A Distributed Access Algorithm for Cellular Radio Systems with Channel Partitioning

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Abstract

Recent results in distributed power control and distributed channel access have demonstrated the possibility of high capacity cellular radio networks without central control. However, these distributed algorithms may not converge completely in practical systems where the rate of channel variation (due to mobility, hand-off, or interfering users entering or leaving the channel) approaches the rate at which power levels can be accurately measured and adjusted. We propose a new channel partitioning technique in which both dynamically allocated and fixed assignment channels are employed. This technique enables rapid, distributed access that is inherently fair. Simulation results indicate that it is robust in responding to user mobility and hand-off while yielding significant capacity gains over traditional fixed assignment systems.
1.0 Introduction

The potential of sophisticated dynamic power and channel allocation (DPCA) algorithms to improve the capacity of frequency division multiple access (FDMA) cellular systems has been explored by many researchers [1-6]. DPCA algorithms adapt the power level and channel allocation for each user to the interference conditions of the channel at each point in time. Typically, the channel conditions will be better than the worst case model used to design fixed channel allocation (FCA) systems [7]. Consequently, on average the DPCA systems will achieve lower interference levels or smaller re-use distances than FCA, both of which indicate better channel utilization. Since the DPCA systems use channels more effectively, they can achieve higher system capacities.

Capacity comparisons between DPCA and FCA systems can be made by simulating the average number of users each system can support at a fixed blocking probability, say 1%. It is assumed that call arrivals are independent and uniformly distributed in space and that call hold times are exponentially distributed. Both the DPCA and FCA systems are given the same number of channels and the same target signal to interference ratio (SIR) level. The offered load per unit area that achieves a 1% blocking level is the measure of user capacity and its units are Erlangs per cell. DPCA has been shown to achieve user capacity improvements of a factor of 4 over FCA in a system with shadow fading [4].

Interference based power control [8] is the most common (and best performing, in terms of user capacity) power control technique employed in DPCA systems. With this technique, user transmitter power levels are adjusted to achieve equal SIR levels. The state of \( M \) users sharing a chan-
nel can be described with a power vector \( p = [p_1, p_2, \ldots, p_M] \) where \( p_i \) is the transmit power level of user \( i \). The SIR for a user \( i \) is:

\[
 r_i = \frac{p_i G_{ii}}{\sum_{j \neq i} p_j G_{ij} + N}
\]

where \( G_{ii} \) is the path gain from user \( i \) to its base station, \( p_j \) is the transmitter power of interfering user \( j \), \( G_{ij} \) is the gain from the interfering user to the base station and \( N \) is additive white receiver noise power. We only consider the uplink path (from user to base station) here, although the same method can be used for the downlink path. The DPCA algorithm strives to maintain the SIR of each user greater than a threshold necessary for communication:

\[
 r_i \geq \gamma_0
\]

The target SIR, \( \gamma_0 \), is determined by the modulation format and bit error rate requirements of the particular system. If equation (2) can be met for every user (a feasible solution) it can be computed from [8]:

\[
 p^* = [I - F]^{-1} u
\]

where \( p^* \) is the power vector that achieves equality in equation (2) for all users, \( I \) is the identity matrix, and \( F \) is a matrix description of the channel where each element \( F_{ij} = \frac{G_{ij}}{G_{ii}} \) for \( i \neq j \) and \( F_{ij} = 0 \) for \( i = j \). The vector \( u \) has elements \( u_i = \frac{\gamma_0 N}{G_{ii}} \).
Distributed DPCA algorithms have been developed [6, 9] that allow the power control solution to be computed without a centralized controller. Distributed DPCA algorithms employ iterative updates of each power level of the form:

\[ p_i(k + 1) = \frac{p_i(k)\gamma_0}{r_i(k)} \]  

(4)

where the index \( k \) has been added to indicate a discrete update of each parameter. Note that this update is fully distributed (no explicit communication is required between users) because each user to basestation link can make its own measurement of \( r_i(k) \). It has been shown [9] that this power iteration will converge to the same solution as equation (3) as \( k \) becomes large:

\[ p^* = \lim_{k \to \infty} p(k) \]  

(5)

To optimize the design of a DPCA system, it is necessary to make the convergence as fast as possible. Power control must be able to compensate for channel changes, such as those that occur for mobile users in shadow fading. In practical systems, the power control updates are limited by the time it takes to accurately measure the SIR level at the receiver and forward the instruction to the transmitter to adjust its power. This can make rapid convergence critical.

For example, consider a system such as IS-54 TDMA that is upgraded to include distributed power control. IS-54 uses 40 millisecond frames. If the receiver uses one frame to measure the SIR level and then instructs the transmitter to adjust its power on the next frame, the fastest update rate is every two frames or 80 milliseconds. Shadow fading often varies over a scale of about 100 meters [10] with a standard deviation of 8 dB. For a mobile moving at 50 mi/hr (22.4 m/s), the fading will change significantly every 4.5 seconds or 56 power updates. To accurately track the channel changes, the power control must be able to converge in much less time.
The convergence properties of distributed power control can be characterized by the error between the current power control setting and the desired solution:

\[ e(k) = p(k) - p^* \]  \hspace{1cm} (6)

where \( e(k) \) is a vector of all the user power level errors. The norm of this error is bounded by [11]:

\[ \|e(k)\| \leq \|F\|^k \|e(0)\| \]  \hspace{1cm} (7)

Tighter bounds on the error as \( k \to \infty \) are known [11], but these are less useful for system design, since these “asymptotic” errors are too small to affect system performance. We are most interested in techniques to minimize the error when \( k \) is small - on the order of 10 or less.

Errors in the power level setting cause a reduction in capacity because users that transmit excessive power create excessive interference and users that do not transmit enough power cannot maintain communications links. It is clear from equation (7) that the error can be minimized if we make an intelligent initial choice for the power level of the new user (which helps to keep \( \|e(0)\| \) small) and if we can keep the norm of \( F \) small. We choose the initial power level for new users with a technique called channel probing. We keep \( \|F\| \) small with channel partitioning.

Channel probing is designed to allow a new user to quickly estimate if it can share a channel with the current set of active users (those that have been previously admitted to the channel and are successfully sharing it). If the new user can be accommodated, the probing algorithm will also determine its initial power level. Previous work in distributed power control yielded a primitive probing technique that would require 80 power control iterations [6] to deliver a result. In this work, we examine a faster technique that can yield practical results in about 5 power control iter-
ations. Probing is performed in a short segment of each transmission frame so that it will not interfere with data transmission, as illustrated in Figure 1. The new user transmits with a fixed power level. Active users continually transmit, measure interference levels, and adjust their power levels according to equation (4). We assume that users are synchronized at the frame level to permit accurate measurements. When a new user starts transmitting a probing signal, the active users will adjust their transmitter power levels to compensate for the increased interference. The new user then measures the change in interference and decides whether or not it is possible to use the channel.

Channel partitioning splits the channel set into two groups. One group is assigned to cells on a fixed basis and employs FCA similar to the current AMPS and IS-54 cellular systems. The second group is power controlled (with the distributed algorithm) and dynamically allocated. Users initially access the network through fixed assignment channels and migrate to power controlled channels, if possible. Users that require high transmitter powers, such as those near cell boundaries, remain in fixed allocation channels. These users have large path losses to their base stations (small $G_{ii}$ terms), and their presence on power controlled channels would greatly increase the norm of the $F$ matrix in equation (7). Thus, by keeping these users in fixed allocation channels, the convergence rate of the distributed power control algorithm is improved. Of course, there is a loss of capacity in keeping the high power users in fixed allocation channels. However, the reduction in capacity is relatively small because the high power users require power levels at or near the maximum level. They do not benefit from power control.

The channel partitioning system also provides a mechanism for hand-off with power control. When a hand-off becomes necessary, the user moves from a power controlled channel in the old
cell to a fixed allocation channel in the new cell. The user then probes for a power controlled channel as if it were a new user. In a similar fashion, a user will hand-off within the same cell if a power controlled channel becomes too congested. The ratio of fixed allocation channels to power controlled channels is selected to maximize the Erlang capacity for a given number of channels.

Another advantage of the channel partitioning system is backward compatibility with existing systems, such as IS-54 TDMA. Since existing cellular radio systems use fixed channel assignment, it may be desirable to migrate them to DPCA in the future to increase capacity. Initially, mobile users would employ older hardware that would not allow distributed power control. These users would occupy fixed allocation channels only. New mobiles that use both fixed allocation and power controlled channels would then be introduced. As users upgrade to newer hardware, fixed allocation channels could be converted to power controlled channels, increasing system capacity.

This paper presents an overview of the access algorithm and its performance. First we explore the system design and explain the details of channel access with channel partitioning and probing. We demonstrate several advantages of the partitioned channel system, such as fairness in user admissions. Next, we compare the user capacity of the partitioned channel DPCA system with other DPCA and FCA systems. Last, we show how channel partitioning is robust with user mobility and hand-off.

2.0 Channel access

To evaluate the benefits of channel partitioning we have designed an access algorithm that employs the concepts that were introduced above. This algorithm is incorporated into a simulation program that is used to evaluate the capacity of the new system. The details of the access algorithm are given in this section.
The partitioned channel system relies on fixed allocation channels for initial access. Fixed allocation channels are assigned to base stations according to a fixed frequency re-use pattern that depends on the cell geometry and required SIR level. We assume a planar, hexagonal, cellular system. Typical reuse values are $K=3, 4, \text{ and } 7$, which correspond to SIR levels of 11.3, 13.8, and 18 dB, using Lee’s co-channel interference reduction factor [7]. We make the assumption in our simulations that when a mobile uses a fixed allocation channel it is always able to obtain its desired SIR. In practice, some fixed channels would provide a lower SIR than desired, due to shadowing or other effects. Fixed channel systems such as AMPS and IS-54 accept outages of this type and attempt to limit them with proper cell placement. The partitioned system will provide equivalent service for users in fixed allocation channels and better service (a guaranteed minimum SIR level) for users in power controlled channels.

All of the power controlled channels are assigned to every base station. Access to power controlled channels is limited by the probing and power control algorithms, however, so the channels will be re-used in neighboring cells only when every user on the channel can maintain its desired SIR. When a mobile using a power controlled channel can no longer maintain its desired SIR, it is transferred back to a fixed allocation channel in the same base station (a re-probe) or a new base station (a hand-off). The mobile then immediately begins probing for a new power controlled channel to access. New users are admitted to the partitioned channel system with the channel access algorithm.

2.1 Channel access algorithm for new users

1. Create a list of nearest neighbor base stations with free fixed allocation channels. (Base stations would provide this information via a setup channel.)

2. If there are no base stations on the list, the new user is blocked.
3. Otherwise, begin transmitting to the nearest base station (highest path gain) on a fixed allocation channel in the data segment. (Do not transmit during the probing segment.)

4. If the path gain to the base station is less than a threshold level, do not continue probing. User is admitted and does not attempt probing again until a hand-off occurs.

5. Otherwise, begin probing on the power controlled channel with the lowest interference level.

6. If the change in measured interference is greater than a threshold level, select a new power controlled channel and repeat probing procedure from step 5.

7. Otherwise, wait 3 power control iterations for power levels to converge.

8. If the SIR in the probing segment is greater than or equal to the required level, begin transmitting on the power controlled channel during both the probing and data segments.

9. Otherwise, return to step 5 to probe another channel.

SIR levels on power controlled channels are maintained with a distributed algorithm that is based on equation (4). We modify the distributed power control algorithm to allow new users to access power controlled channels with less time delay. With the distributed algorithm, users do not have specific knowledge of the interference terms in the denominator. Instead, users compute a power level at each point in time $k$ from the previous time by an update equation:

$$p_i(k) = \mu_i(k-1)p_i(k)$$  \hspace{1cm} (8)

where the update factor, $\mu_i(k-1)$, is computed from the ratio of the desired SIR to the measured SIR:

$$\mu_i(k-1) = \min\left(\frac{\delta \gamma_0}{r_i(k-1)}, \mu_{max}\right)$$  \hspace{1cm} (9)

Here $\gamma_0$ is the desired SIR, $r_i(k-1)$ is the SIR measured in the probing segment of frame $k-1$, and $\delta$ is a safety margin. In the steady-state, the SIR of an active user will be maintained at $\delta \gamma_0$. 

When no users are probing, the interference measured in the probing segment will be entirely due to other active users. In this case, the power control compensates for changes in signal and interference levels caused by user mobility or any other gain changes in the radio channel. The safety margin is determined by the change in the channel gain a user will encounter from frame to frame. If the frame rate is relatively rapid compared to the rate at which the channel changes, $\delta$ may be small. We selected a value of $\delta = 1$ dB for our simulations.

Unlike [6], where new users initially transmit a small power that is increased in fixed steps, the probing algorithm we propose requires users to estimate the power they will require on a power controlled channel. A new user, $i$, will attempt to access a power controlled channel by transmitting a fixed power in the probing segment of:

$$p_i(0) = \frac{\delta_{probe} Y_0 N}{G_{ii}}$$

where $N$ is the receiver noise power, $G_{ii}$ is the gain to the base station, and $\delta_{probe}$ is a probing margin factor. The probing margin is used to offset the difference between the received noise power and the eventual interference level if a feasible admission solution is found by the other users. It is selected empirically. In our simulations we used a value of $\delta_{probe} = 1.5$ dB. A new user transmits the probing signal for a fixed number of frames and measures the change in interference level in the probing segment. If the change in interference is less than $\delta$, it will continue to probe the channel for several power control iterations (typically 3) until the transmitter powers of the active users converge. If the new user achieves the desired SIR, it is admitted to the power controlled channel. If not, it then tries to probe another channel.
In earlier versions of the power control algorithm [6], power updates are always bounded by $\delta$. New users increment their power in steps of $\delta$ and active users never need to increase their power by more than $\delta$ since, by definition, their SIRs are already greater than or equal to $\gamma_0$. The situation with probing segments is different. When a new user probes a channel, it will not directly interfere with active users, since their data is transmitted on the data segment. However, active users will see increased interference from the power updates of other active users. If the increase in interference between two frames is greater than $\delta$, an active user’s SIR will drop below the desired level. Also, since the transmit power is limited, an active user will sometimes need more power than is possible to maintain its SIR. In either case, if a user cannot maintain its SIR it will switch from the active state to the probing state and probe a new power-controlled channel. While probing, its connection will be maintained with a fixed allocation channel.

The maximum change in a power update is bounded by $\mu_{\text{max}}$. The choice of $\mu_{\text{max}} = \delta$ is the most conservative. This will prevent new users from disturbing active users, assuming the active users do not reach their maximum power level. However, it is often better to select a higher level for $\mu_{\text{max}}$. This allows the active users to adapt to new users more quickly, yielding a smaller probing time. Reduced probing time reduces the load on fixed allocation channels, increasing potential capacity. Active users that fail to maintain their SIRs can re-probe and find new power-controlled channels.

The goal is to maintain a balance between new user access, rapid probing, and active user dropping. In the partitioned channel system, the strategy is to use very rapid probing for power-controlled channel access. This strategy arises from the fact that accurate probing measurement are slow, both because of fading in signal levels and because of the time required for the power con-
trol algorithm to converge. User mobility also limits the accuracy of measurements because channel characteristics will change before they can be measured. Rapid probing places less of a load on the fixed allocation channels than slow probing. The fixed allocation channels then have extra capacity which is used to accommodate active users that are forced out of power controlled channels by imperfect probing. For comparison, the probing algorithm used for the partitioned channel system uses 4 to 7 power iteration steps, while previous algorithms [6, 9] might use 40 to 60 steps.

2.2 System Performance

A prominent feature of first admitting new users to fixed allocation channels is that the system is inherently fair. A new user arrival near a base station will have the same probability of being blocked as a new user arrival near a cell boundary. This is demonstrated by the simulation results in Figure 2. The figure contains a histogram of both admitted and blocked users as a function of squared distance from the base station. In regions of equal area at different distances from the base station, the ratio of admitted users to blocked users remains the same. The right side of the histogram shows a roll-off effect in both user blocks and admissions as distance from the base station becomes large. However, the ratio of blocks to admissions remains the same.

The fairness property of our algorithm differs from a direct application of power control based admission policies [4] that will tend to block users at the cell edges more frequently that users near the base station. Since blocking probability is often measured by averaging over the entire cell area, DPCA systems will gain an apparent performance advantage from tending to block users on the cell boundaries. However, in a practical cellular radio system, it is unlikely that a situation where one region has a low probability of blocking and another region has a high probability of blocking will be acceptable. Quality of service will be determined by the higher blocking
probability region and there will be no benefit from averaging the blocking probabilities over the cell area.

The blocking probability for the partitioned system is difficult to analyze because the load on the fixed channel servers cannot be modeled by a simple process with Poisson arrivals. Figure 3 presents a schematic model of the system. A new user enters the system and is served by a fixed allocation channel in the nearest base station. The user then moves into a power controlled channel when it finds one that will allow it to meet the SIR requirement. After time, however, the user may no longer be able to maintain its SIR requirement in the power controlled channel, and it moves back to a fixed allocation channel in the same cell (a re-probe) or a neighboring cell (a hand-off). This occurs because of imperfect probing, finite transmitter dynamic range, and, as we will discuss in Section 4.0, mobility.

A new user is blocked when there are no free fixed allocation channels at the closest base station. However, active users may access fixed allocation channels at neighboring base stations as well as the closest base station. An active user will temporarily hand-off to a neighboring cell, if it can achieve the required SIR at the neighboring base station. This preference system helps to prevent active calls from dropping.

Since fixed allocation channels are used for primarily for communication while probing for power controlled channels, the effective hold time in fixed allocation channels will be a multiple of the time required to probe a power controlled channel. The multiple occurs because it will take an integer number of attempts to find a suitable power controlled channel. Users nearer to the base station will tend to probe fewer power controlled channels. These users will also have the lowest probability of a re-probing event because they will not run out of dynamic range while holding a
power controlled channel. Users near the cell edge, however, will require a longer time to probe for power controlled channels and tend to re-probe often. These users will place the largest load on the fixed allocation channels and will be the primary cause of new user blocking.

### 3.0 Comparison with FCA and DPCA

A set of computer simulations were run to compare the partitioned channel system with FCA and DPCA systems. The simulated system consisted of 19 cells, with blocking statistics measured in the center cell. A total of 18 channels were partitioned into 12 power controlled and 6 fixed assignment. Fixed assignment channels had a re-use factor of 3. The channel model included $R^{-4}$ propagation loss and log-normal shadowing with a standard deviation of 8 dB. Arrivals followed a Poisson process and were uniformly distributed in space. Hold times were exponentially distributed. There is no user mobility in this comparison.

The FCA results were computed from the Erlang-B formula [12], assuming 6 channels (servers) per cell. The DPCA results are from [4, figure 3] and assume a “polite”, centralized interference balancing power control system. This had the highest capacity of the DPCA algorithms investigated by that author. A target SIR, $\gamma_0 = 11$ dB, is used for both the DPCA simulation and the channel partitioning simulation.

Figure 4 presents a plot of the blocking probability of the three systems as a function of Erlang load. As expected, the partitioned system’s capacity is between that of FCA and the best DPCA system. The partitioned system cannot achieve the performance of pure DPCA because of its fixed allocation channels and the use of distributed power control and channel access. However, it can still achieve more than twice the capacity of typical FCA systems.
4.0 Mobility and Hand-off

Mobility and hand-off introduce difficulties for DPCA since channel changes must be accurately tracked to insure that users maintain their SIR levels. Distributed power control systems will experience a reduction in capacity from mobility because users require excess SIR margin to protect themselves from changes in signal and interference levels. The partitioned channel system is designed to be robust under these conditions - adapting well to channel changes and providing a practical way to handle hand-offs. We simulate the partitioned system under mobile conditions and compare its performance to fixed channel systems.

The effects of mobility in FCA systems is analyzed in [13]. Mobility is characterized by the mobility factor, $\theta$, which is the probability that when a user exits a cell it is handing off to another cell. The expected number of cells visited by a user is related to the mobility factor by:

$$M_{\text{cells}} = \frac{1}{1 - \theta} \quad (11)$$

In a similar fashion, the average number of hand-offs per user can be expressed by:

$$M_{\text{handoffs}} = M_{\text{cells}} - 1 = \frac{\theta}{1 - \theta} \quad (12)$$

In [13], the probability of a call failure (blocking during initial access or dropping during hand-off) is shown to be a function of the number of channels, the call load, and the average number of cells visited by a mobile during a call. To maintain a given call failure probability, the number of channels must be increased as either the mobile velocity is increased or the cell size is decreased. The same principle applies to the partitioned channel system. More fixed allocation channels are required to handle hand-offs and probing for new power controlled channels as the level of mobility increases.
We used the following hand-off algorithm for the partitioned channel system in our simulations:

4.1 Hand-off algorithm

1. Create a list of nearest neighbor base stations with free fixed allocation channels. (Base stations would provide this information via a setup channel.)

2. If the nearest (in terms of largest path gain) base station maintains a gain at least 3 dB more than the current base station for 3 power control iterations, continue with the hand-off procedure. Otherwise, do not hand off.

3. If there is still a free fixed allocation channel in the new cell, hand-off to that cell.

4. Otherwise, return to Step 1.

When a user hands-off from one cell to another, there is a chance that a fixed allocation channel will not be available. If this occurs, the user must either be queued (i.e. wait) until a fixed allocation channel is available or forced out of the system (dropped). Dropping users is undesirable, so we choose to queue the active user until a fixed allocation channel is available. The user remains in the old cell on either a fixed allocation channel or a power controlled channel, if feasible. Hand-off occurs when the new cell has a free fixed allocation channel.

The partitioned channel system was simulated and compared to FCA results given in [13]. The partitioned system had a fixed channel re-use factor of K=7 and a corresponding SIR requirement of 18 dB. This is typical for the AMPS and IS-54 TDMA systems. A total of 84 channels are available with 28 set aside as fixed allocation channels (4 per cell) while the remaining 56 are power controlled channels. Users in power controlled channels maintain an SIR of 18 dB. In this simulation, users have 66 dB of dynamic range in their transmitters.

The fixed channel results are for a system with 12 channels per cell. Both the fixed channel results and the partitioned channel simulation have a mobility factor of \( \Theta = 0.5 \). This mobility factor cor-
responds to that of a typical urban cellular radio system [7]. The results are plotted in Figure 5 as blocking probabilities as a function of Erlang load (the product of the arrival rate and the average hold time of the entire call). Mobility and hand-off cause an 11% reduction in capacity for the FCA system and a 22% reduction in capacity for the partitioned channel system. Even with this reduction, the partitioned channel system can still provide twice the capacity of the FCA system.

5.0 Conclusions

Significant capacity gains in cellular systems are possible by replacing fixed channel assignment with DPCA. Distributed algorithms for DPCA are known and have been explored in the literature. These algorithms enhance the practicality of dynamic allocation systems by allowing all decisions to be made with local measurements. However, several challenges remain, including speed of convergence, fairness in access, and robust service in a mobile environment. Channel partitioning addresses these challenges and provides a framework for upgrading existing systems, such as IS-54 TDMA, to higher capacities.

The speed of convergence in distributed power control is limited by the margin $\delta$, the update rate, and the coupling of users in the network. In any high capacity system, it will be necessary to keep $\delta$ as small as possible to limit wasted power. In mobile systems, the update rate will be limited by the frame size and the time required to make accurate SIR measurements. Rapid update rates are not possible. Therefore, to maximize the rate of convergence it helps to limit the number of high power, high interference users in power controlled channels. Channel partitioning allows these users to be placed in fixed assignment channels where they no longer affect the convergence of the power control algorithms. This helps to speed up the convergence of distributed power control and enhances system performance for mobile users.
In most DPCA systems, a user is more likely to find a suitable power and channel assignment if it is located near a base station. A user on a cell boundary may encounter access delays if it must probe many channels when the network is congested. With channel partitioning, new users can be admitted to a system instantaneously and can communicate while a suitable power and channel allocation is found. This promotes fairness, since blocking depends only on the number of users in fixed allocation channels, and not whether a quick solution can be found to the power and channel allocation problem. Users on cell boundaries and users close to the base station see the same set of channels upon admission and therefore receive the same treatment.

Probing and transmission segments allow new users to probe one power controlled channel while communicating on a fixed allocation channel. The probing segment can be made relatively short (a few symbols) since it is only used to make signal and interference measurements. In addition, the probing segment prevents new users from directly interfering with active users. This protects active users from excessive interference and allows new users to quickly determine a power and channel allocation. In some applications, such as an upgrade of IS-54 TDMA, it may be difficult to implement separate probing segments because of hardware constraints. In this case, probing can occur periodically and occupy an entire frame. This will slow convergence of the power control algorithm, however, and there will be a small loss of user capacity compared to a system with probing on every frame.

The partitioned system is robust in a mobile environment. When a user needs to hand-off from one base station to another it can first occupy a fixed allocation channel until it finds a power controlled channel. If a user must leave a power controlled channel it can continue to communicate on a fixed allocation channel until a new power and channel solution is found. If necessary, users
can temporarily hand-off to a neighboring base station if the fixed allocation channels in the current base station are full.

A rigorous model of the channel access process is difficult because of the feedback of users from power controlled channels that compete with new users for access to fixed assignment channels. In general, the arrival process of the users in the feedback path is not Poisson, since there is memory in the system and the transfer of users from power controlled to fixed allocation channels will be correlated in time and space. We have used a simulation to study the performance of the partitioned channel system and found that it works well when probing times are reduced to the shortest possible, resulting in a small load on the fixed assignment channels. This maximizes the number of power controlled channels which helps to maximize the user capacity of the system.

The channel partitioning technique extends previous work in DPCA and provides good results even with shadowing and high levels of mobility. Erlang capacity gains of over 100% are possible compared to fixed channel systems.

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7.0 References


FIGURE 1. Signal Frame Format

Probing Segment | Data Segment

FIGURE 2. Histogram of User Admissions and Blocking

Users

0 2 4 6 8 10 12

meters² (x 10⁶)

0 200 400 600 800 1000 1200 1400 1600

Admitted

Blocked
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FIGURE 3. Network Model

New User Arrival → Power controlled channels → Call Completion
Nearest Base Station
Neighboring Base Stations

Re-probing or Hand-off

FIGURE 4. Comparison with DPCA

![Graph showing comparison between FCA, Channel Partitioning, and DPCA](image-url)

- X-axis: Offered Load per Cell (Erlangs)
- Y-axis: Probability of Call Failure
FIGURE 5. Blocking Probability with Mobility

![Graph showing blocking probability with offered load per cell (Erlangs) on the x-axis and probability of call failure on the y-axis. The graph compares FCA and Channel Partitioning.]