Sharif University of Technology

Computer Engineering Department

Software-Defined Networking

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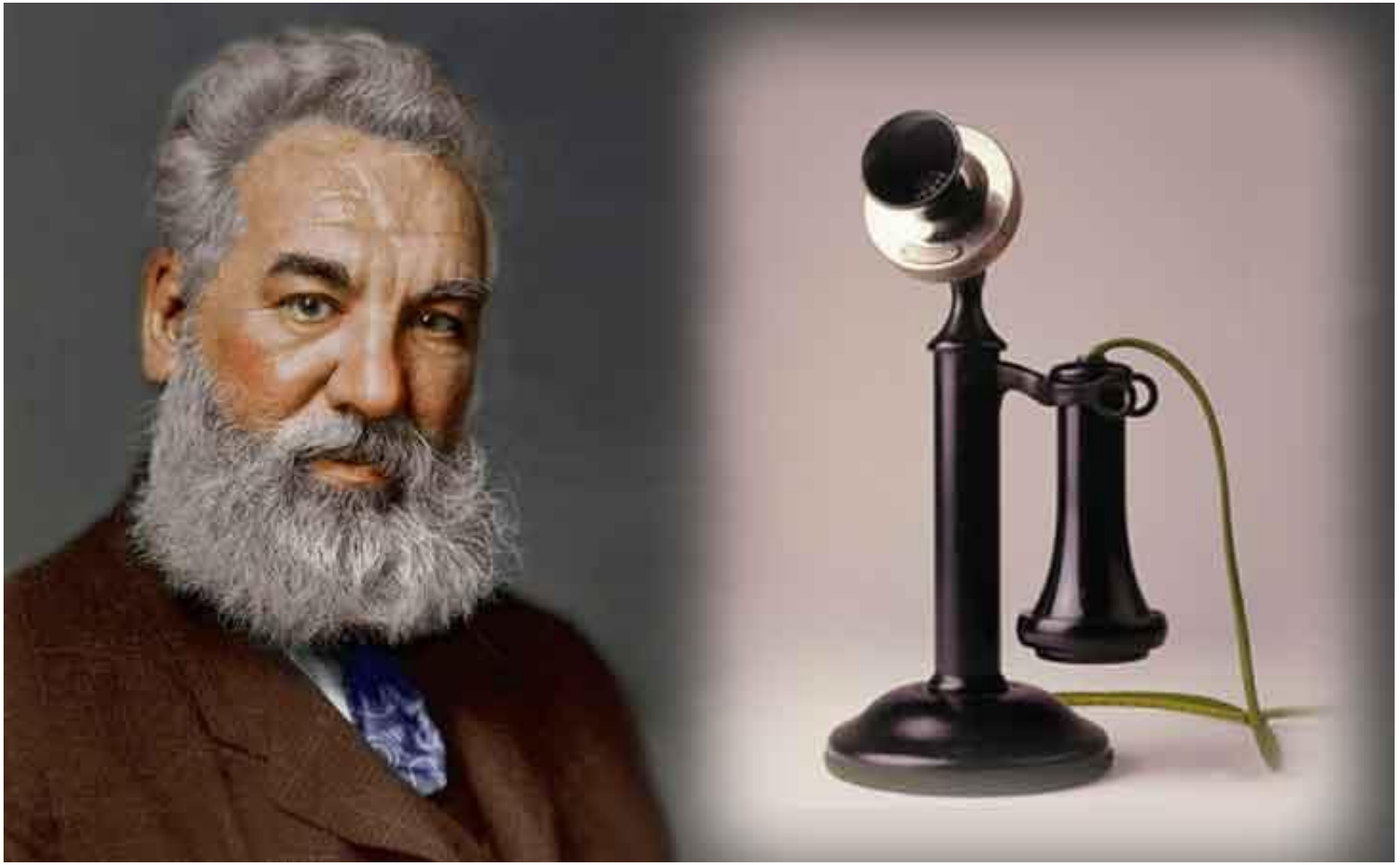
Introduction

Includes slides from courses taught by Mohammad Alizadeh (MIT), Jennifer Rexford (Princeton), and Nick McKeown (Stanford).

Historical Background of the Internet as a Decentralized network

Historical Background

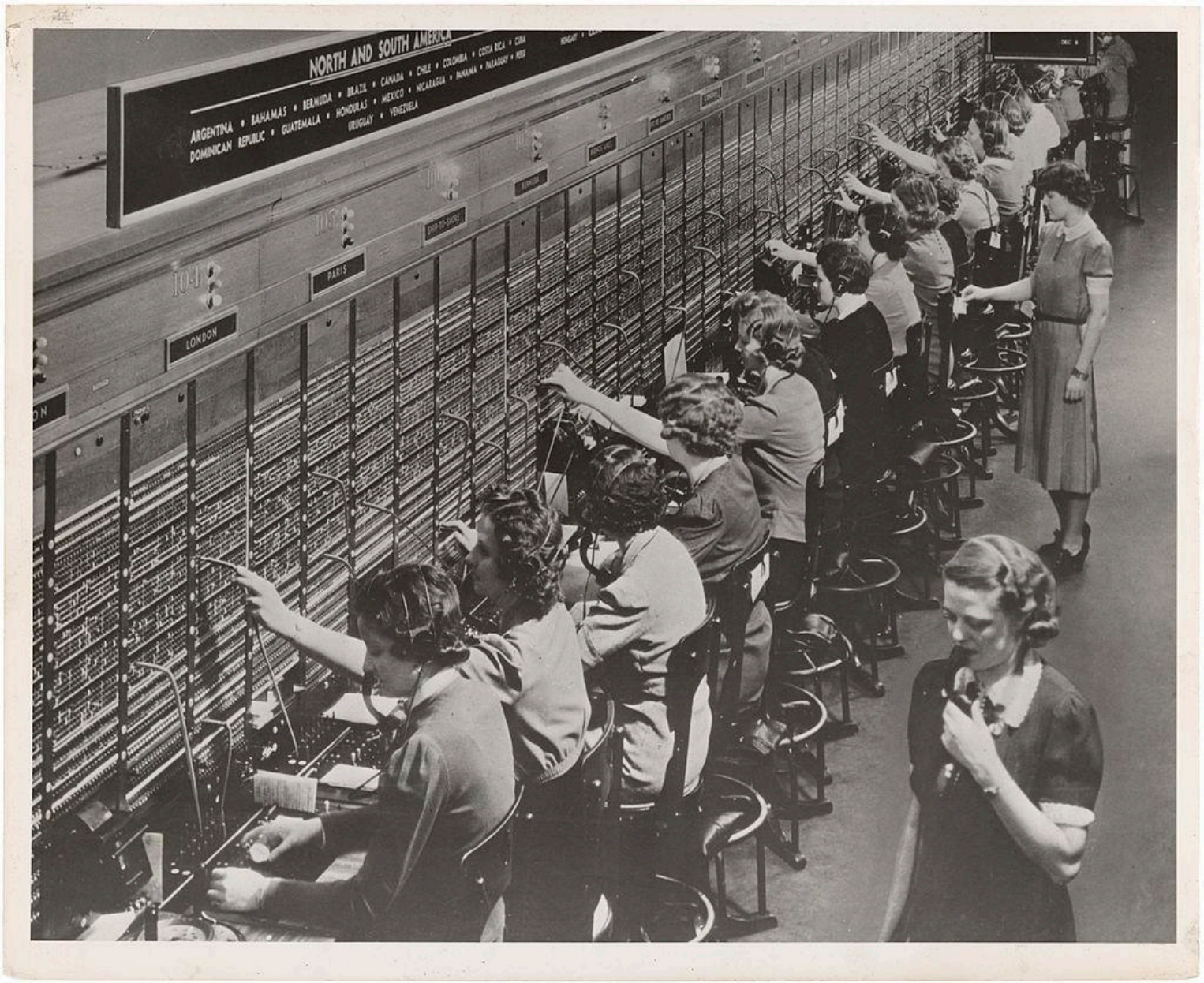
1876



The Telephone Network as a Centralized Circuit-Switched Network

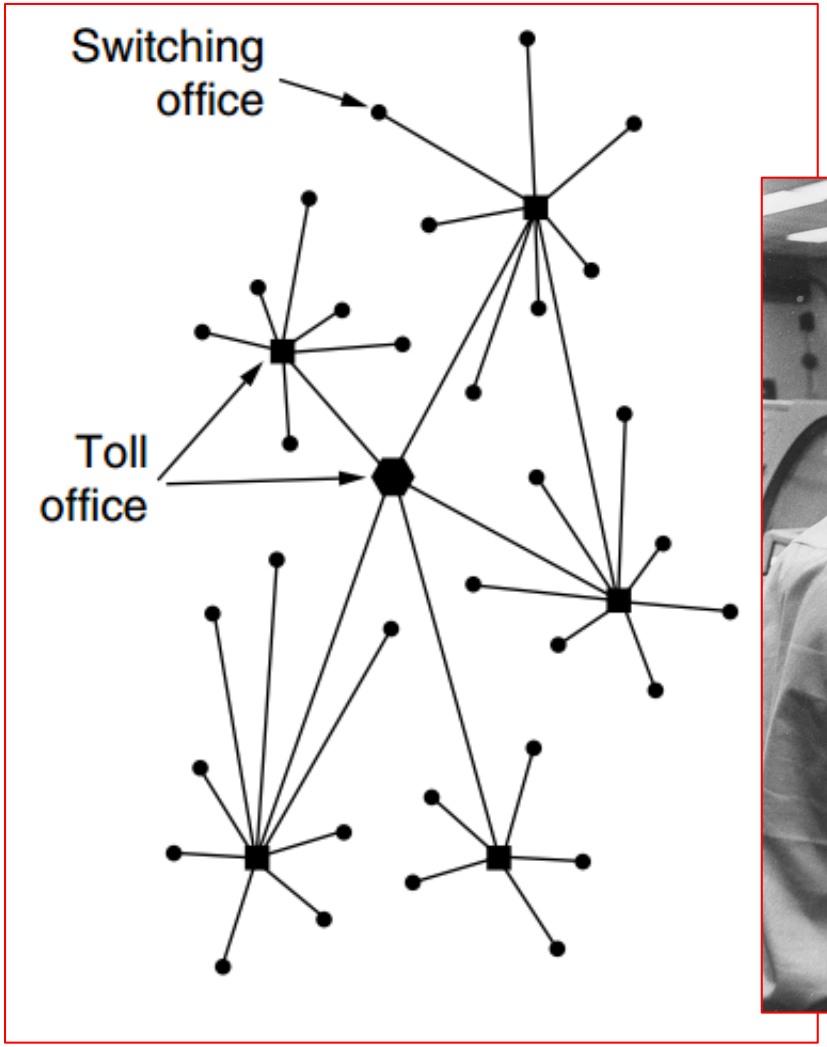
1878

Telephone switchboard



The Telephone Network as a Centralized Circuit-Switched Network

Telephone network

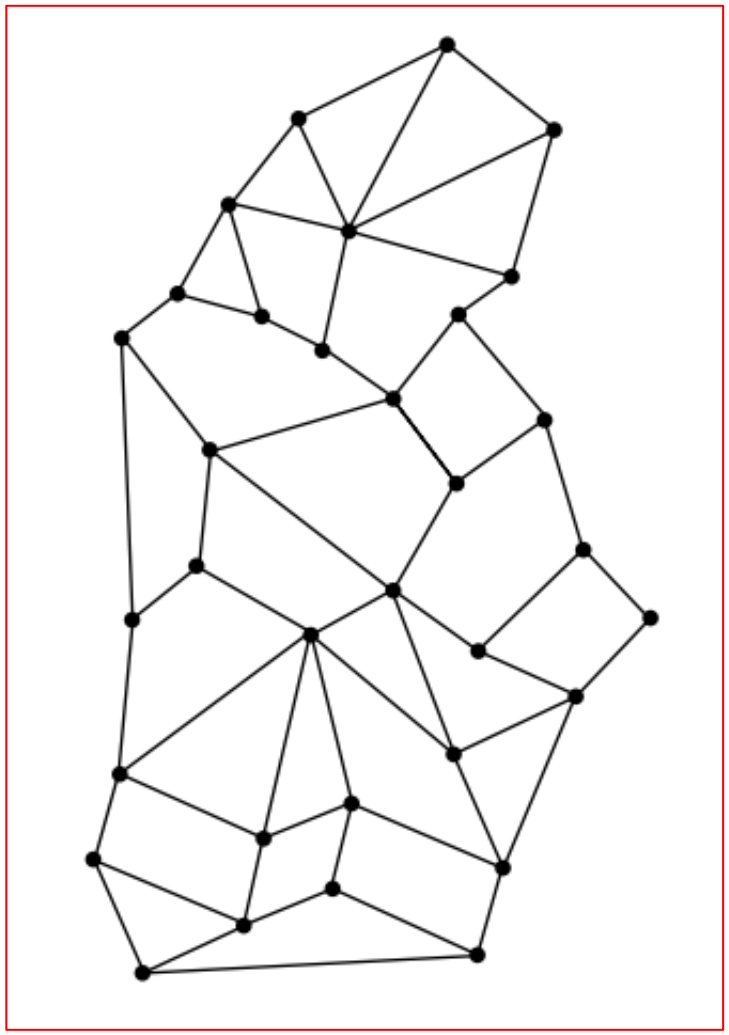


Late 1950s, the cold war

A Decentralized Packet-Switched Network

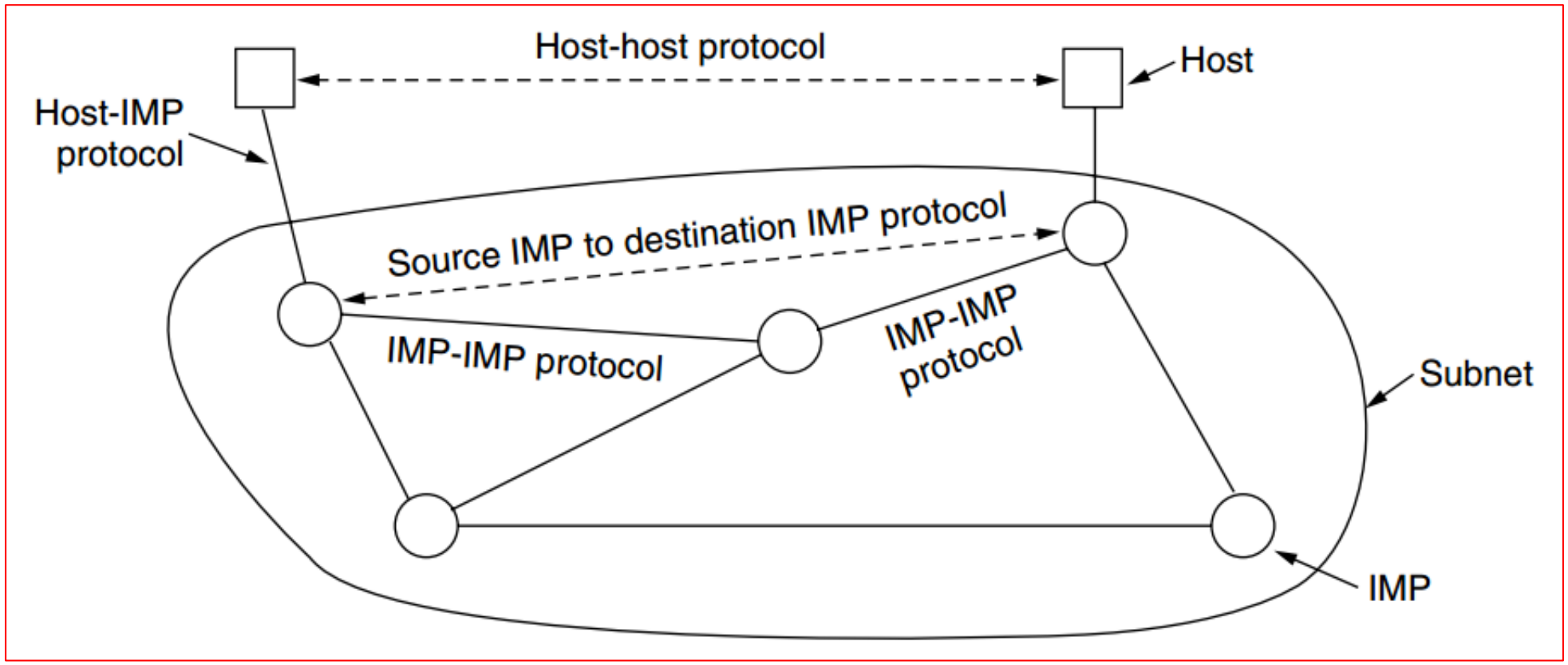
Paul Baran, 1964

Transmitting the voice signals in packets of data that could travel **autonomously** through the network, **finding their own way** toward their destination.

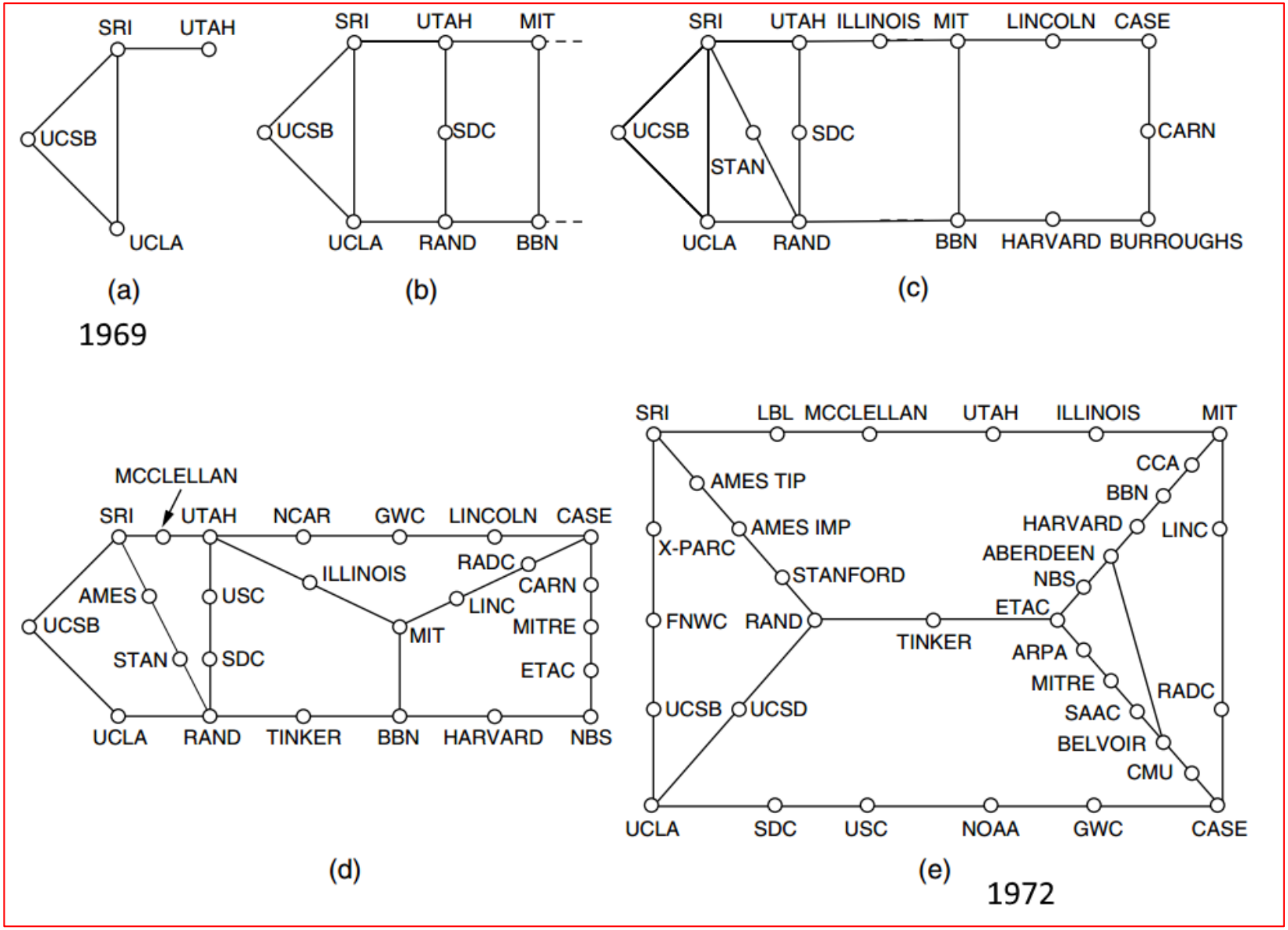


A Decentralized Packet-Switched Network

Larry Roberts, 1967, (DARPA, Defense Advanced Research Agency)



ARPANET


SRI
UTAH
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LINCOLN
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CARN
UCLA
RAND
BBN
HARVARD
BURROUGHS
(c)
MCCLELLAN
SRI
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NCAR
GWC
LINCOLN
CASE
ILLINOIS
RADC
CARN
AMES
USC
LINC
UCSB
MIT
MITRE
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MIT
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AMES TIP
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AMES IMP
HARVARD
LINC
X-PARC
ABERDEEN
STANFORD
NBS
ETAC
FNWC
RAND
TINKER
ARPA
MITRE
RADC
UCSB
UCSD
SAAC
BELVOIR
CMU
UCLA
SDC
USC
NOAA
GWC
CASE
(e)
1972

The Internet

ARPANET, 1969 …

TCP/IP, 1974 …

AlohaNet, 1970s

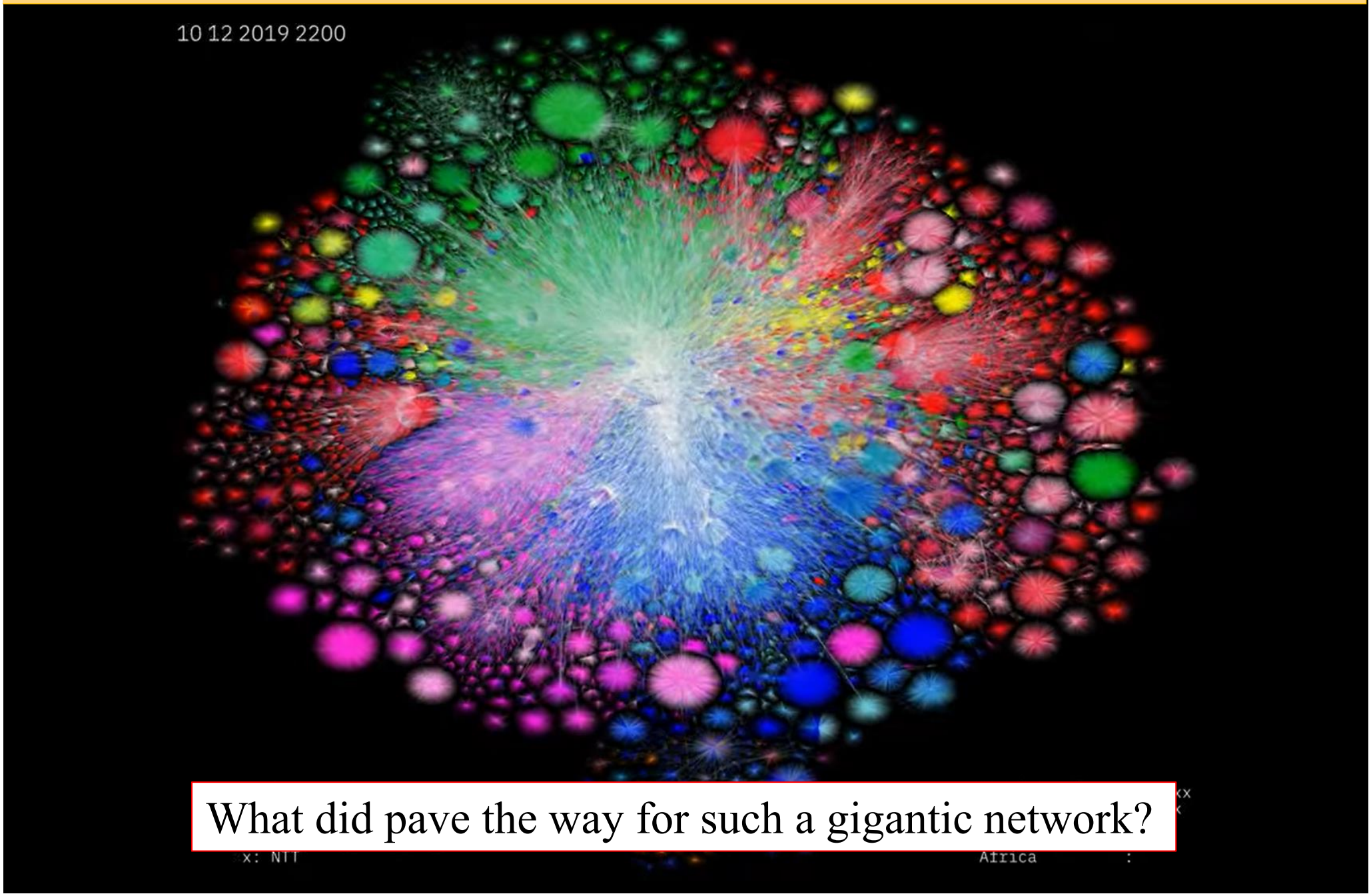
NSFNET, late 1970s

EBONE, 1990s

EuropaNET, 1990s

World Wide Web (WWW), early 1990s

The Opte Project

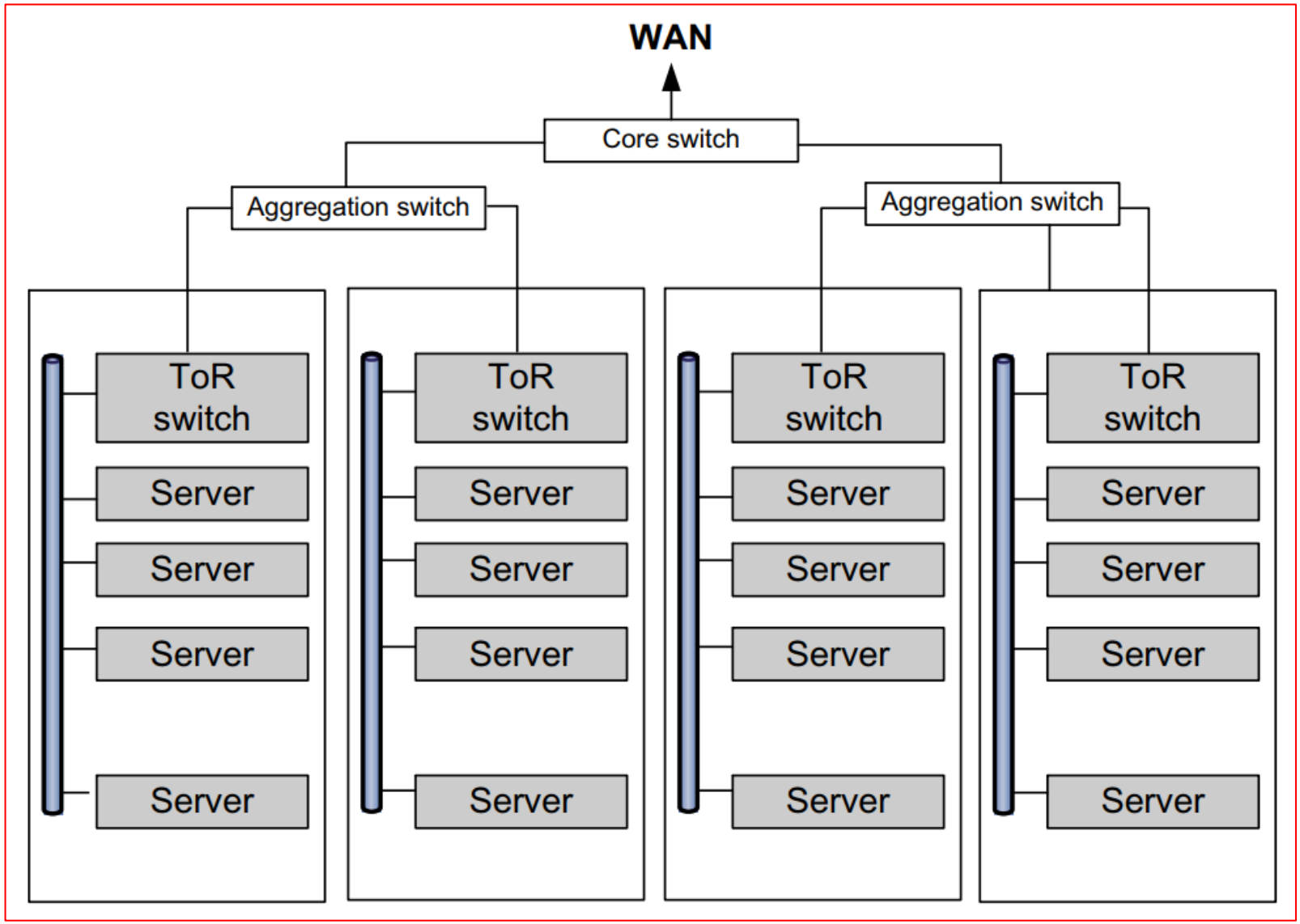


Is the decentralized approach the best for all situations?

Data Center

Large facilities with 10s of thousands of networked servers

Data Center Networking



Standard topologies: 3-Tier, Spine-Leaf, …

What is different about data center networks?

- Environmentally protected warehouses, situated in disaster-unlikely geographies, with redundant power systems.
- Single (and centralized) administrative domain
- Standard and deterministic topology
- Predictive network changes

But data center networks were using the very routing protocols: the complex distributed routing protocols

Distributed Routing Protocol

- Figure out which routers and links are present. **(95%)**
- Run Dijkstra's algorithm to find shortest paths. **(5%)**

From: draft-ietf-ospf-vers2-02 Internet Standard
Updated by: 5709, 6549, 6845, 6860, 7474, 8042 Errata exist
Network Working Group J. Moy
Request for Comments: 2328 Ascend Communications, Inc.
STD: 54 April 1998
Obsoletes: 2178
Category: Standards Track

OSPF Version 2

Status of this Memo

This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

Copyright Notice

Abstract

So what?!

Why don’t we have a simple and centralized routing protocol?

What is the best policy for a routing protocol?

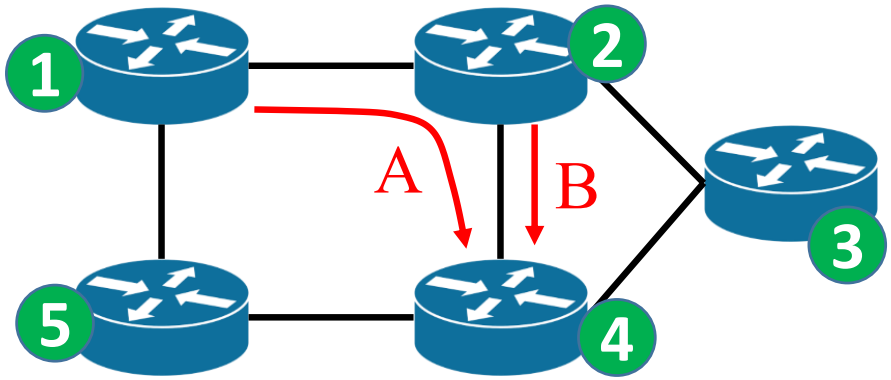
Is it enough to deploy a centralized solution with the policies of current routing protocols?

What opportunities does a centralized approach open up?

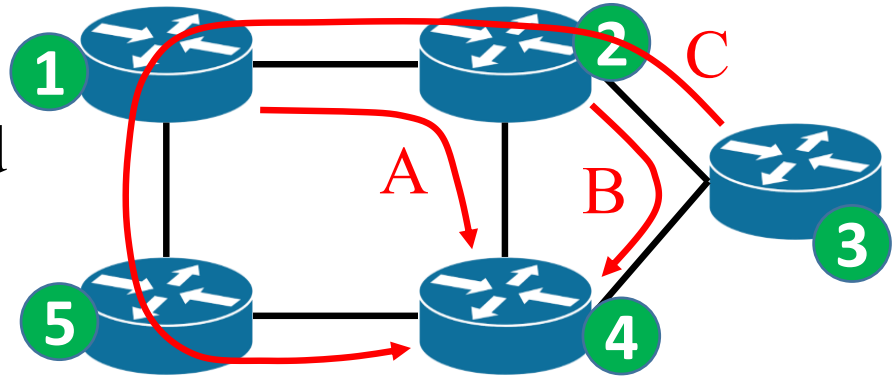
Optimal path placement using a central control
An example of traffic engineering for WANs

Flow A: 1→ 4
Flow B: 2→ 4
Flow C: 3→ 4

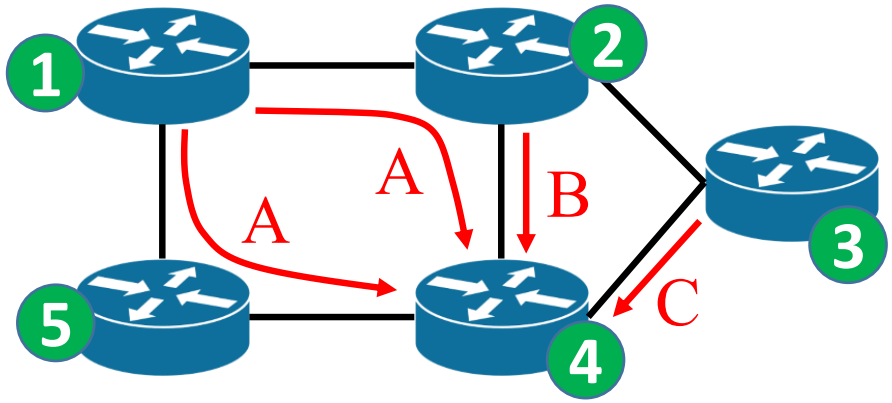
A primitive distributed routing protocol



A state-of-the-art distributed routing protocol

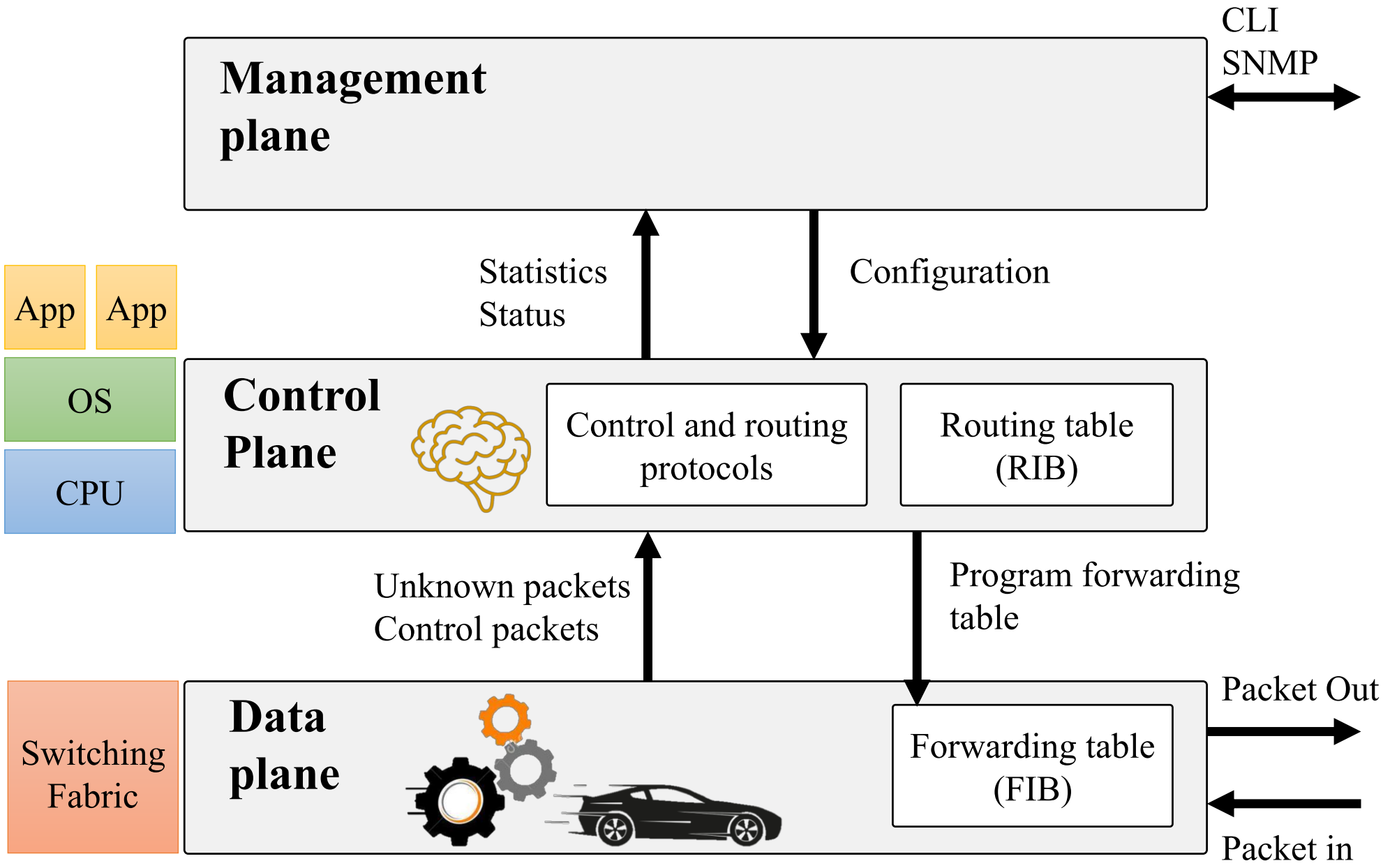


A centralized routing protocol



Service providers and datacenters felt the need to program networks

Traditional Switch Architecture



Data Plane

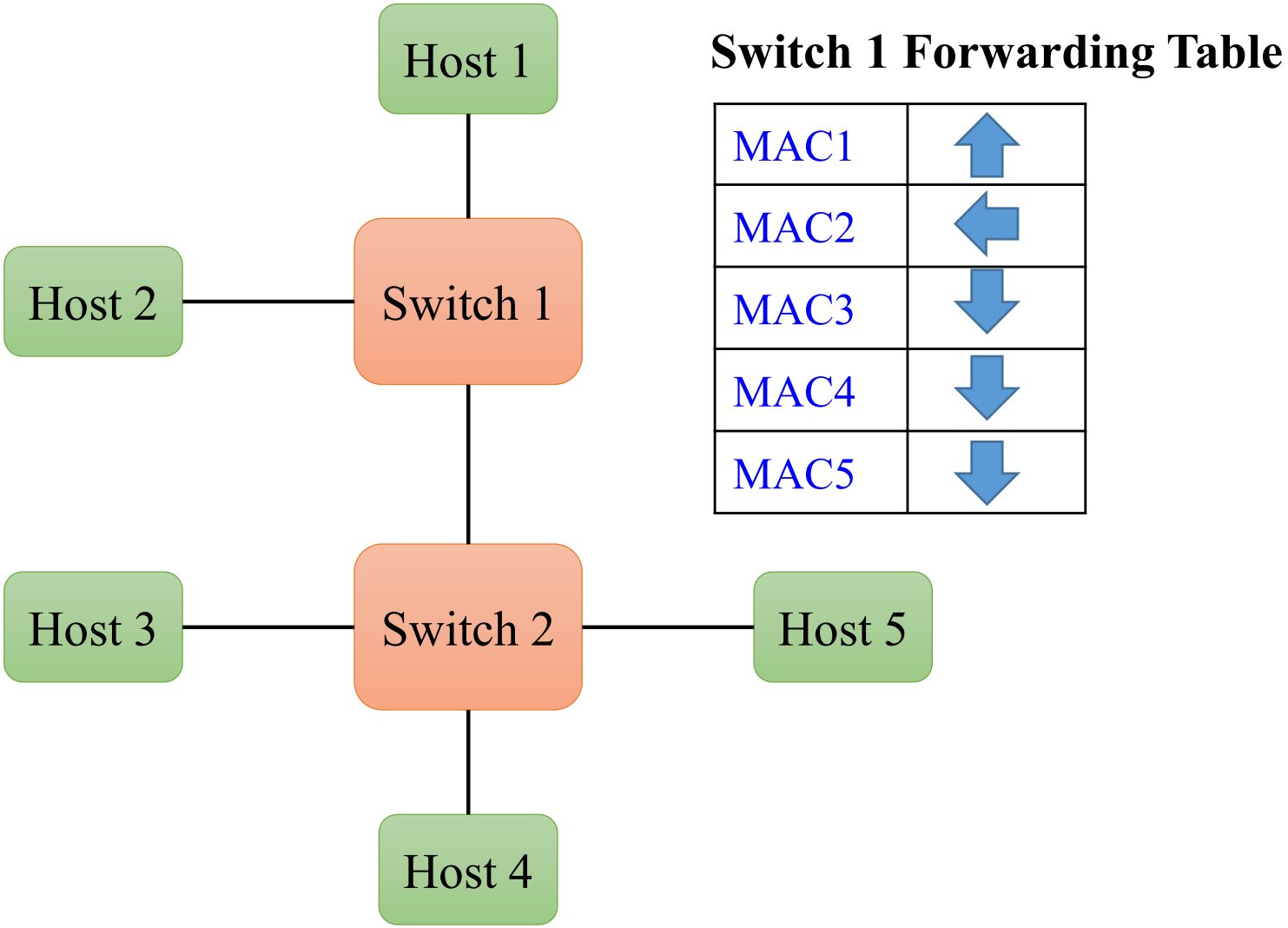
- Consists of ports, switching chip, forwarding tables

- Most packets handled by switch are only touched by the data plane.

- Packet Processing: Matching on some header fields, and performing some actions. (Not all packets can be handled in this way, and they need to be processed by data plane)

- Wide range of functionality: Forwarding, Access control, Header modification, Traffic monitoring, Packet Buffering. Marking, Shaping and scheduling, Deep packet inspection

Data Plane Example: Match on DST MAC



Switch 1 Forwarding Table

MAC1	↑
MAC2	←
MAC3	↓
MAC4	↓
MAC5	↓

Control Plane

- Keep current the information in the forwarding table so that the data plane can independently handle as high a percentage traffic as possible.

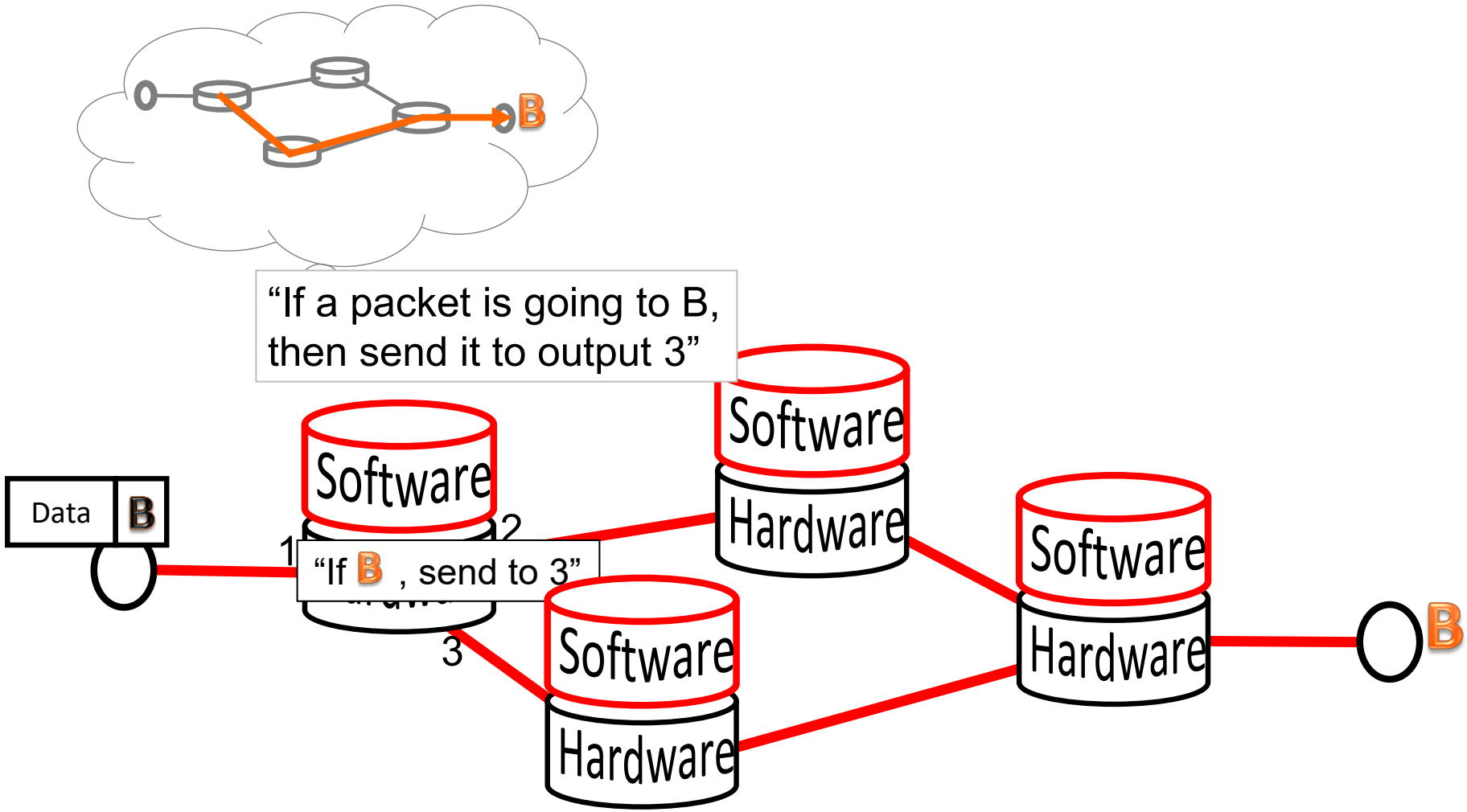
- Processing different control and routing protocols (traditionally distributed) that may affect the forwarding table.

- Computing and populating forwarding tables

- Due to the complexity of the protocols, it is implemented by software in a microprocessor.

Control Plane Example

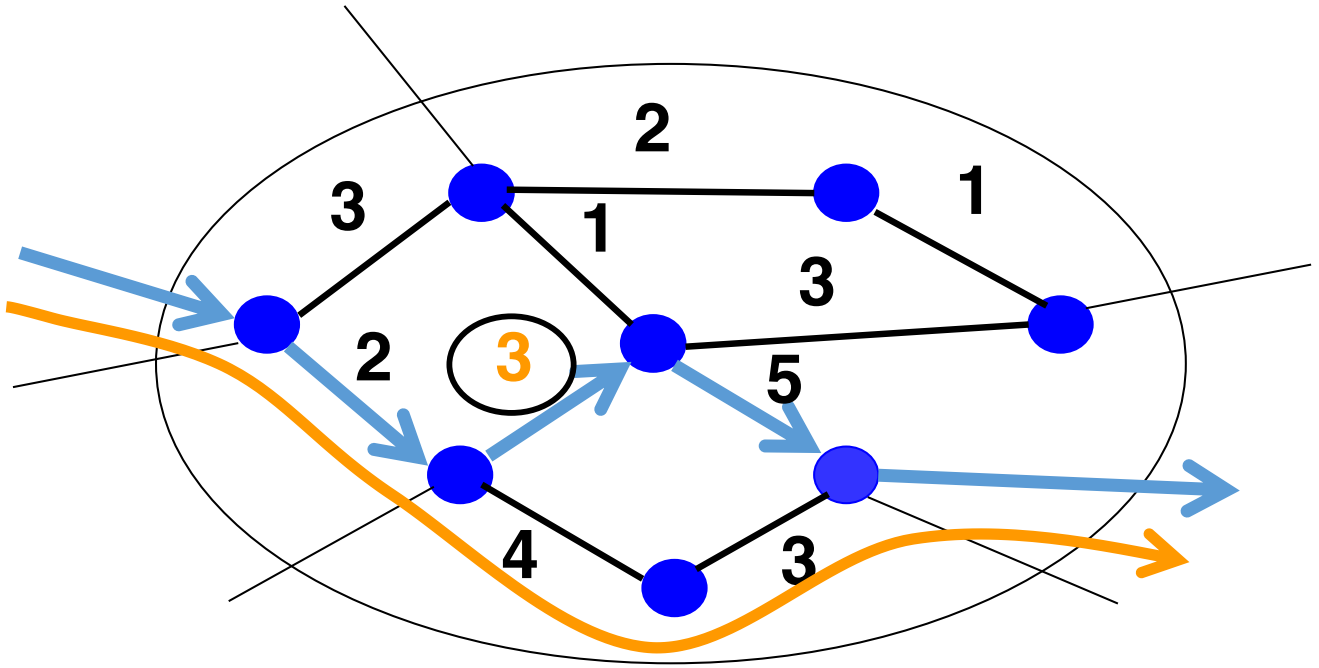
1. Figure out which routers and links are present (topology).
2. Run Dijkstra's algorithm to find shortest paths.



Management Plane

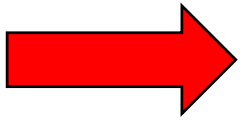
Network administrators configure and monitor the switch through this plane.

Example: Traffic engineering by setting the weights



How can we develop and deploy a network feature or protocol?

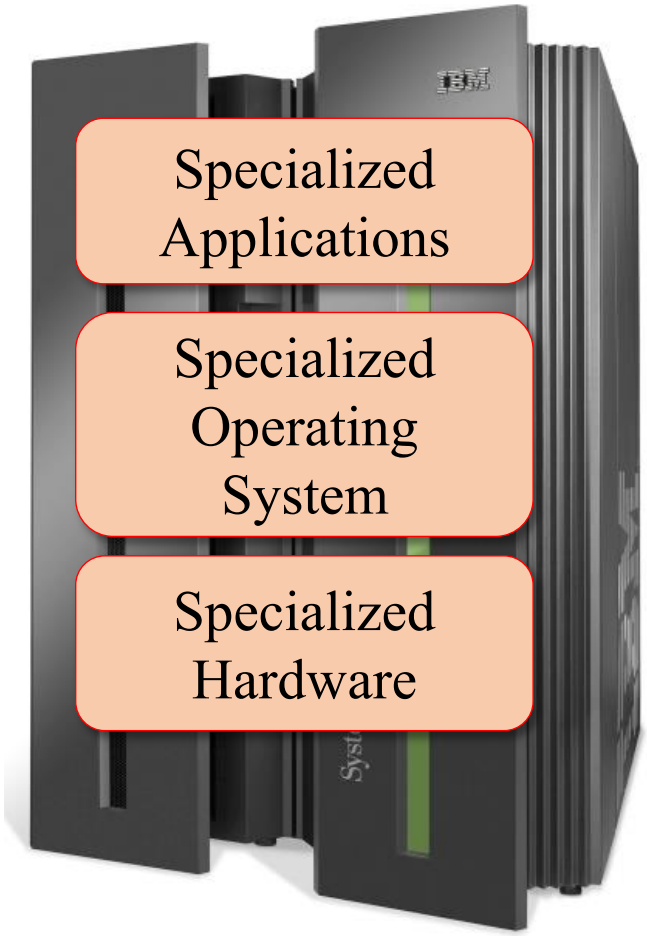
Custom routing protocol



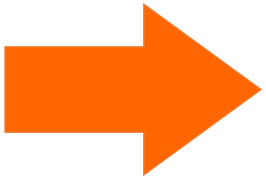
Innovation – Computers vs. Networks

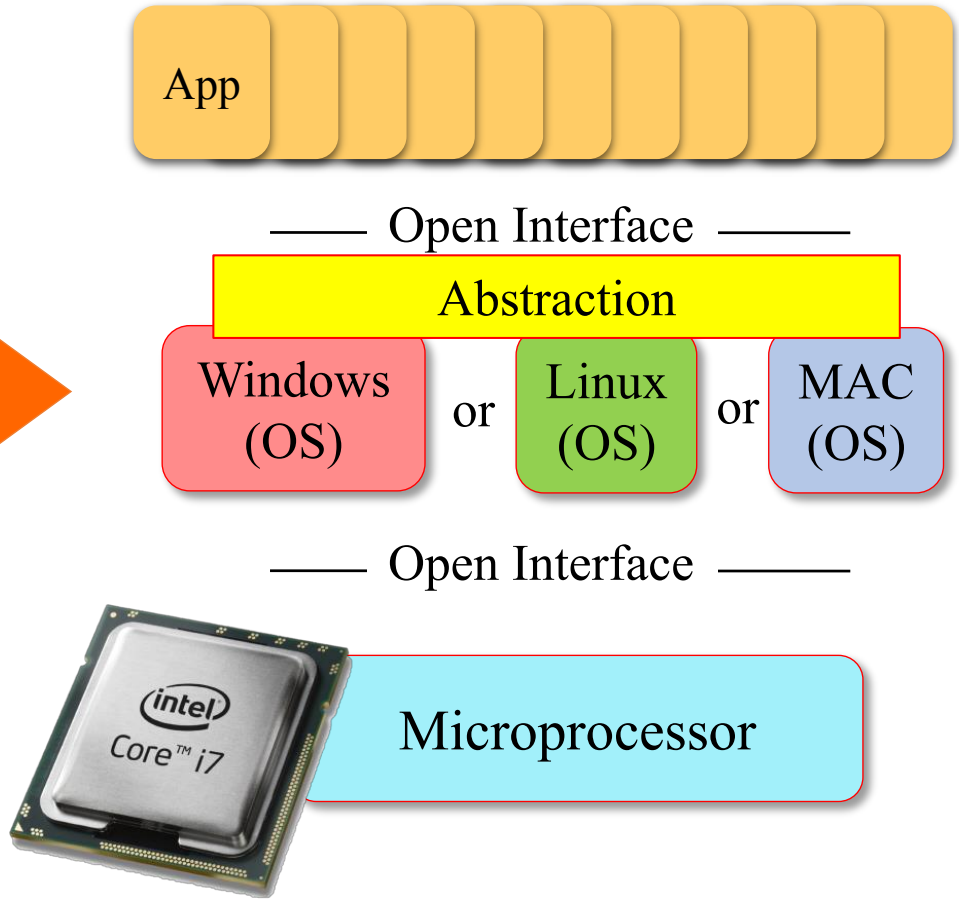
- How difficult is it to create a computer application?
- How difficult is it to create a network feature or protocol?
- What is the difference?
- What are the tools available for each?

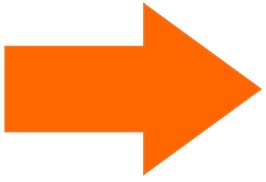
Transformation of the Computer Industry



Vertically integrated
Closed, proprietary
Slow innovation
Small industry







Horizontal
Open interfaces
Rapid innovation
Huge industry

Network Industry

- Vertically integrated, closed, proprietary
- Overly complex
- Too expensive
- Networking industry with “mainframe” mind-set
- Vendor lock-in

Feature

Feature

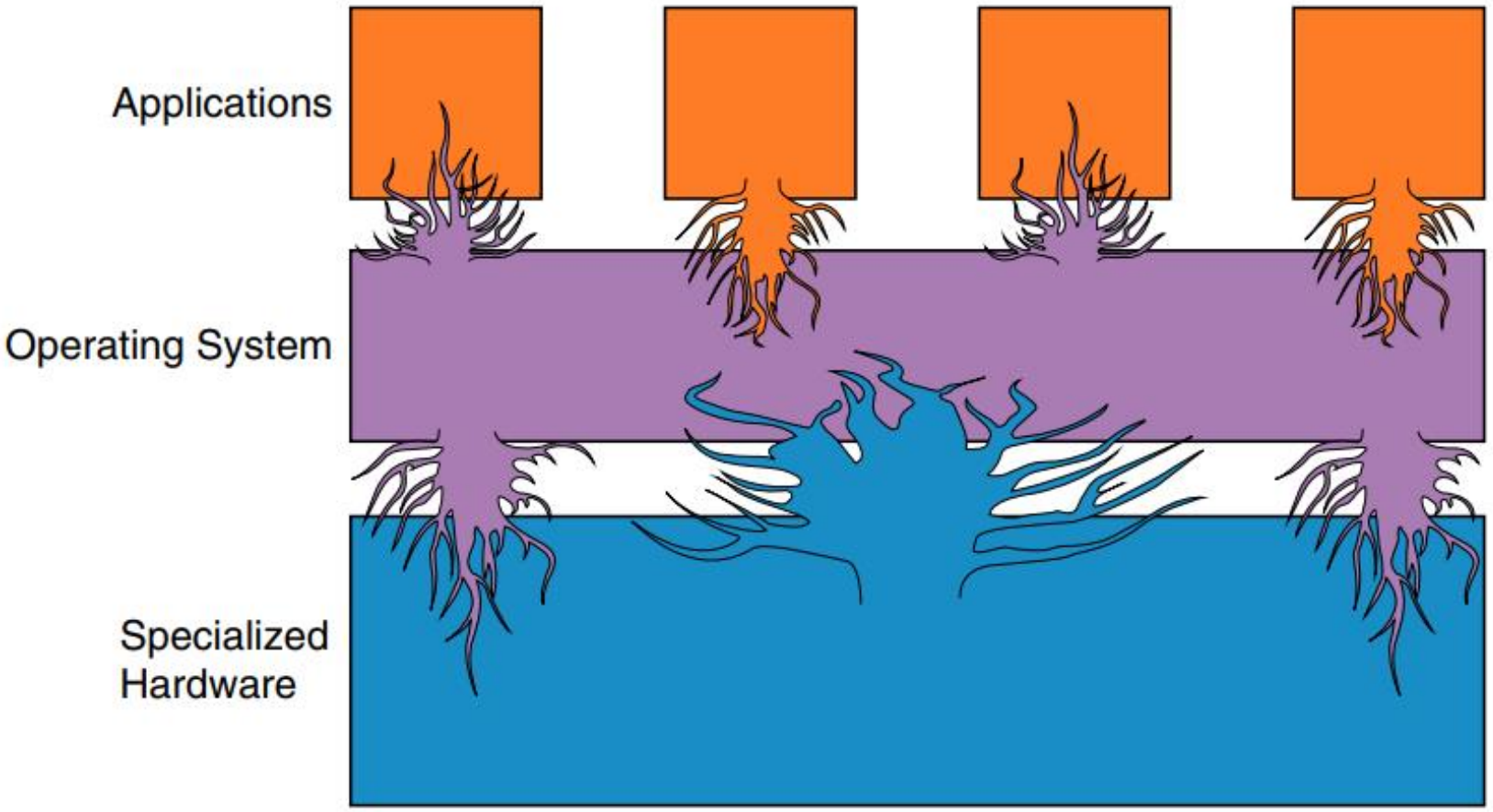
OS

Routing, Management, VPNs,
Security, Access control, …
9000 RFCs
Millions of lines of source code

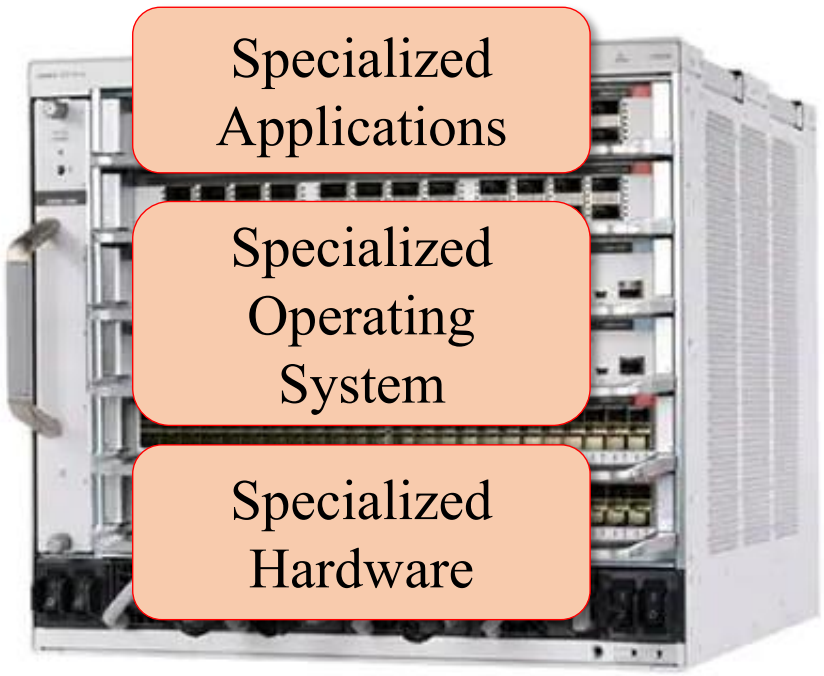
Custom
Hardware

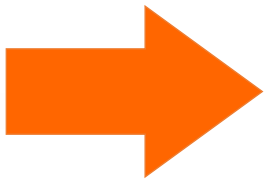
Billions of gates
Bloated
Power hungry

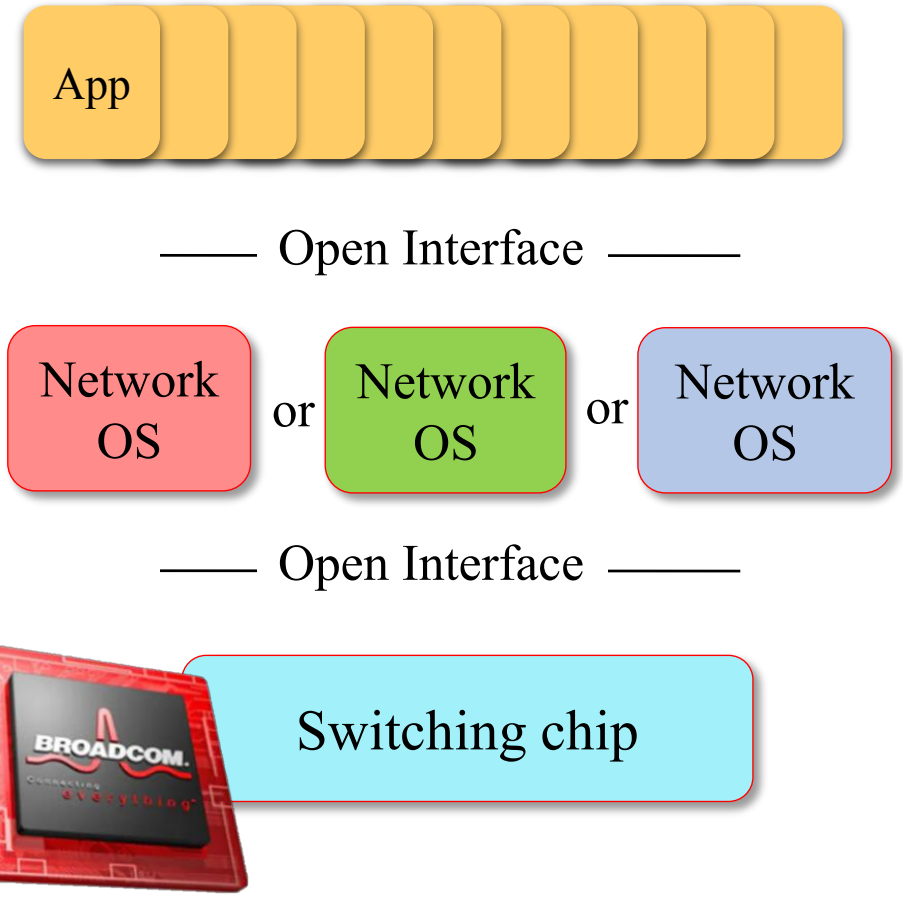
Network Industry – Behind the Scenes



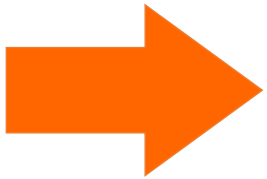
Transformation of the Network Industry







Vertically integrated
Closed, proprietary
Slow innovation



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