Towards a QoS-Oriented Migration Management Approach for Virtualized Networks

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Abstract. Virtualization environments are dynamic and polymorphic, consequently they require complex management for both, physical and virtual elements. This research addresses the need for a management approach that can drive virtual network migration systematically to guarantee the required levels of Quality of Service (QoS) in virtual networks. This paper describes a framework that includes the processes needed to manage QoS in migration scenes. A selection of policies that will help in systematizing QoS-oriented virtual network migration are described as well. Test results are provided with the intention to emphasize the difficulty and need for formal research in this direction.

1 Introduction

Network virtualization continues attracting attention from academia and industry. This paradigm allows several Virtual Networks (VNs) deploy on top of the same physical infrastructure without interfering each other. VNs may come and go over time, they could change their Quality of Service (QoS) requirements and demands over time, and the underlying physical networks may experience their own dynamic changes. In the networking research area, the community has invested significant efforts developing VNs mapping approaches, exploiting majorly the use of metaheuristics to optimize metrics like VN acceptance ratio, embedding cost, and time to embed VNs onto physical infrastructures [1]. Moreover, although these solutions have been proved to be efficient to find trade-offs between physical resource usage and VN provisioning, the development of efficient VNs migration management approaches have received very little attention.

A selection of VN migration aspects have been addressed by three exceptional research works. The authors in reference [2] propose a VN mapping algorithm supporting path splitting and for such split paths a basic migration mechanism is proposed. The authors in reference [3] propose a selective VN migration scheme that prioritizes the hop count of virtual link to drive link migrations of the most critical VNs. More recently authors in reference [4] propose an embedding algorithm with a migration option in which physical link bandwidth (BW) utilization is driven to trigger virtual link migrations. Although these works have addressed VN migration issues, all of them

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leave aside node migration, as well as both, additive and non-additive QoS constraints of the VNs. It is taken for granted by the research community that VN providers (VNPs) must support virtual networks without having to operate under continuous human care, and VNs should be self-(re) configured taking into account the constraints of network elements, the dynamics in the network and the different levels of QoS of the deployed services. Our research work strives to contribute to the state of the art by defining a VN migration management approach intended to maintain QoS of virtual networks. More precisely, we intend to contribute with: (1) novel VN migration mechanisms that keep the required QoS levels of VNs; (2) VN migration strategies that consider the dynamics of the services deployed on VNs, the efficient use of network resources, and the potential costs involved in the migration process; (3) identifying the most appropriate VN migration strategies that converge to QoS delivery and efficient resources usage. This paper presents the initial steps in this direction. Namely, we present an initial migration framework, a selection of QoS-oriented policies and an overall procedure to systematize migration of virtual links.

2 Migration Framework

This section describes our ideas for a QoS-oriented migration framework. In order to maintain the required QoS in the VNs, migration management techniques should be implemented to decide which virtual elements (links, nodes) are subject of reconfiguration, and when to trigger such reconfigurations. The framework includes three components, namely monitoring, virtual network service management, and virtual network embedding management. Monitoring tasks provides information about usage and availability of physical resources (CPU, memory, bandwidth, etc.). QoS management in general requires static and online control over subscribed services [5]. In the context of our work, services are VNs that are first subscribed via VN requests, and they are mapped into the network via a VN embedding process to make them available to the SPs. VN service management includes VN-Subscription that handles the required topology, QoS requirements and the time to activate the VNs as they are requested. This information is used to draw estimates about additive and non-additive QoS constraints of the VNs to be considered in the mapping and also in the migration process. Virtual network embedding management includes two key elements of the framework, namely embedding and VN migration. Embedding deals with finding optimal mappings of VN requests onto the substrate network and it is addressed by means of metaheuristics. VN migration process (described later) is responsible to migrate virtual networks (nodes and links) between physical resources systematically. Both processes have impact on each other in terms of embedding cost, VN acceptance ratio, and revenue.

3 QoS-Oriented Migration Procedure

The foreseen technical approach for QoS-oriented VN migration management process consists of four stages described hereafter. First, resource bottlenecks in physical resources usage are identified through monitoring physical resources. Second, critical virtual links and/or virtual nodes with high potential to get migrated are identified based on the remaining time, arrival time and departure time of the VNs supported by the bottleneck resources. The third stage is a critical one, it is intended to define the physical resources that would support the virtual resources to-be-migrated. This process considers the additive (delay and hop count) and non-additive (CPU and BW) QoS parameters of the VNs supported by bottleneck resources. We define this process as the Virtual Link Migration Problem (VLMP), which consists of finding a physical path p from a given source, s to a given target t such that the path p meets three conditions: availability, feasibility and optimality. (1) Availability: the physical path p should have enough non-additive resources to support the virtual link to be migrated. Lower bound threshold values are defined to meet the CPU and BW constraints of the virtual link subject of reconfiguration. A basic pruning algorithm is used for this condition. (2) Feasibility: the path p should meet additive constraints. Upper bound threshold values are defined to meet the delay and hop count constraints of the virtual link to be migrated. A reverse-Dijkstra algorithm is used to evaluate this condition [6]. (3) Optimality: the path p is chosen based on options that are taken to meet the agreed QoS targets of virtual link to be migrated. The possible options are; minimize delay, minimize BW in use, minimize CPU in use, or a combination of them. A look ahead Dijkstra algorithm is used to evaluate this condition [6].

The three VLMP conditions described earlier are controlled by the threshold values for availability and feasibility conditions, and the optimality option in the third condition. These are critical aspects that drive the migration process. In this regard, we introduce the concept of migration policies as an important aspect to systematize QoS-oriented migration. We believe that the traffic characteristics and the QoS requirements of the VNs can be used to define, classify and prioritize appropriate VN migration processes. For this reason we propose policies that can be used to drive migration systematically, linking the three VLMP conditions with QoS-aware migration decisions. The objective of migration policies is to find paths with low delay (Policy 1), paths with high available BW (Policy 2), paths with high available CPU (Policy 3), paths with high available CPU and BW (Policy 4), paths with high available CPU and BW and low delay (Policy 5), and paths with high available CPU and BW, as well as low delay and hop counts (Policy 6). For example, the network administration would choose Policy 1 to migrate virtual links with low delay constraints, whereas Policy 6 should be used to find high available physical resources for virtual links with low delay and hop count requirements.

4 Partial Results

We have implemented the migration management process described in this paper in a discrete event simulator. This section describes the effect of QoS-oriented migration policies in the embedding process. Six metaheuristics for the embedding were implemented Genetic Algorithm (GA), Ant Colony (AC), Particle Swarm Optimization (PSO), Firefly Algorithm (FA) and Harmony Search (HS). The configuration parameters of our simulations are similar to the ones used in the literature for the same purposes [1]. We have defined three values of QoS parameters for the VN requests,

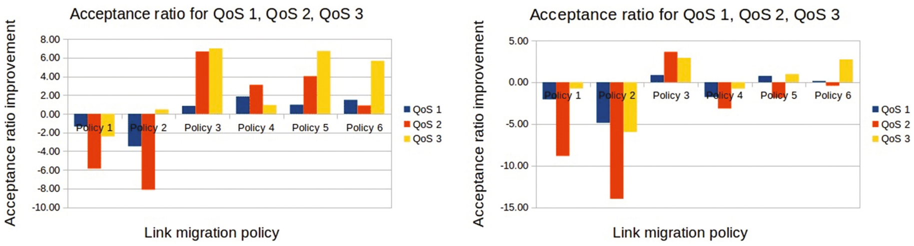

Fig. 1. Improvements (%) for HS (LEFT) and FA (RIGHT) embedding algorithms

modeled as follows: QoS (delay, hop-count, CPU, BW). The three QoS requirements used in our simulations are: QoS1 (20 ms, 3 hops, 60 %, 60 %), QoS2 (10 ms, 4 hops, 50 %, 50 %), and QoS3 (30 ms, 4 hops, 80 %, 80 %) respectively. For each QoS we executed one experiment. Each experiment consisted of 31 execution runs in order to get statistically valid results. Figure 1 shows the results of the HS metaheuristic (left), which outperformed the rest in acceptance ratio metric and the results of FA metaheuristic (right), which is the one with the worst performance out of the six metaheuristics implemented. Very little improvements are achieved for QoS1 in all policies; the highest improvement is 2 % with policy 4. QoS2 and QoS3 are majorly improved by policies 3, 5, and 6; the highest improvement is 6 % with policy 3. Migration policies 1 and 2 do not enhance the embedding in any case with our simulation settings. Through simulation, it is a fact that migration policy enforcement has an effect, which needs to be formally correlated with QoS requirement patterns, VN embedding algorithms and other aspects like topology features and dynamic changes in the physical network. These are important and relevant aspects that will drive our immediate research work.

5 Concluding Remarks and Future Work

We have presented our progress towards a QoS-oriented migration management approach for virtualized network environments. A preliminary framework has been proposed with the intention to identify the required processes needed to manage QoS in migration scenes. A novel contribution of this paper is a migration process driven by policies that systematize QoS-oriented migration. The migration policies are meant to give control capabilities to the network operator as they can be used to define, classify and prioritize appropriate VN migration processes depending on the traffic characteristics and QoS requirements of the VNs. Our preliminary results show that the migration policies have impact depending on the QoS of the VNs. However, more advanced analysis is needed to correlate effective migration policy enforcement with QoS patterns, physical and virtual topology patterns and dynamic changes in the physical network. This will allow the production of self-adapting mechanisms to find trade-offs between optimal resources usage and QoS delivery.

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