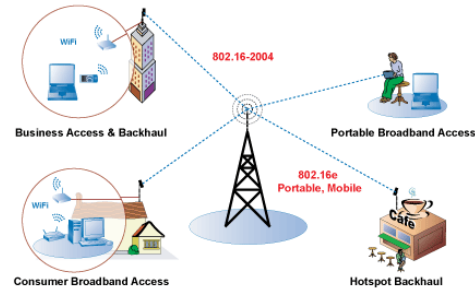# Wireless and Mobile Networking:
Facts, Statistics, and Trends

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Audio/Video recordings of this lecture are available at:

http://www.cse.wustl.edu/~jain/cse574-24/

Student Questions

Overview

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

Note: Slides with newer trends have been added at the end. These are not in the recorded video and will be covered in the class.

Student Questions

Billion Dollar Question

Joan
Quigley

White
House
Astrologer

Student Questions

❑ All I want you to tell me is what will be the hot networking technology in the year 2026

Wireless: History

1880
1900
1920
1940
1960
1980
2000

- 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 $\Rightarrow$ 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

- What exactly is WaveLAN, and how is it different from a WLAN?
WLAN= Wireless LAN
WaveLAN = Wireless service by AT&T
- How did mobile phones work between 1946 and 1970 without cellular? Is cellular just a way to organize the network?
Point to Point. Walkie-talkie.
- How do we communicate to those people in other "cells"? I mean in different frequency?
Cell to cell is generally wired between the cell offices/towers.
- Is this included in the exam?
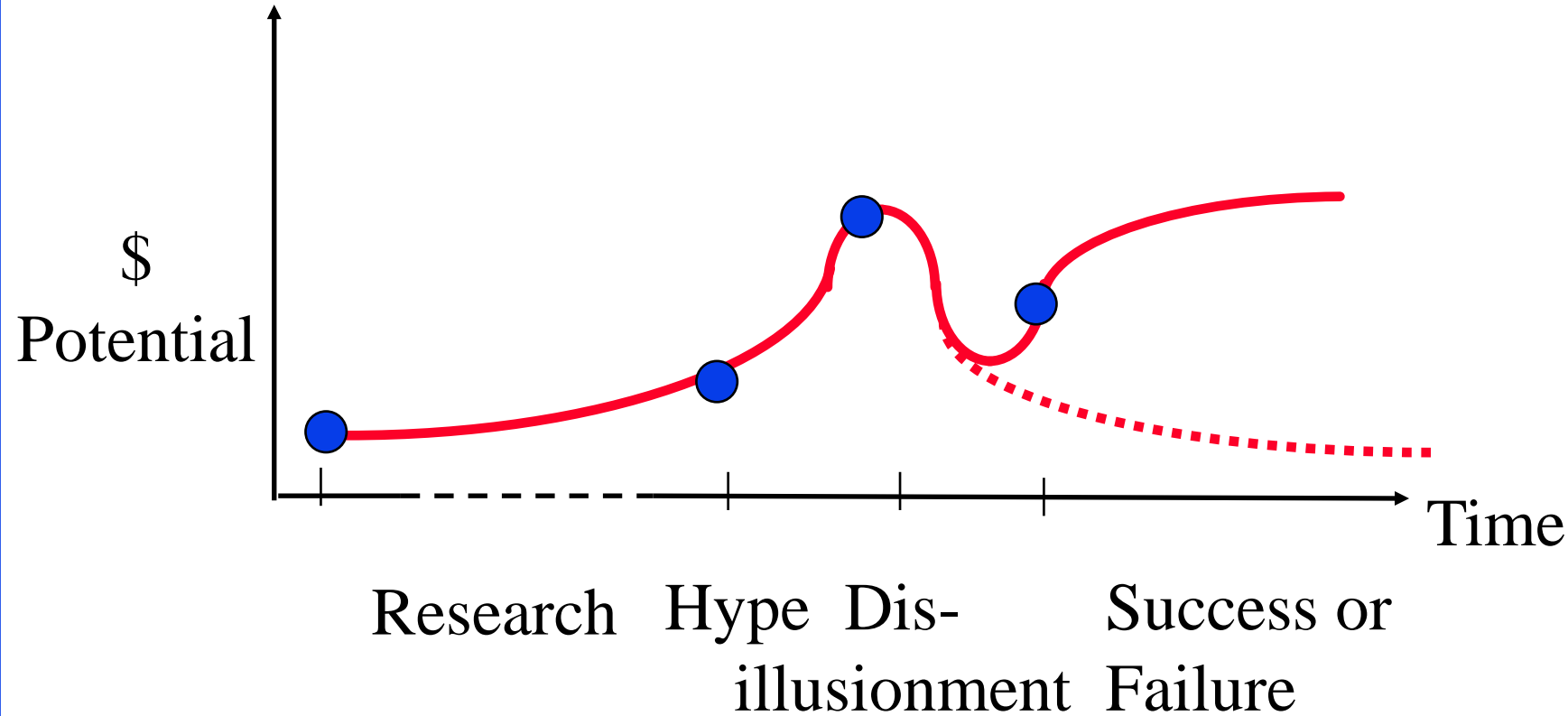*Yes, years are not important.*

Wireless: History

1880
1900
1920
1940
1960
1980
2000

❑ 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

❑ What is the biggest differences between mobile and cellular? If cellular means divide the world into several pieces to receive the signal, does the mobile mean the signal will not be divided?
Cellular is just one way to provide mobile services. Walkie-Talkie is mobile but not cellular.

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Life Cycle of Technologies

$ Potential

Research   Hype   Dis-illusionment   Success or Failure

Time

Student Questions

❑ What do "hype" and "dis" mean in this figure?
Hype = What the world believes. It May or may not be valid.
Disillusionment = Finding that some belief isn't true.

❑ In your experience, what are some factors that move successful technologies out of the "Valley of Disillusionment" and lead to mass adoption.
This is a Billion Dollar question. The number of factors that affect success is too many and too varied. Picture phone is an example.

❑ Do start-ups take over during the research or the hype phase?
Start-ups begin on the 2nd dot from the left and get sold on the 3rd.

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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

- Can you please explain how smart antennas work?

It will be explained briefly in Modules 3 and 4.

Recent Wireless Innovations

- **5G**: Beyond 4G. 2020. 100X LTE
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Student Questions

- For Wi-Fi direct, will the point-to-point direct links between buildings be a form of ad hoc wireless?

  Wi-Fi Direct = Access point built-in, e.g., in printers and other server devices, including smartphones (for screen sharing).

- What frequency range can cognitive radios operate in so far?

  Television frequencies are where they are most required.

Recent Wireless Innovations

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Student Questions

- If "bit cost" is already so low, what do we need 6G for? What current/potential network-based applications are bottlenecked by 5G?

The costs are lower than before but lower is always better. Applications will be discussed during the 6G lecture.

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Recent Wireless Innovations

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Student Questions

- The slide mentions 5G as 'Beyond 4G' with capabilities like 100X LTE. Could you elaborate on what specific technological advancements allow 5G to achieve this leap in performance compared to 4G?
- *OFDMA to be covered in LTE-5G lectures.*

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
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Student Questions

- You said in the recording that 'there is no difference between E&M waves and sound' but isn't that not true?

Sound is not electromagnetic.

- Since cell phones communicate through cell towers, does the internal smart antenna beam towards the cell tower?

It is easier to beam tower antenna than to beam the phone antenna. They both try.

Recent Wireless Innovations

- **5G**: Beyond 4G. 2020. 100X LTE
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Student Questions

❖ Here it is said that 802.11ac: 500Mbps-1 Gbps Wi-Fi. However, Slide 2-16 states that 802.11ac Wave 2 has a peak rate of 6 Gbps compared to Wave 1's 1.3 Gbps. Additionally, in Module 6, the speed is listed as 6.9333 Gbps. Are these values all correct based on real-world situations?

This slide has been corrected. These are all nominal bit rates, not throughput.

❖ Which of those wireless innovations are we expected to know during the exam?

The ones that have been covered in other slides in detail.

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2-6f

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

- I had never heard of the smaller cells before. Do they boost the cell tower's signal, or are they connected to the service another way?

Small cells are now everywhere. Particularly inside shopping malls. Work with a wireless or wired connection to the core network.

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

Student Questions

- From a power standpoint, is it more (or less) efficient to have one regular tower versus an equivalent number of micro, pico, and femto cells?

I am not sure but I think smaller towers may be more power efficient.

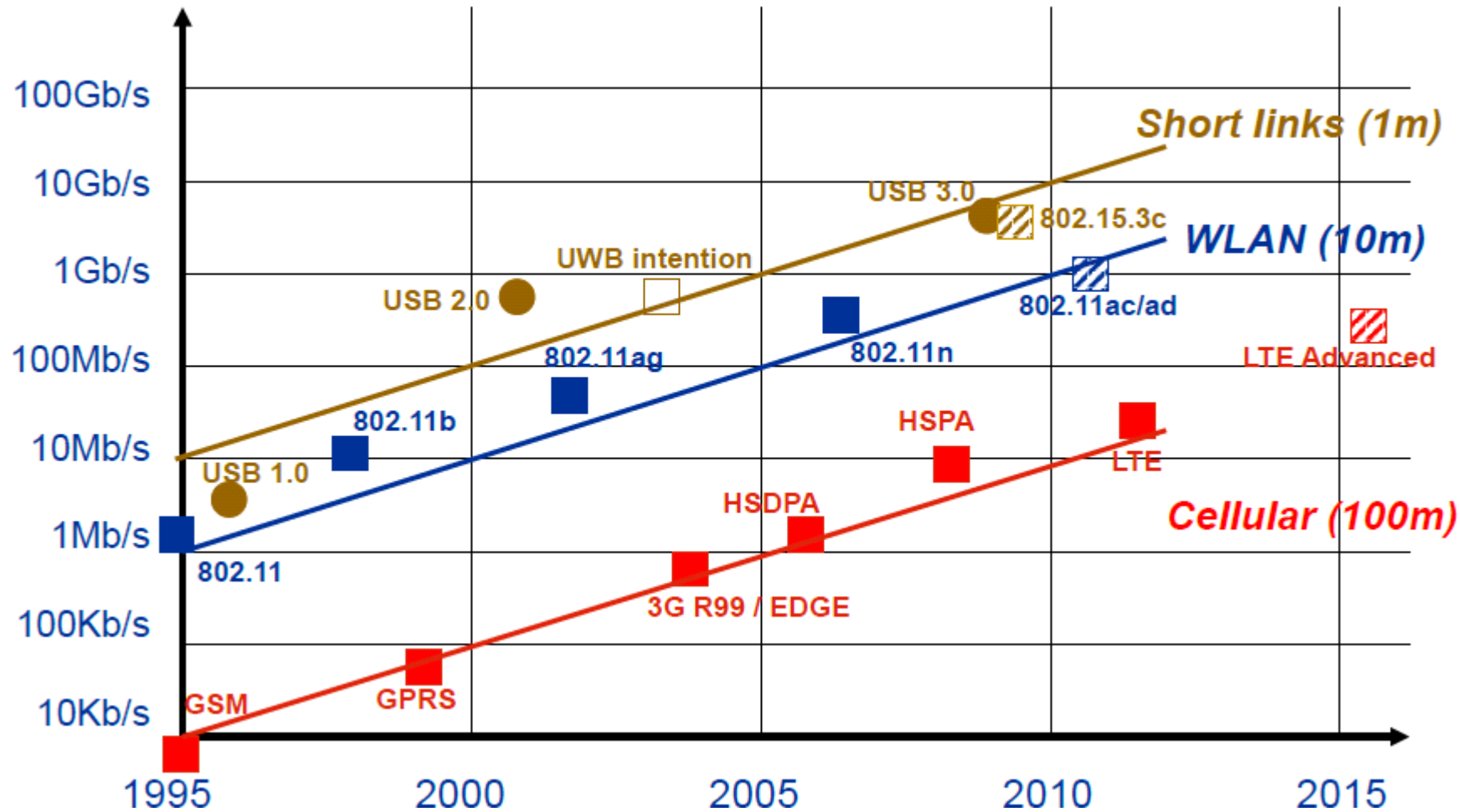- Would it be possible to have micro/pico/femto cells that remain in a low power mode until they receive a signal?

Yes, this is done.

Wireless Innovations (Cont)

- **Small Cells**: 10m to 2km. Includes Micro cells, Pico cells, Femto cells

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- **802.11r**: Fast Base Station transition

- **LTE**: Long-Term Evolution. 3.9G

Student Questions

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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
http://www.cse.wustl.edu/~jain/cse574-24/

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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

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Student Questions

❑ 51% of devices will be M2M, the Internet of things, non-computer. Does that mean 49% of devices will be a computer?

51% M2M = IoT
49% Non-IoT

❑ To clarify: a mobile phone within the Internet of Things?

Thing = Not a computer.
Smartphones are now computers. No longer IoT.

❑ The prediction was made that in 2021 there would be 27.1 billion devices (3.5 per person). Do we know how close that prediction was now that it is 2022?

See homework 2.

Global Mobile Data Forecast [Cisco]

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https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.pdf

Student Questions

- ❑ Why is 17% mobile IP traffic equal to 46% CAGR?
  CAGR = Cumulative annual growth rate = Slope
- ❑ Is data like this required in the exam?
  Not specific numbers but directions, yes.
- ❑ M2M doesn't precisely equal IoT?
  M2M = A machine serving another machine
  IoT = "Things" connected to the Internet
- ❖ Is there any device that could be IoT but not M2M?
  Digital devices controlled via the Internet are IoT, e.g., modern thermostats. M2M is the subset that serves another machine, e.g., Industrial controllers.

- ❑ Do we need to remember all of these numbers and specific names for exam?
  No. You need to remember the direction.

Global Mobile Data Forecast [Cisco]

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https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.pdf

Student Questions

❑ We could call all mobile phones, such as iPhones, as M2M, right? Like there is the "Airdrop" function in each iPhone.

No. M2M operates without human involvement.

❑ Can you please explain what IP traffic is? Does BitTorrent count as IP traffic?

Any traffic that uses IP network layer is IP traffic. BitTorrent uses IP.

Global Mobile Data Forecast [Cisco]

1. Global IP Traffic: 3X in 5 years (2016-2021)
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http://www.cse.wustl.edu/~jain/cse574-24/

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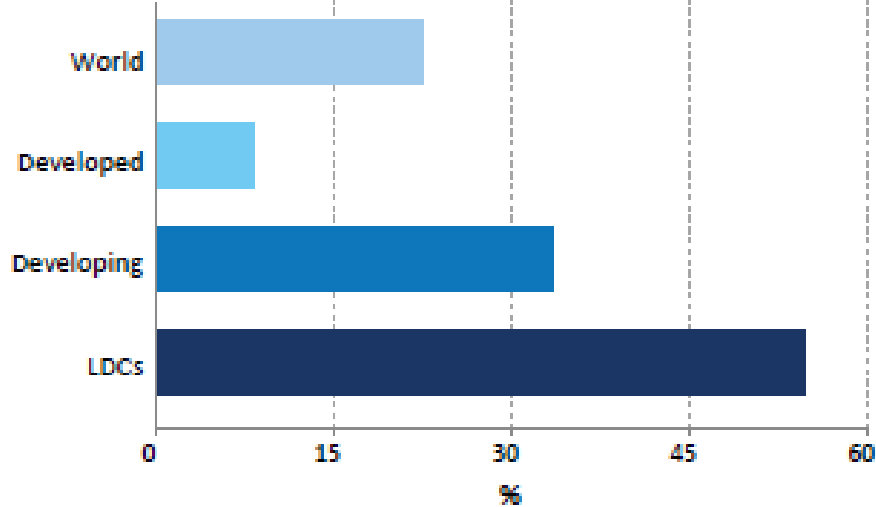
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2-9d

Student Questions

❑ Why is IP video taking so much of all IP traffic?

In general, video is highly resource consuming than other media such as data or voice.
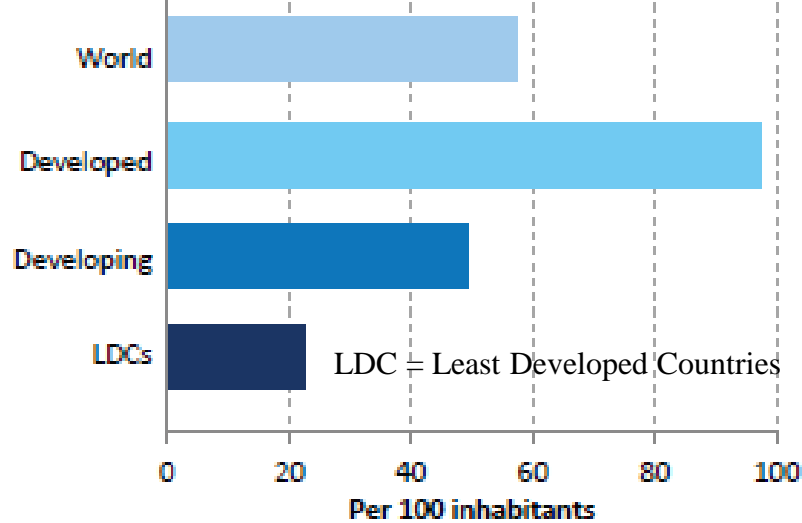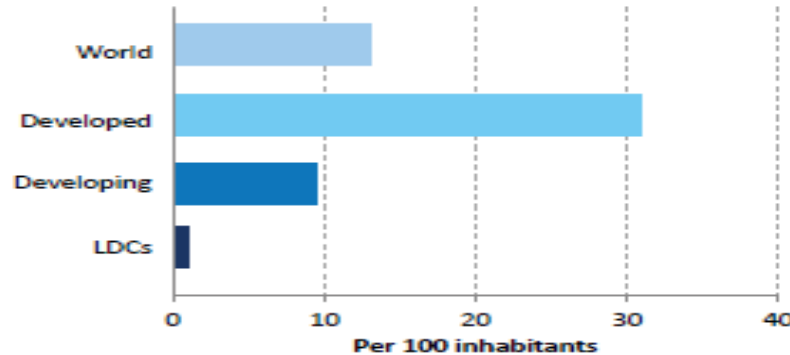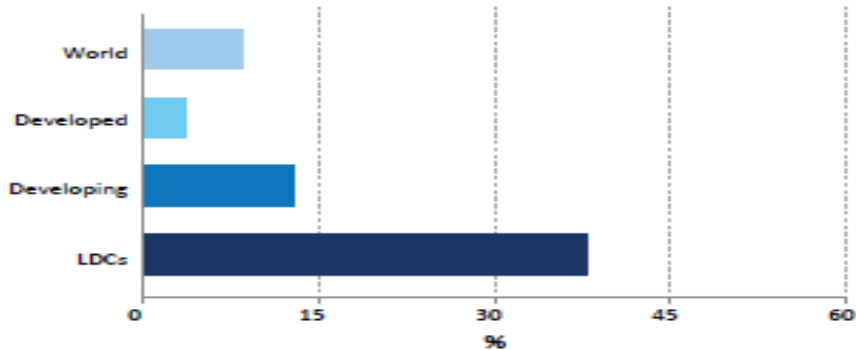
Broadband Subscriptions

Mobile:

Compound Annual Growth Rate (2012-17)

Subscriptions 2017

LDC = Least Developed Countries

Fixed:

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

❑ Are the devices fixed on the ceilings and providing wireless internet access considered Fixed Wireless Access?

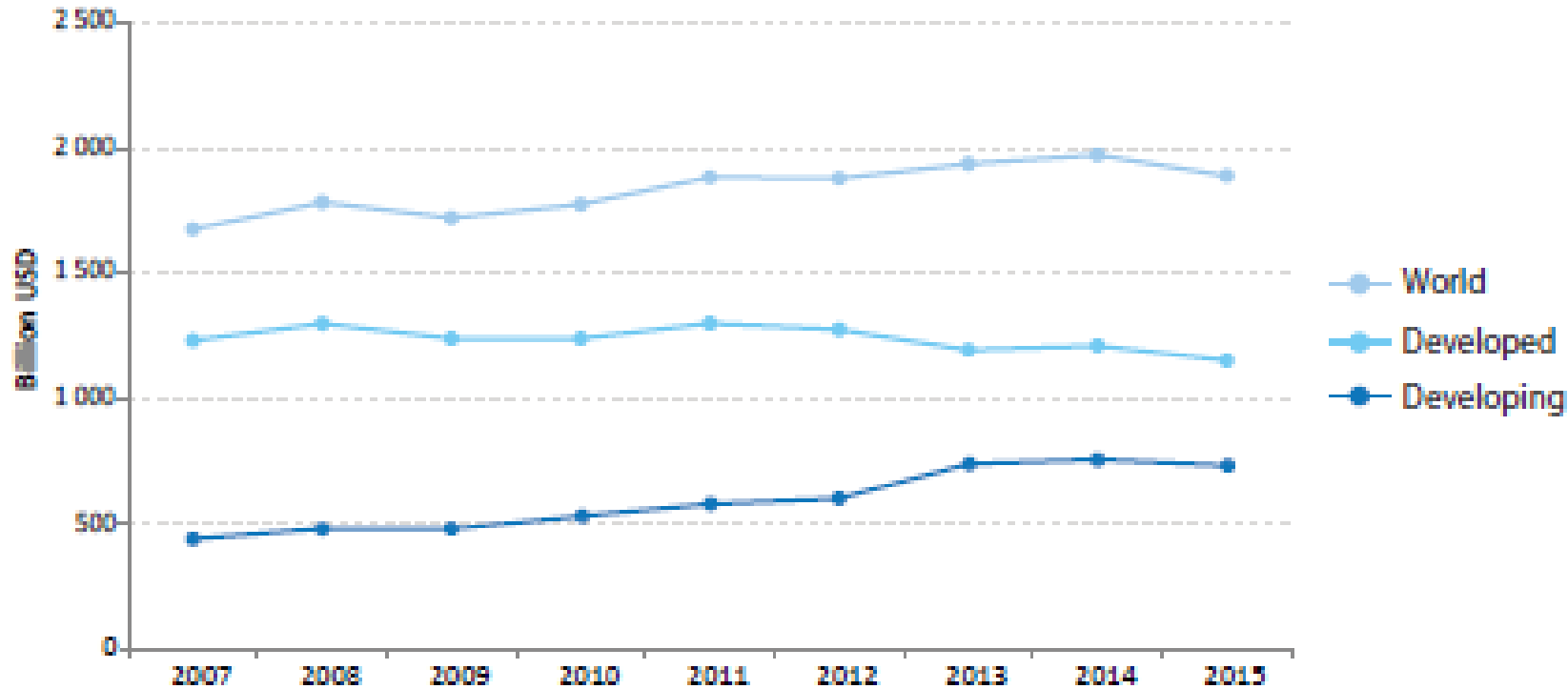*No. Fixed refers to the user not the provider.*

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

Mobile vs. Fixed

Legend:
- Mobile-cellular telephone subscriptions
- Mobile broadband subscriptions
- Individuals using the Internet
- Fixed-broadband subscriptions
- Population covered by 2G mobile-cellular network
- Households with Internet

❑ 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
http://www.cse.wustl.edu/~jain/cse574-24/

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.
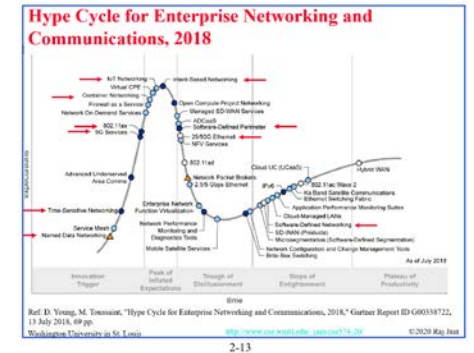
Hype Cycle for Enterprise Networking and Communications, 2018
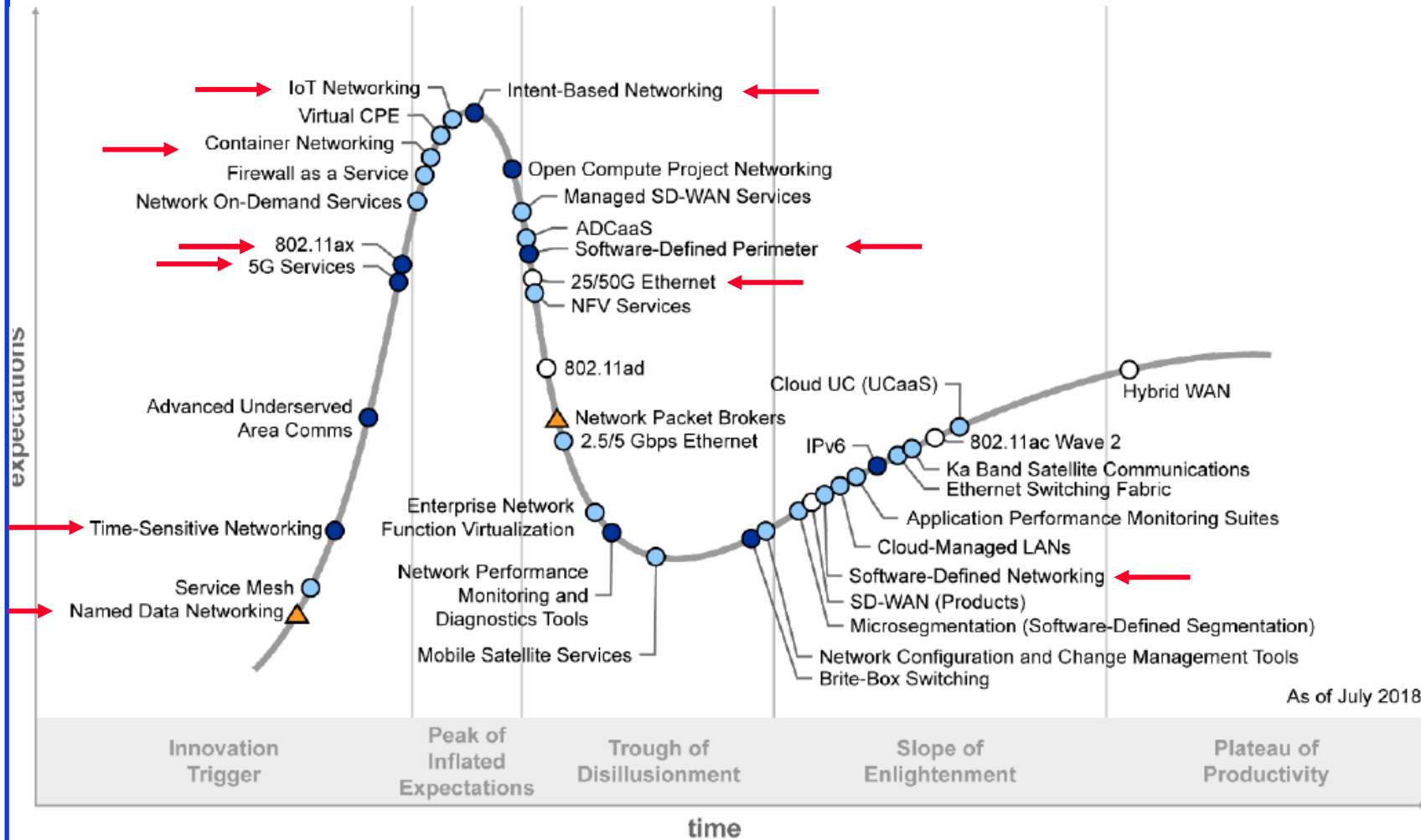
Student Questions

❑ When does the Hype Cycle get updated and released?

Yearly as selected by Gartner, depending upon the industry interest.

❑ You said "we" want to stay on the top-right side of this cycle. Could you please define "we"? I assume that as researchers, we should focus on the research phase.

B.E. = Right
M.E. = Middle
Ph.D. = Left
Startups = Middle
VCs = Top Left
In this graduate course:
  We = You + me
In my lab: We = Ph.D. students

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

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Hype Cycle for Enterprise Networking and Communications, 2018
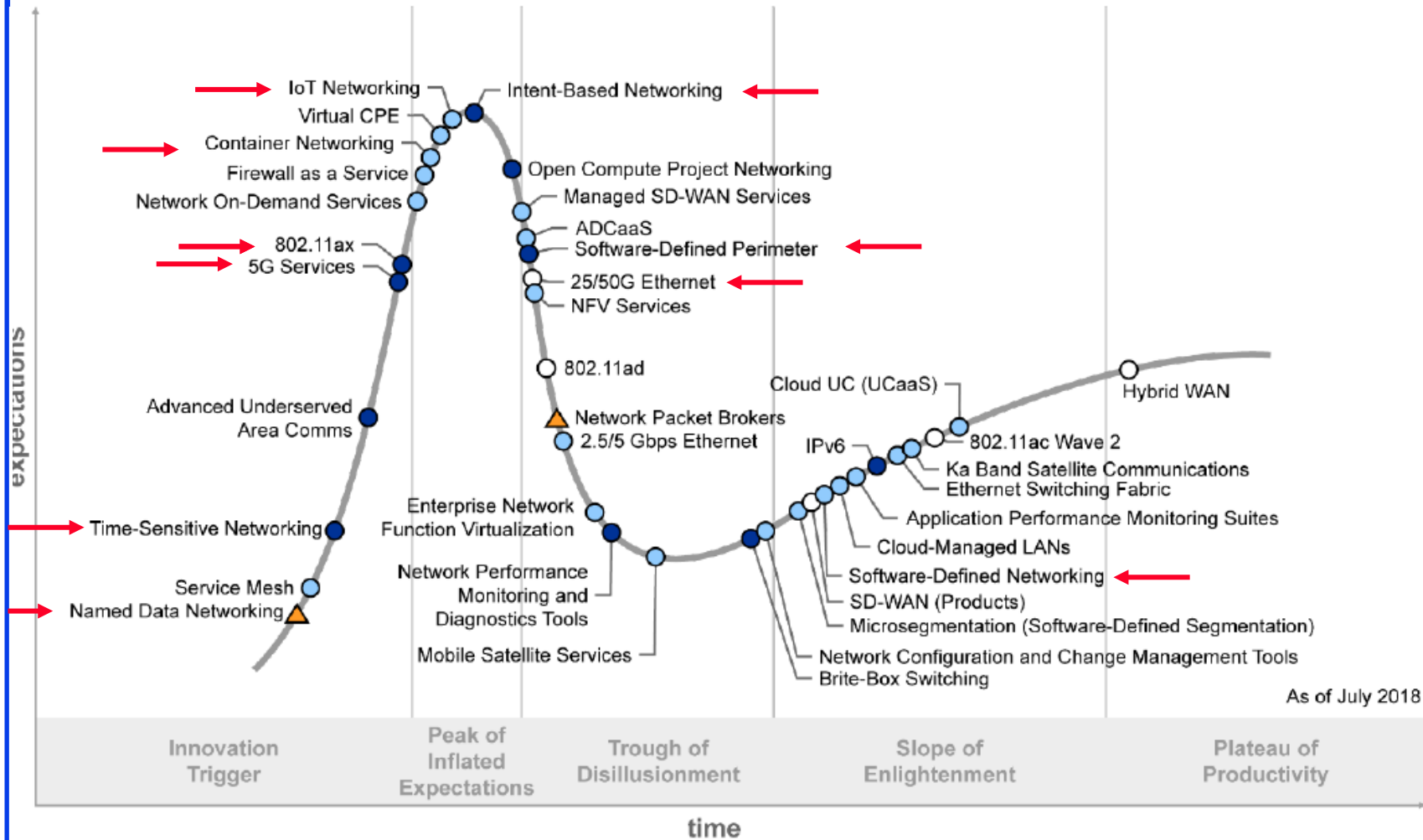
Student Questions

❑ What does the current Hype Cycle look like?
See slides 2-27 onwards.

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

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.

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Student Questions

❑ The service mesh is within a company, correct?

The extent of the mesh is not limited to the company. It could be a single system with many services, e.g., a computer with many services or a data center with many servers.

❑ Could you please explain software-defined networking (SDN) and network function virtualization (VNF) a little bit and the difference between the two? Are they related to Software Defined Perimeter?

There are five classes on SDN in CSE 473.
https://www.cse.wustl.edu/~jain/cse473-22/i_4nld.htm
VNF is covered in two lectures in CSE 570 (Recent Advances in Networking)
https://www.cse.wustl.edu/~jain/cse570-21/m_16nfv.htm
Software-defined perimeter is related to network security (CSE 571).
SDN = Central control of all network policies vs. going to program each device
NFV = Software implementation of network functions, e.g., routing, web service, etc. ⟹ Can share hardware.

Hype Cycle of Connected Homes 2018

Low Power Wide Area
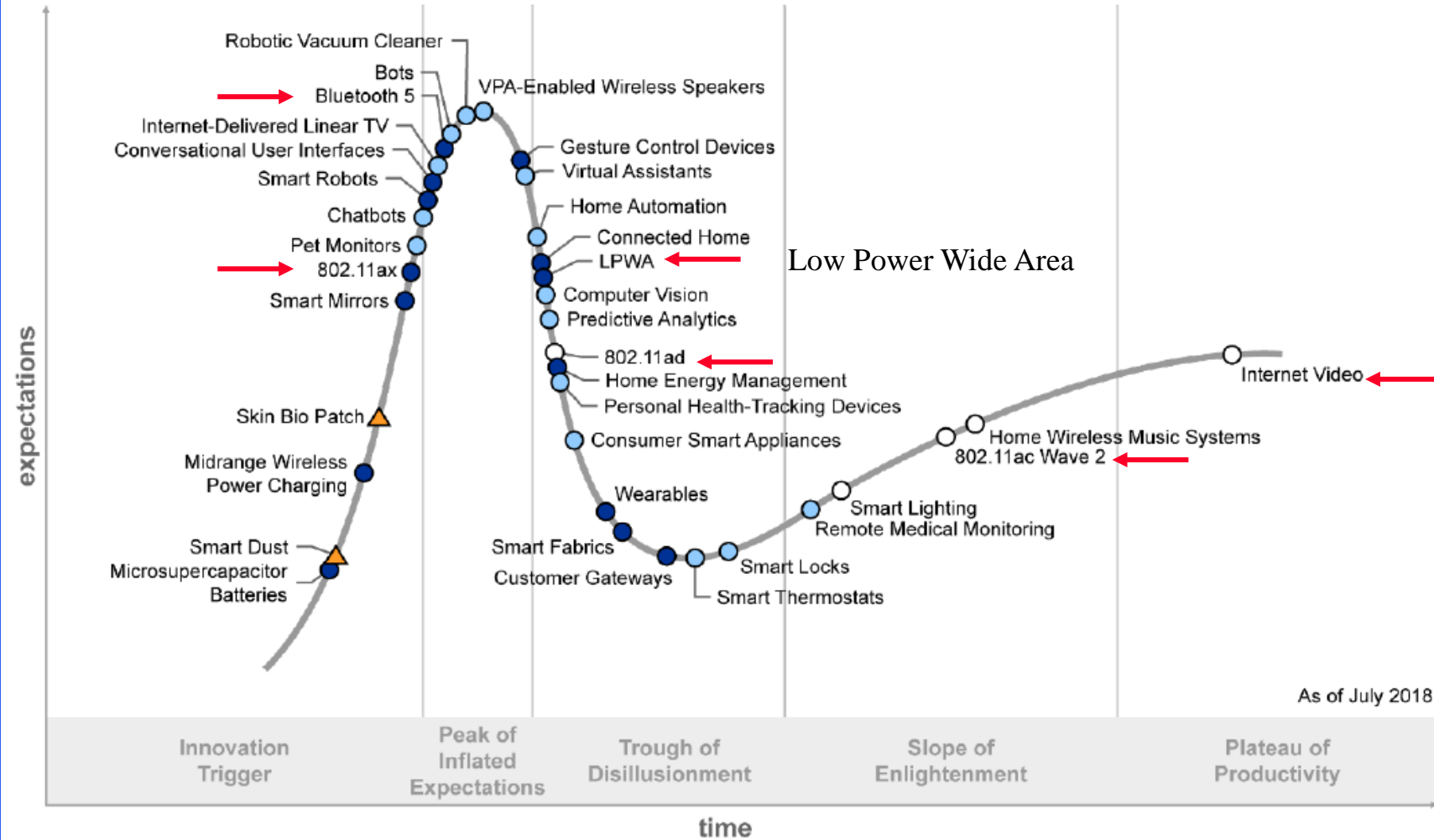
Student Questions

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

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

Student Questions

❑ Of these new wireless technologies you listed, what exists now, and what is still being developed?

Bolded ones are still not here.

❑ Mobile Satellite Service seems so slow. What would be its potential application in the real world?

In the middle of a desert. In the open sea. Non-inhabited areas.

❑ Could mobile satellite services (such as Starlink) replace cellular data 4G/5G services?

They complement each other. Use Starlink if there is no 4G/5G, e.g., 10 miles from the main highway.

❖ Do we need to remember details in this slide?

Yes, when they are covered in detail later. E.g., Wi-Fi 6.

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.
❑ Do many wide-area IoT devices today use cellular as phone companies predicted? What percentage of devices are wide-area?
Very few because of tariffs.
❑ What is the main characteristic(s) of IoT networking? Low power consumption?
Limited compute + Limited power + Large #
Discussed in detail in the IoT module of this course.
Also, in CSE 473 and CSE 570.

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 2024

Student Questions

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Summary: Wireless and Mobile Trends

Student Questions
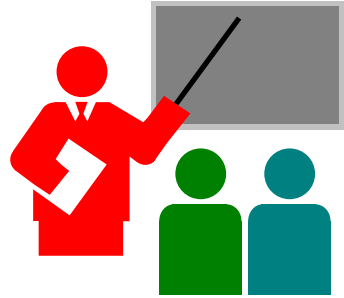
1. Wi-Fi has grown worldwide in just 15 years

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

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Reading List (2024)

❑ Cisco, "2024 Global Networking Trends Report," https://www.cisco.com/c/en/us/solutions/executive-perspectives/annual-internet-report/index.html

❑ ITU, "Measuring digital development: Facts and figures 2023," 2023, 38 pp., https://www.itu.int/hub/publication/d-ind-ict_mdd-2023-1/

Student Questions

❑Will material from the reading list end up on the exam?

Yes.

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References: Gartner Reports (2024)

Gartner Reports are available to WUSTL Students via
https://one.wustl.edu/task/all/gartner

❑ Mike Leibovitz, Andrew Lerner, Karen Brown, Nauman Raja, "Hype Cycle for Enterprise Networking, 2024," 17 June 2024 - ID G00809572, 108 pp.

❑ Peter Kjeldsen, Peter Liu, Sylvain Fabre, "Hype Cycle for Emerging Technologies in the Communications Industry, 2024," 30 July 2024 - ID G00814724, 86 pp.

❑ Kosei Takiishi, Enrique Hernandez-Valencia, "Hype Cycle for Network Infrastructure in the Communications Industry, 2024," 24 July 2024 - ID G00813099, 124 pp.

❑ N. Jones, "Hype Cycle for Wireless Technologies, 2024," 5 Aug 2024, Gartner ID G00812267, 106 pp.

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

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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

Scan This to Download These Slides

Thank You

Raj Jain

http://rajjain.com

Student Questions

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
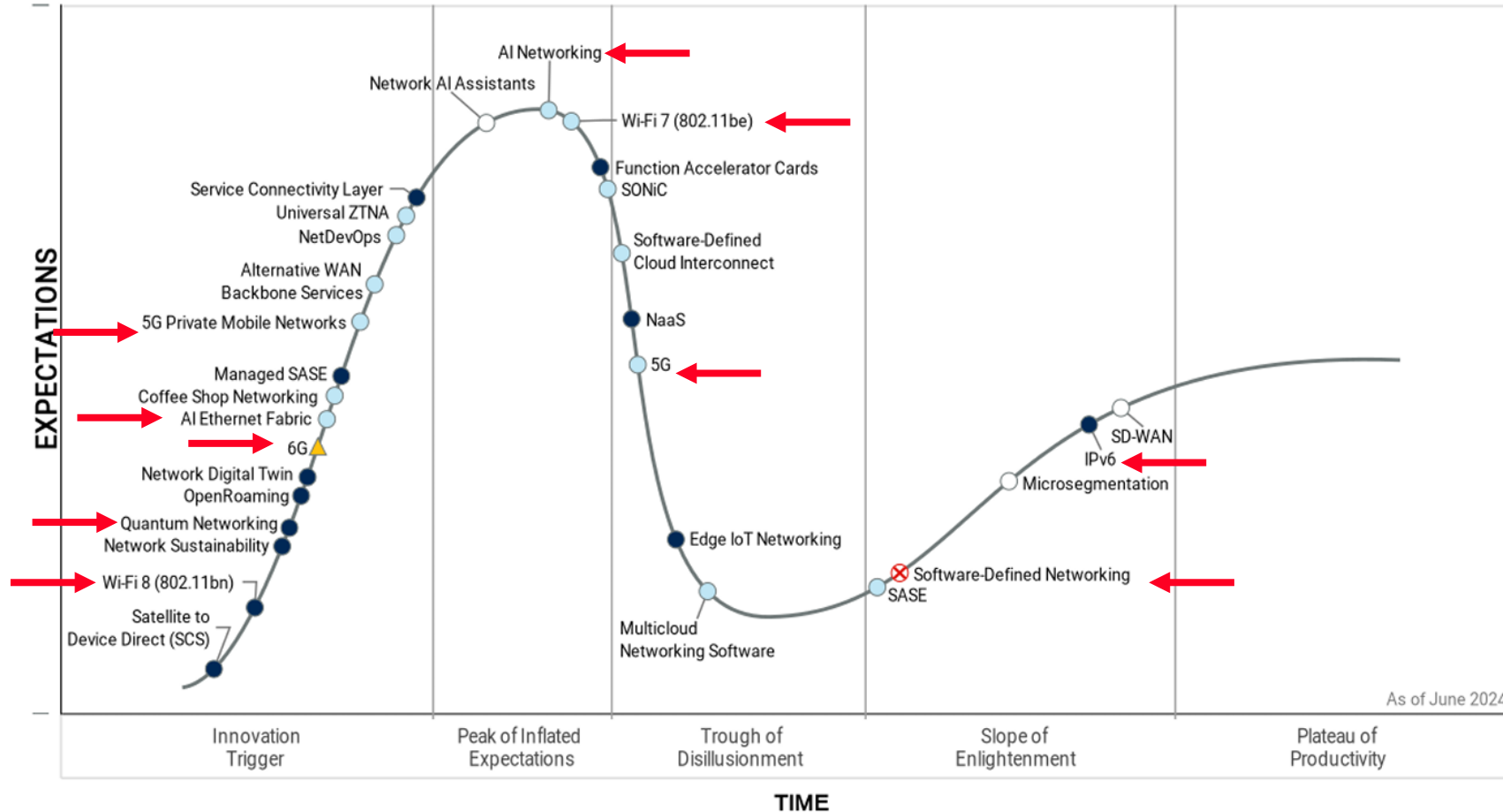
Recent Advances in Networking (Spring 2013),

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

Student Questions

Hype Cycle for Enterprise Networking, 2024

Student Questions

Ref: Mike Leibovitz, Andrew Lerner, Karen Brown, Nauman Raja, "Hype Cycle for Enterprise Networking, 2024," 17 June 2024 - ID G00809572, 108 pp.

What's New in Enterprise Networking

- Enterprise = Company, e.g., Waslmart, Target, WashU, …

- **AI Ethernet Fabric**: Datacenter Etherenet Switches designed to handle AI workload communication requirements, such as, packet loss, high-speed bursting

- **5G Private Mobile Networks**: 5G for factories

- **Network AI assistants**: AI for network FCAPS (Fault detection, Capacity Planning, Accounting, Performance management, and Security)

- **Quantum Networking**: Datacenters with quantum computers.

Student Questions

Hype Cycle for Emerging Technologies in the Communications Industry, 2024
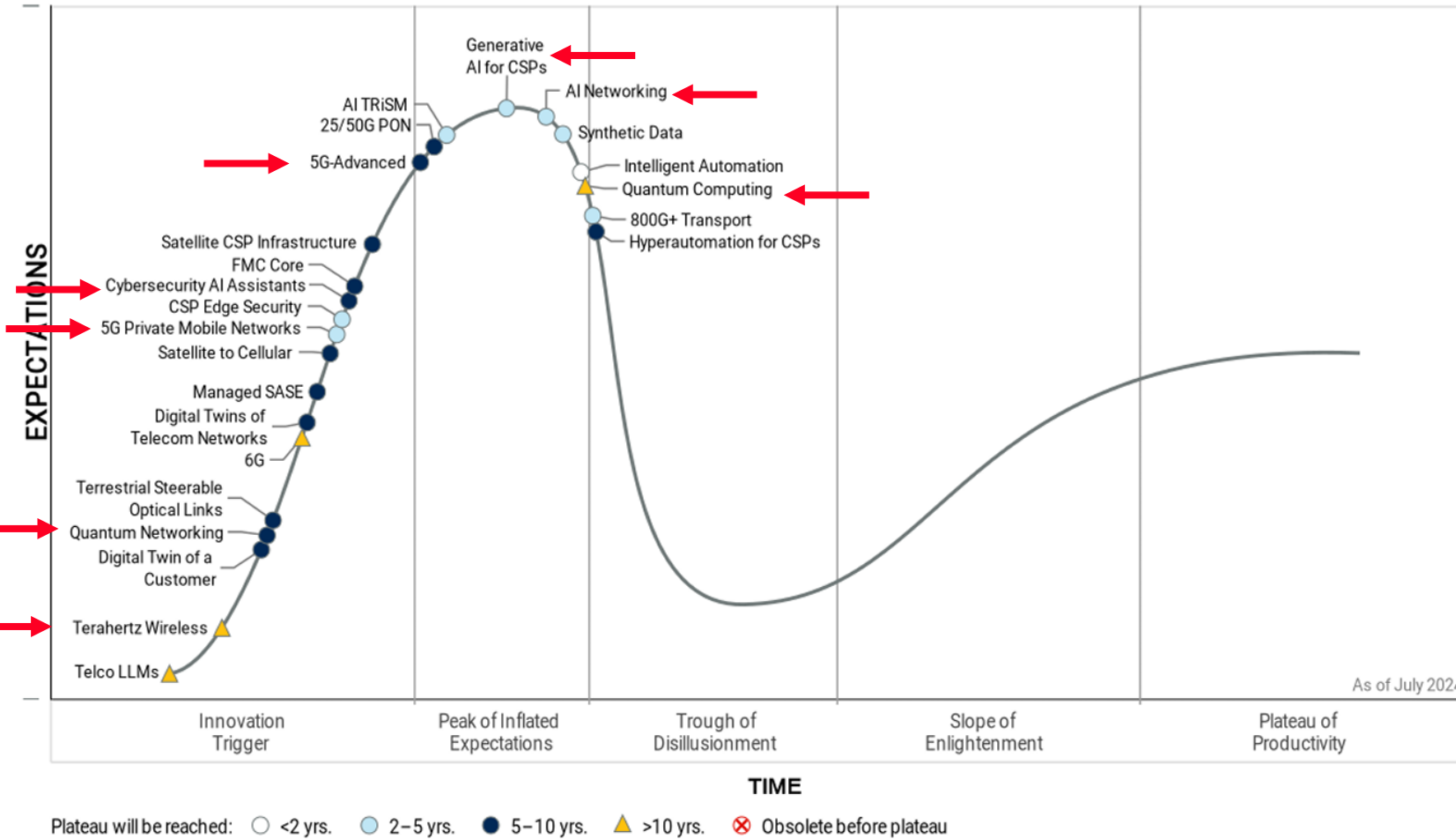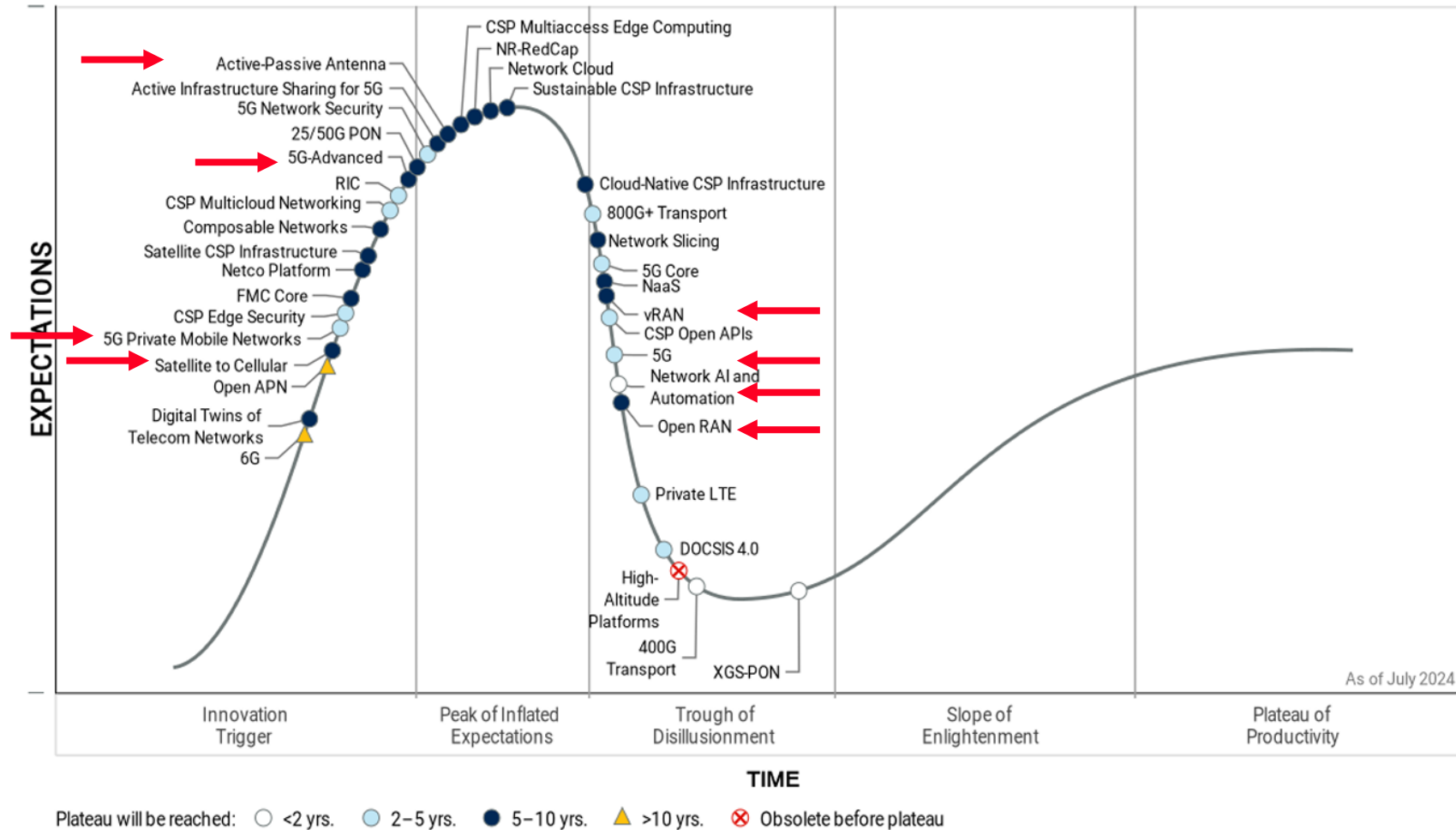

Student Questions

Ref: Peter Kjeldsen, Peter Liu, Sylvain Fabre, "Hype Cycle for Emerging Technologies in the Communications Industry, 2024," 30 July 2024 - ID G00814724, 86 pp.

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What's New in Communications Industry

❑ Communications Industry = Telephone Companies, e.g., AT&T, T-Mobile, Verizon, …

❑ **Generative AI**: AI capable of generating text, images, videos and other data

❑ **5G Advanced**: Between 5G Standardized in 2020, 5G Advanced (2025), 6G (2030)

❑ **TeraHertz Wireless**: Using 0.3 to 10 THz. Moving up from 2.5 and 5.8 GHz in WiFi 5, to 28 GHz (mmWave), and then to THz for massive data rates

Student Questions

Hype Cycle for Network Infrastructure in the Communications Industry, 2024

Student Questions

Ref: Kosei Takiishi, Enrique Hernandez-Valencia, "Hype Cycle for Network Infrastructure in the Communications Industry, 2024," 24 July 2024 - ID G00813099, 124 pp.

Washington University in St. Louis

http://www.cse.wustl.edu/~jain/cse574-24/

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What's New in Infrastructure

❏ Infrastructure = Field hardware, such as base stations and their interconnections

❏ **Open RAN**: Standardized Radio Access Network (RAN). All CSP can use the same hardware = >Economies of scale

❏ **vRAN**: Virtual Radio Access Network. Using Clouds for many base station operations

❏ **Active-Passive Antenna**: Passive Antenna do not have amplifiers (used in older networks). Active antenna have amplifiers and require power (used in 5G onwords). Active-Passive combines both in one box

❏ **Satellite-to-Cellular**: Using satellite backbone for cell networks

Student Questions

Hype Cycle for Wireless Technologies, 2024

Ref: N. Jones, "Hype Cycle for Wireless Technologies, 2024," 5 Aug 2024, Gartner ID G00812267, 106 pp.

Student Questions

What's New in Wireless Technologies

- **Lora**: Long-Range wireless (for meter reading)
- **Bluetooth AoA/AoD**: Angle of arrival and angle of departure for precise positioning
- **Bluetooth Low Energy**: Bluetooth 5
- **Bluetooth Ambient Energy**: Bluetooth V5.1
- **Bluetooth Auracast**: Audio multicast
- **Bluetooth ESL**: Electronic Shelf Labels in stores
- **Backscatter Networking**: Use existing wireless signal to power
- **Ultrawideband**: Using very low power signals
- **Wi-Fi 6, 7, 8**
- See also previous slides for more.

Student Questions

Homework 2 (2024)

Based on the latest Cisco and ITU reports in the reading list, answer the following true/false statements: (Please answer on Canvas).

T F

a. ☐ ☐ Mobile broadband traffic is more than fixed broadband accounts
b. ☐ ☐ More than three-quarters of the world's population own a mobile phone.
c. ☐ ☐ A higher percent of women are using Internet than men.
d. ☐ ☐ There are more mobile cellular subscription than the world population.
e. ☐ ☐ Only 20% of the world population is now covered by 5G
f. ☐ ☐ Integrating networking and broder IT security is the number one concern for businesses.
g. ☐ ☐ AI enabled networking for predictive assurance is currently common in the industry.
h. ☐ ☐ Most companies plan to deploy private data center clusters for running AI workloads.
i. ☐ ☐ Selective and low power modes will help achieve sustainability
j. ☐ ☐ Upgrading wireless connectivity (Wi-Fi) is required for smart buildings.

Student Questions

❖ Why is "AI enabled networking or predictive assurance is currently common in the industry" false? According to the CISCO report, "a majority ... have begun adopting AI capabilities". Another stat says, "60% of respondents expect to have AI-enabled predictive automation in place ... within the next two years".

It is coming, but it is not here. AI-enabled networking for predictive assurance is currently not common in the industry.