Section 1: Week 2: SDN Problem Statement

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# QoS in Software Defined Networks

Software Defined Networking (SDN) represents the next evolutionary step in network design. This is accomplished by a clear separation of application, control, and data planes; such that (1) hardware switches are reduced simple packet forwarding devices; (2) viewing and modifying the network configuration is standardized across vendors; and (3) general purpose programming languages can register for networking events across the pipeline. Having these capabilities enables networks to be highly dynamic and reactive to issues impacting the Service Level Agreements (SLA).

An open research area within software defined networks is mechanisms for increasing the supportable size of Policy Based Routing (PBR) on the Open Flow Tables. This is caused by the finite availability of Ternary Content-Addressable Memory (TCAM) on the physical networking devices (Shood, Yu, & Xiang, 2006). If these tables are unable to continue growing at a sustainable rate this will lead to challenges managing large scale dynamic networks, due to an expected explosion in both legitimate (e.g. IIoT and 5G) and malicious traffic (e.g. DDoS).

## What is TCAM

A commodity workstation using Random Access Memory (RAM) and requires the application to provide an *address* to retrieve the *content*. Networking equipment has the opposite requirement as the packet contains the destination’s virtual IP (content) and needs to be mapped to a virtual switch port (address).

Ternary Content-Addressable Memory (TCAM) addresses this requirement by allowing each bit in the content to represent states (a) on; (b) off; or (c) doesn’t care about ‘x’. Due to the wildcard nature, lookup tables can be queried in parallel and network masks applied very efficiently (Ullah, Ullah, Afzaal, & Lee, 2019).

The amount of TCAM on a device is limited due to (1) the chips are expensive to produce; (2) requires significant power for complex circuits; (3) required power consumption emits large amounts of heat; and (4) the complex circuitry reduces amount of memory that can be placed per square centimeter.

According to Ullah et al, a typical chip contains on the order of 1000 x 144-bit words. This is enough for traditional static networks but will limit innovation as competing consumers fight for these finite resources. The number of words does not directly map to the number of consumers, as filter policies can be implemented by vendors as multiple ‘allow’ and ‘drop’ actions requiring additional entries.

To partially mitigate the scenario vendor’s have introduced the notion of ‘Flow Groups’ as a mechanism to group multiple flows into the same policy entry. However, many business-critical scenarios such as DDoS mitigation and ensuring QoS will require more fine-grained policies.

# Influence of Legitimate Traffic

It is well publicized that the rise of Industrial Internet of Things (IIoT) and 5G wireless are expected to cause a 1000-fold increase in the number of connected devices (Petel, Ali, & Sheth, 2018) (Frodigh, 2018). Each of these devices will need to be registered within the OpenFlow switches as a requirement to correctly route the last hop. In high traffic areas, such as convention centers or autonomous factories, these wireless devices will roam about the premise. This adds further load across multiple physical switches as they must cache the policy for devices that are likely to return soon.

For many scenarios of the Industry 4.0 movement having mechanisms to ensure Quality of Service are required for safety reasons. Frodigh used a contrived example with a balancing robot that relied on external network services for calibration information. As he talked, the network signal was increasingly delayed causing the robot to drunkenly wobble. Eventually the robot tipped over representing cataphoric failure.

These scenarios can be mitigated by either undersubscribing the networking gear or using more granular priority policies. As the size of the network increases it becomes prohibitively expensive to undersubscribe networking equipment (Jain et.al, 2013).

# Influence of Malicious Traffic

It is also well publicized that Distributed Denial of Service attacks are continuing to grow in frequency against enterprises. Akamai Technologies is responsible for the management of Global Content Delivery Networks (CDN); they have reported an annualized increase in attacks at 60% (Singh, Singh, & Kumar, 2017). A literature review suggests that many businesses expect to leverage software defined networking solutions as their mitigation strategy. However, these studies are (1) based on small simulated data sets; (2) addressed only half the scenario; and; (3) ignored the scalability concerns of granular policy requirements.

## Understanding DDoS Scenarios

A Denial of Service (DoS) attack occurs when a malicious actor performs some action on a resource with the goal of preventing another user from accessing it. A Distributed Denial of Service (DDoS) occurs when a malicious actor uses multiple intermediaries to perform the action against the resource.

There are two broad categories of DDoS attacks (a) Network Level and (b) Application Level. Attacking the networking level is often easy to detect because of the sheer volume. Application level is harder to distinguish as its mixed with legitimate traffic.

## Challenges from Limited Data Sets

It is well publicized that server providers are unwilling to share their network traces of DDoS attacks with researchers, as they are concerned about the privacy of their users. This has resulted in researchers operating on limited scale data sets or simulated traffic across small Local Area Networks (LAN). (Feinstien, Schnackenberg, Balupari, & Kindred, 2003) (Singh, Singh, & Kumar, 2017) (Prasetiawan, Abdurohman, & Yulianto, 2017).