Wireless ATM

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Abstract

Wireless and ATM (Asynchronous Transfer Mode) are in it's infancy. No standards have been defined by either the ATM Forum or ITU-T, yet. Research have been going on to develop a protocol that will run on wireless medium without much delay and errors. ATM-type wireless networks will play an important role in the broadband communications network of the future.

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1. Introduction:

Since the late seventies, we have been watching movies and television serials, in which people are using mobile equipment to communicate and exchange multimedia traffic over small, handheld portable equipment. But now, due to the advent of high speed networks (such as ATM), and recent advancement in mobile communications, visions of past are fast becoming a reality. These days people are talking and publishing their works in journals and magazines, on how to achieve this amazing feat of integrating Wireless with Broadband High Speed Networks.

Wireless personal communication networks (PCN) based on new digital technologies have emerged as an important field of activity in telecommunications [1]. This is mainly due to the success of mobile phones, pagers, notebook computers. The days are fast approaching when we can send, receive e-mail or faxes, watch and talk at the same time, from anywhere by using a simple handheld device or a laptop computer. There are numerous applications of wireless networks. In the closing years of the 20th century, the current distinction between telephony and computing will disappear as communication becomes the integrated transmission of information in several media (voice, data, image, and text); customized personal communicators developed from the concepts of personal digital assistants (PDAs) will offer that choice of media [7].

Due to the recent advancement of fiber, next generation wireless networks should be designed so as to easily fit and co-exist with the Broadband ISDN (Integrated Services Digital Network). In order to avoid a serious mismatch between wireline and wireless networks, it is now timely to begin consideration of broadband wireless networks with similar service capabilities (such as constant bit rate, variable bit rate, quality of service etc.) [1].

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2. Wireless Technologies:

Wireless systems are emerging, and the industry is still in it's infancy. Currently, wireless LAN technologies comprise of infrared (IR), UHF radio, spread spectrum, and microwave radio, ranging from frequencies in the region of Ghz in Europe (900 Mhz in the U.S.) to infrared frequencies [7]. The personal communication network (PCN) may use a shared wideband code-division multiple access (CDMA) band, and digital cellular service another time-division multiple access (TDMA).. There is a considerable controversy among experts in the field regarding the relative merits of spread spectrum (CDMA) and narrow-band (TDMA) for private communication network (PCN) [1]. The preferred technique may actually vary with the specific PCN application scenario to be addressed.

- *2.1 Spread Spectrum (CDMA):*The term spread spectrum defines a class of digital radio systems in which the occupied bandwidth is considerably greater than the information rate [7]. The technique was initially proposed for military use, where the difficulties of detecting or jamming such a signal made it an attractive choice for covert communication. The term code-division multiple access (CDMA) is often used in reference to spread spectrum systems and refers to the possibility of transmitting several such signals in the same portion of spectrum by using pseudorandom codes for each one []. This can be achieved by either frequency hopping (A series of pulses of carrier at different frequencies, in a predetermined pattern) or direct sequence (A pseudorandom modulating binary waveform whose symbol rate is a large multiple of the bit rate of the original bit stream) spread spectrum and provides an alternative to frequency division multiple-access (FDMA) or time-division multiple access (TDMA) methods [7].
- *2.2 Time Division Multiple Access (TDMA):*The principle of TDMA is basically simple. Traditionally, voice channels have been created by dividing the radio spectrum into (ever narrower) frequency RF carriers (channels), with one conversation occupying one (duplex) channel [7]. This technique is known as FDMA (frequency division multiple access). TDMA divides the radio carriers into an endlessly repeated sequence of small time slots (channels). Each conversation occupies just one of these time slots. So instead of just one conversation, each radio carrier carry a number of conversations at once [7].

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3. ATM:

ATM (Asynchronous Transfer Mode) has been advocated as an important technology for the wide area interconnection of hetrogeneous networks [6]. In ATM networks, the data is divided into small, fixed length units called cells. The cell is 53 bytes. Each cell contain a 5 byte header which comprises of identification, control priority and routing information. The rest 48 bytes are the actual data. ATM does not provide any error detection operations on the user payload inside the cell, and also provides no retransmission services, and only few operations are performed on the small header.

ATM switches support two kinds of interfaces: user-network inerface (UNI) and network-node interface (NNI). UNI connects ATM end systems (hosts, routers etc.) to an ATM switch, while an NNI may be imprecisely defined as an interface connection two ATM switches together [6]. The ITU-T Recommendation requires that an ATM connection be identified with connection identifiers that are assigned for each user connection in the ATM network [6].

At the UNI, the connection is identified by two values in the cell header: the virtual path identifier (VPI) and the virtual channel identifier (VCI). Both these VPI and VCI combines together to form a virtual circuit identifier.

There are two fundamental types of ATM connections [7][3]:

- *3.1 Permanent Virtual Connections (PVC):*A PVC is a connection set up by some external mechanism, typically network management, in which a set of switches between an ATM source and destination ATM systems are programmed with the appropriate VPI/VCI values. PVCs always require some manual configuration [10].
- *3.2 Switched Virtual Connections (SVC):*An SVC is a connection that is set up automatically through signalling protocol. SVCs does not require the manual interaction needed to set up PVCs and, as such, are likely to be much more widely used. All higher layer protocols operatring over ATM primarily uses SVCs [3].

ATM adaption layers (AALs) provide mechanisms for supporting transport protocols over ATM cells. AAL1 and AAL2 have been defined by the CCITT for use in the wide area for support of constant and variable bit rate services repectively and AAL 3/4 for connection-less data transport. However, AAL5 is being proposed by the ATM-Forum for all types of computer oriented multiservice traffic especially for the local area. AAL5 has lower pay-load overhead per cell and relies on quality of service and statistical mechanisms to provide multi-service capability [6].

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4. Why Wireless ATM ?

Since the beginning, the concept of ATM is end-to-end communications i.e. in a Wide Area Network enviroment, the communication protocol will be the same i.e. ATM, and companies will no longer have to buy extra equipment (like routers or gateways) to interconnect their LANs (local area networks). Also, ATM is considered to reduce the complexity of the network and improve the flexibility while providing end-end consideration of traffic performance [1]. That is why researchers have been stressing that an ATM cell-relay paradigm be adopted as the basis for next generation wireless transport architectures [1].

Both ATM and Wireless are in it's infancy, there are no fixed standards being defined for Wireless ATM, and papers and research is still going on in this area. Therefore I will try to analyze and discuss different ideas and protocols put forward by various researchers in Wireless ATM.

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5. Wireless ATM:

There are several factors that tend to favor the use of ATM cell transport for personal communication network (PCN), including: flexible bandwidth allocation and service type selection for a range of applications, some of which are yet to be defined; efficient multiplexing of traffic from bursty data/multimedia sources; end-to-end provisioning of broadband services over wireless and wireline networks; suitability of available ATM switching equipment for inter-cell switching; improved service reliability with packet switching techniques; ease of interfacing with wired B-ISDN systems that will form the telecommunications backbone [1].

Due to the above factors, Raychaudhri and Wilson, in their paper " ATM-based Transport Architecture for Multiservice Wireless Personal Communication Networks ", recommended adoption of an ATM compatible fixed length cell-relay format for PCN. This will result in a relatively transparent interface to an ATM backbone. By using ATM switching for intercell traffic, the crucial problem of developing a new backbone network with sufficient throughput to support intercommunication among large numbers of small cells is avoided. It is noted that for PCN micro and pico cells with relatively low traffic volumes rather than direct connection to an ATM switch, it may be appropriate to use a lower cost shared media approach (such as TDM passive optical network or IEEE 802.6 optical bus) to interconnect several base stations [1].

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6. Key Issues:

The following are the key issues pertaining to wireless ATM network.

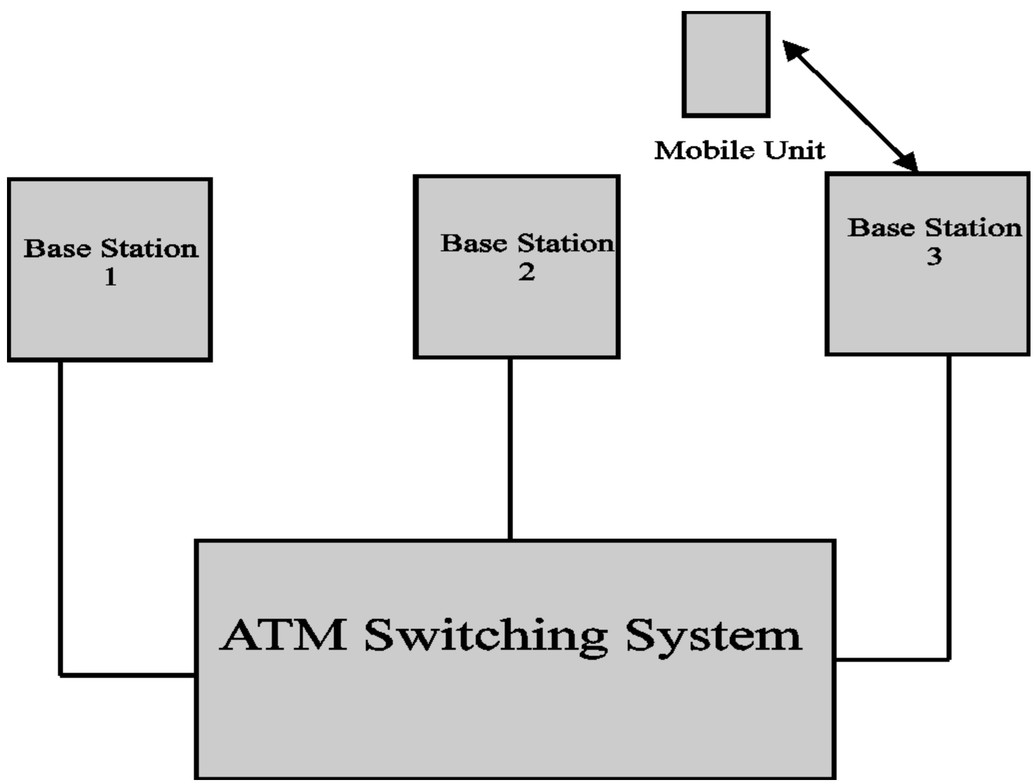
6.1. Architecture:

The architecture proposed by most researchers, composed of a large number of small transmission cells, called pico cells. Each pico cell is served by a base station. All the base station in the network are connected via the wired ATM network. The use of ATM switching for intercell traffic also avoids the crucial problem of developing a new backbone network with sufficient throughput to support intercommunication among large number of small cells [1]. 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 difficulties encountered are the delay apread due to multi-path effects and the lack of a line-of-sight path resulting in high attenuation [2]. 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 [2]. The small cell sizes also gives 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 tansfer packets and converting them to the wired ATM network from the mobile units.

In traditional mobile networks, transmission-cells are "coloured" using frequency division multiplexing or code division multiplexing to prevent interference between cells[2]. Colouring is a wasteful of bandwidth since in order for it to be successful there must be areas between re-use of the colour in which it is idle. These insactive areas could potentially be used for transmission [2].



An illustration of wireless base stations connected through an ATM switch

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6.2 Cell Size:

The ATM cell size (53 bytes) is designed for 64kbps or higher, which may be too big for some wireless LANs (due to low speed and high error rates), therefore wireless LANs may use 16 or 24 byte payload. The ATM header can also be compressed and be expanded to standard ATM at the base station [1]. An example of ATM header compression is to use 2 bytes containing 12-bit VCI (virtual channel identifier) and 4 bit control (payload type, cell loss priority etc.) [1].

One of the cell format proposed by Porter and Hopper [2] is to have a compatible pay-load size and addressing scheme, which should be different from the standard ATM cell format. Mobility should be as transparent as possible to the end-points and therefore the VCIs used by the end-points should not change during hand-over. The allocation of the VCI should remain valid as the mobile moves through different pico-cells within the same domain. The translation of the VCIs should be as simple as possible due to movement between domains. This can be done by splitting the VCI space into a number of fields like Domain Identifier, Mobile Identifier, Base Station Identifier and Virtual Circuit number. A 16 bit CRC is also used to detect bit errors, due to high error rate of mobile networks.

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6.3 Virtual Circuit Management And Packet Routing:

Each processor that attaches to the ATM switch maintains a virtual connection to each other processor over which it passes data packets, as proposed by Comer and Russo [4]. In addition, the processors use a second, separate virtual circuit for routing updates . Therefore, each wireless base station will have two virtual circuits open to each other base station and to each router. As the packet arrives the base station from the mobile wireless unit, it chooses the circuit that leads to the correct destination. Using two connections guarantees that routing information will not be confused with data because data packets never travel on the virtual circuits used for routing, and routing packets never travel on the circuits used for data. The circuits can also be assigned priority to guarantee that stations receive and process routing updates quickly [4].

The standard hop-by-hop routing method for datagrams is not adequate to cope with wireless systems, because then every node of the wireless network must store the location of every mobile system to which a route exists, which represents a large amount of information and database. Secondly, it will become impossible to keep the routing information up to date and consistent throughout the network, since a very larger number of mobile will exist.

Due to the above factors Younger [5] proposed a method by which mobile end-systtems may be added to an internetwork with the minimum of disruption. A "mobile controller" node is required in every subnet of the wireless network. Each of these controllers has its network-layer software enhanced by an additional sublayer which performs routing to mobile systems. Mobile systems are free to move between the subnets, and a network wide name server provides location information when communication with a mobile is to be initiated. A system of local caching of location information and forwarding of data allows movements to be hidden from the Transport Layer [5].

In a wide or local area network, virtual connection establishment is reasonably fast, but is likely to take longer time in wireless netowrks. Therefore it may not be practical to re-establish all virtual circuits whenever a mobile moves between pico-cells. The solution provided by Porter [2] is to isolate the small scale mobility of the mobile from the rest of the wired network latent virtual paths and the Mobile Switching Point (MSP) are used. The MSP provides a routing point through which all virtual circuits to the mobile are routed. From the mobile switching point there may be a number of potential base-stations which can be used to contact the mobile. Each of these routes for virtual circuits is termed a virtual path which can be manipulated by a single signalling command at the MSP. Whenever a virtual path is active, all of the associated virtual circuits will also be active, other virtual paths are latent - the virtual circuits have been established but no traffic is flowing [2].

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6.4 Physical Layer:

The basic design issue for next generation private communication network (PCN) is the selection of modulation methods, and a set of bit rates. A bit rate in the range of 5 -10 Mpbs can be achieved using the existing wireless technologies, in a picocellular enviroment. Thus, with the exception of HDTV, most other ATM applications can be supported. The preferred technique may actually vary with the specific PCN application scenario to be addressed, so that it is likely that both TDMA and CDMA solutions will co-exist [1].

CDMA provides an efficient integrated solution for frequency reuse and multiple access, and can typically achieve a net bandwidth efficiency 2 -4 times that of comparable narrowband approaches [1] [7]. However, a major weakness of CDMA for multiservice PCN is that for a given system bandwidth, spectrum spreading limits the peak user data rate to a relatively low value [1].

Narrow band (TDMA) can be used to achieve high bit rates, as the implementation is well understood, and has been with us for a lon time. In a pico-cellular enviroment, we can achieve a bit rate in the range of 8 -16 Mb/s, by using the narrow band approach. Overall, with a good physical level design, it should be possible for macro (5-10 km), micro (0.5 km), and pico (100m) cells to support baud rates of the order 0.1-0.25 Msym/s, 0.5-1.5 Msym/s and 2-4 Msym/s [1]. These rates should be sufficient enough to accomodate many of the broadband services.

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6.5. Media Acces Control (MAC):

One of the major problem of Wireless ATM is to find a suitable channel sharing/media access control technique at the data-li.k layer. Shared media access leads to poor quantitative performance in wireless networks.

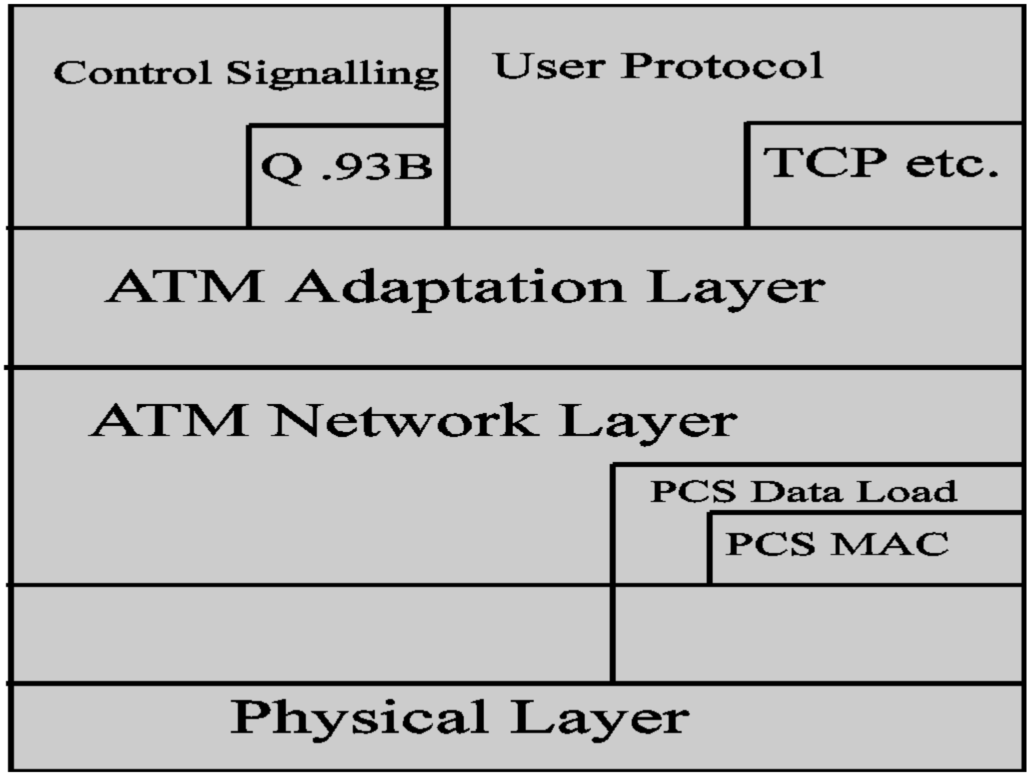
When spread spectrum modulation is used, CDMA is the de-facto mode of operation [1]. Performance results from earlier studies shows that packet CDMA can achieve good traffic multiplexing efficiency and performance for CBR, VBR and low-speed interactive data services [1], but CDMA is limited to less than or equal to 1 Mb/sec at higher speed.

Narrow band modulation (TDMA) can also be used, and researchers also suggested slotted ALOHA with exponential back-off, as the protocol used for MAC. Slotted ALOHA has considerably better delay performance at low utilisation than a fixed allocation scheme and fits well with the statistical multiplexing of ATM [2].

Younger [4] argues that ALOHA and its derivatives are ruled out since less collisions are desirable in a wireless network. CSMA/CD protocol gives the required performance on copper, but is ill suitable for wireless, where all the systems in a cell are not in communication with each other. What he suggests is a reverse channel over which the base station echoes the incoming signal. This could be done at the expense of doubling the bandwidth required, and a busy/idle signal could be broadcast on a separate narrow-band channel. One of the problem to this kind of contention-based method is that in a mixed-media applications access cannot be prioritised, though contention algorithms can be devised which increase the probability that a high-priority message will succeed in capturing the resources it requires [4].

The system proposed by Acampora et al [11][4] uses a form of TDMA (Time Division Multiple Acccess), in which the mobiles in a cell are polled to determine which of them have data to send. The mobiles are then aloowed to transmit in turn on receipt of a token from the base station. After the polling, priority is then given to units which have speech or other continous services, which can send it during the first part of the frame, and the remainder of the frame can be used for data. When the traffic is light, the unit may be allowed to send data in most of the frame. A flag bit can also be used in the packet header which is set if the mobile has more data queued for transmission. This reduces the polling overhead [4].

The challenge in designing the MAC protocol for Wireless ATM is to identify a wireless, multimedia capable MAC, which provides a sufficient degree of transparency for many ATM applications.

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Relation of Wireless Network (PCN) protocol layers of ATM [1]
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6.6. Data Link Layer:

Wireless ATM needs a custom data link layer protocol, and it should be as transparent as possible. A cutom data link protocol is needed due to high error rate and different packet size of Wireless ATM. Wireless ATM may use 16 or 24 byte payload, as 53 byte may be too long for Wireless ATMs. The data link protocol may contain service type definition, error control, segmentation and reassembly, and handoff support.

A service type field is needed so as to indicate whether a packet is of type supervisory/control, CBR, VBR ABR etc. The service type field simplifies base station protocol processing.

Wireless ATM should provide an error control due to high noise interference and poor physical level characteristics of the wireless medium. This is achieved using a PCN packet sequence number filed (e.g. 10 bits) in the header along with a standard 2-byte CRC frmae check sequence trailer [1]. HDLC style retransmission can be used for connectionless data.

Since Wilress ATM may use 16 or 24 byte cells, segmentation and reassembly is required. This can be achieved with a segment counter that uses, for example, the two least significant bits of the error control sequence (PSN) number [1].

Handoff is an important characteristic of wireless. Handoff occurs when the mobile unit leaves the area of one cell and enters the area of another. Therefore soft handoff without any data loss is important for any wireless network, and it should be transparent. This can be implemented by using bits in header, which indicates PDUs before and after the handoff.

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6.7 Network Location and Connection Establishment:

In order to establish connections between the mobile unit and the base station, the mobile must be located. Searching and registeration can pose problems. According to Porter [2]

- Searching: Involves a form of broadcast in which the whole network is queried.
- Registeration: Objects are responsible for their own registeration at a well known registeration point.

Subsequent enquiries about the object are directed to this register using static routing mechanism.The architecture explained by Porter [2] uses a hierarchical registeration scheme. When a mobile is within a domain, it is registered at the appropriate Domain Location Server (DLS) and this registers the mobile at its Home Register (HR). The HR keeps a record of the mobiles current DLS location. Each mobile has a statically bound home address which is mapped to the HR address.

One of the basic requirement of mobile units, is that the units should be allowed to roam freely from cell to cell. This process should not require any user intervention. Detection of movement in the TACS system is performed by having the base-station monitor the recieved signal strength from the mobile [4]. If the signal falls below a preset limit, the switching center looks for another base-station which is recieving a stronger signal and transfers the call to that station. An interval can be set aside in each frame, during which newly arrived or activated mobiles attempt to inform the base-station of their presence.

Connection Establishment is explained in detail by Porter [2]. In connection establishment, the host generates a connection signal, specifying the network address of the two end-points. If the destination address is that of the mobile unit, then the local Domain Location Server (DLS) is contacted. If the local DLS have no knowledge of the unit, then the routing information is forwarded to the Home Registry (HR) of the mobile. The HR returns the address of the remote DLS which in turn returns the address of the mobiles MR (mobile registeration). Once the address of the MR is known, then all the requests are directed to that particular MR. When the connection request arrives at the MR, it first consults the Mobile, which in turn decides whether to accept the call or not. If the mobile accepts the call then it allocates a virtual circuit number and return it to the MR. The MR then creates the virtual circuits between the Mobile Switching Point (MSP) and the remote end-point andadds the new virtual circuit to the active and inactive virtual paths between the MSP and the base stations close to the mobile.

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7. Conclusion:

In this paper I have tried to analyze different issues pertaining to Wirelss ATM, and discussed some of the ideas of different researchers working on it. Wireless and ATM, both are relatively new field, and are still in it's infancey. No standards have been set for Wireless ATM. Researchers have started building experimental Wireless ATM netrworks, and are implementing different protocols over it. ATM-type wireless networks will play an important role in the broadband communications networks of the future.

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