# AAVP: An Innovative Autonomic Architecture for Virtual network Piloting

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# AAVP: an innovative Autonomic Architecute for Virtual network Piloting

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## 1. INTRODUCTION

In the few last years, network virtualization concept has attracted a great deal of interest from both industry and research communities as an important enabler for designing the future Internet architecture. In fact, Internet's success stimulated the development and the deployment of new technologies and advances applications. However, the largest public wide network becomes victim of its own success. Its size and scope are now creating obstacles to future innovations and make difficult the introduction and the deployment of new network technologies [1][2][3].

So, an ambitious vision of futur Internet would include network virtualization. This new paradigm provides a promising way to run multiple architectures simultaneously on a single infrastructur. It enables the sharing of a physical network between many virtual networks and provides a clean separation of services and infrastructures. Besides, it facilitates new ways of doing business by allowing the trading of network resources among multiple providers and customers [3][**?**]. Various architectures, experiments and services can be simultaneously supported by Virtual Networks (VN) [1][2][7].

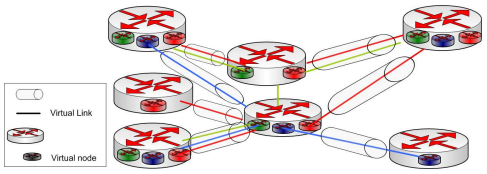


Fig. 1. Network virtualization model

As depicted in Figure 1, a virtual network consists of a set of virtual nodes interconnected via dedicated virtual links. A substrate node is a physical equipment

which is able to support many virtual nodes. Each virtual node belongs to a dedicated virtual network supporting a specific service or protocol. These virtual nodes are interconnected via virtual links shared over one or more substrate links.

Network virtualization presents a diversified Internet architecture. It supports multiple coexisting virtual heterogeneous networks, sharing a common physical substrate. However, network virtualization adds more complexity on network systems. Indeed, every service is hosted inside a virtual machine which itself is hosted inside a physical equipment. These virtual and physical machines must communicate with each other in a reliable manner to guarantee user's requirements and needs. In such a complex and dynamic environment, autonomic management approaches are needed.These approaches aim to address problems associated to current network management by pushing the responsibility of ensuring the proper operation of network to algorithms and processes that exhibit autonomic characteristics [6].

In 2001, IBM proposes the "Autonomic Computing" paradigm [5] to manage the complexity increase in the computing systems. Autonomic Computing is a system management referential that aims to introduce in the systems' core self-regulation mechanisms. The term "autonomic" comes from the human anatomy vocabulary, where the "autonomic nervous system" means the part of our nervous system whose role is the self-regulation of our organism. IBM Research [6] has defined four properties namely self-configuration, self-optimization, self-protecting, self-healing known also as the self-* functions. They have suggested in addition to the self-* properties, a reference model for autonomic control loops necessary to achieve autonomic computing. The autonomic networking pursues the same objectives applying to the large-scale networks. Its goals are to overcome the network complexity by developing new kind of networks capable to self-manage and to support the upcoming growth and complexity.

We outline that the main contribution of our paper is to propose an autonomic framework which is able to self-provision and self-manage virtual resources. The main goal of the proposed multi agent based framework described in this paper is to address "cleverly" management's complexity and to offer reliability and scalability for virtualized networks.

The paper proceeds as follows. Section 2 summarizes the related work. In section 3, we propose and describe AAVP: an Autonomic Architecture for Virtual network Piloting to deal with instantiated resources during the lifetime of the Virtual Network. We describe the testbed setup and experimental results in section 4. Finally, section 5 concludes the paper and presents our ongoing work.

## 2. STATE OF THE ART AND OVERVIEW OF NETWORK VIRTUALIZATION

Network virtualization presents a diversified Internet architecture. It supports multiple coexisting virtual heterogeneous networks, sharing a common physical substrate. Various architectures, experiments and services can be simultaneously supported by Virtual Networks (VN) [1, 2, 16]. In this section, we first present the concept of virtual networks. Then, we describe network virtualization model and actors. Finally, we illustrate the related business scenario.

### 2.1 Virtual network vs VPN

The concept of network virtualization is not new. The co-existence of multiple virtual networks appeared in the networking literature with the VPN (Virtual Private network) based networks. VPNs have known a great success of deployment. They connect multiple distributed sites of one or more enterprises through tunnels over shared or public networks such as the Internet [12]. However, actual network virtualization concept, has offered new commodities among others:

—Virtual networks sharing the same physical infrastructure may have different technologies and protocol stacks. This enables the coexistence of different networking solutions which is not possible with VPN.

—Virtual networks provide a real isolation of virtual network resources which is not possible with VPNs.

—The roles of the infrastructure provider and the virtual network provider are clearly separated in virtual networks. However, they are played by the same entity in the VPN.

### 2.2 Network virtualization' actors

Actors in the network virtualization model are different from those in the traditional networking model. The principal actor in the current Internet is the Internet Service Provider (ISP) [9, 10, 11]. In network virtualization, this main actor is decoupled into two actors: Infrastructure Provider (InP) and Virtual Network Provider (VnP). From commercial point of view, this decoupling amortizes high fixed cost of maintaining a physical presence by sharing capital and operational expenditure across multiple infrastructure providers [13].

2.2.1 *Infrastructure Provider (InP).* The infrastructure provider owns and manages physical network resources in the network virtualization environment. It offers virtual resources to Virtual Network Providers who are its direct clients. It does not offer direct services to virtual network end users. We note that a physical infrastructure can be shared by many InPs. They communicate and collaborate among themselves to create the complete underlying physical infrastructure (4 Fig 2). They are also responsible for its maintenance.

2.2.2 *Virtual Network Provider(VNP).* The Virtual Network Provider is responsible for the creation and the deployment of virtual networks. It leases resources from one or multiple InP (3 Fig 2) to offer end-to-end services to its clients (virtual network users). It can also lease virtual resources to Virtual Network Provider (2 Fig 2). We recall that each virtual network is managed by one VNP. A virtual network provider deploys its own protocols, services and applications in order to meet end user requirements.

2.2.3 *Virtual Network User (VN User).* The VN User requests a virtual network from Virtual Network Provider (1 Fig 2). A virtual network user may connect to multiple virtual network providers for different services. VN users actors generally correspond to end users, specific service providers (for example Internet Service Provider, video games provider, grid computing provider,etc.), etc.

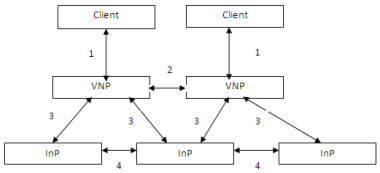


Fig. 2. Intraction model between network virtualization actors

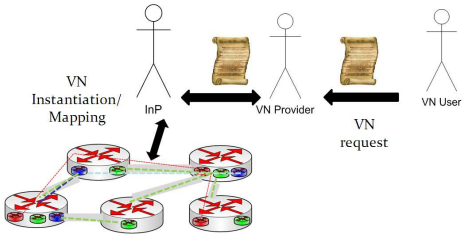


Fig. 3. Business Model

### 2.3 Business Scenario

As depicted in Figure 3, the client (VN User) specifies its service requirements. Then, it delegates the instantiation of the virtual network to the VNP of its choice.

Once the VNP receives the client service request, it generates a VN specification. Then, it negotiates the offer with candidate InPs and splits if necessary the VN resources description into multiple subsets. Based on the VN description, an InP identifies the appropriate substrate resources and allocates them. The InP has also the ability to migrate other VN in order to free resources for new requests. Once the VN is instantiated, the client deploys its service.

## 3. AUTONOMIC SYSTEMS

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## 4. RELATED WORK

We find in the literature a number of systems and techniques that have been put forward to provision and manage virtual networks resources. For virtual network provision, authors propose greedy algorithms to efficiently assign VN to substrate resources. In [7], authors propose an embedding algorithm with admission control and online requests. This algorithm offers periodic re-optimization mechanisms like path splitting and path migration. Moreover, in [8], authors propose a method for mapping a virtual network in a cost-efficient way to ensure that instantiated virtual networks are able to handle any traffic pattern. Besides, [9] proposed an algorithm for virtual network assignments with dynamic reconfiguration.

We note that these proposed approaches are treated on a centralized way. Authors assume the existence of a central entity which has a global view of the entire network and all the information related to each node and link. Based on this vision, this centralized entity takes best Virtual network provision and configuration

decisions. However, in a real environment, network parameters are very dynamic and equipments are numerous and heterogeneous. Hence, a central approach is not suitable and suffers from scalability limitations, information updates problems and high latency decisions.

To manage virtual networks, many papers propose different primitives and mechanisms. [11] proposes VROOM (Virtual Router on the Move), a primitive for virtual network management. It offers a free move of virtual resources (routers and links) from one physical equipment to another to simplify physical network-management tasks. Moreover, [12] proposes techniques for dynamic allocation of processing resources (CPU) to virtual machines. Furthermore, in [13], authors present an autonomic system called VIOLIN. It is a virtual computational environment composed of virtual machines capable of live migration across a multi-domain physical infrastructure.

Besides, an autonomic approach for virtual resource control and management was proposed in [14]. This approach provides a system based on autonomic computing and virtual networks concepts to meet SLA-based IP packet transport service 's requirements on core network infrastructures. However, this proposed architecture has not been implemented and no examples have been presented to instantiate different components. So real performances of proposed system are unknown.

## 5. AAVP:AN AUTONOMIC ARCHITECTURE FOR VIRTUAL NETWORK PILOTING

In this section, we propose an autonomic system to provide resources and manage virtual networks. Using high level goals and based on distributed algorithms and network level knowledge, autonomic entities making our system collaborate together to instantiate and manage virtual resources. This minimizes human intervention and leads to an effective cost operator

Our autonomic and distributed system aims essentially to :

—Reconfigure its instantiated virtual networks at run time as network conditions change over time due to the arrival and departure of VNs,

—Optimize the use of its resources whether physical or virtual to maximize its service revenue. It could be through forecasting variations and future demand,

—Localize, diagnose and identify the problem then repair it by itself and without human intervention.

### 5.1 Network Infrastructure

As depicted in the Figure 4, our autonomic system is composed of physical network equipments (routers, access points, etc.) interconnected with each other through physical links. Each network equipment is able to embed many virtual nodes. Virtual nodes are interconnected with each other through virtual links embedded in physical links. These physical network equipments are piloted by autonomic entities. In order to pilot virtual resources, autonomic entities exchange knowledge within the range of a logical and physical neighborhood. The knowledge concerning the neighborhood of each autonomic entity is called "situated view".

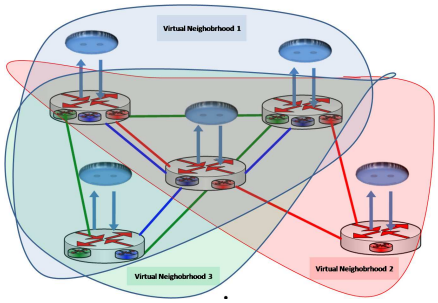



Fig. 4. Virtualized Network Infrastructure

### 5.2 Situated View

The Situated view represents the environment vision of an autonomic entity. This environment is the knowledge concerning local equipment and its neighbors. As depicted in the Figure 4, an autonomic entity may have two types of neighbors:

—Physical neighbors which are neighbors that are physically connected to autonomic entities,

—Logical neighbors which are virtual neighbors. An autonomic entity maintains a neighborhood for each virtual network.

### 5.3 AAVP description

We propose in this article, an autonomic agent-based platform to manage the complexity of virtual network. Moreover, our designed platform is proposed for large scale network. It is distributed and this distribution is possible thanks to autonomous agents which are embedded in routers and disseminated over the network.
An agent is a piece of software which is able to evolve in un uncertain environment and possesses the autonomy to make decisions.
As shown in Figure 5, our architecture consists of the following components:

5.3.1 *Knowledge Base (KB).* The knowledge base represents the core of our autonomic architecture. It offers a common vocabulary to different network equipments which may have different data management tools. Thanks to the knowledge stored in its KB, each autonomic entity acquires a vision of its own equipment and its environment. The knowledge base is organized of classes connected to each other in order to describe the virtual environment of an equipment. These classes are instantiated on individuals which are regularly diffused in a predefined neighborhood (one neighborhood is defined by either a shared network medium or a list of Piloting Agents). New individuals are automatically added to the Knowledge Base of a Piloting Agent upon their receipt from another agent. The situated view concept described above is implemented thanks to the knowledge base.

The Figure 6 depicts the knowledge base model which is represented in Unified Modeling language(UML). We chose UML because of its comprehensive nature widespread in different fields of computer science. As shown in the figure 6, a topology is a set of node interconnected with each other through links. A node

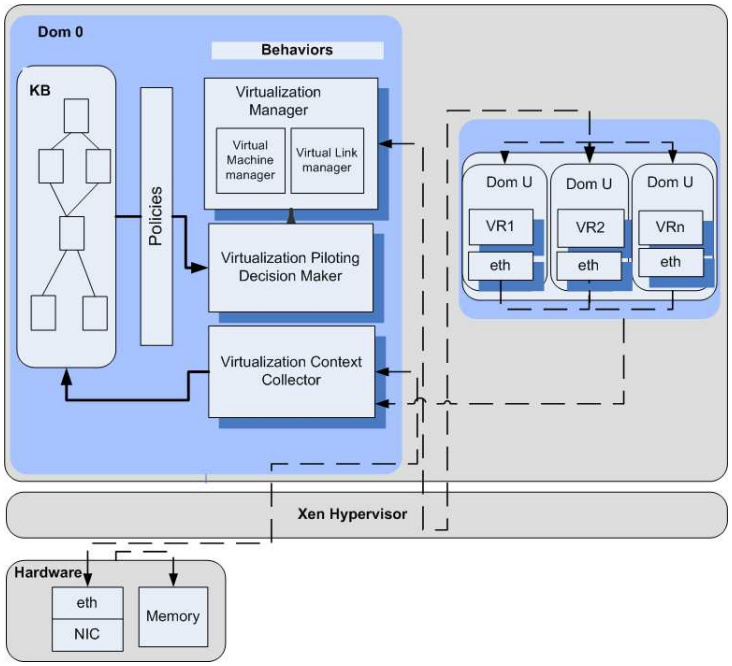



Fig. 5. Autonomic Piloting virtual Network Architecture

embeds an agent and a device. The former represents the proposed autonomic architecture, the latter describes the network equipment structure. In fact, a device may be either a physical device or a virtual one and has static parameters such as location (Region, city, etc.), operating system (Linux, Windows, etc.), Virtual machine nature (Router, Switch, Access Point, etc.), Virtual machine environment type (Xen, VMware, etc.), network stack type (MPLS, TCP/UP, etc.) and interface type (Ethernet, Atm, radio, etc.). A physical device may embed one or more virtual devices and has functional attributes such as available cpu, available memory and available storage. A virtual equipment has also functional attributes such as cpu usage level, memory usage level and storage usage level . Devices are interconnected through links which have their own metrics such as such bandwidth, loss rate, end to end delay. These metrics are computed through raw information gathered from network interfaces(e.g. sent packets rate, received packets rate, lost packets rate ,etc.).
In our implementation, each router may embed a wireless card. So, a router may play the role of an access point or a base station depending on used technology (WIFI, WIMAX, UMTS, etc.).

5.3.2 *Policies.* Policies define rules that control the triggering of behaviors according to the current state information and context.
Policies are defined by the network infrastructure operator in order to meet the customers SLA requirements in terms of resources and QoS. They may be updated

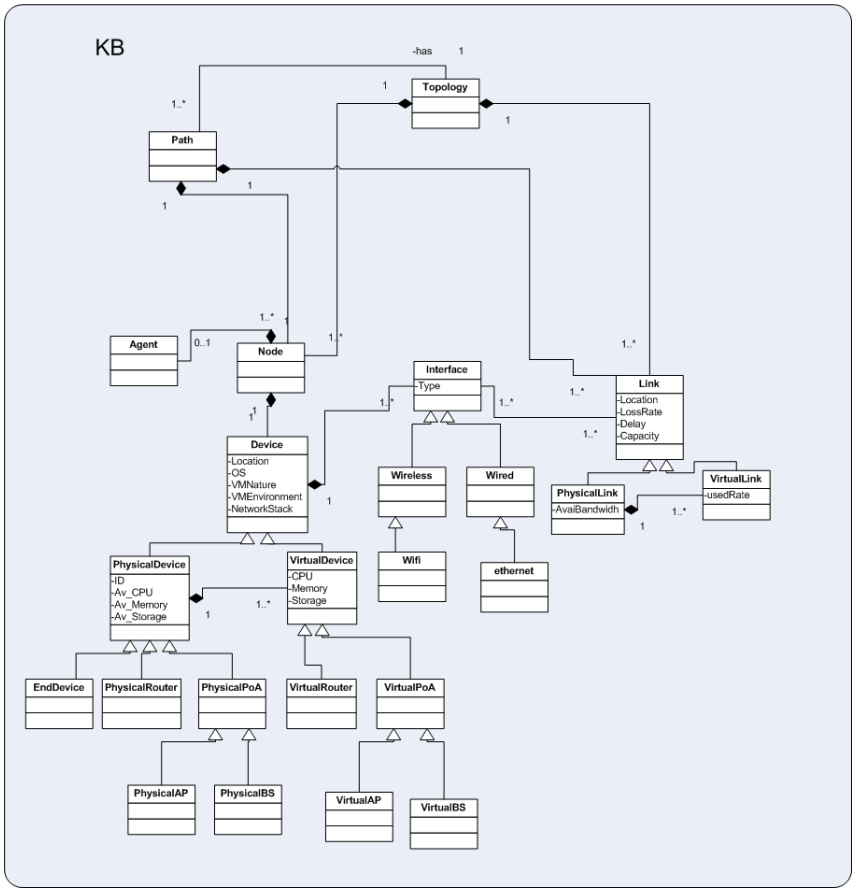



Fig. 6. Ontology-Based Model for virtual network knowledge base

in function of changes of network environment and users.
We proposed in [15] a virtual resources provisioning schema that specifies virtual resources proprieties and associations. This schema is used to instantiate new virtual networks in function of user requirements and the contract on which it agrees with its operator.

5.3.3 *Behaviors.* Behaviors can be viewed as organic components permanently sensing the environment and acting upon it. Technically, behaviors are specific functions executing precise tasks for specific goals. To accomplish their tasks efficiently, they use knowledge information stored in the knowledge base.
We define five principal behaviors :

—**Virtualization Context Collector (VCC)**: this behavior is responsible for supervising and monitoring physical and virtual resources within the physical node. Thanks to the interface Autonomic entity/Network equipment, autonomic entity retrieves raw information and generates metrics that describe the network equip-

ment state. Theses metrics are stored in the knowledge base which is periodically updated.

—**Virtualization Piloting Decision Maker (VPDM)**: this behavior makes decisions according to the knowledge stored in the knowledge base. VPDM decision making is based on the execution of management and instantiation algorithms which must be previously designed. Decision maker can order the instantiation or the delete of new virtual router. It can also order the tuning of the amount of virtual resources allocated to each virtual router. The decision made depends essentially on current state of physical network equipment, the state of the network and the SLA fixed for each type of virtual network.

—**Virtual Resources Managers (VRM)**: these behaviors are in charge of executing actions upon virtual resources according to the decision taken by the behavior "Virtualization Piloting Decision Maker". We distinguish:

  —**Virtual Machine Manager (VMM)**: this behavior manages virtual nodes instantiated in the physical network equipment. Management tasks may be : "instantiate" a virtual machine which means creating a new instance of a virtual machine according to a specific specification, "migrate" a virtual machine that means change the instance of a machine virtual from the local network equipment to a foreign network equipment due to a lack of resources, "destroy" a virtual machine that means deleting the virtual machine and its bookkeeping information, "suspend" a virtual machine which means pause a virtual machine and store its internal state on a file disk, "stop" a virtual machine, "resume" a virtual machine that means executing a virtual machine from a state saved on a file disk.

  —**Virtual link Manager (VLM)**: this behavior manages virtual link instantiated. Task management may be "instantiate" a link, "remove" a link, "modify" a link which means tuning link parameters of a virtual link, and migrate link.

## 6. AAVP: DETAILED DESCRIPTION

We provide in this section a detailed description of the implemented architecture. We note that we use policies as a set of rules to manage and control the access to network resources. They control the triggering of behaviors according to the current state information and context.

In our model, a policy is essentially a set of event-condition-action rules. Rules are organized hierarchically in sets called sub-goals. Each sub-goal corresponds to a set of rules. The conditions of rules are Boolean expressions which can refer to proprieties defined on the virtual network specification. During a policy evaluation cycle, rules with matching condition are triggered. Once a rule is triggered the list of primitives in the right part of the rule is executed.

We proposed in [15] a virtual resources provisioning schema that specifies virtual resources proprieties and associations. This schema is used to instantiate new virtual networks in function of user requirements and according to the contract agreed on with its operator. This SLA defines the policies between different actors in terms of guaranties and penalties.

Figure 7 illustrates the detailed building blocks of AAVP architecture and the interactions between them.

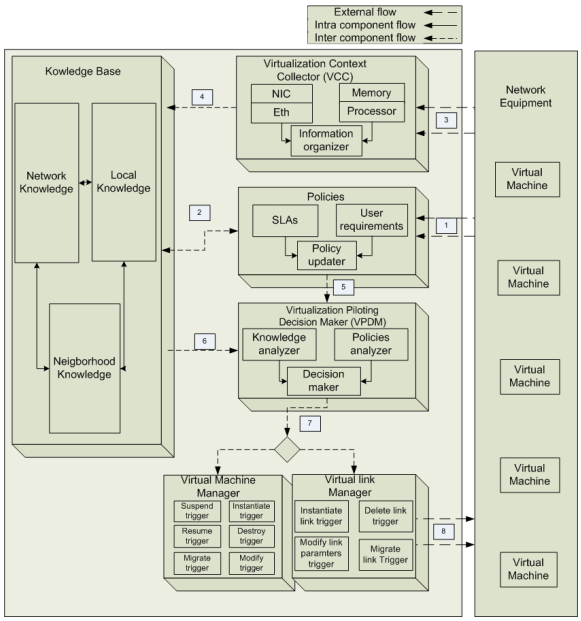



Fig. 7. Detailed AAVP architecture

Policies are defined by the network infrastructure operator in order to meet the customers SLA requirements in terms of resources and QoS and operator goals (1,2 Fig. 7).

To meet changing context, Policiy Updater aims to adapt the policies according to user requirements, environment conditions and operator goals. This process may be automatic thanks to meta-policies. It may also be manual. Sometimes, the network infrastructure operator intervention may be required in order to update and refine predefined policies.

As we have mentioned in the previous section, the VCC implements the information organizer component which is responsible for the raw information structuring. This component updates continuously the knowledge base according to the changing context of the virtualized network. VCC collects raw information from network equipment(3 Fig. 7) thanks to existing tools such as Xentop. Then, the information organizer subcomponent analyzes, aggregates and generates new metrics related to virtualized resources (e.g VCC generates the metric CPU usage level of a virtual machine according to the number of cpu units used by the latter during a time interval T). These metrics as CPU usage, memory usage, error rate etc. are stored in the knowledge base (4 Fig. 7).

VPDM is an intelligent component which acts on behalf of administrators and users and manages virtual resources in an autonomic way. It aims to maintain a desired level of QoS for each instance of virtual network. VPDM analyzes continuously policies (5 Fig. 7) and knowledge stored in KB (6 Fig. 7). In the case of context information change, it uses heuristics to optimize the management of

virtualized resources. For example, if a physical machine can no more support all instantiated machines above it due to a lack of resources or a network bottleneck, it tries first to tune allocated resources of one or more virtual machines according to the SLA of each one. If resources shrinking is not possible or not competent, the physical machine will attempt to search within its physical situated view a physical node to which it can migrate one or more virtual machines. Other mechanisms of optimization can be proposed to maintain the efficiency of the substrate topology. Each physical machine fixes a desired level of allocated resources and tries to maintain continuously a load balancing with others physical machines. In fact, when physical machine becomes overloaded, it triggers a process of migration to an under-utilized physical machine. Moreover, power saving mechanisms can be used to reduce the power consumption in routers, such as turning off under-utilized physical routers and migrating their virtual resources to other physical routers able to host more virtual machines.
As known in decision theory, utility functions can be used to model agents behavior in situation of choice. Utility functions are studied especially in microeconomics theory. We use this concept in our work to represent the attractiveness of a physical router to host a virtual machine. Some properties of the utility function $\mathcal{F}$ are:

—$\mathcal{F}$ increases strictly monotonically when a parameter $x_i$ from the vector $x$ increases and other parameters are kept constant.

—The decision vector $x$ is containing all good parameters defined as decision criterions (i.e the greater value is the better); e.g.the bandwidth is taken directly but 1/loss should be used instead of loss.

The utility function that we used is $\mathcal{U}(x)$ = (1-exp(-$\alpha x$)), where $\alpha$ is the relative weight of the decision vector $x$.
The parameters $\{x_i\}$ that could be used to define the utility function:

—Residual CPU

—Residual Memory

—Bandwith

—1/Packet Loss level

This function calculates the utility of each router according to its performances.

All decisions made by VPDM are communicated to VMM and VLM (7 Fig. 7) which triggers appropriate actions on the network equipment (8 Fig. 7).
Then, VCC updates the knowledge base according to the changing context of the virtualized resources.
s depicted in the figure 7 our architecture is knowledge centered. In fact, most components interacts with the knowledge base in order to guarantee their functionalities.

We have implemented our autonomic architecture in java using Xen environment. In Xen, each virtual machine is hosted in a Guest domain called DomU. Among Guest Domains, there is a single domain which is able to access directly to physical resources. It is called Dom 0.
Our autonomic architecture as presented in Figure 5 is hosted in Dom 0. This

domain is responsible for resources sharing such as CPU and memory. It controls the execution of different virtual machines inside the physical network equipment. We describe in the following section our testbed and preliminary implementation results.

## 7. EXPERIMENTAL STUDY

In order to have an overview of the the effectiveness of our architecture and its ability to self-configure its resources under specific scenarios, we have chosen to setup a real-world testbed instead of network simulations. In fact, due to implementation shortcuts and the simplification of some real-world properties, simulation techniques may lead to results and conclusions which do not reflect the behavior of our solution under realistic constraints.

### 7.1 Experimental Setup

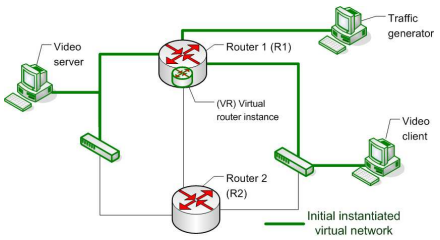



Fig. 8. Virtual Network Testbed

As depicted in Figure 8, the platform of our testbed consists of two routers with 4Go RAM, C2D-2.4 Ghz CPU and six 1Gbit/s network interfaces, embedding our proposed architecture and three end devices (a video server, a traffic generator and a video client) running GNU/Linux. A virtual network VN1 is instantiated between a video server and a video client. It passes through Router1(R1) and it is marked with green color in the Figure 8. The video server sends a video flow with 1 Mbit/s to the video client. This video flow is displayed continually on the latter's screen.

We have performed a set of experimentations to check our autonomic agent ability on detecting network interfaces congestion and network performance degradation. We check also its capacity to make the appropriate decision in order to overcome detected problems and improve network performances.

### 7.2 Scenario and Results

We considered the following scenario. At t=30s, a huge data flow is generated by the host Traffic generator directly connected to R1 and circulated in the virtual network. Due to this traffic, the video displayed in client video 's screen is getting fuzzy (Fig. 9 (a)) which confirms the performance collapse of the virtual network.

To trigger migration, we define the rule R as follows:

**R: If PacketLossLevel $\geq$ Threshold Then trigger migration to the neighbor router having less loaded network interfaces.**


(a) Video before migration (b) Video after migration

Fig. 9. Quality of Video

We defined PacketLossLevel as:

$$PacketLossLevel = \frac{NbrLostSentPackets}{TimeIntervall} \quad (1)$$

where TimeIntervall=100ms

As soon as the rule becomes true, AAVP agent decides to migrate the virtual router instance (VR) which is embedded in router R1. Thus, it searches on its knowledge base the least loaded router which corresponds in this case to the router R2. Then, it triggers the move of VR to router R2. Thanks to this reconfiguration VN1 is able to maintain its performance and the required QoS which results in acceptance video performance as shown in Figure 9 (b). Without adaptation, the VN1 would have probably crashed due to the lack of available resources.

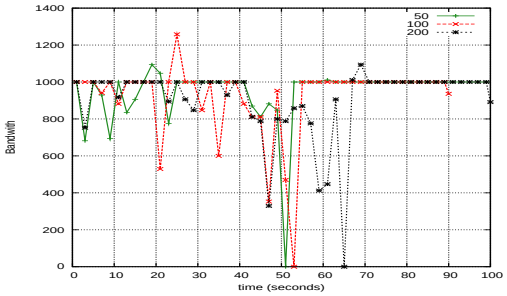
Firstly, we evaluated the performances of AAVP when varying the threshold. Figure 10 shows the bandwidth and the loss variations for each fixed threshold . It is clear that the more the value of the threshold is increased the more migration is delayed and the more the flow is disrupted. This is due to the huge flow sent to the physical router which deteriorates the router's performances. In fact, we notice that for a high value of threshold, the flow takes more time to reach its required QoS after the migration. For these reasons we fix the error threshold to 50 packets/sec.

Figure 11 displays bandwidth and packets loss variation throughout the scenario's execution. We note that, at the beginning, the bandwidth and the loss rate are not stationary. This is due to resources limitation. In fact, for R1, we fixed a low bound of maximum allocated CPU to VR1 in order to cause performance deterioration as soon as the heavy traffic is generated. This leads to a small perturbation of the flow circulating through VR network interface.

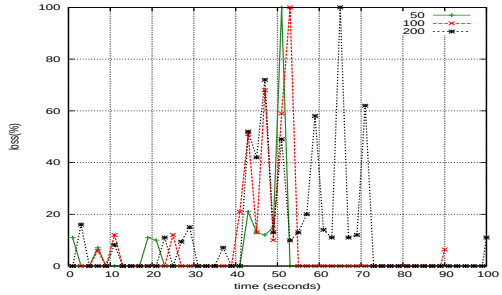
Figure 11 is showing that when using our architecture, AAVP agent reacts to perturbation in less than 7s. In fact, AAVP agent, decides to trigger migration only when PacketLossLevel exceeds 100 packet/s which corresponds to a noticeable degradation of the video quality. In order to reduce reactivity duration, packetLossLevel threshold should be reduced. However this can lead to a premature migration in the case of brief perturbation.

Without a piloting architecture, it is clear that the video streaming server throughput requirement is no more respected due to the networks overload. This is clear through the continous increase of the Loss Rate and the decerase of the Bandwith.

As depicted in Figure 11, the delay of migration, which represents the interruption

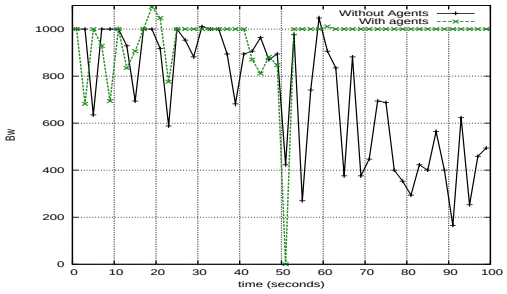



(a) Bandwith variation

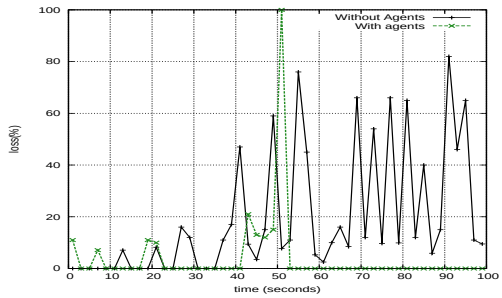



(b) PER variation

Fig. 10. network performances according to the error threshold




(a) Bandwith variation




(b) PER variation

Fig. 11. Network performance evaluation

time on the execution of the video running inside of the moving virtual slice, is less than 2s.

Moreover, results show that once migration is executed, the bandwidth becomes stationary (respectively loss becomes null) which guarantees the QoS required for the video stream.

Previous experiments demonstrate the effectiveness of our architecture and its ability to self-configure its resources in order to maintain a required QoS.

## 8. CONCLUSION

Network virtualization is a promising technique to overcome the internet ossification by providing a shared physical infrastructure for a variety of network services and architectures. However, in spite of its multiple advantages, network virtualization adds more complexity on network systems. In order to address this complexity, we propose in this paper an autonomic architecture for virtual network piloting: AAVP. Each AAVP node consists of three main entities reflecting its ability to monitor, analyze and then manage and optimize the use of network resources.

We have implemented the described autonomic system using Xen environment. First real experimentations presented in this paper are satisfying and prove the ability of our system to automatically reconfigure itself and improve its performances. More experiences are planned for future implementations to evaluate the performance of our proposal with different scenarios. We also plan to evaluate the performances of our system with large-scale experiments through simulations.

## REFERENCES


G. Schaffrath, C. Werle, P. Papadimitriou, A. Feldmann, R. Bless, A. Greenhalgh, A. Wundsam, M. Kind, O. Maennel, L. Mathy, *Network virtualization architecture: proposal and initial prototype*, VISA '09: Proceedings of the 1st ACM workshop on Virtualized infrastructure systems and architectures, pp. 63-72, 2009.

T. Anderson, L. Peterson, S. Shenker and J. Turner, *Overcoming the Internet Impasse Through virtualization*, IEEE Computer Magazine, vol 38,no.4, pp.34-41, 2005.

J. Turner and D. Taylor, *Diversifying the internet*, in Proceeding if the IEEE Global Telecommunications Conference (GLOBCOM'05), vol. 2, 2005.

N. Feamster, L. Gao, and J. Rexford, *How to lease the internet in your spare time*, SIGCOMM Computer Communication Review, vol. 37, no. 1, pp. 61-64, 2007.

IBM Research, IBM and autonomic computing: an Architectural Blueprint for Autonomic Computing, IBM Publication, http://www.ibm.com/autonomic/pdfs/ACwpFinal.pdf, 2003

P. Horn Autonomic computing: IBM's perspective on the state of information technology, also known as IBM's Autonomic Computing, 2001.

M. Yu, Y. Yi, J. Rexford, and M. Chiang., *Rethinking Virtual Network Embedding: Substrate Support for Path Splitting and Migration*, SIGCOMM Comput. Commun. Rev., 38(2):17–29, 2008. Y. Zhu and M. Ammar,

J. Lu, J. Turner., *Efficient Mapping of Virtual Networks onto a Shared Substrate*, Technical Report WUCSE-2006-35, Washington University, 2006.

Y. Zhu and M. Ammar, *Algorithms for Assigning Substrate Network Resources to Virtual Network Components* in IEEE Infocom, 2006.

N. M. M. K. Chowdhury, M. R. Rahman and R. Boutaba, *Virtual network embedding with coordinated node and link mapping*, IEEE INFOCOM, 2009.

Y. Wang, E. Keller, B. Biskeborn, J. Merwe and J. Rexford, *Virtual Routers on the Move: Live Router Migration as a Network-Management Primitive*, IEEE SIGCOMM, 2008.

D. Menasce and M. Bennani*Autonomic Virtualized Environments*, ICAS, 2006.

P. Ruth, J. Dongyan Xu, R. Kennell and S. Goasguen, *Autonomic Live Adaptation of Virtual Computational Environments in a Multi-Domain Infrastructure*

M. Kim Myung S. Kim, A. Tizghadam, A. Leon-Garcia and J. Won- Ki Hong, *Virtual Network based Autonomic Network Resource Control and Management System*, Proc. of IEEE Globecom, pp. 1075-1079, 2005.

I. Fajjari, M. Ayari and G. Pujolle, *VN-SLA: A Virtual Network Specification Schema for Virtual Network Provisioning*, IEEE ICN, 2010