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# An Architectural Proposal for an SDN based Data Centre: A Case Study

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**ABSTRACT**

Software Defined Networking (SDN) is an important approach to network design which uses software to enable networked systems to expand data flow control. Data centre is a facility used to house computer systems and associated components, such as telecommunication equipments, storage systems and backup systems. Networks are a critical component of data centres for getting efficient outputs / results. SDN presents a new architecture that separates the network control plane from the data plane, allowing a centralized controller (or set of controllers) to define forwarding behaviour. These networks have emerged as an efficient network technology capable of supporting the dynamic nature of the network functions and intelligent applications while lowering operating costs through simplified hardware, software and management. In this paper, we present a study of the data centre functioning at Himachal Pradesh Power Corporation Ltd. (HPPCL) Shimla, India. The aim of this paper is to propose an SDN based Architecture for the data centre of this organisation.

Keywords- Control plane, Data Centre, OpenFlow, Software Defined Networking

## 1. INTRODUCTION

Data centre is a facility used to house computer systems and associated components, such as telecommunication equipments, storage systems and backup systems. Networking plays an important role in functioning of a Data Centre. The term Software-defined networking (SDN) has come into use in recent years. However the concept behind SDN has been evolving since 1996, driven by the desire to provide user-controlled management of forwarding data in network nodes [1]. Implementations by research and industry groups include Ipsilon (proposed General Switch Management Protocol, 1996). The Tempest (a framework for safe, resource-assured, programmable networks, 1998 and Internet Engineering Task Force (IETF) Forwarding and Control Element Separation, 2000 and Path Computation Element, 2004. Most recently Ethene (2007) and OpenFlow (2008) have brought the implementation of SDN closer to reality. Ethene is a security management architecture combining simple flow-based switches with a central controller managing admittance and routing of flows. OpenFlow enables entries in the Flow Table to be defined by a server external to the switch. Flow tables contain rules that can be used to match incoming packets and associate them to a number of actions. SDN is not, however, limited to any one of these implementations, but is a general term for the platform [1].

The SDN allows network administrators to manage network services as virtual services through abstraction of lower level functionality. This replaces the task of manual configuration of hardware / networking devices. Software Defined Networking promises to deliver enormous benefits, from reduced costs to more efficient network operations [2]. It introduces a layer of software between bare metal network components and the network administrators who configure and set them. This software layer gives network administrators an opportunity to make their network device adjustments through a software interface instead of having to manually configure hardware and actually physically access network devices. Internet Protocol (IP) based networks were initially built based on the notion of Autonomous Systems (AS). This notion allows networks to scale and extend by connected junctions that forward packets to a reasonable next hop based on partial need-to-know information.

There are several new emerging approaches to networking under the field of SDN, which bring, separation of data and control planes. As elastic cloud architectures and dynamic resource allocation evolve and as mobile computer operating systems and virtual machines usage grows, the need has arisen for an additional layer of Software Defined Networking (SDN). Such a layer allows network operators to specify network services, without coupling these specifications with network interfaces. This enables entities to move between interfaces without changing identities or violating specifications. Such a layer allows network operators to specify network services, without coupling these specifications with network interfaces. This enables entities to move between interfaces without changing identities or violating specifications. Such a layer can also reset some of the complexity build-up in network elements by decoupling identity and flow-specific control logic from basic topology-based forwarding, bridging, and routing [2].

The global software defined control also tracks specific flow contexts based on source and destination identity aspects. A mechanism for driving network hardware has been added and adopted by network equipment manufacturers for the purpose of sharing edge driving between software defined edge and vendor specific bridging and routing. A set of open commands for forwarding was defined in the form of a protocol known as OpenFlow [2]. It enables centralized or distributed globally-aware software controllers to drive the network edge hardware in order to create an easily programmable identity-based overlay on top of the traditional IP core [2].

The SDN allows network administrators to have programmable central control of network traffic without requiring physical access to the network's hardware devices. It decouples the system that makes decisions about where the traffic is to be sent (the control plane) from the underlying system that forwards traffic to the selected destination (the data plane). The Open Networking Foundation was founded to promote SDN standards and engineering as Cloud Computing blurs the boundaries between networks and computers [2].

Himachal Pradesh Power Corporation Limited (HPPCL) in the state of Himachal Pradesh in India, was incorporated in December, 2006 under the Companies Act 1956, with the objective to plan, promote and organize the development of all aspects of hydroelectric power on behalf of Himachal Pradesh State Government (GoHP) and Himachal Pradesh State Electricity Board (HPSEB) in Himachal Pradesh. The GoHP has a 60%, and HPSEB, a 40% shareholding in HPPCL [3].

At present, HPPCL is generating and distributing hydel power through its power projects. Since the electrical power can not be stored in its generators and distribution in real time assumes critical significance and so is true about the data related to it. Hence, HPPCL has implemented an ERP based solution to manage this data and have installed a tier II data centre at its Shimla based office. Since managing the control of the networking part of the centre is a challenging task and keeping in view the advantages of Software Defined Networks, the authors of this paper have made an effort to propose an architecture for the SDN based data centre.

The rest of this paper is organised as follows.

**Section II** presents the review of related literature. **Section III** describes Network Architecture of the Data Centre of HPPCL, Shimla. **Section IV** describes the proposed SDN Architecture for HPPCL. **Section V** describes the Benefits of providing SDN in Data Centre for HPPCL following the conclusions and future work in **Section VI.**

## 2. LITERATURE REVIEW

According to SDN expert Lee Doyle, principal analyst at Doyle research, the most common issue SDN technology addresses is the inability of large data centres to support the requirements of server virtualization [4]. Specifically, SDN enables automated provisioning of virtual networks and network services easily and quickly in order to support new virtual machines. But there are added benefits beyond virtualization of networks. SDN can mean programmability in any part of the network; it can also improve network visibility and reduce operational costs. Specialized switches for SDN are not necessarily required. Some vendors are developing SDN strategies based on Open Flow controllers that will need to interact with Open Flow-friendly switches; however, others will use virtual switches and network overlays to implement SDN and network virtualization architecture that in no way relies on SDN controllers [4].

There are different approaches to SDN architecture - some that depend on centralized controllers and others that use distributed software. In the OpenFlow community, however, a special controller is needed and is used by providers like Big Switch, IBM and NEC. On the other hand, Cisco's SDN architecture supports OpenFlow, but doesn't require an SDN controller. Cisco's strategy embeds intelligence in its Ethernet switches and network management software [4]. We have studied and discussed here the SDN architectures of some specific organisations as below:

**1. SDN Architecture for Big Switch:** Compared to legacy networking architectures that are vertically integrated from the underlying hardware, through the operating system, and into the network application functionality, the inherently open nature of an SDN represents a fundamental shift in power giving us choice, agility and automation of network operations not previously possible [5].

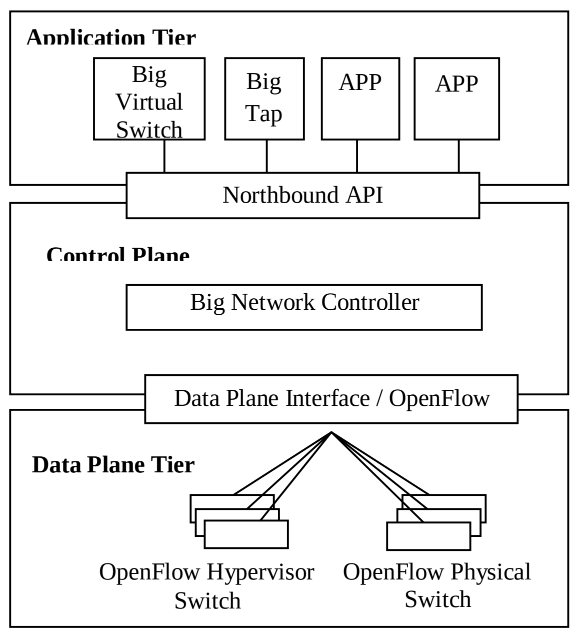


**Figure1:** Three Tier Architecture for the Big Switch Networks Open SDN [5]

**Northbound Open APIs -** Open APIs refer to the software interfaces between the software modules of the controller platform and the SDN applications running atop the network platform. Figure 1 shows the Open SDN architecture focus on Northbound APIs, which expose the universal network abstraction data models and functionality within the Big Network Controller for use by network applications. These interfaces are published and open to customers, partners, and the open source community for development.

**Open Core Controller** – At the centre of the Open SDN architecture is an open core controller which maintains API consistency with the Big Switch Networks commercial controller – Big Network Controller.

**Standards-based Southbound Protocols -** Big Switch Networks focus on standards-based connectivity for the "Southbound Protocols," which define the control communications between the controller platform and data plane devices, including physical and virtual switches [6].

**2. SDN Architecture proposed by CISCO:** Software Defined Networks (SDNs) have become a mainstream topic for research, development, and standardization these days. Figure 2 shows the logical structure of an SDN. In this, a central controller performs all complex functions, including routing, naming, policy declaration, and security checks. This plane constitutes the SDN Control Plane, and consists of one or more SDN servers [6].

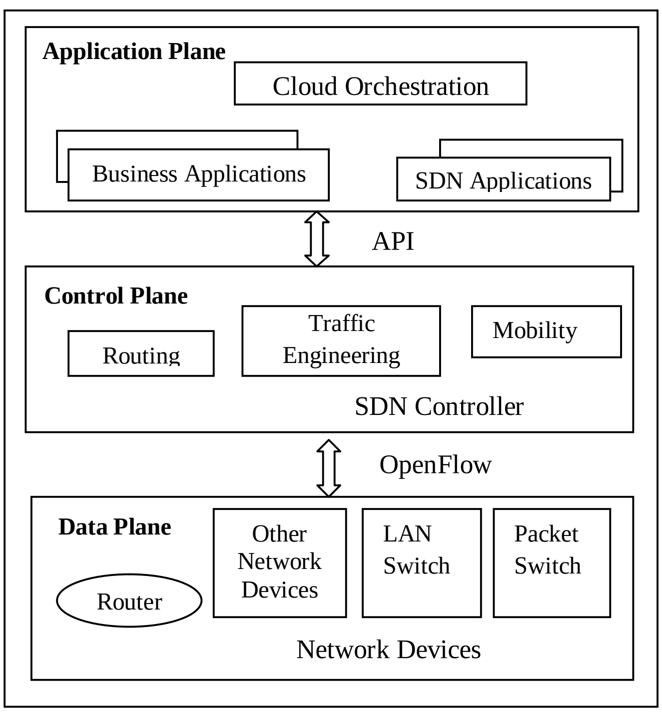


**Figure 2:** SDN Architecture Proposed by CISCO [6]

The SDN Controller defines the data flows that occur in the SDN Data Plane. Each flow through the network must first get permission from the controller, which verifies that the communication is permissible by the network policy. If the controller allows a flow, it computes a route for the flow to take, and adds an entry for that flow in each of the switches along the path. With all complex functions subsumed by the controller, switches simply manage flow tables whose entries can be populated only by the controller. Communication between the controller and the switches uses a standardized protocol and API.

The SDN architecture is remarkably flexible; it can operate with different types of switches and at different protocol layers. SDN controllers and switches can be implemented for Ethernet switches (Layer 2), Internet routers (Layer 3), transport (Layer 4) switching, or application layer switching and routing. SDN relies on the common functions found on networking devices, which essentially involve forwarding packets based on some form of flow definition [6].

**3. SDN Architecture for HP:** As per the SDN architecture proposed by HP, there are three critical components to a building an SDN [7]:

a) The infrastructure which includes the underlying ports and forwarding hardware that move data across the network. figure 3 shows that in an SDN environment, it is important that the infrastructures support a means of programmatic access to its data and control plane separately.

b) The control element of an SDN that resides in a central controller. This control presents an abstracted view of the infrastructure, allowing the network administrator to apply one or more policies across the network. The controller's job is to enforce these policies. A controller needs to communicate with the infrastructure, but must also be able to communicate with applications.

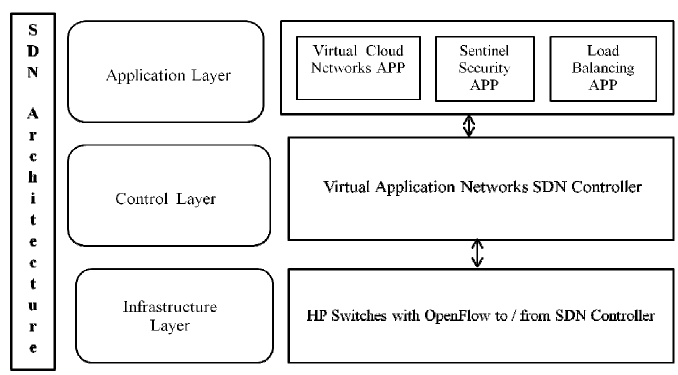


**Figure 3:** SDN Architecture Proposed by HP [7]

c) Applications in an SDN environment which could be compared to the protocols that ran our legacy networks for the past 20 years. The key difference is that SDN applications are presented a view of the entire network, allowing them to focus on optimizing business applications and providing a true end-to-end Service Level Agreement (SLA) comprising performance, quality of service, and security [7].

**4. SDN Architecture for Intel:** Intel Architecture provides network service providers with a standard, reusable, shared platform for SDN that is easy to upgrade and maintain. Figure 4 shows that Intel has been anticipating the shift to SDN and is committed to help network service providers take advantages of this opportunity.

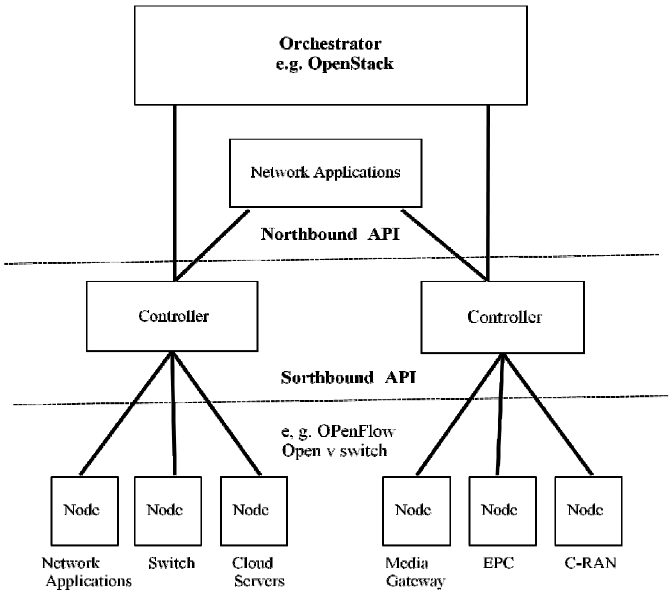


**Figure 4:** SDN Architecture Proposed by Intel [8]

Intel has been exploring the benefits of SDN with several leading fixed and mobile network service providers in Europe, the Americas and Far East [8].

The basic purpose of the communication network is to transfer data from one point to another. Figure 5 shows a traditional static network where network control and data transfer processing both are carried out together by dedicated network equipment.

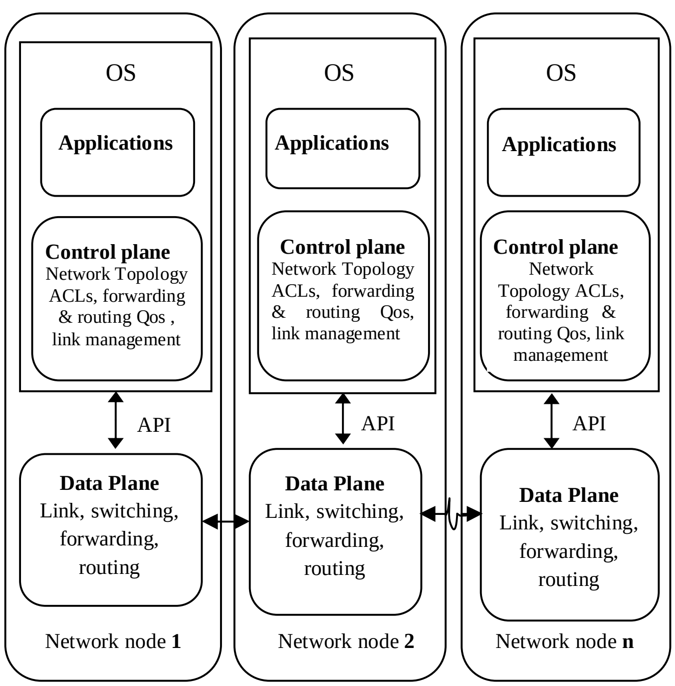


**Figure 5:** The Traditional Network approach

Many enterprises are unable to create business innovation because of aging networking environments. Network design and architectures have remained largely unchanged for more than a decade. While applications and systems have evolved to meet the demands of a world where real time rules, the underlying network infrastructure has not kept pace [8]. Due to the drastic change in the field of information Technology, it is the demand of time to adopt changes in the traditional network architecture to meet out the need of time. SDN is proving to be the solution in this field.

SDN architectures will end up taking many approaches, and each vendor will have a different way of developing its SDN solution. However, the Open Network Foundation (ONF) has made great progress with the standard, and many vendors have already put Open Flow into action. The ONF recommended using Open Flow as the foundation technology for SDN implementation [9].

The ONF recommends that in the SDN architecture, the control and data planes are decoupled, network intelligence and state are logically centralized and the underlying network infrastructure is abstracted from the applications. According to ONF, the SDN focuses on four key features [9]:

- Separation of the control plane from the data plane
- A centralized controller and view of the network
- Open interfaces between the devices in the control plane (controllers) and those in the data plane
- Programmability of the network by external applications

Basically, the design of a data centre network architecture should meet the following objectives [10,11,12,13]:

**Uniform high capacity*:*** The maximum rate of server-to-server traffic flow should be limited only by a) the available capacity on the network-interface cards of the sending and receiving servers and b) assigning servers to a service should be independent of the network topology. It should be possible for an arbitrary host in the data centre to communicate with any other host in the network at the full bandwidth of its local network interface.

**Resiliency:** Failures will be common at scale. The network infrastructure must be fault-tolerant against various types of server failures, link outages, server rack failures. Existing unicast and multicast communications should not be affected to the extent allowed by the underlying physical connectivity.

**Scalability:** The network infrastructure must be able to scale to a large number of servers and allow for incremental expansion.

**Backward compatibility*:*** The network infrastructure should be backward compatible with switches and routers running Ethernet and IP. Because existing data centres have commonly leveraged commodity Ethernet and IP based devices, they should also be used in the new architecture without major modifications.

Keeping in view all of these above mentioned design parameters in addition to the need for flexibility of control through a centralized control of network devices, we propose a generic SDN architecture as shown in figure 6. In this figure we can see that the control plane controls the individual data planes of all the networking devices centrally through an interface called API (Application Programming Interface).

HPPCL has set itself a target of developing 3000 MW Power generating capacity by March 2017 and 5000 MW by the year 2022. Towards achieving this target HPPCL is currently engaged with development of seven Hydro Electric Power (HEP) projects in various parts of the state with a combined potential of 1012 MW [14].

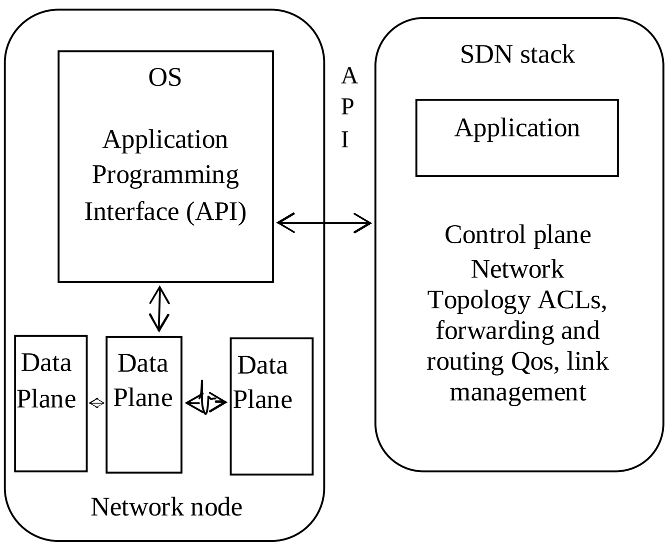


**Figure 6:** A Generic SDN Architecture

HPPCL's various projects are located in the hard hilly areas. The Head office of this organisation is located at Shimla, the capital of Himachal Pradesh state of India. The organisation has recently implemented the ERP solution to cater to its data management needs and a data centre has been established for this purpose.

## 3. EXISTING NETWORK ARCHITECTURE OF DATA CENTRE OF HPPCL, SHIMLA

Data centre is a facility used to house computer systems and associated components, such as telecommunications and storage systems. It generally includes redundant or backup power supplies, redundant data communications connections, environmental controls (e.g., air conditioning, fire suppression) and security devices.

**Networking Provisions at Present**

HPPCL required a secure and reliable network architecture aligned to the technology requirements of the organization. This architecture is based on industry best practices and has characteristics including:

- Availability
- Security

**Availability:** The architecture provides for availability by enabling a redundant network design. Redundant devices and links in each layer of the architecture provides for multiple paths through the core data centre network.

**Security:** The architecture provides for network security comprising of firewalls, Intrusion Detection System/Intrusion Prevention System etc. Network security would have multiple, built-in layers of security. It offers comprehensive and integrated protection from worms, spam, malicious attacks, disasters and wide range of threats and attacks from both inside and outside the network.

An integrated data centre consisting of a primary data centre and a Disaster Recovery (DR) data centre has been implemented for hosting the applications. The DR Data centre network shall mirror the primary data centre network.

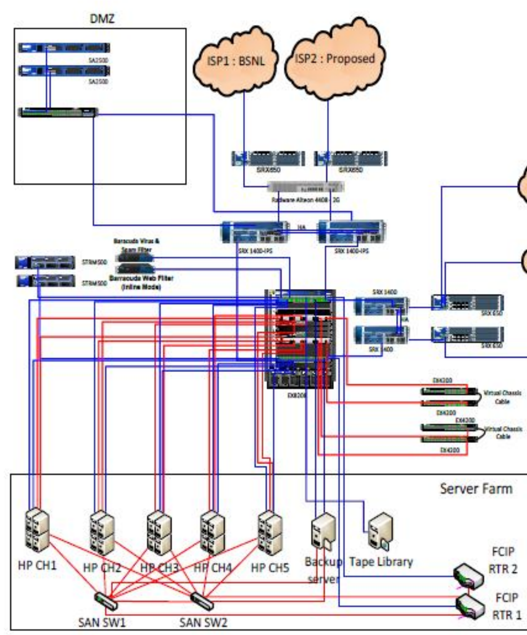


**Figure 7:** Topological Diagram of the Data Centre of HPPCL
*Source: HPPCL Documentation*

The data centre network design should follow the best practices of the industry with tiered physical and application architecture. HP SWAN (Himachal Pradesh State Wide Area Network) is being used as Secondary connectivity to connect all the locations. Multiple applications run inside a single data centre, typically with each application hosted on its own set of (potentially virtual) server machines.

A single data centre network supports two types of traffic: (a) traffic flowing between external end systems and internal servers, and (b) traffic flowing between internal servers. A given application typically involves both of these traffic types. To support external requests from the Internet, an application is associated with one or more publicly visible and routable IP addresses to which the clients on the Internet send their requests and from which they receive replies.

With reference to figure 7 which shows the topological diagram of the data centre of HPPCL. Figure 8 shows the network architecture of its existing data centre. This architecture was generated by the authors as a part of this work after going through the documentation available at HPPCL.
Inside the data centre, requests are spread among a pool of front-end servers that process the requests. This spreading is typically performed by a specialized hardware load balancer [15]. Using conventional load-balancer terminology, the IP address to which requests are sent is called a virtual IP address (VIP) and the IP addresses of the servers over which the requests are spread are known as direct IP addresses (DIPs).

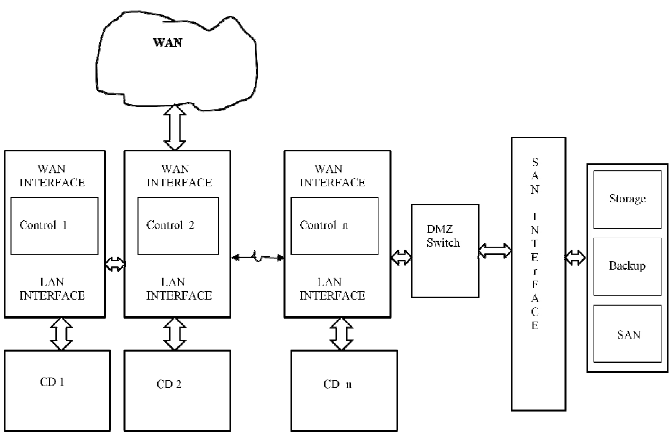


**Figure 8:** The Existing Network Architecture of the Data Centre, HPPCL, Shimla

## 4. PROPOSED SDN ARCHITECTURE FOR DATA CENTRE, HPPCL

SDN is said to be the next generation network technology. It refers to dynamically controlling networks using software. Network control and communication processing are separated. Equipment that only performs communication processing is dynamically controlled by using software on a general purpose server.

As the network evolves with new traffic patterns, especially with the adoption of cloud services and big-data workload sets, network-architecture limitations are realised. Also as applications get virtualized in virtual machines (VMs), many aspects of traditional networking are challenged from addressing schemes and namespaces to the basic notion of a segmented, routing based design [16].

SDN implementation opens up a means for new innovation and new applications. The programmability possible in SDN allows seamless communication at all levels from hardware to software and ultimately to end users (network operators)[16].

*SDN OpenFlow Controller Approach*
Keeping in view the traditional trend and problem set, a new network architecture is emerging under the label of Software defined Networking (SDN) in which the control plane is decoupled from the data forwarding plane and is directly programmable.

Commanded by an Open Network Foundation (ONF), the SDN-enabled disassociation and consolidation of the control plane enables the underlying infrastructure to be abstracted for applications and network services, which can treat the network as a logical or virtual entity. Network control is (logically) centralized in software-based SDN controllers, which maintains a global view of the network. As a result, the network appears to the applications and policy engines as a single, logical switch entity [17].
In reference to figure 8, the authors of this paper have made an effort to propose an SDN Architecture for the HPPCL data centre as figure 9 shows below.

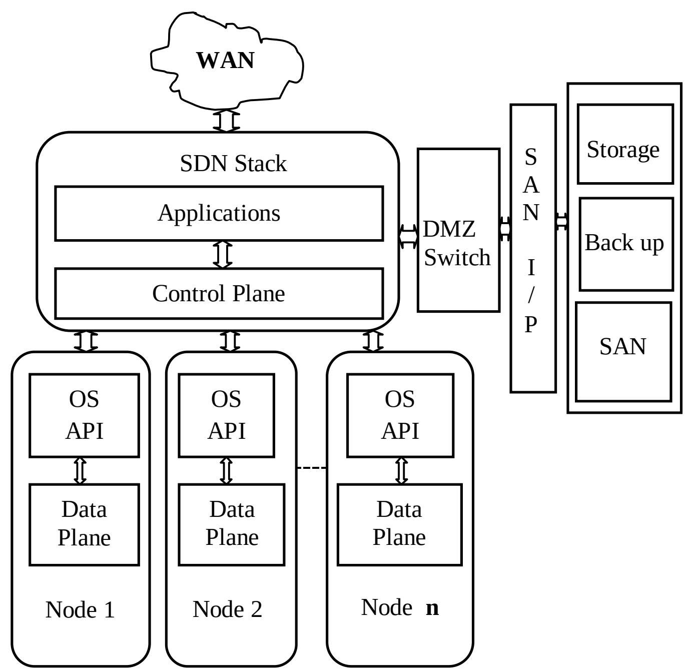


**Figure 9:** Proposed SDN Architecture for Data Centre of HPPCL

With SDN Controllers, IT administrators gain all control over the entire network from a single logical point, which greatly simplifies the network design and operation. SDN also simplifies the network devices themselves, since they interact with the SDN controller only and are not burdened with the complexity and details of network protocols. By centralizing network state in the control layer, SDN gives the flexibility to configure, manage, secure and optimize network resources through automated programmability approaches.

On the basis of various studies we made, it is found that SDN is making the system agile. It reduces the complexity as decoupling the control plane from the data plane.

**The Key Security Challenges:**

The following are some of the key security issues that thereafter the efficient working of the existing data centre at HPPCL:

1. To Protect data centre from threats that cannot be stopped by other security devices
2. To Secure the availability of the most important asset: the data centre services
3. To Protect the data centre infrastructure and connectivity as well as customer services and data
4. To Provide much needed visibility at the data centre edge and inside data centres
5. To Detect emerging threats by looking beyond the borders of the data centre [18,19].

## 5. BENEFITS OF IMPLEMENTING SDN IN DATA CENTRE OF HPPCL

As per the Oracle Data Sheet, SDN boosts application performance and management flexibility by dynamically connecting virtual machines (VMs) and servers to networks, storage devices etc. with gain the performance benefits of up to 80 Gb/sec server to server throughput and realize up to 19 times faster live migration, 12 times faster database queries and 30 times faster backups than legacy networking systems [20]

HPPCL is working in the field of power generation mainly through Hydro Projects in Himachal Pradesh, which is a hilly state and the hydro projects are mostly in far flung hard areas. In such conditions, networking and data centre are very importantly required areas. Networks are becoming more complex day by day. Both users and applications require security, resiliency, privacy, traffic separation, end-to-end virtualization, and priority treatment. Ina legacy network there is a 1:1 relationship between servers and switch ports. With the adoption of server virtualization, network demand has increased dramatically by enabling as many as50 servers behind a single port, each requiring their own network and security policies. The network cannot change or adapt fast enough today without deploying complicated and fragile programmatic network management systems or employing a team of network administrators to make large number of changes per day. SDN is becoming the fruitful approach toward these challenges.

The following are some of the other benefits arising out of using this new network technology i.e. SDN in HPPCL:

1. It can improve network management efficiency because it does not require continuous upgrades.
2. It integrates the department LANs with different policies and reduces installation costs.
3. It provides stable networks and reduces time and costs for the operation management and configuration modifications.

As we can see in the figure below, legacy networks are difficult to automate as the control plane intelligence is distributed. SDN promises an easier, more dynamic interaction with the network through abstraction of the control plane. This reduces the complexity of managing, provisioning, and changing the network.

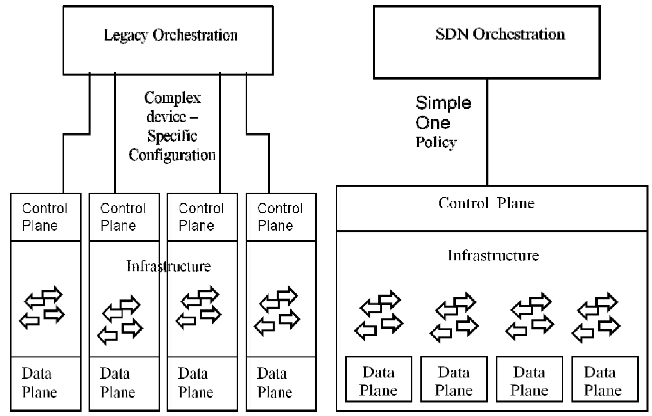


**Figure 10:** Legacy inflexible network architecture vs. SDN [8]

## 6. CONCLUSIONS AND FUTURE WORK

SDN has emerged as a means to improve programmability within the network to support the dynamic nature of future network functions. It provides flexibility, centralised control and open interfaces between nodes, enabling an efficient, adaptive network. A number of challenges linked to this provision have been discussed in this paper. As such, these challenges need to be resolved to get the comprehensive benefits of SDN. It has set a baseline for a new communication method by pushing computation into the network devices, increasing machine-to-machine communication in such a way that we can say that SDN is going to provide an evolutionary step, paving the way for a highly maximised service architecture.

The HPPCL is a public sector organization of the Government of the state of Himachal Pradesh of India that deals with generation of power through hydel projects and its distribution. It generates and manipulates huge chunks of data, most of which is in real time and is indeed critical. Therefore, they have established a data centre for the purpose. The authors examined this data centre and the related documentation and generated a high level architecture for HPPCL's data centre. The authors then proposed a generic SDN architecture after studying various prominent proprietary SDN architectures available in the market today. Based upon this generic SDN architecture and the architecture of HPPCL's existing data centre, a new high level architecture for the existing data centre of the HPPCL has finally been proposed.

As SDN, by its nature, is oriented toward joining different pieces of technology via the orchestration mechanism of a logically centralized controller [21], the author are working on the mapping of this architecture onto the actual implementation of SDN based data centre for the HPPCL.

**REFERENCES**

[1] S. Sezer, S. Hayward, and P. Chouhan , "Are we Ready for SDN? Implementation Challenges for Software-Defined Networks" *IEEE Communications Magazine*, pp. 36-43, July 2013.
[2] http://en.wikipedia.org/wiki/ Software _ Defined _ Networking
[3] http://hppcl.gov.in
[4] http://searchsdn.techtarget.com/news/2240202581/SDN-basics-Five-questions-answered
[5] http://www.bigswitch.com/products/open-sdn
[6] http://www.cisco.com/web/about/ac123/ac147/archived
[7] http://www.hp.com
[8] http://www.intel.com
[9] https://www.opennetworking.org/sdn-resources/sdn-definition
[10] Qi. Zhang, Lu. Cheng and R. Boutaba, "Cloud Computing: State-of-the–Art and Research Challenges" *Journal of International Services and Applications*, pp. 7-18, vol.1, no.1, May 2010
[11] AI-Fares, A. Loukissas and A. Vahdat, "A Scalable, Commodity Data Centre Network Architecture", *ACM SIGCOMM Computer Communication Review*, pp. 63–74, vol. 38, no. 4, October 2008
[12] A. Greenberg and N. Jain, "VL2: A Scalable and Flexible Data Centre Network", *ACM SIGCOMM Computer Communication Review*, pp. 51–62, vol. 39, no. 4, October 2009
[13] C. Guo, G. Lu and D. Li, "BCube: A High Performance, Server-Centric Network Architecture for Modular Data Centres", *ACM SIGCOMM Computer Communication Review*, pp. 63–74, vol. 39, no. 4, October 2008
[14] http://hppcl.gov.in/page/projects.aspx
[15] Kopparapu C., "Load Balancing Servers, Firewalls, and Caches", New York, John Wisely & Sons Inc., 5 Feb. 2002
[16] http://portal.etsi.org/portal/server.pt/community
[17] K. Bakshi, "Considerations for Software Defined Networking (SDN): Approaches and Use Cases", *IEEE Conference Publications,* pp. 1-9, July 2013
[18] http://searchsdn.techtarget.com
[19] www.arbornetworks.com
[20] www.oracle.com
[21] http://www.internetsociety.org/articles/software-defined-networking-current-picture-and-future-expectations