A Proposal Management of The Legacy Network Environment using OpenFlow Control Plane

Fernando N. N. Farias¹, João J. Salvatti¹, Eduardo C. Cerqueira¹, Antônio J. G. Abelém¹

Research Group on Computer Network and Multimedia Communication, Technological Institute, Federal University of Pará (UFPA), Belém, Pará, Brazil¹

{fernnf, cerqueira, salvatti, abelem}@ufpa.br

Abstract—The Future Internet will arise from the convergence of new network concepts and combine technologies, services, media and content. It will offer flexibility and diversity with scalable content and services that are accessible through a wide range of interfaces and devices. However, the biggest challenge now is how to enable and test the proposed approaches so that they can be validated without sacrificing the current production infrastructure. The OpenFlow protocol allows production networking environments such as campus networks, metropolitan networks or R&D networks, to be used as experimental infrastructure hosting, future Internet architectures, software and protocols, in parallel with the production traffic. During rollout, there is a practical problem that arises with Legacy networks that do not support OpenFlow and need to be replaced/upgraded or refined by means of costly network re-engineering. This paper proposes a new OpenFlow architecture with new components, capable of managing Legacy-non-OpenFlow elements by offering a new solution that facilitates the management of Legacy technologies and allows them to be employed in FI experimentation environment and increase the number of experiment with the Legacy Network Environment using OpenFlow control.

Index Terms— The Future Internet Infrastructure, OpenFlow, Software Defined Networks, Management Network

1. INTRODUCTION

The Internet has become a huge success worldwide and is changing the way we interact, work, and entertain. Much of its success is due to the great flexibility of IP (Internet Protocol) technology. However, despite all the success of the Internet, IP core technology is the cause of its own limitations, on these are becoming increasingly more evident. The main objective of these activities, which can be described as the Future Internet (FI) is to formulate and evaluate alternative architectures to replace or complement IP [1].

However, the huge challenge is where will be enabled and tested the proposed approaches in order to efficiently validate them without sacrificing the current infrastructure. Since there will necessity of routers and switches programmable, and as well as resources allocated and monitored on real-scale-experimentations facilities called Testbeds.

OpenFlow [2] is a Software-Defined Network (SDN) enabling technology [3]; characterized by networking hardware, this is controlled via software, which effectively separates the control plane from the data plane (Datapath). This capability enables researchers or administrators to re-program the forwarding behavior of network elements (e.g., routers or switches) in the OpenFlow Datapath, without interfering with the configuration of the production network.

While OpenFlow has attracted a lot of attention from all players in the networking community, with the first commercially supported products already being available, the successful deployment of such a cutting-edge networking is far from seamless [4]. Moreover, it is increasingly being used in experimental infrastructure to support experiments in the FI.

Another issue about OpenFlow, that is essential to the experimentation environment, is the use of virtualized networking. In a similar way to virtualized computing, this seeks to improve resource allocation, allow operators to create checkpoints for their network before making changes, and ensures that competing customers can share the same equipment in a controlled and isolated fashion. It also allows a set of switches to be shared among multiple logical networks, each with the same distinct forwarding logic and using the same hardware-forwarding plane [5].

Nevertheless, today both the FI experimentation facilities and OpenFlow networks currently face a big challenge: how can they integrate these environments with legacy network environments? Initially, it is necessary to conceptualize “Legacy Network” as networks with equipment used by non-
OpenFlow (e.g. the current Internet network) or technologies that are not supported by OpenFlow (e.g. Layer 1 and Layer 0 circuit technologies)

Some of the challenges for OpenFlow networks relate to the compatibility requirements with legacy network protocols. Another issue is OpenFlow is unable to handle or manage legacy equipment by using the same OpenFlow protocol, and as a result, it is extremely difficult to connect two OpenFlow environments with legacy networks. Another issue that arises during rollout, is a practical problem involving legacy switches that do not support the OpenFlow protocol and need to be replaced/upgraded or worked on by means of costly network re-engineering.

Furthermore, with regard to FI experimentation facilities OpenFlow should be extended to support important technologies of legacy networks, such as layer 1 and layer 0 circuits, which in this case can be represented by technologies such as MPLS, GMPLS, SONET/SDH or WDM. These technologies are necessary for the integration of FI experimental facilities worldwide.

The aim of this paper is to introduce a new solution, called LegacyFlow, for bringing OpenFlow-based FI experimentation network with the legacy network environments. The proposed approach previously set up out an architecture that accommodates legacy equipment and its technologies into an OpenFlow network. The solution still provides a new OpenFlow datapath (i.e. virtual datapath), representing legacy devices and translating a set of OpenFlow actions into vendor-specific configurations for Ethernet switches, which are able to interact with non-OpenFlow legacy equipment, and thus create a new approach to hybrid OpenFlow networks.

Following this introduction, the paper is divided into 8 further sections. Section 2 provides a general outline of related works with OpenFlow and Legacy networks. In Section 3, there is a discussion of some challenges related to OpenFlow and Legacy network. Section 4, addresses the question of designing a proposed solution for LegacyFlow. Section 5, offers a view of the architecture of LegacyFlow as well as a detailed description of its components. Section 6 summarizes the operation of LegacyFlow solution. Section 7 has future work related a new ideas to solution. Finally, Section 8 presents the conclusions of paper.

II. RELATED WORKS

The integration between Legacy and the OpenFlow network is a new research topic that is concerned with activities in Future Internet facilities, Software Defined Network (SDN) and Slice Federation Architecture (SFA), and is faced with huge challenges.

In [6], there is a solution of software defined network packet over optical network, which is enabled by the inter-networking of OpenFlow and Legacy GMPLS control plane in an overlay model. In this model, the optical circuit switch is controlled by GMPLS control plane and these two control planes communicate via a UNI interface. Apart from this, the paper describes the control plane architecture, workflow and proof of concept experimental demonstrations of the proposed solution.

In this paper, there is a serious attempt to integrate OpenFlow and Legacy GMPLS technology. However, this solution is not flexible enough to receive other legacy circuit technologies; it is aimed at punctual problem resolution, in this case just GMPLS. In LegacyFlow architecture, there is enough flexibility to meet the requirements of legacy technologies.

In [7], there is a legacy MPLS solution using OpenFlow 1.1 specification [8]. To this proposed approach, a Testbed was built to experiment MPLS-TE and MPLS-VPN solution. The experimentation has used mix de software and physical switches. The software switches are instances of OpenvSwitch [9] which are hosted within the Mininet Environment. The physical switches are new hardware designed to handle MPLS packets and to use OpenFlow framework.

This proposed uses legacy technology based on MPLS, but to put into practice is necessary change all MPLS equipment by new hardware with OpenFlow-based. In this solution is not possible to reuse legacy MPLS device towards an unneeded and costly replacement of OpenFlow compatible equipment.

Finally, [10] is currently enabling remote Legacy IP routing services in a centralized way, as a result of effectively decoupling the forwarding and control planes. In this way, Legacy IP networks become more flexible and allow for the addition and customization of protocols and algorithms, paving the way for the “router-as-a-service” (RaaS) models of networking in the virtual era. RouteFlow is the evolution of our early work on Quagflow - partnering Quagga with OpenFlow and works transparent to the specific routing engine (e.g., XORP, BIRD) as long as it is based on the Linux networking stack.

The proposal of LegacyFlow is to work with Legacy hardware by using the OpenFlow control plane and not direct with the protocol, but the integration of LegacyFlow and RouteFlow would not only increase the proposal when it is not limited to RaaS, but also RaaS and NaaS (Network as a Service) together.

III. CHALLENGES BETWEEN OPENFLOW AND LEGACY NETWORKS

Currently, the OpenFlow framework is the main technology of the FI experimentation networks such as: ofelia [11], GENI [12] and FIBRE [13]. These experimentation facilities use the OpenFlow to set the state of switches and routers so that they can process packets for multiple isolated experimental can be processed simultaneously. On the other hand, since the OpenFlow model still introduces virtualized programmable networks, it could remove this barrier against the entry of new ideas, by increasing the degree of innovation in the network infrastructure.

Attempts to allow existing legacy networks to migrate and
converge with new networking technologies, such as OpenFlow, are coming from many directions. Despite many efforts, but not all the infrastructures are ready to migrate, the reasons being either a lack of knowledge about technology, the support needed for some legacy protocol or the costs of migration.

For these reasons, the legacy networks will always remain a barrier to attempts at integration or connection between the FI experimentation facilities based on OpenFlow and pure OpenFlow networks. Thus, it is worth stressing some of the underlying problems between legacy networks and OpenFlow, such as the integration of the OpenFlow network with the legacy networks, the use of non-compatible technologies and the administration or management of non-OpenFlow equipment.

A. Integrating OpenFlow Networks with Legacy Networks

The legacy network is the main means of integrating the worldwide networks, and with OpenFlow, the networks are not different. At present, if you want to integrate OpenFlow domains, the use of legacy networks is mandatory, unless a private infrastructure is being used with all the OpenFlow-based equipment. This is a problem because the OpenFlow protocols are not compatibles with legacy protocol and they are not possible to integrate them.

Figure 1 illustrates an example of incompatibility by showing the topology discovery protocol used by OpenFlow. The aim of this protocol is to find out the neighbors OpenFlow switches by means of LLDP (Link Layer Discovery Protocol) packets generated by the controller.

B. Use of Legacy Technologies

Another problem with the legacy network is that, currently, it is composed of many technologies that are mainly based on optical circuit networks. One example of the legacy network is the Internet backbone, which comprises a wide range of transport technologies, and offers significant advantages in the core of the Internet. In particular, they are much more scalable; they can switch to much higher data rates; and they consume much less power.

Current OpenFlow specifications do not offer consistent support of circuit technologies such as MPLS, GMPLS, SONET/SDH or WDM. Since these technologies are essential elements for working on legacy networks and on the future Internet, they should not be eliminated. On the contrary, the future Internet network should absorb them into its architecture.

The problem is that the majority of these technologies do not offer essential features for future Internet such as virtualized networking based on slicing and programmability. For example, the GMPLS is considered to be a conservative protocol suite, which leaves little room for innovation because of the complexity of integrating new features with the control plane and its protocol. On the other hand, The OpenFlow can be easily virtualized, and thus network control layer can be sliced to allow continued evolution as experience is gained in the field [15].

C. Management Legacy Equipment

Following in the problems of combining the OpenFlow and Legacy network, we must turn to examining the legacy equipment such as switches, routers and optical devices. Issues about whether or not to use OpenFlow are key concerns among administrators around the world are the OpenFlow ready for use?

The answer is no, since currently, the process of adapting OpenFlow involves replacing legacy switches with OpenFlow switches. This can be a weakness, because the manager of some infrastructures are not prepared to make the financial investment necessary, such as covering the administrative costs involved in replacing them.

Despite being a costly proposition, not every switch can be replaced, because they are paramount in the network production and there is no equivalent OpenFlow-enabled equipment like a legacy core packet switch with the highest
throughput performance, expensive ROADM optical switch or good legacy switches without making it possible to install OpenFlow.

Hence, it is necessary to find means of using the OpenFlow without losing compatibility with the legacy equipment. This will allow an experimental network based on OpenFlow to offer this equipment in its experiments, and thus make their resources more available and allowing them to be virtualized. This is important for the evaluation of the Future Internet solutions.

IV. THE LEGACYFLOW DESIGN

The model proposed focuses on three main issues discussed earlier: 1) The integration of OpenFlow with Legacy networks, 2) The use of Legacy technologies and 3) The management of Legacy equipment. It also helps to evaluate the need to integrate both Legacy and OpenFlow network, by highlighting the initial advantages of the proposal, such as the reuse of equipment, reduction the cost to OpenFlow deployment, and contributing totally for OpenFlow control plane.

First of all, the behavior of a simple OpenFlow network was observed for analyzing a “melting point” between the two networks without weakening key concepts such as programmability and virtualized networks. Another problem was how to manage the legacy equipment that was using the OpenFlow control plane. When the datapath of the operation was examined, it was noticed that the actions received from controller are applied directly on a forward information base (FIB) used for switch. It was thus decided to extend this procedure for remote operations. In other words, a decision was made to translate the actions in remote operations using configurations interfaces such as CLI, WebService or SNMP.

Hence, a key feature of the model proposed is that it introduces a new component that establishes a link between OpenFlow and the Legacy network and is called Legacy datapath (LD) or Virtual datapath (VD). Located in an outer virtual environment, the VD is a new deployment based on standard datapath as Type 1 or 0 and interacts with both Controller and Legacy equipment through special new OpenFlow actions.

As in the case of the OpenFlow network, when a packet is recognized by datapath, it is checked to see if a matching flow entry can be found, for example, if a flow is forwarded to a certain egress point or drops the packet. But if no match is found, the packet is sent to the controller, and then, an action is applied on the switch to treat upcoming packets associated with the flow. The same rule is applied to other switches, which are required to forward flow to its destination.

Moreover, the Legacy datapath cannot send information about packet flows arriving in the box. Thus, these switches will be generally used in the network core that connects the OpenFlow switches for the ingress or egress flow. This only allows the edge switches to be OpenFlow-enabled as illustrated in Figure 2.

When a new flow enters the network, the first packet is sent to the controller that will install the required flow rules on the datapath, so that a tunnel or circuit based on VLAN ID is created between the Legacy equipment. Although this is not limited to VLAN, this circuit can be created by technologies such as MPLS/GMPLS LSP (Label Switching Path) or pure WDM (Wavelength Division Multiplexing) Lightpaths.

As will be shown in the next section, additional architectural components have been created to assist the Legacy datapath in achieving this hybrid SDN mode that integrates the legacy equipment within an OpenFlow network.

V. ARCHITECTURE

In this section, another key element of the LegacyFlow is examined. Moreover, this includes an overview of proposed architecture as well as its layers and components.

Figure 3 depicts the LegacyFlow architecture, which is divided in two layers: 1) Datapath and 2) The Switch Controller. In the datapath layer, there is a new datapath (the Legacy datapath), this layers has direct communication with OpenFlow control plane and switch controller, and provides a bridge between the different features of the legacy equipment.

The switch controller layer is where the configuration modules for each legacy equipment (e.g. switch, router or optical switch) are located and the interface communication will depend on each manufacturer, the most common are WebService, Telnet/CLI and SNMP. Communication between the datapath and switch controller layer is based on IPC (Inter-Process Communication) and maintains the development of the datapath in a way that is independent of the switch controller module, facilitating the integration of new controller modules and just using standard calls.
Another issue is the link between the legacy datapath and switch controller, which is point-to-point; in other words, each legacy datapath is responsible for one kind of switch controller. Currently, the LegacyFlow supports the legacy equipment of the following manufacturers: Extreme Networks and Cisco Systems Network. It has already been under deployment controller for Juniper routers and studies to manage ROADM optical equipment. In addition, OpenVswitch is used in virtual environment.

Following this, there is a detailed description of LegacyFlow components where the Legacy Datapath (VD), Virtual Interface (VIF), and Switch Controller (SLC) are highlighted.

A. Legacy Datapath

The Legacy datapath or Virtual datapath acts as a proxy that receives OpenFlow commands sent by the controller, interprets them, and applies the corresponding actions in a real switch. Currently, the interfaces used to access some devices are SNMP, WebService and CLI. Each legacy switch (part of the hybrid OpenFlow network) is assigned to a virtual datapath that runs in a guest machine (real or virtual) with GNU/Linux OS.

The goal of this virtual datapath is to represent an outside view of an OpenFlow datapath and convey some information about the features of the Legacy switches, such as the following: port numbers, throughput, sent-and-received packets rate, among other issues specified in OpenFlow. As well as providing basic information, the datapath supports a new set of circuit-specific actions. Figure 4 presents an overview of the virtual datapath.

![Figure 3. The LegacyFlow Architecture](image)

![Figure 4. Overview of Datapath developed](image)

The activities that are carried out deal mainly with the characteristics of the circuits:

- Creation of no timeout circuits, in which a VLAN is created within the switch, as well as two interfaces (ingress and egress) and no timeout to remove the switch configuration,
- Creation of timeout VLAN, which has the same functionality as the previous one, but where there is a small difference when the switch configuration is active for a short period of time;
- Creation of a circuit with Quality of Service (QoS), in case the system has to guarantee the performance of flows on switches to apply QoS in the VLAN circuit;
- Sent and received bytes rate, which will inform some statistics of sent and received data to a specific interface;
- Removal of a circuit, when performed, this deletes the switch configuration immediately.

B. Virtual Interface

For start an OpenFlow datapath, it is necessary to pass through the parameters of the network interface. Likewise, the virtual datapath must be started with information of the switch interfaces. The virtual interface element a Linux virtual interface module that it represents the port switch inside of the virtual datapath.

In this way, it was developed that creates virtual network interfaces according to the number of ports of switches and their features, mirroring the actual switch port features such as: throughput, Maximum Transmission Unit (MTU) size, sent and received packets rate, among other values. Depending on
how the switch offers this information, it can be transferred from the switch to virtual interfaces via SNMP or WebService. The Figure 5 represents how is done the connection between legacy datapath and switch.

![Figure 5. Connection between Legacy datapath and Legacy Switch](image)

This module is required to allow the control plane to have a view of legacy equipment features that are similar to what occurs with the OpenFlow equipment; it can manage the states and collect statistical data directly of switch.

Currently, the VIF can represent Layer 2 interface with MAC address, Speed, Link Status, Name and Modes. Besides, It still represents layer 1 port information (WDM) such as Name, Wavelength and Bandwidth.

C. Switch Controller

The switch controller is a technical container used to configure of the legacy equipment. Each form of technology is developed to create a specific configuration sent by the Legacy datapath.

Communication between the Legacy datapath and switch controller is based on IPC, where the Legacy datapath is a client and switch controller is a server. It is developed in this way to facilitate integration of new controllers, which are entirely independent of the programming language or the use of any kind of configuration interface such as SNMP, NetConf, WebService or Telnet/CLI.

Between the switch controller and legacy equipment, there is an out-of-band control channel, which sends configuration commands to the legacy equipment; the port management equipment is generally used to establish this communication. In addition, there is a possibility that this communication will be in-band, but it cannot be assessed in term of its performance and effectiveness within the system.

Finally, each switch controller is limited to handling just one piece of legacy equipment. The information about the equipment, that will be managed, is obtained from the configuration file during the initialization process of the Legacy datapath, which forms a pipeline between the process of communication between the client and server.

VI. LEGACYFLOW in OPERATION

To illustrate the LegacyFlow in operation, it is presented its workings using circuit layer 2 VLAN, in other words, the tunnel or path among legacy switches is based on VLAN ID to show the direction that the packets must follow. But, how was told previously the circuit technology is not limited a layer 2 VLAN. The Figure 6 presents the activity diagram.

![Figure 6. Activity Diagram to circuit creation or removal actions](image)

Initially, the virtual datapath is started and receives as mandatory parameters the legacy datapath switch model, so that it can decide on the correct communication protocol. During the datapath initiation, the virtual interface module is initiated and created virtual interfaces on the operational system according to the ones available in the switch. Using an outer and dedicated out-of-band channel between the switch and the virtual datapath, SNMP connections are created to collect information of the switch interfaces and apply them to the virtual interfaces. Currently, this state is updated every 3 seconds, keeping information more accurate.

After that the switch is registered on Legacy Datapath one specific-manufacture switch controller is initialized for manager the real switch using an inter-process pipeline.
Following the setup phase, the interfaces are connected to the virtual datapath, which can start receiving flow actions from the controller. When commands are received in the datapath, OpenFlow interprets the message and checks whether these actions are compatible with the datapath. The datapath buffer message is responsible for receiving all openflow protocol message and handle to correct action that on diagram is illustrated for delete or new circuit. When the action is called a specific inter-process call is executed such as: set remove circuit or set new circuit. In this case, these actions are counterpart to configuration of remove or create VLAN the on real switch, using parameters such as: ingress and egress port and VLAN ID.

Then, when a flow gets into a qualified OpenFlow switch and the controller identifies source and destination of flow. So, through of path computation module integrates with RouteFlow is calculated one path among Legacy switches. When the circuit is established the flow is forwarding up to destination. In Figure 7, the sequence diagram illustrates how the actions are executed.

The LegacyFlow offers new actions to the Openflow protocol that can be used by any kind of controllers, NOX or BEACON. It opens a way to new application or behavior of Legacy networks and improving its operation. An example is the RouteFlow as NOX controller application, which in the architecture is used to discover and manager topology, combined a path computation module makes path request to RouteFlow, as illustrated on Figure 8.

VII. FUTURE WORKS

With regard to future work, it is recommended that measures could be taken to broaden tests with parts of the architecture, integrate them more closely with other features of OpenFlow framework and extend it to other technologies. In addition, it would be useful to conduct an evaluation of a
FIBRE Testbed.

Also, an experimental validation and performance evaluation is required to measure their feasibility and effectiveness degree.

Besides, the LegacyFlow will be adapted to work with DCN (Dynamic Circuit Network) similar IDC/OSCARS [16], DRAGON [17] or AUTOBHAN [18]. Offering management on-demand over dynamic circuits between openflow domain or experimentation facilities.

VIII. CONCLUSION

LegacyFlow aims at improving the gradual deployment of OpenFlow in production environments, by reusing the legacy equipment without changing the entire infrastructure. This proposal uses circuits between institutions, by enabling experiments to occur in federated environments, which involves using dynamic circuits between them. This is very much in the spirit of the GENI network stitching architecture based on VLANs. This work is in accordance with several activities carried out by the Slice Federation Architecture, including investigations into the interactions with FlowVisor that similarly seek to enable isolated virtual networks.

Finally, the LegacyFlow will be utilized as tool for creation circuit utilizing multi layer technologies compared to GMPLS. But LegacyFlow multilayer unified issues have to be investigates for the control plane, such as protection and restoration, standardization and etc. It is expected that the work presented in this paper contributes to accelerating this procedure.

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