A Low-Loss Strategy for Network Function Virtualization Multicast Optimization

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Abstract. In order to fulfill the multicast task with a service function chain (SFC) requirement and effectively utilize network bandwidth and resources, a low-cost NFV multicast optimization strategy based on Dijkstra's algorithm is proposed for the real-time requirements of wireless network data transmission scenarios. Taking network resource consumption and link bandwidth consumption as evaluation indicators, on the premise of meeting the Service Function Tree (SFT) delay requirements, the Virtual Network Function (VNF) is placed reasonably to realize the embedding of the Service Function Chain (SFC). It creatively proposes the merge rule of VNF in the SFC chain, which reduces the consumption of node resources and link bandwidth while ensuring the connectivity of the network. Experimental results show that the algorithm can effectively reduce the consumption of node resources and link bandwidth under the condition of ensuring low delay, and ensure the real-time and reliability of data transmission.

Keywords: NFV technology · Multicast technology · Network resource consumption · Link bandwidth consumption

1 Introduction

In recent years, the trend of network cloudification has become more and more obvious. Traditional telecommunications services are highly dependent on physical topology and vendor-specific hardware. In order to overcome this problem Software Defined Network (SDN) and Network Function Virtualization (NFV) technologies [1] have been proposed and widely adopted. NFV technology provides an effective solution to the serious hardware and software coupling problem of the 4G core network, which greatly reduces operating time and costs. However, as people's demand for networks further increases, traditional 4G cannot support the surge in mobile data traffic in the future. However, 5G imposes higher requirements on latency and bandwidth [2]. How to improve the network carrying capacity and ensure the real-time performance of data transmission has become an urgent problem to be solved today.

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Under the NFV, multicast is a widely used communication type, which can significantly save bandwidth consumption, and is suitable for real-time data transmission scenarios such as multimedia video sharing and computer cooperative work. Optimizing NFV multicast in SDN can greatly assist 5G research and development. At present, there are studies on this aspect at home and abroad. Literature [3] proposes an approximation algorithm and an online algorithm with guaranteed competition ratio, which realizes the NFV multicast resources supported by SDN under the condition of limited network resource capacity. The rate is the smallest and the network throughput rate is the largest. Reference [4] modeled the deployment and routing of VNF as a linear programming model with the goal of minimizing the number of servers, and proposed a heuristic algorithm based on simulated annealing (SA), which can obtain an approximate optimal solution in a short time. The feasibility is verified by comparing the results of the CPLEX optimizer with the results of the SA algorithm through simulation experiments. The disadvantage of this scheme is that the objective function only considers the computing resources, does not consider the communication resources, and has fewer constraints. Reference [5] studied the optimal SFC embedding problem of NFV multicast. Through the designed two-stage algorithm, the initial feasible solution was generated and the optimized feasible solution was evaluated. The influence of different parameters on the embedded SFT was evaluated. The designed SFT embedding scheme significantly reduces the traffic transmission cost. Most of these studies have focused on optimizing the cost of network resources, and no effective solutions have been proposed for improving bandwidth consumption and latency performance. Therefore, there is an urgent need for a network function virtualization multicast optimization algorithm with low latency, low computing resource consumption, and low bandwidth consumption, which overcomes the deficiencies of the existing technology and adapts to network requirements.

In order to meet the multicast task with service function chain (SFC) requirements, it is necessary to construct a suitable service function tree (SFT) embedded in the shared multicast tree, and use this as a basis for related performance analysis and improvement. The network topology and size of the multicast task are diverse [6], so for a particular NFV multicast task, considering the link bandwidth, VNF setting occupied resources, node resources and algorithm complexity, find the optimal multicast tree in the embedded SFT Is a challenging problem.

This paper presents a network function virtualization multicast optimization algorithm design scheme in the NFV multicast directed network environment supported by SDN. By analyzing the impact of VNF placement on network resource consumption, VNF deployment rules and merge rules are designed to achieve a significant reduction in network computing resources and bandwidth consumption, while ensuring network connectivity. Simulation results show that the NFV multicast optimization scheme proposed in this paper meets the existing network requirements. This is of great significance for improving network performance and ensuring real-time data transmission.

2 Proposed Method

It is known that the NFV multicast resource optimization scheme needs to consider three types of problems in directed network scenarios, namely the placement of VNF, the embedding of SFC, and the determination of VNF merge rules. Through these, optimization of network computing resources and bandwidth consumption is realized. The implementation of the program needs to add NFV elements to the traditional multicast service, set the three types of nodes (source node, intermediate node and target node) of the model reasonably, and perform node calculation resources, link bandwidth (weight) and VNF consumption. The initialization of resources prepares for subsequent algorithm design. Because this paper studies directed networks, the upstream and downstream bandwidths are different, so it is necessary to use the first and the last node serial numbers for effective link naming. Throughout the process, the bandwidth consumed after a certain VNF is not changed by default.

2.1 VNF Layout Rules

The layout problem of VNF is mainly to find the optimal location of VNF without considering the service order constraints. In the process of finding VNF, it is necessary to formulate relevant rules and consider whether node resources and bandwidth can support the placement of VNF. The embedding problem of SFC is more complicated because it requires traffic to traverse a certain number of VNFs in a certain order. Different from the method of placing the VNF first and then finding the appropriate SFC embedding, this paper first finds the shortest path of the source node and the target node through the Dijkstra shortest path algorithm. By judging the node resources and link bandwidth of each node on the shortest path, VNFs are placed in order.Once a certain VNF placed in sequence cannot be placed on the shortest path, it will be stopped, and the capacity is constantly updated during the process. In this step, it is necessary to pay attention to the judgment order of node resources and link bandwidth. According to the actual situation of the data flow, if the bandwidth of the previous link cannot meet the requirements, the shortest path should be disconnected, but if the computing resources of the previous node are not Meet the requirements, you can continue to find the next node that meets the requirements of computing resources.

For unicast tasks with multiple target nodes, the VNF placement results on the shortest path according to the above requirements can be divided into three cases: (1) All VNFs are placed on the shortest path node in sequence. (2) VNF is only partially placed on the node with the shortest path. (3) The first VNF is not placed on the node with the shortest path, that is, no VNF is placed on the shortest path. For case (1), it is only necessary to subtract the initial bandwidth of all links in the shortest path to complete the capacity and bandwidth update. For case (2), the node where the distance between the node where the previous VNF has been placed and the target node is less than two hops. Then select the node with the smallest sum of distances to the two nodes to place the next VNF. If there is a VNF that has not been placed for this SFC, repeat the above operation until it is completely placed. After all VNFs are placed successfully, update the link bandwidth. Once a VNF cannot be placed, the link is broken, and the computing resources previously consumed by placing the VNF are restored. For case (3), first search the network for the point where the distance between the source node and the target node is less than two hops, find the node with the smallest sum of the distance between the two nodes, and place the first VNF. The subsequent process is the same as (2). This completes the VNF placement and SFC embedding process for multi-target unicast. Save the node's consumption of computing resources and link bandwidth at this time, and judge the connection status of SFC and record the number of connections.

2.2 VNF Merge Rule

In existing research, SFC is often embedded in a target network with unicast tasks with multiple targets. For example, maximize the remaining data rate, minimize the number of application nodes, or minimize the traffic delivery delay. The above researches are all SFC embedding problems in unicast tasks, which are both different and related to the research work of this paper. The research in this paper starts with multi-target unicast. After the VNF placement and SFC embedding process is completed, the multi-target unicast scenario will be converted into a multi-cast scenario through VNF merger to achieve VNF and bandwidth sharing, which also greatly reduces the node computing resource consumption.

Before merging, the deployment of each VNF in multi-objective unicast (location and number) is first clarified and calculate the distance between two identical VNF nodes to write into the VNF distance matrix. By calculating the sum of each row of the distance matrix, the distance from the node with the same VNF to all other nodes is obtained. The node represented by the distance and the smallest row is the node to be merged. It is specified that other same VNF nodes with a distance of less than two hops from this node are merged directly, and the rest are not changed. Traverse all VNFs to complete the merge process. At this time, the VNF placement changes. It is necessary to re-judge whether the link bandwidth meets the demand. If not, the link will be disconnected. In the case of leaving only SFCs that satisfy the condition, update the initial values of computing resources and link bandwidth, and save the updated node computing resources and link bandwidth consumption, and determine the number of connected SFC connectivity records.

3 Results and Discussions

The design plan of this paper is to optimize the resource allocation and bandwidth consumption of the multicast service function chain of the entire network. After the VNF placement and SFC embedding are implemented, the data comparison between the multi-target unicast and multicast before and after VNF merge is performed. The network topology (see Fig. 1) has a total of 17 nodes, the initial computing resource cap = [57 58 49 52 55 47 46 42 38 48 50 55 49 48 43 42 51], the initial uplink and downlink bandwidth sum is 5220, and the initial consumption bandwidth w0 = 20. Each time, the source node s and the target node di are randomly generated by a random matrix.

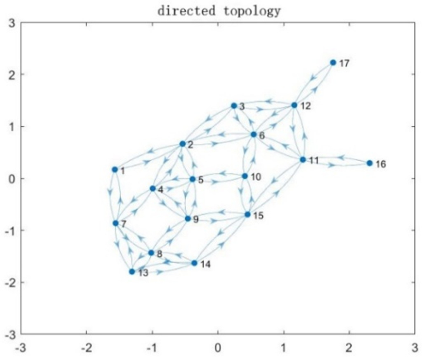

Fig. 1. Directed topology

The results of this paper use computing resource consumption and link bandwidth consumption as indicators to measure its pros and cons. Both show the data capacity and operating speed that the network can carry. Obviously, the smaller the computing resource and bandwidth consumption when a network system implements the same function, the better the network performance.

Each multicast tree is composed of one source node and 6 target nodes, which is equivalent to containing six SFCs. By changing the number of randomly generated SFCs, the running program obtains different results, normalizes the units, and plots the running results in Table 1.

Table 1. Operation result data table.

Number of SFC	Node resource consumption	Link bandwidth consumption	Average bandwidth consumption
24 (before merge)	432	1060	44.1
24 (after merge)	36	900	37.5
48 (before merge)	720	2220	55.5
48 (after merge)	213	1600	48.48
72 (before merge)	792	2700	61.36
72 (after merge)	266	1660	48.82

3.1 Comparison of Computing Resource Consumption

In the process from multi-target unicast to multicast, the VNF merging process is experienced, and the sharing of VNF is realized, which can effectively reduce the consumption of computing resources. Taking 24, 48, and 72 SFCs as examples, a simulation comparison is made. The results are shown in Fig. 2.

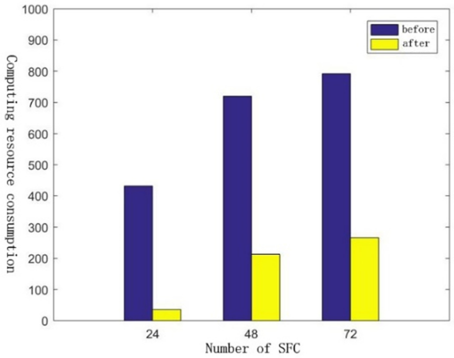

Fig. 2. Compute resource consumption comparison chart

In the figure, the unicast computing resource consumption is 432, 720, 792, and the combined multicast computing resource consumption is 34, 213, and 266 respectively. The gap between the two is obvious. The emergence of multicast significantly saves the node's computing resources Consume.

3.2 Comparison of Bandwidth Consumption

If there are VNFs in the same deployment location and connected in sequence in different SFCs, the repeated paths between these VNFs can be shared and used. Therefore, from multi-target unicast to multicast will definitely reduce the bandwidth consumption, as shown in Fig. 3. Taking 24, 48, and 72 SFCs as examples, the unicast bandwidth consumption is 1060, 2220, and 2700, respectively, and the combined multicast bandwidth consumption is 900, 1600, and 1660, respectively. It is obvious from the figure that at the beginning, the number of SFCs is small, and the link bandwidth and computing resources have little restrictions on the deployment of VNF, and there is not much difference before and after the merger. With the increase in the number of SFCs, within a certain range, the bandwidth savings of multicast is more obvious.

It can be seen from the simulation results that the previous SFC may be broken due to insufficient link bandwidth due to the merge of VNFs, which also partially reduces the bandwidth consumption. Therefore, the total bandwidth consumed by the entire network alone cannot fully explain the problem. By setting the SFC connectivity flag to record the number of SFC connections, and calculate the average bandwidth consumption of each SFC, as shown in Fig. 4. After excluding the impact of the increase or decrease of bandwidth caused by SFC on and off, the difference between the average bandwidth consumption before and after the merger is still increasing. Within a certain range, the more SFCs, the better the optimization effect of average bandwidth consumption.

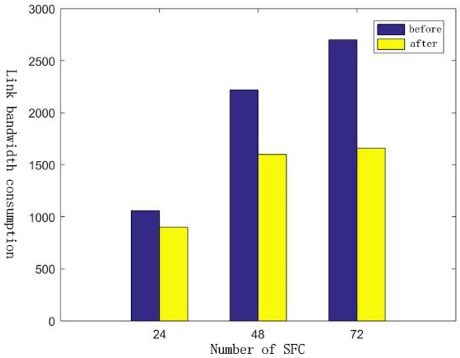

Fig. 3. Link bandwidth consumption comparison chart

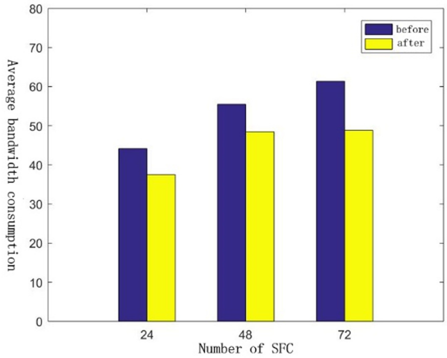

Fig. 4. Average bandwidth consumption comparison chart

4 Conclusions

According to the specific research scenarios, this paper chooses to use the Dijkstra algorithm that can solve the single-source shortest path problem and has a low time complexity to design a network function virtualization multicast resource optimization scheme. VNF deployment, SFC embedding and VNF merge rule design and implementation are completed. Through the analysis of the simulation results, it is known that multicast realizes the sharing of node computing resources and public link bandwidth, which greatly reduces the node computing resources and link bandwidth consumption. It can be predicted from the simulation results that the more complex the network, the more network nodes and links, the more obvious the optimization effect of multicast.

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