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Cost Effective Management Framework for Integrating Software Defined Network: Review

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ABSTRACT
DataCentre networks have seen a paradigm shift with the advent of software-defined networking (SDN), which centralize network decision-making and isolate data from the control plane. Measurement of traffic flow in SDN is comparatively light compared to more conventional techniques. With the use of a centralized controller, it allows flow measuring systems to get beyond the problems with conventional measurement systems, like accuracy and expense. However, a completely physically centralized controller puts the network and the measuring system at risk. Additionally, there is still a problem with the imposed costs related to administration in SND in data Centres. Thus, this research looks at a cost-effective management framework for combining data Centre connectivity and software-defined networks. In particular, the review architype for simplifying data Centre management can creat an appropriate and cost-effective framework for SDN, presented a new cost analysis of a contemporary data Centre, and evaluated the suggested framework against existing benchmarks. As a result, it is recommended that operators of moderating data Centres adopt and suggest a framework for simplifying data Centre management. Create an appropriate and economical framework for SDN. Make a new cost analysis proposal for a contemporary data Centre. Lastly, new SDN policies should be implemented to assess load balancing and show how effective they are in enhancing cost decisions.

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INTRODUCTION

In the current age of digital transformation, data centres are emerging as the operational centres of contemporary enterprises. Their efficacy and efficiency are essential to organisational success. Technological leaders have considerable obstacles in developing economical data centre systems that preserve critical functionalities (Chaudhary et al., 2022). Data centre scalability has been a common technique for organisations to minimise expenses (Imae et al., 2022). Realising this advantage requires the design of data centres that are both efficient and cost-effective.

One of the primary concerns for data centre operators revolves around network infrastructure design. Although it may not directly influence immediate revenue, it constitutes a considerable portion of initial capital investments. Kim et al. (2019) observed that advances in distributed system architectures and related network technologies have complicated the fulfillment of user network demands, often escalating costs. Consequently, minimising network infrastructure costs and overseeing intricate network settings are essential for improving profitability. In contrast to conventional client-server applications that mostly focus on

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client-server interactions, contemporary apps produce substantial machine-to-machine traffic among databases and servers (Sakellaropoulou, 2017).

Traditional networks necessitate significant temporal and financial resources to establish intricate ecosystems (Wang et al., 2015). Virtualization processes and centralized network management, enabled by Software-Defined Networking (SDN), have improved modern data Centre networks (Naudts et al., 2016). SDN is an innovative networking framework that separates the control and data planes of network devices, enhancing management and facilitating innovation through advanced monitoring and regulation tools (Feng et al., 2021). These advances have significantly diminished operational expenses. The expansion of public and private cloud services has markedly enhanced the accessibility of these services (Sakellaropoulou, 2017). To handle escalating data workloads, data centres necessitate massively parallel processing across networked systems, requiring scalability, flexibility, high availability, and robust security.

Efficient network management requires centralised oversight of computing and storage resources critical to business operations (Tahaei et al., 2018). Many mid-sized organisations face challenges in long-term IT planning, resulting in fragmented, underutilized systems that are costly to maintain and secure (Katal et al., 2019). Industry research indicates that 70% of data centre budgets are dedicated to the maintenance of existing applications rather than the adoption of innovative technology (Panwar et al., 2022).

Cost reduction for data centres and cloud services may entail the removal of costly equipment by utilising geo-diversity to establish geo-redundancy. Nonetheless, creating frameworks for distributed state management across several sites continues to be a formidable research challenge (Su et al., 2017). Presently, numerous services deploy individualised solutions for geo-distribution, frequently resulting in inefficiencies (Panwar et al., 2022). For example, Facebook utilises a centralised master data centre for all write operations, while Yahoo! Mail distributes data based on user IDs, demonstrating the compromises between cost and service quality (Luft et al., 2023). The incorporation of SDN into data Centres offers significant prospects for cost savings and operational efficiency, hence improving the productivity of organizations reliant on these facilities. This study seeks to provide a cost-effective management framework that integrates SDN to enhance efficiency in high-capacity data Centre environments.

LITERATURE REVIEW

Cloud Computing

Panagiotakis et al. (2015) and Fernando et al. (2013) characterise cloud computing as a framework that permits worldwide users to access services and store applications and data on the network. Cluster computing refers to the provision of computing resources inside a cloud architecture, accessible to clients on demand, alleviating concerns regarding logistical complications (Moura & Hutchison, 2016). Cloud computing presents a revolutionary method for administering and providing ICT resources to distant users (Mastelic et al., 2015). It functions on t foundation of huge data centres, featuring high-bandwidth infrastructure, comprehensive server virtualisation environments, and supporting systems such as cooling and power supplies (Mastelic et al., 2015).

Data Centre

Hakiri et al. (2014) and Mostafa et al. (2020) clarify that contemporary data centres have several hardware components, including CPUs, memory, storage, and high-speed network interfaces. These are organized on racks, forming clusters of hundreds or thousands of hosts interconnected by high-bandwidth networks. Mateen et al. (2016) assert that these clusters employ thread-level parallelism to manage the requirements of elevated Internet traffic. Kim and Feamster (2013) observe that data centre network traffic frequently displays bursty characteristics, wherein a sudden surge of data packets can impair performance and affect other flows.

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Data Centre Network (DCN)

To provide security, a Data Centre Network (DCN) is designed with the premise that each node is connected to an access port on an end-of-row switch, representing a singular server executing a single instance of an operating system (OS). Additionally, it is presumed that the server remains fixed and does not transition to another physical server. The advent of server virtualisation has contested these assumptions, resulting in increased design difficulties in data centre networks (DCNs). The problems encompass network scalability for virtualisation, virtual machine (VM) mobility, heightened management complexity, and the necessity for convergence support (Bari et al., 2013).

Traditional tiered tree topologies, marked by low reliability and congested any-to-any network configurations, limit task allocation due to their tree-based forwarding structures (Luft et al., 2023). Modern Data Centre Networks (DCNs) include multipath designs that consist of physical connections formed by host servers, typically outfitted with several interfaces and redundant links to enhance fault tolerance and bandwidth distribution (Abbas et al., 2021).

Data Centre Architecture Topologies

Data centre networks (DCNs) commonly employ two primary topologies: server-centric and switch-centric. In switch-centric topologies, servers connect to the network by a single port, with routing intelligence located within the switches. Zafar et al. (2016) contrast this with server-centric designs, where computers with many network ports act as crossbars and are responsible for routing intelligence. Although the conventional three-tier tree design is still extensively ued, the fat-tree topology is known for its scalability, robustness, and cost-effectiveness (Bilal et al., 2013). Both groups have seen the emergence of new designs with the hopes of improving operational consistency, agility, resource efficiency, and cost optimisation, among other things.

Multi-Tier Tree

Conventional distributed control network (DCN) architectures employ a hierarchical configuration of switches with differing connection capacities. Andreiyev (2017) asserts that the Access layer comprises Top of Rack (ToR) switches, facilitating communication across computers inside the same rack. Upon receiving traffic from the ToRs, the upper-tier core switches route it through the aggregation layer switches, facilitating connectivity between racks. High-capacity core switches connect the aggregation layer switches to the network's backbone. To enhance bandwidth capacity and ensure network reliability, redundancy at both the core and aggregation levels is necessary (Sohini, 2017).

A network topology diagram showing the interconnections between various aggregation switches, core switches, ad each ToR switch is shown in Figure 1. Optimising bandwidth capacity and increasing network resilience are the goals of this resource over-provisioning (Yao et al., 2017). The core layer supports north-south traffic and inter-rack communication, and it connects the lower layers while the aggregation layer handles load balancing. It also assures smooth traffic flow between them. See figure 1.

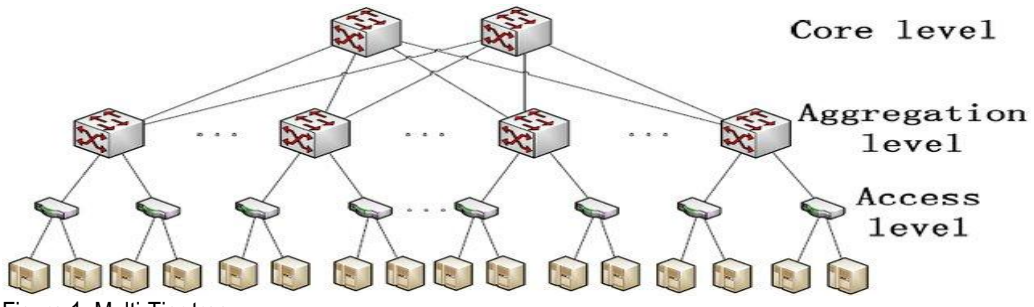

Figure 1: Multi-Tier tree

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Hybrid Cloud DCN

A hybrid cloud model combines features of private and public cloud infrastructures. This architecture safeguards sensitive information in private clouds, while non-essential business processes are executed through public clouds. The Data Centre Network (DCN) is essential for optimizing resource allocation between private and public cloud environments. This configuration provides cloud customers with optimal control over security, performance, and dependability in individual cloud models. The DCN must provide a private cloud infrastructure and guarantee a distinct virtual network for each user, maintaining high stability and safe data segregation to maintain appropriate user access rights. In hybrid cloud architectures, sensitive data is securely stored in private cloud systems, and public clouds manage less important operations. The DCN oversees the seamless integration of these two cloud types, safeguarding the integrity and security of private cloud data while facilitating efficient data transfer between environments without jeopardizing security (Wang et al., 2015). See Figure 2.

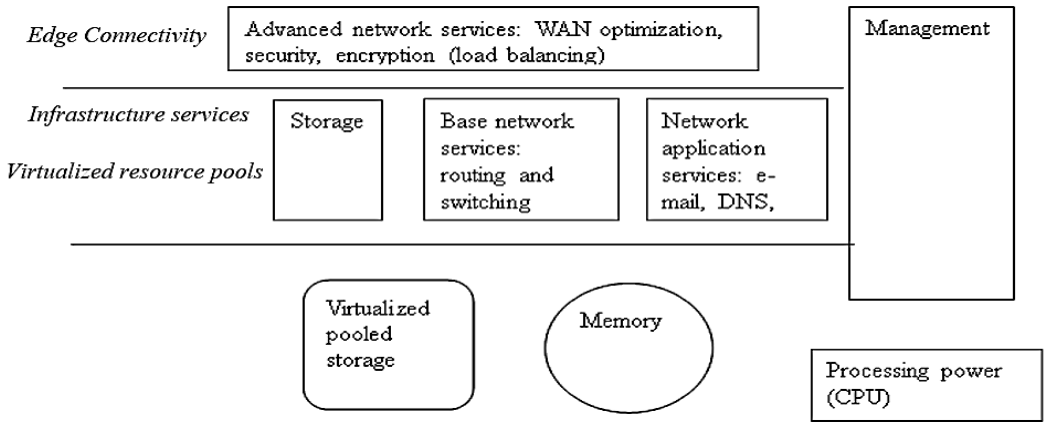

Figure 2: Data Centre Network Architecture
Source: Wang et al. (2015).

The authentication procedure and the interaction of the design components of the security framework and the network architecture for data are depicted in Figure 3 and 4. The complete work flow consists of the following steps: job execution, termination, disconnection, master node and slave node authentication, proxy credential assignment, user authentication, and master node preparation for authentication.

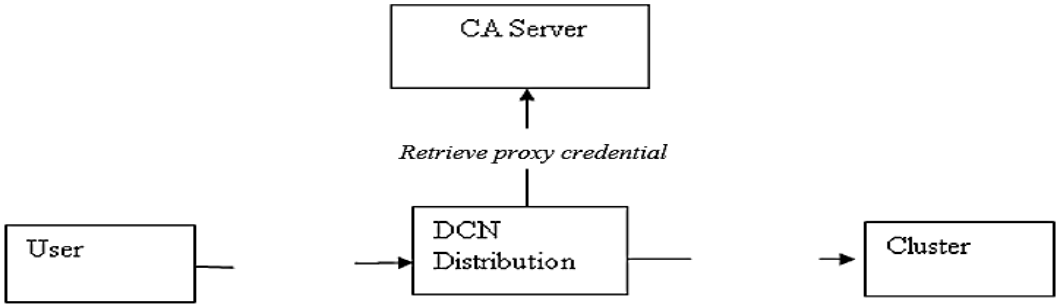

Figure 3: Work Flow data Centre Network Architecture

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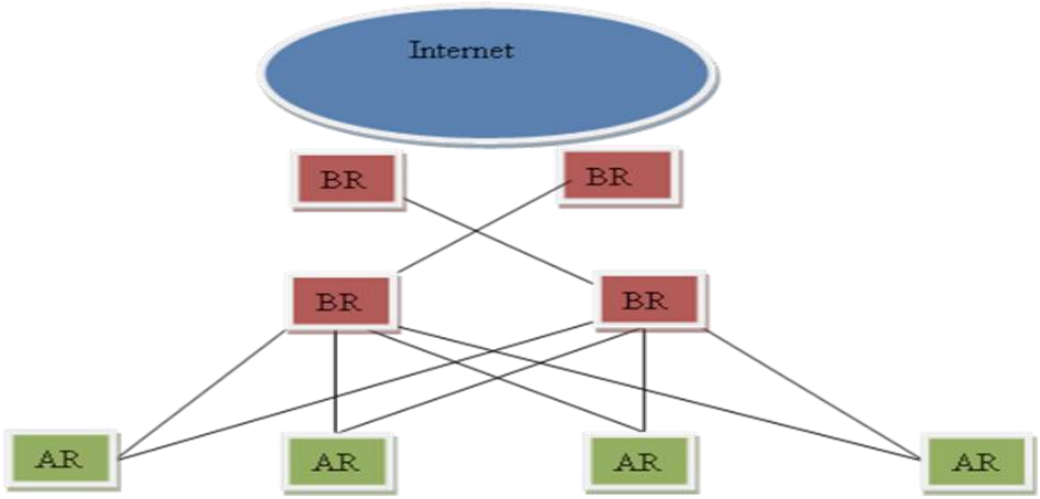

Figure 4: The Network Architecture for Data

BR- Border Routers
R- Access Routers
Data centre layer 3

Software-Defined Networking

Software-Defined Networking (SDN) provides a technique for streamlining network management by separating the control and data planes, enabling direct network programming. The Open Networking Foundation (ONF, 2017) states that Software-Defined Networking (SDN) presents a network architecture in which network control and data forwarding are decoupled and programmable. At the heart of this architecture is the controller, which handles application requests and offers northbound APIs, which are interfaces for application programming. The controller also provides southbound APIs, which manage the data plane of various devices.

Complexity

Software engineers and project managers can utilize approaches to evaluate complexity levels for comparing various design alternatives for a given function or the complete system. This method facilitates the design process and reduces complexity (Wang et al., 2015). By managing the complexity of the software system, objectives such as cost reduction and quality improvement can be achieved. This involves selecting the right personnel for handling the more difficult aspects of WIWI, distributing testing resources, evaluating different programming languages, and estimating development timelines, while also considering grammar rules and design principles (Kokol & Zumer, 1988; Wang et al., 2015).

Management Capabilities

Despite the increasing number of cloud service providers, the advancement of platform capabilities and infrastructure maintenance remains nascent. Many firms find auto-scaling features essential; yet, current solutions for scaling and load balancing necessitate significant enhancement (Harris, 2015). In what ways may data Centre networks and systems be optimized to improve resource utilization and address these challenges? The essential factor is flexibility—the ability to dynamically modify resources in response to demand and assign them from optimal places. Unfortunately, most current networks limit this adaptability, which exacerbates resource fragmentation and results in underused servers (Gray, 2017). This inefficiency also increases operational costs, particularly with the need for dependable power.

Related Work

Du et al. (2024) examined load balancing methodologies in data Centres utilizing

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Software-Defined Networking (SDN). As data Centre networks proliferate and encounter increasing bandwidth demands, conventional network topologies are demonstrating inadequacy. Software-Defined Networking (SDN), which delineates the data and control planes, offers a viable solution to improve network performance. Their research concentrated on incorporating SDN into data Centres to enhance resource allocation and augment overall system efficiency.

Clarke et al. (2023) introduced a system to assess the efficacy of diverse fuel treatment options in reducing risks in southeastern Australia. The research indicated that no singular solution could be universally applicable across geographies, underscoring the necessity for trade-offs. They underscored that cost-effectiveness is significantly contingent upon management priorities. The authors proposed reevaluating existing practices and implementing adaptable, risk-based fire management tactics due to the potential reduction in the efficacy of prescribed burns and the escalation of expenses attributed to climate change. They also advocated for the expansion of the framework to encompass underrepresented values, including those pertaining to Aboriginal traditional burning practices.

Katal et al. (2023) examined energy efficiency in data Centres, emphasizing methods to decrease power usage and mitigate environmental effects, including electronic waste. The research examined international criteria for data Centre energy ratings and emphasized the significance of sustainability in cloud computing. The researchers found energy-efficient methods suitable for several levels, ranging from virtualization to operating systems and apps. Their findings highlighted the difficulties of executing green cloud solutions and incorporated case studies on elements affecting the adoption of sustainable practices in cloud enterprises.

Luft et al. (2023) introduced a system for evaluating the costs, benefits, and adaptability of integrating additive manufacturing (AM) technology into production planning. They offered directives for planners to measure adaptability and enhance production system designs. The report featured a case study demonstrating how additive manufacturing technology could improve manufacturing flexibility through the assessment of various production configurations. This methodology assists plant planners in evaluating the prospective effects of AM at the first stages of the planning process.

Current SDN Architecture

In conventional dispersed network architectures, each network device comprises both a control plane and a data plane, as seen in Figure 14. Various traffic management methods are employed in conventional network setups. However, Software-Defined Networking (SDN) aims to streamline the management of these traditional network infrastructures. The Open Networking Foundation (ONF) defines SDN as an "emerging network framework where the control plane is decoupled from the data plane and can be directly programmed" (ONF, 2017).

Figure 2 illustrates the SDN controller, which is central to the architecture. The controller manages the network by providing southbound APIs for both applications and controlling the data planes of different devices. It tracks all incoming requests and injects transfer data rules into flow tables using various command-line interfaces, such as OpenFlow, TL-1, NETCONF, and SNMP, or initiates distributed control plane signaling from the connection's source (PCEP).

The controller employs a network topology model and traffic load data to compute pathways, providing global visibility. Consequently, the SDN design positions the centralized controller as the core of path computation. This method streamlines the control plane relative to GMPLS and eliminates the necessity for incorporating network features from the state-distribution mechanism. Network operators favor SDN for its ability to integrate with multiple vendors in diverse transport networks.

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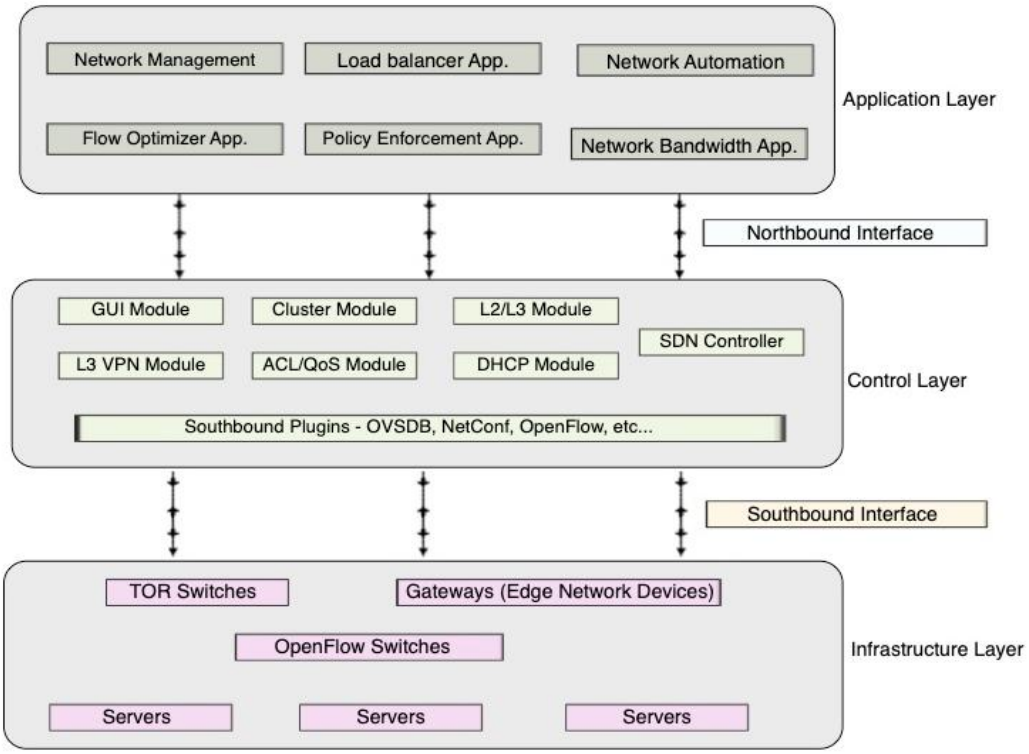

Figure 5: Existing SDN Architecture

The existing framework used for the prior study is shown in Figure 5, which was altered by integrating SDN and DCI for cost effectiveness and management compatibility.

CONCLUSION

Large-scale data Centres and virtualization require dynamic support, automation, and secure cloud-based environments. Software-Defined Networking (SDN), with its extensive advantages and widespread adoption across various sectors, is emerging as the future standard for network architectures. This study focused on comparing traditional network designs with the newer SDN topologies. By integrating advanced network devices, the research introduces innovative methods into the proposed architecture, such as load balancing, the OpenDaylight controller, and performance evaluations. Additionally, it measures their effectiveness in areas like cost management, latency, and throughput using simulation tools. Therefore, Organizations intending to implement SDN should carefully evaluate their specific needs, assess the solutions offered by different vendors, and establish clear migration plans to minimize risks and maximize the expected benefits.

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