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Distant Location Selection Using Genetic Algorithm for Live Migration Method in OpenFlow Networks

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Abstract: In the last decade, the massive undersea earthquake and Tsunami occurred in Taiwan on Tuesday December 26, 2006 and Japan on Friday March 11, 2011. Those natural disasters had affected the telecommunication in the worldwide. They disrupted the infrastructures including not only Internet services but also business and financial transactions. Thus, keeping the system and functions alive are particularly crucial to many organizations relying on them. Migration is one of the solutions to keep the systems alive. This paper introduces a migration technique to migrate network systems from origin sites to other remote sites. We propose a Genetic Algorithm (GA) approach to solve shortest path problems for selecting the best possible remote site prior to initiate a migration. Network virtualization in OpenFlow technology is particularly valuable in the implementation to relocate the systems by using network segmentation technique.

Keywords: Network Virtualization, Migration, Network Paging, Segmentation, Genetic Algorithm, OpenFlow Protocol, Slicing

1. Introduction

Internet and its services have become part of the critical infrastructure in daily live and businesses. We are living in the midst of information technology (IT) innovation involving the changes in use, technology, services, and behavior both users and providers. There is almost no practical approach to experiment with new network protocols such as advanced routing protocols or IP replacement. The most original ideas from the networking research community work without implementation and testing [1].

Availability and reliability of network infrastructures is particularly important parameters, due to the importance of Internet services. Content delivery networks (CDNs) are examples of network systems that should provide information to users at any time. Thus, it is tremendously essential to keep systems and their functions alive. Many organizations connect and rely on such systems both hardware and software.

In December 2006, Taiwan undersea earthquake had affected telecommunications including Internet services in many countries. In [2, 3] reported that cable damages resulted to a 98\% cut-off communication between within the Asian region, US, and Europe. The damages affected not only Internet services but also business and financial transactions. The other disasters, earthquake and Tsunami that recently happened to Japan have been affecting many aspects including telecommunication infrastructure and it services.

The WIDE project held in Japan immediately established Post-Disaster Recovery Internet Project (PDRnet Project) after the earthquake. Many volunteers have joined to the project including universities, research institutes, IT companies, governments, and local staffs. They believe that connecting the Internet will help recovery and relief activities towards a long-term solution for sustainable operation. The PDRnet Project brings the first-aid-Internet connectivity and ICT basic working kit to hospitals. The project also establishes temporary shelters when the regular network service is not yet provided based on the most effective technologies suitable to the place [4].

Migration is one important approach to solve such problems. This approach can solve many problems such as disaster avoidance, system recovery, and load balancing. However, the most difficult work of migration is to move the system which has real-time applications such as online games, video conferencing, or live broadcast streaming. We propose a Genetic Algorithm (GA) approach to get the candidate locations and network virtualization technique to migrate the systems to distant locations.

2. Motivation

Genetic algorithm (GA) has been applied to solve many problems in variety fields, including computer networks and telecommunications. It works best in a wide range of low to high-epistasis [5]. GA offers an effective, optimal technique, and multiple solutions to path/route selections, scheduling problems, and queue management. It is a stochastic (random) process and uses learning based (heuristic method) loosely on principles of biological evolution [6, 7, 8].

Internet including technologies and its services becomes complex networks with highly large members serving many applications. The complexity of the Internet could be a problem for network providers when adopting a new architecture. Because of its multi-provider nature on the

Internet technologies, implementing a new technology or modification of the existing infrastructure requires consensus among them. Alteration to the Internet architecture and deployment new network technology has become restricted and more difficult [9, 10]. Therefore, we use OpenFlow technology (FlowVisor) and network virtualization (NV) to structure networks much simpler.

3. Genetic Algorithm

Goldberg in [11] described the common form of GAs. It solves both constrained and unconstrained optimization problems based on a mechanism of natural selection on natural genetics. Among the evolutionary techniques, GAs are the most extended group of methods representing the application of evolutionary tools that rely on the use of a selection, crossover, mutation operators, and replacement by generations of new individuals [12].

GA is one of the heuristic methods based on probabilistic process and the fittest individual surviving in a population. It is an excellent tool for solving a variety of optimization problems that are not well suited for standard optimization algorithms.

There are three main types of operations of GA, namely selection, crossover, and mutation, at each step, to create the next generation from the current population. Figure 1 shows the flowchart of GA procedure while the following terminologies describing the GA's concepts are shown below:

1. **Chromosome** expresses a possible solution to the problem as a string (a set of bits).
2. **Locus** is a position of gene in a chromosome.
3. **Population** is a set of chromosomes (individuals).
4. **Fitness function** results a fitness value from a chromosome as an input and returns a higher value for better solutions.
5. **Selection method** determines how the individuals, called parents, are selected for breeding from the initial population that contribute to the new population at the next generation.
6. **Crossover operation** determines how parents combine to produce offspring (children) for the next generation.
7. **Mutation operation** applies random changes to individual parents to form children.

The GA commonly starts with an initial population which is represented by chromosomes and repeatedly modifies a population of individual solutions. The initial population can be generated in two ways, heuristic initialization and random initialization. The chromosomes evolve through successive iterations, called generations. During each generation, the solutions represented by the chromosomes of the population are evaluated using some measures of fitness. At each step, the GA selects individuals at random from the current population to be parents. It will use them to produce the offspring (children) for the next generation towards optimal solutions as a better new population.

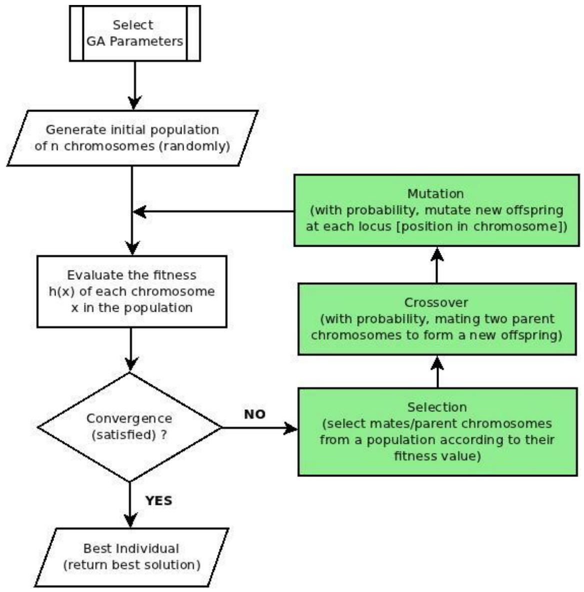

Figure 1. Flowchart of Generation Algorithm

4. OpenFlow Protocol (OFP)

OpenFlow Protocol (OFP) technology [13] has been implemented as a new experimental technology for researchers and practitioners in their production networks. It is an excellent tool as an alternative flow forwarding technique that can communicate within basic function of the switch. It can manage an OpenFlow switch (OFS) from a remote controller as shown in Figure 2. A scheme called FlowVisor in an OFS uses it as a transparent proxy. It has a purpose to control flows between OPS and multiple OpenFlow controllers. FlowVisor provides virtualization technique by creating many slices of network resources and delegates control of each slice to a different controller and enforces isolation between each slice. A slice can be defined by any combination of switch ports, Ethernet address, IP address, ICMP type, and TCP/UDP port [1, 13].

OFP is an open protocol which provides an open and standard way for a controller to communicate to other protocol and technology such as IEEE 802.1Q, IEEE 802.3 and IEEE 802.2 standards. OFS uses Layer 2 (L2) header information to process the flows in a switch, and it comprises many components, namely flow tables, secure channels and the OpenFlow protocol. The switch will use Flow tables to process the flows and a secure channel allows commands and packets to be sent between a controller and the switch and the OpenFlow protocol [1].

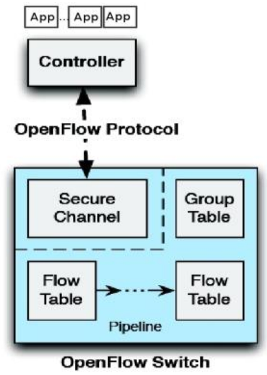

Figure 2. An OpenFlow Switch Communicates with a Controller over a Secure Connection using the OpenFlow Protocol [13].

The OFP is customizable and programmable protocol, and it avoids the need for researchers to program the switch if we specified a standard interface. It is useful to categorize switches into dedicated OFS that do not support normal Layer 2 and Layer 3 processing.

5. Methods

We try to propose the other alternative to establish a network migration to a remote site. We use GA to get the lowest link cost by evaluating each link from origin location to a new remote site. It will look at the flow tables on OpenFlow Controller, slices created by FlowVisor, and router on a border edge network. The objective is to look for a set of flow values within each link from source to destination. GA will solve the shortest-path problems before establish a system migration.

Kanada in [14] has implemented a network-paging based for Wide-Area migration in virtual machines. The authors introduced two network address virtualization technique, namely network segmentation and network paging. They used network paging scheme to solve migration problems.

In this research, we propose to use the other alternative, namely network segmentation with combining Genetic Algorithm to do pre-migration steps. To solve the problem, we define an algorithm to establish the network migration as shown in Algorithm 1.

Algorithm 1: A Network Migration Scheme

STEP 1: Pre-Migration

- Create network slices based on addresses and applications
- Set Origin System: CDN applications, network address spaces (local and global)

STEP 2: Reservation

- Evaluate the shortest path problem using GA from origin site to remote site to get an optimal path for network migration.
- Initialize the selected remote site chosen by GA

STEP 3: Migration Process

- Iterative pre-copy of network address spaces by enabling shadow segmentation
- Copy origin network address spaces WAN and the selected destination spaces on remote site

STEP 4: Post-Migration

- Suspend source network address spaces
- Generate ARP to redirect traffic to new remote site
- Synchronize all remaining process/state to new remote site

STEP 5: Commitment

- Origin system state is released
- Post-process of migration process

STEP 6: Activation

- System on new location (site) is activated
- Connects to local devices (local networks and local hosts)
- Resumes normal operation on new location

6. Results

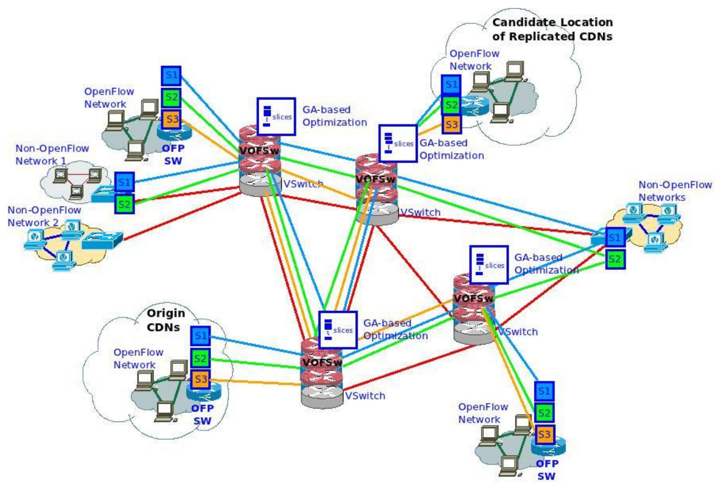

Figure 3. An Example Network Topology in Migration Process

We outline an example network topology to perform network migration as shown in Figure 3. The networks comprise both OpenFlow networks and non-OpenFlow networks. The origin systems, namely Origin Content Data Networks (Origin CDNs) create many slices (i.e. S1, S2, S3) to represent applications or services that run on the system.

The figure shows a candidate remote site as a destination to do the migration. Before migration, we evaluate the average load of each link path from source (origin CDNs) to destination (Replicated CDNs) by using GA.

6.1. Path Selection using Genetic Algorithm

We illustrate the construction of the chromosomes from Figure 3 and Figure 4 as a series of node shown in Figure 5. The chromosome is a genetic representation (i.e. routing or link path). S, Ni (i = 1, 2,… n), and D represent a source node, nodes, and a destination node, respectively. Thus, a chromosome encodes a list of nodes that represents the routing or link path from S to D.

The length of a chromosome depends on the number of nodes from S to D, however, the maximum length is the total number of nodes forming a path in networks. For example, GA can create a chromosome S-N2- N6-D or S- N3- N2- N4- Nk-1- Nk-D. The first locus and the last locus are the source node and the destination code, and the others are randomly selected. The selected node will be removed from the database to prevent double selection and a loop. The encoding process continues until reaching the destination node.

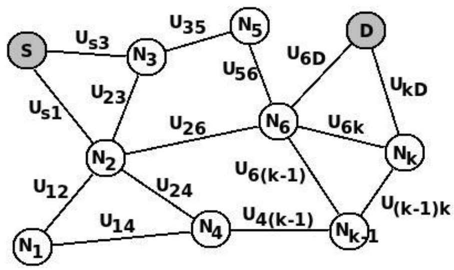

Figure 4. Remote Site Selection by GA

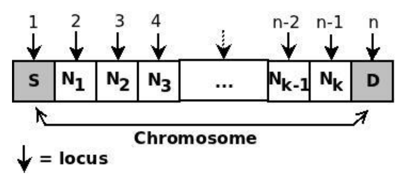

Figure 5. An example of chromosome that represents one of candidate solution

Afterwards, we evaluate the fitness function to get lower average utilization of path from S to D. The objective function defines the most minimum utilization in the path from origin site to the remote site as shown in Formula 1. We define an uncomplicated formula to avoid the complexity in computation to reduce delay.

$$\overline{U}_{ij} = Mean\left(\sum_{i=S}^{D} U_{ij} \times L_{ij}\right) \quad \text{where} \quad U_{ij} = \frac{f_{ij}}{C_{ij}} \quad \text{and} \quad L_{ij} = \begin{cases} = 1; \text{if there is a link from S to D} \\ = 0; \text{otherwise} \end{cases}$$

Formula 1. Average utilization of path from source node to destination node.

6.2. Migration

We use network segmentation based to migrate the origin systems or networks to new remote site. In Figure 5, we illustrate 2 segmentation (or slices, S1 and S2) of virtual networks. The method will map the origin network address space in WAN with no overlap segmentation and duplicate them to reserve in destination. During migration, the users still can access both the origin and destination until the origin state is released as shown in Figure 5.

The purpose of copying a part of the destination network address spaces is to keep the connection still available and provide a transition links from users to the systems. It is profitable to users due to multiple accesses to the same systems.

6.3. Scenario of Evaluation.

This section will provide a scenario of evaluation. It will evaluate the approach whether finding a satisfactory solution or not. GA will evaluate each link on each scenario. Each trial will result best solutions that indicates the lower utilization of link path from source to destination.

Consider a scenario of the evaluation shown in Table 1, which displays an evaluation of GA performance for selecting the better path solution. The entry in each cell of the table is a combination of solutions in each trial. By doing this evaluation, we will know the performance of GA to select the best link condition for migration.

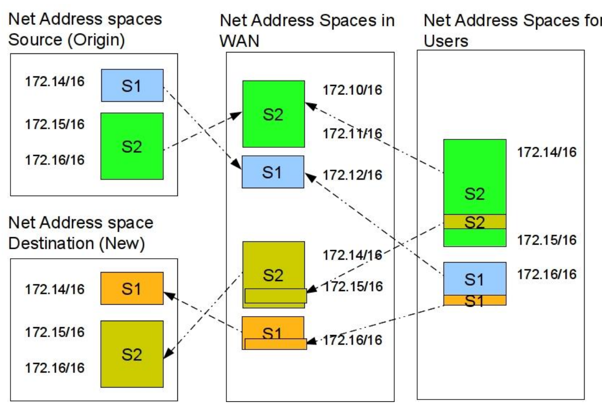

Figure 6. Migration of Network Address

Table 1. Evaluation of Path Selection using GA

Trials	Solution				f(x)
	1	2	…	m	
1	x_{11}	x_{12}	$x_{1\ldots}$	x_{1m}	min$[x_{11,..}, x_{1m}]$
2	x_{21}	x_{22}	$x_{2\ldots}$	x_{2m}	min$[x_{21,..}, x_{2m}]$
…	$x_{\ldots 1}$	$x_{\ldots 2}$	$x_{\ldots}$	$x_{\ldots m}$	min$[x_{\ldots m,..}, x_{\ldots m}]$
n	x_{n1}	x_{n2}	$x_{n\ldots}$	x_{nm}	Min$[x_{n1,\ldots}, x_{nm}]$
GA Performance on Path Selection					Mean[f(x)]

Beside OpenFlow Controller and OpenFlow Switch, we plan to establish management VLAN and routers to keep the network information such as routing and Layer 2 header information.

5. Conclusions

We propose migration scheme that can be used on both non-OpenFlow networks and OpenFlow Networks. The migration scheme will evaluate the shortest-path problem first before establishing the network migration. It will evaluate the average of link utilization from origin sites to candidate remote sites. We hope that this evaluation will decrease the downtime of the migration process such as moving network address reservation to the remote site.

In the next research, we will do the experiment based on the methodology and discussion on section Result. The research will implement the networks in the virtual network testbed that supports OpenFlow technology.

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