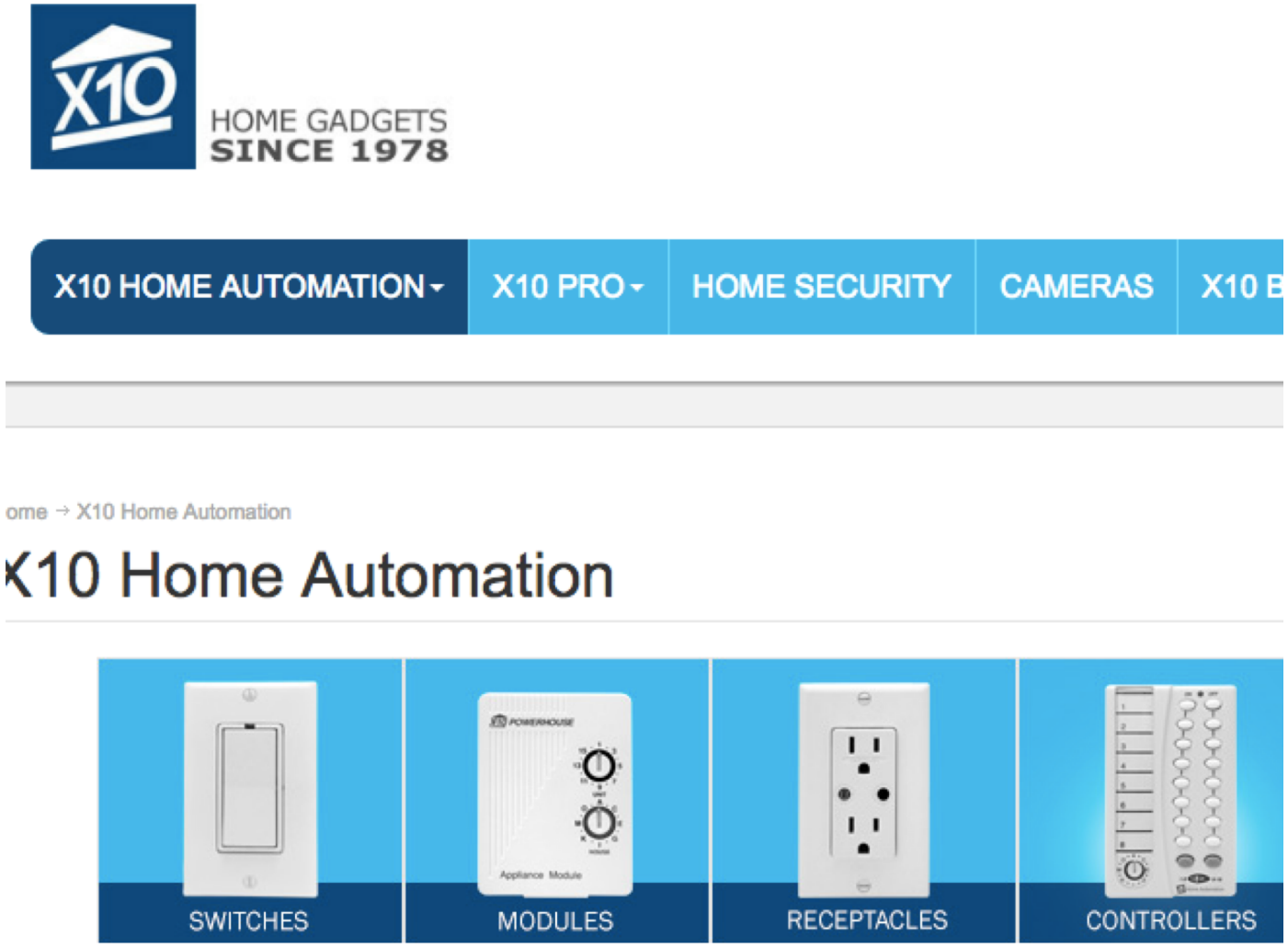
Now it's 2016, and we're nowhere near 1 trillion IoT devices, or even 50 billion for that matter. The current count is somewhere between Gartner's estimate of 6.4 billion (which doesn't include smartphones, tablets, and computers), International Data Corporation's estimate of 9 billion (which also excludes those devices), and IHS's estimate of 17.6 billion (with all such devices included).

Since they first made their projections, both Ericsson and Evans have lowered their expectations from 50 billion for 2020: Evans, who is now CTO of Stringify, says he expects to see 30 billion connected devices by then, while Ericsson figures on 28 billion by 2021. Other firms have adopted similar tones: IHS Markit projects 30.7 billion IoT devices for 2020, and Gartner expects 20.8 billion by that time (excluding smartphones, tablets, and computers). Lastly, IDC anticipates 28.1 billion (again, not counting those devices).

IEEE Spectrum 8/2016

➔ the *keynote estimator*: the higher, the more likely to be cited in a keynote

IoT is not exactly new (1978)



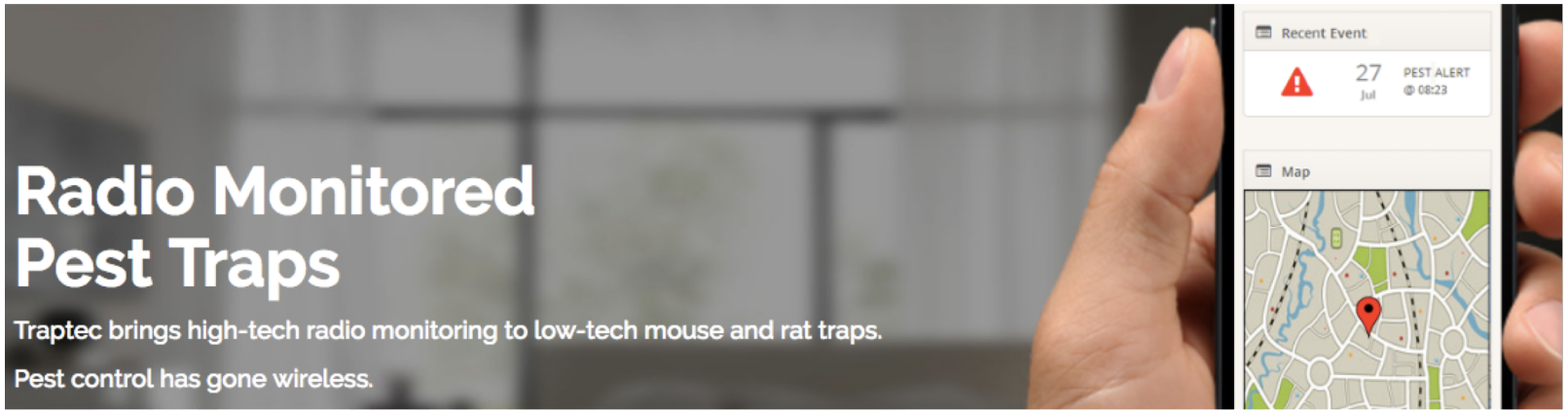
IoT – an idea older than the web (1985)

Peter Lewis (panel discussion 1985)

By connecting devices such as traffic signal control boxes, underground gas station tanks and home refrigerators to supervisory control systems, modems, auto-dialers and cellular phones, we can transmit status of these devices to cell sites, then pipe that data through the Internet and address it to people near and far that need that information. I predict that not only humans, but machines and other things will interactively communicate via the Internet. ***The Internet of Things, or IoT, is the integration of people, processes and technology with connectable devices and sensors to enable remote monitoring, status, manipulation and evaluation of trends of such devices****. When all these technologies and voluminous amounts of Things are interfaced together -- namely, devices/machines, supervisory controllers, cellular and the Internet, there is nothing we cannot connect to and communicate with. What I am calling the Internet of Things will be far reaching.*

From Chetan Sharma Consulting 2016

The IoT killer app



http://www.traptec.eu/

But controlling light switches is still not the best use

Want to turn on the bedroom light? Sure, just pick up your smartphone, enter the unlock code, hit your home screen, find the Hue app, and flick the virtual switch. Suddenly, the smart home has turned a one-push task into a five-click endeavor, leaving Philips in the amusing position of launching a new product, Tap, to effectively replicate the wall switches we always had.

https://techcrunch.com/2014/12/04/the-problem-with-the-internet-of-things/

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?

20 billion devices ≠ 20 billion device 5G connections

cheap connectivity

managed connectivity

hybrid connectivity: cheap + ubiquitous

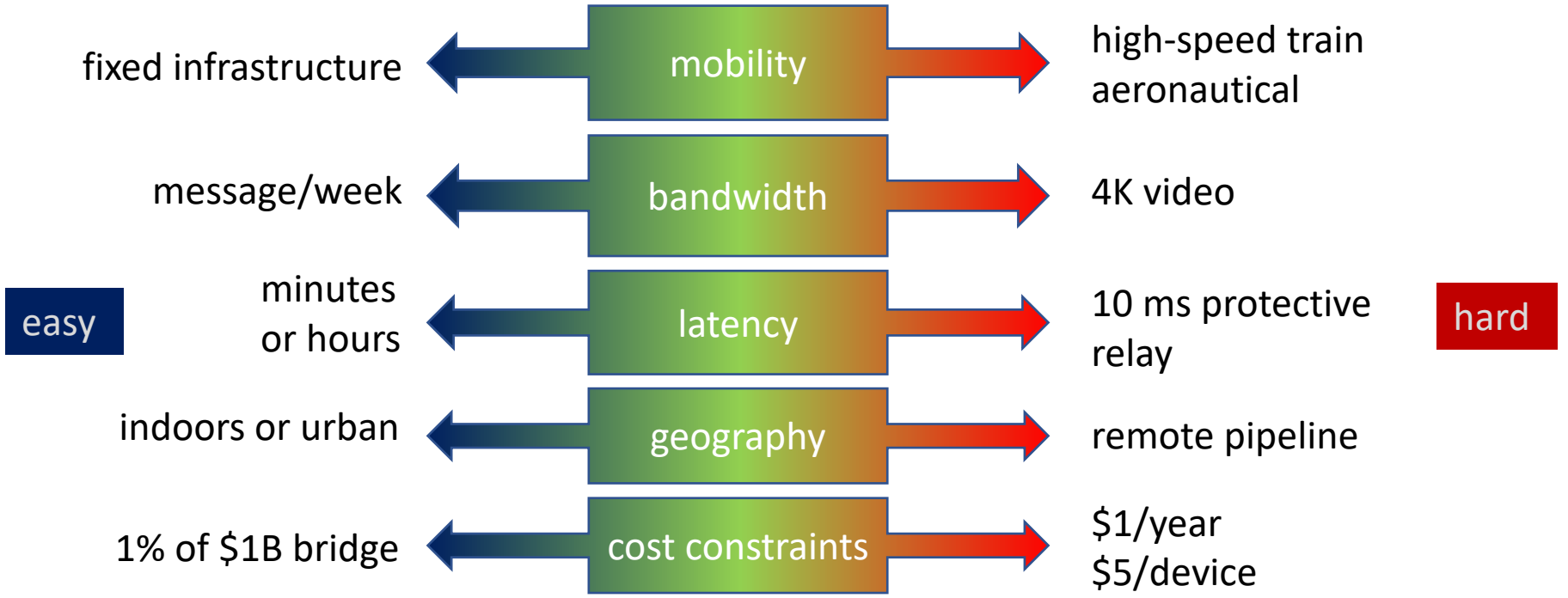
IoT requirements

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

Wide-area Wireless Communication Challenges for the Internet of Things
Harpreet S. Dhillon, Howard Huang, Harish Viswanathan

IoT is not a helpful term

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



What are likely cellular IoT applications?

single provider
no reliance on local Wi-Fi
but: license-free and regional only

nodes / km^2

security cameras
(high BW density)

100% coverage

What is the scale of outdoor and distributed applications?

one per household or business
(e.g., 136M housing units in US)

31,100 in US
but often connected to city fiber network

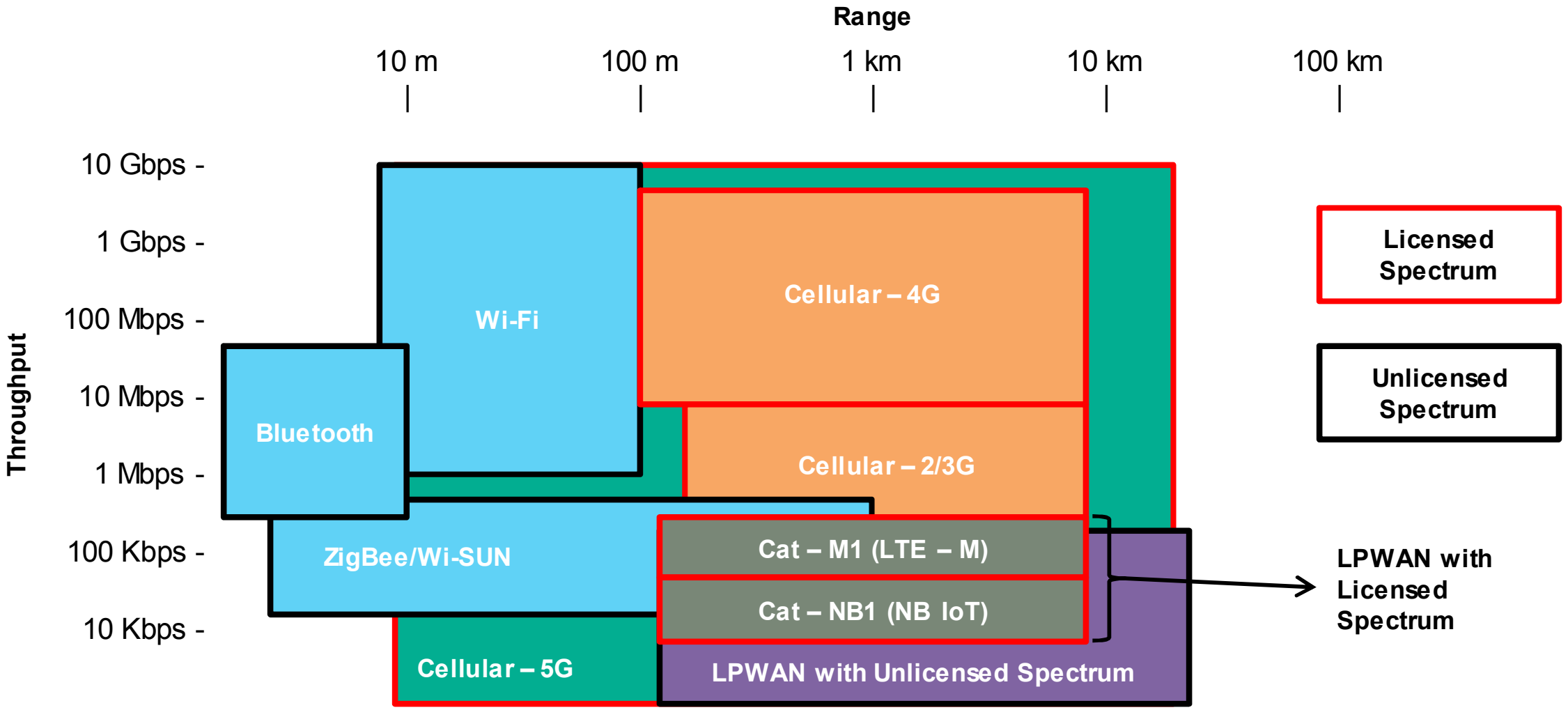
268.8M (US) cars, trucks, …

5 million (US)
62,000 in NYC

26.5M (44M) in US
$2B energy cost / year
Boston: 64k street lights
but: often connected to fiber (5G!)

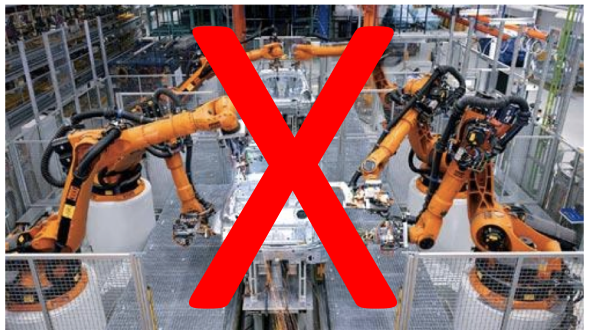
What kind of communication networks?

Dominant challenge	Example	solution
Low monthly cost	Residential	Wi-Fi
High bandwidth outdoors	Stadium (spectators, cameras)	5G mmWave
High bandwidth indoors	University lecture hall	Wi-Fi
Outdoor, but regional	Public transit, metering, traffic signage	NB-IoT, LoRAWAN
Outdoor, on major roads	Connected vehicles	DSRC + LTE?
Outdoor (including marine), 100% coverage, small antenna	Agriculture sensors	Iridium NEXT?
Outdoor (including marine), 100% coverage, antenna size not limited	Agriculture machinery, construction, pipelines, shipping, logistics	LEO satellites?

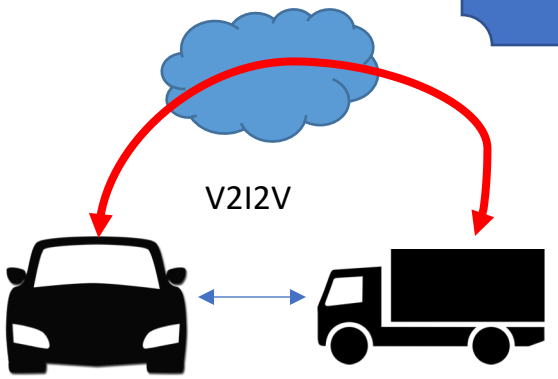


Source: HP Enterprise and Bernstein analysis.

5G low latency



LAN



one-to-many!

EEW
(< 5 s)

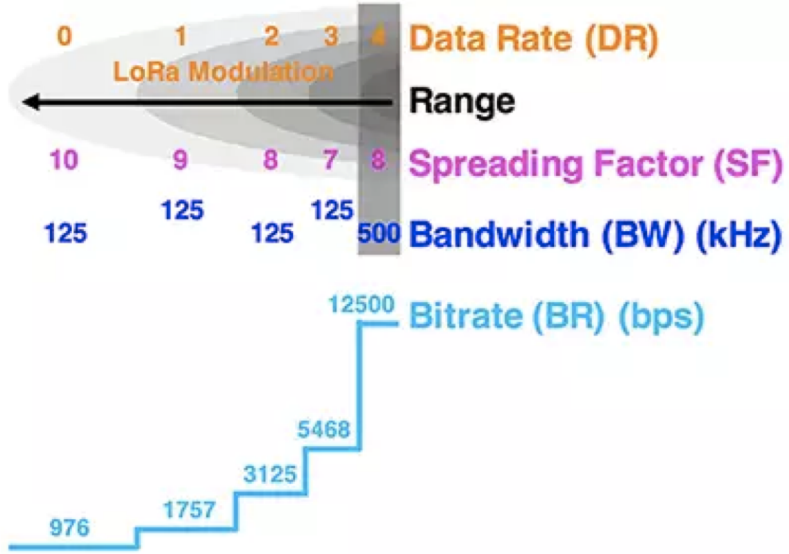
protective relay

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

Challenge for non-carrier IoT networks

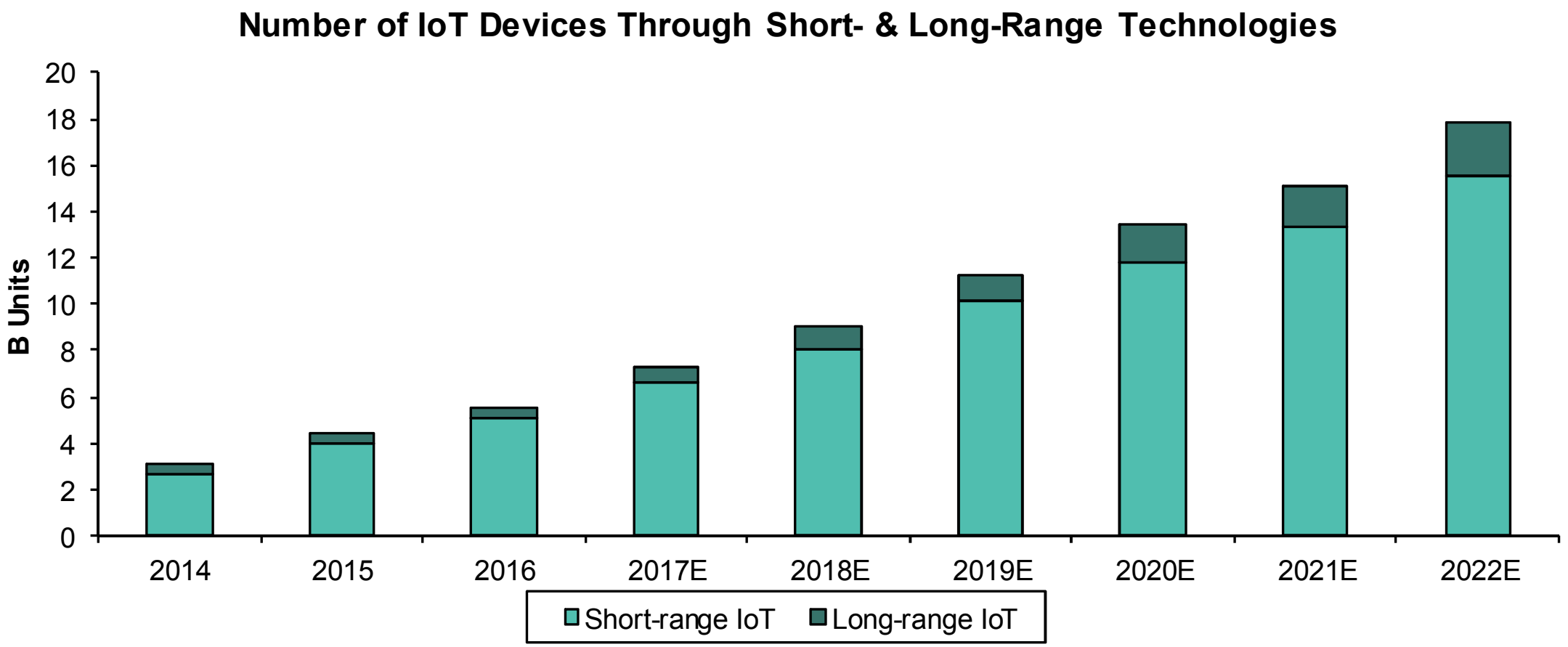
- Need international and near-universal (road) coverage
  - Sigfox: 7 million connections in 20 countries (2017)
    - goal: $1/year connectivity
  - compete with cellular aggregators
  - need to be everywhere before customers interested anywhere
- Challenging pricing model
  - per month?
  - per message (e.g., for lost items & problem reporting)?

Example: gas meter using LoRAWAN

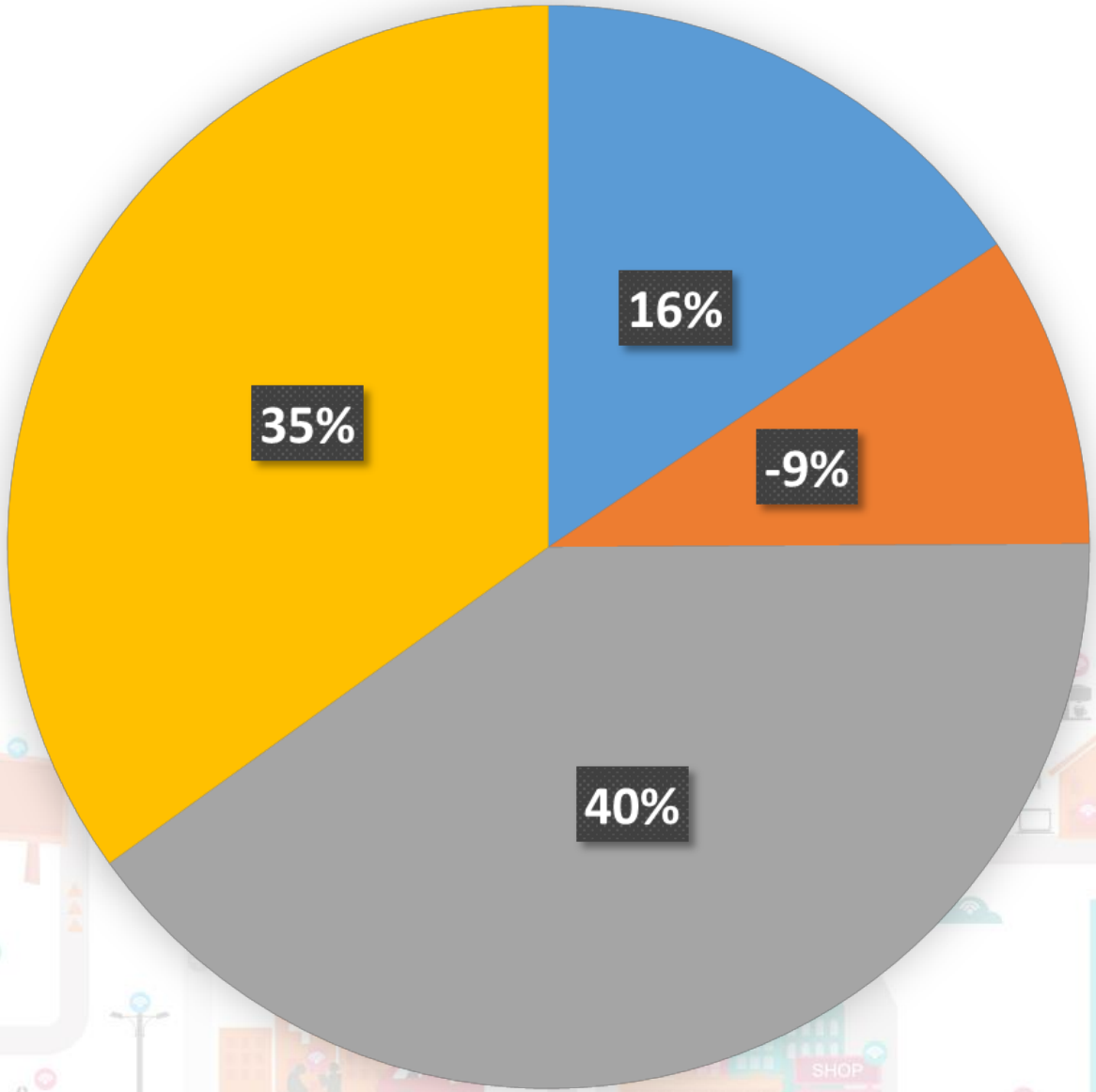


→ works well for IoT applications that are inherently regional (utilities, public transit signage)

Short & long-range IoT networks

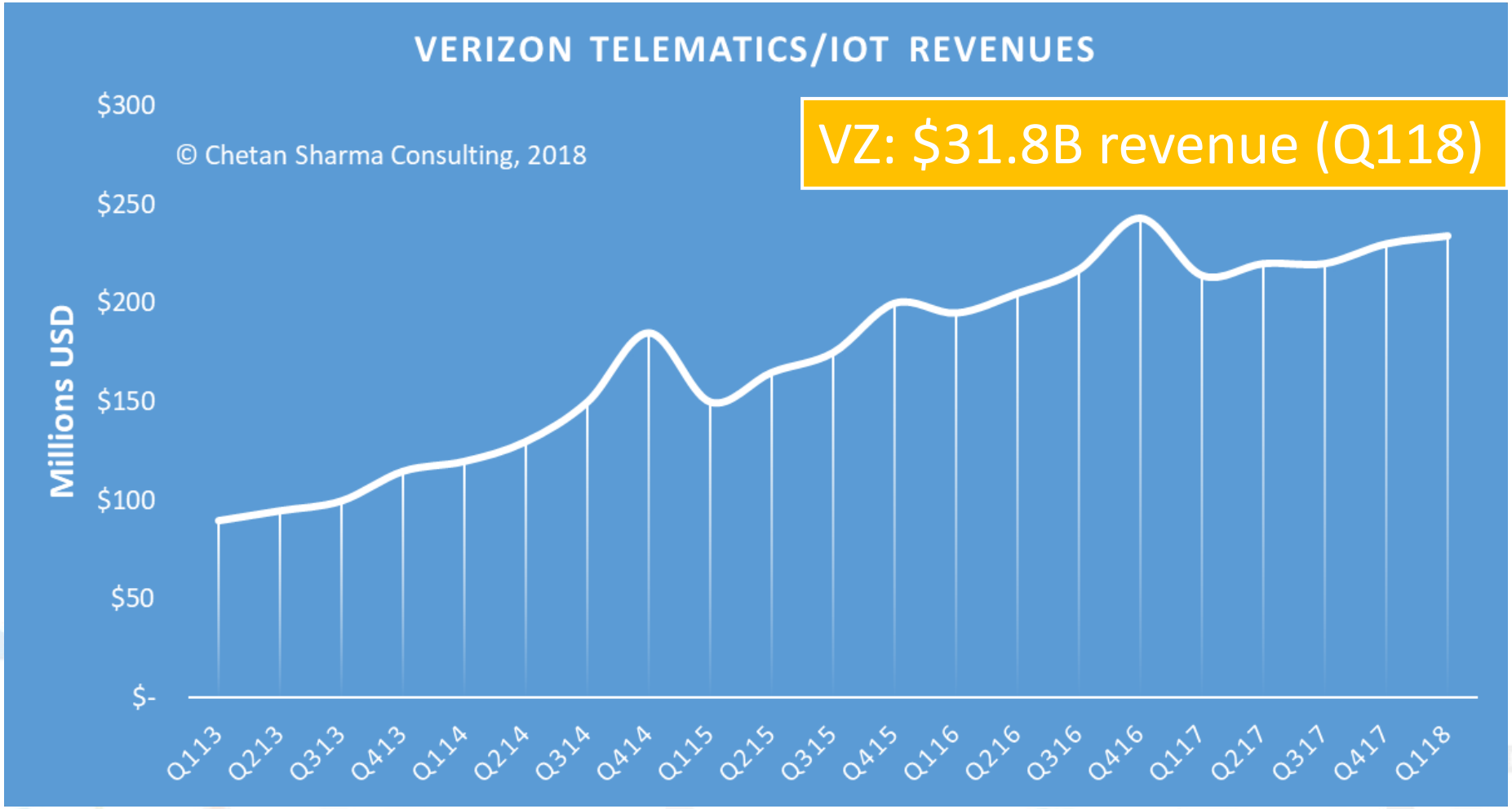


US Q1 2018 - Net-Add Device Distribution



Phone
Tablet
Car
IoT

Verizon telematics + IoT revenue



Alternative: satellite communication

Iridium
two-way

GlobalStar
GPS fix every 10 minutes

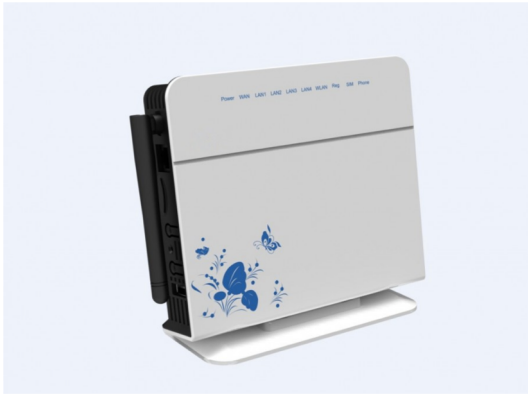
NEXT iridium®

LEO

LEOSAT™

SpaceX launch: Elon Musk's 12,000 satellite Starlink network will beam worldwide internet

(Dubious) economics of fog computing



hyperscale
cloud providers

free
known to OEM

limited
capacity

”free”
privacy assurances
save access BW

limited
capacity

low latency
save backhaul

limited capacity
business model?
heterogeneity
programming model?

low cost (scale, mux.)
well-known interfaces
Paas, SaaS, serverless, bare metal

> 20 ms latency
privacy concerns

Protocols matter, but programmability matters more

- Nobody wants to program raw protocols
- Most significant network application creation advances:
  - 1983: socket API → abstract data stream or datagram
  - 1998: Java network API → mostly names, HTTP, threads
  - 1998: PHP → network input as script variables
  - 2005: Ruby on Rails → simplify common patterns
- Many fine protocols and frameworks failed the programmer hate test
  - e.g., JAIN for VoIP, SOAP for RPC
- Most IoT programmers will not be computer scientists

5G – what exactly is a carrier?

AMERICAN TOWER®
40k towers each (US)

CROWN CASTLE

FiberLight

lightower

zayo

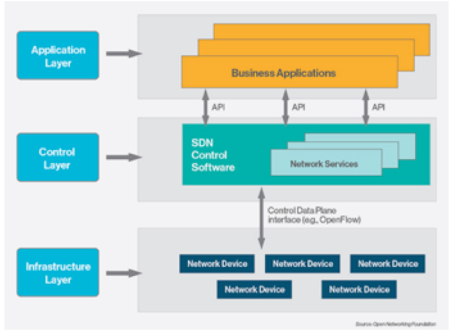
Spectrum DB

Google play

Level3
Cogent

comcast

LTE-U
802.11n
LTE

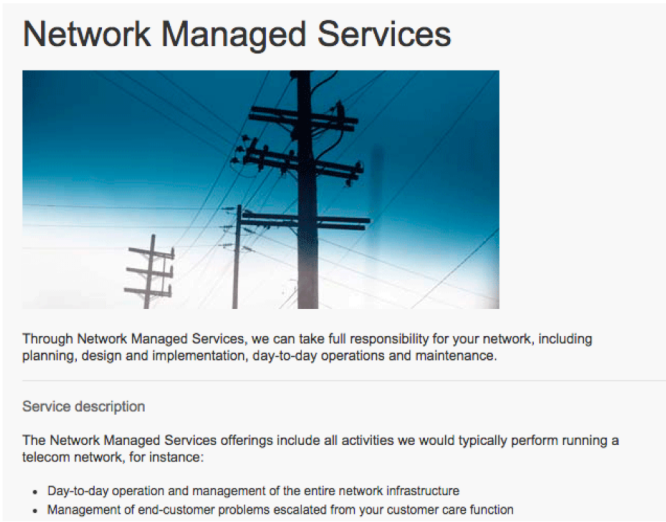


ERICSSON

5G: Carriers as consumer brand

Outside

Inside

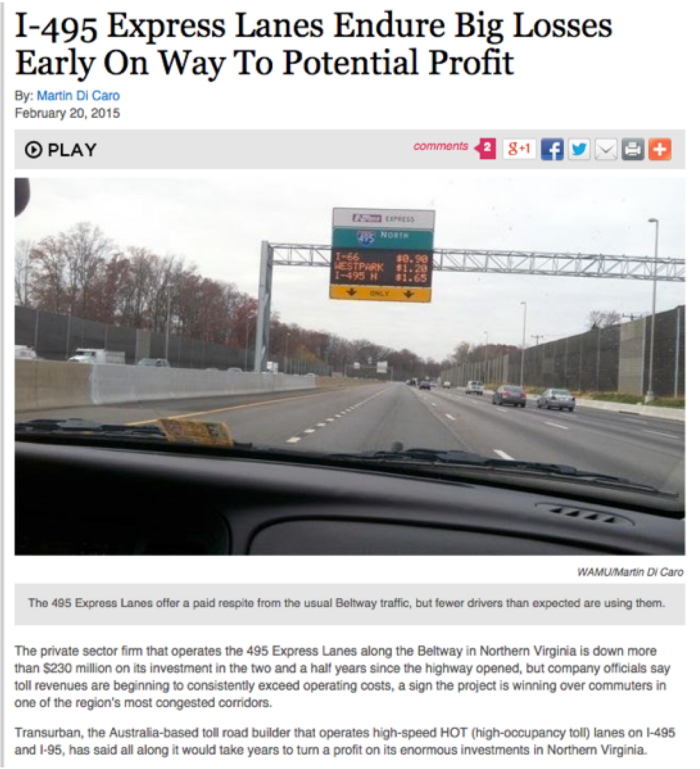


What are carriers good at?

- Research?
- Software development?
  - Who is going to develop those 5G SDN applications?
- OTT applications?
- API-based services?
  - Why did Twilio and Tropo offer voice service APIs and not the ILECs?

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



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

By: Martin Di Caro
February 20, 2015

PLAY

comments 2

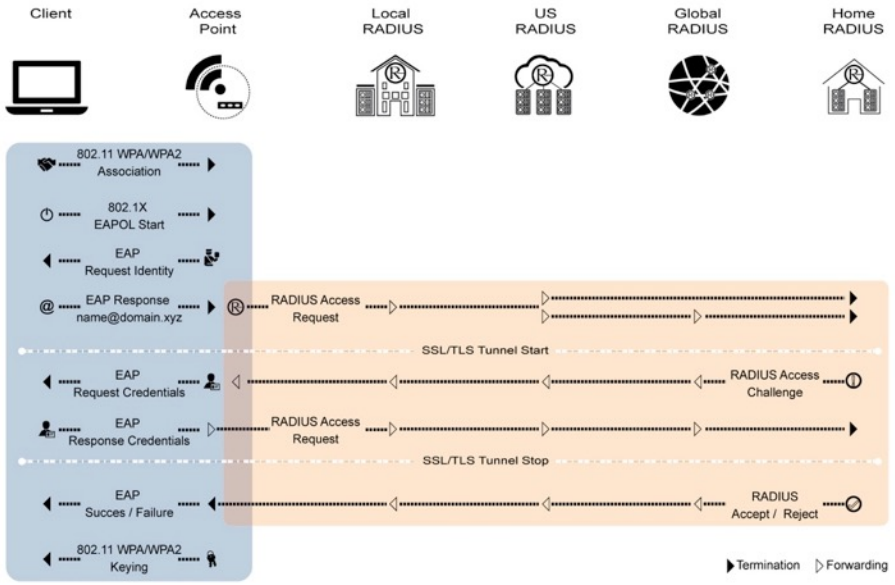
WAMU/Martin Di Caro

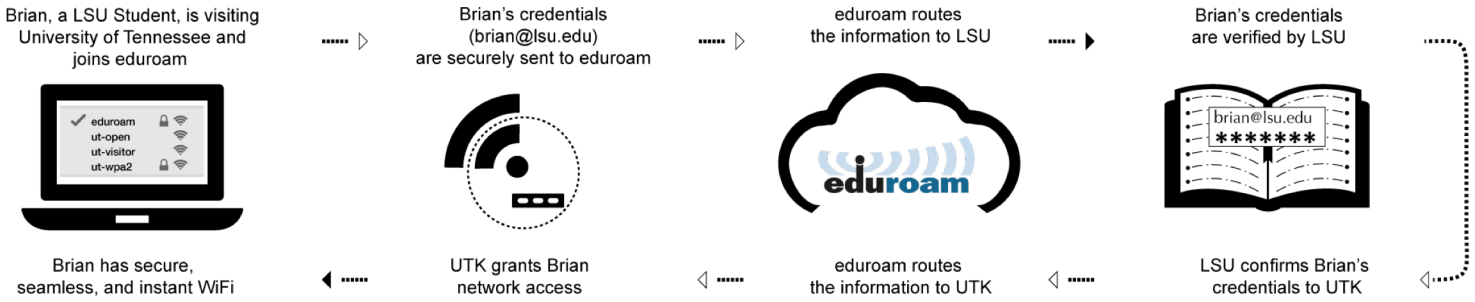
The 495 Express Lanes offer a paid respite from the usual Beltway traffic, but fewer drivers than expected are using them.

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.

5G & IoT prototype: Eduroam





Conclusions

- Treat predictions of market size with extreme caution
  - and IoT population ⋙ your favorite network technology share
  - you will not get your appendix removed via 5G
- Economics challenging for 5G IoT and edge computing
- Key challenges:
  - fragmentation of eco system (one app per device)
  - security and lifecycle
  - failure modes – fail safe?