クラウドコンピューティング基礎論

第7回

創造情報•小林克志

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Outline

- Administravia
- Quiz and homework review
- Internet
  - Packet format
  - Addressing
- Data Center Network Topology
  - Switch / Router
  - Folded Clos / Spine and Leaf

Course Outline

- Administrivia
- Cloud computing
- Service reliability
- Scale-up / Scale-out
- Distributed data stores
- Global services
- Datacenter networkings (1)
- Datacenter networkings (2)
- Network performance
- User experiences
- Network latencies
- Advanced topics

For hands-on exercise : Install two softwares

1.Wireshark : A packet capture and analyzer

- Just install package from http://www.wireshark.org

2.NS2 : Network simulator.

Three options are there:

A. Docker
   - Install docker software and container:
     - https://github.com/ekiourk/docker-ns2
     - X-window server is required. It depends on OS.
B. Native application. If you are using Linux, use this option.
   - Install ns-allinone-2.35 from source because NS-2 package.
     Note that some distribution may not work.
   - X-window, perl, gnuplot are also required.
C. Virtual Machine (VM)
   - Install Hypervisor Software.
     - Oracle VirtualBoX is free.
       vmware or others are also welcome.
   - Linux VM image with NS2 software will be available from the course Web.

演習に向けて：２つのソフトウェアをインストールする

1.パケットアナライザ wireshark

- http://www.wireshark.org を参考にインストールすること。

2.ネットワークシミュレータ NS2

A. Docker

- Docker をインストールし、コンテナを使用する。
  - https://github.com/ekiourk/docker-ns2
  - X-window の設定は OS に依存する。

B. Native

- Linux を利用している場合は、この方法を使う。
- ns-allinone-2.35 を install すること。
  - X-window, perl, gnuplot なども必要となる。

C. VM で動作

- ハイパーバイザの導入
  - Oracle VirtualBoX であれば無償
    vmware 他でもかまわない
- NS2 付きの Linux 仮想マシンイメージを講義ページで配布する

TECHNOLOGY The New York Times

Net Neutrality Has Officially Been Repealed. Here's How That Could Affect You.

By Keith Collins

June 11, 2018

It's official. The Federal Communications Commission's repeal of net neutrality rules, which had required internet service providers to offer equal access to all web content, took effect on Monday.

The rules, enacted by the administration of President Barack Obama in 2015, prohibited internet providers from charging more for certain content or from giving preferential treatment to certain websites.

After the commission voted to repeal the rules in December, it faced a public outcry, legal challenges from state attorneys general and public interest groups, and a push by Democratic lawmakers to overturn the decision. The opponents argued that the repeal would open the door for service providers to censor content online or charge additional fees for better service — something that could hurt small companies — and several states have taken steps to impose the rules on a local level.

Still, the repeal was a big win for Ajit Pai, the F.C.C.'s chairman, who has long opposed the regulations, saying they impeded innovation. He once said they were based on "hypothetical harms and hysterical prophecies of doom."

In an op-ed column published on CNET Monday, Mr. Pai argued that the repeal was good for consumers because it restored the Federal Trade Commission's authority over internet service providers.

"In 2015, the F.C.C. stripped the F.T.C. — the nation's premier consumer protection agency — of its authority over internet service providers. This was a loss for consumers and a mistake we have reversed," Mr. Pai wrote.

["I'm no longer surprised that there was a fight over this," writes our columnist. "Net neutrality was too good for us."]

These are the rules that were repealed

The original rules laid out a regulatory plan that addressed a rapidly changing internet. Under those regulations, broadband service was considered a utility under Title II of the Communications Act, giving the F.C.C. broad power over internet providers. The rules prohibited these practices:

BLOCKING Internet service providers could not discriminate against any lawful content by blocking websites or apps.

THROTTLING Service providers could not slow the transmission of data because of the nature of the content, as long as it was legal.

PAID PRIORITIZATION Service providers could not create an internet fast lane for companies and consumers who paid premiums, and a slow lane for those who didn't.

What's everyone worried about?

Many consumer advocates argued that once the rules were scrapped, broadband providers would begin selling the internet in bundles, not unlike cable television packages. Want access to Facebook and Twitter? Under a bundling system, getting on those sites could require paying for a premium social media package.

Another major concern is that consumers could suffer from pay-to-play deals. Without rules prohibiting paid prioritization, a fast lane could be occupied by big internet and media companies, as well as affluent households, while everyone else would be left in the slow lane.

Some small-business owners are worried, too, that industry giants could pay to get an edge and leave them on an unfair playing field.

Today’s assignment

- Read Microsoft Azure Cosmos DB technical document. Choose one consistency level other than “Strong” among five levels provided by Cosmos DB.

- Tell an application compatible with your chosen consistency level. Why ?

- Submit your answers in Japanese or in English via the course web.

本日の課題

- Microsoft Azure Cosmos DB の技術文書を読む。Cosmos DB が提供する5 つの整合性モデルのうち “Strong” 以外から一つを選択せよ。

- 選んだ整合性レベルに適合するアプリケーションを示せ。理由は？

- 講義 web から日本語か英語で回答すること。

日本経済新聞

東京消防庁の119番不具合、職員の人為ミスか

2011/1/7 21:26 | 日本経済新聞　電子版

　東京都内で５日、災害救急情報システムに不具合が生じ、約４時間半にわたり119番通報がつながりにくくなった問題で、東京消防庁は７日、ＬＡＮケーブルの誤接続が原因だったと発表した。同庁職員の人為的ミスとみられ、同日記者会見した松浦和夫警防参事は「都民に大変な迷惑をかけ、不安を与えてしまい、申し訳ない」と謝罪した。

　システム障害は千代田区の本庁舎内の災害救急情報センターで発生。同庁によると、ホストコンピューターと端末を結ぶ中継器にＬＡＮケーブルが誤接続されたため、過大なデータが流れて処理しきれなくなり、災害現場に応じて自動的に出動部隊を振り分ける機能が停止したという。

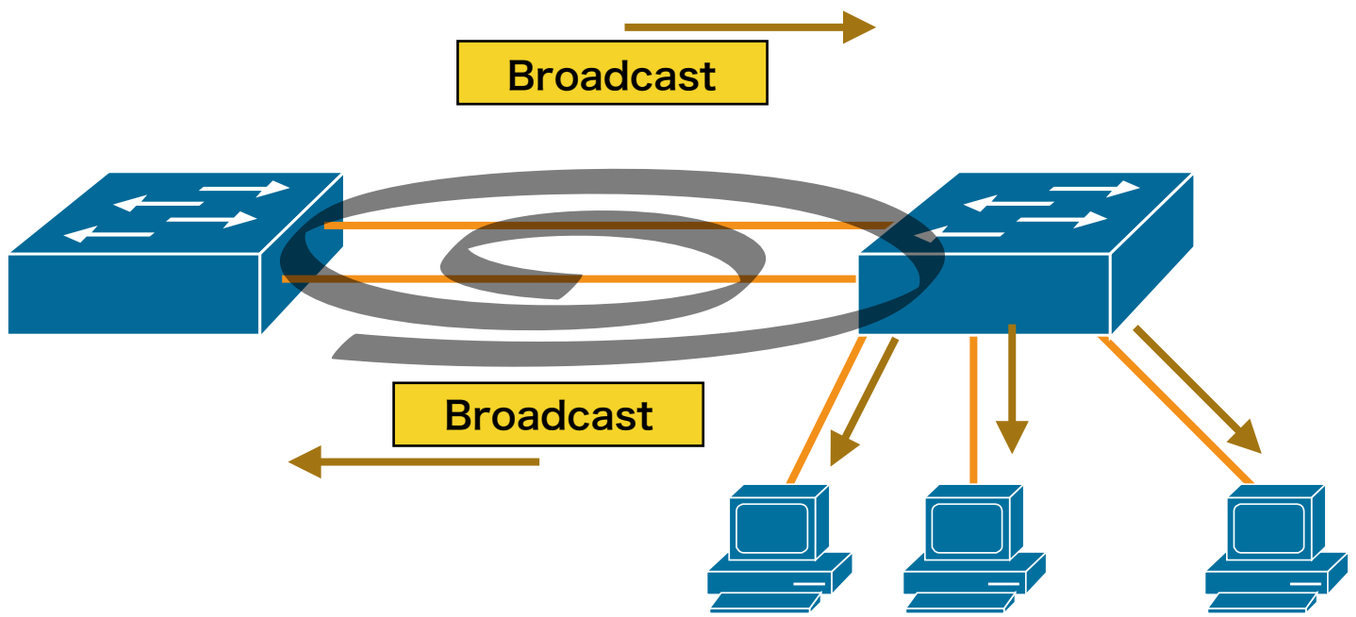
　ＬＡＮケーブルは予備のもので、一方の端子だけ中継器に差し込まれていたが、職員が誤ってもう一方の端子を空いていた差し込み口につないだとみられる。誤接続の時期は不明で、職員も特定できていない。

　同庁は再発防止策として、中継器の空いている差し込み口をふさいだり、ＬＡＮケーブルに「抜き差し厳禁」の印を付けたりしたほか、システムの改善も検討している。

　障害は５日午前10時半ごろ発生。職員が手作業で出動可能な部隊を探し、出動命令を出したために時間がかかり、稲城市と島しょ部を除く都内全域で119番がつながりにくくなった。同庁は、人命に関わる影響は出ていないとしている。

L2 switch and loop

- The most common and critical trouble in Ethernet
  - Broadcast storm caused by L2 switch loop
  - Call center service (aka 119) trouble at Tokyo Fire Department in Jun. 5, 2011
    - Somebody connected an unplugged ethernet cable at open SW port. Then, it caused broadcast storm



Today’s quiz

- Tell your idea(s) to avoid L2 loop trouble such as, probably, Tokyo Fire Department case ?

- Submit your answers in Japanese or in English via the course web.

本日のクイズ

- 東京消防庁で発生した（と推測される）L2 ループ障害を回避する方法のアイディアを記せ。

- 講義 Web フォームから記入すること。

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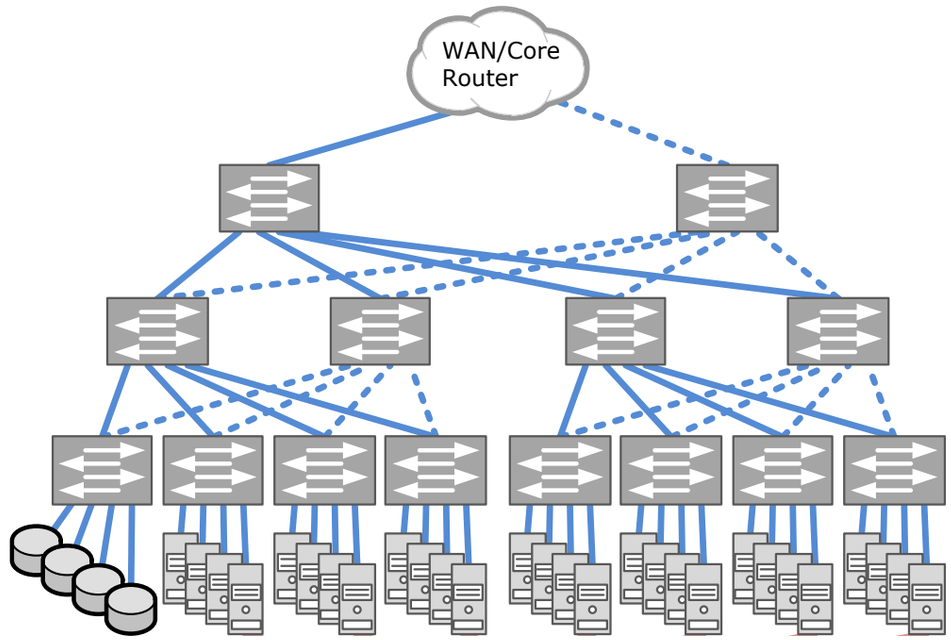
Application
Presentati
Session
Transport
Network
Datalink
Physical

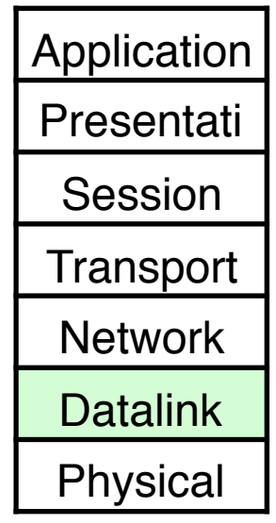
DC networking

- A Key component of cloud computing Infrastructure.
  - External connectivity
  - Interconnect server nodes
    - Not only servers, but storage systems are accommodated by DC networking such with iSCSI, Fibre channel over Ethernet (FCoE).
  - DC networking is based on :
    - Internet Protocol (IP) aka. L3
    - Ethernet (IEEE802.3) aka. L2.
- Reliability : Unlike server troubles, network troubles involves entire DC system.
- Scalable performance : DC require high performance network today due to workload shifting.

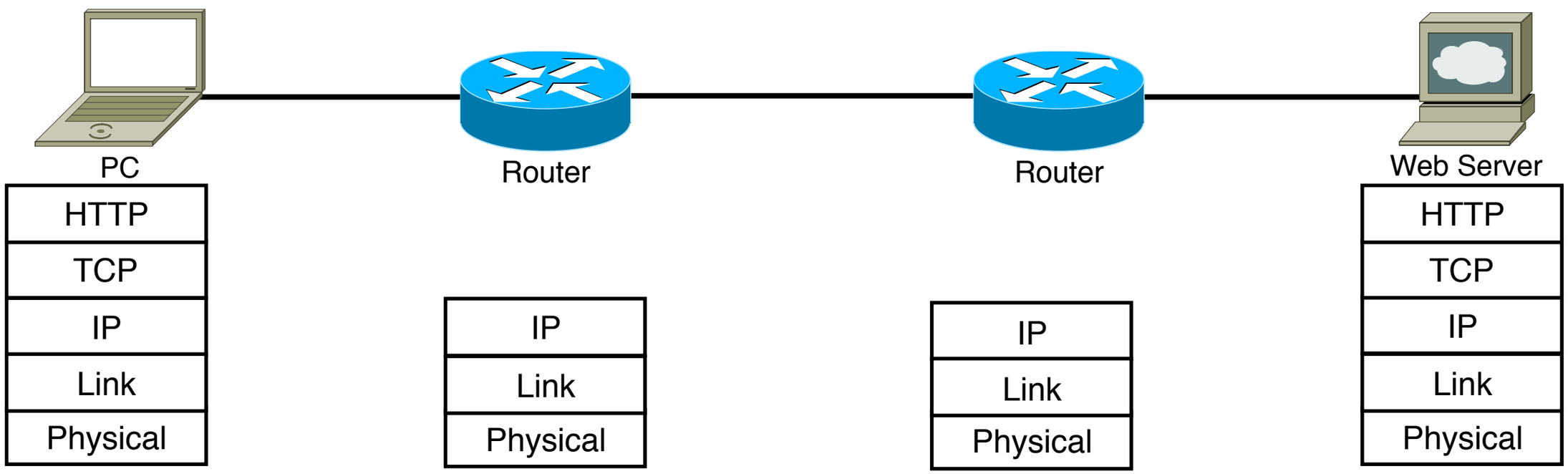


PANDUIT, Flexible Modular Data Center Architecture
Simplifies Operations, 2012

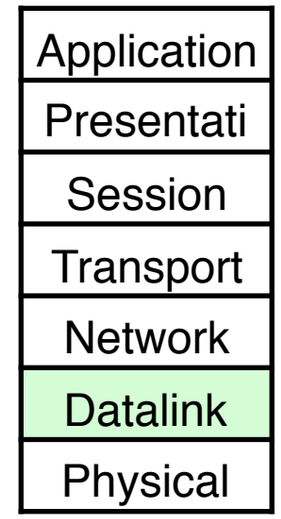
Internet Architecture



- End-to-End:Dumb networks and smart end systems.
  - Networks deliver packets in best-effort basis.
  - End systems take care other than it, e.g., reliability, sequence of data, error check, congestion avoidance.

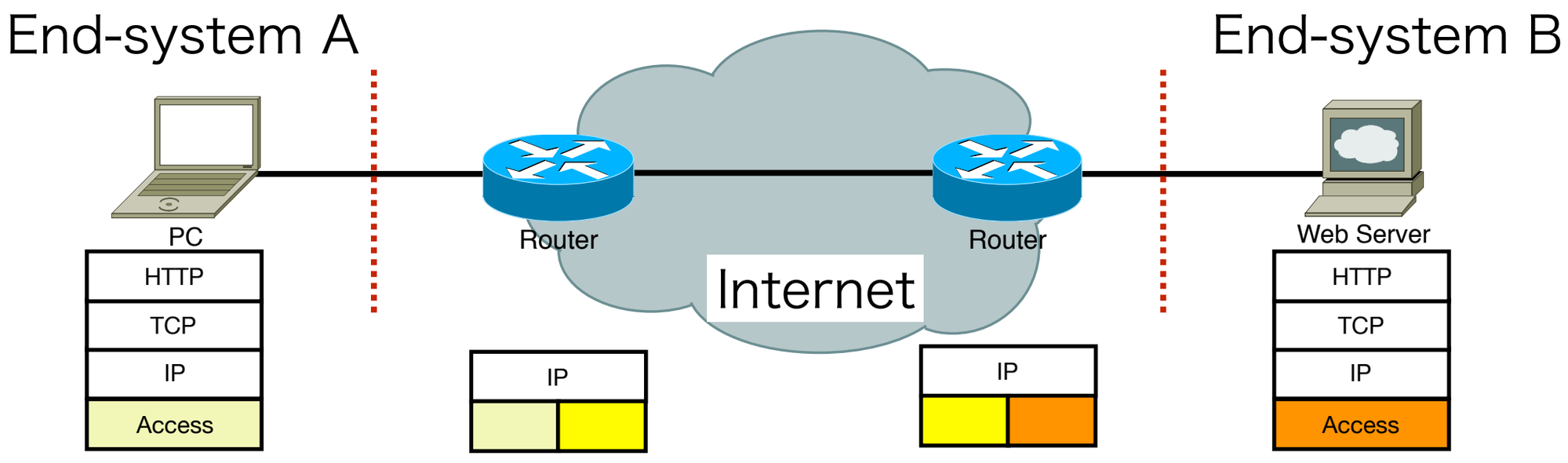


Internet Routers and End-systems

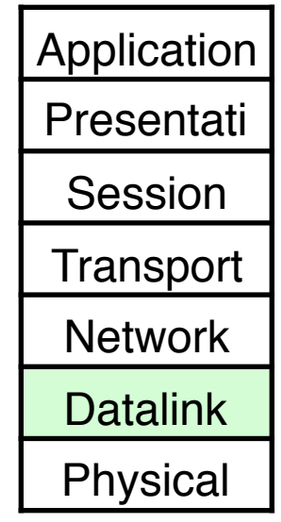


- Based on the architecture, no difference between them. Just a computer connected to a network.

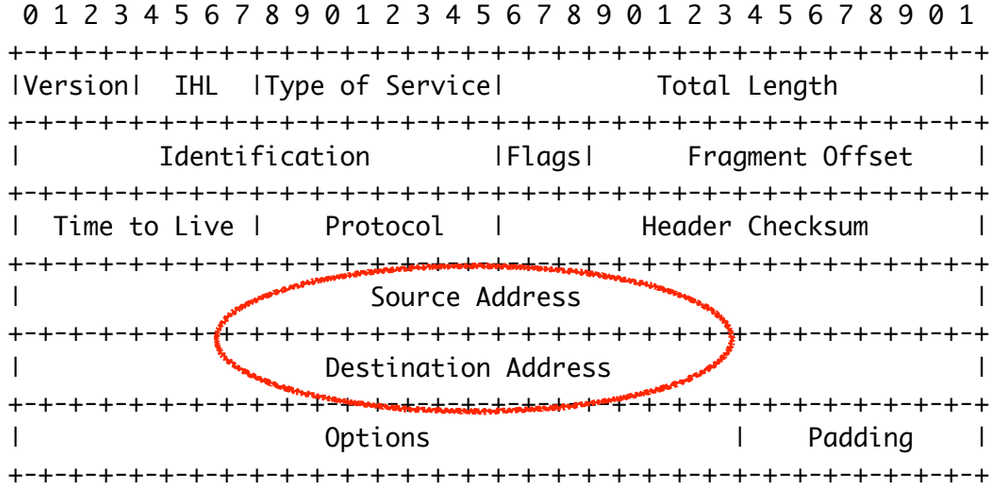
- In real operation, end-systems are managed by end-users, and routers by operators, because operators prefer to define a demarcation point. Operators don't want customer to make any impact to its network, vice and versa.



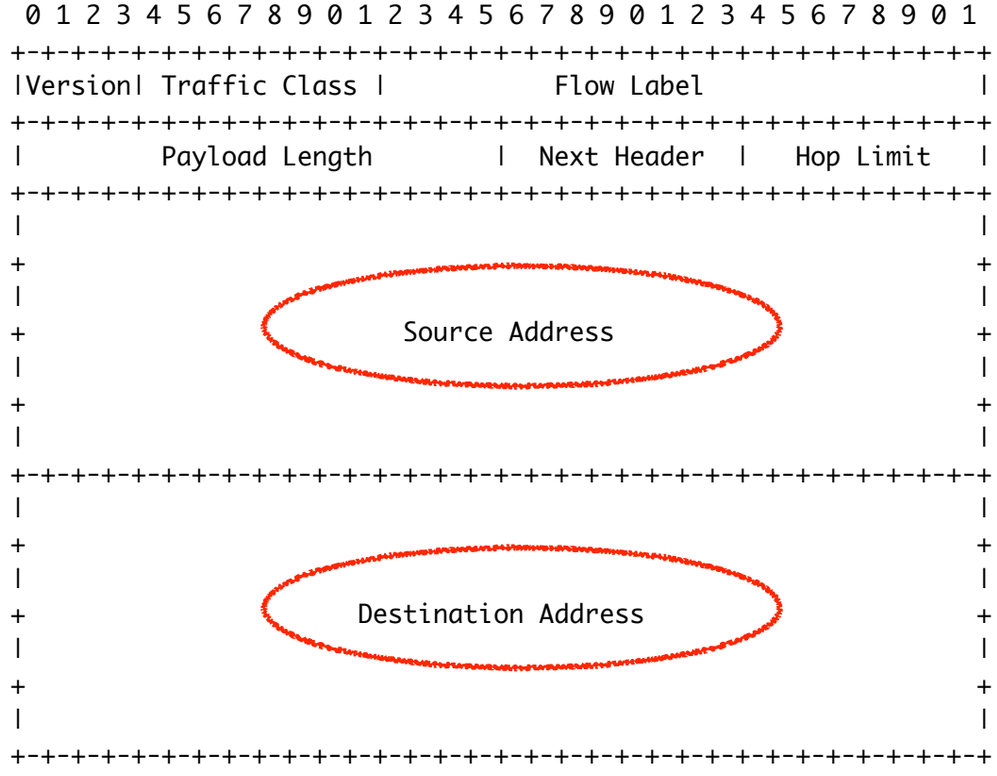
IP Header



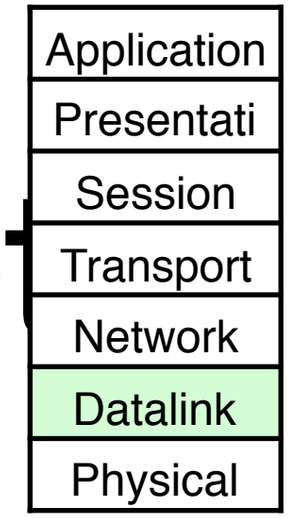
IPv4:



IPv6:



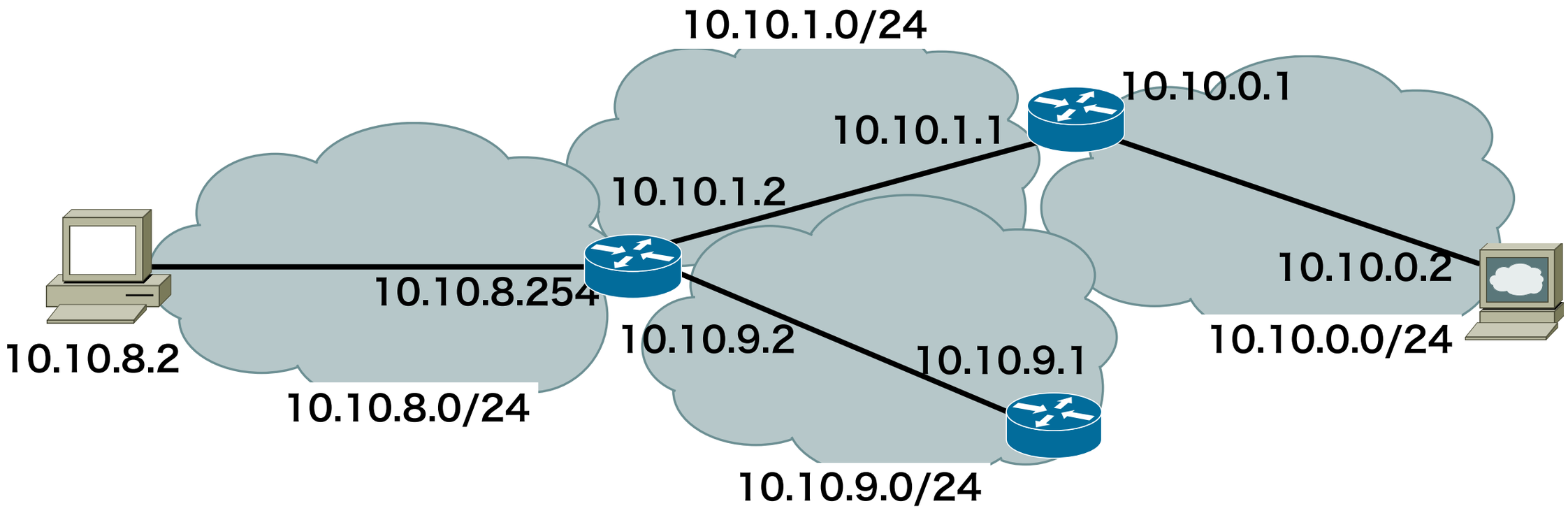
IP address and subnet



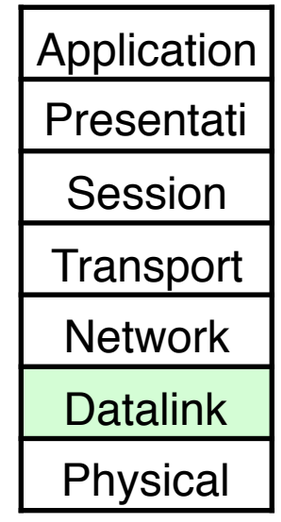
- Managed by IANA (Internet Assigned Number Authority)
  IANA or regional registries assign address space to organizations.

  - An assigned IP address space can be sub-divided into small spaces, subnet.
    10.0.0.0/8 (10.0.0.0 - 10.255.255.255)
    -> 10.0.0.0/16 (10.0.0.0 - 10.0.255.255), 10.1.0.0/16, …. 10.255.0.0/16

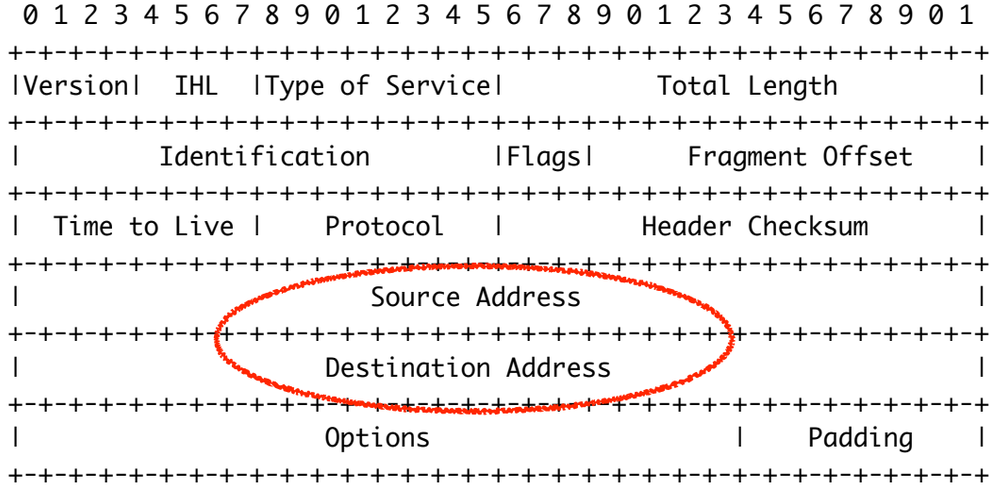
- Unlike Ethernet SW automatically MAC address learning,
  manual operations, such as IP address assignment and IP routing table, are required.



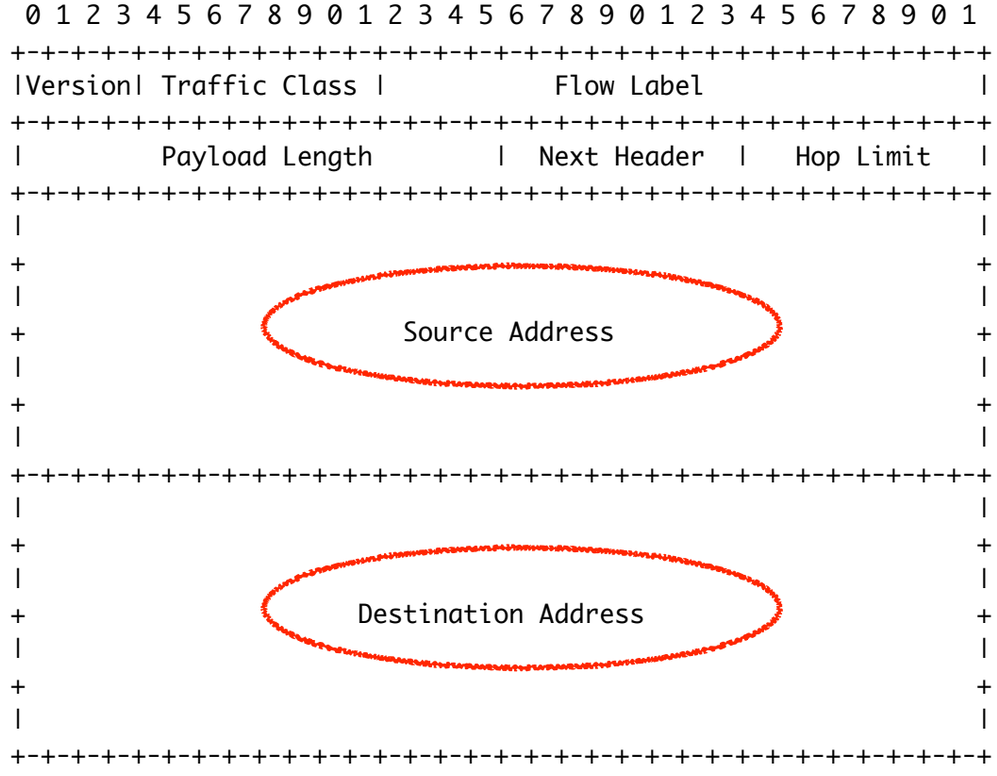
IP Header



IPv4:



IPv6:



Loop prevention with TTL / Hop Limit

Application
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Session
Transport
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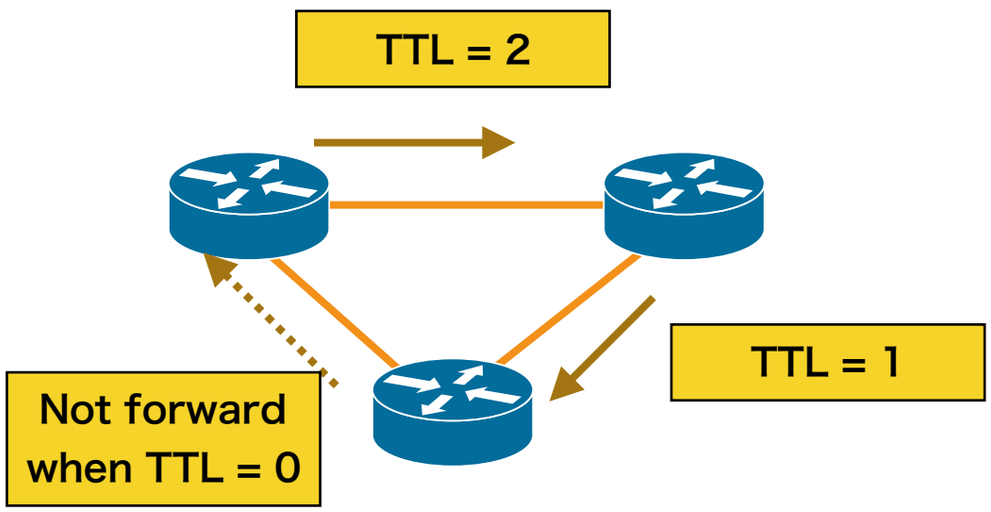
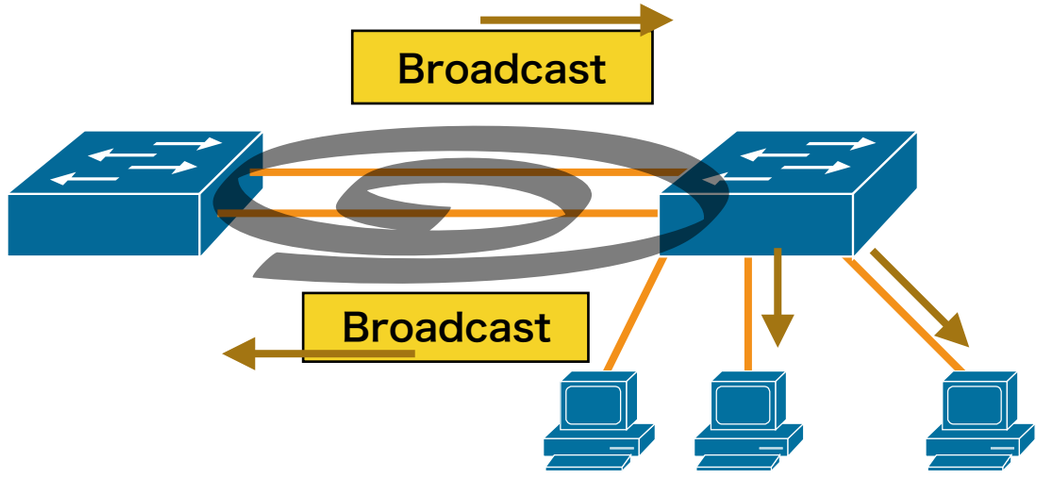
Datalink
Physical

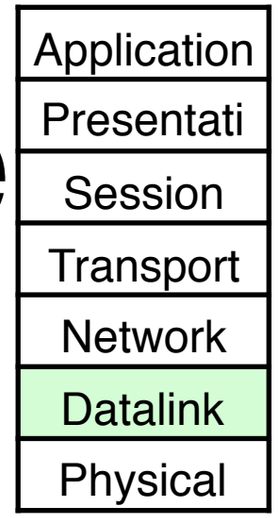
- Routers decrement TTL(IPv4) / Hop Limit(IPv6) when forwarding packets. If it is “zero”, the router discard the packets. Even if a routing loop is happened, packets are discarded no more than the initial TTL / Hop Limit router hops.

Note that if a packet is discarded due to zero TTL, the router sends ICMP Time Exceed error to the packet source.





Internet Control Message Protocol(ICMP)



- Echo / Echo Reply message
  - Check node reachability
    If a node receives a echo message, the node replies it to the packet source.

```
% ping 8.8.8.8
PING 8.8.8.8 (8.8.8.8): 56 data bytes
64 bytes from 8.8.8.8: icmp_seq=0 ttl=55 time=2.545 ms
64 bytes from 8.8.8.8: icmp_seq=1 ttl=55 time=2.596 ms
64 bytes from 8.8.8.8: icmp_seq=2 ttl=55 time=2.601 ms
64 bytes from 8.8.8.8: icmp_seq=3 ttl=55 time=2.498 ms
64 bytes from 8.8.8.8: icmp_seq=4 ttl=55 time=2.538 ms
^C
--- 8.8.8.8 ping statistics ---
5 packets transmitted, 5 packets received, 0.0% packet
loss
round-trip min/avg/max/stddev =
2.498/2.556/2.601/0.039 ms
%
```

- Time Exceeded message
  - If the TTL / Hop Count in an IP headers is zero, the router sends Time Exceeded Message to the source.

```
% traceroute -n 8.8.8.8
traceroute to 8.8.8.8 (8.8.8.8), 64 hops max, 52 byte
packets
 1  157.82.4.1  2.200 ms  1.138 ms  1.123 ms
 2  133.11.140.9  1.335 ms  1.232 ms  1.248 ms
 3  133.11.127.47  1.276 ms  1.315 ms  1.244 ms
 4  133.11.127.93  1.225 ms  1.737 ms  1.263 ms
 5  150.99.190.97  1.660 ms  1.721 ms  1.681 ms
 6  150.99.64.29  1.536 ms  1.654 ms  1.609 ms
 7  210.173.176.243  2.955 ms  2.428 ms  3.673 ms
 8  108.170.242.161  2.724 ms
    108.170.242.193  2.887 ms
    108.170.242.161  2.484 ms
 9  72.14.236.169  3.419 ms
    209.85.255.145  3.696 ms
    209.85.255.173  3.558 ms
10  8.8.8.8  2.656 ms  2.674 ms  2.480 ms
%
```

Postel, Jon. "RFC 792: Internet control message protocol." InterNet Network Working Group (1981).
Conta, Alex, and Mukesh Gupta. "Internet control message protocol (icmpv6) for the internet protocol version 6 (ipv6) specification." (2006).

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Workloads in DC networ

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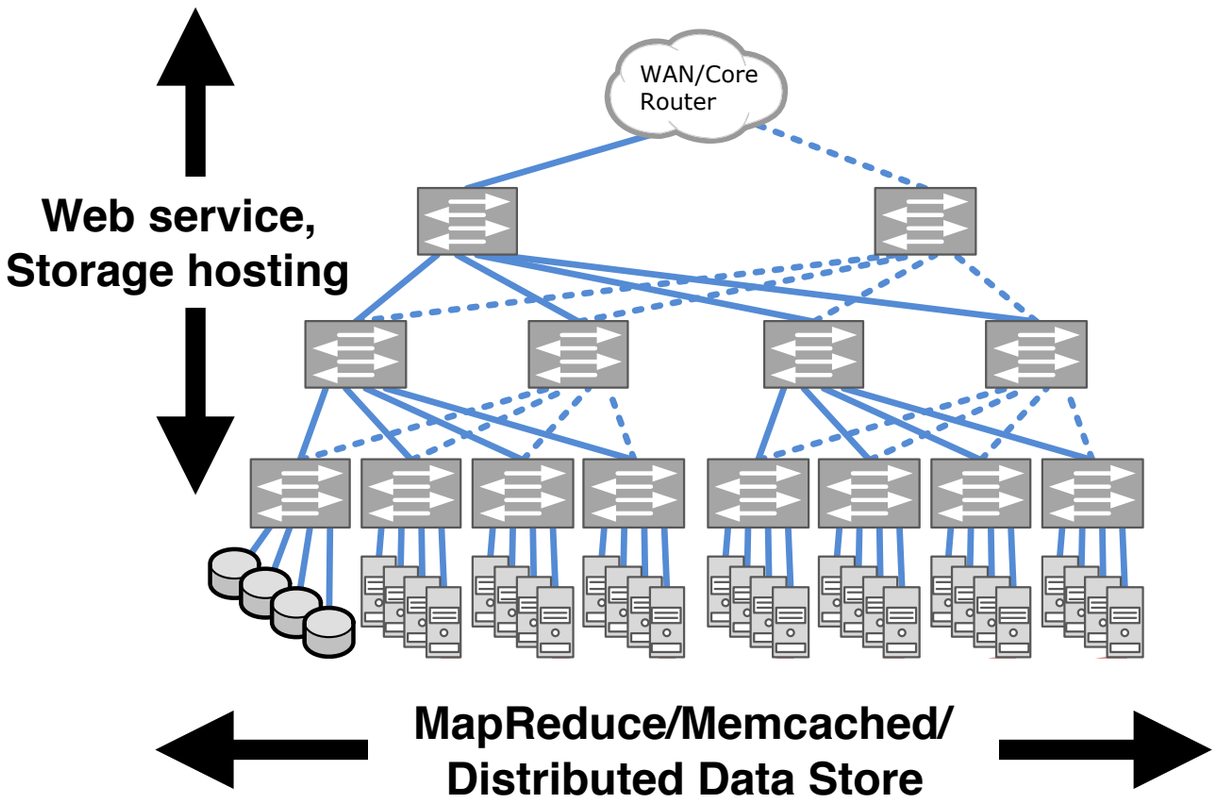
- Traffic Types:
  - External, or North-South:
    - Web services
    - Cloud storages
    - SQL DB
  - Internal, or East-West:
    - MapReduce
    - Memcached
    - Distributed Data Store.
- Workloads are increasing, and are shifting
  from : North-South
  to : East-West traffic.



PANDUIT, Flexible Modular Data Center Architecture
Simplifies Operations, 2012

DC network design
- Legacy -

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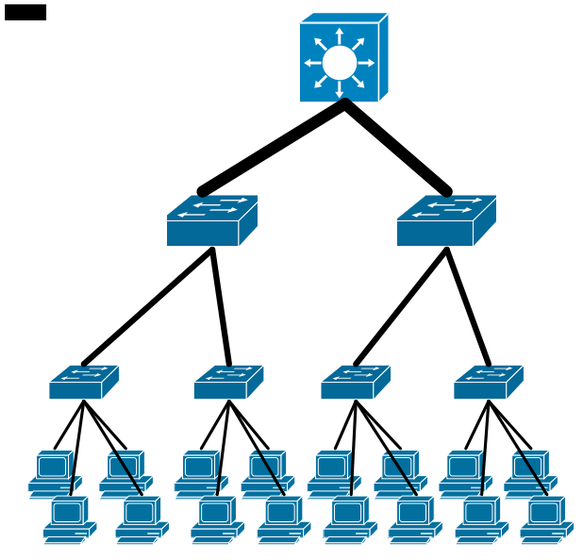
Physical

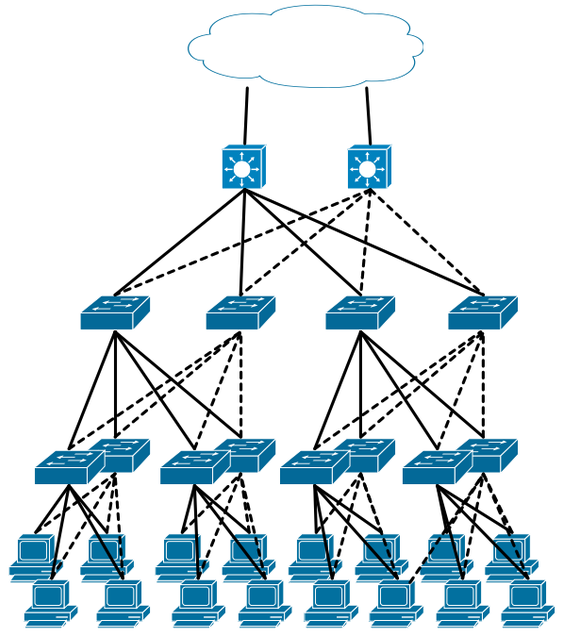
- Simple tree topology
  - Meet North-South traffic
    - Bottleneck at external and/or customer edges.
  - Poor intra-DC throughput
    - Cutting-edge services require East-West BW capacity.



- Fat Tree (non-blocking) is able to accommodates traffic.
  However, Fat Tree is impractical, because:
  - Bigger switches: $$$$, or NA.
  - Fatter BW capacity links: NA,
    even with Link Aggregation Group (LAG)
    - Poor scalability
    - Complexity in operation and management

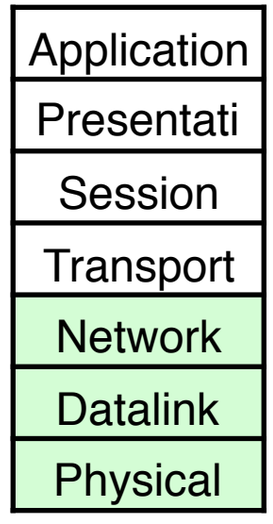
Ling Aggregation Group (LAG)

Fat Tree



Tree (Redundant)

DC network
Switch / Router



- DC networks comprise of ethernet switches.
  - Layer-2 (L2) : Ethernet (IEEE 802.3) frame switching.
  - Layer-3 (L3) : IP packet routing capability.
    Most L3 switches also have L2 functions.
    - The both provide frames/packets forwarding
      according to the destination addresses in the header field.
- A lot of hosts have to be connected.
  - But big ethernet switch, having large number of ports, is $$$$ due to market and technical factors.

  ➡DC networks are shifting from “big” end-of-row, or woven, switches to small top-of-rack (ToR) switches.

Fashion designer Karl Lagerfeld appears at the end of the presentation of Chanel's Spring-Summer 2017 ready-to-wear fashion collection presented Tuesday, Oct.4, 2016 in Paris. (AP Photo/Francois Mori) Francois Mori — AP

FUTURE OF WORK

Chanel's Karl Lagerfeld Turns the Runway Into a Data Center at Paris Fashion Week

Reuters
Oct 04, 2016

Chanel on Tuesday made fun of how much technology was part of people's lives by producing a fashion show at Paris' Grand Palais dedicated to wires, cables, and black data boxes.

Greeted by a huge sign that said "Chanel data center," designer Karl Lagerfeld presented guests with a collection complete with blinking handbags, iridescent tweeds, and fluorescent rays of color splashed on flowing dresses and caps.

The show opened with an all-white tweed suit with a round plastic helmet and boots reminiscent of *Star Wars* warriors (DIS, -0.80%).

"We all depend on it," Lagerfeld, 83, told Reuters TV after the show, referring to technology. "Imagine your life without the telephone and the next step will be artificial intelligence and robots."

Models walking alongside rows of computer hardware wore classic Chanel tweed suits and jackets completed with metallic ballerina shoes.

Get Data Sheet, Fortune's technology newsletter

Accessories included a small black handbag that was effectively a plastic robot with blinking square eyes.

Chanel, which is privately owned, traditionally organizes some of the most striking shows during Paris Fashion Week. The events help the brand preserve its image which is crucial for retaining customers and wooing new ones.

According to figures filed with the Amsterdam exchange, the French luxury goods maker was hit hard by the luxury spending slump last year.

How to build high-BW capacity SW / Router

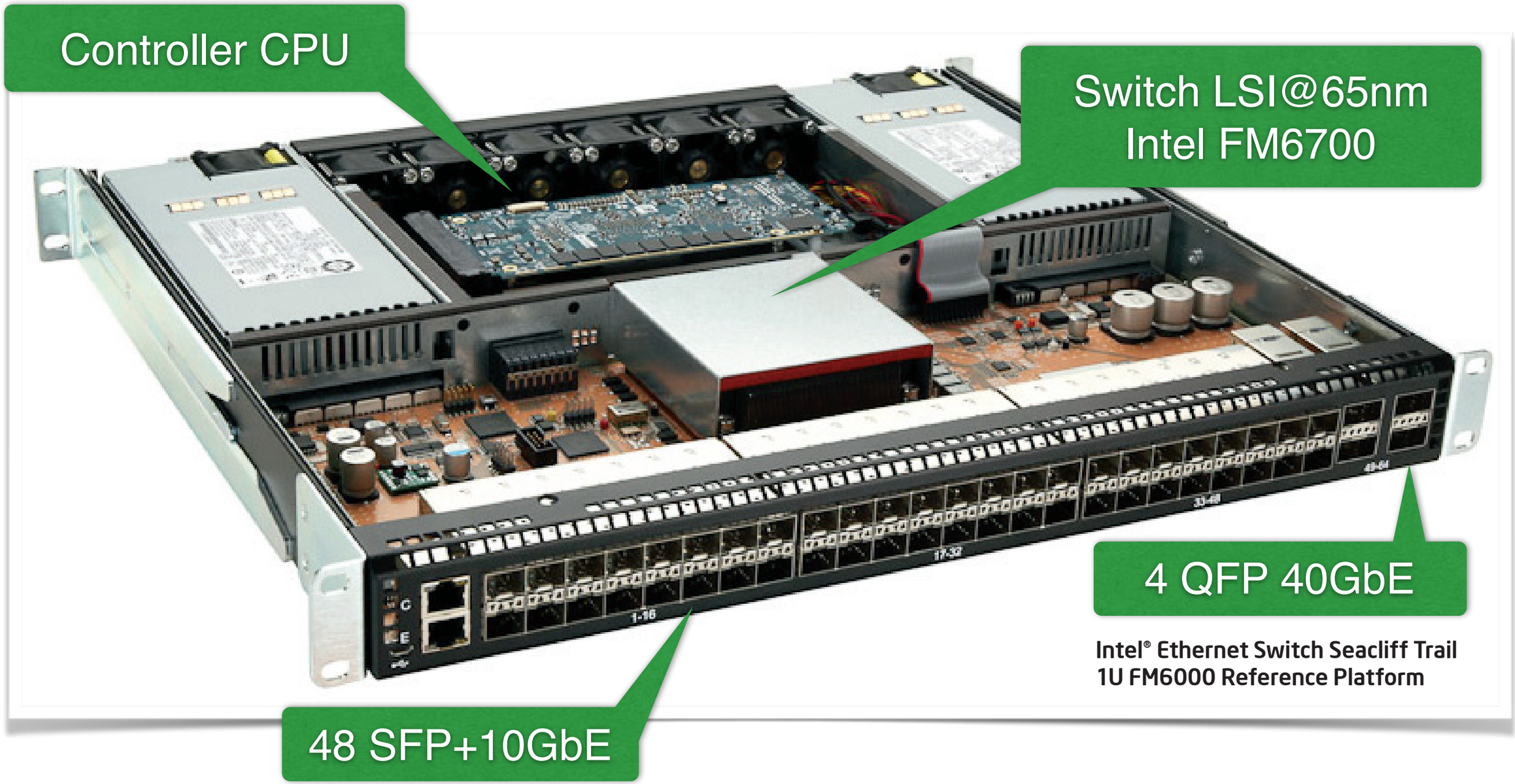
- Big SWs/Routers in market also comprise of LSIs
  - Capacity is bounded by the throughput of the component i.e., LSI
  - LSI Throughput = (Total No. of transceivers) x (BW of transceiver) = (# of LSI pins) x (BW of pin)
- State of art boxes:
  - 40Tbps@Juniper Qfabric: 4 x 21U Interconnect chassis, 128 x 1U Edge chassis.
  - 922Tbps@CRS-X: 8 line-, 4 fabric-card shelves
  - 209Tbps@Huawei NE9000: 49.5U Height

CISCO CRS Series

Juniper QFabric series

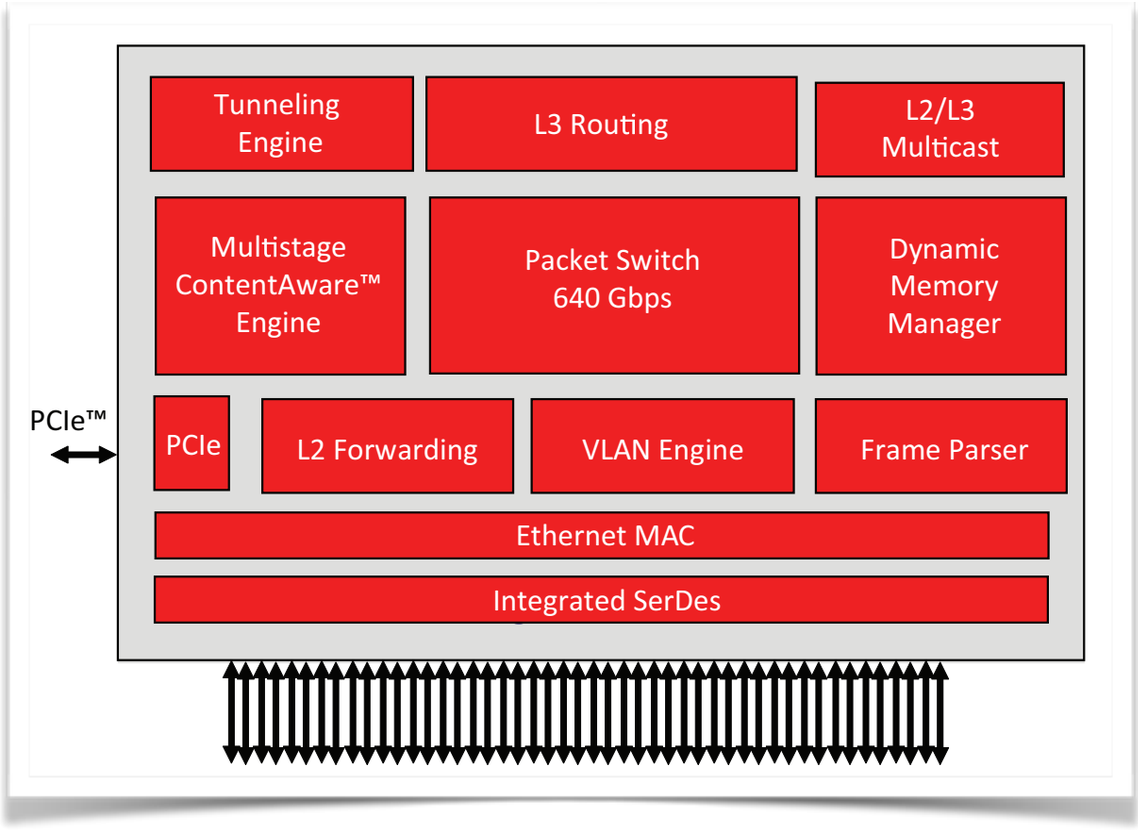
Huawei NE9000

ToR Ethernet Switch

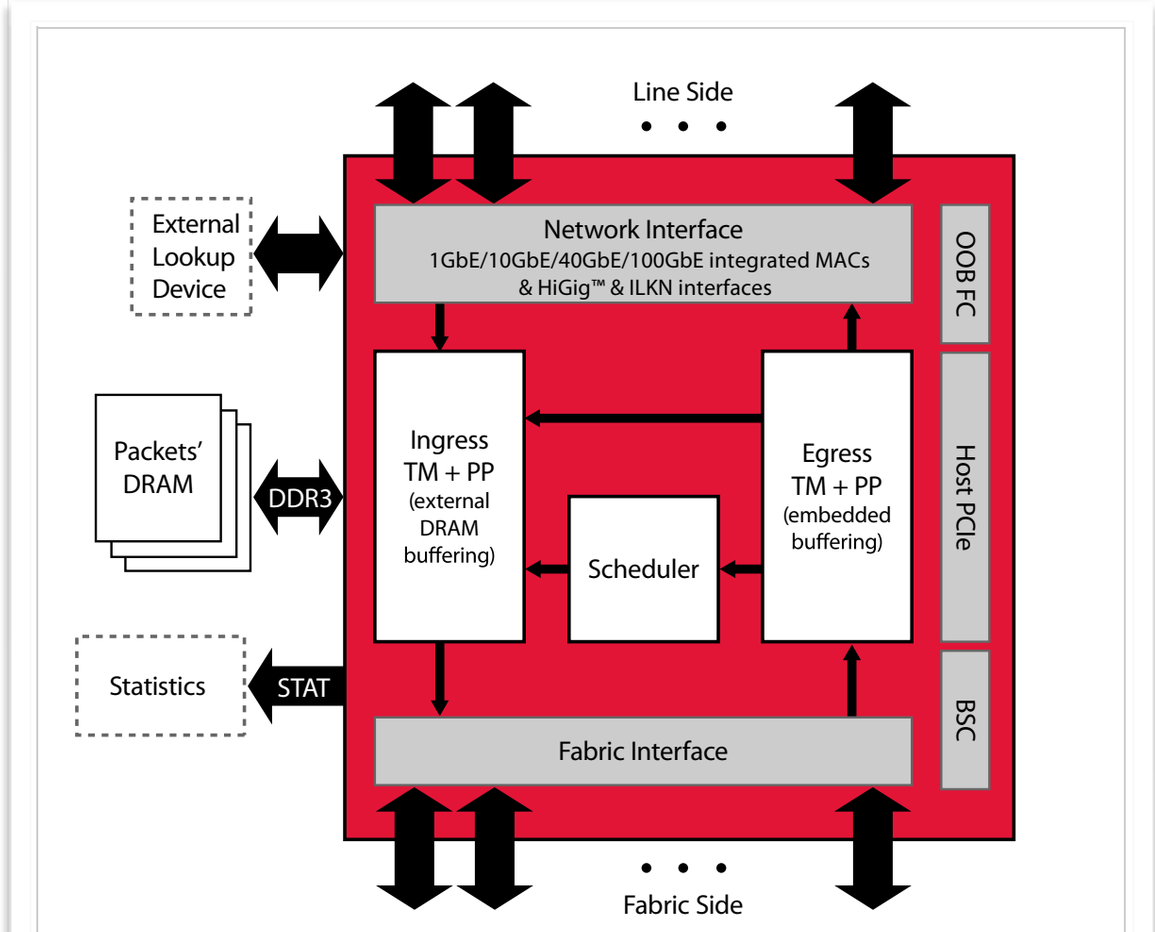


Intel, Intel® Ethernet Switch FM6000 Series 10/40 GbE Low Latency Switching Silicon, 2013

Ethernet Switch LSI



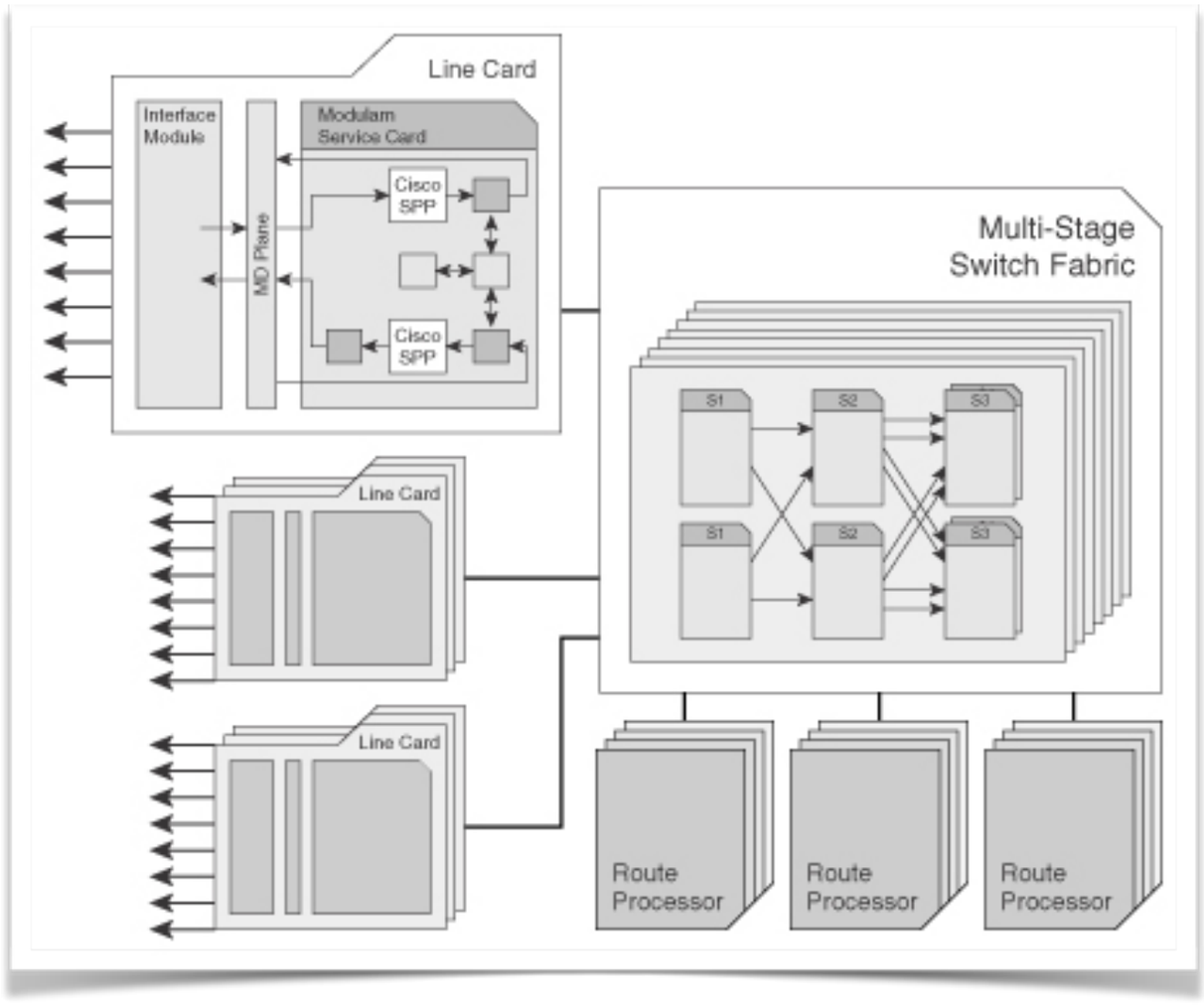
"Broacdcom BCM 56840_PLUS Switching Technology", 2011

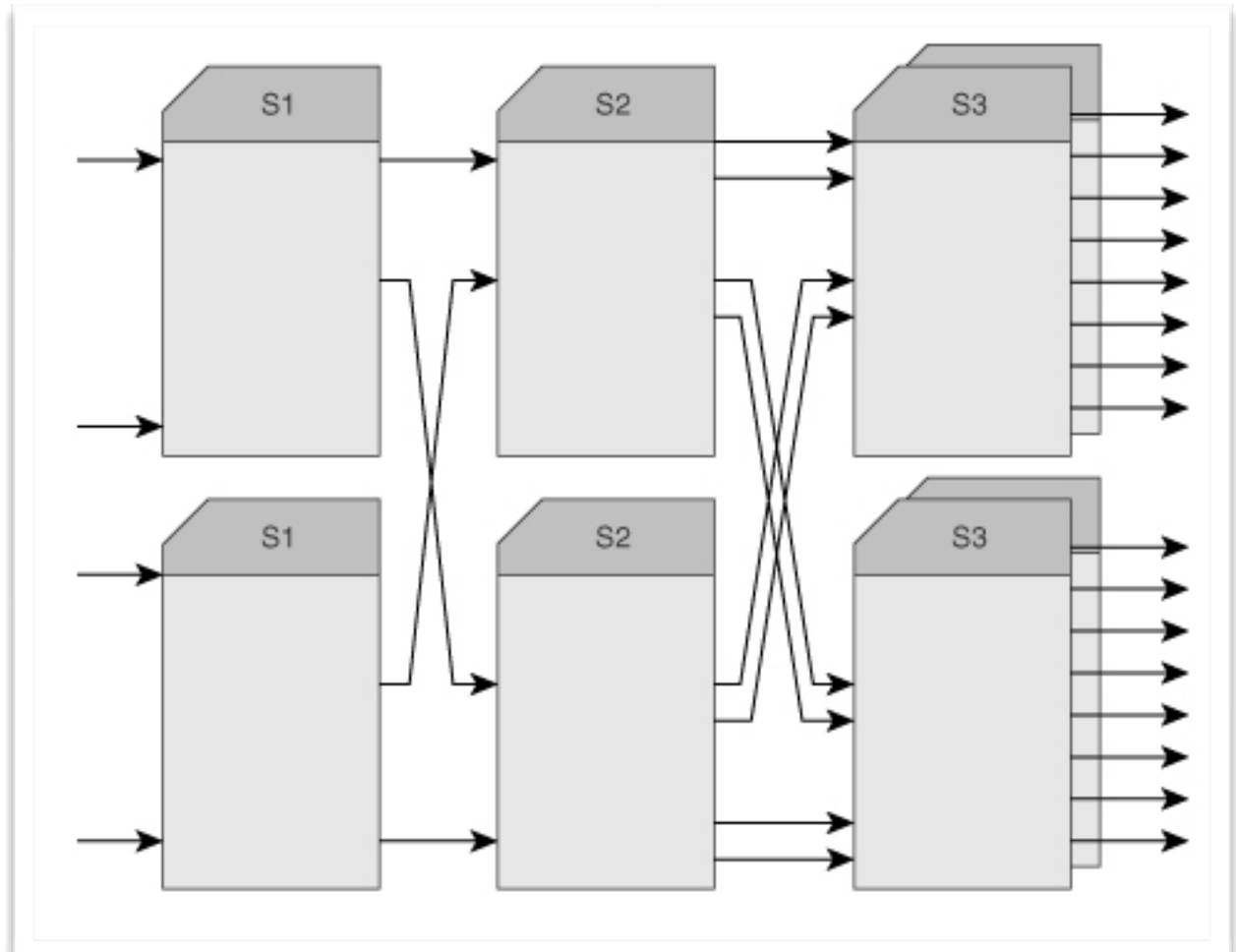


BCM88650 Block Diagram

"Broadcom BCM 88650 Series World Most Dense 100GbE Switching Solution", 2012

CISCO CRS-1 Fabric architecture
- Benes network -





Robert Wood. “A Network Administrator's View of Multiservice Networks”, Cisco Press, 2005

Juniper T-Series Fabric architecture - Clos network -

Figure 10: Three-Stage Clos Topology

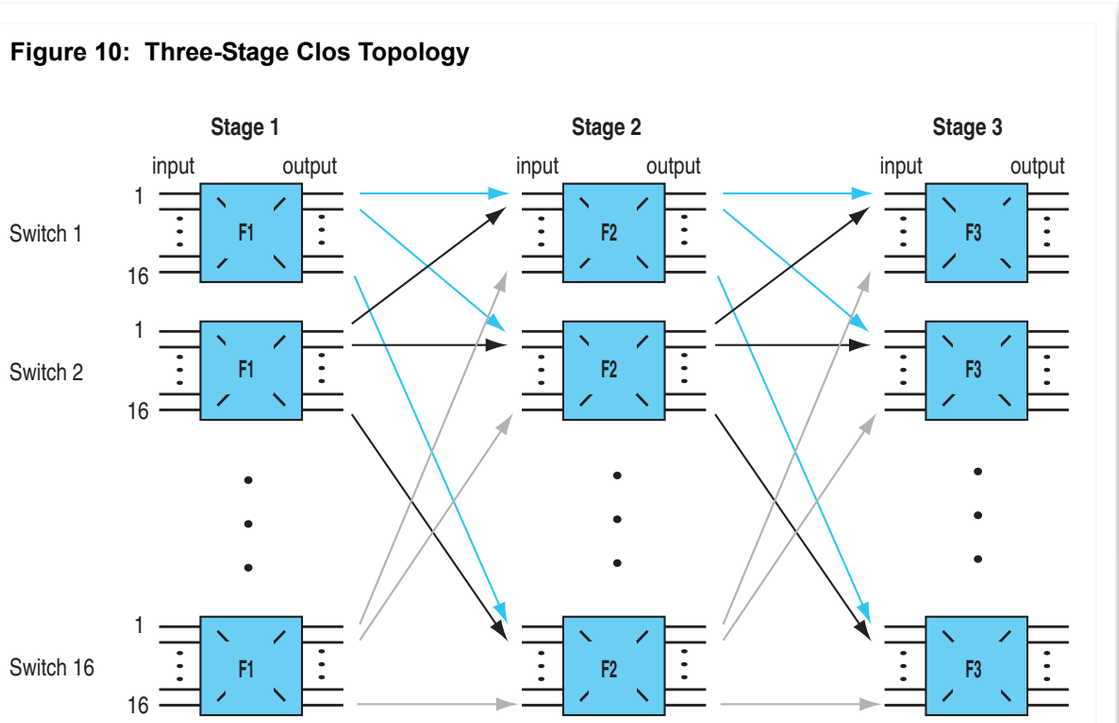
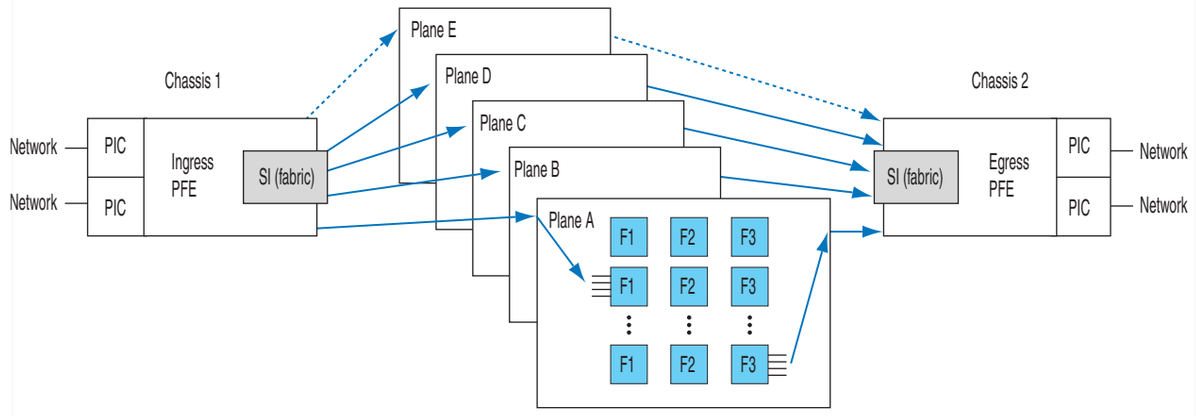


Figure 11: Multichassis Switch Fabric Planes



Juniper, “T-series Routing Platforms: System and Packet Forwarding Architecture”, White paper, 2003

DC network design and cablin with big, or end-of-row SW

Application
Presentati
Session
Transport
Network
Datalink
Physical

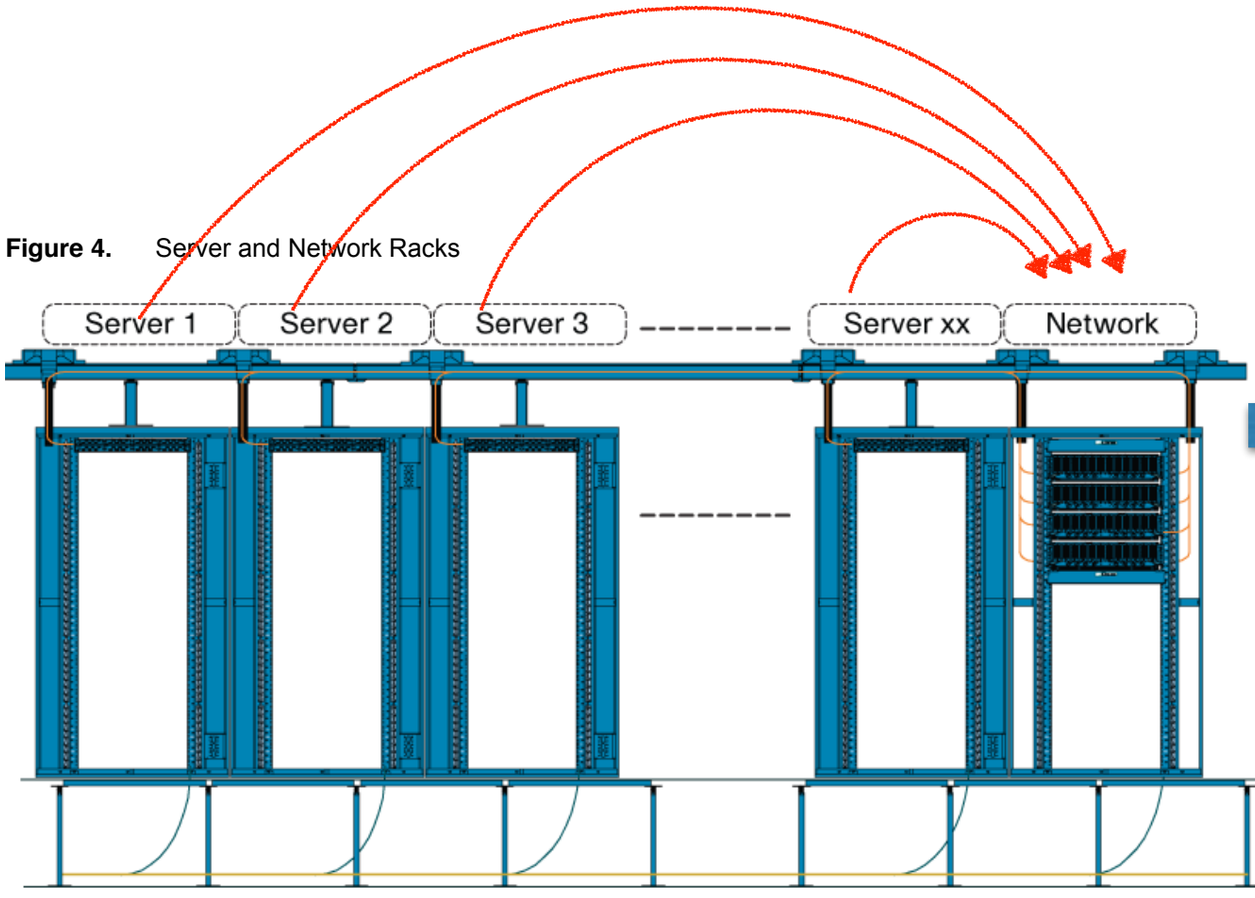
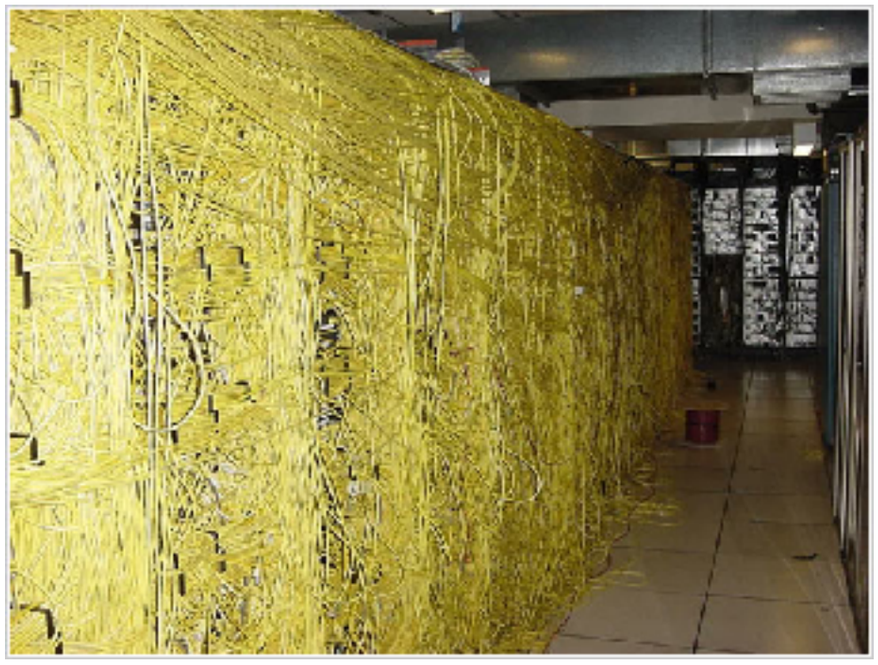


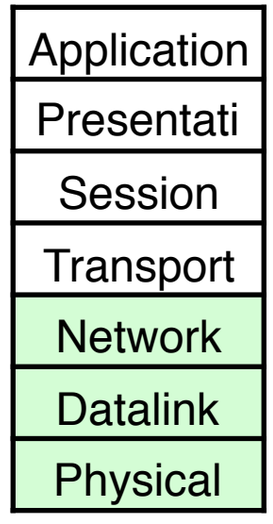
Figure 4. Server and Network Racks



http://royal.pingdom.com/2008/01/09/the-worst-cable-mess

CISCO, “Data Center Top-of-Rack Architecture Design”, 2009

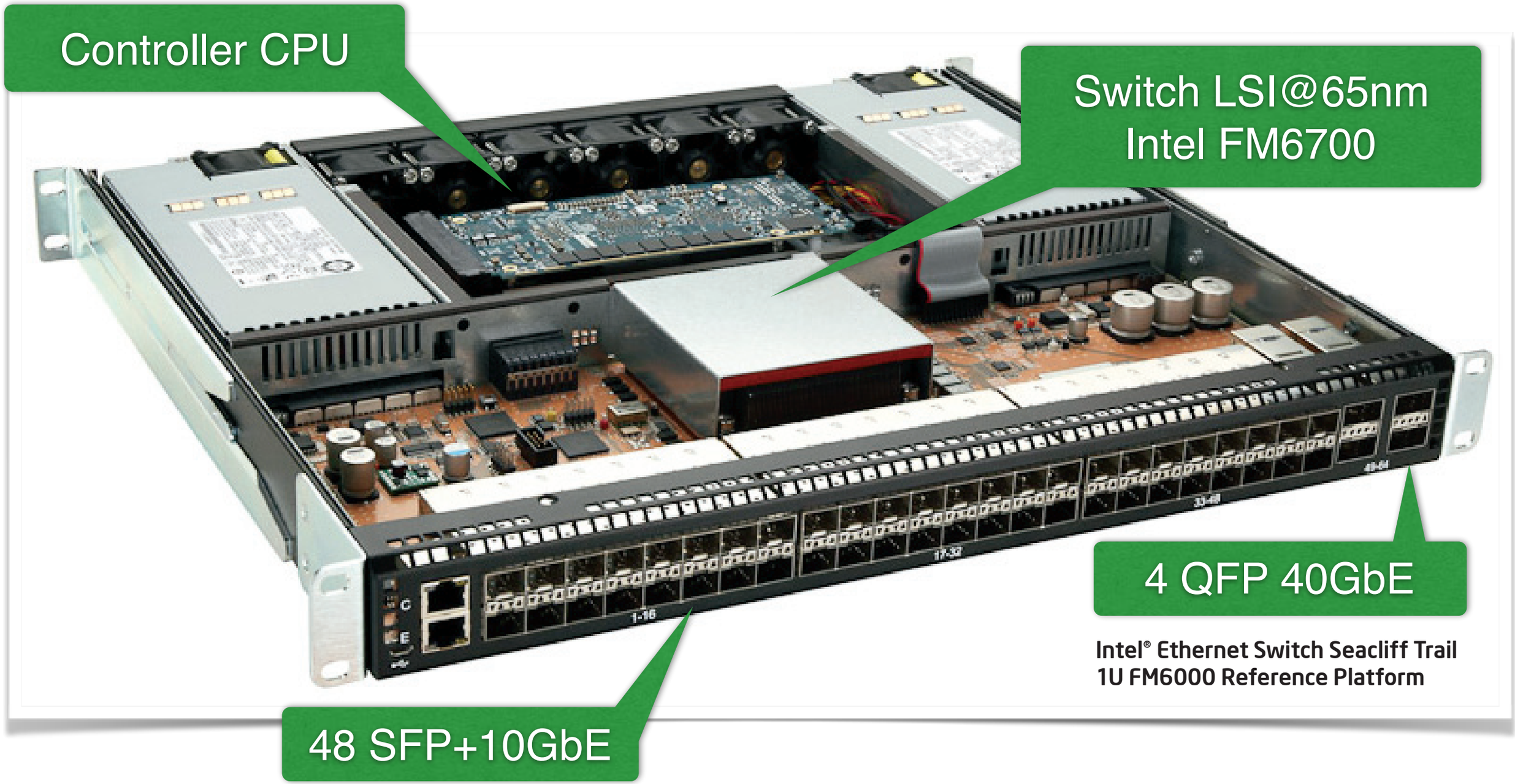
DC network
Switch / Router



- DC networks comprise of ethernet switches.
  - Layer-2 (L2) : Ethernet (IEEE 802.3) frame switching.
  - Layer-3 (L3) : IP packet routing capability.
    Most L3 switches also have L2 functions.
    - The both provide frames/packets forwarding
      according to the destination addresses in the header field.
- A lot of hosts have to be connected.
  - But big ethernet switch, having large number of ports, is $$$$ due to market and technical factors.

  ➡DC networks are shifting from “big” end-of-row, or woven, switches to small top-of-rack (ToR) switches.

ToR Ethernet Switch



Intel, Intel® Ethernet Switch FM6000 Series 10/40 GbE Low Latency Switching Silicon, 2013

Folded Clos (Leaf-Spine) D network

Application
Presentati
Session
Transport
Network
Datalink
Physical

- Scalable and flexible DC network only with ToR switches.
  - Non blocking capacity: as Fat Tree.
  - Over subscription: Cost and performance balance.
  - Able to scale-up from over-subscription to non-blocking.
- Load balance ?
  - Routing

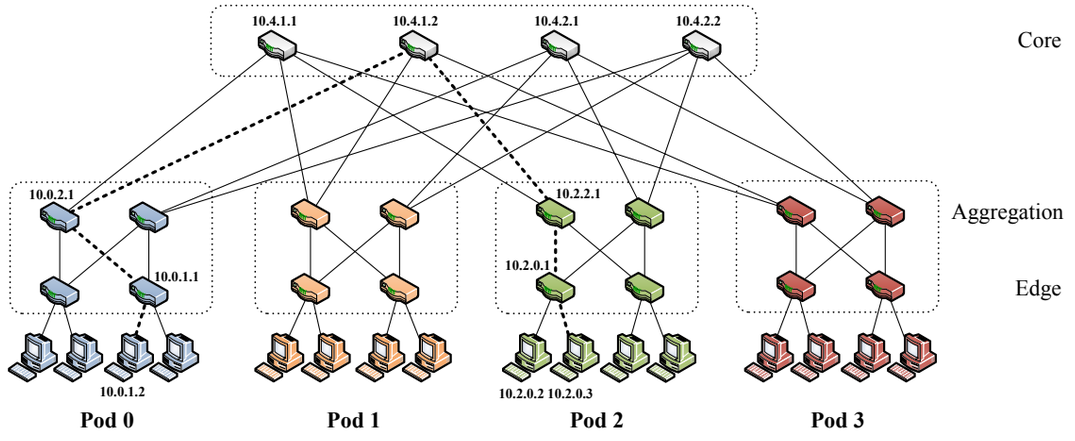


Figure 3: Simple fat-tree topology. Using the two-level routing tables described in Section 3.3, packets from source 10.0.1.2 to destination 10.2.0.3 would take the dashed path.

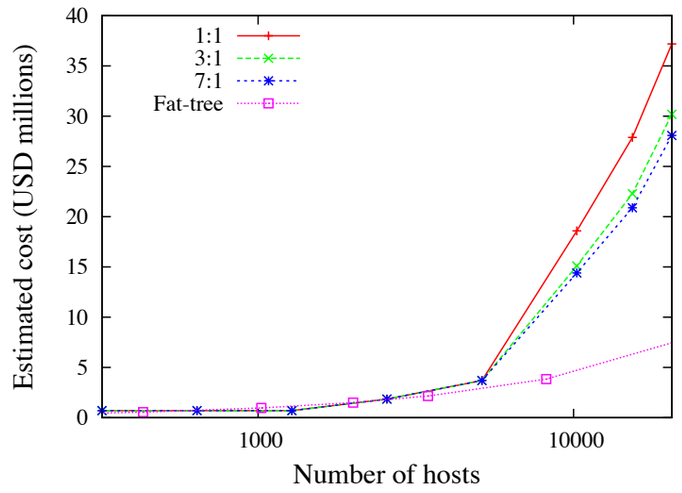


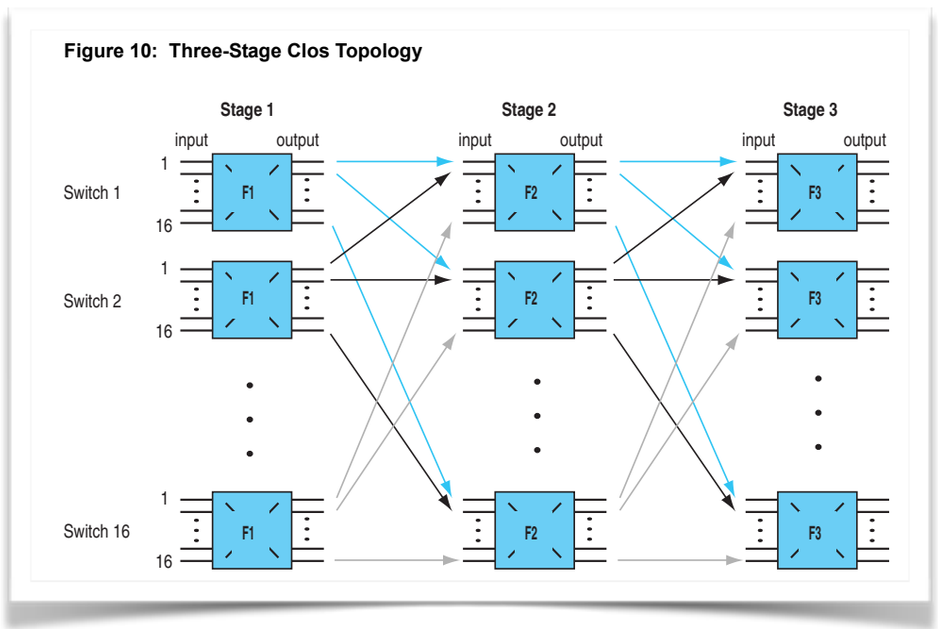
Figure 2: Current cost estimate vs. maximum possible number of hosts for different oversubscription ratios.

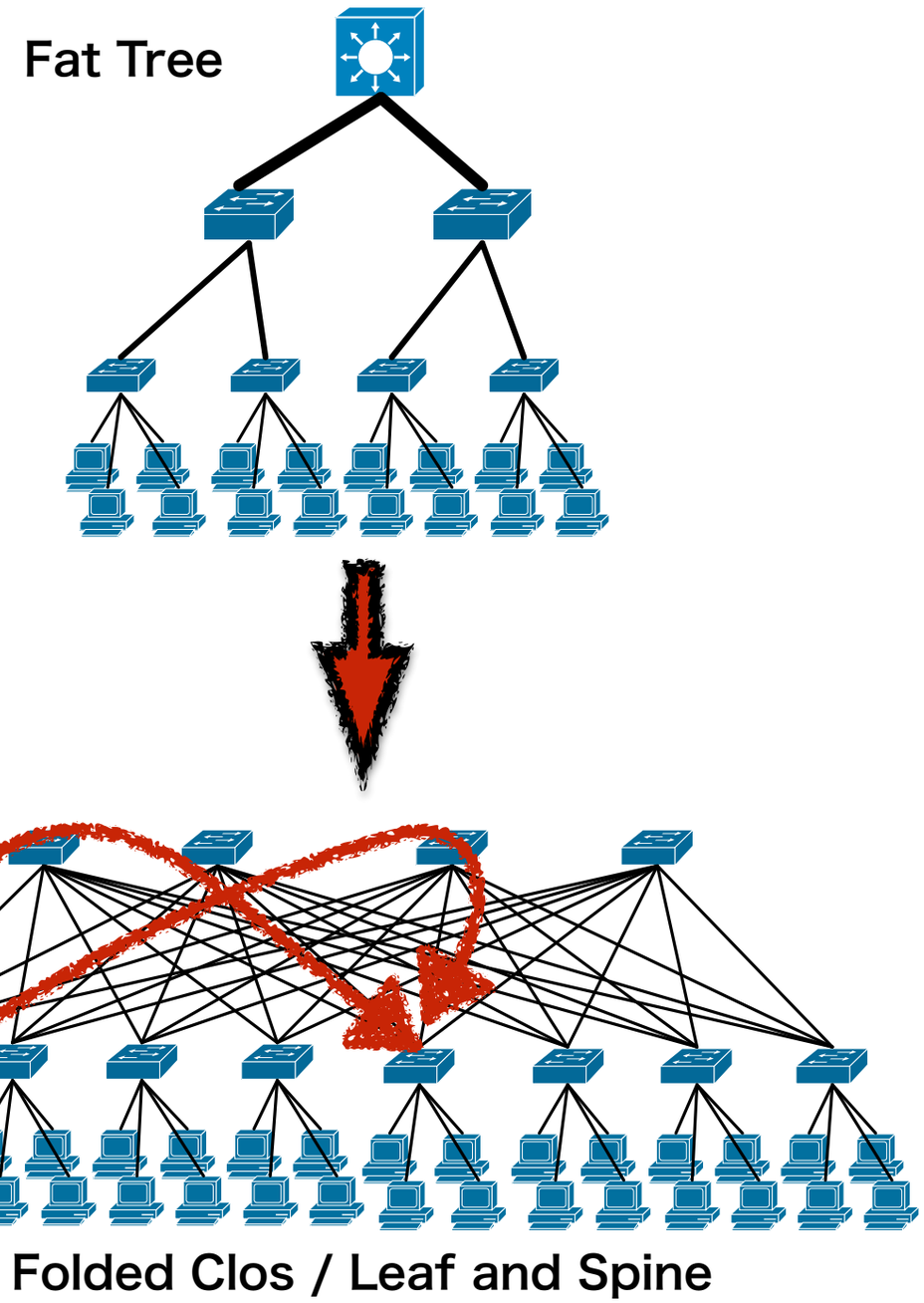
*Al-Fares, Mohammad, Alexander Loukissas, and Amin Vahdat. "A scalable, commodity data center network architecture." *ACM SIGCOMM Computer Communication Review*. Vol. 38. No. 4. ACM, 2008.
** Leiserson, Charles E. "Fat-trees: universal networks for hardware-efficient supercomputing." *Computers, IEEE Transactions on* 100.10 (1985): 892-901.

DC network for horizontal traffic with ToR switches

- In order to accommodate increasing intra-DC traffic, leaf and spine architecture is adopted instead of ordinary spanning tree. On the leaf and spine architecture, traffic load balance can be realized by using Equal Cost Multi Path (ECMP) routing.

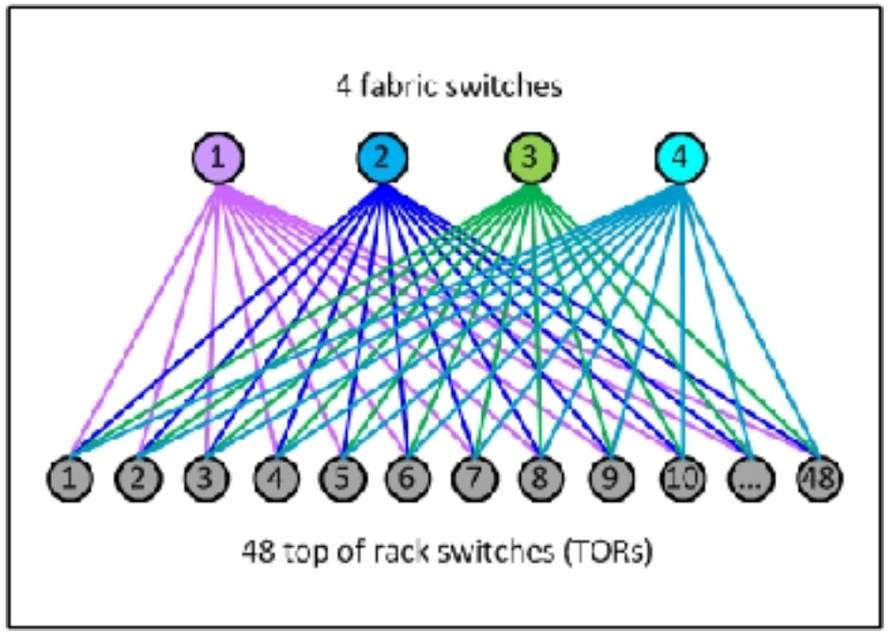
- IP (L3) ECMP routing with BGP4 is popular, while both Ethernet (L2) and other IP routing supports ECMP. This is because BGP4 is well used compared with other ECMP mechanism.

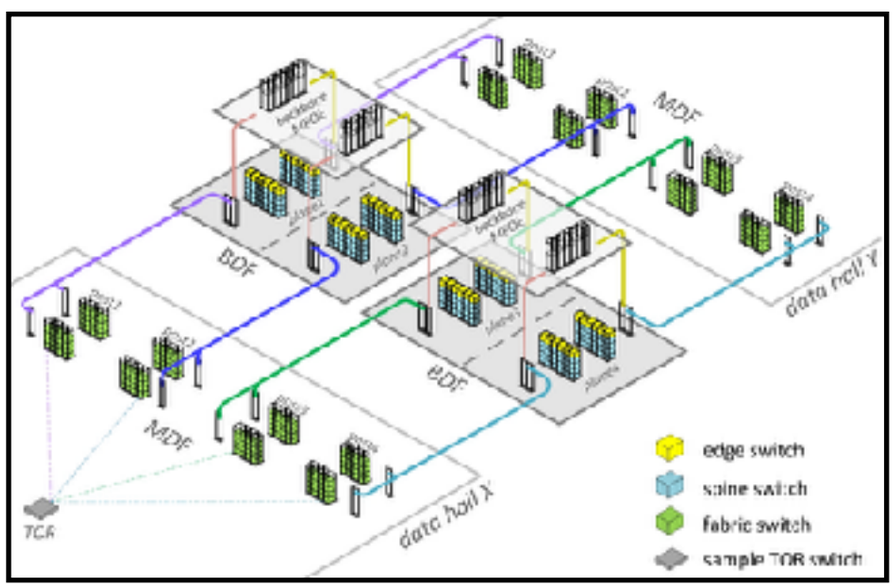


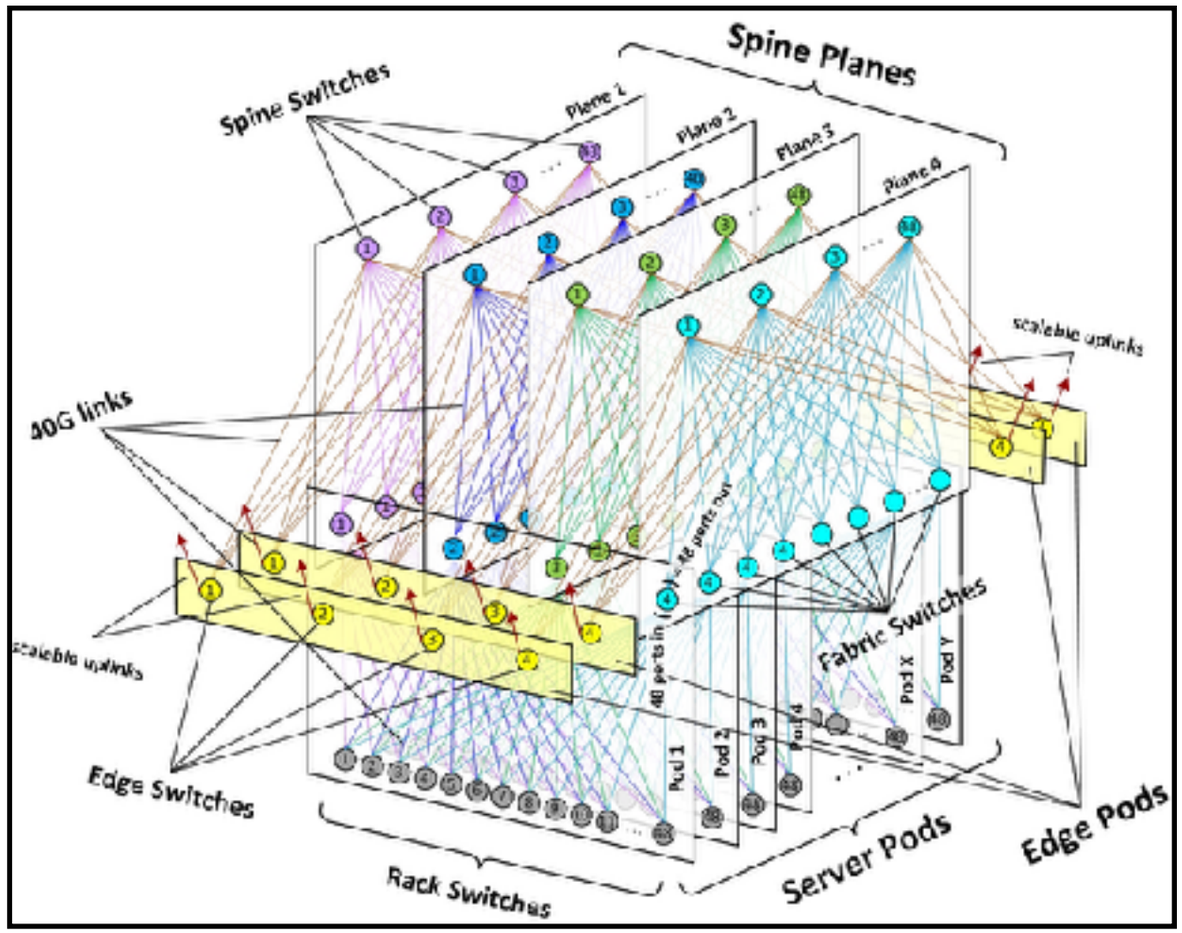


Facebook : 3-level folded Clos networ

Application
Presentati
Session
Transport
Network
Datalink
Physical

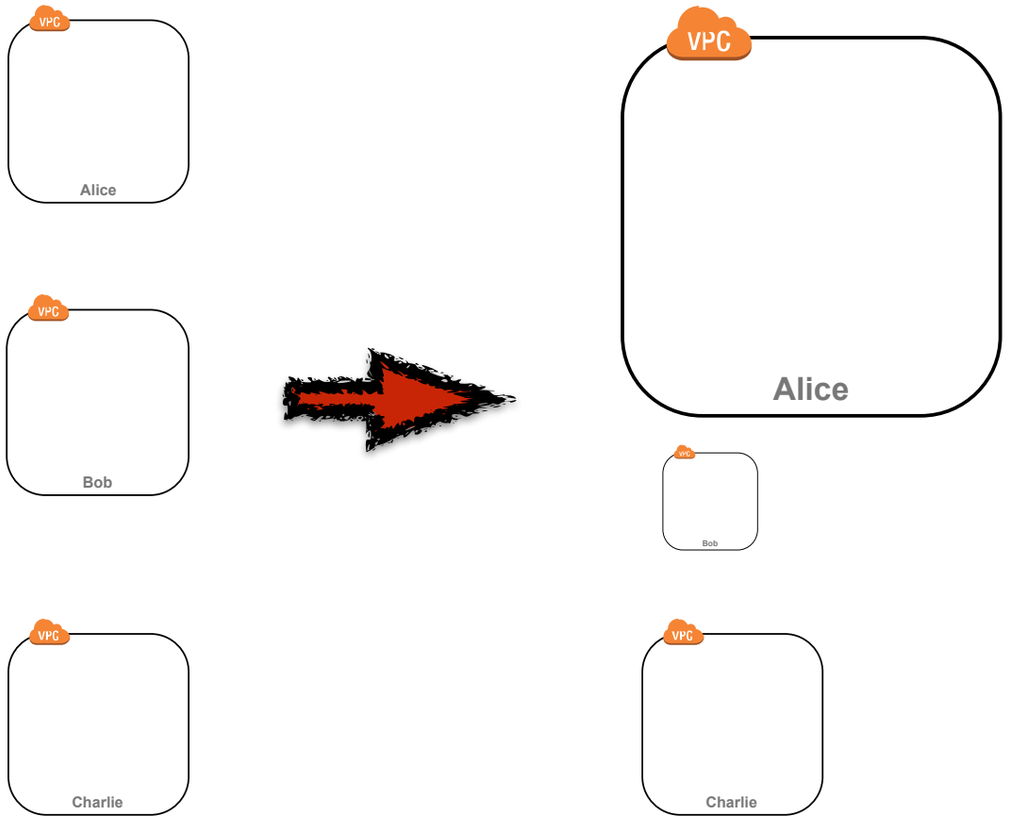


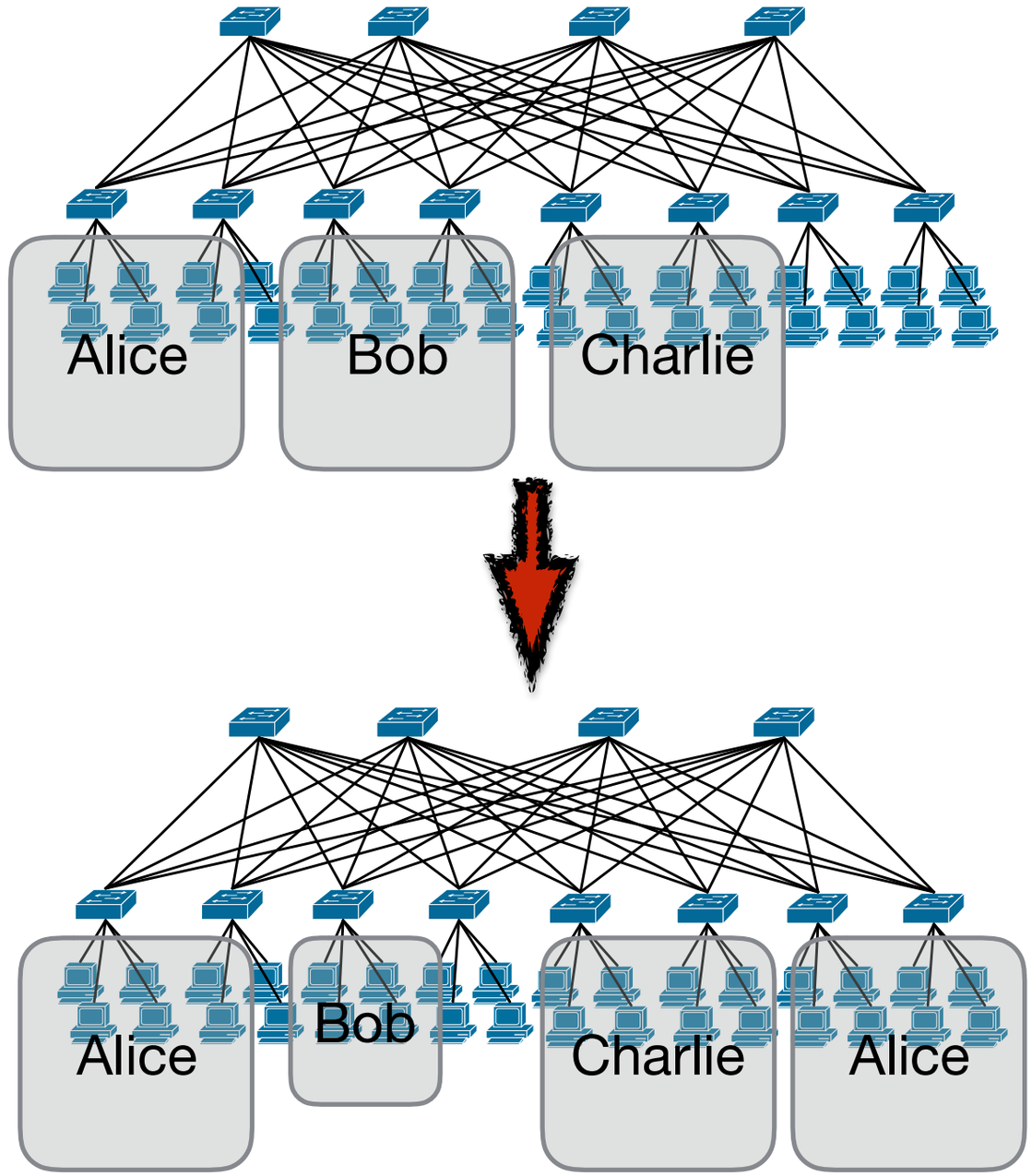




Alexey Andreyev, “Introducing data center fabric, the next-generation Facebook data center network”, Nov. 2014

Virtualization in DC networks





VL2: A Scalable and Flexible Data Center Network

- Folded-Clos + Source route

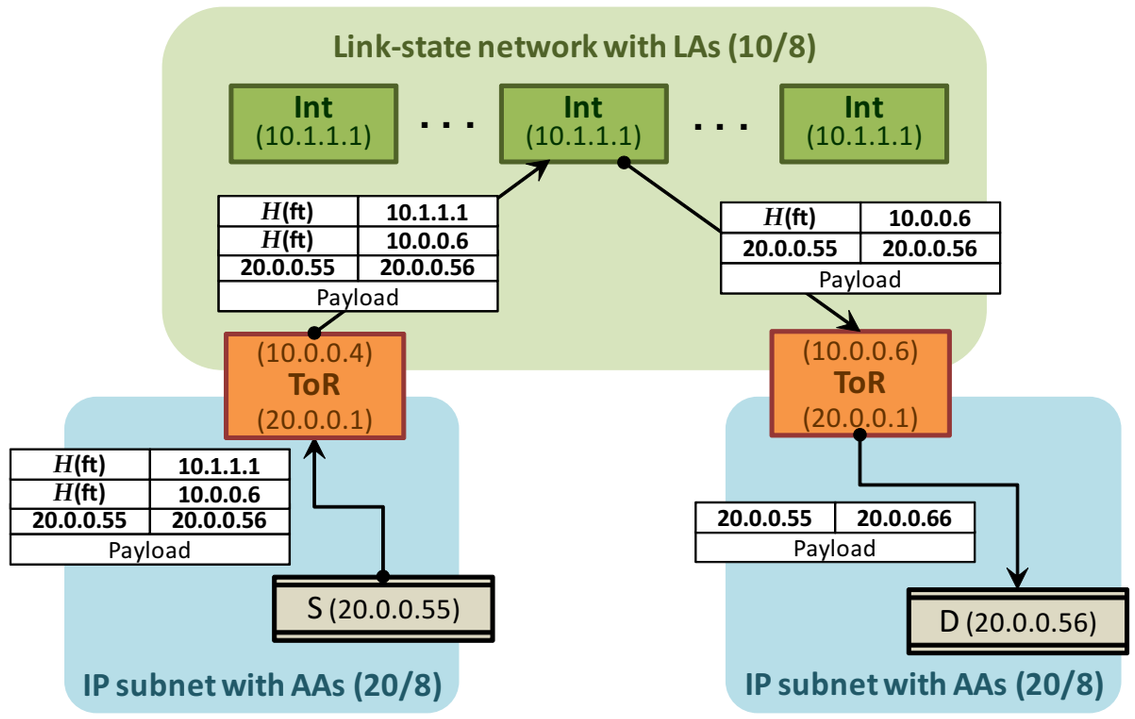


Figure 6: VLB in an example VL2 network. Sender S sends packets to destination D via a randomly-chosen intermediate switch using IP-in-IP encapsulation. AAs are from 20/8, and LAs are from 10/8. H(ft) denotes a hash of the five tuple.

*Greenberg, Albert, et al. "VL2: a scalable and flexible data center network." *ACM SIGCOMM Computer Communication Review*. Vol. 39. No. 4. ACM, 2009.

DCell: A Scalable and Fault-Tolerant Network Structure for Data Centers

- Each cell consists with one small SW and servers.
- Every cell connected in full mesh manner.
  - Serves connected with different cell's servers using 2nd, 3rd ethernet ports.
  - Severs work as ethernet SW.

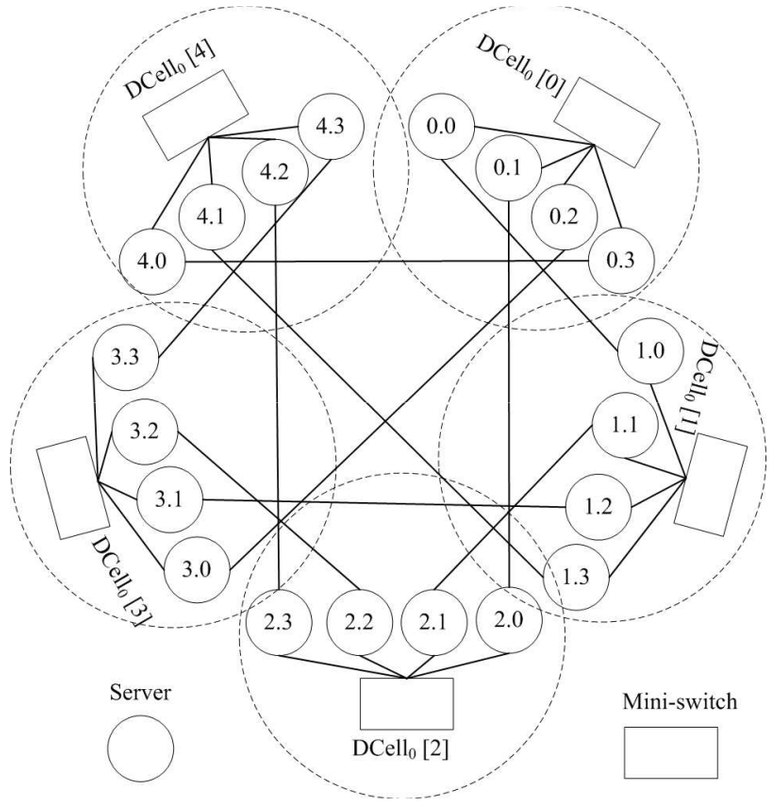


Figure 1: A $DCell_1$ network when n=4. It is composed of 5 $DCell_0$ networks. When we consider each $DCell_0$ as a virtual node, these virtual nodes then form a complete graph.

*Guo, Chuanxiong, et al. "Dcell: a scalable and fault-tolerant network structure for data centers." *ACM SIGCOMM Computer Communication Review*. Vol. 38. No. 4. ACM, 2008.

BCube: a high performance, server-centric network architecture for modular data centers

- Designed for interconnecting container DC.
  - max sever N = n^(k+1)
    - n : SW ports, k +1 : server ports
    - Max. SW hops : k
  - Generalized Hyper-Cube (k+1 D)

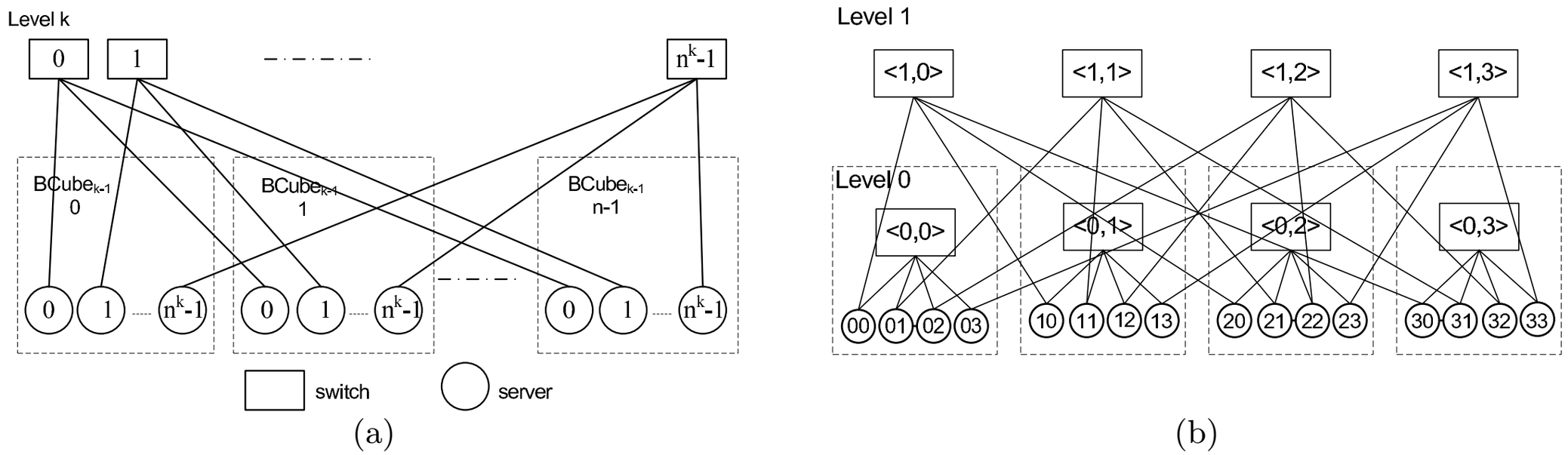


Figure 1: (a)BCube is a leveled structure. A $\mathbf{BCube}_k$ is constructed from n $\mathbf{BCube}_{k-1}$ and n^k n-port switches. (b) A $\mathbf{BCube}_1$ with $n = 4$. In this $\mathbf{BCube}_1$ network, each server has two ports.

*Guo, Chuanxiong, et al. "BCube: a high performance, server-centric network architecture for modular data centers." *ACM SIGCOMM Computer Communication Review* 39.4 (2009): 63-74.

Today’s Assignment

- You should design a DC network with 16,384 (2^14) HW servers.

1.Tell the number of switches with the following conditions:

  - Every SW has 64 ethernet ports
  - Every server has 4 ethernet ports
  - Network topology is folded Clos without over-subscription
  - Link Aggregation Group (LAG) can be used both on SW and server

2.Draw the network topology including all SWs and servers.

3.Note what you take into consideration in your design.

- Submit your answers either in Japanese or in English via the course web.

本日の課題

- 16,384 (2^14) 台の HW server で DC ネットワークを構成したい。

1.以下の条件で必要な SW 台数を示せ

  - SW 側 Ethernet ポートは 64 ポート
  - Server 側 Ethernet ポートは 4 ポート
  - Folded Clos トポロジ Over subscription なし
  - Link Aggregation Group (LAG) は、server, SW とも利用可能

2.サーバおよびSW の接続トポロジを図示せよ

3.上のデザインで考慮した点を示せ

- 講義 Web から提出すること

For hands-on exercise : Install two softwares

1.Wireshark : A packet capture and analyzer

- Just install package from http://www.wireshark.org

2.NS2 : Network simulator.

Three options are there:

A. Docker

- Install docker software and container:
  - https://github.com/ekiourk/docker-ns2
  - X-window server is required. It depends on OS.

B. Native applicationIf you are using Linux, use this option.

- Install ns-allinone-2.35 from source because NS-2 package.
  Note that some distribution may not work.
- X-window, perl, gnuplot are also required.

C. Virtual Machine (VM)

- Install Hypervisor Software.
  - Oracle VirtualBoX is free.
    vmware or others are also welcome.
- Linux VM image with NS2 software will be available from the course Web.

演習に向けて：２つのソフトウェアをインストールする

1.パケットアナライザ wireshark

- http://www.wireshark.org を参考にインストールすること。

2.ネットワークシミュレータ NS2

A. Docker

- Docker をインストールし、コンテナを使用する。
  - https://github.com/ekiourk/docker-ns2
  - X-window の設定は OS に依存する。

B. Native

- Linux を利用している場合は、この方法を使う。
- ns-allinone-2.35 を install すること。
  - X-window, perl, gnuplot なども必要となる。

C. VM で動作

- ハイパーバイザの導入
  - Oracle VirtualBoX であれば無償
    vmware 他でもかまわない
- NS2 付きの Linux 仮想マシンイメージを講義ページで配布する