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Enhancing Performance and Scalability of a Hybrid Circuit-Based Dcn Architecture Through Switching Scheduling and Traffic Prediction

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Abstract: Switches at the data centre need to provide guaranteed scalability, throughput, and resiliency for the large-scale network. In high-capacity Datacenter Network (DCNs) incorporates multistage packet switches for routers. However, conventional switching architecture exhibits limited variation in the space for the switching architecture. The existing available switches are complex and not cost-effective. With profound data center (DC) demand for traffic and optical switching are computed. This paper presented a high scalable packet switching for a DCN environment with the exploitation of Network-on-chip (NoC) with the paradigm of single-hop crossbars with multi-hop switching.A router-based packet switching network connecting SoC components makes up the network on chip. NoC technology offers significant advantages over traditional bus and crossbar communication designs by applying the theory and practises of computer networking to on-chip communication. The developed switches use three-stage switches for OQ-UDN(Output -Queued Unidirectional)NoCswitha central stage network. Developed model uses a hybrid optical network for the DCN (Data Center Network) with integrated OCS (Optical Circuit Switching) and OPS (Optical Packet switching) scheme. The integrated switching uses ToR (Top-of-the-Rack) switches for flexible function over various traffic patterns in DCN. Simulation results expressed that the under different DC traffic loads OPS/OCS DCN exhibits improved network performance.

Keywords: *Data center networks, Datacenter traffic modeling, Hybrid OCS/OPS, Packet Switching,Hybrid OPS/OCS modeling*

1. Introduction

In recent years, it is observed that the application of networksis moving from private to public data centers. In 2016, Cisco global cloud index exhibits a drastic development in the annual global IP traffic expected to reach around 14.1ZB by the year 2020. By 2020, it is observed that cloud workloads can be comprised of public cloud around 68%. The data cloud comprises logic, cloud, and migration of the applications [1]. The drastic development of data centers and resources in the cloud drive towards cloud data centers in a large-scale public environment defined as hyper-scale data centers. Generally, those hyper-scale data centers are operated by large companies like Google, Facebook to minimize CapEx(capital expenditure) with sophisticated maintenance of team. The purchase of key facilities in large volume includes switches, modules of the transceiver, operators of hyper-scale data centerswiththe negotiation of market power with further push down in CapEx.

To support increased large-scale co-located DCs traditional multi-tier DCN architecture is subjected to different challenges [2]. At first, in core switches, the over-subscription ratio is 20:1 and aggregated switches ratio is 4:1 [3], which has dominant traffic within the DCNs. Secondly, traditional DCN is subjected to latency due to each hop processing time and queuing time. The traditional DCN is not able to offerappropriate latency-sensitive services specifically for 5G applications. Additionally, latency of network impacts the satisfaction level of the users. The third challenge associated with the DCN architecture is the increased consumption of power as well as total cost due to high-radix electrical switches. Hence, in present scenario multi-tier, DCN design is minimal ideal to withstand present low-latency and virtualized applications. In present arrangement models, leaf and spine architecture is utilized towithstand high traffic demand [4]. However, the fabric switches demand a large number of connections through fiberas well as high radix switches in electrical routing. At present, the

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construction of single electrical switching is challenging due to the high bandwidth for the port with limited available bandwidth at the chip edges. To withstand the demand several low radix switching gas be connected with Clos topology for construction of high radix chassis switch which leads to increased power consumption concerning densities of the port [5].

International Technology Roadmap for Semiconductors (ITRS) predicted that the DCN architecture must contain per-pin bandwidth and pin count [6]. However, the present leaf-and-spine architecture handles the traffic flow equally but fails to handle locality like Top-of-Rack (ToR) switches or servers. Hence, it is challenging to construct hyper-scale leaf-and-spin DCN architecture for effective performance. Currently, to establish point-to-point DCs interconnections optical signalinghas been used for standards such as 400 Gigabit Ethernet (400G, 400GbE) and 200 Gigabit Ethernet (200G, 200GbE) as per IEEE P802.3bs task force. The transmission technology with optical fiber withstands huge bandwidth for hyper-scale DCs. In DCN with optical switching comprises OCS, OPS [7], an optical TDM concentrated on the reduction of the cost and power-efficient switching for the intra-DCN communications. Optical switching technology exhibits the advantage of DCN those are:

1. Optical switching offers a high radix network with silicon as well asnanophotonictechniquetominimize latency and power consumption.
2. Optical switching is the transparent signal format that provides significant compatibility concerning transmission standards.
3. The advancement in fiber-optic with WDMandSDMincreases capabilities of fiber-link capabilities [8].

Due to drastic advantages, it is expected that in hyper-scale data centers optical switching transmission technology exhibits a significant role in increased traffic demands. In the future, within hyper-scale data centers, optical switching exhibits a significant role inincreased traffic scenarios. To achieve the desired advantage over optical switching technique in a data center network for future hyperscale DCNs. As stated earlier, optical RAM unavailability concentrated optical DCN is impossible for traditional electrical switching for effective optical switching technology in DCN [9]. The redesign of ToRswitchesoptical switching is applied over the DCNs. Over past years, DCNs with optical switching exploration drastic development it provides the leverage ‘over single optical technology. The limitation associated with the flexibility of network architecture exhibits the relatively minimal performance over dynamic traffic environment in DCNs. The relative variation in the communication matrix over DCNs is based on space and time for a dynamic environment. Additionally, over hyper-scale DCNs virtualization of data centersis required by the cloud providers through dynamic resource allocation between multiple DCNs. With future hyperscale, DCN embedding virtualization is more challenging for optical switching in DCNs [10].

This paper presented a hybrid OPS/OCS switching scheme for DCN with programmable architecture. The proposed hybrid OPS/OCS architecture consists of several DCN features for both unicast and broadcast traffic. A Unicast communication occurs when one network device communicates with some other network device. A MultiCast communication takes place between one network device and many, but not all, other network devices. A broadcasting communication occurs when one network device sends data to every other network device.The OPS/OCS switch is deployed in the FPGA-based ToR support variables for fine granularity of the link bandwidth. The network functional features are performed based on the AoD(architecture on demand) for traffic estimation and prediction.The main contribution of this research is to develop a circuit DCN architecture for the enhancement of scheduling the switching during traffic forecasting. The developed architecture is highly scalable and effective.

The paper is organized as follows: In section II presented a related works of switching in the DCN architecture. Section III provides developed hybrid OPS/OCS architecture model for DCN integrated with the topology is presented along with programmable modules in section IV. In section V results analysis for the proposed hybrid OPS/OCS scheme is presented and finallyoverall conclusion is presented in section VI.

2. Related Works

In the future hyperscale, DCNS comprises optical switching methodsthatare categorized as circuit or packet switching. Here, a review related to OCS and OPS scheme for optical DCN is presented. The majority of LPFS(Lager-Port-Count Fiber Switches) use OCS based DCN approach with MEMS(Micro-Electro-Mechanical Systems) or beam-steering with central switches connected with ToRsfor network infrastructure [11]. The DCN architecture scalability is based on OCS withhigh radix LPFS with thousand ports [12]. With ToRpairsoptical links are connected directly through fiber switches as well as capacity of the variable allocatedat each link with leverage WDM(wavelength division multiplexing) technologies such as spectrum selective switches (SSS), WDM transceivers, and so on. With multiple optical channels,high-capacity terabits/s with every link feasibility isevaluated for low-speed electronics in the ToR of channels [13]. The smooth data flow between various racks with high-capacity arelodgedwith minimal latency of optical circuit link. With connectivity degree,ToRhas improved through dense fiber connections with SDMmethods[14]. Bulk long-linked data transfer is estimated based on the bounded degrees such as backups, interprocessor communication, and migrations accommodated in the OCS network.

To withstand the minimal traffic pattern high communication medium is developed with a radix, DCN based OCS that can be reconfigured with frequent DCN topology [15]. The traffic is transferred with a multi-hop direct connection within the remote servers [16]. In fiber switches, solutions are subjected to the prolonged reconfigurable timer which can be implemented for milliseconds. The altered solutions demand O-E-o conversion with each hop with the introduction of channel congestion with intermediate switches with latency in the multi-hop path. On the other hand, OPS-based solution for DCN offers packet-level switching those fits effective traffic pattern estimation. The main approaches adopted for OPS-based DCN areAWGR(Arrayed Wavelength Grating Routers) method [17] and SOA(Semiconductor Optical Amplifier) [18,19]. The previous researches use different DCNs connectionsfor various wavelengths connected to the ToR of the AWGR switches.A semiconductor component that amplifies light is known as a SOA (Semiconductor Optical Amplifier). To get rid of the resonator structure, a semiconductor laser's two facets undergo antireflective processing. The light is magnified by stimulated emission as it reaches the semiconductor from the outside.

TWCsorFTLsorganized over ToR with consideration of destination port in the AWGR with the assignment of the appropriate wavelength. The SOA-based approach uses fast switching with reconfigured DCN presented in nanoseconds [20]. The presented scheme exhibits higher flexibility for every connection with grid-connected AWGR. The adaptive capacity for aggregation uses different wavelengths for each connection defined as wavelength switching in OPS scheme. Issues with the OPS methodexhibits complexity and scalability with limited optical RAM with blocked packets involved in congestion for electronic buffers [21] or fiber array optical delay transmission [22]. That solution uses TWCs, FTLs, or SOAs for a vast range of wire communication for buffer controller and component switching with increased complexity with an increase in DC size. With increased scalability and resiliency topology is constructed for multi-stage with exploited OPS DCN architecture [23]. The latency of each packet is observed for congestion and buffering with the overhead value of 5% - 20% for OPS transmission with the inclusion of inter-slot guard time and synchronization time [24]. Excellent for voice-only communication. does not make efficient use of resources. Any further usage of the circuit switching-specific channels is prohibited. The price is higher when one channel is set aside for each purpose.

3. Proposed programmable optical/electrical data center networking

Constructed programmable optical data centerdesign comprises key technologies such as FPGA -based programmable SIC as illustrated in figure 1. The FPGA architecture comprises OPS/OCS ToR switch in hybrid form, programmable OCS, and OPS for configuration in network. Design of DCN architecture clustered hyper-scale DCN in which cluster incorporates tens/hundreds of rack. All clusters are connected by means of the LPFS based inter-cluster switch. Also, the proposed architecture comprises of SMFs or MCFs connected through clusters with inter-cluster switches with configured connection matrix established between clusters and offers adaptable link capacity between clusters [25]. In this single hop OCS uses, prolonged data flows with a high capacity for inter-cluster communications. In the case of every cluster, LPFS comprises of centralized approach with interconnected ToRs switch through fiber bundles. Within cluster environments different traffic patterns are used for OCS and OPS. The OCS switching is implemented with LPFS with relative setup timer with reduced communication latency. The connection in the OPS network uses OPS/OCS with hybrisToRsandOPS switches connected in clustered LPFS. Deployed sub-functions comprises of OPS switches applied with DCN with OPS topology configured with OCS network.

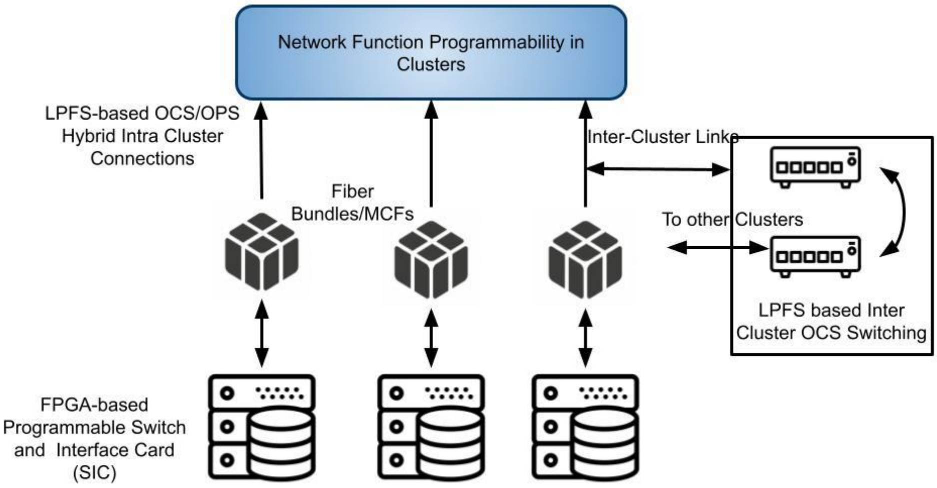


Figure 1: Optical DCNArchitecture

Figure 1 illustrates the switching scenario among the network function programmability where the systems are organized as clusters.

3.1 FPGA-based programmable switch and interface card

The hybrid OCS/OPS comprises the programmable switch and interface card (SIC) which can be replaced with a traditional interface card (NIC) that can be served directly with intense intra-rack communication. The comparison to traditional NIC, SIC offers effective server switching functionality with enabling of the server-center architecture. In OCS/OPS application SIC exhibits flexible functionality over the optical channel in which servers are in the same rack for transmission and reception of the Ethernet frames through SIC with FPGA board [26].

Also, SIC is capable to transfer data between memories and blades for sending and receiving of the TDM/OPS port as per the control plane. The OCS/WDM act as a switch with Layer 2 as per control plane command. With function of switch SIC act as a hop supply for flexible programming in DCN architecture. Communication through intra-rack blade-to-blade provides optical ToR switch communication to attain high function intra-rack communication.

4. OPS/OCS hybrid ToR switch

Constructed programmable hybrid ToR switches comprise the flexible OCS/OPS function for optical channel switch over. Trafficking process and aggregation are based on inter-rack loads for different traffic environments. FPGA platform either loads or unloads traffic for various channel wavelengths for DCN interconnections. The FPGA environment varies either OCS or OPS for different application-aware classification commands in control plane. TORs with optical transceivers comprise the modulation formats of 10Gbps SFP+, 40Gbps QSFP+, or even transceivers. The SSS with a connected transmitter (Tx) and receiver (Rx) exhibits bidirectional communication between the channels. The different optical channels are aggregated using SSS with multi-granularity capacity in the ToRofeach link. The proportion of those links are connected in the OPS system as per link requirement for each ToR with OPS network configuration in DCN. Constructed ToR supports maximal bandwidth of the FPGA total capacity with node degree of radix SSS. Within the ToR level traffic switching is adopted for the switch over function with adaptive capacity assigned with different links with flexible channel assignment for different services.

4.1 OCS network configurations

As illustrated in figure 2 LPFS with inter-cluster and intracluster switches are presented with AoD programmable switch. Upon inter-cluster communication,AoD provides the connection in OCS at the different clusters. The capacity of the link was dynamically programmed with consideration of connection variable links. With inter-cluster communication,AoD offers connection with inter-cluster connection based on OCS with the dynamic program with variable connection links. In figure 2 schematic configuration of the OCS is provided for intra-cluster communications as per the AoD concept. Based on inter-cluster communication switch offers various clusters with respect to OCS. The capacity of the link is dynamically programmed with the provision of variable connection links. With intra-cluster communication,AoD-based switches in clusters offer intra-cluster communication with OCS.

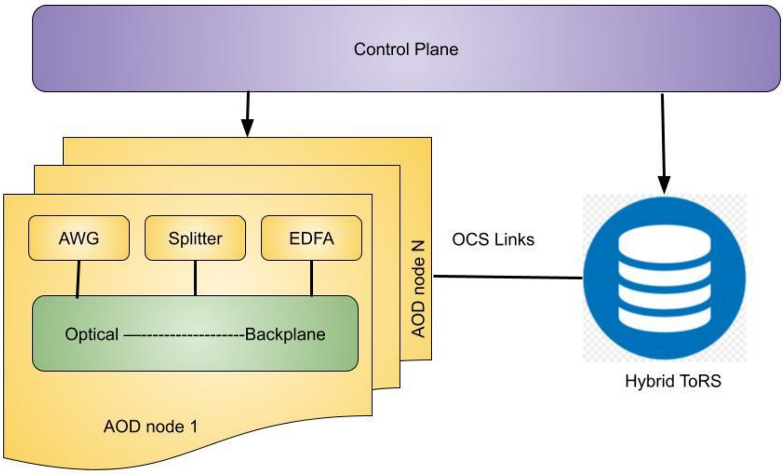


Figure 2: Schematic of OCS configuration

The architecture of OCS is presented in table 1 with consideration of unidirectional operation in the OPS modules. The link is OPS is offered in a simplex way with circulators link established between hybrid ToRs and the OPS network.

Table 1: Summary of OPS network configurations.

Configuration	**Single-rooted Tree**	**Multi-rooted Tree**	**Butterfly**
Description of Architecture	Branch Node- 5: OPS module - 16×16; root node - 1: OPS module - 5 × 5;	Branch Node- 15; OPS module - 10 × 10 root node – 5 OPS module - 15 × 15	OPS nodes - 25: OPS module - 15 × 15;

4.2 Simulation of OPS/OCS hybrid DCN

The traffic pattern of the DC is based on the hybrid DCN to examine network traffic loads. The network traffic patterns are evaluated under the DC with the assumption of ToR with the provision of channel 12 OPS/OCS channel bandwidth of 120Gbps for each channel capacity with varying ToR 10 Gb/s to 120 Gb/s. In figure 3 schematic of the OPS enables waveband switching is presented with the same size as Ethernet packets. With a flexible capacity of the OPS, node switching is provided for the optical waveband with transparent optical wavelength with a semiconductor optical amplifier (SOA). The OPS link bandwidth of the optical packet size in bytes are evaluated using equation (1) [27-29]

$$\mathit{Packet\ size} = \mathit{size\ of\ slot}\ \times \mathit{capacity\ of\ link} \qquad (1)$$

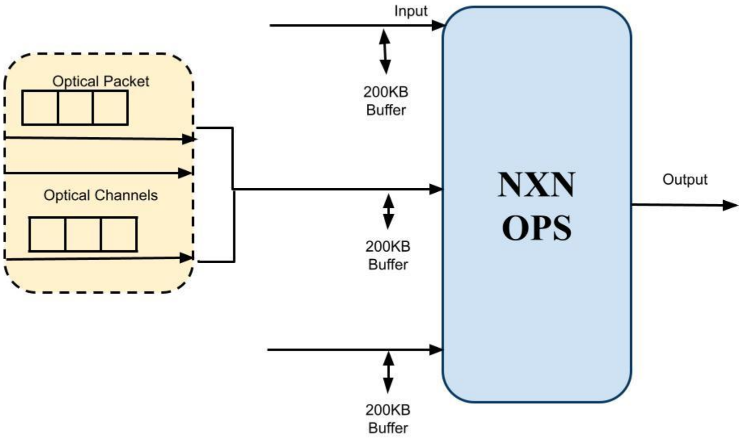


Figure 3: OPS optical waveband switching

The probability of information transmission for packet arrival to the output buffer is stated as $a = 1 - packet\ arrival$, the probability of arrival of output buffer is denoted as $d = 1 - departure\ of\ packet$ with the packet probability in the queue. To evaluate the queue output is defined as follows:

α – The probability of output buffer for the arrived packet at present instances. The packet in the output increment in the unit.

β–The probability value of the cell leaves the queue in the output. The measurement is based on the decrements of the queue in cell buffer.

f–Size of queue is intact with two possible scenarios. The present arrived cells in the output queue without any cells or removed with time step.

The transition matrix is represented in equation (2) with state variation

$$S = \begin{bmatrix} \propto_0 & \beta & 0 \ldots\ldots\ldots\ldots.. \\ \propto & f & \beta \ldots\ldots\ldots\ldots.. \\ 0 & \propto & f \ldots\ldots\ldots\ldots\ldots \end{bmatrix} \qquad (2)$$

Where

$$\propto = Packet\ arrived\ d = Packet\ arrived\ (1 - departure\ of\ packet) \qquad (3)$$

$$\beta = (1 - Packet\ arrived)departure\ of\ packet$$
(4)

$$f = Packet\ arrived * departure\ of\ packet + b\ d$$
(5)

$$= 1 - (\propto + \beta)$$

In the above equation $\propto_0 = 1 - \propto$ and $\beta_0 = 1 - \beta$. The probability of queues in the queue is expressed in equation (6)

$$M = [M_0 \quad M_1 \ldots\ldots\ldots\ldots\ldots. \quad M_B]^l$$
(6)

The output buffer equilibrium is stated as $PM = M$ with difference equation in (7)

$$\begin{cases} \propto M_0 - \beta M_1 = 0 \\ \propto M_{0-1} - gM_1 + \beta M_{i+1} = 0, 0 < i < M \end{cases}$$
(7)

In above equation $M = \propto + \beta$ with queue probability of empty value is defined in equation (8)

$$M_0 = \frac{1 - \tau}{1 - \tau^{B+1}} \qquad (8)$$

τ is stated as the magnitude of distribution vector M is defined in equation (9)

$$\tau = \frac{\propto}{\beta} = \frac{Packet\ arrived\ (1 - departure\ of\ packet)}{Packet\ departed\ (1 - Packet\ arrival)}$$
(9)

The overall queue in the DCN optical switching is computed using equation (10)

$$Th_0 = Packet\ arrived * Departure\ of\ packet\ M_0 + \sum_{i=1}^{M} Departure\ of\ Packet * M_i \qquad (10)$$

Algorithm 1: Load Optimization in the OPD network

```
begin
Sorting of ToRs in descending order
update the new list as $S_{Sort}$
Destination sorting of ToRs in descending order
return the updated destination $D_{sort}$
create the matrix $TM_{sort}$ based on destination model as $S_{Sort}$ and $D_{sort}$
Compute optimization topology of the traffic
if topology = “butterfly – tree” then
    $S_{opt} \leftarrow S_{sort}$
    $D_{opt} \leftarrow D_{sort}$
    $TM_{opt} \leftarrow TM_{sort}$
else
    $k \leftarrow count\ of\ branch\ node$
    $N \leftarrow Number\ of\ rack$
    for m = 1
    while $p \leq N$ do
        return branch
    then
end
return order of branch
```

```
end
end
construct $S_{OPT}$
construct $D_{OPT}$
Construct $TM_{OPT}$
end
end
return $TM_{OPT}$
```

Algorithm 1 illustrates Load Optimization in the OPD network and the procedure indicates that the butterfly tree topology is utilised for this research.

The overall traffic in the network is computed as

$$I_g(n) = \sum_i T_i, \qquad i \in M_g(m)$$

$$S_g(n) = \sum_i S_i, \qquad i \in S_g(m)$$

The distributed ToRs are computed with S_{sort} and D_{sort} with appropriate sub-list with the reduced difference in the traffic loads. The overall architecture of the ToR is illustrated in figure 4.

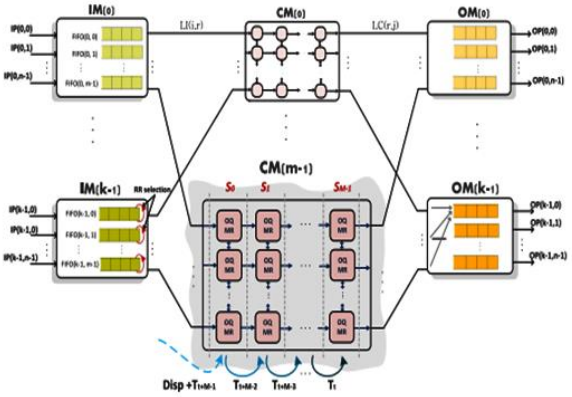


Figure 4: Architecture of Packet Switch with ToR

The blocking probability of the ToR switching is estimated as follows

$$B(r) \le \sum_{j=1}^{x} packet\ arrived(j)$$

5. Performance evaluation

The proposed OPS/OCS comprises of the programmable channel with the channel capacity of 10Gbps with 12 OPS/OCS programmable channel. The maximal bandwidth provided by the ToR is 120 GbpswithToR varying capacity of 10Gb/s to 120 Gb/s. The OPS emulator is programmed and implemented in MATLAB simulation environment. The MATLAB – DCN simulation implementation platform comprises of the assumptions those are different in topologies in terms of average latency and traffic drop rate. Both parameters traffic drop rate as well as average delay are measured in bytes instead of each packet with exhibited network behavior. As stated ToR switch is configured for a hybrid OPS/OCS environment with 2 channel configuration. In figure 5 delay variation of the 256-ports with complete mesh depth of B=3 is provided for uniform packet arrival. The analysis of results expressed that the developed model effectively supports the analytical model.

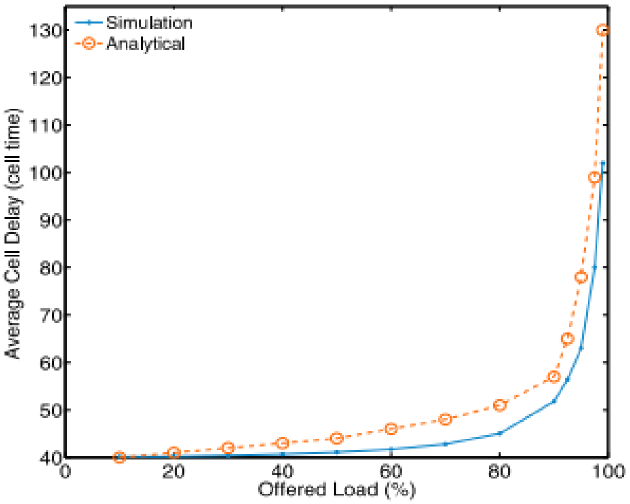


Figure 5: Comparison of traffic load

Delay: DCN switches/ routers need to withstand large-scale communication for data-intensive prerequisites. In this scenario, size of packet exhibits the end-to-end packet latency. Valencyof switch ranges between 4 to 256 with computation of overall delay in OQ ToR UDN.

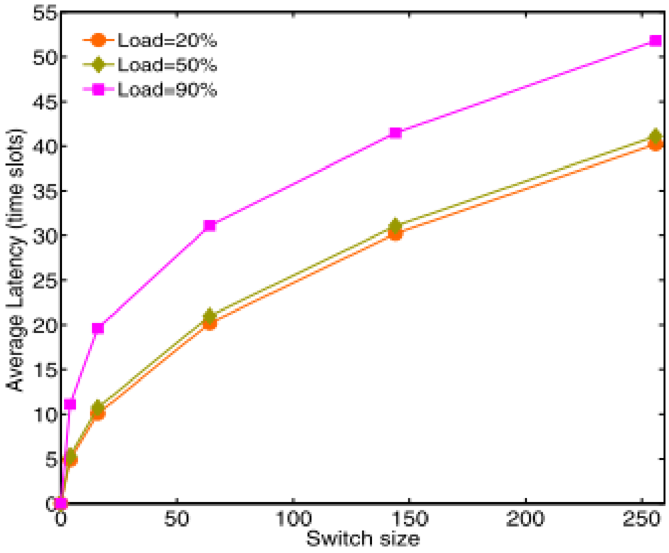


Figure 6: Analysis of latency under different traffic

In figure 6 illustrated the latency of the network concerning switch size and latency is presented. The evaluation is based on consideration of light, medium, and high traffic load conditions. The computation of variation in latency for both light and medium traffic same as without consideration of port count. In the case of high traffic load conditions latency increases drastically concerningthesize of the switch. However, it does not exceed 50-time slots with a load over 90%. The size of the switch can be worked as either single-stage or plugged stage with Clos architecture for valency in the switch. In the proposed model the valency is set as B = 3 with consideration of uniform packet arrival time Bernoulli. The examination expressed that the with respect to input load blocking probability increases exponentially. In figure 7 blocking probability estimation for the DCN architecture is presented.

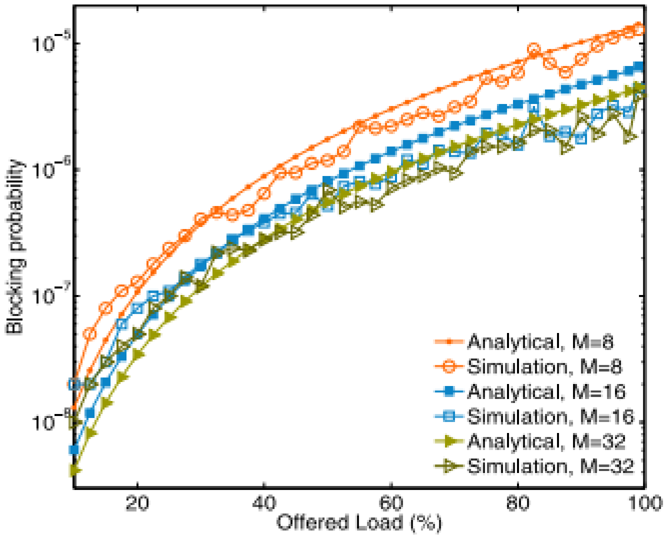
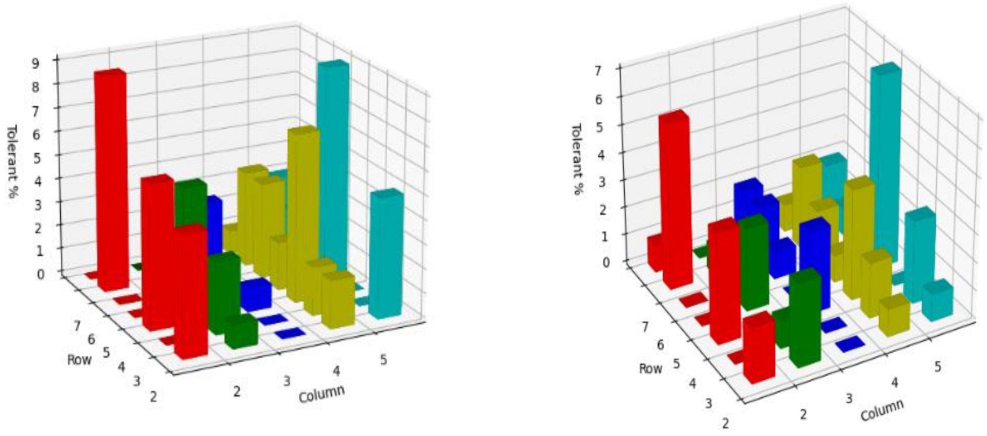


Figure 7: Comparison of Blocking probability

The comparative analysis of the analytical as well as simulation results expressed that for varying switch sizes output buffer capacity lies with packet 3. In table 2 overall performance comparison of the developed OCS/OPS network is provided.

Table 2: Overall Summary of performance

Network	**Parameters**	**OCS + OPS with Single-rooted Tree Topology**	**OCS + OPS with Multi-rooted Tree Topology**	**OCS + OPS with Butterfly Topology***
OCS Network	Drop rate	1.55e−1	1.55e−1	1.55e−1
	Average Latency (s)	-	-	-
OPS Network	Drop Rate	1.21e−1	6.12e−3	2.61e−4
	Average Latency (s)	1.87e−5	6.32e−6	7.13e−7
Capacity at each ToR		11 OCS links with 10 Gb/s each	9 OCS links with 10 Gb/s each	7 OCS links with 10 Gb/s each
		1 OPS links with 10 Gb/s each	1 OPS links with 10 Gb/s each	10 OPS links with 10 Gb/s each



(a) (b)

Figure 8: Variation in blocking rate omega 0.5 and omega 1

In figure 8 variation associated with varying the blocking rate is presented for omega 0.5 andomega 1. The communication medium highly concentrated on the throughput of information exchange. The performance of proposed OPS/OCS model is evaluated for variation in the throughput. In figure 9 comparison of throughput for varying scenarios is presented for DCN architecture. The computation of the throughput percentage with Bernoulli I,i.d arrivals proportion of the throughput is increased linearly with increase in load due to increase in number of packets. The comparative analysis expressed that the throughput increases approximately 4.5% of the overall traffic in the network.

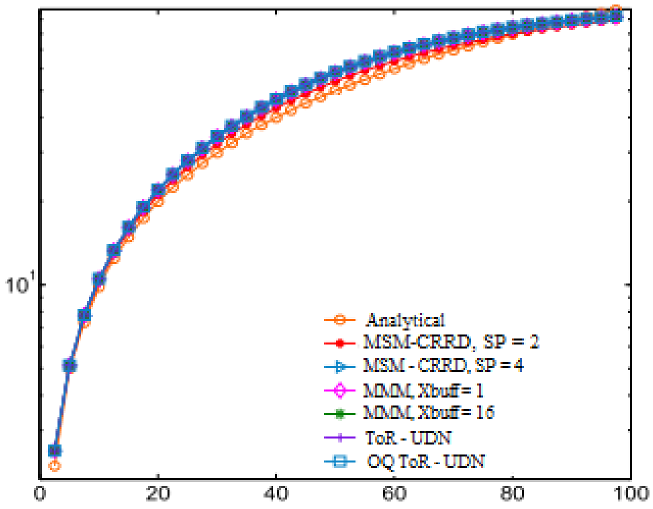


Figure 9: Switch average throughput

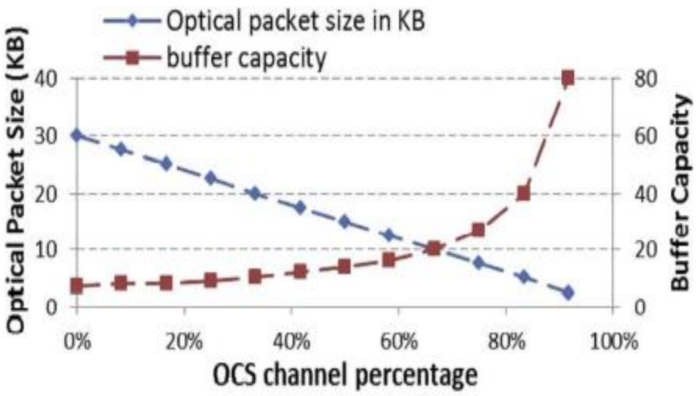


Figure 10: Optical network capacity

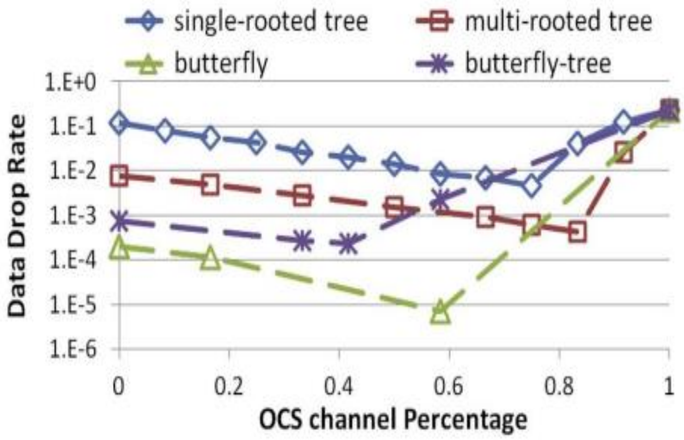


Figure 11: Network packet drop rate

Optical packet size is based on consideration of number of packets that can be buffered concerning the OCS channel medium capacity. Figures10 and 11 illustrate the OCS channel performance with different topologies. The analysis expressed bandwidth drop is higher for an increase in the traffic loads of the network. Also, it is observed that the capacity of OCS is decreased concerning the size of the optical packet which leads to an increment in the OPS buffer capacity.

6. Conclusion

This paper presented a design of OCS/OPS architecture for the programmable optical network for hyper-scale DCs. The developed model combines advantage of both OCS and OPS methodswith application of FPGA – hybrid ToR switching architecture. The DC pattern of the various traffic loads can be accommodated effectively with varying network topologies. The performance of the network is evaluated with different traffic demandsand evaluate the flexibility of network scheme. Simulation results expressed that performance of the network is significantly increased in hybrid OPS/OCS network topologies as per DC traffic. Additionally, the comparison of the proposed hybrid OPS/OCS switching under different topologies is presented. The analysis expressed that the developed OPS/OCS hybrid switching exhibits improved performance in DCs.

Declaration:

Ethics Approval and Consent to Participate:

No participation of humans takes place in this implementation process

Human and Animal Rights:

No violation of Human and Animal Rights is involved.

Funding: No funding is involved in this work.

Conflict of Interest: Conflict of Interest is not applicable in this work.

Authorship contributions:

There is no authorship contribution

Acknowledgment :

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REFERENCES

[1] Qi, H., Shiraz, M., Liu, J. Y., Gani, A., Rahman, Z. A., &Altameem, T. A. (2014). Data center network architecture in cloud computing: review, taxonomy, and open research issues. *Journal of Zhejiang University SCIENCE C*, *15*(9), 776-793.

[2] Sato, K. I. (2018). Realization and application of large-scale fast optical circuit switch for data center networking. *Journal of Lightwave Technology*, *36*(7), 1411-1419.

[3] Mellette, W. M., McGuinness, R., Roy, A., Forencich, A., Papen, G., Snoeren, A. C., & Porter, G. (2017, August). Rotornet: A scalable, low-complexity, optical datacenter network. In *Proceedings of the Conference of the ACM Special Interest Group on Data Communication* (pp. 267-280).

[4] Yan, F., Xue, X., &Calabretta, N. (2018). HiFOST: a scalable and low-latency hybrid data center network architecture based on flow-controlled fast optical switches. *Journal of Optical Communications and Networking*, *10*(7), B1-B14.

[5] Golter, D. A., & Lai, C. W. (2017). Optical switching of defect charge states in 4 H-SiC. *Scientific reports*, *7*(1), 1-5.

[6] Salman, S., Streiffer, C., Chen, H., Benson, T., &Kadav, A. (2018, August). DeepConf: Automating data center network topologies management with machine learning. In *Proceedings of the 2018 Workshop on Network Meets AI & ML* (pp. 8-14).

[7] Avilés-Félix, L., Olivier, A., Li, G., Davies, C. S., Álvaro-Gómez, L., Rubio-Roy, M., ... &Prejbeanu, I. L. (2020). Single-shot all-optical switching of magnetization in Tb/Co multilayer-based electrodes. *Scientific reports*, *10*(1), 1-8.

[8] Xue, X., Pan, B., Chen, S., Prifti, K., Guo, X., Yan, F., ... &Calabretta, N. (2021, June). Experimental Assessments of Fast Optical Switch and Control System for Data Center Networks. In *2021 Optical Fiber Communications Conference and Exhibition (OFC)* (pp. 1-3). IEEE.

[9] Guo, X., Xue, X., Pan, B., Wang, Y., Zhang, S., Exarchakos, G., &Calabretta, N. (2021, June). Experimental Demonstration of a Nanoseconds Optical Switch based Disaggregated Data Center Network. In *2021 Optical Fiber Communications Conference and Exhibition (OFC)* (pp. 1-3). IEEE.

[10] Wang, Z., Feng, J., Xu, J., Chen, X., Zhang, J., Chen, S., & Liu, Y. (2021). HERO: Pbit High-Radix Optical Switch based on Integrated Silicon Photonics for Data Center. *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*.

[11] Bhattacharya, P., Tiwari, A. K., Ladha, A., &Tanwar, S. (2020). A proposed buffer based load balanced optical switch with AO-NACK scheme in modern optical datacenters. In *Proceedings of ICETIT 2019* (pp. 95-106). Springer, Cham.

[12] Sato, K. I. (2020, July). Design and performance of large port count optical switches for intra data centre application. In *2020 22nd International Conference on Transparent Optical Networks (ICTON)* (pp. 1-4). IEEE.

[13] Sherwin, J., &Sreenan, C. J. (2019, October). LogSnap: creating snapshots of OpenFlow data centre networks for offline querying. In *2019 10th International Conference on Networks of the Future (NoF)* (pp. 66-73). IEEE.

[14] Andreades, P. (2020). *Control plane hardware design for optical packet switched data centre networks* (Doctoral dissertation, UCL (University College London)).

[15] Ahearne, S., O'Mahony, N., Boujnah, N., Ghafoor, S., Davy, A., Guerrero, L. G., & Renaud, C. (2019, November). Integrating THz wireless communication links in a data centre network. In *2019 IEEE 2nd 5G World Forum (5GWF)* (pp. 393-398). IEEE.

[16] Alhazmi, A. S., Alsulami, O. Z., El-Gorashi, T. E., Alresheedi, M. T., &Elmirghani, J. M. (2020, July). Data center top of rack switch to multiple spine switches optical wireless uplinks. In *2020 22nd International Conference on Transparent Optical Networks (ICTON)* (pp. 1-4). IEEE.

[17] Gonzalez Sans, X. (2019). *SDN-based control and orchestration of optical data centre networks* (Master's thesis, UniversitatPolitècnica de Catalunya).

[18] Sohini, B. (2017). *Evaluation of data centre networks and future directions* (Doctoral dissertation, Dublin City University).

[19] Prabadevi, B., &Jeyanthi, N. (2017). Security solution for ARP cache poisoning attacks in large data centre networks. *Cybernetics and Information Technologies*, *17*(4), 69-86.

[20] Ballani, H., Costa, P., Behrendt, R., Cletheroe, D., Haller, I., Jozwik, K., ... & Williams, H. (2020, July). Sirius: A flat datacenter network with nanosecond optical switching. In *Proceedings of the Annual conference of the ACM Special Interest Group on Data Communication on the applications, technologies, architectures, and protocols for computer communication* (pp. 782-797).

[21] Benjamin, J. L., Gerard, T., Lavery, D., Bayvel, P., &Zervas, G. (2020). PULSE: optical circuit switched data center architecture operating at nanosecond timescales. *Journal of Lightwave Technology*, *38*(18), 4906-4921.

[22] Papaphilippou, P., Meng, J., &Luk, W. (2020, February). High-performance FPGA network switch architecture. In *Proceedings of the 2020 ACM/SIGDA International Symposium on Field-Programmable Gate Arrays* (pp. 76-85).

[23] Xue, X., Yan, F., Prifti, K., Wang, F., Pan, B., Guo, X., ... &Calabretta, N. (2020). ROTOS: a reconfigurable and cost-effective architecture for high-performance optical data center networks. *Journal of Lightwave Technology*, *38*(13), 3485-3494.

[24] Mukherjee, D., Chakraborty, S., Sarkar, I., Ghosh, A., & Roy, S. (2020). A detailed study on data centre energy efficiency and efficient cooling techniques. *International Journal*, *9*(5).

[25] Luo, L., Foerster, K. T., Schmid, S., & Yu, H. (2020, July). Splitcast: Optimizing multicast flows in reconfigurable datacenter networks. In *IEEE INFOCOM 2020-IEEE Conference on Computer Communications* (pp. 2559-2568). IEEE.

[26] Lange, S., Raja, A. S., Shi, K., Karpov, M., Behrendt, R., Cletheroe, D., ... &Ballani, H. (2020, March). Sub-nanosecond optical switching using chip-based soliton microcombs. In *Optical Fiber Communication Conference* (pp. W2A-4). Optical Society of America.

[27] Lin, J., Patel, K., Stephens, B. E., Sivaraman, A., &Akella, A. (2020). {PANIC}: A High-Performance Programmable {NIC} for Multi-tenant Networks. In *14th {USENIX} Symposium on Operating Systems Design and Implementation ({OSDI} 20)* (pp. 243-259).

[28] Ragab, M., Ashary, E.B., Aljedaibi, W.H., Alzahrani, I.R., Kumar, A., Gupta, D. and Mansour, R.F., 2022. A novel metaheuristics with adaptive neuro-fuzzy inference system for decision making on autonomous unmanned aerial vehicle systems. ISA transactions, Elsevier, 2022. https://www.sciencedirect.com/science/article/abs/pii/S0019057822001598#

[29] AL-Ghamdi, Abdullah S., Mahmoud Ragab, Saad Abdulla AlGhamdi, Amer H. Asseri, Romany F. Mansour, and DeepikaKoundal. "Detection of Dental Diseases through X-Ray Images Using Neural Search Architecture Network." Computational Intelligence and Neuroscience 2022 (2022).