

CSMC 417

Computer Networks

Prof. Ashok K Agrawala

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General

- Instructor - Ashok K. Agrawala
 - agrawala@cs.umd.edu
 - 4149 AVW
- TA – Andrew Pachulski
 - Office Hours –
- Class Meets – Tu Th 9:30 – 10:45 CSIC3117

Prerequisite

- Required Background
 - must have 351 and 330 (412 or 430 would be helpful)
- Expectations
 - Understand the basics of Computer Architecture
 - Experience in implementing non-trivial systems-type projects
 - Should know
 - Processor
 - Memory
 - Kernel vs. user process
 - Familiar with basic probability

Expectations – After the course

- Understand the fundamentals of networking protocols, including protocol layering, basic medium access including wireless protocols, routing, addressing, congestion control
- Understand the principles behind the Internet protocols and some application layer protocols such as http, ftp, and DNS, and a few peer-to-peer systems/protocols such as Gnutella and Chord.
- Understand some of the limitations of the current Internet and its service model
- Understand the causes behind network congestion, and explain the basic methods for alleviating congestion
- Design, implement, and test substantial parts of network protocols

Announcements

- Required Work

- will require about the same amount of effort as 412
 - 412 a (slightly) harder project to debug
 - 417 project is (by design) more ambiguous

- Required Texts

- *Computer Networks* **5th Edition**, Tanenbaum and Wetherall, Prentice Hall 2011. ISBN 0-13-212695-8
- *TCP/IP Sockets in C: A Practical Guide for Programmers* **2nd Edition** by Jeff Donahoo and Ken Calvert, Morgan Kaufmann, 2009. ISBN 978-0123745408

Other Material

- Recommended Texts
 - *Computer Networking, 5e: A Top Down Approach Featuring the Internet* by Jim Kurose and Keith Ross, Addison-Wesley, (ISBN: 0-13-607967). The on-line version of this book is at <http://www.awlonline.com/kurose-ross>.
 - *Computer Networks: A Systems Approach* by Larry Peterson and Bruce Davie, MorganKaufman, 4rd Edition, 2007. ISBN 978-0123705488
 - *An Engineering Approach to Computer Networking*, by S. Keshav. Addison-Wesley, 1997. ISBN 0-201-63442-2
 - *Computer Networking with Internet Protocols* by William Stallings, Prentice-Hall, 2004. ISBN 10: 0131410989
 - *TCP/IP Illustrated* volume 1 by W. Richard Stevens. Addison-Wesley. ISBN: 0-201- 63346-9.
- RFCs

Grading

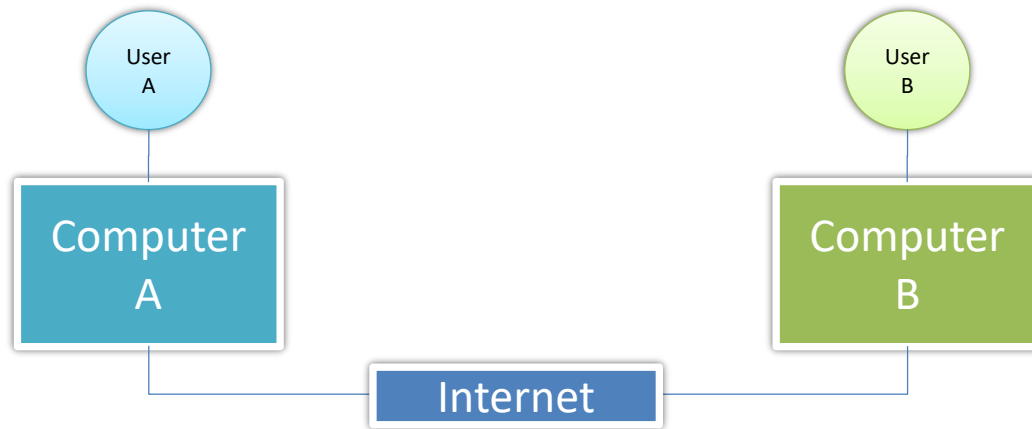
- Final 25%
- In-Term Exam(s) 25%
- Programming Assignments 35%
- Class Participation 15%
 - Pop Quizzes
 - ...

POP Quizzes

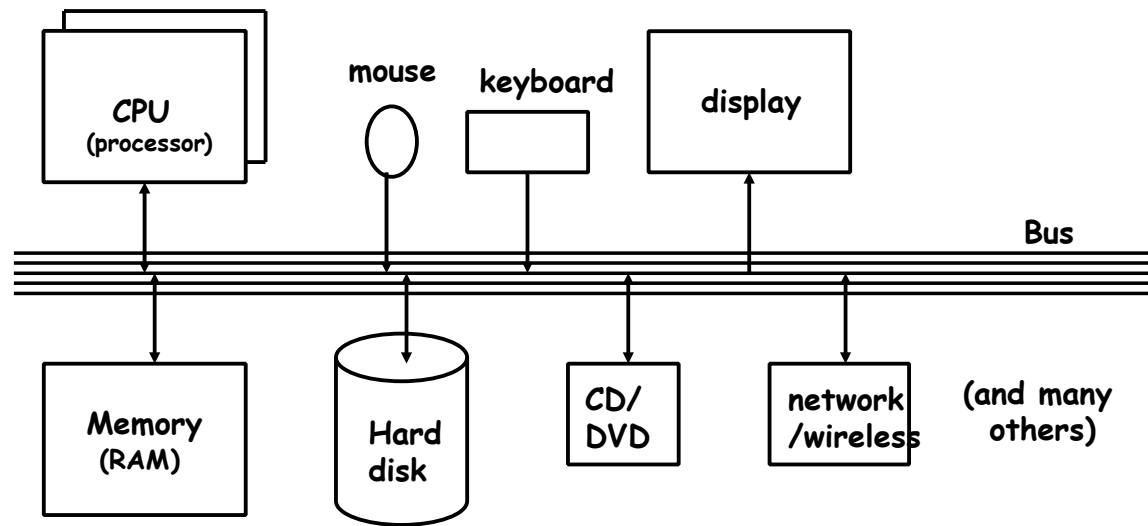
- Unannounced
- Frequent
- In the **beginning** of the class
 - If you come late you miss
 - Missing pop quizzes **will** impact your grade
- Mostly question(s) from the book

What is this course all about?

- Computer Networking
 - ???

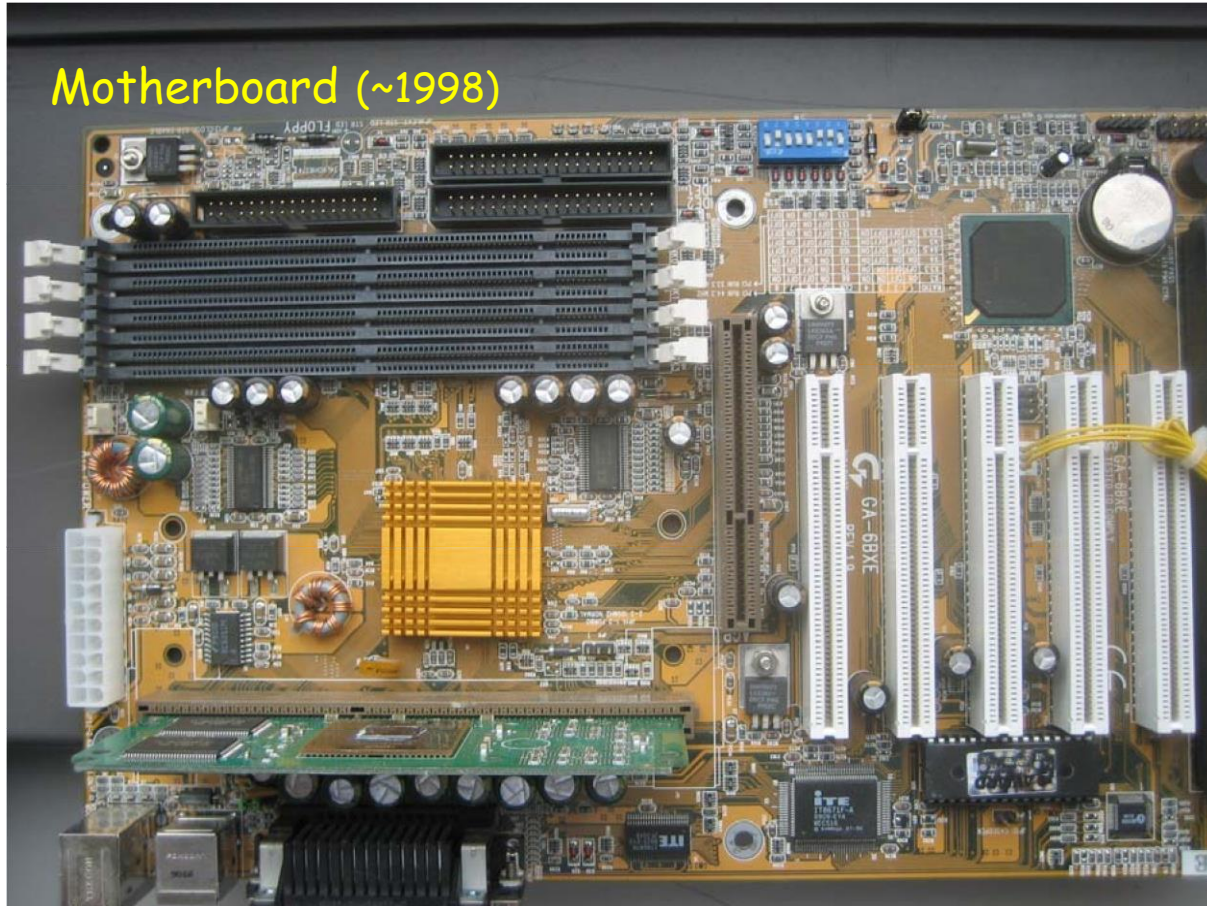


Block Diagram of Typical Laptop/desktop

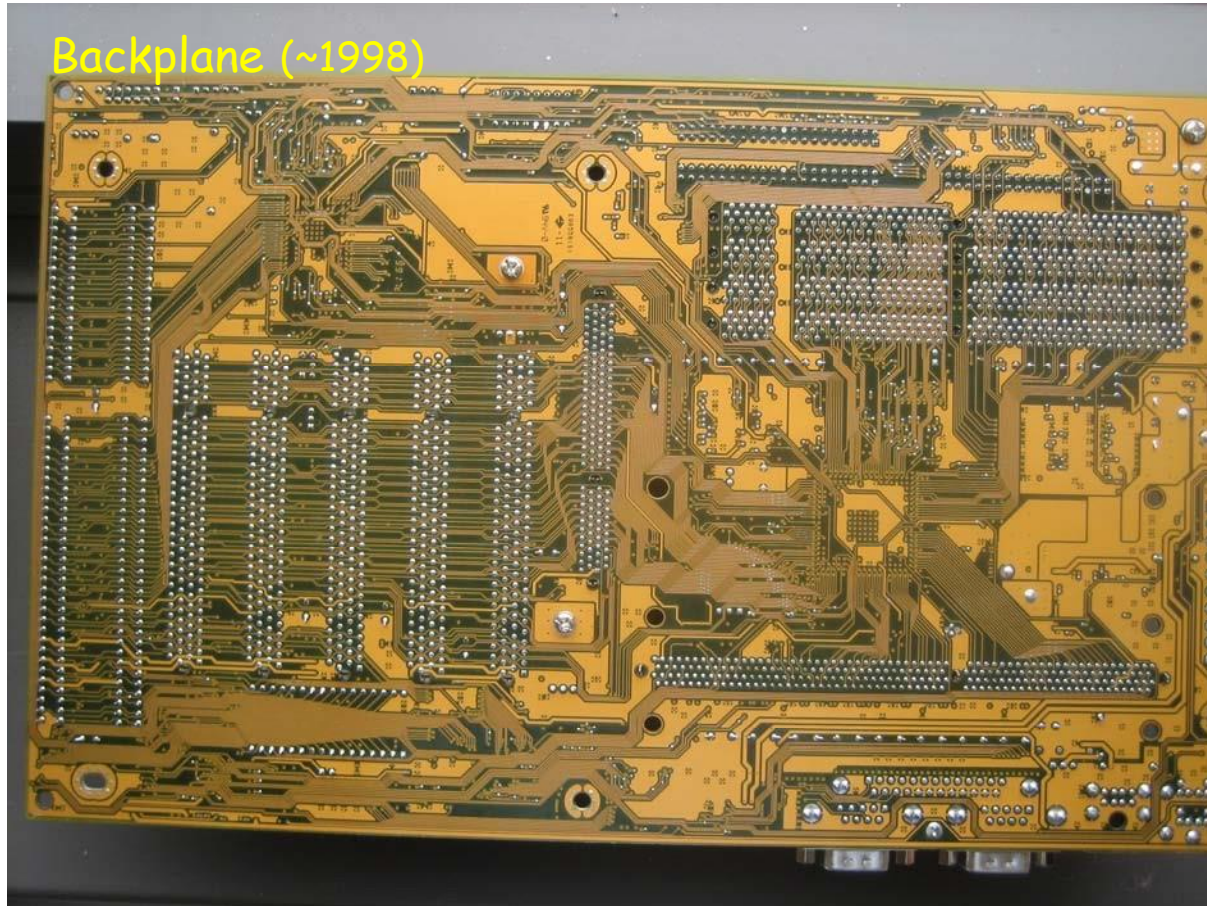


<https://www.cs.princeton.edu/courses/archive/fall11/cos109/02inside.pdf>

Motherboard (~1998)

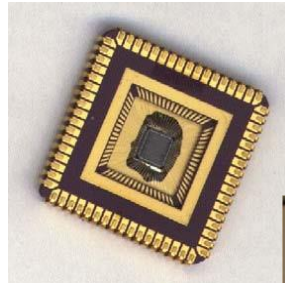
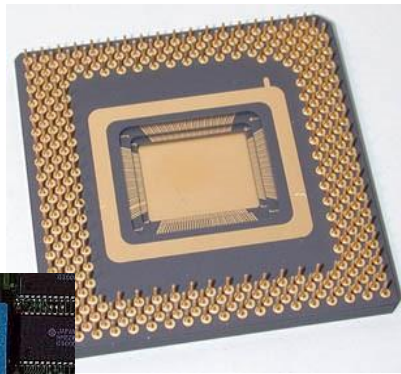


<https://www.cs.princeton.edu/courses/archive/fall11/cos109/02inside.pdf>



<https://www.cs.princeton.edu/courses/archive/fall11/cos109/02inside.pdf>

Some CPU chips



2.5" laptop disk



<https://www.cs.princeton.edu/courses/archive/fall11/cos109/02inside.pdf>

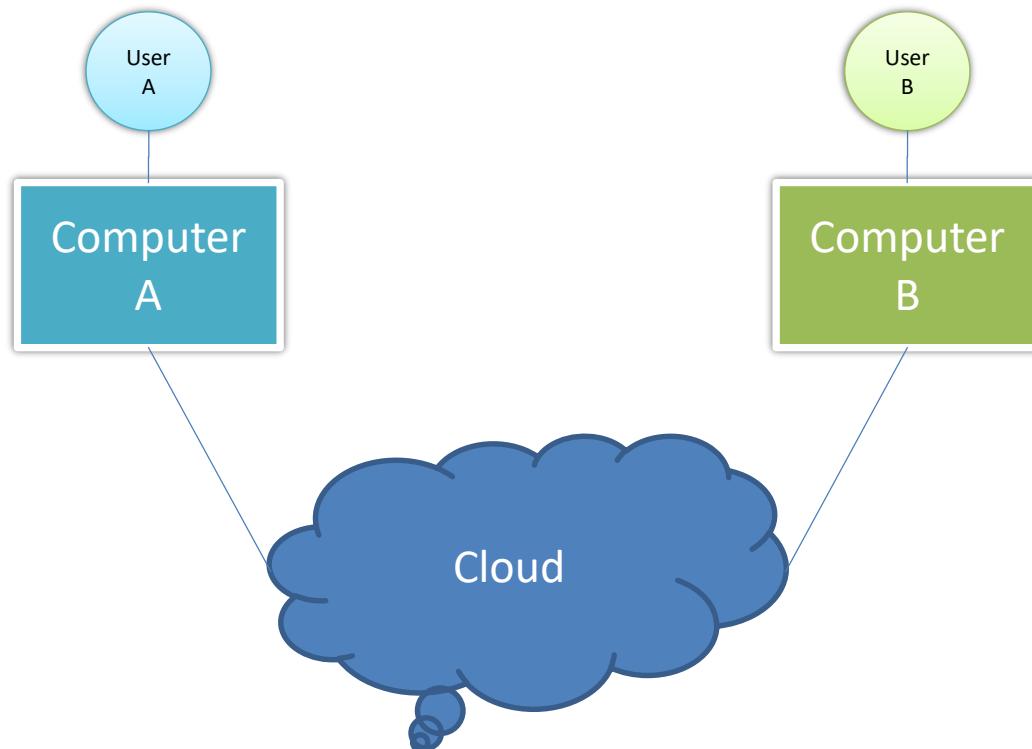


Are these the only computers?

We use a large number and variety of devices with computing capabilities

- Laptops
- Pads
- Smart phones
- Wearables
 - Watches
- Cars
- Appliances
- Speakers
- Light bulbs
- Locks
- Webcams
- Internet of Things (IoT)

What about Cloud ?



**JAN
2018**

DIGITAL AROUND THE WORLD IN 2018

KEY STATISTICAL INDICATORS FOR THE WORLD'S INTERNET, MOBILE, AND SOCIAL MEDIA USERS

TOTAL
POPULATION



we
are
social

7.593
BILLION

URBANISATION:
55%

INTERNET
USERS



4.021
BILLION

PENETRATION:
53%

ACTIVE SOCIAL
MEDIA USERS



we
are
social

3.196
BILLION

PENETRATION:
42%

UNIQUE
MOBILE USERS



5.135
BILLION

PENETRATION:
68%

ACTIVE MOBILE
SOCIAL USERS



2.958
BILLION

PENETRATION:
39%

7

SOURCES: POPULATION: UNITED NATIONS; U.S. CENSUS BUREAU; **INTERNET:** INTERNETWORLDSTATS; ITU; EUROSTAT; INTERNETLIVESTATS; CIA WORLD FACTBOOK; MIDEASTMEDIA.ORG; FACEBOOK; GOVERNMENT OFFICIALS; REGULATORY AUTHORITIES; REPUTABLE MEDIA; **SOCIAL MEDIA** AND **MOBILE SOCIAL MEDIA:** FACEBOOK; TENCENT; VKONTAKTE; KAKAO; NAVER; DING; TECHRASA; SIMILARWEB; KEPIOS ANALYSIS; **MOBILE:** GSMA INTELLIGENCE; GOOGLE; ERICSSON; KEPIOS ANALYSIS. **NOTE:** PENETRATION FIGURES ARE FOR TOTAL POPULATION (ALL AGES).



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Internet Statistics 2018

- *There are **3.812 billion internet users** as at January 20018;*
- *Approx 40% of the world population has an internet connection in 2018. It was less than 1% in 1995*
- ***Asia, as a continent, has the most internet users.** It accounts for 49.7% of global internet users.*
- *China, as a country, has the most internet users; with an estimated 738 million internet users,*
- *US has 287 million, Russia 110 million.*
- *North America has the highest penetration rate 88.1% followed by Europe (80.2%) Australia (69.6%)*
- ***China has the highest percentage of internet users (21.97%),** followed by the U.S. (9.58%) and India (8.33%).*
- ***Falkland Island and Iceland have the highest penetration with 96.9% and 96.5%.***
- *Google processes 6.586 billion searches a day.*
- *56% of all internet traffic is from automated sources such as hacking tools, scrapers and spammers, impersonators, and bots.*
- *332.4 million domain names are registered by Jan 2018. .Com has 131.9 million and .CN has 21.4 million.*

<https://www.websitehostingrating.com/internet-statistics-facts-2018/>

**JAN
2017**

DIGITAL IN THE AMERICAS

KEY STATISTICAL INDICATORS FOR THE REGION'S INTERNET, MOBILE, AND SOCIAL MEDIA USERS

TOTAL
POPULATION



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1,006
MILLION

URBANISATION:
81%

INTERNET
USERS



we
are
social

718
MILLION

PENETRATION:
71%

ACTIVE SOCIAL
MEDIA USERS



we
are
social

599
MILLION

PENETRATION:
60%

MOBILE
SUBSCRIPTIONS



we
are
social

1,069
MILLION

vs. POPULATION:
106%

ACTIVE MOBILE
SOCIAL USERS




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535
MILLION

PENETRATION:
53%

13

SOURCE: POPULATION: UNITED NATIONS, U.S. CENSUS BUREAU; INTERNET: INTERNETWORK DATA, USA INTERNETSTATS, CIA WORLD FACTBOOK, FACEBOOK NATIONAL REGULATORY AUTHORITIES; SOCIAL MEDIA AND MOBILE SOCIAL MEDIA: FACEBOOK, TWITTER, YOUTUBE, LIVE, INTERNET.MI, KAZO, NAVE, RFI, MICHAEL CAFFARAZZI, ZIMMER, DWI; EXTRAPOLATION OF THIS DATA; MOBILE: GSM, ITU, GENCIS, EXTRAPOLATION OF SIM-KIT AND GENCIS DATA.

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UNITED STATES OF AMERICA

A SNAPSHOT OF THE COUNTRY'S KEY DIGITAL STATISTICAL INDICATORS



TOTAL
POPULATION



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**322.9
MILLION**

URBANISATION: 82%

FIGURE REPRESENTS TOTAL NATIONAL
POPULATION, INCLUDING CHILDREN

ACTIVE
INTERNET USERS



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**282.1
MILLION**

PENETRATION: 87%

FIGURE INCLUDES ACCESS VIA
FIXED AND MOBILE CONNECTIONS

ACTIVE SOCIAL
MEDIA USERS



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**192.0
MILLION**

PENETRATION: 59%

FIGURE BASED ON ACTIVE USER
ACCOUNTS, NOT UNIQUE INDIVIDUALS

MOBILE
CONNECTIONS



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**342.4
MILLION**

vs POPULATION: 106%

FIGURE REPRESENTS MOBILE
SUBSCRIPTIONS, NOT UNIQUE USERS

ACTIVE MOBILE
SOCIAL USERS



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**169.0
MILLION**

PENETRATION: 52%

FIGURE BASED ON ACTIVE USER
ACCOUNTS, NOT UNIQUE INDIVIDUALS

JAN
2018

DEVICE USAGE

PERCENTAGE OF THE ADULT POPULATION* THAT CURRENTLY USES EACH KIND OF DEVICE [SURVEY-BASED]



MOBILE PHONE
(ANY TYPE)



95%

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SMART
PHONE



75%

Google

LAPTOP OR
DESKTOP COMPUTER



57%



TABLET
COMPUTER



20%

TELEVISION
(ANY KIND)



97%

Google

DEVICE FOR STREAMING
INTERNET CONTENT TO TV



10%



E-READER
DEVICE



1%

we
are
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WEARABLE
TECH DEVICE



4%

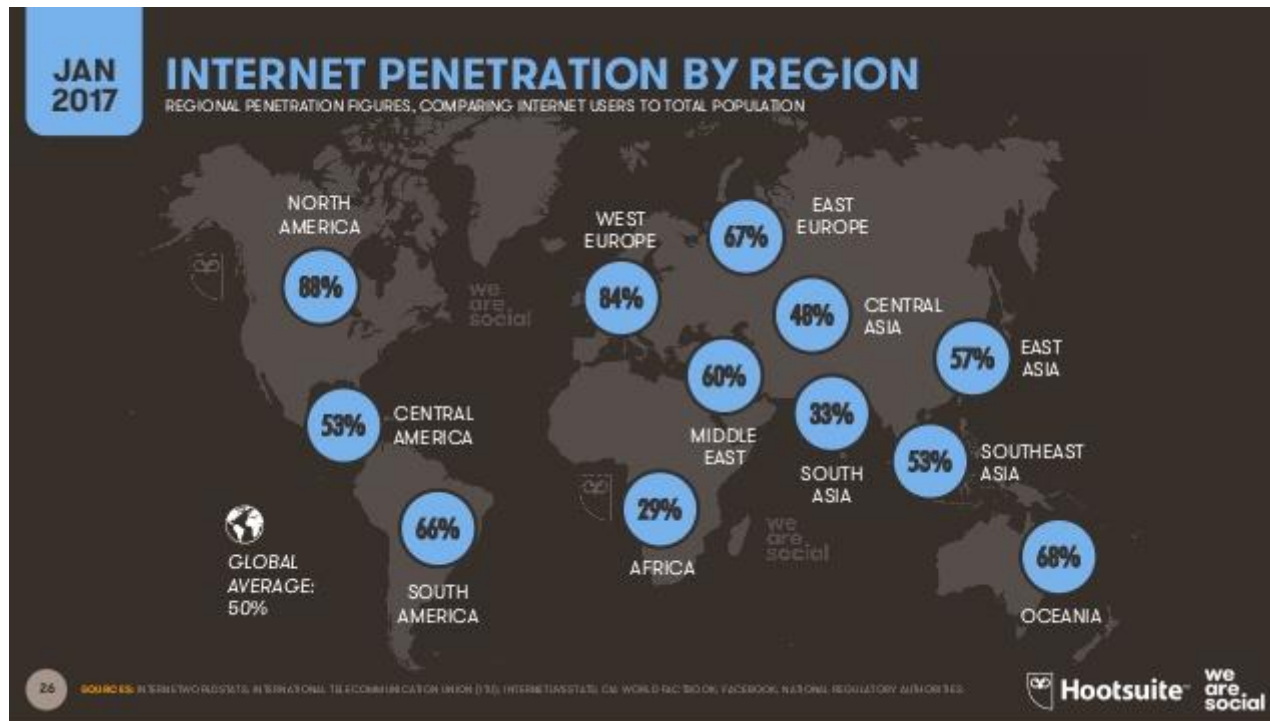
58

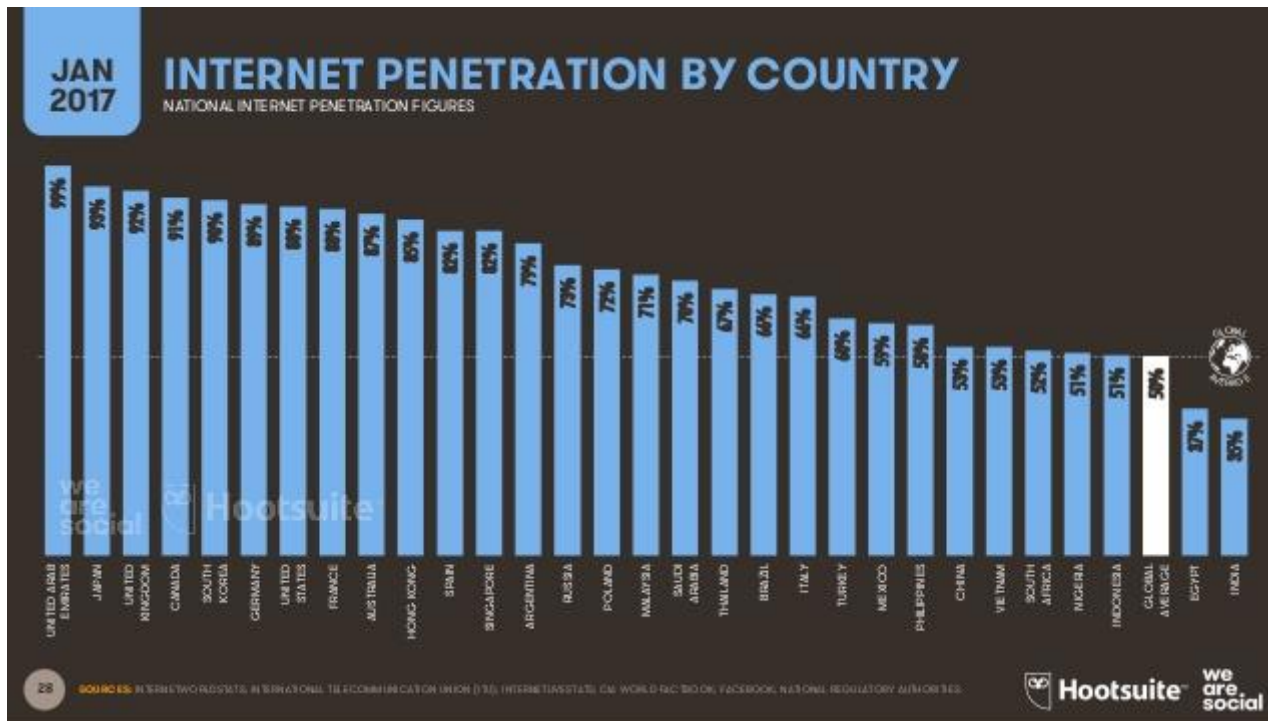
SOURCE: GOOGLE CONSUMER BAROMETER, JANUARY 2018. FIGURES BASED ON RESPONSES TO A SURVEY. *NOTE: DATA REPRESENTS ADULT RESPONDENTS ONLY. PLEASE SEE THE NOTES AT THE END OF THIS REPORT FOR MORE INFORMATION ON GOOGLE'S METHODOLOGY AND THIRD-PARTY DEFINITIONS.

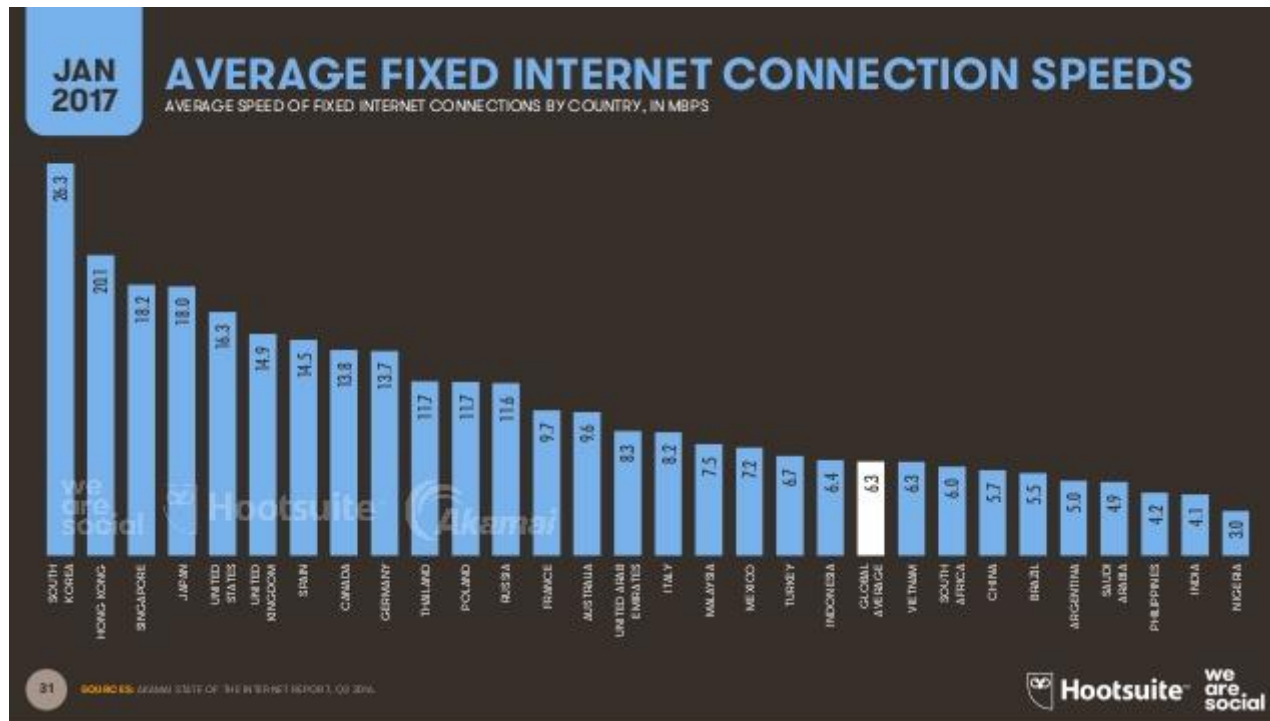


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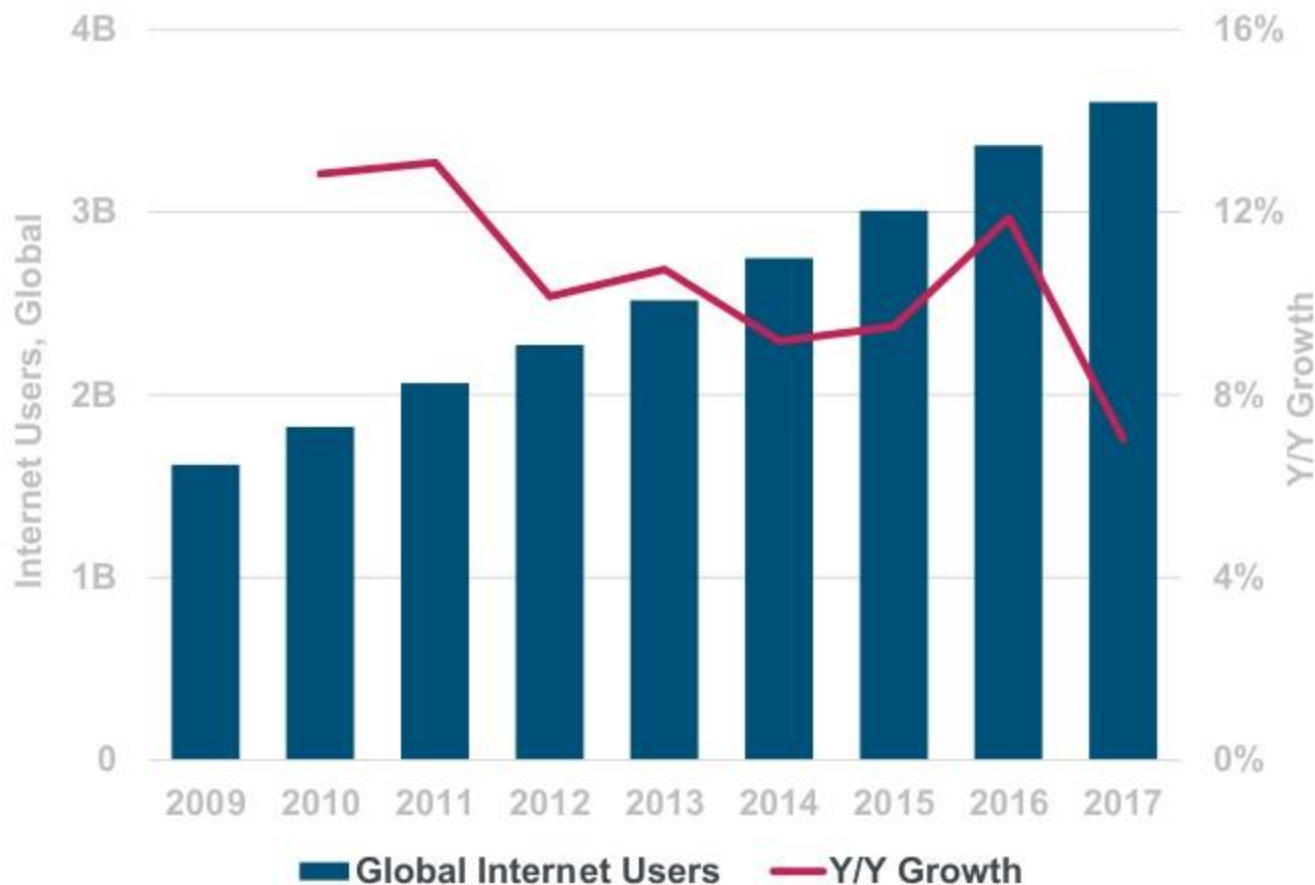






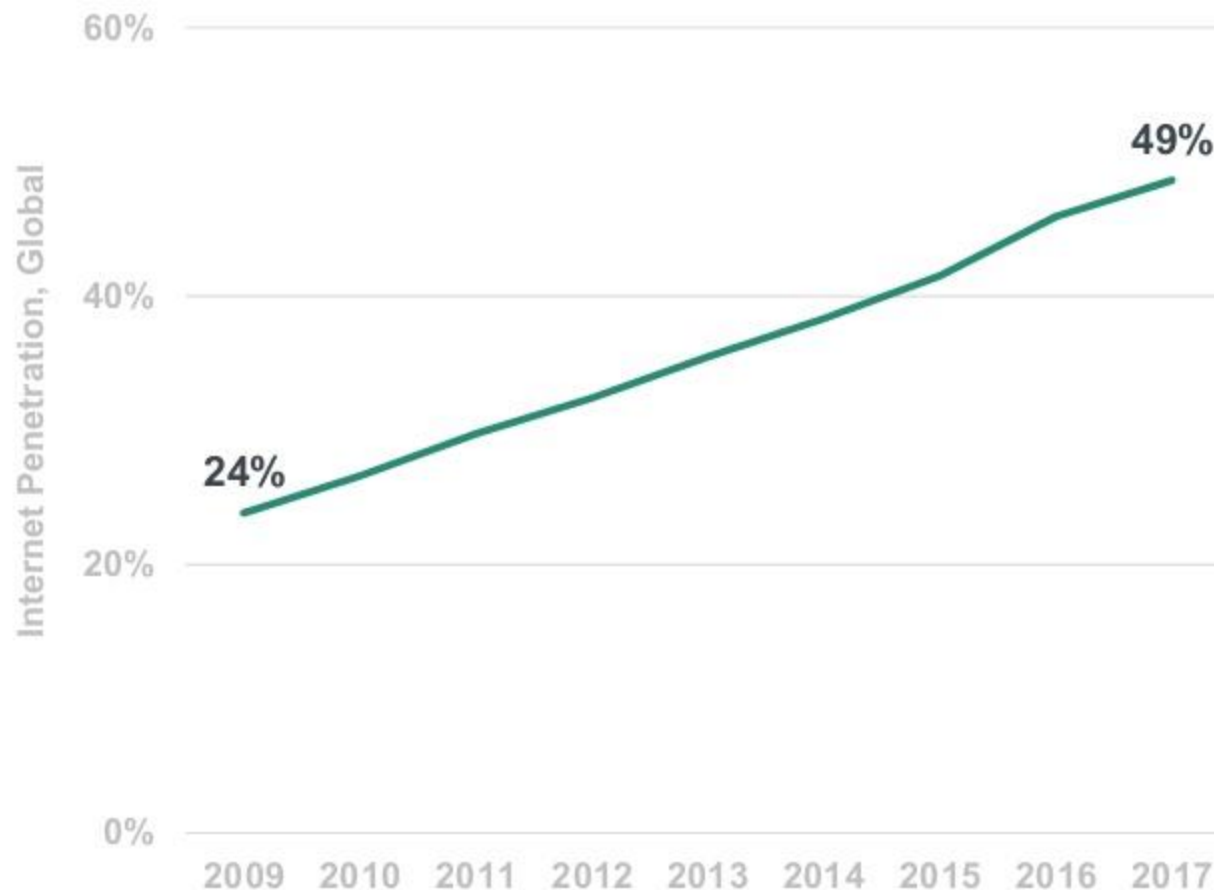
Global Internet Users = Slowing Growth @ +7% vs. +12% Y/Y

Internet Users vs. Y/Y Growth



Global Internet Users = 3.6B @ >50% of Population (2018)

Internet Penetration



JAN
2018

E-COMMERCE DETAIL: CONSUMER GOODS

AN OVERVIEW OF THE E-COMMERCE MARKET FOR CONSUMER GOODS, WITH VALUES IN UNITED STATES DOLLARS

TOTAL NUMBER OF PEOPLE
PURCHASING CONSUMER
GOODS VIA E-COMMERCE



1.77
BILLION

YEAR-ON-YEAR CHANGE:

+8%

PENETRATION OF CONSUMER
GOODS E-COMMERCE
(TOTAL POPULATION)



23%

VALUE OF THE CONSUMER
GOODS E-COMMERCE MARKET
(TOTAL ANNUAL SALES REVENUE)



\$1.474
TRILLION

YEAR-ON-YEAR CHANGE:

+16%

AVERAGE ANNUAL REVENUE
PER USER OF CONSUMER
GOODS E-COMMERCE (ARPU)



\$833

YEAR-ON-YEAR CHANGE:

+7%

131

SOURCE: STATISTA DIGITAL MARKET OUTLOOK, E-COMMERCE INDUSTRY, ACCESSED JANUARY 2018. **NOTES:** FIGURES REPRESENT SALES OF PHYSICAL GOODS VIA DIGITAL CHANNELS ON ANY DEVICE TO PRIVATE END USERS, AND DO NOT INCLUDE DIGITAL MEDIA, DIGITAL SERVICES SUCH AS TRAVEL OR SOFTWARE, B2B PRODUCTS AND SERVICES, RESALE OF USED GOODS, OR SALES BETWEEN PRIVATE PERSONS (P2P COMMERCE). PENETRATION FIGURE REPRESENTS PERCENTAGE OF TOTAL POPULATION, REGARDLESS OF AGE.



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AUG
2017

SHARE OF WEB TRAFFIC BY DEVICE

BASED ON EACH DEVICE'S SHARE OF ALL WEB PAGES SERVED TO WEB BROWSERS

LAPTOPS &
DESKTOPS



41%

YEAR-ON-YEAR CHANGE:
-18%

MOBILE
PHONES



54%

YEAR-ON-YEAR CHANGE:
+21%

TABLET
DEVICES



5%

YEAR-ON-YEAR CHANGE:
-7%

OTHER
DEVICES




0.14%

YEAR-ON-YEAR CHANGE:
+27%

8

SOURCE: STATCOUNTER, AUGUST 2017.

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**AUG
2017**

PERSPECTIVE: MOBILE USERS vs. CONNECTIONS

COMPARING THE NUMBER OF UNIQUE INDIVIDUALS USING MOBILE PHONES TO THE NUMBER OF MOBILE SUBSCRIPTIONS IN USE

GSMA INTELLIGENCE DATA

TOTAL NUMBER
OF MOBILE USERS
(UNIQUE INDIVIDUALS)



5.052
BILLION

TOTAL NUMBER
OF MOBILE
CONNECTIONS



8.228
BILLION



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ERICSSON MOBILITY REPORT DATA

TOTAL NUMBER
OF MOBILE USERS
(UNIQUE INDIVIDUALS)



5.200
BILLION

TOTAL NUMBER
OF MOBILE
CONNECTIONS

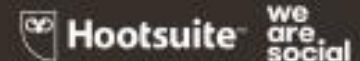


7.600
BILLION



15

SOURCES: GSMA INTELLIGENCE, Q3 2016; ERICSSON MOBILITY REPORT, JUNE 2017.



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2017**

MOBILE CONNECTIONS BY DEVICE

BASED ON GLOBAL SMARTPHONE CONNECTIONS COMPARED TO TOTAL GLOBAL MOBILE CONNECTIONS

TOTAL GLOBAL
CONNECTIONS
(ALL DEVICES)*



8.05
BILLION

CONNECTIONS
USED ON SMART-
PHONE DEVICES



4.42
BILLION

SHARE OF SMART-
PHONE CONNECTIONS
vs. TOTAL CONNECTIONS



55%

CONNECTIONS
USED ON FEATURE-
PHONE DEVICES



3.38
BILLION

SHARE OF FEATURE-
PHONE CONNECTIONS
vs. TOTAL CONNECTIONS

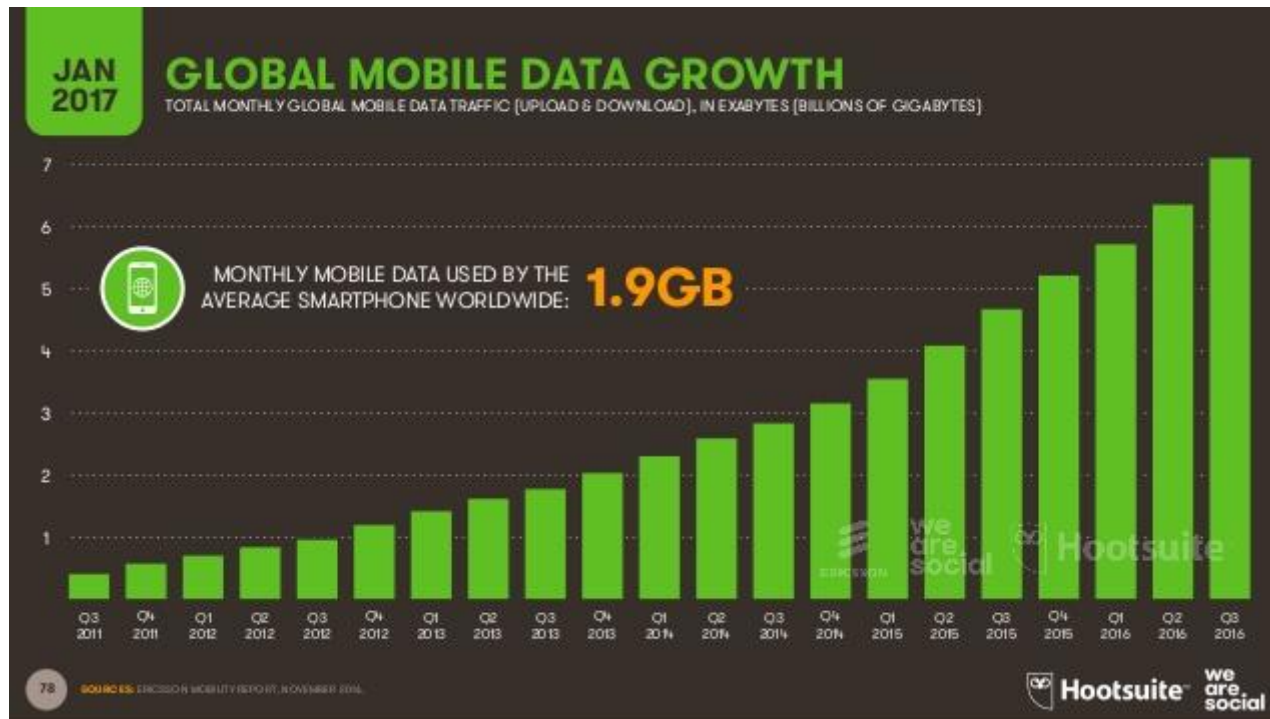


42%

74

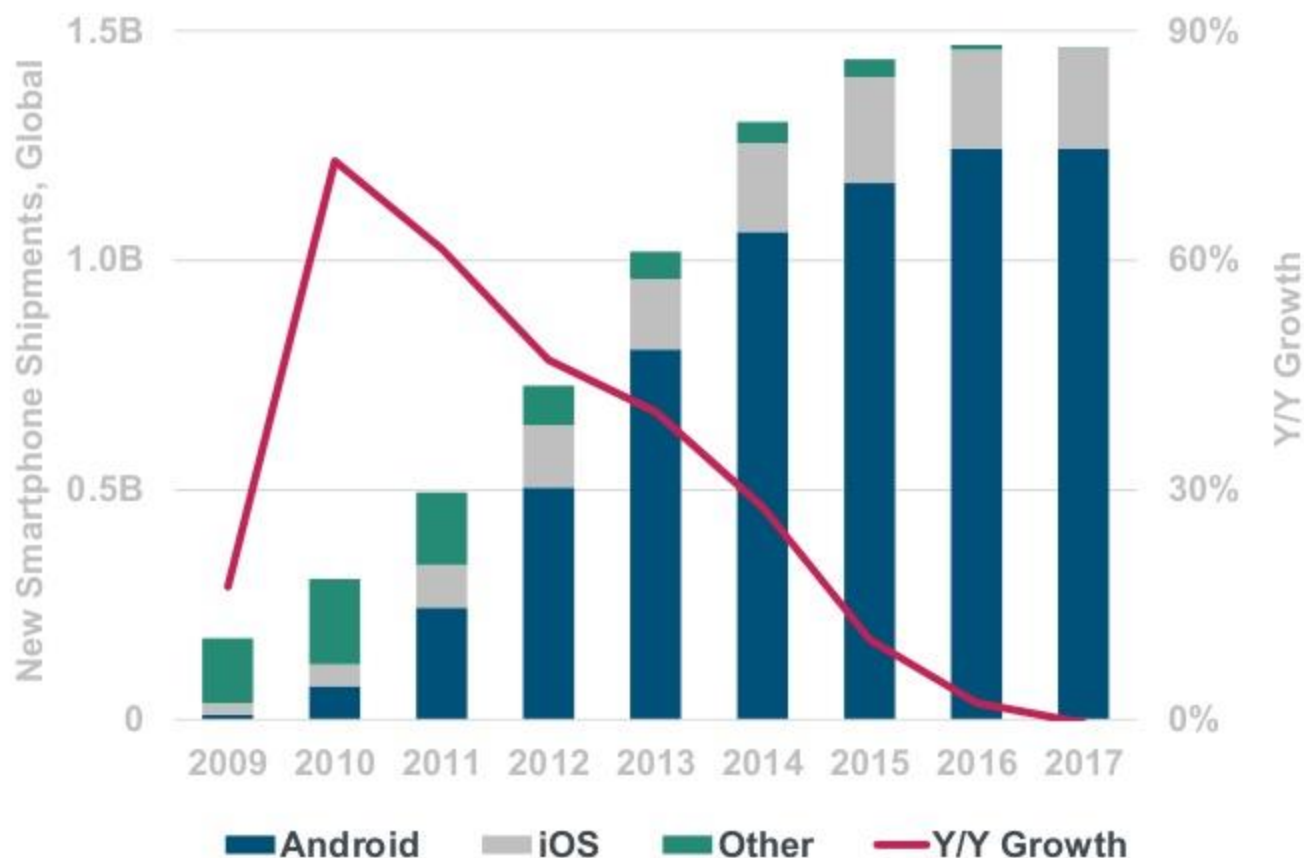
SOURCES: GSMA INTELLIGENCE, Q4 2016 & Q1 2017; ERICSSON MOBILITY REPORT, NOVEMBER 2016. ***NOTE:** TOTAL GLOBAL CONNECTIONS INCLUDE APPROXIMATELY 250 MILLION MOBILE CONNECTIONS (3.3% OF THE TOTAL) USED BY PCS, TABLETS, AND MOBILE ROUTER DEVICES.

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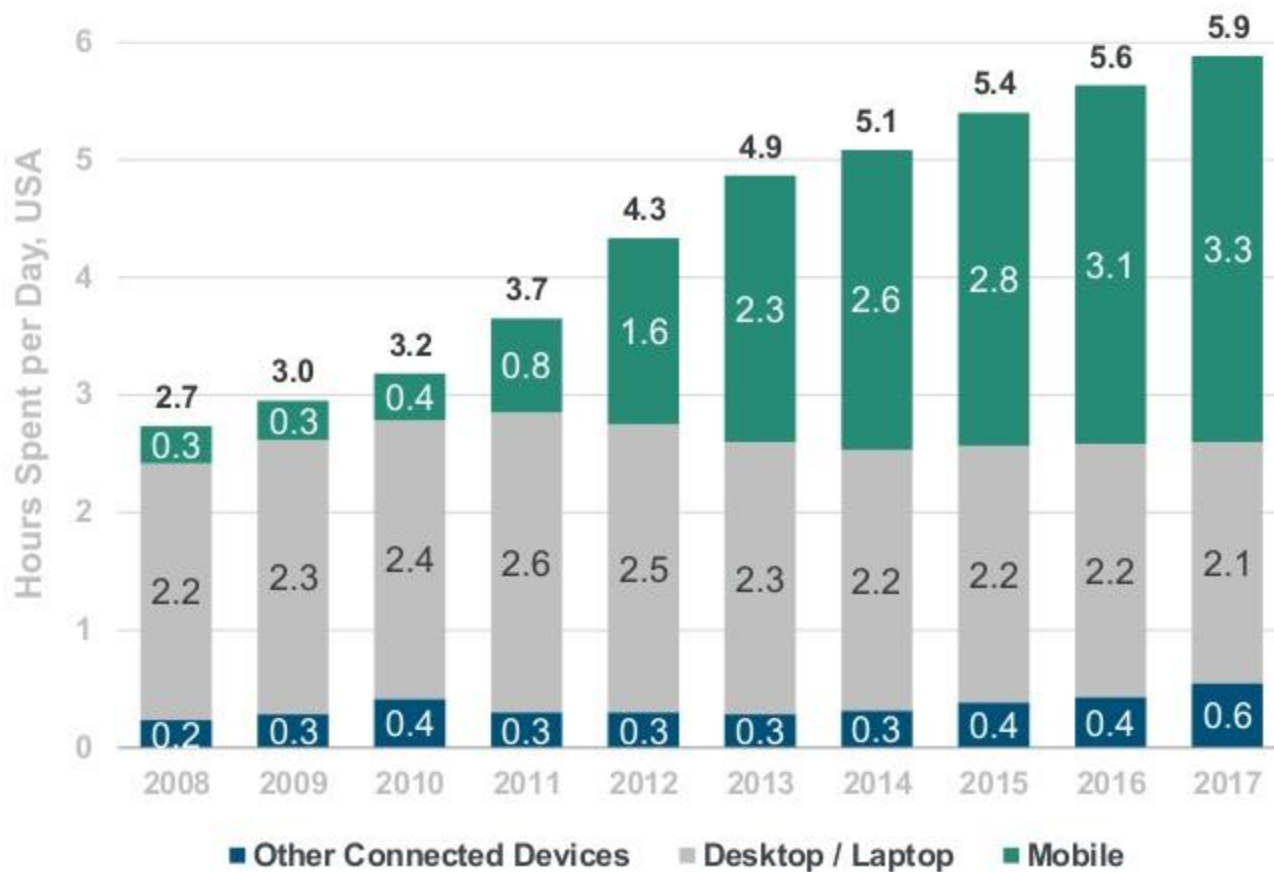
Global New Smartphone Unit Shipments = No Growth @ 0% vs. +2% Y/Y

New Smartphone Unit Shipments vs. Y/Y Growth



Digital Media Usage @ +4% Growth... 5.9 Hours per Day (Not Deduped)

Daily Hours Spent with Digital Media per Adult User



Devices = Better / Faster / Cheaper

Apple iPhone

2016



'Portrait' Photos
Water Resistant

2017



Face Tracking
Full Device Display
Wireless Charging

Google Android

2016



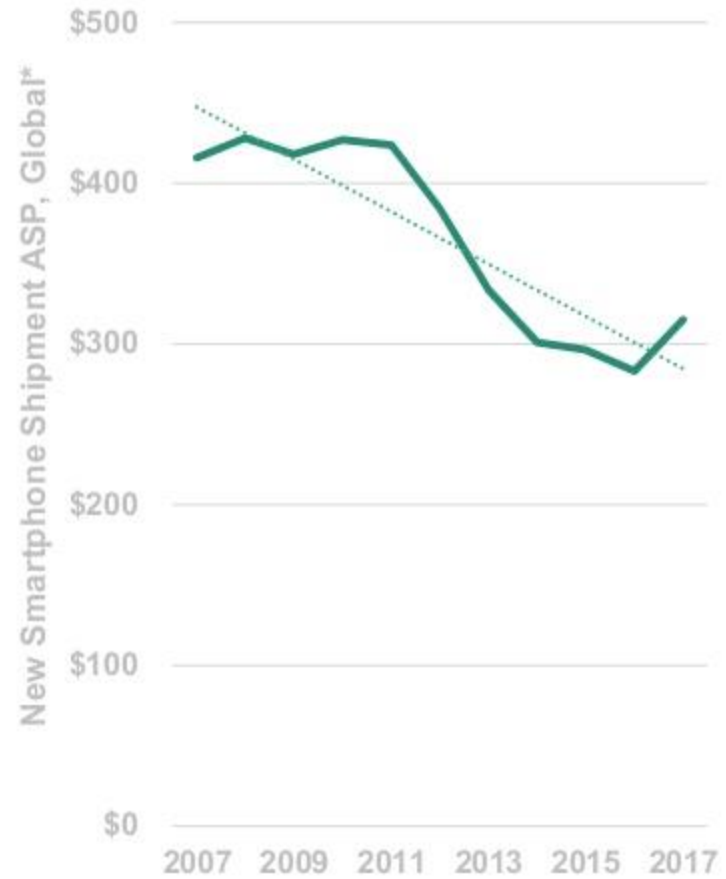
Google Assistant
'AI-Assisted'
Photo Editing

2017



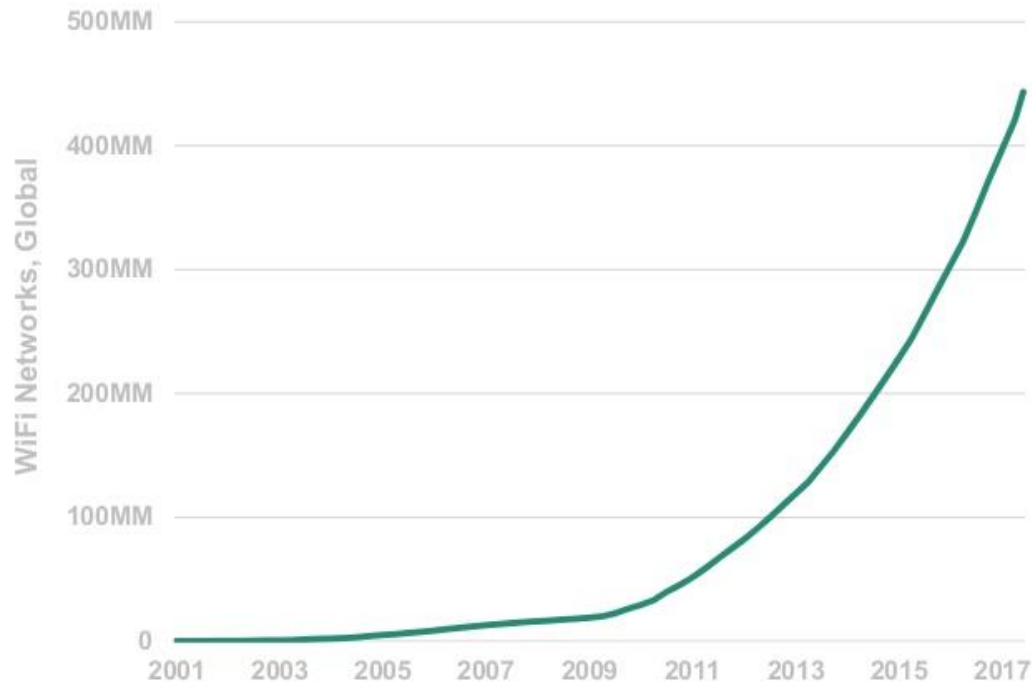
'Lens' Smart
Image Recognition
Always-On Display

New Smartphone Shipments – ASP



Access = WiFi Adoption Rising

WiFi Networks

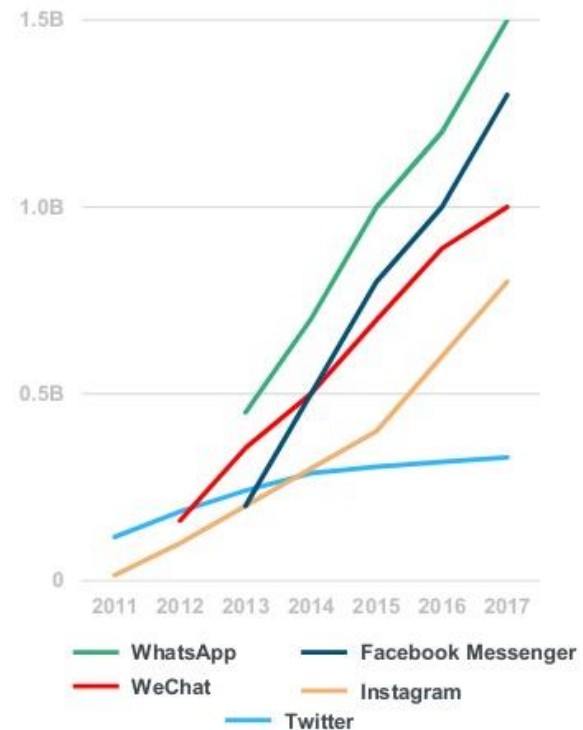


Messaging = Extensibility Expanding

Messaging Tencent (2000 → 2018)

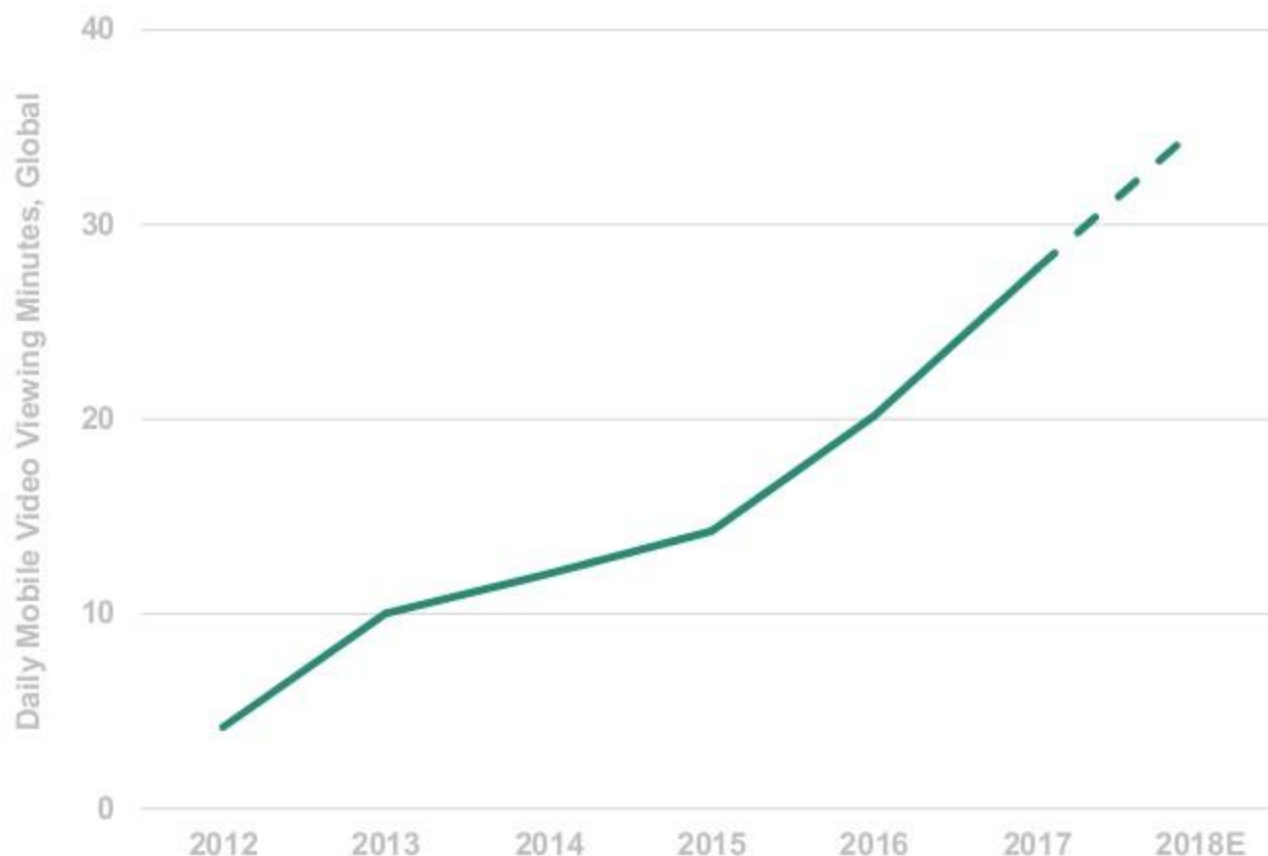


Messenger MAUs



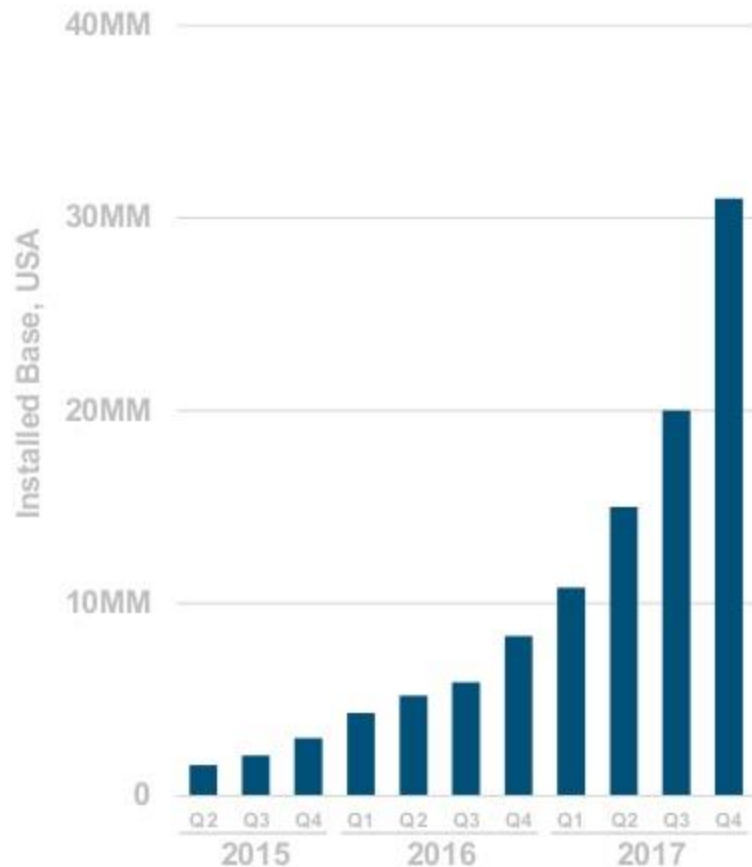
Video = Mobile Adoption Climbing...

Mobile Video Usage

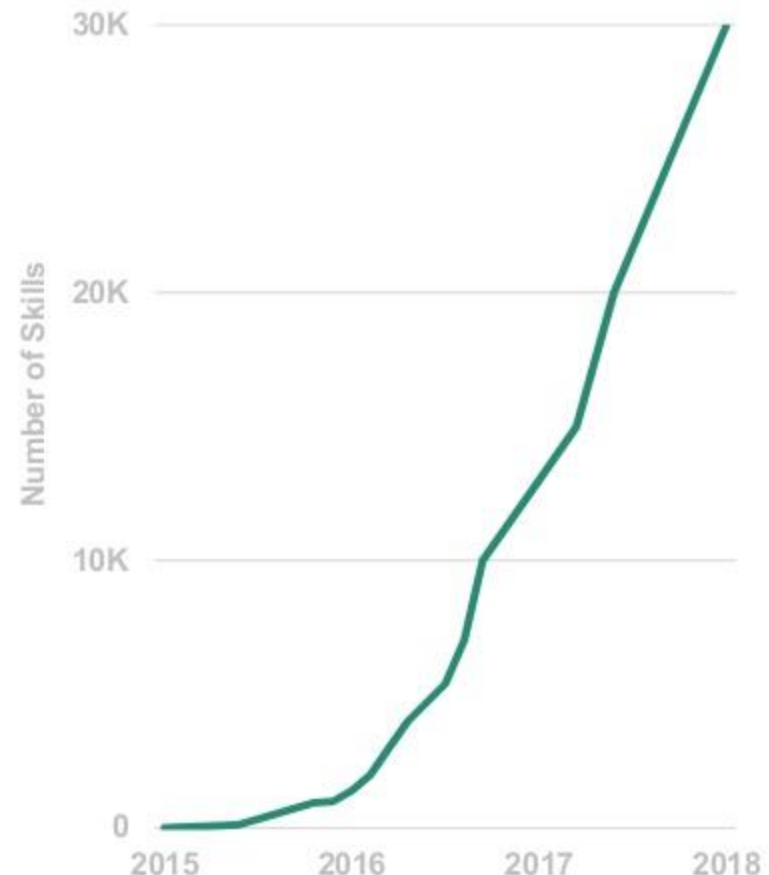


...Voice = Product Lift Off

Amazon Echo Installed Base

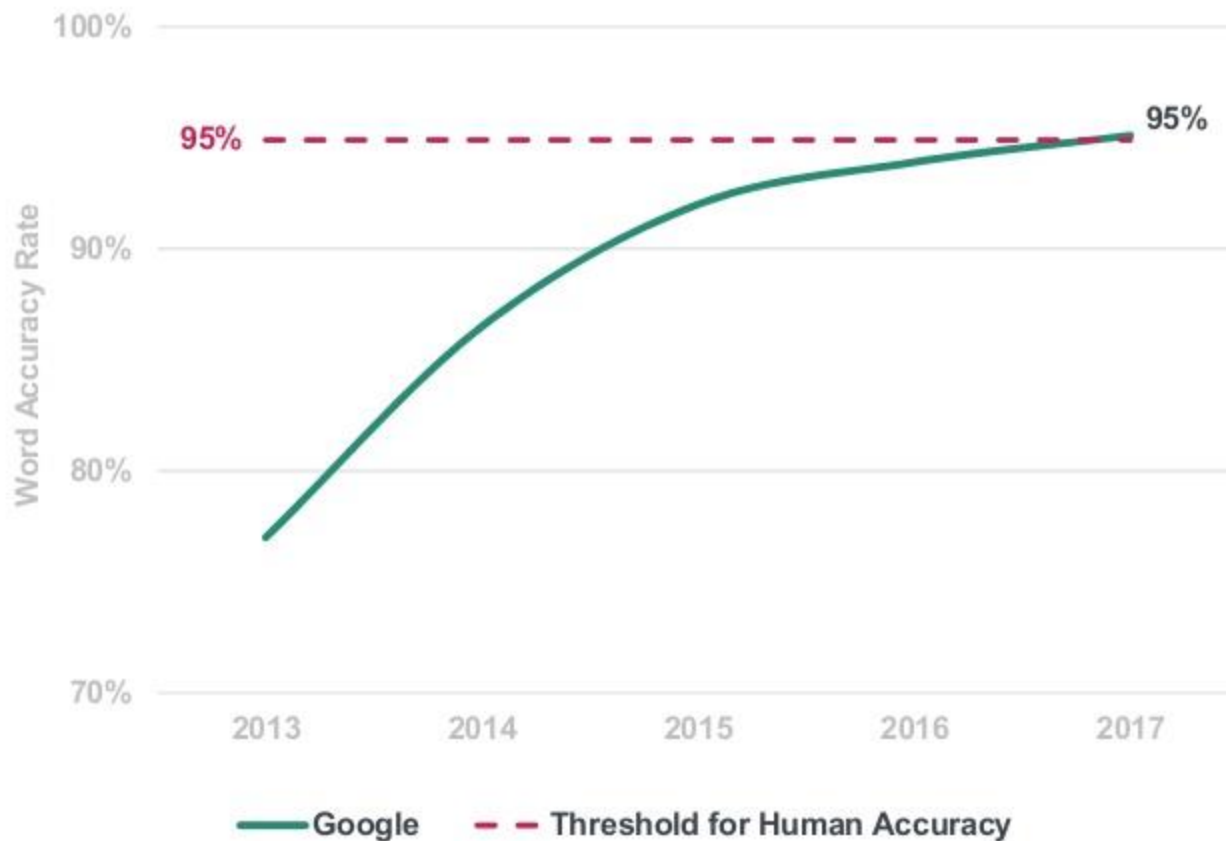


Amazon Echo Skills



Voice = Technology Lift Off...

Google Machine Learning Word Accuracy



Domain Name Statistics 2016

- *There are currently **123.78 million** registered .com domain names, making the .com TLD the top domain name extension. This is followed by the .tk TLD with 27.7 million registered domain names.*
- *The .com TLD accounts for 50% of all registered TLDs.*
- *As of November 2015, there are a total of 1096 TLDs.*
- *The most expensive domain name ever sold is Insurance.com, for \$35.6 million in 2010.*

Web Hosting and Website 2016

- *There are currently 966 million websites in the world today.*



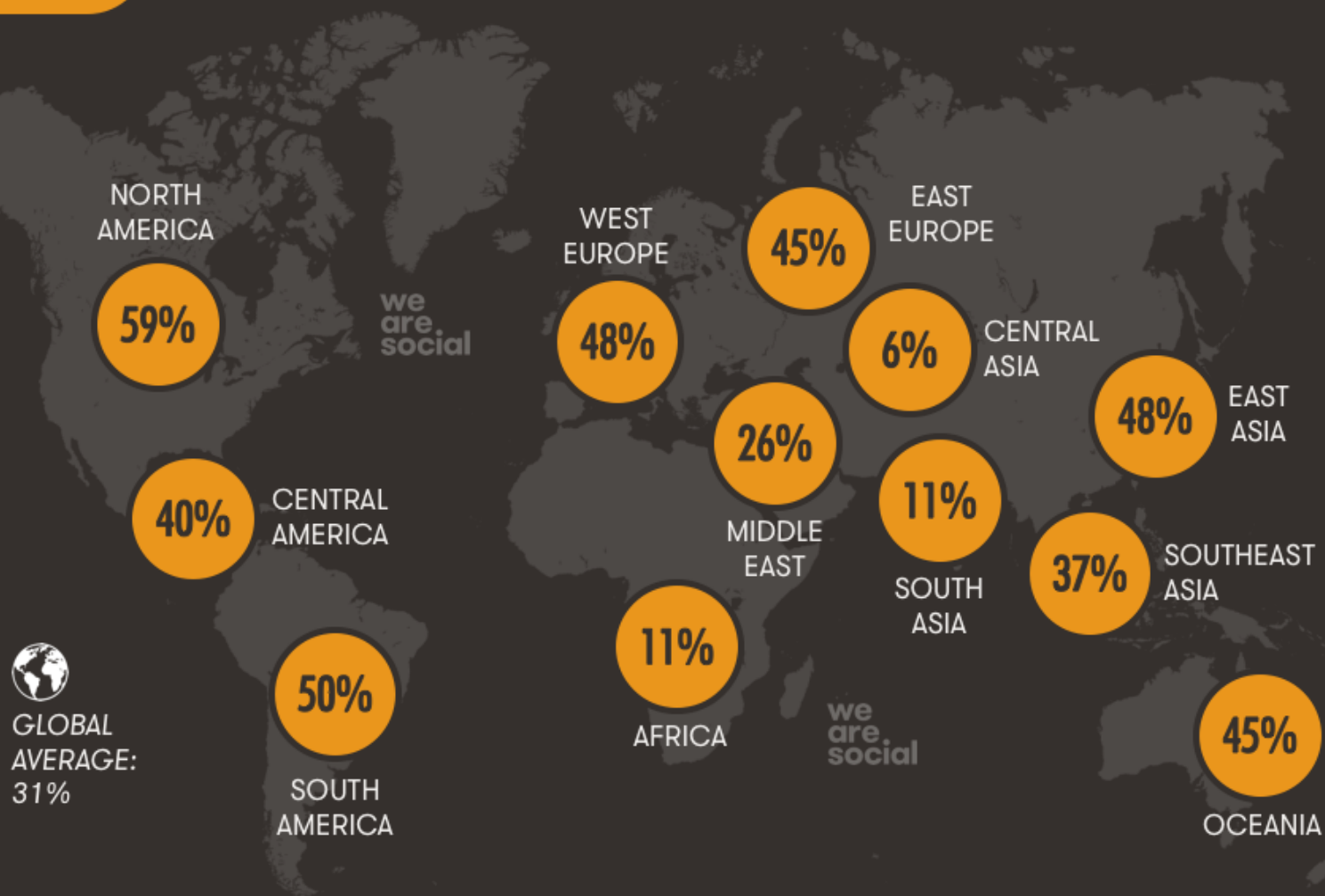
Web Hosting and Website 2016

- *The highest number of websites connected to internet was 1 billion; this happened in September 2014, but the number eventually declined and is expected to be achievable again by mid 2016.*
- *The world's first website was published on August 6, 1991 by British physicists Tim Berners-Lee.*
- *Only 44% of web traffic is from humans; a massive 56% of web traffic is from bots, impersonators, hacking tools, scrapers and spammers.*
- *39% of web servers are hosted on Apache.*
- *Google is the #1 most popular website in the world, followed by Facebook and YouTube.*
- *The average e-commerce site takes 7.12 seconds to load in Internet Explorer 9, an average of 7.15 seconds to load in Firefox 7 and an average of 7.5 seconds to load in Google Chrome.*
- *Google uses [site speed](#) as a ranking factor.*
- *The most [popular CMS is WordPress](#), powering 25.4% of all websites in the world and responsible for over 76.5 million [blogs](#).*
- *An estimated 37,000 websites are hacked every day.*

**JAN
2016**

SOCIAL MEDIA USE

TOTAL ACTIVE ACCOUNTS ON THE TOP SOCIAL NETWORK IN EACH COUNTRY, COMPARED TO POPULATION



**JAN
2018**

GLOBAL FACEBOOK REACH & ENGAGEMENT

AVERAGE POST REACH COMPARED TO TOTAL PAGE LIKES, AND ENGAGEMENT RATES BASED ON ACTUAL POST REACH

AVERAGE MONTHLY
CHANGE IN PAGE LIKES



+0.20%

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are
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AVERAGE POST REACH
vs. PAGE LIKES



10.7%

locowise

AVERAGE ORGANIC
REACH vs. PAGE LIKES



8.0%

locowise

PERCENTAGE OF PAGES
USING PAID MEDIA



22.1%

locowise

AVERAGE PAID REACH
vs. TOTAL REACH



26.8%

AVERAGE ENGAGEMENT
(ALL POST TYPES)



4.20%

locowise

AVERAGE VIDEO POST
ENGAGEMENT



5.23%

locowise

AVERAGE PHOTO
POST ENGAGEMENT



4.42%

locowise

AVERAGE LINK POST
ENGAGEMENT



3.90%

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AVERAGE STATUS
POST ENGAGEMENT



3.70%

1

SOURCE: LOCOWISE, JANUARY 2018. DATA REPRESENTS AVERAGE FIGURES FOR FULL-YEAR 2017. **NOTES:** REACH FIGURES COMPARE THE NUMBER OF TIMES A POST WAS SERVED IN USERS' NEWSFEEDS TO THE TOTAL NUMBER OF 'FANS' (I.E. USERS THAT HAD LIKED THE PAGE) AT THE TIME THE POST WAS PUBLISHED. ENGAGEMENT RATES COMPARE THE NUMBER OF PEOPLE WHO INTERACTED WITH A POST TO THE TOTAL NUMBER OF UNIQUE USERS TO WHOM THAT POST WAS SERVED, REGARDLESS OF WHETHER THOSE USERS WERE FANS OF THE PAGE AT THAT TIME.



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GLOBAL E-COMMERCE REVENUES

TOTAL VALUE OF THE CONSUMER (B2C) E-COMMERCE MARKET, AND AVERAGE E-COMMERCE REVENUE PER USER

NUMBER OF PEOPLE
PURCHASING VIA
E-COMMERCE



1.61
BILLION

E-COMMERCE PENETRATION
(NUMBER OF PURCHASERS
vs. TOTAL POPULATION)



22%

TOTAL VALUE OF
GLOBAL E-COMMERCE
MARKET IN 2016 (IN US\$)



\$1.915
TRILLION


AVERAGE ANNUAL
E-COMMERCE REVENUE
PER USER IN 2016 (IN US\$)



\$1,189

91

SOURCES: EXTRAPOLATED FROM ESTATISTICS ON THE GLOBAL E-COMMERCE INDUSTRY, JANUARY 2017, AND DATA FROM EMARKETER. NO FIGURES ON FIGURES REPRESENT PERCENTAGE OF TOTAL POPULATION, REGARDLESS OF AGE.

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E-commerce and Conversion Statistics 2016

- *40% of global internet users, or more than 1 billion people, have bought products or goods online.*
- *The U.S. e-commerce economy is worth \$349 billion while China's e-commerce economy is worth \$562.66 billion.*
- *A single second delay in your website loading time can result in a 7% loss in conversion, and 40% of web users will abandon a website if it takes longer than 3 seconds to load.*
- *Slow loading websites cost the U.S. e-commerce market more than \$500 billion annually.*
- *Online retail sales in the U.K. reached an estimated £52.25 billion in 2015, with the average shopper spending £1,174.*
- *Worldwide B2C e-commerce sales reached \$1.7 trillion in 2015, and it is estimated to reach \$2.35 trillion by 2018.*
- *8 out of 10 consumers will shop online if offered free shipping.*

E-commerce and Conversion Statistics 2016

- *Personalized recommendations can increase conversion rates by up to 5.5 times.*
- *51% of U.S. online shoppers cite slow site loading times as the top reason they abandon a purchase.*
- *34% of British consumers cite a store's reputable brand name for being their reason for shopping with a brand, while 38% cite social media interaction as their reason for visiting a retailer's website.*
- *40% of shoppers consult 3 or more channels, often in the process of shopping, before making a purchase; that's a massive increase from 10% in 2002, and it goes to show the increasing importance of having an online presence in as many places as possible.*
- *While mobile internet usage is high, desktop and tablet internet usage still leads for conversions; an estimated 8.52% of desktop users add to cart and an estimated 2.78% convert to sales. This is much higher than Smartphone conversion rates with an estimated 4.70% add to cart rate and an estimated 0.80% sales conversion rate. The number is much higher when you consider conversion rates from tablets and other mobile devices, but desktop still leads when it comes to actual sales.*
- *An increase in site speed from 8 to 2 seconds can boost your conversion rate by 74% (this is based on data monitoring real user activity from 33 major retailers).*

E-commerce and Conversion Statistics 2016

- *Increasingly shrinking attention span keeps influencing e-commerce; in 2010, a page that took 6 seconds to load suffered a 40% loss in conversion. Today, a page that takes 6 seconds to load will experience a 50% loss in conversion.*
- *The abandonment rate for mobile shopping cart is higher (at 97%) than that of desktop shopping carts (at 70 – 75%).*
- *E-commerce sales from social media grew by 202% in 2014, and is expected to further increase.*
- *The average human attention span has declined from 12 seconds in the year 2000 to 8 seconds now. This is much shorter than the attention span of a goldfish (at 9 seconds). This was revealed by a recent study by Microsoft Corp. that surveyed 2,000 people and monitored brain activity of 112 others using electroencephalograms (EEGs).*

JAN
2017

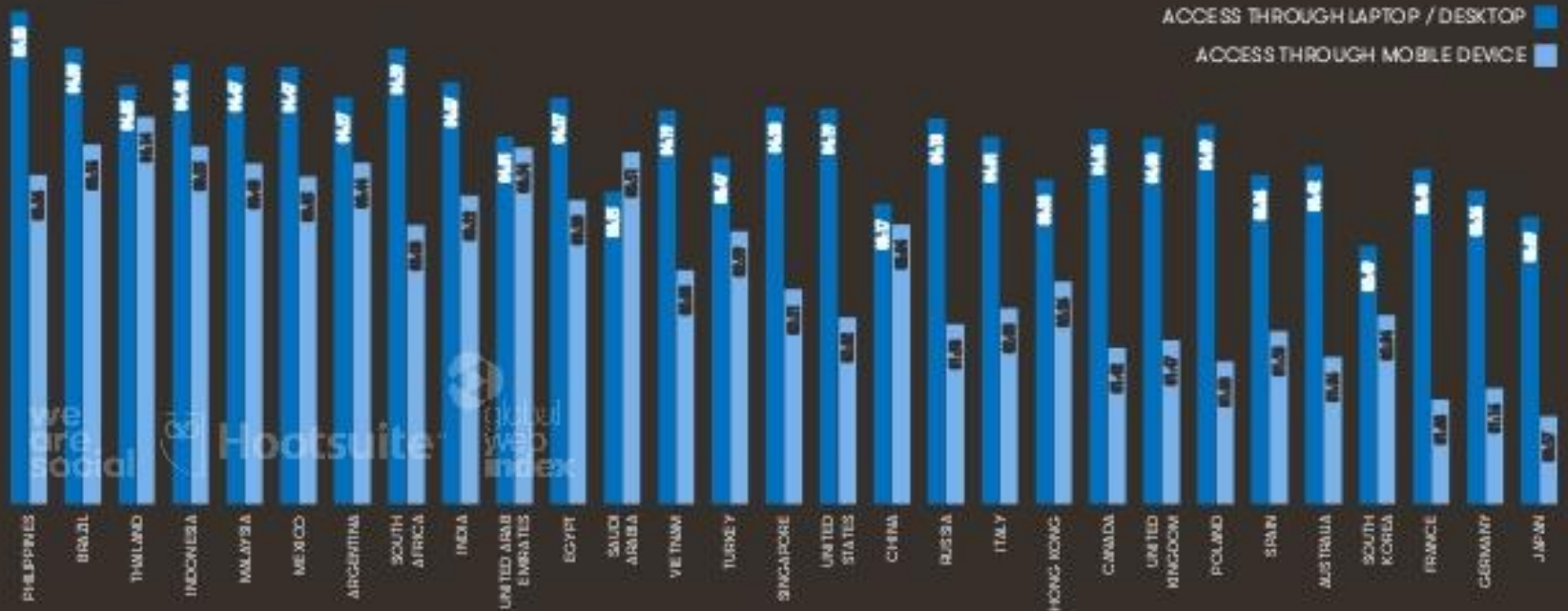
TIME SPENT ON THE INTERNET

AVERAGE NUMBER OF HOURS SPENT USING THE INTERNET PER DAY, SPLIT BY COMPUTER USE AND MOBILE PHONE USE [SURVEY BASED]

NOTE THAT TIMES CAN BE ADDED TOGETHER TO FIND TOTAL INTERNET TIME BY COUNTRY; RANKINGS ARE IN ORDER OF TOTAL TIME SPENT USING THE INTERNET EACH DAY

ACCESS THROUGH LAPTOP / DESKTOP

ACCESS THROUGH MOBILE DEVICE

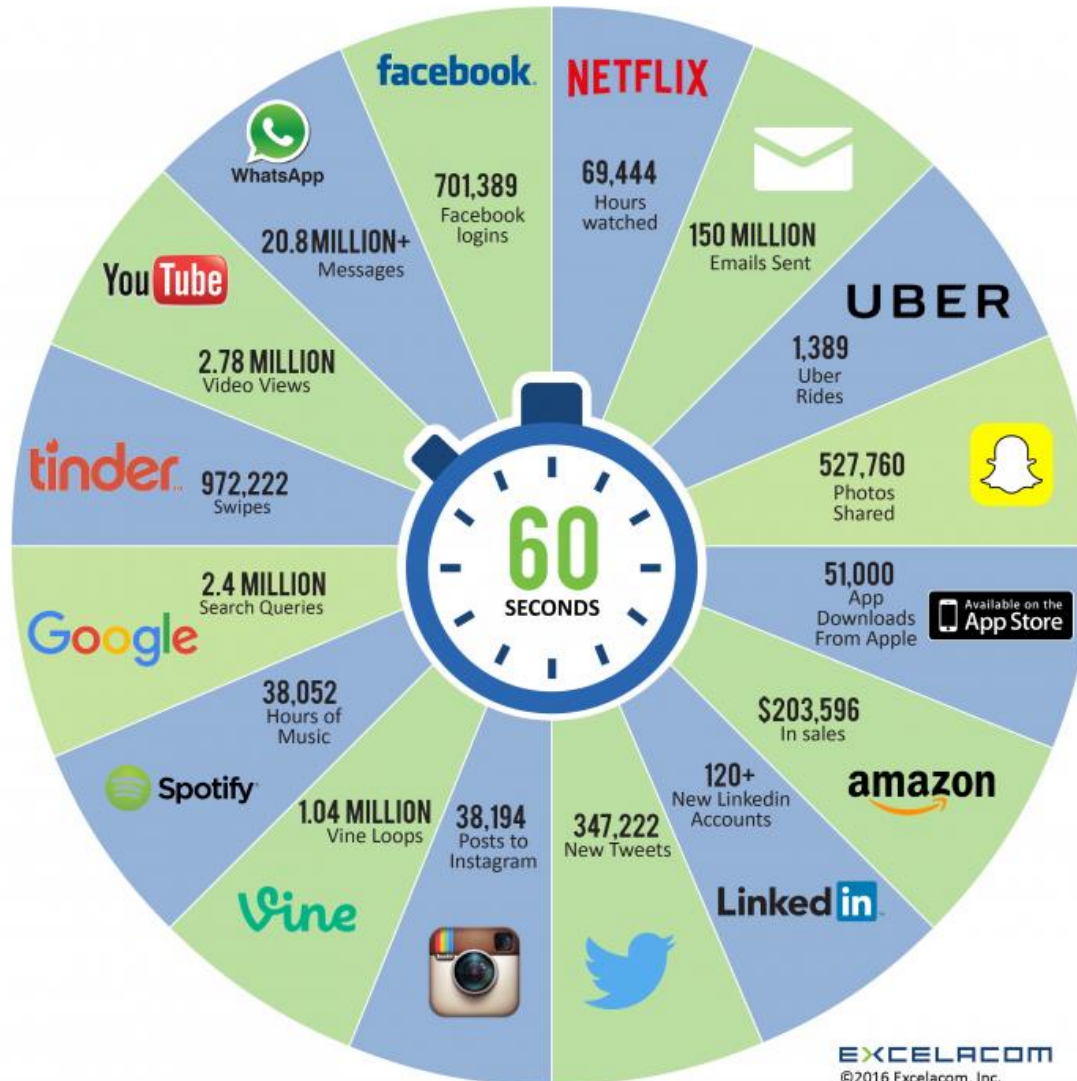


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SOURCE: CLOUDBER INDEX Q3 2016, BASED ON A SURVEY OF INTERNET USERS AGED 16-64

Hootsuite we are social

2016 What happens in an INTERNET MINUTE?



GROWTH IN THE INTERNET OF THINGS

THE NUMBER OF CONNECTED DEVICES WILL EXCEED **50 BILLION** BY 2020

