Media Switch for Multimedia Services

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Abstract The convergence of telecommunications, computing and content industries has been one of the major trends during the recent years. The convergence has led to the creation of a wide range of multimedia services, which are available in digital form through broadband networks. There is a need for network nodes that are capable of interfacing to different kinds of networks and implementing a programmable service platform for multimedia services. As a solution to this need, this paper introduces the Media Switch, which is able to combine different switching disciplines into a compact fabric and provides a platform for multimedia services. Finally, example services based on the Media Switch prototype are presented.

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1. INTRODUCTION

The development of broadband networks will provide capacity for new interactive multimedia services, which will become available for fixed network and mobile terminal users. This development will be based on new broadband network service architectures, which will support user controlled easy and rapid service creation and deployment.

Broadband networks, such as B-ISDN (Broadband Integrated Services Digital Network), are foreseen to be used in delivering future services. ATM (Asynchronous Transfer Mode) has been considered as a unifying transmission technology, capable of supporting a large variety of connections with different and sometimes contradicting requirements [1]. Another important trend is the upswing of Internet, which has boosted popularity of the TCP/IP (Transport Control Protocol/ Internet Protocol) protocol suite. Thus IP transmission over ATM has been a target for standardisation [2, 10].

However, IP over ATM and related IP switching schemes (e.g., IP/ATM, ARIS and Tag switching [9, 10]) introduce unnecessary overhead and duplication of functionality [15]. Hence, more advanced transport methods have been developed, e.g., MPLS (Multi-Protocol Label Switching) and Differentiated Services concept [8, 15]. Other examples include concepts to transmit IP directly in physical level transport frames, e.g., in SDH/SONET (Synchronous Digital Hierarchy/ Synchronous Optical Network) frames [8]. Moreover, concepts called IP over photons have been studied [7].

Believe in ATM is largely based on the fact that it is quite a mature concept supporting a large set of service requirements. Although, ATM is mainly used in trunk networks, it is extending to the access network along with new access techniques. Examples of these are the various DSL (Digital Subscriber Loop) solutions, e.g., ADSL and VDSL, aimed at extending usage of the traditional copper based local loops. Competing solutions include cable modems, developed to utilise CATV networks. The conventional PSTN (Public Switched Telephony Network) still has a stabile position and is envisioned to hold its position for a lengthy period of transition.

Therefore, it can be concluded that the evolving multimedia services will be offered to users over a diverse set of networks, based on different transport and switching technologies. Hence, equipment capable of supporting multiple switching schemes will be needed. This paper introduces the Media Switch that supports multidiscipline switching and routing of multimedia services. Chapter 2 presents the concept of multidiscipline switching and highlights the major implementation issues. Chapter 3 introduces the Media Switch to integrate circuit, packet and cell switching and, additionally, touches the issues of signalling, call control and service platform. Chapter 4 describes multimedia services developed applying the Media Switch. Chapter 5 has the concluding discussion.

2. MULTIDISCIPLINE SWITCHING

A conventional telecommunications switch is a single discipline switch and connects to a homogeneous transport network, which implies switching of fixed size data units, e.g., 8-bit time-slots or 53-octet cells. A homogeneous network may support different and even variable data rates, but the basic unit of data to be switched is common to all supported rates.

2.1 Multiple disciplines and switch fabric

A multidiscipline switch connects to different sorts of networks and supports heterogeneous transport technologies. This means, e.g., switching of multiple fixed length data units and support of different switching disciplines. The different data units are usually carried through the switch fabric in containers that include also information of the type of carried data and routing information. Fig. 1 depicts the concept of multidiscipline switching.

Examples of interconnection networks used in composing switch fabrics are multidrops, rings, crossbars and multistages (such as Banyan and Delta) [13]. Shared buses, e.g., multidrops and rings, are the most flexible ones for multidiscipline implementations. The different data units can be carried in common fixed length containers or a special container type is dedicated to each data unit type. The common container solution would simplify design and control of the physical bus, while possibly leading to inefficient use of the system resources. The resources could be used effectively by having variable size containers, but control of such a system becomes complicated.

The use of data unit specific containers allows each container type to be controlled separately and the physical switch can implement several virtual switches (Fig. 2). The switch resources are permanently shared among the related systems and container dimensioning becomes a crucial issue [4, 14].

Figure 1. A multidiscipline switch implementing three different switching concepts.

2.2 Network interfaces

A multidiscipline switch needs a diverse set of interfaces, which usually perform tasks such as physical signal and bit rate adaptation, line-encoding/-decoding, timing extraction, packet assembly/disassembly, multiplexing/demultiplexing and buffering. Since the physical fabric does not normally include much intelligence, the interfaces must be equipped with logic to process the incoming data to fit into the containers. Extra logic is needed to convert incoming network addresses into the switch's own address format. The switch uses these addresses for local routing and flow control. In the output interface, the containers are disassembled and the data units are reassembled to form the original packets. In some applications, the switch specific addresses are mapped to the destination network addresses. The interfaces also need a mechanism to communicate with the control block.

2.3 Switch control

Due to the nature of supported transport technologies, their signalling procedures, connection types, quality of service (QoS) parameters and even supported services may require different control discipline. The implementation is easier if the switch, call and service control are separated, leading to a three layered control architecture [11]. "Standard" interfaces can be fixed between the adjacent control layers. Changes to the layers can now be made independently while maintaining compatibility between them. Example solutions identifying the three control layers are presented in [5] and [11].

In practice, a multidiscipline switch combines several control and service architectures into a compact control system. Each requires its own set of protocols and a straightforward solution is to implement the protocol stacks (of each virtual switch) separately. Thus, each stack and associated call control functions work as if they were run on top of a physical switch of that particular network architecture. A common control block is needed to manage switch resources, convert application level connection commands to physical connections and perform physical level routing of the data units.

3. MEDIA SWITCH

The Media Switch has been developed in the SCOMS (Software Configurable Multidiscipline Switch) project at VTT Information Technology and Helsinki University of Technology. It integrates time-slot, cell and packet switching into a single fabric. The platform comprises the switch fabric, interfaces to associated transport networks and a switch control unit (Fig. 2).

3.1 Switch fabric

The switch fabric implements three virtual switches and is based on the FSR (Frame Synchronized Ring) switching concept [13]. FSR has characteristics necessary to implement the fundamental features of multidiscipline switching, e.g., support of real-time multicasting, flexible addressing capabilities and simultaneous switching of different size data units.

Basically, FSR is a slotted ring consisting of nodes connected together with unidirectional point-to-point links. Due its advanced MAC (Medium Access Control) and the use of destination release policy, FSR is able to support multiple simultaneous connections. Data is conveyed in fixed size containers, which can be dimensioned individually. This allows multiple virtual switches to be implemented into a single fabric.

Each virtual switch occupies selected FSR nodes equipped with associated line interfaces. Nodes can be configured to support any of the three switches. Switch configuration can be changed dynamically by replacing any interface card by any other one and modifying configuration registers in the control unit. FRS's performance has been analysed and compared to other interconnection networks, e.g., in [12] and [13]. Dimensioning of the FSR bus in multidiscipline environment has been analysed in [4] and [14].

Figure 2. Block diagram of Media Switch.

3.2 Time-slot, cell and packet switching

In the PDH network, the basic unit of data is an 8-bit byte. Constant stream of these bytes (repeated at 8 kHz rate) forms the circuit switched 64 kbit/s channel. **Time-slot switching** refers here to switching of these 8-bit bytes belonging to individual connections. On the switching bus, the time-slots are conveyed in special PDH containers each carrying 16 time-slots (of

a selected connection) at a time. In practice, this means that a permanent share of the switching capacity is assigned for PDH, which guarantees delay and bit rate requirements of PDH traffic.

Routing of the containers through the switch is based on FSR's addressing mechanism. In the line interfaces, PDH channel numbers are converted to FSR addresses, which are used by the switching bus to route the containers automatically from the input interface to the output one. In the output interface, the containers are disassembled and the received time-slots are forwarded into the addressed output channel.

In ATM networks, all information is carried in 53-octet cells. Bit rates and quality measures of individual connections may differ from others and even the bit rate of a single connection may vary with time. Thus, the nature of **cell switching** differs greatly from time-slot switching and cells are carried in containers dimensioned to hold exactly one cell. To route the ATM containers through the switching bus, ATM addresses are converted to FSR addresses. Physical routing of the ATM containers is performed in a similar way as routing of the PDH containers. In the output interface, the FSR addresses are further mapped to outbound ATM addresses.

The IP packet lengths vary from a few dozens of bytes to 64 kbytes and to manage with the varying packet sizes, the IP packets must be segmented into mini-packets. These are the data units encapsulated into special IP containers. Due to the bursty nature of IP traffic, **IP packet switching** resembles switching of ATM cells. However, manipulation of IP packets differs greatly from that of cells. In the input interface, IP packet headers are examined and the IP address is mapped to an FSR address. Based on that mapping, each segment is routed through the switch to its output interface, where the packet is reassembled and sent to the destined link.

3.3 Network interfaces

The Media Switch is equipped with line interfaces to have connections to the ATM, PDH and IP trunk and access networks. ATM and IP traffic are carried over STM-1 links at 155 Mbit/s. 64 kbit/s PSTN traffic is carried over E1 links at 2 Mbit/s. On the access network, ATM traffic is carried over E1 and ADSL (Asynchronous Digital Subscriber Line) links and IP traffic over Ethernet. Correspondingly, 64 kbit/s PSTN traffic is carried over E1, $nx64$ kbit/s and N-ISDN (2B+D) links.

3.4 Switch control

Since the switch houses three totally different switching schemes, the call control block includes separate software packages for ATM, PDH and

IP call control. Fig. 3 illustrates one possible configuration of the protocol stacks. The three network architectures have their own signalling and control modules that are executed independently. The fabric control module offers network specific APIs (Application Programming Interfaces) that implement functions to reserve resources and manage connections through the switch. The control unit is connected to the switch with an ATM/STM-1 link, and all protocols receive their signalling messages from the switch interfaces in reserved ATM virtual channels (VC). Therefore, a line interface must map the incoming signalling messages to a specific ATM VC, used for transferring the messages to the control unit. ATM/STM-1 was chosen for the control unit connection, because it offers a straightforward way to manage the various control and signalling connections.

The PDH and ATM signalling and call control stacks resemble each others, having signalling links with every neighbouring N-ISDN or ATM device. PDH calls are established between PDH interfaces, likewise ATM connections can be set up only between ATM interfaces. The IP control module differs from the two others, because it has no connection oriented call model. The IP routing protocols receive routing information from all IP interfaces and the routing control module constructs the routing tables based on the received information. The routing tables are uploaded periodically to the line interfaces that perform routing of the actual IP data packets.

Figure 3. Separate call control stacks for the three network architectures.

3.5 Service platform

The multidiscipline bus functionality is encapsulated in MAC software layer, which in turn is available through the Operating System (OS). The switch protocol stacks with real time demands run as priority processes on the Operating System. The LINUX operating system has been chosen for the switch OS. The protocol stacks and data stream oriented functions are collected as Control Software Packages available on the OS.

There are three Control Software Packages designed for the use of the processes running on the Operating System: Switch Control Modules,

Routing Modules and Execution Environments. The Switch Control Modules include the protocol stacks of the three switching schemes. The Routing Modules manage the IP routing tables and related address mappings and include the corresponding routing protocols, e.g., RIP, OSPF and BGP.

Applications interact with the application specific Execution Environments that provide interfaces to switch hardware, manage resources and control resource contention. To ensure this control, all Execution Environments access switch resources through the switch OS, which mediates all access to resources, including transmission, storage and computation. Execution Environment API is used by applications to identify or modify specific packet header fields, e.g., for filtering or triggering purposes, or to create multicast copies of specified packets.

An Active Network (AN) Execution Environment supports active applications and consists of an AN core, building blocks and building block APIs. The AN core adds to switch OS the ability to deal with Active Network abstractions and interfaces. Building blocks are pieces of code that can be added to the Execution Environment at runtime. Building blocks represent the functional entities of the switch that either perform action or allow access to information of the switch resources. Payload oriented Execution Environment can also be implemented to support applications providing compression/decompression or encryption/decryption functions.

The Switch Control and Routing Modules have been developed in the Tove and Calypso projects described in the next Chapter. The Execution Environments are under development and the multicast function has been tested in Calypso TV distribution service.

Figure 4. Service platform.

4. MULTIMEDIA SERVICES

The Media Switch prototype has been used as a pilot environment in several broadband service research projects, such as Tove, Calypso, Go and Active Networks.

4.1 Tove, Calypso and Go

The principle of the **Tove** architecture was the separation of service, call and fabric control. This allows the lowest level of switching to be relatively stable and simple, whereas the highest level of services offers flexible support for creation and deployment of new services. The intermediate control level may change, when for example a new signalling protocol is introduced or the call-processing model is updated.

The Tove prototype platform implements a layered control architecture, based on the standardised B-ISDN concepts and protocols [11]. The service control is separated from the basic call and connection control using the IN (Intelligent Network) model 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.

In the **Calypso** architecture [6] the services are implemented as distributed applications consisting of the service clients in the end user terminals and service agents in the access network nodes. The service clients and agents communicate using a generic network layer service that provides connectivity and data transport. TCP/IP protocol suite is suggested to be used in facilitating quick development and prototyping of the distributed service client/agent model using the existing protocols, services and applications of the IP networks. The service client/agent environment and the Calypso SEE (Service Execution Environment) is based on Java due to the inherent support of distributed networking applications and code mobility.

The **Go** project is aimed at creating a vision of the future mobile communications. The project studies both applications and the underlying wireless access based on the hierarchical dynamic Mobile IP system [3]. The mobile user can access the Internet either anonymously or with a known address by using the Mobile IP. The anonymous access is used by enabling the dynamic IP address configuration (DHCP). The project is interested in the user and quality of service aspects. There exist a number of related applications, such as mobile use of mail, mobile use of WWW and mobile use of video and audio, which will be tested.

4.2 Active Networks

In the Active Networks project, an AN Execution Environment architecture has been developed on top of the switch OS. It consists of an AN core, building blocks and building block APIs. The AN core offers an extensible environment for developing and running active applications. Building Blocks was specified for use in Media Switch according to IEEE P1520 architecture. Building block APIs form a user level library that provides the

user with the ability to program the switch by using standard object-oriented abstractions and compose a variety of active applications.

Filtering firewall active application can extend the filtering firewall into the application layer and uses application layer header's to grant or deny packet forwarding. The packet filtering together with an on-line installation of active applications could be used for bandwidth management needs. Dynamic flow identification may be used to provide guaranteed QoS for real-time services like video streaming and VoIP.

4.3 Service examples

Two broadband services that have been piloted using the Tove and Calypso platforms are described below. Current implementations of the services operate only in a fixed broadband network, but using the Go technology, the services would be accessible also from mobile terminals.

4.3.1 Tove music on demand service

The Tove platform has been demonstrated using an on-demand music service. The server is a workstation equipped with a CD player and a server application that is able to play and transmit the music to an ATM virtual channel. The application registers an ATM SAP (Service Access Point) that is listened for incoming connections. The clients call the service through standard ATM Forum UNI 3.1 or ITU-T Q.2931 signalling procedure. Extra functionality, e.g., special billing schemes, can be implemented using the IN service model. Once the call has been set up, the server starts transmitting the requested piece of music. The service terminates and the connection is released upon user request or when the requested piece is finished.

4.3.2 Calypso TV distribution service

The Calypso TV distribution service demonstrates the delivery of TV programs over broadband network (see Fig. 5). The TV channels are implemented as unidirectional point-to-multipoint ATM VCs originating from a server host. The server creates a multicast VC for each TV channel, informs the service agent in the access node about the new channels and starts transmitting MPEG-1 encoded video streams directly over ATM AAL5.

When the client application is started in the user's terminal, it connects to the service agent running in the Calypso switch controller. The service agent opens a VC in the client's link and starts listening for channel requests. When the user selects a channel using an infrared remote controller, the agent joins the client's VC as a leaf to the multicast tree of the selected

channel. When the user changes channel, the agent prunes the client's VC from the old channel and joins it to the new one. The received program is viewed with a separate viewer application launched by the client.

The second phase of the Calypso TV service will allow operation in a network spanning over more than one ATM switch. The service agent in the access node must now be able to forward the channel request upstream in case the requested TV channel multicast tree does not reach the access node. The request is forwarded until the multicast tree is reached, and a new leaf is merged to the multicast VC. The channel leave requests must also be forwarded upstream if the leaving user is the only one in the access node.

Figure 5. Calypso TV distribution service

5. CONCLUSIONS

This paper introduces a multidiscipline switching concept as a solution to tackle with the different transmission and switching concepts. The main benefit is to share the physical switching resource among different networks. If interworking between the different network architectures is supported, more complex services can be implemented. A generic solution, housing two or more virtual switches in a compact unit, would effectively cut down installation and maintenance costs of the future broadband networks.

The Media Switch integrating 64 kbit/s based circuit, ATM cell and IP packet switching is presented as a multidiscipline switch application. The physical switching platform is based on the FSR (Frame Synchronized Ring) concept. FSR's ring-shaped switching bus is dimensioned to perform effectively by implementing separate transport containers for circuit, cell and packet switched traffic. Control of the switch applies multi-layered control architecture, dividing the control functions into fabric, network and service control layers. Signalling protocols of the different transport systems are implemented separately, although, they use services of the common fabric control layer. Interworking between the different networks can be supported by a shared interworking call control layer that manages calls originating and terminating in different networks.

Currently, the Media Switch and its control architecture is in implementation phase. The first prototype offers interworking between the IP, ATM and PDH networks. Further work will include configuration and management application development.

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TRAFFIC ENGINEERING