Evolution of ATM high-speed multiservices broadband integrated network

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Evolution of ATM High-Speed Multiservices Broadband Integrated Network

Titu I. BAJENESCO, La Conversion

Zusammenfassung

Die Entwicklung schneller diensteintegrierender ATM-Breitbandnetze

Zur Übermittlung von Trägern mit grosser Bandbreite erfordert die Entwicklung integrierter Breitbandnetze mit Mehrfachnutzung die Unterstützung durch entsprechend leistungsfähige Netze. Anhand einiger möglicher Einführungsstrategien wird aufgezeigt, wie sich diese Netze in Richtung angestrebtes B-ISDN auf ATM-Basis entwickeln. Die Feldversuche führen vor Augen, dass bei Benutzern langsam das Bedürfnis entsteht, problemlos auf modernste Kommunikationsdienste zugreifen zu können. Einen weiteren Schritt in diese Richtung stellt der europaweite Pilotversuch dar (Beginn vorgesehen für Anfang 1995), der es zudem dem Netzbetreiber ermöglicht, die Benutzerbedürfnisse präziser einzuschätzen, damit die definitiven ATM-Netze auf die tatsächlichen Kundenanforderungen zugeschnitten werden können.

Résumé

Le développement de réseaux ATM à large bande et à intégration de services

Pour transmettre des porteuses à très large bande, il est nécessaire d'épauler les réseaux à large bande à utilisation multiple en cours de développement par la mise en place de réseaux performants. En se fondant sur des stratégies d'introduction envisageables, on montre comment de tels réseaux du type ATM évoluent en prévision du réseau RNIS à large bande souhaité. Les essais sur le terrain montrent que les utilisateurs désirent peu à peu pouvoir accéder facilement aux services de télécommunication les plus modernes. Une autre étape dans cette direction est la mise en place du réseau pilote paneuropéen (vraisemblablement pour le début de 1995). Il permettra aux opérateurs de réseaux d'évaluer de manière plus précise les besoins des utilisateurs afin que l'on puisse aménager les réseaux ATM définitifs en fonction des besoins effectifs des clients.

Riassunto

Lo sviluppo di reti rapide a larga banda ATM con integrazione dei servizi

Lo sviluppo di reti a larga banda integrate per uso multiplo richiede, per la trasmissione di portanti a larga banda, il supporto di reti potenti corrispondenti. Sulla base di alcune strategie di introduzione possibili, l'autore illustra in che modo queste reti si sviluppano sulla rete ISDN a larga banda su base ATM. Le prove in campo dimostrano che gli utilizzatori cominciano ad avvertire il bisogno di usufruire facilmente di servizi di comunicazione più moderni. Un ulteriore passo in questa direzione è rappresentato dalla prova pilota (che prenderà l'avvio all'inizio del 1995) eseguita a livello europeo, la quale consentirà ai gestori di rete di valutare con maggiore precisione le esigenze degli utilizzatori. Le reti ATM definitive potranno così essere concepite in modo da soddisfare pienamente le reali esigenze dei clienti.

Summary

Evolution of ATM High-Speed Multiservices Broadband Integrated Network

The evolution of multiservices broadband integrated networks needs the support of network capabilities to transport high bandwidth carriers. The evolution of these networks towards the target B-ISDN based on ATM is highlighted through some possible introduction strategies. The field trials demonstrate the emerging need by the users to have easy access to advanced communication services. A further step is the European pilot test (due to commence in early 1995) which will also enable operators to more accurately assess user needs so that the live ATM networks will be tailored to meet customer requirements.

1 *Introduction*

Broadband ISDN (B-ISDN) is the target network architecture for supporting telecommunications services in the 1990s and beyond. Routing is an essential part of a real broadband network, and technology is now at a stage where it can be offered up to 10 Gbit/s[1]. With this speed and the efficient digital coding of video, the huge market of TV signals is open for telecommunications networks. Areas now dominated by analogue processing will benefit from the inherent quality-maintaining property of digital transmission switching.

Asynchronous Transfer Mode (ATM) combines properties of circuit switching and packet switching and it has the potential to offer simultaneously high-speed and flexible connections. Unlike ISDN, ATM matches both the local-area and wide-area communications requirements of the applications. As a result, islands of ATM are beginning to develop in LANs and private networks, and the interconnection of such islands will yield substantial economies of scope. Cost effective services will be made possible through

[1] The SONET standard transmission rate is currently about 2.5 Gbit/s and will likely be defined at 10 Gbit/s in the near future. Current experimental systems in the research labs have demonstrated transmission at 32 Gbit/s on a single fibre! The recent invention of the erbium-doped fibre amplifier will have a significant impact on optical transmission systems

rapid advances in coding algorithms and VLSI technology. An ATM environment can provide a high degree of flexibility in large capacity communication systems by taking advantage of the inherent burstiness of information. In the public arena, *cell relay*[2] will be implemented within a number of different services.

As a *multiplexing technology,* ATM's particular strength lies in its ability to provide large, instantaneous bandwidths for traffic characterized by high *burstiness* (i. e. short bursts of intense activity followed by relatively long lull periods), while permitting other traffic to use that bandwidth between bursts. This means that it makes very efficient use of network capacity for a wide range of communications services, especially data communications between computers, which can be very bursty. As a *standard,* ATM is highly versatile and globally recognized; it can be applied in every area of networking. This means that it holds out the prospect of seamless interconnection between different networks and systems, and the amalgamation in a common infrastructure of services which are currently supported on separate dedicated networks. No one knows what traffic demands will be in the future, but ATM has every chance of being able to cope with. ATM will be introduced into public networks gradually, selectively and as the culmination of many interrelated network-technology developments. For the end-user of TC (large corporate network user) the economies of ATM are clearly favourable, despite high initial costs [1].

ATM is a *connection-oriented* network like X.25 and frame relay; any transfer of data over the network involves two stages: an initial *connection establishment phase* followed by the *data transfer phase.* One of the major feature of ATM is the sheer speed at which it can operate (today: link speeds of 155 Mbit/s; in the near future: up to the Gbit/s range).

Perhaps the key word [2] when considering the impact of ATM is *unification.* ATM is the first technology that allows the combination of isochronous traffic, such as voice and video, with variable traffic sources such as data, on a single network.[3]

2 ATM – dialtone for the next decade

The real question is whether or not ATM can become the *dialtone* for the next decade. The matter revolves on economics which are not known at present. Will it be economically feasible to convert all communications signals (voice, data and image) to standard, small packets and to route intelligently these packets at every node in the network? Or will this service be so gold-plated that conventional circuit switching will predominate well into the next century? A given customer ought to be able to use the maximum capability of the network, but in short time segments. This is the idea behind ATM and packet networks in general. When your packet traverses the network, the bits are sent at a rate of 155 Mbit/s. But when your packet is completed, the network turns its attention to someone else's packet.

3 Key elements

There are three key elements in a ATM network: the *terminal adaptor* (TA), the *multi-service concentrator* and the ATM *cross-connect and switching equipment.* All these three basic functions can be combined in the same equipment, in a variety of combinations, singly, any two of three or all three together. An *ATM network* is divided into the *operator domain* and the *customer domain.* Within the operator domain are two areas: *transport* and *access.* The transport domain comprises transit, cross-connect and switching systems. The equipment is very large and has typically several hundred access ports each, working at 155 Mbps through multiple ports [3].

The *operator access domain* consists of cross-connect and switching equipment as well as ATM concentrators; the equipment is much smaller with typically 32 lines as a maximum. The ATM concentrators aggregate a wide variety of bit rate ATM services from the remote users, at data rates from 2 Mbit/s to 155 Mbit/s. The concentrator will also have special lines to handle *non-ATM services* such as frame relay or G.703/704, which are transformed into ATM for circulation around the transport network. The transformation of these non-ATM services into ATM format is *transparent* to the customer but enables the operator to maximize the use of his network.

The *customer ATM domain* is also divided into two areas: the *local networks* and the *customer access to the operator network.* The local network is effectively the customer premises equipment and would include PCs, workstations, X.25 datacomms systems, routers, Ethernet/Token Ring networks and videoconferencing. The *customer access* consists of multiservice ATM cross-connects, switches and concentrators – with the different functionalities realized by the management system or by the signalling. In the initial deployment of ATM, the different customer premises equipment is all linked individually to an ATM device in the customer access. This device acts as a combined terminal adaptor/concentrator, converting the different inputs to ATM format, and the routing them into the operator's access network.[4]

4 Charging policy

Ideally, it would seem that each packet should carry a paid stamp, or some such way of charging by the

[2] *Cell relay ATM* is a general term which includes B-ISDN, a service offer, and ATM, a service technology

[3] ATM is the unique ability to provide guaranteed amounts of bandwidth to isochronous traffic along with predictable transit delays and at the same time carrying variable bit rate traffic. Voice requires the provision of a fixed amount of bandwidth and predictable delay characteristics; video may require fixed or variable bandwidth depending on the encoding techniques used, transit delay and transit delay variation must be minimized. Data is less demanding as it requires variable bandwidth and is very insensitive to transit delay in most circumstances. Looking towards the future it is obvious that the distinction between traffic types becomes increasingly blurred

[4] Alternatively, individual equipment within the customer premises can be fitted with terminal adaptors, providing ATM-format outputs. This is linked individually to the ATM concentrator and in to the operator's network

packet. However, it seems agreed that the overhead of administering such a charging policy would be exorbitant. Even today the cost of billing is among the largest costs associated with telecommunications. At the opposite extreme would be the policy of having a standard access charge, independent of actual packet use. Such a policy would depend on statistics to even the load on the network. The benefit would be low overhead for administration, but the problem would be that resellers would take advantage of the pricing policy by packaging multiple users into a single low-cost channel, thereby defeating the statistical averaging that packet communication depends on.[5]

ATM is a suitable technique for a variety of other high speed switching and multiplexing tasks and is likely to be widely adopted as it will become well understood and easy to implement.[6] The ATM can also create a *multiservices high-speed broadband integrated network.* The interest in such a choice is at least twofold:

- The MAN will have to communicate with the future B-ISDN; if these networks use the same transfer technique, the interconnecting problems will be simplified [6, 7, 8].
- Some components could be used both by the two types of networks and by their terminals [8, 9].

5 *How to migrate to an ATM backbone?*

Broadband connections (>1.5 Mbit/s in USA and 2.048 Mbit/s in Europe) are already established today on a permanent (or semipermanent) basis for business customers (leased lines). A first step to improve the network flexibility is to introduce cross-connect systems both in the local loop and in the transit part of the network. However, it is recognized that a maximum of flexibility can be only achieved with an ATM broadband switched network (B-ISDN), in which a combination of cross-connect and switching equipment will be in operation. A possible scenario [4] towards such an network could be divided in four steps:

- permanent (or semipermanent) ATM end-to-end connections for business customers;
- switched ATM end-to-end connection for a limited number of customers, mainly business oriented;
- switched ATM connection between customers and service providers (e. g. for application based on retrieval services) for business and residential subscribers in some areas of the network;
- full ATM B-ISDN capabilities.

Basically so-called *overlay* and *island strategies* can be envisaged with the three categories of transmission systems described above, providing the ATM cross-connect and switching equipment supports three types of different interfaces.

The migration to an ATM backbone network must be achieved with *minimal disruption* to existing users of the network and so as to achieve economic benefits as soon as possible. Perhaps the easiest area to deal with is the migration of existing data traffic onto an ATM backbone. In most networks this traffic will be concentrated by routers and packet switches which are then connected over dedicated leased lines or bandwidth providing using TDM equipment [5]. ATM interfaces are already available for some routers and packet switches simplifying the migration; at the same time some ATM switches provide adaptation interfaces allowing the direct connection of LAN devices or packet switched traffic. The most immediate benefit of migrating data traffic onto an ATM backbone is the transition from fixed bandwidth leased line or TDM connections between sites to a variable bit rate ATM service. Data traffic can therefore use any available bandwidth in the backbone network even if the amount available is constantly varying [10].

Benefits:

- Reduction in the end-to-end transit delays over the network due to the reduction in packetization delay in the switches.
- The ATM switch passes the traffic over the network as a constant bit rate (CBR) ATM connection.
- In order to emulate a leased line the ATM switch will need to allocate more than the bandwidth of the line being emulated. (Approx. 2.3 Mbit/s of ATM bandwidth is required to emulate a 2.048-Mbit/s leased line).

6 *SDH and ATM*

According to ITU-T, this dynamic duo will form together the common core of the future B-ISDN. But technically, neither SDH *(Synchronous Digital Hierarchy)* nor ATM require the other. SDH is a rapidly maturing technology that many operators are putting into service today to carry ordinary telephone service and wideband data traffic. ATM – while a still immature technology and not fully standardized – promises to push public and privat networks alike into the broadband era. Many of the services made possible by 4×3×1 cross-connects or add-drop multiplexers, such as rapid provisioning and dynamic reconfiguration of leased lines, would better be provided by ATM. It is probable that SDH will dominate cross-connect functions in the higher-level regions of operator trunk networks. We must note that ATM cells do not

[5] There are numerous studies today that describe schemes for *policing* packet networks, i. e., hardware and software system which ensure that no user can abuse the average and peak cell rates associated with his tariff. It seems to me that there is a moral difficulty with these schemes because they pass on to every fair user of the network the cost of protecting against unfair use. Of course, the same is true of scrambling in satellite systems, but that does not make this approach less objectionable

[6] Currently, ATM is only defined for SONET (Synchronous Optical Network) speeds. To become a viable technology for global enterprise networks and interLAN networks, critical LAN and WAN interoperability issues, including signalling, call set-up definitions, flow control, congestion management and call billing, need to be established. Another factor slowing the growth of ATM's deployment is the uncertainty of the course of network multimedia applications. To date, it is unknown what applications will be available, how applications will be tailored to serve corporate networking needs or how multimedia applications will behave on the network

need a synchronized frame such as those provided by SDH and PDH, because the header's error check-field can be used to delimit cell boundaries.

7 Pan-European Test Network

The idea of an universal broadband network has beguiled networks operators, equipment suppliers and politicians for well over a decade [11...16]. But it's becoming clear, that widespread deployment of universal broadband networks based on optical fibre, reaching both residential and business customer, will not begin in most parts of Europe until after the year 2005. Obstacles relate to regulations, tariffs, standards and co-ordination between Telecommunication Operators (TO) in providing trans-border communications. Lack of regulatory conditions enabling interconnection of these 'new' networks to the established public networks also present a barrier to potential competitors.

Eighteen European countries have signed a *Memorandum of Understanding* on the development of ATM and a number of large scale pilot projects are currently underway. National networks are being implemented, each with three cross-connects, a number of concentrators and an international node connecting the national network to the ATM networks of adjacent countries. These networks will be going in live in 1994.

The high and non-competitive leased line tariffs are a significant threat to growth of wide-spread high-speed networks across Europe. There is a wide variation in tariffs between European countries, and the cost of pan-European 2-Mbit/s leased lines is estimated at five to ten times that of the equivalent capacity in the US. However, by the end of this decade, it is likely that users will have a choice of a range of high-speed networks and services, potentially offered by competitive suppliers capable of supporting them across Europe.

The market justifications for broadband development stem from both business and residential applications, with the former driving initial broadband investment. Among professional applications, *high-speed data communications will generate the strongest demand.* Applications include globe-spanning interconnections of LANs as well as high-speed data links among terminals, work stations and host computers. In addition, the multimedia terminal currently under development in many places will require broadband for the video component. They will also be used as backbone networks for other data communications, including frame relay and circuit emulation services.

Residential applications represent a huge potential market for braodband services, although it is important to note that private customers are not willing to spend as much for telecommunications as business customers. Distribution of TV and radio programmes will be among the applications. Video-on-demand services – which will become more important than simple programme distribution – could become a *key driver* for broadband. Video information distribution can go beyond movies to include educational services and video shopping.[7]

8 Is ATM ready for commercial service?

According to both pioneers and sceptical experts, ATM implementation is proceeding apace for enterprise local-area networks. But the ATM Forum – which now has more than 550 members world-wide – must spend more time on public network issues. Some of that detailed work (specifications for LAN emulation, interworking with frame relay [FR] and SMDS Switched Multimegabit Data Service, new ATM adaptation layers, low-speed [E1/T1] access and switched virtual circuits) is expected to be completed by next spring (1995).

More cautious telecoms carriers say that other services – like leased circuits, frame relay and ISDN – can meet immediate customer demands. They are not looking to deploy ATM before late 1995 or 1996, when standards will be more mature and bandwidth needs more pronounced.

Firstly, carriers seek specifications for available bit rate services, which will essentially turn the public network into a wide-area router network, allocating bandwidth on demand. Available bit rate is especially well-suited to interconnecting LANs, but even optimists do not expect specifications to be completed before next year (1995).

Secondly, congestion management becomes exponentially more difficult with megabits and gigabits of data vying for public network resources. Buffer memory sizes in switches and other equipment are proved inadequate, and trial users are losing data. As a result, carriers cannot offer quality-of-service guarantees on the most sophisticated ATM services.

Thirdly, the computer systems that handle a public network operations like billing, service ordering and maintenance must be adapted for ATM.

Among European carriers, Telecom Finland is on track to provide ATM services – including direct 155 Mbps connections – from September 1994. France Telecom plans to offer two ATM-derived services (a LAN interconnect service and a service to replace leased circuits in corporate networks) by the end of this year. Driving force is the increasing appetite for bandwidth of their customers, because the applications built to use burgeoning computing power – groupware, multimedia, compound document handling, imaging and videoconferencing – are

[7] Two basic technologies are being implemented to develop broadband networks: ATM – which *provides the means to package and distribute information* – and SDH, which *provides th means to transmit the information.* ATM networks are built around three main elements; the lowest-level element, the ATM access node, provides the mutliplexing and concentration functions for information entering (or leaving) the system. Connections are established or released by the network operator in a semipermanent connection switch (SPC), also known as a permanent virtual connection (PVC) switch or a cross-connect switch. Finally, a call-by-call switch handles broadband signalling as well as various call services.

eating up network bandwidth. On many corporate backbones, data traffic is doubling every 18 months.

The ATM pioneers are focusing on areas where demand is most immediate, especially LAN interconnection. Supporters say ATM is unique because it provides specific, very high-speed bandwidth connections to customers while filling carrier backbones more efficiently and economically. E3-(34 Mbit/s-) leased circuits can handle most LAN speeds, but few users can afford them. Packet switching technologies (X.25, FR) allocate bandwidth more flexibly than leased circuits but cannot operate at 10 Mbit/s or above.

A number of economic studies showed that for high-speed data services alone, ATM could not pay (it is not competitive with other services like FR and leased circuits, and over a seven-to-ten-year period, it will be not possible to earn a return from it). A better strategy would be to use ATM for integrated services, such as video and voice, with the aim to enhance the traditional telephony network and to permit providing the high-speed data services at marginal cost. In other words: waiting for mature ATM standards and equipment. The gaps are numerous; to begin with existing standards which do not yet permit true bandwidth on demand. Users must reserve a network speed, compromising one of ATM's most significant advantages. But constant bit rate offers you no statistical gain, because you allways allocate the peak rate. To solve this traffic-control issue is one of the major tasks, and this needs time.

Variable bit rate service (a second type of ATM service and one already standardized) is more flexible. It offers a sustained information rate, similar to the committed information rate in FR services, for normal traffic loads, and a peak rate for occasional higher loads.[8] Even variable bit rate service, however, is not properly adapted for very bursty traffic streams especially where the main source is LAN. The real answer would be available bit rate services; the user doesn't need reservation. He just sends through network.

To avoid a situation where cells are lost, we do need some kind of feedback mechanism for the user device to tell him how fast it can send data at any one time. An adapter card for a PC, workstation or LAN hub could monitor feedback from the public network to slow down or speed up data flow from the premises according to available bandwidth in the wide area. A likely configuration once available bit rate services are defined is to dedicate part of the network to constant bit rate and the rest to available bit rate. This mixture of services will probably require much work and further investigation on traffic control. The ATM Forum or ETSI may decide not to define or to standardize such an interface[9], to focus less on LANs and more on the needs of public network operators.

[8] France Telecom and Telecom Finland both intend to offer this kind of service.

[9] Traffic control and congestion management are easier at the LAN level than at the wide-area level, because of lower volume and because traffic generally goes to the same place. With the rigors of the public network, vendors schemes for handling buffers break down badly.

Whether as a trial or as a routine application (like replacing a LAN-to-LAN private line or a point-to-point video link), that's what customers are doing to understand how to integrate ATM into their networks. The first-generation ATM switches is inadequately when handling large data volumes: Buffers overflow and discard cells rather than wait to retransmit. Larger buffer sizes and buffer capacities will better support a wide variety of services on a single switch fabric, and this is what ATM is designed to do Traffic management will keep vendors and operators occupied for at least the next two years. Meanwhile, carriers, their switch vendors and database management experts must meld ATM switches with billing, troubleshooting, service provisioning, maintenance and other systems. These are a less visible (but not less important) fabric of the public network.

The business case for users to buy ATM services remains uncertain, especially in Europe. ATM's greatest benefit is for bursty LAN traffic, but since most of that traffic is successfully handled at speeds of less than 2 Mbit/s, users are unlikely to pay a premium for ATM.

Elsewhere, carriers are pricing their ATM services at a high enough level to prevent them from cannibalizing leased-circuit revenues, which account for about 5 % of all European telephone company revenues.[10] Users have many latent requirements for new applications (especially strategic applications that help them to compete). They're just beginning to explore using ATM for that.

9 Conclusion

Technology does not occur in a vacuum, and we all realize that massive forces are extant in the world that will have more to do with the future of telecommunications than the invention of new electronic devices. *Globalization* – of business, the economy, and technology – might be foremost among these forces. If giga bandwidth is really needed in the backbone, ATM is clearly a winner. Because ATM is a switched star configuration, the total capacity of the backbone is theoretically the sum of the links to the switch (in an FDDI ring, the limit is the ring speed). Unlike FDDI, ATM employs a statistical rather than deterministic switching approach, which makes ATM non-conducive to bursts of data. Although thresholds can be set to reduce the likelihood of congestion on ATM-based networks, it still can occur because each individual device determines when to send and receive data, rather than the network itself. High costs in implementing will also come from the switches themselves, making the technology's implementation too expensive for a majority of companies. The first ATM premises switches on the market will be priced at approx. $5000 per port, well over current FDDI-over-copper wire products, which now range at some $1000 per adapter and $1500 per hub or concentrator port. The task of ATM in the backbone is simpler and

[10] France Telecom says its ATM services will allow companies to save up to 30 % over a comparable leased-circuit network

better defined than other ATM areas. This means that many of the available products in the ATM fields are targeted for backbone applications. The development of alternatives is a good thing as it maintains competition which in turn stimulates technology advances and provides the user with multiple options.

But the real story behind ATM is that its applications – those which require ATM service to happen at all –, won't develop until real cracks begin to appear in tariffing structures; real changes in the way people use technology come when cost and assumptions change. Cost-effectiveness with ATM relates almost entirely to the size of the market; if ATM is a success, then the cost/benefit justification will be straight-forward. If not – especially in the early stages of market growth – then there may be problems ...

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