Active Networks in Implementing a Virtual Home Environment

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Abstract

This paper discusses how certain aspects of Virtual Home Environment (VHE) can be realised by Active Networks (AN). First, both concepts are introduced to the reader. Some problems related to the implementation of VHE are then pointed out, and possible solutions provided by Active Networks are suggested. Finally, the reader is presented with an outline of a VHE service implemented with AN.

1 Introduction

The need to provide sophisticated services to mobile customers has lead to the concept of Virtual Home Environment. It is a framework for providing roaming users their customised services basically anywhere. However, there are certain technical issues related to VHE which must be dealt with before the implementation is viable. Chapter 2 discusses VHE and some of the requirements presented by it in more detail.

Active Network is a novel approach to enhance the capabilities of a packet routing network. The basic ideas of active networks and the concept of Application Layer Active Networking (ALAN) are presented in Chapter 3. Both of them offer a possibility to increase the level of service and the performance of traditional networks and make it easier to introduce new services. The use of active networks for implementing certain key elements of VHE might prove to be valuable. Active networks could enhance some critical parts of the data path from the service provider to the customer and thus increase the performance and flexibility of a VHE implementation. These issues are discussed further in Chapter 4.

In order to make the idea of using active networks in the implementation of a VHE more concrete, an outline of a transcoding service is introduced in Chapter 5. This example specifically shows how the advantages of the ALAN tehnique could offer help in the realization of a VHE. The presented service allows the quality of a datastream sent from a service provider to be adjusted dynamically according to the capabilities of the receiving terminal. This adjusting is one the requirements presented by the VHE concept.

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2 Description of Virtual Home Environment

There are many definitions used by different standardisation bodies to describe the term Virtual Home Environment, VHE. One of them, suggested by the VESPER project, is:

“VHE main feature is that the customised environment will be following the user while he/she is roaming within different networks and using different terminals.” [2]

In other words, a Virtual Home Environment means the capability to provide a service with a consistent look and feel while the user is roaming outside her home network. It offers service portability and session mobility across service provider and network boundaries regardless of the type of terminal used. Additionally, the VHE concept establishes that service provision and network management can be separated so that they may be provided by different parties. Also, the variety of operators involved should be hidden from the user. [2]

The concept of VHE can be considered from two viewpoints: the business view related to the VHE and the technical perspective which is used when considering the implementation of the VHE.

2.1 Business view of VHE

The relevant actors and systems participating in a VHE business view are presented in Figure 1. Their functions are elaborated in the following paragraphs.

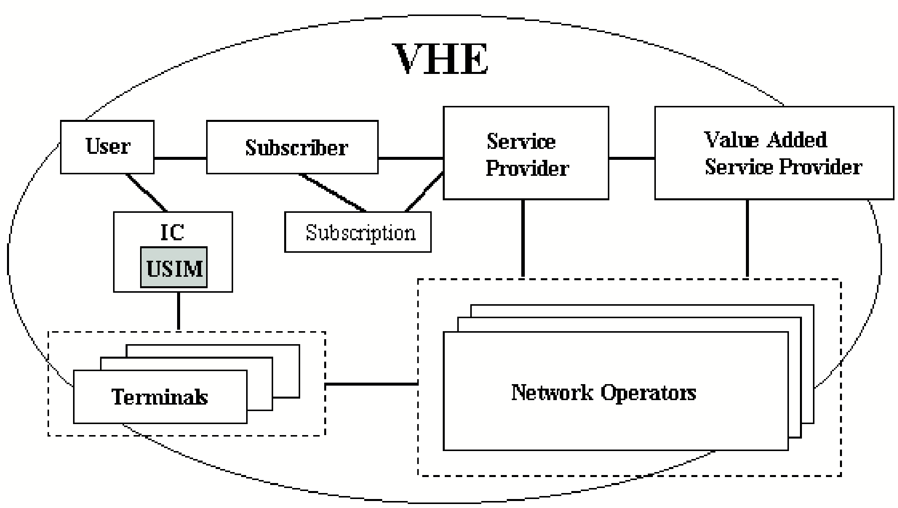

Figure 1: Roles of the VHE business model. [2]

The user and the subscriber are considered to be distinct, as there might be a number of customised user profiles defined for each subscriber. A subscriber makes a contract with a service provider, which can co-operate with one or more additional value added service providers to produce the subscribed service. Each of the service providers uses the network

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connectivity provided by various network operators. [2]

The user connects to the network and uses the subscribed services by a terminal. A terminal may hold an Integrated Card (IC) which is used to store one or more subscriber's identity modules. The module shown in the figure 1 is UMTS Subscriber Identity Module (USIM). [2]

The depicted view of the service provision model is static because it does not present home and serving domains separately. Therefore the picture does not change if the user is roaming outside her home network.

Each of the roles and systems presented above must support and contribute to the concept of VHE before its implementation as required by the user is viable.

2.2 Technical view of VHE

The implementation of a VHE places specific technical requirements on the mobile environment. Some of the key elements are listed below [2]:

- **Ubiquitous access** states that the user should be able to access the system from any terminal of supported type.
- **Personalization** of the service environment provides the user the possibility to change certain characteristics, like the appearance of the interface or the language of the service, according to his/her personal preferences. A set of such customisations is called a user profile.
- **Adaptability** means that the type of terminal should not limit the number of services available. Each service should be able to adapt to the capabilities of different terminals.
- **Consistency** covers a lot of distinct requirements, but it basically states that all user modifiable data and every user profile should be guaranteed to be consistent in every situation. For example, if a user suspends a video stream on one terminal, then switches to another kind of terminal and resumes the session, the video and voice he first receives should be those provided immediately after the suspension.
- **Portability** is the requirement to support downloading of specific parts of services into the terminal. This would be a necessary feature for instance in services that implement e-commerce or business-to-business transactions. Using digital cash might require certain terminal part of the application to be downloaded before use and then be removed afterwards.
- **Reliability** means that the information in user profiles should be protected against loss or damage of terminal equipment. The profiles could be backed up by the appropriate operators to meet this requirement.
- **Security** in VHE means that the user and the operators should be provided a secure environment where information and services are available only to the authorised parties. The means to achieve this requirement are numerous, such as encryption of data and digital signatures.

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3 What Are Active Networks?

The term Active Network (AN) refers to network components like routers and switches that are capable of customised computations on the messages flowing through them. "The point of having an active network is to support programming or customizing of most aspects of packet processing, including routing, output scheduling, congestion behavior, etc." [1]

The concept of active network has been designed primarily to enhance the features of a generic packet routing network. A circuit switched network like ATM could also benefit from certain elements of AN, like programmable switches presented in 3.1.1. There are practically no restrictions placed on the selection of protocol when implementing active networks.

The nodes in active networks can process and manipulate the data packets on a per user or per application basis. In contrast, the common routers used nowadays are only able to modify the packet headers, not the payload. In addition, the manipulation in legacy routers is done in an identical way for every packet without considering the user or application that sends it. [10]

Figure 2 illustrates how active routers can co-exist with legacy routers in an IP network and do application specific processing on datagrams passing through them.

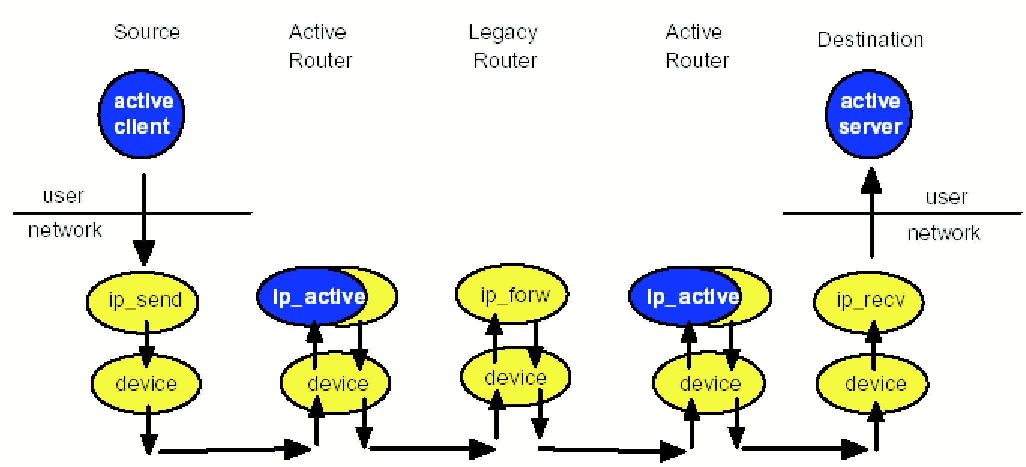

Figure 2: Application based processing of IP packets in an active network. [9]

The need for computation done within the network infrastructure is driven by such applications as firewalls, web proxies and multicast routers. At the moment they use ad hoc approaches to implement the specified tasks. The redundant processing of packets at several protocol layers causes performance to suffer. Furthermore, introducing new standards or services to the existing architectural model has proved to be difficult and time consuming. In case of a protocol it takes about ten years for a prototype to be ready for large scale deployment. [9]

Active networks are intended to solve the aforementioned problems by providing a generic execution environment inside the network components. Each node supports equivalent computational models which can be used to run arbitrary code and access node resources and capabilities. The users and administrators are able to program and configure the behaviour of the network to best suit the needs of applications. New services can be introduced simply by changing the behaviour of necessary nodes.

3.1 Programming Active Nodes

Figure 3 shows an overview of how an active network node processes arriving packets. The node can either use the stationary service components downloaded beforehand into the node or execute the code contained in the packets. These two basic AN approaches, called programmable switches (out-of-band injecting of code) and capsules (in-band data transfer), are discussed in the following paragraphs.

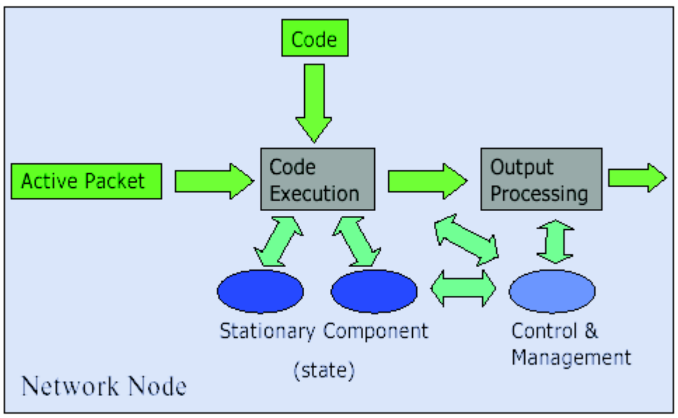

Figure 3: Active Packet Processing in an Active Network Node. [3]

3.1.1 Programmable Switches

The term programmable switch is actually a misnomer. It suggests that the network component in question performs functions only on the data-link layer (level 2). The term is meant to refer to all data-link or network layer (layer 3) components which have the characteristics described below.

When implementing active networks by programmable switches the behaviour or state of a node is changed by injecting customised programs through an out-of-band management channel. When the datagrams then flow through the node the packet headers are examined as usual. The appropriate functions stored in the node are deduced from the headers and used for additional processing of the packets. Thus, the programmable switches act much like traditional routers or switches but the computing done on the packets can be dynamically altered if needed. [1, 9, 10]

Using programmable switches separates loading and execution of programs in active nodes. The mechanism might be useful when the services provided in the network are selected by administrators instead of individual users. The administrators would be able to extend router capabilities as necessary by uploading suitable programs. [9]

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3.1.2 Capsules

Capsules take the idea of dynamic loading of programs a step further. Each packet carries a piece of user specified code which is executed at every node along its path. The passive packets of traditional routing are replaced by miniature programs that run on the processing environment provided by the node. The nature and capabilities of the environment can vary from simple routing service of IPv4 to a powerful programming language like Java or one simulating a Turing machine. Even multiple concurrent environments could exist in the same node. [1, 9]

An example implementation of capsules called Smart Packets is presented in [7] and [8].

3.2 Application Layer Active Networking

The deployment of active network concept on the router level presents certain problems. Security, safety and resource management become important issues when a third party is allowed to deploy protocol code into the equipment of a service provider. The programs running on active nodes would need to be approved and possibly proofed to be correct before they could be used. This would result in increased costs and longer time-to-market. [5]

An alternative to changing functionality of routers has been presented in the form of Application Layer Active Networking (ALAN). It implements the ideas of active networks on application layer instead of the lower router layer. The ALAN system utilizes Dynamic Proxy Servers (DPS) to enhance communication between clients and servers. Figure 4 presents an overview of the ALAN architecture. [5]

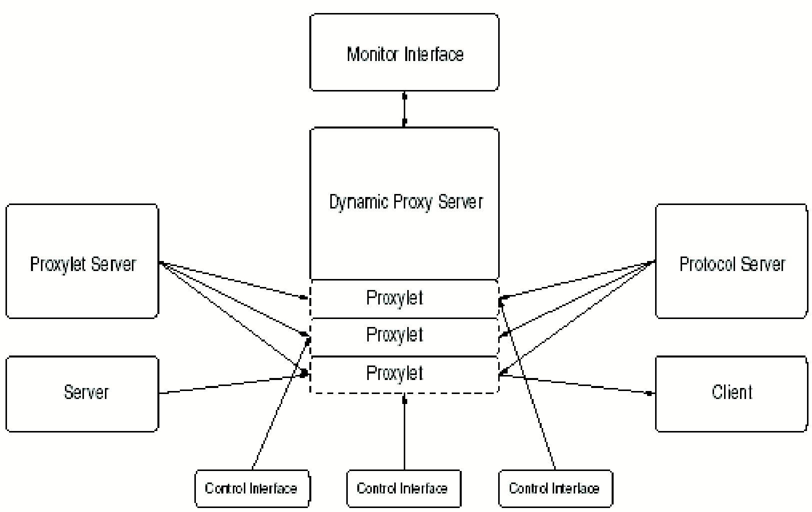

Figure 4: ALAN basic architecture. [5]

The Dynamic Proxy Servers are located in optimal points in the network and the client-server connection is routed through them. They are capable of downloading proxylets from Proxylet Servers. Proxylets are programmes (like applets and servlets) that provide

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enhanced functionality which is used by the DPS to improve the level of service. Appropriate protocol stacks can be downloaded from Protocol Servers and used to adapt the data flow according to need. [5]

The placement of Dynamic Proxy Servers in the network is a multi-metric problem and is discussed in [6]. In the same document the name Dynamic Proxy Server is changed to Execution Environment for Proxylets (EEP).

4 Using Active Networks in Virtual Home Environment

The need to support users roaming in different networks causes the implementation of VHE to face problems concerning scalability, reliability, security and quality of service [11]. The list of technical requirements presented earlier in Chapter 2.2 shows the kind of capabilities a VHE implementation requires. A partial solution to some of these issues could be provided by using active networking techniques in certain tasks of service provision.

First, it has to realized that an active network in any of its forms, be it programmable switches, capsules, ALAN or some hybrid of these, will not be able to overcome all the obstacles currently facing VHE implementations. It will not be able provide access to the roaming users any better than the current solutions. Consistency and reliability as presented in Chapter 2.2 are also features which probably cannot be helped by active networks. They involve technical aspects which the active networks were not designed to address.

The use of active networks is better suited for other kind of activities. Due to the fact that there can be multiple parties involved in service provision, data might have to travel through several networks before reaching the roaming user. One of the advantages of using ALAN in this kind of scenario would be the optimization it can do when transmitting data. The protocols and algorithms used in communications could be changed on the fly if the need would arise. This would make it possible to pack data that is sent over a slow, congested line. The data would be extracted to its original form when it reached the proxy server located near the user end. As the decision to switch from one protocol to another for the duration of data transmission would be transparent to both the sender and the receiver it would not require changes to either of them. The example service described in Chapter 5 also makes use of a similar ALAN technique to increase the adaptability of the system.

In addition to increasing throughput of data, active networks might handle issues concerning VHE security. Packet filtering in active nodes on the router level could be feasible because of the superior performance over the traditional software based scanners. The updating of filtering rules would be possible as the code could be dynamically uploaded to the nodes. Also virus scanners could be inserted directly into the appropriate active components, further improving the level of security provided to roaming users. However, this would require that the managing of the update procedure of such scanners was taken care of.

The ALAN approach to security could be the adaptation of ciphering algorithms used in data transmission to match the security capabilities of the participants. The DPS servers might have the option to weaken the used algorithm within certain limits if the performance

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of the terminal equipment was not sufficient to handle strong cryptography. At the same time the communication between the DPSs would remain as secure as necessary.

The personalisation of the service environment is another key element of VHE. It could be implemented by using Virtual Active Networks (VAN). VAN implements a generic active service which consists of a graph of virtual active nodes managed by a provider. A customer using the VAN sees an abstraction of an actual active network with all of its bandwidth and computing resources. Each customer using a VAN has access to a seemingly real active network where new active services can be deployed at will. Each VAN is isolated from each other and managed separately by the corresponding customer, independently of the service provider. Only the actual infrastructure on which the VANs are built on is managed by the provider. [4]

The concept of VAN is still quite new and under continuous study. Nevertheless, it can be argued that if each user in a mobile environment could be provided with a private VAN it would greatly benefit service personalization. Users could implement and manage their own services and therefore customise them as far as they would like. Service providers might also offer some basic building blocks which could easily be combined by the users in order to create sophisticated services and customisations.

The VHE requirement concerning portability is similar to the basic architecture used in programmable swithes or ALAN proxies; applications or parts of them are loaded into the terminal only as needed. Therefore the same kind of methods that are used for the on-demand downloading of code in active nodes or dynamic proxy servers might be utilized also in the terminal equipment.

5 A Transcoding Service for VHE

One of the technical requirements of VHE is the need to adapt the quality of service to the level supported by the terminal. Implementing quality of service across service provider network boundaries brings about difficulties.

Let us consider an example where a roaming customer wants to receive a video stream from a value added service provider. Instead of having to negoatiate a suitable bandwidth in every network used between the customer and the service provider, the service uses Proxylet Servers.

When the type and capabilities of the terminal are known, the DPS nearest to the service provider decides, using built-in logic, the format in which the stream will be delivered. The DPS downloads an appropriate protocol stack or a proxylet which can handle the required data transformations. It then finds some other DPS which is located near the terminal and requests for a connection using the chosen protocol. The result is a chain of proxy servers communicating with each other using data format supported by the terminal. Finally, the service is started up and data is streamed through the path of DPSs to the terminal.

Alternatively, the appropriate transmission format can be chosen at a later stage. In such a case, the stream is delivered in its original form all the way to the DPS nearest to the terminal. There it is transcoded into a suitable form before delivery.

Which of these methods to choose depends on whether it would save a lot of bandwidth to do the transcoding as early as possible and whether it would be efficient to upload protocol stacks to every DPS along the way.

The presented service exploits ALAN by dynamically choosing the most efficient way of transmission by taking several variables into consideration. The distance and type of network between the terminal and the service provider can also affect the selection of the protocol. Normally, such optimizations would be impossible due to the lack of common technologies supported by all participating parties.

6 Conclusion

Introduction of active networks on the router level does not seem probable in the near future. The idea looks good on paper, but the goal to avoid time consuming standardisation involved with traditional protocols and services might not be removed by active networks. Careful specification would still be needed before arbitrary code could be released into the network routers. Also the performance of basic packet routing task done by active nodes would have to increase in order to rival the legacy routers. Therefore the approach of building active networks on the routing level is not likely to help in the implementation of a VHE.

On the other hand, when active networks are implemented on the application level, that is, by realizing the ALAN concept, some benefits for the VHE can be foreseen. The prototypes of ALAN services have proved to be useful and efficient. A number of them, including a compressor service and a low latency implementation of a tcp bridge, can be found in [5]. The document includes performance measurements and discussion about the ease of development and deployment. Some of these prototypes seem interesting also from the VHE perspective. A possibility to move logic involved in the dynamic service provision into the network offers flexibility and faster development of new services. At the same time the customers can be provided with the required services in every network and the level of service can be adjusted dynamically.

Using Virtual Active Network (VAN) adds the element of a separated environment for each customer. In such a system the deployment of active services is no longer dependent on the network operator. The development of sophisticated services taking advantage of network resources is faster and the benefits provided by active components to a virtual home environment become more apparent.

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7 Further Information

http://vesper.intranet.gr/

http://nms.lcs.mit.edu/activeware/

http://www.cogs.susx.ac.uk/users/roryg/research/literature.html