The Internet of Things and Wireless QoS

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College of Applied Science and Technology

April, 2017

The New Reality – The Connected World

- Huge growth in
  - Number of advanced devices
  - Bandwidth requirements
- New services
  - Cloud based applications and storage
- Changing behaviors
  - Always connected
  - Social media
- Changes in customer's expectations
  - Ubiquitous connectivity between people, data and applications

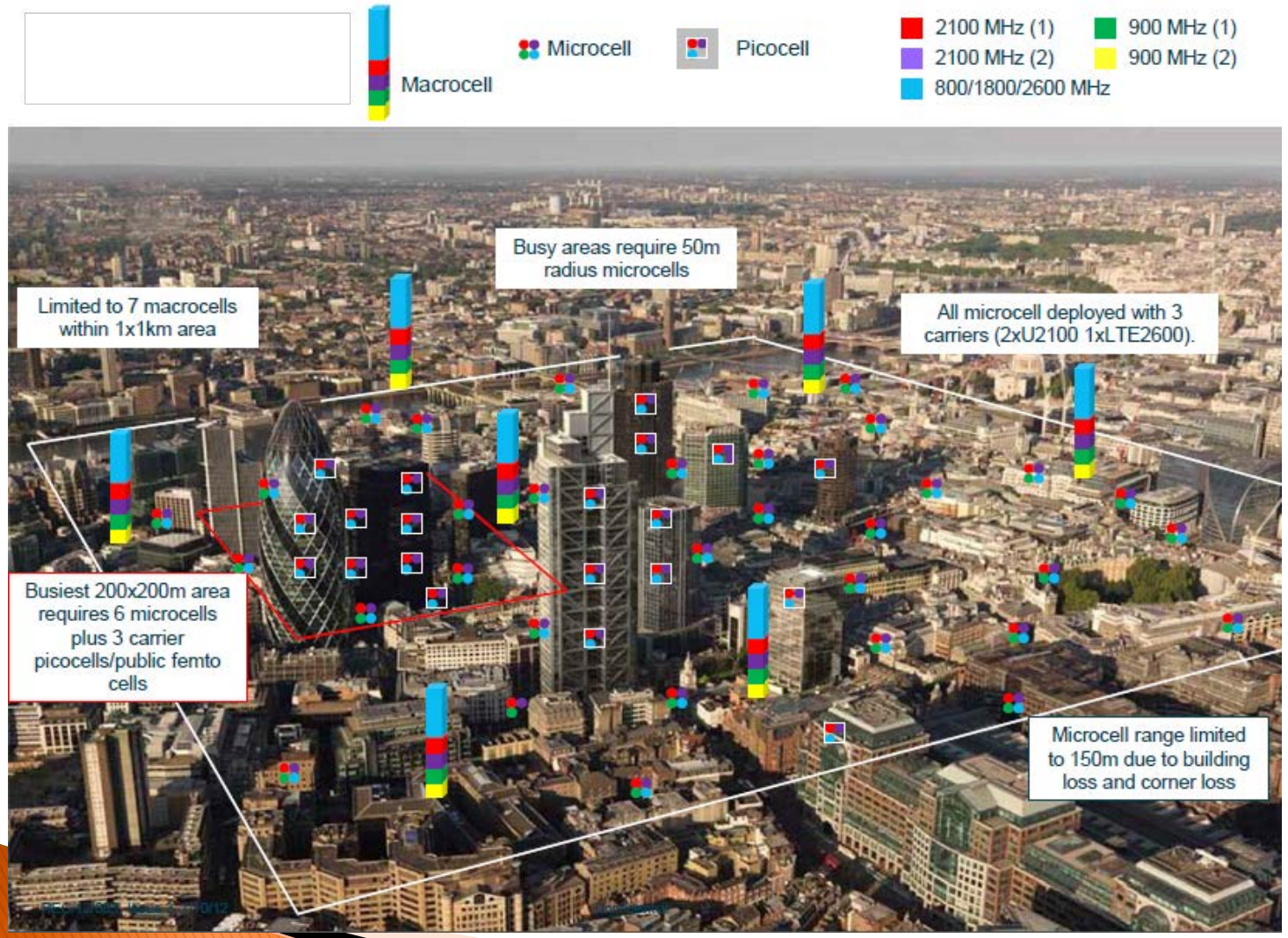
What's happening to the Network?

Mobile Network circa 2005

- Primary 2G, 3G technology
- 1 – 3 vendors
- GBs of traffic
- 10,000s of cells
- 1,000s of configuration changes each day
- Use of drive testing to check coverage

What's Happening to the Network?

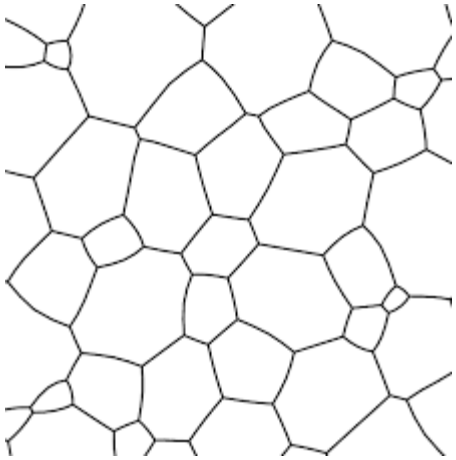
Mobile Network Today

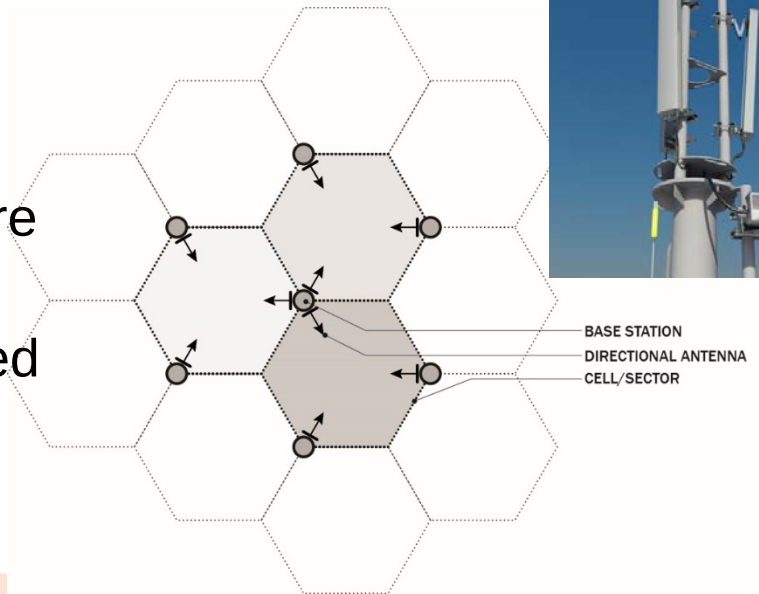


- 2G, 3G, LTE, Macro, Micro, Pico Small Cells, Wi-Fi
- Many vendors
- TBs of traffic
- 100,000's of cells
- 10,000s of configuration changes per day
- Drive testing is not practical

Cellular Networks are Complex!

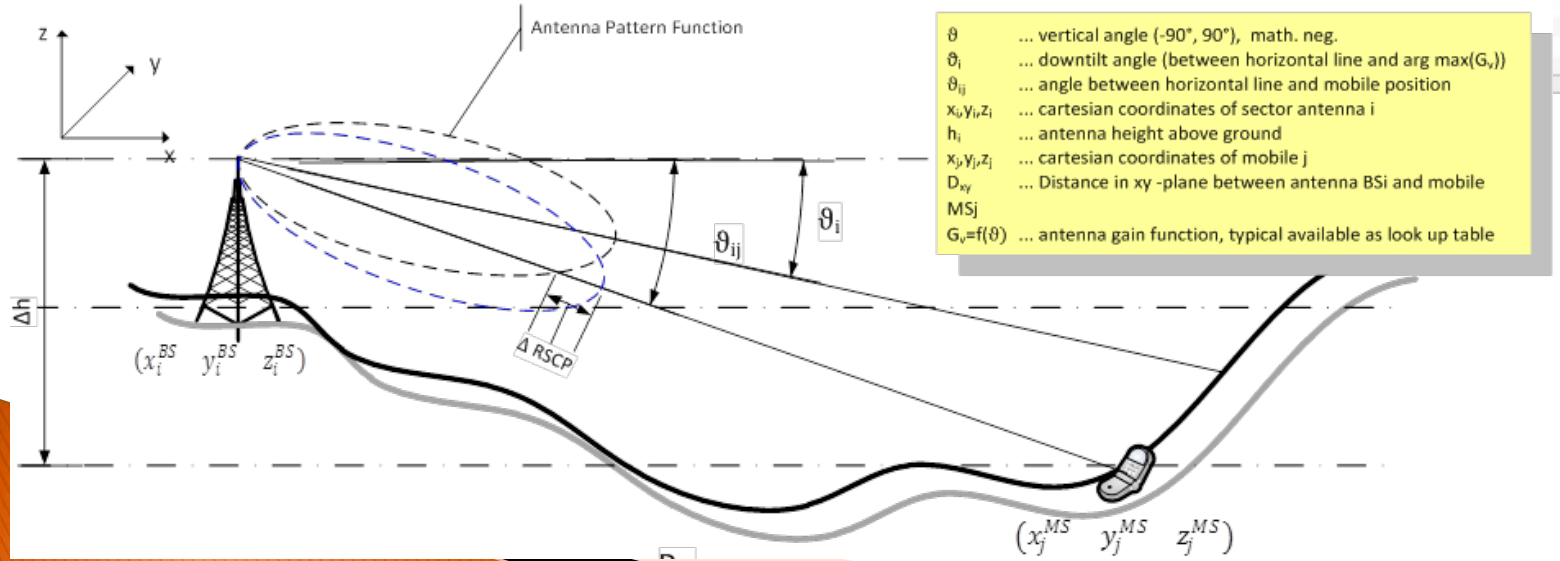
- Coverage area is irregular and dynamic
  - Each technology (3G, 4G, LTE) supports different bandwidths and range
  - Coverage and capacity reduces as load increases - both inside each cell and between cells
  - Need to balance trade-off between footprint, throughput and capacity
- Signal strength does not equate to bandwidth
- Constantly expanding/evolving as more capacity (base stations) and new technologies (e.g. LTE+, 5G) are added





Coverage and Capacity Optimization

- Need to configure and optimize the thousands of parameters in each base station across the entire network



ϑ	... vertical angle (-90°, 90°), math. neg.
ϑ_i	... downtilt angle (between horizontal line and arg max(G_v))
ϑ_{ij}	... angle between horizontal line and mobile position
x_i, y_i, z_i	... cartesian coordinates of sector antenna i
h_i	... antenna height above ground
x_j, y_j, z_j	... cartesian coordinates of mobile j
D_{xy}	... Distance in xy -plane between antenna BSi and mobile
MSj	
$G_v=f(\vartheta)$	... antenna gain function, typical available as look up table

Self Organizing Networks (SON)
Automatic Configuration of Network Parameters

Automatic Neighbor Relations (ANR)

Self optimization by automatic neighbor relationship addition/ removal and re-prioritization.

Self Healing (SH)

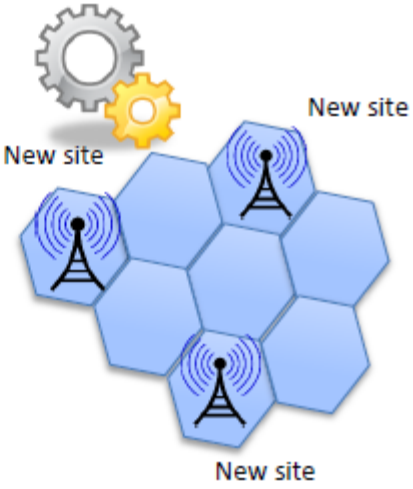
Respond to Outage Alarm by changing coverage footprint of neighboring cells as well as parameter changes.

Mobility Load Balancing (MLB)

Alleviates network congestion by automatic load balancing based on the cell load using combination of parameters as well as cell footprint.

Plug-n-play (PnP)

Self configuration for new sites coming on air. Configure neighbors and parameters after initial turn-up.



Self Organizing Networks
Use Cases and Acquisitions

R·I·T

Solved

Partially Solved

Open

MDT	PCI	ANR	CCO	MLB	MRO
Minimize drive test	Physical cell identifier	Automatic neighbour relations	Coverage & capacity optimization	Mobility load balancing	Mobility robustness

QoS	APO	SH	ES	FQ	SC
Quality of service	Automatic parameter optimization	Self Healing	Energy savings management	2G frequency planning	Scrambling code assignment

GEO	VIP	CORP	CEPM	INC	LTA	CKPI	ROAM	TNA	RAB	HIA
Subscriber geo-location	VIP tracking	Corporate customer analysis	Customer experience problem management	Indoor coverage analysis	Location throughput analysis	Customer experience KPIs	Roaming location detection	Transport network analysis	Handset problematic RAB detection	Handset impact assessment

DPP	NA	SIA	HA	COMP	BEN	WLK	NRA	NCIA	CCM	SCSS
Drive test post processing	Network acceptance	Swap impact assessment	Handset acceptance	Competitive benchmark analysis	Regional benchmark analysis	Indoor walk test analysis	Network readiness assessment	Network change impact assessment	Physical capacity extension	Small cell site selection

COD	CHD	HOT	TCA	NQA	VDT
Cell outage detection	Coverage hole detection	Hotspot detection	Technology coverage analysis	Network quality analysis	Virtual drive test

Amdocs – Actix, Celcite: $350M
JDSU – Arieso: $85M
Cisco – Intucell: $475M

Teoco – Aircom: $350M
Infovista – Mentum: $100M
Ericsson – Optimi: $75

Geolocation

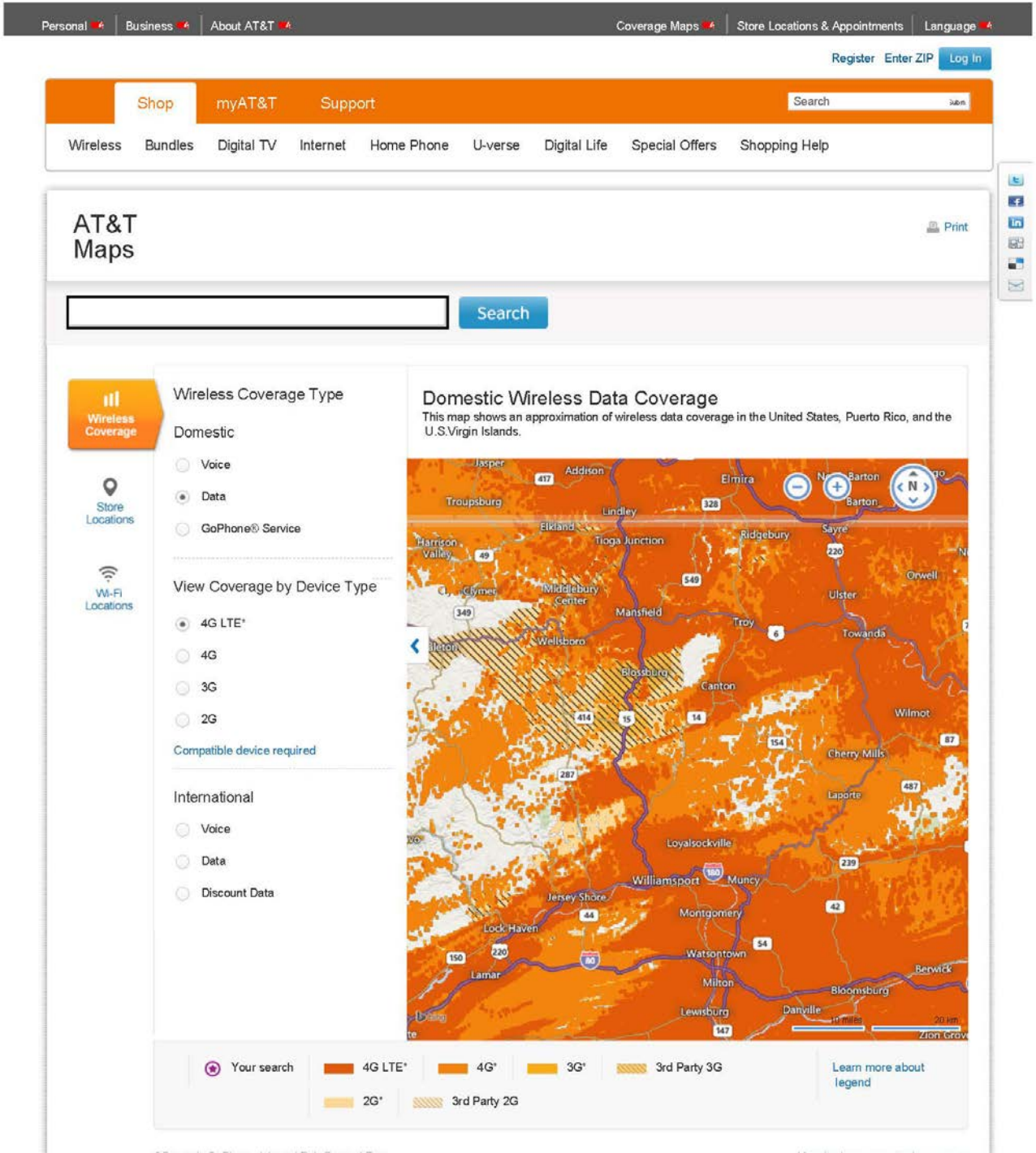
Blocked call rate < 2% and
Dropped data sessions < 10%

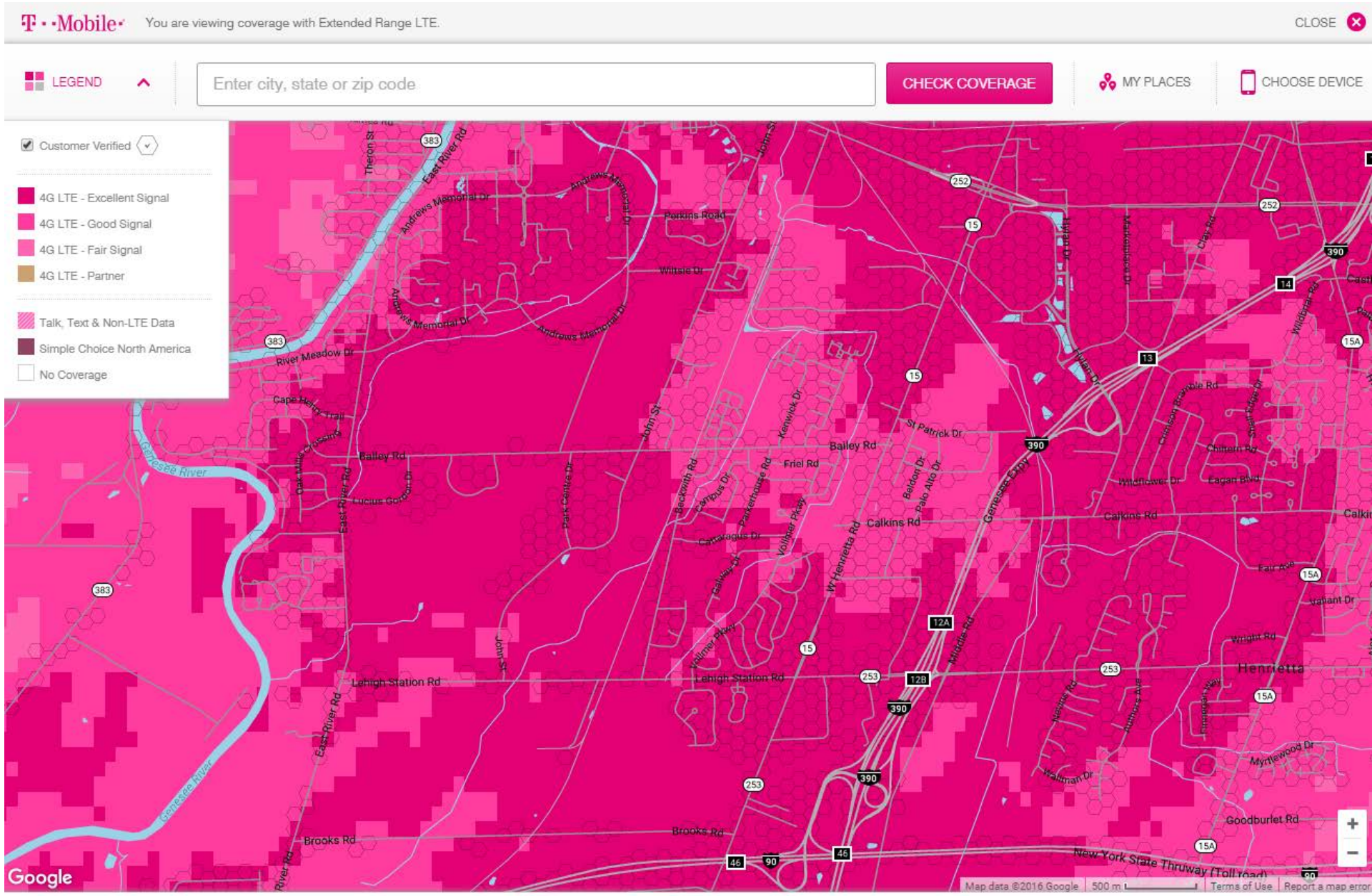
Heat Map – 100m x100m Grid

- 2G/3G/4G base stations provide aggregated metrics across the entire cell that hide localized issues e.g.
  - Dropped Calls
  - Dropped Sessions
  - Data Throughput
- Geolocation
  - Complex, real-time, big-data algorithm decomposing and correlating cell metrics to grid
  - Grid represents performance for that square across all covering cells
- Geolocation can be used to determine
  - Indoor versus outdoor performance
  - Tracing of individual customer's movement
  - Monitor geographical locations such as a enterprise location, shopping mall (group of buildings) or roads
  - Performance of different device types

Questions

- Why are wireless networks called Cellular Networks?
- Name three types of Self-Organizing Network Use Cases

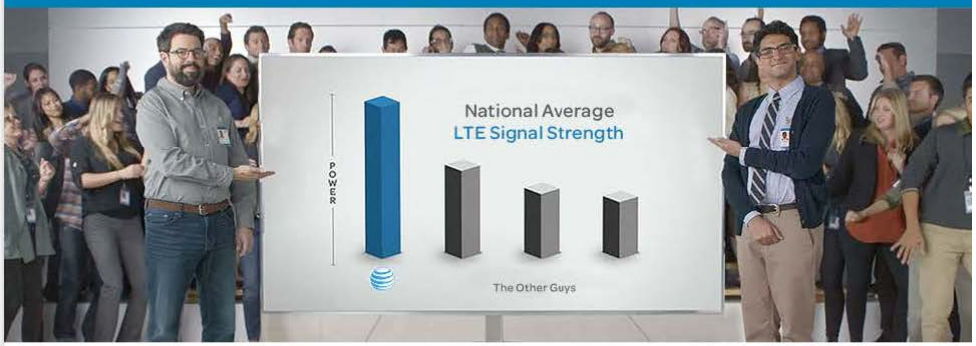

Personal
Business
About AT&T
Coverage Maps
Store Locations & Appointments
Language
Register
Enter ZIP
Log In
Shop
myAT&T
Support
Search
Wireless
Bundles
Digital TV
Internet
Home Phone
U-verse
Digital Life
Special Offers
Shopping Help
AT&T Maps
Print
Search
Wireless Coverage
Store Locations
Wi-Fi Locations
Wireless Coverage Type
Domestic
Voice
Data
GoPhone® Service
View Coverage by Device Type
4G LTE*
4G
3G
2G
Compatible device required
International
Voice
Data
Discount Data
Domestic Wireless Data Coverage
This map shows an approximation of wireless data coverage in the United States, Puerto Rico, and the U.S.Virgin Islands.
Jasper
Addison
Elmira
Barton
Troupsburg
Lindley
Elkland
Tioga Junction
Ridgebury
Sayre
Harrison Valley
Orwell
Middlebury Center
Mansfield
Troy
Ulster
Towanda
Wellsboro
Blossburg
Canton
Wilmot
Cherry Mills
Laporte
Loyalsockville
Williamsport
Muncy
Jersey Shore
Montgomery
Lock Haven
Watsontown
Lamar
Milton
Berwick
Bloomsburg
Lewisburg
Danville
Your search
4G LTE*
4G*
3G*
3rd Party 3G
2G*
3rd Party 2G
Learn more about legend


T··Mobile·
You are viewing coverage with Extended Range LTE.
CLOSE
LEGEND
Enter city, state or zip code
CHECK COVERAGE
MY PLACES
CHOOSE DEVICE
Customer Verified
4G LTE - Excellent Signal
4G LTE - Good Signal
4G LTE - Fair Signal
4G LTE - Partner
Talk, Text & Non-LTE Data
Simple Choice North America
No Coverage
Google
Map data ©2016 Google
500 m
Terms of Use
Report a map error

Questions

- Are you happy with the data and/or voice services from your provider
- Does your bandwidth vary by time of day, day of week, location?
- How did you decide which service provider to use?
  - Cost
  - Services – voice, data, security, etc.
  - Coverage information for your house from the service provider
  - Advertising
  - Word of mouth
- What bandwidth do you get on your smartphone?
- What bandwidth do you get at home?
- Why do cable operators give you unlimited data and commit to a bandwidth while wireless operators limit your data and do not commit to anything regarding bandwidth, availability, etc.?
- What bandwidth do you need on your smartphone?

AT&T's network now has the nation's *strongest* LTE signal.



Yes, you read that right.
AT&T's network now has the nation's strongest LTE signal[1].

By doing things like placing LTE radios at the top of towers to maximize power and optimizing cell site density we've engineered our network to provide an optimal signal experience.

1 Claim based ONLY on avg. LTE signal strength for national carriers. LTE is a trademark of ETSI. LTE not avail. everywhere.

AT&T is the nation's most reliable LTE network.

What does it mean to have LTE?

It means you can stream clear, crisp video, download songs in a few beats, apps almost instantly, and so much more.

4GLTE

Claim based on nationwide carriers' 4G LTE.

AT&T covers more than 99% of Americans.

Overall, AT&T covers over 320 million people with its voice and data service, with over 300 million people covered by our 4G LTE network.
What does this mean for you?

The Best COVERAGE

A phone is only as good as the network it's on.®
Verizon's super-fast 4G LTE network is the most reliable and in more places than any other 4G LTE network.

- Only Verizon's 4G network is 100% LTE.
- Covers over 97% of Americans.

Seeing is believing. Compare Verizon 4G LTE coverage to other 4G LTE networks.

Find a Detailed Coverage Map of Your Area

ALASKA CUSTOMERS, CLICK HERE TO VIEW YOUR NEW COVERAGE MAPS.

Voice and Non-4G LTE data service Available Outside 4G LTE Coverage Area.

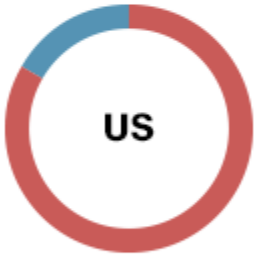
Verizon is #1 where it counts the most.

According to RootMetrics©, the largest inc
and overall network performance in the U.S

And after 3,851,608 tests, 239,941 miles dr

See the report >

Rankings based on the RootMetrics US National RootScore
Your experiences may vary. The RootMetrics award is not a



AT&T	1
Sprint	0
T-Mobile	0
Verizon	6

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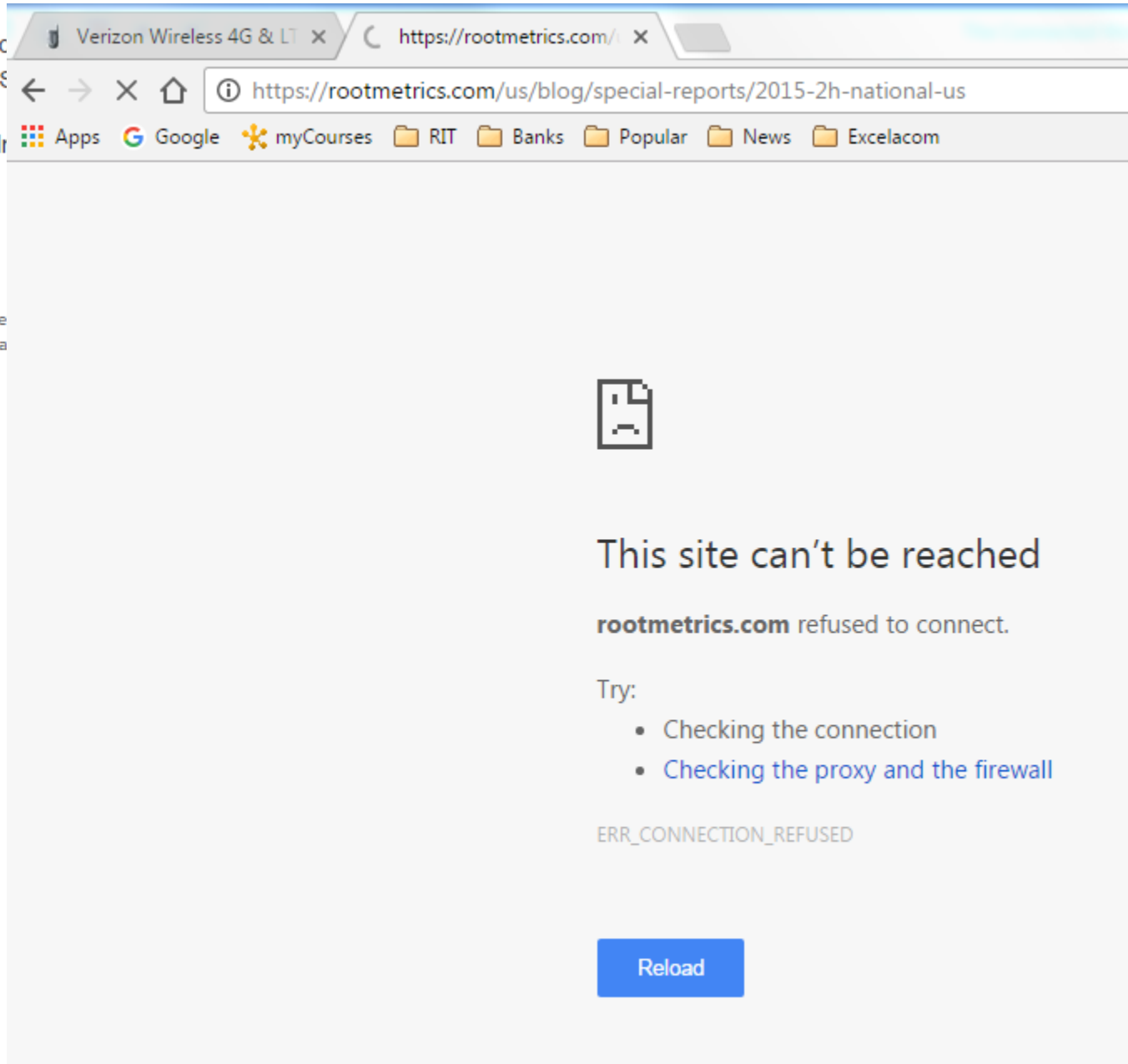


10.21.15

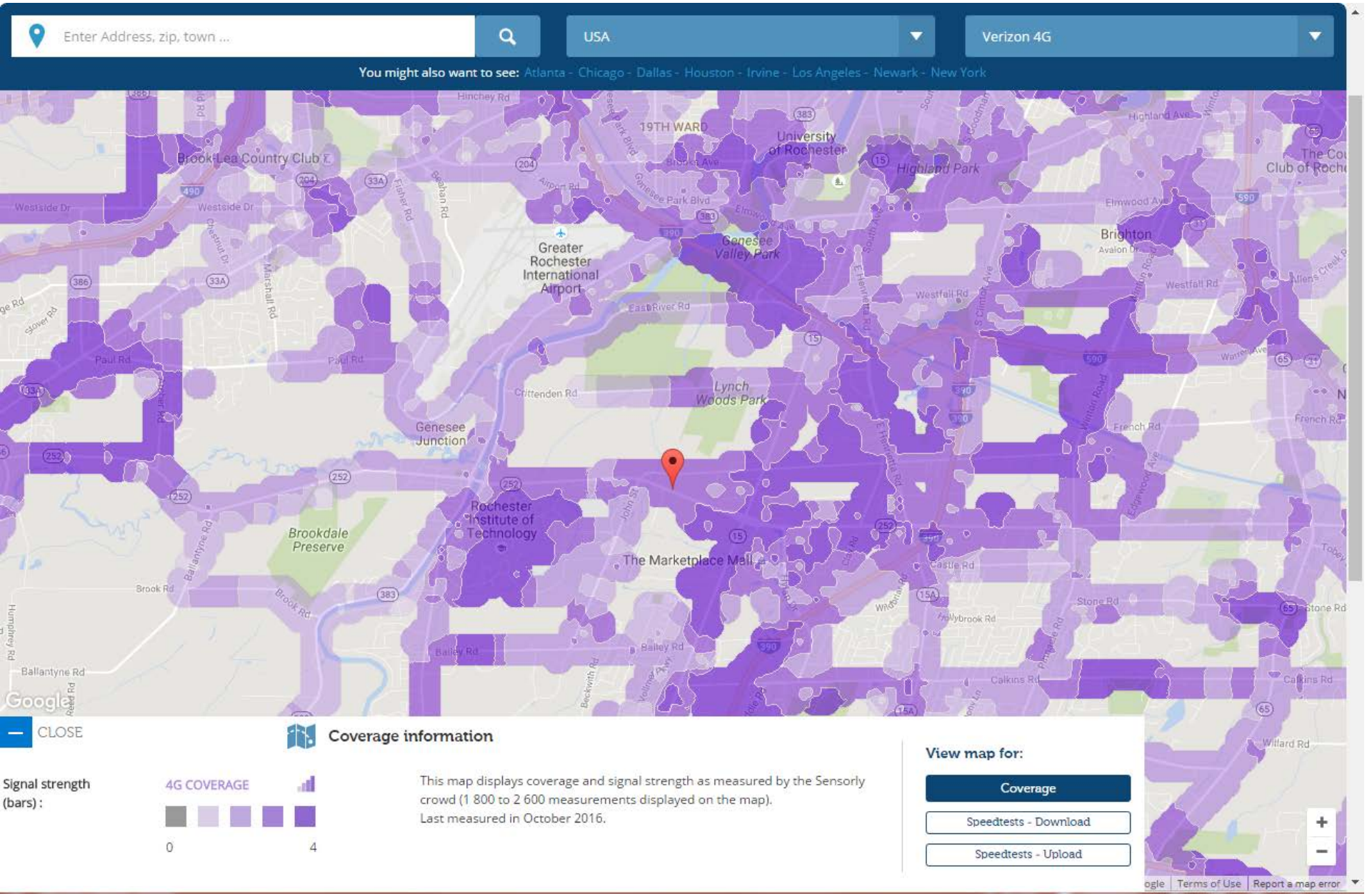
SCHUMER LAUNCHES STATEWIDE CROWDSOURCING CAMPAIGN TO COLLECT NY DEAD ZONE LOCATIONS TO HELP FEDS INVESTIGATE DECEPTIVE COVERAGE MAPS; SENATOR SAYS WIRELESS CARRIERS ARE WRONGLY CLAIMING QUALITY RECEPTION ON COVERAGE MAPS IN UPSTATE NY; IN REALITY, AREAS MAY BE DEAD ZONES

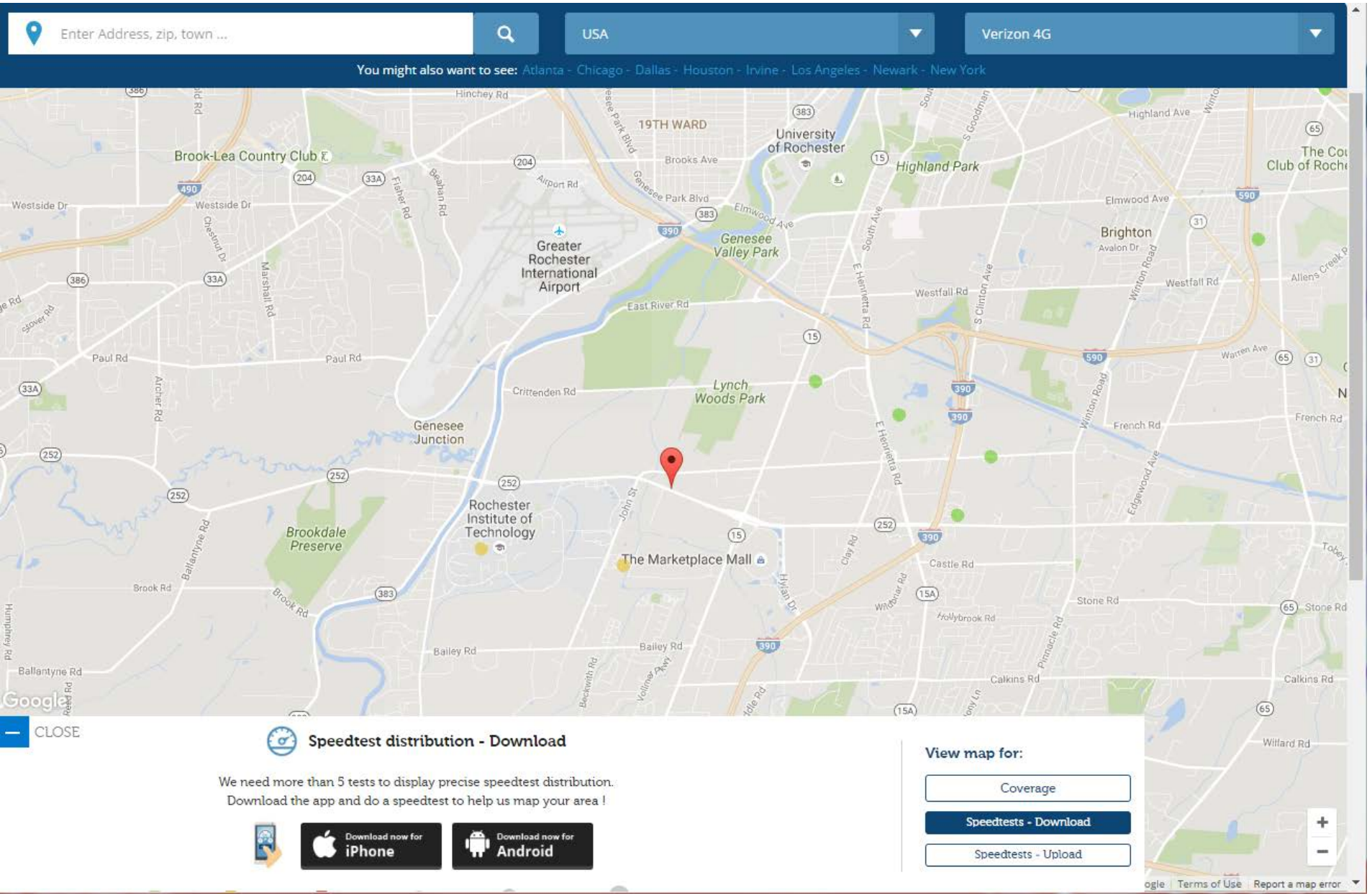
Major Wireless Carriers Are Displaying Areas In Upstate Counties As Having Good Quality Coverage, When Many Of Those Areas Are Actually Dead Zones; Schumer Launches Online Campaign To Help Identify Dead Zones

New Yorkers Can Go Online To Submit Their Dead Zones Directly To The Senator's Office – Results Will Be Sent Directly To FCC To Crack Down On False Coverage Maps

Schumer: Submit Your Cell Phone Dead Zones To Schumer.Senate.Gov/WirelessDeadzone

On a conference call with reporters, U.S. Senator Charles E. Schumer today announced his office will be conducting a statewide crowdsourcing campaign to identify and locate dead zones in Upstate New York. Schumer said the information will be used to help crack down on wireless carriers who are falsely listing their service on coverage maps throughout New York State. Schumer has been pushing the Federal Communications Commission (FCC) to investigate if network providers are fairly and accurately advertising wireless coverage so that consumers can make informed choices. Schumer said that the information on dead zones provided by New York residents will enable the FCC to pinpoint the exact locations where wireless companies are false reporting good coverage, and then crack down on the lack of accuracy in those coverage maps.


Enter Address, zip, town ...
USA
Verizon 4G
You might also want to see: Atlanta - Chicago - Dallas - Houston - Irvine - Los Angeles - Newark - New York
Brook-Lea Country Club
19TH WARD
University of Rochester
Highland Park
Greater Rochester International Airport
Genesee Valley Park
Brighton
Lynch Woods Park
Genesee Junction
Rochester Institute of Technology
Brookdale Preserve
The Marketplace Mall
Ballantyne Rd
Google
CLOSE
Coverage information
Signal strength (bars) :
4G COVERAGE
0
4
This map displays coverage and signal strength as measured by the Sensorly crowd (1 800 to 2 600 measurements displayed on the map).
Last measured in October 2016.
View map for:
Coverage
Speedtests - Download
Speedtests - Upload
Terms of Use
Report a map error


Enter Address, zip, town ...
USA
Verizon 4G
You might also want to see: Atlanta - Chicago - Dallas - Houston - Irvine - Los Angeles - Newark - New York
Brook-Lea Country Club
19TH WARD
University of Rochester
Highland Park
Greater Rochester International Airport
Genesee Valley Park
Brighton
Genesee Junction
Lynch Woods Park
Rochester Institute of Technology
Brookdale Preserve
The Marketplace Mall
Google
CLOSE
Speedtest distribution - Download
We need more than 5 tests to display precise speedtest distribution.
Download the app and do a speedtest to help us map your area !
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Probe calls Time Warner Cable's Internet speeds 'abysmal'

Kevin McCoy , USA TODAY 6:30 p.m. EDT June 8, 2016

(Photo: Richard Drew, AP)

Preliminary results of a New York investigation found that Time Warner Cable gave customers far slower Internet speeds than advertised, resulting in movies freezing, websites loading endlessly and games becoming non-responsive.

The New York Attorney General's office disclosed the tentative findings in a Wednesday letter that urged Charter Communications (CHTR) to make major service improvements following its recently completed $79 billion acquisition of Time Warner Cable.

Approved in May by the Federal Communications Commission, the deal also included the Bright House Networks and created the world's second-largest cable TV and Internet provider. Charter is rebranding the companies under the name Spectrum. Time Warner Cable served 29 states, and provided video, high-speed data and voice service to an estimated 16 million customers.

"In short, what we have seen in our investigation so far suggests that Time Warner Cable has earned the miserable reputation it enjoys among consumers," Tim Wu, senior enforcement counsel for New York Attorney General Eric Schneiderman, wrote to Thomas Rutledge, Charter Communications' chairman and CEO.

"In advertisement after advertisement, Time Warner Cable promised a 'blazing fast,' 'super-reliable' Internet connection," the letter said. "Yet it appears that the company has been failing to take adequate or necessary steps to keep pace with the demand of Time Warner Cable customers."

Service Requirements

	Bandwidth Requirements	Data Loss Importance	Delay Importance	Jitter Importance
Email	Low	High	Low	Low
Voice	Low	Medium	High	High
SMS	Very Low	Important	Low	Low
Video	Very High	Medium	High	High
Data	Depends	Depends	Depends	Depends

Quality Metrics

- Voice - Mean Opinion Score (MOS) is a subjective measurement where listeners sit in a "quiet room" and score call quality as they perceived it (1 to 5). Per ITU-T recommendation P.800, "The talker should be seated in a quiet room with volume between 30 and 120 m3 and a reverberation time less than 500 ms \The room noise level must be below 30 dBA with no dominant peaks in the spectrum"
- Other metrics include - Perceptual Evaluation of Video Quality, Perceptual Evaluation of Audio Quality, Peak signal-to-noise ratio, etc.

UK Benchmarking and Ofcom

Issues

- Average across all operators
- Average across the entire day
- Average across a region
- Only provides information on 4G bandwidth

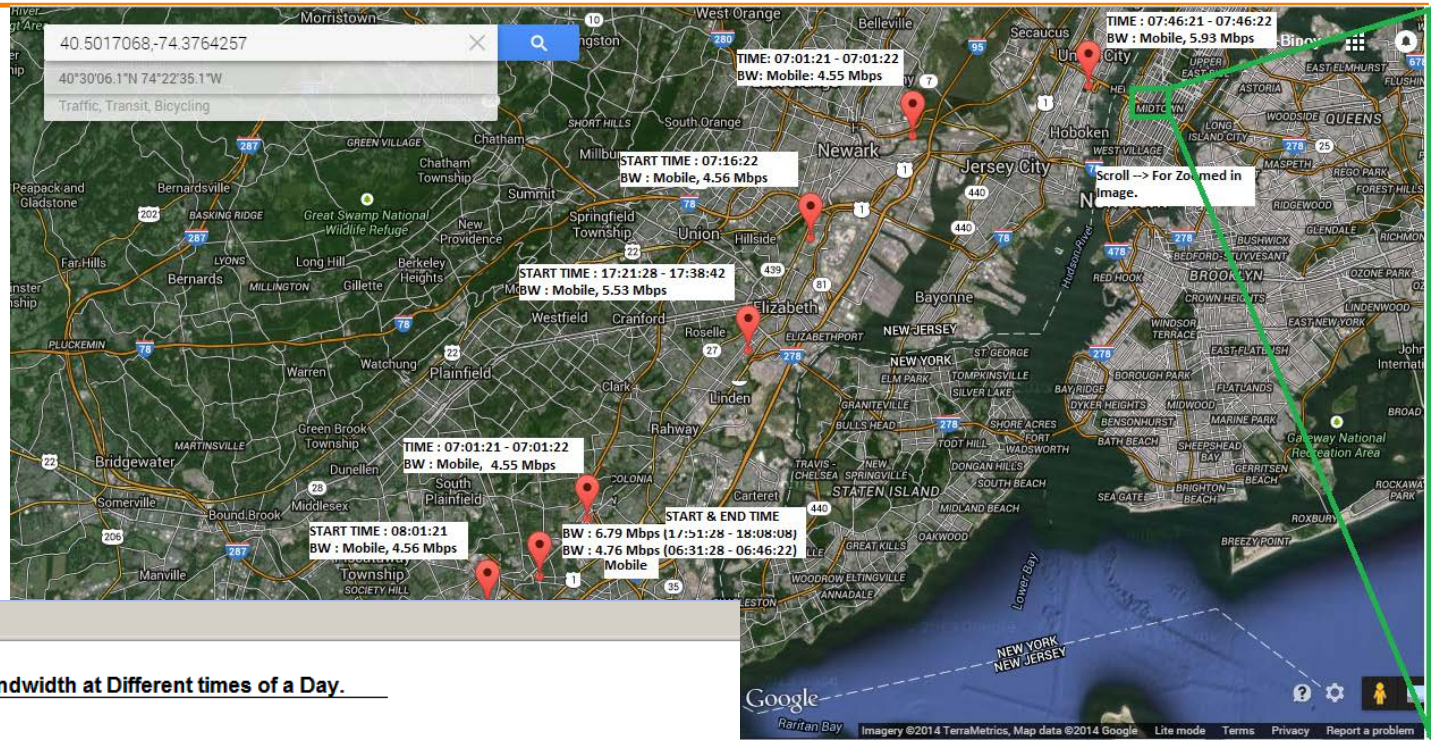
The **State of the Mobile Network report** found that EE had the greatest availability of 4G networks, on 64%, with Vodafone on 60%. 02 was slightly behind on 59.9%. And 3 offered the least availability, with 43.7%.

REGION	Average 4G availability	Average 4G speed
London	69.7%	18.8Mbps
Yorkshire and Humberside	61.3%	22.8Mbps
North East	60.3%	20.1Mbps
Northern Ireland	58.5%	23.3Mbps
North West	54.8%	20.6Mbps
South East	54.3%	21.9Mbps
West Midlands	52.3%	21.6Mbps
Scotland	50.4%	21.1Mbps
East Midlands	49.9%	22.8Mbps
East of England	48.9%	22.3Mbps
South West	45.7%	20.9Mbps
Wales	35.4%	21.7Mbps

Research at RIT

Service and Network Quality Metrics

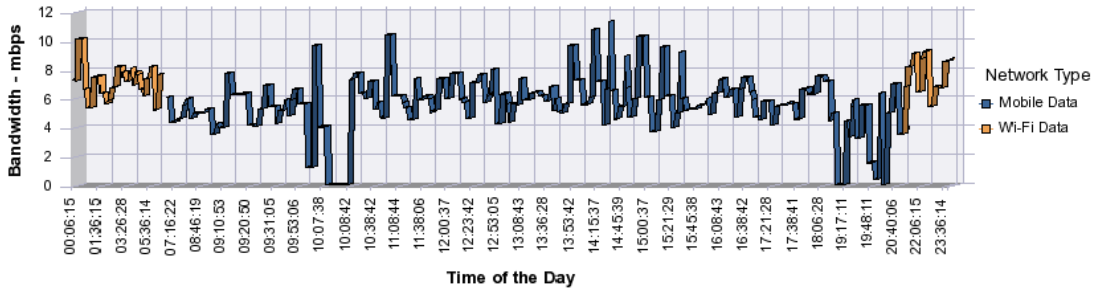
- Call clarity
- Dropped calls
- Bandwidth
- Delay
- Location
- Application
- Time of Day
- Operator



All Network Type | 1

Average Data Bandwidth at Different times of a Day.

Bandwidth_Context	Network Type	Data Consumed
5.73	Mobile Data	96,595,196
7.33	Wi-Fi Data	50,014,130



Connected World Initiative

- Team is developing new technology and methodologies leveraging latest research in big data analytics to measure, predict and share geo-located wireless network quality
  - Voice metrics - dropped calls, voice clarity, error rates, etc.
  - Data metrics - bandwidth, delay, signal strength, etc.
  - Initial trials have been conducted in 6 States in the US, Eastern Europe and South America
- Research team includes faculty, graduate students and undergraduate students from College of Applied Science and Technology (CAST) and College of Computing and Information Sciences (GCCIS)
- If you wish to participate, please drop an email to me
  - Yossi.nygate@rit.edu

Questions

- What is the difference between Wireless and Wi-Fi services
- How many of you use Wi-Fi when outside?
- Is Wi-Fi outside (e.g. in a shopping mall or at a Starbucks) better than your regular operator's service?
- What happens if the Wi-Fi coverage in your house is bad in one room?
- Would you agree to crowd-share your home Wi-Fi with other people?
- Would you agree to share information from your car regarding coverage?

Other Options to Increase Coverage - Wi-Fi Offload

Based on current location, time of day, day of week, network and Wi-Fi signal strength, historical performance, current congestion, subscriber profile, battery strength, etc.

Location based	• E.g. In stadium prefer Wi-Fi network provided by Venue operator to keep 3G network free for other users
Time/day	• During rush hours in shopping mall/metro stations – preferred Wi-Fi network • During off-peak hours – prefer 3G network
User profile/usage	• Premium user – prefer Wi-Fi network • Revenue Optimization – During initial period of billing cycle – prefer 3G network
Quality of Experience	• If 4G is congested offload to Wi-Fi unless Wi-Fi is congested too • Apply usage based offload only if Wi-Fi and 4G are in good shape

Decision Process

Enables taking best end-2-end decision on subscriber connectivity. The process is defined by 4 main steps of processing

DETECT

Detect network condition and device behavior

SELECT

Select best network by evaluating QoS and monetization in real time

CONNECT

Seamlessly Connect to the selected network

ANALYZE

Collect and Analyze user profiles and network behavior

Usage based offload scenario - A

NXT Customer Plan

2GB 3G Plan
Unlimited Wi-FI

The IAC knows what application Janice is using and will not offload her if she is using an app that will be affected by a network change e.g Voip

What's going on?

Janice is on 4G
quality is high

Wi-Fi is available
quality ***is lower***

Janice has only used about 10% of her 3G quota

April 5th

Policy from IAC decides she is not offloaded to Wi-Fi but is kept on the 3G Network

BSS

Policy

Smart Connection Manager

Profiles

Analytics

Intelligent Access Controller

nxt 4G

TreeNet Wi Fi

The Smart Connection Manager checks with the QoS policy rules on the Intelligent Access Controller (IAC) based on historical data it knows Wi-Fi is good. Checks 3G real time which is also good

Next it checks her monthly data consumption against her price plan. It's the 1st week of the month and she has only used 0.2GB of her 2GB plan

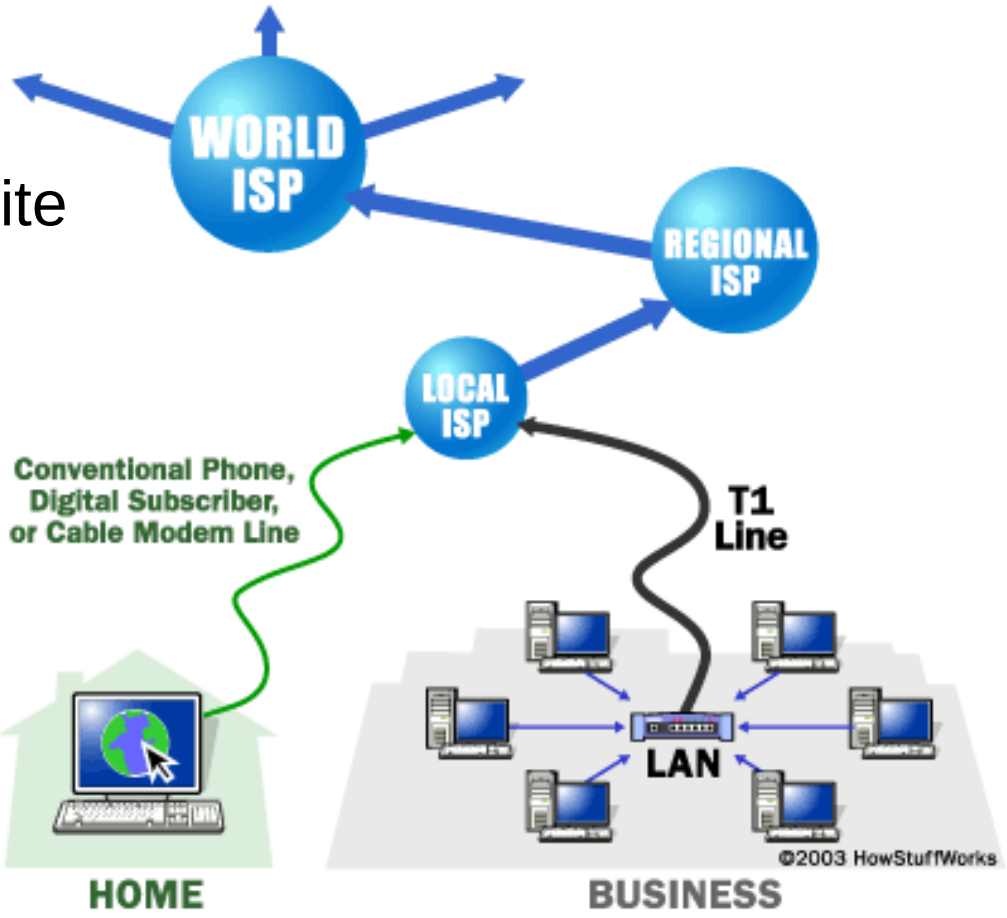
Janice remains on 4G because 4G is better and due to revenue optimization

Questions

- Why would a wireless operator wish to implement Wi-Fi offload?
- Why would a cable operator wish to implement Wi-Fi access?

Internet of Computers (IoC)

The **Internet** is a global system of interconnected computer networks that use the standard Internet protocol suite to link several billion devices worldwide. It is a *network of networks.*



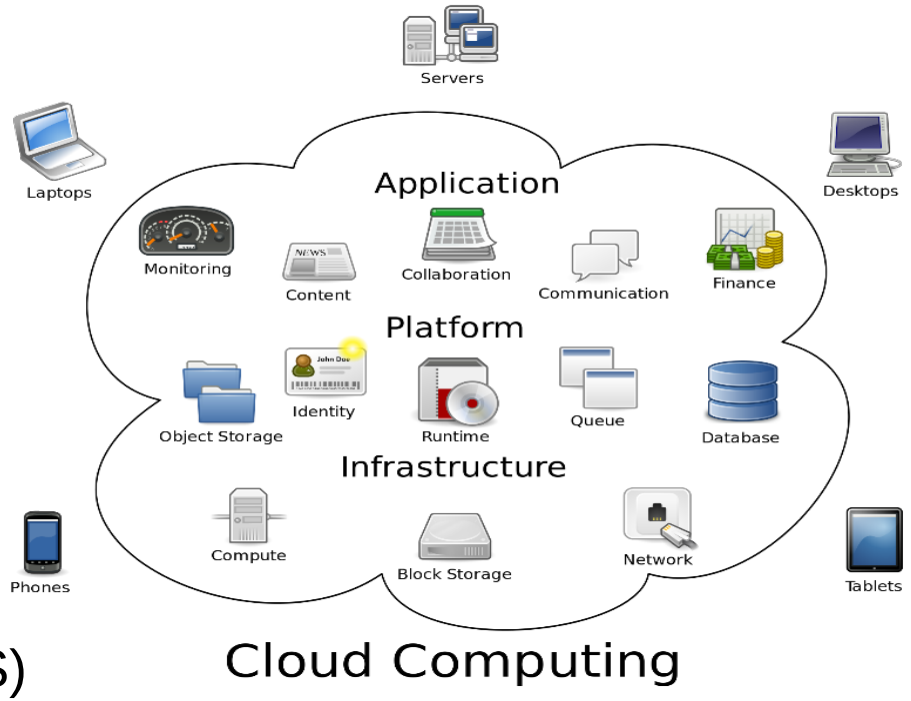
Internet of Documents (IoD)

- The World Wide Web, abbreviated as WWW or the Web, is a system of interlinked documents accessed via the Internet
- Key Technologies
  - Uniform Resource Locator (URL)
  - Uniform Resource Identifier (URI)
  - Hypertext Markup Language (HTML)
  - Hypertext Transfer Protocol (HTTP)
  - Web server and web browser (client)

Internet of Resources (IoR) – Cloud Computing

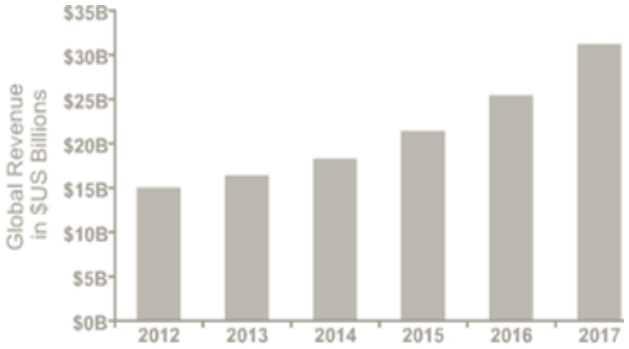
- Ubiquitous, on-demand access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services)
- Relies on sharing of resources to achieve coherence and economy of scale, similar to a utility (like the electricity grid) over a network

- Models include
  - Software as a Service (SaaS)
  - Infrastructure as a Service (IaaS)



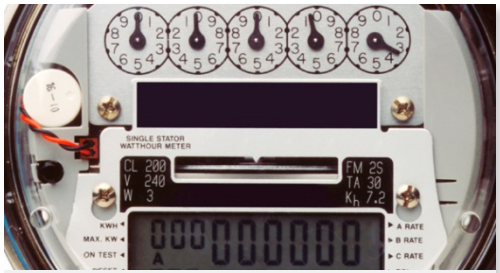
Internet of Things

M2M CONNECTIONS TO TOP 4B BY 2017 ($31B IN REVENUE)



mHealth $58.8B in revenue by **2020,** 32.3% CAGR from 2013

Automotive connected car market will reach **$131.9B** by **2019,** 34.7% CAGR from 2013

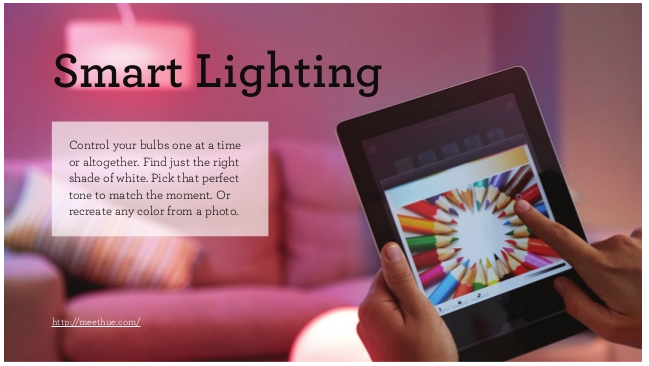


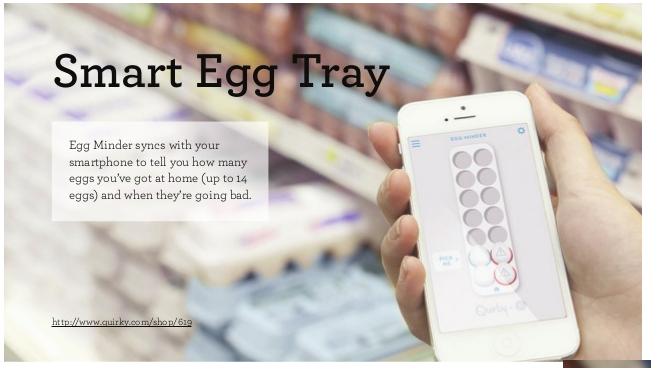
Energy and utilities will account for **23%** of M2M connections by 2018

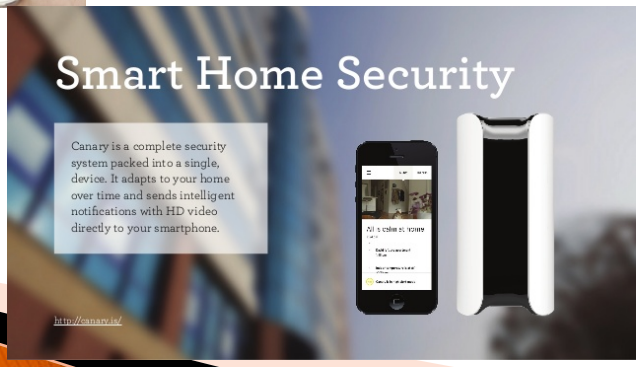
North America, APAC and Western Europe lead the market

Source: Allied Market Research, Transparency Market Research, Ovum

Home Automation



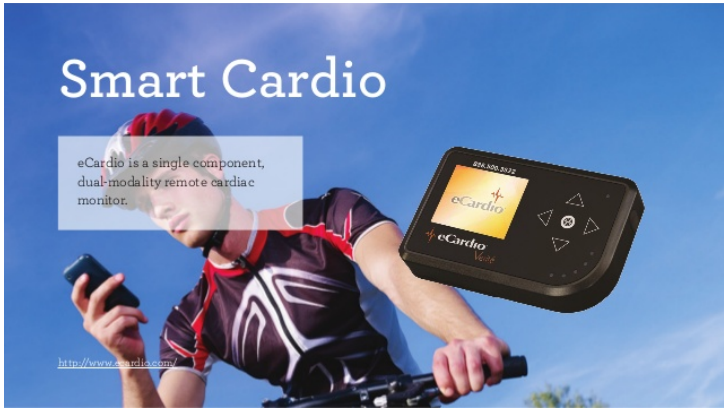


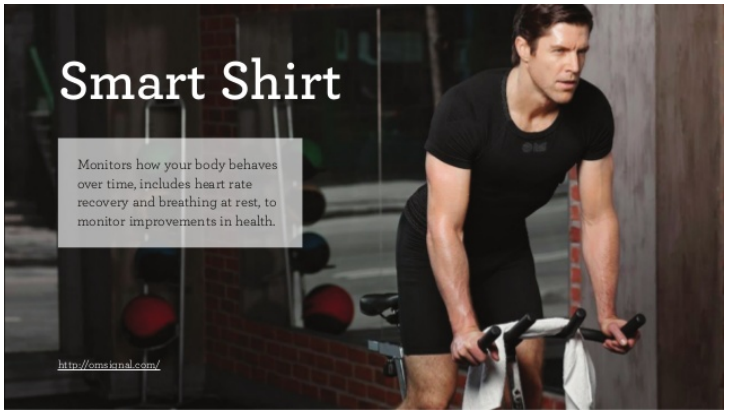


Health

Glucose Monitoring
A cellular-powered glucose meter transmits each test result to a secure server and provides instant feedback and coaching to patients. This equips doctors, nurses, diabetes educators with real-time clinical data.
http://www.telcare.com/

Blood Pressure Monitor
Simply slip on the cuff, turn on the Wireless Blood Pressure Monitor and the Health Mate app will automatically launch.
http://www.withings.com/us/blood-pressure-monitor.html

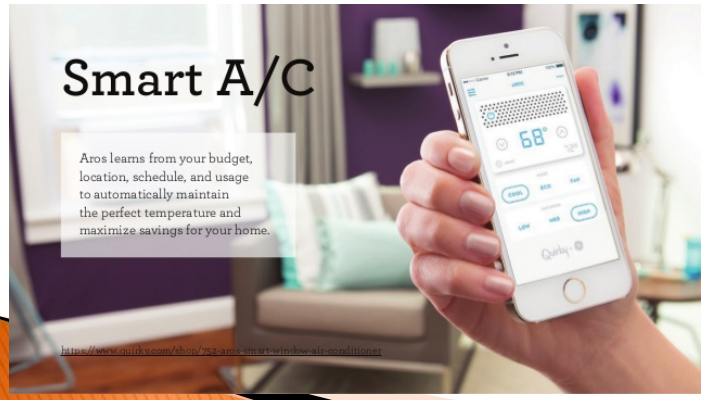

Smart Cardio
eCardio is a single component, dual-modality remote cardiac monitor.
http://www.ecardio.com/

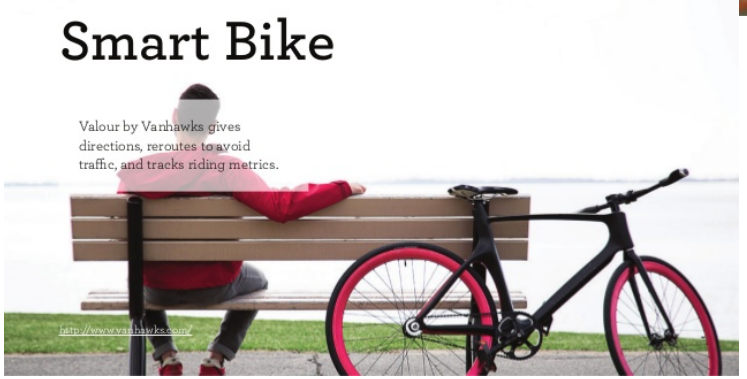

Smart Shirt
Monitors how your body behaves over time, includes heart rate recovery and breathing at rest, to monitor improvements in health.
http://omsignal.com/

Environment

Ninja Block

Tracks water pipe bursts and motion in the house while away





Transportation

Verizon Buys Big Into IoT W

Yossi

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IOT / AUTOMOTIVE

Verizon Buys Big Into IoT With $2.4B Fleetmatics Deal

NEWS ANALYSIS
DAN JONES,
Mobile Editor

8/1/2016

COMMENT (3)

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Verizon is bolstering its profile in the fleet tracking business, buying Fleetmatics Group plc for $2.4 billion in an all-cash deal.

The deal -- at $60 per share -- is a nearly 40% premium over Fleetmatics' closing share price of $42.96 Friday. Dublin, Ireland-based Fleetmatics was founded in 2004 and has 1,200 employees, over 37,000 customers and approximately 737,000 subscribers. The company develops GPS location-based employee status, fuel and billing desktop and mobile software.

"Fleetmatics is a market leader in North America -- and increasingly internationally -- and they've developed a wide-range of compelling SaaS-based products and solutions for small- and medium-sized businesses," said Andrés Irlando, CEO of Verizon Telematics, of the deal.

Want to know more about IoT? Visit the Light Reading IoT section.

Although the connected car has caught the hype wave, Verizon has long been in

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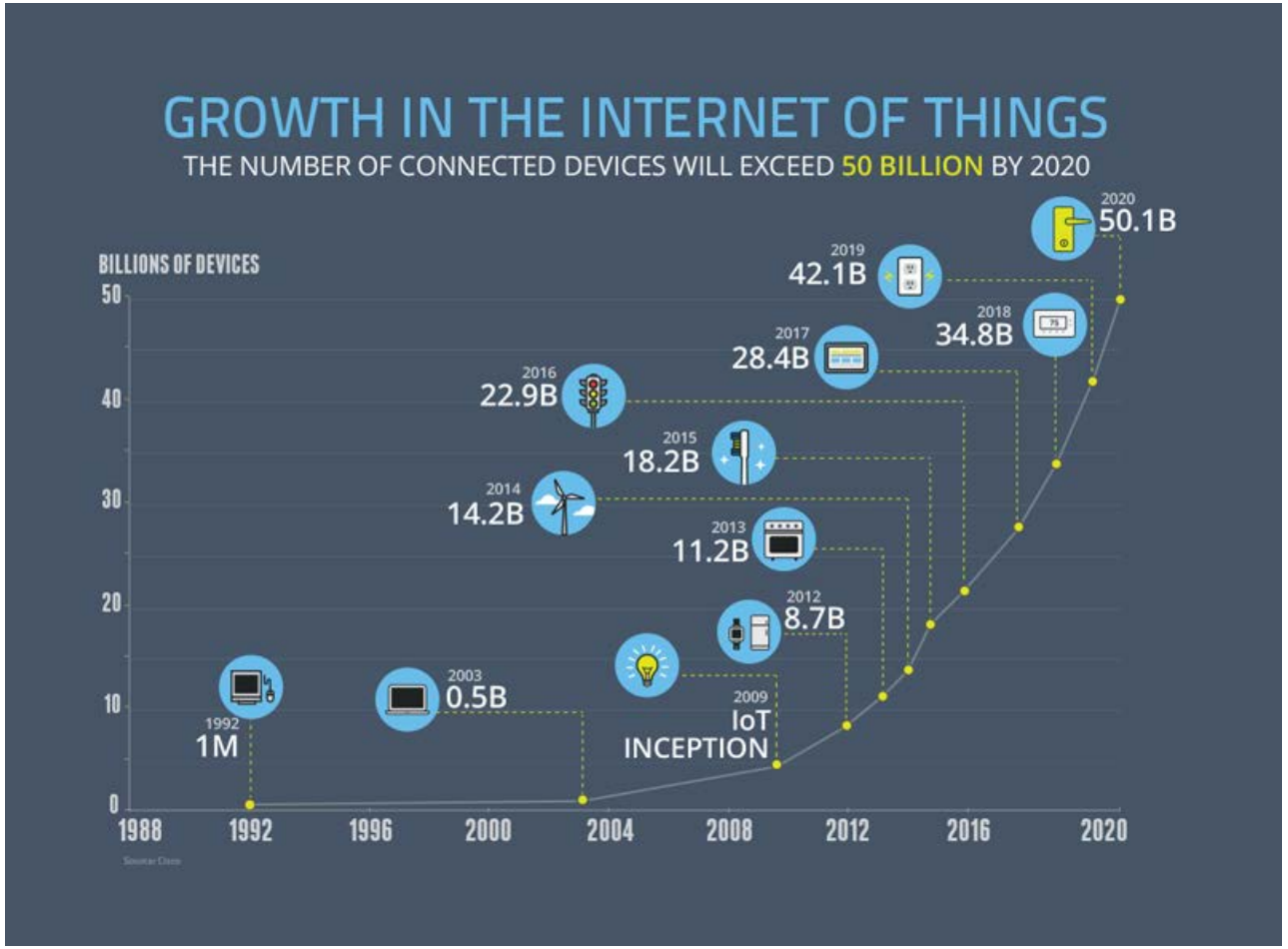
EDUCATIONAL RESOURCES ARCHIVE

The Connected World

- Over 50 billion devices are expected to be connected to the internet by 2020 from about 25 billion today

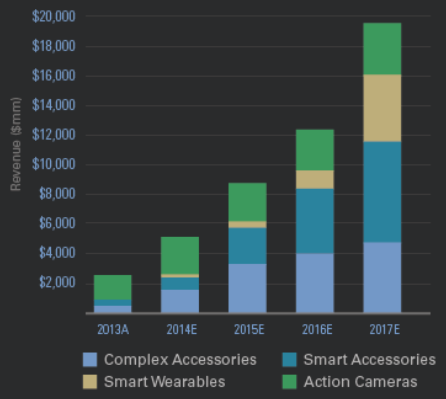


Future of IoT

WEARABLES

Source: IDC, Goldman Sachs Investment Research

Connected wearable devices include categories such as fitness bands, smart watches, smart glasses and action cameras.

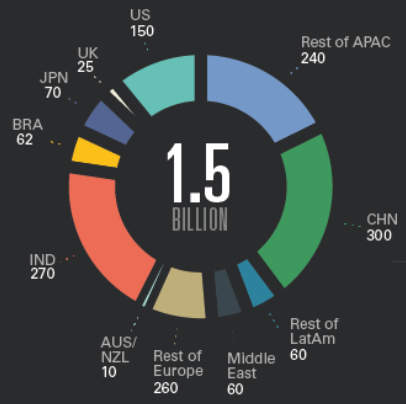


Wearable devices to reach about $20bn by 2017, growing at over 60% CAGR

CITIES

Source: Company data, Goldman Sachs Investment Research

Smart meters, which monitor water, gas and electric usage, play a key role in helping cities analyze data, create efficiency and connect to the IoT.

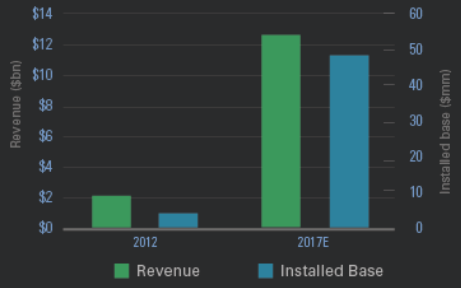


Approximate estimate of smart meter opportunity by geography, in millions

HOMES

Source: Berg Insight

Connected homes include connecting household appliances to the network, with resulting advantages including improved security, remote management of devices, and energy management.

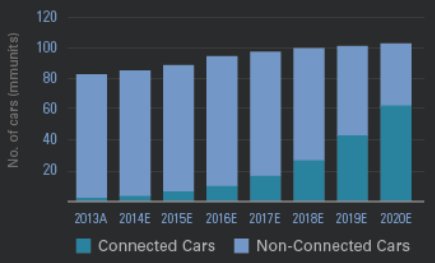


North America and Europe home automation systems

CARS

Source: Gartner (March 2014), Company data, Goldman Sachs Investment Research

Connected cars are vehicles that connect to the internet and may also feature the ability to communicate with other vehicles and infrastructure, such as traffic lights.



Connected cars penetration is being driven by applications in the following: safety, vehicle diagnostics, infotainment and navigation, and fleet management.

R·I·T

Thank You