Instituto Tecnológico y de Estudios Superiores de Monterrey

Campus Monterrey

PROGRAMA DE GRADUADOS EN COMPUTACION, INFORMACION Y COMUNICACIONES

Rerouting and Handoff Management in a Mobile Wireless ATM Network

THESIS

Presented as partial fulfillment of the requirements for the academic degree of

Master of Science in Information Technology

Francisco Javier Pulido Carrillo

June 1999

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A mis padres Celestial y terrenales, sin su ayuda no lo hubiera logrado, y por que lo que soy, es gracias a ellos.

A mi amada esposa Leizle, por su paciencia, amor y determinación

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Resúmen

Recientemente, los desarrollos tecnológicos han marcado el rumbo a seguir para los Sistemas de Comunicación Personal. El nuevo paradigma de comunicación para servicios personales requerirá la coexistencia de tecnologías tales como las redes alámbricas e inalámbricas. El interés ha sido también en la conjunción de redes de Modo de Transmisión Asíncrona, *Asynchronous Transfer Mode* (ATM) y las tecnologías de acceso inalámbrico para satisfacer las nuevas demandas. En esta investigación, nos enfocamos a algunos problemas relacionados con la transportación de la información a través de una red ATM-Inalámbrica ***wireless-ATM*** tomando en cuenta los aspectos relacionados con la mobilidad y el efecto en el ruteo de la información a través de la parte alámbrica ATM del sistema.

Seguimos las técnicas y aspectos mencionados en [9] donde son tratados los esquemas de reruteo para Handoff en redes wireless ATM. En [9] es presentado un nuevo procedimiento de reruteo llamado **Nearest Common Node Rerouting** (NCNR). NCNR se concentra en el Handoff interzonas, donde una zona es atendida por un switch ATM y comprende varias Estaciones Base, *Base Station* (BS). El Handoff intrazona no es estudiado. El Handoff interzonas require técnicas de manejo de reruteo, en cambio el Handoff intrazona requiere el manejo de tablas de transición de Circuitos Virtuales, *Virtual Circuit* (VC). NCNR es también modificado para considerar el manejo de tráfico sensible y tráfico dependiente del throughput. Es presentada también una comparación entre NCNR y otros esquemas de reruteo tales como el Source Routing Mobile Circuit (SRMC) [27], BAHAMA [18] y Virtual Connection Tree (VCT). [9] También contiene nuevas medidas de desempeño enfocadas a la comparación de algoritmos de reruteo tales como el número de mensajes de señalización intercambiados durante un proceso de Handoff y reruteo, el número de nodos en la red involucrados en el reruteo, el tiempo en el que se ejecuta un Handoff, etc.

En general, NCNR se basa en encontrar la raíz que es común a las zonas que están involucradas en el proceso de Handoff. Nuestro objetivo viene de la motivación de que NCNR puede ser mejorado, y para eso proponemos modificaciones y una mezcla de esquemas para lograr esta mejora. Básicamente lo que proponemos es construir un árbol como en el algoritmo de reruteo VCT en donde tenemos que un árbol virtual está formado por un nuevo nodo raíz el cual está conectado al backbone de la red ATM. Los nodos conectados a este nodo raíz forma la estructura del árbol. Nuestro planteamiento utiliza, como en el enfoque de SRMC, el concepto de *Tetheret Point* (TP) que sirve como el nodo raíz en el árbol de conecciones que se utilizan para completar un Handoff. Con una conección ha sido establecida por primera vez todas las rutas potenciales en la red desde el TP hacia las ramas del VCT debido a posibles intentos de Handoff son reconocidos por la red, y estas conecciones son prestablecidas. A diferencia del algoritmo VCT, ningún recurso es reservado, la estructura del VCT podría ser construida en las estaciones base, en los móbiles, o en los respectivos TP de cada ruta.

Ahora, este algoritmo deberá buscar y encontrar el Nodo Común más Cercano *Nearest Common Node* (NCN) para todas las ramas involucradas en el proceso de Handoff, (la rama donde se encuentra el móbil actualmente y la rama a donde el móbil se está tratando de mover) la cual es común para ambas ramas en su camino hacia el TP, y como consecuencia hacia el destino final. En este esquema, eliminamos la necesidad de comunicación entre switches al buscar el NCN, el cual, en el caso de una red una gran cantidad de tráfico y que necesite garantizar la calidad del servicio, esto representa una verdadera mejora. En el peor de los casos, el TP será el nodo elegido para manejar el proceso de Handoff y obtener los recursos necesarios. Otra mejora al algoritmo NCNR toma lugar cuando el NCN no puede encontrar una ruta hacia el usuario terminal declarando por lo tanto al Handoff improcedente provocandose la terminación de la llamada, nosotros proponemos que si esto sucede el algoritmo deberá tratar de encontrar repetidamente otro NCN arriba de cada switch de cruce de rutas escogido anteriormente, hasta que encuentre un NCN que pueda encontrar una ruta hacia el punto final. Si esto no es posible la llamada deberá finalizar, finalmente después de que se completa un Handoff, el TP deberá ser actualizado y determinar las nuevas posibles rutas.

En suma, tomamos las ventajas de la características distribuídas y dinámicas de NCNR y la robustes del algoritmo VCT junto con el concepto de TP en SRMC a fin de analizar el rendimiento bajo diferentes tipos y condiciones de tráfico incluyendo mobilidad en los usuarios y métodos de *cell equencing* para ATM.

Abstract

Recently, technological development has established the trends to be followed for Personal Communication Systems (PCS). The new communication paradigm of personal services will require coexistence of technologies such as those in wireless and wireline networks. The interest has been in the conjunction of Asynchronous Transfer Mode (ATM) networks and wireless access technologies to satisfy new demands. In this research, we focus on some problems related to the transport of information through a wireless-ATM network taking into account mobility issues that effect the routing of information through the wireline ATM part of the system.

We follow the techniques and issues in [9], where rerouting schemes for handoffs in wireless-ATM networks are treated. In [9], a new rerouting procedure called Nearest Common Node Rerouting (NCNR) scheme is presented. NCNR concentrates on the *interzone* handoff, where a zone is serviced by one ATM switch and comprises several Base Stations (BS). The *intrazone* handoff is not treated. The interzone handoff will require rerouting management techniques whereas the intrazone handoff requires management of Virtual Circuit (VC) translation tables. NCNR is also modified to consider delay-sensitive traffic and throughput-dependent traffic. A comparison of NCNR with other rerouting schemes such as Source Routing Mobile Circuit (SRMC) [27], BAHAMA [18] and virtual Connection Tree (VCT) (1) is presented. [9] also contains new performance measures focused on the rerouting comparison such as the number of signaling messages exchanged during a handoff and a rerouting, the number of network nodes involved in the rerouting, the time to execute a handoff, etc.

In general, NCNR is based on finding the root that is common to the zones that are involved in the handoff procedure. Our objective comes from the motivation that NCNR could be improved, and we propose modifications and merge of schemes to achieve this improvement. We propose to build a tree as in the VCT rerouting algorithm where we have that a virtual tree is formed by a root node that is attached to the backbone of the ATM network. The nodes connected to that root node form the tree structure. Our approach uses the concept of a Tethered Point (TP), as in the SRMC approach, to serve as the root in the connection tree for handoffs. When a connection is first being established, all potential network routes from the TP to the leaves of the VCT due to possible handoff attempts are recognized by the network, and these connections are pre-established. Unlike the VCT algorithm, no resources are reserved. The VCT structure could be built in the BSs, or in the mobiles or in the TPs.

Now, this algorithm must search and find the Nearest Common Node (NCN) for the both leaves involved in the handoff, (the leaf where the mobile is now and the leaf where the mobile is trying to move into) which is common to both leaves in their way to the TP, and by consequence to the endpoint. In this scheme, we eliminated the need to make communication between switches searching the NCN, which in the case of a network with large amounts of traffic and guaranteed quality of service, represents a real improvement. In the worst case, the TP will be the chosen node to carry out the handoff procedure and obtain the resources to make

it possible. Another improvement to the NCNR algorithm takes place when the NCN cannot trace a route to the user terminal declaring the handoff null, so the call is finished, we propose that if this happens the algorithm should try to find repeatedly, another NCN above the crossover switch or switches chosen before, until it finds an NCN which can find a route to the endpoint. If this is not possible the call should be finished, finally after the completion of the handoff, the TP may be migrated and new possible network routes are determinated.

In summary, we will take the advantage of the distributed and dynamic characteristics of NCNR and the robustness of the VCT algorithm with the TP concept from SRMC in order to analyze the performance under different traffic classes and traffic conditions including mobility of users and ATM cell sequencing methods.

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Chapter I

Introduction.

During the 20th Century, the key technology has been information gathering, processing, and distribution. Among other developments, we have seen the installation of worldwide telephone networks, the invention of radio and television, the birth and unprecedented growth of computer industry, and the launching of communication satellites. [25]

In this framework, all these developments have given origin to users who need to be on line all the time. For such users, twisted pairs, coaxial cables and optical fibers are not very useful; they need to obtain information for their laptops, notebooks, etc. and all kind of machines without been attached to a specific infrastructure. For such users the answer is wireless communications, in part that is why mobile computers, such as notebook computers and Personal Digital Assistants (PDAs), are the fastest-growing segment of the computer industry. Many of the owners of these computers have desktop machines on LANs and WANs back at the office and want to be connected to their home base even when away from home or en route. Since having a wired connection is impossible in cars and airplanes, there is a lot of interest in wireless networks. In this section we will briefly introduce this topic. [25]

Actually, digital wireless communication is not a new idea. As early as 1901, the italian physicist Guglielmo Marconi demonstrated a ship-to-shore wireless telegraph using Morse Code (dots and dashes are binary, after all). Modern digital wireless systems have better performance, but the basic idea is the same. Additional information about these systems can be found in Garg and Wilkes, 1996; and Pahlavan *et. al.*,1995.[25]

Wireless networks have many uses. A common one is the portable office. People on the road often want to use their portable electronic equipment to send and receive telephone calls, faxes, and electronic mail, read remote files, login on remote machines, and so on, and do this from anywhere on land, sea, or air. [25]

Wireless networks are of great value to fleets of trucks, taxis, buses, and repairpersons for keeping in contact with home. Another use is for rescue workers at disaster sites (fires, floods, earthquakes, etc.) where the telephone system has been destroyed. Computers there can send messages, keep records, and so on. [25]

Finally, wireless networks are important to the military. If you have to be able to fight a war anywhere on earth on short notice, counting on using the local networking infrastructure is probably not a good idea. It is better to bring your own.

Table 1.1 Combinations of wireless networks and mobile computing.

Wireless	Mobile	Applications
No	No	Stationary workstations in offices
No	Yes	Using a portable in a hotel, train maintenance
Yes	No	LANs in older, unwired buildings
Yes	Yes	Portable office; PDA for store inventory

Although wireless networking and mobile computing are often related, they are not identical, as Table 1-1 shows. Portable computers are sometimes wired. For example, if a traveler plugs a portable computer into the telephone jack in a hotel, we have mobility without a wireless network. Another example is some one carrying a portable computer along as he inspects a train for technical problems, here a long cord can trail along behind (vacuum cleaner model). [25]

On the other hand, some wireless computers are not portable. An important example here is a company that owns an older building that does not have network cabling installed and wants to connect its computers. Installing a wireless LAN may require little more than buying a small box with some electronics and setting up some antennas. This solution may be cheaper than wiring the building. [25]

Although wireless LANs are easy to install, they also have some disadvantages. Typically they have a capacity of 1-2 Mbps, which is much slower than wired LANs. The error rates are often much higher, too, and the transmissions from different computers can interfere with one another. [25]

But of course, there are also the true mobile, wireless applications, ranging from the portable office to people walking around a store with a PDA doing inventory. At many busy airports, car rental return clerks work out in the parking lot with wireless portable computers. They type in the license plate number of returning cars, and their portable, which has a built-in printer, calls the main computer, gets the rental information, and prints out the bill on the spot. True mobile computing is discussed further in Forman and Zahorjan, 1994. [25]

Wireless networks come in many forms. Some universities are already installing antennas all over campus to allow students to sit under the trees and consult the library's card catalog. Here the computers communicate directly with the wireless LAN in digital form. Another possibility is using a cellular (i.e., portable) telephone with a traditional analog modem. Direct digital cellular service, called **CDPD (Cellular Digital Packet Data)** is becoming available in many cities. [25]

Finally, it is possible to have different combinations of wired and wireless networking. For example, we can depict an airplane with a number of people using modems and seat-back telephones to call the office. Each call is independent of the other ones. A much more efficient option, however, is the flying LAN. Here each seat comes equipped with an Ethernet connector into which passengers can plug their computers. A single router on the aircraft maintains a radio link with some router on the ground, changing routers as it flies along. This configuration is just a traditional LAN, except that is connection to the outside world happens to be a radio link instead of a hardwired line. [25]

While many people believe that wireless portable computers are the wave of the future, at least one dissenting voice has been hard. Bob Metcalfe, the inventor of Ethernet, has written: "Mobile wireless computers are like mobile pipeless bathrooms-portapotties. They will be common on vehicles, and at construction sites, and rock concerts. My advice is to wire up your home and stay there" (Metcalfe, 1995). Will most people follow Metcalfe's advice? Time will tell. [25]

1.1 Background.

In the present time telephone companies are faced with a far more fundamental problem; multiple networks. POTS (Plain Old Telephone Services) and Telex use the old circuit – switched network. Each of the new data services such as SMDS (Switched Multimegabit Data Service) and frame relay uses its own packet-switching network. DQDB (Digital Queue Dual Bus) is different from these, and the internal telephone company call management network (SSN 7, Signaling System Number 7) is yet another network. Maintaining all these separate networks in major headache, and there is another network, cable television, that the telephone companies do not control and would like to,[25]. It is in this frame that it is necessary to note another problem which is growing in importance among the service providers and has to be solved in a satisfactory way, this situation is the wireless network access to wide networks with great bandwidth, (ATM networks for example), and the problems implied with this kind of access, (keeping Quality of service, mobile addressing etc.)

The perceived solution is not to invent a single network for the future that will replace the entire telephone system and all the specialized networks with a single integrated network for all kinds of information transfer. This new network will have a huge data rate compared to all existing networks and services and will make possible to offer a large variety of new services. This is not a small project, and it certainly not going to happen overnight, but it is now under way. [25]

The new wide area service is called **B-ISDN (Broadband Integrated Services Digital Networks)**. It will offer video on demand, live television from many sources, full motion multimedia electronic mail, CD-quality music, LAN interconnection, high-speed data transport for science and industry and many other services that have not yet even been thought of, all over the telephone line. [25]

The underlying technology that makes B-ISDN possible is called **ATM (Asynchronous Transfer Mode)** because it is not synchronous (tied to a master clock), as most long distance telephone lines are. Note that the acronym ATM here has nothing to do with the Automated Teller Machines many banks provide (although an ATM machine can use an ATM network to talk to its bank). [25]

A great deal of work has already been done on ATM and on the B-ISDN system that uses it, although there is more ahead.

The use of a cell-switching technology is a gigantic break with the 100-year old tradition of circuit-switching (establishing a copper path) within the telephone system. There are a variety of reasons why cell switching was chosen, among them are the following. First, cell switching is highly flexible and can handle both constant rate traffic (audio, video) and variable rate traffic (data) easily. Second, at the very high protocols envisioned (gigabits per second are within reach) , digital switching of cells is easier than using traditional multiplexing techniques, especially using fiber optics. Third, for television distribution, broadcasting is essential; cell switching can provide this and circuit switching cannot. [25]

ATM networks are connection-oriented. Making a call requires first sending a message to set up the connection. After that, sub sequent cells all follow the same path to the destination. Cell delivery is not guaranteed, but their order is. If cells 1 and 2 are sent in that order, then if both arrive, they will arrive in that order, never first 2 then 1. [25]

ATM, networks are organized like traditional WANs, with lines and switches (routers). The intended speeds for ATM networks are 155 Mbps and 622 Mbps, with the possibility of gigabit speeds later. [25]

Some basic aspects which distinguish wireline from wireless communications are as follows. Certainly, any consideration of wireless ATM must take these distinctions into account.

1.1.1 Limited Spectrum [5].

The radio spectrum, and therefore the capacity available for wireless access service, is generally limited by regulation. Thus, unlike wireline communications wherein an increasing user population can easily be served by deploying additional wire (or fiber) facilities to connect those users to the network (thereby increasing the total capacity available to serve that increasing population), the available radio spectrum cannot arbitrarily be expanded. The cellular approach resolves this dilemma by dividing the service area into radio cells, each equipped with a base station, and reusing the allocated spectrum as often as possible among the radio cells, subject to constraints imposed by co-channel interference among the cells. Hence, as the user population grows, or users individually demand greater capacity, the cells must be divided such that a greater number of geographically smaller cells are available to serve the demand; again, frequency reuse among the greater number of smaller cells is mandatory. Limited spectrum also drives the need for spectrally efficient modulation and source compression coding to remove signaling information redundancy.

1.1.2 Wireless ATM [5].

Developments in modern telecommunications are preceding along two distinct and unrelated trajectories: the ongoing evolution of the worldwide wireline infrastructure toward increasing support for broadband multimedia services, and the proliferation of cellular-based radio access to support pedestrian and vehicular voice and data services. The first is characterized by bandwidth on demand at multimegabit-per-second peak rates, packet switched transport, virtual circuit connections, and statistical sharing of collective network resources among groups of virtual connections, with resources consumed only when packets are generated. The second is characterized by fixed-bandwidth circuit-switched connections; the bandwidth of each connection is equal to that needed to transport a compressed digital voice signal (that is, a few tens of kilobits per second), and each such connection is given exclusive use of a small portion of the network resources for the entire duration of that connection.

Recently, considerable interest has begun to focus on the topic of "Wireless ATM". In the emerging wireline broadband network, subscribers may request from among several types of virtual connections, each characterized by some allowable traffic profile. User information originating in any arbitrary format and comprising continuous or variable-bit-rate voice, data, image, or video will be converted and presented to the network as a sequence of ATM "cells". Each cell contains a payload field plus a routing header containing a virtual connection number, and flows along a route chosen by the Admission Controller at connection setup. The user of a virtual connection can flow packets along that virtual connection as long as the incidence of packets arrivals does not exceed the allowable traffic profile for the request class of virtual connection and, since virtual connections statiscally share the network resources, it is of paramount importance that the Admission Control computers limit the number and type of established virtual connections such that agreed-upon quality-of-service (QoS) metrics are maintained. As used in this context, QoS refers to traffic dependent performance metrics such as message delay or likelihood of message loss. The Admission Controller may partition the resources into independently managed sets such that the overall management complexity is acceptable, although this generally involves some compromise in overall network utilization efficiency.

As the demand for broadband service is further driven by the increased usage of on-line services, Internet access, World Wide Web sites, video on demand, and multimedia archiving, and as business, education, scientific, and recreational, dependencies on broadband services grow, it is indeed fitting that researchers and service providers examine the feasibility of extending ATM-like virtual connectivity from the wireline to the wireless domain. Certainly, adequate radio spectrum has been allocated in the mobile cellular and personal communications bands (and even greater spectrum is available in higher frequency bands) that the notion of bandwidth on demand al multimegabit-per-second access rates of at least tens of megabits per second becomes ponderable. Needed, however, are new multiple access approaches for sharing this spectrum in a manner different from the narrow band, rigid partitioning characteristics of second-generation digital cellular circuit switching systems, along with means of supporting mobility and maintaining QoS guarantees.

1.1.2.1 The Need for Wireless ATM [11].

A typical reaction to the concept of wireless ATM is to question the compatibility of several aspects of the ATM protocol and the wireless channel. First, considering the fact that ATM was designed for media whose bit error rates are very low (about 10^{-10}) it is questioned whether ATM will work at all in the highly noisy wireless environment. The environment in question is typically a multiaccess channel that may be also time-varying. Second, the wireless channel is an expensive resource in terms of bandwidth, whereas ATM was designed for bandwidth for simplicity in switching. Every ATM cell carries a header with an overhead of about 10 percent. Even this much overhead is considered too high for the shared radio channel. In addition, the potential need to transmit single ATM cells means the system should be capable of transmitting individual cells. However, the physical layer over-head associated with the transmission of individual cells, due to channel equalization and timing (synchronization), can exceed this 10 percent overhead and potentially reach the size of an ATM cell, or even exceed it. If so, then the inefficiency of the resulting system may outweigh the advantages of wireless access.

However, if these problems are solved, there are significant advantages to wireless ATM. For example, there will be software that uses ATM as the transport medium. As a wireless LAN application, wireless ATM provides this software seamless access to an ATM network. This is beneficial for mobile users as well as for reconfigurability. Also, residential video delivery applications are useful for providing broadband access to residences without investing in new infrastructure.

1.2 Justification and Objective [9].

The rising of wireless communications paired with the rapid developments in ATM networking technology signals the start of a new era in telecommunications. In this era the users will not only need higher bandwidth; they will also demand mobility. A typical future wireless user may be carrying a handheld computer with audio and video conferencing capabilities and may demand high-speed data communication on the order of 10 Mb/s or higher. A wireless ATM network, which is designed to provide high-speed isochronous and asynchronous communications for wireless users, is a good match for these demands.

In a network where users are mobile, handoff becomes an important function of the network. Handoff is implemented by the network to give the users freedom of motion beyond a limited wireless coverage area while they are communicating. This may be contrasted to a cordless phone where users are mobile only within a limited coverage area. The handoff is the procedure by which a user's radio link is transferred from one radio port to another through the network without an interruption of the user connection. In this work, we first summarize the handoff procedure in the wireless ATM network; we will explain the set of handoff procedures for a wireless ATM network named "Nearest Common Node Rerouting" or NCNR for rerouting connections to support a handoff event. We will compare the NCNR handoff scheme to the existing schemes in the literature and discuss the benefits of NCNR over them. Finally we propose a novel procedure (Best Semi-Route Found, BSRF) for rerouting connections, and we will conclude by comparing the proposed handoff scheme against NCNR and as a result with the existing handoff schemes.

Our vision and the motivation for these job is that NCNR could be improved, our proposal is based in part on other existing algorithms and it could be seen as an interesting merge of some ideas so it can be said that the central purpose for this thesis is to present another algorithm called ***Best Semi-Roue Found*** (BSRF). After having studied the NCNR algorithm, we have noted that NCNR could fast find a new switch, and through it, be able to reach the new location to the mobile, but this strategy could not be very effective, if we talk in terms of the number of blocked calls, failed handoffs, and in general the link usage. We will analyze NCNR's performance through a simulation program based in the NCNR's algorithm and compare it with Best Semi-Roue Found (BSRF) which will be analyzed through a simulation program too, using the same criteria.

1.3 Work Contents.

In Chapter I we present a brief introduction about concepts which will be used along all the work as Wireless Networks, ATM, Wireless ATM Networks, the problems and benefits related whit the use of this technologies. It's also presented also the matter for this thesis and the persecuted objective, finally are presented currently jobs related. Chapter II contains the rerouting problem for a Wireless Network with mobile users, and the handoff concept, used by the wireless network to continue a call which is already in the network but the user has moved to other cell. The specific handoff definitions which will be used along this job, a briefly description of some rerouting methods its benefits and disadvantages, the Nearest Common Node Rerouting algorithm will be complete described and they will be compared against the rerouting methods previously described.

In Chapter III the central motivation for the job is presented, the problems founded in NCNR algorithm, and as a consequence why we think is possible to improve the performance obtained with the NCNR algorithm. Is formally presented the *Best Semi-Route Found* (BSFR) algorithm and is mentioned the way in which will be realized the compare (through simulation programs); finally basic suppositions are presented, as the network scheme. For Chapter IV is given a description in deep of the BSRF algorithm, the algorithm is described in detail using the assumptions presented in chapter three, a flow diagram for both algorithms implemented in the respective simulation are also presented, for a better rerouting understanding.

Chapter V is dedicated to present the numerical results obtained through a variety of program simulation executions under different scenarios, each scenario is complete described, partial conclusions are also done. Finally in Chapter VI are presented general conclusions of the thesis and interesting experiences found along the thesis development, are also given some ideas which we consider could be helpful to anyone who is interested in this thesis continuation, or in any job development in a similar area.

Chapter II
Background.

The rapid worldwide growth of digital wireless communication services motivates a new generation of mobile switching networks to serve as infrastructure for such services. Given the wide range of radio access technologies being deployed for both telephony and Internet access, (and as a logic result the need for good algorithms which deliver the packets produced by the network at the right place in the right order), new mobile switching architectures are needed to provide generic, cost effective support for a variety of cellular, Personal Communications Services (PCS) and wireless data technologies. In addition, Mobile networks being deployed in the next few years should be capable of smooth migration to future broadband services based on high-speed wireless access technologies, such as wireless asynchronous transfer mode (ATM). [6]

Presently, there exists a wide range of technologies for supporting mobile users. Examples include cellular telephony [17, 23], PCS [21], and mobile Internet Protocol (IP) [19]. Regardless of the specific protocol, all such technologies must support two fundamentals mechanisms:

- Locating users prior to or during connection establishment.
- Rerouting connections when users move.

Thus, in order to support mobility, each of these existing technologies replicate mobility supporting functionality within their respective network infrastructures . [6]

In a network where users are mobile, handoff and all the procedures involved, (like cell sequence, rerouting etc.) play an important function in the network. Handoff is implemented by the network to give the users freedom of motion beyond a limited wireless coverage area while they are communicating. The *handoff* is the procedure by which a user's radio link is transferred from one radio port to another through the network without an interruption of the user connection [9, 14].

We'll first summarize the general handoff and routing mobile procedure in the wireless ATM networks; we then explain a procedure called Nearest Common Node Rerouting or NCNR for rerouting connections in the wireless connections in the wireless ATM network to support a handoff event. And finally we will finishing comparing NCNR against a novel procedure called BDRF. [1,9,18,27,28].

2.1 Routing for Mobile Hosts [25].

Millions of people have portable computers nowadays, and they generally want to read their email and access their normal file systems wherever in the world
they may be. These mobile hosts introduce a new complication: to route a packet to a mobile host, the network first has to find it. The subject of incorporating mobile hosts into a network is very young, but in this section we will sketch some of the issues here and give a possible solution.

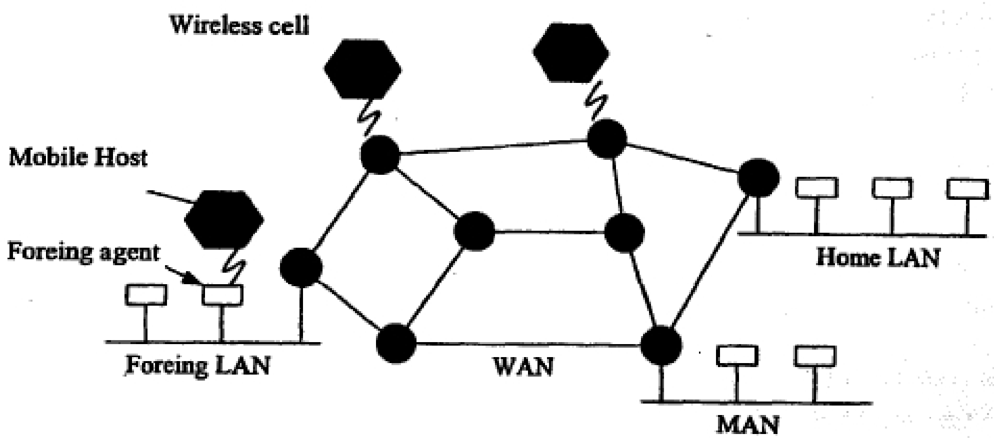


Figure 2.1 **A WAN to which LAN's, MAN's and Wireless cells are attached.**

The model of the world that network designers tipically use is shown in Figure 2.1 Here we have a WAN consisting of routers and hosts (which in our case correspond to mobiles or radio port controllers and ATM switches). Connected to the WAN are LANs, MANs and wireless cells.

Users who never move are said to be stationary. They are connected to the network by copper wires or fiber optics. In contrast, we can distinguish two other kinds of users. Migratory users are basically stationary users who move from one fixed site to another from time to time but use the network only when they are physically connected to it. Roaming users actually compute on the run and want to maintain their connections as they move around. We will use the term **mobile users** to mean either of the latter two categories, that is, all users who are away from home.

All users are assumed to have a permanent **home location** that never changes. User also have a permanent home address that can be used to determine their home locations, analogous to the way the telephone number 1-212-5551212 indicates the United States (country code 1) and Manhattan (212). The routing goal in systems with mobile users is to make it possible to send packets to mobile users using their home addresses, and have the packets efficiently reach them wherever they may be. The trick, of course is to find them.

In the model of Fig. 2.1, the world is divided up (geographically) into small units. Let us call them areas (which are not the same are type mentionet above), where an area is typically a LAN or wireless cell. Each area has one or more **foreign agents**, wich keep track of all mobile users visiting the area. In addition, each area has a **home agent**, which keeps track of users whose home is in the area, but who are currently visiting another area.

When a new user enters an area, either by connecting to it (e.g. plugging into the LAN), or just wandering into the cell, his computer must register itself with the foreign agent there. The registration procedure typically works like this:

1. Periodically, each foreign agent broadcasts a packet announcing its existence and address. A newly arrived mobile host may wait for one of these messages, but if none arrives quickly enough, the mobile host can broadcast a packet saying: "Are there any foreign agents around?"
2. The mobile host registers with the foreign agent, giving its home address, current data link layer address, and some security information.
3. The foreign agent contacts the mobile host's home agent and says: "One of your hosts is over here." The message from the foreign agent to the home agent contains the foreign agent's network address. It also includes the security information, to convince the home agent that the mobile host is really there.
4. The home agent examines the security information, which contains a timestamp, to prove that is was generated within the past few seconds. If it is happy, it tells the foreign agent to proceed.
5. When the foreign agent gets the acknowledgement from the home agent, it makes an entry in its tables and informs the mobile host that it is now registered.

Ideally, when a user leaves an area, that, too, should be announced to allow deregistration, but many users abruptly turn off their computers when done.

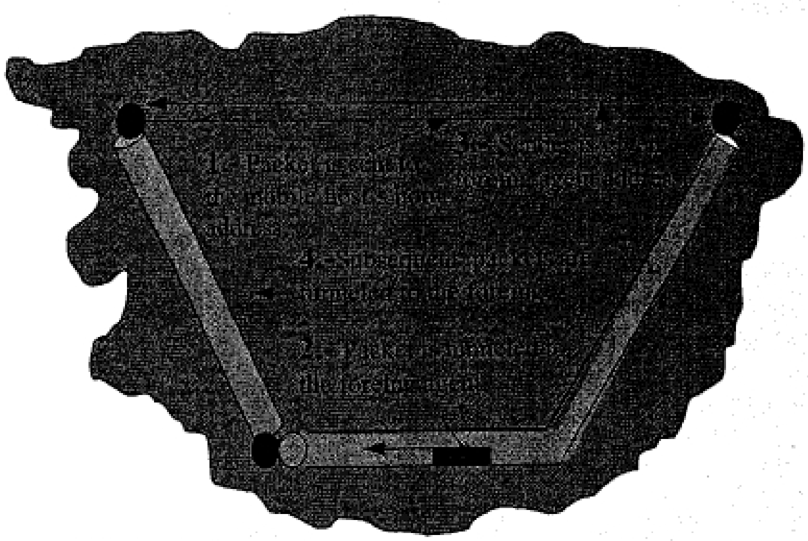


Fig 2.2 Packet routing for mobile users.

When a packet sent to a mobile user is routed to the user's home LAN because that is what the address says should be done, as illustrated in step 1 of Figure 2.2 Packets sent to the mobile user on its home LAN are intercepted by the home agent. The home agent then looks up the mobile user's new (temporary) location and finds the address of the foreign agent handling the mobile user. The home agent then does two things. First, it encapsulates the packet in the payload field of an outer packet and sends the latter to the foreign agent (step 2 in Fig. 2.2). This mechanism is called tunneling; we will look at it in more detail later. After getting the encapsulated packet, the foreign agent removes the original packet from the payload field and sends it to the mobile user as a data link frame.

Second, the home agent tells the sender to henceforth send packets to the mobile host by encapsulating them in the payload of packets explicitly addressed to the foreign agent, instead of just sending them to the mobile user's home address (step 3). Subsequent packets can now be routed directly to the user via the foreign agent (step 4), bypassing the home location entirely.

The various schemes that have been proposed differ in several ways. First, there is the issue of how much of this protocol is carried out by the routers (or switches) and how much by the hosts (mobiles), and in the latter case, by which layer in the hosts. Second, a few schemes, routers along the way record mapped addressed so they can intercept and redirect traffic even before it gets to the home location. Third, in some schemes each visitor is given a unique temporary address; in others, the temporary address refers to an agent that handles traffic for all visitors. Fourth, the schemes differ in how they actually manage to arrange for packets that are addressed to one destination to be delivered to a different one. One choice is changing the destination address and just retransmitting the modified packet. Alternatively, the whole packet, home address and all, can be encapsulated inside the payload of another packet sent to the temporary address. Finally, the schemes differ in their security aspects. In general, when a host or router gets a message of the form "Starting right now, please send all of Cayla's mail to me" not this is a good idea. Several mobile host protocols are discussed and compared in (Ioannidis and Maguire, 1993; Myles and Skellern, 1993; Perkins, 1993; Teraoka *et al.*, 1993 and Wada et al., 1993).

2.1.1 Handoff Procedure.

The handoff procedure is performed to ensure the integrity of a radio connection and to minimize interference to the users in the coverage area of neighboring cells. [13,14]. The wireless ATM network consists of radio ports, user terminals, and network interface equipment [7,8]. A user terminal might have a few simultaneous connections in the wireless ATM network. When a handoff occurs these connections may need to be rerouted. In this job we assume that a group of radio ports is connected to the same wireless ATM network interface equipment. This collection of ports is called a zone [8].

The zone architecture is illustrated in Figure 2-3. The zone is managed by the zone manager process. There are two levels in a handoff event:. Network-level and radio-level. The radio-level handoff is the actual transfer of the radio link between two ports; the network-level handoff supports the radio–level handoff by performing rerouting and buffering. The radio level

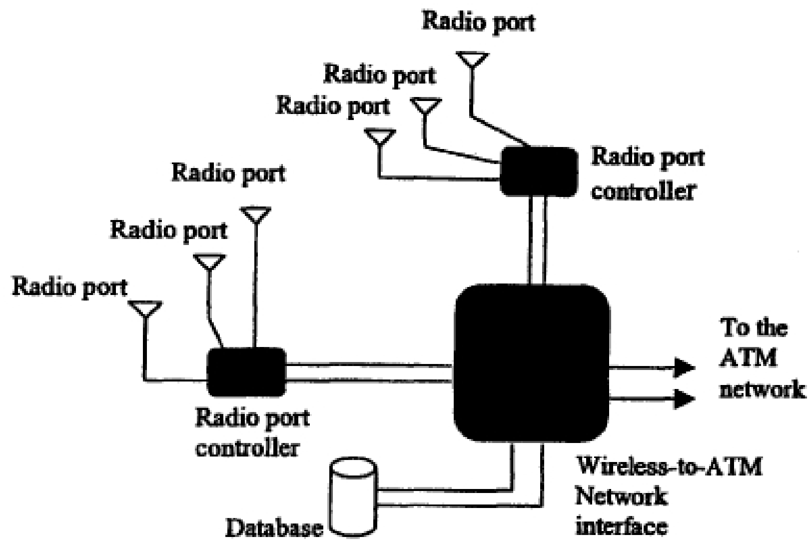


Figure 2.3 A zone in the wireless ATM network.

handoff determines some of the procedures used in network-level handoff, as shall be seen later. We also assume that the zone managers have some knowledge about the neighboring zones, and the network address of neighboring zones are stored in a lookup table which is updated periodically by means of an update protocol through a signaling channel. We refer to the user communication device as the *user terminal* and the termination point for the user connection as the *endpoint.*

The wireless ATM network architecture used in this job is discussed in detail in chapter tree we will use the same the methods presented in [7,8] by which a handoff transaction may be implemented in a wireless ATM network using either the current ATM signaling protocols [10] or a migratory wireless signaling protocol; therefore, we limit our scope in this article to the rerouting of wireless ATM connections which is a crucial part of the handoff procedure.

We also assume that these zones are interconnected by wireless ATM network switching nodes. Based on the "zone" concept, a few different situations for rerouting may be investigated:

2.1.1.1 A Handoff within a Zone (Intrazone Handoff).

In the intrazone handoff the user is moving within the zone. The only rerouting performed in this case is in the wireless ATM network interface equipment within the zone. Specifically, the zone manager is responsible for the correct update of ATM virtual circuit translation tables within the zone [7,8]; however, this type of rerouting does not require wide-area ATM network switching; hence, it will not be discussed any further.

2.1.1.2 A Handoff between Two Zones (Interzone Handoff).

The interzone handoff occurs when the radio ports involved in the handoff belong to different zones. In this case the rerouting involves the wireless ATM network. An interzone handoff might require rerouting at one or more wireless ATM switches, depending on the location of handoff and topology network. This type of rerouting will be discussed in the next section.

2.2 Related works [9].

Two Connection Re-routing Schemes for Wireless ATM.

To support mobile multimedia computing, one interesting approach is to extend ATM technology to wireless networks. This extension, termed "Wireless ATM", presents several interesting challenges such as managing an end-to-end ATM connection (using connection re-routing) and location management, handling high error rate performance of wireless links, maintaining the ATM cell sequence, and supporting quality of service (QoS) requirement. In this environment, since the access point for a mobile user is not fixed, a technique/scheme is required to maintain the end-to-end ATM connection with user mobility. Recently, the design of such rerouting schemes has received some consideration in the literature. This paper presents two such schemes, termed RAC (Rearrange ATM Connection) and EAC (Extend ATM Connection), which can be used in isolation or in conjunction to support connection management in wireless ATM networks. The choice to use one or both schemes could be based on desired level of bandwidth utilization, level of implementation complexity, and the acceptable level of connection processing load. When used in conjunction, these schemes place the handoff processing in ATM network first provided that NCP (Network Call Processor) is not overloaded. However if NCP is overloaded or if NCP is unable to process the (RAC) request due to insufficient bandwidth between switches in the new path, then the connection extension (EAC) is performed in wireless network. EAC includes detection and removal of any possible triangular or circular path that may be caused due to connection extension.

Smart Buffering Technique for Lossless Hard Handover in Wireless ATM Networks.

The introduction of ATM technology in wireless environments, allowing mobile terminals to support multimedia traffic, is a subject of significant interest. Towards this objective, the mobility procedures need to be designed in an efficient way that will minimize the QoS deterioration, imposed by the movement of the users. This paper discusses the network architecture, its constituent functional entities, as well as the algorithms needed in support of mobility. In order to achieve minimum impact on the connection quality when a user crosses the boundaries of a cell, a so called "smart buffering technique" has been designed. Throughout the proposed design, special provision has been taken to minimize modifications or extensions, required on existing fixed ATM infrastructure. In this respect, existing versions of B-ISDN signaling protocols (Q.2931, ATMF UNI 3.1) are considered, which are enhanced by a supplementary mobility related protocol.

Keywords: ATM, multimedia traffic, lossless handover, QoS, B-ISDN signaling.

A Dynamic Wired-Resource Reservation Scheme with a Connection Rerouting method on ATM-based PCN.

In this paper, is proposed a connection rerouting method for fast inter-switch Handoffs, and is also proposed a dynamic resource reservation scheme based on the proposed connection rerouting method, for the ATM-based persona communications network. The proposed rerouting method reduces the delay in the connection rerouting by reserving VPI/VCIs for possible inter-switch handoff calls in advance. This job categorizes the traffic carried in wired/wireless networks into two classes (Class I: real-time and delay-sensitive traffic, Class II: non-real-time and delay-tolerable traffic). The proposed resource reservation scheme statistically reserves the wired resources in separate ways according to the classes of the possible inter-switch handoff calls. The simulation results for this job shows that the proposed scheme reduces dropping rate of inter-switch handoff calls below 2-3x1010^{-1} times the blocking rate of new calls during heavy load and also keeps the probability of dropping of inter-switch handoff class with Class I traffic. The results also show that the proposed scheme can flexibly cope with the time-variant environment than the fixed reservation scheme.

2.3 A comparison of Existing Rerouting Schemes for Wireless ATM Networks.

In this section are first presented some rerouting algorithms which already exist, and in subsecuent sections is presented the comparation between those rerouting algorithms against NCNR.

2.3.1 Yuan-Biswas Rerouting Scheme.

In this wireless ATM handoff scheme the rerouting of connections for handoff is based on the rerouting of connections at designated handoff switching equipment (HOS). The handoff procedure described in [28] does not specify how the HOS is determined. The example in that text uses the initial wireless ATM switch as the HOS, which is turn is very similar to cell forwarding. It is assumed that the base stations in the wireless ATM network are interconnected by permanent virtual circuits. A handoff between two ports (or base stations) attached to the *same* wireless ATM switch is handled by just updating translations tables in one switch. A handoff between two ports attached to different ATM switches is handled by forwarding the ATM cells destined for the user terminal to the user's new ATM switch. This new add-on connection is established before the first switch acts as a handoff server (switch).

2.3.2 VCT: Virtual-Connection-Tree-Based Rerouting Algorithm.

In the VTC handoff algorithm the concept of a virtual connection tree is utilized. A virtual connection tree is formed by a root node that is attached to the backbone ATM network. The nodes connected to that root node form the tree structure. When a mobile terminal establishes a wireless ATM connection, a connection tree is formed from the root node to the leaves in the tree effectively producing a point-to-multi-point connection; however, the mobile terminal is utilizing only one leaf node at time, whereas the rest of the multi-point connection is not utilized. When the mobile moves within the tree, a new leaf node becomes active, and the connection is continued using one of the pre-established circuits. When a mobile steps out the coverage area of the VCT, the network establishes a new tree surrounding the mobile.

2.3.3 Source Routing Mobile Circuit Rerouting.

The SRMC rerouting approach is an improvement of VTC rerouting. In this approach the rerouting functions are distributed over time. The SRMC approach uses the concept of a tethered point (TP) to serve as the root in the connection tree for handoff. When a connection is first being established, all potential network routes from the TP to the leaves due to possible handoff attempts are recognized by the network, and these connections are pre-established. Unlike the VCT algorithm , no resources are reserved. Once the handoff is initiate, only the resources for the active handoff connection are reserved. After the completion of the handoff, the TP may be migrated and new possible network routes are determined. The differences between SRMC and NCNR will be discussed later. The reader is referred to [27] for details in this scheme.

2.3.4 Rerouting for Interzone Handoff using NCNR.

The rerouting for an interzone handoff involves one or more wireless ATM switches. In this section we will describe the interzone handoff procedure "Nearest Common Node Rerouting" (NCNR) as is described in [9]. NCNR attempts to perform the rerouting for a handoff at the closest ATM network node that is common to both zones involved in the handoff transaction. The term "common" is used to denote a network node that is hierarchically above both of the zones in question or a parent of both zones in the network topology tree.

NCNR minimizes the resources required for rerouting and conserves network bandwidth by eliminating unnecessary connections (discussed later). As mentioned previously, the users of the wireless ATM network may subscribe to services ranging from time-sensitive traffic types (audio, video) to throughput-dependent traffic types (data, file transfers, World Wide Web access). We note that the traffic type of the connection involved in the handoff is known by the zone managers. The two kinds of traffic types impose different constraints on the network and the handoff process. For example, time-sensitive voice traffic will not be easy to buffer due to a constant cell generation rate and strict time delay constraints; however, it can tolerate occasional loss of cells. On the other hand, data traffic will not tolerate cell loss, but may tolerate delays on the order of a few hundred milliseconds. The NCNR procedure for time sensitive and throughput-dependent traffic will hence be different. We also note that, occasionally, a handoff will be attempted without any warning due to severe fading in the radio environment. In such case, the upper-layer protocols will be responsible for recovery of user connection and lost cells. This case is analogous to cell loss in the fixed ATM network due to severe congestion and should be treated in a similar manner.

Note also that due to the manner of the foxed network, the transmission delay and latency of the links from the nearest common node (NCN) to the zones involved in the handoff are assumed to be negligible compared to the radio transmission medium. In this section we first explain the NCNR procedure for time (delay)-sensitive traffic. We will the conclude by explaining the NCNR procedure for throughput-dependent traffic based on the NCNR for time-sensitive traffic.

2.3.4.1 Algorithm for the NCNR for Time-Sensitive Traffic (NCNR-TS).

The algorithm for NCNR is explained in the following paragraphs, and it can be seen graphically in figures 4.1, 4.2 and 4.3.

The NCNR for time-sensitive traffic is performed as follows:

1. A handoff session between zones A and B is started. Let B be the candidate zone for the handoff and A be the present zone.

2. The zone manager of A first checks to see if a direct physical link (not involving any other network nodes) between A and B exists. There are two possible cases if this condition is satisfied.

- If A is a parent (*The parent is determined by means of either the network topology in a hierarchical network or closeness in terms of hops to the end point. The endpoint is defined as the terminating point for the user connection in he network*) of B, then A notifies B and the new connection Is established without any further network involvement. After the connection is established, A acts an anchor (*The word anchor is commonly used to refer to a network point that the user connection is forwarded through to the candidate zone until the handoff is completed*) for the connection. Until the stability of the handoff (*The stability of the handoff is used in reference to the radio link transfer which may take longer than one burst during a handoff event. During this period the user terminal may use both networks points for information transfer*) is established both A and B act as network connection points for the user connection. This process is explained in detail in step 6 of this procedure. Once the radio-level handoff is completed, A acts only as a wireless ATM switch in the connection path.

- If B is a parent of A, then A sends a message to B relaying the handoff request. B then acts as an anchor for the handoff procedure. Until the stability of the handoff is established, both A and B may be used for information transfer from/to the terminal to/from the network (see step 6 of this procedure). Once the handoff is stable, B deletes the user connection from itself to A. The rerouting is thus completed.

3. If A and B are not connected by a direct physical link, then the zone manager of A (ZMA) contacts the endpoint for the user connection by sending a *handoff start* messages. (*If there are more than one connection for one user, then this procedure is applied to all of the connections*). The handoff start message contains the ATM addresses of zones A and B and the endpoint for the user connection.

4. The handoff start message traverses the network from A to the endpoint for the user connection. Upon receiving this message, the network switching nodes on this path check to see whether all three ATM addresses are routed on different egress ports of the switch (Fig. 2). When such a node is found it is designated as the NCN. The NCN sets the NCN bit in the handoff start message. The rest of the switches on this path do not perform the egress port test. (*Another possible implementation will be not forward this message after the NCN is found. Both forwarding the message to the endpoint we allow the user applications to adjust to the handoff process*).

5. The NCN the forwards a *reroute* message to all of the switches located between B and itself. The nodes that receive the reroute message first check for resource availability; if the resources required by the connection are available, the necessary connections are established and circuit translation tables are set up. If the resources are not available, the handoff attempt fails and the involved parties are notified.

6. When the reroute message is received by *B*, a *reroute acknowledgment* message is sent from B to A. This message completes the rerouting process. The radio-level handoff is attempted at this point by employing the procedures discussed in [7,8]. As the radio-level is started, the NCN starts to forward the user information to both A and B in a point-to-multipoint manner. This multiparty connection is necessary until the radio-level handoff is stabilized. The radio-level handoff may extend beyond one radio burst in most radio systems as the user terminal tries to select the optimal link. Especially when a user is in a fading environment, a small motion of the terminal may cause the radio link to switch back and forth between the two radio ports involved in the handoff; hence, a point-to-multipoint link from the NCN to both A and B ensures the timely delivery of time-sensitive information. We note here that the user information may be discarded at the zone which is not in contact with the user terminal and transmitted from the zone which is in contact with the terminal. This zone is the zone that is currently receiving the uplink transmission from the portable. If

a zone has not received an uplink transmission from the portable in a given radio transmission frame, it must assume it is not active for the next downlink radio transmission period (see [7,13,14] for details on the handoff procedure). In the uplink direction, the information may be transmitted through either zone involved in the handoff (*If a soft handoff scheme such as in code division access, CDMA, is being employed, where the uplink information is being received simultaneously by two radio ports, then the NCN may be responsible for combining and sequencing the uplink information*) and correctly routed to the endpoint by the NCN. Occasionally, the portable may receive duplicate information; since we are discussing time sensitive traffic, the duplicate information may be determined by the time sequence information and discarded accordingly.

7. If the radio-level handoff is successful(*The radio-level handoff is successful only when the stability of the new radio link is established. The determination of the stability of the new link of the new link is beyond the scope of this job*), the connection between A and the NCN is cleared by A by sending a *clear connection* message to the NCN. After the handoff is completed, any buffered time-sensitive data that has not expired will be transmitted to the current zone associated with the portable; expired data are discarded at the zones. For time sensitive traffic, recovery of lost data may only be possible by interpolation of information, which is beyond the scope of this job.

2.3.4.2 NCNR for Throughput-Dependent Traffic (NCNR-TD).

NCNR for throughput-dependent traffic is very similar to the procedure employed for time-sensitive traffic. Throughput-dependent traffic is not sensitive to small (on the order of few hundred milliseconds) delays; however, the lost of information is not tolerated by this traffic type. A typical example of this traffic type is file transfers. We can take advantage of the delay-tolerant nature of this traffic in the rerouting process. The NCNR for throughput-dependent traffic differs from the procedure for NCNR-TS as follows.

1. As the radio-level handoff is started, the downlink user information is buffered at both A and B. No user information is transmitted in the downlink direction until the radio level handoff is completed. Once the radio-level handoff is complete, the information is transmitted in a first-in first-out (FIFO) manner.
2. If A's buffer is non-empty before the handoff is started, then A's buffer is transmitted to the user terminal if possible, otherwise, these data are transmitted to B and go in front of all other cells buffered for transmission. This preserves the cell sequence.
3. In the uplink direction, before the radio level handoff is started the traffic is transmitted through A if possible; otherwise, it is buffered at the terminal. As the radio-level handoff is started, the user terminal starts buffering the user information. Once the handoff is stabilized the buffered information is transmitted.

These differences ensure the integrity of user data as well as the cell sequence. The cell sequence aspects of rerouting are discussed in the next section.

We also note that multiple connection may be rerouted in the network using the virtual path concept. By assigning a virtual path identifier for connections between a user and multiple endpoints, and performing the rerouting on the virtual path instead of on a virtual circuit basis, an efficient rerouting of multiple connections may be achieved.

2.3.5 Comparison of NCNR against the Yuan-Biswas.

The first point of interest is the cell forwarding in the network is the ease of cell resequencing. When the ATM switch associated with the previous port acts as an anchor for the rerouting, all the cells still go through the previously established path in the network before traversing the new add-on section established because a handoff. This guarantees the preservation of cell sequence and also means that either the anchor ATM switch [18] (the handoff switch [28]) or the new ATM switch might need to buffer some of the cells before the handoff is successfully completed. For only one user this might not be a significant administrative load; however, the simulations in [7] predict handoff rates of 10 or more handoffs per second in a cellular environment. In such a scenario the buffering of cells due to handoff may become a burden to the network. In NCNR the buffering is mostly performed for throughput-dependent traffic and only when the radio level handoff is being performed. Moreover, for time-sensitive traffic, buffering is not feasible, and the Yuan-Biswas rerouting scheme do not allow for supporting a user connection through two radio ports while the handoff stabilizes. This may ultimately cause a problem for time-sensitive traffic streams.

Another problem with the cell-forwarding model is that it inherently assumes a flat (or ring) network model where all neighboring ATM switches (or zones) will have direct connections in between. The reason for this assumption is that in a flat network cell forwarding does indeed minimize the number of ATM switches involved in a handoff. However, in a hierarchically organized network, cell-forwarding-based rerouting automatically involves the nodes referred to as the NCNs in this job. Once the NCN is involved in cell forwarding it is more advantageous to use the NCNR scheme proposed herein. This is primarily because of two points:

- When the NCN is involved in the handoff, the network bandwith is actually minimized when the connection is simply rerouted to the new ATM swtich (zone) of the wireless network This prevents the waste of bandwidth for the portion of the forwarding connection between the NCN and the previous ATM switch (zone).
- Utilization of NCNR means that the data for all the connections involved in the handoff are buffered at the zones. Buffering of data is hence performed at the edge of the network, requiring no intervention from ATM switching equipment. NCNR also preserves cell sequence.

Another possible problem with cell forwarding is the fact that for a fast-moving user in a system that has small radio coverage areas, there will be a network trail left behind the user consisting of cell forwarding among multiple zones: The NCNR always performs the rerouting at the NCN, thereby minimizing the amount of bandwidth used and the amount of rerouting.

2.3.6 Comparison of NCNR against the VCT-Based Handoff Algorithm.

- NCNR takes the concept proposed by VCT one step further by deleting the need for multiple virtual circuits to be reserved at a given time to support a single connection. The zone concept utilized in this article is effectively equivalent to the connection tree concept given in [1]. The zone manager node is the root, the radio ports attached to the zone manager node the leaves. Since the radio ports and the zone manager maintain constant communication there is no need for multiple virtual circuits [8].
- NCNR guarantees the preservation of cell sequence. VCT-based handoff does not implement cell sequence preservation. The mobile is responsible for cell sequencing.
- NCNR recognizes the differing constraints associated with time-sensitive and throughput-dependent traffic types and implements the handoff procedure to accommodate both types of traffic in an efficient manner. VCT-based routing, described in [1], does not address this issue.

Because of these reasons, NCNR may be superior to VCT-based handoff.

2.3.7 Comparison of NCNR against the SRMC Algorithm.

The SRMC algorithm improves the VCT handoff algorithm by addressing most of the concerns expressed in the previous sections. The SRMC does not reserve bandwidth in the connection tree until the actual rerouting is performed. This clearly is an advantage over the VCT algorithm. When compared to the NCNR, however, we can still point these unaddressed issues:

- SRMC, by predetermining all possible handoff paths from a root node, attempts to avoid the actual connection establishment during handoff. It does not however, avoid the resource allocation that must be performed before the actual rerouting is completed. This resource allocation process involves sending a message from the root node (TP) in the connection tree to all the nodes on the active path. There are also messages sent from the leaf node to the root node to notify the TP of an ongoing handoff attempt. In summary, a pair of messages are sent for notification and for resource allocation from one side of the connection tree to the other. Since the root node has to be involved in all handoff attempts, even an attempt between neighboring nodes is managed through the root node. When we compare this with NCNR we see that the worst case in NCNR degenerates to the SRMC algorithm in terms of the number of messages sent between the NCN and nodes involved in the handoff. When the nodes involved in the handoff are neighbors, the NCNR outperforms the SRMC since the messages go up only one level in the hierarchy. Therefore, in terms of the number of messages sent between the nodes in the network hierarchy, NCNR is at worst comparable to, and for neighbors better than, SRMC.

- SRMC uses the centralized intelligent network (IN) concept for predetermining the possible routes that may be involved in a handoff. When a user does not perform a handoff, all the overhead of calculating these possible routes is wasted. It is also not clear whether the most resource-intensive part of a handoff rerouting is resource allocation or finding a possible route for rerouting. NCNR, on the other hand, is a fully distributed algorithm. It performs the work only when it is necessary, avoiding wasted computational overhead.

- SRMC does not address the constraints associated with different traffic types (see the previous discussion).
- SRMC inherently assumes a hierarchical topology. The sheme is not effective in a flat network.

It remains to be determined whether NCNR or SMRC will have the best performance in terms of speed of handoff. However, in terms of efficiency we believe that NCNR will indeed outperform SRMC for the reasons stated in this section.

2.3.8 Comparison of NCNR against the Ywan-Biswas, VCT and SRMC algorithms.

The comparisons of previous were realized under tree type structures, we still have to determine if NCNR still gives better performance over the other algorithms described before, in a fully connected network.

It is necessary to say that these considerations were done without a formal analysis of numerical results for the algorithms in a network on equality of circumstances, however due to the behavior observed and described in the algorithms, we believe that NCNR should give a better performance than Ywan-Wissajes and VCT. In the Ywan-Bissajes case this is clearly observed because the probability to create a loop is still large enough, and due to this situation still exists a great probability to produce a great waste of resources; a similar scenario of waste of resources would be observed with the VCT algorithm.

However, where it would be harder to make a precise judgment is on the performance of SRMC against NCNR when both algorithms deal with a fully connected network. For this precise comparison it would be necessary an SRMC algorithm implementation which works with networks so it could be compared against the NCNR implementation already done.

Chapter III

Model Description.

As we have said before in a network where users are mobile, handoff protocols are necessary to reroute existing active connections when the user moves to a different radio port. That is why handoff plays an important function in the network, giving to the users a great freedom of motion beyond a limited wireless coverage area while they are communicating. In the previous chapters we have summarized the set of handoff procedures for a wireless ATM network named "*Nearest Common Node Rerouting*" or NCNR for rerouting connections to support a handoff event.

Some of the objections we found in NCNR is that it looks for the first NCN (Nearest Common Node) which is able to reach the new mobile location, of course this guarantees speed, but what if the switch and the route chosen are not the best?, certainly if we calculate a total new route we will find the best route, but we are trying to find a route which does not change significantly the existing one, but at the same time which helps to distribute the network change as bests it could possible be. We also think that there exists a great probability to saturate in the network the down links before up links.

Best Semi-Roue Found (BSRF) algorithm mentioned, makes some interesting algorithm merge, for example it builds a tree as in the Virtual-Connection-Tree VCT rerouting algorithm, as a result we'll have a virtual tree which is formed by a "*root node*" that is attached to the backbone ATM network. The nodes connected to the root node form the tree structure. Our approach uses the concept of a Tethered Point (TP), as in the SRMC approach to serve as the root in the connection tree for handoff. When a connection is first being established, all potential network routes from the TP to the leaves due to possible handoff attempts are recognized by the network, and these connections are pre-established. Unlike the VCT algorithm, no resources are reserved.

Now, either in the base station, in the mobile or in the TP, or wherever it been kept the tree structure which was built, this device must search and find the Nearest Common Node (NCN) for both leaves, (the leave where the mobile is now and the leave where is trying to change, actually is right here where the difference exists between NCNR and BSRF) which are common for both leaves in their way to the TP, and by consequence to the endpoint. In the BSRF scheme it's eliminated the need to make communication inter switches searching the NCN, because we are using a signaling channel, the communication inter-switch problem it results easier to solve because we don't use communication inter-switches, besides we assume that the storage's capacity it's contemplated by the vendors, however the processing overhead to process all the needed information is still present, which in case of a great congestion network it represents a real improvement, in the other hand this approach implies a great processing and storage's capacity.

In the worst of cases the TP will be the chosen node, and from the TP will be realized the procedures to contact and obtain the resources to make possible the handoff, and here is another improvement to the NCNR algorithm, if the NCN can't trace a route to the user terminal the handoff is declared null, so the call is finished, we propose instead to analyze all the possible routes proposed by the switches under the TP, until it finds a NCN which can trace the best route from itself to the zone where the mobile wants to move. If is not possible the call should be finished, finally after the completion of the handoff, the TP may be migrated and new possible network routes are determined.

We consider that the packet's rerouting management is doing in an acceptable way in the NCNR algorithm and it's nor proposed nothing at respect.

3.1 Best Semi-Route Found Model (BSRF).

Before we describe the model, we have to determine under what kind of network we are going to work and its topology. Figure 3.1 represents the network under which we will work

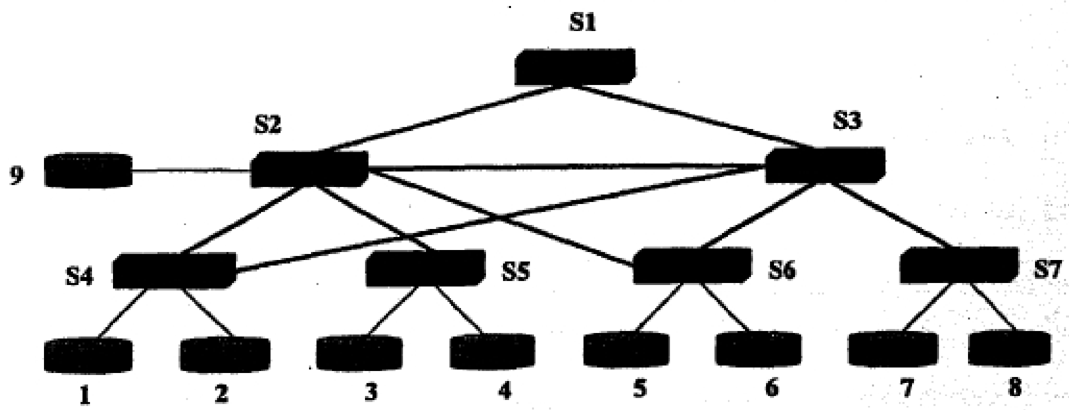


Figure 3.1 **Network Scheme which will be used.**

Where **S1,...,S7** represent ATM switches and **1,...,9** represent zones under the ATM switches control. The figure 3.1 will be used because of its clarity representing how the connections are distributed, switches, zones etc., however we know this is not the way a wireless network is observed in real life, and that's why Figure 3.2 represents the same network distribution as that in Figure 3.1, but in a real life implementation; we can also see the neighboring cells, and so determine from where to where a mobile can move along the network.

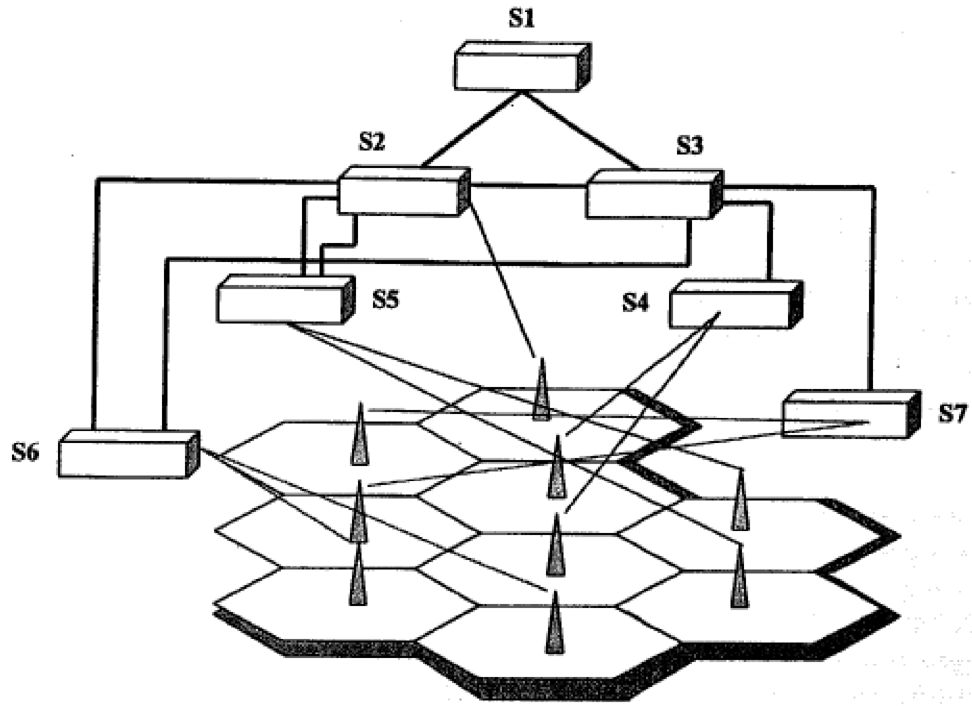


Figure 3.2 Real life appreciation of the Network scheme wich will be used.

3.1.1 Assumptions.

We carry out the simulations under the following assumptions

- There exists a signaling channel in the network through which all the control information are interchanged.
- The switches have enough storage and processing capacity to handle the information generated in the network
- When a mobile arrives for the first time an OSPF algorithm is used to determine the route from the mobile to the end point, then when a handoff is executed the BSRF algorithm is used to perform the rerouting.
- The handoff management at the radio level, is beyond the scope of this job and we suppose it is performed well and without problems.

Now entering in matter the algorithm basically carries out the following:

After a mobile has entered the network and has a route assigned, some time later, it can do two things (besides staying in the cell, which in this case is not relevant), finishing the call or ask for a handoff (in the simulation we'll consider different rates for this two actions), if the second option is chosen then the zone notifies to the network that a handoff is going to happen.

At this moment the switch where the tree information is stored asks for routes to the switches involved in the handoff process (the switches under the TP). The switches then perform the following, each one of the switches involved tries to find a route to the zone where the mobile is moving, the switches performs an exhaustive search in deep analyzing all the possibilities, if it's possible for the switch to find a route or various routes, then the route or routes are proposed indicating the number a links since the zone to the TP, (obviously the routes cross the switch), in this point is necessary to point that exists an important situation to considerate, if any link has a low number of VC's available (previously defined), then the new route are proposed with an advice, the winner route will be which has the minimum number of links from the zone from where the mobile is moving to the TP, however if the winner has advice of "Low number of VCs", the following option will be chosen, an advised route only will be chosen if doesn't exits another best route without advice.

At this point, after the switch has been chosen as the new bridge between the oldest links and the news, it's important to note that is not necessary a *reroute* message to all of the switches located between B and the switch: because the switch before to propose the route, verify for resource availability through the signaling channel; so, when the route proposed is accepted, the resources required by the connection are surely available, the next step is that the necessary connections be established and circuit translation tables be set up. However if any switch could find a route where the resources are not available, the handoff attempt fails and the involved parties are notified.

The packet rerouting, necessary to preserve the cell sequencing either for time-sensitive traffic, and not time-sensitive traffic are managed in the same way as NCNR does it.

Chapter IV

BSRF, A new Rerouting Scheme.

In the previous chapter we have presented the Best Semi-Route Found (**BSRF**) algorithm; in present chapter we'll describe in detail the BSFR algorithm implemented in one of the simulation programs which will serve to compare both algorithms.

As it has been mentioned before, part of the motivation for this work is that even if NCNR is a good algorithm, we think that it presents some procedures that could be improved, We think that using the policies in the NCNR algorithm the network is in risk to saturate the links which cross the low levels (*Again the parents and children, which are in high and low levels, are determined by means of either the network topology in a hierarchical network or closeness in terms of hops to the end pointn*), that is because the algorithm always looks for the first route that could find, and in consequence the low level links are filled first, that's why we think this strategy could not be not very effective.

4.1 Best Semi-Route Found (BSRF), complete Description.

4.1.1 Beginning suppositions.

We will work in the simulations under the following suppositions

- There exists a signaling channel in the network through which all the control information is interchanged.
- The switches have enough storage and processing capacity to handle the information generated in the network
- When a mobile arrives for the first time, an OSPF algorithm is used to determine the route from the mobile to the end point, then when a handoff is requested the Best Semi-Route Found or NCNR algorithm is used to perform the rerouting.
- The handoff management at radio level, is beyond the scope of this work and we suppose it is performed well and without problems.

4.1.2 Best Semi-Route Found algorithm for Time-Sensitive Traffic.

The algorithm for BSRF is explained in the following paragraphs and it can be seen graphically in figures 4.1, 4.2 and 4.4 .

1. A mobile arrives to the zone covered by a switch, then an OSPF algorithm is used to determine the route from the mobile to the end point and a virtual tree is formed, as a result we'll have a virtual tree which is formed by a "*root node*" that is attached to the backbone ATM network, then all potential network routes from the TP to the leaves due to possible handoff attempts are recognized by the network, and these connections are pre-established, however unlike the VCT algorithm, no resources are reserved, the mobile stays during a time exponentially distributed, and a process to determine what to do is performed.
2. The mobile has three options:
   - Stay in the cell for another exponentially distributed time.
   - Finish the call
   - Perform a handoff to a neighboring cell.

* If the fist option is chosen, a new time to check the next event for that mobile is programmed in the event queue and the simulations continue performing the next event.

* If the second option is chosen the simulations continue performing the next event, and not more events are programmed for that call, occupied capacity is released.

3. If the third option is chosen and the mobile is moving from the A zone to the B zone then a handoff session between zones A and B is started. In this example B is the candidate zone for the handoff and A the present zone.
4. Before doing anything else the zone manager of A checks to see if a direct physical link (without involving any other network nodes) between A and B exists. Here there are two possible cases if this condition is satisfied.
   - If A is a parent (*The parent is determined by means of either the network topology in a hierarchical network or closeness in terms of hops to the end point. The endpoint is defined as the terminating point for the user connection in the network*) of B, then A notifies B and the new connection is established without any further network involvement. After the connection is established, A acts as an anchor (*The word anchor is commonly used to refer to a network point that the user connection is forwarded through to the candidate zone until the handoff is completed*) for the connection. Until the stability of the handoff (*The stability of the handoff is used in reference to the radio link transfer which may take longer than one burst during a handoff event. During this period the user terminal may use both network points for information transfer*) is established, both A and B act as network connection points for the user connection. This process is explained in detail in step 6 of this procedure. Once the radio-level handoff is completed, A acts only as a wireless ATM switch in the connection path.

- If B is a parent of A, then A sends a message to B relaying the handoff request. B then acts as an anchor for the handoff procedure. Until the stability of the handoff is established, both A and B may be used for information transfer from/to the terminal to/from the network (see step 6 of this procedure). Once the handoff is stable, B deletes the user connection from itself to A. The rerouting is thus completed.

5. If A and B are not connected by a direct physical link, then the switch where the tree information is stored (this switch is the immediately above the mobile) asks for routes to the switches involved in the handoff process (the switches under the TP). The switches then perform the following, each one of the switches involved tries to find a route to the zone where the mobile is moving, the switches perform an exhaustive search in deep analyzing all the possibilities, if is possible for the switch to find a route or various routes, then the route or routes are proposed indicating the number a links from the zone to the TP, (obviously the routes cross the switch), at this point it is necessary to note that there exists an important situation to consider, if any link has a low number of VC's available (previously defined), then the new route is proposed with an *advice*, the winner route will be the one that has the minimum number of links from the zone from where the mobile is moving to the TP, however if the winner has an *advice* of "Low number of VCs", the following option will be chosen, an advised route will be chosen only if does not exists another best route without *advice.*

6. After the switch has been chosen as the new bridge between the oldest links and the new, it is not necessary a *reroute* message to all of the switches located between B and the switch: that is because before the switch propose the route, verifies resource availability through the signaling channel; so when the proposed route is accepted, the resources required by the connection are available, the next step is that the necessary connections are established and circuit translation tables are set up. However if any switch could find a route because the resources are not available, the handoff attempt fails and the involved parties are notified.

7. When the reroute message is received by *B*, a *reroute acknowledgment* message is sent from B to A. This message completes the rerouting process. The radio-level handoff is attempted at this point by employing the procedures discussed in [7,8]. As the radio-level is started, the bridge switch starts to forward the user information to both A and B in a point-to-multipoint manner. This multiparty connection is necessary until the radio-level handoff is stabilized . The radio-level handoff may extend beyond one radio burst in most radio systems as the user terminal tries to select the optimal link. Especially when a user is in a fading environment, a small motion of the terminal may cause the radio link to switch back and forth between the two radio ports involved in the handoff; hence, a point-to-multipoint link from the bridge switch to both A and B ensures the timely delivery of time-sensitive information. We note here that the user information may be discarded at the zone which is not in contact with the user terminal and transmitted from the zone which is in contact with the terminal. This zone is the zone that is currently receiving the uplink transmission from the portable. If a zone has not received an uplink transmission from the portable in a given radio transmission frame, it must assume it is not active for the next downlink radio transmission period (see [7,13,14] for details on the handoff procedure). In the uplink

direction, the information may be transmitted through either zone involved in the handoff (*If a soft handoff scheme such as in Code Division Multiple access, CDMA, is being employed, where the uplink information is being received simultaneously by two radio ports, then the NCN may be responsible for combining and sequencing the uplink information*) and correctly routed to the endpoint by the bridge switch. Occasionally, the portable may receive duplicate information; since we are discussing time sensitive traffic, the duplicate information may be determined by the time sequence information and discarded accordingly.

8. If the radio-level handoff is successful (*The radio-level handoff is successful only when the stability of the new radio link is established. The determination of the stability of the new link is beyond the scope of this work*), the connection between A and the NCN is cleared by A by sending a clear connection message to the NCN. After the handoff is completed, any buffered time-sensitive data that has not expired will be transmitted to the current zone associated with the portable; expired data are discarded at the zones. For time sensitive traffic, recovery of lost data may only be possible by interpolation of information, which is beyond the scope of this work.

4.1.3 Best Semi-Route Found algorithm for throughput-dependent.

Best Semi-Route Found (BSRF) algorithm for throughput-dependent traffic is in a lot of ways very similar to the Best Semi-Route Found (BSRF) algorithm utilized for time-sensitive traffic. However we know that throughput-dependent traffic is really not sensitive to small (this talking in the order of about just a few hundred milliseconds) delays; however, the lost of information is in any way, absolutely not tolerated by this traffic type. The most typical example of this traffic type is file transfers, and this delay-tolerant nature of this traffic, represents an advantage in the rerouting process. The NCNR for throughput-dependent traffic differs from the procedure for NCNR-TS as follows.

Here there are some differences between Best Semi-Route Found (BSRF) for throughput-dependent traffic and Best Semi-Route Found (BSRF)-TS.

1. As the radio-level handoff is started, the downlink user information is buffered at both A and B. No user information is transmitted in the downlink direction until the radio level handoff is completed. Once the radio-level handoff is complete, the information is transmitted in a first-in first-out (FIFO) manner.
2. If A's buffer is non-empty before the handoff is started, then A's buffer is transmitted to the user terminal if possible, otherwise, these data are transmitted to B and go in front of all other cells buffered for transmission. This preserves the cell sequence.
3. In the uplink direction, before the radio level handoff is started the traffic is transmitted through A if possible; otherwise, it is buffered at the terminal. As the radio-level handoff is started, the user terminal starts buffering the user information. Once the handoff is stabilized the buffered information is transmitted.

These differences ensure the integrity of user data as well as the cell sequence.

The packets rerouting, necessary to preserve the cell sequencing either for time-sensitive traffic, and not time-sensitive traffic are managed in the same way as NCNR does it.

4.2 Simulation program description.

It is not the intention of this section to present a complete description of the simulation programs, however we feel it is important to present in a comprehensive way, the main steps realized by both algorithms (NCNR and BSRF).The four flow-diagrams in figures 4.1 to 4.4 describe the procedures performed by the simulation to handle a particular event.

4.2.1 Main Procedure.

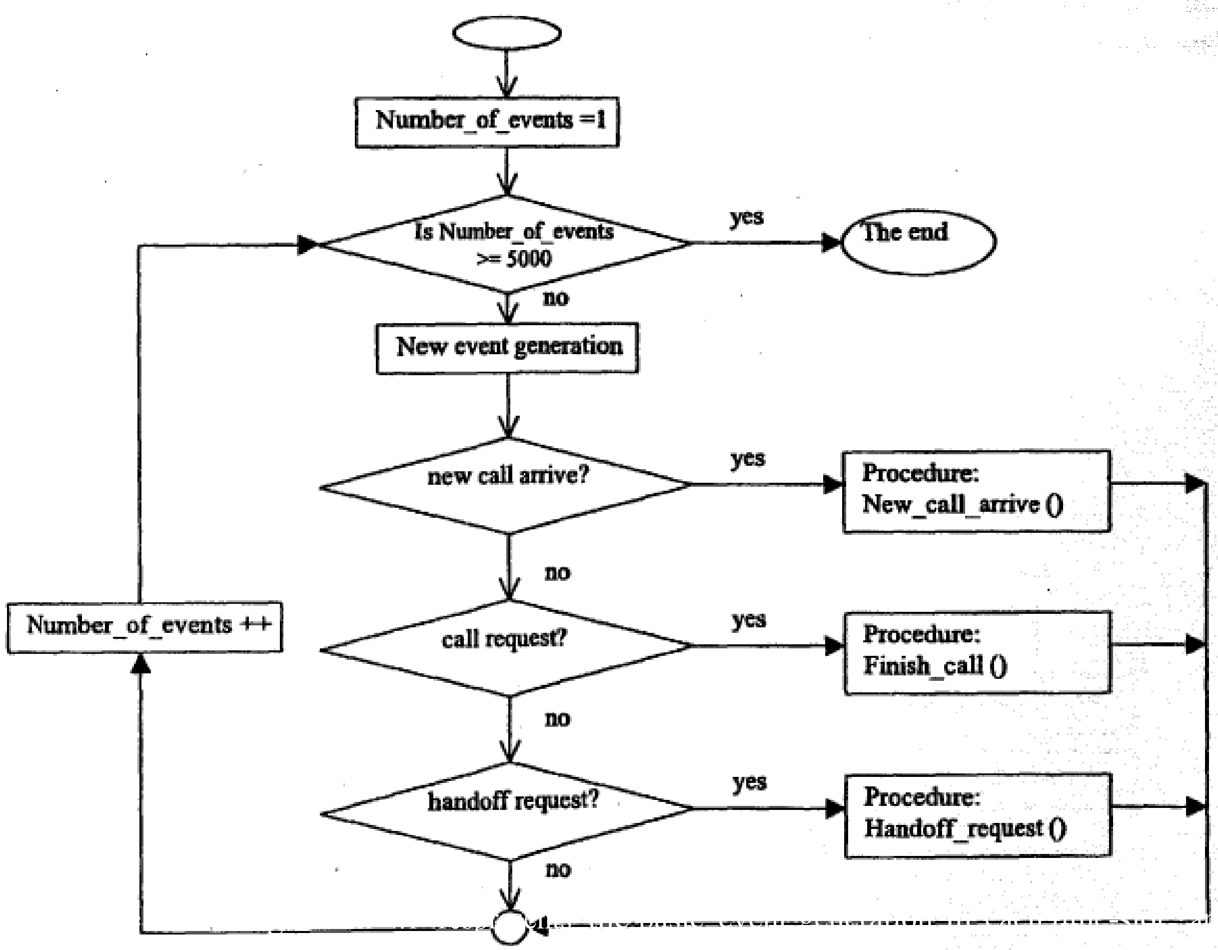


Figure 4.1 **Main Procedure for both Simulations.**

The flow-diagram in 4.1 respresents the basic event generation in each time-slot, an event typically could be:

A new call arrives: A new mobile user arrives to the network each cell has its own average probability to produce this event, a route from the mobile's location to the end-point must be, if possible, assigned by the OSPF algorithm.

A handoff request: The mobile tries to change its location, so a new route from the new mobile's location to the end-point must be, if possible, assigned by the NCNR or BSRF algorithm.

A finished call: The mobile user finishes its call, and all the resources used are released.

4.2.2 Handoff request procedure.

Due to we are interested in analyze the NCNR and BSRF rerouting algorithms, the New_call_arrive and Finish_all are not presented, besides we considere it quite simple and irrelevant for the analysis.

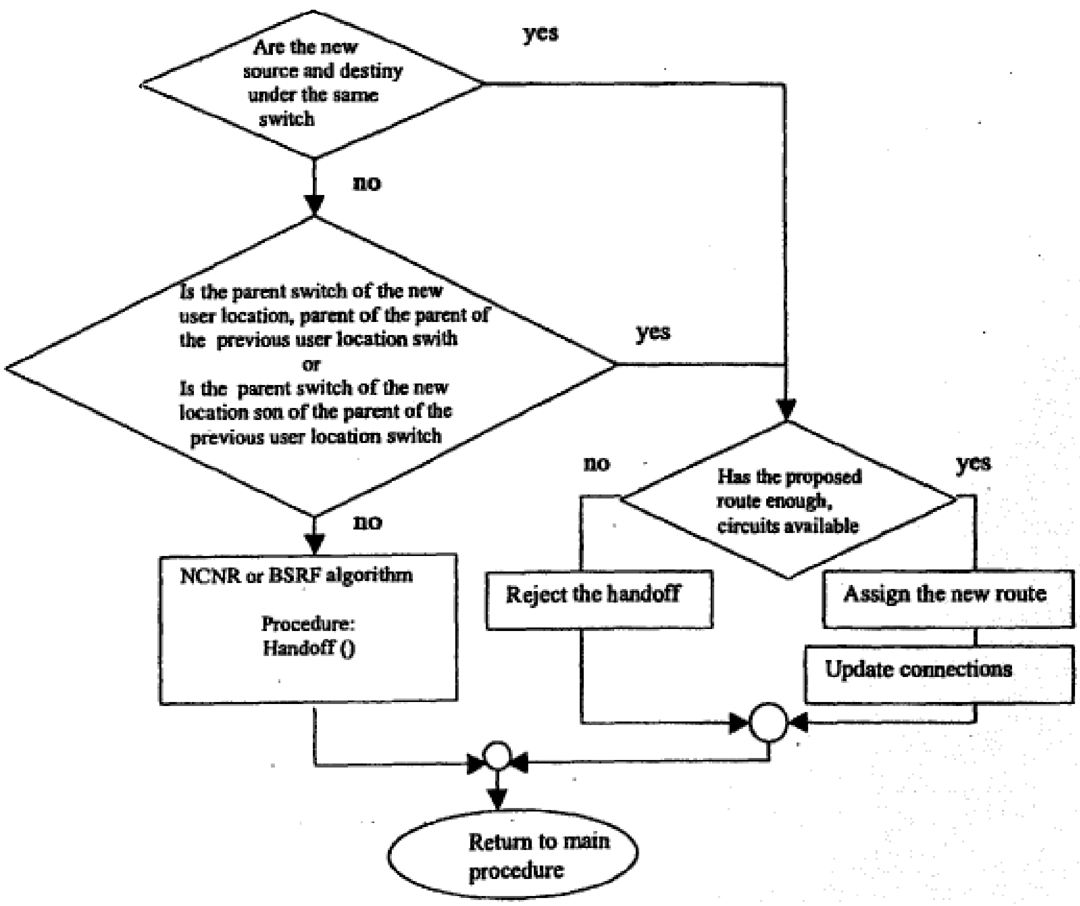


Figure 4.2 Management of Handoff Request.

4.2.2.1 NCNR Handoff Request Procedure.

The next diagram intends to illustrate how the NCNR algorithm handle a handoff request.

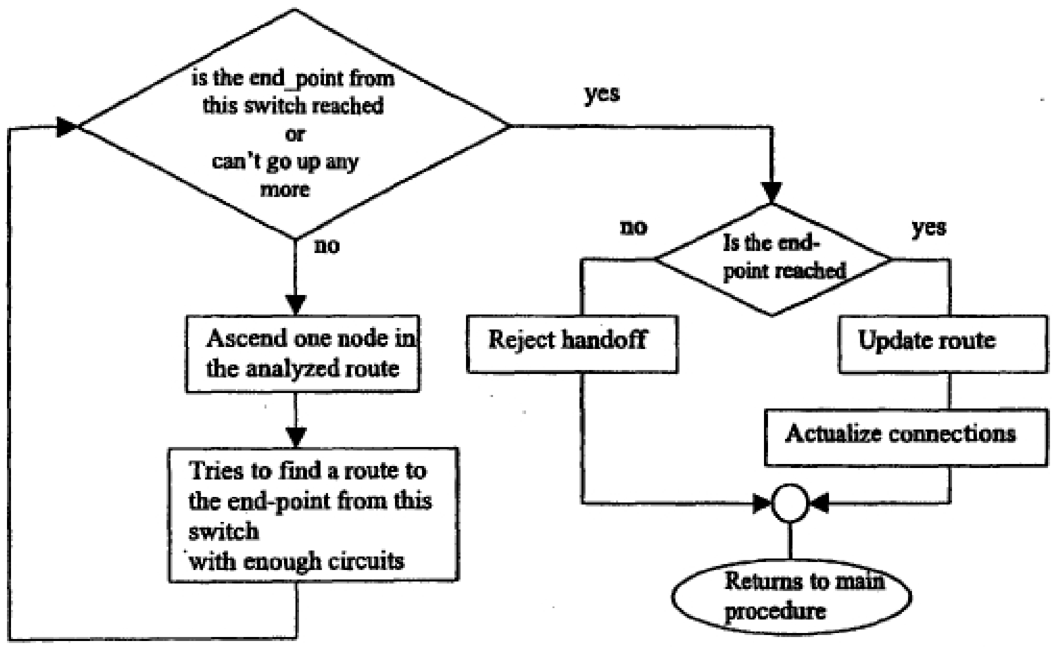


Figure 4.3 Handle of Handoff Request by NCNR algorithm.

4.2.2.2 BSRF Handoff Request Procedure.

The following diagram tries to illustrate how the BSRF algorithm handle a handoff request.

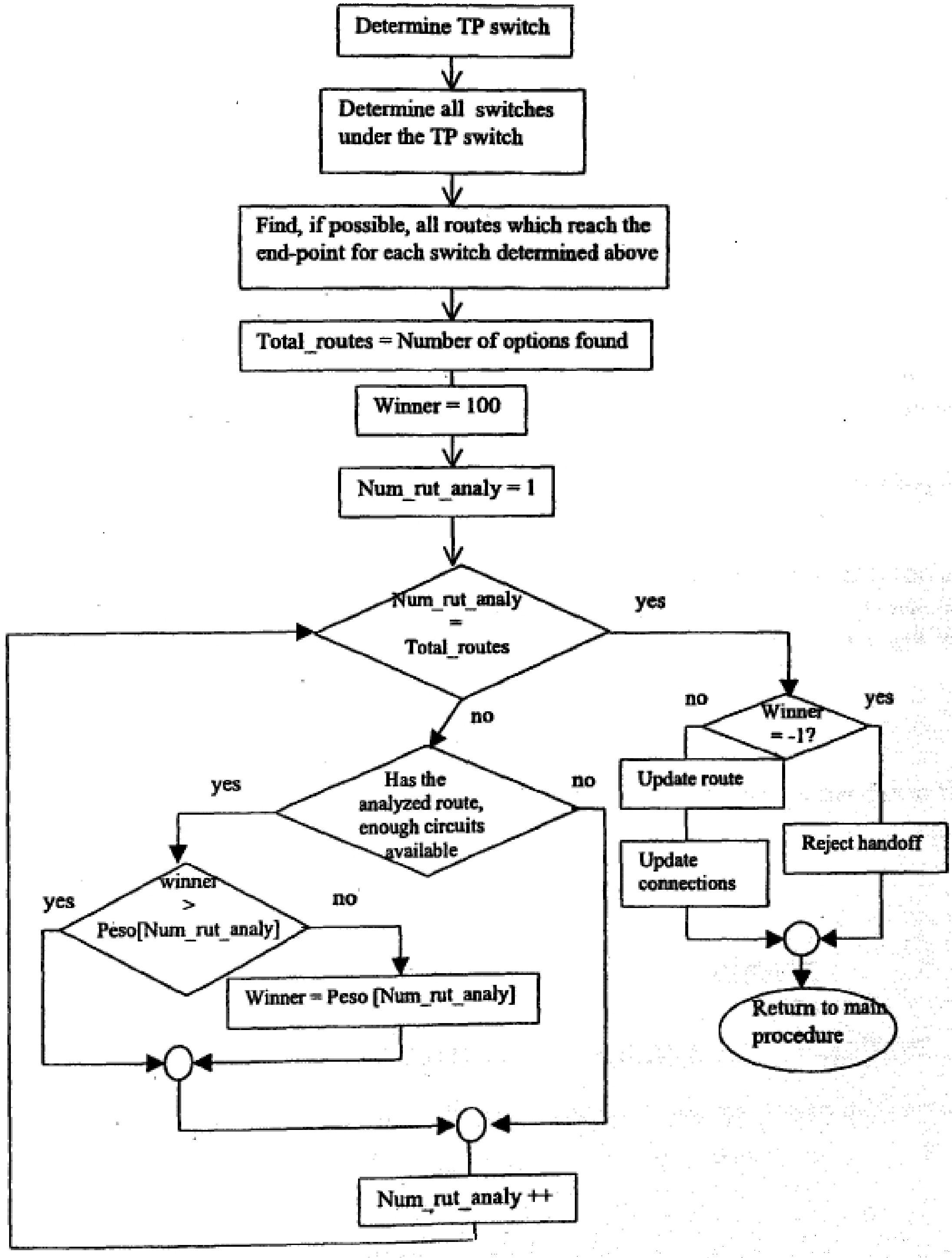


Figure 4.4 Handle of Handoff Request by BSRF algorithm.

Chapter V

Numerical Results.

In the present chapter the numerical results obtained after the execution of both network simulation programs will be presented. The performance measures presented are the probability to reject a new call, and to reject a handoff request for the entire network proposed.

Other results presented are the probability to reject a new call or a handoff request in a specific cell, and the total time used by the computer to execute the simulations.

The results are obtained by varying the average arrival rate for new calls in the cells, in some simulations all the arrival rates were changed together, in others the arrival rates into cell 1 was changed keeping constant the remaining. Cell 1 was chosen since it is the cell with the most neighbors, and its arrival rate will affect more than that of other cells.

5.1 Simulation Specification.

All the numerical results were obtained in the same computer equipment, a Sun Sparc Ultra-IIi 5 with 128 Mb of RAM.

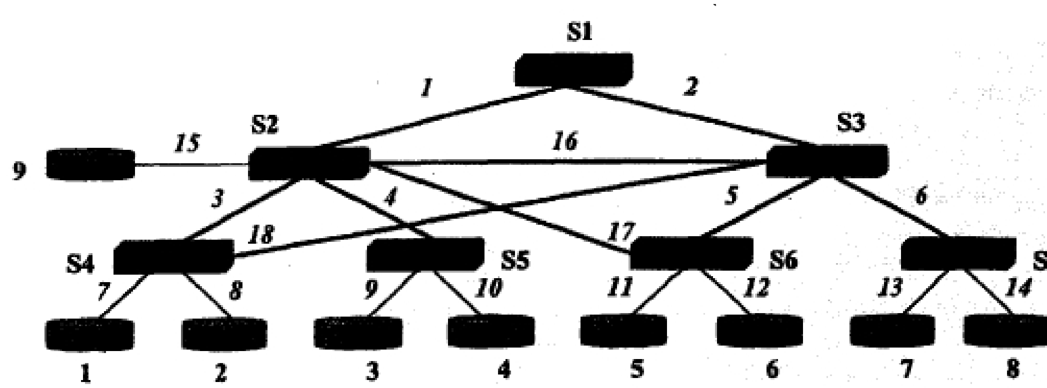


Figure 5.11 Network Scheme.

With the objective to have the same scenario, both rerouting algorithms will be analyzed in the same network scheme, described in Section 3.1 and presented again in Figure 5.1, now assigning an identification number to each link, we will work also with the following suppositions.

The assumptions considered are the same as those in Section 4.2 and the following

- For simplicity we assume that all calls request one unit of capacity per link
- Capacity in cells is considered infinity, so blocking will be, only due to the wireline network and the link connecting the switches with the cells.
- When a mobile finish, all its links are realesed.
- There are fourty units of capacity in each link

With the idea to obtain more general results in the simulations and to see how both rerouting schemes behave with different load, in the experiments the average arrival rate per cell is varied, in one hundred, seventy-five, sixty, fifty, fourty, twenty, fifteen, ten, five, two point five percent of a generic link capacity.

A new call request is blocked when the OSPF algorithm cannot find a route, to allocate the call through all the path.

A handoff request is blocked when the rerouting algorithm cannot find a new route according to its specific criteria described in Section 2.3.4 for NCNR scheme and in Section 4.1.2 for BSRF scheme.

5.2 Results and Discussion

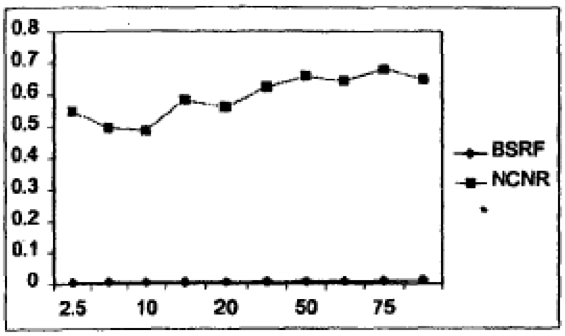
In all the simulations carried out, we assumed that new call arrives were described by Poisson processes and that a new call, already in progress, has a residence time exponentially distributed in the cell were it was generated. A handoff call in progress also has an exponentially distributed cell residence time.

When the residence time of a call in progress, either new call or handoff cal, expires, then the user must make a decision, the user can move into an adjacent cell, in other words causing a handoff, or the user can terminate the call departing from the network.

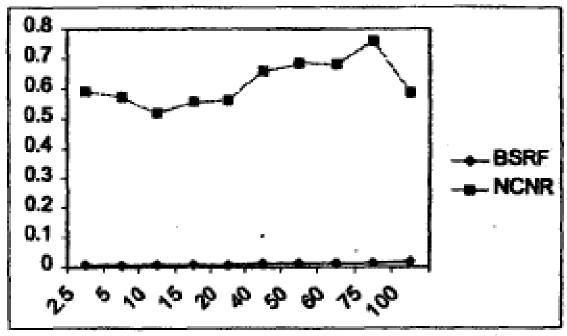
In order to carry out this simple mobility model, we assign probabilities of departure from the network and probability of handing off to an adjacent cell. We consider three cases: Low mobility has a probability of departure of 0.95, Medium mobility of .75, and high mobility of .60, this means that for low mobility a user causes a handoff with a probability of 0.05, for medium mobility this is 0.25 and for high mobility this is 0.4.

5.2.1 Analysis of Network behave, Scenario one.

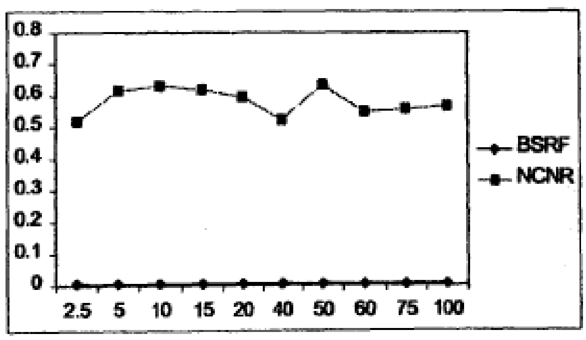
In the next section are presented the behave, in a graphic representation, observed in all the network under the specific assumptions for scenario one.



a) Probability to reject a handoff in cell 1 with a high arrival rate.



b) Probability to reject a handoff in cell 1with a medium arrival rate.

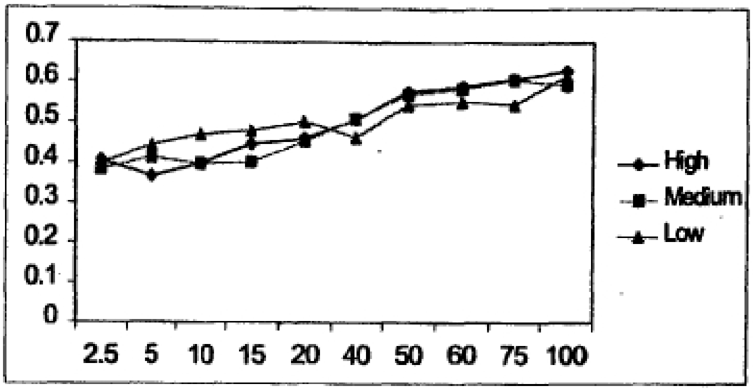


c) Probability to reject a handoff in cell 1 with a low arrival rate.

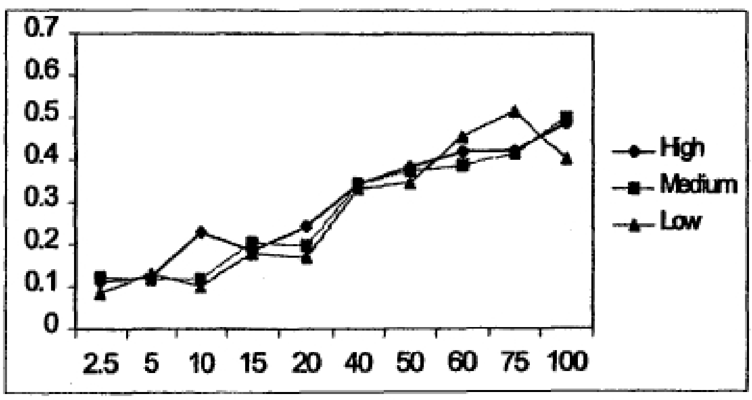
Figure 5.1 **Probability to reject a handoff request in cell 1.**

In Figure 5.1 are presented the probability to reject a handoff request in cell 1 varying the average arrival rate in all the cells, from 100 to 2.5 percent of the capacity for a generic link with 40 circuits of capacity, in each graphic are presented the results obtained for NCNR and BSRF so a comparison can be done.

Figure 5.1 a) represents that case in which the mobility of mobile is high, this means that the probability that the user moves to a neighbor cell is 0.4, Figure 5.1 b) represents that case in which the mobility of mobile is medium, this means that the probability that the user moves to a neighbor cell is 0.25, Figure 5.1 c) represents that case in which the mobility of mobile is low, this means that the probability that the user moves to a neighbor cell is 0.25, In Figure 5.2 and 5.3 are presented the probability to reject a handoff request for NCNR and BSRC algorithm. In both cases was used an OSPF algorithm to manage the new call arrive.



5.2 Probability to reject a handoff with a high, medium, and low arrival rate in NCNR.

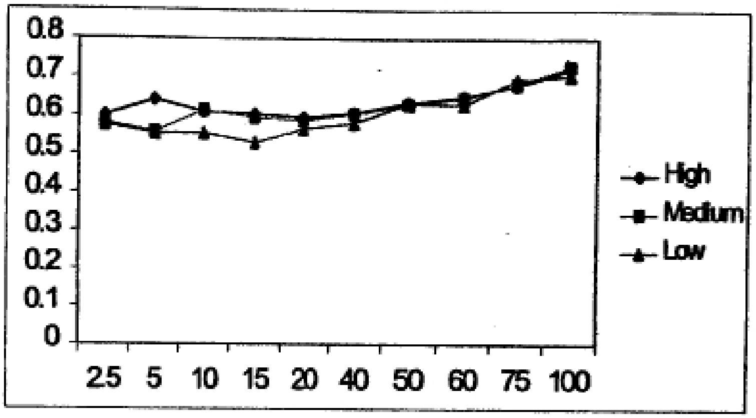


5.3 Probability to reject a handoff with a high, medium, and low arrival rate in BSRF.

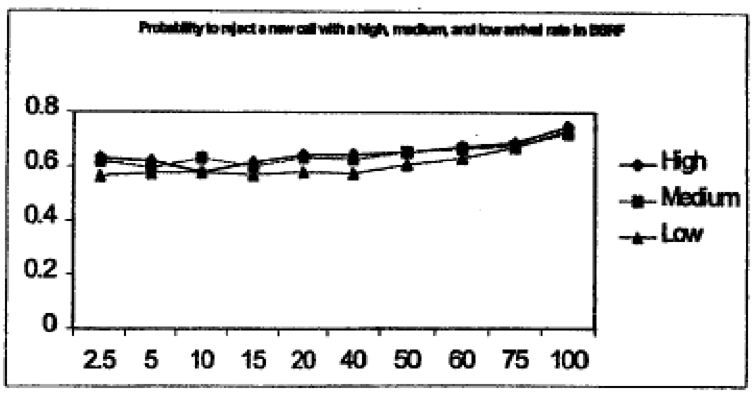
The figures 5.2 and 5.3 presents the probability to reject a handoff request in all the network, in Figure 5.2 was used a scheme using NCNR algorithm and in Figure 5.3 was used a scheme using BSRF algorithm. Both figures, 5.2 and 5.3 were obtained setting each link of the network in 40 circuits of capacity, then was varied the cell arrival rate for each cell in the network from 100 to 2.5 percent of the capacity for the generic link with 40 circuits of capacity.

Finally for each arrival rate is also varied the probability that occurs a handoff to an adjacent cell. The three cases were plotted: Low mobility with has a probability of handing off of 0.05, Medium mobility of .25, and high mobility of .40.

In Figure 5.4 and 5.5 are presented the probability to reject a new call arrive using the NCNR or BSRC algorithm to manage the handoff request according the case. In both cases was used an OSPF algorithm to manage the new call arrive.



5.4 Probability to reject a new call with a high, medium, and low arrival rate in NCNR.



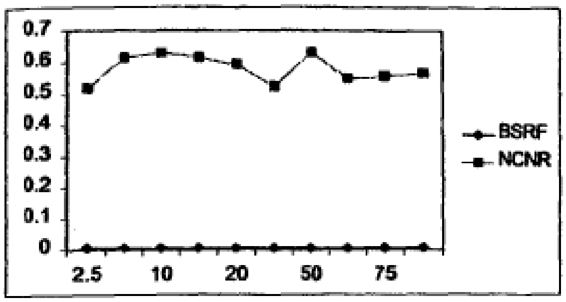
5.5 Probability to reject a new call with a high, medium, and low arrival rate in BSRF.

The figures 5.4 and 5.5 presents the probability to reject a new call arrive in all the network, in Figure 5.4 was used a scheme using NCNR algorithm and in Figure 5.5 was used a scheme using BSRF algorithm. Both figures, 5.4 and 5.5 were obtained setting each link of the network in 40 circuits of capacity, then was varied the cell arrival rate for each cell in the network from 100 to 2.5 percent of the capacity for the generic link with 40 circuits of capacity.

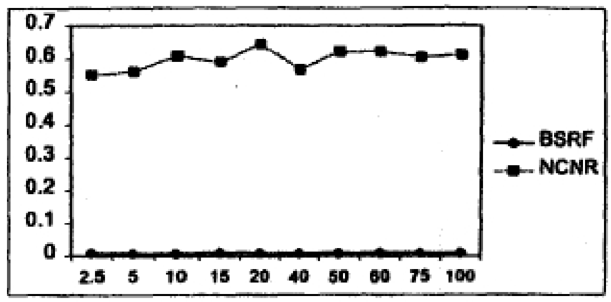
Finally for each arrival rate is also varied the probability that occurs a handoff to an adjacent cell. The three cases were plotted: Low mobility with has a probability of handing off of 0.05, Medium mobility of .25, and high mobility of .40.

5.2.1 Analysis of Network behave, Scenario two.

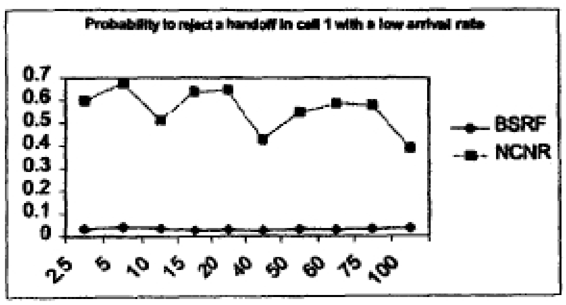
In the next section are presented the behave, in a graphic representation, observed in all the network under the specific assumptions for scenario two.



a) Probability to reject a handoff in cell 1 with a high arrival rate.



b) Probability to reject a handoff in cell 1 with a medium arrival rate.



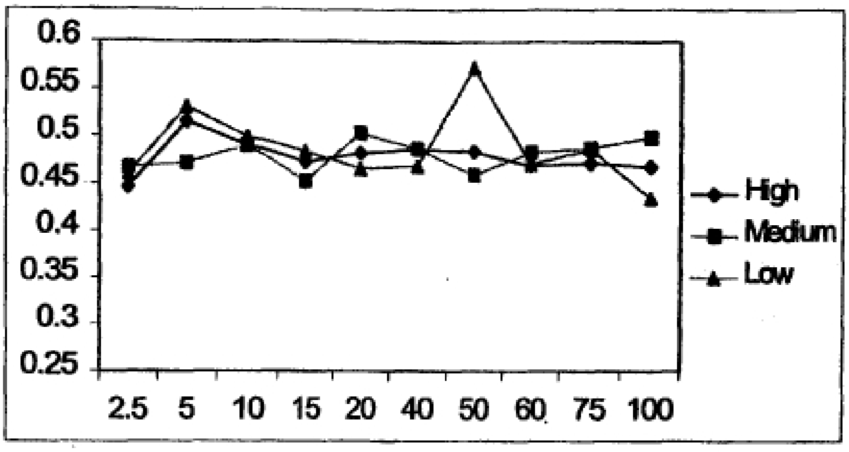
c) Probability to reject a handoff in cell 1 with a low arrival rate.

Figure 5.6 Probability to reject a handoff request in cell 1.

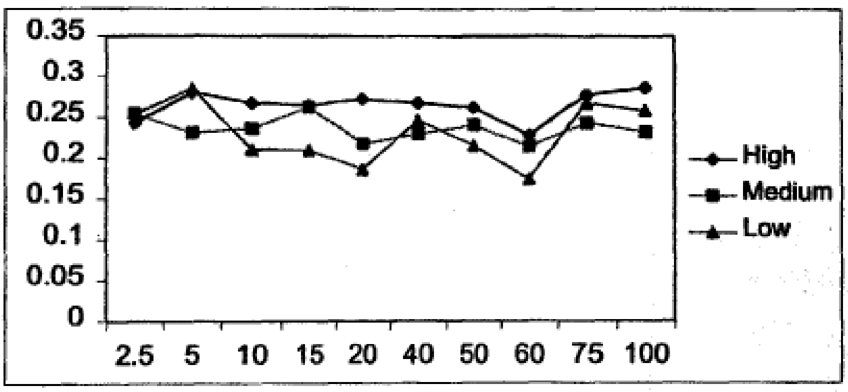
In Figure 5.6 are presented the probability to reject a handoff request in cell 1 varying the average arrival rate just in cell 1 from 100 to 2.5 of a generic link of 40 circuits of capacity, and keeping the arrival rate in the rest of the cell in twenty five percent of a generic link with fourty circuits of capacity, in each graphic are presented the results obtained for NCNR and BSRF so a comparison can be done.

Figure 5.6 a) represents that case in which the mobility of mobile is high, this means that the probability that the user moves to a neighbor cell is 0.4, Figure 5.6 b) represents that case in which the mobility of mobile is medium, this means that the probability that the user moves to a neighbor cell is 0.25, Figure 5.6 c) represents that case in which the mobility of mobile is low, this means that the probability that the user moves to a neighbor cell is 0.25.

In Figure 5.7 and 5.8 are presented the probability to reject a handoff request for NCNR and BSRC algorithm. In both cases was used an OSPF algorithm to manage the new call arrive.



5.7 Probability to reject a handoff with a high, medium, and low arrival rate in NCNR.

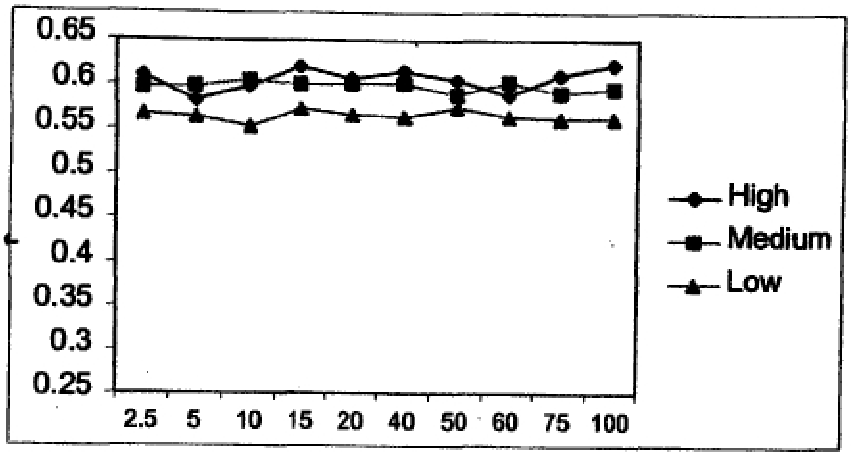


5.8 Probability to reject a handoff with a high, medium, and low arrival rate in BSRF.

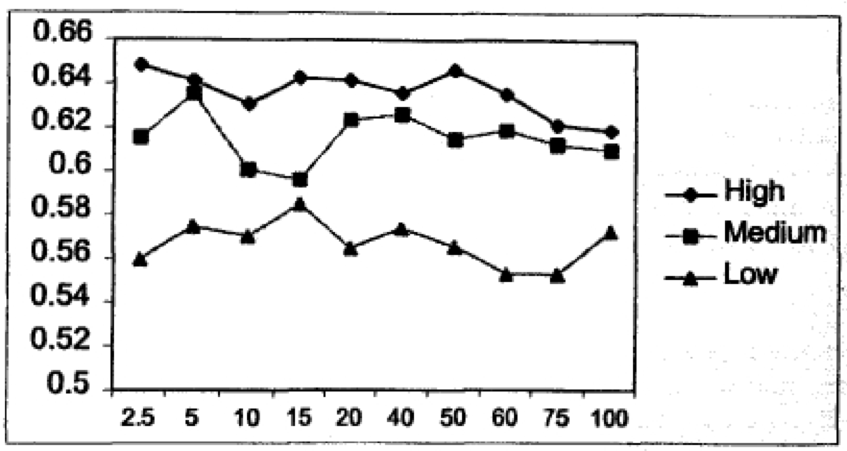
The figures 5.7 and 5.8 presents the probability to reject a handoff request in all the network, in Figure 5.7 was used a scheme using NCNR algorithm and in Figure 5.8 was used a scheme using BSRF algorithm. Both figures, 5.7 and 5.8 were obtained setting each link of the network in 10 circuits of capacity, then was varied the cell arrival rate just in cell one from 100 to 2.5 percent of the capacity for the generic link with 40 circuits of capacity.

Finally for each arrival rate is also varied the probability that occurs a handoff to an adjacent cell. The three cases were plotted: Low mobility with has a probability of handing off of 0.05, Medium mobility of .25, and high mobility of .40.

In Figure 5.9 and 5.10 are presented the probability to reject a new call arrive using the NCNR or BSRC algorithm to manage the handoff request according the case. In both cases was used an OSPF algorithm to manage the new call arrive.



5.9 Probability to reject a new call with a high, medium, and low arrival rate in NCNR.



5.10 Probability to reject a new call with a high, medium, and low arrival rate in BSRF.

The figures 5.9 and 5.10 presents the probability to reject a new call arrive in all the network, in Figure 5.9 was used a scheme using NCNR algorithm and in Figure 5.10 was used a scheme using BSRF algorithm. Both figures, 5.4 and 5.5 were obtained setting each link of the network in 40 circuits of capacity, then was varied the cell arrival rate for each cell in the network from 100 to 2.5 percent of the capacity for the generic link with 40 circuits of capacity.

Finally for each arrival rate is also varied the probability that occurs a handoff to an adjacent cell. The three cases were plotted: Low mobility with has a probability of handing off of 0.05, Medium mobility of .25, and high mobility of 0.40.

Chapter VI
Final Conclusions.

6.1 Introduction.

The world of the telecommunications, and more specific the area of personal communications, is in the actual time, a each moment a more important sector, which is experimenting a great development year by year, and is in this frame that people who work in every branch of the telecommunications area are always trying to improve which is susceptible to be improved, and generally almost everything is.

The rerouting problem is one of the many which exists in the area of the wireless communications, and as has been presented along this job, exists a great variety of solutions available now in the market, and others which are still under development; the main objective of this thesis was to propose a new rerouting algorithm based in a mixture of other which already exists, and compare it, through a simulation program, with one of the best rerouting algorithms for rerouting as the NCNR is.

Our rerouting algorithm received the name of Best Semi-Route Foud or BSRF, and consists basically in analyzing more viable options to complete the handoff request than in NCNR, as has been said in NCNR if the first option to reach the end-point has links with lack of circuit problems then the handoff request is rejected, and the new proposal is based under the premise that if is done a little bit more of analysis, assuming a little bit more work's overload is possible to obtain better results.

6.2 General Conclusions and personal experiences.

6.2.1 General Conclusions based in Numerical Results.

In the past chapter were presented conclusions by section; in this section is our intention to present a more general results based in all the information presented in chapter five, and also comment about the problems and situations found along the thesis development.

First is necessary to say that it was analyzed a great number of possibilities, and under different types of scenarios, all this with the idea to obtain more general results and be able to obtain sufficient information under which can be done conclusions closer to reality.

The first conclusion reached is that the BSFR algorithm has an advantage in average in 14 percentage points completing handoff request over NCNR algorithm, this advantage can be observed clearly in the graphics presented in section 5.3. This BSRF advantage over NCNR however has a price to be paid, in this case is that NCNR has an advantage in 9.8 percentage point in average accepting new call request over BSRF, both measures refers to the performance of the entire network using an OSPF algorithm to find for the first time the mobile arrives to the network, the path to the end-point.

The behave however has a good reason which explains it, and it's because, as has been mentioned above, due to with the OSPF and BSRF scheme the average probability to complete a handoff request is higher than using OSPF and NCNR, the number of circuits which remains to accept a new call request is each link are considerably reduced, that gives as consequence that when a new call request arrives will be more difficult to the OSPF algorithm find a complete path without lack of circuits problems; in the other side as in the NCNR algorithm the average probability to complete a handoff is lower, the number of circuits which remains in the links to complete a new call request are much more, and as a result the OSPF algorithm can find a path without any kind of lack of circuits problems. Another explication for this behave is that the OSPF do exploits the upper links which are not very used by the NCNR algorithm because due to its procedures, the lower links are very exploited and but not the upper, in BSRF the link's use is more fair, and so is more difficult to find a complete path to the end-point with this scheme.

The reader could think, how is possible that if NCNR has a better new call acceptance average rate than BSRF this has a better handoff request acceptance average rate?, if OSPF can't find a complete path without problems must be because there are not enough circuits in the links to complete the new call request, then how BSRF algorithm can find it to complete a handoff request?. Even seems difficult to answer this questions, the correct answers, are not very difficult at all, the main reason to this behave is because in BSRF algorithm is have not been analyzed the complete path, and because are analyzed much more options to reroute the path since the TP node previously designed, it's important to note that when the OSPF is trying to find a path to the new call request is just one of the links hasn't enough circuits available all the path is rejected, but when is been performed the BSRF algorithm the probability to find a link without circuit available is reduced, because are analyzed less links. Another reason because is easier to complete a handoff request is that in BSRF the algorithm has a mechanism to avoid the use in excess for any link, that is, the algorithm always gives preference to routes which has more that 5 circuits available.

This general conclusion can be seen reflected in the analysis of handoff request probability and new call arrive request acceptance in a very representative cell as number 1, as the results show the same behave was observed in this cell.

Another disadvantage for the NCNR algorithm found, as we will explain in the next section, was that the NCNR algorithm does not work with networks only with networks structured as trees, so in order to be able to compare the NCNR algorithm against the OSPF it was necessary modify the NCNR algorithm in the implementation, so it can work with networks and not just with networks structured as tree.

6.2.1.1 Algorithm complexity.

The NCNR algorithm complexity, compare it against the BSFR algorithm complexity, is notably lower due to the natural behave of both algorithms, this could be easily observed in the number of steps that must be followed before obtain the best route.

For example if we analyze the worst of the cases for NCNR and BSRF, the number of comparisons done in this case (the worst) for NCNR are the same number done in the BSFR in every analysis, this obviously comparing always the same case, with the same needs. For both algorithms are assumed a signaling channel trough which the routing packets are interchanged in the network, however in the NCNR algorithm there is not anything such a routing table, and so the memory usage is better than in BSFR which indeed uses routing tables in all the switches which are used to determine which routes should be analyzed, in the other side the delay in the NCNR algorithm could be a significant variable which were not analyzed in the present job

6.2.2 Experiences along the thesis development

There are not much to report or along the thesis development, we think was just one relevant thing that was that NCNR algorithm wasn't designed, or al least doesn't indicate it is, to work with networks just with networks structured as trees, we doesn't noted that until we start to run the simulations, which reports problems when it was running, the problem was detected, in the procedure dedicated to find a route in a recursive way, this procedure always failed when it tried to visit a branch which conduce the procedure to a loop. After been resolved this problem the works continued in a normally way.

Other thing which had to be assumed was the use of the OSPF algorithm, to determine how to reach a new call request, because in the NCNR specification nothing is said about, however we felt too, that this choose wasn't as important as to alter the results, and wouldn't be different use this or other similar algorithm.

6.3 Future Works

As it was mentioned in the beginning of this section, this area is susceptible to be improved. We consider this work as an interesting advance in the rerouting algorithms, however we feel there exist some things that can be added to the job which will help to obtain better results, one of this could be to integrate to the BSRF simulation program a procedure to simulate the interchange of routing tables needed to determine if there exists a route form one switch to other, this information is assumed that exists and is passed through a control channel, here it would be interesting to see what happens if the routing tables are not updated when a handoff or a new call request arrives to the network (the routing tables are updated every 30 seconds by some routing protocols and every 90 seconds by others).

Another improvement could be to integrate the management of video, voice and data traffic in the links with their respective circuit needs, and to determine the new call and handoff request acceptance probability for each traffic type; and finally as a total future work, it could be done a complete new rerouting algorithm better than the presented in this thesis.

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