Title: Wireless ATM Radio Access Layer Requirements

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Abstract: This contribution proposes a set of requirements for the Radio Access Layer of a Wireless ATM system. It is in response to the request for requirements made in [1]. These requirements are based on experience gained from a prototype wireless ATM LAN system.

1 Introduction

This contribution outlines the requirements for the PHY, MAC and DLC layers of a wireless ATM system. As such it does not attempt to specify any solutions. We believe that these requirements are achievable with current and near-term technology in low cost solutions.

At Olivetti Research, we have been engaged in research into wireless ATM systems for a number of years and have developed a prototype wireless ATM in-building LAN [2]. This system is based around a large number of low-cost base stations which provide a wireless ‘drop cable’ to mobiles. It operates at 2.45GHz in the unlicensed ISM band and using QPSK modulation provides a 10Mbit/s raw data rate per transmission cell. A reservation based TDMA protocol is used for media access while co-channel interference is avoided using frequency colouring of adjacent cells. The end systems see a standard ATM link and multimedia applications involving multiple audio and video streams are commonly used. We draw on experience from the design, development and testing of this prototype in proposing the following requirements.

As described in more detail in [3], we envisage a number of distinct service scenarios for wireless ATM. Specific scenarios addressed are the provision of ‘in-building’ wireless ATM access to mobile devices in a workplace or residential environment and the provision of a wireless ATM ‘last hop’ from public ATM services to buildings.

2 Physical Layer Requirements

2.1 Frequency Bands

It is important when specifying requirements for a PHY to target appropriate available frequency bands. A variety of factors including the cost, characteristics and prevailing etiquette need consideration when choosing frequency bands.

For the in-building scenario a frequency band which provides reasonable penetration through walls and surrounding objects is required to give good overall coverage to mobiles. This precludes the use of higher frequency bands above, say, 10GHz which tend to be more highly attenuated by walls and partitions. In Europe, the 5GHz band is under the control of the ETSI RES10 committee who are specifying the HIPERLAN standards and it is proposed that Type II HIPERLAN will provide 20Mb/s+ wireless ATM access in this band [4]. In the US, the FCC has issued a Notice of Proposed Rule Making for the 5GHz NII/SUPERNet [5] band to which the ATM Forum has responded in a positive and pro-active way. It would therefore appear prudent to consider the use of the 5GHz band for unlicensed, in-building wireless ATM access.

For the wireless last hop scenario, it is considered that near line-of-sight connectivity will be available and that trunk data rates will be required. These data rates will potentially need a much larger bandwidth and suggest the use of higher frequency bands. A possible choice is the 59-64GHz (aka 60GHz) band allocated by the FCC for unlicensed use and which is currently under consideration by the Millimeter Wave Communications Working Group [6].

2.2 Data Rates

The in-building scenario aims to provide wireless ATM connectivity to mobile devices including network computers, displays, cameras and web terminals as well as to relatively static devices such as HDTVs, speakers, hi-fi equipment etc. These devices will, for the large part, be consumer electronics and will require low-cost network interfaces. Their required data rates will be dependent on the application but will, in general, match the data rates currently proposed for ATM end systems in the workplace and in the home. High data rates are less essential for mobile devices with more limited power and processing budgets.

The ATM Forum has approved 25Mbit/s as a standard PHY data rate for low cost ATM solutions. Interfaces providing this data rate are becoming available for the desktop and are also being proposed in the Residential Broadband (RBB) group [7] for home distribution. We consider that a shared data rate of 25Mbit/s per base station is sufficient for most applications and is achievable with current and near-term technology; larger aggregate system throughputs can be provided with the addition of more base stations.

The last hop scenario will enable bridging between home or local area networks and the public ATM networks and therefore needs to provide higher data rates to the end systems. In this scenario, the end systems are not mobile and therefore don't have power budget restrictions. Furthermore, careful installation can mitigate the limiting effects of multipath on the data rate. With a proposed bandwidth of 5GHz in the 60GHz band, we consider that a shared data rate of 155Mbit/s per base station is achievable.

2.3 Error Rates

ATM technology has been designed to run over fiber-optic connections with bit-error rates (BERs) of 10^{-9} and less. Typically an indoor radio environment exhibits BERs of up to 10^{-3}. There is, therefore, a requirement to utilise techniques at the PHY, MAC and DLC layers which mitigate these BER conditions. In an indoor fading environment bit errors can be very bursty. This reduces the effectiveness of Forward

Error Correction (FEC) when used in isolation. Techniques such as antenna diversity and equalisation may be used to reduce the effects of multipath. However, we consider that even with these PHY methods, BERs will still be too high to support a tolerable cell loss ratio (CLR) for standard adaptation layers and that procedures are needed throughout the radio access layer to counter this problem.

2.4 Range and Transmission Power

Coverage will be provided in the in-building scenario by a number of base stations, where each transmission cell provides connectivity to a reasonably small number of devices, many of which will be mobile. Increasing the number of non-interfering base stations has the advantages of improving the overall continuity of coverage and providing a higher aggregate system throughput. A range of 20-30 metres will provide coverage to a physical area the size of a house or a small number of offices. In larger areas, this range strikes a balance between the density of mobiles and the rate of handovers which will occur for mobiles moving at walking pace. In our wireless ATM prototype, a transmission power of approximately 10mW gives a range of up to 15 metres. We suggest that, in general, a transmission power of less than 100mW is required to cover this range.

Coverage will be provided to a number of buildings in the last hop scenario by a single base station. The range required will depend on the density of buildings being covered but will typically be 100-300 metres. In this scenario, both end systems are not mobile so the setup can be carefully configured with the use of directional antennas. This reduces the necessary transmission power and allows for an improved spatial reuse of frequency. At 60GHz, commercial technology exists which using highly directional antennas, gives a kilometre range with a transmission power of tens of mWs. We therefore suggest that a transmission power of less than 100mW is required to cover this range.

2.5 Modulation Efficiency

At all frequencies, radio bandwidth is a scarce resource and as the frequency decreases so does the available bandwidth. It is therefore important, especially at 5GHz, to utilise an efficient modulation technique. Bps/Hz is a common measure of modulation efficiency but it is more useful to talk about Bps/Hz/Unit Volume. This gives a much better measure of the frequency efficiency as it takes into account the spatial reuse of frequencies between adjacent cells. Simply increasing the Bps/Hz requires a higher C/I ratio and also increases the complexity of the receiver. Trade offs are required to balance the cost and complexity of receivers and the spatial reuse of frequency against the efficiency in Bps/Hz of the modulation scheme.

2.6 Channelisation

To allow users of the frequency band to coexist in an efficient manner both within a transmission cell and between cells, some form of channelisation is required using TDMA, FDMA or CDMA. At the data rates under consideration CDMA would require an impractical amount of bandwidth for an adequate processing gain and is therefore deemed unsuitable for either purpose.

We do not believe that TDMA is suitable for inter-cell channelisation because at the proposed data rates it would require symbol processing rates which would unnecessarily impact the multipath performance. Furthermore, TDMA would require a close synchronisation between base stations increasing the overall system complexity. Hence we suggest that FDMA is used for inter-cell channelisation since it is a practical solution which doesn’t impact the radio interface and obviates the need for fine-grain coordination cooperation between base stations thereby simplifying the overall system architecture.

Within a cell we suggest that TDMA is used as it allows for the flexible and dynamic allocation of bandwidth both between upstream and downstream and between users, a solution that most closely matches the anticipated traffic characteristics.

2.7 Turnaround Time

Turnaround time in an RF interface is the time between the end of a transmission and the start of a reception. As the turnaround time has a physical lower bound relatively independent of the data rate, it is important, especially at higher data rates, to minimise this overhead. Some of this overhead can be mitigated in the design of the MAC protocol and from experimentation, we believe that a channel utilisation of 60-70% is a reasonable target. To achieve this the turnaround time in a 25Mbps system should be less than 5µs given a multi-cell framing structure.

3 Medium Access Control Requirements

Unlike switched ATM systems, a wireless ATM system needs to have some method for mediating access to the shared channel. The access control needs to provide a fair and efficient method for a frequently changing population of mobiles to gain upstream access to the channel. The requirements in a wireless ATM system are very stringent as the MAC protocol has to provide guarantees for both isochronous and asynchronous traffic types in the face of an unreliable channel. Some of these issues are being addressed in the RBB group [7] in the context of shared cable access. This MAC protocol, however, also has to facilitate efficient handover between base stations for mobile end systems. There is necessarily overhead introduced by the MAC protocol to control access to the channel and this should be minimised to maximise the channel efficiency.

3.1 Access Point or Ad-hoc

There are two fundamental approaches to wireless networking topologies: ad-hoc and access point. We consider that the primary advantage of wireless ATM will be to give wireless devices access to wired ATM services in the local and wide areas. For example, most home consumer devices will be receiving data from service providers in the wide area. This type of service can only be provided through a device connected to the wired network and therefore implies the use of an access point based network.

In an ad-hoc topology network without central control, it will be very difficult to give any QoS guarantees to connections as users will interact with one another in an uncontrolled and unpredictable manner Designing a wireless ATM system to support such an ad-hoc topology will necessarily introduce large overheads in the system which will impact the real time performance of the network. Designing the system for an access point approach has the advantages of providing a much higher bandwidth utilisation, allowing the system to manage and control the QoS of connections and giving wireless devices access to the wired ATM infrastructure. We consider that for wireless ATM systems, a centrally controlled access point based architecture is required and, where necessary, there can be some limited support for an ad-hoc style which provides no QoS guarantees and incurs significant overhead.

3.2 Quality of Service

One of the primary advantages of ATM is its ability to give QoS guarantees to connections. we believe that a true wireless ATM system and specifically its MAC protocol needs to support all the Traffic Management service categories [8]. Currently these service categories are CBR, rt-VBR, nrt-VBR, UBR and ABR. Depending on the service category and the parameters chosen, different error control techniques may need to be employed in order to maintain the traffic contract. As mobile devices move between base stations, some QoS renegotiation may be required to maintain levels of service to the connections entering and already using the cell. In an indoor fading environment, however, it may not always be possible to make and maintain concrete guarantees and new QoS paradigms may be required.

3.3 Framing Structure

From our experience, the majority of the traffic load in a LAN environment is generated by bursty variable rate sources; this is especially true in many multimedia environments. Furthermore, the distribution of traffic between the upstream and downstream directions may often be highly asymmetric and this distribution can change rapidly over time. To minimise the latency and jitter of time-bounded traffic sources and to maximise the utilisation of the channel, the MAC needs to allocate the available bandwidth in a flexible and dynamic manner.

A number of applications and endpoints will require support for single cell traffic. Some MAC protocols attempt to combine these cells into multi-cell packets for efficiency but we consider that to minimise latency and jitter, the MAC protocol needs to support the transmission of single cells. In some scenarios, it is conceivable that there will be a large number of sources, each transmitting single-cell CBR traffic. This type of traffic should also be efficiently handled by the MAC protocol.

3.4 Addressing

To enable registration and identification procedures, a mechanism for uniquely identifying mobiles to the wired infrastructure is required. An obvious solution is to employ a globally unique MAC address such as a 48-bit IEEE MAC address as currently used in Ethernet interfaces. This address could be used as the End System Indicator in private ATM addresses. Once registered, a mobile need not be distinguished by this MAC address but would use a much shorter identifier which has only local significance.

3.5 Power Saving

Many wireless ATM devices will be portable battery powered devices with limited power budgets. It is, therefore, important to consider power saving techniques in all the radio access protocol layers. For these devices the ability to power down during periods of inactivity and while waiting for predetermined events (e.g. the next CBR cell) will be very important. There is therefore a requirement that control techniques for power conservation are incorporated into the MAC protocol.

Conventional approaches to traffic shaping tend to spread out bursts of cells. However, in a mobile environment this may not be suitable for both power saving and MAC efficiency reasons. A mobile may wish to sleep between bursts to conserve power and hence it may be appropriate to shape traffic into bursts. Furthermore, MAC protocols are generally more efficient if cells are transmitted contiguously. New approaches to traffic shaping which afford these advantages are required.

4 Data Link Control Requirements

To attain cell loss rates approaching those of wired ATM, the reliability of the radio channel needs to be increased using link level error control procedures. The choice and use of these error control procedures will be strongly determined by the traffic service category and parameters of the individual connection. The data link layer therefore requires access to QoS information pertaining to each connection and will need to maintain per-connection state. This will require a tight coupling of the DLC and MAC layers.

Techniques to recover from bit errors include the use of FEC and the use of a CRC in combination with an Automatic Repeat Request (ARQ). As previously discussed the effectiveness of FEC is reduced in an indoor fading environment. An ARQ approach, however, needs careful design so that repeats do not violate the traffic contract of a connection. This is especially true in the case of the CDV of real time CBR or rt-VBR connections. We consider, though, that even for real time connections, the use of ARQ can significantly curtail the cell loss rate whilst maintaining the QoS of these connections. For example, at 25Mbit/s 2 ms corresponds to 100 cell times which offers considerable scope for repetitions.

To support a per-cell ARQ, we believe that the MAC layer should present a cell-based interface to the DLC layer.

5 Portability Considerations

Many devices utilising a wireless ATM interface will be portable computers. This type of device will require a PCMCIA-type implementation. The cost, form factor and power consumption of this interface should be appropriate for a low cost solution for portable endpoints with limited power budgets. While not requirements in themselves, these goals may influence many of the decisions affecting the PHY, MAC and DLC designs.

6 Specific PHY Requirements

	In-Building	**Last Hop**
Frequency Band	5GHz HIPERLAN/NII/SUPERNet	60GHz
Data Rate	25Mb/s per cell	155Mb/s per cell
Range	< 30 metres	< 300 metres
Number of Users (avg.)	< 10	< 50
Number of Users (max.)	< 100	< 100
Transmission Power	< 100mW	< 100mW
Target BER	10^{-4}	10^{-6}
Turnaround Time	< 5μs	< 5 μs
Handover Support	Yes	No
Portability	Yes	No

7 Conclusions

In this contribution, we have outlined the issues affecting the choice of requirements for the radio access layers of the main service scenarios. Drawing from our experience of designing and building a prototype in-building wireless ATM LAN, we have proposed a number of requirements for the PHY, MAC and DLC layers of both an in-building and last-hop wireless ATM system.

8 References

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