Title Placeholder

Subtitle Placeholer

Networks and Distributed System

Group unknown - 10^{th} semester

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STUDENT REPORT

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Title:
Title Placeholder
- *Subtitle Placeholer*

Theme:
Master's thesis

Project Period:
10th semester
Networks and Distributed System
February – June, 2014

Project Group:
unknown

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Copies: 3

Page Numbers: 9

Date of Completion: March 11, 2014

Abstract:

Nowadays networks use different kind of mechanisms in order to give priority to a certain sort of traffic to process the packets in a different way depending on their application. The most common way to achieve this is using Differentiated Service, marking the packets depending on their application (giving higher preference to those that are more important or time sensitive such as Voice over IP, or Video on Demand). However, determining resource allocation per class of service must be done with knowledge about traffic demands for the various traffic classes, keeping a fixed amount of bandwidth for each class, which results in a poor utilization of resources.

In the last years, a new networking approach called Software-Defined Networking (SDN) is emerging fast. This approach is based on the separation of data and control planes. Such approach allows the network administrator to have a more dynamic control of the network behaviour. The purpose of this project is to analyse the possibilities that SDN provides to develop a more efficient resources allocation along the network.

Preface

This is a report of a student project conducted on the 4^{th} semester of Networks and Distributed Systems, at Aalborg University. This project serves as a Master Thesis as the requirements of the master's programme dictate. This is applied in the comparison of a designed application used for Cognitive Networks concepts over a Software-Defined Network (SDN).

In this project Floodlight is used as an SDN controller, and the network is simulated using mininet software.

Aalborg University, March 11, 2014

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1 Introduction

This introduction chapter tries to give a general view of the existing problems in the actual networks, and how new emergent technologies can help to improve the network possibilities and capabilities in order to achieve a more flexible approach and adapt to todays needs.

1.1 Motivation

In the last 20 years networks requirements have been changing constantly, the amount of traffic have been increasing exponentially and more demanding end-to-end goals are needed. However, the networks architectures have been unchanged, increasing the complexity and hindering its configuration. In order to adapt to the new needs, new network paradigms such as Software-Defined Networking (SDN), cognitive networks or automatic networks are emerging fast due the interests of carriers and ISPs.

The first things to analyse are the problems of the existing networks. They have become a barrier to creating new, innovative services within a single data centre, on interconnected data centres, or within enterprises, and an even larger barrier to the continued growth of the Internet.

The main problem in conventional networks (i.e. non SDN), is that each router has to be configured individually because is the same network element (router) who has both, data and control plane. Nowadays there are hundreds of network monitoring and management tools[1], and several protocols to configure the elements such as Multiprotocol Label Switching (MPLS) [2] or NETCONF[3]. On the other hand, there are also a bunch of routing protocols e.g. Routing Information Protocol (RIP)[4], Enhanced Interior Gateway Routing Protocol (EIGRP)[5] or Shortest Path Bridging (SPB)[6]. However, with the SDN approach, having a centralised control plane, it's much easier to make a more efficient and dynamic management and control of the network since we have a global overview of the network.

[1] Standford Network Monitoring and Management Tools list.
[2] MPLS architecture RFC 3031
[3] Network Configuration Protocol (NETCONF) RFC 6241
[4] RIP Version 2 RFC 2453
[5] CISCO Enhanced Interior Gateway Routing Protocol (EIGRP)
[6] SPB IEEE Std 802.1aq

Protocols tend to be defined in isolation, however, with each solving a specific problem and without the benefit of any fundamental abstractions. This has resulted in one of the primary limitations of today's networks: complexity. For example, to add or move any device, IT must touch multiple switches, routers, firewalls, Web authentication portals, etc. and update ACLs, VLANs, Quality of Services (QoS), and other protocol-based mechanisms using device-level management tools. In addition, network topology, vendor switch model, and software version all must be taken into account. Due to this complexity, today's networks are relatively static as IT seeks to minimise the risk of service disruption.

The motivation of this Master's Thesis is to take advantage of the new centralised networking approach of SDN to dynamically allocate the appropriated resources (appropriated QoS) to each sort of service or user.

1.2 Quality of Service

Nowadays networking QoS can be divided in 3 classes, Best Effort (BE), Integrated Services (IntServ) and Differentiated Services (DiffServ). Each of this approaches have their own positive and negative things. This sections give a general overview of each in order to understand the problems and the current methods to achieve end-to-end goals, dealing with the different kind of packets.

Table 1.1 summarises the features of this three types of QoS, specifying the service, service scope, complexity and scalability of each one.

Table 1.1: QoS comparison

	Best-Effort	IntServ	DiffServ
Service	Connectivity No isolation No guarantees	Per flow isolation, Per flow guarantee	Per aggregation isolation, Per aggregation guarantee
Service Scope	End-to-end	End-to-end	Domain
Complexity	No setup	Per flow setup	Long term setup
Scalability	Highly scalable, nodes maintain only routing state	Not scalable (each router maintains per flow state)	Scalable (edge routers maintains per aggregate state and core routers per class state)

1.2.1 Best Effort

Best Effort is the current way the Internet is working, and is equal to do nothing with the packets, meaning that the service provided depends on the actual state of the network.

The positive points about BE is that is highly scalable, since the nodes just maintain routing state, and there is no need of any set-up. On the other hand this approach has no assurances about delivery, no control access, no isolation and no guarantees.

1.2.2 Integrated Services

Integrated Services guarantees specific resources for a specific flow, which means that can guarantee a QoS for the flow. IntServ uses the Resource Reservation Protocol (RSVP)[7] as a signalling protocol, which is the responsible of sending specific messages to the network nodes to reserve the required resources per each data stream. RSVP declares the QoS requirements and characterise the traffic of the the flow.

IntServ allow to differentiate three kinds of services: Guaranteed (real-time applications), Controlled load (applications that can adapt to network conditions within a certain performance window) and Best effort.

Even though IntServ ensures the specific QoS required per each flow, it has large scalability problems because maintaining states by routers in high speed networks is difficult due to the very large number of flows., besides all the routers have to be RSVP compatible.

1.2.3 Differential Services

Due the limitations of IntServ (1.2.2), DiffServ appeared solving some of the problems. DiffServ consist on marking the packets with a priority stamp (Differenciated Service Code Point or DSCP) on the edge routers, and the core networks use this stamp to know the forwarding priority. Doing this labelling suppose time, but since it is done in the edge routers, where the links speed are slower, it doesn't represent a problem.

This method is scalable, since doesn't need to maintain state info in each router, and flexible to service models as well as has a simpler signalling than RSVP.

However, DiffServ has also some limitations. This method works just within a certain domain, and it cannot guarantee end-to-end goals since it cannot provide per flow bandwidth and delay guarantees. This methodology is not motivated to real-time applications but economic reasons.

1.2.4 MPLS Traffic Engineering (MPLS-TE)

In a traditional Internet Protocol (IP) network each router performs an IP lookup for each packet to determine the next-hop based on its own routing table, and forwards the packet to that router. Each router makes its own independent routing decisions, until the final destination is reached. Multi-Protocol Label Switching (MPLS)[8] does a label switching instead. That means that the first router does a routing lookup but instead of finding a next-hop, it finds the final destination router and applies a label (or "shim") based on this information. The next routers will check this label to route the packet without needing

[7] Resource ReSerVation Protocol (RSVP) RFC 2205.
[8] MPLS architecture RFC 3031

to perform any additional IP lookups. The idea was to have only the first router doing an IP lookup, then all future routes in the network could do switching matching based on a label, reducing the load on the core routers, where high-performance was the most difficult to achieve, and distribute the routing lookups across edge routers.

MPLS-TE DiffServ Aware (DS-TE)

1.3 Software-Defined Networking

One of the tendencies that seems to have more power for the next generation networking is Software-Defined Networking (SDN). One of the reasons to believe that SDN will be *the one* is that some big companies, such as Google, are already using it[9] [10].

SDN is a new network architecture that allows be programmed as if it were a computer. It provides an abstraction of the forwarding function decoupling the data plane from control plane, which gives freedom to manage different topologies, protocols without many restrictions from the physical layer.

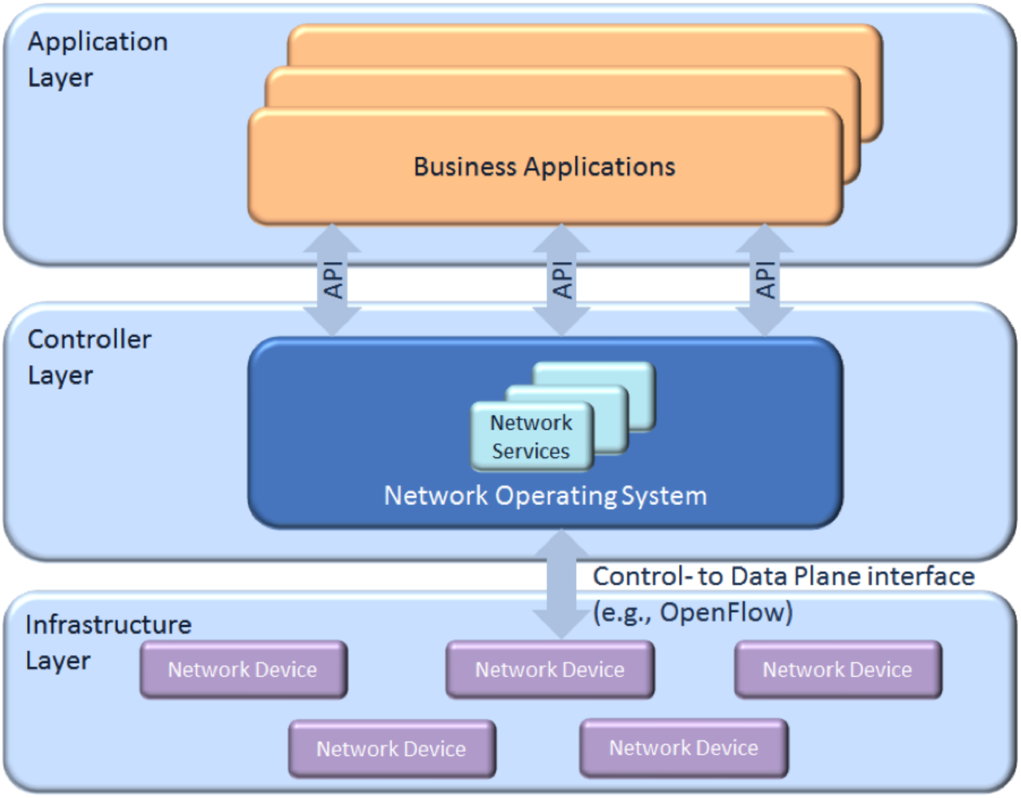

Figure 1.1: SDN architecture (image from Open Networking Foundation)

[9]Google's white paper: Inter-Datacenter WAN with centralised using SDN and OpenFlow.
[10]B4: Experience with a Globally-Deployed Software Defined WAN.

1.3.1 OpenFlow

OpenFlow is the protocol used to communicate the controller with all the Network Elements (NE). Is an open standard that provides a standardised hook to allow researchers to run experiments, without requiring vendors to expose the internal workings of their network devices. OpenFlow is currently being implemented by major vendors, with OpenFlow-enabled switches now commercially available.

1.4 Cognitive Networks

Another hot topic which should be considered for this project is the concept of Cognitive Networks (CN), since the centralised controller of SDN allow us to sense the environment and act consequently. Looking at the relevant literature, we can find a huge number of definitions of CNs, one of them can be find in a paper written by the Department of Electrical and Computer Engineering at Virginia Tech [1]:

A cognitive network has a cognitive process that can perceive current network conditions, and then plan, decide and act on those conditions. The network can learn from these adaptations and use them to make future decisions, all while taking into account end-to-end goals.

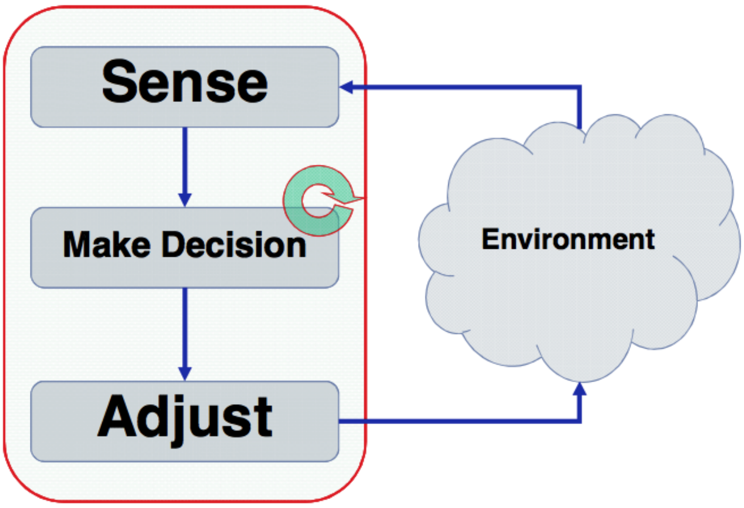

Figure 1.2: Cognitive process

A CN operates in light of end-to-end goals. This means that the scope of the cognitive network is operating above the goals of the individual network elements. Instead, it operates within the scope of a data flow, which may include many network elements. Many flows may traverse a single network element, which means that the cognitive network needs to be able to prioritise these flows. By interacting with the Storage Area Network (SAN), the cognitive network tries to maintain a set of end-to-end goals (such as routing optimisations, connectivity, trust management, etc.) by modifying the elements of the

SAN. The cognitive elements associated with each flow are allowed to act selfishly and independently (in the context of the entire network) to achieve local goals.

There are several mechanisms to apply the cognitive concepts to machine learning. The choice of machine learning algorithm depends on what the the network goals are and how these problems are set up. Complex cognitive networks may have several cognition processes operating, each using mechanisms appropriate for the problem being solved.

1.5 Problem formulation

Data traffic in networks have been increasing exponentially since the beginning of networking at the same time that new kind of services and connection requirements appear. Those factors have led to a more complex networks that cannot satisfy the needs of carriers nor users.

As explained in this introduction chapter, the current networks have several limitations to adapt to end-to-end goals requirements for the different sort of services. Determining resource allocation per class of service must be done with knowledge about traffic demands for the various traffic classes, keeping a fixed amount of bandwidth for each class, which results in a poor utilisation of resources. Nowadays methodologies are static, or need specific network equipment, which leads to a non-scalable and expensive systems.

The aim of this project is to analyse the possibilities that Software-Defined Networking bring us to develop an application able to sense the state of the network and adapt its behaviour in order to achieve a better performance and better resource utilisation of the network.

Bibliography

[1] Ryan W. Thomas, Luiz A. DaSilva, A. B. M. (2005). Cognitive networks. Paper, The Bradley Department of Electrical and Computer Engineering.

A Project proposal