Mobile ATM Handoff and Performance Analysis

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Abstract

This paper extends the work of [2] to a mobile environment. In that work, the equilibrium buffer fill distribution is described by a set of differential equations assuming sources alternate asynchronously between exponentially distributed periods in "on" and "off" states. This paper extends that work by including the probabilities that mobile sources have links to that buffer. The sources represent mobile user nodes, and the buffer represents the capacity of a switch. Some familiarity with [2] is assumed. The result of this extension is an algorithm which uses mobile parameters such as speed, call rates per unit area, cell area, and call duration and determines queue fill distribution at the ATM level. This can be used to determine the effects of various ATM handoff schemes which are reviewed.

1: Introduction

It is generally recognized that the next generation of mobile systems will be B-ISDN compatible. It is still at an early stage and relatively few in-depth papers have been published on such systems. The papers that have been written are very general, high level overviews of how such mobile systems might operate. As a typical example [6] discusses where features should be implemented, what hardware should run those features, and what the protocol might look like. Papers that consider the specific area of handoff are even more rare.

This paper will focus on the specific topic of handoff. This is, *prima facie*, closely related to congestion control. As the shared access medium, available air bandwidth, becomes loaded, adding more cells[1] and reducing the cell area will distribute the load and reduce interference. However, this will increase the number of handoffs which occur, thus emphasizing the need for handoffs which are as efficient as possible.

It appears that there has been little work done concerning the effects of mobility on ATM. This paper will attempt to build a foundation for analyzing mobile ATM networks by extending [2]. This analysis would be useful for analysis of the base station queue fill distribution and probability of cell loss in a mobile environment. It would also be useful for simplifing mobile CBR cell simulations.

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[1] Note that there is a potential for confusion between an ATM cell and the cell referring to the area covered by a base station. The term, "cell area", will be used for the latter.

2: Mobile Systems Analysis

This section extends the work of [2] to a mobile environment. In that work, the equilibrium buffer fill distribution is described by a set of differential equations assuming sources alternate asynchronously between exponentially distributed periods in "on" and "off" states.

An extension to that work will be made by including the probabilities that mobile sources have links to that buffer. The sources represent mobile user nodes, and the buffer represents a switch.

In [2], the queue fill distribution is determined for multiple constant rate on-off sources. However, it assumes that the number of sources remains constant over a sufficient period of time for the equilibrium probabilities to be valid. There are at least two ways of extending [2] to a mobile CDMA cellular environment.

Consider the ATM cell queue fill distribution at the base station. The simplest, but least accurate extension is to determine the average number of channels used per cell area as $t \to \infty$. However, there is nothing to stop mobile units from concentrating in a small number of cell areas at some time. However, there is a hard limit on the number of sources a base station will accept because each base station has a limited number of CDMA codes [5]. Once this number is reached, further handoffs into such a cell will cause their connections to terminate. Thus, determining how many codes to assign to a base station is a critical design choice.

Note that code assignment can be dynamic, but this will not be considered here in order to help simplify the analysis. Also, cell areas can be designed to overlap [5]. Although this can increase the probability of interference, it has a beneficial effect on handoff. When a mobile unit determines that a handoff is likely to occur and the cell it will enter has no channels avaliable, the mobile unit can continue to use the cell within which it currently resides, and queue the handoff to the next cell. If a channel becomes avaliable in the destination cell before the mobile leaves its current cell, the handoff can take place succesfully. It would be interesting to see the effect of queueing the handoffs. Again, in order to keep the computation simple for this paper, this will not be considered.

Another possible extension of [2] to the mobile environment would be to determine the CDMA channel holding time distribution. Note that this paper makes the simplifing assumption that each mobile unit is a single ATM source multiplexed at the base station. In general, each mobile unit would be a set of sources; however, this could again be a future extension of this paper.

In order to attempt this extension of [2], this paper will make use of the notation in [4]. There are two probability distributions that need to be developed: the channel holding time and the equilibrium probability of the number of channels used per base switch. The channel hold time is the probability that a particular base station's channel will be in use at a given time, or that a particular source still exists in [2]. Knowing the equilibrium probability of channels in use for a given base switch is also useful for extending [2] as will be shown later.

The first of many simplifying assumptions is that there is a known average number of new calls per second per unit area. Let this be λ_R where R is the radius of the particular cell area. Handoffs are attempted at an average rate per cell, λ_{Rh}. The ratio of handoff attempts to new call attempts will be $\gamma_o \stackrel{\Delta}{=} \frac{\lambda_{Rh}}{\lambda_R}$.

Let P_B be the average number of new call attempts which are blocked. Then new calls are accepted at an average rate of $\lambda_{Rc} = \lambda_R(1 - P_B)$. Similarly, let P_{fh} be the average number of handoff attempts which are blocked. Then handoff calls are accepted at a rate $\lambda_{Rhc} = \lambda_{Rh}(1 - P_{fh})$. The ratio of the average accepted handoffs to the average number of new calls accepted is $\gamma_c \stackrel{\Delta}{=} \frac{\lambda_{Rhc}}{\lambda_{Rc}}$. The channel holding time, T_h , is a random variable defined as the time beginning when a channel is accessed, either via a new call or handoff, until the channel is released, via handoff or call completion. In order to define this, another random variable, T_M is defined. T_M is the time duration of a normal call, regardless of handoff or blocking. It is simplified as an exponential with average value, $\frac{1}{\mu_M}$. Thus the pdf is

$$f_{T_M}(t) = \mu_M e^{-\mu_M t}. \tag{1}$$

The strategy for determining the channel holding time distribution is to consider the time remaining for a call which has not been handed off yet, T_{Hn}, and the time remaining after a handoff, T_{Hh}. Since the call duration, T_M is memoryless, the time remaining for a call after handoff has the same distribution as the original call duration. Let T_n be the time the mobile unit remains in the original cell area, and T_h be the time the mobile resides in the cell area after handoff. T_{Hn} is the minimum of the call duration, T_M, or the dwell time in the originating cell area, T_n. A similar reasoning applies to the cell area into which a mobile unit has moved after a handoff; T_{Hh} is the minimum of the call duration, T_M, or the dwell time in the cell area after handoff, T_h.

Thus,

$$\begin{aligned} F_{T_{Hn}}(t) &= F_{T_M}(t) + F_{T_n}(t)(1 - F_{T_M}(t)) \\ F_{T_{Hh}}(t) &= F_{T_M}(t) + F_{T_h}(t)(1 - F_{T_M}(t)) \end{aligned} \tag{2}$$

where $(1 - F_{T_M}(t))$ is the probability that a call does not complete within the current cell area.

The distribution of channel holding time in a particular cell area is a weighted function of the equations in 2,

$$F_{T_H}(t) = \frac{\lambda_{Rc}}{\lambda_{Rc} + \lambda_{Rhc}} F_{T_{Hn}}(t) + \frac{\lambda_{Rhc}}{\lambda_{Rc} + \lambda_{Rhc}} F_{T_{Hh}}(t) \tag{3}$$

Subsituting the values from 1,

$$F_{T_H}(t) = 1 - e^{-\mu_M t} + \frac{e^{-\mu_M t}}{1 + \gamma_c}(F_{T_n}(t) + \gamma_c F_{T_h}(t)) \tag{4}$$

and differentiating to get the pdf,

$$\begin{aligned} f_{T_H}(t) &= \mu_M e^{-\mu_M t} \\ &\quad + \frac{e^{-\mu_M t}}{1 + \gamma_c}\left[f_{T_n}(t) + \gamma_c f_{T_h}(t)\right] \\ &\quad - \frac{e^{-\mu_M t}}{1 + \gamma_c}\left[F_{T_n}(t) + \gamma_c F_{T_h}(t)\right] \end{aligned} \tag{5}$$

To determine the equilibrium probability of the number of mobile hosts using a base station, approximate the channel holding time as simply an exponential distribution. The birth-death Markov chain can be used to find the equilibrium probability of the number of sources in each cell area. The *up rates* are $\lambda_R + \lambda_{Rh}$ and the *down rates* are multiples of the mean channel hold time.

Putting the Markov chain in closed form,

$$P_j = \frac{(\lambda_R + \lambda_{Rh})^j}{j!\mu_H^j} P_0 \tag{6}$$

where,

$$P_0 = \frac{1}{\sum_{k=0}^{C} \frac{(\lambda_R + \lambda_{Rh})^k}{k!\mu_H^k}} \tag{7}$$

Note that C is the total number of channels for a base station and handoffs will fail with probability P_C, i.e. all channels in that cell area are currently in use.

Now we are ready to begin looking at the analysis of Anick, Mitra, and Sondhi. Assume that the number of mobile hosts in a cell area is independent of whether its CBR source is on or off. We can now modify the probability that i sources are on and the queue fill is less than x by incorporating the probability that there are at least i sources, 8.

$$P_{i_{mobile}}(t, x) \stackrel{\Delta}{=} P_{j \geq i} \; and \; P_i(t, x). \tag{8}$$

$P_i(t, x)$ is the probability that at time t, i sources are on, and the number of items in the buffer does not exceed x. $P_{j \geq i}$ is the probability that there are at least i sources sending data to the buffer. $P_{j \geq i}$ can be found from 6 as follows,

$$M_i = \sum_{j=i}^{C} P_j. \tag{9}$$

The buffer fill distribution as defined in [2] is

$$\begin{aligned} P_i(t + \Delta t, x) = \{N - (i - 1)\}\,\lambda \Delta t P_{i-1}(t, x) \\ + (i + 1)\Delta t P_{i+1}(t, x) \\ + \left\{1 - \left((N - i)\lambda + i\right)\right\} \Delta t P_i(t, x - (i - c)\Delta t) \\ + O(\Delta t^2). \end{aligned} \tag{10}$$

Now that the channel equilibrium probabilities have been determined, we can account for the fact that the sources are mobile. Since the channel equilibrium probabilities have no dependence on time, the method of solution in [2] can be used with minor modifications,

$$\begin{aligned} P_i(t+\Delta t, x) = \{N-(i-1)\}\, \lambda \Delta t P_{i-1}(t,x) M_{i-1} \\ +(i+1)\Delta t P_{i+1}(t,x) M_{i+1} \\ +\left\{1-\big((N-i)\lambda+i\big)\right\} \Delta t P_i(t, x-(i-c)\Delta t) M_i \\ +O(\Delta t^2) \end{aligned} \quad (11)$$

From [2], $F_i(x)$ is the equilibrium probability that i sources are on, and the buffer content does not exceed x. Thus $F_i(\infty)$ is the probability that i out of N sources are simultaneously on. In the mobile environment, this is now,

$$F_i(\infty) = \sum_{j=1}^{C} P_j \binom{C}{j} \left(\frac{\lambda}{1+\lambda}\right)^j \left(\frac{1}{1+\lambda}\right)^{C-j}. \quad (12)$$

The mobile extension from equation 8 carries through [2] for example, equation (13) in [2] is now,

$$\phi_{i_{mobile}} \triangleq \phi_i P_{j=i} \quad (13)$$

and

$$\Phi(1) = \sum_{i=0}^{C} \phi_i P_{j=i}. \quad (14)$$

ϕ_i is the right eigenvector of

$$zD\phi = M\phi \quad (15)$$

where D and M are matrices used to represent the differential equation in 10.

$\Phi(x)$ is the generating function of ϕ. These values are useful in [2] for solving the equalibrium buffer fill differential equation. The remainder of the solution is straight forward from [2]. Thus it has been shown how an analysis of constant bit rate on-off sources which model fixed length ATM packet sources, is extended to a mobile environment.

2.1: Example

The following is a simple example of the analysis using the same parameters as the simulation in the next section. The parameters required are:

1. $R = 1.5$ miles
2. $\lambda_R = 0.06$ calls/sec/square mile
3. $T_M = 40$ secs
4. $V_{max} = 0.03$ miles/sec
5. $C = 3$ channels per base station

From the equations in the previous section, we can develop an analytical solution for the remaining parameters. Using basic probability the integral of equation 5 should be one. Also, μ_H is an exponential approximation of 4, which can be found by taking the integral of the difference of 4 and μ_H and setting the result to zero,

$$\int_0^\infty f_{TH}(t)dt = 1 \quad (16)$$

$$\int_0^\infty \left[F_{TH}(t) - e^{\mu_H t}\right] dt = 0. \quad (17)$$

This provides two equations and two unknowns which provide the solution for $\lambda_{Rh} = 2.16$ and $\mu_H = 9.48$. These values can be used to determine the P_j which can then be used in our extension of [2] as discussed previously. In the graph of P_j shown in figure 1, it appears that there will be a high probability of blocking, since $P_B = P_C = P_3$. This is compared with an arrival rate of 0.01 calls/sec/unit area, which has a maximum of two channels per station, and a lower blocking probability.

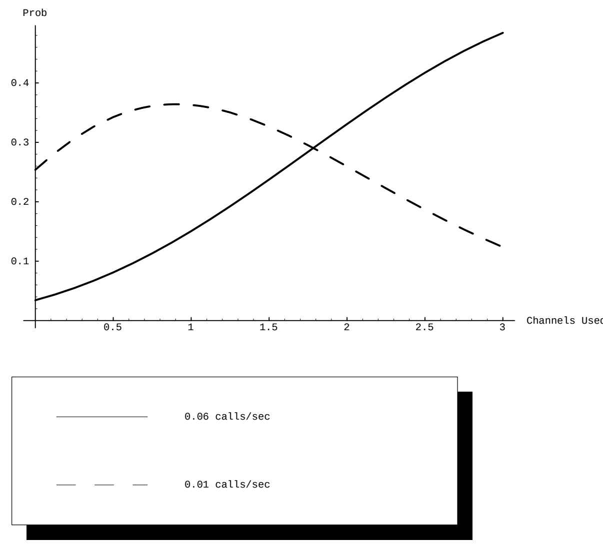

Figure 1. Channel Usage Prob. Density Function.

2.2: Simulation and Results

The mobile communications system model[2] is shown in figure 2. It is an open system; mobile hosts are generated at rate with inter-arrival time specified by **Exp Pulse Mean**, initiate a call for an average exponential duration specified by **Mean Session Length**, and exit the system when either the call is complete or the mobile moves out of all cell areas.

The first step is to create the base stations and their cell areas. The total number of base stations is:

$$\textbf{Base Station Matrix Size}^2 \quad (18)$$

[2]A mobile cellular telephone system library comes with the BONeS software. As much as possible of that library is used as a basis for this simulation.

Figure 2. Top Level Mobile System.

and they are located in a square array. They all have the same number of channels, **Total Channels for Base Station**. Each cell area can be approximated as a circle with radius:

$$\frac{\textbf{Distance Between Base Stations}}{2} \tag{19}$$

Mobile hosts are created in **Create Mobile Users**. All the mobile parameters are uniformly distributed, except the session duration which is exponential and agrees with equation 1 of our analysis. New mobiles enter the system with an interarrival time of **Exp Pulse Mean**. The mobile host will arrive at a location uniformly distributed anywhere in the area covered by all cells. Since a mobile makes one call in its lifetime, a mobile host represents a single connection. Thus,

$$\lambda_R = \frac{1}{(\textbf{Exp Pulse Mean})(Total\ Cell\ Area)(B)} \tag{20}$$

where B is the number of base stations.

The following modules act upon the mobile hosts throughout their lifetime. The mobile hosts are assigned the nearest base station **Assign Base Station to Mobiles Users**, and an avaliable channel from that base station **Assign Channel to Mobile Users**. Then all mobile hosts dwell in their cell areas for time **Delta Time Delay Mobile Users**. The mobile host then moves to its next location which may be uniformly chosen from **Direction of Motion Options** and may lead to a new cell or completely outside the cellular system **Move Mobile Users**.

After moving, the quality of signal is checked and if below a given criteria[3] the channel is released (**Release Channel**) and the mobile host is reassigned to a new base station (**Assign Base Station to Mobile Users**).

Figure 3 shows the channel hold time versus the average length of connection time and the speed of the mobile units. *Channel hold time* is the average amount of time a channel is used by a mobile user. *Channels used* is the average number of channels in use **at a base station**. Note that the direction of travel by a mobile user is uniformly chosen from North, South, East, or West. A more sophisticated analysis of speed and direction is contained in [7]. The average channel hold time increases with the average connection time as expected. However, the average connection time increases as the mobile speed is increased, which is counter-intuitive. One would expect faster mobiles to use more channels for a shorter amount of time.

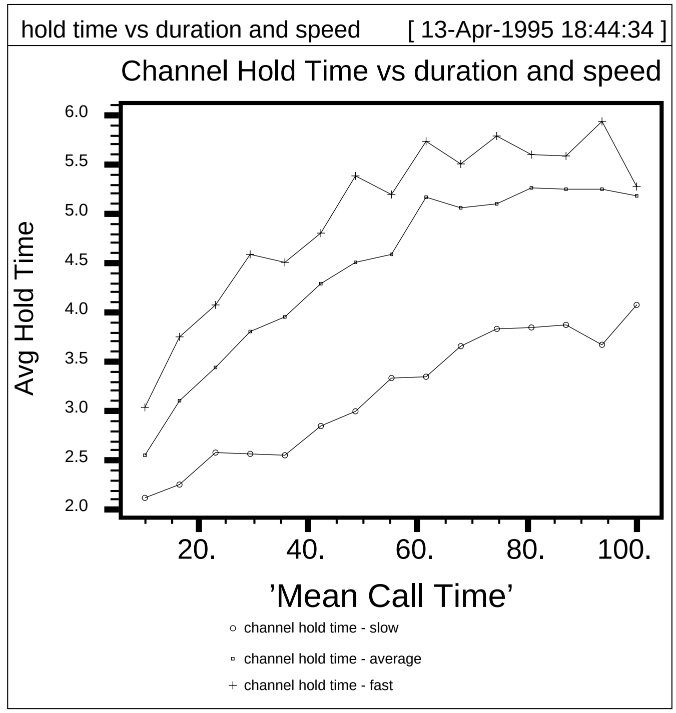

Figure 3. Mean Channel Hold Time vs Call Duration and Speed.

In figure 4 the average number of channels used is graphed versus average length of connection time and the speed of the mobile units. Again as the average length of connection time increases the number of channels used increases. But from this limited number of simulations, the number of channels used seems to be insensitive to the speed of the mobile units which is again somewhat counter-intuitive. One might expect faster mobile units to pass through more cell areas and use more channels.

Figure 5 shows the average number of handoffs, with each handoff weighted by the inverse of its channel holding time, T_H. Thus if there are an equal number of handoffs, but the channel holding times of one was larger than the other, the one with the larger holding times will have a smaller value. This can be a more useful measure than the simple average of the number of handoffs, because it takes into account the frequency as well as the number of handoffs. It appears that mean call time does not have a significant impact on this measure, however, mobile speed does have a significant impact. Faster mobiles have a higher weighted average handoff as expected.

The next set of figures (6, 7, 8) shows the effect of cell area on channel hold time, channels used, and handoffs. Note that λ_R, which is the call arrival rate per unit area, remains constant. If the total number of calls generated per cell area remained constant as cell area increased, the channel hold time would approach the call duration time

[3] In this case, if the distance between a mobile host and its currently assigned base station is greater than $\frac{2}{3}\sqrt{D^2 - \left(\frac{D}{2}\right)^2}$ where D is the distance between base stations, then the channel quality is considered unacceptable.

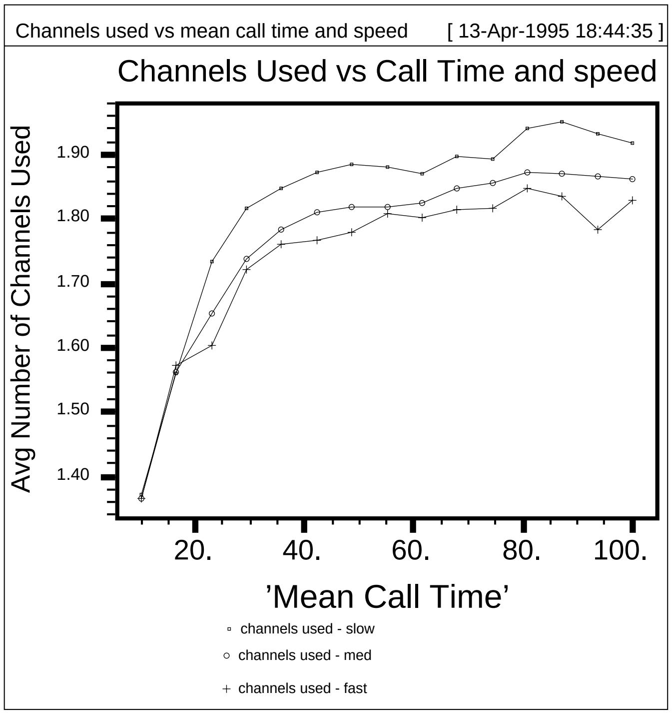

Figure 4. Mean Channels Used vs Call Duration and Speed.

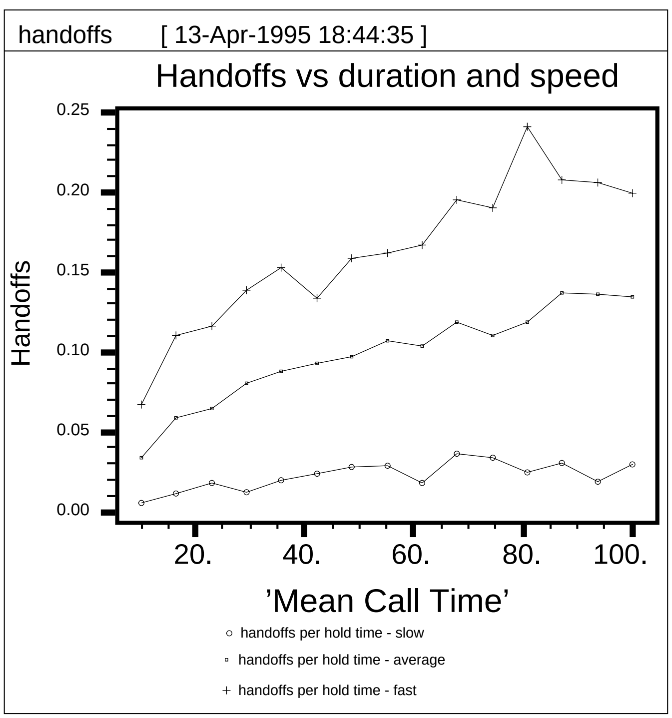

Figure 5. Handoffs vs Call Duration and Speed.

and there would be fewer handoffs. However, in this case, although a larger cell area has a larger area in which mobile units can move around, it will also generate more mobile units.

Figure 6 shows that the average channel hold time decreases as the cell areas become larger. Although the cell areas are larger, the number of channels remains constant. Thus there are fewer handoffs as shown in figure 8.

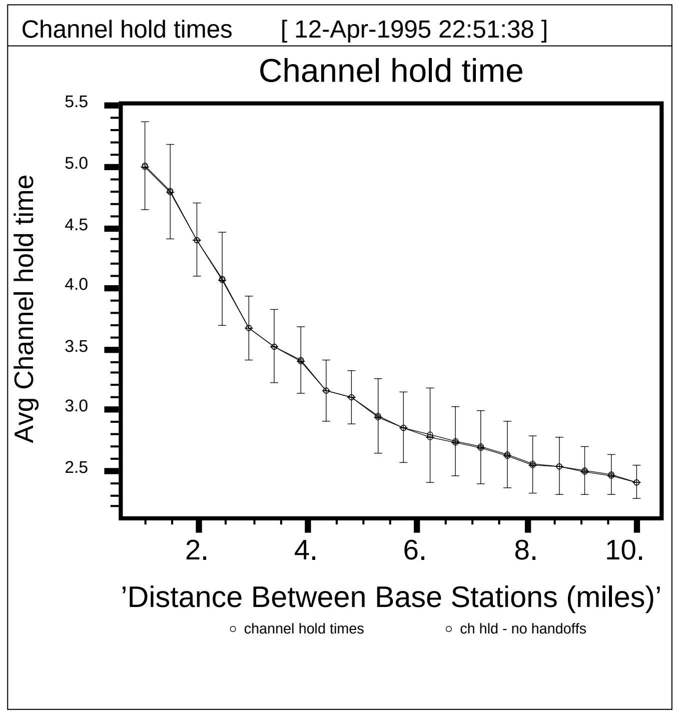

Figure 6. Average Channel Hold Time vs Cell Area.

2.3: Future Work

The simulation should be enhanced by adding uniform rate "on-off" sources to the mobile units and examining the queue distribution at the base stations in order to verify section 2:.

3: Overview of Handoff Methods

Now that we have developed a method for analyzing mobile ATM performance, we can consider some of the handoff mechanisms. Three possible methods for handoff are considered here:

1. Handoff Tree [1]
2. Pivotal[4] Connection Handoff [3]
3. Home/Foreign Agent Based Mechanism [9]
4. Loose Source Routing [8]

Note that of these four methods, only number 1 was designed specifically for an ATM system. The remaining methods in this paper are loosely based on other protocols.

[4] I chose this term because one end of a connection is a llowed to change, while the other remains fixed.

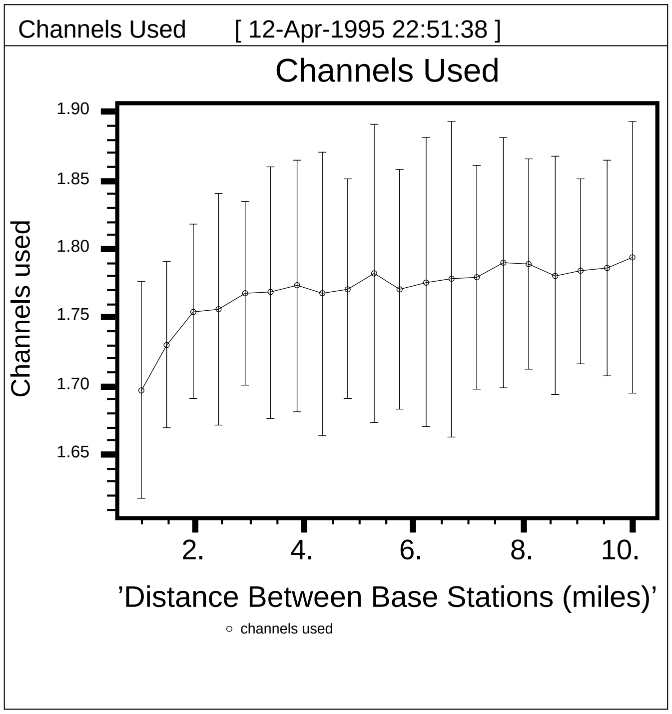

Figure 7. Average Number of Channels Used vs Cell Area.

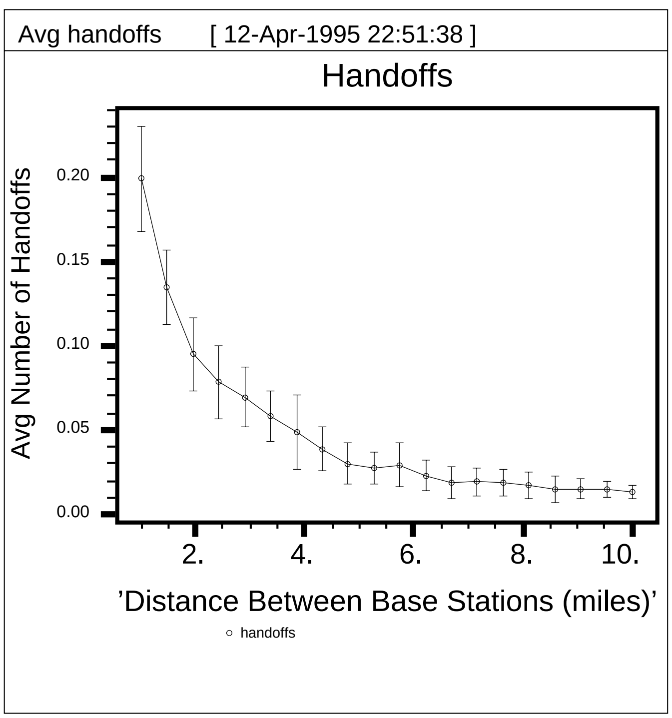

Figure 8. Average Number of Handoffs vs Cell Area.

This paper will consider three criteria for the analysis of the above handoff methods: traffic overhead, delay, and impact on the network architecture. This paper will attempt to extend [2] so that these performance characteristics can be analyzed in a mobile environment.

Handoff mechanisms will involve some type of traffic overhead. The process of moving from one base station to another successfully requires that a change of state be communicated to some component of the mobile system. There is also the possible traffic overhead due to retransmission of lost packets while the handoff is in progress.

The delay criteria refers specifically to the delay seen by the mobile user as the user performs a handoff. The delay may be due in part to the traffic overhead, but there may be additional processing delays required to implement the handoff itself.

Finally the impact on the network architecture considers how a fixed network would have to be modified in order to implement the handoff method, e.g. how would an ATM switch, or the protocol itself need to be modified in order to implement the particular method.

4: Handoff Tree

This method, described in [1], is the simplest, however, it is the least flexible and has some disadvantages. In this method, multiple base stations (neighborhood) are combined under the control of a root switch in a tree structure. All traffic within a neighborhood flows through the root switch. This method does not eliminate handoffs, as there are handoffs between neighborhoods; it simply adds another hierachical level. Also, the root switch requires special hardware and must be able to handle all traffic in both directions for its neighborhood. This method is much like a point to multipoint connection, with the root as the single point and the possible mobile host connections as multiple points.

A mobile host is provisioned with use of all the VCs for all the base stations in its neighborhood. When the mobile host moves within another base station's cell area, it simply begins using the VC for that base station. When the root switch notices traffic arriving from that VC, it knows the mobile host is using another base station and updates its switching table accordingly.

Although a neighborhood is provisioned with connections from the root switch to every base station in the neighborhood for every mobile host, the mobile host will only be using at most two connections simultaneously for soft handoff. Because the root switch to base station connection is always avaliable for every mobile host handoffs are relatively quick; however, this creates an insidious problem. Mobile hosts can all congregate around one base station; there is nothing to limit them from all using their VCs and overwhelming the base station's capacity[5].

The analysis in [1] attempts to determine the probability of overload at a base station with a uniform probability of a mobile using a base station.

[5]This is in contrast to the previously discussed handoff methods which request a new channel during handoff. If all channels are in use when another mobile host enters a cell area, that mobile host is not allowed access and forced to terminate its connection. Obviously this is not good for the mobile host, but it maintains the integrity of the base station.

5: Pivotal Connection Handoff

This would probably be the most complex method to implement. It allows a mobile system to handoff from one switch to another transparently to itself or its peer at the ATM layer. It has the disadvantage of requiring a complex intermediate switch. This method maintains the same ATM packet format, but requires non-standard signalling.

The essential concept is that within the path of every mobile-to-mobile, or mobile-to-fixed connection there is a device called a mobile support switch. This mobile support switch is an ATM switch with additional handoff capabilities. It can freeze and save the state of an end-point connection, establish the connection in another mobile support switch, and delete but not close, the end-point of a connection. The base end of the connection is a logical entity which floats with the base station to which the mobile is currently connected. The fixed end of the connection never changes. Buffers can be used on the fixed end-points of the connection to hold cells which accumulate while the handoff is in progress.

6: Home/Foreign Agent Based Handoff

This architecture requires that every base switch has a home agent and foreign agent. Every mobile is initially associated with a base station; this information is registered in the home agent. This will be most efficient if the home base station is the one whose cell area the mobile unit will have the longest average dwell time. When the mobile moves to another cell area, the mobile unit will register with the foreign agent for that switch. It is the responsibility of the foreign agent to find and update the corresponding home base station for a given mobile unit. The foreign switch is able to communicate with the home switch via standard ATM.

All communication is performed as though the destination mobile resided on a connection with its home switch. The mobile network is also provisioned as though it was a fixed network with all mobiles directly connected to their home switch. However, if the destination mobile unit has moved from its home switch to another cell area, the home switch transparently handles the switching the ATM cells to the proper base station switch. This could occur by encapsulating the ATM cell within another another ATM cell, or by directly modifying the switching table.

This handoff architecture has the advantage of maintaining standard ATM switching and packet format. The primary disadvantage is that ATM cells must always travel to the home switch regardless of whether the destination mobile is connected to that base switch; e.g. the communicating mobile units may actually be within the same cell area, but the ATM cell would first travel to the home switch, then back to the current cell.

6.1: Loose Source Routing

In this method we modify the ATM packet to carry a trace of the switches it has passed through along its path. The foreign agents from the previous section already know the base switches to which all mobile units are currently connected. The foreign agents can exchange information concerning the number of hops from every switch to every mobile unit. Thus an optimal switching route can be determined; it is no longer necessary to connect to the home switch.

7: Summary

This paper attempted to extend [2] to a mobile environment. It also presented the results of a simulation of a mobile environment in preparation for simulating the extension. The mobile environment adds several new dimensions to fixed communications analysis, such as cell area, speed, direction, channel holding time, channels used at a base station, frequency of handoffs, etc... This simulation concentrated on finding channel hold time, T_H, and the average number of channels used, P_j, which are required for the extension of [2].

This paper also suggested areas for further research such as extending [2] to mobiles which are treated as multiple CBR sources, analyzing queued handoffs, and enhancing the channel hold time and number of channels used by using a PDE for the speed and direction analysis as in [7]. Finally, these results can be used to analyze and simulate the various methods of handoff.

References

[1] Anthony S. Acampora and Mahmoud Naghshineh. An architecture and methodology for mobile-executed handoff in cellular atm networks. *IEEE Journal of Selected Areas in Communication*, June 1994.

[2] D. Anick, D. Mitra, and M. M. Sondhi. Stochastic theory of a data-handling system with multiple sources. *Bell System Technical Journal*, Dec 1982.

[3] Ajay Bakre and B. R. Badrinath. I-tcp: Indirect tcp for mobile hosts.

[4] Daehyoung Hong and Stephen S. Rappaport. Traffic model and performance analysis for cellular mobile radio telephone systems with prioritized and nonprioritized handoff procedures. *IEEE Transactions on Vehicular Technology*, Aug 1986.

[5] William Y. Lee. Overview of cellular cdma. *IEEE Transactions on Vehicular Technology*, May 1991.

[6] Kathleen S. Meier, Gregory P.Pollini, and David J. Goodman. Network protocols for the cellular packet switch. *IEEE Transactions on Communications*, Feb/Mar/Apr 1994.

[7] Kin K. Leung nad William A. Massey and Ward Whitt. Traffic models for wireless communications networks. *IEEE Journal of Selected Areas in Communication*, October 1994.

[8] Charles Perkins. Providing continous network access to mobile hosts using tcp/ip.

[9] W. A. Simpson, editor. *draft-ietf-mobileip-protocol-05.txt*. Mobile-IP Working Group, July 1994.