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Lecture 3

Data Center Network Traffic Characteristics

Network Traffic Characteristics

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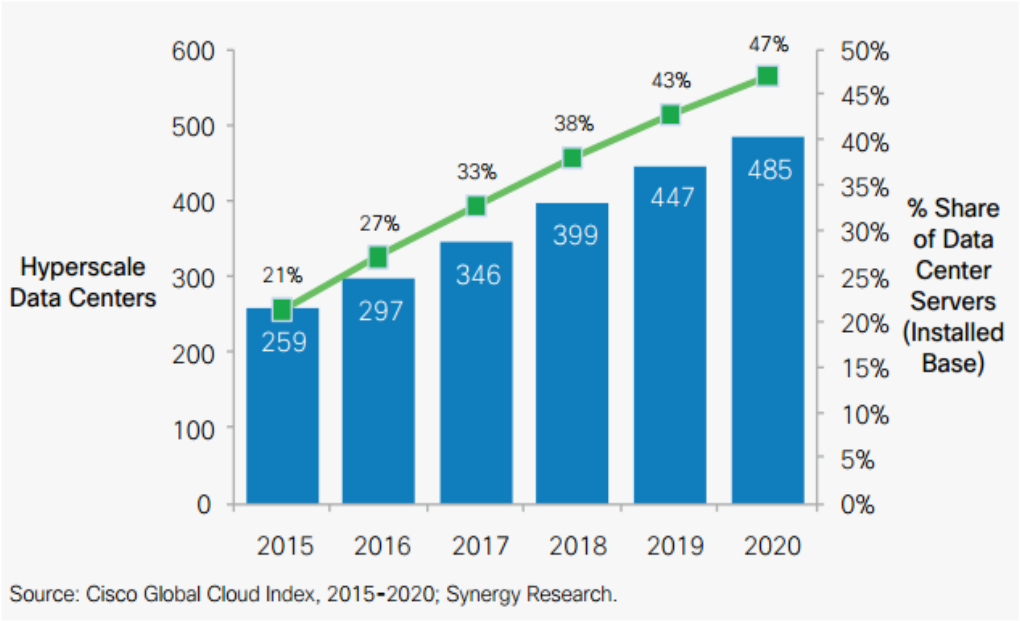
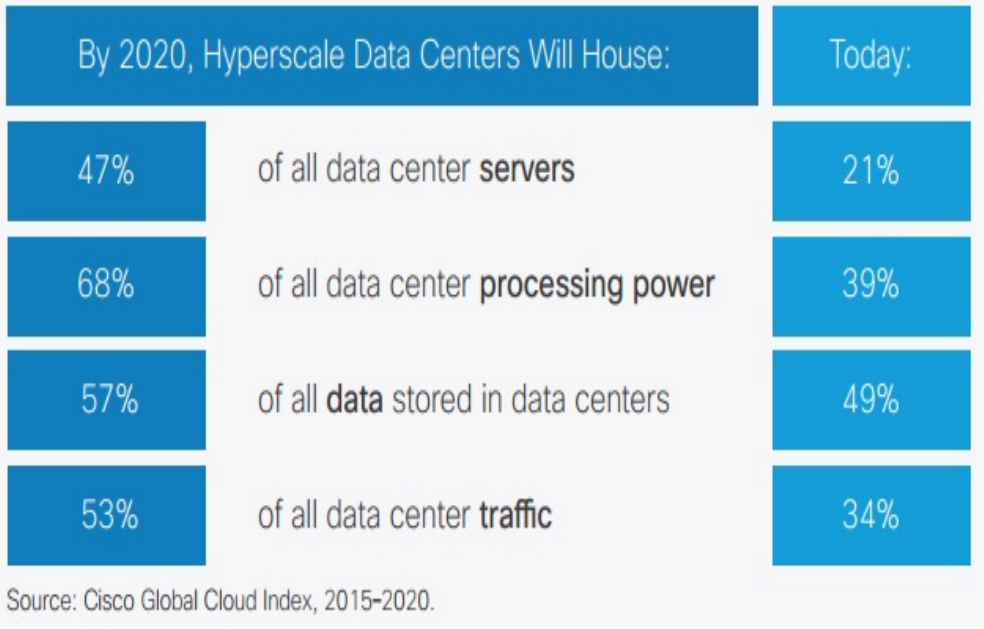
- An understanding of the data center traffic characteristics is required to design a high-performance network.
- Some traffic characteristics can be common, and others be very different between data center categories.
  - University campus data centers
  - Private enterprise data centers
  - Cloud-computing data centers
  - High performance computing

Hyperscale Data Centers

- Hyperscale data centers will grow from 259 in number at the end of 2015 to 485 by 2020. They will represent 47 percent of all installed data center servers by 2020.
- Traffic within hyperscale data centers will quintuple by 2020. Hyperscale data centers already account for 34 percent of total traffic within all data centers and will account for 53 percent by 2020.



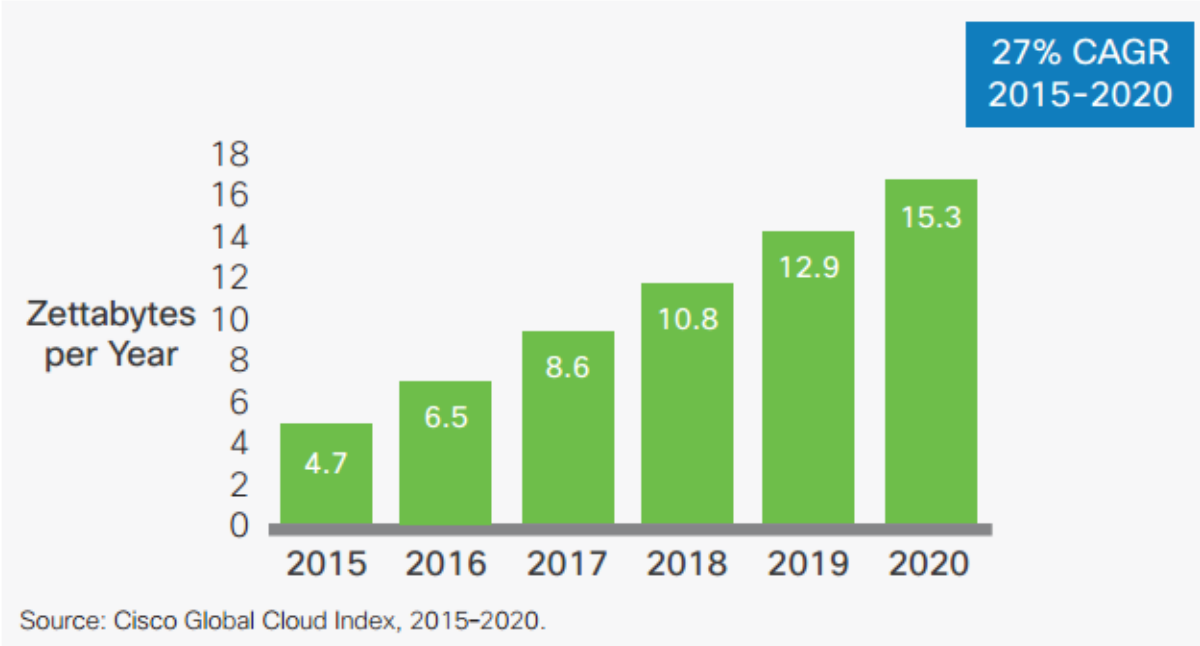
Source: Cisco Global Cloud Index, 2015-2020; Synergy Research.



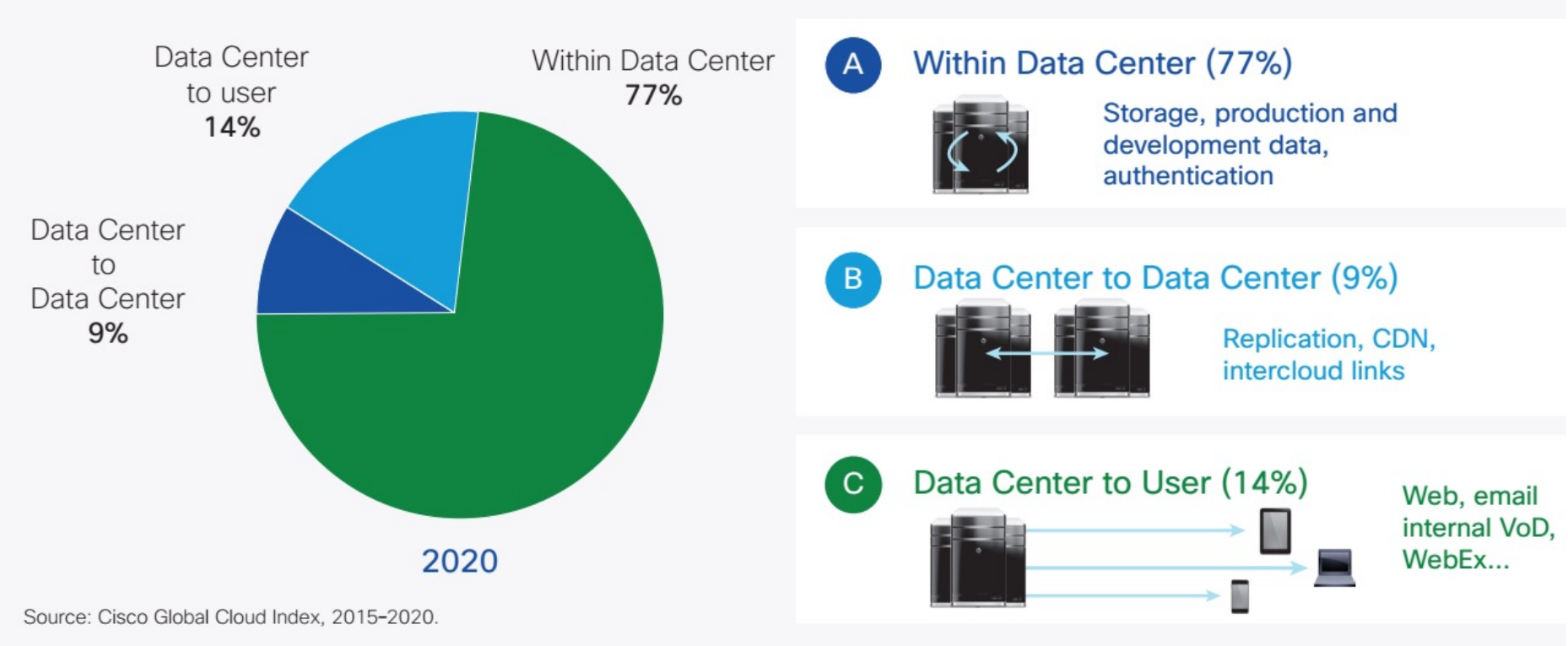
Source: Cisco Global Cloud Index, 2015-2020.

Data center IP traffic

- Annual global data center IP traffic will reach 15.3 zettabytes (ZB) (1.3 ZB per month) by the end of 2020, up from 4.7 ZB per year (390 exabytes [EB] per month) in 2015.
- Global data center IP traffic will grow 3-fold over the next 5 years. Overall, data center IP traffic will grow at a compound annual growth rate (CAGR) of 27 percent from 2015 to 2020.



Data center traffic destinations: most traffic remains within the Data Center



- Big data is a significant driver of traffic within the data center
- Traffic between data centers is growing faster than either traffic to end users or traffic within the data center
- East-west traffic dominates data ceter traffic

Network Traffic Characteristics

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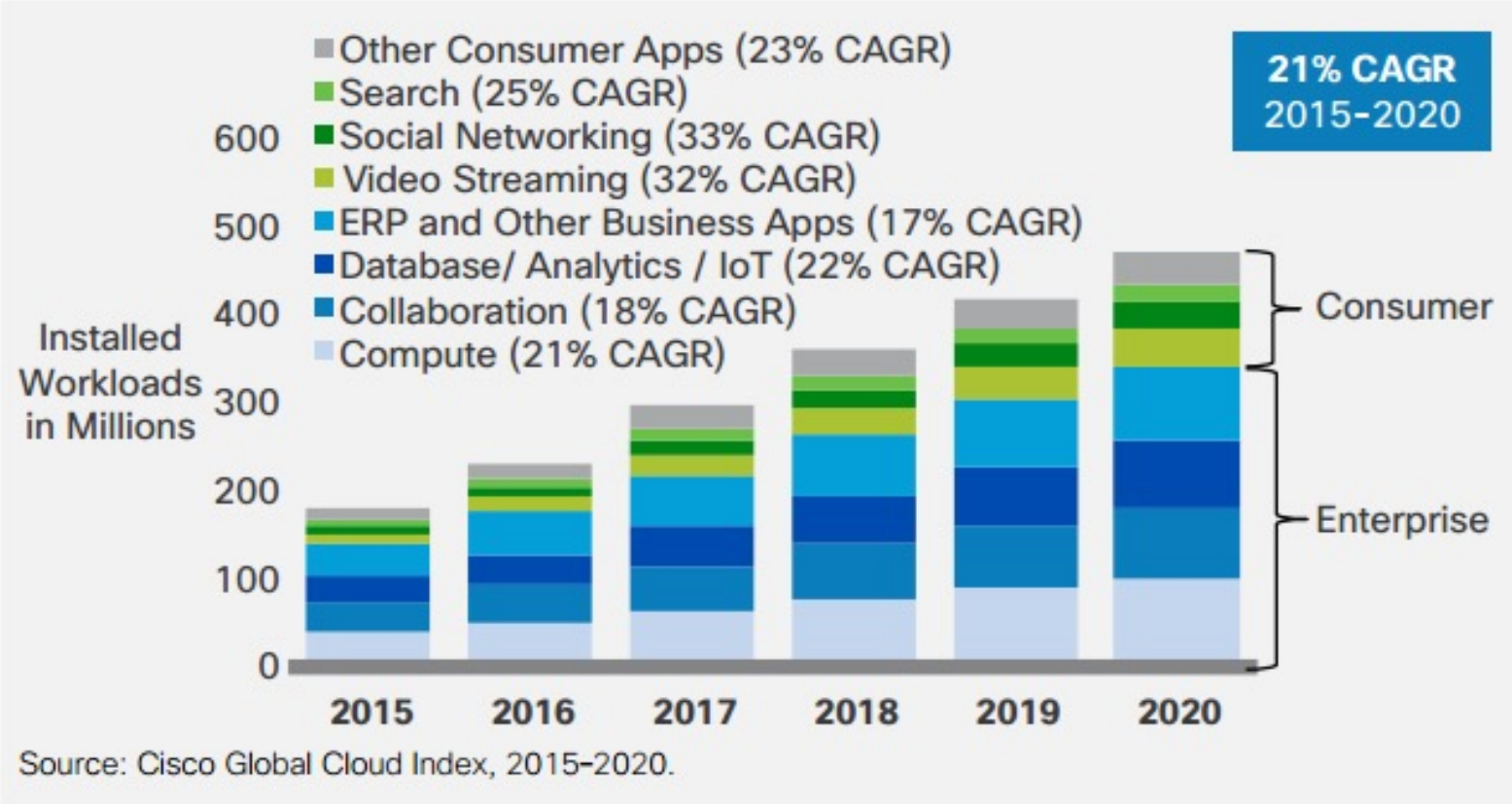
Main features of network traffic and their influence on the design of the optical network.

- Applications
- Traffic flow
  - Flow size and duration
  - Traffic flow locality
  - Concurrent traffic flows
- Packet size
- Link utilization

Traffic Characteristics: Applications

- In campus data centers majority of the traffic is HTTP traffic.
- In private data centers and data centers used for cloud computing, the traffic is dominated by HTTP, HTTPS, LDAP, and DataBase (e.g., MapReduce) traffic.



Traffic Characteristics: Duration & Concurrent flows

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A traffic flow is specified as an established link (usually TCP) between two servers.

- **Traffic flow size and duration:**
  - Most traffic flow sizes are small (i.e., less than 10KB) and a significant fraction of these flows last under a few hundreds of milliseconds.
  - The duration of a traffic flow can affect the design of the optical topology.
- **Concurrent traffic flows:** The number of concurrent traffic flows per server.
  - The average number is around 10 per server in the majority of the data centers.

Traffic characteristics: flow size and durations

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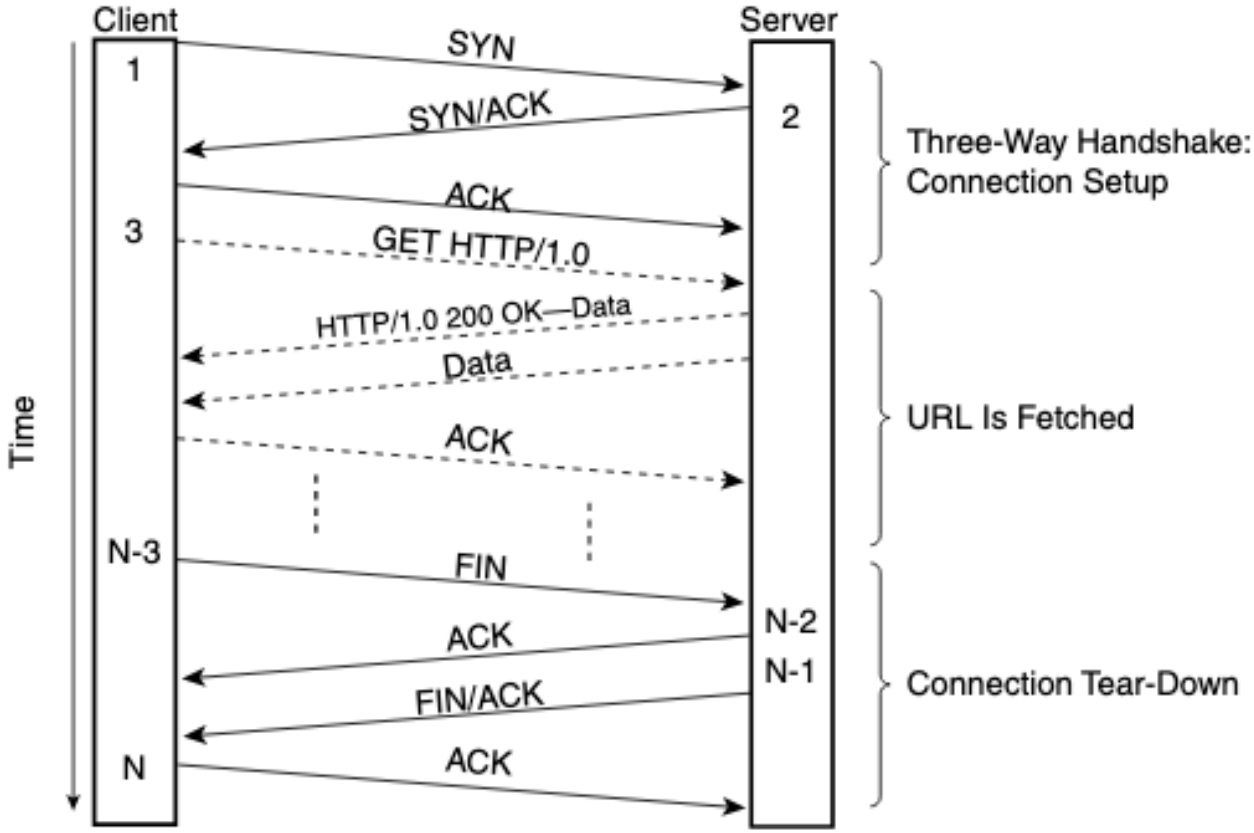
- **Elephant flows:** bulk data transfer, also called, that are large volume and relatively long-lasting flows usually generated by data backup, virtual machine migration, etc.
  - Large bandwidth but without strict temporal constraints, account for approximately 80% of total traffic
- **Mice flows:** short-lived data exchange, e.g., transactional traffic, web browsing, search queries.
  - Sensitive to latency and have deadline constraint eventually defined by a Service Level Agreement (SLA) between cloud provider.

Short-lived connections

After the user types the URL, a connection request is sent (SYN) and the connection is established. The web page associated with the URL in the reques is loaded, and the TCP connection is torn down.



- Connection setup packets (SYN, SYN/ACK, and ACK)
- The HTTP connection request and the HTTP response
- Download of the web page, including ACKs
- Connection teardown packets (FIN, FIN/ACK, and ACK)

Traffic Characteristics: **Traffic flow locality**

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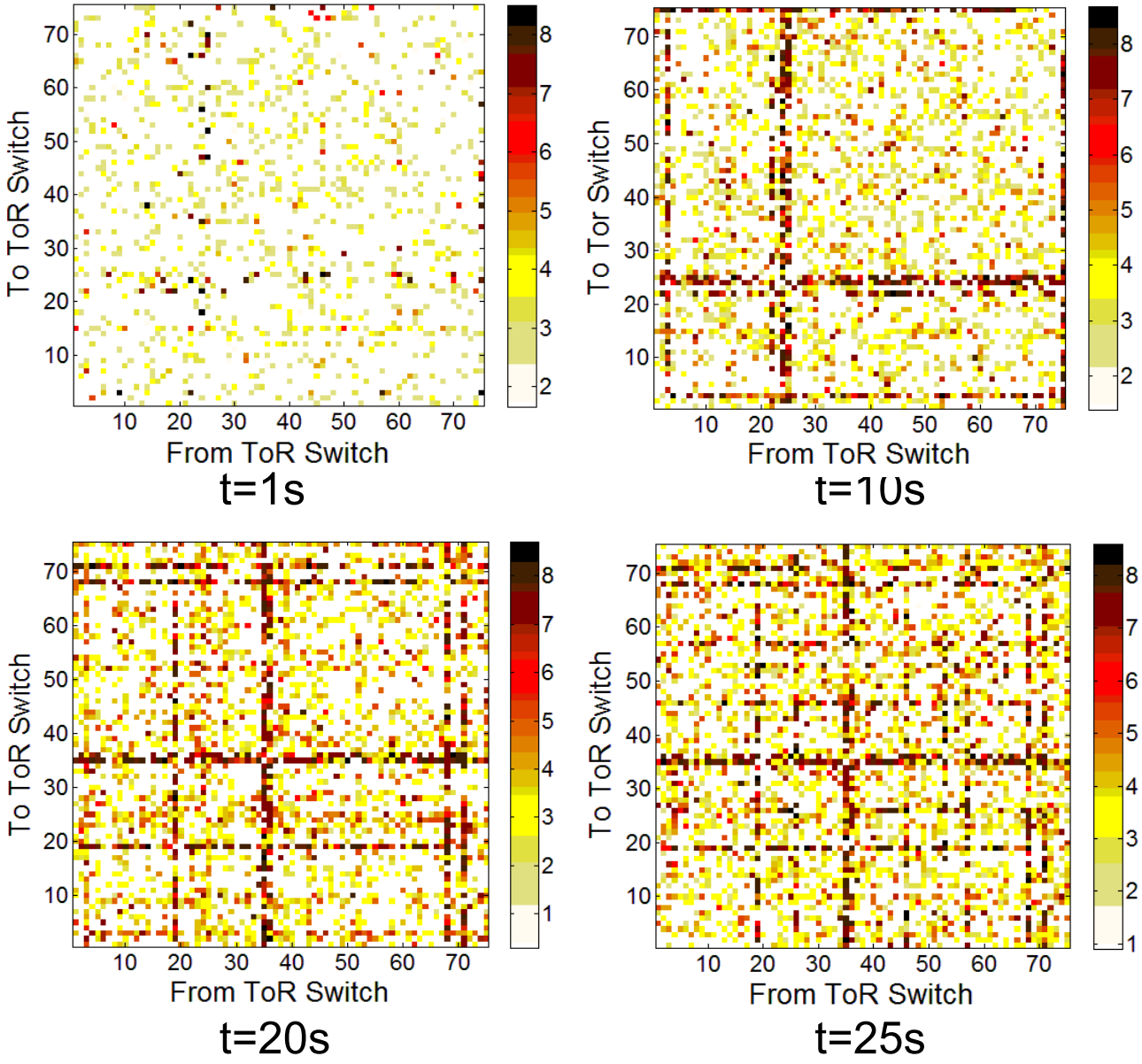
- **Traffic flow ratio for inter-rack traffic**: 10 to 80% depending on applications.
  - Cloud computing: up to 80% intra-rack communication.
- The traffic flow locality affects network topology.
  - High inter-rack communication traffic: high-speed networks are required between the racks
  - Low-cost commodity switches can be used inside the rack.

Therefore, an efficient optical network can provide the required bandwidth demand between the racks while low-cost electronic switches can be utilized for intra-rack communication.

Traffic locality in DCN



Network Traffic Characteristics

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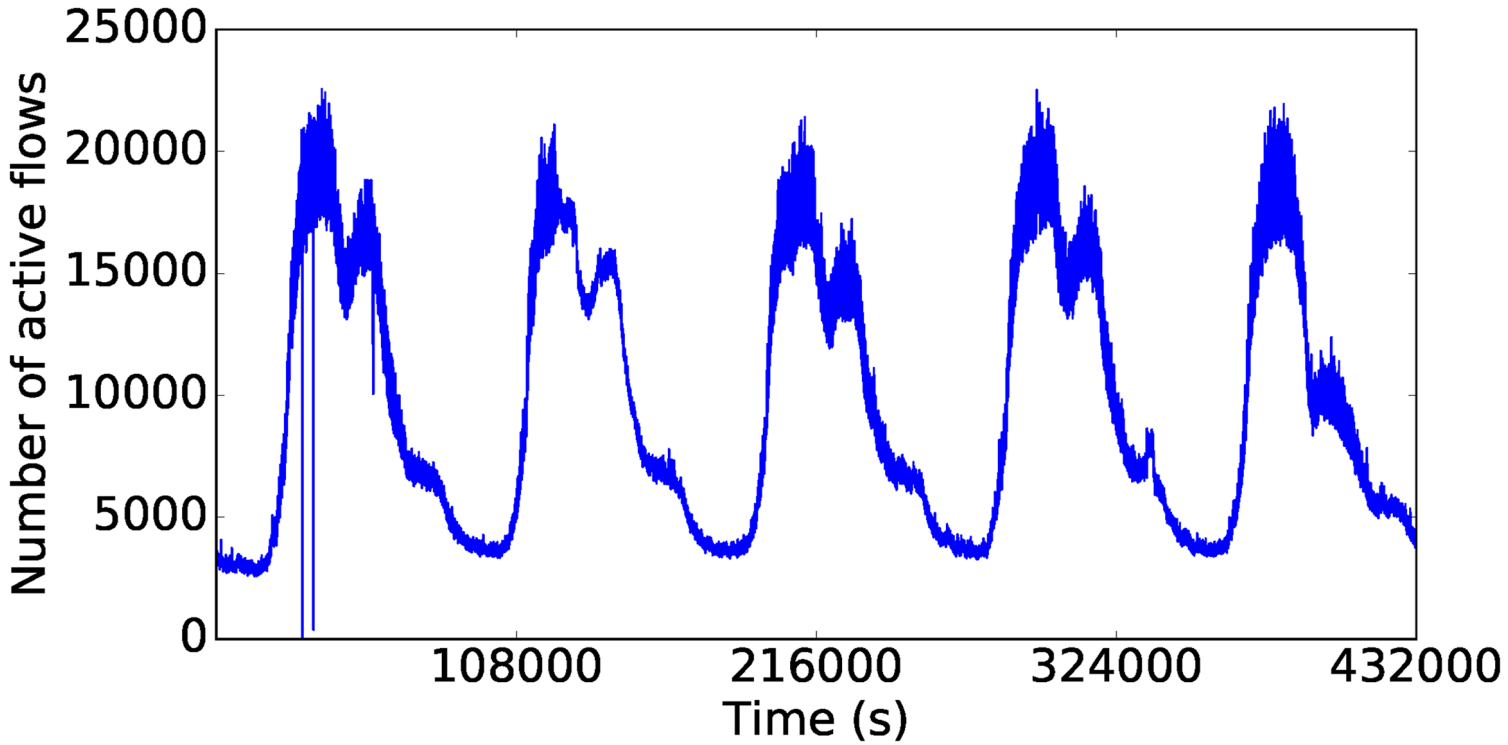
- Traffic fluctuations and patterns

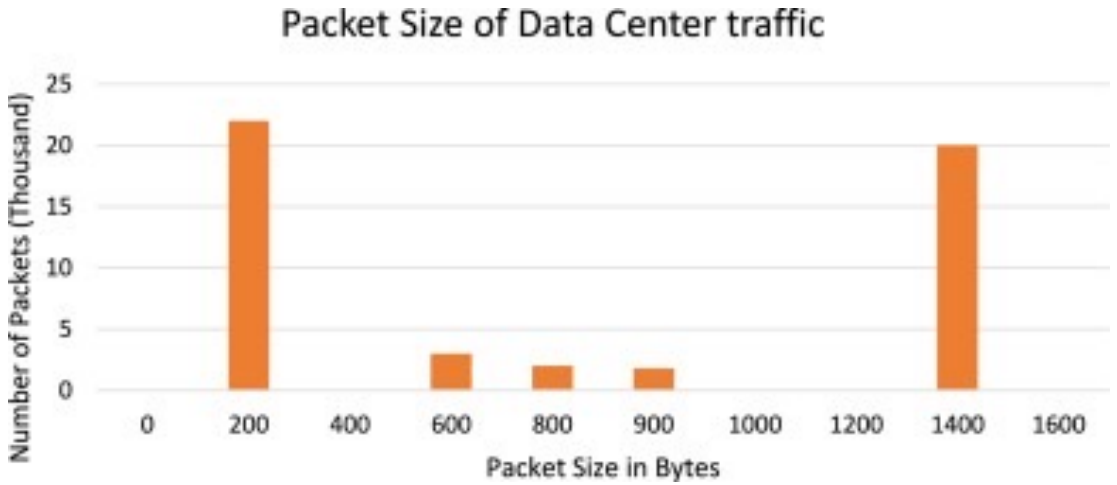


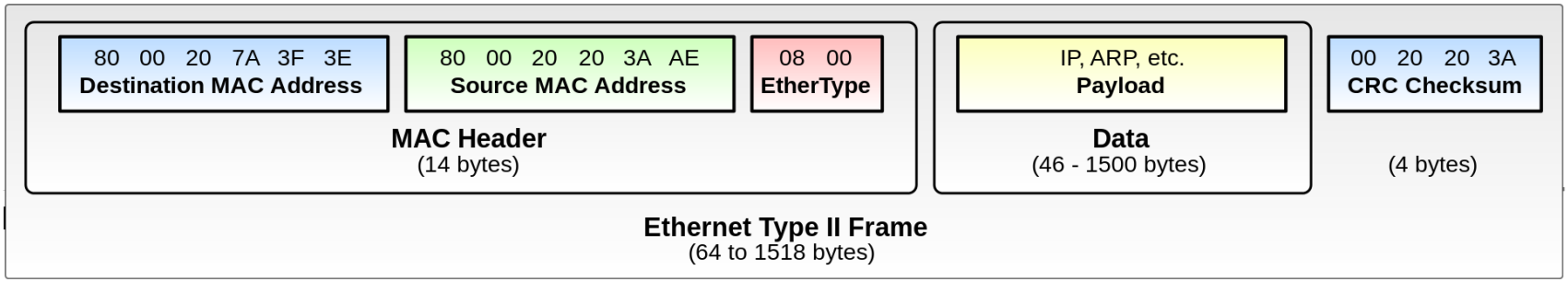
Daily traffic fluctuation for a search service in one datacenter;
Y-axis is traffic measured in queries per second.

A. Mozo, B. Ordozgoiti, and S. Gómez-Canaval, "Forecasting short-term data center network traffic load with convolutional neural networks," *PLOS ONE*, vol. 13, no. 2, p. e0191939, Feb. 2018, doi: 10.1371/journal.pone.0191939.

Traffic Characteristics: Packet

- **Packet size:** The packet size in data centers exhibit a **bimodal pattern with most packet sizes clustering around 200 and 1,400 bytes**.
  - Packets are either small control packets or are parts of large files that are fragmented to the maximum packet size of the Ethernet networks (1,550 bytes).





Traffic Characteristics: Link utilization

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- **Link utilization:** Link utilization inside the rack and in the aggregate level is quite low, while the utilization on the core level is quite high.
  - Higher bandwidth links are required especially in the core network
  - 1 Gbps Ethernet networks inside the rack can sustain the future network demands.

Performance metrics for network devices.

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Performance metrics indicate the capability of a device to perform under load.

- **Throughput:** The maximum rate at which none of the offered frames are dropped by the device.
  - Absolute throughput number: bits per second (BPS)
  - Packets per second: PPS.

Media	64 Byte Packets	1518 Byte Packets
Ethernet	14,881	812
Fast Ethernet	148,810	8128
Gigabit Ethernet	1,488,100	81,280

Packet size: 64 bytes - 1518 bytes.

Performance metrics for network devices

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- **Frame and Packet loss:** Percentage of frames/packets that should have been forwarded by a network device under steady state (constant) load that were not forwarded due to lack of resources.
- **Latency:** Provides a view of the time delays that might be experienced by traffic through the DUT, typically measured in microseconds or even nanoseconds.
  - Latency for store and forward devices
  - Latency for bit-forwarding devices

Connection Capability

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- Connection processing rate

  The maximum rate of new connections the device is able to process.

- Concurrent connection (CC)

  The number of simultaneous connections the device is able to track and process.

Questions:

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How much data centre bandwidth do you really need to build a campus data centre for remote teaching?

Reference

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References:

1. Benson T., Anand A., Akella A, Zhang M, “Understanding data center traffic characteristics”, In Proceedings of the 1st ACM workshop on Research on enterprise networking, ACM, New York, pp 65-72, 2009
2. Benson T, Akella A, Maltz DA, “Network traffic characteristics of data centers in the wild. In: Proceedings of the 10th annual conference on Internet measurement (IMC). ACM, New York, pp 267–280, 2010
3. Kandula S, Sengupta S, Greenberg A, Patel P, Chaiken R, “The nature of data center traffic: measurements & analysis.” In: Proceedings of the 9th ACM SIGCOMM conference on internet measurement conference, IMC ’09. ACM, New York, pp 202–208, 2009
4. http://www.standardsuniversity.org/e-magazine/august-2016-volume-6/evolution-ethernet-standards-ieee-802-3-working-group/

Summary

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- Main features of network traffic and their influence on the design of the optical network.
- Performance metrics for network devices.