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Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

CSU33031 – Computer Networks

Introduction

Stefan Weber

email: sweber@tcd.ie

Office: Lloyd 1.41

Overview

- Motivation
- Housekeeping
- Overview of Assignments

Motivation

2 use-cases

- Internet Architecture
  - Contrast between the textbook-version of the Internet

    Cloud-focussed Internet & Edge Networks

- Virtual Deployments
  - Docker, Kubernetes, etc

Mail from Recent Graduate

Hi Stefan,

I hope you received my submission and are enjoying the read!

Id like to share with you that I'm starting work as a Kubernetes Engineer at a German company largely due to the dissertation and the time I spent learning about Kubernetes.

Id like to thank you for guiding me along the way and giving me such a great topic to work on. My employer was impressed !

Hope you have a good start to your year. My close friend is starting the Future Networks Masters you put together and is looking forward to it.

Liebe Grüße,

HOST-HOST Communication, 1970

- Paul Barran, On Distributed Communication Networks, IEEE Transactions on Communication Systems, Volume 12, No. 1, March 1964
- Introduced Concepts of
  - Distributed Networks
  - Routing (hot-potato-routing)
  - Packet-Switching (message-block)
- Name worth mentioning: Bob Kahn

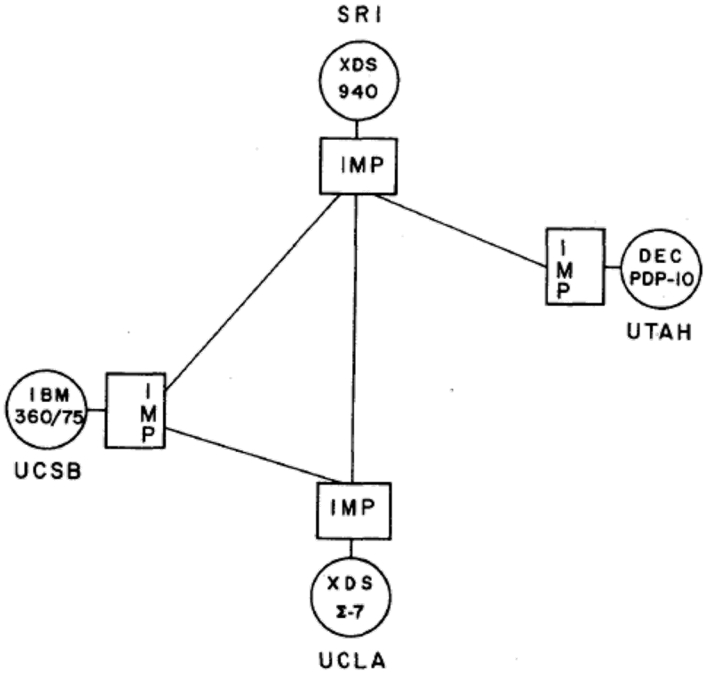
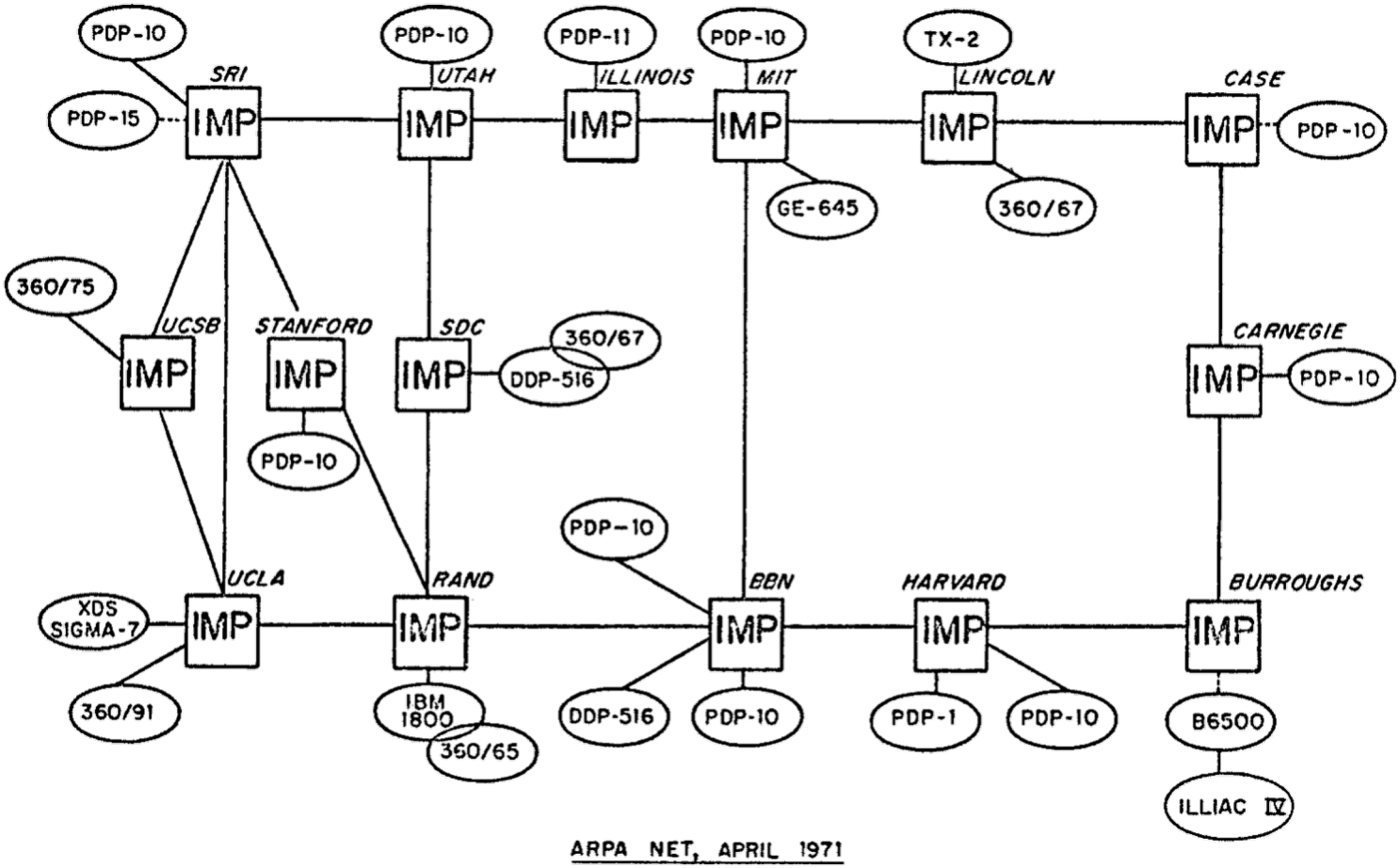


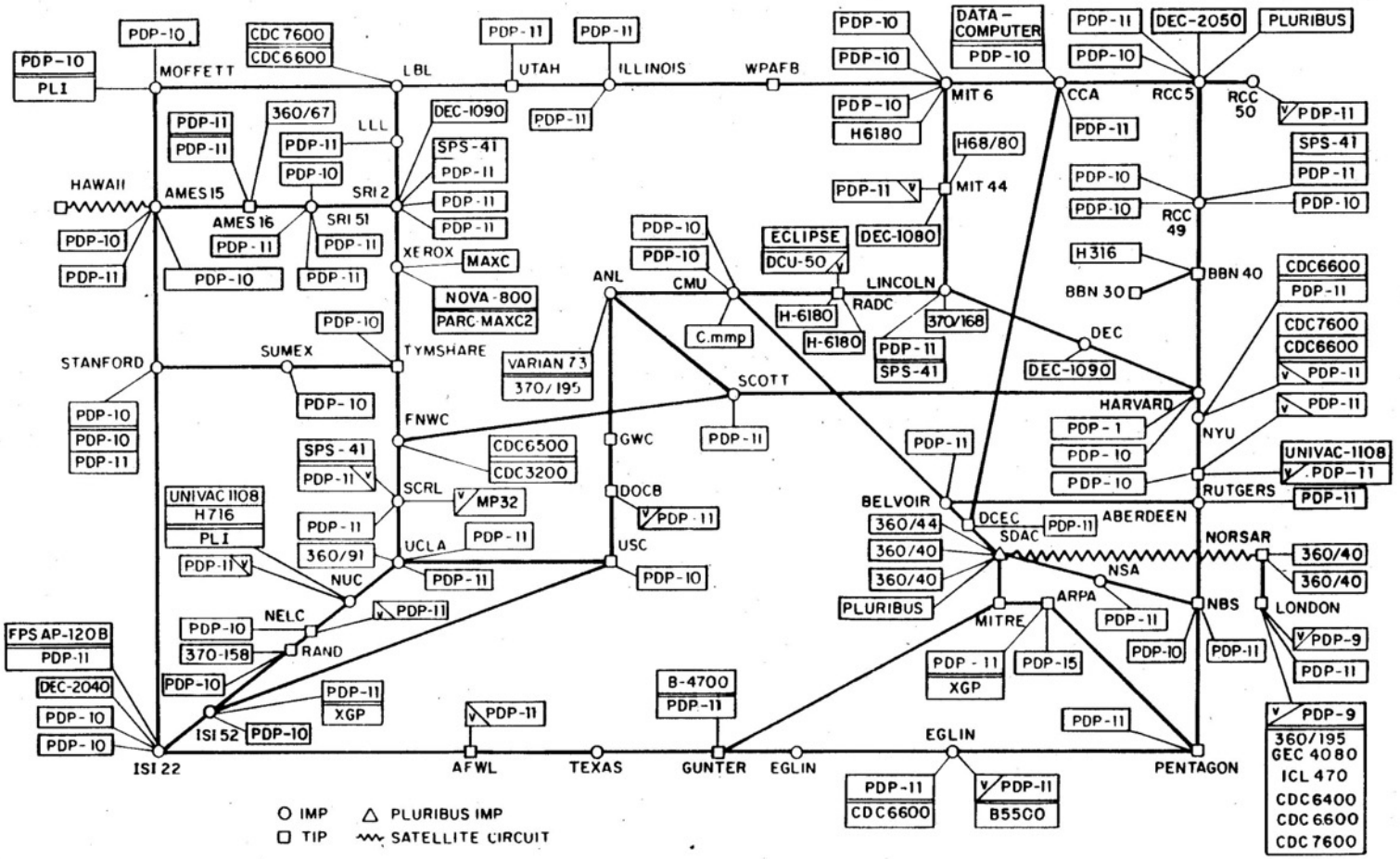
Figure 1—Initial network configuration

* C. Stephen Carr, Stephen D. Crocker, and Vinton G. Cerf, HOST-HOST Communication Protocol in the ARPA Network, Spring Joint Computer Conference, pages 589-597, Atlantic City, NJ, USA, May 1970

ARPANET 1971



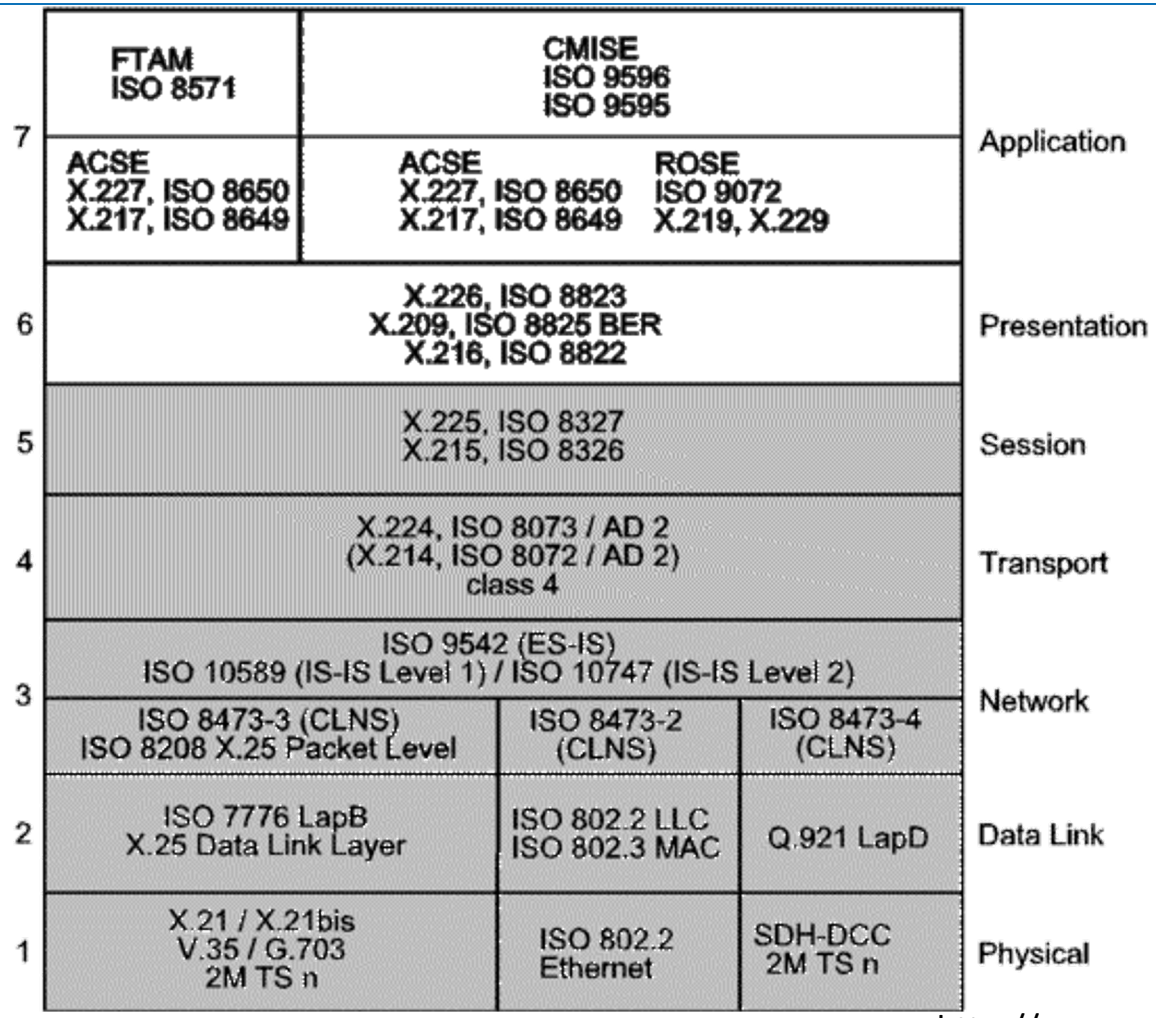
ARPANET 1977



(PLEASE NOTE THAT WHILE THIS MAP SHOWS THE HOST POPULATION OF THE NETWORK ACCORDING TO THE BEST INFORMATION OBTAINABLE, NO CLAIM CAN BE MADE FOR ITS ACCURACY)

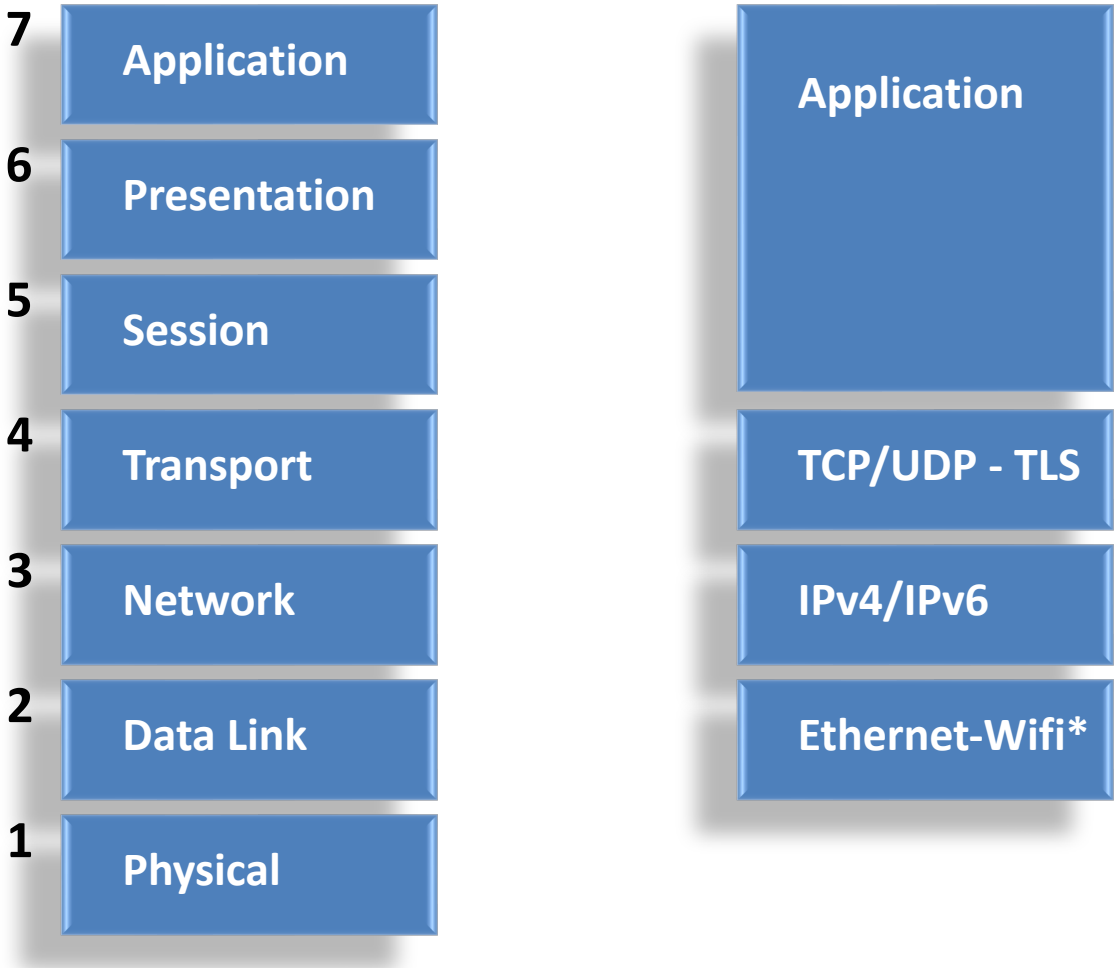
NAMES SHOWN ARE IMP NAMES, NOT (NECESSARILY) HOST NAMES

OSI Stack Populated with Protocols



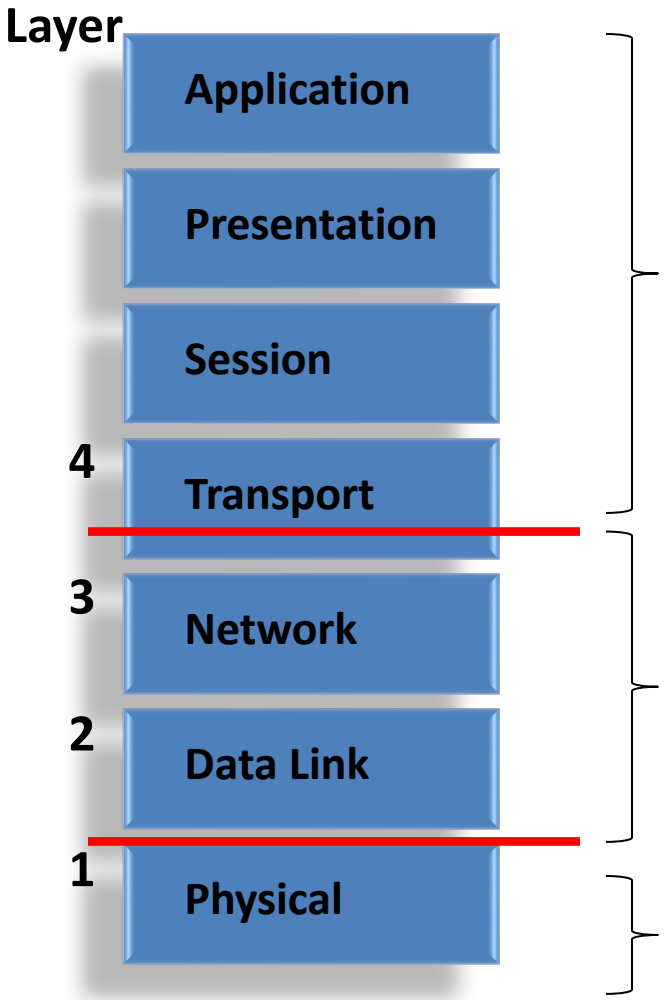
http://www.cellsoft.de/telecom/dcn.htm

OSI Stack vs TCP/IP



Wifi – spelled 802.11 b/g/n/ac/ax/??

CSU33031 in the OSI Stack

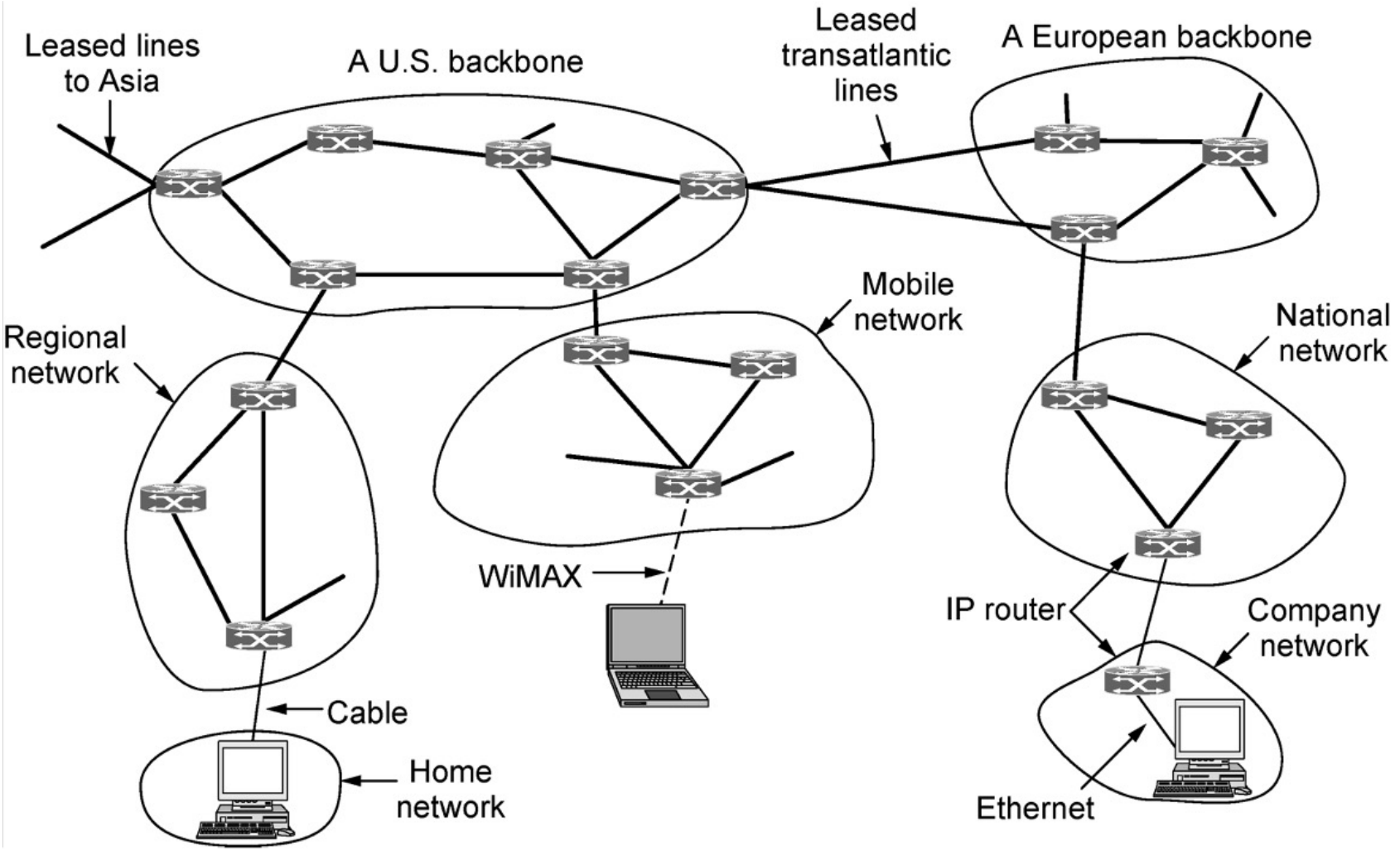


CSU33032 (Hitesh T.)
- Protocols
- Security/Cryptography

CSU33031
- Networks - multihop comms
- Comms over 1 link

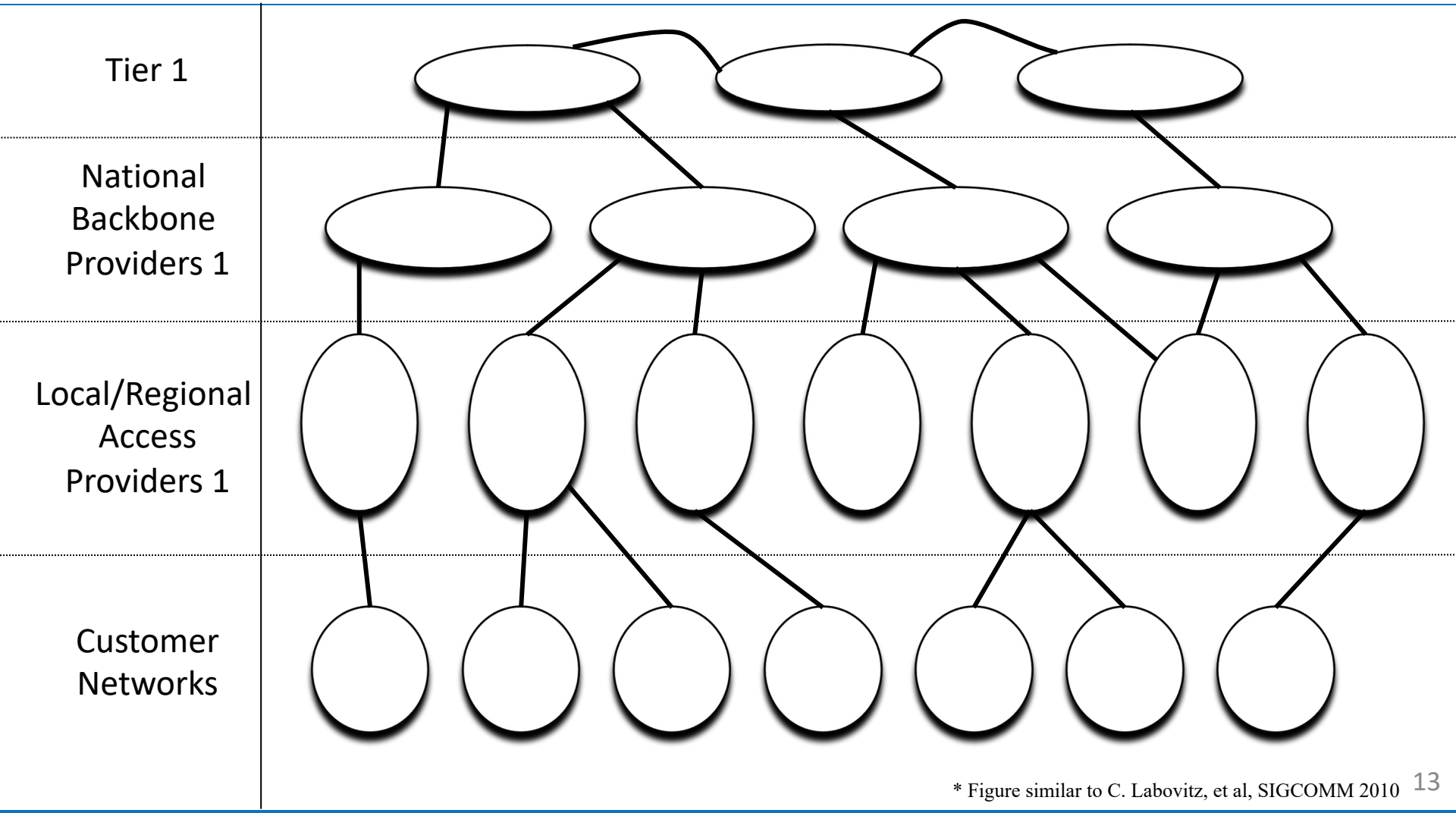
Collection of Networks

The Traditional Textbook View



* Figure is courtesy of A. Tanenbaum

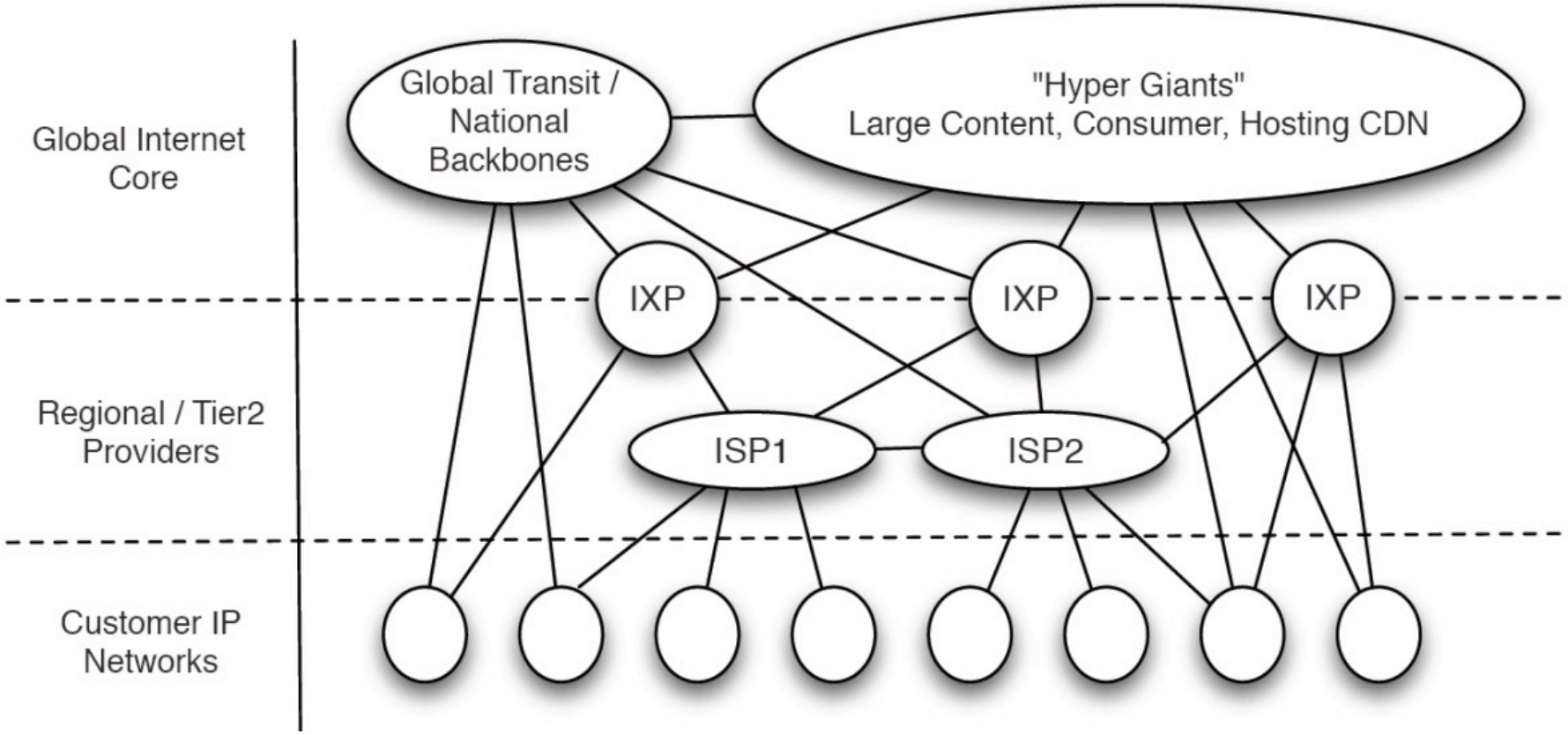
Traditional Logical Internet Topology



* Figure similar to C. Labovitz, et al, SIGCOMM 2010

‘Logical’ Internet Topology

(~2009-2010)



Consolidation of the Internet is real, Craig Labovitz

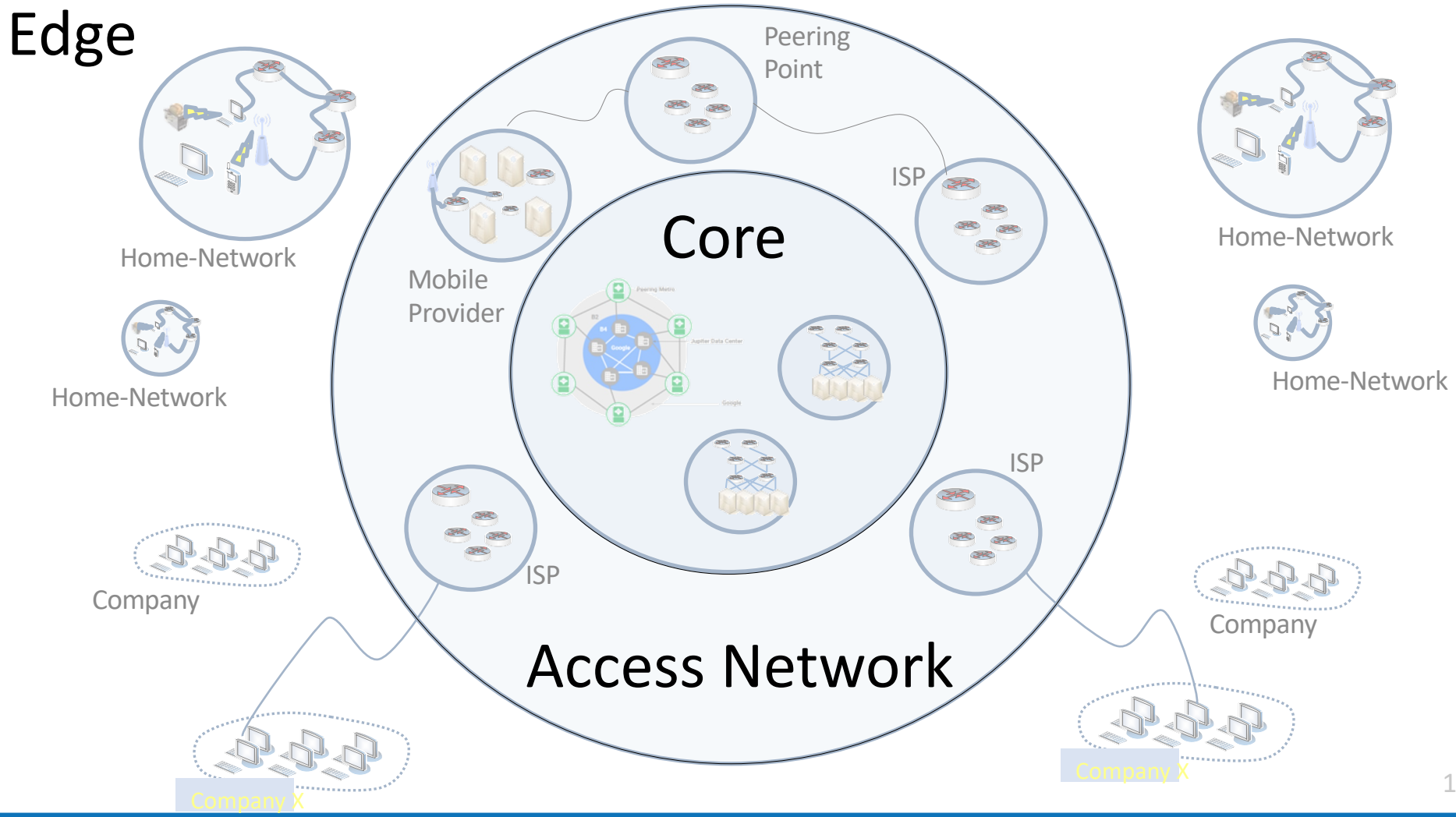
- 5-10 Companies – 50-70% of the network traffic
- Peering tends to dominate

https://www.youtube.com/watch?v=QK8cggBXF4U

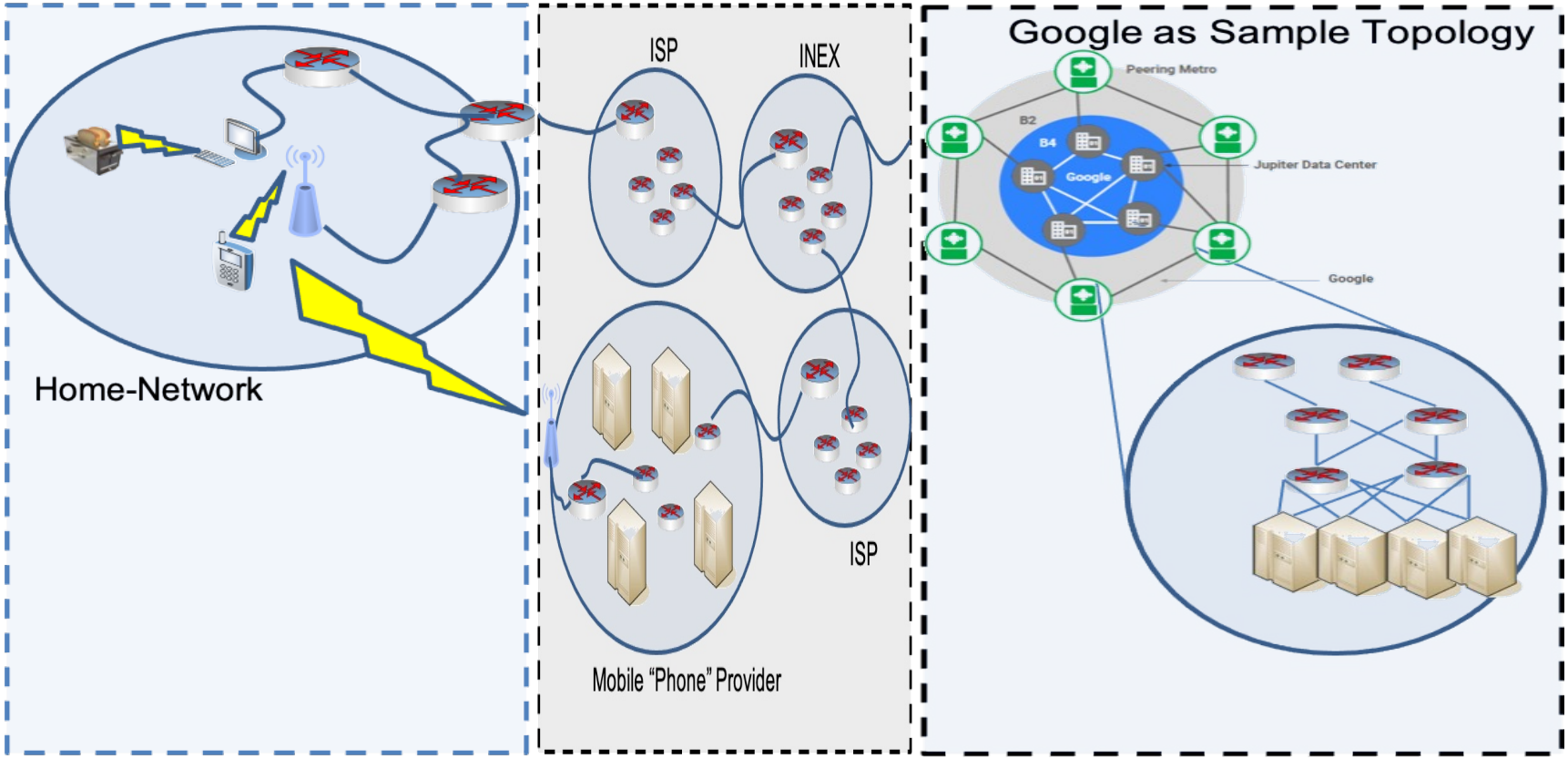
Feb 25 2019

* Figure is courtesy of C. Labovitz, et al, SIGCOMM 2010

Today's Internet

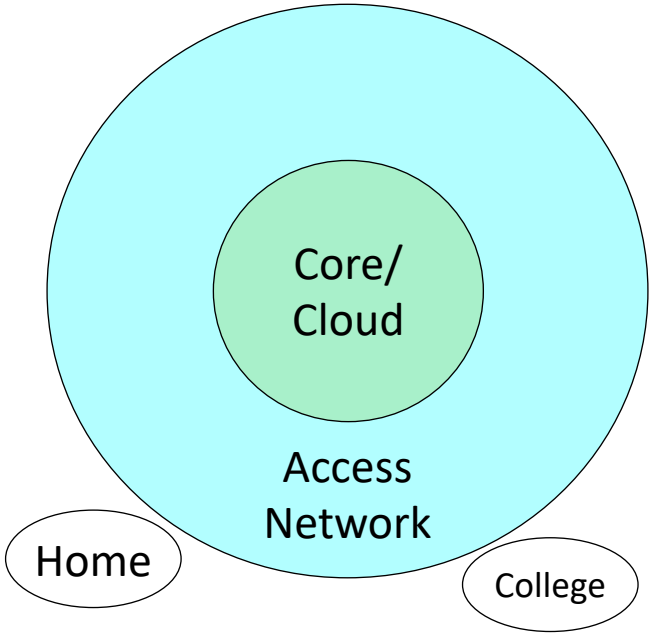


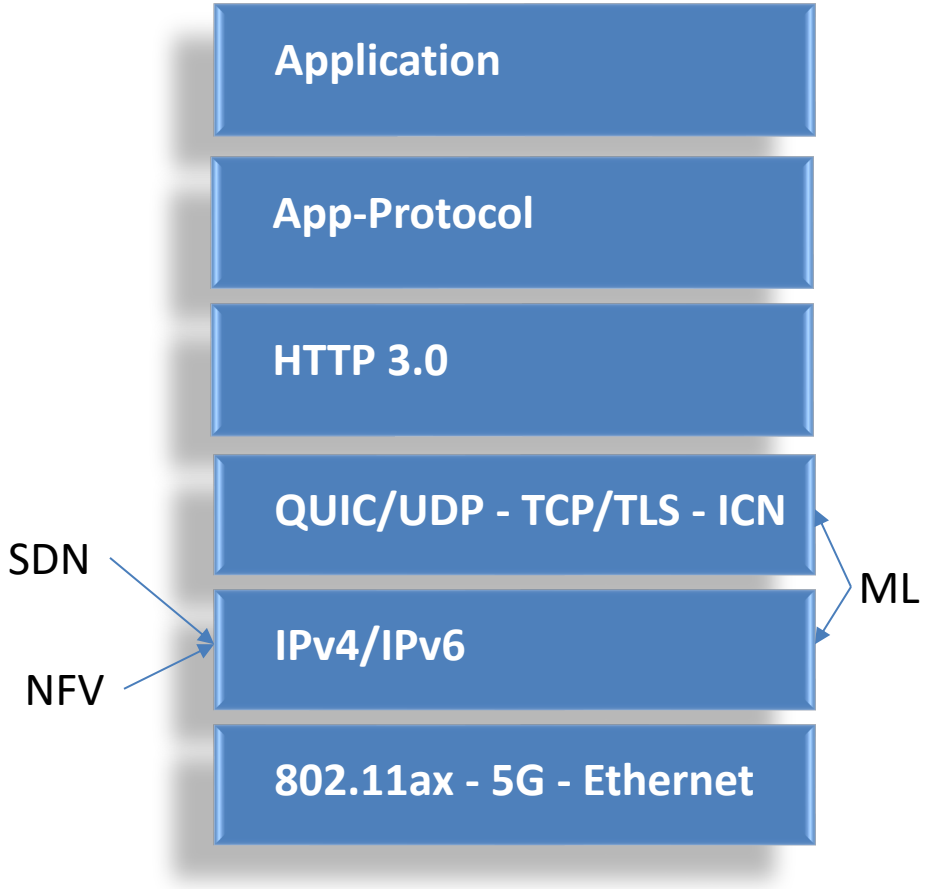
Today's Internet



Edge Networks	Access Networks	Core
IOT-land	Traditional Internet (getting smaller)	Cloud Providers

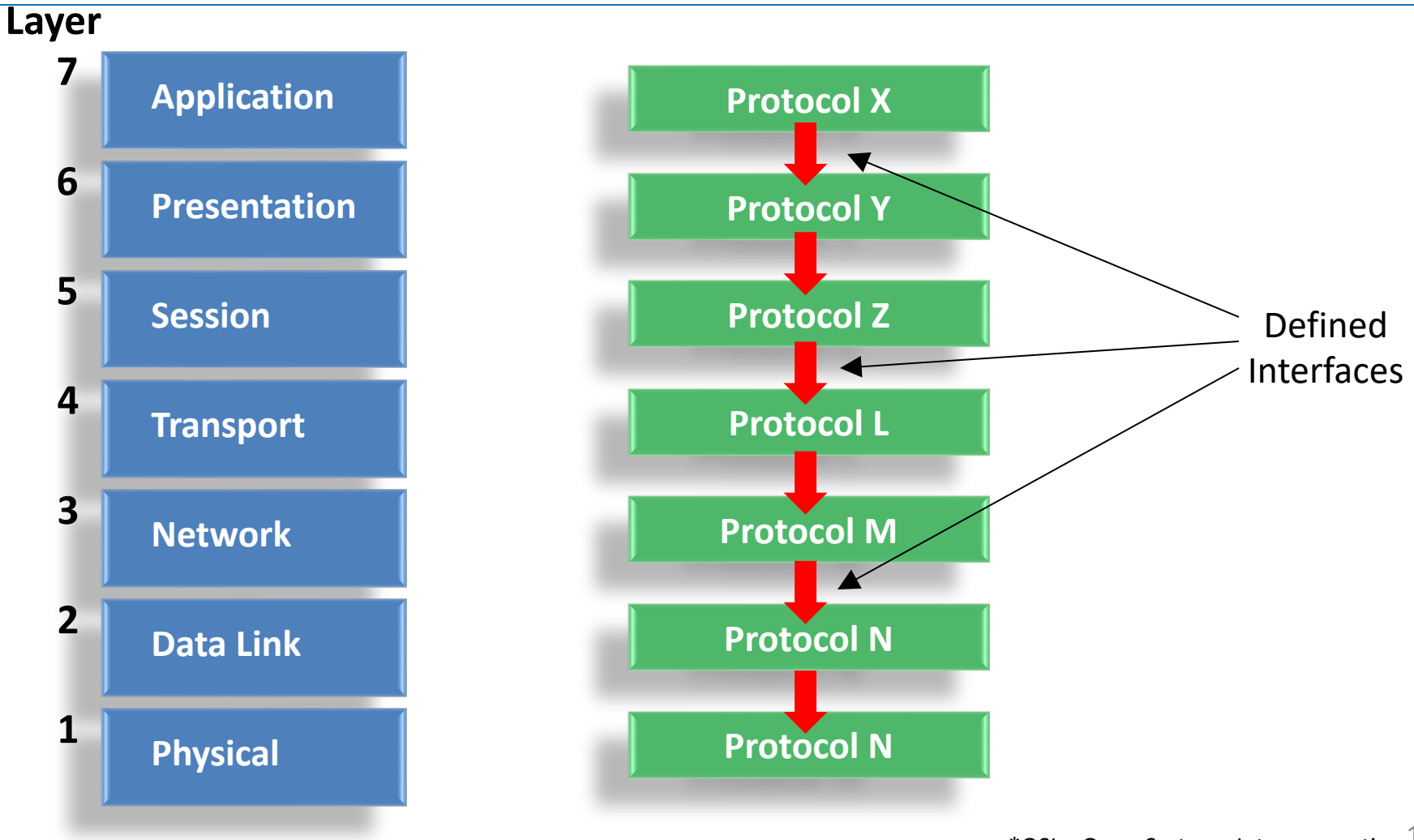
Today's View (Not in Textbooks)





Software-Defined Networking (SDN)
Network Function Virtualization (NFV)
Machine Learning (ML)

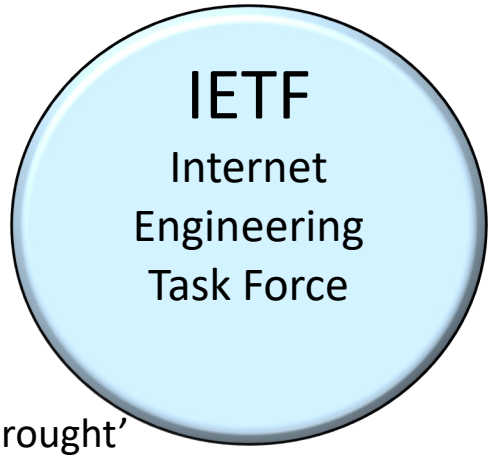
OSI* Stack



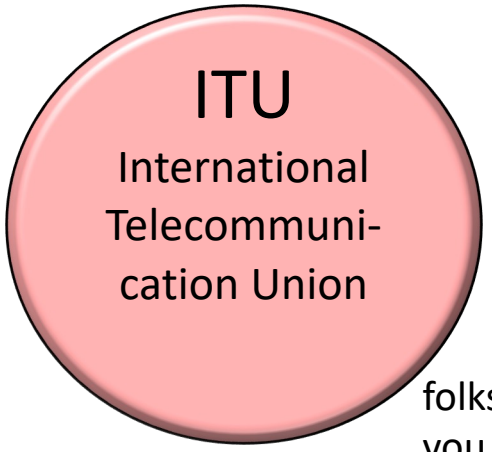
*OSI = Open Systems Interconnection

The Good, the Bad, and the Ugly

Also known as “your beloved standards bodies”



folks who ‘brought’ you the Internet i.e. RFCs, IANA, etc



folks who ‘brought’ you ATM, 4G, 5G, etc

folks who ‘brought’ you Wifi and Ethernet i.e. 802.11* and 802.3*, etc

ITU Diagram Example

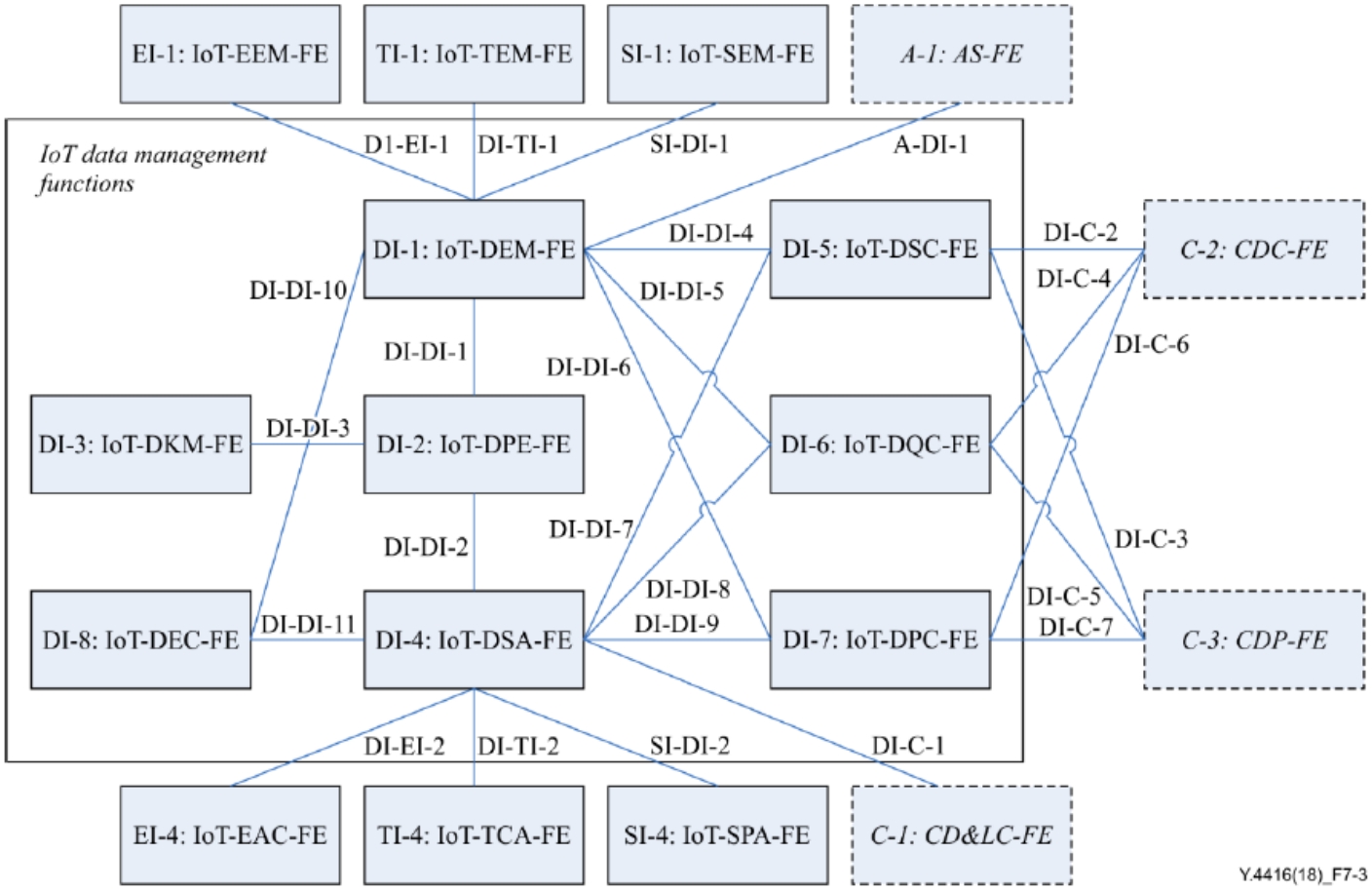
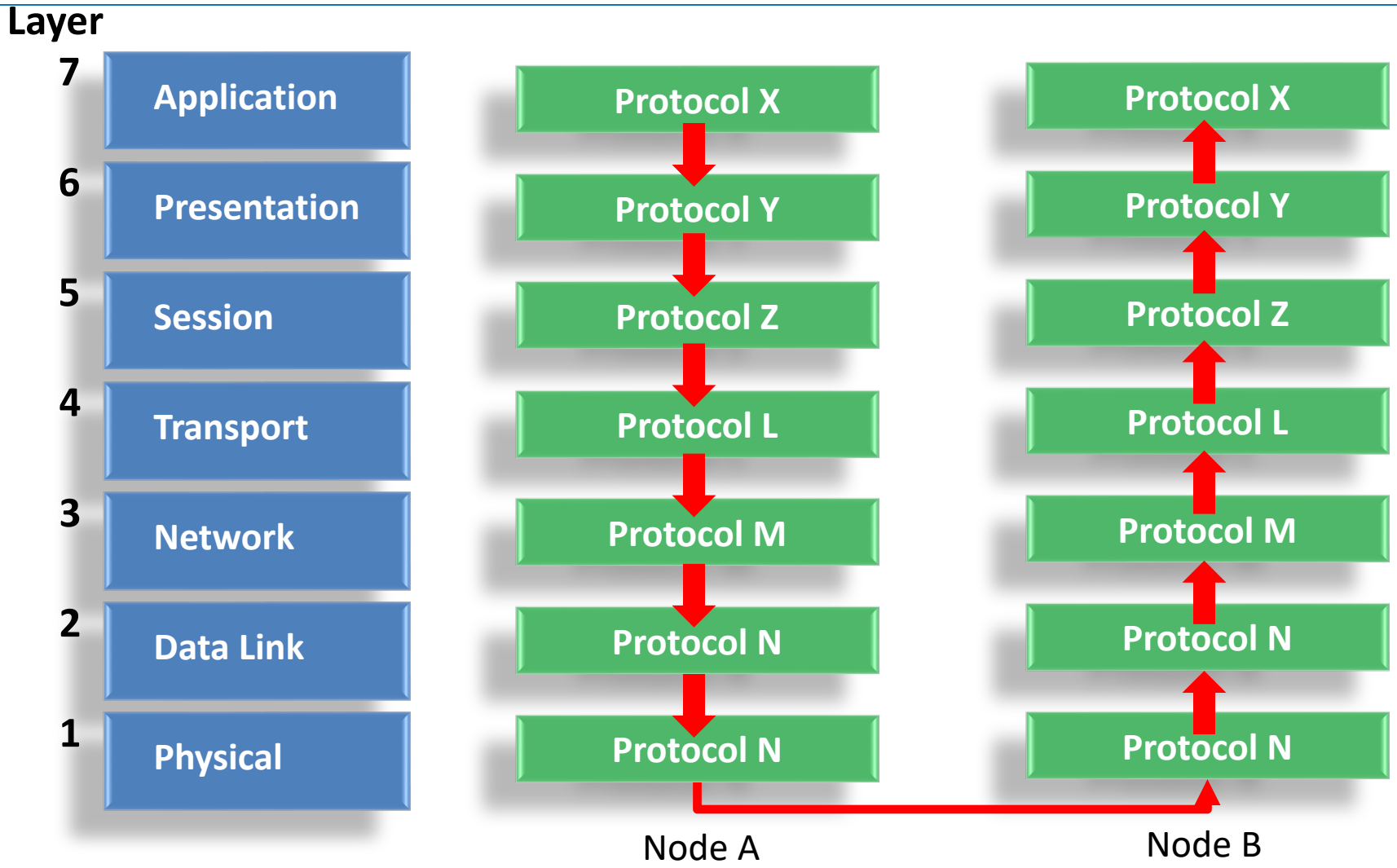


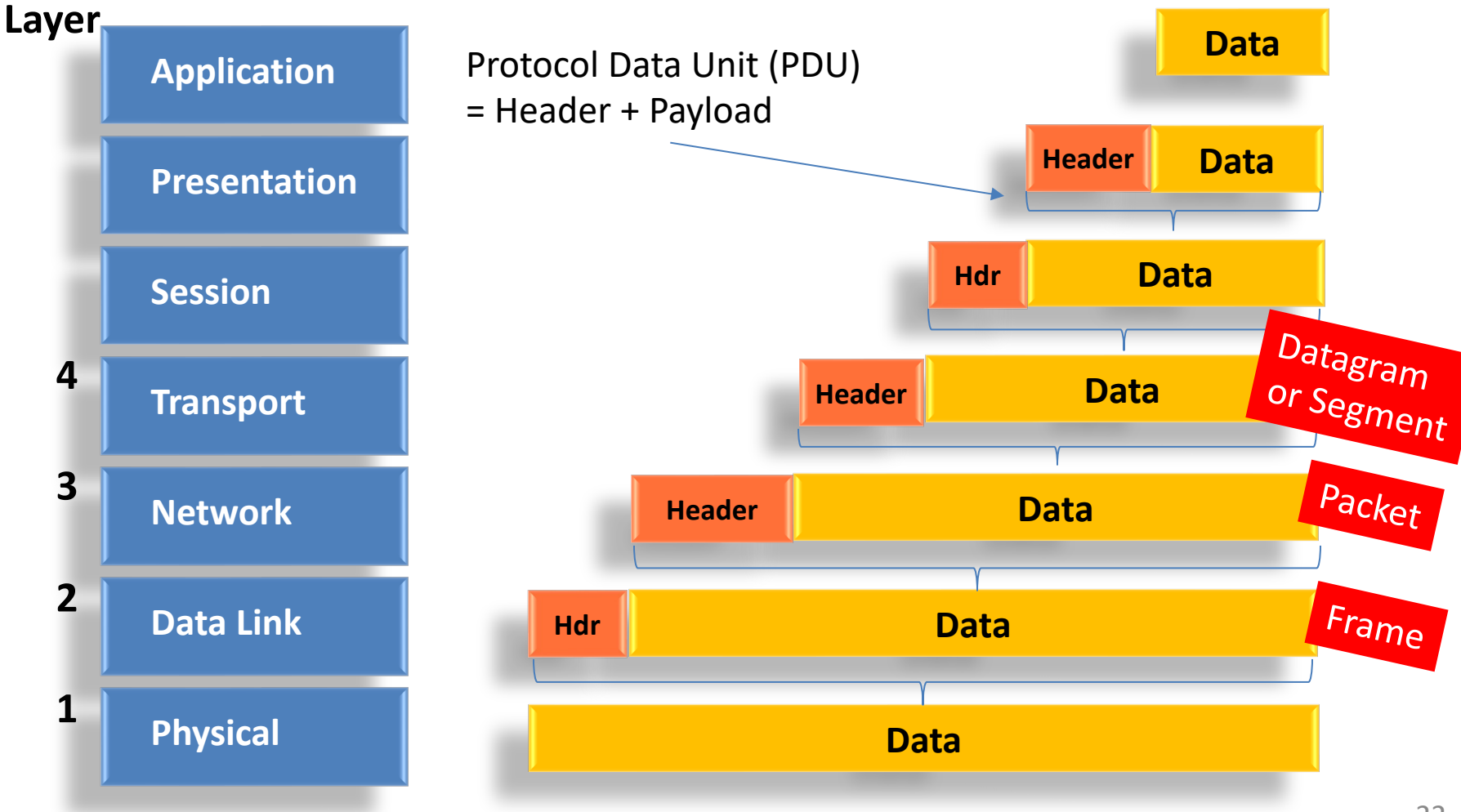
Figure 7-3 – IoT data management functional entities

Rec. ITU-T Y.4416 (06/2018) 20

OSI Stack


Layer
7
Application
6
Presentation
5
Session
4
Transport
3
Network
2
Data Link
1
Physical
Protocol X
Protocol Y
Protocol Z
Protocol L
Protocol M
Protocol N
Protocol N
Protocol X
Protocol Y
Protocol Z
Protocol L
Protocol M
Protocol N
Protocol N
Node A
Node B

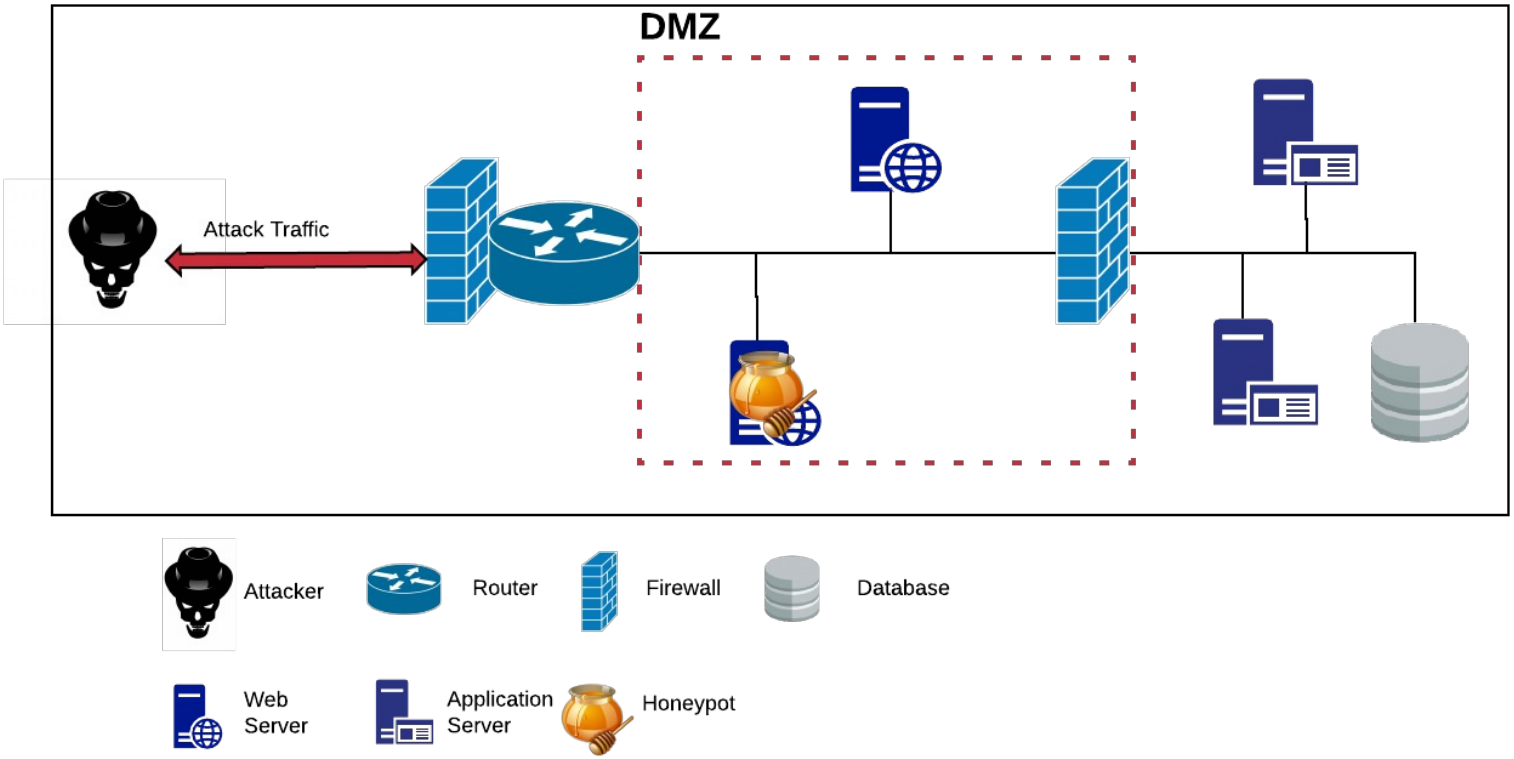
OSI Stack & Data Units



Payload - also called Service Data Unit (SDU) - if you say SDU, though, most people will blankly stare at you!

From a Developer's Point-Of-View

Traditional Network Topology

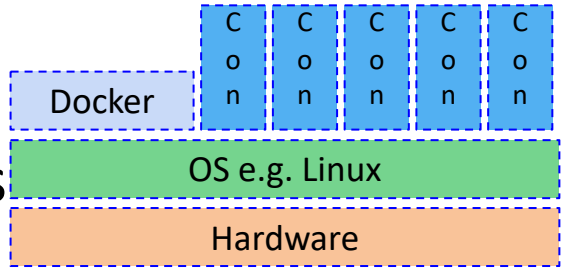


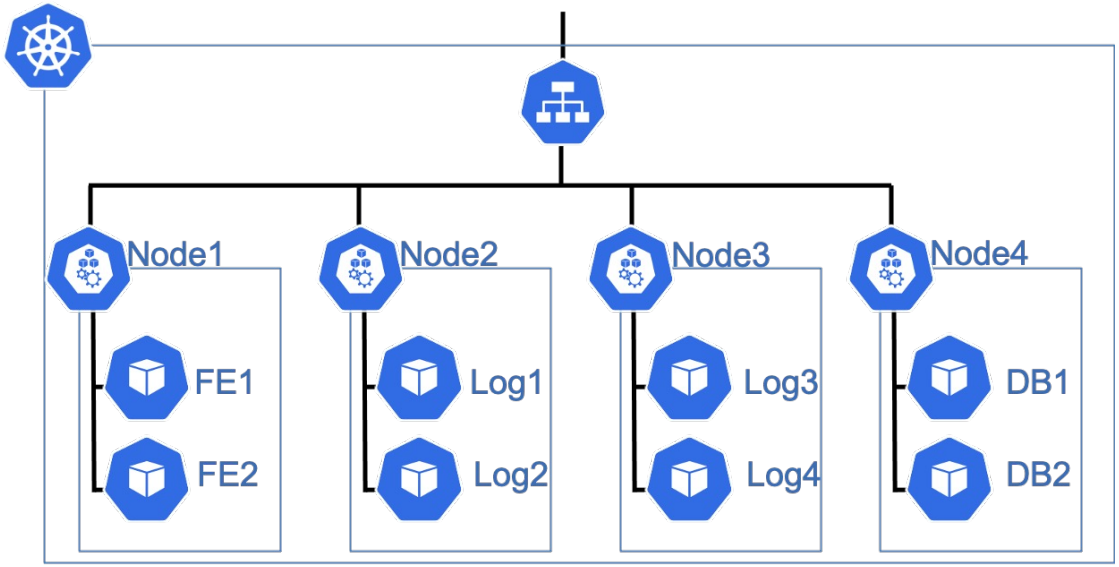
* Figure is courtesy of A. Higgins, https://www.scss.tcd.ie/Stefan.Weber/PDFs/Amber%20Higgins%20-%20MAI%20Dissertation%202018.pdf

Virtualized Infrastructures

e.g. Kubernetes

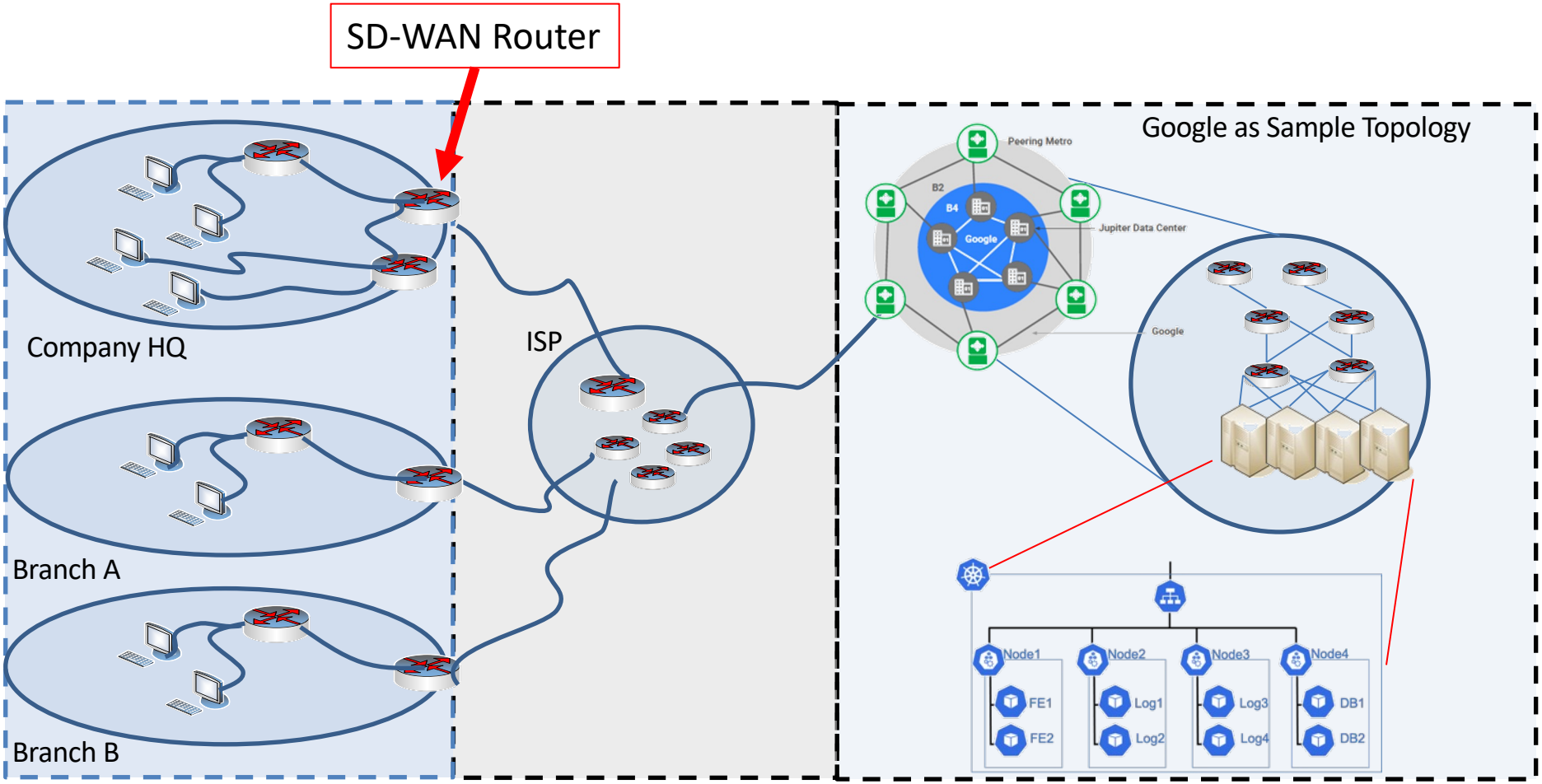
- Microservices <sigh...buzzzwords>
- Deployments controlled by yaml files
- Infrastructure w/ sub nets, nodes and pods, based on a concept called ‘containers’





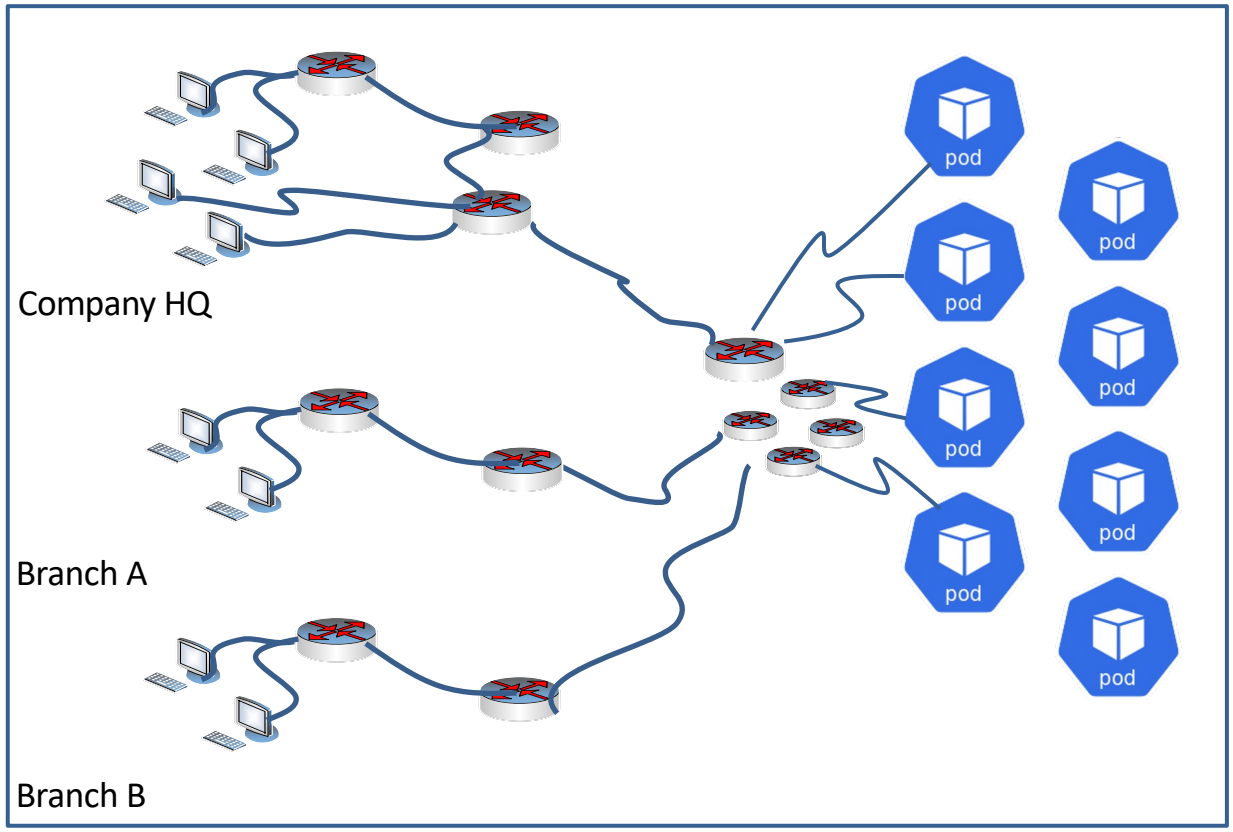
Software-Define Wide-Area Networks

(Private Networks)

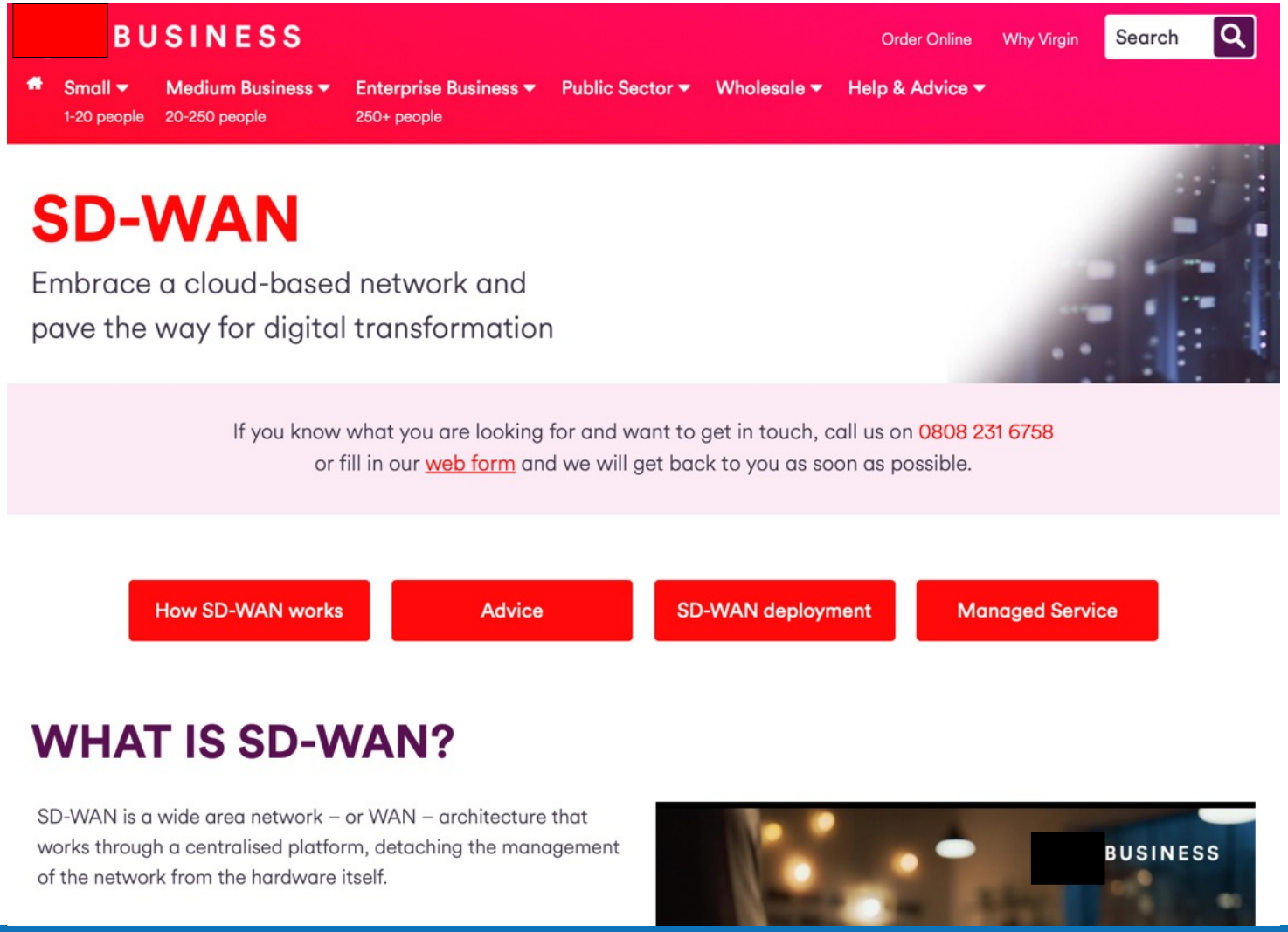


Software-Defined Wide-Area Networks

(Private Networks)



Example from a Local Provider



OpenFlow publication - 2008

OpenFlow: Enabling Innovation in Campus Networks

Nick McKeown
Stanford University

Tom Anderson
University of Washington

Hari Balakrishnan
MIT

Guru Parulkar
Stanford University

Larry Peterson
Princeton University

Jennifer Rexford
Princeton University

Scott Shenker
University of California, Berkeley

Jonathan Turner
Washington University in St. Louis

This article is an editorial note submitted to CCR. It has NOT been peer reviewed.
Authors take full responsibility for this article's technical content.
Comments can be posted through CCR Online.

ACM SIGCOMM Computer Communication Review 69 Volume 38, Number 2, April 2008

Nick Feamster – SDN Lectures:

https://www.youtube.com/playlist?list=PLpherdrLyny8YN4M24iRJBMCXkLcGbmhY

Predictions/Statements in CS

(Psst - we're **really** bad at this!)

- "I think there is a world market for maybe five computers."
  Thomas Watson, President of IBM, 1943
- "There is no reason anyone would want a computer in their home."
  Ken Olsen, Founder of Digital Equipment Corporation, 1977
- "I predict the Internet in 1996 will catastrophically collapse."
  Robert Metcalfe, 1995
- "IPv6 is dead."
  David Cheriton, SOSP 1999

Recent Publication/Apr 2021

Revitalizing the Public Internet By Making it Extensible

Hari Balakrishnan[1], Sujata Banerjee[2], Israel Cidon[2], David Culler[3], Deborah Estrin[4], Ethan Katz-Bassett[5], Arvind Krishnamurthy[6], James McCauley[7], Nick McKeown[8], Aurojit Panda[9], Sylvia Ratnasamy[10], Jennifer Rexford[11], Michael Schapira[12], Scott Shenker[10,13], Ion Stoica[10], David Tennenhouse[2], Amin Vahdat[3], Ellen Zegura[14*]

[1] MIT, [2] VMware, [3] Google, [4] Cornell Tech, [5] Columbia, [6] UWashington, [7] Mount Holyoke, [8] Stanford, [9] NYU, [10] UC Berkeley, [11] Princeton, [12] HUJI, [13] ICSI, [14] Georgia Tech

Contact:shenker@icsi.berkeley.edu

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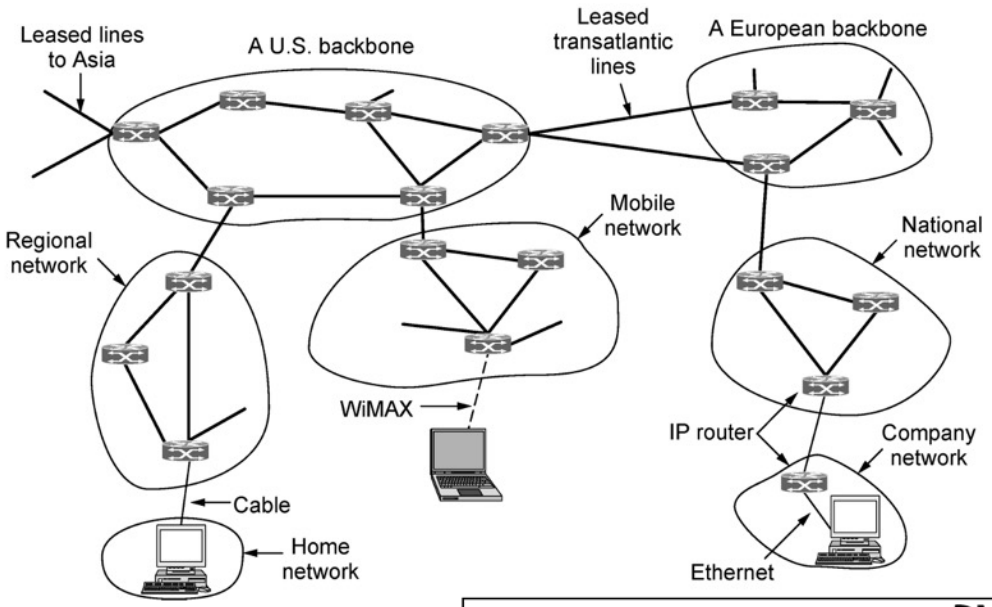
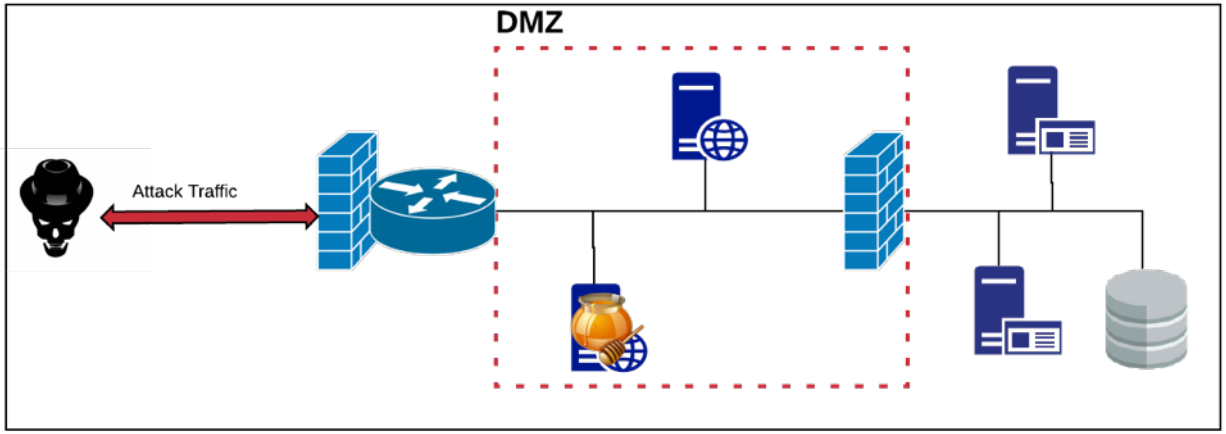
The authors take full responsibility for this article's technical content. Comments can be posted through CCR Online.

ACM SIGCOMM Computer Communication Review Volume 51 Issue 2, April 2021

Textbook View

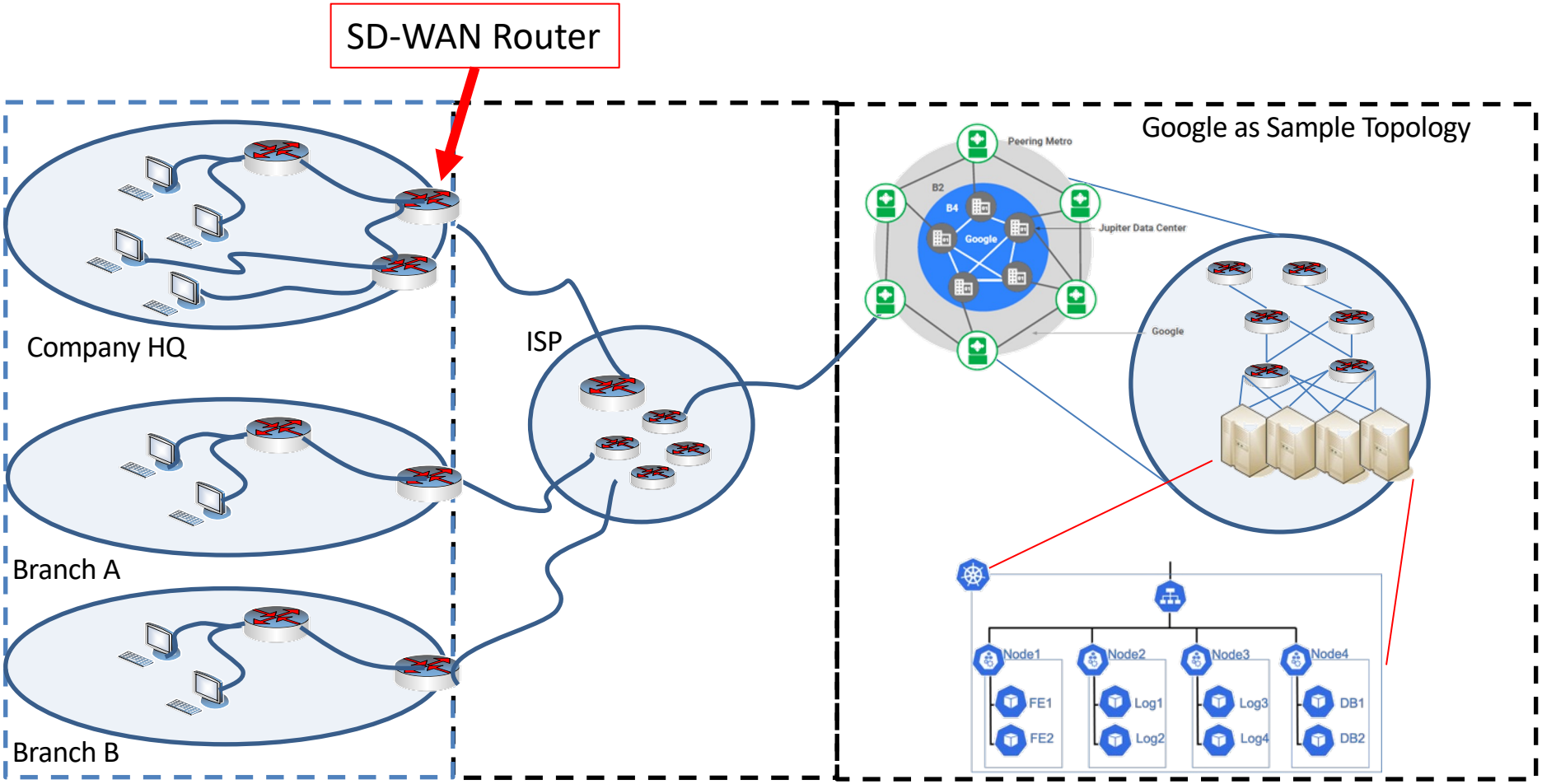




* Figure is courtesy of A. Tanenbaum

Approximation of Current Networks

(Private Networks)



Housekeeping (updated)

- Lectures
  - 12 weeks (– reading week)
  - 2 slots per week, DOLT 2.57

    Mondays 13:00-14:00

    Tuesdays 15:00-16:00

Exam Prep Session: **TBC**
Thu, Dec 8th, 11:00

- Labs → clinics
  - 1 slot per week
  - Mondays 15:00-16:00, L2.01/.02

Videos on Blackboard: David Weatherall

- Tutorials
  - 1 slot per week
  - Thursdays 13:00-14:00, online

Recommended Books

- Andrew Tanenbaum & David Wetherall (& Nick Feamster)
  - Title: Computer Networks
  - ISBN: 9781292024226
  - Chapter 1, 2, 3-5 – in 5th edition
- J.F. Kurose and K.W. Ross
  - Title: Computer Networking: A Top-Down Approach
  - ISBN: 9780133594140
- Behrouz A. Forouzan
  - Title: Data Communications and Networking
  - ISBN: 9780071315869

Background Reading

- Resources section in Blackboard - Amin Vahdat et al:
  - B4: Experience with a Globally-Deployed Software Defined WAN, SIGCOMM 2013
  - Jupiter Rising: A Decade of Clos Topologies and Centralized Control in Google s Datacenter Network, SIGCOMM 2015
  - Taking the Edge off with Espresso, SIGCOMM 2017
- Katie Hafner, Where Wizards Stay Up Late: The Origins Of The Internet, Simon & Schuster, Jan. 1998
- John Day, Patterns in Network Architecture: A Return to Fundamentals, Prentice Hall, Dec. 2007

Tutorials

- Error Detection and Correction
- Error and Flow Control
- Internet Protocol
- Routing
- Point-to-Point Protocol / HDLC
- Medium Access Control
- …

Lectures, Labs & Tutorials

- Lectures
- Tutorials
- Labs/Assignments
  - File Request
  - Packet Filtering

- Attendance
  - Use common sense ☺

Exam/Coursework Weighting

- 40% - Exam
- 60% - Coursework
- Pass 40%
- Supplemental: 100% Exam

Assignments

- Assignment 1:

  File Req - Protocol Design

  Marking:

  5% - 1st video: initial impl., capture, topology

  5% - 2nd video: progress, capture,

  20% Final Submission

  50% Implemented/Documented Functionality

  50% Documentation

- Assignment 2:

  Packet Filtering Protocol

Assignment Timeline

- Preliminary Deadlines for submissions:

  28th September: Assignment 1 – Part 1 – Video/PCAP

  12th October: Assignment 1 – Part 2 – Video/PCAP

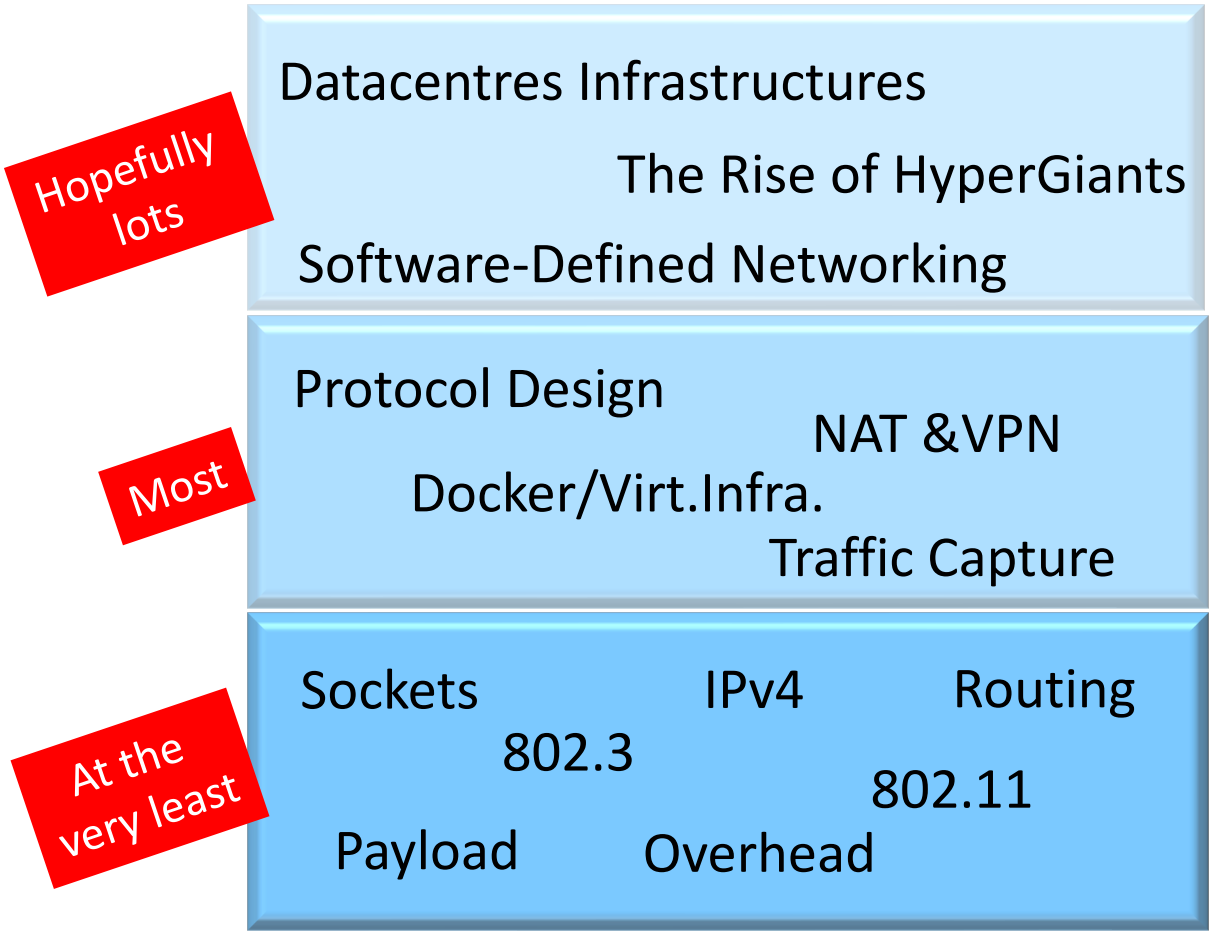
  28nd October: Assignment 1 – Part 3 – FileReq report

  November: Assignment 2 – Packet Filtering

- Submission through Blackboard
- **Deadlines on Blackboard count**

mymodule.tcd.ie

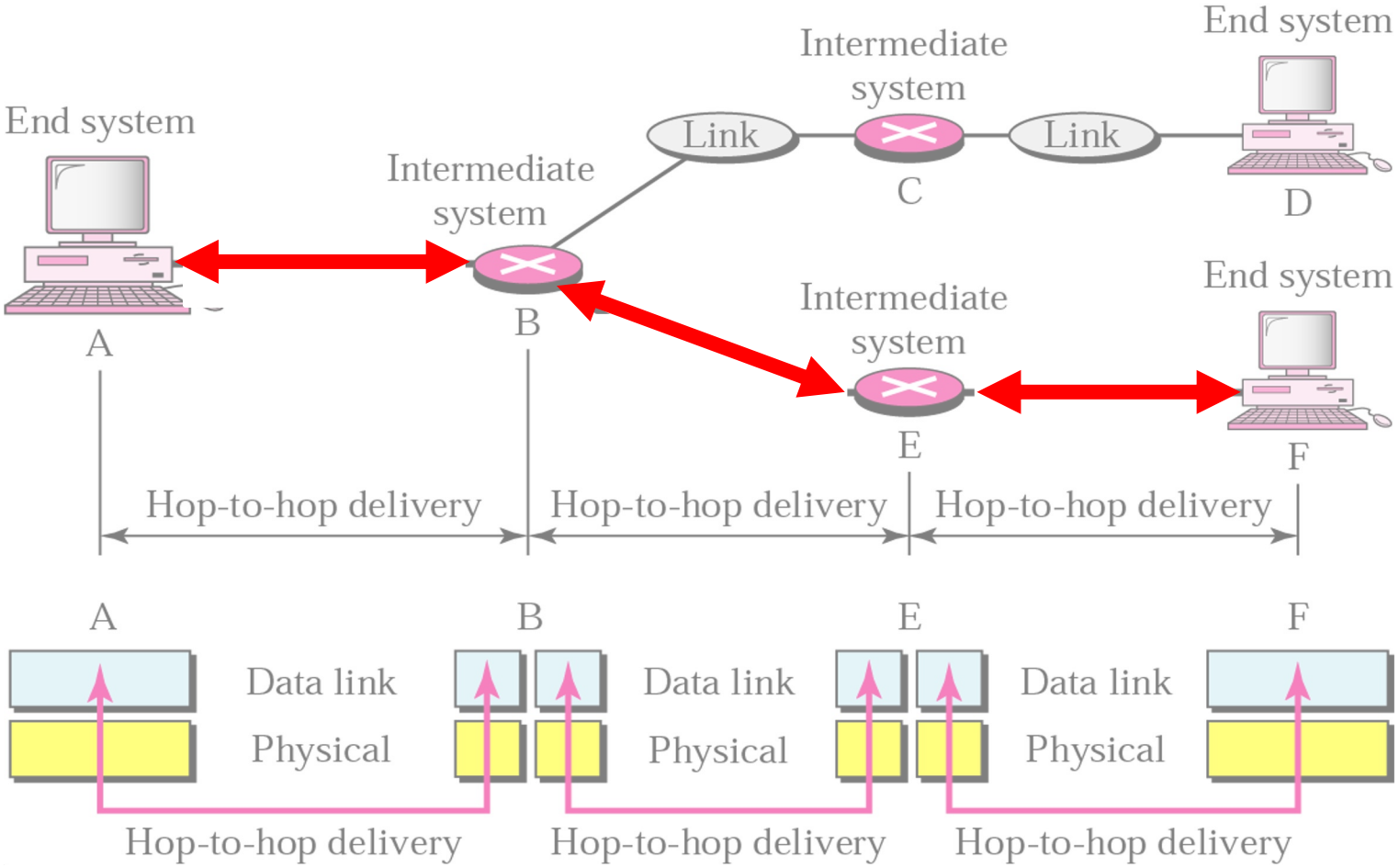
Learning Outcomes



Environments:

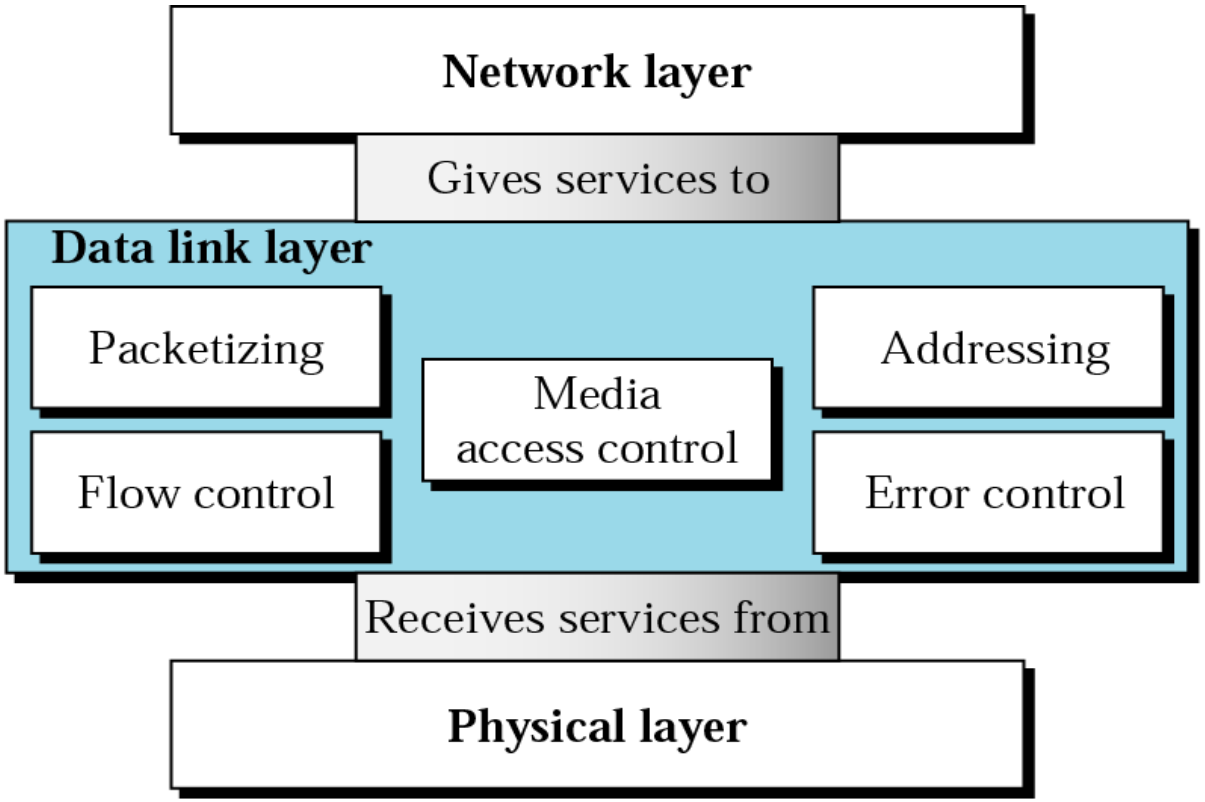
- Multiple Computers
- Containers / Docker
- Mininet
- Kubernetes

Starting Low-down: The Link Layer



* Figure is courtesy of B. Forouzan

Duties of the Link Layer



The link layer is responsible for transmitting frames from one station to the next.

* Figure is courtesy of B. Forouzan

Tomorrow: Assignment 1

- Tomorrow: Talking about Assignment 1

- Blackboard: David Wetherall videos
  - 03a-01_Overview_of_the_Link_Layer.mp4
  - 03a-02_Framing.mp4
  - 03b-02_Retransmissions.mp4

  &

  - 06-05_Sliding_Window.mp4
  - 06-06_Flow_Control.mp4
  - 01-01 to 01-10 – Background, if you have time

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The University of Dublin