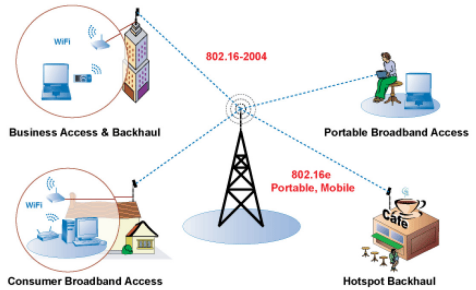
Wireless and Mobile Networking: Facts, Statistics, and Trends



Raj Jain
Washington University in Saint Louis
Saint Louis, MO 63130
Jain@cse.wustl.edu

Audio/Video recordings of this lecture are available at:

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Student Questions

Overview

1. Wireless: History
2. Life Cycle of Technologies
3. Recent Wireless Innovations
4. Wireless Trends
5. Internet of Things

Student Questions

Billion Dollar Question

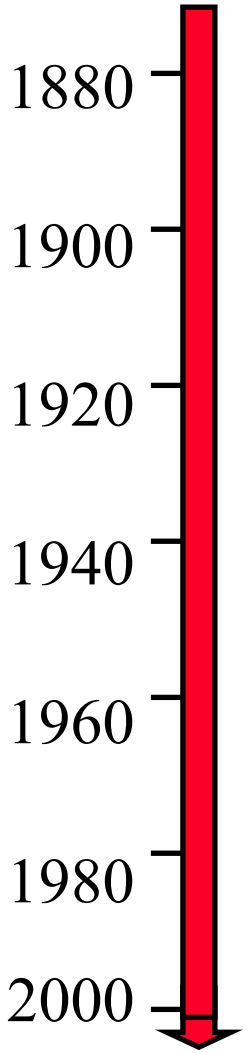
Joan Quigley

White House Astrologer

- All I want you to tell me is what will be the hot networking technology in the year 2020

Student Questions

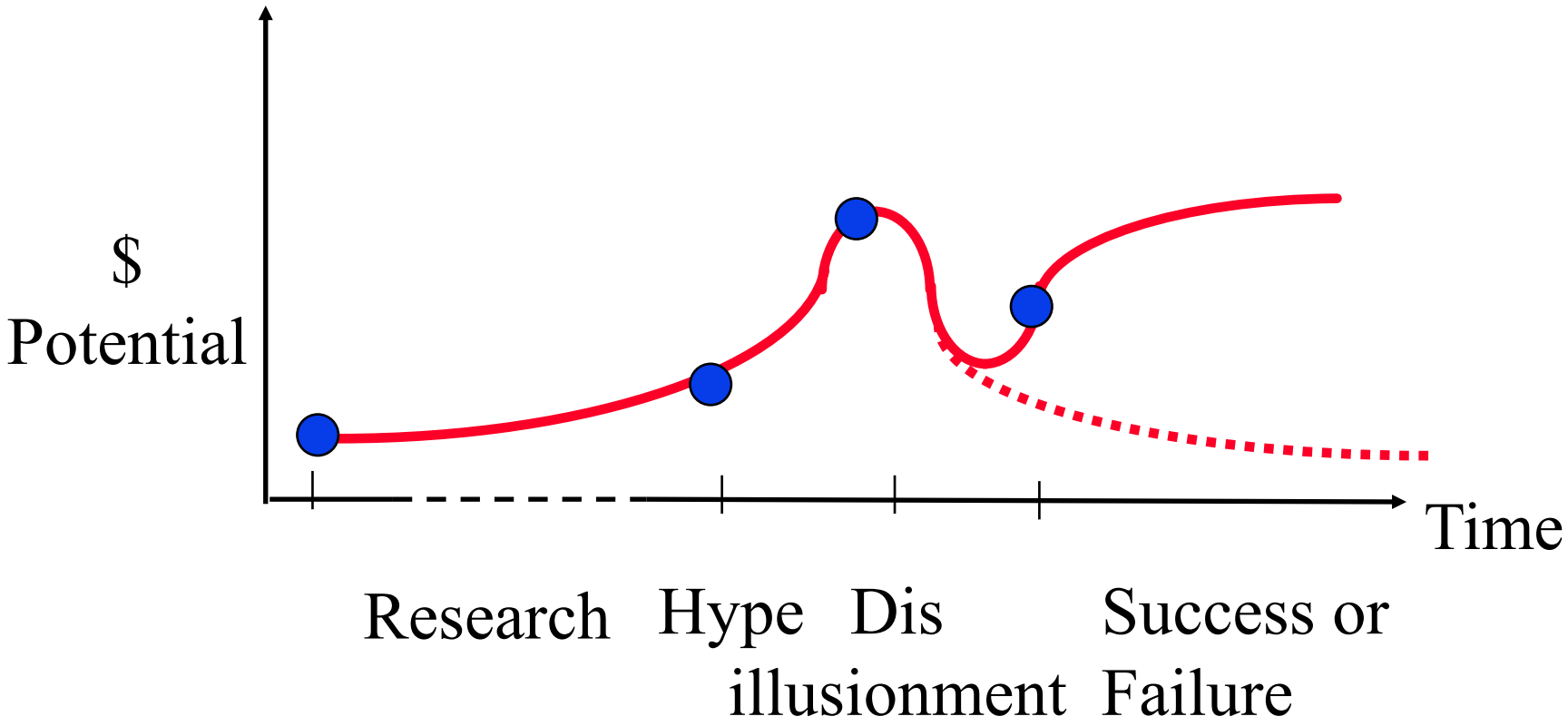
Wireless: History



- 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

Student Questions

Life Cycle of Technologies



Student Questions

Recent Wireless Innovations

- **5G**: Beyond 4G. 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 Wi-Fi
- **Wi-Fi Direct**: Point-to-Point Wi-Fi without access point
- **802.11u**: Authentication for 802.11 hotspots

Student Questions

- Since 802.11ad exists now -- what is the "next" thing for wireless?

See Slide 6S-9 in the "Supplement to Wireless LANs Part II: 802.11a/b/g/n/ac"

IEEE 802.11 Activities

- **P802.11ay**: Increase the data rate in 60 GHz band Enhancement of 802.11ad
- **P802.11az**: Next generation positioning with improved accuracy, scalability, and directionality
- **P802.11ba**: Low power control stations
- **P802.11bb**: Light Communications
- **P802.11bc**: Enhanced broadcase service
- **P802.11bd**: Next Generation Vehicle-to-X
- **Real time applications**: Latency and stability issues with mobile and multiplayer games, robotics and industrial automation

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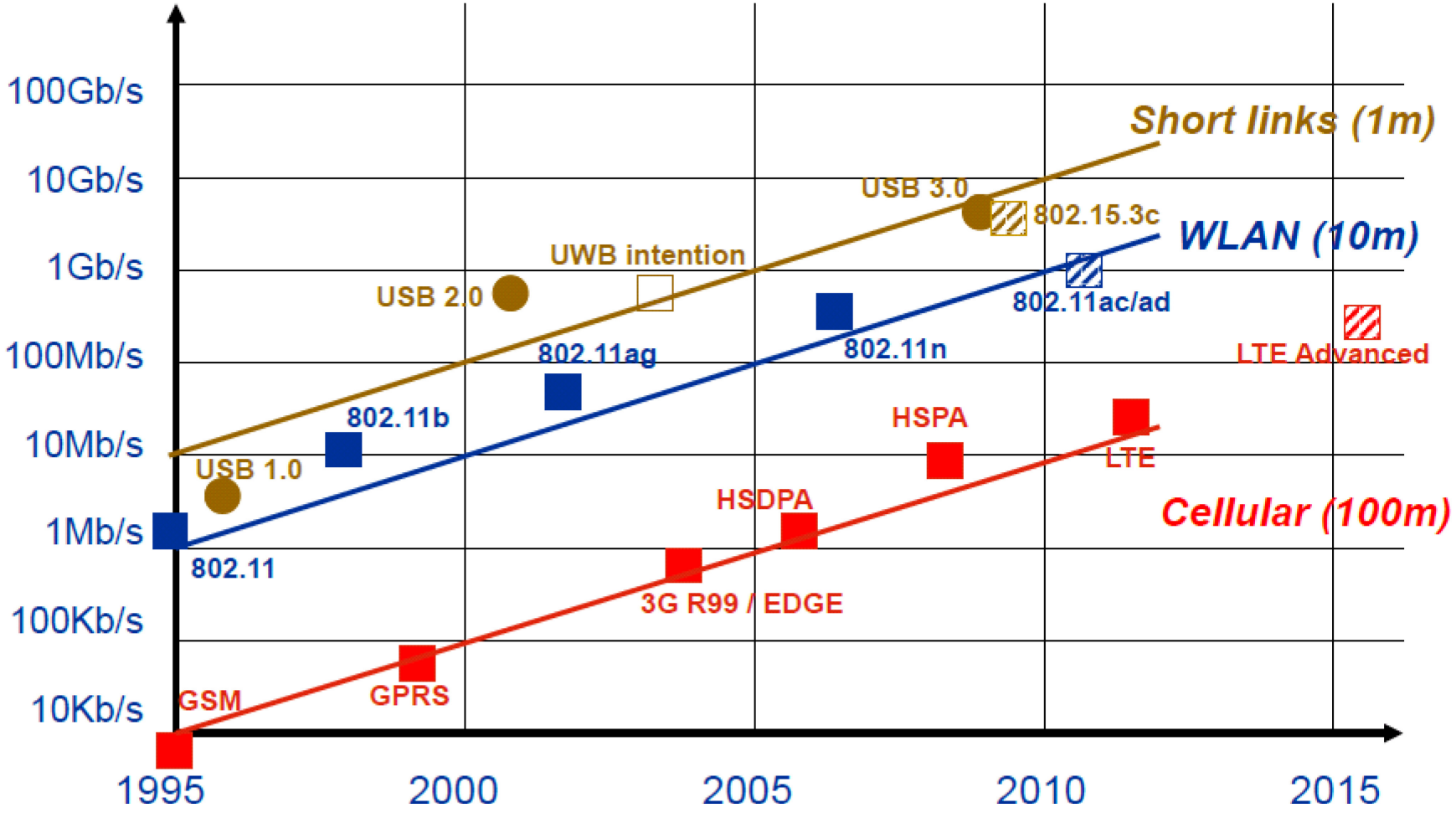
6S-9

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 Wi-Fi**: 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 Wi-Fi for 802.11
- **802.11r**: Fast Base Station transition
- **LTE**: Long-Term Evolution. 3.9G

Student Questions

Wireless Speed Trends



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

Student Questions

- Where would 5G be on this graph? Will it be close to (or above?) the WLAN line since it is 100X more powerful than LTE?

5G is on the red line. It is the next generation of LTE advanced.

Global Mobile Data Forecast [Cisco]

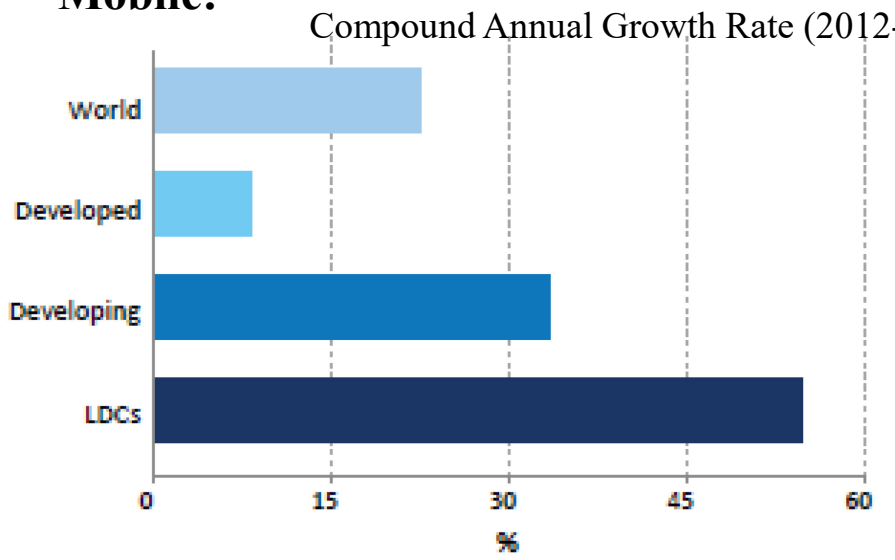
1. Global IP Traffic: 3X in 5 years (2016-2021)
   $\Rightarrow$ 24% Compound Annual Growth Rate (CAGR)
2. Busy hour traffic growing faster: 3.2X in 5 years
3. Fixed/Wi-Fi will be 46% of total IP traffic
4. Fixed/wired will be 37%
5. Mobile will be 17% = 46% CAGR
6. IP Video will be 82% of all IP traffic
7. 27.1 billion devices in 2021 $\Rightarrow$ 3.5 devices per person
8. 43% of devices will be mobile
9. 51% of devices will be M2M (PCs 5%, Tablets 3%)
10. Average broadband speed 53 Mbps

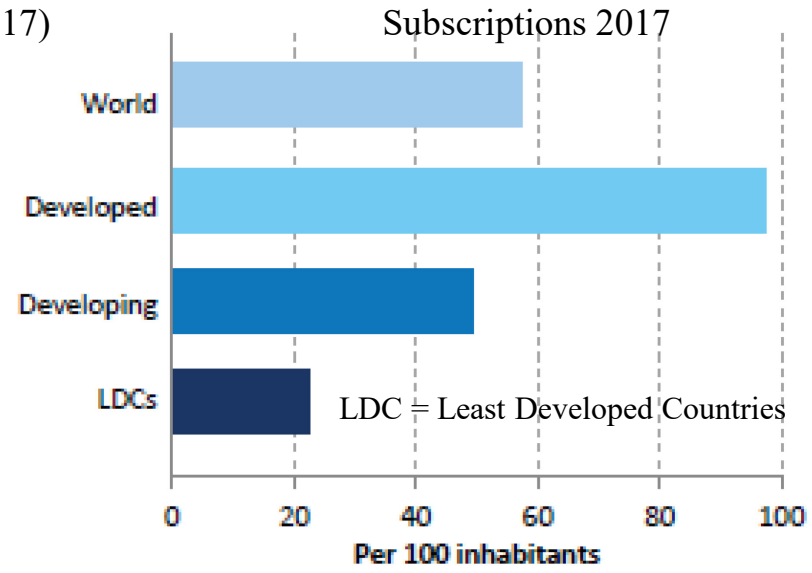
Ref: Cisco, "Cisco Visual Networking Index: Forecast and Methodology, 2016-2021" June 6 ,2017, 17 pp.
https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.pdf

Student Questions

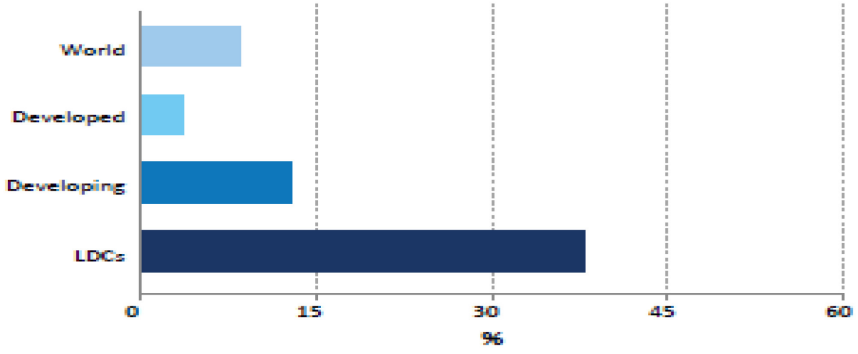
Broadband Subscriptions

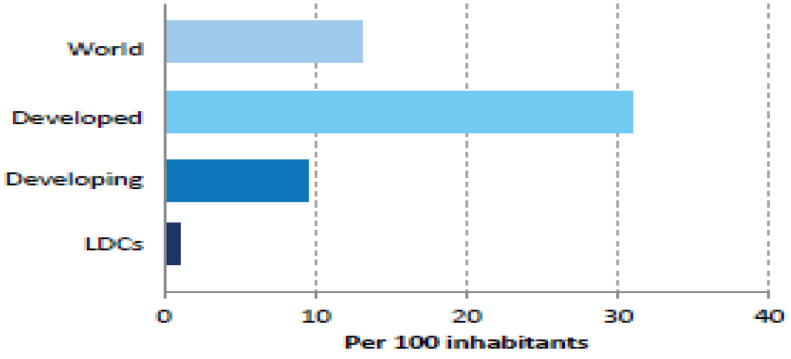
Mobile:





Fixed:





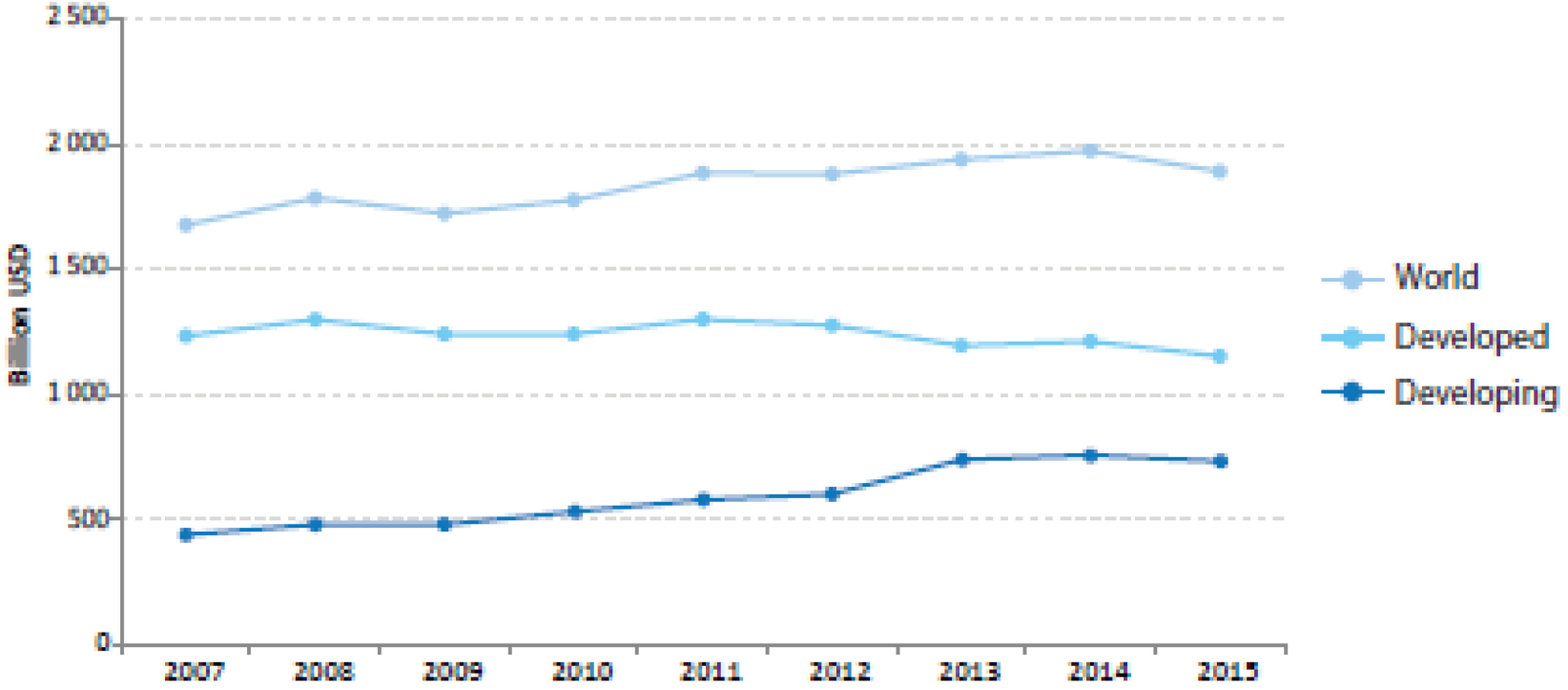
Ref: ITU, "ICT Facts and Figures 2017," 8 pp., https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2017.pdf

Student Questions

- With fixed traffic decreasing, are there any technology that leverages the existing fixed telephone infrastructure like White-Fi?

Yes, core part of fixed telephone infrastructure was fiber. It is being used for Internet and Video delivery. The edge's were copper that are being used to provided DSL internet but are being replaced by fiber to provide high speed Internet and Video. Telephone ⇒ Telecommunications

Telecom Revenues



- Revenues declined by 4% between 2014 and 2015.

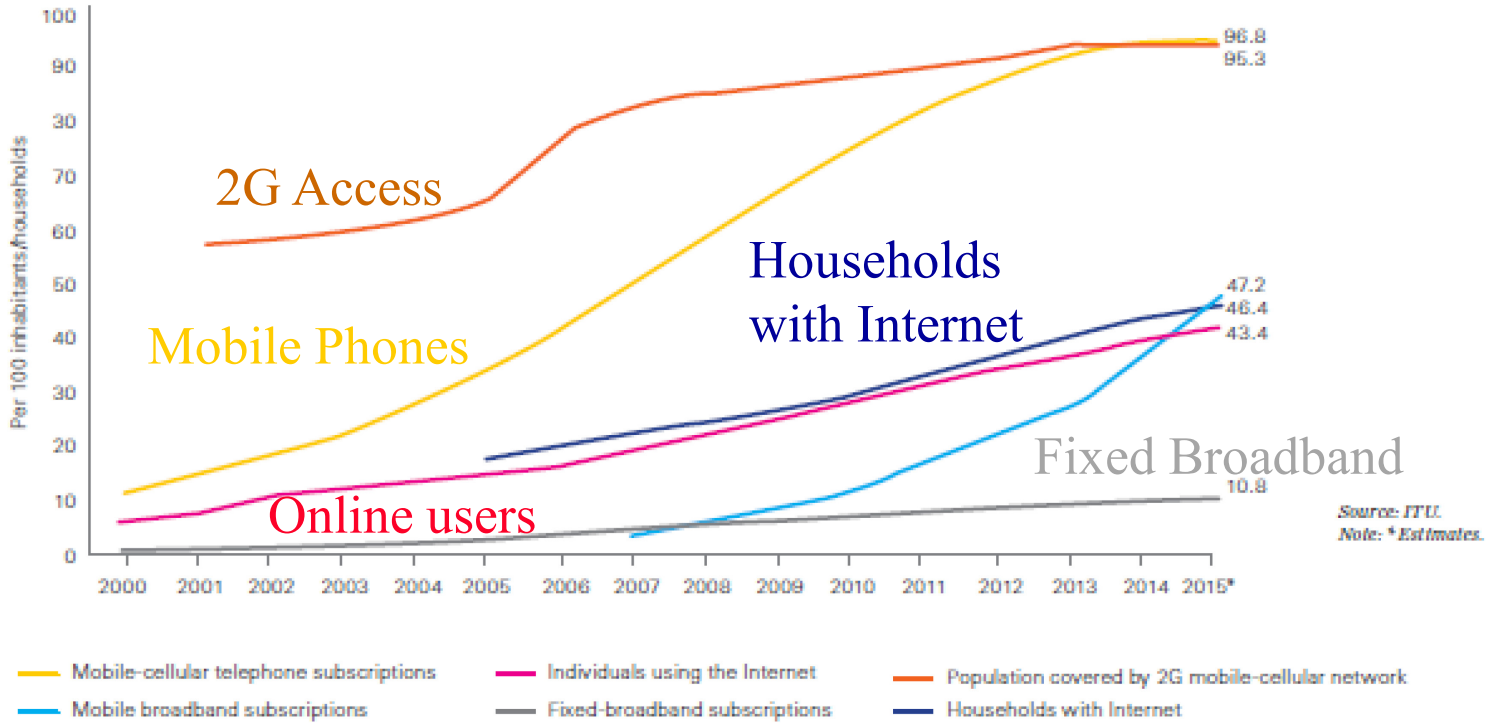
Ref: ITU, "ICT Facts and Figures 2017," 8 pp., https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2017.pdf

Student Questions

- Are telecom revenues still declining in 2020? I would think the opposite due to most work being moved online

Lower price and higher cost is continuing. I have 200 Mbps for $50/month. Used to get 110 bps on modem for $50/month in 1974.

Mobile vs. Fixed



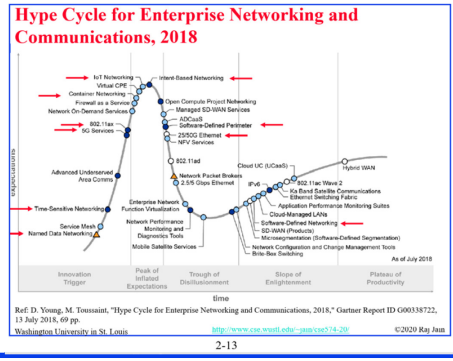
- Mobile phones rather than fixed broadband is the future for internet access

Ref: ITU, "ICT Facts and Figures: The world in 2015," http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx

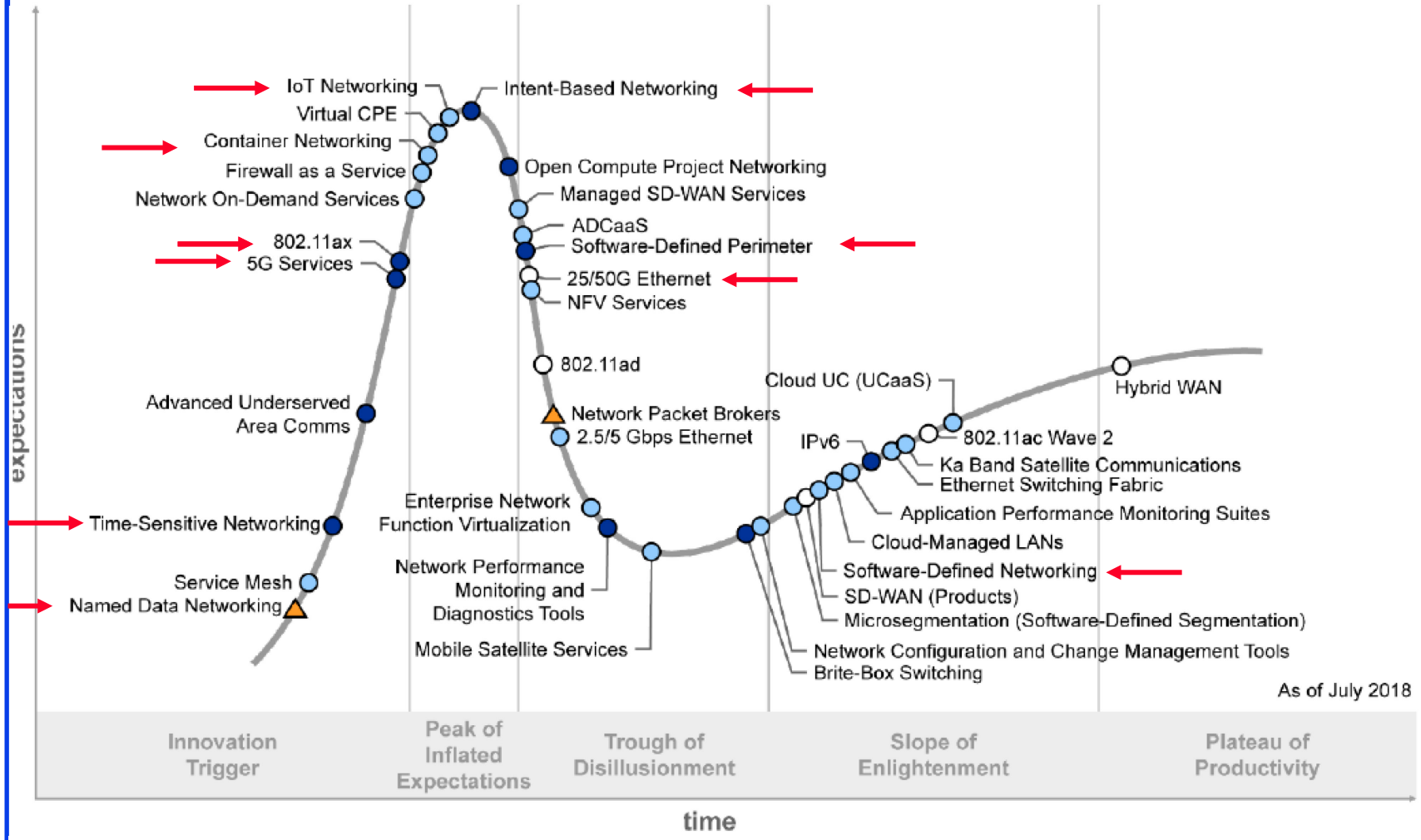
Student Questions

- Why is 802.11ad in the trough of disillusionment if it is being widely deployed in current routers?

Trough does not mean death. It means not enough profit. Profits are high when the hype is high. During wide deployment, profit is from low-cost manufacturing. Inventors move on to the next thing that is high on the hype.



Hype Cycle for Enterprise Networking and Communications, 2018



Ref: D. Young, M. Toussaint, "Hype Cycle for Enterprise Networking and Communications, 2018," Gartner Report ID G00338722, 13 July 2018, 69 pp.

Student Questions

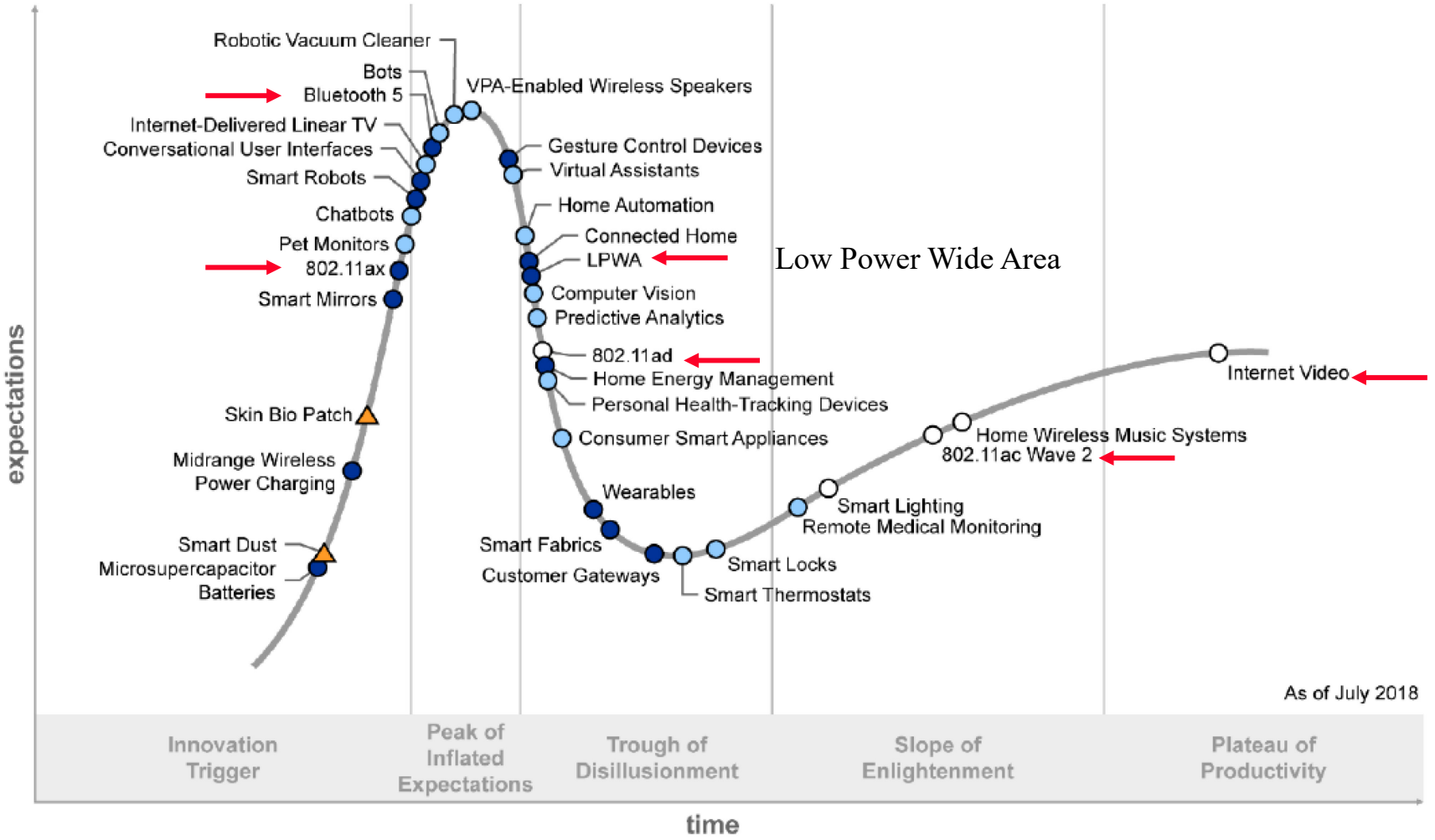
New Networking Tech

- Service Mesh: µService-to-µservice communication
- Time Sensitive Networking: IEEE standards for real-time
- Container Networking: IP address management and service registration for containers using embedded switches and routers
- Virtual Customer Premise Equipment: CPEs using standard equipment and Virtual network functions for routers, firewalls, …
- Software Defined Perimeter: Logical separation of network-connected nodes in to a secure computing enclave
- Micro segmentation: Software defined segmentation to isolate applications in a cloud or datacenter using firewalls or crypto
- 2.5G/5G and 25G/50G Ethernet

Ref: D. Young, M. Toussaint, "Hype Cycle for Enterprise Networking and Communications, 2018," Gartner Report ID G00338722, 13 July 2018, 69 pp.

Student Questions

Hype Cycle of Connected Homes 2018



Ref: F. Elizalde, "Hype Cycle for the Connected Home, 2018," Gartner Report ID G00340387, 30 July 2018, 68 pp.

Student Questions

New Wireless Technologies

- 802.11ac Wave 2: Peak rate of 6 Gbps vs. 1.3 Gbps for Wave 1 using 2.4 and 5.8 GHz
- 802.11ad: 7 Gbps using 60 GHz (millimeter wave)
- **802.11ax**: user throughput 4x 801.11ac
- Bluetooth 5: Longer range than Bluetooth 4.2, higher speeds, mesh networking (Approved Dec 2016)
- Low Powered Wide Area (LPWA): For IoT. LTE Cat-M1, EC-GSM-IoT, LTE Cat-NB1, LoRa, Sigfox, RPMA, FlexNet, WiSUN, Synergize
- Mobile Satellite Services: 500 kbps and **up**

Student Questions

- Of these new wireless technologies you listed, what exists now, and what is still being developed?
- *Bolded ones are still not here.*

Ref: F. Elizalde, "Hype Cycle for the Connected Home, 2018," Gartner Report ID G00340387, 30 July 2018, 68 pp.

Internet of Things

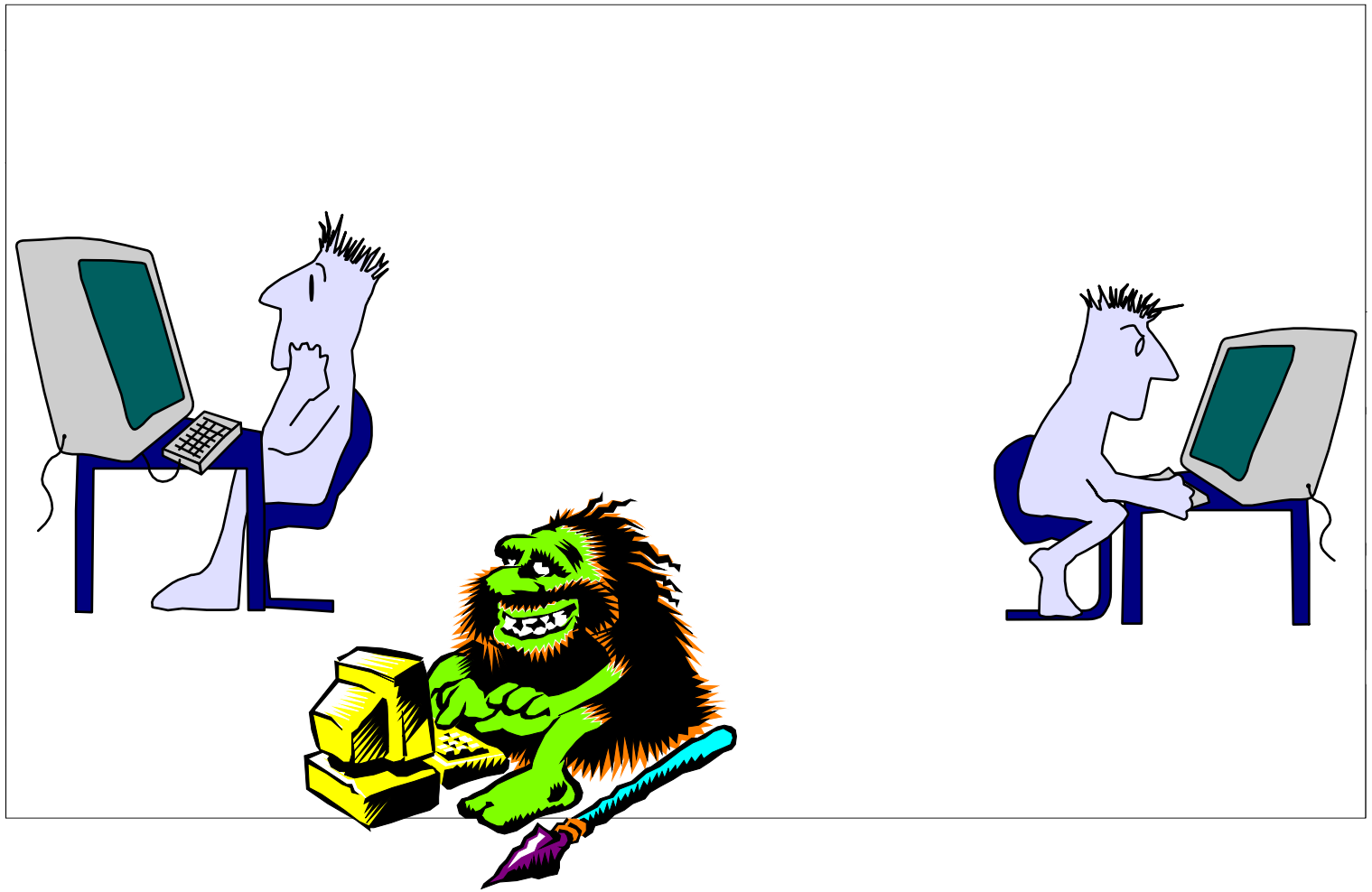
- More IoT devices than mobile phones in 2018
- 70% of wide-area IoT devices will use cellular
- Cisco predicts $457B by 2020 with a CAGR of 28%
- Statista predicts $8.9T in 2020
- Accenture estimates IIoT $14.2T by 2020
- Manufacturing dominates IoT connections

Student Questions

- Can you explain what you mean by "Manufacturing dominates IoT connections"?
- More IoT (sensors) are used in manufacturing plants than in home.

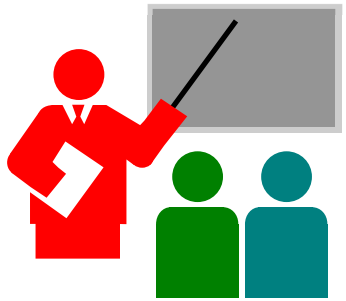
Ref: L. Columbus, "2017 Roundup of Internet of Things Forecasts," December 10, 2017, https://www.forbes.com/sites/louiscolumbus/2017/12/10/2017-roundup-of-internet-of-things-forecasts/
Postscapes, "IoT Market Forecasts," August 20, 2018, https://www.forbes.com/sites/louiscolumbus/2017/12/10/2017-roundup-of-internet-of-things-forecasts/

Cavemen of 2020



Student Questions

Summary: Wireless and Mobile Trends



1. Wi-Fi 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

Student Questions

Reading List

- Cisco, "Cisco Annual Internet Report (2018–2023) White Paper," March 9, 2020, 17 pp., https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.pdf
- ITU, "Measuring Digital Development Facts and Figures 2019," 15 pp., https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2019.pdf

Student Questions

Homework 2

Fill in the blanks. (Some blanks may take more than one word).
Use the **latest information from the reading list** in the previous slide.

1. The gender gap among Internet users in developing countries is _____.
2. Mobile broadband subscription continue to _____.
3. Households are _____ likely to have internet access at home than to have a computer.
4. ____% of world population lives within the reach of a mobile cellular signal.
5. International bandwidth usage is _____ in Asia and Pacific than in the Americas.
6. Number of devices connected to IP networks will be more than _____ times the global population by 2023.
7. M2M connections will be half of the global connected devices and connections by 2023.
8. Connected home applications will have nearly _____ of M2M share by 2023.
9. Connected car applications will grow at ____% CAGR duing 2018-2023.

Student Questions

References

- D. Young, M. Toussaint, "Hype Cycle for Enterprise Networking and Communications, 2018," Gartner Report ID G00338722, 13 July 2018, 69 pp.
- F. Elizalde, "Hype Cycle for the Connected Home, 2018," Gartner Report ID G00340387, 30 July 2018, 68 pp.
- L. Columbus, "2017 Roundup of Internet of Things Forecasts," December 10, 2017, https://www.forbes.com/sites/louiscolumbus/2017/12/10/2017-roundup-of-internet-of-things-forecasts/
- Postscapes, "IoT Market Forecasts," August 20, 2018, https://www.forbes.com/sites/louiscolumbus/2017/12/10/2017-roundup-of-internet-of-things-forecasts/

Student Questions

Acronyms

- AT&T American Telephone and Telegraph
- CAGR Cumulative Annual Growth Rate
- CIO Chief Information Officer
- CIS Commonwealth of Independent States
- CMO Chief Marketing Officer
- CPE Customer Premises Equipment
- 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
- ITU International Telecommunications Union
- KISDI Korea Information Society Development Institute
- LDC Least Developed Countries

Student Questions

Acronyms (Cont)

- LTE — Long-Term Evolution
- MIMO — Multiple Input Multiple Output
- NFC — Near Field Communications
- NGO — Non-Governmental Organization
- OFDM — Orthogonal Frequency Division Multiplexing
- RFID — Radio Frequency Identification
- SSD — Solid-state Storage Drive
- TD-LTE — Time-Division Duplixing Long-Term Evolution
- TeraHz — 10^{12} Hertz
- THz — Tera Hertz
- TV — Television
- US — United States
- USB — Universal Serial Bus
- Wi-Fi — Wireless Fidelity
- WiGig — Gigabit Wireless
- WLAN — Wireless Local Area Network
- ZigBee — Trade name for 802.15.4

Student Questions

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Raj Jain
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http://www.cse.wustl.edu/~jain/cse574-20/j_02trn.htm

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Related Modules

CSE567M: Computer Systems Analysis (Spring 2013),
https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n_1X0bWWNyZcof

CSE473S: Introduction to Computer Networks (Fall 2011),

https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcgy5e_10TiDw

Recent Advances in Networking (Spring 2013),
https://www.youtube.com/playlist?list=PLjGG94etKypLHyBN8mOgwJLHD2FFIMGq5

CSE571S: Network Security (Fall 2011),

https://www.youtube.com/playlist?list=PLjGG94etKypKvzfVtutHcPFJXumyyg93u

Video Podcasts of Prof. Raj Jain's Lectures,
https://www.youtube.com/channel/UCN4-5wzNP9-ruOzQMs-8NUw

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