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Faculty of Engineering

Department of Electrical and Electronics Engineering

WIRELESS ASYNCHRONOUS TRANSFER MODE

Graduation Project
EE- 400

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ABSTRACT

Wireless Asynchronous Transfer Mode (WATM) networks pose new traffic management problems. Wireless ATM is expected to provide seamless connection between mobile terminal and wired ATM so that any future application requiring any Quality of service (QoS) is supported. At present the wireless Network is efficient enough to provide data service to mobile users. The inherent characteristics of ATM like the availability of abundant bandwidth and provision of the Quality of Service guarantees are applied in the wireless media, which gives rise to the Wireless ATM. Wireless ATM in terms of a number of complementary architectures. They provide an efficient way to structure the complex problem of defining a modern telecommunication network, into a set of more manageable sub problems the user view of wireless ATM is captured in a service architecture based on the corresponding fixed ATM models. The integrated service architecture allows seamless communication between the mobile users and fixed ATM services and users.

A network operator view is reflected in a network architecture that allows operators to extend, in a modular way, fixed ATM networks to also support mobile users.

INTRODUCTION

In this project WATM, is studied with intensive care. Wireless ATM will be viewed as a mandatory access technology to broadband networks in order to provide users with truly integrated services. The project viewed by identifying relevant system requirements for wireless ATM .The project comprises of four chapters

Chapter 1 this section briefly reviews traffic management in Asynchronous Transfer Mode (ATM) networks. Since ATM networks are connection-oriented, a connection-setup phase occurs before the flow of user-data begins. During connection-setup, the user may signal various Quality of Service (QoS) parameters and traffic characteristics to the network via the User-Network Interface (UNI) protocol. For end-to-end transmission,

Chapter 2gives the basic concepts of WATM .Its basic parameters are discussesed, moreover its services and sub-system design in order to get the complete knowledge of WATM.

Chapter 3 gives an over-view of Architecture of WATM such as prevalent architecture, swan Architecture, Wamis Architecture, Radio architecture, Enhance fixed architecture, Relevant Wireless Architecture are discuss. In detail

Chapter 4 covers the WATM networks architecture, WATM protocols, switching techniques and WATM Handover on Wireless ATM (WATM) networks. These technologies will support various multimedia applications. WATM is expected to provide significantly high bit-rate services to meet the demand for handling multimedia information, such as teleconferences, moving pictures, and large files. Furthermore, WATM is required to provide a variety of services like CBR, VBR, ABR, and UBR and flexible connection.

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1. OVERVIEW OF ATM

1.1 Background of ATM

ATM has been advocated as an important technology for the wide area interconnection of heterogeneous networks. In ATM networks, the data is divided into small, fixed length units called cells. The cell is 53 bytes. Each cell contains a 5 byte header; this header contains the identification, control priority, and routing information. The other 48 bytes are the actual data. ATM does not provide any error detection operations on the user payload, inside the cell, and also offers no retransmission services.

1.2 Introduction

The Broadband Integrated Services Digital Network (BISDN) supports digital transmission at rates greater than 1.544 Mbps. This service includes the transfer of voice, video, and data through public and private networks. Asynchronous Transfer Mode (ATM) is being developed as one of the techniques that will enable the BISDN to transport this wide variety of services. ATM standards are evolving under the guidance of the International Telecommunications Union- Telecommunications Standards Sector (ITU-T). These standards are being developed to enable services requiring large bandwidths such as distributed supercomputing and telemedicine and services requiring a smaller bandwidth such as voice to operate in a cost effective manner on the same network. The standards also define the protocols required to interface other network services such as Switched Multi mega bit Data Services (SMDS). ATM standards are written in such a way that services that are in use today and new services that are under development can use the same network. ATM combines circuit switch routing of public telephone networks, packet switching of private data networks, and the asynchronous multiplexing of a packet switch. It is a cell switching and multiplexing technique that supports switching in public and private networks.

Constant transmission delay and guaranteed capacity, two benefits of circuit switching, are combined with the flexibility and efficiency of handling intermittent packet type data.2 ATM is connection-oriented and converts all incoming data into a 53 byte cell. The cell consists of a five.

1.3 ATM Connection Types

There are two types of connections available at this time with ATM, point-to-point and point to-multipoint. Point-to-point connections can be unidirectional or bidirectional. Point-to-multipoint can be unidirectional only. Multipoint-to-multipoint is not available yet. There is no method for a receiver to identify the cells from individual sources since the cells would be interleaved from multiple sources. This prohibits proper reassembly of the cells into the proper data frames at the receiver.

1.4 ATM Multiplexing

ATM uses asynchronous multiplexing instead of synchronous. In synchronous time division multiplexing (TDM) users are pre-assigned to time slots. In ATM time slots are assigned only when a user has data to send. TDM is inefficient in relation to ATM in two respects. In TDM an idle code is transmitted in a time slot in which there is no user traffic. In ATM idle codes are not required when there is no user data to send. ATM does, however, use idle cells to adapt the rate of the ATM cells to the physical transmission medium. The idle cells are discarded at the receiver and are not processed in the same manner as user data. This is more efficient than synchronous TDM since in that method idle time slots are sent and processed as user data. ATM transport is an advantage for the user since he pays only for the cells he sends and not for a dedicated channel he may not fully utilize. Also, in synchronous TDM if a user has a lot of data to send he must wait until his time slot arrives even if all of the other timeslots are empty. With ATM a user sends data when he needs to send. This is certainly more efficient and is an advantage for the network provider since the network is used to process and transport data instead of idle codes.

1.5 ATM Quality of Service

One important concept developed in ATM is quality of service (QOS). When an end station connects to the ATM network it establishes its requirements for the quality of the connection. These requirements are known as QOS parameters and include the required bandwidth, average sustained bandwidth, and burst size.3 ATM devices must adhere to these requirements and they do so by various methods. Switches may use queues to prevent data bursts, limit the peak data rate, and smooth jitter. Congestion may be controlled by routing cells through less congested nodes or switches or by discarding cells if the user agrees. The discard agreement is negotiated when the service application is made.

1.6 ATM Virtual Circuits and Paths

ATM also uses virtual circuits and paths (VC's and VP's) extensively. A VC is a bidirectional logical connection between the ends of a communication connection. A VP is a bidirectional logical grouping of VC's that have the same destination. The VC's and VP's are used to transport cells from one ATM entity to the next. Their use will be explained later.

1.7 ATM Cell Structure

Each ATM cell is 53 bytes in length. The first five bytes form the cell header while the last 48 bytes carry user or control data. The information in the cell header is used to establish connections and route cells. The cell header uses one of the two formats defined by the ITU-T. The formats are the User-Network Interface (UNI) and the Network-Node Interface (NNI). The UNI defines the interface between the user and the network while the NNI defines the interface between ATM networks and ATM nodes. In the UNI header format there are six fields that form a five byte header. They are as follows:

1) Generic Flow Control (GFC)- This field is four bits in length and provides local functions such as identifying multiple stations that share the same ATM interface. It provides flow control at the UNI for traffic originating at the user and directed

1) flow.

2) Virtual Path Identifier (VPI)- This field is eight bits in length and is used with the next field to identify the next destination of the cell as it is routed through the ATM network. This yields 256 (28 = 256) possible VP's.

3) Virtual Circuit Identifier (VCI)- This field is 16 bits in length and it also identifies the next destination of the cell as it progresses through the network. This provides 65,536 (216 = 65,536) possible VC's.

4) Payload Type (PT)- This field is three bits in length. The first bit indicates whether a cell has user data or ATM control data. If bit one is set to 1 the cell contains ATM control data that will be used for management functions. If bit one is set to 0 the cell contains user data. When bit one is set to 0 bit two is used to indicate congestion. A congested switch will set bit two to 1 to inform an end node that it is congested.5 The third bit is used in some applications to indicate if this is the last cell in a user frame.

5) Congestion Loss Priority (CLP)- This field is one bit in length and indicates if a cell can be discarded if it encounters extreme congestion in the network. The value of this bit depends on the QOS parameters requested by the user when the service is requested. If the CLP bit is set to 1 the cell may be discarded during congestion. Cells with the CLP bit set to 0 have higher priority and are not discarded if possible.6 Cells in an application such as video coding may be dropped without degrading the video quality. Also, this bit could be set for those user cells transmitted in excess of the negotiated rate.7

6) Header Error Control (HEC)- This field is eight bits in length and uses the polynomial x8 + x2 + x + 1 to perform a cyclic redundancy check (CRC).8
The polynomial is only applied to the first four bytes of the header. The contents of this field are the resulting eight bit CRC.

The NNI header is the same as the UNI header except that there is no GFC field. GFC is only used for traffic originating at a user and transmitted toward the network. It is not required at the NNI. Instead those four bits are added to the VPI field for a total of 12 bits. This increases the number of VP's from 256 to 4,096 (212 = 4,096).

1.8 BISDN Protocol Reference Model

A Protocol Reference Model (PRM) has been defined for BISDN for ATM. The model has three layers that are similar to the first three layers of the Open Systems Interconnection (OSI) Reference Model. The physical layer of BISDN is roughly equivalent to OSI layer one and performs bit level functions such as timing for those services that require timing.9 The ATM layer is similar to the lower edge of OSI layer two. It generates the cell header. The ATM Adaptation Layer (AAL) is similar to the upper edge of layer 2 and layer three of the OSI Reference Model. It adapts various services to ATM cells. Above the AAL there are higher layer protocols representing the traditional transports and applications of the OSI Reference Model.10 The AAL also provides service dependent functions to those upper layers of the OSI Reference Model. The BISDN PRM also uses three planes. The three planes are user, control, and management. The user plane provides for user information to flow along with its associated control fields for flow control and error recovery. The control plane includes all connection control functions such as signaling functions required for connection setup, supervision, and release. The management plane provides both layer and plane management functions. The layer management function performs layer specific management functions while plane management coordinates the functions of the entire system.11 See Figure 1.1 for a model of the layers and planes in the BISDN PRM.

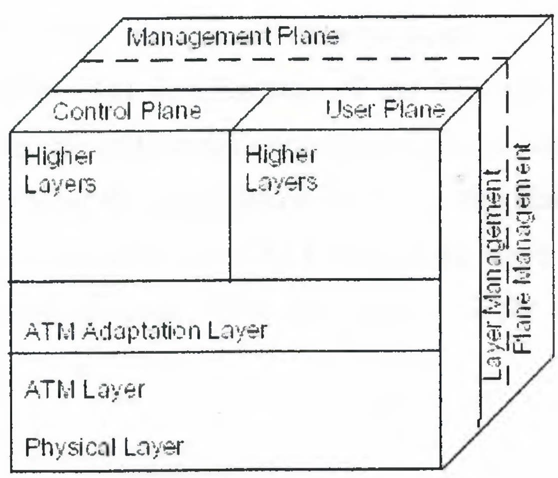

Figure 1.1 BISDN protocol reference model

1.8.1 Physical Layer

The physical layer contains two sub layers, the Physical Medium (PM) and Transmission Convergence (TC) sub layers, and is common to all services. ATM can be transported using fiber, coaxial cable, or twisted pair. The PM sub layer provides the bit transmission functions including bit alignment and timing, line coding, and electrical/optical conversion.12 The physical connection to the transmission medium is handled at this sub layer. The TC sub layer has five functions. The first is generation and recovery of the transmission frame. This function places cells in the proper format for the physical medium in use. The second function is to adapt the received data to the ATM cell flow. When receiving data from the user this transmission frame adaptation function adapts the received payload to the ATM cell structure. When transmitting data toward the user, this function removes the ATM cell structure. The third function is the cell delineation function which enables the ATM receiver to recover cell boundaries. The fourth function is header error control. This is where the eight bit CRC is formed and placed in the HEC field of the cell header in the transmit direction. At the receiver the error control code is generated again on the first four bytes of the cell header and compared to the CRC value that was received in the HEC field. If the value matches, processing continues. If not, the cell is discarded. This prevents cells from reaching incorrect destinations if there are errors in the VCI or VPI fields. This reduces requests for retransmission, helps to control congestion, and ensures high speed data transport.13 If cells are discarded or there are errors the ATM node or switch does not request retransmission. The application must initiate the retransmission request .The last function of the TC sub layer is cell rate decoupling. This function inserts idle cells in the transmit direction to adapt the rate of the ATM cells to the payload capacity of the transmission system. It also discards idle cells in the receive direction. As stated in Section 2.0 ATM Multiplexing these idle cells are not dependent on user data as in synchronous TDM. See Figure 1.2 for a diagram of the Physical Layer.

1.8.2 ATM Layer

The ATM layer is also common to all services. It handles the functions of the cell header independent of the type of user data or physical media. This maintains flexibility in the ATM layer. With the exception of the HEC value the ATM layer generates and extracts the cell header in the transmit and receive directions respectively. The HEC value is obtained from the TC sub layer of the physical layer and is placed in the cell header at this layer.14 The ATM layer also multiplexes cells from individual VC's and VP's and different types of physical media into one cell stream in the transmit direction. In the receive direction, the cell stream is divided into individual cell flows with respect to the VC's or VP's of the cells. Since this layer is independent of the physical transport media cells from various types of services and media can be combined into one cell stream for transmission. They can be recovered and placed in their respective formats at the receiver. Each entity that is part of or accesses an ATM network has some type of address. The address may be an ATM address or an address that is used in the application such as a Media Access Control (MAC) address used in the Institute of Electrical and Electronics Engineers (IEEE) 802 Local Area Network (LAN) specification.15 At an ATM node or switch the ATM layer obtains the address or Service Access Point (SAP) identifiers from the next layer, the AAL, and translates them into VCI's and VPI's. At the ATM layer the VCI's and VPI's are used to determine the next destination of the cell. When the destination is determined the VCI and VPI values are changed before the cell is transmitted to the next node or switch. GFC is another function of the ATM layer. As explained in Section 5.0 ATM Cell Structure it supports control of ATM traffic flow in a customer network. The information is contained in the GFC field of the cell header. See Figure 1.2 for a diagram of the ATM Layer.

1.8.3 AAL Layer

Since the various BISDN applications do not require the same functions, the applications are placed in categories of service classes and the third layer of the PRM, the AAL, handles the functions of the various services. This layer provides the link between the various applications and ATM functions. The AAL supports the higher layer functions of the user and control planes. It translates between larger service data units (SDU's) of the upper layer processes and ATM cells through two sub layers, the Segmentation and Reassembly (SAR) sub layer and Convergence Sub layer (CS). The SAR receives cells from the upper layer protocols (NetWare, AppleTalk, or Internet Protocol for example) and breaks them into 48 byte segments to form the payload of the ATM cell.16 At the receiver this sub layer reassembles the contents of the cells into data units to be delivered to the higher layer protocols.17 The CS is for message identification and clock recovery for those services that require it. There are four different AAL classes, defined for different services.18 Class A is for constant bit rate, connection-oriented services that require timing. Voice is an example. Class B is for variable bit rate, connection-oriented services that require timing. Video is an example. Class C is for variable bit rate, connection-oriented services that do not require timing. X.25 is an example. Class D is for variable bit rate, connectionless services that do not require timing. LAN interconnection is an example.19 Although ATM is connection-oriented, connectionless applications are not excluded from using ATM for transport. The higher layers determine the connection orientation for each application. Four AAL types support the four classes. AAL1 and 2 correspond to Classes A and B respectively. AAL 3/4 and 5 can be used for Classes C and D.20 See Table 1.1 for a diagram of the AAL.

Table 1.1 Layers and sub-layers of BISDN Protocol Reference Model

AAL	Convergence Sublayer	
	Segmentation and Reassembly Sublayer	
ATM		Generic Flow Control Cell Header Generation/Extraction Cell VPI/VCI Translation Cell Multiplexing and Demultiplexing
PHYSICAL	Transmission Convergence Sublayer	Cell Rate Decoupling HEC Header Sequence Generator/Verification Cell Delineation Transmission Frame Adaptation Transmission Frame Generation/Recovery
	Physical Medium Sublayer	Bit Timing Physical Medium

1.9 ATM Signaling

Signaling is another major function for ATM. When an endpoint device wants to establish a connection with another endpoint device, the transmitting endpoint device sends a signaling packet to its ATM switch. The packet contains the address of the receiving endpoint device along with the QOS parameters. The address is translated to the proper ATM address by the ATM layer. The signaling packet is examined by the switch and if there is a table entry for the endpoint device and the QOS parameters can be met, the switch establishes a VC on the input link and forwards the request to the interface for the endpoint device as specified in the table. The request may be sent through several ATM nodes or switches prior to reaching the endpoint device. Each node or switch in the path examines the signaling packet and routes it to the next node or switch if the QOS parameters can be met. The VC is being built as the signaling packet is forwarded. If any node or switch cannot meet the QOS parameters the request is rejected and a rejection message is returned to the originator. This includes the endpoint at the destination. When the signaling packet arrives at the endpoint and if the QOS parameters can be met the endpoint device responds with an accept message. That message traverses back to the originator via the VC that has just been established. The originator of the request receives the accept message from its directly connected ATM switch along with the VCI and VPI values the originator should use.21 The routing table entries at each node are written at the connection establishment phase for each connection.22 This is an example of what makes ATM connection-oriented. A connection must be established before any user data is transmitted. This not only establishes the link, it also helps control congestion. This connection sequence prevents user data from entering the network before there is a path to its intended destination. This helps to ensure there is a physical connection available, that the QOS parameters can be met, that no errors have occurred in the transmission of the cell headers during setup, and that the cells will arrive at their proper destinations. This aids in controlling potential network congestion by not sending cells that cannot arrive at their proper destinations or meet transmission requirements. When the connection is established the cells can begin to flow toward their destinations. Since ATM uses VC's and VP's all cells associated with the signaling packet follow the same path as that packet.23 Cells are relayed at intermediate nodes or switches in the network by forwarding cells from one ATM entity to another.

Cells can be relayed from one VP to another or one VC to another, either in the same or different VP. This switch from an incoming link to an outgoing link is done by first reading the incoming VPI and VCI fields. The second step is to perform a table lookup to find the correct outgoing link and determine the new VPI's and VCI's. Finally, the cell is delivered to the corresponding outgoing link with the new header information. The cell is received at the incoming port at the next node or switch and the process is repeated until the cell arrives at its intended endpoint. Connection release is similar in that a disconnect packet is sent when a user disconnects. As the disconnect packet traverses the network the VC's and VP's used in building the connection are released.

1.10 ATM Switch

One of the main functions of the ATM switch is to receive cells on a port and switch those cells to the proper output port.24 The ATM switch uses the VPI and VCI fields of the cell header to identify the next network segment the cell needs to access on its way to its final destination. The ATM switch is a composite of a VP switch and a VP/VC switch. In a VP switch the VCI's bound for the same intermediate destination are multiplexed into VP's. The ATM switch can perform an operation on a single VP and affect numerous VC's.

For instance, many VC's bound for the same intermediate node or switch can be placed in the same VP. When the VP is switched all of the VC's are switched simultaneously using only the VPI. The VCI's pass through the VP switch unchanged and have no significance in routing the cells. Since only the VP was switched only the VPI is changed. Since the VCI's remain the same the number of fields that must be changed as the cells pass through the switch is reduced. Switching at the VP level and only changing the VPI's reduces the amount of processing time required by the switch and improves its performance.25 An example is provided in Section 9.0 Routing.

The VP/VC switch switches cells using the VCI's as well as the VPI's. In the VP/VC switch the VP's are classified as terminating or not terminating in this switch. The switch checks the VPI to determine whether this VP terminates at this node or not. If not, this is a VP switch and the VPI is changed to one used as an output link and the cell is switched to that port. If the VP terminates at this switch it is a VP/VC switch and the VCI is used to determine the new VPI and VCI to be assigned for the output link. The values of both are changed in the latter case and the cell is switched to its output port. An example is provided in ATM Routing. Another major function of the switch is congestion control. The switch may police traffic to determine the amount of congestion.

This involves measuring the traffic flow and comparing it to the agreed upon QOS. Since the number of cells arriving at a switch bound for the same destination may exceed the bandwidth available at the output port, the switch may queue cells until this condition, known as contention, subsides. If the contention lasts too long the buffer for the queue may not be large enough and some cells may be discarded, depending on the state of the CLP bit. If the cells are discard eligible and the congestion rate is exceeded any ATM switch handling the cells can discard them. Another method for congestion control is to ensure that cells are destined for the desired endpoint. This concern for congestion is one reason that the cell header is checked for accuracy as the cell makes its way through the network. Congestion control is a major concern for ATM switch designers. For instance, if one cell of a Fiber Distributed Data Interface (FDDI) frame is routed to the incorrect destination and discarded, 93 cells must be retransmitted.26.This leads to an exponential increase in congestion.

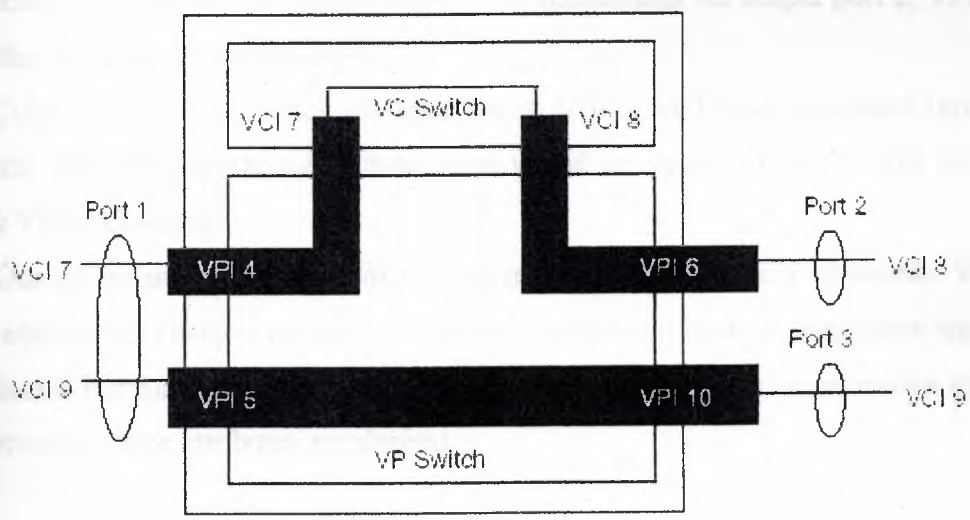

Figure 1.2 Vp and Vp/Vc switch

1.11 ATM Routing

Routing in ATM networks is performed by using routing tables for VC's and VP's. VC links are defined by the routing table entries of two nodes or switches connected by point-to-point physical links. To establish a connection between two ATM entities the VCI's and VPI's to be used by the transmitter and receiver are assigned at connection setup. The routing tables of the intermediate nodes or switches along the path are updated during the connection setup as explained earlier. VP's are semi-permanent connections and the routing tables for the VP switch are preset by network management functions. Each VP has a defined bandwidth, however, and that limits the number of VC's that can be multiplexed.27 VPI's are usually used to route cells between two nodes that originate, delete, or terminate VP's. VCI's are usually used at the end nodes to distinguish between connections. A VC and a VP would be identical in a single hop.28 Table 1.1 and Figure 1.3 help to illustrate how the routing table, VP, and VP/VC switch interact. A table in the switch maps input ports to output ports based on the VPI and VCI fields in the cell header. As cells are routed to the output ports the VPI and possibly the VCI values are changed. For example, according to Table 1 cells that enter the switch on input port 1, VPI 4, VCI 7 are processed through the VC switch and will be transmitted via output port 2, VPI 6, VCI 8. Both the VCI and VPI are changed.

Cells that enter the switch on input port 1, VPI 5, VCI 9 are processed through the VP switch. According to the table, those cells would be output on port 3, VPI 10, VCI 9. Only the VPI is changed.

One of the major functions of routing in an ATM network is to reroute VC's and VP's to account for changes in network operating conditions such as congestion and link or node failures. Rerouting may be required to meet QOS parameters. To maintain routing in ATM networks, three attributes are desired:

1) Quick changes in the bandwidth allocated for a VC or VP.
2) Quick detection of failures and fast rerouting of VP's with failed components.
3) Flexible means of adding and deleting VP's to adjust to variability of traffic at different times.

Rerouting decisions can be made at any node or switch and distributed as necessary to other nodes or switches via network control overhead.29

One example of those attributes is the manner in which network failures are handled. Although there are several methods for rerouting during failures they all involve the use of backup VP's. In the event of a failure at or between nodes a VP alarm indication signal (VP-AIS) is sent downstream to the destination endpoint of the VP as notification of the failure. If the failure affects only the originating-terminating direction of transmission the terminating endpoint sends a VP far-end receive failure (VP-FERF) to the originating endpoint via the same VP. The originating endpoint is then advised that there is a failure and cells must be rerouted to the backup VP. If, however, the failure is bidirectional sending the VP-FERF on the same VP is to no avail. Instead a backup VP must be activated and the VP-FERF must be sent on the backup. In either the unidirectional or bidirectional failure the backup VP can only be activated if it meets QOS parameters for the traffic. When traffic is rerouted one potential problem is that cells may not arrive in the proper sequence.

Rerouted cells could reach the VP destination ahead of the cells that were on the working VP prior to the failure. One solution is to share the last link from the ATM node or switch to the destination endpoint between the working and backup VP's and reroute both directions of the VP at the endpoints. This ensures that no multipath conditions exist and cell sequence is maintained.30 This routing scheme using backup VP's updates the routing tables at the VP endpoints when the alarm cells are terminated. For the link on which the alarm cell was received all corresponding VPI entries are replaced with the VPI of the backup VP.31 The VCI's remain the same. This allows faster processing and restoral since the VCI's are not changed. Similar routing changes occur when nodes or switches encounter congestion. Routing tables enable nodes and switches to reroute cells dynamically by using alternate routes. ATM is capable of transporting multiple types of services simultaneously on the same network.

All data is placed in cells of uniform size. The BISDN PRM adapts the various applications to the ATM cells and prepares the cells for transport over different types of physical media. The cell header contains information concerning cell routing using VCI's and VPI's. Cells from various applications with the same destination can be interleaved to share physical facilities. This allows network providers to transport different types of services using the same physical facilities. This is an advantage for network providers in that facilities can be fully utilized. It is an advantage for end users since they can connect their various networks and only pay for the data they are sending. QOS parameters are specified when the service application is made. These parameters determine the level of quality the user expects for his application and includes the bandwidth required for the amount of data and rate at which he wishes to send.

To maintain the desired QOS ATM nodes and switches constantly evaluate traffic and other network conditions. Traffic can be rerouted if there is extreme congestion or a node, switch, or facility failure in the network. To aid in fast transport of the cells ATM uses VC's and VP's. VC's bound for the same destination are multiplexed into the same VP. By switching a VP the entire group of VC's is switched.

This helps to reduce processing time and increases the speed of the switch. Each ATM node or switch uses the VCI's and VPI's to determine the next node or switch the cell needs to access. The end-to-end VC is built as the connection is setup from node-to-node. The setup cell must reach the endpoint destination and be acknowledged before user data can be sent. This aids in congestion control. Congestion control is a major topic in ATM. The network monitors itself constantly for failures and congestion.

If either is encountered the cells are rerouted. Also, to ensure that ATM cells arrive at their proper destinations ATM performs error checks and is connection-oriented. These attributes ensure that cells are not sent to incorrect destinations because of transmission 16 errors that occur and that cells have physical paths to their destinations prior to being placed on the network. Since ATM can transport all types of services via different physical interconnections it can be used anywhere.

The network provider can utilize it for transporting numerous types of services and utilize various physical facilities that are already in place. End users can connect several types of services to the same network and only pay for the data they send. ATM holds much promise for the future of all types of services, voice, video, and data.

Table1.2 Routing

Input			Output		
Port	VPI	VCI	Port	VPI	VCI
1	4	7	2	6	8
2	6	8	1	4	7
1	5	9	3	10	9
3	10	9	1	5	9

2. ASPECTS OF WATM

2.1 Introduction to Wireless ATM

Recently, consideration interest has begun to focus on the extension of broadband wired ATM in to the wireless medium. This extension has been motivated by the increasing importance and production of portable computing/telecommunications applications in both the business and consumer markets. The rapid penetration of cellular phones and laptop PCs during the previous decade is proof that users place significant value on portability as a key feature which enables tighter integration of such technologies with their daily lives. In the last six years, first-generation multimedia capabilities (such as CD-ROM video) have become available on portable PCs, reflecting the increasingly mainstream role of multimedia in computer applications. As multimedia features continue their inevitable Migration to portable devices such as laptop PCs, personal digital assistants (PDAs), and personal information assistants (PIAs), wireless extensions to broadband networks will have to support user requirements. Such broadband wireless services could first start in the private local area network (LAN) scenario, gradually moving to microcellular public personal communications services (PCS) systems if the technology proves feasible for general consumer use. The extension of the wired broadband networks into the wireless medium will provide these portable applications with global access to any other application Any where. Figure 2.1 shows a network diagram illustrating the wireless/wired ATM network Concept.

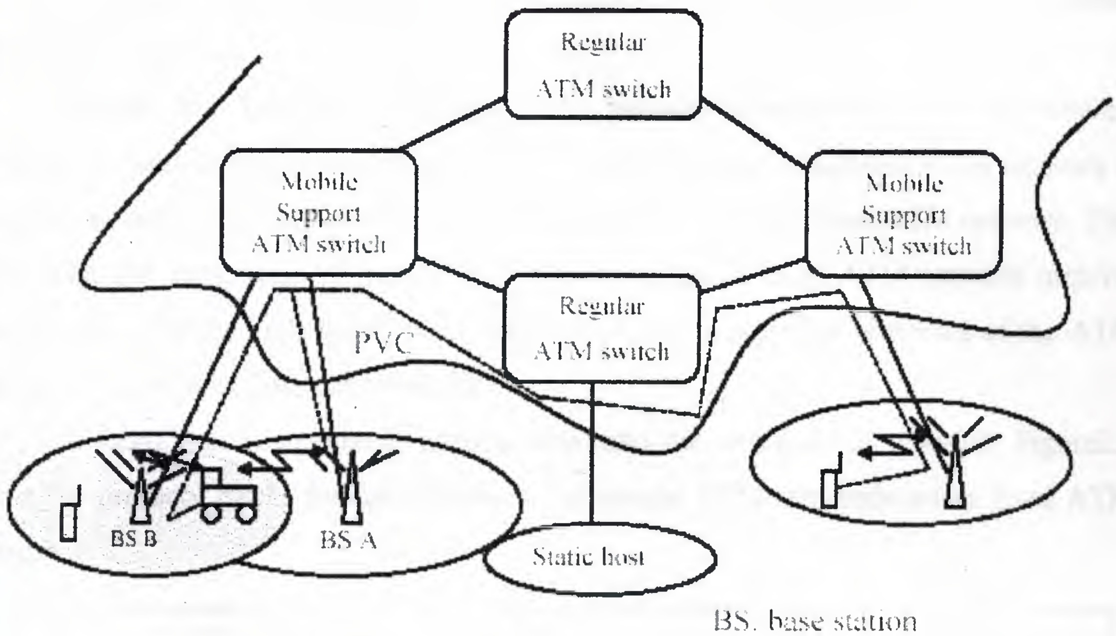

Figure 2.1 Wireless/Wired ATM network

Wireless ATM combines the advantages of freedom of movement for end users that wireless networks provide and the statistical multiplexing (flexible bandwidth allocation) and quality of service (QoS) guarantees that wired ATM networks provide. Such qualities are not supported in the existing wireless local area networks (LANs), which were designed with mainly conventional LAN data traffic in mind [1,2].A typical reaction to the concept of wireless ATM is to question the compatibility of several aspects of the conventional ATM protocol stack and the wireless medium. First, since ATM was designed for a medium whose bit error rates are very low (about 10 -10) it is questioned whether ATM will work at all in the wireless medium which is characterized by a very noisy and time-varying environment. Second, the wireless medium has limited (with a

Maximum rate of about 34Mb/s) and expensive resources in terms of bandwidth, whereas ATM was designed for a bandwidth- rich environment. ATM efficiently trades off bandwidth for simplicity in switching and stack protocol. In addition every ATM cell carries a header with an overhead of about 10 percent. The wireless medium requires its own control protocol stack. This generates an extra overhead in the packet header, which results in unnecessary reduction in the efficiency of the wireless channel bandwidth. This overhead is highly undesirable in such an expensive medium, and keeping it to a minimum is research challenge.

In order to reduce the complexity of the gateway between the wired and wireless networks as well as processing time, it is very important that a wireless ATM network is designed in such a way to provide seamless networking with the wired ATM network. This means that full integration of mobile ATM terminals into a fixed ATM network requires transmission of ATM cells over the air interface in such a way that protocols of the ATM adaptation layer (AAL) are not involved.

Thus, the radio link is integrated transparently into the wired ATM network. Figure2.2 shows the protocol stacks for full integration of mobile ATM terminals into a fixed ATM network.3

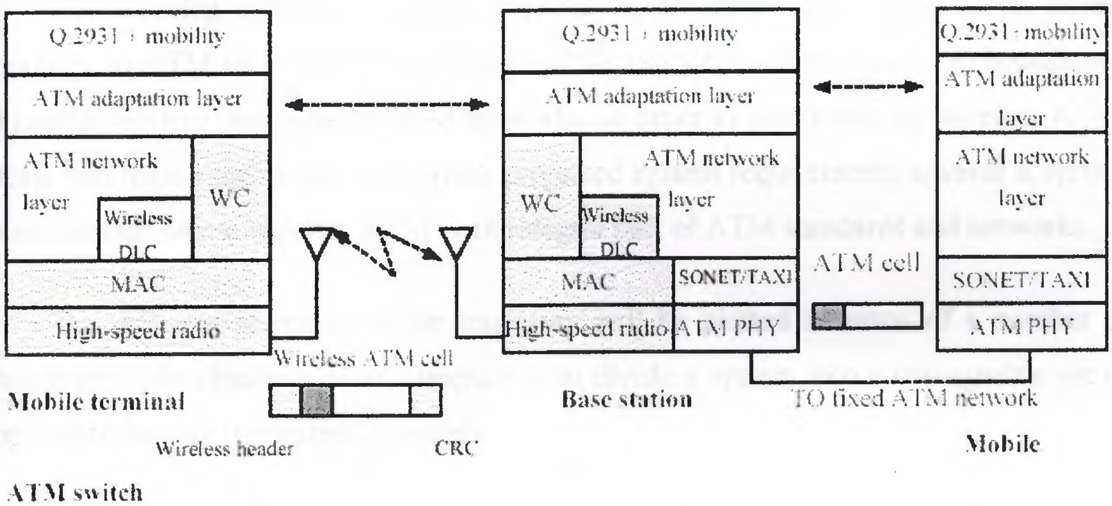

Figure2. 2. Protocol stack for full integration of mobile ATM terminals Into a fixed ATM network.

The base station (BS) provides the gate for wired ATM networks to access the wireless ATM network. There are two scenarios for role of the BS in the WATM network. The first scenario is to terminate the AAL layer at the BS, as shown in Fig. 2.2. The second scenario is for the BS to relay ATM cells back and forth to the wired and wireless networks. In the second approach, the BS does not perform any AAL protocol functions. Since broadband ATM connections will be stretched over wireless links, end-to-end Performance of a connection will be primarily determined by the performance over the wireless link(s). Two major issues are introduced into ATM technology development when the wireless aspect is added: protocol extensions (Mobile ATM protocol extension) and protocol innovations (Radio access layer protocol). Protocol innovations deal with the shared unreliable transmission medium, which can be further decomposed into several key design components: high-speed radio physical layer (PHY), medium access control (MAC), data link control (DLC), and radio resource management (Wireless control).Protocol extensions deal with terminal mobility, which can also be further decomposed into several key design components: mobility of terminals, handoff control, location management, and routing and QoS control.

2.2 Methodology and structure

The working hypothesis is that wireless ATM should be defined as an access technology to ATM or B-ISDN, providing mobile users transparent access to broadband, multimedia services deployed on ATM networks. In order to test results for wireless ATM, indicate that there exists a trajectory from projected system requirements towards a system implementation where wireless ATM is an integral part of ATM standards and networks.

The different segments of the trajectory will be plotted in terms of a number of architectures. The objective of architecture is to divide a system into a manageable set of components that can be treated separately.

In general, architecture defines a system in terms of a number of subsystems and their interfaces. Large and complex systems such as wireless ATM benefit from being defined in terms of a number of architectures, each describing some orthogonal aspects of the system. Together, the separate architectures should provide a comprehensive description of the system.

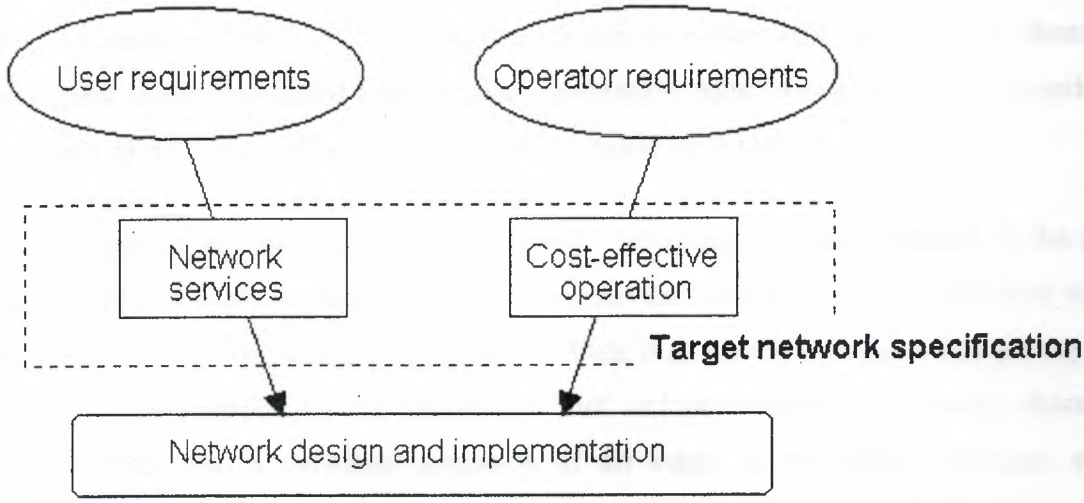

Figure 2.3 Model of wireless ATM

Before it is possible to discuss specific architectures for wireless ATM, the concepts of architecture and wireless ATM need definitions. Architecture neither definition will be formal; instead a qualitative discussion is given.

Wireless or mobile communication has proven immensely successful in recent years. The commercial success of the second generation mobile systems, and in particular of the GSM (Global System for Mobile communication) system, has brought widespread attention to the benefits of wireless access and mobile services. As a consequence, confidence in wireless communication has been strengthened and there seems to be little doubt that wireless networking will be pervasive in the not too distant future.

This confidence in a wireless future is one of the key factors behind the emergence of the concept of wireless ATM. Even though it already has a name, the concept of wireless ATM itself is still rather vague. The problem is not that there wouldn't exist views on the nature of wireless ATM, the situation is rather the contrary: many, partly contradictory, views exist as most observers seem to have a different one.

The problem of defining wireless ATM will be approached by trying to find some of the user and business justifications for it. The assumption here is that understanding why and how people or organizations would use wireless ATM, will also implicitly define it. .

When discussing the reasons why wireless ATM is emerging with such strength and speed, a number of technology push as well as user or market pull issues can be identified. When these issues are added together, they invariably point in one direction: towards the emergence of a wireless multimedia technology based on ATM.

A key aspect, driving the need for more advanced wireless solutions, is the rapid sophistication of end-user telecommunications services and applications. Nowhere is this trend more clearly visible than on the World Wide Web (*WWW*). In just a few short years, the WWW has transformed the previously 'dull and professional', essentially character-based, Internet into a veritable explosion of all kinds of multimedia services, easily accessed by millions of technical and non-technical users alike. And in the wake of the success of the WWW, wireless manufacturers and operators are desperately trying to get on the multimedia bandwagon. Such a trend, once started, is impossible to stop. Users that have become used to the ease of use and flashy *look-and-feel* of the WWW will never be satisfied with anything less.

Hand-in-hand with the introduction of multimedia services goes the development of portable, multimedia capable end-user platforms; the word terminal seems here totally outdated and inappropriate! Today's laptop computers can already be equipped with full multimedia capabilities, including support for sound and video. Even smaller, hand-held equipment (often referred to as personal organizers or personal digital assistants, PDA) sport many multimedia features. It becomes a reasonable proposition to assume that, if not all, at least most customers of future wireless networks will access them using equipment that is very portable but also programmable and has highly sophisticated multimedia capabilities.

Finally, we are faced with the emergence of ATM. Few networking technologies have raised so quickly from the research laboratories into the headlines of networking magazines and into the marketing speeches of every establishment. Consequently, some of the main distinguishing features of wireless ATM are that it: extends the connection-oriented, multi-service and Quality of Service based network paradigm of fixed ATM networks to the wireless field, provides mobile users with access to fixed and wireless ATM services in a manner that maintains the control and cell relay semantics of ATM, supports wireless access to telecommunication services with a high multimedia content, including but not limited to, interactive voice and video and packet data, provides at least limited terminal mobility, i.e. the capability of a user to maintain communication through a fixed infrastructure while moving the wireless ATM terminal equipment between access point, is deployed well integrated into the ATM infrastructure used for fixed communication, in a way that does not negatively affect fixed-only communication, is implemented in a way that allows sharing of key network resources, such as transmission links and switches.

To complete the definition of wireless ATM, it can be useful to also add a few considerations about what wireless ATM is not. Wireless ATM does not imply a certain radio interface or any particular radio interface bit rate range; just as for fixed ATM, wireless access to an ATM network can be provided at any bit rate; evidently the services that can (usefully) be provided are limited by the available bandwidth, but in this respect wireless ATM in no way differs from its fixed counterpart, does not preclude the provision of mobile or location specific services; even though such services are not currently specified for fixed ATM users, it seems likely that also mobile specific services can be defined within the bounds of the ATM semantics.

2.3 Basic Concept

The basic idea of wireless ATM is to use a standard ATM cell for network – level functions, while adding a wireless header/trailer on the radio link for wireless-channel specific protocol sub-layers (medium access control, data link control and wireless network control), as shown in Fig.1 3.ATM virtual circuits with QoS control are supported on an end-to-end basis via standard ATM signaling functions, which are terminated at the mobile unit . Terminal-migration related functions such as handoff control and location management are handled by suitable mobility support extensions to ATM signaling/control protocols implemented at the radio port (base station) and switches within the fixed network. Wireless ATM network specifications can thus be partitioned into:

1) Radio access layer protocols for wireless-link-specific protocols.

2) Mobile ATM for radio-independent mobility control functions.

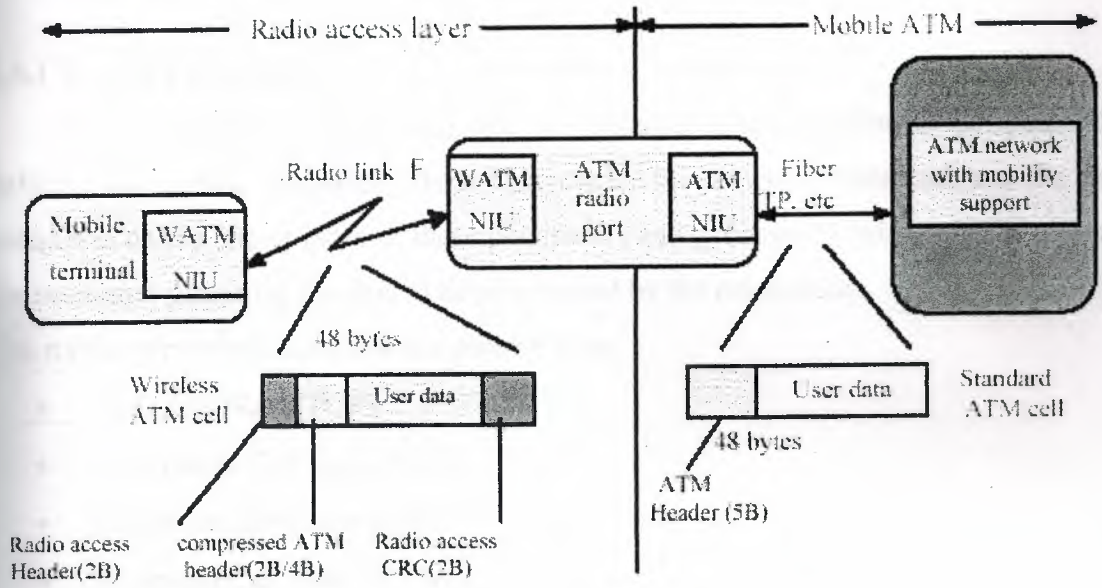

Figure 2.3. Wireless ATM network concept

2.4 Protocol Stack

The proposed wireless ATM network has a protocol stack fully harmonized with that of standard ATM. The idea is to fully integrated new wireless-channel-specific physical, medium access control (MAC), data link control (DLC), and wireless network control sub-layers into the ATM protocol stack, as shown in Fig. 1 [2].

2.5 Quality of Service Parameters

The Quality of Service is one of the important considerations in any ATM network, since the network is expected to have copious bandwidth. But the Wireless ATM, dealing with the wireless media lacks in this respect and additionally has the disadvantage of having lossy channels. These make the QoS parameters difficult to be guaranteed in the wireless media. Specifying the parameters in the wireless channel for the QoS is one of the tasks for effectively handling the guarantees. In this section, a brief introduction to the parameters considered in the wired ATM networks is given and then the parameters for the wireless ATM networks are talked about. The service categories, the traffic parameters and the QoS parameters.

2.5.1 Traffic Parameters

Traffic parameters along with the QoS parameters are required to be specified, for defining the service categories. These characterize the network underneath and the service categories define one or more of these parameters and guarantee a value, which is generally the minimum guarantee that has to be maintained by the connection.

The traffic parameters for ATM are given below

- Peak Cell Rate (PCR)
- Sustainable Cell Rate (SCR)
- Maximum Burst Rate (MBR)
- Minimum Cell Rate (MCR)

These parameters are self-explanatory. Peak Cell Rate specifies the maximum rate, which can be accepted by the interface. Sustained Cell Rate denotes the average cell rate. Maximum Burst Rate is the number of cells that can burst above the Sustained Cell Rate.

2.5.2 QoS Parameters

While the traffic parameters characterize the network, the end-to-end connection management has to be done with the Quality of Service parameters such as:

- Cell Delay Variation
- ·Maximum Cell Transfer Delay
- ·Cell Loss Ratio

Depending on the preferences of the QoS parameters and the Traffic parameters, the service categories in the connections are defined.

2.6 Service Categories in Wireless ATM Networks

The service categories differentiate the nature of the connections established between the end hosts according to the type of the application. The traffic and the QoS parameters can be directly mapped onto the service categories. Service category is classified as real-time and non real- time.

2.6.1 Constant Bit Rate (CBR)

This is used by connections, which demand fixed amount of bandwidth throughout and the source provides the data at or below the Peak Cell Rate. This category is intended for real-time applications, those requiring tightly constrained Cell Transfer Delay (CTD) and Cell Delay Variation (CDV), but is not restricted to these applications. It would be appropriate for voice and video applications.

2.6.2 Real-Time Variable Bit Rate (rt-VBR)

The real-time VBR service category is intended for time-sensitive applications and is appropriate for voice and video applications. Sources are expected to transmit at a rate, which varies with time. Traffic parameters are Peak Cell Rate (PCR), Sustainable Cell Rate (SCR) and Maximum Burst Size (MBS). Variable rate traffic can be generated by the source, and the QoS guarantee is made for bursty traffic.

2.6.3 Non-Real-Time (nrt-VBR)

The non-real time VBR service category is intended for applications, which have bursty traffic characteristics and do not have tight constraints on delay and delay variation. As for rt-VBR, traffic parameters are PCR, SCR and MBS. For those cells, which are transferred within the traffic contract, the application expects a low Cell Loss Ratio (CLR). For all cells, it expects a bound on the Cell Transfer Delay (CTD). Non-real time VBR service may support statistical multiplexing of connections.

2.6.4 Available Bit Rate (ABR)

The Available Bit Rate (ABR) is a service category intended for sources having the ability to reduce or increase their information rate if the network requires them to do so. This allows them to exploit the changes in the ATM layer transfer characteristics like bandwidth availability, subsequent to connection establishment. Fair share of the available bandwidth can be utilized by the source by adapting the traffic according to the Resource Management Control cells, which are sent as feedback about the network conditions.

2.6.5 Unspecified Bit Rate (UBR)

The Unspecified Bit Rate (UBR) service category is intended for non-critical applications, which require a "best effort" service and neither require tightly constrained delay and delay variation, nor a specified quality of service. UBR sources are expected to transmit non-continuous bursts of cells. UBR service does not specify traffic related service guarantees. Specifically, UBR does not include the notion of a per-connection negotiated bandwidth.

2.7 Sub system Design

A wireless ATM system broadly consists of a radio access layer and mobile ATM network, as discussed previously. These two major subsystems can be further decomposed into the following key design components:

1.) Radio access layer protocols are

- High-speed radio physical layer (PHY)
- Medium access control (MAC)
- Data link control (DLC)
- Wireless control

2). Mobile ATM protocol extensions

- Handoff control
- Location management
- Routing and QoS control

2.7.1 Radio Access Layer

The radio access layer consists of several new protocol sub layers necessary to extend ATM services over a wireless link. The major functions of this layer include high speed physical-level transmission/reception, MAC for channel sharing by multiple terminals, DLC for amelioration of radio channel impairments, and wireless control for radio resource management and meta signaling.

2.7.1.1Radio Physical Layer

Wireless ATM requires a high-speed radio modem capable of providing reasonable reliable transmission in micro cell and Pico cell environments with cell radius in the range of 100-500 m. Although such systems may operate in various frequency bands depending on national and international regulatory policies, they are typically associated with new 5 GHz national information infrastructure (NII)/Super net band in the United States or the high-performance LAN (HIPERLAN) band in Europe. Higher-frequency systems operating at either 20/30 GHz or 60 GHz may also be viable in the future, at least for some usage scenarios. Typical target bit rates for wireless ATM PHY are in the region of 25 Mb/s, comparable to the 25 Mb/s unshielded twisted pair (UTP) Specification adopted as a PHY option by the ATM Forum. The 25 Mb/s value is based on a goal of per-VC service bit rates in the range of at least 1-2 Mb/s sustained and 5-1-Mb/s peak. In addition to operating at a high bit rate, the modem must support burst operation with relatively short preambles consistent with transmission of short control packets and ATM cells.

Candidate modulation methods for the WATM PHY layer are equalized quadrature phase shift keying (QPSK)/quadrature amplitude modulation (QAM), multi carrier orthogonal frequency division multiplexing (OFDM), and spread spectrum CDMA. QPSK/QAM technology at similar bit rates has been proven to work in digital TV/cable TV (CATV) environments, but does require a fairly complex equalizer. OFDM does not require equalization, but involves a computationally complex frequency transformation and incurs higher bit transmission delays due to multi carrier operation.

The CDMA option is also an important option in view of capacity and signal robustness advantages, but further work is required to identify a method for efficient multi rate/burst operation with peak service bit rates as high as 10 Mb/s. In each case, multilevel modulation methods (such as 16-QAM) may be desirable given that the micro cell environment is usually not power-limited, while spectrum efficiency is a major cost driver in commercial system deployment. Selection of modulation method and bit rate for the WATM PHY is an important standardization issue facing both European Telephone

Standard Institute (ETSI) RES10. and ATM Forum, and some results may be anticipated in the 1997 time frame.

2.7.1.2 Medium Access Control

A MAC protocol is a set of rules to control the access to a shared wireless communication medium among various users. These users, in the context of the wireless communication network, are active users within the cell (local users), handoffs from neighboring cells, and new users requesting access within the cell.

For wireless ATM, the defined MAC protocol must provide support for standard ATM services as defined in existing ATM standards, including continues bit rate (CBR), variable bit rate (VBR), available bit rate (ABR), and unspecified bit rate (UBR) traffic classes. Therefore, the defined MAC must expand the statistical multiplexing of wired ATM multiplexers into the wireless scenario in a manner different from a narrowband rigid-partitioning second-generation digital cellular circuit-switching system, along with the means of supporting mobility and maintaining QoS.

Multiple access schemes and protocols are classified according to the bandwidth allocation mechanism, which can be static or dynamic, and to the type of control mechanism being exercised. In general, multiple access schemes can be classified into the following three main categories:

2.7.1.3 Fixed assignment techniques.

Techniques such as frequency division multiple access (FDMA) and time-division multiple access (TDMA) are inappropriate for the integrated wireless networks simply because of the inefficient radio channel spectrum utilization. It is widely accepted that the dominant services in the broadband environment are VBR services. Code-division multiple access (CDMA) is a fixed and random assignment scheme as well. It has several distinguishing advantages such as almost zero channel access delay, bandwidth efficiency, and excellent statistical multiplexing. However, it suffers from significant drawbacks such as transmission rate limitations, power control problems, and BS complexity. These problems, especially the transmission rate limitation, have made usage of CDMA in the integrated wireless network inappropriate [1].

2.7.1.4 Random Assignment

These schemes are inappropriate as well because of the large delay due to the contention resolution process. Although carrier sense multiple access with collision detection (CSMA/CD) provides the wire line network with very high throughput, it has been inhibited by the difficulty of sensing remote carriers in the presence of local transmission in the radio environment. The signal from the local transmitter will overload the receiver, disabling any attempt to sense remote transmission [1].

2.7.1.5 Demand Assignment

Achieve high channel throughput by requiring users to reserve communications bandwidth. A portion of the channel capacity is required in this reservation stage. The reservation sub channel is accessed by users according to a multiple access protocol, typically TDMA or slotted ALOHA. Short reservation packets are sent to request channel time; the shorter they are, the less capacity necessary for the reservation sub channel. Once channel time is reserved, information packets are transmitted conflict free. Conflicts occur only on the small-capacity reservation sub channel.

At low Through puts, through, the message delay is increased over that of random access techniques. Users must wait for their reservations to be accepted, and for their assigned transmission times. Control of the reservation and transmission stages can be either centralized or distributed.

A common example of demand assignment with central control is polling: each user is addressed, sequentially by a central station, for transmission privileges. The proper operation of a centrally controlled system, however, depends on the reliability of the controller. Demand assignment with distributed control avoids this problem. With distributed control, users base their actions entirely on information available to everyone. Broadcast channels provide full connectivity; hence, actions are determined by the transmission history of the channel. All users listen for reservation packets and apply the same distributed scheduling algorithm. Requests are made on either a contention or fixed-assignment basis [3].

2.7.2 Data Link Control

A DLC layer is necessary to mitigate the effect of radio channel errors before cells are released to the ATM network layer. Since end-to-end ATM performance is sensitive to cell loss, powerful error control procedures are a requirement for the WATM radio access segment. Available options include error detection/retransmission protocols and forward error correction methods (tailored for each ATM service classes). A unique consideration for wireless ATM is the requirement for relatively low delay jitter for QoS-based services such as VBR and CBR, indicating a possible need for new time-constrained retransmission control procedures. For ABR, this DLC method follows traditional selective reject (SREJ) automatic repeat request (ARQ) procedures on a burst-by-burst basis, without time limits for completion. For CBR and VBR, the DLC operates within a finite buffering interval that is specified by the application during VC setup. In this case, because CBR or VBR allocation is periodic, additional ABR allocations are made at the MAC layer to support retransmitted cells.

2.7.3Wireless control

The wireless control sub layer is needed for support of control plane functions at the radio access layer and its integration with the ATM network. These functions include radio resource control and management functions at the PHY, MAC, and DLC layers. In addition, this layer includes meta signaling capabilities needed to complete the control path between the radio link and the traditional ATM signaling/control layer. Primary functions of this wireless control layer are terminal migration, handoff control, and radio resource management functions. Functions under consideration include authentication/registration of terminals to radio ports, power measurements/control, hand off Indication/start/confirm, data link state transfer, and disconnection handling. An interesting wireless control function is connection state (DLC buffers, MAC State, etc.) transfer from one radio port to another for smooth handoff with minimal cell loss [2].

2.7.4 Mobile ATM

Mobile ATM is used to denote the set of enhancements needed to support terminal mobility within a fixed ATM network. The major functions of mobile ATM are location management for mapping of user names to their current locations, and handoff control for dynamic rerouting of VCs during terminal migration. Note that mobile ATM is intended to be independent of the specific radio access technology used. This means that in addition to supporting end-to-end wireless ATM services via the WATM radio access layer outlined above, mobile ATM capabilities can be used to provide an interconnection infrastructure for existing PCS, cellular, and wireless LAN applications.

2.7.4.1 Handoff control

When a mobile moves from one cell to another while a connection is in Progress, the continuity and the quality of the connection must be maintained. The backbone network must switch the access point from the previous BS to the BS, which is currently serving the mobile. The process of transferring the control of an on-going connection due to the mobile's movement is known as the handoff control. Handoff management for WATM network poses a great challenge to current ATM protocol. ATM is a connection-oriented technology, with a connection establishment phase prior to data exchange. Once a connection is established, its routing path remains unchanged until data exchange is finished. However, in the WATM environment, end hosts are expected to move frequently from one location to another location. When the quality of a radio link between a wireless terminal and its BS degrades, new BS with acceptable quality must be found, and network control functions of both the fixed and wireless network need to be invoked. In the backbone network, handoff requires the establishment of a new route, which transports the packets destined to (or originated from) the wireless terminal to (or from) the new BS. The handoff issue will be aggravated since the handoff frequency increases substantially when the future WATM geographical cell structure adopts either micro cell or Pico cell architecture [4].

2.7.4.2 Location management

Location management is a generic capability required in networks supporting terminal migration. This function is required in both the end-to-end wireless ATM scenario (where the mobile has an ATM address) and the PCS/cellular/WLAN backbone scenario (where the mobile has a legacy telephone number, IP address, or MAC address). Location management provides a mapping between unique mobile device "name" and "routing-id" which is used to locate the current endpoint to which the device is attached. In the all-ATM scenario, this mapping corresponds to the mobile endpoint, while in the PCS/cellular/WLAN case, the mapping is to the ATM radio port currently associated with the mobile. Location management functions outlined above can be based on methods similar to those used in cellular/PCS systems, via the familiar "home location/visitor location" concept used in GSM, IS-41, and so forth. More distributed location management algorithms which do not necessarily require call setups to go through a home location register are also possible, potentially reducing call establishment delay. An important implementation issue here is the degree to which location services should be integrated with existing ATM call control and routing software

2.7.4.3 Routing and QoS control

There are two key issues regarding how handoff effects the QoS of an existing connection. First, when a network accepts a connection to a fixed end point, the requested QoS is made available to the connection during its lifetime with a high probability in the absence of network failures. The same cannot be said for a connections to a mobile end-point which is rerouted when the mobile terminal changes its radio port. This may occur, for example, when the mobile terminal moves under the coverage area of a radio port which is unable to provide the same QoS as that provided by the previous radio port. In this situation, the end-to-end QoS parameters of the connection will needed to be renegotiated.

The second issue is that of minimizing the effects of QoS disruption during the process of handoff. Connection handoff entails a period of time during which the end-to-end connection data path is complete. The extent to which this disruption affects application performance depends on the nature of the application and the period of disruption. For example, a voice application can withstand short disruption, but a data application cannot tolerate any. In some cases applications may mask the effects of disruption using different strategies. For example, lost segments of a data connection may extrapolate from current information to compensate for lost data. Either way, data loss may by perceived as a Disruption of the negotiated QoS.One way to minimize QoS disruption during handoff is to ensure a "lossless handoff" [5].

To ensure a lossless handoff, all cells in transit during the handoff process are buffered with in the network (at a switch or a radio port) to maintain in –sequence cell delivery(without loss) to the mobile terminal. In general, the sequence of actions [5] is:

1-The crossover switch sends a "marker" cell along the existing connection segment to the current radio port. Thereafter, it shifts the data path to follow the connection segment to the new radio port.

2-The new radio port buffers incoming cells along the (new) connection segment from the cross over switch.

3-The current radio port buffers all cells in the period between receiving a Handoff Confirm (from the mobile terminal) and the marker cell (from the crossover switch). It then transfers the buffered cells to the new radio port.

4-Once the new radio port receives the buffered cells from the current radio port, it first delivers these cells followed by cells that were buffered locally.

Transfer of buffered cells from the existing radio port to the new radio port ensures that cells are not delivered out of order, and buffering cells at both radio ports ensure that cells are not lost.

For some applications, the cell transfer delay and delay variation may be more important than avoiding cell loss. In this case, depending on the allowable delay variation, the current radio port may transfer the buffered cells to the new radio port without waiting for the marker cell arrives.

3. WATM ARCHITECTURE

The architecture proposed for wireless ATM is composed of a large number of small transmission cells called Pico cells. Each Pico cell is served by a base station. All the base stations in the network are connected via the wired ATM network. The use of ATM switching for inter cell traffic also avoids the crucial problem of developing a new backbone network with sufficient throughput to support intercommunication among large number of small cells. To avoid hard boundaries between Pico-cells, the base stations can operate on the same frequency.

Reducing the size of the Pico-cells has major advantages in mitigating some of the major problems associated with in-building wireless LANs. The main difficulty encountered is the delay due to multi-path effects and the lack of a line-of-sight path resulting in high attenuation. Pico-cells can also have some drawbacks as compared to larger cells. There are a small number of mobiles, on average, within range of any base-station, so base-station cost and connectivity is critical. As cell size is reduced, hand-over rate also increases. By using the same frequency, no hand-over will be required at the physical layer. The small cell sizes also give us the flexibility of reusing the same frequency, thus avoiding the problem of running out of bandwidth.

The mobile units in the cell communicate with only the base-station serving that particular cell, and not with other mobile units. The basic role of the base station is interconnection between the LAN or WAN and the wireless subnets, and also to transfer packets and converting them to the wired ATM network from the mobile units.

In traditional mobile networks, transmission-cells are "colored" using frequency division multiplexing or code division multiplexing to prevent interference between cells. Coloring is a wasteful of bandwidth because in order for it to be successful there must be areas between re-use which are idle. These inactive areas could potentially be used for transmission.

The following diagram shows a typical ATM to Base Station Connection:

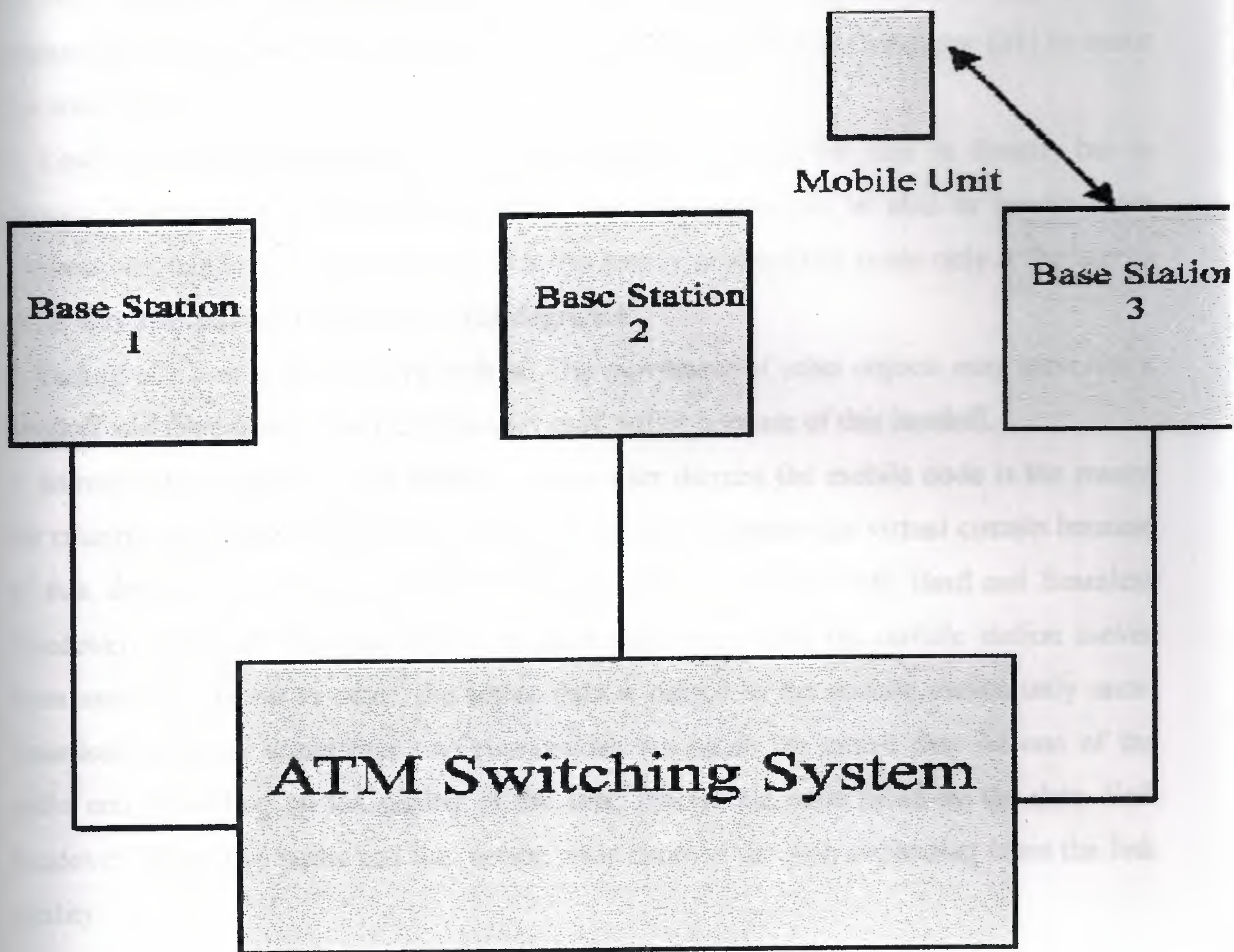

Figure 3.1 ATM to Base Station Connection

3.1 Prevalent Architectures

The architectures that address the issues we discuss are mainly introduced. The purpose of discussing the architectures as a separate section is that in the subsequent sections the architectures, which address those issues are discussed. Understanding the architectures of the systems give the necessary fundamentals for understanding the problems in providing the Quality of Service. The architectures are described only in the QoS provision point of view. This section does not attempt to provide information about the finer details of the systems. The handoff mechanisms of the individual systems are discussed along with since the handover also has a major role in affecting the Quality of service guarantees. The reasons for a handover to occur are multifold and they are not necessarily handled only upon mobility. Some of the reasons for a handover [31] to occur are stated below:

1. Load balancing between adjacent cells: This does not help the user in directly but to provide betterment for the network and for the base station to be able to handle more connections, handover might be made. But this handover should be made only if the user is in no way affected and the quality is not degraded.

2. Fading of a link to a stationary mobile: The movement of other objects may stimulate a handoff and there is no reason that the user shall suffer because of this handoff.

3. Movement of a mobile: The mobility of the user thereby the mobile node is the reason for causing this handover and it may not be possible to maintain the virtual circuits because of this, though its desirable. Some of the terms in handover are Soft, Hard and Seamless Handover, which are detailed below. In Hard handover, when the mobile station moves from one base station to other, the active data is passed to the mobile station only once. Seamless handover establishes two connections but sends the active data on one of the paths and depending on the quality of the link, the mobile node picks up the data. Soft handover allows two paths and the mobile node chooses the path depending upon the link quality.

3.2 AQuaFWin Architecture

The network architecture of AQuaFWin is hierarchical and the mobile nodes are grouped into clusters. Each cluster has a cluster head chosen by a distributed election protocol. Clusters are connected to base stations which provide the mobility support and are directly connected to the wired infrastructure. Supervisor Node (SN) connects a group of base stations and the supervisor nodes logically separate the mobile and fixed part of the system. Each layer in the architecture are QoS aware and extend support to maintaining the guarantee provided.

3.3 SWAN Architecture

The purpose of Seamless Wireless ATM Network, as the name implies is to deliver seamless multimedia to the mobile user in an indoor setting [20]. One of the major variations of SWAN from other architectures discussed is that, the end hosts and the base stations have to have FAWN wireless adapter cards. The base stations, which are conventional personal computers functionally acting as mobility-aware switches. The end hosts can be dumb (multimedia terminals, cameras etc) or smart (PDAs, laptops etc). SWAN depends on the MAC layer and imposes restrictions by making it handle cell scheduling, error control etc, according to the QoS parameters.

3.4 WAMIS Architecture

WAMIS (Wireless Adaptive Multimedia Information System)[14] differs from other architectures by providing support to multimedia and mobile applications still having a multi hop architecture .Adaptability is a main consideration in WAMIS architecture, since it is designed to support real time multimedia. A subnet layer in the system is designed to support reliable transmission efficiently. QoS routing along with clustering is made use of, since this is inherently a multi hop architecture. Clustering is distinctly used for resource management in this. Fast reservations and soft-state schemes are the key features of the system.

3.5 Broker QoS Management Architecture

QoS management architecture is proposed to maintain user-defined QoS levels over an entire session in spite of the channel and network conditions. Based on brokers, negotiation protocols and coders and decoders, this architecture addresses the issue of QoS Adaptation in a combined wired and wireless ATM environment, which is realistic. Soft QoS is tackled through resource reservation schemes.
End systems are assumed to be capable of coding and decoding methods. Access points employ error control modules and the variation of the level of these schemes can be made with the knowledge of quality and capacity of the channel.

3.6 ORL Radio ATM Architecture

The ORL Radio ATM architecture is dealt here, since the architecture also take into consideration the Quality of Service guarantees. A base station serves large numbers of Pico cells and the wired network connects the base stations. Each base station supports a single radio frequency and they convert the ATM cell headers into radio ATM format. Sets of base stations are organized into domains under a single controller. The interesting aspect of the ORL Radio ATM architecture is the way the handoff is carried out. Since the system supports real time applications, it is necessary to continue providing the promised QoS to the user even if he is on the move.

3.7 User Requirements

Wireless ATM clearly addresses the needs of users with portable equipment. It is therefore essential that it not only provides a cordless link to ATM but also supports some level of terminal or user mobility, so that communication is possible wherever the user takes the 'terminal'. While moving between remote locations, the terminal equipment would probably be powered off and hence one can assume that communication will be restarted in each location. This means that wireless ATM should support discrete mobility or roaming. The other mobility requirement is that the user should be able to move around in each (limited) location while maintaining active communication. This requires handover *support.*

Deploying just a single service that is used by both fixed and mobile users alike, removes the costly need to maintain different service offerings for each access technology. End users will also demand that the same service is accessible from both mobile and fixed terminals. As the number of services and applications increases, it is not reasonable to assume that customers will accept that they are forced to access the same (type of) service in a different way when mobile. Networks therefore need not only support mobile multimedia communication, but it must be done in a way that allows a single service to be offered to all users, regardless of access technology. In the case of wireless ATM, the service is deployed on the fixed ATM network and wireless ATM provides the mobile access.

3.8 Operator Requirements

The initial operator view of wireless ATM is of course determined by user requirements; there is no point for an operator to build a network that does not meet these. Having stated this rather obvious starting point, it is necessary to establish some kind of vision of the baseline network and operational environment of the operators of wireless networks.

The organizations, inclined to deploy wireless ATM, will also be operating fixed ATM networks. It is realistic to assume that an operator in most cases will have a fixed ATM infrastructure in place when wireless ATM is deployed. It is important that this infrastructure can be efficiently *shared* between mobile and fixed users in order to achieve potential economies of scale. The savings, inherent in sharing a single infrastructure, are important in particular from a private operator (or network) perspective. The benefit for small enterprise networks of having a single, high performance switching infrastructure that supports both fixed and user communication could be significant, as it avoids costly duplication of functionality and the need to support overlapping networks. The enterprise networks are also most likely to benefit from the flexibility of sharing the network infrastructure, as the corporate networks are most susceptible to frequent changes.

Another way in which fixed and wireless services could be offered would be by service providers. A service provider could combine the services offered by various operators, both fixed and mobile, into comprehensive packages. This is evidently much facilitated if the basic capabilities and service features are comparable. Integrating mobile and fixed communication also addresses the main concern of operators that of cost-effective service provision. The increase in mobile communication will vary from network to network and will be difficult to predict. An operator will want to be able to start small and grow as needed. This means that the initial investment to enhance the fixed infrastructure for mobile communication should be small and that further investments can be done in small increments. This allows small companies to effectively employ the technology and allows large networks to initially implement spot coverage and other special services and then to grow coverage as demand increases.

In general, the initial cost of purchasing and installing a network is a small part of the overall network cost. The main cost of a network is incurred in its operation. These costs result from functions such as network management, user support and help desks, marketing and sales support, etc. The economic operation of wireless ATM is best ensured if these functions can be shared, as far as possible, between the fixed and wireless network segments.

To sum up, it seems that the operator requirements for wireless ATM is to enable maximal sharing and reuse of fixed ATM resources and functions, including the streamlining of all aspects of network operation. In the private networks, this will be an important way to drive down the cost of advanced networking solutions. In the public networks, it will be a requirement in order for an operator to survival.

3.9 Target System Requirements

Based on the user and operator requirements outlined above, a number of system requirements for wireless ATM can be identified.

3.9.1 Semantics of Fixed ATM Networks

Wireless ATM needs to support the full multimedia, multi-service semantics of fixed ATM. This is required, on the one hand, to support the intrinsic service requirements on wireless ATM to support multimedia. On the other hand, full ATM semantics must be supported in order to allow seamless access to all services deployed on the fixed ATM network. The requirement to support full ATM semantics should be understood to refer to 'types' of features. For instance, all ATM service categories (CBR, VBR,) should be supported, but the bandwidth and *QoS* that can be provided to a category will probably be limited by at least the radio interface. As ATM networks develop, wireless ATM should quickly track the modifications; therefore just supporting a 'snapshot' of ATM capabilities is not a viable long term alternative.

3.9.2 Transparency.

Mobility should be transparent to the parties involved in communication. Communication between a fixed and a mobile terminal should be possible even if the fixed terminal has no special knowledge of the other user's mobility. Note that this does not exclude the possibility that a mobile-aware fixed terminal implements extra features that optimize communication with mobiles. The transparency requirement also applies from the point of view of applications, using the communication services. Applications that can be executed on fixed ATM terminals should be able to execute unmodified and with reasonable efficiency also on wireless ATM terminals. Again, this does not preclude that mobile-aware applications can provide special optimizations, based on mobile specific information.

3.9.3 Parallel Developments of Radio and Fixed Networks

To achieve seamless roaming capabilities for a user, wireless ATM needs to support a number of radio interfaces. Some of the basic laws of physics make it desirable to use different radio interfaces in different environments. For instance, the cell radius is affected by the frequency selected, and this in turn affects many of the basic radio designs. Radio networks designed to cover (relatively speaking) large cells will probably employ different radio techniques from networks that support small cells and very high user densities. The fact that different radio interfaces are deployed should not restrict access to services in any other way than by limiting the bandwidth (and possibly achievable QoS), all service types should still be accessible. To achieve this, wireless ATM needs to be divided into radio and network aspects as suggested in [GR96]. This allows generic wireless ATM features to be developed independently of radio interfaces.

3.9.4 Developments of Fixed ATM Networks

Wireless ATM does not start from a clean slate when it comes to the fixed infrastructure. Wireless ATM is a reasonable proposition only when it is compatible with the development of fixed ATM.

3.10 Integration of Wireless and Fixed ATM Architectures

The way in which the architectures for wireless and fixed ATM relate, must reflect the design objectives for wireless ATM outlined in the previous section. The key to the successful development of wireless ATM becomes how such integration is achieved.

From a user perspective, the term integration means that a network appears as a seamless, coherent entity. While accessing a service, a user should not need to be aware of whether access is by way of cables or radio. This includes technical aspects, such as maintaining the same user interface and user procedures across environments and treating network problems in a consistent way. Integration also includes significant non-technical aspects such as common charging policies and subscription mechanisms, maintaining the same user identity ('phone number') across environments, a single help desk for all network related problems, etc.

From a network design perspective, integration touches upon a number of network aspects. It includes using the same network functions and protocols for common functions, sharing network infrastructure and providing the same set of services. Integration is also an aid in achieving adequate network performance for wireless users. Inter working implies the use of protocol conversion or other adaptation mechanisms in the end-to-end connection. The more users must be supported, and the higher the transmission speeds get, the more difficult such conversions become in terms of ensuring sufficient performance. Integration avoids the pitfalls of inter working by applying the same mechanisms and protocols end-to-end.

Another consideration favoring integration is network evolution. If a network is based on the inter working paradigm, there is a significant risk that the development of each segment of the network will proceed at a different pace or even diverge altogether. In this case, the requirements for consistent and universal service support are put in jeopardy. Again, integration avoids the problem by only providing a single service definition applicable across all environments.

Accepting the argument that integration of mobility into fixed ATM is the essence of wireless ATM, a development path as shown in figure 3.3 is obtained for wireless ATM. figure 3.3 is simply a consequence of the network evolution, shown in figure 3.3. The existing fixed ATM network and the enhancements due to mobility form the starting points. The end point, possibly reached through a number of intermediate stages, is an ATM network supporting both fixed and mobile communication by integrating the mobility specific enhancements into a single system.

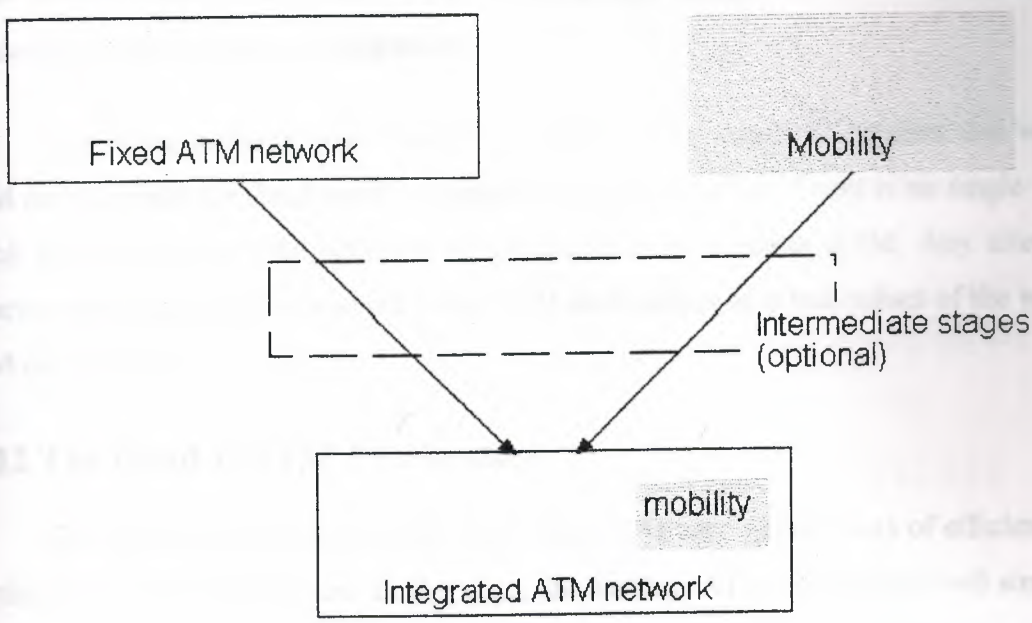

Figure 3.3 Development towards an ATM network integrating mobility.

3.11 Integration Models

The objective of integrating mobility into fixed ATM needs to be reflected in the architectures used to define wireless ATM. This section will discuss how the integration of mobility can be reflected in the (sub-) architectures defining wireless ATM. The starting point for architecture, integrating fixed and wireless ATM, is the existing set of ATM specifications. This fact is underlined by the recent activities of the ATM Forum in formulating what has been called the Anchorage Accord. So far, the ATM market has been hampered by standards 'turbulence' as new standards have emerged by the month. To allow manufactures and operators to finally reap the benefits of the standardization effort, ATM developments must now stabilize. This has been recognized within the ATM Forum, where the current set of ATM standards will form a baseline for advanced ATM equipment. The Anchorage Accord specifies that new standards will, at least for some time, be introduced as backward compatible enhancements to the current standards. This allows inter working between equipment conforming to different releases of the standards and thus ensures investment protection for all parties involved. This is seen as one of the major preconditions for the emergence of a rapidly growing ATM market. The development of an ATM network, supporting mobility, must therefore also be an evolution from current ATM standards in order to achieve integration.

Integrating mobility with the existing set of ATM standards requires that wireless ATM architectures are (backward) compatible with fixed ATM. There is no single way in which integration could be reflected in architecture for wireless ATM. Any alternative however must maintain the relevant fixed ATM architecture as a true subset of the wireless ATM architecture.

3.12 The Fixed WATM Architecture

The simplest alternative is that wirelesses ATM can, without loss of efficiency, re-use the fixed ATM architecture. In this case, the wireless ATM architecture will simply be equal to the fixed ATM architecture. It will be rare that wireless ATM simply re-uses the architecture for fixed ATM as this would mean that wireless operation doesn't introduce any functional changes to the related fixed network architecture. This alternative is illustrated in figure 3.4

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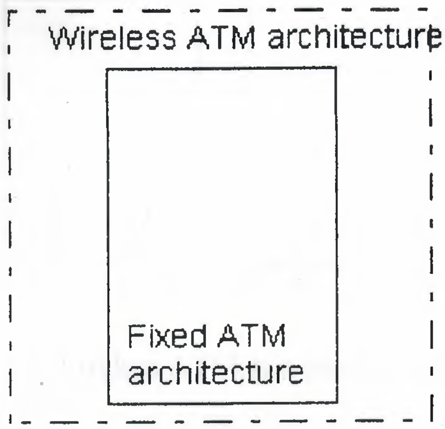

Figure 3.4 Re-use of the fixed ATM architecture in wireless ATM.

3.13 Parallel Architectural Component

In some cases, wireless ATM simply introduces additional features into the network in a way that allows these features to remain clearly separated from the fixed network aspects. If the features are orthogonal with fixed ATM, wireless ATM could be introduced by simply adding a separate, parallel architecture for it. In its purest form, this alternative is rather unlikely. A similar and more relevant option is that the wireless architecture has a very simple interface with fixed ATM, preferably at an already existing architectural interface. The basic structure of the resulting architecture is shown in figure 3.4. This alternative has one very desirable feature in that it allows wireless ATM to be introduced as a modular addition to fixed ATM. Modularity is very attractive as it allows fixed-only networks to be deployed without considering mobile aspects, while fully retaining the option to later extend the fixed network to support mobility. In particular when the mobile architecture is very extensive compared to the fixed one, would a modular system structure allow significant savings in fixed-only networks.

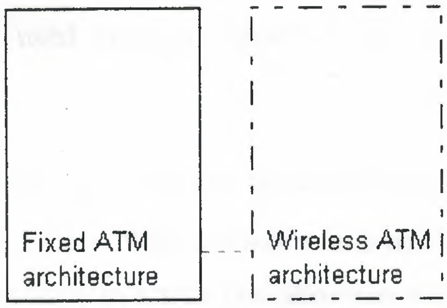

Figure 3.4 Wireless ATM as a parallel architecture.

3.14 Enhance Fixed ATM Architecture

For the most fundamental aspects of ATM, the most likely way in which wireless system architectures are derived from fixed networks, is by modifying the already existing architecture. For some aspects of wireless ATM, this approach is unavoidable if any ATM network is to support wireless users. In the cases where modifications are necessary, it seems that the extent of the modifications can be kept very limited and that enhancing the fixed architectures therefore is possible.

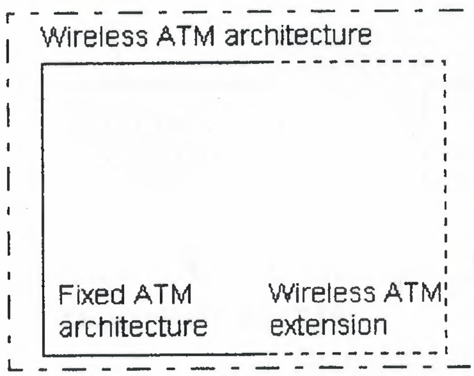

Figure 3.5 Wireless ATM as an enhancement to fixed ATM.

Unfortunately, there are a few problems inherent in extending the architecture. Equipment built to earlier standards might not be able to exploit the new architecture. In the case of wireless ATM, this would not be a serious problem if large scale deployment of (fixed) ATM only starts after the mobile-enhanced architecture has been adopted. This emphasizes the urgency for the work on wireless ATM. Secondly, equipment conforming to the enhanced architecture but used only to support fixed communication, might suffer a performance penalty.

In the case of wireless ATM, the two disadvantages outlined above are outweighed by the potential benefits. Only'mobile-ready' architecture can ensure the smooth introduction of pervasive mobility in a way that allows services and application to gain full benefits of mobility.

3.15 Relevant Wireless ATM Architectures

As has been pointed out, a number of complementary architectures can be employed to define a system. To achieve the objectives of this thesis, a sufficient number of architectures need to be selected to allow a system description according to . The selection that has been made is shown in figure 3.6

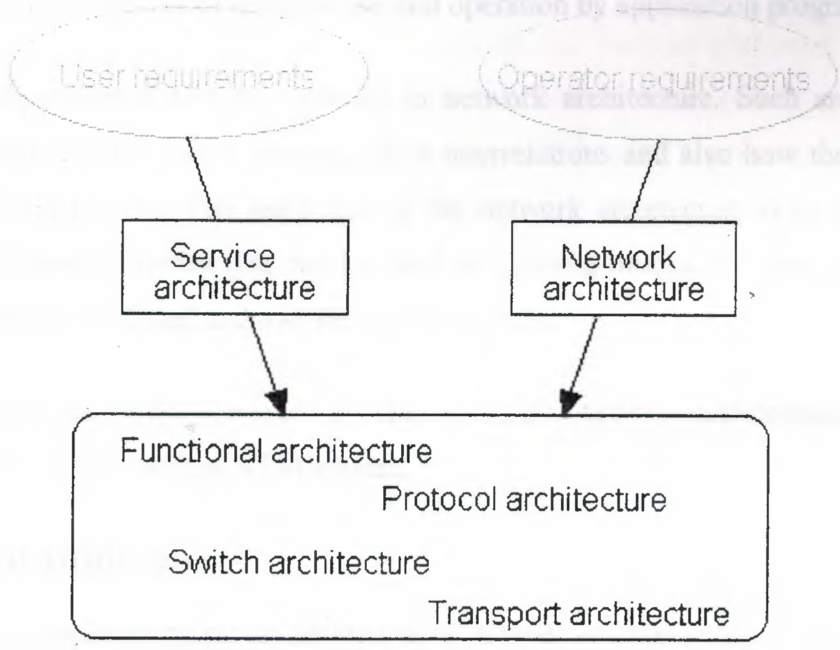

Figure 3.6 Architectures selected to describe the feasibility of wireless ATM.

In figure 3.6, user requirements of wireless ATM are captured in service architecture. The requirement that wireless ATM should provide the same service paradigm as a fixed ATM network is taken as the starting point to discuss the relevance of the ATM service architecture and modifications required to adapt it to mobile systems.

The purpose of service architecture is two-fold. During the network design stage, a simple yet powerful model of the network requirements should be sought. These are derived through some process, starting from the expected user requirements. The user requirements potentially span a very wide spectrum. To be useful, service architecture must be defined in terms of a sufficiently small set of points or regions with the continuum formed by all possible user requirements.

The second purpose of service architecture is to provide a simple model of the capabilities of a network to potential network users. In this role of the architecture, end users can benefit from it, as they need a clear view of network capabilities in order to subscribe to a network. Here, service architecture mainly performs a descriptive function. The service architecture is of more crucial importance to another group of network users, the application developers. End users are (and certainly need to be in *QoS*-based networks) shielded from the actual details of network use and operation by application programs.

The operator requirements will be captured in network architecture. Such architecture defines the network elements of a network, their interrelations and also how the wireless entities relate to fixed ATM. The main aim of the network architecture is to divide the network into a number of nodes that can be used as building blocks for integrated ATM networks, supporting both fixed and mobile communication.

According to the model presented in , the service and network architectures provide a description of the target wireless ATM system.

3.15.1 Functional Architecture.

A network implementation is defined as a number of interacting functions. The functions could roughly be divided into the contro*l* of a network and the transport of the user data. In a network such as ATM, utilizing out-of-band signaling, this division roughly coincides with the control and user planes. Accordingly, a functional architecture is a description of the control plane. Within the control plane, a number of decision making and near real-time control functions is executed. In the case of ATM, the main such control functions are call admission and set-up. These are also needed in wireless ATM but they must be complemented by a number of mobile specific functions. A functional architecture of wireless ATM must provide a model of how these functions interact.

3.15.2 Transport Architecture.

In the user plane, application data is transported. In the case of ATM, the main function of the user plane is to implement cell relay for ATM cells. The user plane and related functions are responsible for ensuring connection QoS. Due to their real-time nature, some ATM network functions are connected to the user plane. These include policing and flow control. The reason for identifying these functions as transport or user plane functions is that they must potentially be applied to each cell. Cell level functions typically require significantly different implementation methods than functions executed only once or a few times per call (for instance call set-up).

3.15.3 Protocol Architecture

Protocol architecture refers to a description of the various protocols and their layering in a communication network. Protocol architecture covers more than just the layering principles used. It identifies the protocols used at each layer of each system interface. Protocol architecture can be further subdivided into the control (signaling protocol architecture) and user planes.

3.15.4 Switch Architecture

The key components of any ATM network are the switches. Since switches play such a central role in ATM, the feasibility of integrating mobile specific functions that affect connection routing (for instance handover) is dependent on whether switch architectures can be enhanced to support mobility. A number of options to implement ATM switches exist. Depending on the basic design selected, a number of alternative switch architectures emerge. Wireless ATM could have a rather profound impact on ATM switch architectures when the same switches are used to support both fixed and wireless communication.

In the above selection, a number of important architectures have been excluded. To give a flavor of the overall scope of the issues of wireless ATM, some of the remaining architectures are briefly listed.

3.15.5 Management Architecture

The management of a network is perhaps the most common network support function, as it is required in all networks. Typical networks consist of 100's, perhaps 1000's of different nodes or components manufactured by different vendors. To be able to manage such a network efficiently, management architecture and related standards are needed. Today, most network management systems are based on agent/manager architecture, and the Simple Network Management Protocol (SNMP) is probably the most widely used management protocol.

End system hardware architecture. The end system (terminal), used in a communication system, is evidently of great interest to the user. It is also a key element of creating a market where different manufactures can operate to provide complete terminal solutions as well as components, such as interface cards or communications software. Typical hardware architectures are based on existing computer platforms, but other architectures could be envisaged as well. One of the reasons to exclude end-system considerations from this thesis is that end-system architectures are seldom standardized and are thus mainly a manufacturer-specific concern.

3.15.6 Application Architecture

Increasingly, communication services are used by interactive software. As the services increase in complexity, so do the applications. To enable rapid and efficient application development, applications also need to become more structured. A number of approaches to enable software portability and modularity have been devised. These include the use of standardised Application Programming Interfaces (API), object oriented software, distributed processing and the use of so-called middleware and advanced operating system features. Regardless of the technique chosen, a description of how applications are expected to use the communication services is needed and can be included in application architecture. As application architectures seldom are ATM specific, this very broad subject has been excluded.

3.15.7 Security Architecture

While the importance of network security grows each day, mobile communication adds new security considerations. These include policies and functions needed to ensure, on the one hand, user mobility, and on the other, sufficient protection of networks, application and data. Of the disciplines related to mobile communication, security is one of the most complex and certainly requires a much more in-depth treatment than would be possible in this thesis. It has been noted that security has been identified as an important part of general ATM work, and that the security problems that relate to mobile systems are in no way unique to wireless ATM. Thus existing work on security can form the basis for security architecture for wireless ATM.

3.15.8 Service Architecture

In this thesis, the role of the service architecture is to span the conceptual gap between user requirements for, and the implementation of, wireless ATM. In other work, this step has often been handled by defining a number of target applications and listing their requirements in terms of parameters and their values. For networks providing a single type of service, this has been a reasonable procedure. With the advent of multi-service networks, the problem space has grown significantly. If describing a network, providing a single type of service, is considered a one-dimensional problem, describing a multi-service network must be viewed as at least a two-dimensional but possibly N-dimensional problem. Simply compiling a list of parameters and their relevant values does not sufficiently describe such a network.

Instead of simply listing a number of parameters, the service requirements of wireless ATM will be defined using architecture. Transforming user requirements into a set of service components allows service architecture to capture the requirements in a concise way. This is a much more powerful approach than simply identifying a number of applications and their parameters.

The concept of Quality of Service is the foundation of the ATM service architecture. This chapter will therefore focus on extending the QoS principles of fixed ATM to the wireless area. First, the role of the network in overall multimedia service provision is discussed. Next, the role of Quality of Service in multimedia, multi-service networks is presented. Then the components of the ATM service architecture and in particular the related QoS mechanisms are presented and their applicability to wireless ATM networks discussed. Finally, service architecture, based on the existing fixed ATM network, is developed for wireless ATM.

4. WATM NETWORKS

A network is built of a number of systems, mostly referred to as nodes, and the physical links connecting them. Network architecture defines the types of nodes that can exist in a network and how they can be connected. The main nodes of a fixed ATM network are the switches and the ATM terminals. The physical links play a minor role in typical network architectures; in general only the types of links that can be used are enumerated.

4.1 Fixed ATM Networks

The central component of an ATM network is the switch. Most ATM standards relate, in one way or another, to the behavior of the switch. The purpose of the switches is to interconnect user equipment; this being the second main node type of fixed ATM networks.

To interconnect the nodes of fixed ATM networks, two principal network interfaces have been identified; the User-Network Interface (UNI) and the Network-Network Interface (NNI, also referred to as the Network-Node Interface). The UNI connects user equipment to the ATM network, while the NNI interface is used to interconnect ATM switches. This section will discuss the architectural issues of fixed ATM networks by presenting the roles of these two interfaces.

4.1.1 UNI Interface

User equipment accesses the services, provided by an ATM network, over the UNI interface. This is done by requesting ATM connections to be set-up or released. The user equipment can vary in complexity from only a single workstation to a complete, user-owned or user-operated ATM network with hundreds or thousands of connected workstations.

The ATM Forum reference configuration is in many ways simpler than the ITU one. It is also more oriented towards describing actual physical interfaces and emphasizes the commonalties between the different parts of the ATM network to reduce the overall complexity. The ATM Forum reference configuration is shown in figure 4.1

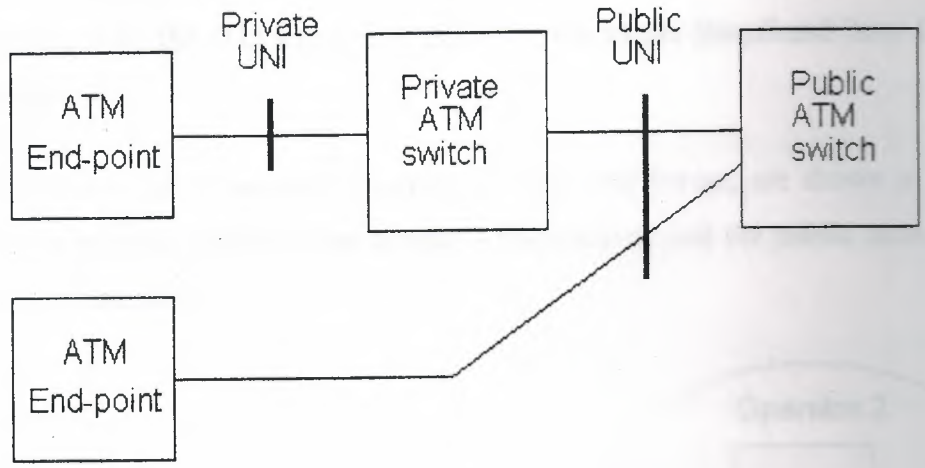

Figure 4.1 ATM Forum reference configurations.

For connecting equipment to an ATM network, the ATM Forum reference configuration only specifies two interfaces, a public UNI and a private UNI, and even these are effectively identical. One of the reasons for having two different UNIs is the different requirements put on the physical layer(s) used at each interface. In a private environment, the distance between the user device and the switch will mostly be quite short. In a public environment, the physical layer must support data transmission over long distances, and hence a different physical layer might be needed. The functionality supported at an interface (other than the physical characteristics, such as transmission speed) are not affected by the choice of a physical interface.

4.1.2 NNI Interface

The NNI interface is used to interconnect ATM switch equipment. Three main types of NNI interfaces can be distinguished:

- between switches belonging to a private ATM network; this interface is being defined by the ATM Forum under the name of Private NNI or PNNI,

- between switches in the public network belonging the same operator; this interface is being defined mainly by the ITU even though public operators could adopt the ATM Forum PNNI interface also for public networks,
- Switches in the public network belonging to different operators, the interface are being defined by the ITU and by the ATM Forum as the Broadband Inter Carrier Interface (B-ICI).

The various NNI interfaces, mapped according to the ATM Forum, are shown in figure 4.2 Note that the interface between the private ATM network and the public network of operator 1 is a UNI interface.

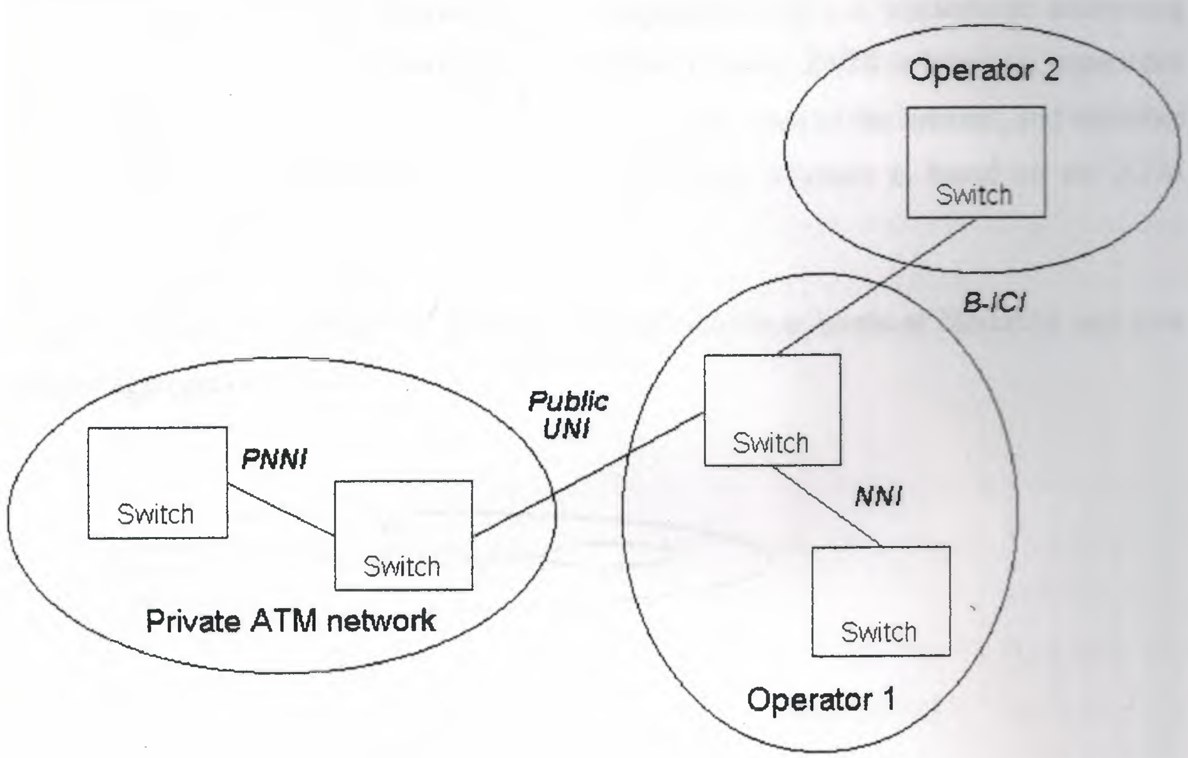

Figure 4.2 ATM network interfaces.

The 'functional' role of the NNI is very different from the UNI. At the NNI, switches interact to route a connection set-up from the call originator towards the destination. This is a non-trivial function with many sub-tasks. It includes finding where the called party (the destination of the call set-up) is located and selecting a route through the network from the originator to the destination. The route must also ensure that the QoS, requested for the connection, is honored.

4.1.3 Connection Routing

Routing a call set-up in an ATM network is the most important and complex NNI function. Routing is closely related to the addressing structure used. In an ATM network, each terminal has an address that uniquely identifies the terminal. This address is used in the ATM call set-up. The ATM address is distinct from the VPI and VCI used in the ATM cell header.

The PNNI protocol provides a good example of how a hierarchical addressing structure can be used in a network with fixed terminals only. PNNI is based on experience obtained from routing protocols used in packet networks, such as the Internet, and therefore has a hierarchy similar to these. The PNNI addressing structure is based on the ATM Forum NSAP address.

Figure 4.3 shows an example of a PNNI network with three levels of hierarchy and how address aggregation is used.

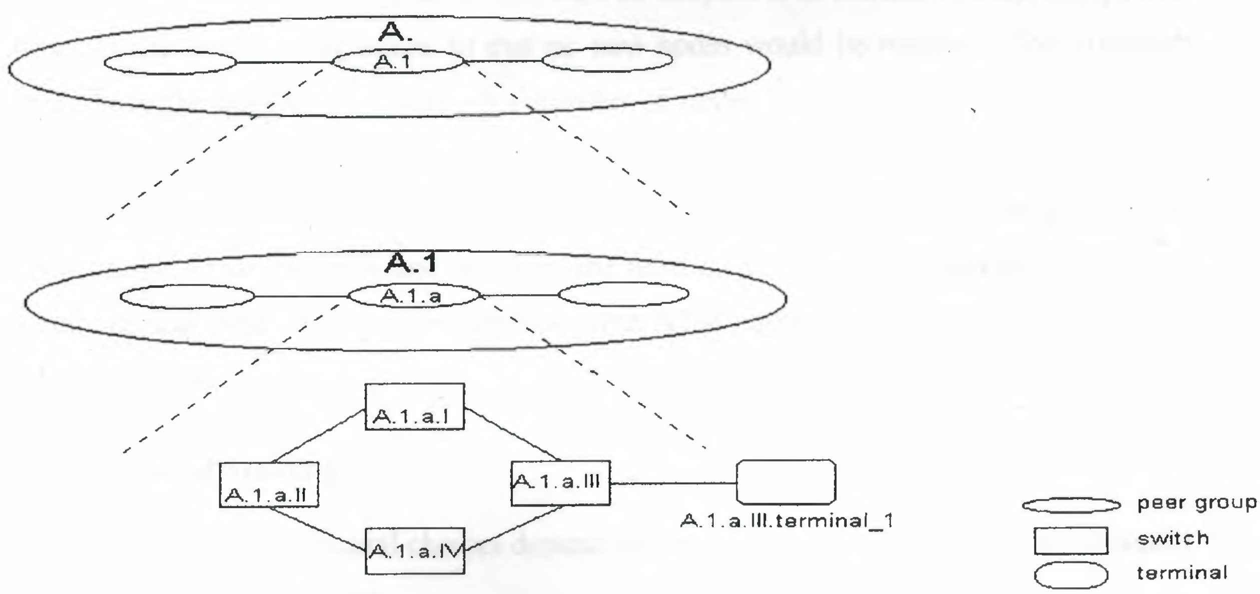

Figure 4.3 An example of a PNNI network

This is shown in figure 4.3 At the level of the overall network (A), the nodes, both switches and terminals, within the hierarchy shown can be referred to with the aggregated address A.1. Thus at the topmost level, any address with a prefix A.1 can be routed to the logical node A.1 for further processing. If the target address is A.1.a.III.terminal_1, these processes of stepwise refining the location address is continued as one proceeds down the routing and address hierarchy.

PNNI can also support terminals with addresses that do not match the PNNI address hierarchy.

4.2 Wireless Extension of ATM Network Architecture

The network architecture of wireless ATM can be conceived along two main lines. One possible approach would be to keep the existing nodes of an ATM network (mainly the switches) as unchanged as possible and introduce any mobility specific functionality as new, separate nodes. This has the benefit of being backwards compatible with existing installations and standards and thus has little impact on networks intended for fixed only communication. The main drawback of this approach is that it creates an overlay network for wireless ATM.

The other extreme approach that could be adopted is to include all mobility specific functionality into existing nodes so that no new nodes would be required. This approach could have the benefit of reducing the number of nodes and allowing all networks to be fully mobile capable. It would however introduce significant overhead into those networks that do not serve mobile users. The final architectural choice probably lies somewhere between these two extremes and balances the need to integrate some aspects of mobility while keeping some other aspects separate from ATM equipment, intended for fixed only communication.

4.2.1 Impact of Mobility

The basic architectural choices depend on whether the UNI or the NNI are enhanced with mobile specific features.

At the UNI, most service access aspects of a mobile user are rather similar to fixed users and the same connection management mechanisms are useable both for fixed and wireless users. If user mobility covers more than one UNI interface, mobility specific enhancements are required to support handovers and the resulting connection reconfiguration. The ability of a user to appear at any one of a multitude of interfaces, results in stringent requirements on dynamic user identification and authentication.

4.2.2 Overlay Mobility

In a network corresponding to our definition of overlay mobility, all mobile specific equipment is 'outside' the ATM network. The ATM network in itself does not provide any support for wireless ATM. In this respect, it falls outside the options listed in . The overlay equipment is connected to the ATM network over the ATM UNI interface, and the ATM network only provides switched or permanent ATM connections between the mobility specific equipment or to fixed users.

Figure 4.4 provides a schematic layout for a mobile system based on the overlay mobility concept. As can be seen, the overall network can be divided into two domains, the mobile network and the (standard) ATM network. In most proposals, the mobile specific part consists of two node types. The first type is a mobility support node, labelled "Mobility node" in Figure 4.4. The second type is the base station that is connected to the mobility support node. In most suggestions, the base station is rather simple and mainly performs radio-to-wire conversion. The mobility support node has most of the responsibility for controlling mobile communication. This includes tracking users, performing local connection management and providing support for handovers between base stations and, in some cases, between mobility support nodes as well. For wireless ATM, the mobility support node is in most cases an enhanced ATM switch with significant non-standard functionality. In particular, the signaling protocols are often 'tailor' made and not based on standard ATM signaling protocols.

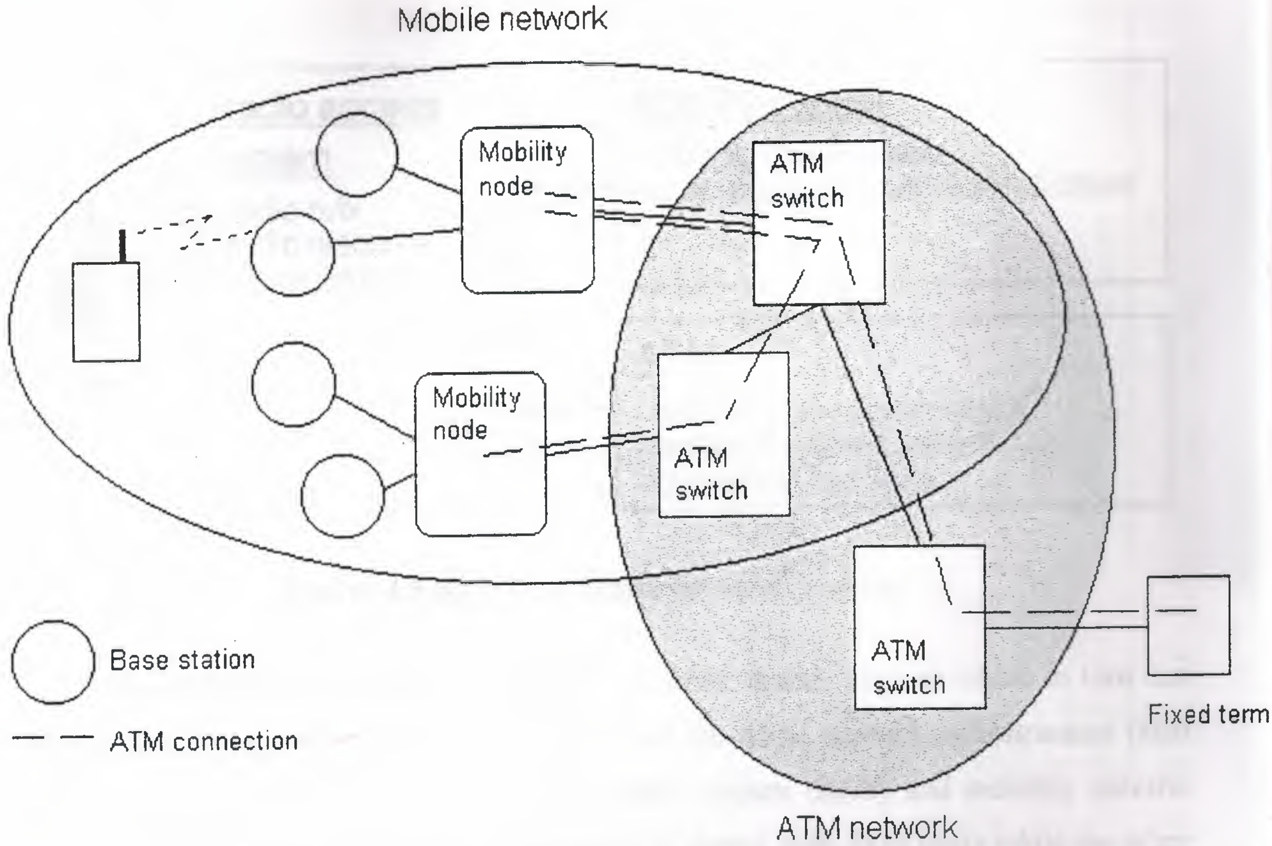

Figure 4.4 Basic structure of edge-to-edge mobility in ATM

4.3 Wireless ATM Network Architecture

There already exists significant work describing the characteristics of an ATM network integrating mobility.

The main features are here rather similar, and the resulting basic network architectures could be described using the simple overall architecture in, commonly used to describe the network architecture of the UMTS system.

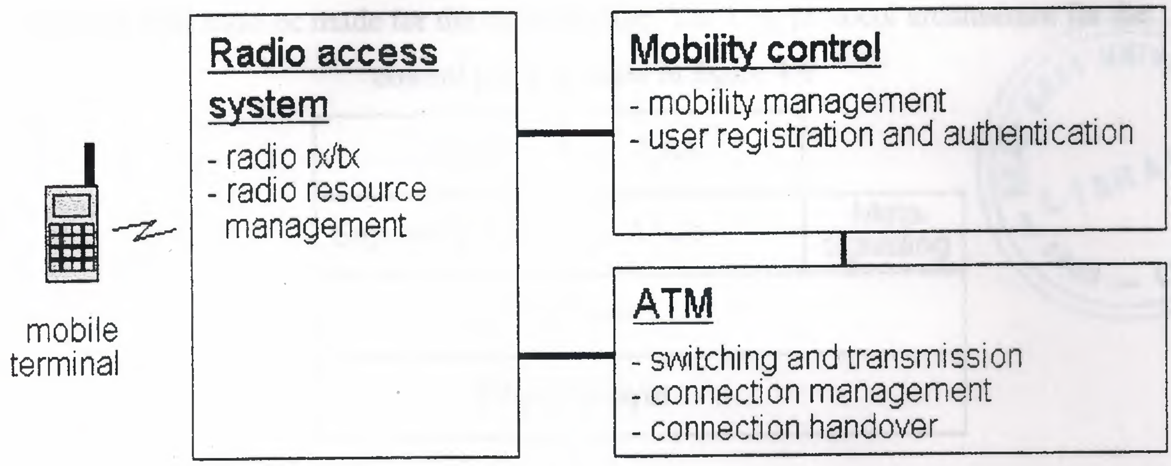

Figure 4.5 Basic architecture for wireless ATM.

The architecture in Figure 4.5 consists of three blocks, each of which in turn can have significant internal structure. The blocks are the ATM network infrastructure (also referred to as the core network), the radio access system (RAS) and mobility specific control. Of these components, the ATM network is shared with fixed users while the other two allow the core ATM network to be extended in a modular fashion to support mobile users.

4.4 The ATM Protocol Architecture

The protocol architecture for fixed ATM networks can be viewed separately for the user and control planes. The user plane architecture is simple and shown in.

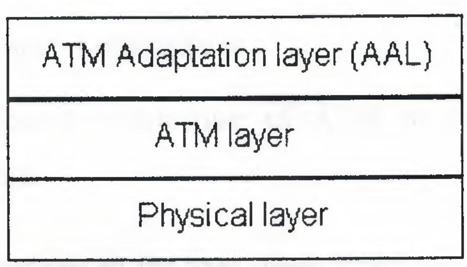

Figure 4.5 User plane protocol architecture for ATM.

The control plane architecture is somewhat more elaborate. A distinction between the UNI and the NNI must be made for the control plane. The UNI protocol architecture for the control plane is show in figure 4.6

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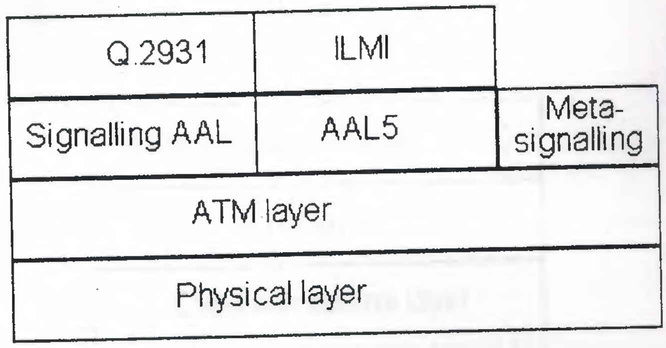

Figure 4.6 Control plane protocol architecture of ATM.

In the UNI control plane, the connection control protocol, generically referred to by its ITU name Q.2931 [is used to control connection set-up and release. The Integrated Layer Management Interface (ILMI), protocol, defined by the ATM Forum, is used for interface management and functions such as address assignment. In addition, the ITU has defined a protocol, using which a user terminal can obtain a signaling channel. This protocol is called meta signaling.

At the NNI in private networks, the PNNI protocol replaces the Q.2931 in ATM Forum recommendations. In the ATM Forum, both the UNI and the NNI protocol architectures are rather rigid, based mainly on assigning a standard VCI value to different protocols.

4.4.1 Wireless ATM Protocol Architecture

To extend the protocol architecture of ATM to support wireless users, two objectives must be considered.

Firstly, any modifications to the user plane protocol stack should occur below the ATM layer. Only if the ATM and upper layers remain unmodified, can the objectives of end-to-end transparency be achieved.

The second objective is that signaling should remain compatible with fixed ATM where common functions exist, but be implemented as a modular extension for mobile specific aspects

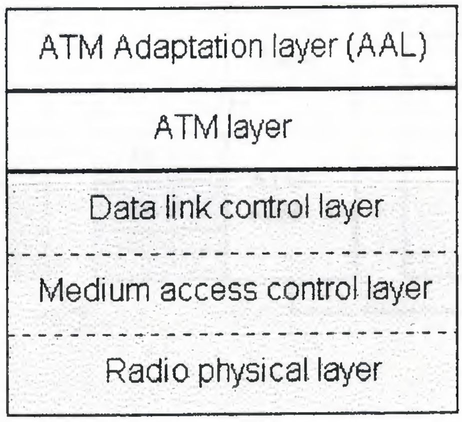

Figure 4.7 Extended user plane protocol architecture for wireless ATM.

In Figure 4.7, the radio physical layer is responsible for radio transmission aspects such as modulation and power control. This layer is quite dependent on the targeted frequency range and cell size.

The medium access control (MAC) layer allows the radio interface to be shared. In wireless ATM, a key aspect of the MAC is to allow each ATM VC to be separately processed at the radio interface.

The wireless data link control layer is typically used to enhance the error performance of the lower layers within the QoS delay bounds of the connections. Mechanisms such as selective retransmission could be used.

The main theme seems to be that the fixed ATM connection control protocol is reused for connection management. In some cases, mobility is embedded into the connection control protocol, but most proposals use a separate protocol for mobility specific functions. Such an alternative for the UNI is illustrated in figure 4.8

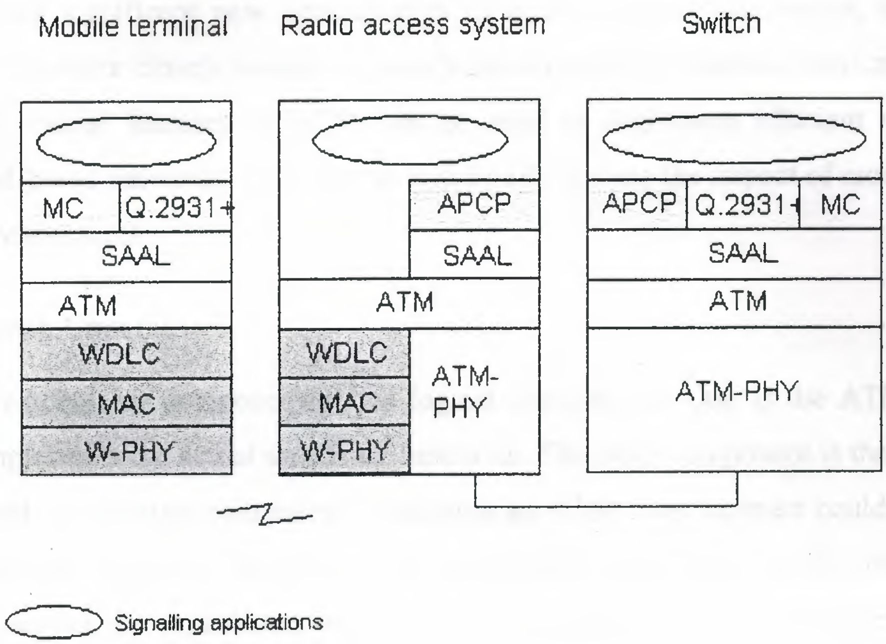

Figure 4.8 Control plane protocol architecture at the wireless ATM switch UNI.

In figure 4.8 Q.2931+ refers to a generic, enhanced version of the fixed ATM connection management protocol (either ITU Q.2931 or ATM Forum 4.0). The basic protocol has been enhanced to support handover.

4.5 Switch Architecture

The ATM switch is the central component of an ATM network; most ATM features and capabilities are implemented in the switch. An ATM switch can be implemented in a number of different ways. The main design alternatives are typically described using generic switch architectures, which then are refined by manufacturers.

In integrated network architecture, the ATM switch must, in addition to the functions shared with fixed ATM, also implement a minimum set of mobile related switching functions. This includes at least connection reconfiguration in the case of inter-UNI handover. To make integrating mobility into ATM switches feasible, the mobility specific enhancement should be small in terms of increased switch complexity the switching functions of ATM differ from those of circuit switched networks, such as the

ISDN. Consequently, introducing mobility support into ATM offers a different set of problems but also significant new opportunities. Due to its pocketsize nature, mobility support in ATM is more closely related to today's packet networks than to classical circuit switching. The special features of ATM can be used to implement efficient mobility support in ATM-based networks. This section will briefly discuss the impact of mobility on ATM switch architectures.

4.5.1 ATM Switch Capabilities

ATM switches are composed of two logical components. One is the ATM cross connect that implements the actual switching functions. The other component is the control part of the switch. A network component containing an ATM cross connect could also be called a multiplexer if it only has limited or no control capabilities. As the following discussion focuses on the capabilities of the ATM cross connect, it is applicable also to multiplexers, etc.

The purpose of the ATM cross connect is to forward ATM cells between its ports. The cross connect performs three main tasks. For each cell arriving at an input port, the cross connects must:

- decide on the output port to which the cell must be routed,
- modify the cell header to the correct header information required on the link corresponding to the new output port (this includes setting new VC and VP values),
- Buffer cells, when several cells simultaneously compete for a single output port or to compensate for timing differences in cell slots for the input and output ports.

An ATM cross connect can be described using a simple model, shown in figure 4.9 The example does not consider 'non-switching' functions, such as UPC, flow control or congestion notification that also should be viewed as part of the transport functions of a complete switch.

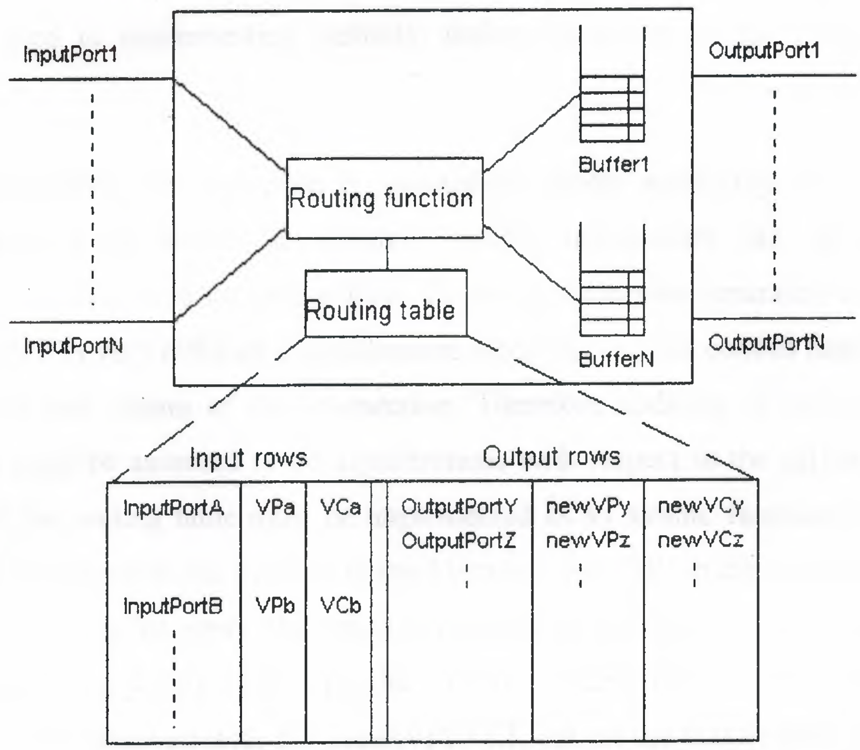

Figure 4.9 Basic functions of an ATM switch

In figure 4.9 a routing function in the cross connect receives cells from VP/VCs on the input ports. The routing function access a routing table using a combination of the input port, VCI and VPI of the received cell. The routing information for each cell is found in the routing table. The routing information indicates the output port to which the cell should be sent as well as the new VPI/VCI values that should be inserted into the cell header. The routing function places the cell in a buffer. When the output port becomes idle, the next cell in the buffer is sent over the output port.

Figure 4.9 illustrates the general function of a cross connects without any loss of generality. The description is however done using a specific architecture, normally referred to as routing table driven and output buffered. The actions of routing, header substitution and buffering can also be performed in a different order. Contains an extensive overview of existing ATM switch architectures.

A number of ATM features can be derived from the basic architecture, shown in figure 4.9. They can be used in implementing mobility, mainly handover, in an ATM cross connect.

- Connection rerouting. A connection is rerouted by simply modifying the routing table. Depending on switch architecture, routing information can be either centralized (accessed once for each cell) or distributed (accessed separately in each switch stage). It is very difficult to synchronies signaling and the control functions, related to the cell stream of that connection. Therefore updating of the routing information must be assumed to be asynchronous with respect to the cell stream. Updating of the routing table must be implemented as an atomic function so that rerouting of a connection can be implemented between two cells in the cell stream.
- Asymmetry. As can be seen, the routing function is asymmetric. The routing function operates on a cell with a specific VPI/VCI value, received on a specific input port. A cell received with the same VPI/VCI, but on the output port, can be routed (if required) in a totally different manner. Therefore switches can, if needed, process the uplink and downlink directions of a connection differently.
- Support for multicast. The routing function supports multicasting as a natural extension of the basic functionality. Multicasting only implies that several outputs are listed for a specific input value and that the cell to be routed is copied (with different header values) to the different destinations. A number of proposals exist for implementing handover using multicasting and hence multicast support is of interest. Combining the multicast capability with asymmetry, as mentioned above, indicates that a connection can use multicast in one direction without necessarily using it in the other.
- Various buffering strategies. A cross connect can employ buffers at many places and for many purposes. Possible buffering strategies include input buffering (each cell is stored in a buffer before routing/forwarding), output buffering (shown in 4.9), per VP or per VC buffering, a combination of the previous, etc. The implication is that an unspecified number of ATM cells, pertaining to a given connection, could be present in the various buffers of a cross connect at any given instant. For connections with no delay guarantees, it is consequently not reasonable to provide

tight estimates on the upper bound of the latency of the switch and reasonable mobility schemes should therefore not be based on assumptions about switch latency.

The introduction of ABR will certainly impact switch architectures, as supporting ABR will require a number of new switch functions. Supporting ER flow control will place the most requirements on switches. To support ER, a switch needs to be able to perform at least the following functions in real time:

- Monitor user cell streams for RM cells and extract them for processing.
- Process, in real-time, the contents of the RM cells.
- Estimate, in real-time, the fair share to be allocated to a connection.
- Update the RM cell according to the fair share and re-insert it into the ATM cell stream of the connection.

Not much has yet been published about switch architectures conforming to the ATM Forum ABR flow control specification. It is therefore not possible to give examples of how switch architectures will evolve to support ABR.

4.6 WATM Handover

Handover is one of the major task for a mobile system to be able to support continues mobility into different radio coverage areas. It is defined as procedure taking place when a mobile change the current used radio channel to another radio channel during an existing and active radio connection.

Several different handover schemes have been proposed for WATM. The evaluation of the different proposals are though closely related to what issues are regarded the most important to preserve together with implementation complexity.

For real time services delay and delay sensitivity is very important. For the non real time services an optimization of the handover solution is performed to prevent cell loss and bit errors. If it would be possible to use different handover schemes for different types of traffic, perhaps it would be easier to preserve the requirements of each service class. This would though introduce more complexity constructing the supporting mobility management functionality, and is for the time being regarded not relevant.

4.6.1 Handover Terminology

In connection with the network structure it is common to distinguish between two different handover regions or domains

4.6.1.1 Radio Handover

Radio handover is taking place within a serving region of one access point (AP). A mobile station can move between radio ports (RP) but stay within the coverage region of an AP. This radio handover, as the name indicates, only involves the Radio Access Layer (RAL) of the protocol architecture. The switching takes place in the Logical Link Control (LLC) layer. No network routing has to be done in this case i.e. the ATM layer is not involved.

4.6.1.2 Network Handover

Network handover takes place if the mobile moves between End User ATM switch (EMAS-E) serving regions. The network layers of the architecture will then be involved in the handover procedure, and in this case the VPI/VCI of the connection to the mobile station may be changed.

4.6.1.3 Hard Handover

This is often denoted brake-before-make. Moving between to RPs the connection held by the old RP is released before the connection to the mobile through the new RP is established.

4.6.1.4 Soft Handover

This is often denoted make-before-brake. The connection through the new AP is established and data and control messages are transferred on the new connection before the old one is released. After a short time period the old connection is released.

When mobile moves into a new coverage region the signal strength from the current RP fades while the signal strength from up-coming RPs grows stronger. These new RP(s) identifies them self in the control signals received by the mobile terminal. The Mobile terminal (MT) and the current RP both notice that the MT starts to move to far apart and the network will try to hand the connection over to a new RP. Now both the MT and the RP may initiate the handover. In either case the handover signals must be carried on one signaling paths to the RP. If the handover control signaling messages is carried on the already established connections between the MT and the RP it is denoted backward handover or connected handover. The handover signals move backwards into the old coverage region. Opposite, if the handover signals are transferred towards the new RP on the not yet established connection the MT is doing a forward handover or a disconnected handover.

4.6.1.5 WATM Handover Support

WATM supports handover by means of an infrastructure containing radio ports (RP), Access Points (AP), End-user Mobility enabled Switch-Entry (EMAS-E) and Crossover Switches (COS). The EMAS-E and the COS can be the same entity if the EMAS-E has the capability to re-route the connections between EMAS-Es in cases of handover. The AP and the EMAS-E can be physical modular components, or they can be integrated in one physical unit. Each AP can serve several radio ports and several AP can be under the control of one EMAS-E. Communication between EMAS-Es is routed through Crossover Switches, or EMASes. The COS will be the nearest ATM switch able to re-route the connections. The EMAS-E and the MT communicates over the common UNI protocol, only enhanced with some dedicated mobility support. In addition the ATM Forum has specified functionality that is required between the ATM convergence layer (ATM-CL) and the RAL regarding radio resource management. These functions will include service-related information, ATM connection establishment and release indications, and connection handover support.

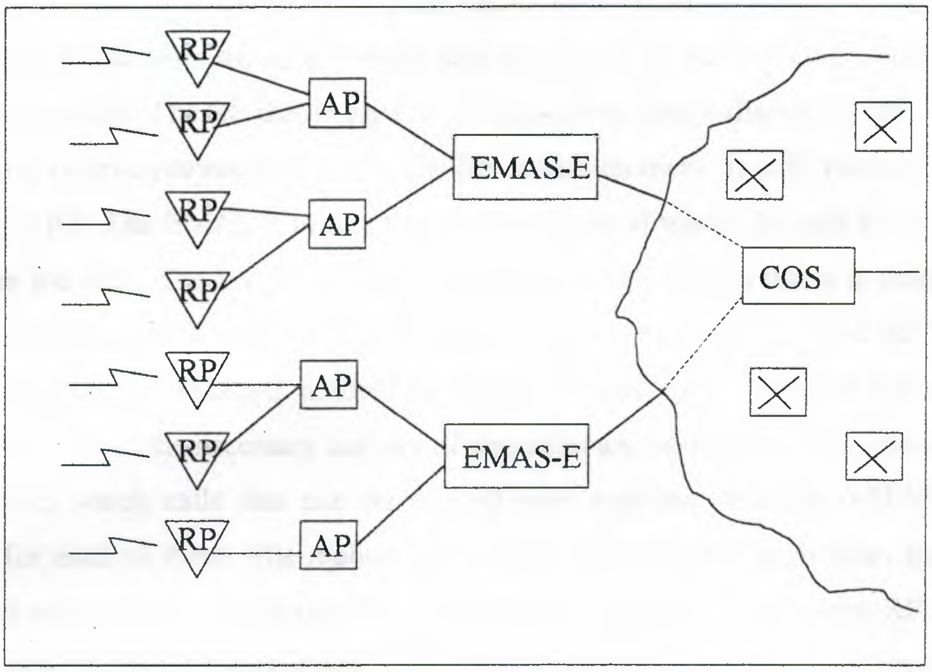

Figure 4.10 Radio access configurations for WATM

Between the EMAS-E and the COS, a mobility enhanced version of the NNI protocol (NNI+M) is deployed. Figure 4.10 illustrates the network configuration of WATM, and figure 6-2 depicts the reference model for the radio access.

The assumption of the ATM Forum for the Capability Set 1 (CS1) is to support both radio and network handover, deploying the hard handover scheme. No re-negotiation of ATM traffic contract or QoS parameters will be supported. Handover control messages will be transported over dedicated control channels between different EMAS-Em's. A Handover Control Channel (HCC) is specified to transfer the handover control messages between the EMAS-Es optionally through a COS/EMAS.

Both backward and forward handover will be supported by WATM. Backward handover is usually first choice. In case the radio link is disrupted or lost In one or another way, the ATM level will be notified by the radio level, and a forward handover procedure will be initiated to recover the connection.

A successful handover procedure will contain the following steps. The mobile station initiates the handover by sending a handover request message containing the call references of all the calls involved, and a prioritized list of actual possible radio ports to take over the calls. The EMAS-E wills quire the AP(s) handling the actual RP(s) to identify a certain RP to take over the calls. Notice that there may be several calls involved in the handover procedure. The RP that is capable of supporting most calls will be preferred. The AP does not reserve resources at a specific RP at this moment. It only responds with the identity of a RP. The EMAS-E makes the final decision of which AP and RP that will be taking over the calls. The EMAS-E then notifies the mobile station that it is ready to hand over a certain number of call references, and the identities of the AP and RP involved. Immediately after the EMAS-E notifies the target AP, and the AP notifies the actual RP. The AP then reserve the necessary amount of resources and responds to the EMAS-E that it is ready, and which calls that can be handed over together with the VPI/VCI values allocated for each of them. The mobile station then disassociates itself from the old RP, releases all radio resources from this RP, and makes an association to the new RP.

Finally the mobile station communicates to the EMAS-E that it is ready to resume to normal communication phase and the EMAS-E respond with the VPI/VCIs of the calls that successfully made it through the handover phase.

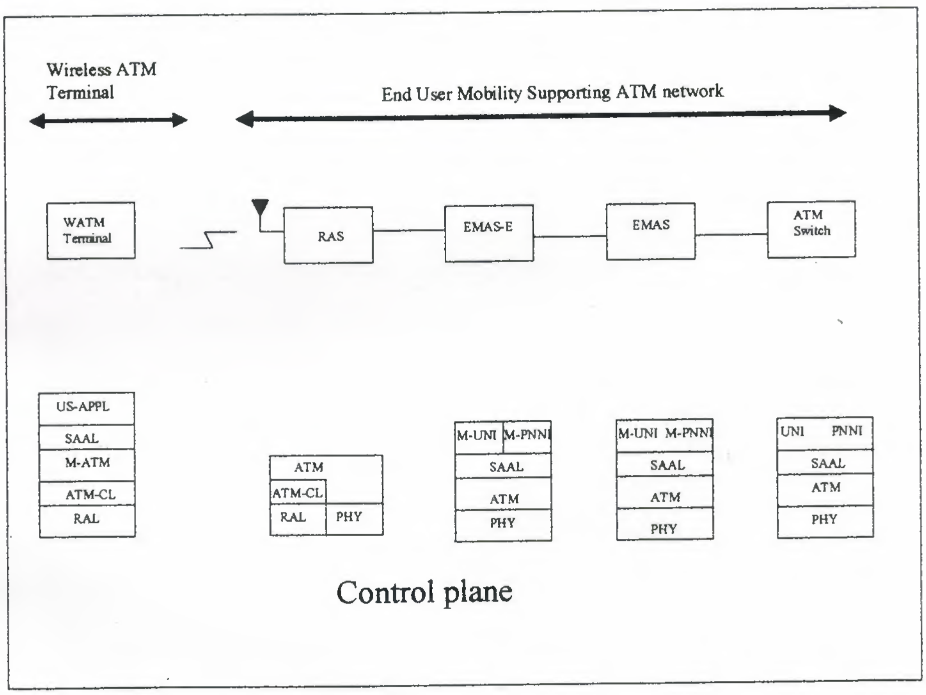

Fig. 4.11 Protocol reference model for the radio access in WATM

WATM operates with three different handover scenarios:

1-Intra RAS (Radio Access System), Handover between different RP within the domain of one AP. The EMAS-E and the ATM level, is not necessarily involved if the radio layer implement radio handover functionality

2-Intra EMAS-E, Handover between different AP, only involving one EMAS-E. The ATM level is involved in this case and ATM level handover must be implemented.

inter

3-EMAS-E., This handover scenario involves different EMAS-E(es). To re-route the connection from one EMAS-E to the other EMAS-E, the connection may have to be re-routed through a COS.

The overall functionality of WATM handover is therefore pretty mature. Many problems regarding WATM handover are though still unsolved. The problems remaining are mostly focused on detailed algorithms for routing decision, resource information gathering from surrounding RP, signaling messages details and QoS consideration during the handover phase.

CONCLUSION

The age of wireless communication has started and will in all likelihood be transformed into the age of wireless broadband communication sooner than we expect. Wireless ATM is an emerging technology that seems to possess all the capabilities required to successfully provide a networking platform for wireless broadband systems.

The basic capabilities of ATM such as multi service, multimedia capabilities, applicability for the whole range of services regardless of bandwidth, and the widespread deployment in both public and private environments. This makes ATM a unique base technology for wireless broadband networks.

As the ATM standards process is still on-going, a unique opportunity exists to achieve integration of mobile and fixed communication. The ATM Forum Anchorage Accord defines a set of standards as a base line for future work. This set of standards is sufficiently advanced to form a good basis for work on wireless systems. They can be used in wireless ATM according to the basic principles, ensuring backward compatibility and customer investment protection. Of course much work is still needed, but if the opportunity is seized, ATM networks could, in a few years' time, emerge as a broadband infrastructure well justifying the serving all kinds of communication needs for all types of users, including mobile ones.

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