CAPACITY IN A TWO CELL
SPREAD SPECTRUM NETWORK

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Abstract
This paper reviews recent work on spread spectrum network capacity. The network
is shown to have a capacity that is equitably shared amongst the users via power control.
This solution is much simpler than the bandwidth partitioning of the FDMA/reuse
approach. The capacity gains from using spread spectrum, arising from the averaging
and multiplexing, are also emphasised.

MOBILE RADIO; SPREAD SPECTRUM; POWER CONTROL; NETWORK CAPACITY

1 Introduction
In this paper we review some recent work on the capacity of spread spectrum radio networks.
The demands a user places on a mobile radio network are inherently variable: interference
fluctuations, bursty traffic, and possibly different data rate requirements. We examine the
benefits obtained from multiplexing all users onto a spread spectrum channel.

On the uplink of a two cell network there is a nonlinear relationship between the capacities
of each cell; this tradeoff between cell capacities happens automatically, demonstrating
that spread spectrum with power control is an effective mechanism for sharing network
capacity. The received powers on the downlink are inherently more variable as the receivers
are mobile. Nevertheless, we prove a law of large numbers showing that in a large scale
system the uplink and downlink have the same capacity. With macro-diversity there is a
pooling of receiver capacities and adjacent cell interference effectively disappears. A single
capacity can be associated with the whole network.

2 The uplink of a two cell network

2.1 The capacity region
The theory of spread spectrum is reviewed in [8] and was first suggested for mobile radio in
[1]. New interest in spread spectrum for mobile has been stimulated since the appearance
of [3].

Consider the two cell network depicted in figure 1. We have $M_0$ users in cell 0 and $M_1$
users in cell 1 and we wish to characterise the capacity region $\mathcal{R}$ given a total bandwidth of
$W$ Hz. It is well known that the performance criterion for such a spread spectrum system
can be expressed in terms of a signal to noise density ratio. Most commonly the bit error
to noise spectral density ratio ($\frac{E_b}{N_0}$) is used ([9]) but here we multiply it by the bit rate and
work with the signal power to noise density ratio ($SNR$). We define $\mathcal{R}$ to be the set of all pairs $(M_0, M_1)$ such that each user can achieve an $SNR$ of $\alpha$.

That power control in spread spectrum has the capability to equalise the $SNRs$ of the users was first recognised in [7]. We take this approach here.

![Figure 1: A two cell network](image)

Suppose that the $M_0$ users in cell 0 power control so that they are received at cell site 0 at power $Q_0$ and the $M_1$ users in cell 1 power control so that they are received at cell site 1 at power $Q_1$. Note $Q_0$ and $Q_1$ will be allowed to vary with $M_0$ and $M_1$. The cell 0 users create interference at receiver 1 and the cell 1 users create interference at receiver 0. We shall first use the law of large numbers to approximate the cell 0 interference at receiver 1 by $M_0 \bar{\gamma} Q_0$ and the cell 1 interference at receiver 0 by $M_1 \bar{\gamma} Q_1$; $\bar{\gamma}$ here represents an average fading effect and we assume it is less than unity. The use of the law of large numbers, valid in a large scale system, is a feature of the analysis of spread spectrum schemes. In practice, of course, capacity is reduced by an $O(\sqrt{W})$ term (as $W \uparrow \infty$) because a guarantee must be given on performance quality. For example, if we specify that the powers required to achieve $\alpha$ only exceed the maximum available power a proportion $10^{-6}$ of the time then we lose some capacity. The law of large numbers is just saying that this is negligible on the $O(W)$ scale. However, it cannot be ignored in practice and we take a large deviations approach in section 2.4. For now we write down the signal to noise density equations as:

$$SNR_0 = \frac{WQ_0}{(M_0 - 1)Q_0 + M_1 \bar{\gamma} Q_1 + \eta W} = \alpha$$  \hspace{1cm} (1)

$$SNR_1 = \frac{WQ_1}{M_0 \bar{\gamma} Q_0 + (M_1 - 1)Q_1 + \eta W} = \alpha$$  \hspace{1cm} (2)

where $\frac{\eta}{2}$ is the spectral density of the external noise, which we assume is white. It is the problem of power control to find the required received powers $Q_0$ and $Q_1$. These are given
by the equations

\[
Q_0 = \frac{\eta W \alpha (M_1 \tilde{\gamma} \alpha + W - (M_1 - 1) \alpha)}{[W - \alpha(M_0 - 1)][W - \alpha(M_1 - 1)] - M_0 M_1 \tilde{\gamma}^2 \alpha^2}
\]

\[
Q_1 = \frac{\eta W \alpha (M_0 \tilde{\gamma} \alpha + W - (M_0 - 1) \alpha)}{[W - \alpha(M_0 - 1)][W - \alpha(M_1 - 1)] - M_0 M_1 \tilde{\gamma}^2 \alpha^2}
\]

and we can immediately write down the conditions on \(M_0\) and \(M_1\) that enable a solution for \(Q_0\) and \(Q_1\) to be found:

\[
W - \alpha(M_0 - 1) > 0
\]

\[
W - \alpha(M_1 - 1) > 0
\]

and

\[
[W - \alpha(M_0 - 1)][W - \alpha(M_1 - 1)] - M_0 M_1 \tilde{\gamma}^2 \alpha^2 > 0
\]

We shall denote the set of feasible \((M_0, M_1)\) by \(\mathcal{R}\). In section 2.2 we consider the question of power control and exhibit a simple, decentralised algorithm that solves (3), but for now we concentrate on finding a more explicit representation for (4).

For convenience we allow \((M_0, M_1)\) to take nonintegral values and solve for equality in (4) to obtain a boundary to the feasible region. Indeed, even integral points on the boundary are not achievable as infinite received power is required.

It is not difficult to show that the boundary of \(\mathcal{R}\) can be parametrised as follows:

\[
\mathcal{R} = \{(M_0, M_1) : M_0 = f \left( \frac{W}{\alpha} + 1 \right), M_1 = \frac{1 - f}{1 - f + f \tilde{\gamma}^2} \left( \frac{W}{\alpha} + 1 \right), 0 \leq f \leq 1 \}
\]

Thus if both cells are to have equal numbers then

\[
M_0 = M_1 = \frac{1}{1 + \tilde{\gamma}} \left( \frac{W}{\alpha} + 1 \right)
\]

at capacity.

It is of interest to compare \(\mathcal{R}\) with the capacity region for a system with constant received powers. In [2] a capacity region for a hexagonal cellular system is given. The two cell analogue of this is

\[
M_0 + \tilde{\gamma} M_1 \leq \frac{W}{\alpha} + 1
\]

\[
\tilde{\gamma} M_0 + M_1 \leq \frac{W}{\alpha} + 1
\]

Both the capacity regions (4) and (5) are depicted in figure 2, for \(W = 12.5\) MHz, the bandwidth allocated to mobile radio and \(\alpha = 40.09\) KHz, corresponding to an \(\frac{E_b}{N_0}\) requirement of 7 dB as used in [3]. Our choice of \(\tilde{\gamma} = 0.1\) is approximately one-sixth of the inter-cell interference term of 0.56 quoted in [8] for a system with six adjacent cells.

Note that although the region with power adaptation is only marginally larger than that with constant powers, adaptive power control has the potential for allowing effects to propagate through the network. The objective is to have a single network-wide capacity that is shared amongst the users via power control. Note that if \(M_0 > M_1\) then by (3)
Figure 2: Comparison of capacity regions

$Q_0 > Q_1$ and vice versa. We conjecture that a decrease in received power levels in a large number of cells may allow significant extra capacity in some other part of the network. A low demand in one part of the network may allow a high demand in another part even if the distance would seem to preclude any direct interaction (powers typically fade as the inverse fourth power of distance).

Another point is that our power control can mitigate interference fluctuations, as in section 2.4. In addition, it leads naturally to considering expanding and contracting cells ([6]). As $Q_0$ increases due to high demand in cell 0, cell 0 contracts and cell 1 expands to take up some of this demand. This is difficult to analyse, but the extension to macrodiversity is examined in section 4. Significant increases in capacity are observed for this more sophisticated power control.

Another reason for considering our capacity region is that a simple, decentralised power control algorithm exists which can be used as a basis for call acceptance and control: if the received power level in one cell becomes high this indicates that the capacity is being saturated in that cell. We suggest that this might generalise to larger networks so that power control itself can share the capacity resources of the entire network over all the users. In section 2.4 we shall consider how this power control can offset the fluctuations in interference so that performance guarantees can be made.

### 2.2 A decentralised power control algorithm

In [7], the $SNR$ balancing problem is shown to have a solution provided a function of the required $SNR$ does not exceed the largest real eigenvalue of a matrix corresponding to the power gains of each user. The corresponding eigenvector gives the solutions for the transmitted powers.

The idea behind our algorithm is to balance the $SNRs$ in a decentralised way: let $Q_i$ increase if the users in cell $i$ have an $SNR$ below $\alpha$ and let $Q_i$ decrease if the users have an $SNR$ above $\alpha$. At any given time there is a received power that will achieve $\alpha$ in the current interference environment. In cell 0 we need a received power level of $\frac{\alpha M_0^2 Q_1 + nW}{W - n(M_s-1)}$. 


where $Q_1$ is the current received power level in cell 1, and in cell 1 we need a received power level of $\frac{\alpha M_0^2 Q_0 + \rho W \alpha}{W - \alpha(M_0 - 1)}$. Consider the following differential equations:

$$\dot{Q} = f(Q)$$

where $f$ is defined by

$$f \left( \frac{Q_0}{Q_1} \right) = \rho \left( \frac{\alpha M_0^2 Q_0 + \rho W \alpha}{W - \alpha(M_0 - 1)} - Q_0 \right) - \frac{\alpha M_1^2 Q_1 + \rho W \alpha}{W - \alpha(M_1 - 1)} - Q_1$$

(6)

and $\rho$ is a scale factor with units of $Hz$.

**Lemma 1** The ODE (6) has a unique, globally stable equilibrium point given by (3) provided $(M_0, M_1) \in \mathcal{R}$

**Proof**

It is trivial to verify that an equilibrium point must be a solution to (3). To prove global stability we note that the system (6) is linear and $\nabla f$ has eigenvalues

$$-1 \pm \sqrt{-1 - \frac{\alpha \sqrt{M_0 M_1 \gamma^2}}{\sqrt{(W - \alpha(M_0 - 1))(W - \alpha(M_1 - 1))}}}$$

Thus, provided $(M_0, M_1) \in \mathcal{R}$ and hence satisfies (4), both eigenvalues are negative and the system is globally stable.

The algorithm will seek out the correct received powers $(Q_0, Q_1)$ for a given $(M_0, M_1)$. The speed of convergence in real time depends on the value of the scale parameter $\rho$, itself determined by hardware. As mobiles arrive, depart and handover, the algorithm allows the powers $Q_0$ and $Q_1$ to adapt so as to keep all $SNRs$ at $\alpha$. Note that the closer the number of users is to the boundary of $\mathcal{R}$ the slower the convergence. Note also that as the boundary is approached the equilibrium received powers tend to infinity. A phase portrait is depicted in figure 3.

The paper [12] has recently been brought to our attention. It takes the same approach as that of [7], namely equalising the $SNRs$ of the users, but it does so in a decentralised way. The algorithm utilises the power method for finding the dominant eigenvalue of a matrix. Neither paper includes external noise and so the solutions for powers are not unique; this creates problems such as power escalation that are not encountered in our algorithm. Neither do they relate network capacity and algorithm stability. On the other hand, both papers deal with general cellular networks, rather than just the two cell case.

We have assumed so far that the fluctuations in interference arising from fading and voice activity can be neglected. In practice there will be power fluctuations on a fast time scale to cope with the fluctuations in interference not included in the model. We consider this issue in section 2.4. The mobile transmitter powers themselves will be highly variable in order to cope with the changing environment of the mobile (this of course depends on the level of mobility). In the next section we consider the constraint on capacity imposed by a maximum transmitter power level.
Figure 3: Phase portrait for power control

2.3 Transmitter power level constraints

A maximum transmitter power level must reduce the capacity region, since $Q_0$ and $Q_1$ tend to infinity as the boundary of $\mathcal{R}$ is approached. Suppose that $M_0 = M_1$ and that a mobile transmitting at full power in the worse case position is received at power $Q$. Then we can solve (3) for $M$ and find that

$$M = \left( \frac{1}{1 + \gamma} \left( \frac{W}{\alpha} + 1 - \frac{\eta W}{Q} \right) \right)^{-1}$$  \hspace{1cm} (7)$$

The reduction in capacity is $\frac{\eta W}{Q}$ and this can be several mobiles in a large bandwidth system. For example, a typical value of $\frac{Q_0}{W}$ in a 1.25 MHz system is $-1$ dB, according to [3], and so in a 12.5 MHz system it is about $-11$ dB. Thus the reduction term $\frac{\eta W}{Q}$ is about 12 in a 12.5 MHz system. Of course, in a large bandwidth system this will be small in comparison to $\frac{W}{\alpha}$. This suggests that we can expect to be close to the boundary of the capacity region and not exceed the maximum power constraint. Indeed, a single user transmitting to a receiver in noise of spectral density $\eta/2$ needs a received power of $\eta \alpha$ to achieve a $SNR$ of $\alpha$. Let

$$Q = K \left( 1 + \frac{\alpha}{W} \right)^{-1} \eta \alpha \approx K \eta \alpha$$

Then

$$\frac{W}{\alpha} + 1 - \frac{\eta W}{Q} = \left( 1 - \frac{1}{K} \right) \left( \frac{W}{\alpha} + 1 \right)$$

so that only a moderate multiple $K$ of the basic power level $\eta \alpha$ is needed to get very close to capacity.
We stated above that $Q$ corresponds to a worst case mobile. This was taken for the sake of argument and corresponds to no tolerance for degraded performance. In practice, one will guarantee performance a certain proportion of the time, perhaps $1 - 10^{-6}$, for when power level fluctuations and voice activity are considered it becomes impossible to guarantee performance all the time. Certain locations with very strong fading may occur with a low enough frequency to ignore; a large deviations analysis is required.

### 2.4 Interference fluctuations

In this section we consider an $O\left(W^{\frac{1}{2}}\right)$ reduction in capacity so that the probability that a fluctuation in interference renders the system infeasible is negligible. We use power control to counteract these fluctuations in interference.

Suppose for simplicity that both cells have $M$ users. In each cell the interference from the other cell has mean $M\bar{\gamma}Q$ but the fluctuations are $O(\sqrt{M})Q$. Consider the worst case in which both fluctuations are above $M\bar{\gamma}Q$ by the same amount, which we denote by $FQ$. The signal to noise density ratio in both cells is then

$$\frac{WQ}{(M - 1)Q + M\bar{\gamma}Q + FQ + \eta W}$$

and in the limit as $Q \uparrow \infty$ we get the limiting capacity of

$$\left(\frac{W}{\alpha} + 1 - \frac{F}{\bar{\gamma}}\right)$$

users. In fact, it is clear from (7) that with a maximum received power constraint of $Q$ the capacity is

$$M = \left(\frac{W}{\alpha} + 1 - \frac{F}{\bar{\gamma}} - \frac{\eta W}{Q}\right)$$

Note that $F$ is $O(\sqrt{W})$ and $\frac{\eta W}{Q}$ is $O(W)$ so as $W$ grows large the fluctuations from other users become less and less significant and the external noise becomes the dominating effect.

Consider now the case that the fluctuations in interference are of different magnitudes. Let the number in each cell be $M$ but suppose that $F_0$ is the value for the interference from cell 0 and $F_1$ is the value for the interference from cell 1. Then the signal to noise density equations are

$$\frac{WQ_0}{(M - 1)Q_0 + M\bar{\gamma}Q_1 + F_1Q_1 + \eta W} = \alpha$$

$$\frac{WQ_1}{(M - 1)Q_1 + M\bar{\gamma}Q_0 + F_0Q_0 + \eta W} = \alpha$$

It is shown in [6] that a sufficient condition for a solution in $Q_0, Q_1$ existing is

$$M = \frac{1}{1 + \bar{\gamma}} \left(\frac{W}{\alpha} + 1 - \frac{F_0 + F_1}{2}\right)$$

The conclusion is that by using power control we only need to ensure that the average of interference fluctuations does not go too high. Thus the large deviations approach is the following. Let $M$ be defined by

$$M = \frac{1}{1 + \bar{\gamma}} \left(\frac{W}{\alpha} + 1 - \frac{\eta W}{Q}\right)$$
where $Q$ is the maximum received power level. We choose $F$ so that the average of the fluctuation in each cell goes above $F$ only a tiny proportion of the time, given by the performance guarantee. When the average fluctuation does go above $F$, $Q$ is not sufficient to ensure a signal to noise density ratio of $\alpha$ and so performance is degraded.

3 The downlink of a two cell system

The downlink requires a more sophisticated power control that can adapt very quickly as the interference environment of a mobile changes. Of course, the transmitted power level on the uplink has a high variance as well, but the received power levels vary only slowly. On the downlink the danger is that the fluctuations in interference will render the system infeasible, but we show that the probability of infeasibility can be made very small in a large scale system.

Consider the two cell system depicted in figure 4.

![Cell 0 and Cell 1 diagram]

**Figure 4: A two cell network**

Label the users in cell 0 $(1,0) \cdots (M_0,0)$ and those in cell 1 $(1,1) \cdots (M_1,1)$. Let $Q_{i,0}$ be the transmitted power of the signal destined for user $(i,0)$ by cell site 0. Similarly, let $Q_{i,1}$ be the transmitted power of the signal destined for user $(i,1)$ by cell site 1. Let $\gamma_{0,(i,0)} Q_{i,0}$ be the interference at user $i$ of the signal intended for that user and let $\gamma_{1,(i,0)} Q$ be the interference at user $(i,0)$ of a signal from cell site 1 transmitted at power $Q$. Then the signal to noise density ratio at user $(i,0)$ is given by

$$SNR_{(i,0)} = \frac{W \gamma_{0,(i,0)} Q_{i,0}}{\sum_{j=1}^{M_0} I[j \neq i] \gamma_{0,(i,0)} Q_{j,0} + \sum_{j=1}^{M_1} Q_{j,1} \gamma_{1,(i,0)} + \eta W}$$
Assume

\[
\begin{bmatrix}
\gamma_0(i,1) \\
\gamma_1(i,1)
\end{bmatrix}
= \mathbb{E} \begin{bmatrix}
\gamma_1(i,0) \\
\gamma_0(i,0)
\end{bmatrix} \equiv \tilde{\gamma}
\]

\[
\mathbb{E} [\gamma_0(i,0)] = \mathbb{E} [\gamma_1(i,1)] \equiv \bar{\mu}
\]

In [6] it is shown that it is required that

\[ [W - (M_0 - 1)\alpha][W - (M_1 - 1)\alpha] - \sum_{i=1}^{M_0} \sum_{j=1}^{M_1} \frac{\gamma_0(i,1) \gamma_1(i,0)}{\gamma_1(i,1) \gamma_0(i,0)} \alpha^2 > 0 \]  \tag{8}

in order for the \textit{SNR} equations to have a solution. We wish to place a constraint on the number of users to prevent the left hand side of (8) from becoming negative (or zero). In section 2.1 we have shown that (4) describes the set of feasible \((M_0, M_1)\) on the uplink. Maximum power levels and the consideration of interference fluctuations reduces this set as described in sections 2.3 and 2.4. Here, interference fluctuations are much more significant as the receivers are now mobile. Indeed, if \(M_0\) and \(M_1\) are \(O(W)\) then the variance of (8) is \(O(W^3)\), so we must constrain \(M_0\) and \(M_1\) in order to bound the left hand side of (8) away from zero. We remark that (8) corresponds to the denominator of the total transmitted power at either receiver, so the transmitted powers tend to infinity as the left hand side of (8) tends to zero. Our approach is to impose a power constraint and obtain a law of large numbers showing that the average power used per signal will tend to a constant. For simplicity, we again assume that \(M \equiv M_0 = M_1\); we want to bound \(M\) by imposing feasibility and power constraints. Fix \(Q\) and let \(M(W)\) be defined by

\[
M(W) = \frac{1}{1 + \tilde{\gamma}} \left[ \frac{W}{\alpha} + 1 - \frac{\eta W \bar{\mu}}{Q} \right]
\]

Then as \(W \uparrow \infty\) we obtain the following central limit theorem ([6])

**Theorem 1** As \(W \uparrow \infty\) the probability of infeasibility (no solution for powers) tends to zero, the average per-user transmitted power tends to \(Q\) and the total transmitted power in each cell is

\[ M(W)Q + O(W^{1/2}) \]

4 Two receiver macro-diversity

It seems reasonable to consider systems in which distributed coding takes place. This is because it is the frequency spectrum that is the beleaguered resource, not communication between receivers connected by, say, optical fibres. The main motivation is to remove the other-cell interference (including interference fluctuations). Macrodiversity is considered in [3] and [10] where a mobile near a cell boundary can commence cell site diversity mode and be processed by several cell sites simultaneously. All cell sites forward their demodulated data to the system controller which chooses the signal of the highest quality. Our approach is to use all signals in the demodulation so that distributed coding actually takes place.

Consider the uplink of a two receiver network depicted in figure 5.
Let there be $M$ users attempting to communicate with receivers 0 and 1. Let $Q_i$ be the transmitted power of user $i$ and $\gamma_i^0 Q_i$, $\gamma_i^1 Q_i$ the received powers at receivers 0 and 1 respectively. Define $Q_0^{(t)}, Q_1^{(t)}$ by

$$Q_0^{(t)} = \sum_{i=1}^{M} \gamma_i^0 Q_i$$

$$Q_1^{(t)} = \sum_{i=1}^{M} \gamma_i^1 Q_i$$

so that $Q_0^{(t)}$ and $Q_1^{(t)}$ are the total received powers at each receiver.

What precisely is signal to noise density in a two receiver macro-diversity system? It is shown in Appendix A of [5] that the sum of the signal to noise density ratios is the relevant performance criteria when signal to noise power is low (true for spread spectrum, not for FDMA/reuse). This result is generalised in [4] to arbitrary numbers of receivers. Thus the $SNR$ requirement is that

$$\frac{\gamma_i^0 Q_i W}{Q_0^{(t)} + \eta W} + \frac{\gamma_i^1 Q_i W}{Q_1^{(t)} + \eta W} = \alpha \quad i = 1 \cdots M$$

It is shown in [5] that these $M$ equations can be solved simultaneously for the $Q_i$ provided that $M$ is sufficiently small.

**Theorem 2** The capacity of the two receiver network with a signal to noise density ratio requirement of $\alpha$ is $\frac{2W}{\alpha}$.

The interpretation is that the total bandwidth is $2W$ and each user requires a bandwidth of $\alpha$ Hz. It is shown in [5] that each receiver has a bandwidth of $W$ and that as capacity is approached these bandwidths are pooled. It is also shown there that a decentralised power control algorithm converges to the powers that satisfy the $SNR$ equations, provided that the system is below capacity.
It is shown in [5] that further constraints are imposed on network capacity by maximum
transmitter power levels. Nevertheless, the overall constraint bites provided that traffic is
sufficiently uniform. We conclude that a network-wide notion of capacity exists. We suggest
that the adaptive cellular power control algorithm of section 2.2 is a first step towards this
objective and that it could be enhanced by allowing cells to expand and contract.

5 Conclusions

We conclude that capacity can be equitably shared amongst the users in a two cell network
via power control. The power control algorithm exhibited has the virtue of simplicity;
indeed, it is decentralised in nature, only requiring a transmitter to know its current signal
to noise density ratio (\( SNR \)). This should be contrasted with the difficult task of allocating
capacity fairly with dynamic channel assignment in FDMA/reuse systems ([11]). Of course,
our power control algorithm requires hardware that can detect and react quickly to changes
in interference levels. Whether this can be achieved in practice is an engineering question
that we have not pursued.

We have taken various approaches (large deviations and the law of large numbers) which
indicate that power control can deal with the variability inherent in a mobile radio network.
We have not considered voice activity at all, although this is where most variability comes
from. A large deviations approach can be applied using the capacity region defined in the
present paper to obtain the capacity region of the voice activity model.

Note that spread spectrum takes automatic advantage of voice activity. It is shown in
[5] how the cost of the variability in activity decreases with the scale of the system. This is
due to averaging and the law of large numbers. The law of large numbers implies that the
single cell capacity of \( C \) is reduced to \( \frac{1}{1+\gamma} C \) with the presence of an adjacent cell, where \( \gamma \) is an
average interference effect. In FDMA/reuse systems the reuse factor reduces capacity
and this is based on worst case considerations. We have not made direct comparisons
with FDMA/reuse as this seems more relevant in the context of a larger network, but it is
apparent that spread spectrum has many advantages from a spectrum efficiency point of
view ([3], [5], [7]).

In the final example of a two receiver network with macrodiversity the whole network
becomes a single channel. In this case each receiver has a capacity of \( \frac{W}{\alpha} \) users. Without
diversity the per cell capacity was seen to be \( \frac{1}{1+\gamma} \frac{W}{2} \) where \( \gamma \) gives the average interference
from the adjacent cell. With macrodiversity interference is reduced; this is because all
signals carry information. This benefit from macrodiversity does not transfer across to
FDMA/reuse: signal to noise powers must be small. This is not to say that some small
gains cannot be made from macrodiversity in FDMA/reuse. We have hardly touched on
the other benefits of multiplexing that occur when traffic fall into separate classes with
different rates and in particular when traffic is bursty.

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