# A Control Architecture for a Multidiscipline Switch

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## *Abstract*

*To carry the tomorrow's interactive multimedia services the underlying transport network must be able to support a large variety of connections. These connections may set most varying bit rate, delay, error rate, etc. requirements for the transport system. A number of networking concepts have been piloted, but none of them has gained ultimate acceptance. ATM technology has been the most popular one, but it has been reported to have certain shortcomings and, therefore, other transport concepts have also been considered.*

*It can be envisaged that heterogeneous transport solutions will be used for delivering future multimedia services. This inevitably leads to the situation that bit streams are carried over multiple networks which implement different transport technologies. Thus network elements, such as switches, should be able to interface to different networks and support switching of dissimilar data units. As a solution to the emerging problem, this paper introduces the concept of multidiscipline switching which combines two or more transmission technologies into a compact fabric.*

*In order to support different networks and services carried on them, a sophisticated service and control architecture is needed. Reported experiments on distributed switching, combined with separation of fabric control from connection and service control, have given encouraging directions to tackle with the implementation problem. As an example, a switching solution combining time-slot, cell and packet switching is presented.*

# 1. Introduction

Evolution of multimedia is entering from pilot projects to real customer services. An important part of the piloting phase has been development and evaluation of possible transport and switching technologies capable of supporting delivery of the tested services [1]. None of the transport concepts has shown superior performance and the development work is likely to continue for some time.

The various services set different and sometimes contradicting requirements (e.g. related to delay tolerance, bit rates and bit error rates) for the underlying network and utilized transmission methods. Even a single multimedia service may combine several simultaneous bit streams (e.g. voice, data and video) which may set ambiguous requirements for the network. Thus, physical transmission as well as higher layer transport protocols should cope with differentiated, changing and unpredictable requirements of specific services.

Future services are expected to be delivered over broadband networks such as B-ISDN (Broadband Integrated Services Digital Network), and ATM (Asynchronous Transfer Mode) is foreseen as a unifying transmission and switching technology that is capable of offering support for a large variety of services [1]. Another important trend is the rapid growth of Internet which has increased the importance of the TCP/IP (Transport Control Protocol/Internet Protocol) protocol suite and applications built on top of it. Consequently, IP transmission over ATM has been a standardization target [2, 3]. As networks transporting Internet traffic get more and more congested, response times increase and more efficient transport and routing solutions are required. The most favoured direction is replacing routers with switches. In ATM networks, concepts such as IP switching or tag switching have been developed to lower delays in routing nodes [4].

However, IP over ATM introduces unnecessary overhead, not to mention the overhead present in various IP switching schemes developed to accelerate IP routing. Furthermore, transmission of (MPEG-2) coded video and TV-programs encounter quite a high overhead percentage lowering the available payload bandwidth [1]. For these reasons, other transport methods have been proposed, e.g., so called native IP concepts, in which IP traffic is conveyed directly in physical level transport frames, e.g., over SDH (Synchronous Digital Hierarchy) or even PDH (Plesiochronous Digital Hierarchy) networks. Development of such concepts is in the early stage, but great expectations are placed on them.

It can be envisaged that in the near future various multimedia services will be offered to users over a diverse set of transport networks which are based on different transport and switching technologies. Due to this, there will be a need for equipment capable of supporting multiple switching schemes. This article introduces a multidiscipline switching concept to support switching of multimedia services carried over heterogeneous transport networks. Chapter 2 clarifies the concept of multidiscipline switching and introduces an experimental solution to integrate cell, packet and (64 kbit/s) time-slot switching. Chapter 3 introduces two possible control architectures for the experimental switch. Chapter 4 includes the concluding discussion and further work proposals.

## 2 Multidiscipline switching

A conventional telecommunications switch connects to a homogeneous transmission and switching network which implies switching of fixed length data units, e.g., 8-bit time-slots of the PDH networks or 53-octet cells of ATM. Homogeneous transport technology may, however, support different and even variable data rates, but the basic unit of data that can be switched is common to all supported rates. Thus, such equipment can be considered to be single discipline switches.

### 2.1 Multiple disciplines and switching bus

A multidiscipline switch supports heterogeneous transport technologies, i.e., switching of multiple fixed length data units, each dedicated to a specific transport technology. In order to cope with different switching disciplines, the switch must have a common way to route the dissimilar data units through the switching bus. This can be done by conveying the data units in containers (here called frames) which include additional information about the type of the carried data unit and necessary routing information. Each frame type is independent of the others and, therefore, the physical switch can be considered to include several virtual switches. Figure 1 illustrates the concept of multidiscipline switching.

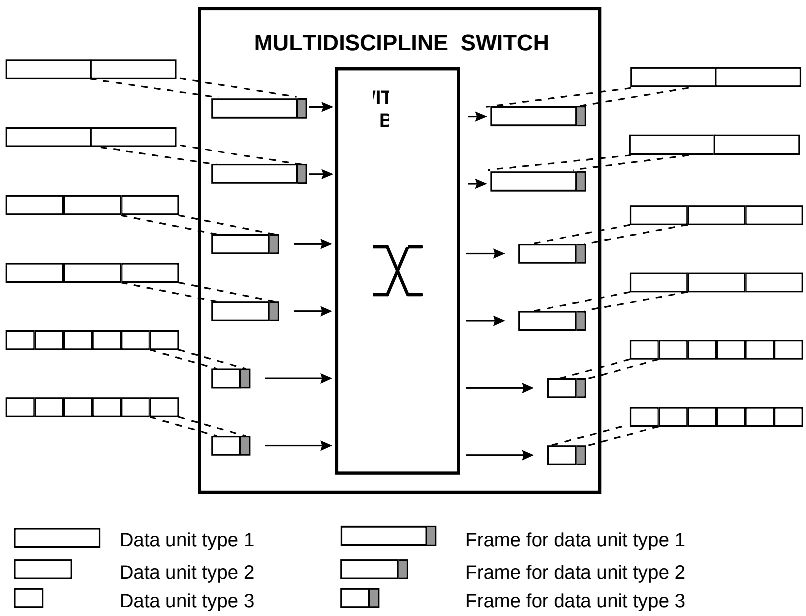


**Figure 1** A multidiscipline switch implementing three different frame types

Physical level switching is performed using a common switching bus or each virtual switch has dedicated links inside the switching bus. It is also possible that only certain internal links are shared and the rest are dedicated to individual switches. Examples of interconnection architectures used in constructing switching buses are multidrop buses, rings, crossbars and various multistage structures (such as Banyan and Delta) [5]. Use of a shared bus means that the data units of different length are conveyed either in commonly dimensioned fixed length frames or a special frame type is dedicated to each of them. The common frame would simplify design and control of the physical bus, while possibly leading to inefficient use of system resources. When transmitting short data units, part of the frame would be empty, thus leading to waste of switching capacity. Waste of capacity could be avoided by using variable size frames. However, control of such a system, enabling re-dimensioning of the frames on-the-fly, becomes very complicated. The problem of dimensioning a switching bus by adjusting frame sizes for different data units is discussed in [6, 7].

Dedication of links for individual data unit types would allow the use of specially dimensioned frames, but the overall switching system would be an inflexible one. Only certain inputs and outputs could be assigned for a specific transport network (having a certain size data unit). If internal links can be shared by several types of data unit, only a common fixed sized frame would be a reasonable solution even though it means waste of switching capacity. The other solution to have dedicated frames would make synchronization and control of the common internal links a very demanding task.

## 2.2 Switch control

In addition to different data unit sizes, the multidiscipline switch should adapt to different physical interfaces and support different call control schemes. Due to the different nature of associated transmission technologies (e.g., ATM and PDH), their signalling procedures, connection types, quality of service parameters and even supported services may require entirely different control discipline. Additionally, transmission related issues such as physical interfaces, buffering needs, timing and synchronisation differ from a concept to another, and the conventional way to implement these functions in a single switch makes the implementation complicated.

The implementation can be simplified if physical switch control, call control and service control are separated from each others, leading to a three layered control architecture [8]. The first step is to fix "standard" interfaces between the layers. This can be done by adding "middle-ware" between the adjacent control layers [1]. Changes to the individual layers can now be made independently while maintaining compatibility between them. Solutions identifying the three control layers are presented in [9] and [10]. Figure 2 illustrates the three layered control architecture.

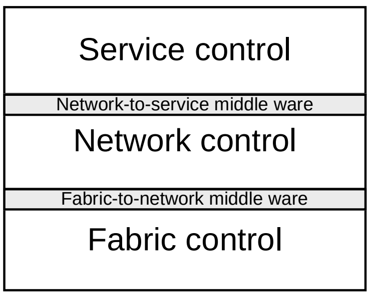


**Figure 2** Three layered control architecture

### 2.3 An experimental multidiscipline switch

As a concrete example of multidiscipline switching, let us look at the case of integrating (64 kbit/s PDH) time-slot, (ATM) cell and (IP) packet switching into a single fabric. The switching platform comprises the switching bus, interfaces to connect the switch to the trunk and access networks and the switch control part (see Figure 3). The presented SCOMS (Software Configurable Multidiscipline Switch) switch is being developed in a research project at Helsinki University of Technology and VTT Information Technology.

**Switching bus**

The switching bus, implementing three virtual switches (one for time-slot, one for cell and one for packet switching), is based on a bus concept, called the Frame Synchronized Ring (FSR) [5]. The FSR concept, developed and patented by VTT Information Technology, has characteristics important in implementing the various features fundamental to multidiscipline switching. These include, e.g., inherent support for real-time multicasting, versatile addressing capabilities and support for 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 to its sophisticated MAC (Medium Access Control) and the use of destination release policy, FSR is able to support multiple simultaneous connections (i.e., spatial reuse). Data is conveyed in fixed size containers, called frames, which can be dimensioned individually. This allows implementation of multiple virtual switches into a single fabric. The performance of FSR has been analysed, e.g., in [5] and [11], and comparisons to other interconnection networks have shown competitive performance, especially, in ATM applications [12]. A bridging solution, utilising FSR as the backbone technology for delivering multimedia services is introduced in [13].

On the physical level, all the three virtual switches occupy selected FSR nodes which are equipped with associated interfaces (implemented as plug-in cards). Individual FSR nodes can be configured freely to support either of the three switches. Switch configuration can be changed dynamically by replacing a line card of type one by another type and modifying configuration registers in the switch control block.

**Time-slot switching**

In PDH the basic unit of data is an 8-bit octet. Constant stream of these octets (repeated at the rate of 8 kHz) form the circuit switched 64 kbit/s channel. Time-slot switching refers here to switching of these 8-bit octets belonging to individual 64 kbit/s connections. On the switching bus, the time-slots are conveyed in specially dimensioned frames. In practice, this means that a permanent share of FSR's switching capacity is assigned to PDH traffic which guarantees that delay and bit rate requirements set for PDH transmission are met. In order to avoid unnecessarily high framing overhead, several time-slots (belonging to the same connection) can be transferred in a single frame.

Routing of frames through the switch is based on FSR addressing mechanism. On the line cards, the PDH channel numbers are converted to FSR addresses which are used by the switching bus to route the FSR frames automatically from the source interface to the destination one. On the receiving interface card, the frames are disassembled and the received time-slots are forwarded into the outbound channel.

## Cell switching

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 individual cells are conveyed in frames dimensioned to hold exactly one cell. To route the assembled FSR frames through the switching bus, ATM virtual path (VPI) and connection (VCI) identifiers have to be converted to FSR addresses. Physical routing of these frames is performed in a similar manner as routing of the frames carrying time-slots. On the destination interface, the FSR addresses are further converted to outbound ATM VPI/VCI values. Due to the bursty nature of ATM traffic, buffering in the ATM interfaces becomes a more critical issue than in the case of PDH traffic.

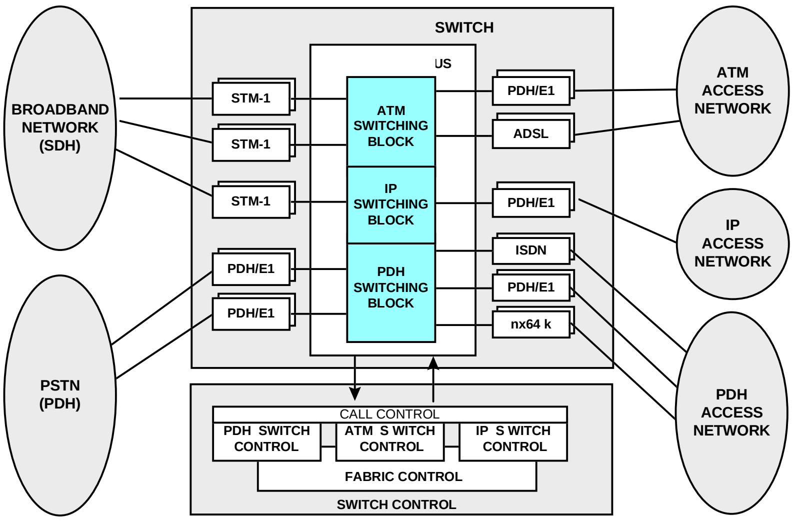


**Figure 3** Block diagram of the experimented multidiscipline switch

## Packet switching

In IP networks, the length of the packets vary from a few dozens of octets to 64 000 octets and to manage with the long and varying packet sizes, the IP packets must be segmented into mini-packets. These are the data units which are further encapsulated into frames, specially dimensioned to carry IP traffic. IP traffic is bursty in nature and thus the process of switching IP packets resembles that of ATM cells, but manipulation of individual packets differ greatly from manipulation of cells. In the input interface, IP packet headers are examined and the IP address is mapped to an FSR address that is used only inside the switch. Based on that mapping, each segment of the packet is routed through the bus to its destination interface, where the packet is reassembled and sent to the external network.

Managing the IP routing tables (mappings from destination IP addresses to internal FSR addresses used to route the packets through the switching fabric) is a complex task. The most efficient solution would be to store the routing tables locally into each IP interface card, but as the tables may grow relatively large, the memory requirement may become a limitation. Another issue is the updating of the routing tables. It is done in typical IP networks dynamically by using routing protocols, such as RIP, OSPF and BGP, but implementing these protocols in the interface cards might make the cards unnecessarily complex. Due to these problems the external control workstation should be used for running the routing protocols and routing tables would be periodically downloaded to the interface cards. If the memory of the cards becomes a limitation, the cards could cache only the most recently used routes and query the rest from the control workstation. However, efficient data structures and lookup algorithms for IP address tables have been developed [14], so this should not become an issue in all but the biggest networks.

## 3. Control architecture of a multidiscipline switch

A multidiscipline switching system must combine several control and service architectures into a compact control system. Each architecture requires its own set of protocols, so a straightforward solution is to implement the protocol stacks of each virtual switch independently of each other. In this case, each protocol stack and associated call control function work as if they were run on top of a physical switch of that particular network architecture. The gain from multidiscipline switching would be the ability to share the physical switching bus resource between different networks. However, by supporting interworking between the different network architectures, more complex services can be implemented.

### 3.1 Independent control modules

Figure 4 represents one possible configuration of the protocol stacks in the control workstation of a SCOMS switch. The three network architectures have their own signalling and control modules that are executed independently of each other. The switch control module offers network specific APIs (Application Programming Interfaces) that implement functions necessary to reserve resources and manage connections through the switching fabric. The control workstation is connected to the switch via an ATM link, and all protocols receive their signalling messages from the switch interfaces in a reserved ATM virtual channel. This means that the interface cards of the switch must map the incoming signalling virtual channel, signalling time-slot or routing protocol messages to the special ATM virtual channel that is used to transfer the messages to the control workstation.

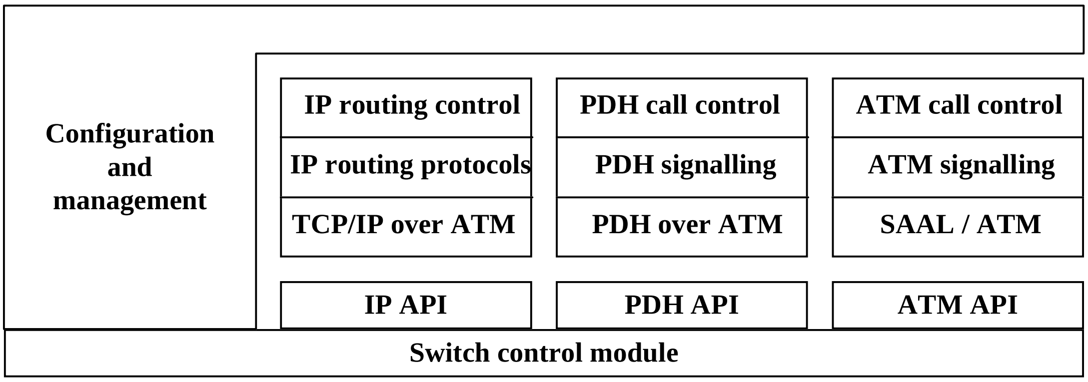


**Figure 4** SCOMS switch controller with independent call controls for different network architectures

In this configuration, the different control architectures are completely independent of each other. The PDH signalling and call control as well as ATM signalling and call control are similar, having signalling links with each neighboring N-ISDN or ATM device. Calls originating from PDH interfaces must terminate on PDH interfaces, likewise ATM connections can be set up only between two ATM interfaces. The IP control module is different from the two others, because it has no connection oriented call model. The IP routing protocols of the switch controller receive routing information from all IP interfaces and the routing control module constructs the routing tables according to the received information. The routing tables are uploaded periodically to the interface cards that perform the routing of the actual IP data packets.

### 3.2 Interworking call control

The above configuration can be enhanced by introducing an interworking call model that is able to route calls between different network architectures. This kind of configuration is illustrated in Figure 5.

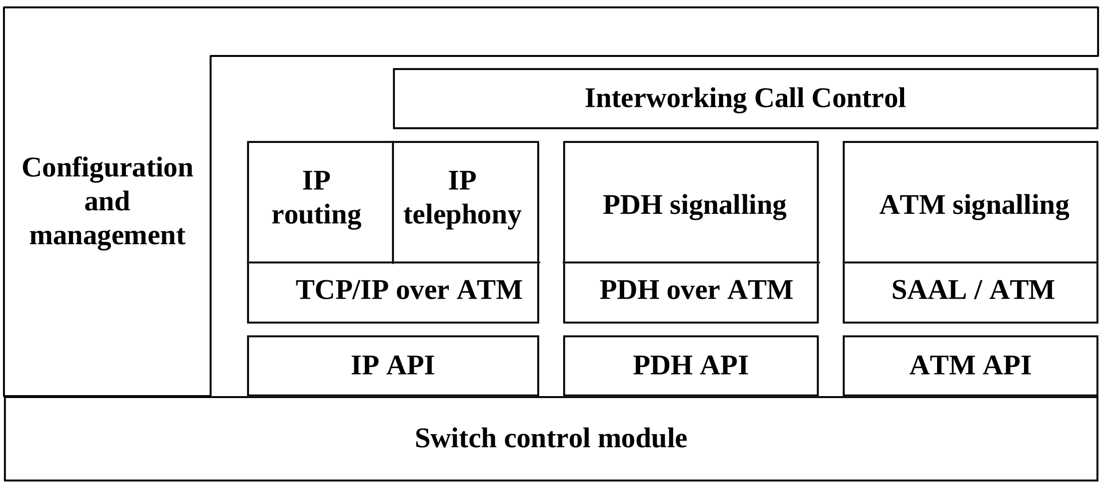


**Figure 5** SCOMS switch controller with an interworking call control

In this configuration, the different protocol stacks are linked together via a shared call control. The call control must be able to decode, process and forward connection setup requests from each protocol stack. The call control interworking function maps the connection setup parameters between the different network architectures and maintains connection state for all connections going through the switching fabric. The originating and terminating legs of the connections may now be in different networks. Also IP telephony protocol stacks have been added to support interworking between IP phones and PDH or ATM phones; the IP routing protocols and routing control remain the same as in the previous case.

It is required that interworking is also supported on the physical layer. For example, a PDH interface card must be able to extract an incoming time-slot and convert it to an outgoing ATM virtual channel, when an interworking call between PDH and ATM networks is made, and similar conversions must be done in other interworking cases, too. It is also possible that conversions between different codings must be done, for example, PDH A-law or $\mu$-law voice coding must be converted to the coding used by an IP phone application. This kind of application level coding conversions could be done by an external server, however, to reduce the complexity of the interface cards.

## 4. Conclusions and further work

Advanced multimedia services set demanding and sometimes contradicting requirements for the underlying transport network. During the recent years existing transport technologies have been evaluated and refinements to guarantee reliable transfer of data have been proposed. ATM technology has been envisaged to become the prevailing technology due to its flexibility. However, in some time-critical applications ATM faces unavoidable transmission overhead which leads to inefficient use of transmission capacity. Therefore, other transmission and switching concepts have also been considered. In the short run, there will be several alternatives to transport multimedia services, which implies that switching nodes will connect to networks that support different transmission and switching technologies.

In this article, a multidiscipline switching concept is introduced as a solution to tackle with different transmission and switching concepts. A generic solution, housing two or more virtual switches in a compact unit, would effectively cut down installation and maintenance costs of future broadband networks. Implementing several switching schemes into a single fabric poses a number of demanding research and development topics. Problems to be solved include, e.g., switching of variable size data units, different call control and signalling methods, varying buffering needs and different timing requirements. Innovations related to distributed switching and separation of physical fabric control from call connection and service control, are seen to enable development of such a multidiscipline switch.

As an example, a switching solution integrating 64 kbit/s based time-slot, ATM cell and IP packet switching is presented. The physical switching platform is based on the FSR (Frame Synchronized Ring) concept, demonstrated to perform well in broadband switching applications. FSR's ring-shaped switching bus is dimensioned to perform effectively by implementing separate transport frames for time-slot, cell and packet based traffic. Control of the switch applies multi-layered control architecture, dividing the control functions into fabric, network and service control layers. Compatibility between the adjacent layers is guaranteed by implementing combining middle-ware. Signalling protocols of the different transport networks are implemented separately, although they use services of the common fabric control layer. Interworking between the different networks can be supported by an shared, interworking call control module that is able to manage calls whose originating and terminating sides are in different networks.

Currently the SCOMS switch control architecture is in design and implementation phase, and the first prototype of an interworking call control supporting ATM and PDH networks is expected by the end of the year 1999. Further work on SCOMS will include service architecture considerations as well as configuration and management application development. The inherent support for TCP/IP networking enables interesting possibilities to utilize ideas developed in the Calypso project for distributed service control and web-based management.

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