УДК 621.391
Hassan Mohamed Muhi-Aldeen, graduate student
Odessa National Polytechnic University
Tkachova O. B., teacher, Doctoral student of the department of infocommunication engineering,
Kharkiv National University of Radio Electronics

A METHOD OF NETWORK RESOURCE ALLOCATION IN THE NETWORKS SUPPORTING NFV TECHNOLOGY

Hassan Mohamed Muhi-Aldeen, Tkachova O. B. A Method of Network resource allocation in the Networks supporting NFV technology. Typical problems of modern telecommunication networks development were analyzed. New method of telecommunication network resources relocation and virtualization was proposed and got mathematical simulation. Developed algorithm takes into account relocation and performance of physical node parameters which are requested to provide the services with the required quality of service level. It was noted that the main advantage of the proposed method is the generation a set of paths to the physical nodes located in the same local area as a degrading service. The experiment results have shown that the total cost of migration could be reduced for the scheme that includes developed algorithms.
Keywords: telecommunication networks, virtualization, NFV Infrastructure, virtual node, resources allocation, objective function, ETSI.

Мухи Алдин Хассан Мохамед, Ткачева Е. Б. Метод распределения сетевых ресурсов в сетях, поддерживающих технологию NFV. Проведен анализ наиболее характерных проблем современных телекоммуникационных сетей. В результате анализа был предложен новый метод перераспределения компонентов и виртуализации сетевых телекоммуникационных сетей; на основе данного метода был построен соответствующий математический аппарат, который адекватно отображает происходящие в сетях процессы. Разработанный алгоритм учитывает параметр производительности узлов системы, которые запрашиваются при предоставлении соответствующих услуг с требуемым уровнем качества обслуживания. Было отмечено, что основным преимуществом предлагаемого метода является создание набора путей к физическим узлам, расположенным в той же локальной области, что и сервис, который подлежит дальнейшей реорганизации. Результаты эксперимента показали, что общая стоимость реорганизации может быть существенно уменьшена в случае внедрения схемы, которая включает разработанные алгоритмы оптимизации системы.
Ключевые слова: телекоммуникационные сети, виртуализация, инфраструктура NFV, виртуальный узел, распределение ресурсов, целевая функция, ETSI.

Мухі Алдін Хассан Мохамед, **Ткачова О. Б. Метод розподілу мережевих ресурсів в мережах, що підтримують технологію NFV.** Проведено аналіз найбільш характерних проблем сучасних телекомунікаційних мереж. В результаті аналізу було запропоновано новий метод перерозподілу компонентів і віртуалізації мережевих телекомунікаційних мереж; на основі даного методу було побудовано відповідний математичний апарат, який адекватно відображає процеси, що відбуваються у мережі. Розроблений алгоритм враховує параметр продуктивності вузлів системи, які запитуються при наданні відповідних послуг з необхідним рівнем якості обслуговування. Було відзначено, що основною перевагою запропонованого методу є створення набору шляхів до фізичних вузлів, розташованих в тій же локальній області, що і сервіс, який підлягає подальшій реорганізації. Результати експерименту показали, що загальна вартість реорганізації може бути істотно зменшена в разі впровадження схеми, яка включає розроблені алгоритми оптимізації системи.
Ключові слова: телекомунікаційні мережі, віртуалізація, інфраструктура NFV, віртуальний вузол, розподіл ресурсів, цільова функція, ETSI.

Introduction. The development of modern telecommunication networks is fraught with a number of difficulties: the increase in the volume and the expansion of the functionality of the services provided entails complicating the management mechanisms and increasing the requirements for the equipment of the network infrastructure [1]. Thus, a number of tasks of the session and application layers are superimposed on the network equipment of the transport and data link layer [2, 3], as well as the need to support a number of additional protocols responsible for managing the transmitted information. The current situation leads either to an increase in the cost of the network infrastructure, or to the occurrence of overloads in the network and, as a result, to a decrease in the quality of the provided services. The level of virtualization is a set of abstractions: virtual machines with different operating systems (OS) and applications and storage centers. They provide the formation and provision of services to end users.

The creation and implementation of networks supporting Network Function Virtualization (NFV) is one of the most promising ways to solve the problem of improving the quality of services. Due to the fact that NFV [2,3] technology allows the software to implement a wide range of functions and services, which are currently provided only by network equipment implemented as hardware (firewalls, edge routers, switches, access servers and others), in the form of open source software. Thus, with the use of

© Hassan Mohamed Muhi-Aldeen , Tkachova O. B.

NFV technology, any type of service can be quickly implemented and provided to the customers in required time and quality terms.

As the popularity of NFV grows, the complexity of their management systems also increases. For example, incorrect resources allocation in the network supporting NFV may result in irrational use and the accuracy of the following problems:

- disbalanced resources distribution/unloading between logical fragments networks in case the intensity of requests for services is low. The disbalance of resources distribution leads to an unjustified increase in the financial costs of supporting both the virtual environment and the physical network lied in the basement;
- potential overload in those areas of the network where the intensity of requests for services is high, which leads to the occurrence of failures and denials of access, and, consequently, the reduction in reliability entails the imposition of penalties.

To eliminate the above disadvantages, the mechanisms of dynamic redistribution of network resources or migration of virtual nodes. However, when developing such mechanisms, several difficulties arise related to the unreasonably high cost of accurately calculating the load intensity, the distribution of requests for virtual network resources, and the level of popularity of the services provided [4, 5].

Lots of work on the development of methods for redistributing network resources is based on the distribution of virtual resources, where the objective function are minimizing bandwidth in the communication channels [6], increasing the level of availability by reserving resources [7] or expensive self-organizing network [8]. The application of approaches [6-8] allows to adapt well enough to network overloads, but it does not allow to estimate the cost of this adaptation - the cost of redistribution of resources, which in some cases leads to inefficient use of resources. Thus, the development of an algorithm that reacts responsibly to the deterioration of service quality in multiservice networks supporting NFV technology, as well as the cost of the process of reallocation of network resources, is an actual task.

Planning and allocation of resources in the networks supporting NFV technology. Accordance to the ETSI recommendations [9, 10], the architecture of the networks supporting Network Function Virtualization technology includes three main components: physical nodes (resources), virtual nodes (resources) и платформы управления и оркестровки сервисов (NFV MANO). The block diagram of the architecture of the network supporting network functions virtualization is shown in Fig. 1.

For a correct cooperation between the physical and virtual components of a network infrastructure component responsible MANO. According to the specifications and recommendations of ETSI [25], the main purpose of the MANO system is to manage the processes of providing services to end users: the MANO system coordinates all actions of the NFV infrastructure equipment, including the search and allocation of network resources required for the formation and provision of services, as well as support and monitoring of the services condition throughout the life cycle.

The NFV Infrastructure (NFVI) is a single platform for processing, storing and transferring data, which is realized through the interaction of physical and virtual network resources. Physical resources of NFVI include server hardware, switching and routing equipment, data storage systems and communication channels. The well-coordinated interaction of these components ensures the correct data transfer from the end user to the computing elements, and vice versa.

The level of virtualization is a set of abstractions: virtual machines with different operating systems (OS) and applications and storage centers. It is provide the formation and provision of services to end users.

Usually the allocate of additional resources both virtual and physical is required during the services provision process. In this case, the lack of physical resources leads to the limitation of virtual resources and, as a consequence, degradation of the quality of services running on virtual nodes. The different mechanisms are implemented with the aim to maintain requested quality of service [4-8], that allow to increase network performance due to forwarding service to the less loaded physical node [7], minimize the required bandwidth [6] during migration process, increase availability due to resources redundancy [8]. The existing algorithms for redistribution of network resources have a common significant drawback - the adoption of a management solution based on statistical data, which does not allow to evaluate the current interaction of network resources.

© Hassan Mohamed Muhi-Aldeen , Tkachova O. B.

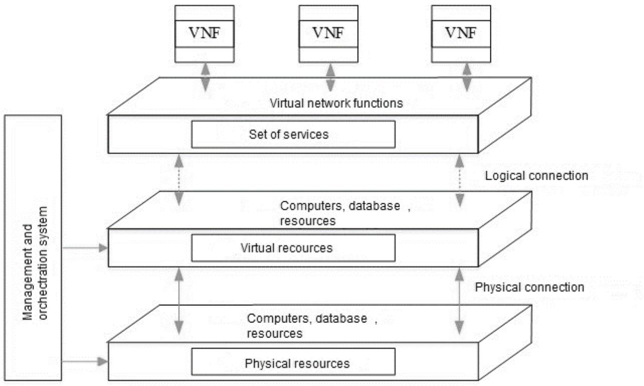

Fig.1.

In order to describe the interaction of network components in the development of the migration algorithm, it was suggesting to use a model approach [11]. The physical infrastructure of a multiservice network is represented by an oriented graph:

$$G_s = (N_s, E_s), \tag{1}$$

where

N_s is the set of network nodes, $\{n_{s1}, n_{s2}, n_{s3}, ... \in N_s)$,

E_s is the set of links between nodes $\{l_{s1}, l_{s2}, l_{s3}, ... \in E_s)$.

The virtual network architecture worked over physical architecture also can be represented by oriented graph (fig. 1):

$$G_v = (N_v, E_v), \tag{2}$$

where

N_v is the set of virtual nodes realized over physical nodes, $\{n_{v1}, n_{v2}, n_{v3}, ... \in N_v)$,

E_v is the set of links between virtual nodes, $\{l_{v1}, l_{v2}, l_{v3}, ... \in E_v)$. Each virtual node $n_{vs}, \{v \in N_v)$ is characterized by performance, each arc is characterized by bandwidth capacity $a_{l_v}(t)$.

In RFC 7149 [12], IETF P1903.3 [13], ETSI GS NFV 002 [14] proposed to provide analysis and further evaluation the set of network characteristics with aim to provide the complex estimation of service provision quality. Proposed to analyses the following network characteristics:

- cost of service provision *c(s)*;
- response time *t(s)*;
- reliability *r(s)*;
- availability *a(s)*.

In general, the value of chosen network characteristics *t(s), r(s), a(s)* can characterize by complex indicator. The value of complex indicator depends on as well as performance both physical and virtual nodes and bandwidth ability. The complex performance and bandwidth can characterize by the following equation:

$$\begin{aligned} p_s(t) &= p_{n_s}(t) + p_{v_s}(t); \\ Th_s(t) &= \min(Th_{l_s}(t), Th_{l_v}(t)), \end{aligned} \tag{3}$$

where

$p_{n_s}(t)$ is performance of physical node in the time t,

$p_{v_s}(t)$ is performance of virtual node in the time t.

Virtual node performance always depends on physical node performance $p_{v_s}(t) < p_{n_s}(t)$.

© Hassan Mohamed Muhi-Aldeen , Tkachova O. B.

$Th_{l_s}(t)$ is an available bandwidth of physical channel in the time t,

$Th_{l_v}(t)$ is in available bandwidth in the time t. Bandwidth of virtual channel always depends on bandwidth of physical channel $Th_{l_s}(t)$ and cannot bigger that $Th_{l_s}(t)$: $Th_{l_v}(t) < Th_{l_s}(t)$,

In case of the physical node is not able to provide necessary for the effective operation of virtual resources performance and, as result, the required level of quality cannot be provided the mechanisms resource allocation are activated.

Reallocation of resources is carried out by migrating the virtual node from original physical node to another, less-loaded, physical node. Proposed method of resources relocation based on the analysis of the current performance of physical nodes and cost of migration.

The result of the functioning of the algorithm is a set of physical nodes with the required level of performance, the cost of migration for which is the smallest.

The objective function $Q()$ of proposed method can be characterized by the following formalization:

$$Q(p_s, C_{tot}(n_v)) \to \min_{CP_\alpha}, \tag{4}$$

where

p_s is the performance,

c_s is the cost of migration,

CP_α the management rules and policies.

In the analyzed case the optimization task can be reduced to the search of minimum value of the total cost of network resources reallocation - $\min(C_{tot}(n_v))$

The total cost of resources reallocation includes the following components:

- the “deploying” cost. The “deploying” cost is the cost of the degradation service implementation on another physical environment. The “deploying” cost includes the cost of service downtime during the selection of alternative physical nodes and preparation for implementation, $C_{reloc}(n_v)$;

- the cost of connection maintaining or migration cost. The cost of connection maintaining is the cost of service movements between new physical environment and environment where degradation service located. The cost of connection maintaining includes the cost bandwidth reservation and support of requested performance, $C_{mig}(n_v)$.

The total resources allocation cost can be characterized by the following equation:

$$C_{tot}(n_v) = C_{suspend}(n_v) + p_{n_s^r}(t) * C(M_{N_v^r}(n^r)) + \sum_{l_s} \sum_{l_v \in M_{L_v^r}} C(M_{L_v^r}(l^r)), \tag{5}$$

where

$p_{n_s^r}(t)$ is the alternative physical node corresponded to the QoS requirements;

$C(M_{N_v^r}(n^r)$ is the “deploying cost”;

$C(M_{L_v^r}(l^r)$ is the migration cost.

The migration cost of includes the cost of allocating / reserving the bandwidth required for migration. The migration cost can be determine by the following equation:

$$C_{mig}(n_v) = C(l_s) * \sum_{l_s \in p_{mig}(n_v^r)} \min Th_{l_v^r}, \tag{7}$$

where

$l_s \in p_{mig}(n_v^r)$ is the route for migration of degradation service to the new physical node.

© Hassan Mohamed Muhi-Aldeen , Tkachova O. B.

The total migration cost includes the cost of reallocation of resources and direct cost of migration:

$$C_{tot}(n_v) = C_{reloc}(n_v) + C_{mig}(n_v) . \quad (8)$$

The main aim of proposed algorithm of resources allocation is the find out such the rought $l_s \in p_{mig}(n_v^r)$ for migration that has minimum total component of the cost of redistribution is minimized $C_{tot}(n_v) \to \min$

To archive the aim the following steps are proposed:

- the definition of virtual nodes set, the migration of which is necessary – nodes with the load constantly increasing, and productivity, with increasing load, decreases (as a rule, there is a decrease in the physical node);

- the definition of the set of most suitable for migration physical nodes, which are located in one zone with a degrading service. As such nodes are the most tolerant to crashes and overloads;

- searching the routes allowed to ensure the lowest cost and final choice of nodes for migration. the algorithm should effectively map nodes and links to achieve the minimum goal of redistribution and migration;

- $C_{reloc}(n_v)$ and $C_{mig}(n_v)$ calculation.

A pseudo-code describing the behavior of the developed algorithm can be represented as follows:

```
Reallocate(nv, min(Ctot(nv)))
RealLocationResult←failure
Remap Ctot(nv) ←∞
Search neartnrv
if neartnv is less than required then
  for all ns ∈ near nv(degrad)
     do map nv in ns
     for all lv ∈ Snv do
     re-map virtual node to physical node
   end for
if Ns mapping succeeds then
ReallocationResult success
if Creloc(Ns) < Creloc(Ns+i)  then
    do route nv(degrad) in Ns
    for all lv ∈ Es ∩ Ev do
       do route nv in ns
       for all lv ∈ Snv do
route virtual link ls onto a substrate path α using shortest path
algorithm
       end if
      end if
     end if
end for
if ReallocationResult = Success then
Add Creloc(nv) + Cmig(nv) to Ctot(nv)
end if
end if
return ReallocationResult
```

Evaluation of the proposed method of resources allocation

Mininet network emulator was used [15] to simulate activities of the fragment of network supporting NFV technology. The topology of the experimental fragment of the network is shown in Fig. 2.

© Hassan Mohamed Muhi-Aldeen , Tkachova O. B.

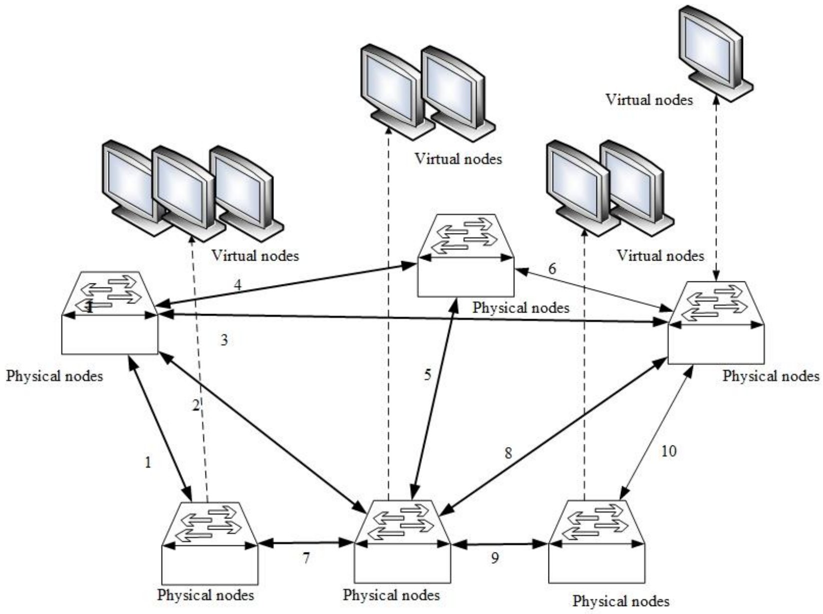

Fig. 2. Fragment of the experimental network

During theexperiment the following well-known algorithms has been used: RSforEVN [8], DVNMA_NS [16] and proposed algorithm.

The following metrics has been used for experimental results evaluation:

- the “deploying” cost $C_{reloc}(n_v)$;
- the migration cost $C_{mig}(n_v)$.

The following data has been used as an input data:

- the threshold of physical node performance– 80%;
- bandwidth threshold – 1,2 Mbps;
- response time threshold – 350 ms;
- maximum data value is allowed in case of migration – 780 Mb.

Experimental result is provided in the Table 1.

Table 1.

Experimental result

The “deploying” cost $C_{reloc}(n_v)$		
RSforEVN	DVNMA_NS	Proposed algorithm
77	450	97
The cost of migration $C_{mig}(n_v)$		
RSforEVN	DVNMA_NS	Proposed algorithm
126	457	115

As the results of the experiment show, the cost of the planned reallocation of the resources of the developed algorithm is not significantly inferior to the cost of RSforEVN, but 4.5 times less than the cost of DVNMA_NS, and when estimating the cost of migration, it is minimal. The main advantage of the developed algorithm is the choice of the nearest alternative physical nodes, the performance of which does not exceed the specified limit, which allows to significantly reduce the cost of migration.

Conclusion. The method of network resources relocation in networks supporting network function virtualization is proposed in the work. The proposed algorithm takes into account such network parameters as a cost of resources relocation and performance of physical node requested to provide the services with the required QoS level. The main advantage of the proposed method is the generation a set of paths to the physical nodes located in the same local area as a degrading service.

The model includes two stages: generation the set of paths based on the criteria (2)-(4) and calculation of migration cost for each paths (5)-(8).

© Hassan Mohamed Muhi-Aldeen , Tkachova O. B.

The experiment results show the total cost of migration is reduced in the case of using proposed algorithms.

1. Agushaka J. O. Effect of Weighting Scheme to QoS Properties in Web Service Discovery/Agushaka J.O., Lawal M. M., Bagiwa, A. M. and Abdullahi B. F//International Journal of Computer Science and Information Security Vol. 7 No. 3 March 2010. P.92-100.
2. ETSI Industry Specification Group (ISG). NFV, ETSI GS NFV 002 V1.2.1: Network Functions Virtualisation (NFV); Architectural Framework [online]. Available at: http://www.etsi.org/deliver/etsigs/NFV/001099/002/01.02.0160/gsNFV002v010201p.pdf, December 2014.
3. ETSI Industry Specification Group (ISG). NFV, ETSI GS NFV-MAN 001 V1.1.1: Network Functions Virtualisation (NFV); Management and Orchestration, http://www.etsi.org/deliver/etsigs/NFV-MAN/001099/001/01.01.0160/gsNFV-MAN001v010101p.pdf, December 2014.
4. Tran P.N., Timm-Giel A. Reconfiguration of virtual network mapping considering service disruption. In: (ICC), 2013. P.160-169.
5. Lu J., Turner M., Efficient Mapping of Virtual Networks onto a Shared Substrate. Tech. rept. Washington University in St. Louis, Jonathan. 2006. 152 p.
6. Zhang S., Sheng Q. and all. Virtual Network Embedding with Opportunistic Resource Sharing. Parallel and Distributed Systems, IEEE Transactions, 2014. Vol. 25(3), P. 816–827.
7. Zhani M.F., Zhang Q., Simon G. VDC Planner: Dynamic migration-aware Virtual Data Center embedding for clouds. In: Integrated Network Management (IM 2013), 2013 IFIP/IEEE International Symposium on. 2014. P.112–118.
8. Jmila H., Houidi I., Zeghlache D. RSforVNE: Node Reallocation Algorithm for Virtual Networks Adaptation. In: 19th IEEE Symposium on Computers and Communications (IEEE ISCC 2014).
9. NFV.Network Operator Perspectives on Industry Progress. Online. Available at: https://portal.etsi.org/NFV/NFV_White_Paper2.pdf
10. Infonetics Research, Inc. SDN and NFV Strategies: Global Service Provider Survey [Электронный ресурс]. 2014 39 с. Режим доступа: http://alu.us.neolane.net/res/img/286758382c7e061c52883e873cee02e6.pdf
11. Поповский В. В. Математические основы управления и адаптации в телекоммуникационных системах: [учебник] / В. В. Поповский, В. Ф. Олейник. - Х. : СМИТ, 2011. 362 с. ISBN 978-966-2028-72-0.
12. ITU-T Recommendation E.802. Series E: Overall network operation, telephone service, service operations and human factors - Framework and methodologies for the determination and application of QoS parameters. Geneva: International Telecommunications Union. – 2007.
13. P1903.3 - Standard for Self-Organizing Management Protocols of Next Generation Service Overlay Network (NGSON)
14. GS NFV 002 Network Functions Virtualisation (NFV); Architectural Framework. 15. Mininet: An Instant Virtual Network on your Laptop (or other PC) [Элекронный ресурс] – Режим доступа: http://mininet.org/
15. Sun G., Yu H., Anand V. A cost efficient framework and algorithm for embedding dynamic virtual network requests. Future Generation Comp. Syst., 2013. Vol. 29(1), P.1265–1277.

© Hassan Mohamed Muhi-Aldeen , Tkachova O. B.