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Research on Feedback-Sensitive Resource Mapping Algorithm Based On Simulated Annealing in SDN

Wei Guang Guo, Jun Luo, Song Han, Zu Yao Zhang, Ye Ge*

CN Navy, Beijing, China
War Gaming Lab, NCC, Nanjing

Abstract

The large-scale software define network resource mapping was a complicated problem which focused on the resource mapping model. In this paper, a solution based on simulated annealing algorithm has been proposed in which the feedback got greatly improvements, will be a specific implementation of the resource mapping. ①

Keywords: Resource mapping, Software define network, simulated annealing algorithm

1 Resource Mapping Modeling and Solution

It is the key step of resource mapping to abstract and model the specific large-scale software customization network simulation problem. In this paper, an abstract theoretical model is set up. A simple network is taken as an example to introduce the process of establishing the model.

* Corresponding author. Tel: +13951700970; E-mail address:lj_1981@126.com
① Rodofile N, Radke K, Foo E. Real-time and interactive attacks on DNP3 critical infrastructure using Scapy[J].2015.

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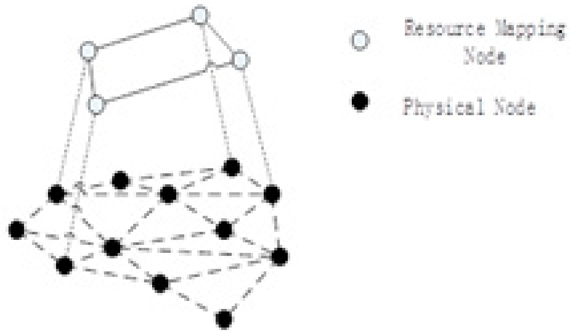

Figure1-1 map of resource mapping

Figure 1-1 is the logical topology of the simplified target, which consists of 3 host nodes and 1 router nodes.

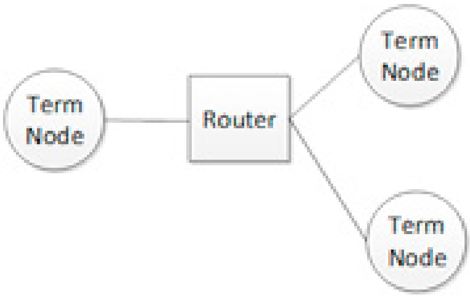

Figure1-2 logical topology

Figure 1-2 is the physical resource topology in the simulation environment, which consists of 4 entity hosts and 1 entity switches, each of which hosts 3 network interfaces.

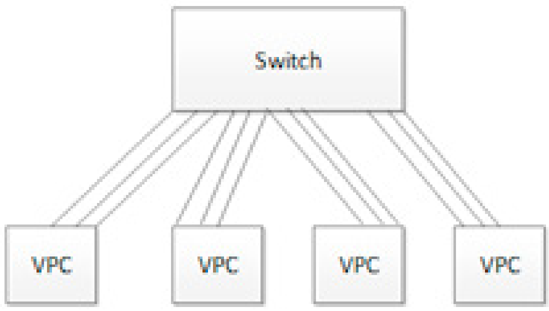

Figure 1-3 physical topology

Figure 1-4 is the result of the final mapping, and all nodes in the logical topology are mapped to the host. By setting a virtual LAN on the switch, a transmission link between nodes is implemented.

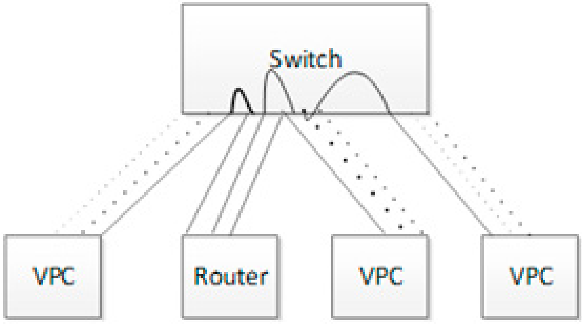

Figure 1-4The physical topology after mapping

1.1 Resource mapping model

It is necessary to give physical nodes and links to the virtual topology, while ensuring that scarce physical resources are not exhausted as quickly as possible, such as network bandwidth. A poor mapping reduces the performance of large-scale software self-defined network simulation, or requires manual intervention at mapping time. This resource mapping problem is similar to that of graph planning and graph embedding, but its specific goals and constraints make it different from these two problems.

There are four aspects considering in the mapping of network resources:

1 The input, including the description of virtual topology and physical resources.

2 The virtual node is mapped to the physical node to ensure that the virtual node& apps needs are satisfied.

3 Mapping virtual links of physical links are to minimize the consumption of bottleneck resources in physical topology.②

4 In sharing resources, avoid using scarce resources as far as possible and maximize the retention of these resources for later use.

1.2 Resource mapping solution

1.2.1 Network LINK

When mapping a node, resource mapping requires the use of bottleneck link traffic resources in the actual physical topology.③ This problem is similar to the NP hard problem: the traveling salesman problem. Given the specific parameters, an undirected graph G (V, E) can be constructed with a positive integer boundary cost. Similarly, we can also construct a physical topology T, corresponding to G. We also construct a virtual network topology V, and one solution is to map the virtual loop V to T with the lowest resource of the physical switch, which is the solution to the traveling salesman problem.

In virtual topology, resource mapping accepts 2 types of network connections: links and local area networks. A link is only a point to point connection between virtual nodes, and contains information about the required bandwidth; the LAN refers to a virtual "Lan node" topology, and all members of the LAN use a standard LAN node link.

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②Wroclawski J, Benzel T, Blythe J, et al. DETERLab and the DETER Project[M]

③The GENI Book. Springer, Cham, 2016:35-62. Srivastava S, Anmulwar S, Sapkal A M, et al. Comparative study of various traffic generator tools[C]

1.2.2 Node type

As the network platform becomes larger and larger, the hardware will become more heterogeneous. For these different configuration hardware nodes, specifying a specific type of hardware is important to maintain the consistency of the network simulation, such as running experiments on a particular hardware in the past, and now this particular hardware operation experiment is needed to ensure consistent results. To solve this problem, a simple type system is designed for resource mapping. Each node in a virtual topology gives a type, and each node in the physical topology gives a list of types that can be satisfied, because a physical node can satisfy more than one type. In addition, each type of physical node is associated with the number of nodes that can be accommodated by this type. This allows multiple virtual nodes to share one physical node.

2 Feedback Sensitive Resource Mapping Algorithm Based on Simulated Annealing

2.1 An overview of the algorithm

The resource mapping uses the random heuristic algorithm, which can help to find the approximate optimal solution in a short time. After the whole comparison, the project chooses the simulated annealing method. ④Simulated annealing algorithm is a random heuristic search technology. Initially used for VLSI design, it is often used in combination optimization problems. It requires a cost function and a generating function. The cost function determines the quality of a particular configuration, and generates changes in the configuration of the function control. The algorithm starts with a very high temperature, so almost all new configurations will be accepted. After a large number of iterations (at least hundreds of thousands of times), the cooling schedule controls the temperature slowly until the final configuration. Obviously, this may not be the best solution, but the goal of the algorithm is to get an approximate optimal solution. Next, we will discuss how the system introduces the simulated annealing method to the design and implementation of resource mapping.

2.2 Algorithm implementation

2.2.1 Initial configuration

A method of simulated annealing is used for resource mapping. Usually, simulated annealing starts with a randomly generated configuration. Resource mapping uses a different strategy, and the violation of resource mapping allows it to start from an empty configuration, that is, no virtual node is mapped to a physical node. For generating functions, mapping unallocated nodes is preceded by other transformations, so the algorithm starts to run some time to reach an effective configuration, which is better than giving an initial configuration randomly, because type information is taken into account.

2.2.2 Cost function

The cost function of the resource map calculates the score of the new configuration and selects a better configuration. Resource mapping will look for all possible links between nodes (direct links, internal links to switches, link between switches) and select one. Direct links are selected first, followed by internal links of switches, and links between switches. For the link between switches, resource mapping uses the shortest path algorithm to find the optimal link mode. If no link is found, any mapping is punished.

A penalty score for a configuration is obtained from the nodes and links it uses (see table 2-1). Internal links of nodes are not punished; links that do not pass any switches are punishing only; slightly higher penalties are internal links to switches.

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④ Engineering and Computational Sciences (RACES), 2014 Recent Advances in. IEEE, 2014:1-6. Duarte V, Farruca N. Using libPcap for monitoring distributed applications[C]

Table 2-1 cost value mapping of resource mapping

Physical resources	Cost score
Node internal link	0.00
Direct link	0.01
Switch internal link	0.01
Inter switch link	0.20
Physical node	0.20
Switchboard	0.50
Physical equivalence class	0.50

Compared with links, the computing cost of LAN is higher because the link only involves 2 nodes, their scoring time is constant, but the local area network can contain many nodes, and their scoring time is linearly increased depending on the number of nodes. Resource mapping treats LAN Connections as a "Lan node". LAN nodes exist only in virtual topology, and in physical topology. The LAN nodes are dynamically bound in the physical topology, and each LAN link within the bound physical switch is the internal link of the switch. All nodes on other physical switches calculate penalty scores. Therefore, when the LAN node reassigns, the penalty score of all related nodes must be recalculated. This is a very time-consuming operation, so it is very prudent to remap the LAN nodes before the annealing process is over to reduce the calculation time, which has a small impact on the final mapping results.

2.2.3 Violation

When simulated annealing is applied, an infeasible solution is allowed, that is, a solution that violates the basic constraint. The main problem is to overuse the bottleneck bandwidth between switches. There are two benefits of allowing the infeasible solution. First, this makes the generating function simpler, because it does not need to consider the feasibility problem; secondly, it makes the search easier to escape the local extremum. If the generating function rejects the unfeasible solution, some mapping conditions will be eliminated, which makes the disconnectedness of various solutions lower, resulting in the isolation of the solution space, which may make the search fall into the local optimal, and allow the existence of the violation, and can smooth the cost function, making the solution space more continuous. Figure 2-1 shows that it is necessary to get into the global optimal from a local best advantage.

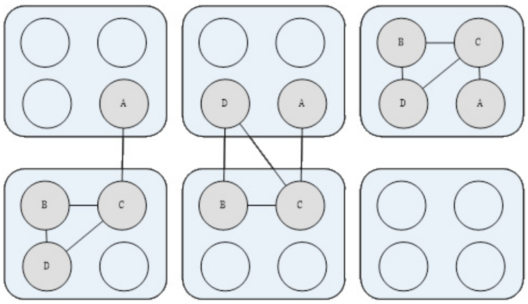

Figure 2-1 allows a violation to help get an optimal solution

It is assumed that there are at most 1 link between switches, and the middle graph has a violation, but as an excess, the optimal solution of all the nodes on the right side in one switch is obtained.

2.2.4 Physical equivalence class

In the physical resources of the system, many simulators have no difference in hardware and network links, and the physical equivalence class is introduced to help resource mapping reduce the computing time and improve the calculation results. [⑤]For generating functions, these nodes are equivalent, and the scores that map any virtual node are the same. Using this equivalence, the amount of calculation can be reduced. The calculation of the solution is related to the number of physical nodes and the product of the number of virtual nodes. If we can effectively reduce the number of physical nodes or the number of virtual nodes to be calculated, the search space can be reduced and the time of calculation can be reduced. In the actual process, reducing physical nodes is more feasible. For example, 168 simulator nodes can actually be divided into 4 equivalent classes, so that the number of physical nodes is reduced by two orders of magnitude, and there is no way to achieve such a significant reduction for virtual nodes.

3 Experimental Results

By default, resource mapping uses polynomial time cooling schemes. At the beginning of the melting stage, almost all configurations at this temperature are accepted. The temperature decreases with the formation of some new configurations. Temperature reduction is controlled by function to ensure that the cost function value is distributed smoothly in the temperature change. Finally, when the derivative of the average cost function reaches an appropriate low value, the algorithm is terminated. The cooling parameters are selected by empirical observation.

The cooling time is linearly related to the two parameters: the number of virtual nodes and the number of physical equivalence classes. The temperature decreasing function and the termination condition depends on how to converge quickly to a good solution.The temperature is reduced proportionately, and the ratio is constant, determined by the chosen time. These two cooling schemes are useful for large topology mapping. In particular, the latter can set a longer computation time to search for better solutions.

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