Broadband Network Architectures: Two Approaches

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Abstract

To support a wide range of multimedia services future fixed and wireless broadband network capabilities should allow the distribution of service functions between the customer terminals and the network nodes. Intelligent Networks[1] (IN) can be considered as the bridging technology between the customer based service management and the service execution in the networks. Considering the mobile and broadband technologies it is a natural question, how the concept of intelligence will develop. To satisfy multimedia service needs future broadband networks should support distributed operations for easy service creation and deployment. In this paper we describe two approaches studied in the Telecommunications Software and Multimedia Laboratory of Helsinki University of Technology.

1 Introduction

The introduction of multimedia broadband services creates a need to control complex combinations of service components and resources. Broadband networks are able to support interactive multimedia services including applications to electronic papers and publishing, digital interactive TV and audio, multimedia on demand services for banking, shopping, news and leisure. The technological requirements for these services are cost effective broadband transmission and access technologies, flexible management and control of networks and the support of mobility. When the cost-effective broadband access technology is available, interactive business and consumer services based on video and multimedia will become possible. However, in addition to access technology also network control infrastructure must be ready before the service and content providers are able to enter the market.

In modern telephony technology the most promising computerised control and management concept is the Intelligent Network (IN) [1], which can be considered as the bridging

[1] By IN we refer here to the general concept of introducing intelligence into networks rather than the standardised IN network architectures, such as ITU-T CS-1 and derivatives thereof.

technology between the customer based service management and the service execution in the networks. A trend of distributing the service applications between terminals and network nodes can be seen., an example of which can be found in the specifications of UMTS (Universal Mobile Telecommunications System) [2]. In this paper we describe two network architectures that are designed to support multimedia services in broadband networks.

2 Transparent Object-oriented Virtual Exchange (TOVE)

TOVE research project has its origins in the ongoing integration of the telecommunication and data networks. B-ISDN (Broadband Integrated Services Digital Network) is an effort to create a single unified, global high-speed network architecture for transmission of speech, data, images and video services. ATM (Asynchronous Transfer Mode) has been selected to be the transport technology for B-ISDN. B-ISDN may also be used as the infrastructure for the future wireless networks such as UMTS and Mobile Broadband System (MBS). TOVE project considers B-ISDN as the target broadband networking environment.

In the first phase of the TOVE project the middleware for supporting distributed call and connection control functions and has been developed. The middleware is used to implement a modular ATM switch software and a virtual ATM exchange prototype based on that software. The exchange will be used as a platform for piloting different call and connection control solutions. Prototypes are used to demonstrate the feasibility of different architectures and configurations and also prototype applications will be built in parallel with the development of the infrastructure. The following subsections describe the key issues that have been addressed in the design of the TOVE architecture

2.1 Object Virtual Operations System ++

Telecommunications software and protocols are becoming increasingly complex and at the same time they must be efficient, reliable and flexible. Also, software has to be developed in parallel with the emerging standards that may change during the development. Protocol software development is traditionally carried out in classical design and implementation methods or code generation methods with CASE (Computer-Aided Software Engineering) tools for specific languages, such as SDL (Specification and Description Language) [3]. However, TOVE project has adopted an object-oriented approach by using an object framework for network programming. The framework has its roots in the OVOPS (Object Virtual Operations System) [4] and it was named OVOPS++ to indicate the adoption of the Conduits+ framework [5] for supporting protocol software development. The framework uses extensively design patterns [6], descriptions of proven solutions to general design problems.

In TOVE the OVOPS++ framework is used to define the overall structure of the protocol architecture by partitioning the control functions and ATM protocol stacks into classes and objects that are managed and executed by the OVOPS++ runtime part. The benefits of the object-oriented framework lie in the reusability of the code common to all protocol software, which allows the developers concentrate on the protocol at hand rather than the general problems of protocol software engineering. Also better readability and documentation of the software is achieved due to the design pattern approach, which enables quick learning and better communication among the development team.

2.2 Virtual exchange

One of the main principles of the TOVE architecture is the separation of control from switching, which has lead to the concept of Virtual Exchange (VE). In this approach the Switch Controller (SwC) is logically and physically separated from the ATM switching fabric, so that the switch includes only a minimal software necessary for opening and closing of virtual circuits. This requires that the switch and the controller implement a control protocol that is used for communication between them. One example of such a protocol is GSMP (General Switch Management Protocol) [7].

Different associations between fabrics and controllers are possible. If one-to-one association is used, the combination can be considered as a traditional ATM switch with the distinction that the controller is an external general purpose workstation rather than an integrated unit. One-to-many or many-to-one associations are possible when expected signalling load is not comparable to the performance of the switch controller. Different FCP and SwC configurations are illustrated in Figure 1. The architecture has been named virtual exchange due to the fact that several switching fabrics may be represented to the user of the VE interface as a single, virtual ATM switch.

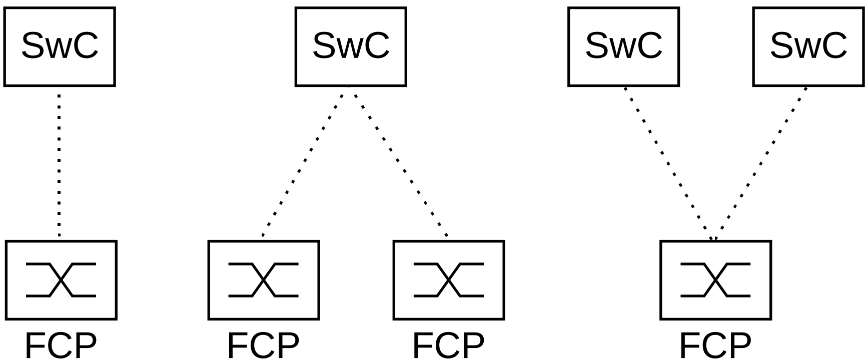

Figure 1 TOVE architecture divides Service Switching Point (SSP) into Fabric Control Point (FCP) and Switch Controller (SwC) parts. Fabric Control Points and Switch Controllers may be used in different configurations depending on application requirements.

2.3 TOVE and IN

More flexibility is gained by offering an open interface to the call and connection control as well as hooks for triggers that activate external IN (Intelligent Network) functions. Provided that access control and authentication are properly handled, call and bearer control can be distributed to service functions, even to the user applications, and the operation and provision of new services become independent of the basic network functions. This gives the ability to introduce new services or change existing ones quickly without having to modify the basic network functions [8]. The approach taken is to follow ITU-T standardised IN (Intelligent Network) principles.

The CCF (Call Control Function) of the TOVE architecture includes the BCSM (Basic Call State Model), which is a high-level description of the CCF activities required to establish and maintain communication paths for users. The BCSM provides a framework for describing basic call and connection events that can lead to the invocation of IN service logic instances or should be reported to active service logic instances. This triggering mechanism allows the SCF (Service Control Function) of a separate physical entity to control the basic call processing and to take the actions necessary for service execution. An enhanced Call State Model is being developed in TOVE project, the demands for which are analysed in [9].

The connection between TOVE CCF and external IN systems will be implemented in a method based on CORBA (Common Object Resource Broker Architecture) [10] and being studied by OMG (Object Management Group). The BCSM triggers and callback functions are defined with CORBA IDL (Interface Description Language) interfaces, so that the IN events are represented as CORBA remote method calls within TOVE software. The method calls are processed by an external IN gateway, which translates them to standard SS#7 (Signalling System #7) messages that can be relayed through the legacy SS#7 network. This technology is discussed in detail in [11].

2.4 TOVE architecture

The separation of service control, call control and fabric control forms a three-level control architecture, which is the main principle of the TOVE architecture. This separation of different levels of control allows the lowest level of switching be relatively stable and simple, whereas the highest level of services can be under constant modification and development as new services are being created and deployed into the network. The intermediate control level may require changes to be made, when for example new signalling protocol is introduced or the call processing model needs to be updated to support new service classes.

The TOVE prototype platform is an implementation of the layered control architecture, based on the standardised B-ISDN concepts and protocols. The service control is separated from the basic call and connection control using the IN concept and CORBA technology. Both access signalling across UNI (User-to-Network Interface) and network signalling across the NNI (Network-to-Network Interface) are supported using ITU-T standards (Q.2931 and B-ISUP / MTP-3). The FSR (Frame Synchronised Ring) [12] switching fabric architecture developed by the Technical Research Centre of Finland has been used as the first hardware platform. A complete overview of the elements of the TOVE architecture is given in Figure 2.

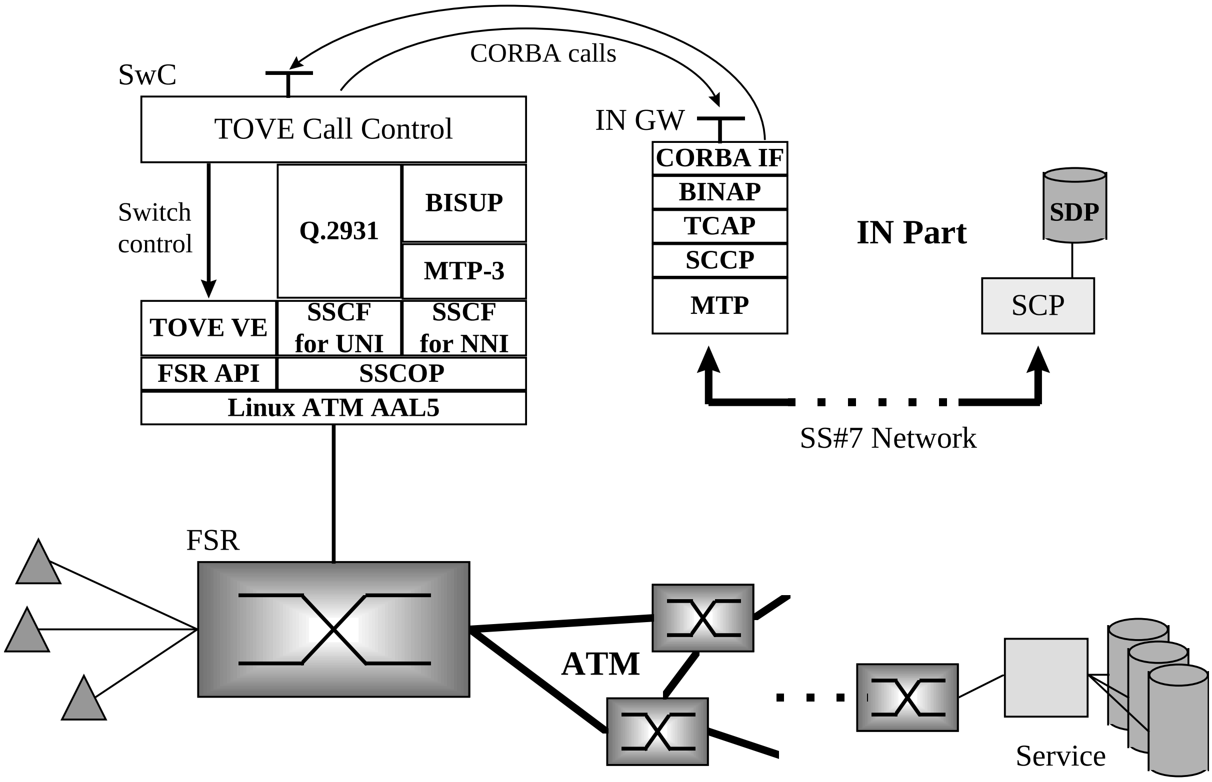

Figure 2 TOVE architecture

3 Calypso

In TOVE project the emergence of a global broadband services network is expected to proceed from the core to the edges of the network, a natural consequence of which is building on existing standards and architectures such as B-ISDN. While this statement certainly remains valid, a different approach can be found by changing the mindset from the backbone networks and legacy systems to the access networks and end user systems. The Calypso project has grown from this idea and its goal is to experiment with different kind of service scenarios to prove concepts and identify the requirements of the future broadband multimedia services networks. By restricting the application domain to the local access networks it is possible to concentrate on the interaction between users and services, leaving the global interoperability issues aside. However, they cannot be completely forgotten and naturally there must be interoperability at least at the local level and global interoperability through gateways. This means that also Calypso needs a network architecture, but it can be relatively simple and based on the end user requirements rather than those of the B-ISDN or some other global scale architecture.

3.1 Layered control model for broadband networks

TOVE project separated control from the switching on one hand and service control from the basic call and connection control on the other. This resulted in three layers of control, which can be further generalised into an abstract control model. This model consists of fabric control, network control and service control and it is described in Figure 3 and the explanations below.

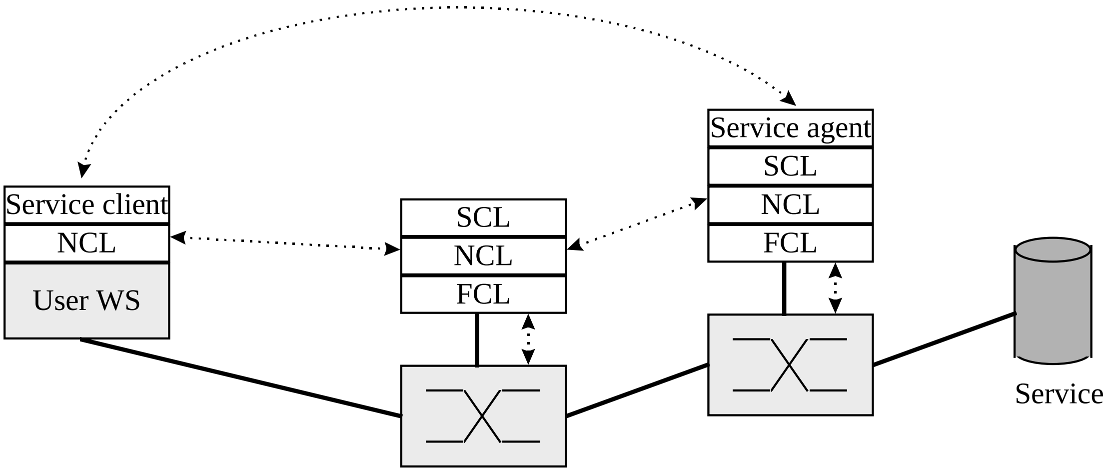

Figure 3 Layered control model for broadband networking

- **Fabric Control Layer** FCL is closest to the switching hardware, its function being to provide the network layer a hardware independent control interface for managing connections in an ATM switch. The communication at the FCL occurs only locally between the switching hardware and the software controlling it. FCL might be implemented for example as a wrapper to GSMP or some proprietary switch control interface provided by the switch vendor.
- **Network Control Layer** Whereas FCL is concerned with the control of individual switching fabrics, NCL handles end-to-end connections which consist of chains of connection legs between network nodes. Connections may be simple point-to-point virtual channels, or they may branch (point-to-multipoint) or become rerouted from a physical link to another (handovers, mobility). The communication at the NCL occurs between peer nodes, and an implementation should provide at least a routed network layer protocol for transporting data between network nodes, a routing protocol to exchange network topology information and a protocol for reserving and establishing connections through the network.
- **Service Control Layer** The highest level of control is the SCL where entire service sessions are managed. Service sessions consist of one or more individual connections (e.g. audio and video streams together with a bidirectional data connection could form one multimedia service session) and they typically include user authentication in the beginning as well as other necessary negotiations to set up the session. The communication at the SCL occurs between service clients and service agents, which in turn use the connection set-up service of the NCL to establish connections. We point out that at this level the communication methods between clients and agents can be service specific instead of using predefined protocols such as INAP (Intelligent Network Application Part), because the service data is transported across the network using the generic transport service of the NCL.

3.2 Calypso architecture

The scope of the Calypso architecture is restricted to the domestic broadband access networks that connect to a high-performance backbone network. The backbone is viewed as an abstract source of services that the clients access using Calypso network as a mediator, a ‘middle-man’ that provides the end-user applications a unified interface to the services from heterogeneous sources such as the public ATM network, the Internet or PSTN (Public Switched Telephone Network). This approach has been taken due to the belief that the networking requirements will remain heterogeneous, e.g. Internet-style networking and B-ISDN networking are not likely to converge in the near future, but both are important and must be supported in end user applications.

Calypso addresses this problem by defining an architecture in which the services are controlled by distributing the service access mechanism into service clients in the end user terminals that communicate with service agents in the access network nodes. The service agents in turn are able to perform the signalling procedure or whatever needs to be done to access the service and bring it to the user terminal. This kind of approach hides the complexity of the service access from the user application by separating service specific access functions (i.e. the interface between user application and the service) from the generic connection procedure (e.g. ATM signalling). The service agents act as proxies that provide the user application an interface that can be completely service specific instead of being mapped on some generic connection procedure.

The implementation of this architecture is based on the layered control model outlined in Chapter 3.1. In Calypso the Network Control Layer is used to provide connectivity and data transport within access networks, so that the user applications are able to communicate with the service agents in the network nodes. TCP/IP protocol suite is suggested to be used as the technology of the NCL, to facilitate quick development and prototyping of the distributed service client/agent model. The service client/agent environment and the Service Control Layer (in Calypso called the SEE, Service Execution Environment) will be based on Java due to the inherent support of distributed networking applications and code mobility of the language. Figure 4 represents the Calypso architecture and more detailed descriptions of the Calypso service architecture can be found in [13, 14].

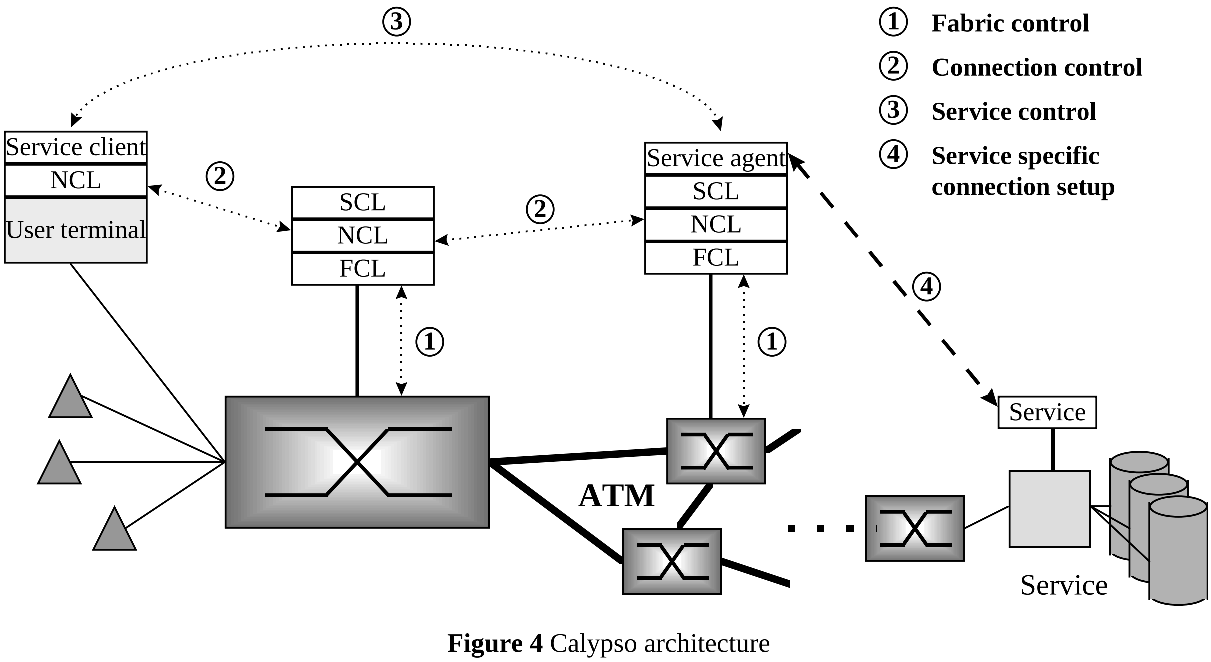

Figure 4 Calypso architecture

4 Service Provision Aspects

Currently, the Internet and in particular hypermedia document based World Wide Web (WWW) has become one of the most important environment for multimedia services. It is probable that the emerging Internet and WWW environments form a new commercial Service Creation Environment, which will emphasize the role of the service and content providers in the new market situation that the opening of the European telecommunications market will create. Also the importance of the Internet as an user interface to multimedia services must not be underestimated because of the large user base that has already accustomed to the browser based interface to media.

The idea of Service Icons as a graphical or multimedia representation of the available services has been proposed in [15]. These icons would represent available services, e.g. interactive multimedia documents or digital audio or video material in multimedia server and they could be accessed by the user's WWW browser. This kind of model suits well into the Calypso architecture, in which the services are managed and accessed by distributed service applications. This is easily achieved due to the use of Java technology in the implementation of the Service Execution Environment of the Calypso architecture. Also the creation and deployment of new services is easy if the service provides can develop their service applications in an environment that gives the basic tools and interfaces for efficient service management and network control, which is the main principle of the Calypso SEE.

5 Conclusions

We have described two broadband network architectures studied and developed in the Helsinki University of Technology. Both are motivated by the foreseen emergence of a new broadband network information infrastructure that will be the core of the universal multimedia services network. However, TOVE architecture is based on the standardised work on B-ISDN architecture, which is an international effort to bring broadband technology from the core of the network to the edges, whereas Calypso architecture is limited to the access networks and focused on the service architecture and end user aspects.

In spite of the architectural differences, TOVE and Calypso are complementary rather than contradictory. It can be said that Calypso architecture creates a new level of abstraction between the end users and the services, which separates the access network from the backbone network This abstraction is necessary to support heterogeneous networking and combining services from diverse sources while maintaining unified network interface for the end user applications. The result is a network architecture that supports a wide range of services, rapid creation and deployment of new services as well as interoperability with legacy systems.

Acknowledgements

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