High Speed and Mobility – Communications in the Fast Lane?

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Abstract

The growing interest in distributed computing and computer networking in general on the one hand and advances in telecommunication services on the other hand have given rise to considerable R&D efforts in the area of high speed networking. The ATM (Asynchronous Transfer Mode) technology which will be used to realize the future Broadband-ISDN offers the capabilities to integrate high bandwidth multimedia and conventional data communications applications. Multimedia to the desktop and even to private homes seems to be the trend in this field for the immediate future.

The second field that has been experiencing a continuous growth in recent years is mobile communications: With the tremendous success of the mobile telephone and the advent of new mobile computing applications there seems to be a growing demand for making the high performance multimedia applications currently emerging in the fixed networks available to the mobile user.

In this paper we examine the possibility, and feasibility, of integrating high speed and mobility. Taking the ATM technology as the starting point we examine possible approaches for extending fixed high-speed networks via dedicated wireless links to the mobile user. Taking the technological limitations of wireless communications into account we examine the feasibility to provide the mobile user with a quality of service comparable to that experienced in fixed networks.

Keywords

High speed networks, ATM, wireless networks, mobile computing, Quality of Service, interworking, proxy architectures

1 INTRODUCTION

High speed networks have for a long time been applied in computer communications for LAN interconnection, remote personal communications, information retrieval and document transfer. Within the past ten years, two other mainstreams of development in the area of tele- and data communications have become increasingly important:

R&D efforts in broadband telecommunications via B-ISDN have founded a suitable basis for highly bandwidth intensive applications like video phone, multimedia document transfer and even digital video transmissions to set-top boxes in the private home area. Additionally, the growing interest of customers in these new communication concepts has lead to an ever-increasing acceptance of data communication services and of public information networks like the Internet. This has resulted in an enormous market potential for both the business and the private sector. Even national governments have become aware of the importance and the global role of this technology field, and have smoothed the way into a future networking community by a number of necessary decisions, like the ongoing deregulation of the European telecommunication market.

With mobile communications a second key technology has undergone a tremendous growth over the past decade. Inspired by the success of mobile telephony customers are now getting used to be able to communicate wherever they currently roam. “Mobile desktop” and “wireless office” are just two of the popular buzzwords indicating this trend.

The investigation of technologies enabling high service quality in mobile networks is one of the most challenging goals of today’s research and development in computer networking. The transformation of state of the art wired technologies like Asynchronous Transfer Mode (ATM) with their capacity and service capabilities, i.e. different service types and guaranteed Quality of Service (QoS), into the future Universal Mobile Telecommunications System (UMTS) is investigated in various international projects.

In this report, we describe the implications of this integration of mobility into high speed networks. We focus on ATM as the most promising candidate for future broadband networks. We discuss technical problems rooted for instance in the limited availability of frequency resources and in the generally lower QoS which can be offered over a radio interface. Taking these technological limitations into account, we evaluate whether it is useful and feasible to adapt the full range of services of a wired environment to a mobile one. Finally, we suggest possible partial solutions which fulfil the design goals of next generation integrated systems.

2 HIGH SPEED SERVICES AND THEIR IMPACTS ON TRANSFER SYSTEMS

Fig. 1 gives an overview on major networks participating in the evolution of today’s and future broadband technologies. The need for packet switching technology supporting data communications was early discovered in the mid 70’s and soon resulted in the standardization of the X.25 protocol suite. In parallel, local networks with capacities around the 10 Mbps held their advent into business and manufacturing environments, leading to the establishment of the 802 subcommittees. Only a few years later, local high speed networks like the Fibre Distributed Data Interface (FDDI) and the first cell-based network, the Distributed Queue Dual Bus (DQDB), both

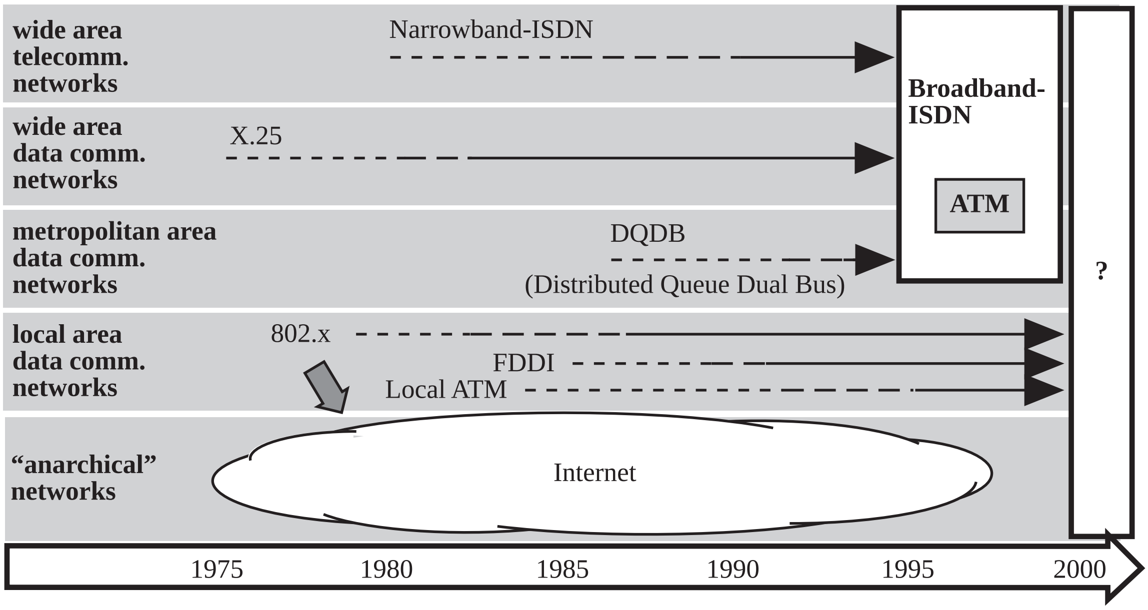

Figure 1 History of High Speed Networks.

already with capacities in the hundreds of Mbps, were developed and standardized. In the early 80’s, information digitalization of audio and video streams became more and more feasible. The resulting generalization of information into the overall concept commonly described as multimedia, necessitated the distribution of different information services using only one common network technology instead of several networks each serving one application. This paved the way for the (international) telecommunications industry to establish Integrated Services Digital Networks (ISDN) for both the private and the business sector.

2.1 ATM – Integrated Broadband Communications

Today, narrowband services introduced as the first step towards the global integrated broadband network can no longer provide the basis for highly bandwidth intensive applications like video telephony, multimedia document transfer or digital video transmissions to the private home. Within only a few years, existing network structures have been overtaken by an enormous demand for communication, which was mainly pushed by the exponential growth of the (private) PC market and the globalization of corporate structures. Both user groups “play” with modern information retrieval systems which are for example based on World Wide Web (WWW) technology. Companies can additionally benefit from distributed 24 hour utilization of their system capacities, from freight & fleet management systems to support „just-in-time“ delivery, or from video telephony to lower their travelling expenses. Most of these applications are somehow based on the exchange of multimedia information, which enforces the integrated and synchronized handling of discrete and continuous media using a common technology.

A major problem is rooted in the diverging performance requirements of distributed multimedia applications: Plain text transmissions have very stringent requirements on the tolerable bit error rate (BER), but can be performed on a best-effort basis regarding their delay boundaries and usually also their required bandwidth. Audio and speech communication are comparatively

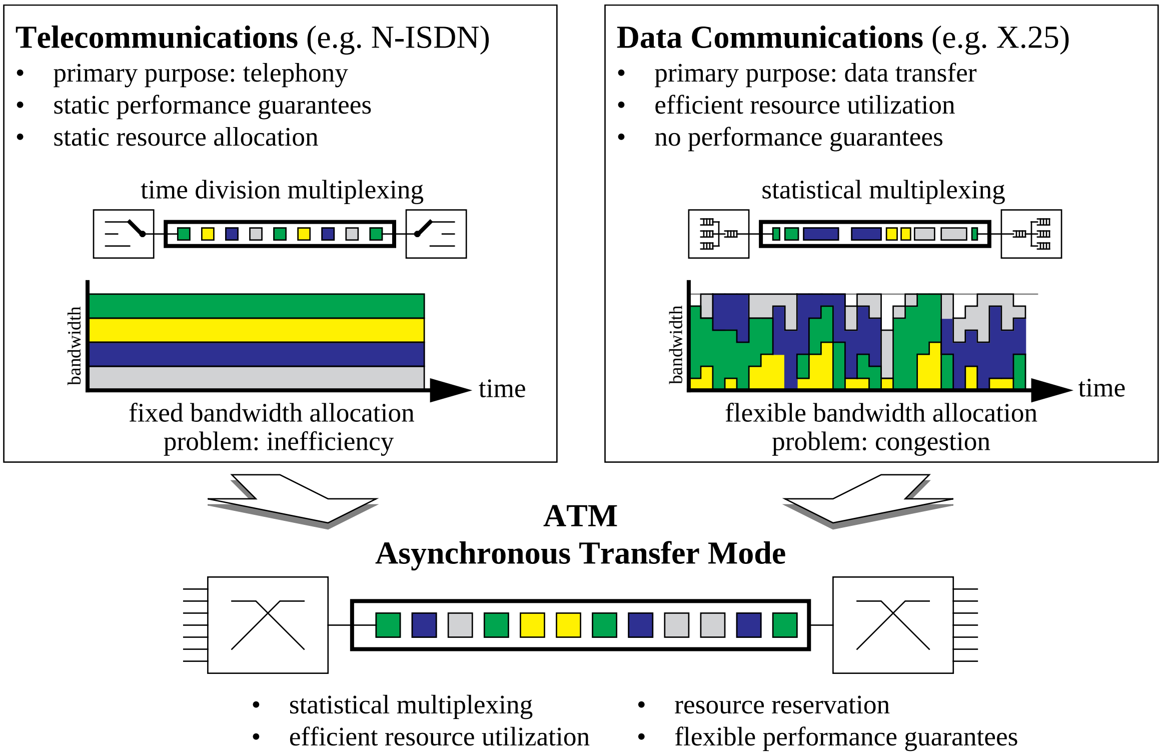

Figure 2 ATM - Integrating Data- and Telecommunications

uncritical concerning both bandwidth and BER, but demand for real-time network services establishing well-known bounds on packet delays and on the delay variances. Similar bounds hold for video applications, which additionally are extremely bandwidth consuming. All in all, the synchronization of heterogenous streams with completely diverging QoS requirements has imposed much higher constraints on networking technology than can be met by N-ISDN. However, there is already a new technology available which is perfectly suited to heterogenous service profiles: Asynchronous Transfer Mode (ATM) with its cell-based data transfer has been selected as the network protocol suite for the Broadband-ISDN.

Within the past few years ATM has proven its capability to serve as the future networking standard for tele- as well as data communication applications. It was soon discovered that ATM also meets the requirements for a wide-spread deployment in ATM local area networks and even to private premises. The ATM technology’s primary goal is the integration of traditional telecommunication services and data communications, and thus the support of a wide range of traffic types with different communication requirements within a single network. It is based on small, fixed size cells with a payload of 48 bytes, which are transported via virtual paths and circuits in a connection-oriented fashion. ATM supports fixed bandwidth traffic (constant bit rate, CBR) as well as statistically multiplexed variable bandwidth traffic (variable bit rate, VBR) and guarantees delivery within certain timing restraints (see Fig. 2). These service classes are primarily aimed at telecommunication services (voice- and videotelephony) as well as the traffic generated by modern distributed multimedia applications. Additionally, service classes like ABR (available bit rate) and UBR (unspecified bit rate) for traditional data communication applications without explicit timing or bandwidth requirements can also be supported.

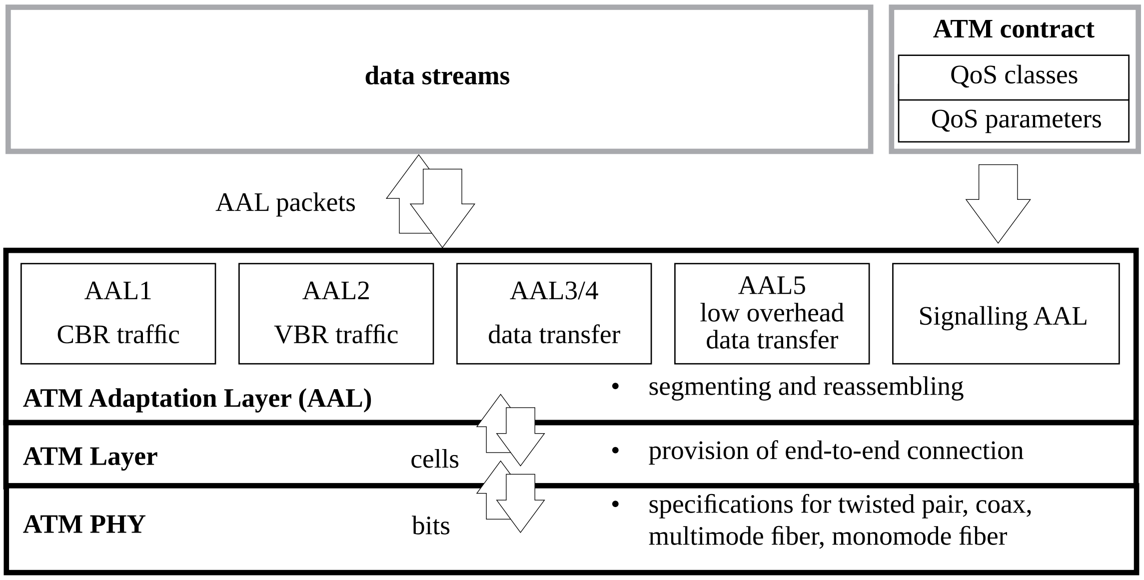

Figure 3 ATM protocol stack

The ATM system architecture consists of a media dependent physical layer, the ATM layer dealing with the mapping of cells to connections, and the ATM Adaptation Layers (AAL) which handle segmentation and reassembly of user packets. The different AALs and their service characteristics are shown in Fig. 3. Call control, multiparty operations and the negotiations of QoS parameters are handled by the ATM signalling. Signalling messages are exchanged between end system and network as well as between end systems via dedicated signalling VP/VCs. The implications of ATM's design concepts for wireless communications are discussed in section 4.

2.2 The need for Transport Protocol redesign

To conclude these introductory statements we give an example of the unexpected contradiction which may turn out between a "perfectly" working technology and its application in real-world environments: Some four years ago the World Wide Web (WWW) appeared out of the blue and helped the Internet to play the role which researchers had long since awarded to it. There were several reasons for this success: Firstly, the graphical user interface manages to combine different applications like file transfer and information systems under one common platform. Secondly, the setup of private information servers via the very basic and standardized Hyper-Text Markup Language (HTML) can now be done in a straight-forward fashion and without any knowledge about technological details. Thirdly, the underlying concept of a global (virtual) network structure which can be easily traversed via so-called Universal Resource Locators (URLs) helps users to quickly find their desired information and allowed a rapid commercialization of the Internet. What was once intended for network navigation soon emerged as the dominant distributed application for both the business and the private sector.

However, there is also another side of the coin: The HyperText Transport Protocol (HTTP), which is used to transmit web pages via TCP, opens one connection for each fragment of a document, like in-line images, video and audio files and text. Thus, a web page consisting of *n* (usu-

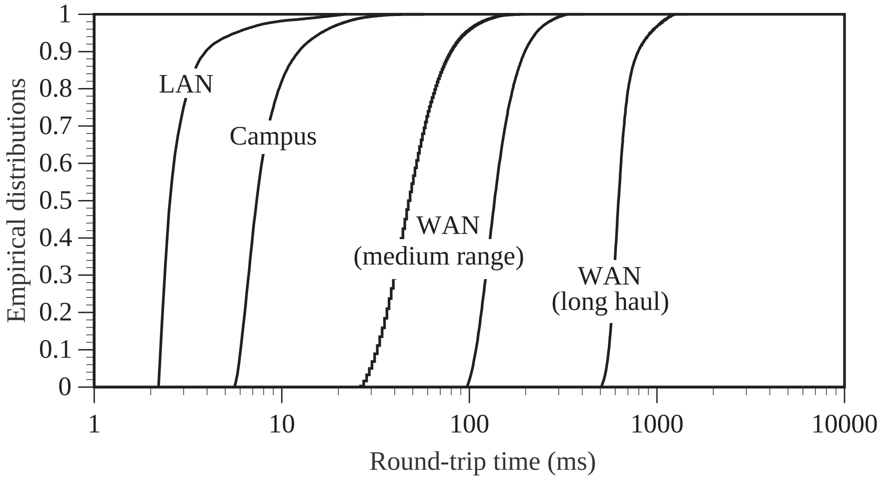

Figure 4 Measured Internet Delays

ally very short) fragments occupies *n* transport connections, all of which are only used for a few tens of milliseconds. Now, TCP as a reliable transport protocol must keep book about “recently” closed connections to be able to correctly interpret datagrams which are received too late. This is achieved by remaining in a “wait state” for four minutes (two times the maximum segment lifetime). Newly established connections must therefore choose a new pair of connection endpoint identifiers during this time. For servers with high visit rates this may cause severe problems due to table management overhead: For example, the AltaVista search engine with some 12 million accesses at a single weekday has to maintain on average 40000 new search requests in four minutes. As can be imagined, the introduced delays and packet delay jitters can be immense for such highly frequented information servers (Davids, 1994, Karabek, 1995a).

Another quite variable overhead on the duration of web transactions is imposed by the packet transmission delays variances and the unreliability of the underlying IP service. Fig. 4 gives an overview on measurements to representative Internet hosts (Fasbender, 1995b). As can be seen (note the logarithmic scale used for the x-axis), IP delays observe heavy-tail distributions, where means and variances sharply increase with the distance between source and destination. We could also show that the packet loss rates are in the order of between 0.5 percent for local area connections and up to 50 percent for wide-area communications.

Summing up, we note that the Internet protocol “suite” is totally unsuitable for transaction-oriented time-critical traffic, as soon as one leaves the local area. Of course, this is nothing new and can be experienced “in the field” every day. However, we think that there may be also some lessons to be learned from the above: OSI and TCP/IP based high speed data services can only be supported in geographically restricted areas or broadband islands. Consequently, the underlying protocol suites must be carefully (re-)designed and extensively tested against unexpected misbehavior, to provide applications with services which are best geared to their differing QoS requirements. Native ATM protocols replacing TCP/IP are a first necessary step in the right direction (Karabek, 1995b).

3 MOBILE COMPUTING

Wireless and mobile access to communication services is offered in various existing networks: For example, mobile networks according to the Global System for Mobile Communications (GSM) and the Digital Cellular System (DCS) standards (Mouly, 1992) and cordless telecommunications based on the Digital European Cordless Telecommunications (DECT) standard extend the services available for fixed telecommunication networks (e.g. ISDN services like speech and fax) for mobile and wireless users (Spaniol, 1995). In parallel, the emerging Wireless LAN standards and a number of proprietary products are primarily targeted at replacing the last meters of wiring to end-systems in highly-fluctuated office (data) networks or in environments where no cable-based installations are possible. However, for all of the above mentioned systems the service quality – for example in terms of available transmission capacities and bit error rates – is less than it is offered by fixed networks. Therefore, third generation mobile systems like the Universal Mobile Telecommunications System (UMTS) aim at an integration of different services offered by fixed, cordless and mobile (cellular and satellite) networks, improving speech quality and the variety of data services provided (Chia, 1992). UMTS will offer at least Narrowband ISDN (N-ISDN) basic services, while B-ISDN is considered for the backbone structure. Fig. 5 illustrates this evolution of wireless and mobile networks.

Future mobile data and multimedia applications will cover a vast field ranging from mobile extensions of today’s fixed applications (for nomadic and mobile computing) to future wireless office scenarios including wireless multimedia services. However, the demand for mobile data services will also arise from totally different fields of applications, like telematic services for Road Transport Informatics (RTI), e.g. advanced traveller and tourist information, or Teleaction services for palmtop computers allowing applications like Teleshopping and Telebanking to go mobile (see also Fig. 6). Clearly, existing mobile networks are not sufficient to realize the high bandwidth requirements for multimedia services and short response times, e.g. for interactive applications in wireless office environments (Spaniol, 1995) or for wireless access to the WWW

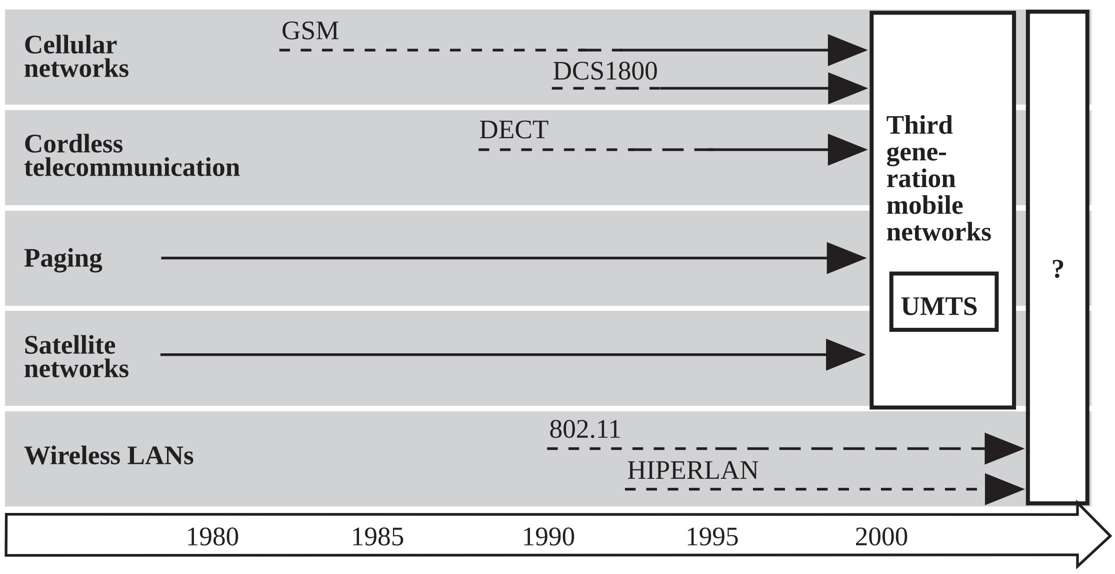

Figure 5 Evolution of Wireless Networks.

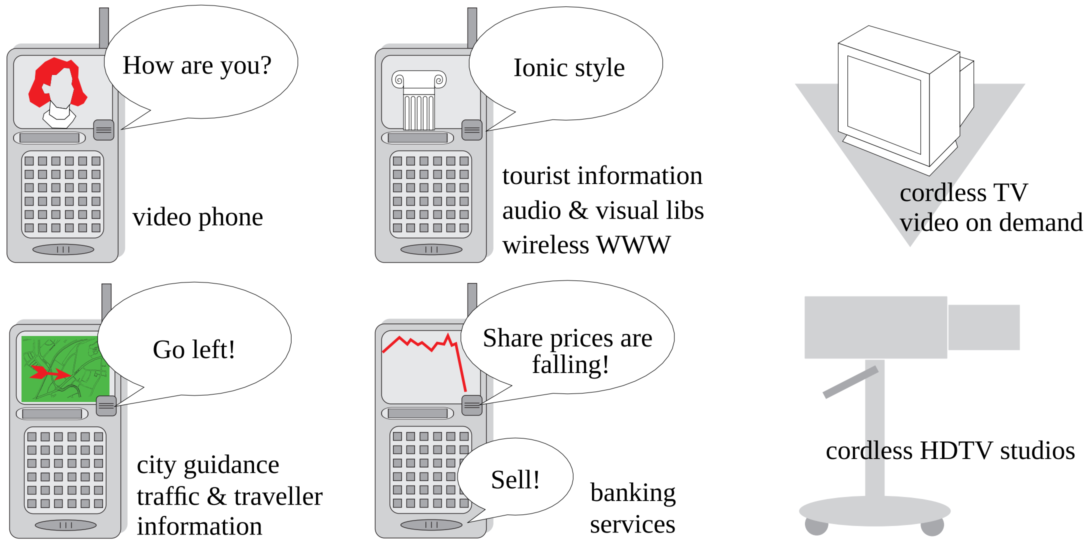

Figure 6 Examples of mobile and wireless multimedia applications.

(Kaashoek, 1994). This demand can only be met by directly accessing high performance networks such as ATM via a wireless link. In general, the access to high speed services is more and more required in local environments (Fernandes, 1995).

The requirement of terminal mobility (i.e. service availability in the whole coverage area and movement during service) leads to specific system architectures (Spaniol, 1995). Here we will only focus on the investigation of interworking aspects between ATM and wireless networks in a nomadic computing environment, and their consequences for end-to-end communication. With respect to the scope of our discussion we also abstract from the technical details of the radio access system of the wireless segment. Suitable air interfaces and protocols for medium access control, channel sharing and error control are currently under research and development, e.g. Fernandes (1995), IEEE 802.11 (1994), Phipps (1994). In general, we assume the existence of two types of communication (radio) channels: signalling and traffic channels. At least one of the signalling channels will be controlled in a random access fashion or by other distributed access mechanisms to enable a mobile station to initiate communications with the base station. Additionally, there are broadcast signalling channels used to inform mobile stations about network parameters and mobile terminated connection requests. A third type, point-to-point signalling channels are used to negotiate connection specific (QoS) parameter according to the ATM contract which have to be guaranteed by the base station for the assigned traffic channel(s). Thus, most of the radio resource allocation will be managed centrally.

Before we discuss different approaches for wireless ATM access we briefly motivate the conflict between the requirements to support high capacity services and terminal mobility. This can be illustrated by the following (simplified) considerations:

The maximum radius of a radio cell is given by

$$\text{radio cell radius} \quad = \quad sup\{d \mid snr(d) > const\}$$

Thus, the lower the signal to noise ratio *snr*, the smaller are the cells. The *snr* also depends on the received power $p_r(d)$ and on the bandwidth *b* with

$$snr(d) = \frac{p_r(d)}{\left(c_1 \cdot b + \sum p_i\right) \cdot c_2},$$

where $\sum p_i$ gives the interference power and c_1 and c_2 are constants.

In consequence, a high bandwidth reduces the *snr*. Neglecting fading effects due to shadowing and multipath propagation of signals, the received power is given by the transmission power p_t reduced by the free space propagation loss $(\lambda / (4\pi d))^2$ and by a frequency and distance dependent attenuation coefficient $\alpha(\lambda, d)$:

$$\overline{p_r}(d) = p_t \cdot \left(\frac{\lambda}{4\pi \cdot d}\right)^2 \cdot \alpha(\lambda, d) \cdot c_3,$$

where c_3 is a constant.

High bandwidth requirements can only be met by using e.g. frequencies in the 60 GHz range. Hence, an acceptable *snr* can only be achieved for short distances between transmitter and receiver resulting in (very) small cells of a few meters indoor and about 100 m outdoor. With decreasing size of radio cells the unrestricted support of terminal mobility yields an increasing signalling load due to handover and location update. Thus, the higher the bitrate the lower the mobility!

4 WIRELESS ATM ACCESS

As motivated in the previous sections, “ATM to the mobile desktop” seems just to be the next logical step in the development of integrated broadband communications. Unfortunately though, ATM has been developed based on two important presumptions: Firstly, the Virtual Path/Channel concept has been designed for the interconnection of fixed stations, and secondly, the ATM technology assumes an extremely reliable underlying transmission medium. Both assumptions are violated when integrating wireless networks with ATM technology: Users will demand uninterrupted service availability and guaranteed Quality-of-Service (QoS) even when they are “on the move”. Since connection redirection is not supported by the static VCI/VPI concept, extensive research is currently done in the area of handover control and location management, see Fasbender (1995a), Fernandes (1995). Furthermore, wireless access media are highly vulnerable to link disruptions and show a considerably higher overall bit error rate caused for example by multipath fading and hidden stations. Hence, leaving error control to the end systems leads to (unnecessary) additional traffic on the relatively reliable fixed network due to retransmissions for which only the wireless part of the network is responsible. Furthermore, the additional signalling requirements of mobile systems, in particular for mobility management, cannot be met by ATM’s UNI (User Network Interface).

The network structure we consider for studying schemes for wireless ATM access comprises Mobile Stations (MSs) and a wireless access network, where the base stations are responsible for the wireless links to the MSs on the one hand, and are connected to the wired ATM backbone on the other, as illustrated in Fig. 7. As mentioned above, the ATM architecture is designed based on the assumption of a reliable physical link with bit error rates between 10^{-8} and 10^{-12}. This link characteristic is no longer valid for radio transmission. Assuming that one cell of an

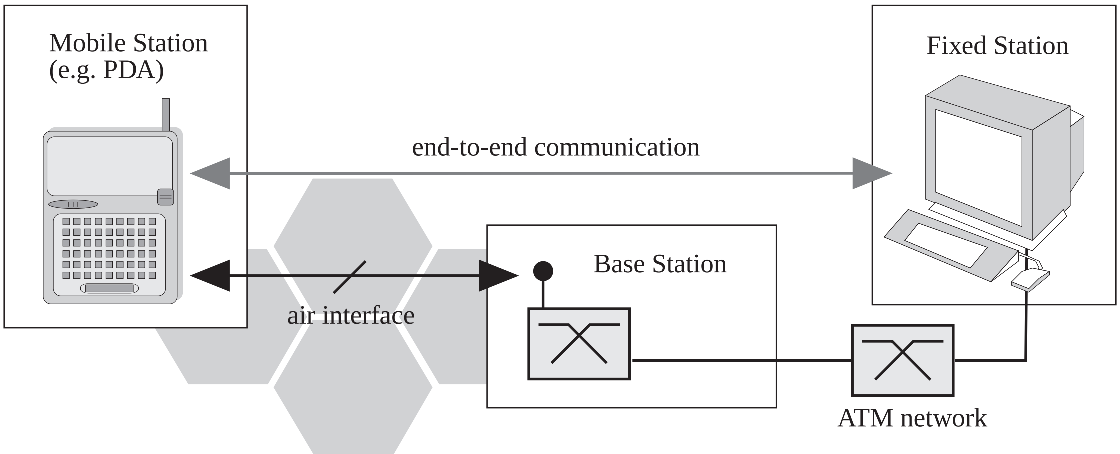

Figure 7 Assumed network structure.

AAL packet transmitted by the mobile is lost on the wireless link, ATM does not support a retransmission and the whole AAL packet is corrupted. However, ATM would still transmit all other cells of the packet across the network and would finally recognize that the packet is erroneous at the AAL peer entity, where the packet would be deleted. At last, the transport protocol would encounter a sequence error or a timeout and would initiate a retransmission. The result is a poor performance on the one hand, and additional load for the fixed ATM network by "trash cells" on the other (see also Fig. 8).

Thus, the interworking level between the ATM fixed network and its wireless extension becomes the crucial point. In general, interworking can be achieved on ATM layer or higher, depending on the desired level of ATM conformance on the wireless link. For example, Raychaudhuri (1994) adopted the cell-relay paradigm to the wireless interface as an "early architectural view" for future personal communication networks. The Mobile Broadband System (MBS) design philosophy (Fernandes, 1995) and the proposals for ATM-based wireless local area networks by Eng (1995) and Porter (1994) make use of encapsulating one or more ATM cells into wireless MAC frames and employing error control mechanisms at the air interface. With this approach a radio link specific cell format may be used (e.g. including sequence numbers), while the redundant transmission of ATM cell headers can be omitted. A variety of other, non-ATM-specific solutions achieve interworking at or above the transport layer, see Caceres (1995) and Yavatkar (1994). These approaches can of course be easily adopted to an ATM-based wired switching network.

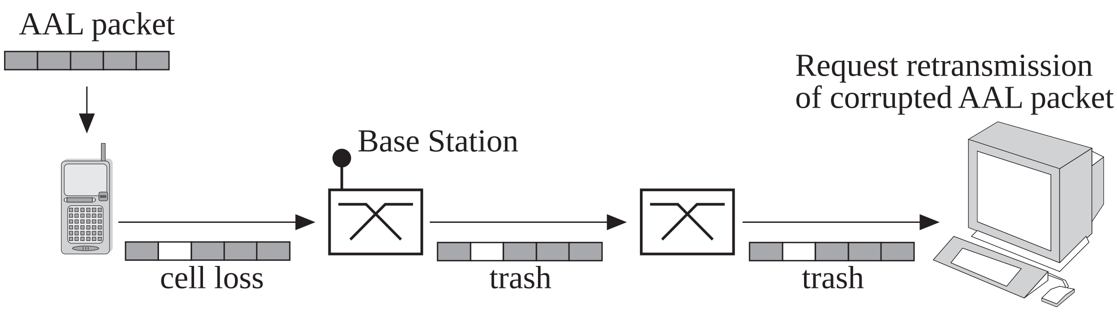

Figure 8 Problem of end-to-end communication in an wireless environment.

In the rest of this section we focus on performance issues of encapsulating one or more ATM cells into wireless MAC frames, and we introduce a solution “in-between”, where convergence between wired and wireless part of the network is attained at the AAL.

4.1 Interworking at ATM layer

A solution currently discussed in the literature is the introduction of a dedicated “wireless ATM layer” responsible for media access control (MAC) on the wireless link, encapsulating ATM cells on the air (see Eng, 1995, and Porter, 1994). The base station, which is basically an ATM switch, handles the interworking between mobile and fixed network at ATM layer (see Fig. 9) leaving the AAL unchanged. Thus the transmission of ATM headers on the wireless link can be avoided and the reliability of the wireless link can be increased by applying Forward Error Correction (FEC) mechanisms. This *link transparency* also allows cell based retransmissions on the last hop to the mobile station, which drastically reduces the amount of wasted bandwidth in the reliable backbone network. However, additional (but compared to the unnecessarily transmitted ATM headers much smaller) overhead for sequence numbers is introduced in this solution.

Based on a simple modelling approach the following results estimate the performance benefits of the ATM cell encapsulation solution. Typically, the model of a radio channel distinguishes between long term and short term fluctuations of the signal strength, resulting in different bit error states on the wireless link (e.g. ‘low BER’, ‘high BER’, ‘no connection’). Realizing that the sojourn times in error states of a wireless link are high compared to the cell transmission times (for a 155 Mbps ATM link some 380.000 cells may arrive at the base station in just one second), we assume stochastically independent bit errors at the air interface. The performance is evaluated for different bit error rates. ATM cells are encapsulated in MAC frames of size 1 and 10 cells, respectively, and we allow one retransmission per MAC frame.

Fig. 10 shows the results of the analysis for bit error rates of 10^{-4} and 10^{-8}, respectively. As expected it can be observed that the amount of erroneous AAL packets, and thus the percentage of end-to-end retransmissions at AAL level, can be drastically reduced by ARQ schemes. The percentage of additional traffic at the radio interface is in the order of the cell error rate, e.g. 4 per cent in the case of BER = 10^{-4} and only $4 \cdot 10^{-6}$ per cent at BER = 10^{-8}.

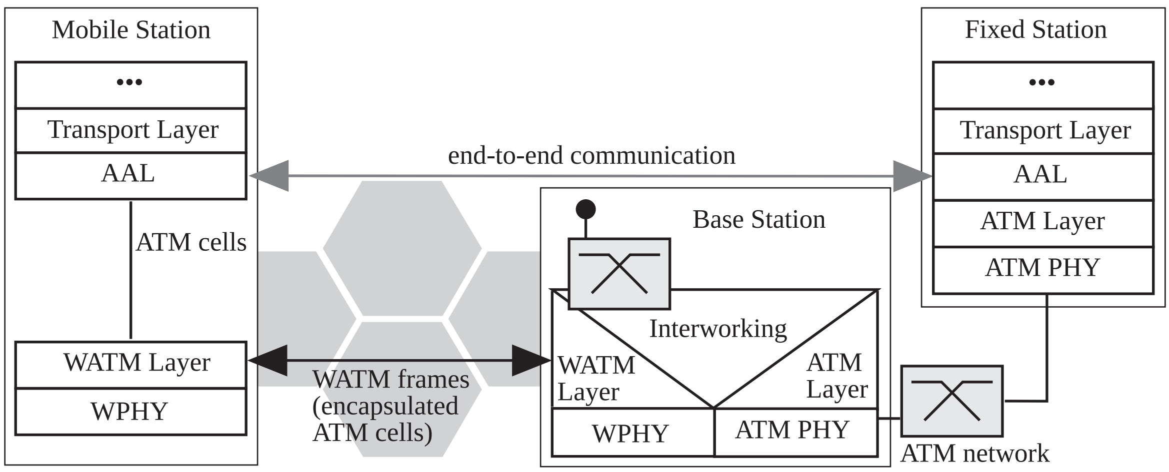

Figure 9 Interworking at ATM layer.

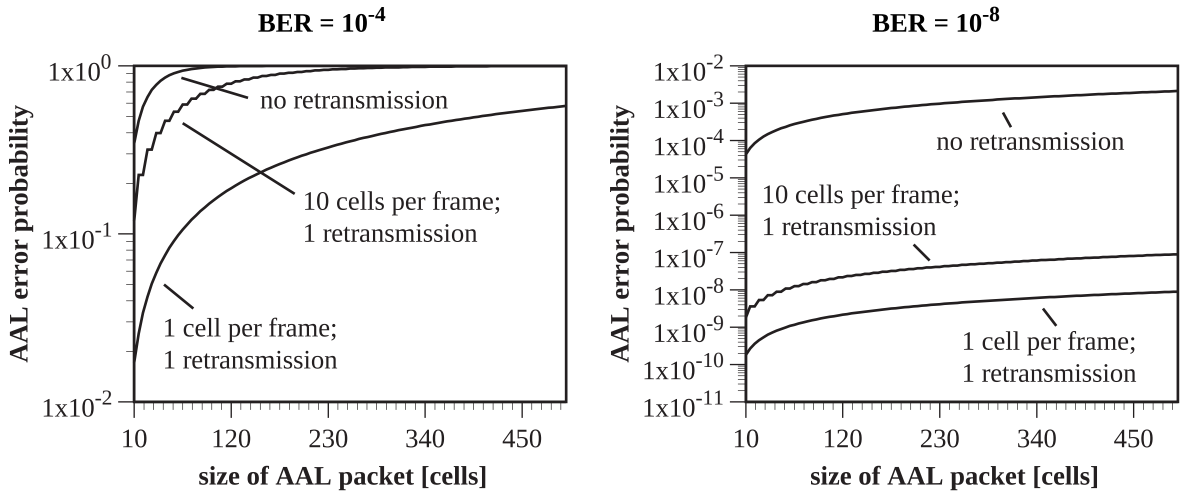

Figure 10 Performance of ATM encapsulation.

Nevertheless, the transmission of corrupted AAL5 packets to the end systems results in an unnecessary load at the transport layer. In addition, the real drawback seems to be that retransmissions are part of the connection's reserved bandwidth and therefore lead to a violation of the connection's traffic contract, yielding that the number of retransmissions has to be kept in a limited range, e.g. at most once per MAC frame.

4.2 Interworking at AAL

To reduce the load at transport layer, which is the main problem of the previously discussed approach, the basic idea is to include knowledge of the wireless medium at the AAL level by introducing a "wireless AAL" responsible for the transmission between mobile station and base station, as illustrated by Fig. 11. Interworking is done at AAL, resulting in a *service transparency* which solves the problem of forwarding corrupted AAL5 packets and enables the implementation of intelligent caching and filtering schemes at the interworking unit. Instead of AAL packets small, repeatable packets are (transparently) exchanged between mobile unit and base station. These small packets are temporarily stored in the base station for retransmission purposes, until the base station has successfully assembled a complete AAL packet which is then transmitted to the peer entity via the ATM infrastructure. This avoids the unnecessary transmission of corrupted ATM cells on the ATM fixed network and thus reduces the traffic load on the fixed network. The process of QoS negotiation is controlled by the base station's interworking unit, which has the role of a network agent of the mobile station and handles all AAL issues on its behalf.

In Fig. 12 the AAL interworking approach is evaluated against the encapsulation solution, again using the two bit error rate extremes and varying the number of possible cell retransmissions per AAL packet (for comparability reasons we assume that the frame size equals one ATM cell size, although a hybrid approach encapsulating two or more ATM cells in a MAC frame would further improve the AAL error probabilities). Since we allow only a fixed number of MAC frame retransmissions for each AAL frame, this solution performs slightly

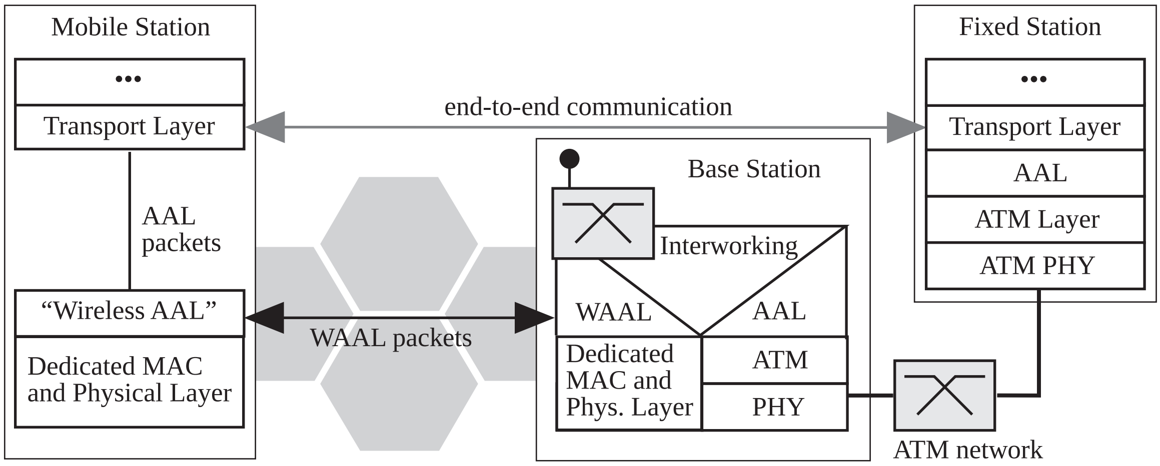

Figure 11 Interworking at ATM Adaptation Layer.

worse than ATM level interworking with an equal number of retransmissions per cell (compare Fig. 10 for the case of 1 retransmission). However, our approach leads to a much smaller additional overhead at the air interface. It should be noted that AAL error rates for the case of 10 retransmissions at a bit error rate of 10^{-8} vary between 10^{-19} and 10^{-17} and are therefore not included in the figure.

If the buffer of the base station fills up for incoming traffic (e.g., due to down times of the link) AAL packets will be lost. This will then again trigger the congestion and error control mechanisms of the Transport Protocol on an end-to-end level and, depending on the transport protocol, leads to sub-optimal end-to-end performance. Additionally, even occasional retransmissions lead to a slow build-up of buffered packets in the base station, since the channel capacity on both networks is equal and there is no notification scheme that would order the sender to temporarily reduce its transmission rate. This would only be feasible if interworking is done at transport layer (see for example Fasbender, 1996) leading to a solution where ATM is completely terminated at the base station.

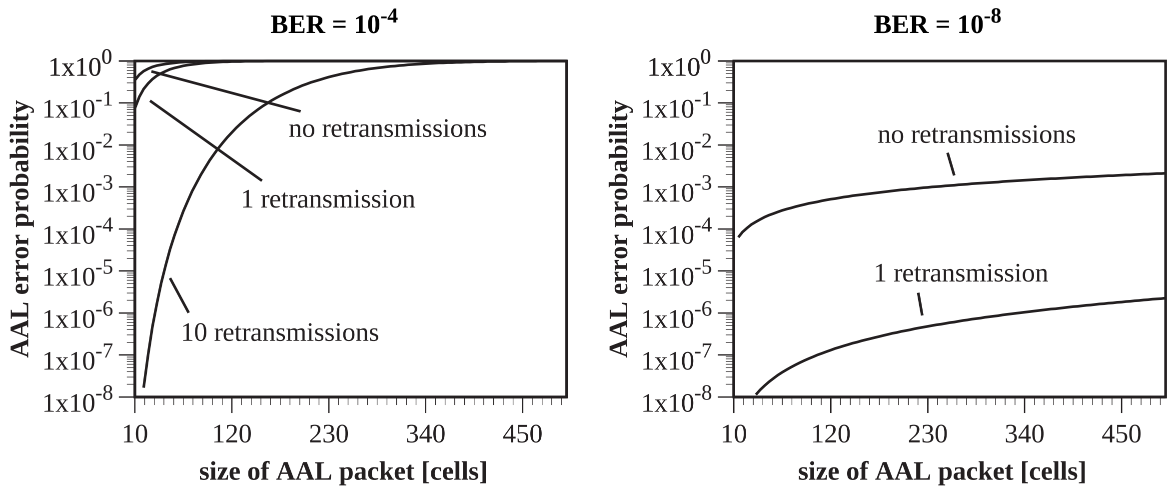

Figure 12 Performance of AAL interworking.

For some real-time applications such as audio and video there is no need to store packets in the base stations for retransmissions. The system will benefit from the approach of a WAAL layer even for real time traffic: If cells get destroyed, only these data elements (and not whole AAL frames) are lost for the receiver. In this scheme the lost data could be substituted by artificial data to ensure that the user still receives a "complete" AAL frame. Thus, loss tolerant applications can benefit from interworking at AAL by passing all correctly received cells within AAL frames to the applications instead of dropping complete frames in case of cell loss.

5 CONCLUSIONS

High speed connectivity with QoS guarantees and mobile communications have become the key technologies for the emerging information society. Integrating these technologies to offer mobile high speed connectivity seems to be the next step to be taken. The enormous market potential for the envisioned applications and services in mobile high speed networks provides a strong motivation for research and development efforts in this key area.

In this paper we have discussed major aspects of bridging the gap between wireless access and ATM networks. Architectures for wireless access to ATM depend on the desired level of conformance to the ATM reference model and therefore differ in the interworking scheme between wireless and fixed part of the network. It was shown that wireless ATM access can be provided on all layers of the ATM reference model. However, in addition to the differing technical complexity of the presented solutions, performance investigations indicate that ATM interworking should be placed on AAL level or higher. Especially these proxy approaches solve several problems of end-to-end communication via wireless links and enable disconnected operations, which will be an important feature to realize distributed systems with wireless components and in particular to introduce wireless office applications.

However, the technological limitations of wireless communications and the purely "fixed network" design philosophy of ATM lead to a variety of questions which are yet unanswered. Unrestricted terminal mobility with permanent access to high speed services will remain a vision if problems like different frequency allocation strategies between neighboring countries or handover management of ATM connections are not solved satisfactorily. It is likely that mobile broadband services can only be supported within locally restricted areas. And, even if future achievements in millimeterwave technology and protocol design will result in a steadily increasing bandwidth provision for mobile access to distributed environments, the question may be asked whether the solutions of tomorrow will suffice next years user demands.

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