A QLearning Based Business Differentiating Routing Mechanism in SDN Architecture

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Abstract. With the diversified development of the current network, users’ demand grows as well which brings great challenge for its load ability. In this paper, we purpose a QLearning based business differentiating routing mechanism in SDN architecture to guarantee users’ routing QoS. To realize that, this paper designed four modules (discovery of link, classification of link, intensive learning and Q-value table sending) to assign different paths to data streams of different attributes. The experiment shows that this algorithm can decrease the packet loss rate to less than 5% and for some of the data streams, this rate is almost 0, simultaneously, it also helps the delay problem.

1. Introduction
By the end of December 2017, the population of Chinese cyber citizens was 420 million and the penetration rose to 55.8%, according to the "41th China Internet Development Statistics Report" [1] released by the China Internet Network Information Centre (CNNIC). With the continuous development and progress of Internet technology and various new technologies, the demand of users has changed from single data transmission to data, video, interactive and multimedia network applications. The rise of a new type of streaming media business represented by microblog, hissing, fast hand, Internet disk and video websites has also further increased the diversification of network demand. All these changes pose a great challenge to the load ability of the network. The traditional IP network infrastructure is closed, which makes strategy deployment difficult, and its security and flexibility are also insufficient, thus, Nick McKeown of Stanford University proposed a new architecture called software defined Networking (SDN) [2].

SDN is a network decoupling control plane and forwarding plane. It has the characteristics of separation of control and forwarding, open programming interface and centralized control. In a traditional network, the switch/router learns and maintains routing tables by itself, while in the SDN environment, the switch routes forwarding according to the flow table. In the current SDN network, most routing algorithms still use the shortest path algorithm measured by the number of hops to get the optimal path. However, these algorithms do not take into account the delay, bandwidth and resource utilization rate and other factors, the selection of the link is not necessarily the optimal path as well as there may be a link selected by multiple business flow in the case of the optimal path of link congestion and resource waste, and so on. Therefore, this paper proposed a routing algorithm based on business classification to effectively solve the existing problems of SDN routing algorithms.
2. Research status

The QoS problem of routing has always been a hot topic in academic circles. In the traditional network architecture, there are many methods to guarantee the QoS of users.

Such as Best Effort model (do your Best model) [3], is a single service model using the first-in, first-out scheduling principle to send messages as many as possible, but for the time delay and reliability problems, this method does not provide any guarantee. The integrated service model [4] is another example, it defines a business as a guaranteed service, a load-controlled business and a full-done business. The RSVP (Resource Reservation Protocol) is used between the sender and receiver as the signalling of each data stream, and each network unit along the way from the recipient to the sender supports the QoS control mechanism by reserving resources for every data stream.

Academia and industry have done a lot of research on routing strategy in SDN environment. Paper[5] proposed an equivalent multipath selection algorithm based on the link busy trend value, link trend in the network is used to characterize the possible amount of the link, and the link bandwidth represents the transmission capacity of the link, then, It calculates the busy trend value of the link, and selects the path with the minimum busy trend in the bottleneck link in the equivalent multipath, so as to avoid the traffic flow in the hot chain as far as possible, this algorithm can effectively avoid the congestion, increase the throughput and improve the utilization of the resources, however, the discrepancy of flow characteristics cannot be taken into account, which has an impact on the choice of optimal schemes. Paper [6] proposed the concept of HiQoS in their paper to guarantee the transmission bandwidth of different services by using multiple paths and queuing mechanism from the source to the destination node. At the same time, the author also proposed a fault detection strategy that updates the state of the link every other time so that when a fault occurs, the packet can be rerouted. This method can effectively reduce the hourly delay and the routing has a certain robustness, but the single path transmission makes the source not fully utilized and is not taken care of all factors. Paper [7~8] proposed a home FlowQoS architecture, which uses the application identity and flow table rules to forward traffic at the appropriate rate on the home router, the FlowQoS controller identifies the upstream and downlink traffic and configures the QoS demands, which gives priority to the user specified application stream to adapt to the user's preference. This method can satisfy users' priority for application and improve the forwarding rate of traffics, however, the packet loss rate of packets is not taken into account.

Based on the existing research results, this paper proposed a routing algorithm based on business classification. In this paper, we classified the traffic flow according to attributes, then, combined the link delay, bandwidth and packet loss rate to establish the weight value formula, and using machine learning algorithm to optimize it dynamically so as to select the appropriate route for routing.

3. Design and implementation of mechanism

In order to realize the routing algorithm based on the service classification under SDN environment, this paper proposes the following path planning system, as shown in Figure 3-1, mainly including four modules (link discovery, link classification, intensive learning training and Q value table sending), and the topology, as shown in Figure 3-2, consists of 7 switches and 16 hosts.
3.1 Division of business
With the continuous development of network technology, the types of network services are increasing and different kinds of packets have different needs for QoS. According to the division of network services by 3GPP [9], they divide network traffic into four types: conversational services, streaming media service, interactive service and data class service.

Conversational service: it is a one-way transmission, a real-time service which does not require interactive, such as video calls, and has a high requirement for time delay while can bear a certain packet loss rate.

Streaming media service: a kind of unilaterally real-time business, such as video on demand, e-commerce, and so on, the requirement for delay and packet loss rate is relatively high.

Interactive service: it is an online data interaction service with request response mode for a terminal user and remote device, it is a non-real-time service with a certain requirement for time delay and packet loss rate, such as web browsing, network games and so on.

Data class service: non-real-time business, such as background E-mail acceptance, file download, etc., has higher requirement for packet loss rate and lower delay requirement.

In this paper, the ToS domain in the packet header domain is used to distinguish the type of packet service type. In the OpenFlow V1.0, the packet header domain of the flow table includes 12 tuples (Tuple), and the related contents are showed in Table 3-1, [10].

| Ingress port | Ether Source | Ether Type | VLAN ID | VLAN Priority | IP Src | IP Dst | IP Port | IP Tos | TCP/UDP Src Port | TCP/UDP Des Port |
|--------------|--------------|------------|---------|----------------|--------|--------|---------|--------|------------------|------------------|

3.2 Routing planning based on QLearning algorithm
The main process of QLearning is shown in Fig. 3-3 [11], in its learning process, the optimal value is approximated by the continuous iteration of \( Q(S, A) \) and the core of process is

\[
Q(S, A) \leftarrow Q(S, A) + \alpha [R + \gamma \max A' Q(S', A') - Q(S, A)] ,
\]

\( \alpha \) denotes the learning efficiency and \( r \) denotes the rewards. The whole algorithm is constantly updating the values in Qtable, and then according to the new value to determine what kind of action to take in a state. Once the Q table training is completed, the Q value table sending module sent it to all
OpenFlow switches for new traffic packet so it can easily find a forwarding path from the $s$ node in the obtained matrix according to its own properties.

3.3 Information acquisition and processing

In this paper, when selecting the optimal path, four factors, such as link delay (donated by D), available bandwidth (donated by B), packet loss rate (donated by L), and bandwidth utilization (donated by U), are considered. Considering the positive and negative correlation of each factor, four different weights $\alpha, \beta, \gamma, \lambda$ are assigned to it respectively, and the formula of the reward value in the QLearning algorithm can be obtained as follows:

$$R = (\beta \ast B - \alpha \ast D - \gamma \ast L - \lambda \ast U) \ast 100$$

And the weight relationship is shown in Table 3-2.

| kind                      | relation            |
|---------------------------|---------------------|
| Conversational service    | $\alpha > \lambda > \beta > \gamma$ |
| Streaming media service   | $\alpha > \gamma > \lambda > \beta$ |
| Interactive service       | $\gamma > \alpha > \beta > \lambda$ |
| Data class service        | $\gamma > \beta > \lambda > \alpha$ |

In order to get all the data information in the link, the Iperf tool is used to monitor all the data. At the same time, in order to make a unified consideration of the data, the min-max standard method [12] is used to normalize all the data, so that all the data can be mapped into [0,1]. The calculation method is as follows:

$$X^* = \frac{X - X_{\text{min}}}{X_{\text{max}} - X_{\text{min}}}$$

4. Experiment and result analysis

In this paper, the mininet tool is used to build the underlying network. The ToS value of the four traffic flows is specified as Table 4-1, and the corresponding parameter assignment is shown in Table 4-2.

| KIND                      | TOS |
|---------------------------|-----|
| CONVERSATIONAL SERVICE    | 4   |
| STREAMING MEDIA SERVICE    | 8   |
| INTERACTIVE SERVICE       | 16  |
| DATA CLASS SERVICE        | 32  |
Table 4-2 Parameter assignment

| KIND                      | α    | β    | γ    | λ    |
|---------------------------|------|------|------|------|
| CONVERSATIONAL SERVICE    | 0.8  | 0.4  | 0.2  | 0.6  |
| STREAMING MEDIA SERVICE   | 0.8  | 0.2  | 0.6  | 0.4  |
| INTERACTIVE SERVICE       | 0.6  | 0.4  | 0.8  | 0.2  |
| DATA CLASS SERVICE        | 0.2  | 0.6  | 0.8  | 0.4  |

In different cycles, the accuracy rate of routing selection of QLearning algorithm is shown in table 4-3. It can be seen from the table that with the increase of training cycle, the accuracy rate is continuously approaching 100%. In this topology, when the training cycle reaches 40, it converges basically.

| Cycle | 5     | 10    | 20    | 30    | 40    | 50    | 60    | 70    |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Accuracy | 60.3% | 75.6% | 94.6% | 98.7% | 99.8% | 99.9% | 99.9% | 100% |

4.1 Result analysis
In this paper, the experimental results are compared with the ECMP algorithm [13] and the ant colony algorithm of paper [14]. After several experiments, the delay and packet loss rate of each routing algorithm for 4 kinds of services are shown at Figure 4-1 and 4-2, (from the left to right respectively, session service, streaming media service, interactive service and data class service and ◆ donates the EPMC algorithm, ▲ donates the algorithm in this paper and ● donates the ant colony algorithm).

From Figure 4-1 and 4-2, we can see that our algorithm can guarantee the packet loss rate for four different properties and reduce the delay effectively. The results are obviously superior to the existing algorithms, especially in the conversational service and data class service.

5. Conclusion
In this paper, a routing QoS security mechanism based on QLearning algorithm and business flow attributes is proposed. The network resource utilization ratio is rationally allocated to avoid local congestion, and users’ QoS demand are satisfied as much as possible. Of course, the algorithm in this paper also has some limitations. In the future, we will use a deeper machine learning algorithm, such as Double Deep QLearning, to train the model. At the same time, the algorithm is based on fixed topology while the network topology is often dynamic. Thus, there are still some shortcomings for further study.

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