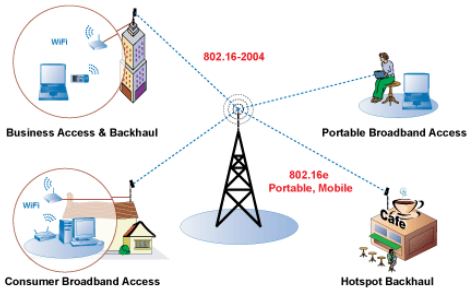
Wireless and Mobile Networking: Facts, Statistics, and Trends



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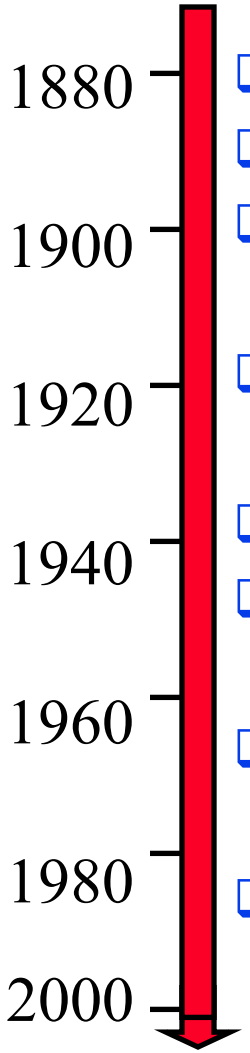
Audio/Video recordings of this lecture are available at:

http://www.cse.wustl.edu/~jain/cse574-14/

Overview

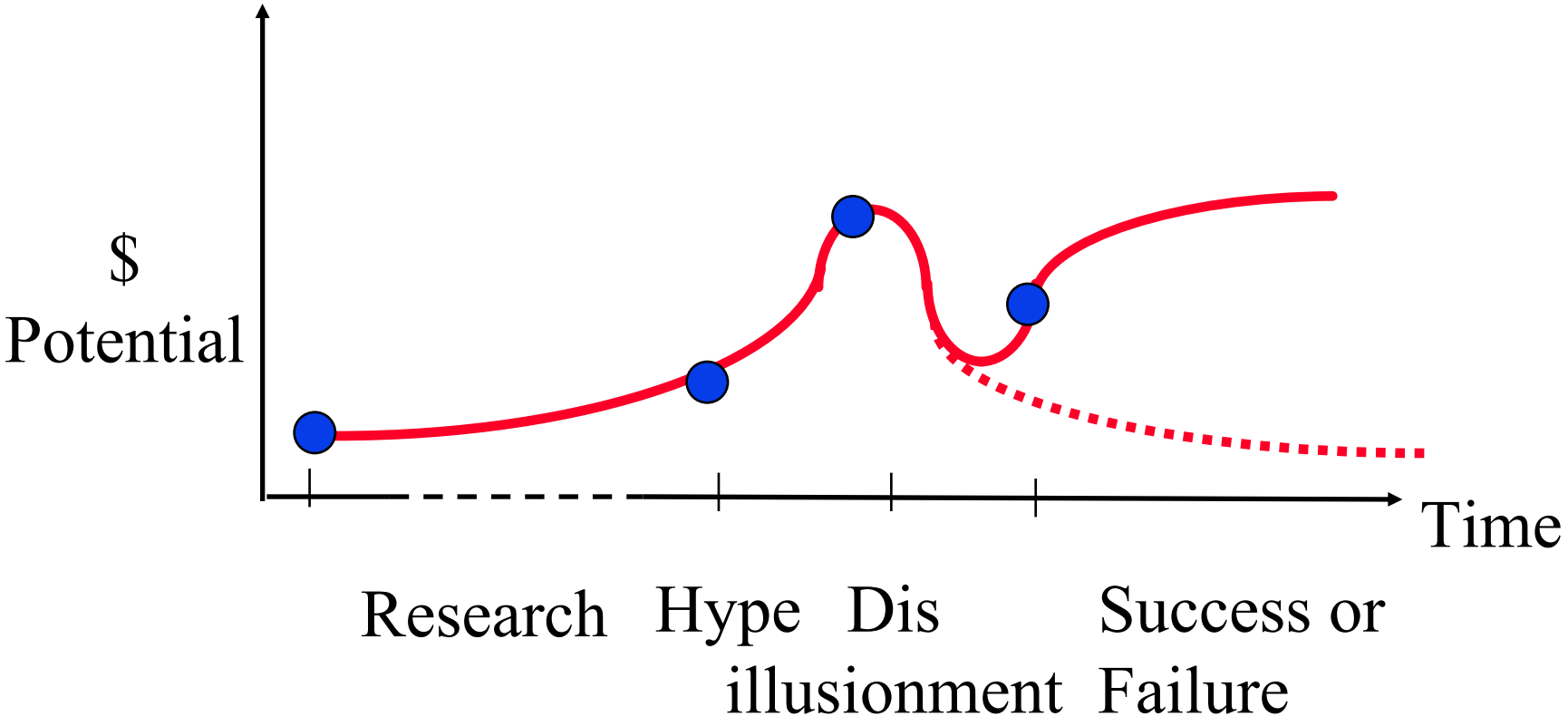
1. Wireless: History
2. Wireless Infrastructure Hype Cycle 2013
3. Wireless Speed Trends (Moore's Law)
4. Global Mobile Data Forecast [Cisco]
5. Trends

Wireless: History

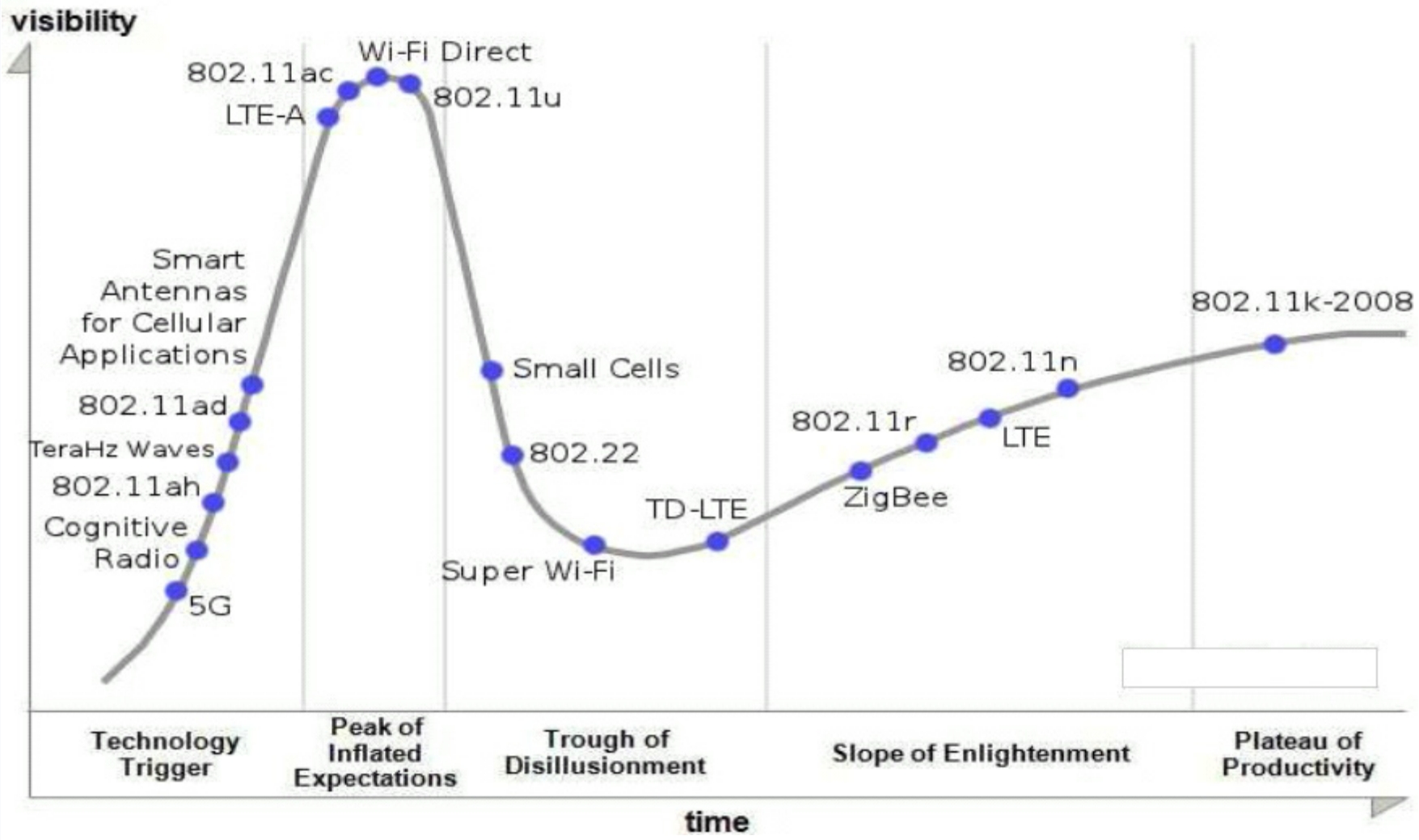


- 1880: Hertz discovered electromagnetic waves
- 1898: First commercial radio data service
- 1921: First Mobile Radio:
  Wireless dispatch system for Detroit Police
- 1946: First Mobile Telephone Service:
  In St. Louis by AT&T. Half-duplex ⇒ Push to talk.
- 1970: First Cellular Phone Service: AT&T Chicago
- 1971: First Wireless Data Network:
  Aloha at University of Hawaii
- 1990: First Commercial WLAN Product AT&T WaveLAN
- 1997: First WLAN Standard - IEEE 802.11 2Mbps

Life Cycle of Technologies



Wireless Networking Infrastructure Hype Cycle 2013



Ref: A. Chokalingam, "Gigabit Access in Wireless," Second Annual NKN Workshop, Bangalore 18 October 2013, http://nkn.in/nkn-workshop2013/images/presentation/2nd_annual_nkn_workshop_ac_d4.pdf

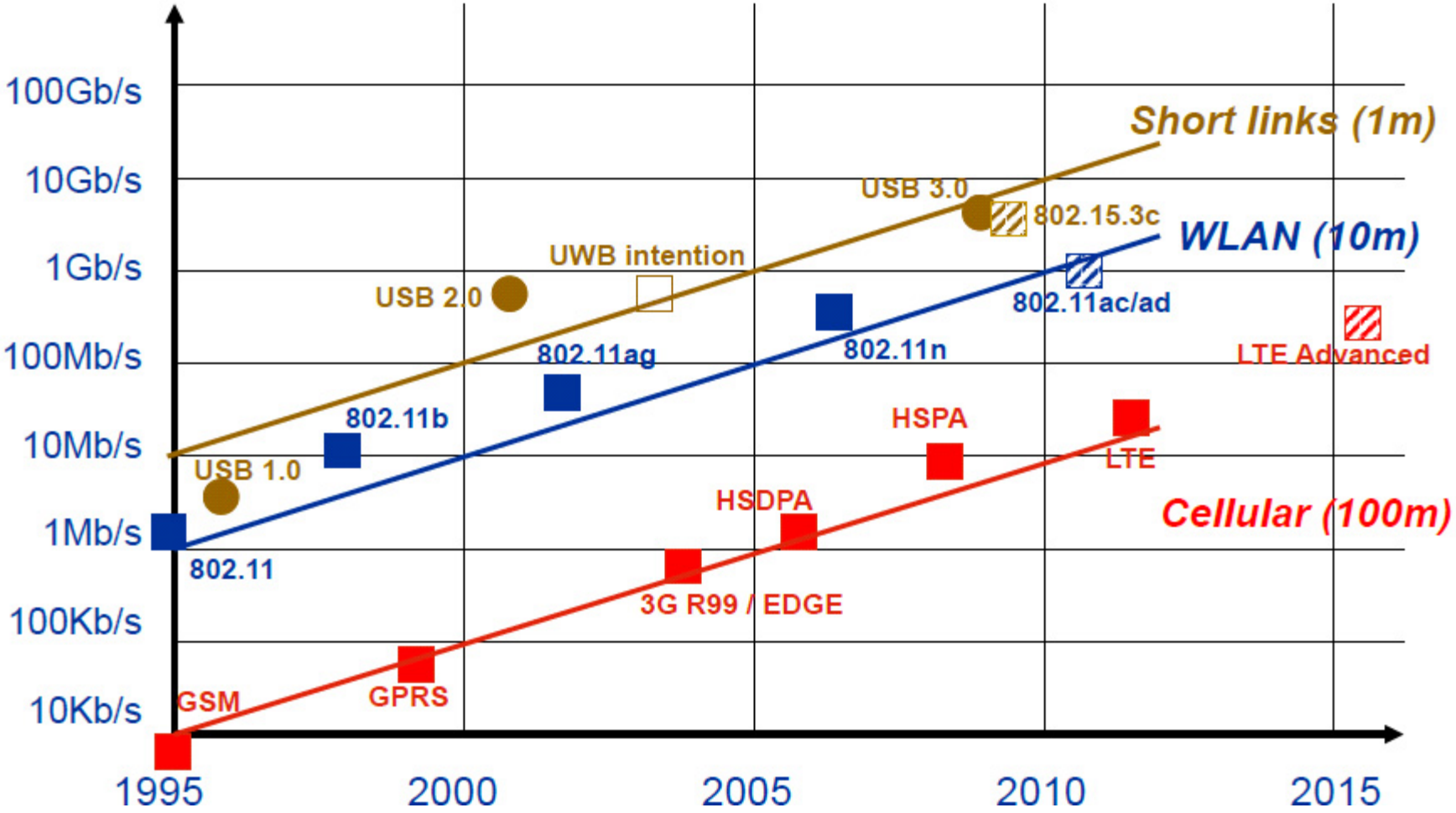
Wireless Innovations

- **5G**: Beyond 4G. Expected in 2020. 100X LTE
- **Cognitive Radio**: Find unused channels and use them
- **802.11ah**: Low-speed coordinated communication for M2M
- **TeraHz Waves**: Sub-millimeter waves. 1 mm to 0.1mm wavelength. 0.3 to 3THz. Between Radio and light
- **802.11ad**: WiGig. Gigabit Wireless
- **Smart Antennas**: Antenna arrays that can orient towards direction of arrival
- **LTE-Advanced**: Next generation of LTE. Real 4G. 1 Gbps
- **802.11ac**: 500Mbps-1 Gbps WiFi
- **WiFi Direct**: Point-to-Point WiFi without access point
- **802.11u**: Authentication for 802.11 hotspots

Wireless Innovations (Cont)

- **Small Cells**: 10m to 2km. Includes Micro cells, Pico cells, Femto cells
- **802.22**: Wireless regional area network using white spaces in TV channels
- **Super WiFi**: Long-distance internet access using TV white spaces
- **TD-LTE**: LTE using time-division duplexing rather than frequency division duplexing
- **ZigBee**: Trade name for 802.15.4 personal area networks. Like WiFi for 802.11
- **802.11r**: Fast Base Station transition
- **LTE**: Long-Term Evolution. 3.9G
- **802.11n**: WiFi with multiple antennas
- **802.11k**: Discover the best AP before transition

Wireless Speed Trends



- Doubling every 18 months ⇒ Moore's Law

Ref: G. Fettweis, "The limits of 4G and how to design a new 5G Phy," http://www.ieee-ctw.org/2013/slides/Fettweis.pdf

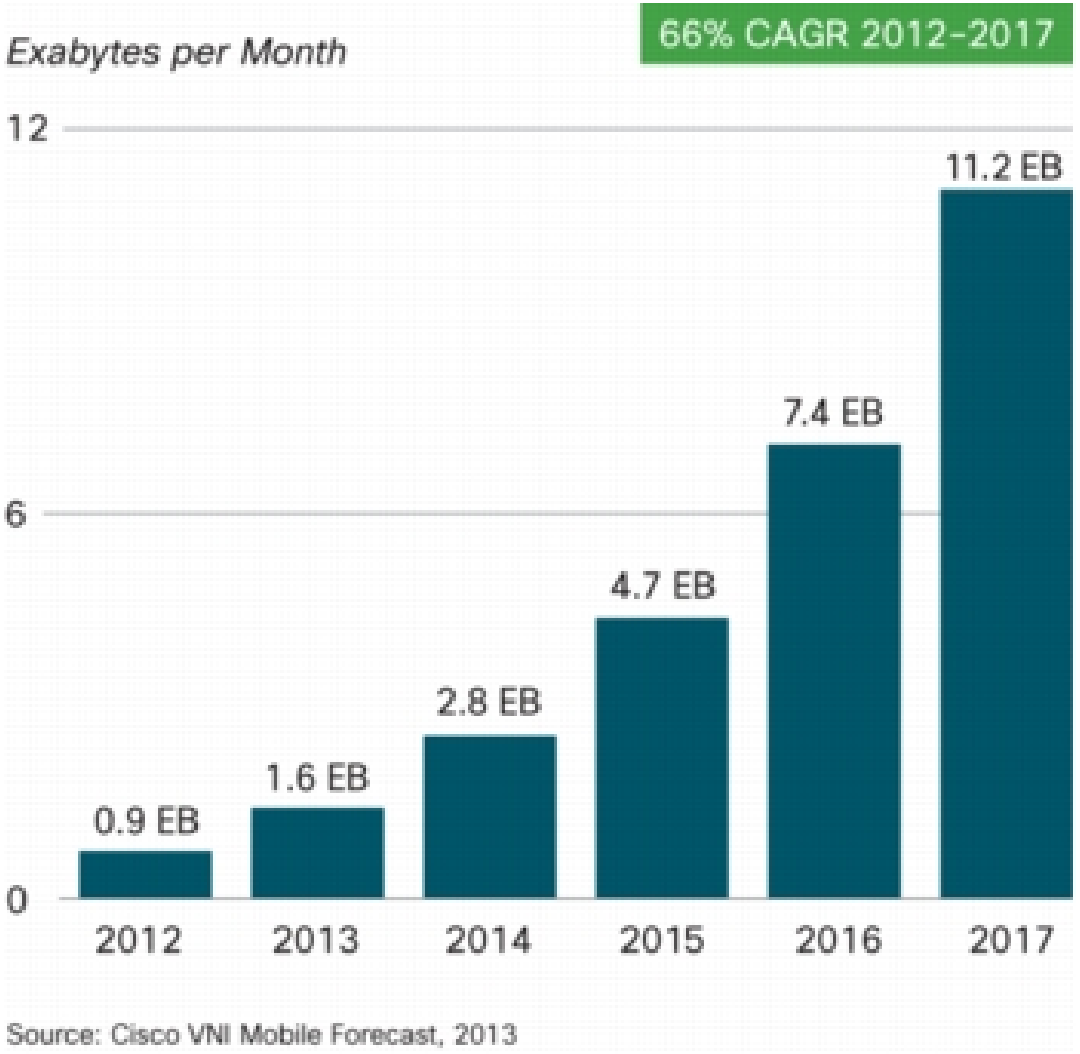
Global Mobile Data Forecast [Cisco]

- Global Mobile data grew 70% in 2012
- 885 Peta bytes per month in 2012
  from 75 Peta bytes per month in 2000
- Mobile video traffic is more than 50% of the mobile traffic
- Connection speeds doubled
  526 kbps in 2012 up from 248 kbps in 2011
- 4G

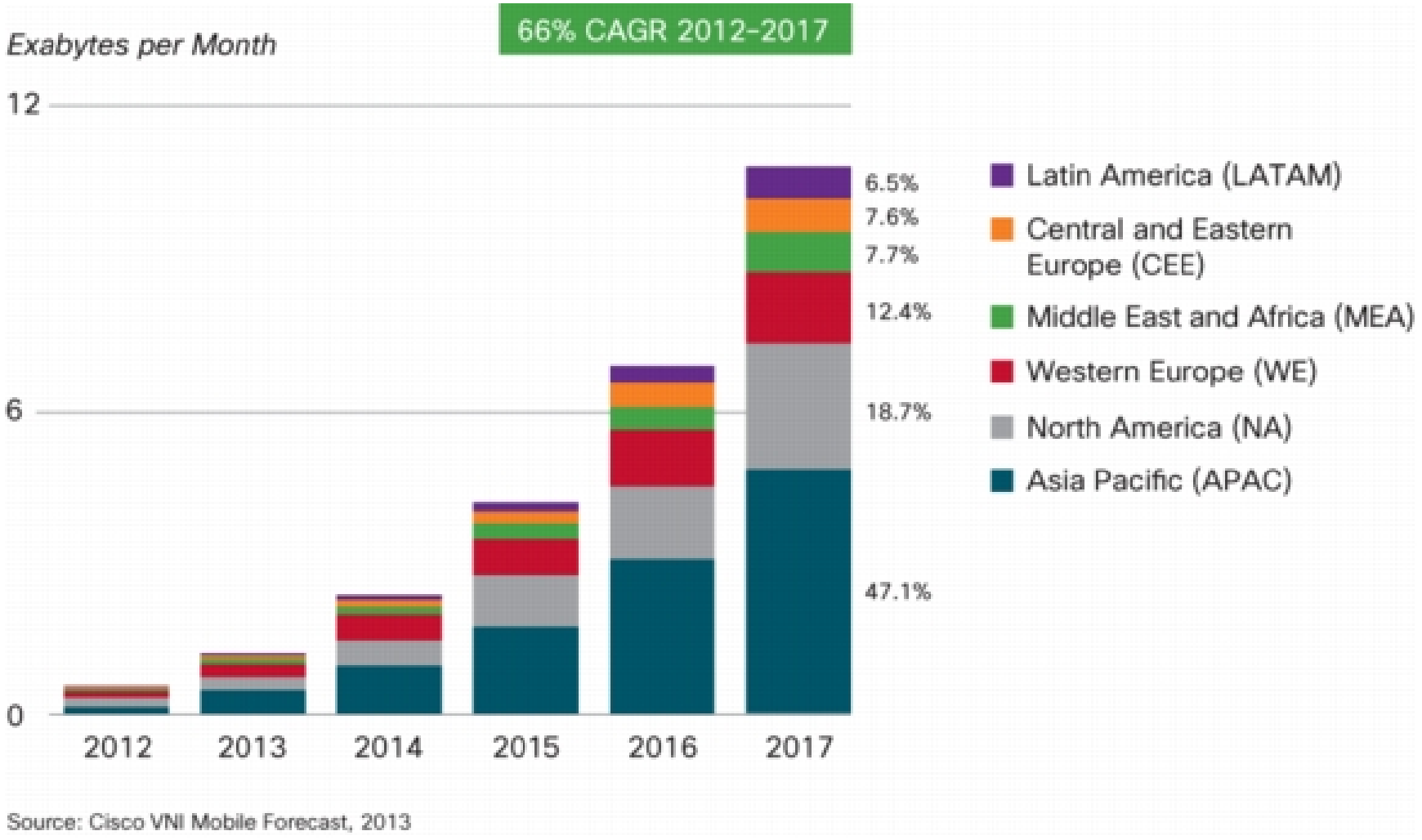
Note: The next 12 slides are all from Cisco VNI

Ref: Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update
http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

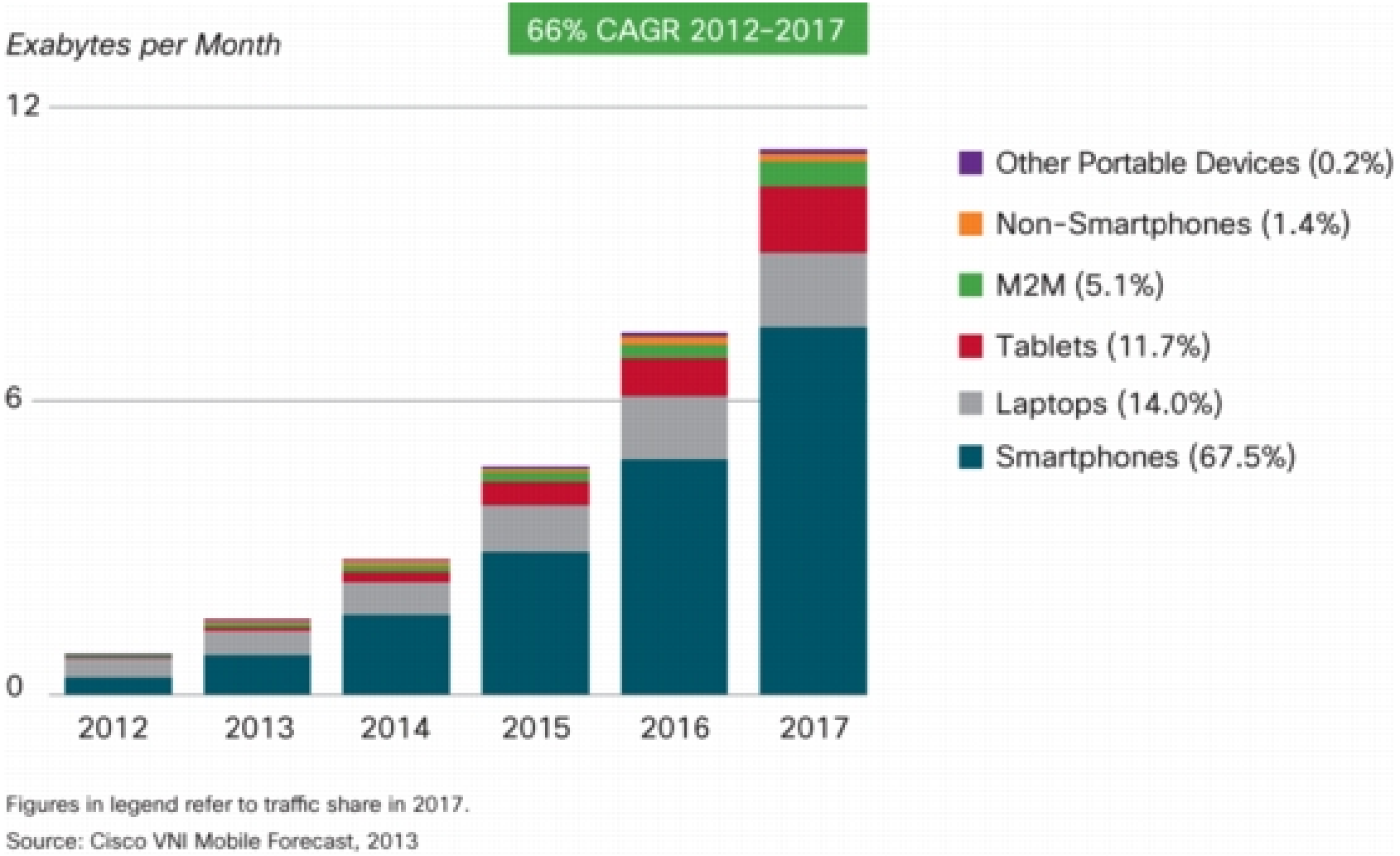
Exponential Growth in Mobile Data



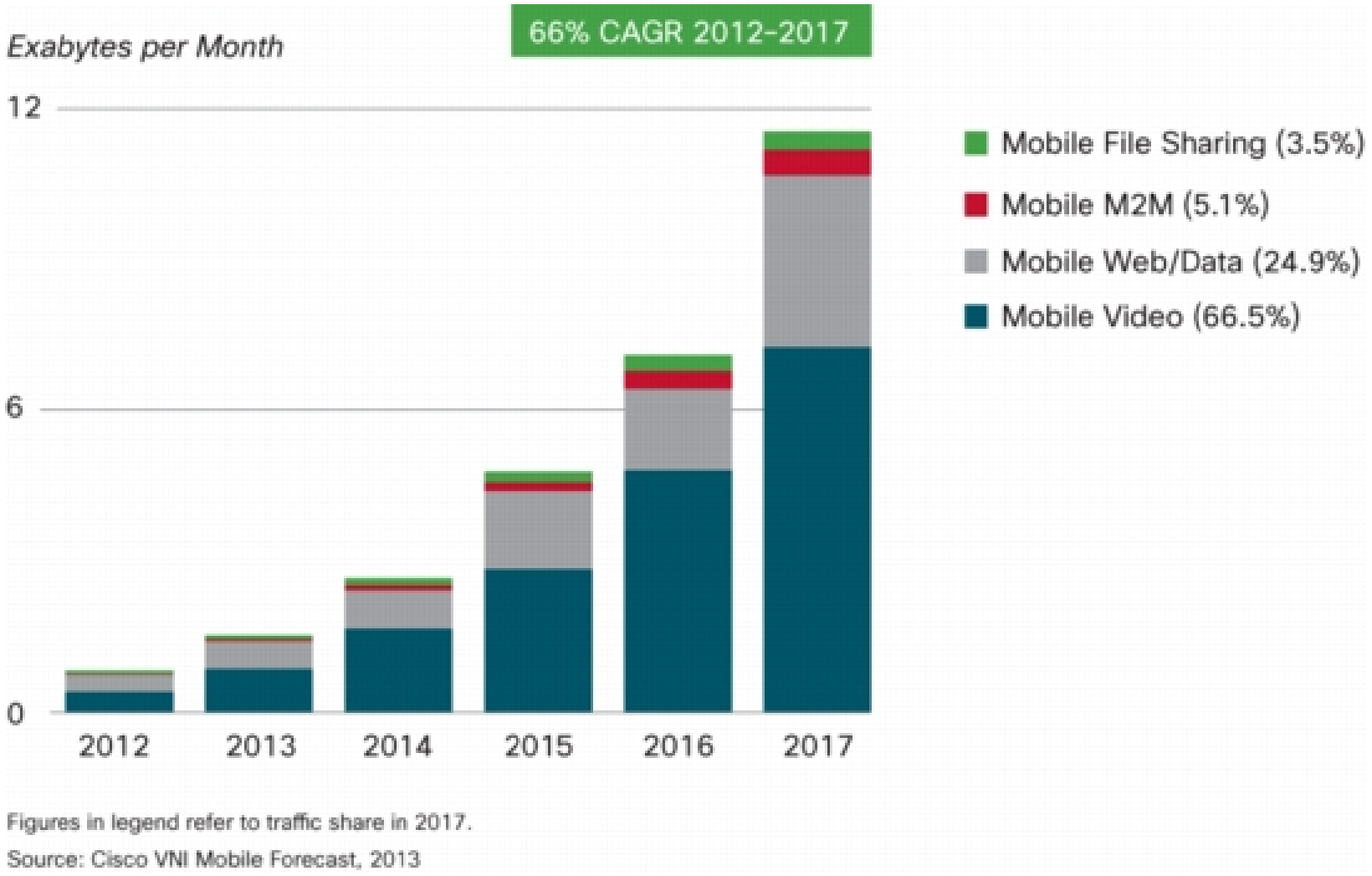
Highest Growth in Asia Pacific



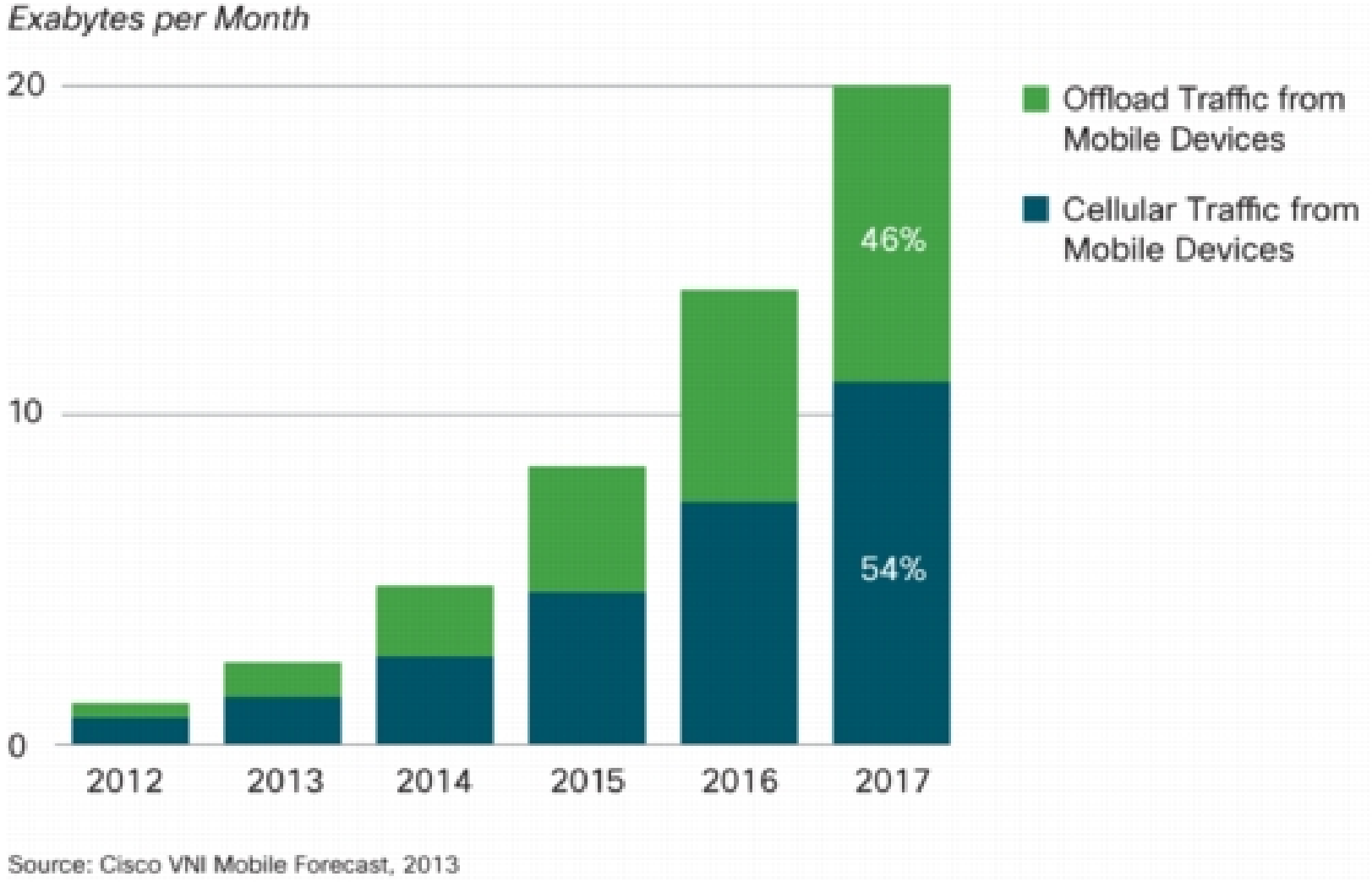
Most Traffic due to Smart Phones



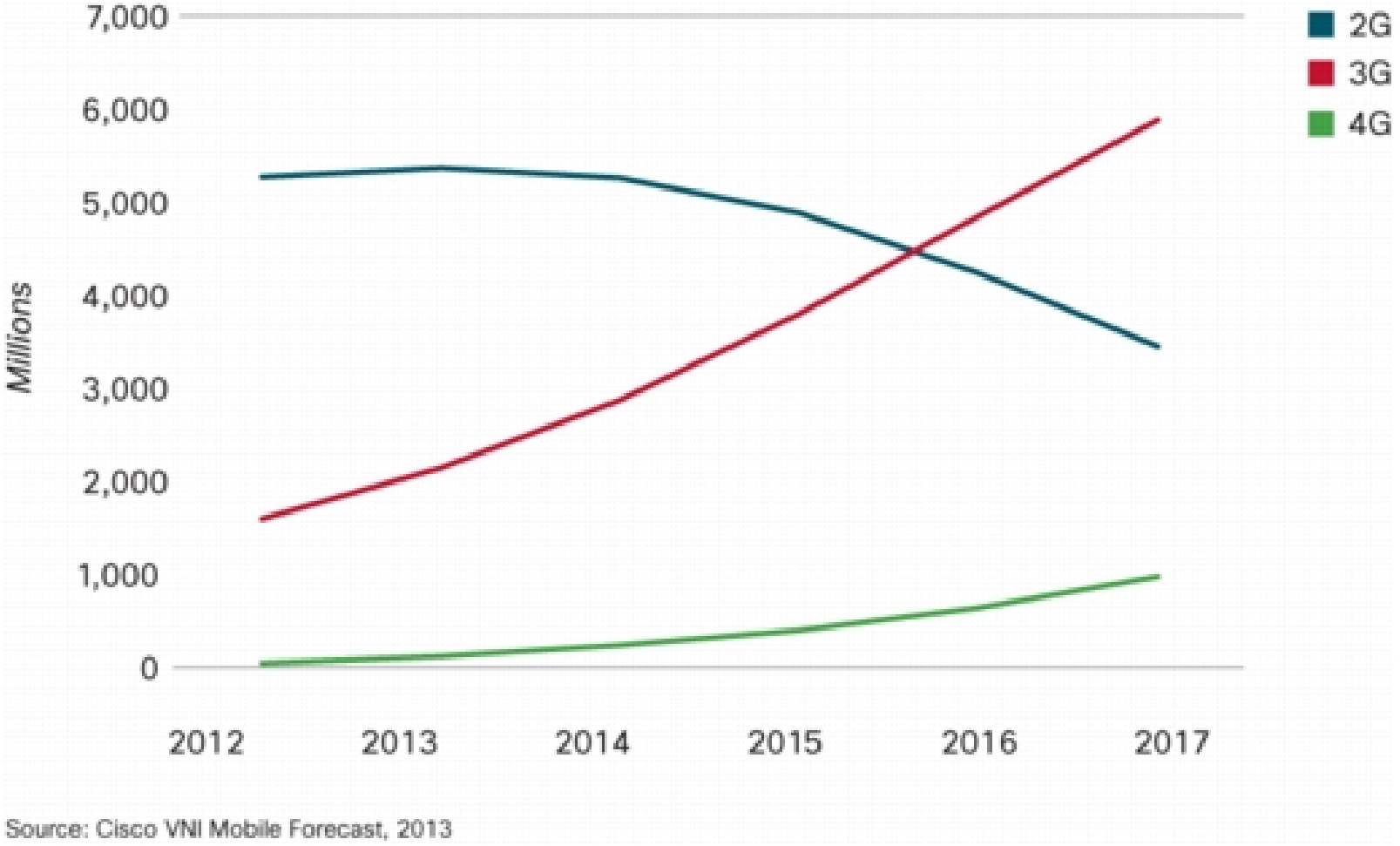
Majority of Traffic due to Mobile Video



Offload from Cellular to Fixed

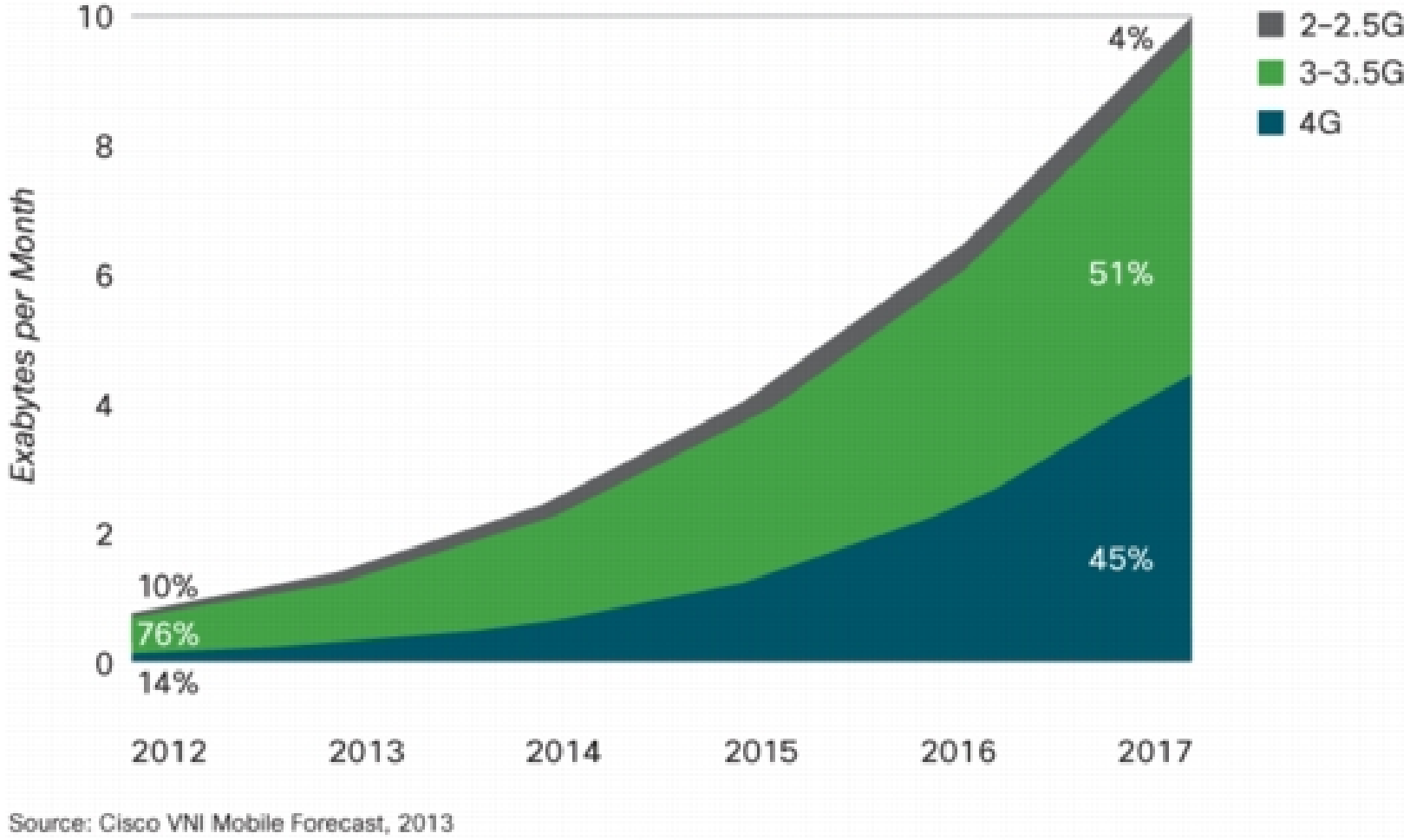


3G and 4G on the Rise

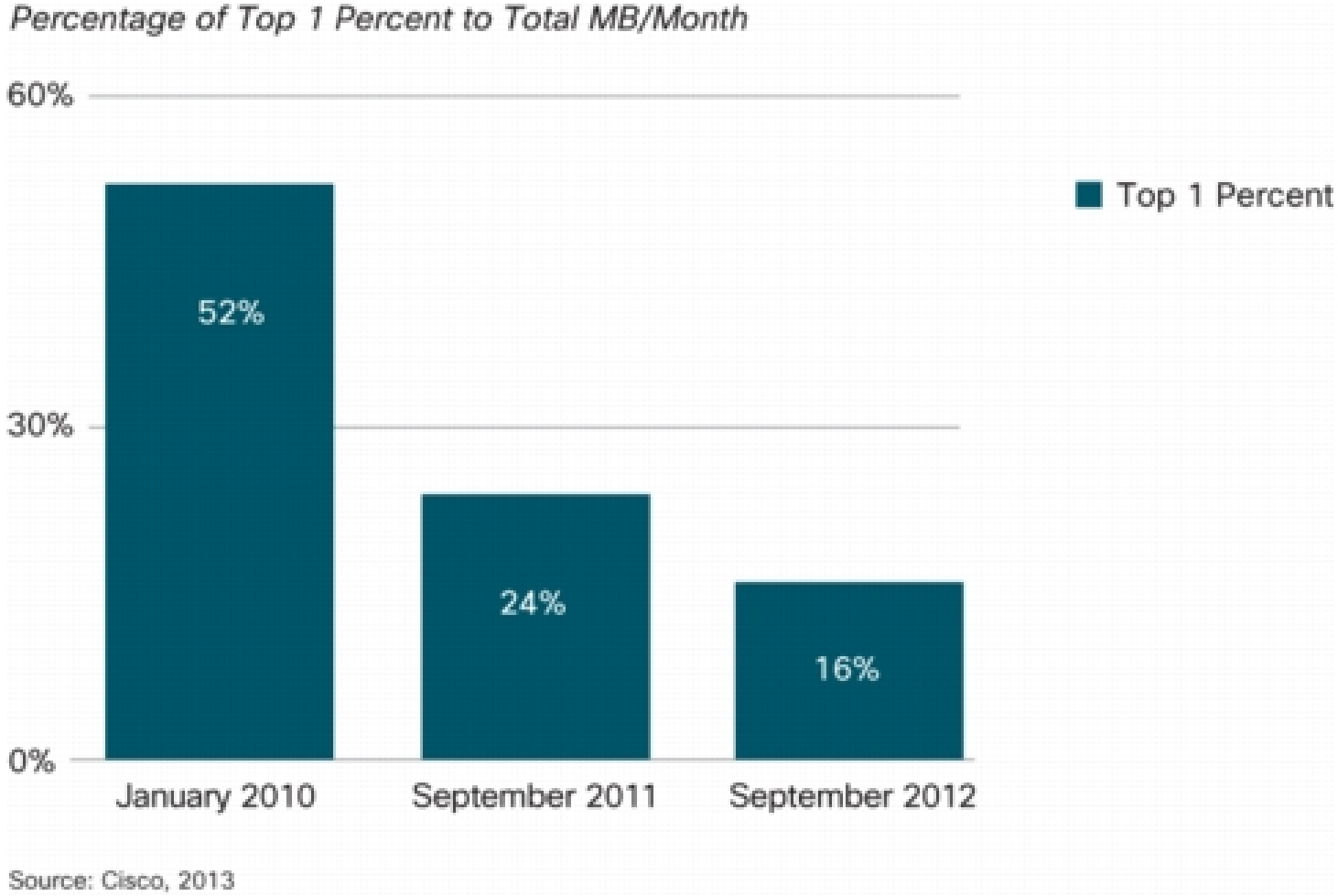


Source: Cisco VNI Mobile Forecast, 2013

2G vs. 3G vs. 4G Traffic Volume

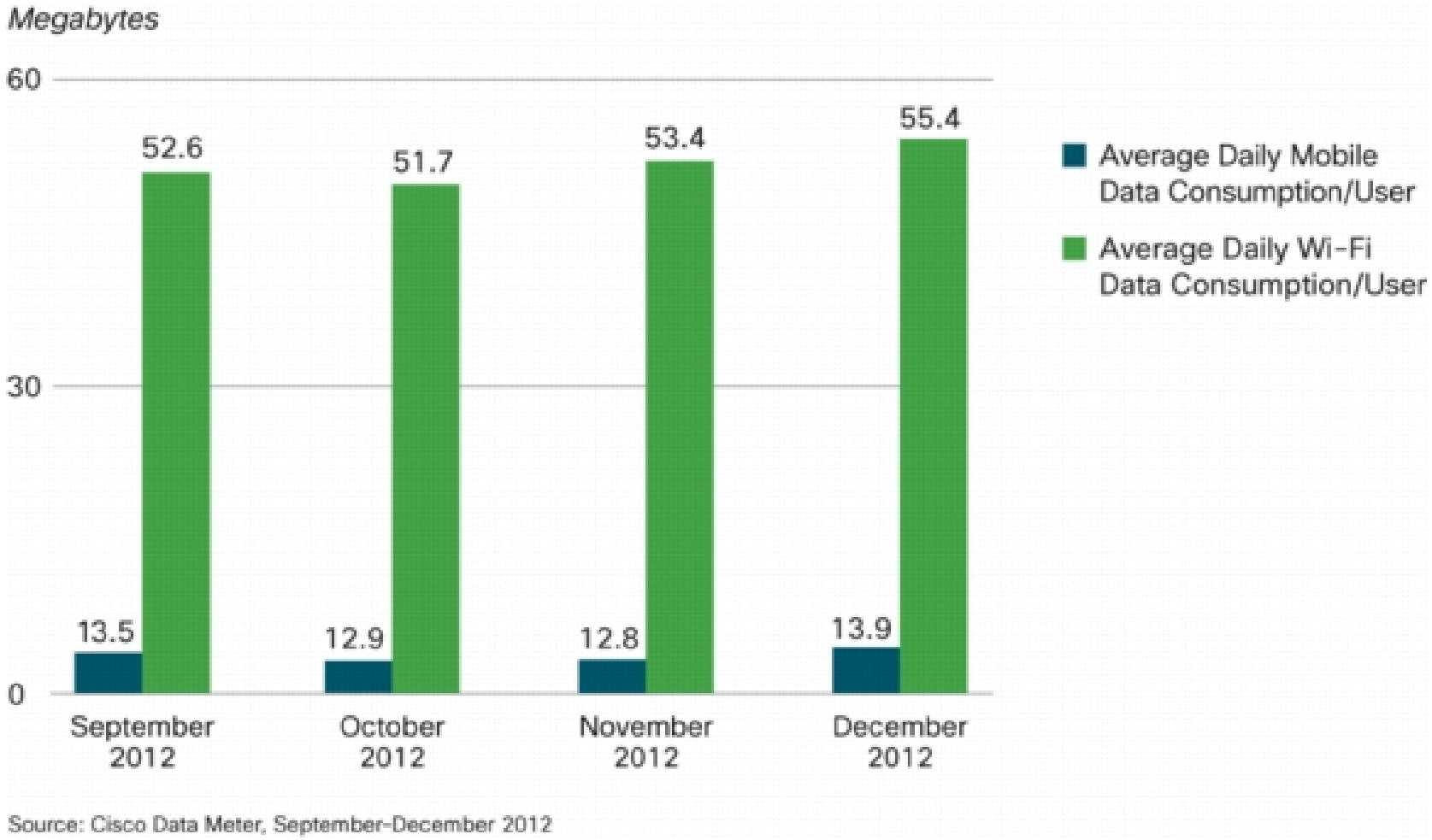


Top 1% Users



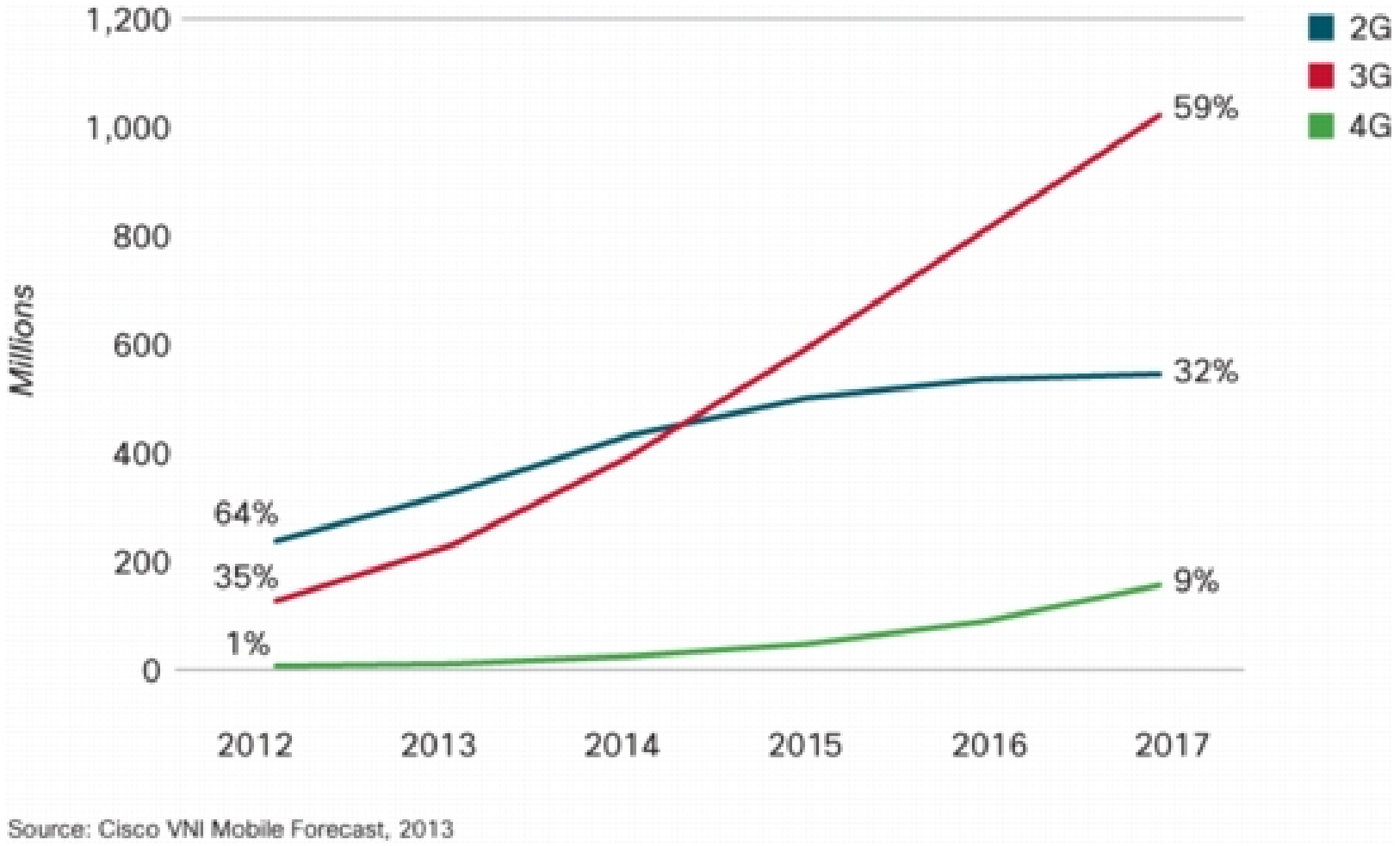
- In January 2010, top 1% users generated 52% of traffic

Cellular vs. WiFi



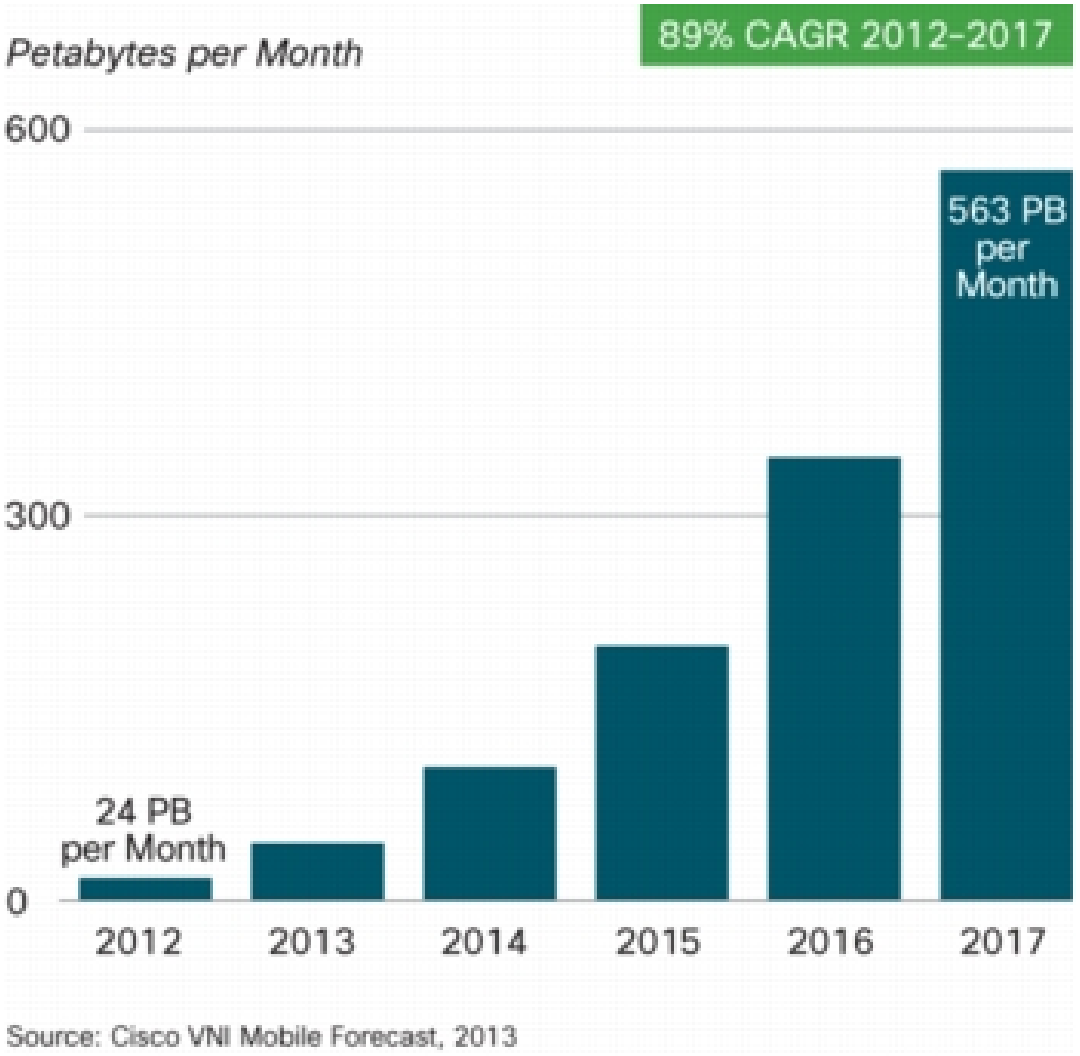
- 4 times more WiFi

Machine to Machine Modules

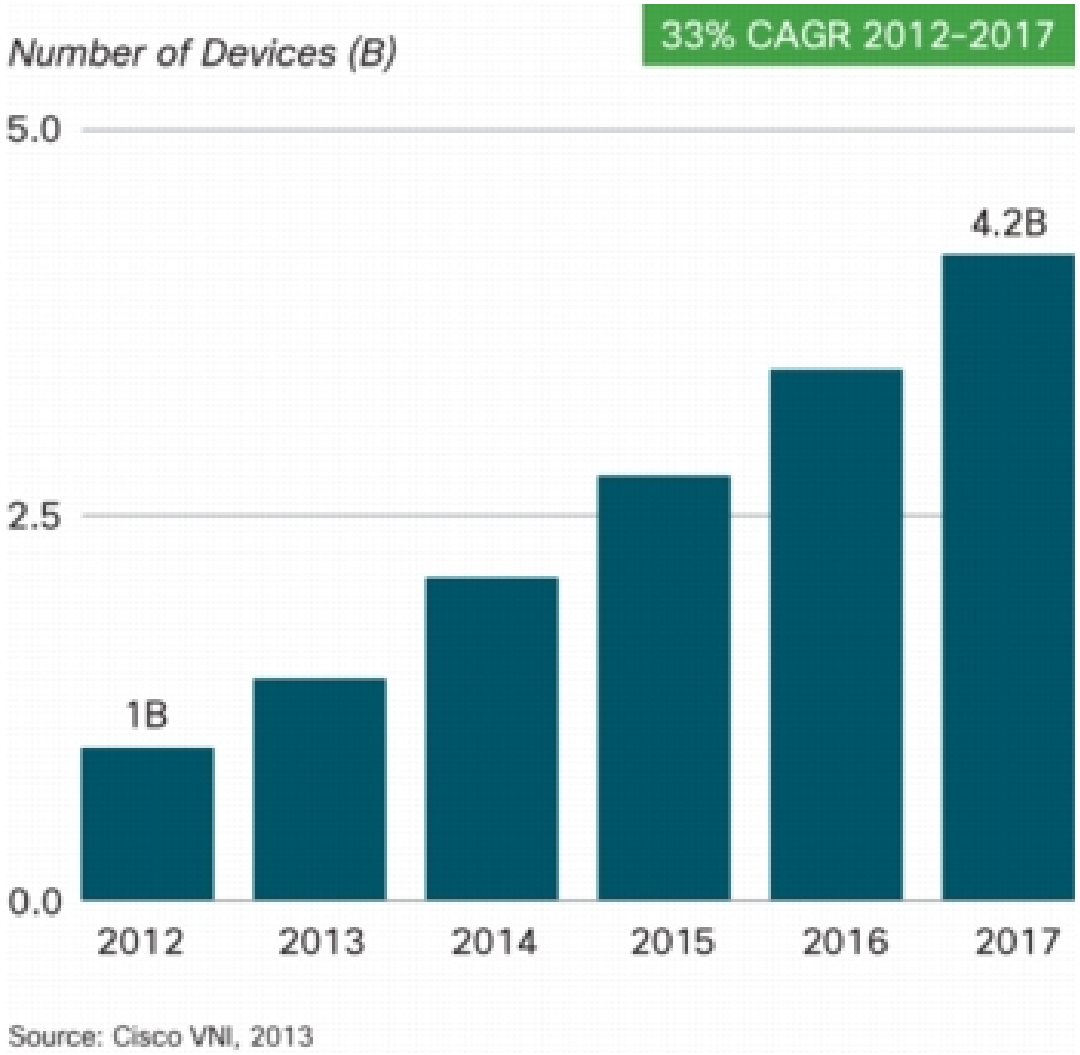


- Security, health, Sensors ⇒ Internet of things

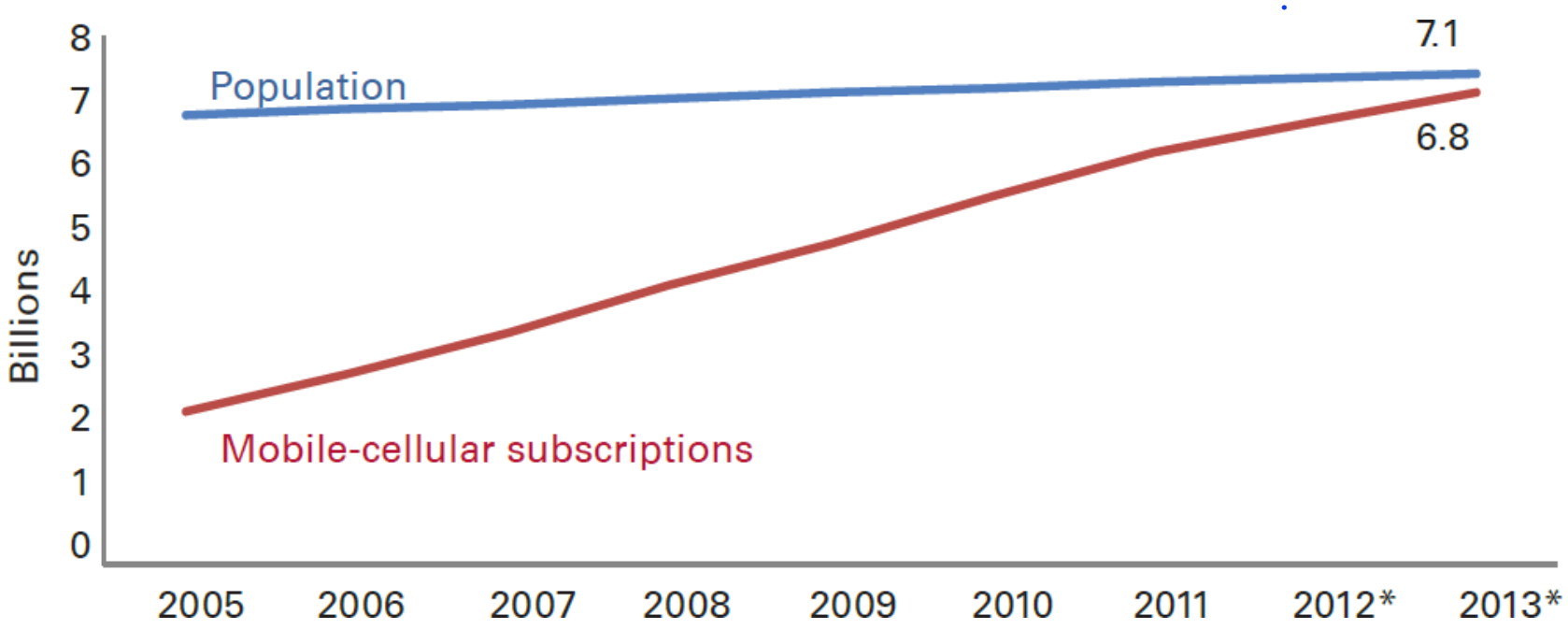
Machine to Machine Traffic



Mobile Devices with IPv6



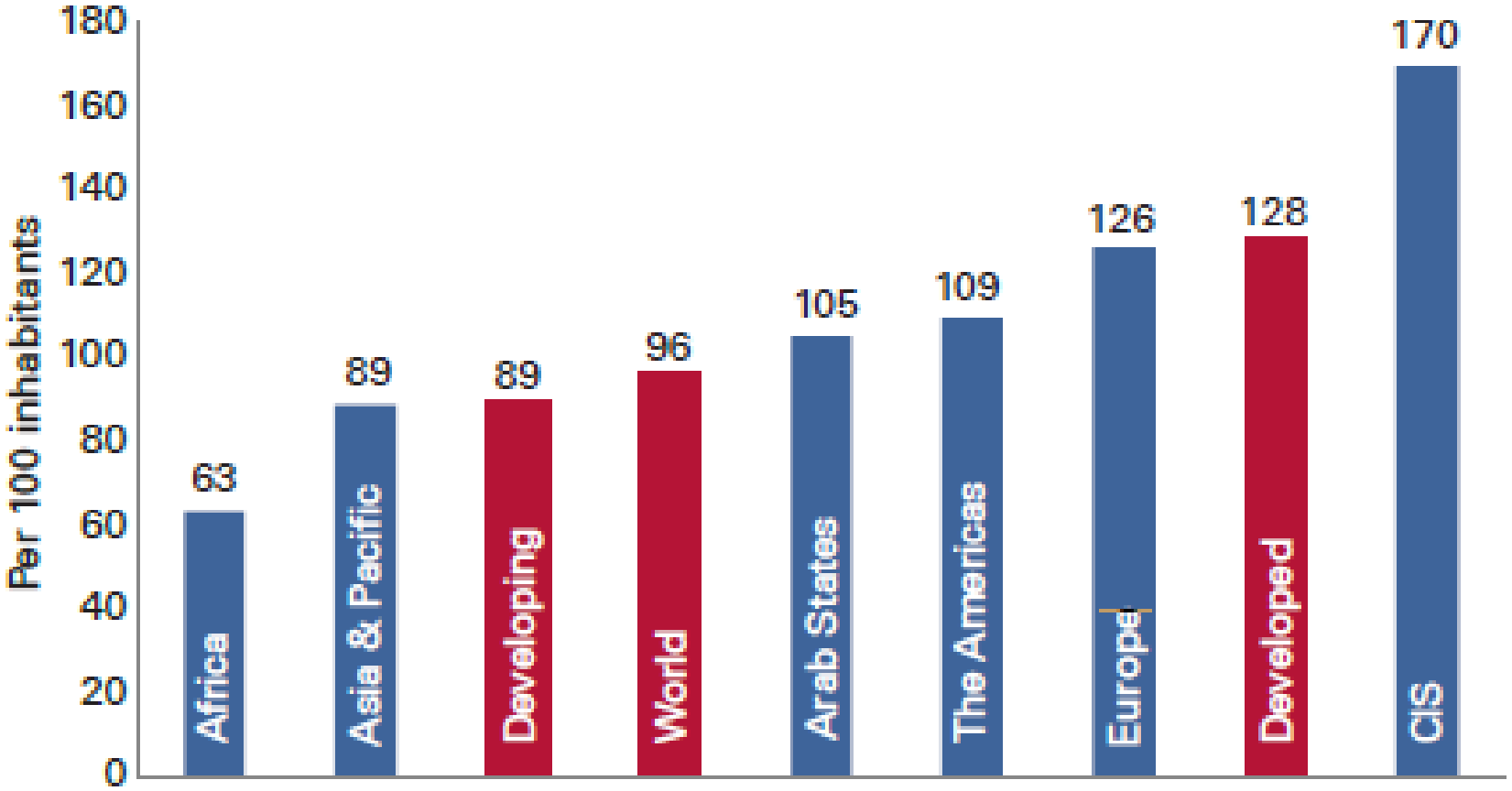
100% Mobile Cellular Penetration



- 96% globally, 128% in developed countries, 89% in developing countries

Ref: ITU, "The world in 2013: ICT Facts and Figures," http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx

Mobile Penetration



- CIS = Commonwealth of Independent States

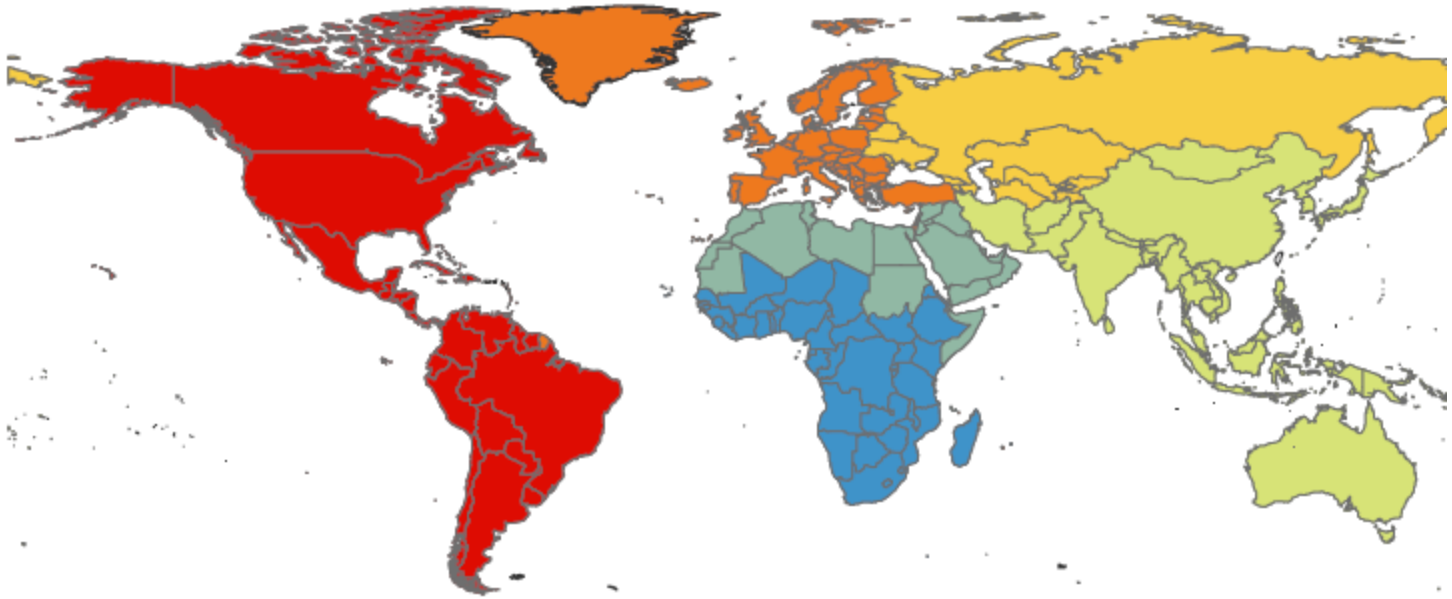
Ref: ITU, "The world in 2013: ICT Facts and Figures," http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx

Growth of Mobile Broadband

Americas
460 million subscriptions
48% penetration
28% CAGR (2010-2013)

Europe
422 million subscriptions
68% penetration
33% CAGR (2010-2013)

CIS
129 million subscriptions
46% penetration
27% CAGR (2010-2013)



Arab States
71 million subscriptions
19% penetration
55% CAGR (2010-2013)

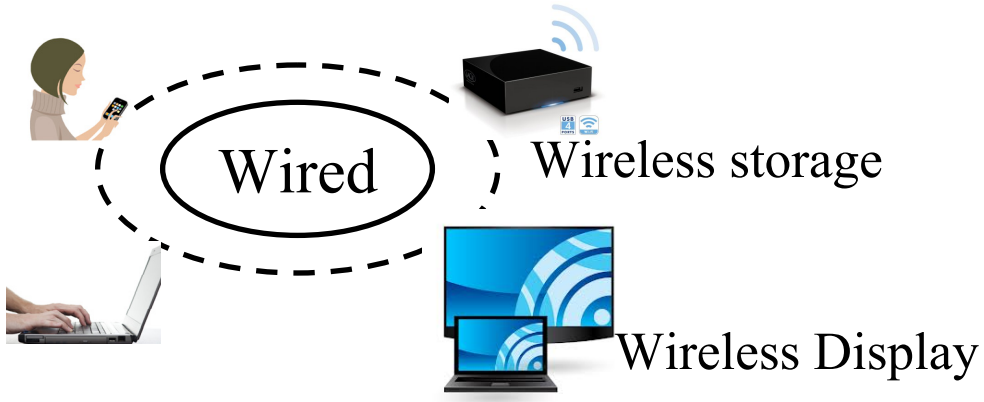
Africa
93 million subscriptions
11% penetration
82% CAGR (2010-2013)

Asia-Pacific
895 million subscriptions
22% penetration
45% CAGR (2010-2013)

Ref: ITU, "The world in 2013: ICT Facts and Figures," http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx

Trend: Access is All Wireless

- Wireless, in the form of WiFi, started in 1999.
  - First it was an option.
  - Now it is standard in all computing devices
- Most of the access (end user connectivity) is wireless
- Mobile phones, tablets have multiple wireless technologies: 2G, 3G, 4G, WiFi, Bluetooth, NFC but no wired connectivity



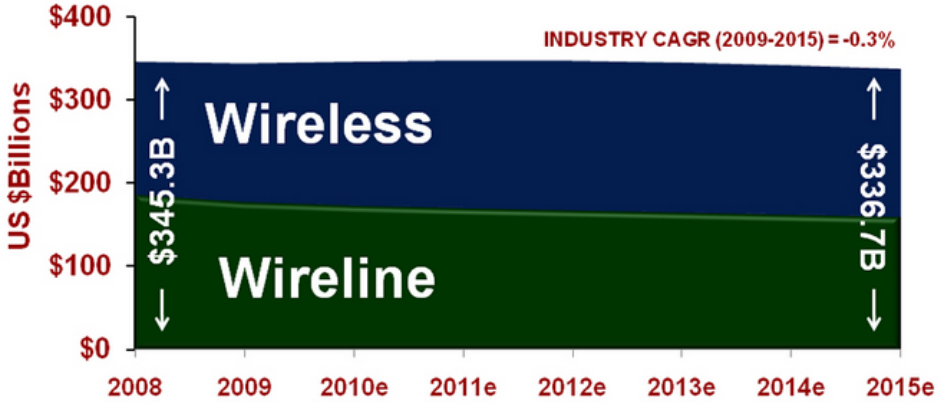
Trend: End-user Computing is all Mobile

- 2007: Apple introduced iPhone
- 68-83% of people in the United States have smart phones. 56% worldwide.
- Internet is now available to masses
- A large fraction of population uses smart phones and tablets as their sole computing, communication, entertainment device
- Operating systems: Android, iOS, and Windows
  All about mobiles

Ref: http://247wallst.com/telecom-wireless/2013/05/22/top-ten-u-s-wireless-trends-in-2013-for-investors-to-bank-on/

Trend: Most Revenue in Wireless

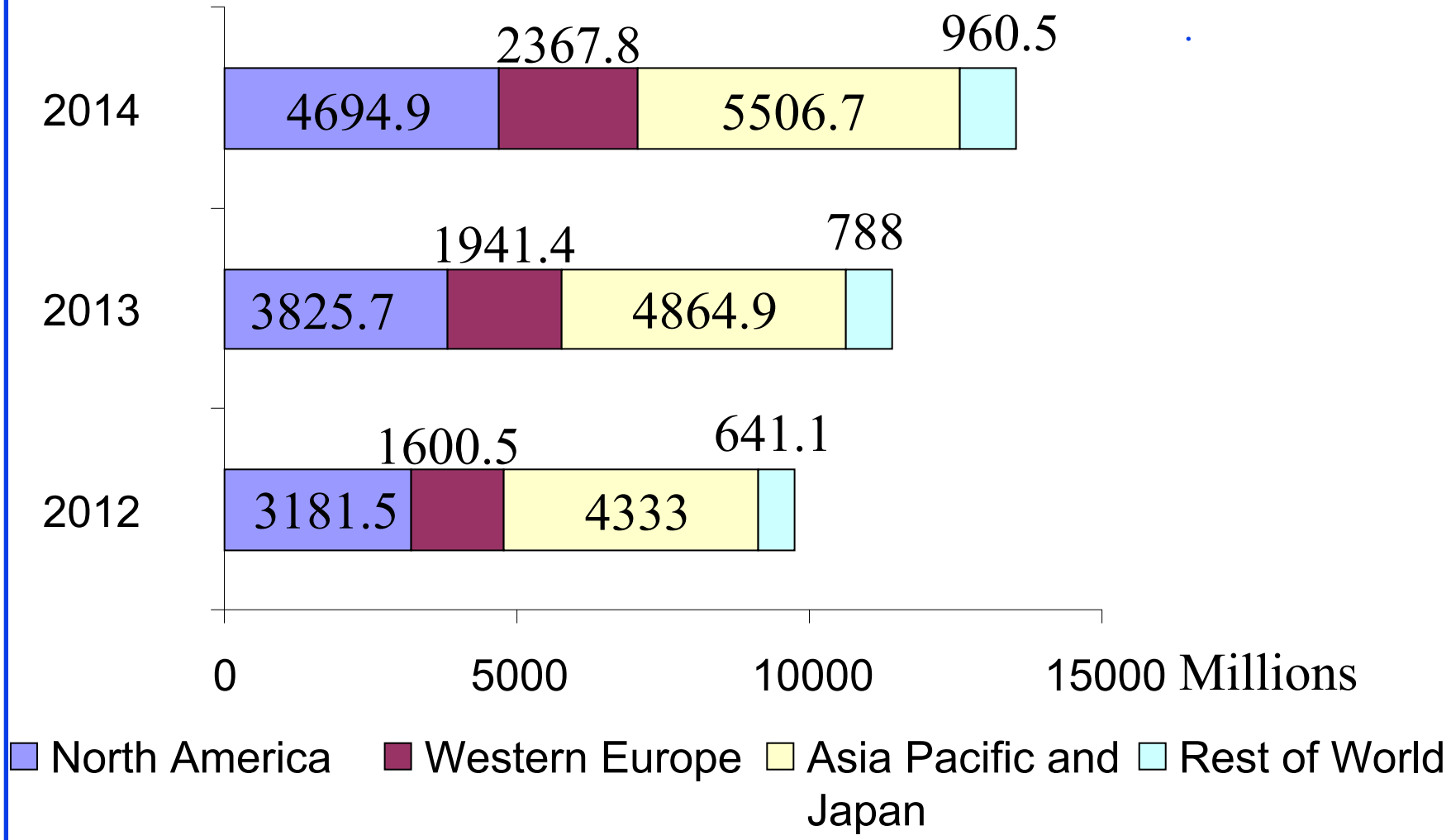
- US Wireless industry is valued at $195.5 billion ≥ publishing, agriculture, hotels and lodging, air transportation, and motion picture and recording.
- Wireless industry directly/indirectly provides more than 2.6% of all US employment
- Wireless revenue is expanding



Ref: http://www.ctia.org/your-wireless-life/how-wireless-works/wireless-quick-facts

http://atlantic-acm.com/index.php?option=com_content&view=article&id=557%3Avisual-dataline-us-telecom-wireless-and-wireline-service-revenues-2010-2015&catid=46%3A2010-datalines&Itemid=20

Mobile Advertising Revenue



Ref: http://www.supermonitoring.com/blog/2013/09/23/state-of-mobile-2013-infographic/

Trend: Distributed App Development

- Desktop Era: Large software packages – office, Photoshop, …, each costing $100-$1000 per seat
- Mobile Era: $0.99 apps or free apps for desktop publishing, image manipulation, …
- Millions of App developers versus a large software company
- Personal Apps to Enterprise Apps
- 2 Billion Apps with 50 billion downloads
- 70 Apps stores
- Mobile presence critical - Apps for Facebook, New York Times, ...

Ref: http://www.mobilestatistics.com/mobile-statistics

Trend: Cloud Computing and Storage

- High-Speed Wireless
  ⇒ Remote computing and storage
  ⇒ Ideal for mobile devices
- Cloud storage:
  - Google Drive, iCloud, Sky Drive, Drop Box
- Cloud Computing:
  - Google Docs, Office 360, …

Internet of Things

- Only 1% of things around us is connected.
  Refrigerator, car, washing machine, heater, a/c, garage door, should all be connected but are not.
- From 10 Billion today to 50 Billion in 2020
  Should include processes, data, things, and people.
- $14 Trillion over 10 years
  ⇒ Third in the list of top 10 strategic technologies by Gartner
  (After Mobile devices, Mobile Apps, but before Clouds, …)
- a.k.a. **Internet of Everything** by Cisco
  Smarter Planet by IBM
  Industrial Internet by GE
  Cyber-Physical Systems (CPS)
  Internet of European Things (more popular in Europe)

Ref: "Gartner Identifies Top 10 Strategic Technologies,"
http://www.cioinsight.com/it-news-trends/gartner-identifies-top-10-strategic-technologies.html
Ref: J. Bradley, "The Internet of Everything: Creating Better Experiences in Unimaginable Ways," Nov 21, 2013,
http://blogs.cisco.com/ioe/the-internet-of-everything-creating-better-experiences-in-unimaginable-ways/#more-131793

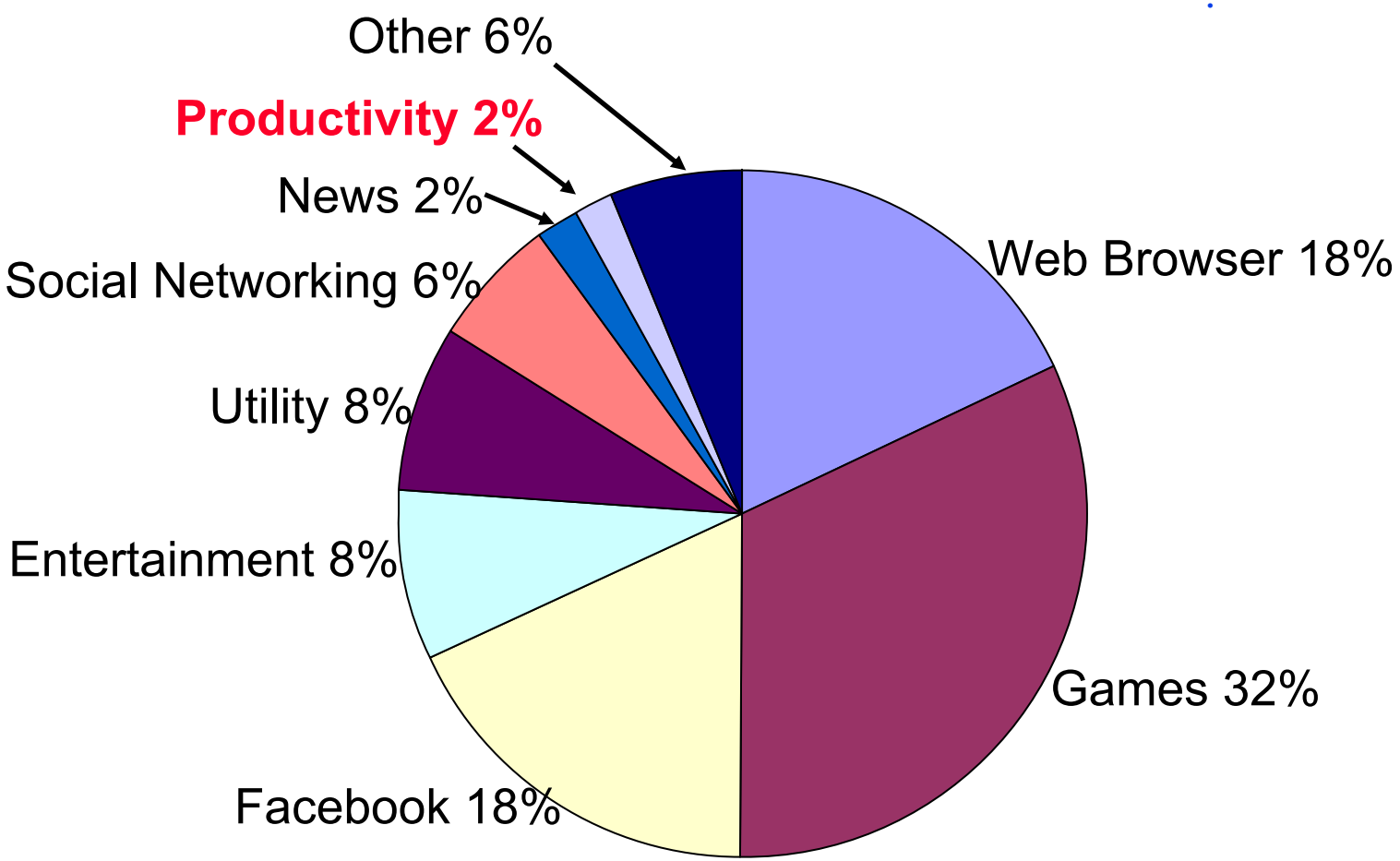
IEEE Communications Society Digital Library: Top 10 Downloads (Nov 2013)

1. Performance Analysis of Macrodiversity MIMO Systems with MMSE and ZF Receivers in Flat Rayleigh Fading
2. Are we ready for SDN? Implementation challenges for software-defined networks
3. A survey on sensor networks
4. A simple transmit diversity technique for wireless communications
5. Performance analysis of the IEEE 802.11 distributed coordination function
6. Cognitive radio: brain-empowered wireless communications
7. A Survey of Defense Mechanisms Against Distributed Denial of Service (DDoS) Flooding Attacks
8. Improving network management with software defined networking
9. A survey of spectrum sensing algorithms for cognitive radio applications
10. Network virtualization and software defined networking for cloud computing: a survey

Observation: 7 wireless, 2 SDN, 1 Security.

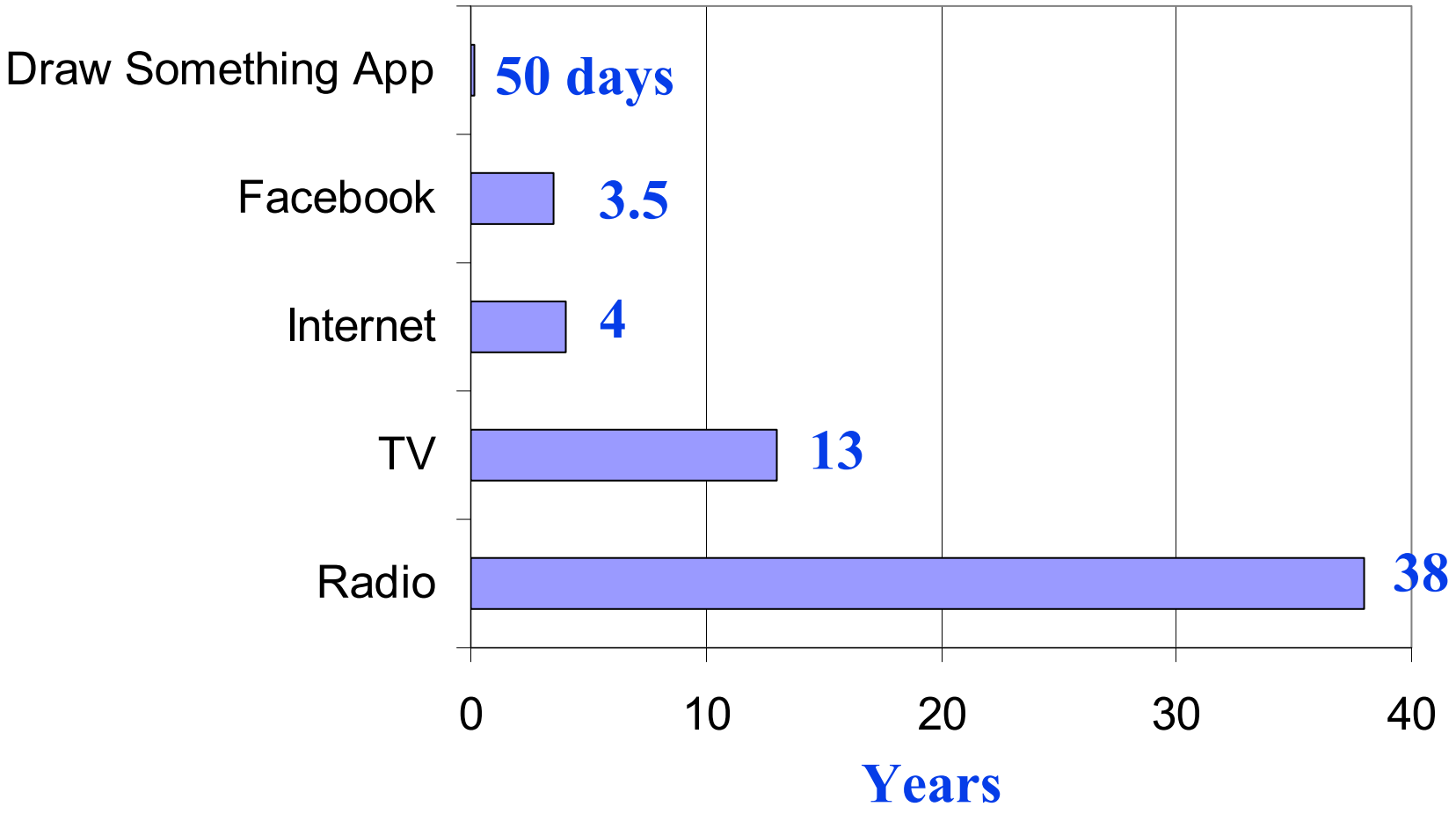
Ref: http://www.comsoc.org/topten

Time Spent on Mobiles



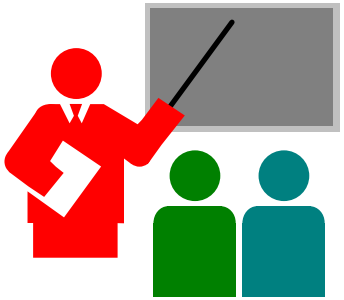
Ref: http://www.supermonitoring.com/blog/2013/09/23/state-of-mobile-2013-infographic/

Time to Reach 50M Users



Ref: http://www.supermonitoring.com/blog/2013/09/23/state-of-mobile-2013-infographic/

Summary: Wireless and Mobile Trends



1. WiFi has grown worldwide in just 15 years
2. 5G, Cognitive radio, M2M, TeraHz, Smart Antennas, LTE Advanced are topics for active research.
3. Wireless speed growth is following Moore's Law
4. Mobile subscriptions are approaching world population
5. Most of the traffic is video, growth in asia pacific

Acronyms

- AP Access Point
- CIO Chief Information Officer
- CIS Commonwealth of Independent
- CMO Chief Marketing Officer
- CPS Cyber-Physical Systems
- DDoS Distributed Denial of Service
- DSL Digital Subscriber Line
- GB Giga Byte
- GE General Electric
- GHz Giga Hertz
- Hz Hertz
- ICT Information and Communications Technologies
- IEEE Institution of Electrical and Electronic Engineers
- iOS iPhone Operating System
- IPTS Institute for Prospective Technological Studies
- IPv6 Internet Protocol Version 6

Acronyms (Cont)

- ITU International Telecommunications Union
- KISDI Korea Information Society Development Institute
- LTE Long-Term Evolution
- MIMO Multiple Input Multiple Output
- MMSE Minimum Mean Squared Error
- NFC Near Field Communications
- NGO Non-Governmental Organization
- OFDM Orthogonal Frequency Division Multiplexing
- RAN Regional Area Networks
- RFID Radio Frequency Identification
- SDN Software-defined networks
- SSD Solid-state Storage Drive
- TD-LTE Time-Division Duplixing Long-Term Evolution
- TeraHz 10^{12} Hertz
- THz Tera Hertz
- TV Television

Acronyms (Cont)

- US United States
- USB Universal Serial Bus
- VNI Visual Networking Index
- WiFi Wireless Fidelity
- WiGig Gigabit Wireless
- WLAN Wireless Local Area Network
- WPAN Wireless Personal Area Network
- ZigBee Trade name for 802.15.4

Reading List

- Cisco, "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update," http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html
- ITU, "The world in 2013: ICT Facts and Figures," http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx"
- Gartner, "Gartner Identifies Top 10 Strategic Technologies," http://www.cioinsight.com/it-news-trends/gartner-identifies-top-10-strategic-technologies.html
- Super Monitoring, "State of the Mobile 2013 (infographic)," http://www.supermonitoring.com/blog/2013/09/23/state-of-mobile-2013-infographic/
- G. Fettweis, "The limits of 4G and how to design a new 5G Phy," http://www.ieee-ctw.org/2013/slides/Fettweis.pdf

Reading List (Cont)

- CTIA, "Wireless Quick Facts," http://www.ctia.org/your-wireless-life/how-wireless-works/wireless-quick-facts
- A. Chokalingam, "Gigabit Access in Wireless," Second Annual NKN Workshop, Bangalore
- 24/7 Wall Street, "Top Ten U.S. Wireless Trends in 2013 for Investors to Bank On," http://247wallst.com/telecom-wireless/2013/05/22/top-ten-u-s-wireless-trends-in-2013-for-investors-to-bank-on/

Wikipedia Links

- http://en.wikipedia.org/wiki/White_spaces
- http://en.wikipedia.org/wiki/IEEE_802.11ah
- http://spectrum.ieee.org/aerospace/military/the-truth-about-terahertz
- http://en.wikipedia.org/wiki/802.11ad
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- http://en.wikipedia.org/wiki/LTE_Advanced
- http://en.wikipedia.org/wiki/IEEE_802.11ac
- http://en.wikipedia.org/wiki/Multi-user_MIMO
- http://en.wikipedia.org/wiki/Wi-Fi_Direct
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Wikipedia Links (Cont)

- http://en.wikipedia.org/wiki/Small_cell
- http://en.wikipedia.org/wiki/IEEE_802.22
- http://en.wikipedia.org/wiki/Super_Wi-Fi
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- IEEE, "ComSoc: Top Ten," http://www.comsoc.org/topten
- J. Bradley, "The Internet of Everything: Creating Better Experiences in Unimaginable Ways," Nov 21, 2013, http://blogs.cisco.com/ioe/the-internet-of-everything-creating-better-experiences-in-unimaginable-ways/#more-131793
- Mobile Statistics, http://www.mobilestatistics.com/mobile-statistics