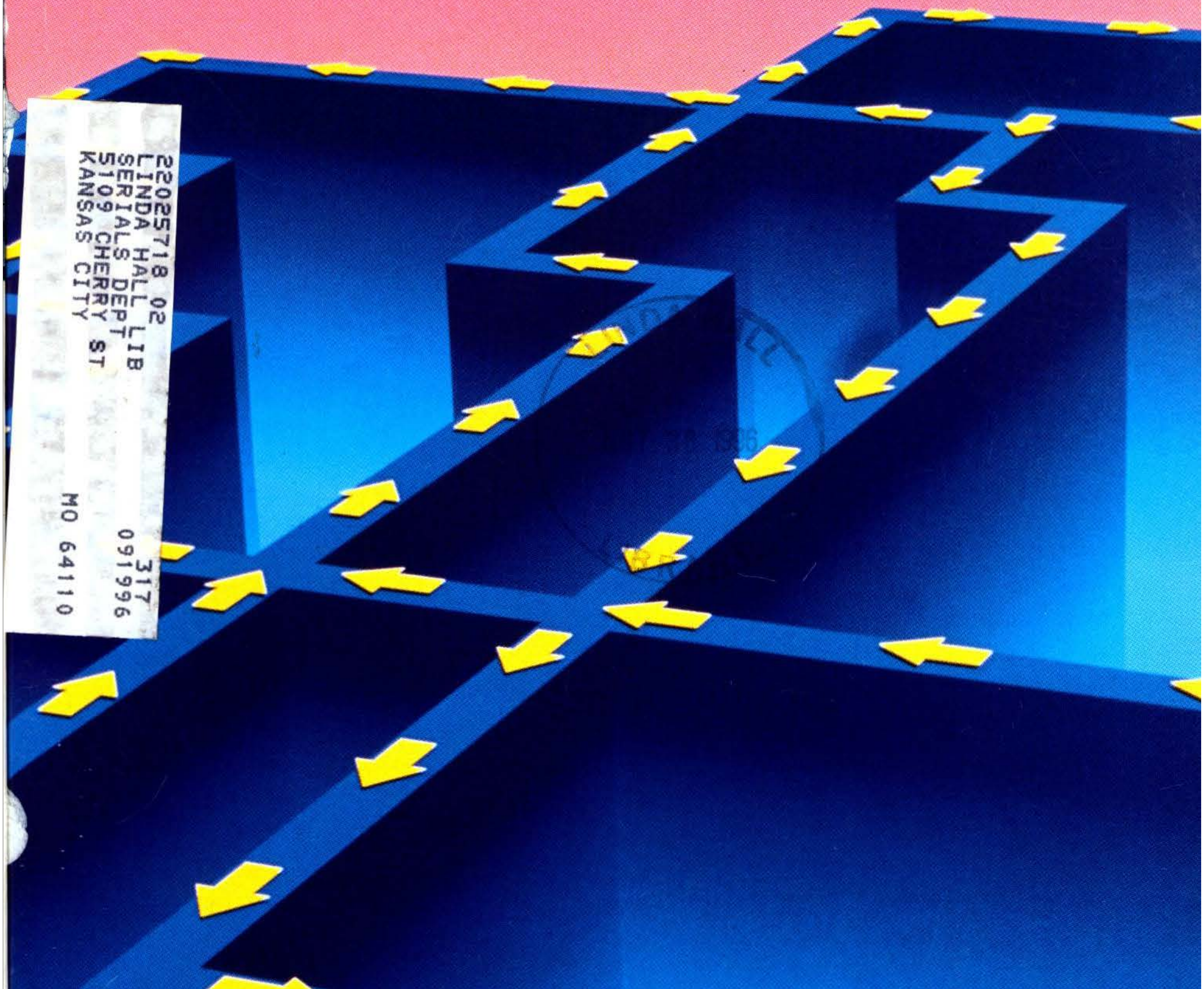
IEEE
September/October 1996 Vol. 10 No. 5

NETWORK®

THE MAGAZINE OF GLOBAL INFORMATION EXCHANGE

Resource Management in ATM Networks
•
Voice over ATM
•
Monitoring and Control of ATM Networks



IEEE NETWORK®

THE MAGAZINE OF GLOBAL INFORMATION EXCHANGE

SEPTEMBER/OCTOBER 1996 VOL. 10 NO. 5

■ THIS ISSUE features discussions on management and control of ATM networks.

Cover illustration: Image Bank

FEATURES

Icons explained

The mortarboard indicates a tutorial article.

The light bulb indicates an article that describes a unique idea or a new approach.

The meshing gears indicate an article that describes an implementation.

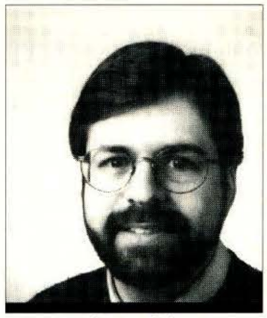
The graph indicates an article that contains measurements from a real system.

The sigma indicates an article that contains theory or analysis.

The clock indicates a timely article.

DEPARTMENTS

New Sponsors for IEEE Network



David C. Feldmeier

I am pleased to announce that in addition to the IEEE Communications Society, IEEE Network is now co-sponsored by the IEEE Computer Society and the Internet Society. The co-sponsorship begins in 1997, and shortly I will be adding members of the co-sponsoring societies to the editorial board of IEEE Network. My thanks to Tom Plevyak, the ComSoc Director of Publications, and Steve Weinstein for putting together the co-sponsorship agreement. My thanks as well to Ron Williams of the Computer Society, and Don Heath of the Internet Society.

Throughout my tenure as Editor and Chief, I have worked to include more articles on data communication, network computing, and the Internet in *IEEE Network*. I have continued the shift in article coverage that started under Craig Partridge, the previous Editor in Chief. I believe that the co-sponsorship of *IEEE Network* will make a good magazine even better. The new sponsors of *IEEE Network* provide a new source of articles on some of today's hottest topics in communication, as well as a new source of readers. I look forward to these changes, which will allow *IEEE Network* to publish more articles of higher quality that are central to the interests of our readers.

On another note, as some of you may already know, I recently left Bellcore to become Director of Strategic Planning at MUSIC Semiconductors. MUSIC sells hardware to accelerate protocol processing to many of the big data networking and telecommunication companies, and I'll be specifying new devices to expand the product line. For me, the job is a chance to learn new skills and to commercialize some of my research. So far, the job has been fun, although MUSIC is two orders of magnitude smaller than Bellcore, and it takes some adjustment. I keep waiting for things to settle down, and I'm starting to realize that it's not going to happen. We're hiring new people rapidly, and the organization chart is mostly theoretical. As with any other small company, I usually end up doing a bunch of different things every week. I feel like I should have four or five different business cards.

IEEE NETWORK ISSN 0890-8044 is published bimonthly by the Institute of Electrical and Electronics Engineers, Inc. Headquarters address: IEEE Publishing Services, 345 East 47th Street, New York, NY 10017-2394, USA. Tel: +1 212-705-7018; e-mail: ieee.network@ieee.org. Responsibility for the contents rests upon authors of signed articles and not the IEEE or its members. Unless otherwise specified, the IEEE neither endorses nor sanctions any positions or actions espoused in *IEEE Network*.

ANNUAL SUBSCRIPTION: $22 in addition to IEEE Communications Society or any other IEEE Society member dues. Non-member prices: $115. Single copy prices: Member, $10; Non-member, $20.

EDITORIAL CORRESPONDENCE: Address to: Dave Feldmeier, Editor-in-Chief, *IEEE Network*, IEEE Communications Society, 345 East 47th Street, New York, NY 10017-2394, USA; e-mail: d.feldmeier@ieee.org.

POSTMASTER: Send address changes to *IEEE Network*, IEEE, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA. Printed in USA. Second-class postage paid at New York, NY and at additional mailing offices.

SUBSCRIPTIONS, orders, address changes should be sent to IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA. Tel. +1-908-981-0060. GST Reg# 125634188.

ADVERTISING: Advertising is accepted at the discretion of the publisher. Address correspondence to *IEEE Network*,

Resource Management with Virtual Paths in ATM Networks

V. J. Friesen, J. J. Harms, and J. W. Wong

Abstract

In an ATM network, a virtual path connection (VPC) is a labeled path which can be used to transport a bundle of virtual channel connections (VCCs) and to manage the resources used by these connections. Using the virtual path concept, the network is organized as a collection of VPCs which form a VPC, or logical, overlay network. If the VPCs are permanent or semi-permanent and have reserved capacity, establishing new VCCs requires simple connection admission decisions at the VPC terminators of existing VPCs. This would enable faster connection establishment since transit nodes are not involved in the connection setup. The virtual path concept also allows the possibility of segregating traffic types according to quality of service requirements. However, the extent to which VPC provisioning is able to improve network efficiency is dependent on the resource management decisions that determine the VPC topology and capacity allocations. This is a survey article on resource management using virtual paths in an ATM network. Of interest are techniques which modify the VPC topology and capacity assignments in order to adapt to changing traffic conditions and possible network failures. The resource management activities employed to facilitate such adaptation can be categorized by the timescale on which they operate. On the shortest timescale are strategies for dynamically making minor changes to the VPC topology or capacity assignments. On a somewhat longer timescale are strategies for making more widespread modifications to the VPC overlay network. This would be appropriate for traffic changes based on time of day and for recovering from network failures. Finally, on an even longer timescale, strategies may be employed to design a general VPC overlay network, to be used at startup or after major network upgrades. Solutions to VPC resource management for each of these timescales are discussed.

In asynchronous transfer mode (ATM) networks, multiplexing and switching are performed on 53-byte cells which are transported across the network on virtual channel connections (VCCs) [1]. A virtual path connection (VPC) is a labeled path which can be used to transport, process, and manage a bundle of VCCs. Two levels of cell forwarding are defined: virtual path (VP) and virtual channel (VC), which use the virtual path identifier (VPI) and virtual channel identifier (VCI) fields in the cell header, respectively [2].

A VPC can be characterized by its two *VPC terminators*, a physical route between these terminators, and a possible assigned capacity. A VCC, on the other hand, traverses a set of concatenated VPCs. An example of this relationship between the VPC and VCC is shown in Fig. 1. At the originating VPC terminator (node A), a cell belonging to a given VCC is identified by a VCI (i.e., VCI 6). This VCI, as well as the identifier of the VPC used to carry this VCC (i.e., VPI 4), are then written in the header of the cell. At the other end of the VPC (node D), VCI and VPI translation takes place for transmission onto the next VPC. At transit nodes, only the VPI label needs to be recognized, and the VCI field remains unchanged. Transit nodes are therefore freed from performing VCI translation when routing cells.[1]

In general, a VCC is constructed from one or more VPCs (or *VC links*). The number of VPCs traversed by a VCC will be referred to as its *VPC hop count*. Likewise, a VPC is constructed from one or more physical links (or *VP links*). The number of physical links traversed by a VPC (or a VCC) will be referred to as its *physical hop count*. In Fig. 1, the VCC has a VPC hop count of two and a physical hop count of five,, while VPC 1 and VPC 2 have physical hop counts of three and two, respectively.

Using the virtual path concept, the network is organized as a collection of VPCs which form a VPC, or logical, overlay network (Fig. 2). In this logical network, links correspond to VPCs, while nodes correspond to VPC terminators. The logi-

---

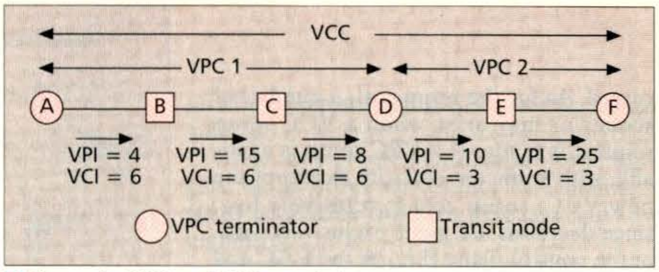
[1] *In fact, a VCC need not be transported exclusively within a system of VPCs. There may be individual VCC routing prior to reaching the first VPC, after leaving the last VPC, or along the entire route. For the purposes of our discussion, we largely ignore these cases.*

cal network can be modified (both the configuration of the logical links and their capacities) according to resource provisioning decisions, whereby the network can adapt to changing conditions. In general, the possible node types in the physical network are:

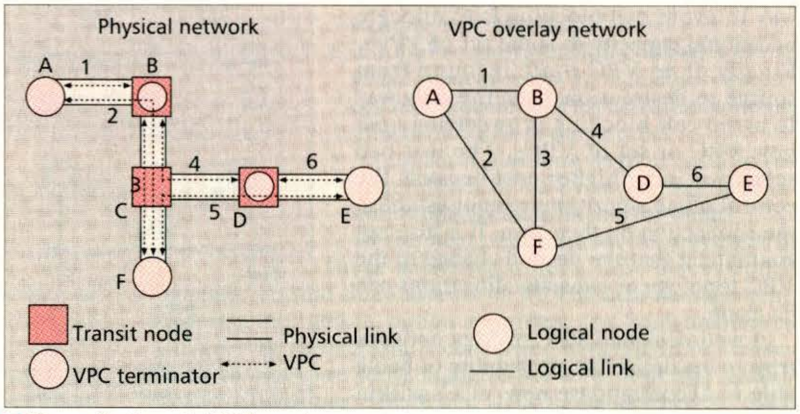
- VP transit nodes
- VPC terminators
- Composite nodes

Composite nodes serve as VPC terminators for some VPCs and transit nodes for the other VPCs. These three types are also referred to as VP node, VC node, and VP-VC node, respectively [2].

In the network of Fig. 2, nodes A, E, and F are VPC terminators, node C is a transit node, and nodes B and D are composite nodes. Consider nodes A and F. They are connected by a number of VPC routes. One of the routes consists of VPC 2, which takes the path A-B-C-F. This route is called a *direct route*, since it has a VPC hop count of one. In relation to nodes A and F, this is referred to as a *direct VPC*. Another possible route between nodes A and F can be constructed by concatenating VPC 1 (A-B) with VPC 3 (B-C-F). This is an *indirect route* which has a VPC hop count of two. Note that both of these routes have a physical hop count of three. The VPC hop count is therefore not a clear indicator of the physical hop count.



■ Figure 1. *VCI and VPI translation.*



■ Figure 2. *Sample VPC overlay network.*

We note that several VPCs may traverse a given link, and several VCCs may be routed over each of these VPCs, as illustrated in Fig. 3. Given these relationships, the provisioning of resources in a VP-based network can be viewed on three separate timescales, corresponding to the physical network (long-term), the VPC overlay network (medium-term), and the individual VCCs (short-term) [3]. With respect to resource management activities, VCCs are provisioned on a call-by-call basis by the control plane, which makes both connection admission control (CAC) and *route selection* decisions [4]. On the timescale of VPC provisioning, resource management activities are more likely to be handled by the management plane and include *VPC topology* and *VPC capacity allocation* decisions.

VPCs, as defined in the standards [5], play a role in both traffic control and network resource management. Some of the advantages which can be realized through the use of the virtual path concept are [5–7]:

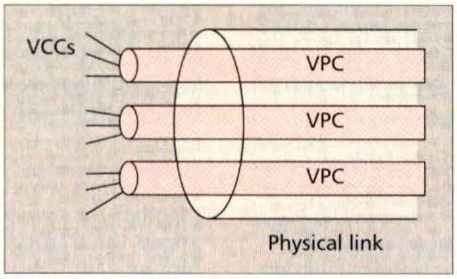
- Simplified connection admission (involving only VPC terminators)
- Simplified routing at transit nodes (i.e., based on VPI only)
- Adaptability to varying traffic and network failures through dynamic resource management
- The ability to implement priority control by segregating traffic with different quality of service (QoS).[2]

While the benefit offered by these advantages, and therefore the roles appropriate for VPCs, depend on how control costs and transmission costs are defined (see, e.g., [11, 12]), the most common view is that the primary role of VPCs is to enhance operating efficiency by the means stated above.

[2] *We note that virtual networks [8–10] have also been proposed as a means of segregating traffic by service type. Using this concept, routing management could still be handled by VPCs, while bandwidth management may be*

This is a survey article on virtual path management in ATM networks. The key management tasks involve VPC topology and VPC capacity allocation. These are discussed in the following section. Our survey is organized around four VP management activities. In the third section, successive VPC capacity reallocation is discussed. Successive reallocation is concerned with changes in capacities allocated to specific VPCs. The next activity, discussed in the fourth section, is successive topology reconfiguration. This involves a slight modification to the VPC overlay network (e.g., the addition of a new VPC to facilitate resource management). The fifth section is concerned with scenarios where significant changes to the VPC topology, and corresponding capacity allocations, are performed. This may occur, for instance, in response to predicted changes in demand (e.g., time of day). In the sixth section, long-term VPC topology planning is discussed. Long-term planning is applicable to VPC topological design at startup or after a physical network upgrade. Finally, the last section provides some concluding remarks.

The VPC Topology and Capacity Allocation Problems



■ Figure 3. *VCCs, VPCs, and the physical*

The extent to which VPC provisioning is able to improve network efficiency is highly dependent on its ability to provide VCCs with low setup and switching costs, while maintaining a low call blocking probability. This, in turn, is dependent on the VPC topology and capacity allocations resulting from resource management decisions.

In general, the switching cost of a VCC increases with the physical hop

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | **sales@docketalarm.com** | **1-866-77-FASTCASE**

fastcase® Smarter legal research.