ATM Technology and E-Learning Initiatives

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INTRODUCTION

The remarkable popularity of Web-based applications featuring text, voice, still images, animations, full-motion video and/or graphics and spiraling demand for broadband technologies that provision seamless multimedia delivery motivate implementation of asynchronous transfer mode (ATM) in an array of electronic learning (e-learning) environments (Parr & Curran, 2000). Asynchronous refers to ATM capabilities in supporting intermittent bit rates and traffic patterns in response to actual demand, and transfer mode indicates ATM capabilities in transporting multiple types of network traffic.

E-learning describes instructional situations in which teachers and students are physically separated (Lee, Hou & Lee, 2003; Hunter & Carr, 2002). ATM is a high-speed, high-performance multiplexing and switching communications technology that bridges the space between instructors and learners by providing bandwidth on demand for enabling interactive real-time communications services and delivery of multimedia instructional materials with quality-of-service (QoS) guarantees.

Research trials and full-scale ATM implementations in K-12 schools and post-secondary institutions conducted since the 1990s demonstrate this technology's versatility in enabling telementoring, telecollaborative research and access to e-learning enrichment courses. However, with enormous bandwidth provided via high-capacity 10 Gigabit Ethernet, wavelength division multiplexing (WDM) and dense WDM (DWDM) backbone networks; high costs of ATM equipment and service contracts; and interoperability problems between different generations of ATM core components such as switches, ATM is no longer regarded as a universal broadband solution.

Despite technical and financial issues, ATM networks continue to support on-demand access to Web-based course content and multimedia applications. ATM implementations facilitate the seamless integration of diverse network components that include computer systems, servers, middleware, Web caches, courseware tools, digital library materials and instructional resources such as streaming video clips in dynamic e-learning system environments. National research and education networks (NRENs) in countries that include Belgium, Croatia, Estonia, Greece, Israel, Latvia, Moldavia, Portugal, Spain, Switzerland and Turkey use ATM in conjunction with technologies such as Internet protocol (IP), synchronous digital hierarchy (SDH), WDM and DWDM in supporting synchronous and asynchronous collaboration, scientific investigations and e-learning initiatives (TERENA, 2003).

This article reviews major research initiatives contributing to ATM development. ATM technical fundamentals and representative ATM specifications are described. Capabilities of ATM technology in supporting e-learning applications and solutions are examined. Finally, trends in ATM implementation are explored.

BACKGROUND

Bell Labs initiated work on ATM research projects during the 1960s and subsequently developed cell switching architecture for transporting bursty network traffic. Initially known as asynchronous time-division multiplexing (ATDM), ATM was originally viewed as a replacement for the time-division multiplexing (TDM) protocol that supported transmission of time-dependent and time-independent traffic and assigned each fixed-sized packet or cell to a fixed timeslot for transmission. In contrast to TDM, the ATM protocol dynamically allocated timeslots to cells on demand to accommodate application requirements.

In the 1990s, the foundation for practical ATM e-learning implementations was established in the European Union (EU) with the Joint ATM Experiment on European Services (JAMES); Trans-European

Network-34.368 Mbps or megabits per second (TEN-34); and TEN-155.52 Mbps (TEN-155) projects. EU NRENs such as Super Joint Academic Network (SuperJANET) in the United Kingdom and SURFnet in The Netherlands demonstrated ATMs' dependable support of multimedia applications with QoS guarantees, interactive videoconferences and IP multicasts via optical connections at rates reaching 2.488 gigabits per second (Gbps, or in OC-48 in terms of optical carrier levels).

Implemented between 1994 and 1999, the European Commission (EC) Advanced Communications Technology and Services (ACTS) Program demonstrated ATM technical capabilities in interworking with wireline and wireless implementations. For instance, the EC ACTS COIAS (convergence of Internet ATM satellite) project confirmed the use of IP version 6 (IPv6) in enhancing network functions in hybrid satellite and ATM networks. The EC ACTS AMUSE initiative validated ATM-over-asynchronous digital subscriber line (ADSL) capabilities in delivering time-critical interactive broadband services to residential users (Di Concetto, Pavarani, Rosa, Rossi, Paul & Di Martino, 1999).

A successor to the EC ACTS Program, the EC Community Research and Development Information Service (CORDIS) Fifth Framework Information Society Technologies (IST) Program sponsored technical initiatives in the ATM arena between 1998 and 2002. For example, the open platform for enhanced interactive services (OPENISE) project verified capabilities of the ATM platform in interworking with ADSL and ADSL.Lite in supporting multimedia services and voice-over-ATM implementations. The creation and deployment of end user services in premium IP networks (CADENUS) initiative confirmed the effectiveness of ATM, IP and multiprotocol label switching (MPLS) operations in facilitating delivery of multimedia applications with QoS guarantees via mixed-mode wireline and wireless platform. The IASON (generic evaluation platform for services interoperability and networks) project validated the use of ATM in conjunction with an array of wireline and wireless technologies including universal mobile telecommunications systems (UMTS), IP, integrated services digital network (ISDN) and general packet radio service (GPRS) technologies. The WINMAN (WDM and IP network management) initiative demonstrated ATM, SDH and DWDM support of reliable IP transport and IP operations in conjunction with flexible and extendible network architectures. The NETAGE (advanced network adapter for the new generation of mobile and IP-based networks) initiative verified ATM, ISDN and IP functions in interworking with global systems for mobile communications (GSM), a 2G (second generation) cellular solution, and GPRS implementations.

Research findings from the Fifth Framework Program also contributed to the design of the transborder e-learning initiative sponsored by the EC. Based on integrated information and communications technology (ICT), this initiative supports advanced e-learning applications that respect language and cultural diversity and promotes digital literacy, telecollaborative research, professional development and lifelong education.

In the United States (U.S.), an IP-over-ATM-over-synchronous optical network (SONET) infrastructure served as the platform for the very high-speed broadband network service (vBNS) and its successor vBNS+, one of the two backbone networks that originally provided connections to Internet2 (I2). A next-generation research and education network, sponsored by the University Consortium for Advanced Internet Development (UCAID), I2 supports advanced research and distance education applications with QoS guarantees. Although replacement of ATM with ultra-fast DWDM technology as the I2 network core is under way, ATM technology continues to provision multimedia services at I2 member institutions that include the Universities of Michigan, Mississippi and Southern Mississippi, and Northeastern and Mississippi State Universities.

ATM TECHNICAL FUNDAMENTALS

To achieve fast transmission rates, ATM uses a standard fixed-sized 53-byte cell featuring a 5-byte header or addressing and routing mechanism that contains a virtual channel identifier (VCI), a virtual path indicator (VPI) and an error-detection field and a 48-byte payload or information field for transmission. ATM supports operations over physical media that include twisted copper wire pair and optical fiber with optical rates at 13.27 Gbps (OC-192). Since ATM enables connection-oriented services, information is transported when a virtual channel is estab-

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