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Research Article

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Sizing Network Capacity at different aggregation Levels

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Abstract This paper explores the pivotal role of a "network scaffold" in efficiently managing incoming and outgoing traffic within data center environments. Emphasizing the concept of "internal traffic," it underscores the significance of per-server contributions to the overall network capacity. The primary objective is to formulate precise equations for calculating network hardware capacity at potential congestion points while considering the dampening effect for accurate capacity planning.

In a detailed scenario involving 35 servers per Top of Rack (ToR), 7 ToRs per Spine, and connections to Data Center Interconnect (DCI) and Leaf Centers (LCs), the paper provides comprehensive equations that account for empirical traffic observations. This approach ensures the optimization of network performance, reliability, and substantial cost savings.

The analysis includes congestion points such as TOR <> Spine, Spine <> DCI, and DCI <> Router, addressing each with a focus on realistic traffic scenarios. The proposed framework enables data center operators to make informed decisions about network hardware requirements, leading to enhanced efficiency and minimized operational costs. This paper contributes valuable insights to the field of data center network design and optimization.

Keywords Network Capacity Planning, Dampening Effect, Data Center Traffic Dynamics, Internal, Traffic Patterns, Congestion Points, Equations for, Capacity Calculation, Empirical Observations, Cost Savings, Data Center Optimization, Top of Rack (ToR), Peak Traffic Time Analysis

1. Introduction

Within the intricate workings of a data center, the seamless collaboration between server resources and network hardware stands as a cornerstone in efficiently processing incoming requests. At the heart of this synergy lies the network scaffold, a critical infrastructure that facilitates the fluid transportation of data between clients and servers. This paper embarks on a comprehensive analysis of the internal traffic dynamics within this environment, with a particular focus on understanding the distinct contribution of each server to the overall network capacity.

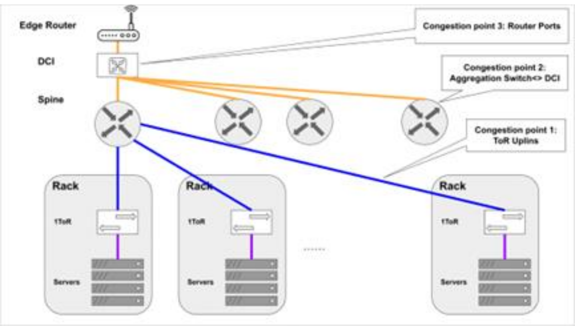
A. Internal Traffic Patterns and Network Efficiency

As we delve further into the analysis of internal traffic patterns within a data center, it becomes evident that the optimization of network efficiency is contingent upon understanding the intricate dynamics of both ingress and egress data flows for each server.

In the realm of data center operations, ingress traffic refers to the data flowing into the server, while egress traffic pertains to the data exiting the server. The interplay between these two components defines the overall internal traffic, and its optimal management is crucial for sustaining a high level of network performance.

One key metric in evaluating the contribution of individual servers to network capacity is the determination of the maximum of ingress and egress traffic. By identifying this peak value for each server, administrators can gain insights into the server's potential impact on the network's overall throughput. Efficient network operation relies on balancing the internal traffic across servers to prevent bottlenecks and ensure a smooth flow of data. Servers with high ingress or egress traffic may become focal points for optimization efforts or capacity upgrades. Understanding these patterns allows for proactive measures to enhance network robustness.

Furthermore, this analysis goes beyond mere quantitative assessment, considering the qualitative aspects of internal traffic patterns. Factors such as peak traffic times, data prioritization, and redundancy measures are explored to fortify the network against potential disruptions.



The comprehensive understanding of internal traffic dynamics, with a focus on the distinct contribution of each server, is pivotal for maintaining an agile and reliable data center network. This paper aims to unravel the intricacies of internal traffic patterns, providing valuable insights for network administrators and engineers striving to optimize performance and ensure the seamless functioning of the data center ecosystem.

2. Methodology

A. Dampening Effect in Network Capacity Planning

In the intricate landscape of data center architecture, understanding and optimizing network hardware capacity at congestion points is paramount. The dampening effect plays a crucial role in aligning theoretical calculations with real-world scenarios. It is a corrective factor applied to account for the asynchronous peaks of individual servers, ensuring a more accurate representation of traffic patterns and avoiding overestimation of capacity requirements.

1. Asynchronous Peaks: Servers within a data center do not necessarily reach their peak traffic levels simultaneously. The usage patterns of different servers often vary due to factors such as workload distribution, user activity, and application demands.
2. Dampening Factor (D): The dampening factor, denoted as D, represents the ratio between the theoretical peak traffic and the empirically observed total peak traffic. It is usually expressed as a decimal between 0 and 1.

When calculating network capacity, it might be tempting to base projections solely on the sum of individual server peaks. However, this approach can lead to inflated capacity requirements, as the peaks of all servers rarely coincide. The dampening effect adjusts for this discrepancy by reducing the theoretical peak traffic to a more realistic level.

$$D = \frac{\text{Empirically Observed Total Peak Traffic}}{\text{Theoretical Sum of Individual Server Peaks}}$$

Equation for Dampening Effect (D)

If $D = 1$, there is no dampening effect, indicating that all servers reach their peaks simultaneously.

If $D < 1$, the dampening effect is in play, acknowledging that the total peak is less than the sum of individual peaks.

B. Example

Let's delve into the equations, incorporating detailed explanations for each term, in a scenario with 35 servers per Top of Rack (ToR), 7 ToRs per Spine, and connections from Spine to Data Center Interconnect (DCI), and further to multiple Leaf Centers (LCs). The total server traffic is 3 Gbps, aiming to break down the needed capacity at each layer.

1.Congestion Point 1: TOR <> Spine

Total Uplink Capacity at TOR = Peak Server Traffic × Servers per TOR × Dampening Factor (D1)

a) Peak Server Traffic: The maximum data flow from a single server, often observed during peak usage.
b) Servers per TOR: The number of servers connected to a Top of Rack (ToR) switch.
c) Dampening Factor *(D1):* An empirical factor (0.85 to 0.9) accounting for the asynchronous peaks of servers, ensuring more realistic capacity planning.

Total Uplink Capacity at TOR = 3 Gbps × 35 × 0.9 ≈ 95Gbps

Considering N+1 redundancy and deploying 2x100 Gbps, the adjusted total traffic becomes 200 Gbps, resulting in substantial cost savings. The Damping factor at this scale results in a 33% reduction in the required capacity, translating to substantial cost savings. These savings become even more significant when extrapolated to data centers with hundreds of thousands of servers.

2. Congestion Point 2: Spine <> DCI

Total Traffic at SPINE <> DCI = Total Servers × Damping factor at the TOR level (D1) × Dampening Factor at Spine Level (D2)

a) Total Servers: The cumulative number of servers contributing to the traffic.
b) Dampening Factor at Spine Level (D2): An empirical factor (0.65 to 0.7) reflecting the separate occurrence of peaks in different spines, influenced by internal data center traffic management tools, such as traffic failover between data centers and internal compute or storage load management.

Total Traffic at SPINE <> DCI = 3 × 35 × 7 × 0.9 × 0.7 ≈ 463Gbps

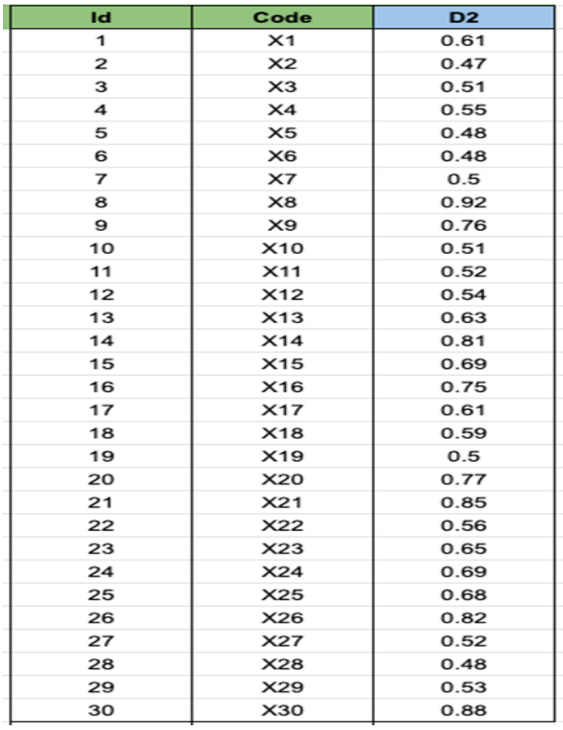
This equation reflects a 37% reduction compared to the sum of peaks, leading to cost savings in DCI capacity and router port requirements.

3. Congestion Point 3: DCI <> Router

Router Capacity=Total Traffic at SPINE <> DCI

Beyond this point, with no further aggregation, no additional dampening effect is expected or monitored. However, the savings from the previous point directly translate to savings at the router level. The router capacity, measured in the number of 100 Gbps ports, is affected by the reduced DCI capacity. The diminished need for ports resulting from D1 and D2 contributes to savings in port capacity on the router, further optimizing resource utilization and minimizing costs.

Below is sample dampening factor at Spine Level for various ids and cods.



Id	Code	D2
1	X1	0.61
2	X2	0.47
3	X3	0.51
4	X4	0.55
5	X5	0.48
6	X6	0.48
7	X7	0.5
8	X8	0.92
9	X9	0.76
10	X10	0.51
11	X11	0.52
12	X12	0.54
13	X13	0.63
14	X14	0.81
15	X15	0.69
16	X16	0.75
17	X17	0.61
18	X18	0.59
19	X19	0.5
20	X20	0.77
21	X21	0.85
22	X22	0.56
23	X23	0.65
24	X24	0.69
25	X25	0.68
26	X26	0.82
27	X27	0.52
28	X28	0.48
29	X29	0.53
30	X30	0.88

Conclusion

In conclusion, this paper has laid the foundation for a sophisticated framework that revolutionizes capacity planning within data center environments. By intricately considering the dampening effect on peak traffic, our approach surpasses traditional methods, offering a more nuanced and accurate perspective.

The equations formulated for each congestion point provide a granular understanding of network requirements, allowing for precise resource allocation. The incorporation of empirical observations, particularly through the dampening effect, ensures that capacity estimations align closely with real-world traffic patterns. This not only optimizes network performance but also guarantees the reliability of the entire infrastructure.

One notable outcome of our approach is the realization of substantial cost savings. Through meticulous calculations and considerations, we have demonstrated how accounting for the dampening effect results in more efficient resource utilization. This is particularly significant when extrapolated to data centers with extensive server deployments, where even a modest reduction in capacity requirements translates into significant financial benefits.

In essence, this paper contributes a valuable paradigm for capacity planning, emphasizing the importance of empirical insights and the dampening effect. It equips network administrators and engineers with a more accurate and cost-effective toolset for managing the complexities of data center traffic dynamics, ultimately fostering a resilient and high-performing data center ecosystem.

References

[1]. Y. Chen, S. Jain, V. K. Adhikari, Z. -L. Zhang and K. Xu, "A first look at inter-data center traffic characteristics via Yahoo! datasets," 2011 Proceedings IEEE INFOCOM, Shanghai, China, 2011, pp. 1620-1628, doi: 10.1109/INFCOM.2011.5934955.

[2]. F. Tajedin, M. Farhoudi, A. Samiei and B. Akbari, "DTE:Dynamic Traffic Engineering in Software Defined Data Center Networks," 2019 International Conference on Computer Engineering, Network, and Intelligent Multimedia (CENIM), Surabaya, Indonesia, 2019, pp. 1-6, doi: 10.1109/CENIM48368.2019.8973350.

[3]. R. Tang, "Innovations for Data Center Network Optimization," 2021 International Conference on Computer Information Science and Artificial Intelligence (CISAI), Kunming, China, 2021, pp. 610-615, doi: 10.1109/CISAI54367.2021.00123.

[4]. A. Shivashankarappa, S. Basavanna and R. Dharmalingam, "Performance Optimization of a Data Center Using Virtualization Technology: A Case Study Utilizing DEMATEL Method," 2015 3rd International Conference on Future Internet of Things and Cloud, Rome, Italy, 2015, pp. 564-572, doi: 10.1109/FiCloud.2015.72.

[5]. A. Qazi, F. Rehman, T. Maqsood, K. -M. Ko, Y. -W. Chong and S. Mustafa, "Network Optimization Through Traffic Patterns and Efficient Bandwidth Consumption in Large DCN," 2018 Second World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4), London, UK, 2018, pp. 65-71, doi: 10.1109/WorldS4.2018.8611475.

[6]. M. S. Ghanim, K. Shaaban and A. Siam, "An Artificial Intelligence Approach to Estimate Peak-Hour Travel Time," 2023 Intermountain Engineering, Technology and Computing (IETC), Provo, UT, USA, 2023, pp. 197-202, doi: 10.1109/IETC57902.2023.10152121.

[7]. T. Hoefler, A. Hendel and D. Roweth, "The Convergence of Hyperscale Data Center and High-Performance Computing Networks," in Computer, vol. 55, no. 7, pp. 29-37, July 2022, doi: 10.1109/MC.2022.3158437.

[8]. S. -A. Reinemo, T. Skeie and M. K. Wadekar, "Ethernet for High-Performance Data centers: On the New IEEE Datacenter Bridging Standards," in IEEE Micro, vol. 30, no. 4, pp. 42-51, July-Aug. 2010, doi: 10.1109/MM.2010.65.

[9]. M. Levy and J. O. Hallstrom, "A new approach to data center infrastructure monitoring and management (DCIMM)," 2017 IEEE 7th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, USA, 2017, pp. 1-6, doi: 10.1109/CCWC.2017.7868412.