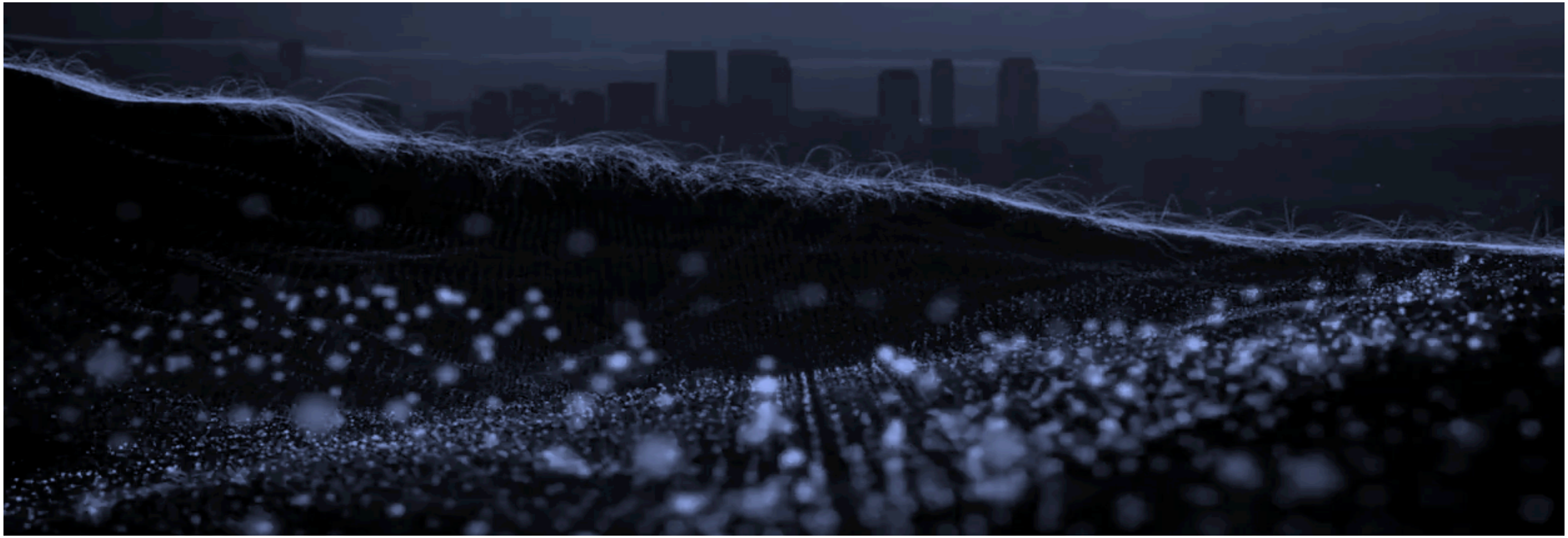
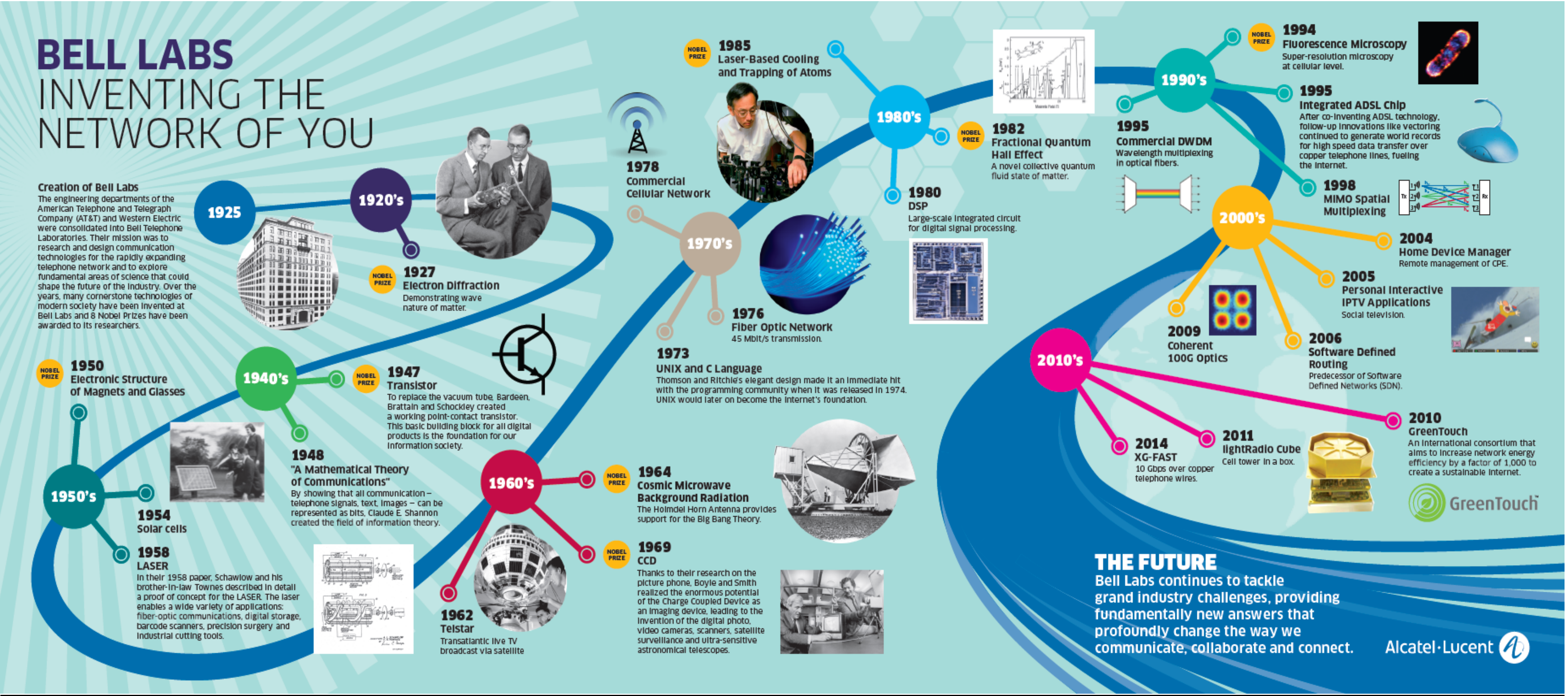


FUTURE COMMUNICATION CLOUDS

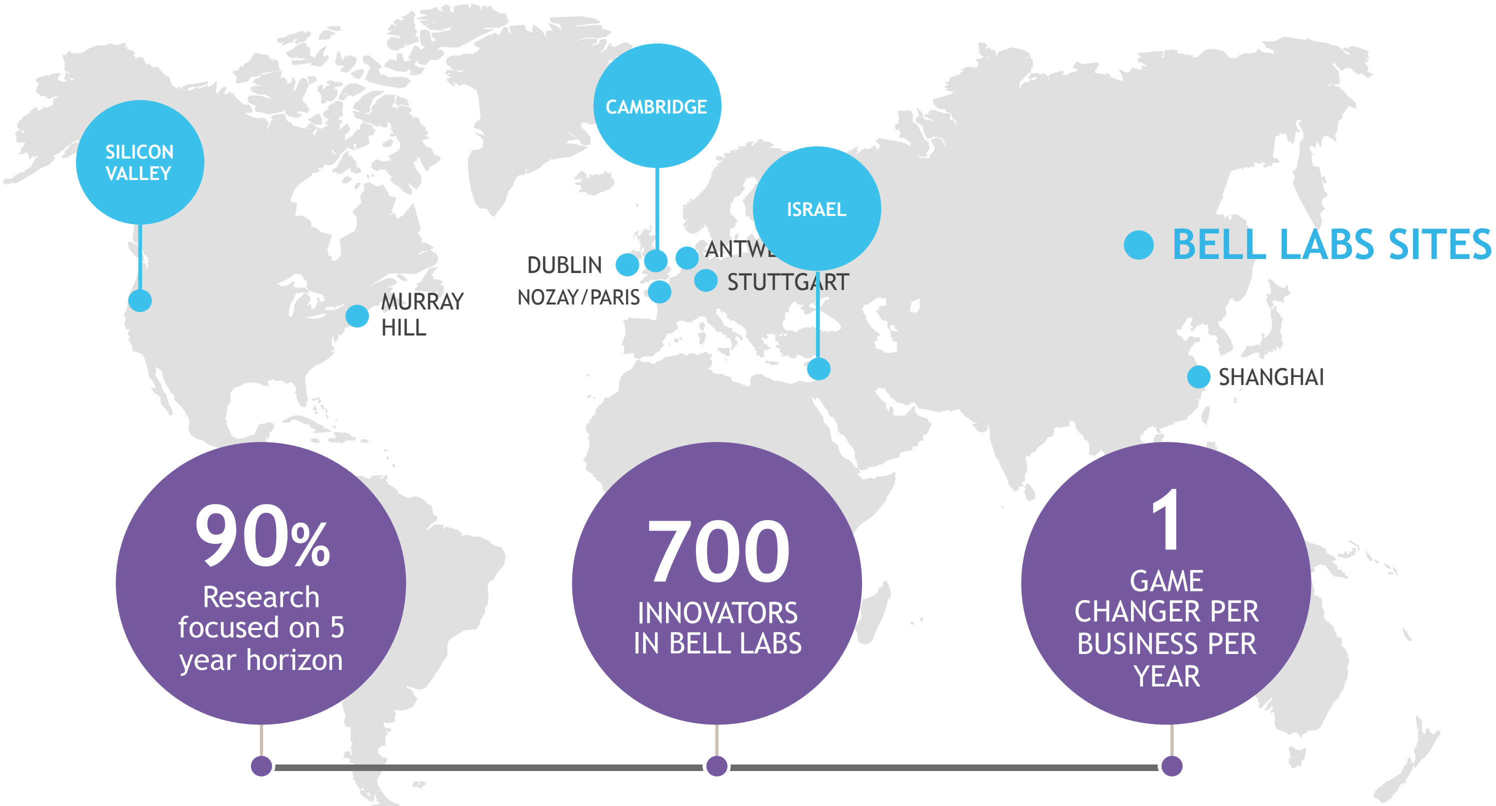
Krishan Sabnani

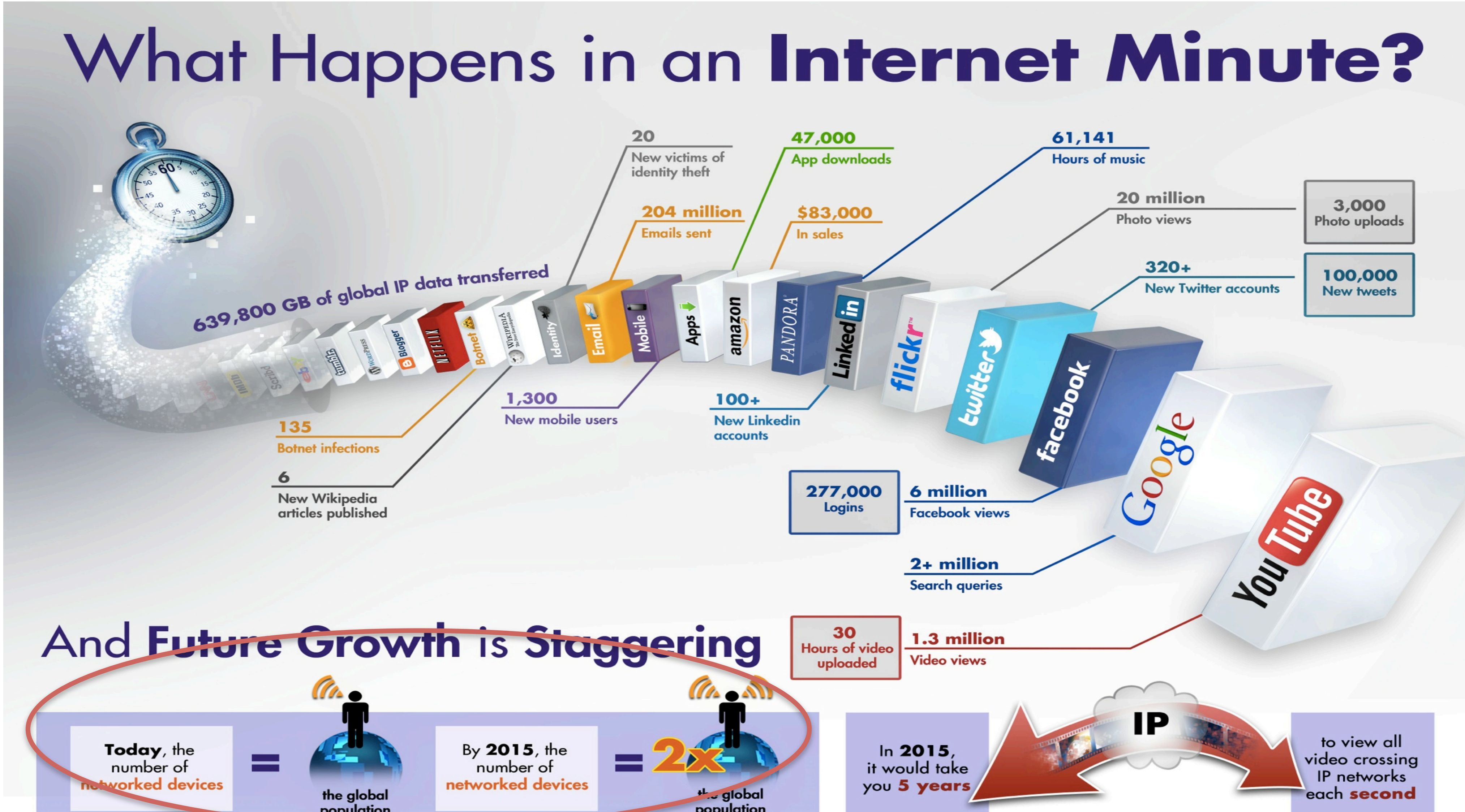
Bell Labs


BELL LABS
INVENTING THE NETWORK OF YOU
Creation of Bell Labs
The engineering departments of the American Telephone and Telegraph Company (AT&T) and Western Electric were consolidated into Bell Telephone Laboratories. Their mission was to research and design communication technologies for the rapidly expanding telephone network and to explore fundamental areas of science that could shape the future of the industry. Over the years, many cornerstone technologies of modern society have been invented at Bell Labs and 8 Nobel Prizes have been awarded to its researchers.
1925
1920's
NOBEL PRIZE
1927
Electron Diffraction
Demonstrating wave nature of matter.
1940's
NOBEL PRIZE
1947
Transistor
To replace the vacuum tube, Bardeen, Brattain and Schockley created a working point-contact transistor. This basic building block for all digital products is the foundation for our information society.
1948
"A Mathematical Theory of Communications"
By showing that all communication – telephone signals, text, images – can be represented as bits, Claude E. Shannon created the field of information theory.
NOBEL PRIZE
1950
Electronic Structure of Magnets and Glasses
1950's
1954
Solar cells
1958
LASER
In their 1958 paper, Schawlow and his brother-in-law Townes described in detail a proof of concept for the LASER. The laser enables a wide variety of applications: fiber-optic communications, digital storage, barcode scanners, precision surgery and industrial cutting tools.
1960's
1962
Telstar
Transatlantic live TV broadcast via satellite
NOBEL PRIZE
1964
Cosmic Microwave Background Radiation
The Holmdel Horn Antenna provides support for the Big Bang Theory.
NOBEL PRIZE
1969
CCD
Thanks to their research on the picture phone, Boyle and Smith realized the enormous potential of the Charge Coupled Device as an imaging device, leading to the invention of the digital photo, video cameras, scanners, satellite surveillance and ultra-sensitive astronomical telescopes.
1970's
1978
Commercial Cellular Network
1973
UNIX and C Language
Thomson and Ritchie's elegant design made it an immediate hit with the programming community when it was released in 1974. UNIX would later on become the Internet's foundation.
1976
Fiber Optic Network
45 Mbit/s transmission.
1980's
NOBEL PRIZE
1985
Laser-Based Cooling and Trapping of Atoms
NOBEL PRIZE
1982
Fractional Quantum Hall Effect
A novel collective quantum fluid state of matter.
1980
DSP
Large-scale integrated circuit for digital signal processing.
1990's
NOBEL PRIZE
1994
Fluorescence Microscopy
Super-resolution microscopy at cellular level.
1995
Integrated ADSL Chip
After co-inventing ADSL technology, follow-up innovations like vectoring continued to generate world records for high speed data transfer over copper telephone lines, fueling the Internet.
1995
Commercial DWDM
Wavelength multiplexing in optical fibers.
1998
MIMO Spatial Multiplexing
2000's
2004
Home Device Manager
Remote management of CPE.
2005
Personal Interactive IPTV Applications
Social television.
2009
Coherent 100G Optics
2006
Software Defined Routing
Predecessor of Software Defined Networks (SDN).
2010's
2010
GreenTouch
An international consortium that aims to increase network energy efficiency by a factor of 1,000 to create a sustainable Internet.
2011
lightRadio Cube
Cell tower in a box.
2014
XG-FAST
10 Gbps over copper telephone wires.
GreenTouch
THE FUTURE
Bell Labs continues to tackle grand industry challenges, providing fundamentally new answers that profoundly change the way we communicate, collaborate and connect.
Alcatel·Lucent

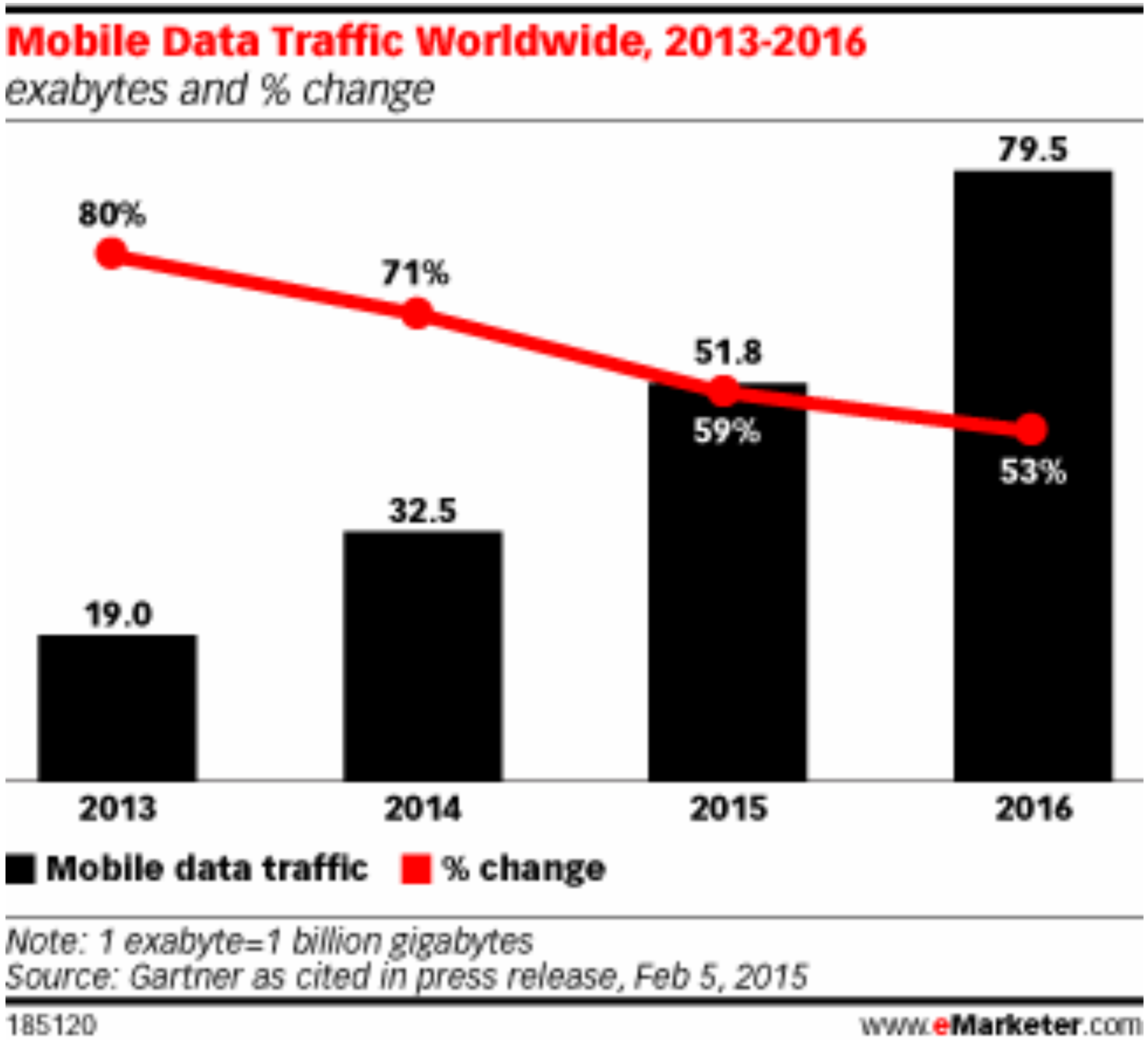
Who/Where We Are

GLOBAL INNOVATION





Credit: Intel Corporation


Mobile Data Traffic Worldwide, 2013-2016
exabytes and % change
79.5
80%
71%
51.8
59%
53%
32.5
19.0
2013
2014
2015
2016
Mobile data traffic
% change
Note: 1 exabyte=1 billion gigabytes
Source: Gartner as cited in press release, Feb 5, 2015
185120
www.eMarketer.com

SOME CUSTOMER STORIES

- I want a network which is elastic, that scales with my business, software definable and on-demand
  - John Donovan – COO AT&T

- If Google bought Sprint, with its spare change, and converted it to a company that runs like Google, they would crush us…
- We need to break 130 years of Alexander Graham Bell's way of doing things
- I am going to build a truly elastic, programmable network
  - Ben Parker – VP, Verizon Wireless

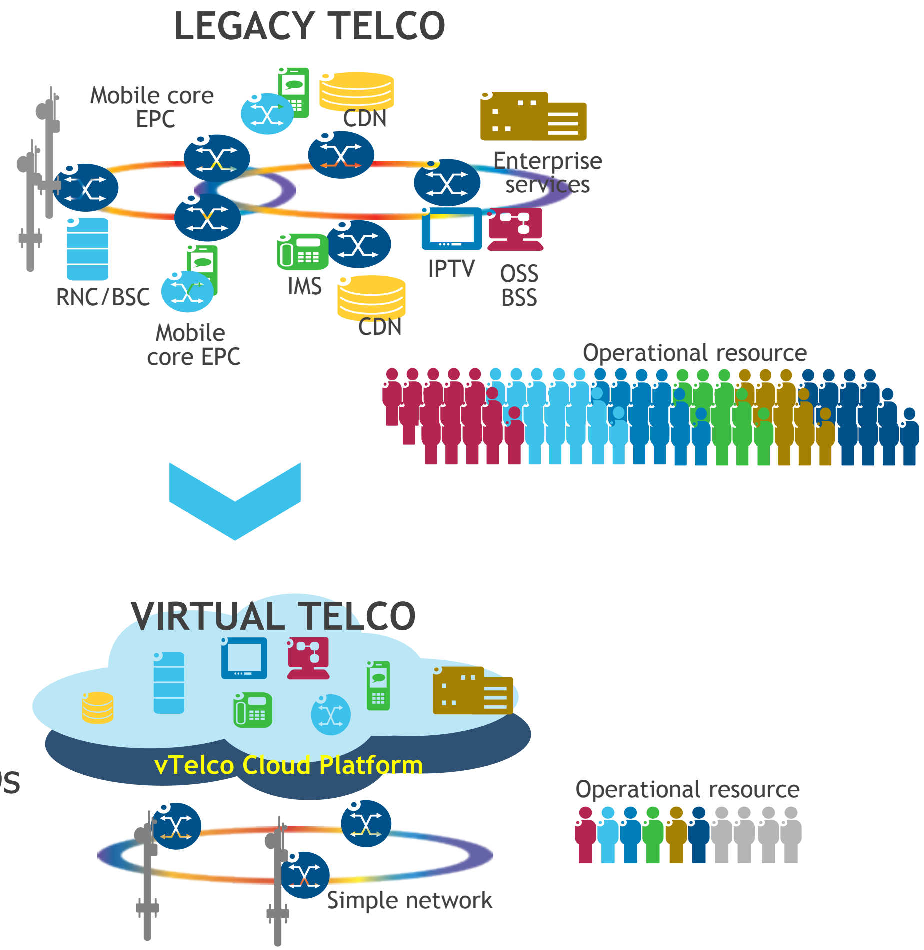
SOME CUSTOMER STORIES
It's all about OPEX!

- Google has 1000 devices in its spare parts inventory, a Telecom Provider has 50,000
- Need trained personnel to maintain all the different boxes we have
- One network for mobile and fixed

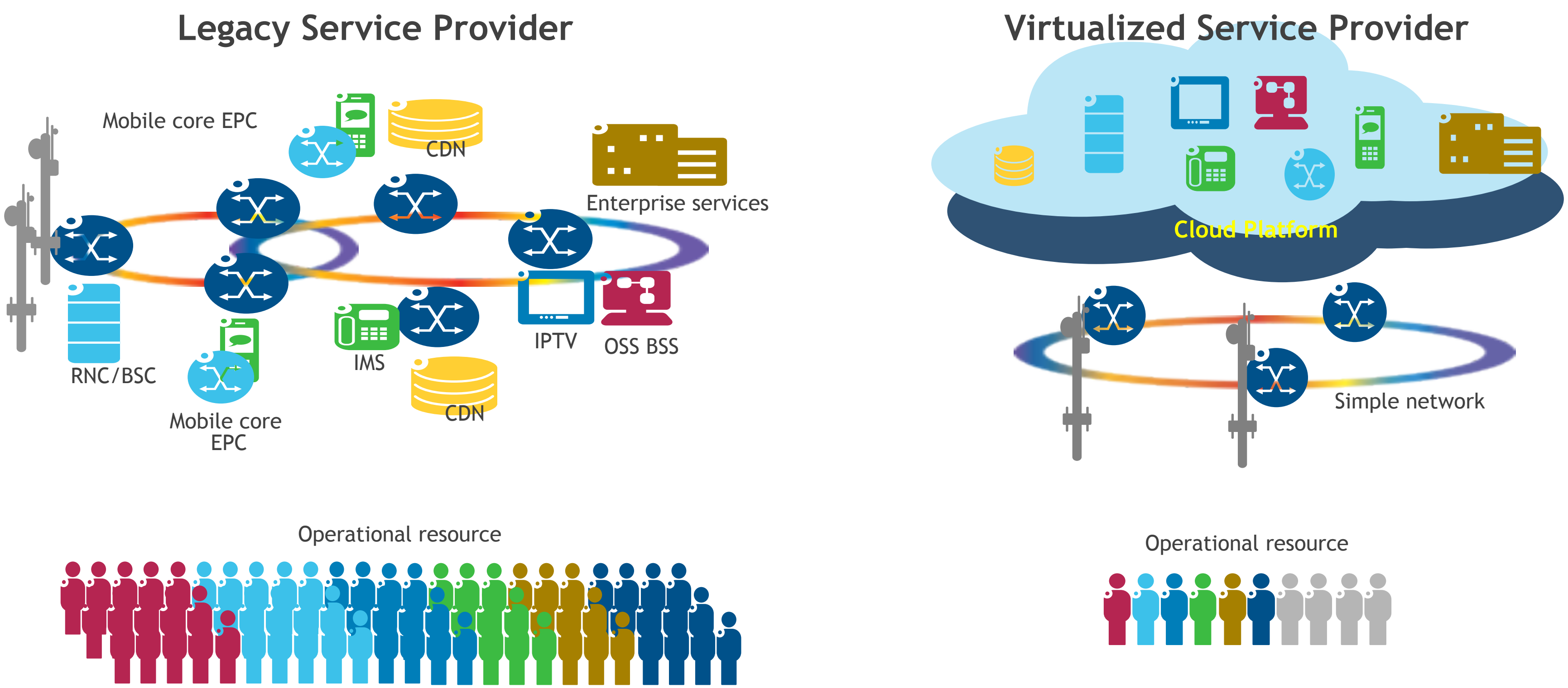
Network Function Virtualization

Network Function Virtualization aka vTelco

- Perceived benefits
  - Reduced equipment cost
  - Reduced power, space and operational expenses
  - Faster Time-to-Market
- Requirements for success
  - Portability between vendors and hypervisors
  - Full automation
  - Co-existence with legacy networks
- NFV Industry Specification Group (ISG)
  - Operator-led under the auspices of ETSI
  - Started in January 2013
  - Study NFV and drive standardization efforts in other SDOs



Network Function Virtualization
Moving Network Functionality to the Cloud



Overview

Current cellular networks face many performance issues created by modern applications

- Bandwidth limitation
- Inability to deal with short bursts of data

  -> Sample solutions: Massive MIMO, mm waves, Aloha like-schemes in 5G

- Tight delay needs especially for a new class of resource- and interaction-intensive applications can not be met by even these enhanced networks

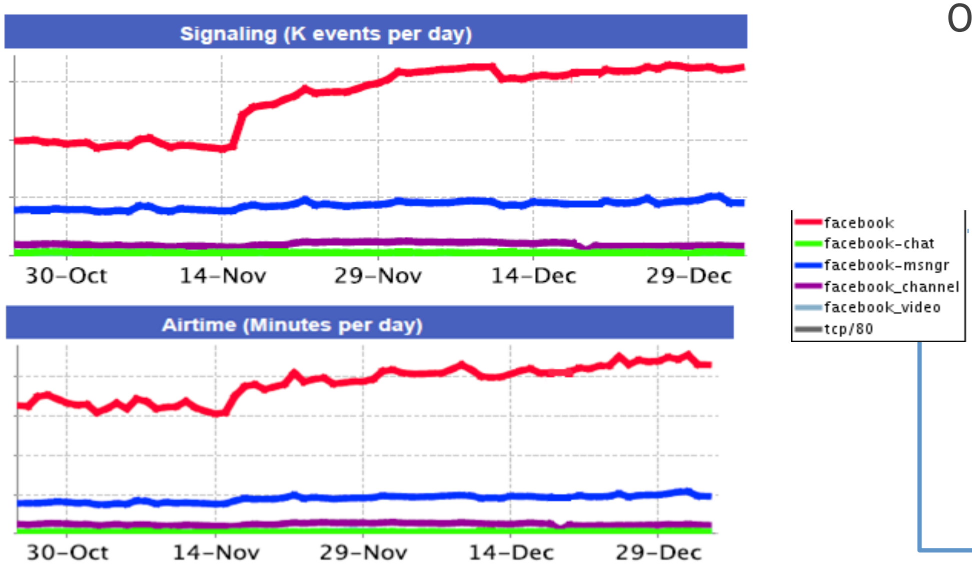
  -> Solution : Create an overlay network of **Cloudlets**

- Efficient use of network capacity

  -> One Solution: Preload content using **Mobile Smartloading (MSL)**

  -

An Application Upgrade can Significantly Increase Network Load



Application	Airtime % Change	Signaling % Change	Volume % Change	Subscriber % Change
facebook	27%	60%	0%	4%
facebook_channel	9%	15%	9%	-3%
facebook_video	390%	277%	366%	154%
facebook-chat	16%	-3%	11%	-17%
facebook-msngr	23%	18%	17%	6%

On Nov 15 of 2013, Facebook released new versions of their mobile app for Android and iOS.

FACEBOOK SIGNALING INCREASED

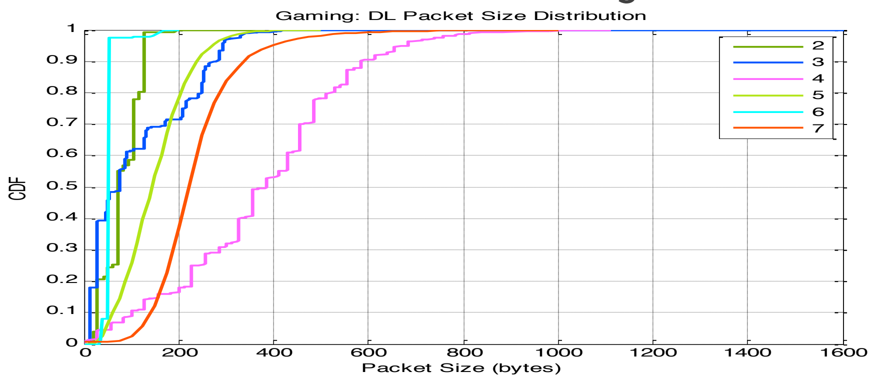
- 60% increase in Facebook signaling
- 25% increase in Facebook airtime
- increase in the amount of signaling per user
- 5-10% increase in overall signaling load!!

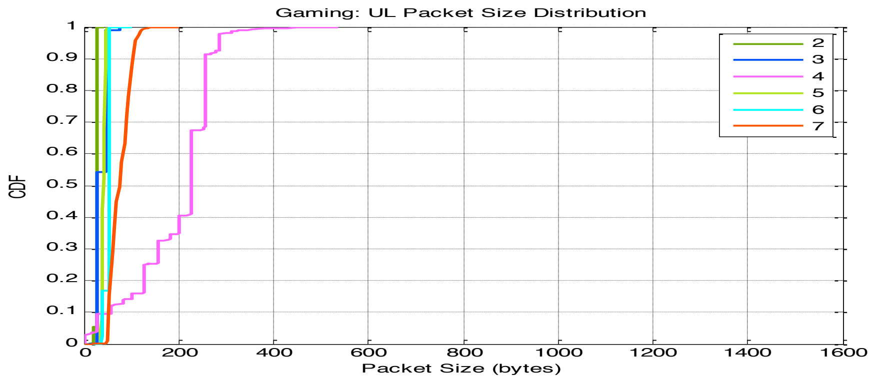
FACEBOOK VIDEO USAGE INCREASED

- 350% increase in Facebook video volume
- more subscribers using video – maybe sharing news feeds

Predominance of Short Bursts

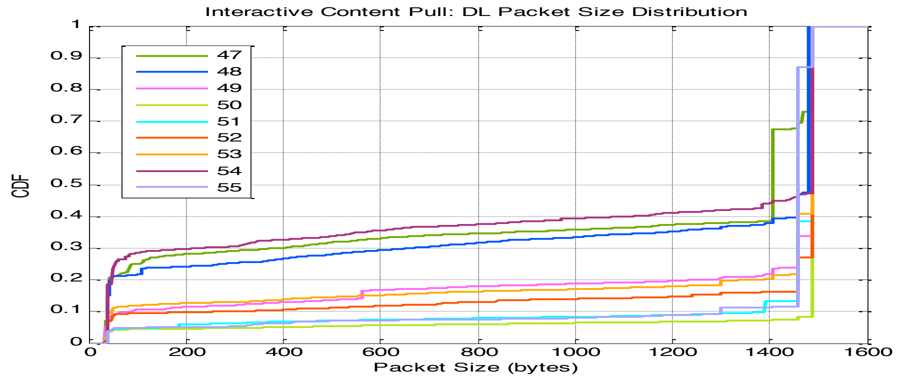
Gaming



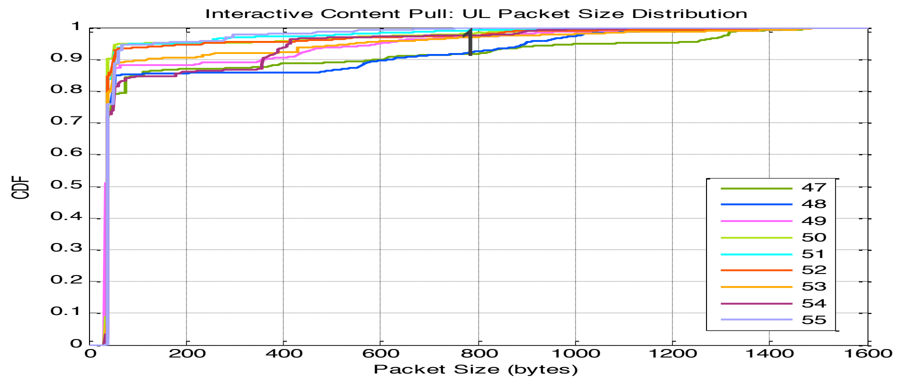


Interactive Content

Downlink



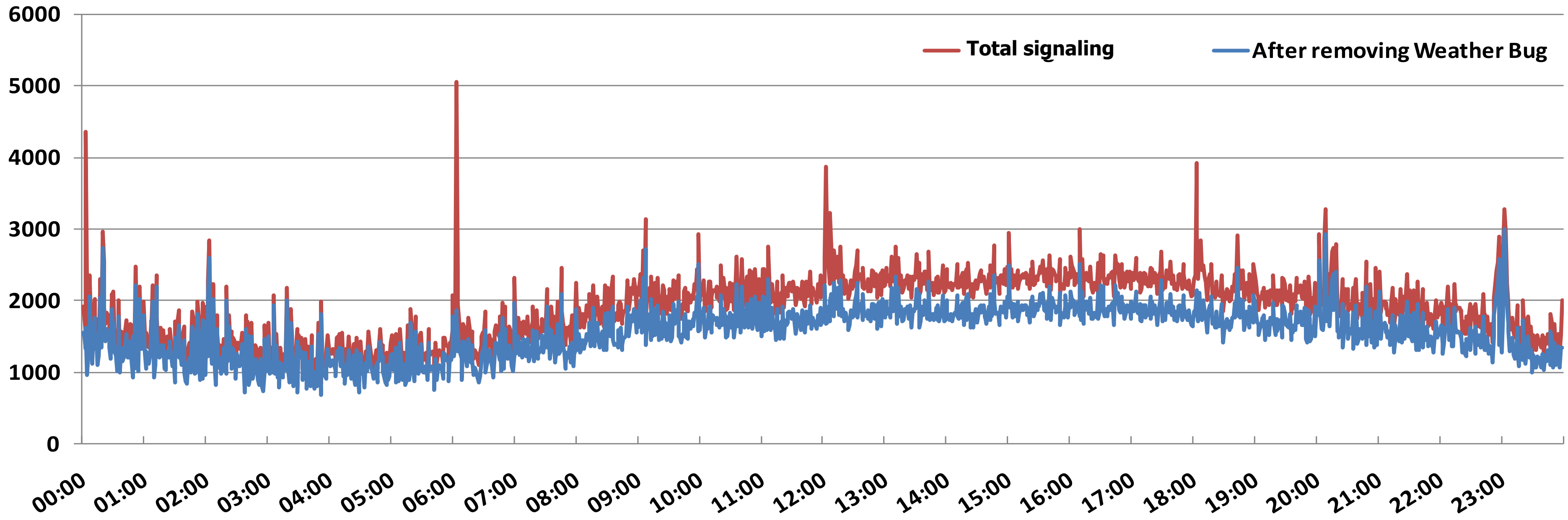
Uplink



Data taken from 3GPP TR 36.822 v1.0.2

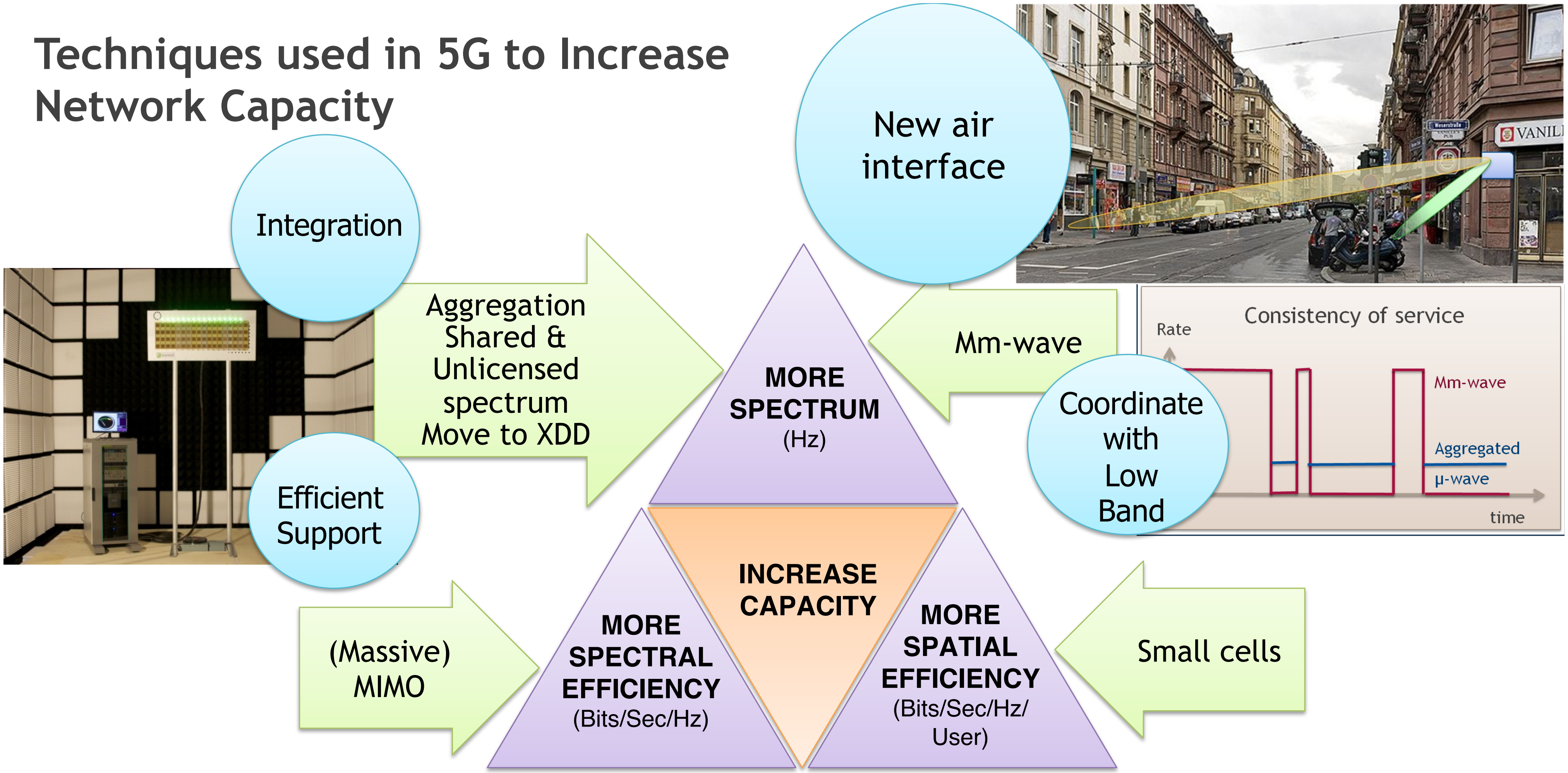
More than 50% of Today's 4G Traffic is Short Bursts of a Few 100 Bytes

An Example of Signaling Overload – Burst of Short Packets
Wireless Ignorant Applications can Take Down Control Planes



Millions of Android phones running one weather application all contact server once every 6 hours in a synchronized way that cause signaling spikes overloading the control plane

Techniques used in 5G to Increase Network Capacity



Working towards a Solution for Short Bursts
New Air Interface and Protocols for 5G

- Efficiently support very low latency scenarios
- Efficiently support short burst applications (Aloha-like scheme)
- Enable low energy user and machine devices
- Allow fast random access for long battery life devices
- Flexibly support both short burst traffic and high bandwidth traffic in same spectrum


5G IS ABOUT A
COMMUNICATIONS SERVICE THAT ADAPTS TO THE CONSUMER,
RATHER THAN THE CONSUMER ADAPTING TO THE COMMUNICATIONS SERVICE.
Alcatel·Lucent

An Overlay of Cloudlets for Resource- and Interaction-Intensive Applications

Wireless Networks and Cloud Infrastructure will not Meet Latency Needs for Resource- and Interaction-Intensive Applications

- Many mobile and NFV applications require latency of a few 10's of msec
  - Current networks and cloud infrastructure can not provide acceptable experience
- Bring computing close to users
- Cloudlets provide a compute assist for applications near the network edge
  - Mobile devices such as Google Glass do not have the necessary processing power
- This overlay is similar to a CDN network
  - It brings cloud-computing-resources and relevant content close to the clients

Some charts from a keynote by Mahadev Satyanarayanan at ACM Mobicase 2014, "Cloudlets: *At the Leading Edge of Cloud-Mobile Convergence*" and a keynote by Victor Bahl at Microsoft Devices & Networking Summit 2015, "emergence of micro data center (cloudlets/edges) for mobile computing".

New Resource- and Interaction-Intensive Applications (Enabled by Wearable Devices such as Google Glass)

- Entirely new genre of applications
- Combine mobile and cloud with *real-time cognitive engines*
  - scene analysis, object/person recognition, speech recognition, language translation, planning, navigation, question-answering technology, voice synthesis, …
- Seamlessly integrated into inner loop of human perception and cognition

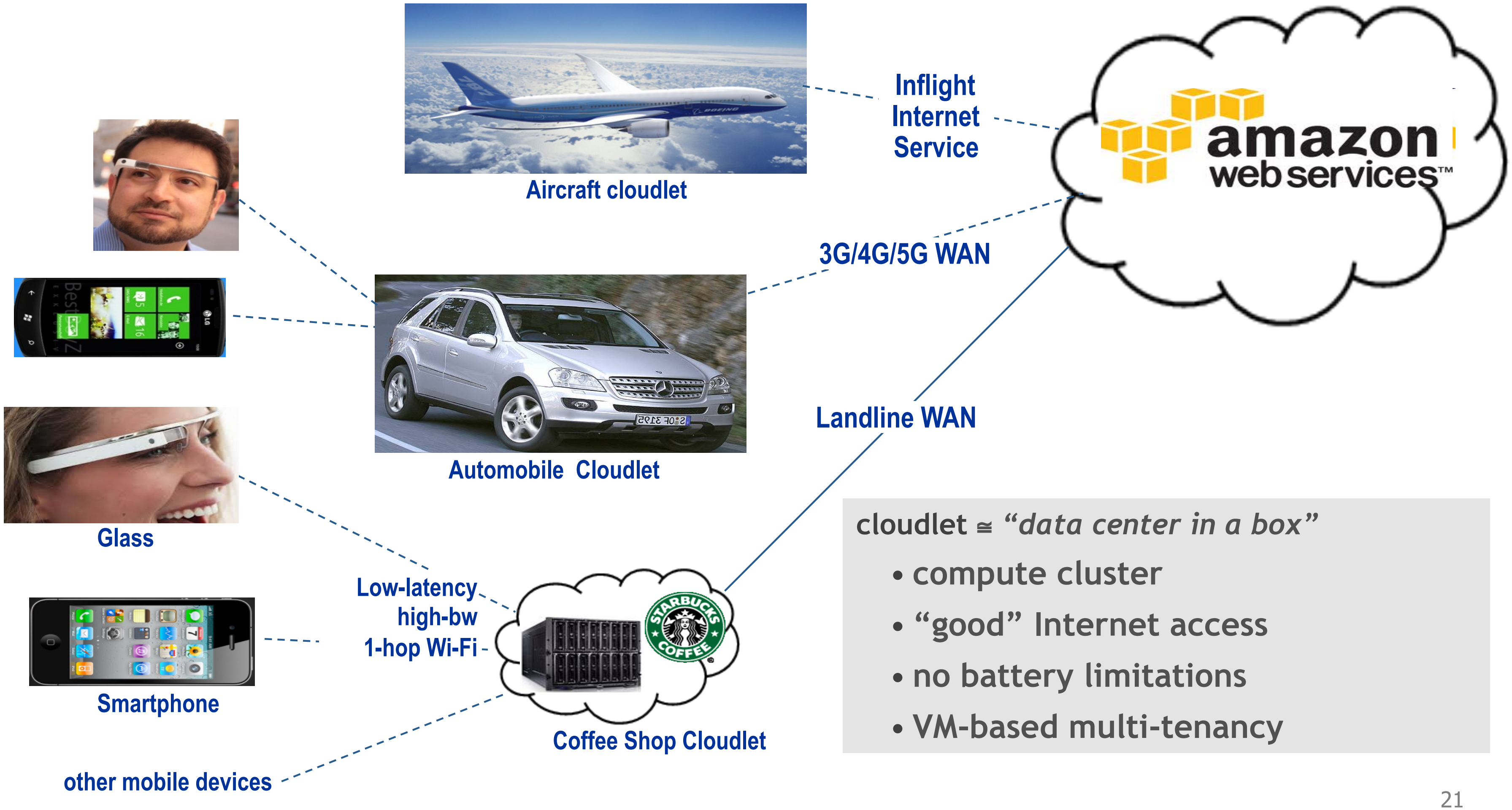
Crisp Interactive Response

- Humans are amazingly fast, accurate and robust
  - face detection under hostile conditions < 700 ms
    - (low lighting, distorted optics)
  - face recognition 370 ms – 620 ms
  - is this sound from a human? 4 ms
  - Head tracking < 16 ms (2004 NASA study, Ellis et al)
- Not enough to just match humans
  - we need to be "superhuman"
  - allow enough time budget for additional cognitive processing
  - consistent with the theme of the *"Tactile Internet"*

Safe goal: *E2E Latency < "few tens of ms"*

Bring the Cloud Closer

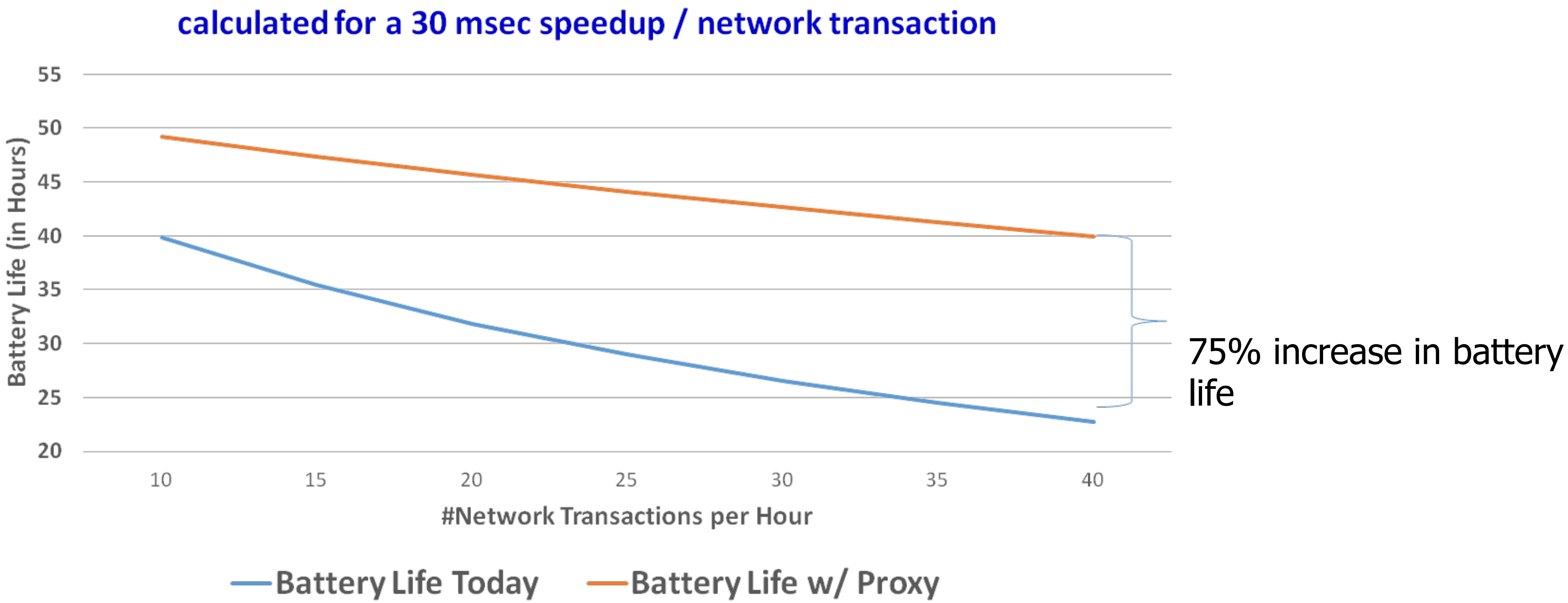
Create a Small Cloudlet Nearby



cloudlet ≅ *“data center in a box”*

- compute cluster
- “good” Internet access
- no battery limitations
- VM-based multi-tenancy

Especially Good for Mobile Devices
battery life improvement



these types of saving occur across the board for all battery types and all types of mobile devices

* Samsung Standard LI-ION battery with rating of 1500mAh/3.7Vdc

Saving Bandwidth

security, traffic, tracking

locating objects of interest

customer queue analytics

current approach

- upload the captured video to the cloud for remote analysis

observations

- too much data captured per hour (>10GB/hour)
- bandwidth limits scale and use of system
- unable to support near real-time tracking & security

Micro Data Centers Exist Today

Myoonet

Used as private clouds today

Need to be re-purposed as cloudlets
i.e., as "2nd-tier infrastructure"

Mobile Smartloading

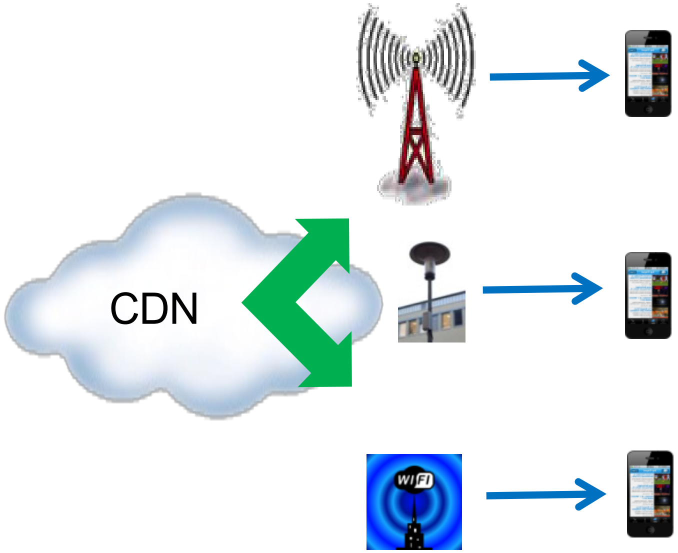
Efficient Use of Network Capacity & Faster Content Access

What is Mobile Smartloading (MSL)?

Congestion-aware automatic download and/or upload of any multimedia content to a smart-phone or tablet, selecting the most appropriate time and access technology

- HD viewing experience---stall/buffer free---even during peak periods
- Least cost delivery--using surplus RAN capacity, WiFi, Small Cells
- Policy-based opportunistic pre-loading---network, device, and user aware
- Excess capacity monetization for additional ARPU---Off-peak pricing

Opportunistic Pre-placement of Content into User Devices



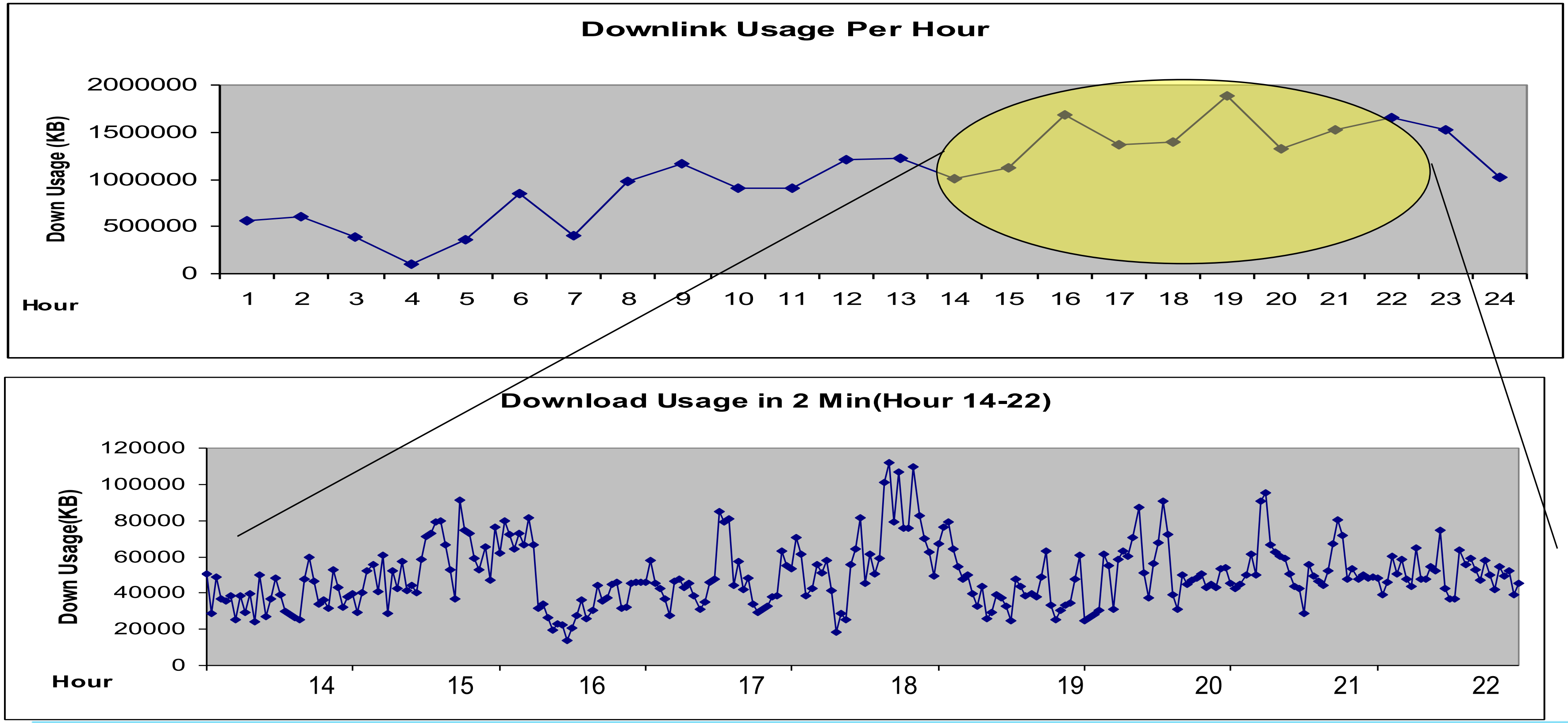
- When the cell site is not congested
- When in range of a high capacity metro cell
- When at home with WiFi Access

- Cloud based, policy driven delivery scheduling
- With consideration for device battery & storage, Network congestion & quality
- Automatic suspend/resume to handle changes in network and device state

Benefits for Mobile Operators

Network Efficiency	• Defer expensive RAN upgrades • Fully maximize network utilization
Increase ARPU	• Sell Smartloaded apps & pricing • Monetize unused capacity
Greater Relevance	• Leverage network intelligence • Tap into App ecosystem $$

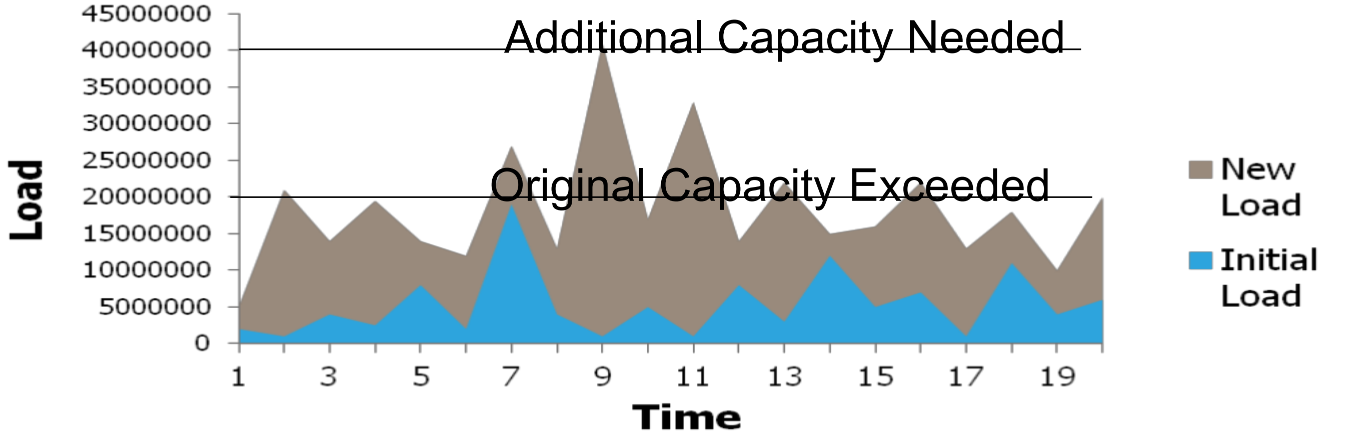
Data Traffic Trends: At The Base Station



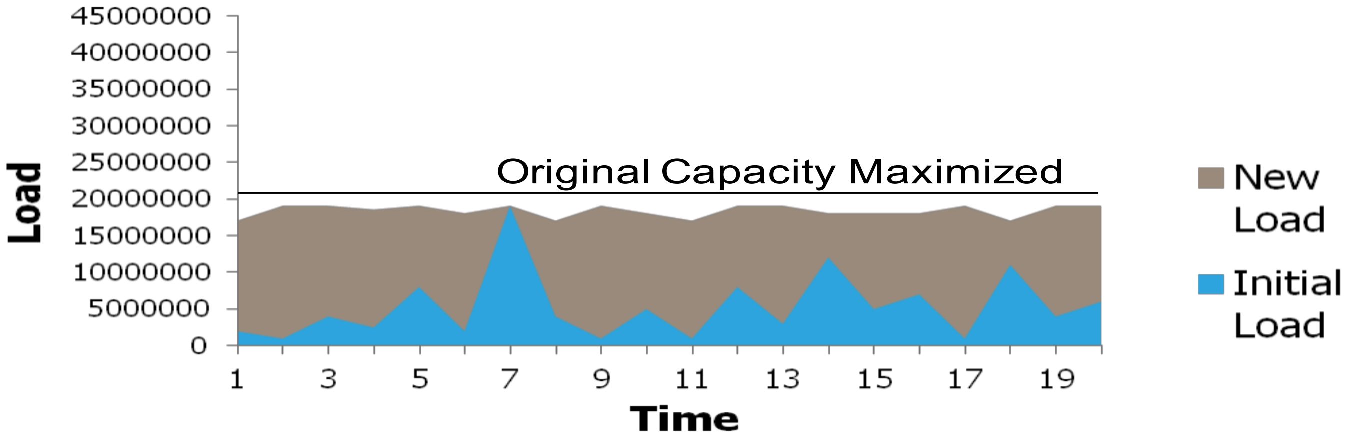
- Peaks are instantaneous with minute by minute fluctuations
- There are quiet times even in busy periods

MSL Increases Utilization and Lowers Capex

Without Mobile Smartloading Data Traffic Grows With Uncontrolled Peaks



With Mobile Smartloading DataTraffic Grows Smoothly & Efficiently



Conclusions

- Current wireless networks have performance issues such as limited bandwidth and inability to deal with short bursts of packets
  - They are being fixed in 5G
- Even these fixes will not deal with latency requirements for resource-and interaction-intensive applications
  - An overlay of Cloudlets
- Efficient usage of wireless networks
  - An example: Mobile Smartloading (MSL)

Predictions

- Future networks will be converged and network functions will be virtualized.
- CDNs will be enhanced to add computing close to users. The result will be similar to an overlay of cloudlets
- Content will be preloaded onto smartphones
- Spaces around us will be software-defined