Exploring Novel Applications of Open SDN

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*Abstract:*

*Software-Defined Networking (SDN) represents a paradigm shift in network architecture and management, introducing a transformative approach to routing and control. By employing logically centralized control software, SDN effectively decouples the network data plane from the control plane, offering unprecedented flexibility and scalability. This paper presents a comprehensive overview of SDN technology, delving into its fundamental design principles and surveying the extensive research efforts dedicated to SDN network architectures and applications. Through an in-depth analysis of the current landscape of SDN development, this paper examines the multifaceted driving forces behind SDN deployment and provides insights into its future trends.*

*Keywords: Software-Defined Networking, SDN, Transmission Control Protocol (TCP), Application Programming Interface (API)*

*1. Introduction*

The existing network architecture is encumbered by complexity, which manifests in several limitations, including inconsistent policies, inability to scale, and vendor dependence [1]. Primarily, the current network design revolves around packet accessibility. To fulfill the reliability, scalability, security, and QoS requirements of diverse applications, various network protocols have been independently designed and developed to address specific application issues. Consequently, network devices such as routers and switches supporting these protocols have grown increasingly intricate. This complexity amplifies maintenance overheads, the risk of errors, and impedes further innovation. Consequently, network operators tend to be conservative in introducing network changes for risk management purposes. Adapting the current network architecture to the emerging trends of virtualization and mobility becomes challenging.

Secondly, the advent of mobile devices with wireless networking and cloud computing has significantly altered network traffic patterns. The widespread use of virtual machines and mobile devices leads to frequent dynamic network node migrations and updates in network topology. Such topology changes pose substantial challenges to the existing network [1].

Lastly, internet companies like Google and Facebook are required to deliver network services on a much larger scale compared to ordinary service providers, necessitating dynamic traffic scheduling and load balancing within their network infrastructure. Unfortunately, the existing network infrastructure falls short in meeting these challenges due to its rigidity and complexity.

1. Basic Concepts of SDN

The Open Networking Foundation (ONF) is a user-driven organization committed to promoting and adopting Software-Defined Networking (SDN) through the development of open standards [7]. The ONF white paper [1] in 2012 defined the concept of SDN and introduced its standard protocol, Open Flow. It highlighted three primary goals of SDN: Demonstrate the generality of SDN architecture and its capacity to foster innovation .Enable large-scale experiments with campus production networks .Enable multiple concurrent experiments using slicing and virtualization on the same physical SDN infrastructure.

Network Applications of SDN The architecture of SDN has introduced unparalleled network controllability. This enhanced controllability has led to a significant number of applications based on SDN and the provision of services to upper-layer applications through APIs (also known as north-bound interfaces). The control layer offers device abstraction to conceal device-specific details from applications .In the application layer, network operators and application developers manage the network through programmable interfaces to meet their business requirements. This includes tasks such as managing routing, access control, bandwidth, traffic engineering, quality of service, processor and storage optimization, and energy usage. This eliminates the need for traditional error-prone manual configurations.

3. Research Directions of SDN

SDN has been deployed in various settings, including campus networks [8, 9], enterprise data centers (such as Google), and even some carrier networks. The adoption of SDN has accelerated in recent years. While the idea of separating the control and data planes is not new, there are inherent reasons why such a network architecture has only been widely deployed recently.

Firstly, the mass production of multi-core technology has not only reduced the cost of network equipment but has also enabled the use of general-purpose CPUs for network policy computation and packet forwarding. Secondly, the increasing number of heterogeneous networks (such as IPv6, optical networks, and wireless networks) with different functions necessitates flexible network devices for interoperability. Thirdly, the proliferation of virtualization and cloud computing has generated new demands in network management, including flow monitoring and traffic scheduling.

With the open and standard features provided by SDN, applications can fully utilize the network processing power, monitor network status precisely, and automatically manage network operations to meet the current trends of mobility and virtualization. There are two main research directions in SDN. The design of SDN network structure and its basic components. Web applications based on SDN.

3.1.1 SDN Network Monitoring and Measurement

Conventional network measurement methods usually adopt either flow-based or sketch-based approach .Flow-based approach faces a number of challenges because it needs to sample and count packet in data plane in order to detect burst flows .High sample rate brings unbearable overhead, while low sample rate is less accurate.Sketch-basedapproachismoretheoreticalatthisstage.Usuallyonesketch-based algorithm can only solve a specific problem. It is almost impossible for manufactures to design specials witch hardware to support these individual algorithms. For example, heavy hitter detection algorithm [10] targeted for space saving relies on customized switch chips to perform some of it sanctions.

Open Sketch[11] proposed to complete network measurement tasks in two planes, as shown in Figure 1. To keep the data plane simple and flexible, Open Sketch designsasimplethree-stagepipeline(hashing,filtering,andcounting),thusallowscustomizedandefficientdatacollections.Theconfigurationissimple,fast,anddeployableon existing commercial switches .On the control plane, Open Sketch provides a measurement library for users to implement the measurement logic. The interaction with the data plane is handled by the library.

**Controller**

**Configure**

**Queryandreport**

**Switch**

**Switch**

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**Measurementdataplane**

**Switch**

**CPU(interactionsWiththe controller)**

**Measurementdataplane**

**Switch**

**CPU(interactionsWiththe controller)**

**MeasurementLibrary**

**MeasurementPrograms**

*1TrendAnalysis*

Even though the SDN has attracted wide academic and industry interest and effort, it is still in its early development stage. Our survey shows that the current focus of SDN research and development is on building the necessary pieces and its developer eco-system for a full feature SDN operation system, including hardware or data plane isolation(Ethane[5]),operationAPIdefinition(NOX[13],Onix[14],andMaestro[17]),validationlayer(FortNOX)[12],

Reliability and flexibility. In SDN, we believe an identical trend will emerge. For network operators,powerful tools will be appreciated virtualized data-plane resource pools to applications and resource scheduling to migrate control plane user applicationsindifferentphysicalnetworkdevicestransparently.Weawarethekeydifferenceintheunderlyingdata and resource between SDN applications and cloud applications[13.However, the rapid development of network bandwidth with new communication technologies will make on-demand routing efficient and cost-effective enoughtobepossible,particularwithindatacenters,ISPs,andautonomous systems. With such trend of certainty, SDN virtualization and resource scheduling will arm network operators with new business models. For example, network operators can rent out their edge or core devices to otherISPswithoutexposingtheircoreservicetorisks.Furthermore,on-demandandusage-basednetworkdatadigest and analytic service can also be provided without compromising data privacy, security and integrity. Such model could become valuable in Internet of Things where real-time data sharing between instrumented sensors (data providers)and data consumers could be different entities[14].

With wide usage of data-plane abstraction and virtualization ,a number of virtualization configuration or profiles will surface to satisfy the requirements of distinctandtypicalcategoriescontrolplaneapplications.Forexample,applicationsmanipulatestheroutingofsomeparticular streams for certain destinations could consumemuchlessresourcesthanapplicationsthatdetectsdistributeddenial of service attacks. Typical virtualization profiles may still lead to resource utilization inefficiency as applications tend to use larger resource profiles. This is because it is hard for applications to understand their resource consumption at and meanwhile estimate their work load accurately[15,17]. Application definednetworkwillbecometherealitytoaddresstheseconcerns.Applicationcanmanagethenetworkresourceinrealtimewiththevirtualizationorchestration system .With this, the application can definethevirtualizationnetworksystemontheflyinsteadofdetermining the type of system they need up front. One may argue that this requires an over-complicated billing system that may also confuse the developer. However, advance in bothbusinessmodelandresourceschedulingtechnologycanaddresstheseproblem.

The primary driving force as analyzed above, the key driving force that can make the evolution to application defined networks can be summarized into three points:1) the rapid developmentofhardwaretechnology,2)theemergedbusinessmodelprovidingincentives,and3)newtypesofapplications[18,19,20].

1)Hardwareevolvement:Thesoftwareindustryhasexperiencedanevolutionwiththeboomingopensourcecommunitiesandtechnologies,withsophisticatedlargescaleanddistributedsoftwaresystemsuchasOpenStackandHadoop.WiththenewdevelopmentinfieldprogrammablegatearrayandopenmicrocontrollerssuchasArduino,customizable system-on-a-chip make hardware and software integrated system readily feasible for average developers. We already see the activities in commercially available new devices with enhanced user experiences, such as wearable devices and sensors, enabled by more efficient design and advanced manufacturing.TheseeffortsinopenhardwarewillbringmorepowerfulASICfornetworkingdevices,enablingvirtualizationanddistributedsysteminSDN.

2)Newcloudandnetworkinfrastructureeconomics:Cloudcomputinghasledtheindustryinbothtechnologyandbusinessmodel.Notonlyithasmadelargescaleon-demandinformationserviceaffordable,ithassuccessfullychangedtheserviceindustryfromtheownershipmodeltothesubscriptionmodel.Thecloudservicehasbeencategorizedintovarioustiersofservicesfordifferentcloudresource,suchascomputation,storage,database, etc. The networking service is usually provided to the user in terms of IPs and bandwidth. With the improved SDN technology, network application and its management could offer new business mode lt the cloud service provider[22].

Additionally, in the eco-system of network infrastructure, traditional telecom operator and ISP operator will start to playa more important role, since they will benefit from SDN not only in terms of easy management, but also an open network service platform. This service platform can offer various service such as traffic analysis, DoS prevention, spam tracking, anti-virus, etc. Thus creating new business model and incentive for fast SDN technology deployment.

3)Newapplications:Besidesthecloudandtelcomindustrymentionedabove,thenext“killer”applicationmight appear from Internet of Things (IOT). The Internet ofthings(IOT)isthefastgrowingindustrythatwillfundamentallychangethewayoflife.Inadditiontoinstrumented sensors and the cloud service, IOT requires an advanced network to interconnect the sensors in the physicalworldandtransmitthedatatotheselecteddestinations.SomeIOTapplicationscenariosrequirereal-timedatasharing and access control where accessing data from cloud server may not be best option .Example includes criticalindustrycontrolsystemdemandingreal-timeresponse,on-premise raw data access, sensor topology changes and auto-adaption, data sharing in emergency situations, etc .In these scenarios, the network infrastructure will have to be flexible enough to provide local data analysis, data service, and access control, which provides great opportunity for SDN based applications[23].

2.Conclusions and Outlook

Network re-configuration is complicated and error-prone, especially for large networks and data centres due to the tight coupling of network hardware and its control software.SDN separates the network control and management from the data forwarding. This allows the operators to control and manage routing policies in software without affecting the data operation of physical devices. Compared with the traditional network, the core change of SDN is to isolate the control mechanisms of switches, routers and other devices into a control layer, makes the devices only forward packets according to flow tables issued by the controllers ,there by becoming simpler and more efficient.

Software defined networks has very strong and bold I would say vision which entails us to have out of box thinking about the ways to program network more efficiently without being distracted by the constraints and limitations of existing technologies.

Instead of just devising software defined network’s applications with open flow protocols, we really need to give some thought of how we can mange network efficiently from this technology and what type of controls we can develop to control the network easily and balance the vision with practical strategy for implementation of this technology.

Despite great enthusiasm and efforts from the academic and industry, SDN technology still faces many challenges in the design, deployment and acceptance .In this paper we summarize the current research status ,goals and corresponding solutions of SDN. We also analyze the future research trends of SDN: 1) Network standardization work determines the success of SDN; 2) It is important to develop application development tools; 3) SDN enables newsecuritymodel;4)Theexpansionofheterogeneousnetworkpromotesmulti-networkintegration;5)BuildthefutureInternetbasedonSDNtechnology.

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