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Research Article
Transitional Approaches for PERN Migration to SDN

[1]Abdul Malik, [2]M. Malook Rind, [2]M.Y. Koondhar and [2]Asadullah Shah

[1]British Malaysian Institute, Universiti Kuala Lumpur, 53100 Gombak, Selangor, Malaysia
[2]KICT, International Islamic University Malaysia, 53100 Gombak, Selangor, Malaysia

Abstract
With the emerging concepts of internet of things (IOT), Bring Your Own Device (BYOD), smart homes, vehicular *ad hoc* networks (VANET), mobility and new service demands, legacy networking approaches are being considered complex and inefficient. In recent past a new approach called Software Defined Networking (SDN) has emerged to revolutionize the four decades old networking approaches. The SDN's capability to programmatically control and modify the network behavior has given extra edge to its wide scale proliferation. After some large scale successful deployments by Google, VMware, Facebook etc., SDN has attained huge research and vendor attention. Almost all large scale National Research and Education Networks (NRENs) have prepared OpenFlow based SDN testbeds for collaborative future networking research. Pakistan Education Research Network (PERN) project is still lagging behind in utilizing its network infrastructure for research and experimentation purpose. Although, green field network migration of PERN is a challenging task and requires lot of budget and technical expertise, transitional approaches are the best ways to migrate from legacy networking to SDN. This study highlights the role of SDN and its deployments in educational research networks for next generation network experimentations. This study proposes transitional approaches for the migration of PERN towards OpenFlow based SDN environment. In this study, it will also discuss how SDN based PERN can facilitate IT, telecommunication, software engineering, computer scientists and network engineering researchers in conducting future network experimentation.

Key words: SDN, PERN, IOT, bring your own device, OpenFlow

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Corresponding Author: Abdul Malik, British Malaysian Institute, Universiti Kuala Lumpur, 53100 Gombak, Selangor, Malaysia

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INTRODUCTION

The term internet of things (IOT) has recently been evolved with an aim to anticipate the concept of digital society in which almost everything or an object can be connected and accessed from anywhere at any time through internet. Current core internet routing and switching protocols invented almost four decades ago have been engineered and optimized time to time to cope with increasing bandwidth hungry applications. Promotion of Wi-Fi technology is fueling Bring Your Own Device (BYOD) phenomenon and it is being forecasted that by the end of 2015, more than 200 million employees will bring their own device for official use[1]. New challenges related to continuous growth of "Big data" and dramatic changes of network traffic are exposing the ability of legacy networking protocols and existing IT infrastructures[2]. According to Kreutz *et al*.[3], it seems hard to manage the unpredictable future network traffic growth with traditional IP networking approaches. Furthermore, the vertically integrated nature of legacy networks, i.e., control plane (decides how to handle network traffic) and data plane (forwards network traffic according to the decisions made by the control plane) tightly coupled in one device, limits network evolution and innovation, flexibility, network abstraction, real time network change behavior and network programmability. Software defined networking has emerged to be an evolutionary approach to reshape the traditional network design with an ability to programmatically modify the behavior of network devices[4-7]. The core concept is the separation of control layer "The brain" of the networking devices i.e., routers and switches from forwarding layer "The muscles[8]". It does not only fulfills the current networking and internet requirements, but also provides an opportunity to bring innovations with its beauty of customization and programmability[9]. Its advantages include centralized control, better user experience, reduced complexity and huge decrease in systems and equipment cost[5]. The SDN is being considered a new approach towards future internet[6]. With SDN, corporate, campus networks, large scale telecom and data service providers get unprecedented automation, programmability and network control to enable them build highly flexible, robust and scalable networks[10]. Currently SDN momentum has gained huge industry attention by forming Open Networking Foundation (ONF)[11] which has more than 150 members companies including Google, Microsoft, Yahoo, Facebook, Verizon, Deutsche Telekom and others. Both technology and equipment are commercially available and adopted by some huge operators including Google, Facebook, Amazon, NTT/NEC Japan, Verizon, Goldman Sachs[11]. Similarly some very large equipment manufactures and networking market giants including Cisco, Juniper, NEC, HP, Brocade, Alcatel-Lucent, IBM, Dell, VMware have launched their new SDN and OpenFlow[12] enabled switches and routers[13].

Today's campus networks are also experiencing huge increase in network provisioning change requests due to mobility and inter-university research collaboration concepts. Students, faculty, staff, researcher and visitors not only bring their own device within campus but also bring their personal applications such as iCloud, Face Time, Dropbox and others, which appeal for ubiquitous data access with changing requirements[14]. Proliferation of network complexity in terms of optimal service utilization, service requests by users, inter-and intra-university research collaborations, policy and security change requests, need special consideration for real time network change behavior. Future internet research verification and deployment appeal the need to construct testbeds over existing national and international research and engineering networks[15]. There is a need for open collaborative research environment to explore new ways to optimize today's networking techniques, which can only be achieved through the deployment of SDN.

To compliance with these ever-changing demands and challenges, it is inevitable to reshape national research and education networks (NRENs) for collaborative research[16]. Pakistan Education and Research Network (PERN) is the only research and education network of Pakistan, aimed to provide communication infrastructure to all universities and institutions, to fulfill their networking and internet requirements. Although PERN is providing inter-university connectivity to all universities in Pakistan, its traditional networking infrastructure is not being used as a testbed for future networking research. Existing PERN is based on the legacy networking protocols, standards and approaches (http://www.pern.edu.pk/). This coarse-grained technique does not seems fit for emerging network experimentations such as IP mobility, wireless handover etc.[17]. In line with this thinking of HU *et al*.[2], virtually it is impossible to meet current data transmission requirements by using traditional network architectures. Motivated by mentioned future and next generation challenges, we argue that PERN need to be upgraded to SDN to contribute and actively participate in future networking research. Keeping in mind the budget and technical constraints, it is not viable to go for green field deployment in the first go[18]. In this study, we define feasible transitional approaches for easy migration of existing network infrastructure of PERN towards SDN environment. We also discuss how OpenFlow based SDN approach can facilitate IT, Telecommunication, software engineering, computer scientists and network engineering researchers in conducting future network experimentation.

OPENFLOW AND SDN ARCHITECTURE

OpenFlow is an open standard protocol that has received large scale acceptance both by research community and network and telecom industry[5,19]. OpenFlow (Mckeown *et al.*[12] protocol is specifically designed for SDN by ONF for high performance, robust communication between controller and multiple vendor's OpenFlow enabled network devices[7]. Today almost all network device manufactures and vendors are producing routers and switches with OpenFlow capability, making OpenFlow a next generation protocol for communication networks[7]. OpenFlow was initially deployed in campus networks, with an aim to conduct experimental networking research within a research-friendly operational setting on "Clean-slate" network architectures[20]. At GENI (Global Environment for Network Innovations) (http://www.geni.net/) project, OpenFlow is being used as a key protocol for carrying out the major experimentation for future networking approaches including internet2[17].

Figure 1 illustrates the complete architecture of software defined networking. At the bottom, are the vendor independent OpenFlow enabled data plane devices called forwarding devices. These forwarding devices have one or more packet handling rules (flow tables) to make necessary actions (e.g., forward a packet to the controller, forward a packet to specific ports, rewrite packet headers or drop a packet). These flow rules advised by SDN/OpenFlow controller instruct the forwarding device to behave like a switch, router, firewall, traffic shaper, load balancer etc. In middle, is the "Network brain" the SDN/OpenFlow controller, which has a global view of whole network, holds the control logic to plays its role similar to an operating system. It communicates with forwarding devices (data plane) and applications (management plane) via southbound and northbound interfaces. The uppermost plane is called the management plane that includes the programmable applications which define polices for switching, routing, monitoring, load balancing, firewalls and so forth. These policies are then communicated to forwarding devices through controller for the required change in the forwarding device's behavior.

Some of the driving forces behind rapid proliferation of SDN and OpenFlow are, changing traffic patterns including East-West traffic, North-South traffic, QoS demands, traffic prioritization, varying traffic patterns and rising need of mobility[14]. OpenFlow based SDN has sought huge attention towards implementation and experimentation in campus networks[1,14,21,22] and other networking research testbeds[2,15,23]. At present GENI (http://www.geni.net/) project is playing a leading role in exploring the potentials of SDN for variety of its application areas[23].

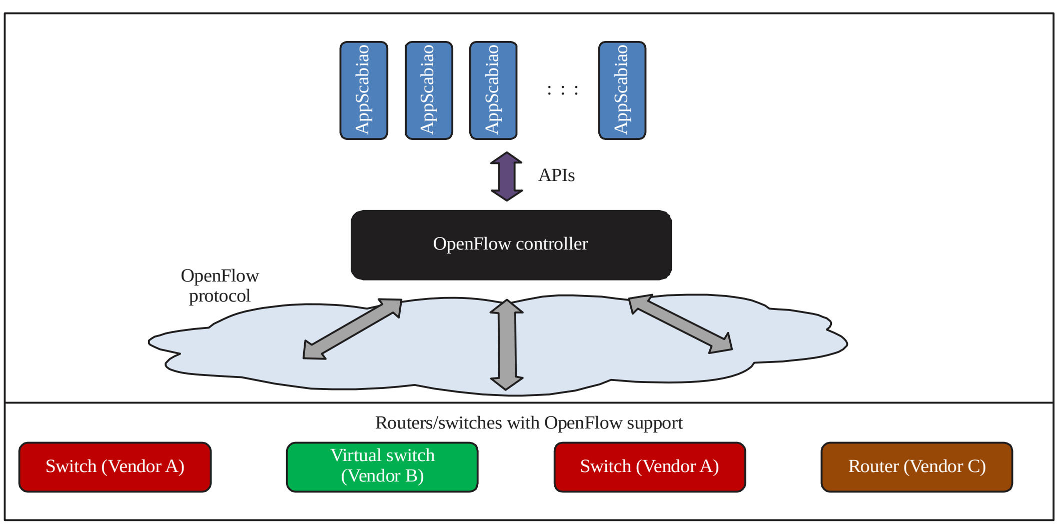

Fig. 1: SDN architecture

PROPOSED TRANSITIONAL APPROACHES FOR PERN

Almost all NRENs and community partner of PERN including Asia Pacific Advanced Network (ASAN) (http://www.apan.net/), Trans-Eurasia Information Network (TEIN3)(http://www.tein3.net/server/show/nav.2196), National Science Foundation (NSF)[24], internet2 (http://www. internet2. edu/)[25], GEANT2 (http://geant2.archive.geant.net/) are working to prepare OpenFlow enabled SDN based testbeds for future networking research. Many large scale projects including Japan's NWGN (New-Generation Network) (http://forum.nwgn.jp/english/ index. html), United State's GENI (Global Environment for Network Innovations) (http://www.geni.net/), European Union's Future Internet Research and Experimentation (FIRE)[26], OpenFlow in Europe: Linking Infrastructure and Applications (OFELIA)[27] and Brazilian Future Internet testbeds experimentation between BRazil and Europe (FIBRE)[26] have already deployed OpenFlow based SDN for research. The OF@TEIN (Trans-Eurasia Information Network), a project funded by Korean government is also gradually heading towards building an OpenFlow based tesbed[15]. Telecom Italia has taken research initiative for SDN testbed creation by connecting and modifying the existing campus networking of five main universities of Italy under Joint Open Lab Network (JOLnet) project.

At present Higher Education Commission (HEC) of Pakistan is providing IT facilities including; Internet, Intranet (VPLAN), digital library, Video/VOIP, Local content hosting, e-mail, video conferencing, file sharing, interactive lecturing, etc. through PERN project (http://www.pern.edu.pk/). PERN is aimed not only to interlink all the public/private degree awarding institutes/universities but also to facilitate the educational and research related services and information to the users[28,29] (Fig. 2).

The PERN has optical fiber based hierarchical topology and running legacy IP routing protocols within it and with peer networks; TEIN3 and the US National Science Foundation (NSF)[29]. Inconsistent policies, inability to scale, operational complexity, vendor dependency, labor intensiveness etc. are being considered as the constraints of traditional networking approaches to cope with the upcoming diversified dynamic data demands. With the successful migration of some large scale networks of Google, Stanford campus network, VMware, Facebook etc. SDN migration has proved itself to be the next generation networking technology to replace the legacy solutions[11]. Similarly the idea behind GENI (http://www.geni.net/), to migrate the campus and educational networks and virtualize programmable network infrastructure for experimental research and innovation has changed the way traditional NRENs have been working. It has become vital to prepare and plan network architecture that enable researchers to examine current and future SDN applications, to test SDN based protocols implementation, services and to explore future research directions[13]. Rip-and-replace migration strategy is not considered a viable decision for the replacement of any network infrastructure[3]. Network up gradation and migration requires some operational, technical and financial challenges and demand answer of few questions like: What will be the benefits of partial transition? Which portion or devices like switches, router, firewall etc. be replaced in first place to maximize the benefits. Enterprises and research networks mostly begin transition from existing to new infrastructure in a staged process[30]. Sometimes a portion of whole network is upgraded at one time to see the consequence of change[30]. Planning the full migration or staged up gradation depends on the need and budget in hand. Although, keeping the budget constraint in mind it is difficult to go for green field network up gradation of PERN from legacy architecture to SDN based new paradigm, there are certain transitional approaches analogous to IPv4 to IPv6 migration. We propose and explain three transitional approaches for easy and staged migration of current PERN to SDN.

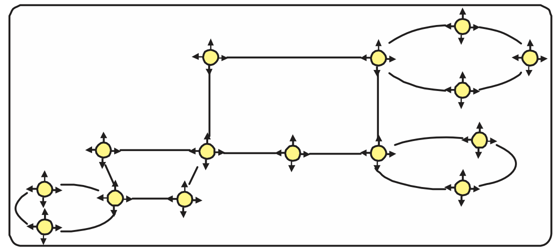

Fig. 2: PERN logical network

Dual-stack: In this approach all the network element of PERN need to function in hybrid manner i.e., support of SDN functionality as well as legacy IP routing and switching protocols. This requires total replacement of some old network elements, firmware up gradation of some network elements and addition of OpenFlow software packages in some newly manufactured hybrid (Legacy+SDN) network elements. This approach results in two side-by-side virtual network creation and requires prior decision for the traffic flow, i.e., whether traffic will flow in legacy flow space or in SDN[12]. The only drawback of this approach is that every new added element need to by hybrid and legacy hardware cannot be integrated with the hybrid elements. In Fig. 3a dual-stack migration scenario for PERN is depicted.

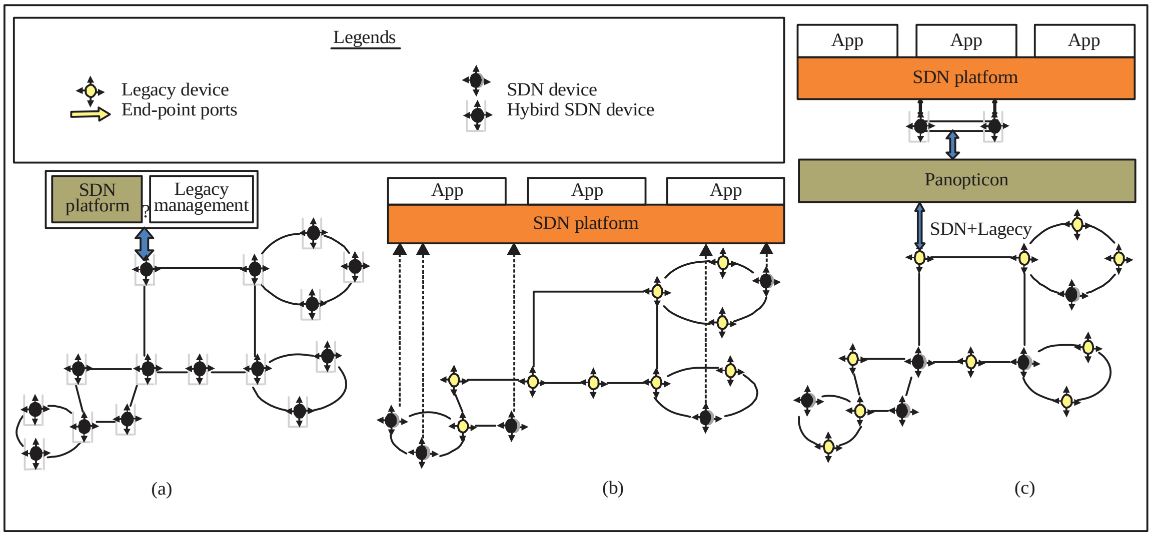

Fig. 3(a-c): Proposed transitional approaches (a) Dual-stack, (b) Access edge and (c) Mixed deployment

Access edge: This approach poses that SDN network element (i.e., OpenFlow enabled devices) can be added at the edge/access of existing infrastructure of PERN. The SDN holds the full control over the policies of edge networks including the addition and introduction of any new network functionality. This type of transition requires fewer budgets for PERN to deploy SDN network elements at its access i.e., gateway routers in every university/institute. Figure 3b illustrates the scenario for PERN using this approach.

Mixed approach: This option facilitates the integration of existing legacy network elements of PERN with new addition of fully OpenFlow based SDN network element in a mixed fashion, thus it exposes the network abstraction as a logical SDN environment. Using this approach relatively a small subset of SDN network element may suffice to control the PERN network traffic programmatically. As per Panopticon[30] approach, this partially deployed SDN approach for PERN can act like a full scale SDN deployment. In Fig. 3c proposed Panopticon based approach is proposed as an easy transition strategy for PERN migration towards SDN.

Since total migration to SDN based infrastructure can be expensive, almost all large telecom and networking equipment manufactures suggest transitional migration strategy. However, Routeflow[31], Cardigan[32], OSHI[33] and Virtual Routing Engine (VRE) system[34] using Mininet[35], MiniNExT[36], OpenFlow v1.3 and above[7] are few of the approaches and emulation tools for to help in migration of legacy infrastructures to SDN.

IMPLICATIONS, CONCLUSION AND FUTURE WORK

In this study we proposed some transitional approaches for the OpenFlow-enabled SDN migration of PERN. Main benefits of SDN and OpenFlow deployments in campus networking are cost saving, including both Opex and Capex, high performance, improved uptime, better management, resource flexibility and enhanced security. The proposed migration of PERN on SDN would be very helpful for the pre-production network experimentation. Just like US Network Science Foundation's Global Environment for Network Innovations (GENI) project, our proposed SDN based network will provide a platform to the researchers, students and educators to build their own virtual networks (slices) for experimentation that can span throughout whole PERN. Universities connected through PERN can start internship programs and other networking research initiatives for building a collaborative environment which can promote and produce new solutions to support rapid pace of innovation in next generation computing technologies. Thus, the proposed migration of PERN to SDN environment would be helpful in achieving goals such as, the concurrent experimentation over same physical underlying infrastructure; testing validation of various SDN/OpenFlow experimental hypotheses; evaluation of performance of SDN architecture in real deployment settings and improving software stacks and tools for future SDN deployments.

This study is in progress and we aim to simulate all three proposed prototype deployments of OpenFlow based SDN in

PERN project for easy and error free migration. Our long-time goal is to simulate how the SDN based slicing mechanism can help Pakistani researchers to best utilize PERN's physical Infrastructure for future network experimentation.

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