LETTER

User-Programmable Flexible ATM Network Architecture, Active-ATM

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SUMMARY This article proposes active-ATM, a flexible, simple and cost-effective ATM-WAN architecture that can handle multiple user-customized ATM-layer protocols, such as ABR and ABT, by using a simple universal ATM transit network. The proposed active-ATM architecture enables the construction of flexible networks that can evolve easily. With active-ATM and the ATM multi-protocol emulation network architecture called ALPEN, it is easy to implement new ATM-layer protocols by using user-created programs called active-program capsules that modify only the edge nodes. Because these user-sent program capsules can be used to quickly customize the edge nodes, there is no waiting for standardization and implementation of new services. The ATM-layer protocols are emulated only at the edge nodes, making the transit network independent of customer ATM-layer protocols. The active-ATM edge node is based on the flexible programmable node architecture called PUN (programmable unified node). The PUN is a platform for user-programmable ATM-layer services; it is achieved by using programmable devices, such as FPGAs and DSPs. An prototype system has demonstrated the flexibility of the resulting ATM network. The active-ATM architecture is an efficient approach to implementing multimedia, multi-protocol ATM services in an ATM WAN.

key words: *ATM, multimedia, ABR*

1. Introduction

The asynchronous transfer mode (ATM) protocol, a key technology for future multimedia networks, will need to support a wide range of different quality of service (QoS) requirements for multimedia services. Various ATM-layer protocols that provide different transport capabilities have been proposed: available bit rate (ABR), unspecified bit rate (UBR), UBR+, ATM burst transfer (ABT), etc. An ATM network must be able to support these transport capabilities flexibly and dynamically. As new multimedia services are introduced, the network must also support them. Currently, it can take as long as three years to standardize and implement a new service. Future ATM networks must be made flexible so that the introduction of new services requiring a new protocol or a different QoS is easier.

Flexible and programmable ATM switches called programmable unified nodes (PUNs) has been proposed for fast and flexible service creation [1]. PUNs are composed of field-programmable gate arrays (FPGAs) and/or digital signal processors (DSPs). They can be easily programmed and customized to provide new functionalities.

Active networks have been proposed for providing Internet Protocol services [2]–[5]. Active networks depart from traditional packet switching in two ways: (1) user data may be modified, transformed, or processed within the network, and (2) users may control their network service by using active capsules containing program fragments to be executed at each switch. Active capsules allow users to essentially "program" network elements and thus achieve a high degree of flexible control over their network service, and possibly create new services quickly without waiting for switch manufacture or standardization.

The other new approach is protocol emulation of an ATM wide-area network (WAN). This is so-called ATM multi-protocol emulation network (ALPEN). It is flexible enough to allow the easy introduction of new ATM-layer protocols into an ATM network [6]. In ALPEN, all ATM-layer protocols are emulated at the ATM-WAN's edge nodes. These edge nodes control the user traffic according to performance data received from the transit network. The ATM transit network is kept simple by using periodical route performance check (PRPC) sequences that do not depend on the ATM-layer protocols.

We propose flexible ATM network architecture called an "active-ATM network" that combines the related concepts of ALPEN, active network, programmable ATM nodes and management cells [7]–[10]. Active-management cells carry active capsules that program the ALPEN edge nodes to provide the required user functions. All protocols are emulated at the edge nodes, enabling the transit network to be simple and universal. In this article, we describe the concept of the active-ATM network and discuss a prototype implementation. The active-ATM concept will enable the creation of more flexible B-ISDN networks.

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2. Active-ATM Network

2. 1 Concept

The optimum ATM network is a flexible and customized integrated-service transport network architecture that can quickly satisfy different users and service requirements for different ATM transport mechanisms and functions. Our active-ATM network is a flexible, simple, and cost-effective ATM-WAN architecture that can handle multiple user-customized ATM-layer protocols, such as ABR and ABT.

The proposed active-ATM network is achieved by using set-up scheme. In the set-up scheme, a set-up program capsule is transferred to the active-ATM network before data communication begins. When the network receives the capsule, it provides the specified ATM-layer service protocol. After receiving an acknowledgment, data communication is started using the specified service protocol. Detail sequence is shown in next session.

Incorporating the ALPEN concept into the active-ATM network results in a flexible user interface and universal high-speed transit across the network. The active-ATM based on ALPEN is shown in Fig. 1. The user sends program capsules for customizing the ATM-layer functions to the edge nodes. Active capsules are sent via a separate mode at a higher layer; they use the same virtual-channel identifier(VCI) with a special payload-type identifier(PTI). Figure 1 shows ATM-layer protocols being customized for different users at the edge nodes. The transit network uses the PRPC universal protocol.

2. 2 Operation

In the "set-up scheme," the active capsules use packets distinct from the regular data packets but the same VCI connection. For the communication-setup phase, user-customized ATM-layer protocol codes are transmitted by the program capsule, as shown in Fig. 2. The customized functions are programmed into the PUNs.

An example based on detailed communication sequence is shown in Fig. 3. Only ALPEN's edge nodes are based on PUN. After a connection is established by the regular connection-setup processor, ATM-layer functions and protocols are defined by active-capsule transfer through the connection.

During the setup sequence, for guaranteed services such as CBR(Constant Bit Rate)and VBR(Variable Bit Rate), the required bandwidth is reserved deteministically or statistically along the route. In addition, these services do not need additional ATM

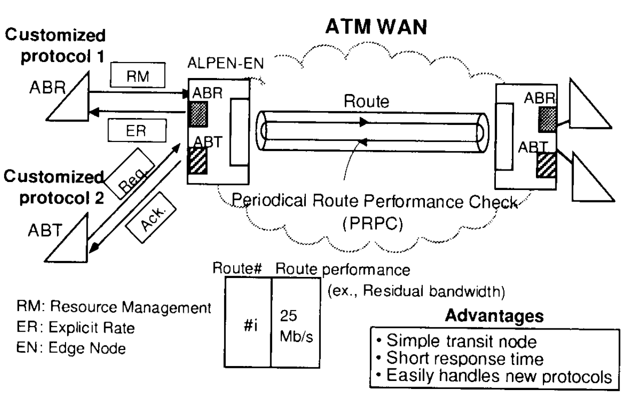

Fig. 1 Active-ATM, ABR, and ABT emulation based on ALPEN PRPC.

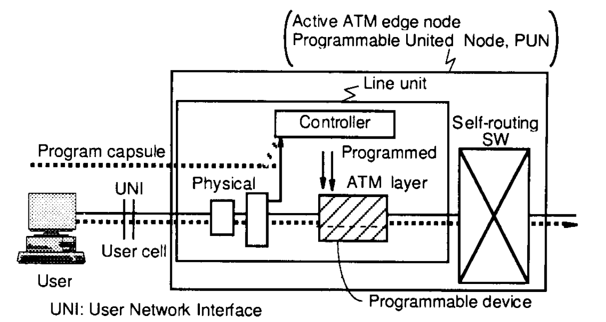

Fig. 2 Basic operation of Active-ATM network based on ALPEN program capsules are used to configurate nodes.

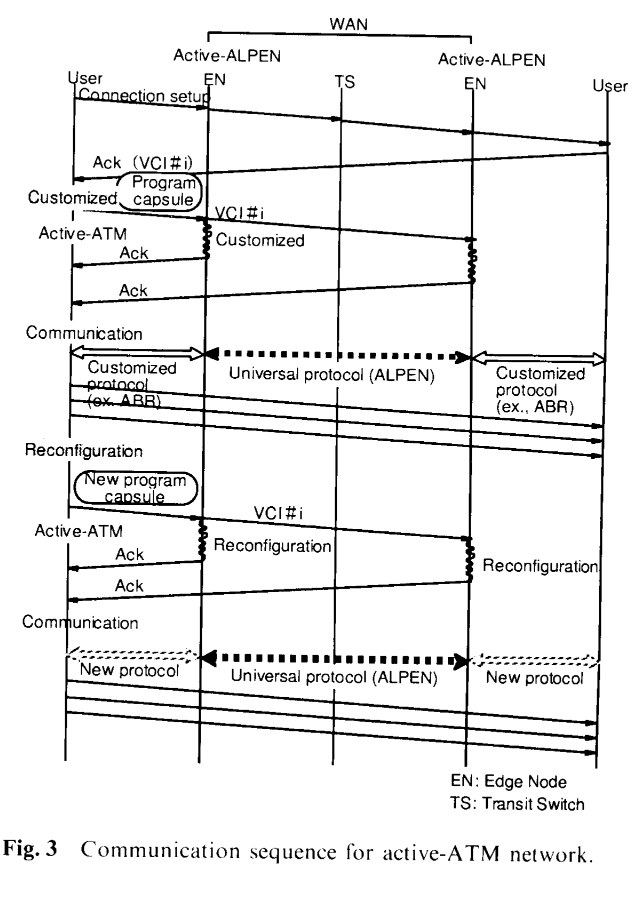

Fig. 3 Communication sequence for active-ATM network.

layer protocols.

The ATM-layer functions are reconfigured, if necessary, by a new program capsule, as shown in Fig. 3. By using this active-ATM function, a user does not need to wait for standards to be completed and implemented.

2.3 User Isolation

Each user can employ a different customized protocol. For the UBR/UBR+ protocol, fairness between users is important for network management. ALPEN provides residual bandwidth along the route, but each user may send a different cell stream according to the user-customized protocol. If a service requires fairness, Active-ATM network employs a VS/VD scheme at the edge node to isolate each user. From outside the network, the user can control a limited number of network parameters such as the rate between the edge node and the user by sending active capsules, while functions inside the network can not be customized by the user. More detailed performance studies are required.

3. Experiment of Active-ATM Based on PUN Platform

We developed a PUN platform that can support several active-ATM protocols to confirm the active-ATM transport capability. It consists of a self-routing switch and programmable line units(LUs). In the LUs, as shown in Fig. 4, basic functions are provided by using programmable devices.

Sophisticated ATM-layer protocols were achieved by using the active-ATM concept. We demonstrated the four modes of programmable ATM-layer functions, mode AT to D. These modes were ATM flow control protocols, such as ABR. Modes A and B were ABR [11] with binary and explicit-rate(ER) mode, respectively. Modes C and D were original ATM WAN rate-control protocols proposed by NTT [12]. Each function was created by programming the PUN appropriately.

For ABR-based flow control, a large cell buffer composed of high-speed SRAMs(Static Random Access Memories) was used. Such high-speed functions, as cell selection and cell generation were achieved using FPGAs. The controller, which has handles the complicated functions for ABR calculation, was composed of high-speed DSPs.

The line units were constructed using a combination of fast DSPs(TI TMS320C44-60) and FPGAs (ALTELA FLEX 8000, net utilization of programmable gates=28-82%). An overview photograph of the demonstration prototype is shown in Fig. 5. The experimental network consisted of two active-ATM edge nodes and a user-terminal adapter. The adapter was modified to support the ATM-layer functions as ABR and ABT. A standard ATM-layer tester was connected to the adapter.

The PUN line unit consisting of FPGAs and DSPs. The DSP board integrates optical transceivers for UNI and self-routing switching. Functions are controlled by a Motorola 68040 micro-processor via a VME bus. VS/VD(virtual source/virtual destination) or a per-VC shaper for fair queue weighting are also user programmable. The VS/VD buffer module can handle a maximum of 128 K cell/VC, with an 8-bit

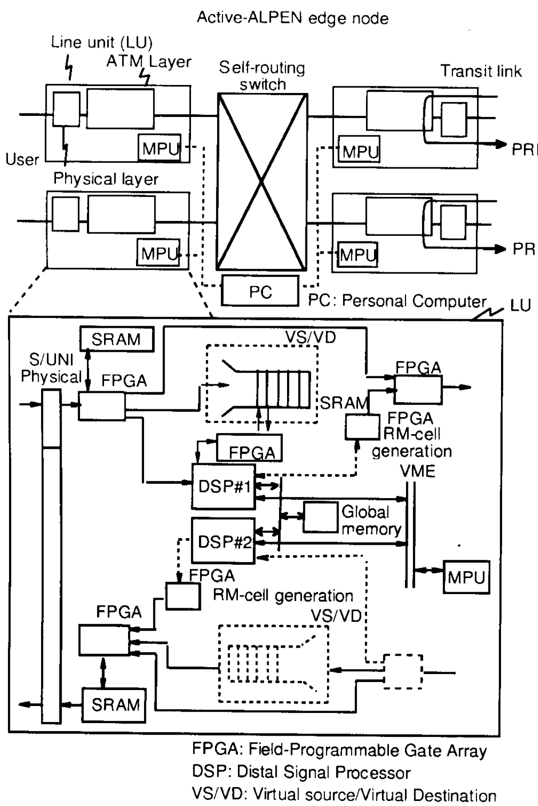

Fig. 4 Block diagram of fabricated PUN system prototype.

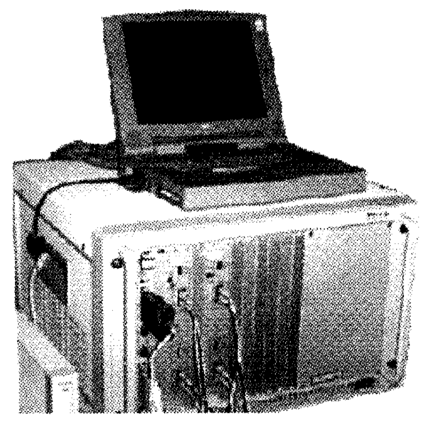

Fig. 5 Overview of active-ATM PUN prototype system.(Edge node)

VCI. The prototype system demonstrated that our proposed active-ATM architecture enables users to communicate via ATM more flexibly and dynamically. The active-ATM network is well suited to future B-ISDNs.

4. Conclusions

Our proposed active-ATM network offers the usual advantages of ATM while providing the user with more flexible control of their network services. Active-program capsules enables users to create new ATM service protocols at the WAN edge nodes. The transit network uses a simple, high-speed universal protocol. The result is a simple cost-effective WAN concept that is suitable for future B-ISDNs. Prototype testing confirmed that using programmable unified nodes made the network more flexible. The proposed active-ATM architecture will facilitate the development of innovative B-ISDN ATM transport functions.

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