Projet SD-WAN

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1 Introduction

WAN or Wide Area Network is the network connecting websites from companies and the Internet. These websites are connected using MLPS or Multi protocol Label Switching, a protocol conceived in the 1990s avoiding routers to lose time searching for routing tables.

Over the years, the traffic flow has become increasingly complex as companies now use cloud providers to launch their applications therefore the MLPS protocol does not work as it is out of their perimeter.

This is where SD-WAN comes in action. SD-WAN is a software-defined approach to managing the WAN that allows a centralized controller to optimize the multi-cloud application experience and greatly simplify WAN operations.
SD-WAN has many pros such as no bandwidth penalties and the cost effective ability to mic and match network links depending on their type or importance, all while being cheaper than MLPS.

Finally for the objective of our project, is to integrate a form of Machine Learning model capable of analysing and deciding which way should a message use in order to go from point A to point B all the while using a ONF's product Onos, a ”scale-out architecture to provide the resiliency and scalability required to meet the rigors of production carrier environments”. The area of Machine Learning we will use is Reinforcement Learning. Reinforcement Learning consists of training a ML model in order to make a sequence of decision. The decision maker a.k.a the Agent learns to make to achieve a goal in certain environments. In our case, the agent will have to understand the environment which is the network and make decisions such as the way our message should go from point A to point B.

This report does not go as far as the usage of Reinforcement Learning. This report tries to explain the objectives and methods in a mathematical point of the network and the constraints that surrounds it.

2 Motivation

These past two decades, we have observed the exponential growth of the internet and its part in the world's communication infrastructure. According to the CISCO annual network report (1), two-thirds of the world population will have access to the internet and ”the number of devices connected to IP networks will be more than three times the global population by 2023”, finally CISCO predicts that the increasing reliance on cloud is increasing WAN traffic, by 2022, CISCO predicts WAN traffic will reach 5.3 exabytes per month (2).

Today, tens of thousands of Autonomous Systems (AS) are used today by institutions from universities to internet providers. In order to send a message from one computer to another. If we consider 1 computer sending a message to another while they do not share the same AS or Point of presence, the message will most likely bounce by multiple ASes before reaching its destination.

according to the FutureWAN'18 Summit (3), 75% companies experience network outages on a daily/weekly basis affecting critical applications.

Finally, Artificial Intelligence is used in numerous domains of technology but it is has yet to reach its omnipresence in Network programming as seen in (5). The usage of Artificial Intelligence can enhance performances, respond to dynamic networks, applications and security conditions.

3 Objectives

We consider multiple problems network related, the first is the shortest path, second is the delay and last is the ressource allocation (bandwidth). Each of those are apply to the different flows in the network in order to minimise this specific criterion. We represent each of those by similar equations that we will minimise using different method. This approach can be related to an opposite to Ford-Fulkerson graph problem.

In fact, the traffic generated through a transport connection between two nodes (source and destination) can be represented by a flow f. Usually, a flow can be split between several routes into sub-flows inside the core network due to the dynamics of the routing protocols, the links states, and the data demand rate.

The max-min (or maximin) fairness was first introduced in the context of networking by Bertsekas and Gallager (ref 4) as a design objective for flow control schemes.

4 Methode

We consider the simplest case when each transport connection is represented by a single flow (a sequence of packets on the same path).

For the purpose of formalizing the description of the problem, we introduce the following notation. A node (server or client) will be represented by the link that connects it to the network core. The network is assumed to be made of a set of L links defined by i and j representing the two nodes connected by this link. Each link l has a capacity Cap and to supplement our simulation we also add an used capacity U and an associated delay d. To find the best way to minimize the saturation in the links, we also added a score S given to each edges to a given node 1 representing the least saturated edge and N_{edges} the most saturated one. The element $v_{i,j}$ of the matrix V is equal to one if flow f goes through link l. We also consider the minimum bandwidth needed for this packet to be passed bdw and the total number of node N. Each problem we minimize $Cost$ correspond to specific equations

$\sum_{i,j}^{N,N} V_{i,j}$ Shortest path

$\sum_{i,j}^{N,N} u_{i,j}$ Delay

$\sum_{i,j}^{N,N} Cap_{i,j}/U_{i,j}$ Bandwidth ratio

$\sum_{i,j}^{N,N} S_{i,j}$ Delay

4.1 Objective function

The formula we minimize

$$\sum_{i,j}^{N,N} Cost_{i,j} * V_{i,j}$$

We also squared our $Cost$ function to increase it's importance

$$\sum_{i,j}^{N,N} Cost_{i,j}^2 * V_{i,j}$$

$$i, j \in N, N$$

4.2 Constraint on capacity

$$V_{i,j} * bdw + U_{i,j} \leq Cap_{i,j}$$

$$i, j \in N, N$$

4.3 General constraints

$$rhs = \begin{cases} 1 & \text{if it is source node} \\ -1 & \text{if it is destination node} \\ 0 & \text{otherwise} \end{cases}$$

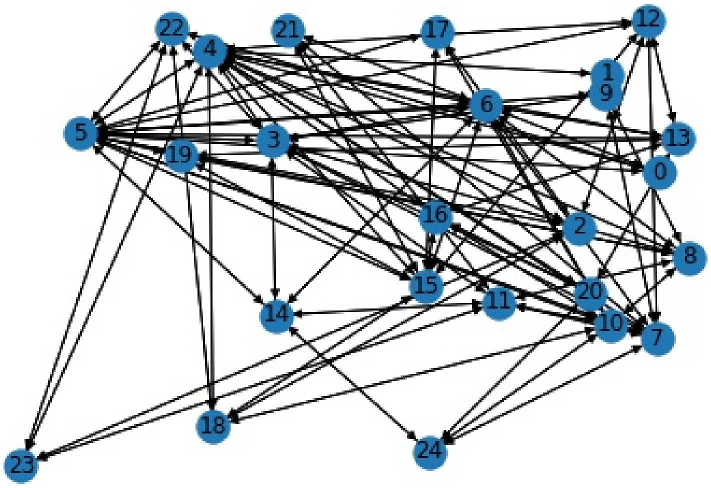
$$\sum_{i,k}^{N,N} V_{i,k} - \sum_{k,j}^{N,N} V_{k,j} = rhs$$

$$i, j, k \in N, N, N$$

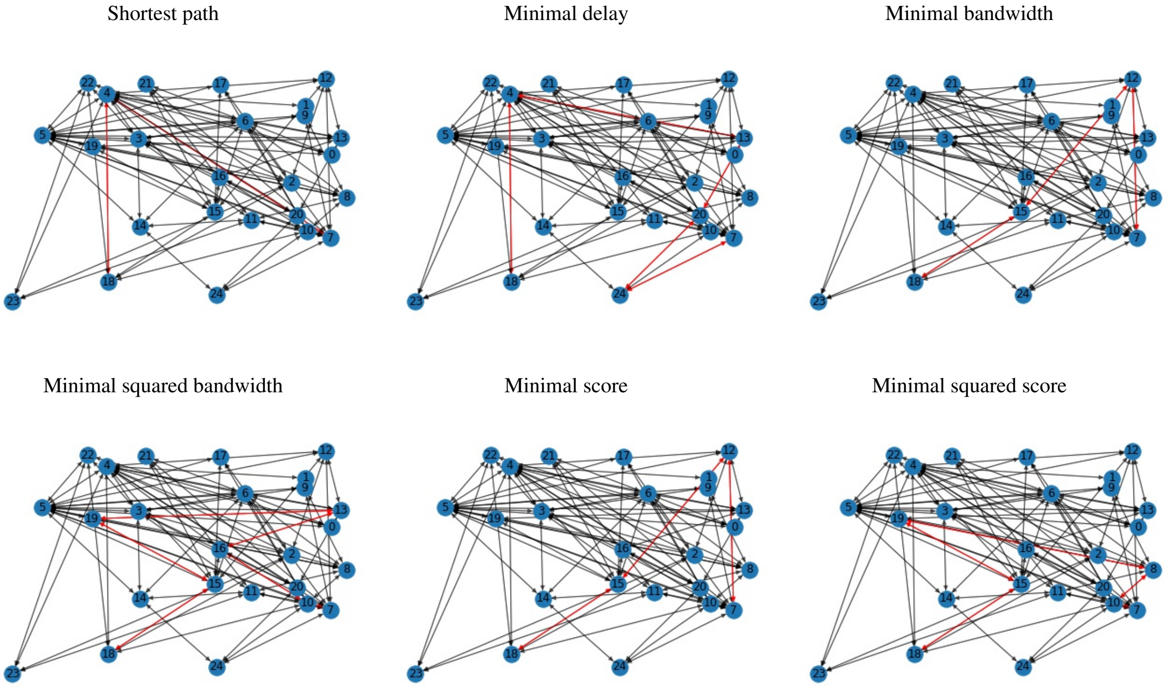
We implemented those functions using Pulp for the mathematical part and Networkx for creating our model.

From a random model (Figure 1) generated using Networkx, this is an example of architecture.

Figure 1: Original



Here is the results (Figure 2) of the previously mentioned equations generated using Pulp.


Shortest path

Minimal delay

Minimal bandwidth

Minimal squared bandwidth

Minimal score

Minimal squared score

Figure 2: Results with Pulp and Networkx (Source=7,Target=18)

5 Conclusion

As you understood, SD-wan is the next step for a more efficient global network. We plan to elaborate a more accurate and modular RL-model.
Our main network model tool, Onos, will be essential to polish our RL-model. Onos will create an environment that will be used to train our agents in real time.
Our different results show that every scenario will have a better end with The OpenFlow as the main SDN protocol.
Moreover, the usage of XMPP in other SDN solutions is very limited.

6 Perspective

SD-wan will probably increase efficiency of the global network. About commercial interest we can logical think that a faster network will have plenty different financial outcome for internet provider or cloud provider

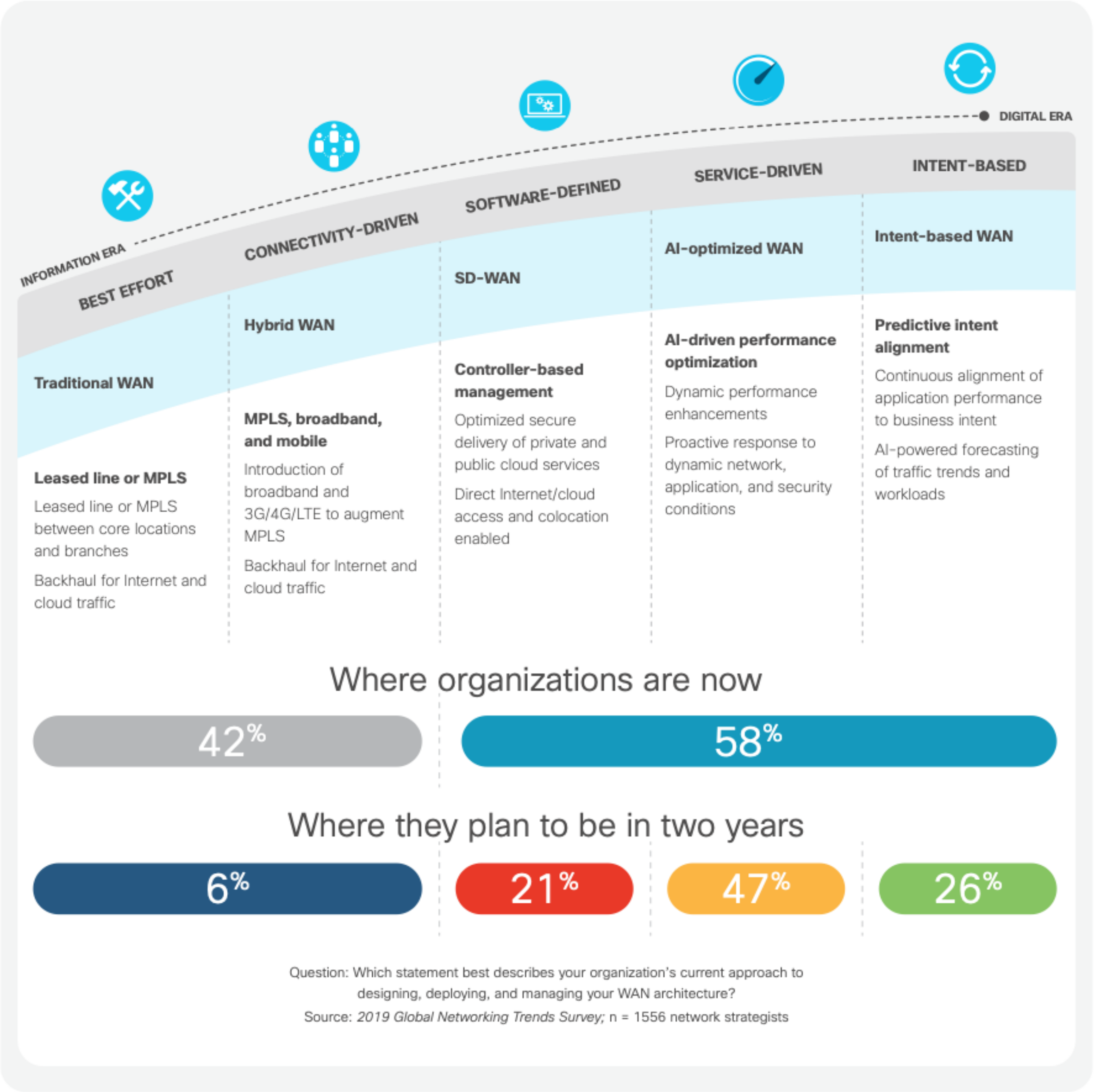
7 Annexe

1. `https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectiv`
   `annual-internet-report/white-paper-c11-741490.html`

2. `https://www.cisco.com/c/dam/m/en_us/solutions/enterprise-networks/`
   `networking-report/files/GLBL-ENG_NB-06_0_NA_RPT_PDF_MOFU-no-Networking`
   `rpten018612_5.pdf`
   page 42

3. `https://www.cisco.com/c/dam/global/en_uk/solutions/enterprise-networks/`
   `sd-wan/nb-06-SD-WAN-FutureWANSurveyResults.pdf?oid=ifgen014762`

4. `https://web.mit.edu/dimitrib/www/datanets.html`



Leased line or MPLS

Leased line or MPLS between core locations and branches

Backhaul for Internet and cloud traffic

MPLS, broadband, and mobile

Introduction of broadband and 3G/4G/LTE to augment MPLS

Backhaul for Internet and cloud traffic

Controller-based management

Optimized secure delivery of private and public cloud services

Direct Internet/cloud access and colocation enabled

AI-driven performance optimization

Dynamic performance enhancements

Proactive response to dynamic network, application, and security conditions

Predictive intent alignment

Continuous alignment of application performance to business intent

AI-powered forecasting of traffic trends and workloads

Question: Which statement best describes your organization's current approach to designing, deploying, and managing your WAN architecture?

Source: *2019 Global Networking Trends Survey;* n = 1556 network strategists

5.

6. `https://www.sdxcentral.com/networking/sd-wan/definitions/software-defi`