Service Provisioning and Management in Virtual Private Active Networks

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Abstract

Service providers have been motivated to develop and offer new services to their customers. The key question is what kind of futuristic and practical services customers need. This paper presents a novel service called Virtual Private Active Network (VPAN) which allows clients to create Virtual Private Networks (VPNs) among domains using Active Network (AN) technology. This service is new in the sense of we show how to provide VPNs using the AN technology and how to perform the policy-based management in this scenario. We briefly outline the Mobile Service Management System for Virtual Active Networks (MS2VAN) which is a framework we developed to offer Virtual Active Networks (VANs) and manage services in the same domain. Afterwards, we show how the MS2VAN can be used to provide and manage VPANs. We present the protocol to let a user create a VPAN, the protocol to allow a user to enter in a VPAN and, finally, the protocol to manage VPANs.

1 Introduction

Currently, after the advent of the Telecom, providers are looking forward to offering new classes of customized services to customers. In this context, the Active Network (AN) technology is particularly attractive to be used in Telecom environments, due to its facility to send data and code to specific locations in the network.

With AN technology, the customization of services can be achieved by partitioning the network into *Virtual Active Networks* (VANs), in which customers can lease from service providers. A VAN is a Virtual Private Network (VPN) developed using AN technology. Based on the VAN concept, we implemented a framework (MS2VAN) based on a hierarchical model we have proposed to manage mobile services in VANs, which allows a customer to install, configure and run active services on his own VAN in the same domain [8]. In the present article, we describe how the MS2VAN framework can be used to provide and manage a novel service which we call Virtual Private Active Network or just VPAN. The main difference between a VAN and a VPAN is that a VAN is developed using only nodes of the same domain, and a VPAN is developed using nodes of different domains. A VPAN allows customers of these different domains to share and exchange services using AN technology. This kind of service can be used by providers to let users of a domain communicate with users of another one. For instance, suppose that a group of researchers located in different companies needs to work together in a project. The connectivity among them can be done by means of a VPN, and even more, it can be easily deployed using the VPAN concept. These researchers might want to share resources and/or send and receive applications to be tested in different domains. This scenario is very common in groups which work on integrated development of software.

Many approaches taken today have focused on AN technology. Some works describe architectures or software architectures to provide and manage telecommunication services [7]. In this context, an architecture for network management that offers active services is presented in [6]. In [8], a model for management of mobile services in VANs is described, and how the management information is collected across the Management Information Bases (MIBs) distributed in three hierarchy levels of management is shown. Considering that active networking has demonstrated its potential for Telecom environments, an approach for service management in this kind of environment is presented in [1]. All these approaches do not mention VPAN neither its management. In addition to these researches on AN technology, there are many challenges to develop business environments. The VPN concept has been discussed as a good solution to improve workgroup computing over the Internet [5]. In this context, it seems that using AN technology can be a starting point to create new solutions to provide VPNs. Taking into account the features from these approaches, our framework has incorporated some important aspects for Telecom environments such as: policy-based management, VANs, mobile services, mobile agent-based management and VPANs, the focus of this paper.

The paper is organized as follows. In the next section we briefly review the basic concepts about active networking, VANs and VPANs. Section 3 outlines our infrastructure and its components. Section 4 is dedicated to the VPAN service and the protocols which were created to support it. Finally, Section 5 presents the conclusion and gives an outlook on further research.

2 Active Networks, VANs and VPANs

Active Networking [3] breaks with the tradition where the nodes only route packets according to their routing tables. Users can program the network by injecting their programs into it. The AN nodes can receive, send and run these external programs using local computational resources. An important service offered by active networking is the VAN provisioning. A VAN can be described as a graph of virtual active nodes connected by virtual links where active packets can travel within a VAN or between different VANs [2]. A VAN can be only created using nodes of the same domain and every user must belong to some VAN. A VAN is a kind of VPN implemented using AN technology. The VAN concept is a very useful solution to isolate groups of customers and offer specific services to each customer's domain. While a VAN is only created using nodes of the same domain, a VPAN can be formed by nodes of different domains. Thus, a customer of a domain can install a VPAN to get services from other domains that are not present in his domain.

Figure 1 shows the differences between VANs and VPANs. We can see that a domain can have more than one VAN. All the VANs are developed using only nodes of the same domain. On the other hand, we can see a VPAN developed using nodes from different domains.

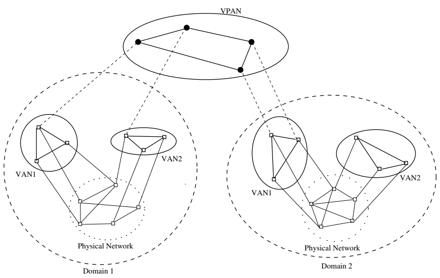

Figure 1. VANs and VPANs.

3 The Framework for Service Installation and Management

The framework we developed includes components to support creation of VANs and VPANs, and service installation and management in VANs and VPANs. In this section we briefly present these components, the defined policies and the configuration actions. Our model has a static manager responsible for the global management, getting a global view of all VANs of a domain. To manage VPANs, this static manager has to communicate with other managers of other domains to get information about a specific VPAN. Since VPANs are formed using nodes of various different domains, each manager in each domain is responsible for collecting information of its own domain. We show how management operations are performed in VPANs in Section 4. The model has one-hop mobile agents for collecting accounting and performance data in each node. Getting the responses about accounting and performance, the manager (human) can take actions towards the configuration functional area. These management questions are divided into five cases: per service, per host, per VAN, per VPAN and per domain. Next, we present the components of the model taking into account their responsibilities to manage VANs and VPANs.

3.1 Components of the Infrastructure

The infrastructure has components to manage a domain and it is composed of a Management Remote Application (MRA), a Management Center (MC), a Service Provider (SP), a Local Naming Service (LNS) and the Distributed Management Agents (LM and MAEA) as described below (Fig. 2). This figure shows a domain with two VANs (A and B) and how the components of the framework are organized after installing these two VANs. We can see that node *X* belongs to both VANs, but the model separates each one for service management. Figure 2 also shows that this domain has a node that belongs to a VPAN. This node, which we call node Y and belongs to VAN B, makes part of the VPAN L in this example.

In Figure 2 we can see that when a customer wants to install a VAN, he contacts the SP (Service Provider) and when a customer wants to install a VPAN he contacts the GMA (Global Manager Agent, see below). In the first case (installing a VAN), the customer might inform if he wants to make part of any VPAN further. Even more, the customer can inform what services he is interested in using when a VPAN is installed and what hosts he will release to belong to a VPAN. The SP sends this information to the GMA, which in turn, sends to the PC (Permission Controller, see below).

The components of the infrastructure are:

- **Management Remote Application - MRA**

  This application presents to the manager (human) the interface with the methods related to management questions (accounting, performance and configuration). The MRA invokes remote methods on the

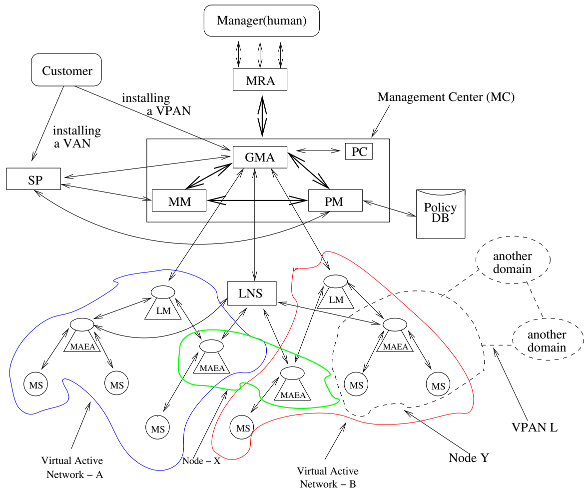

Figure 2. Components of the Infrastructure and their relationship in a domain.

Global Manager Agent (GMA, see below) for collecting management data.

- **Service Provider - SP**

  It is responsible for offering services to customers. When a client sends a capsule to the SP to create a VAN and its services or to add a new service to his VAN, the SP notifies the Global Manager Agent (GMA) and the *Migration Manager* (MM, see below) about this. Also, in a service migration or removal, the SP notifies the MM to control its migration tables and notifies the GMA to update its local information about the VANs. When a client that belongs to a VPAN contacts the SP to require a service which belongs to another domain of that VPAN, the SP contacts the GMA which, in turn, is responsible for contacting other GMAs to require the service.

- **Policy Manager - PM**: This component is responsible for controlling, insertion, updating and removal of a policy in the database;

- **Migration Manager - MM**: When a new VAN is created, the services in its hosts must be managed and, therefore, this component sends accounting management agents to the nodes. The MM controls each service migration over the network applying the policies on each one regardless of the migration is performed between nodes belonging to a VPAN or not.

- **Global Manager Agent - GMA**: It is the centralized static manager of the model. There is only one GMA in a domain. This component is responsible for analyzing accounting, performance and configuration data on all VANs and their services. The GMA collects and analyzes management information of nodes of its domain which belong to VPANs. It is responsible for contacting other GMAs from other domains to install a new VPAN or collect management information about it and its services. Furthermore, it notifies the MM to send performance agents to specific hosts. The GMA contacts the PC (Permission Controller) to transfer information from the SP and to verify the possibility of creating a new VPAN.

- **Permission Controller - PC**: This component is responsible for controlling the VPANs creation. It allows or not a VPAN to be created based on the information received from the GMA. The PC and the GMA are responsible for releasing nodes and services to make part of new VPANs.

- **Local Manager - LM**: There is an LM per VAN. It is responsible for the management of its VAN and it collects data of each *Managed Active Element Agent* (MAEA, see below) located in the hosts of the VAN. One of the aims here is to filter the information before sending it to the GMA.

- **Managed Active Element Agent - MAEA**: It is responsible for the management of one or more services in a host of a VAN and VPAN (in the case that the host belongs to a VPAN), being the lower level of the management. There is an MAEA per host per VAN. We can see in Fig. 2 that although the node Y belongs to the VPAN L, it firstly belongs to the VAN B. Then, the MAEA located in that node belonging to the VAN B is responsible for collecting management information of the node regardless of the node belongs to a VPAN or not. This agent is an interface between the ***Managed Service*** (MS) and the management system.

- **Local Naming Service - LNS**

  It is the naming service of a domain. This component receives the service location and the service identifier and creates a reference that indicates where the service is located. The management agents search in this component to get service references.

The management system collects accounting and performance data. Accounting information is collected throughout the hierarchical model following the sequence: Human $\rightarrow$ GMA $\rightarrow$ LM $\rightarrow$ MAEA $\rightarrow$ MS. On the other hand, to collect performance data, the management system sends one-hop mobile agents to the hosts where the services are located [8]. We depict how to collect management information in a VPAN in Section 4.

3.2 Policies

Two possible solutions can be realized when a client requires a service. The first solution considers that whenever a client needs a service, a new copy of this service is created and sent to the client. The second alternative considers that whenever a client requires for a service, a copy of this service in a node may migrate to attend the customer requirement. Both solutions are unfeasible whether their consequences are considered. To install a new service copy for each customer will flood the network with services. To migrate a service from a node to another to attend customer requirements will result in many migrations. Thus, we have proposed an intermediate solution defining some policies to minimize both, the number of service copies and the number of migrations.

We created six representative policies:

1. There are three kinds of service: internal services which can only migrate in the same VAN, external services which can migrate between VANs, and VPAN services which can migrate among domains which belong to the same VPAN;
2. A service S has a limited number of copies in the network (**L1**): $S_1, S_2, ..., S_n$, where $n \leq$**L1**;
3. A service S has a maximum bound of times to migrate in a period of time (**M1**). Each copy of S, S_i, has to follow this threshold;
4. The SP can install a new service copy requested by a user until a threshold of **L2** (L2≤L1).
5. The Least Recently Used Service (LRUS) will be the candidate copy to migrate to the destination host when a customer requires a new service. This happens if the threshold L2 was already reached;
6. A service copy may be removed if it does not migrate a minimum bound of times in a period of time.

4 Active Network-based Virtual Private Network Service - VPAN

The VPN service enables different organizations or companies to create private networks by using public network resources. In our model, a VPN can be created from different VANs belonging to different domains becoming a *Virtual Private Active Network* (VPAN). This is a common case when different organizations or companies located in different domains want to define a private network among them. Our framework is able to manage not only a single domain with various VANs belonging to the same domain, but also VPANs formed by nodes from different domains.

To support this new kind of scenario, we developed three protocols: the protocol to install a VPAN, the protocol to enter in a VPAN and the protocol to manage VPANs. Section 4.4 presents how the service migration happens and how the policy-based management is performed in VPANs.

4.1 Protocol to install a VPAN

The first protocol allows a customer to create a new VPAN. Since every user makes part of some VAN, any user can start off the installation. A customer can define the topology of the VPAN choosing a node or a set of nodes from his local VAN and specifying other VANs located in different domains in order to connect them into a single VAN to build a virtual enterprise. The VPAN installation has some different steps to follow if compared to traditional single domain scenarios [8]. Next, we present the protocol to install a new VPAN (see Figure 3).

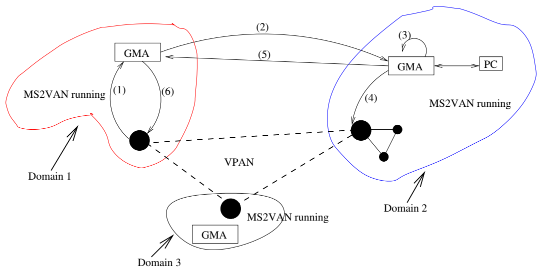

Figure 3. Protocol to install a VPAN.

1. A customer who desires to install a VPAN contacts his local GMA[1]. The customer sends a capsule to the GMA informing the service he wants, the nodes of his VAN and what other domains will make part of the new VPAN. The concept of service refers to the set of facilities or resources which will be used to attend the customers. For example, our team of researchers needs to watch a video to define further plans and exchange some information about the video while it is being watched. Another example is when a researcher of a domain needs to run some programs or use some resources that are located in another domain. Having a VPAN installed, this type of scenario is easily created;
2. The local GMA interacts with the GMAs from other domains in order to define and negotiate the provisioning of the VPAN (negotiation about the Quality of Service (QoS) can be performed in this phase). Figure 3 shows only the interaction between domains 1 and 2 but the interaction between domains 1 and 3 is performed as well. In phase 2, the GMAs which are involved in the VPAN installation exchange information about their users who are allowed to enter in the VPAN

[1] GMA of the domain from where a customer is starting the process of installing or entering in a VPAN.

after installing it. This information is sent to each PC in each domain since that information will be used by the protocol which allows or not a user to enter in a VPAN (4.2);

3. Each contacted GMA has to choose a set of nodes to be offered to the new VPAN. Therefore, the GMA contacts the PC to verify the permission to install this new VPAN. The PC is aware of customers who want to make part of this VPAN to use a specific service and, therefore, it contacts the customers of its domain to notify that a new VPAN is being created to use that service. At this point, customers who want to make part of the VPAN to use the mentioned service can do so by leasing their nodes to the VPAN. GMA and PC are in charge of analysing some reliability aspects at this phase verifying customers and domains;
4. After having the set of nodes and the required service installed on them, the GMA forwards to these nodes information concerning the domain and the customer who required this new VPAN;
5. Each contacted GMA sends back the results. If all domains achieve an agreement, the VPAN can be installed;
6. The local GMA notifies the customer who started the installation. The VPAN at this moment is installed and all nodes belonging to it can send and receive services.

The protocol to extinguish a VPAN is simple. Only the customer who required the installation of the VPAN can release it. At this time, all the services which are out of their domain have to migrate to their home domain (the place where a service was created) before releasing the VPAN. When all the services are located in their own domains, the VPAN is extinguished.

4.2 Protocol to enter in a VPAN

The second protocol we have proposed is to allow a user to enter in a VPAN previously installed. Figure 4 shows how this protocol is executed.

First of all, a customer contacts his local GMA informing that he wants to enter in a VPAN (1). Afterwards, the local GMA contacts each GMA whose domain makes part of the VPAN (2). Each contacted GMA decides together with the PC whether this new customer is allowed to enter or not (3). This decision is performed based on the information exchanged in phase 2 of the protocol to install a VPAN (see 4.1). If the new customer is allowed to enter, nodes belonging to the VPAN are notified by their GMAs about a new user (4). Finally, each GMA sends an answer back to the local GMA (5) which notifies the local nodes and reports the results to the customer who started the process to enter in a VPAN.

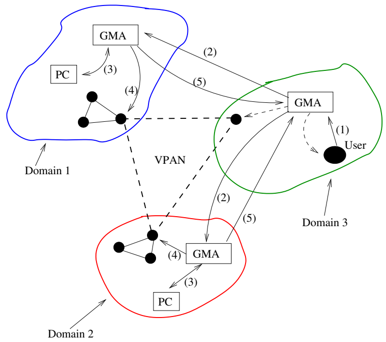

Figure 4. Protocol to enter in a VPAN.

When a client wants to leave a VPAN, he needs to contact his local GMA to inform about this. The services and/or resources that the client was using are released and/or sent back to their home domain. The local GMA notifies other GMAs that a user of its domain has left.

4.3 Protocol to manage VPANs

The last protocol we describe is to allow the management of VPANs. To get information about the VPANs (accounting and performance data), the management system of a domain needs to contact the management system of other domains. This communication among them is only made through the GMAs. Figure 5 depicts this scenario in which the manager of the domain 2 wants to collect monitoring information about the VPAN.

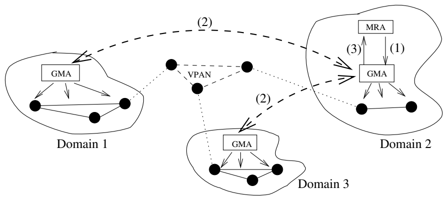

Figure 5. Protocol to get management information of a VPAN.

The figure shows that the VPAN is created from domains 1, 2 and 3. A management operation is initiated from domain 2 to collect data about the VPAN (1). The domain 2's GMA interacts with the other GMAs to get VPAN management information (2). Upon receiving the management information from other domains, the GMA which has started the management operation returns back the results to the MRA (3). Each GMA has information about the VPANs which belong to it. Figure 6 depicts the MRA after a management operation for displaying the local VANs (VAN1 and VAN2) and the VPANs which belong to the domain 2. The VPAN1 includes the host (1.1.1.2) of the local domain (domain 2) and other two domains (domains 1 and 3).

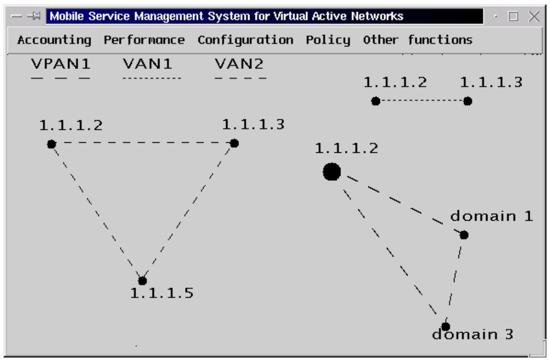

Figure 6. MRA after collecting information about VANs and VPANs.

4.4 Service migration in VPANs

Once a service has been installed in a node belonging to a VPAN, it can migrate among all the nodes belonging to that VPAN. Every service belongs to a unique domain (home domain). Therefore, a service can migrate among VANs of its home domain and among nodes belonging to the same VPAN. The service cannot enter in other domains to attend customer requirements from there, except in nodes of the domains that belong to the same VPAN. Then, customers who want to use a service that does not belong to his domain have to necessarily enter in a VPAN.

It is important to say that our framework is able to provide and manage mobile services but, in fact, some applications do not have or do not need mobile services. Typically in VPNs, customers just need an infrastructure to exchange or share information or resources. For instance, in a group of researchers that needs to watch a video and exchange data, there is no mobile services in that application indeed. As shortly commented in the Introduction, a group of researchers can be developing a software (integrated development of software). In this case, the participants of each domain can be responsible for developing some specific parts of the software. Therefore, participants of the group need to receive applications being developed in other domains to be implemented and tested in the local domain. Hence, the application must migrate, like a mobile service, from a domain to another and this migration can be managed by our system.

An important point about migrations in VPANs is how a customer requires a service. Customers send a capsule to the local SP indicating what service is required. If the required service is not local, GMA contacts other domains which belong to that VPAN to order the service. Receiving the answers from the other domains, the local GMA chooses one of them and acknowledges it. The selected GMA is responsible for sending the service to the customer who is requiring that service. This scenario can be seen in Figure 7 and is explained in below paragraph.

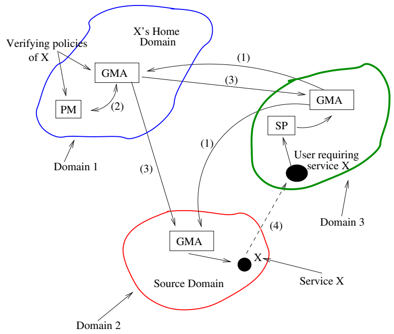

Figure 7. How the policy-based management is performed in a VPAN.

Policies are applied on services belonging to VPANs in the same way as they are applied into domains. To migrate a service in a VPAN, all the policies have to be verified in order to allow or not that migration. Policies in our model are always verified by the home domain. In Figure 7 we define a service X whose home domain is domain 1. We can see that service X is out of its domain, i.e., it is in the domain 2. Now, a customer of the domain 3 is requiring the service X. Note that, it is not the domain 2 (source domain) that applies the policies over the service X, because the domain 2 does not have those policies neither information about the migrations of service X. As explained in the above paragraph, when a user wants to install a service, the local GMA has to contact other GMAs (1). By doing this, X's home domain is contacted too, and at that time all the policies of service X are verified by its home domain (2). X's home domain sends back the results to domain 3 and notifies domain 1 that service X can migrate, considering that the policies allow this migration (3). Upon the domain 2 receives the notification from the domain 1, the service X migrates to the domain 3 to attend the customer requirement (4).

Figure 8 shows some migrations of the **serviceA** among three domains using the VPAN installed among those three domains. We can see that serviceA's home domain is the domain 2 (the starting point). ServiceA migrated from the domain 2 to the domain 1 (host 1.1.1.3), and afterwards, from the domain 1 to the domain 3 (host 1.1.1.5). Now, serviceA is on host 1.1.1.1 belonging to the domain 2. Below each migration, we can see some accounting information in

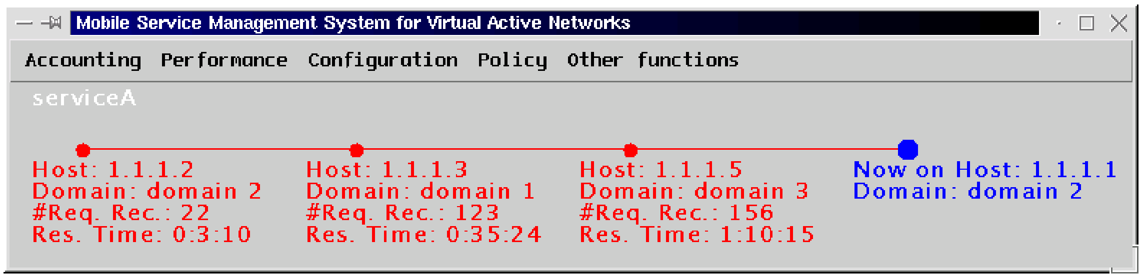

Figure 8. Service migration in a VPAN (among domains).

each host.

5 Conclusion and Future Work

In this paper we presented the MS2VAN, a framework for service provisioning and management in Telecom environments which are based on AN technology. This framework allows to install and manage not only VANs but also a novel and futuristic service named VPAN. This service is considered new in the sense of a VPN can be created using Active Network technology which offers many facilities to send and receive services in the network. Having a VPAN, customers of different domains can share and exchange services in a private way. We presented the protocol to create a VPAN, the protocol to allow a customer to enter in a VPAN, and the protocol to manage VPANs. The framework is able to perform the management of mobile services and their migration among VANs and domains belonging to the same VPAN.

The proposed management model is based on a mobile agent platform and considers three management functional areas: accounting, performance and configuration. We have used a mobile agent platform due to its facilities to send management agents to the hosts. This model is flexible in the sense of management questions can be answered from different levels: per service, per host, per VAN, per domain and per VPAN. The implementation has showed that the proposed framework can successfully handle Telecom environments with mobile services, VANs and VPANs, opening up a potential further study.

In order to improve the service provisioning, we plan to introduce a negotiation phase between clients and the service provider. With this new functionality, both client and provider could define some agreements on QoS. Finally, although currently we have only one SP, we intend to have more than one service provider offering same or different services.

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