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Performance Analysis of SNR in MIMO OFDM Downlink System

***Sachin Suresh Chouthe*[1], *Jaya Rajesh Vattam*[2]**

[1]Student, Dept. of EXTC Alamuri Ratnamala Institute of Engineering and Technology, Shahapur, Maharashtra, India

[2]Assistant professor, Dept. of EE, Alamuri Ratnamala Institute of Engineering and Technology, Shahapur, Maharashtra, India

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ABSTRACT

The goal of future wireless communications systems is to provide a wide variety of high quality high-rate services with minimum requirements on spectrum, power consumption and hardware complexity. Toward this end, proper system structures as well as robust system designs are required to meet the challenges in wireless transmissions, such as multipath fading, limited spectrum resource, and interference. Recent research results have unveiled the multiple-input multiple-output (MIMO) system as a potential candidate to play a key role in future wireless. A MIMO wireless system is commonly deployed by using multiple transmit and receive antennas. Early work on multi-antenna systems involves the use of antenna arrays at the receiver to provide spatial diversity against the random destructive effect of fading. There is a recent rich literature on employing multiple antennas at the transmitter and achieving diversity through space-time coding when there is no channel state information at the transmitter (CSIT), or through transmit beam forming when there is perfect CSIT.

1. INTRODUCTION

The spatial domain can be expanded to increase data rate by utilizing numerous transmit and receive antennas. A coherent MIMO channel can be represented as a set of parallel Gaussian channels, whereas a flat-fading SISO Gaussian channel only offers a single narrow data pipe. This feature makes it appealing to deal with the limited amount of wireless spectrum and the strict power constraints on terminals by creating multiple data pipes for data transmission without the need for additional power or spectrum. The Bell Laboratories Layered Space-Time (BLAST) architecture can be used to obtain the spatial multiplexing gain, which is the increase in ergodic capacity that a coherent MIMO channel achieves over that of an a SISO channel. It's interesting to note that MIMO space-time-coded systems fight channel randomness whereas MIMO spatial multiplexing systems take advantage of it. A MIMO system can concurrently accomplish diversity benefits and spatial multiplexing, but there is a fundamental tradeoff between the two. The spatial diversity of networks resulting from the deployment of antenna arrays at both the transmitter and the receivers can be utilized in bandwidth-limited wireless networks to reduce interference between multiple users and improve overall performance. When numerous users share a common bandwidth, beamforming is a spatial diversity technique used at both the transmitter and the receiver to raise each user's signal-to-interference-plus-noise ratio (SINR). In a wireless multiple-input multiple-output (MIMO) downlink system, we take into consideration the joint optimization of transmit power, linear transmit beam formers at the base station, and linear receive beam formers at the mobile users.

The total transmits power and the minimum weighted SINR are two crucial performance measures in a wireless network. It is evident that the network's resource cost is closely correlated with the overall transmit power. At first look, it seems that the minimal weighted SINR merely describes the user who performs the lowest in relation to a set of user priorities. On the other hand, if all users are given the same priority, then maximizing the least weighted SINR essentially equates to equalizing the weighted SINR performance of all users (where the weights reflect the user priorities). Therefore, one tactic for maintaining the appropriate degree of fairness in the network is to maximize the lowest weighted SINR. Conventional wireless cellular networks are made to accommodate a high number of users and offer extensive network coverage. The most recent 3GPP LTE-advanced study looked into heterogeneous network deployments to boost network coverage, particularly inside buildings, and increase system performance. Within the same frequency range, heterogeneous networks combine lower-tier femtocells for improved performance (e.g., optimizing outage probability) with higher-tier microcells to increase network reach. However, Interference management is essential for heterogeneous users to regulate their transmit power effectively, thereby reducing performance degradation caused by interference. Additionally, decentralized deployment can be improved by enabling users to adjust their transmit power with minimal signaling overhead.

Heterogeneous cellular networks combine traditional cellular networks with microcells supported by low-power nodes (LPNs) like microcells, picocells, femtocells, relays, and distributed antennas, operating within the same frequency band as microcells. Variations exist in elements like transmit power and coverage zones. Low-power nodes extend coverage in areas with inadequate signal strength and fill coverage gaps during deployment. Moreover, alongside these benefits, heterogeneous cellular networks encounter certain challenges, including interference, self-organization, backhauling, and handover. Interference, an inevitable aspect of heterogeneous networks, detrimentally affects network performance by diminishing the

Signal-to-Interference-Noise Ratio (SINR). As a result, various methods of interference reduction have been investigated in scholarly literature.

2. OBJECTIVE:

- To study and compare the performance of SIMO MISO and MIMO.
- To study and compare the performance using power control and without power control.
- To implement MATLAB code for ideal power management during Rayleigh fading.
- To analysis outage probability.
- To study of ideal power management during Rayleigh fading.
- To find the outage probability verses SINR for various number of users.

3. LITERATURE SURVEY:

The downlink weighting vector design encompasses multiple criteria crucial for maximizing the efficiency of smart antenna systems and achieving optimal power allocation when the orientations of the weighting vectors are identified. It aims to equalize the downlink performance of each user by markedly decreasing the output power. Given that power amplifiers at the base station represent the costliest subsystems, employing this method could result in substantial cost savings for the base station. Implementing a smart antenna system offers the potential to expand the base station's coverage, lower its expenses, counteract fading, and enhance both system capacity and performance. It is investigated how to maximize the total bit rates that are sent from the base station to several terminals. The more intriguing problem in wireless communications is maximizing the least SINR (Signal-to-Interference-plus-Noise-Ratio) among all links that go from the base station to the various terminals. The optimal set of downlink weighting vectors (DWV) is much more difficult to find than its uplink counterpart because, while the optimal weight design problem for uplink can be handled separately, the design of the DWVs for all of the terminals is entwined and cannot be separated. The downlink spatial signatures of all of the active terminals can be obtained from the uplink. For voice communications, for example, it is appropriate to take into account a worst-case signal-to-interference-and-noise-ratio (SINR), or the minimum of the SINRs for each individual terminal sharing the same carrier frequency and time slot. This is an objective function that is suitable for real communication applications. [1]

4. PROBLEM DEFINITION

An essential performance metric for dependable wireless communication is outage probability. When the received Signal-to-Interference-and-Noise Ratio (SINR), which is frequently calculated from the quality-of-service requirement, drops below a certain threshold, a link outage is announced. Other network characteristics, such as flaws brought on by channel statistical fading, additive background noise, user mobility, and the dynamics of power control updates, also affect the statistics of the SINR and, by extension, the outage probability. In this study, power control optimization for wireless networks with Rayleigh fading channels is being considered.

4.1 Present Investigation

MIMO is effectively a radio antenna technology as it uses multiple antennas at the transmitter and receiver to enable a variety of signal paths to carry the data, choosing separate paths for each antenna to enable multiple signal paths to be used.

- *Spatial diversity:* When we speak of spatial diversity in this more restricted sense, we frequently mean transmit and receive diversity. These two approaches are utilized to increase the signal-to-noise ratio and are distinguished by enhancing the system's dependability about different types of fading.

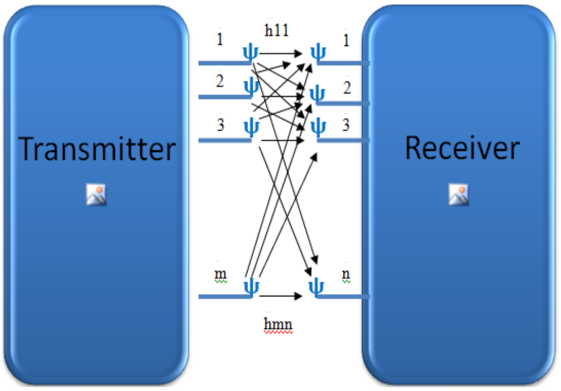


Figure1: MIMO - Multiple Input Multiple Output

- *Spatial multiplexing:* By using the many routes to convey more traffic and boosting data throughput capabilities, this type of MIMO is used to give greater data capacity.

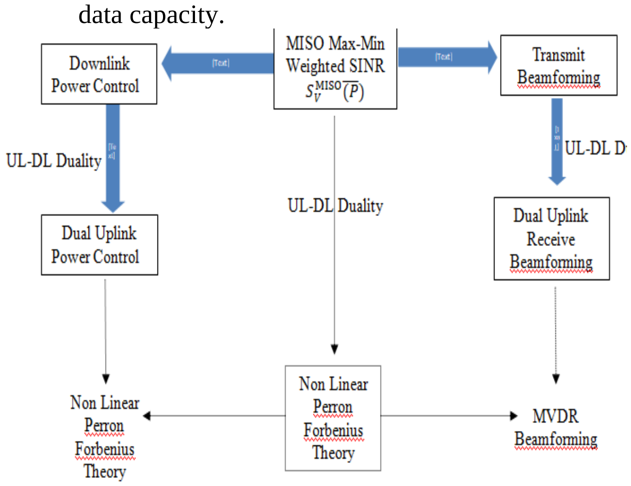


Figure2(a): MISO Max-MinWeighted SINR

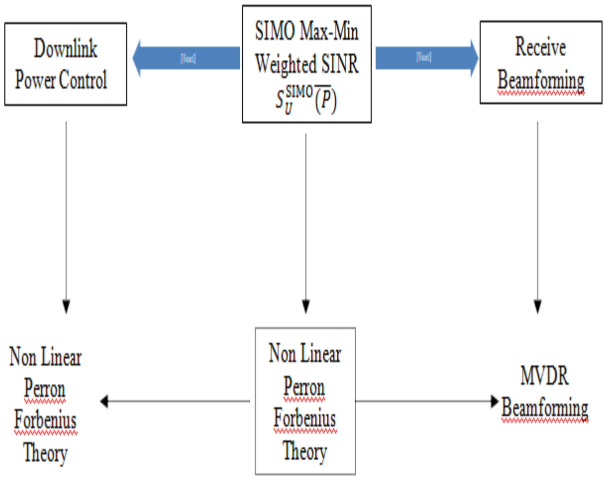


Figure 2 :(b) SIMO Max-Min Weighted SINR

4.2 Fading in Wireless Channels

Radio waves travel in empty space after propagating from a transmitting antenna, experiencing various diffraction, diffraction, absorption, reflection, and scattering effects. Buildings, bridges, hills, trees, and other obstacles in their route, as well as the atmosphere and the topography of the ground, all have a significant impact on them. Most of the distinguishing qualities of the received signal are caused by these various physical events. The height of the mobile antenna in the majority of cellular or mobile systems may be lower than the surrounding structures. It is therefore extremely unlikely that there would be a direct or line-of-sight link connecting the transmitter and the receiver. In this scenario, the buildings' reflection, scattering, and diffraction over and/or around them are the principal causes of propagation. In actuality, as illustrated in the picture below, the broadcast signal travels via multiple pathways with varying time delays before reaching the receiver, resulting in a multipath scenario.

These multipath waves with randomly distributed phases and amplitudes combine at the receiver to produce a signal that varies both in space and time. Because of this shift in the phase connection between the incoming radio waves, a receiver at one point may receive a signal that is very different from another location that is only a short distance away. The loudness of the transmission fluctuates significantly as a result. Fading is the term used to describe this phenomenon of random fluctuations in the received signal strength.

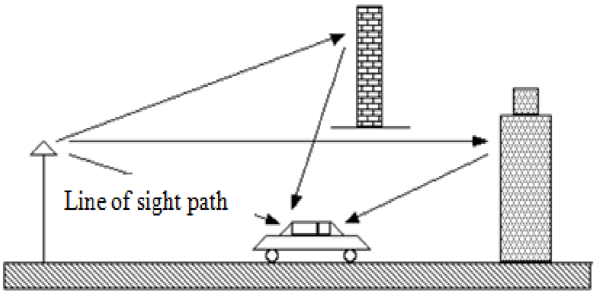


Figure 3 : Fading in Wireless Channels

4.3 Optimal power control in Rayleigh fading

Rayleigh fading (flat fading) is a statistical model that describes how a radio signal, such the one utilized by wireless devices, is affected by its propagation environment. Rayleigh fading models posit that the strength of a signal transmitted through a communication channel will undergo random fluctuations, known as fading, following a Rayleigh distribution, which arises from the radial component of the sum of two independent Gaussian random variables. This model is considered suitable for describing signal propagation in tropospheric and ionospheric conditions, as well as the impact of densely populated urban areas on radio signal transmission. Rayleigh fading is commonly utilized in scenarios where there isn't a prominent propagation path directly between the transmitter and receiver. In cases where such a direct path exists, Rician fading might be a more suitable model to consider.

4.4 Used Algorithms:

Algorithm 1: MIMO Max Min Weighted SINR

Initialize: arbitrary $P^{(0)} € \mathbb{R}_{++}^{LX1}$, and $u_l^{(0)} € \mathbb{C}^{NX1}$, $v_l^{(0)} € \mathbb{C}^{NX1}$ for l=1,.....,L, such that $w^T P^{(0)} \leq L$ and $\|u_l^{(0)}\| = 1$, $\|v_l^{(0)}\| = 1$ for all l.

1) Update receive beamformers:

$$v_l^{(n+1)} = v_l^{MVDR}(P^{(n)}),\ l = 1,\dots,L.$$

2) Compute auxiliary variables:

$$\widetilde{pl} = \left(\frac{\beta t}{SINR_l^{DL}(P^{(n)}, U^{(n)}, v_l^{(n+1)}}\right) p_l^{(n)}$$

for $l = 1,\dots\dots,L$.

3 Update downlink powers:

$$p^{(n+1)} = \frac{\bar{p}}{w^T \tilde{p}} \cdot \tilde{p}.$$

4) Compute dual uplink powers:

$$q^{(n)} = (I - D^{DL} F^T)^{-1} D^{DL} w.$$

5) Update transmit beamformers:

$$u_l^{(n+1)} = u_l^{MVDR}(q^{(n)}),\ l = 1,\dots\dots,L.$$

6) Compute dual auxiliary variables:

$$\widetilde{ql} = \left(\frac{\beta t}{SINR_l^{UL}(q^{(n)}, V^{(n+1)}, u_l^{(n+1)}}\right) q_l^{(n)}$$

for $l = 1,\dots\dots,L$.

7) Compute dual uplink powers:

$$q^{(n+1)} = \frac{\bar{p}}{n^T \tilde{q}} \cdot \tilde{q}$$

8) Compute downlink powers:

$$P^{(n+1)} = (I - D^{DL} F)^{-1} D^{UL} n.$$

Algorithm 2: Parametric Search Initialization Algorithm

Input:
Desired power constriant $\bar{P}$.
Fixed step-size $\bar{P}_\delta$.
Fixed tolerence ϵ.
A total power constriant $\bar{P}^{(1)}$ such that the network is operating in low SNR region.
Arbitrary $\bar{P}^{(0)} \in \mathbb{R}_{++}^{Lx1}$, and $u_l^{(0)} \in \mathbb{C}^{Nx1}$,
$v_t^{(0)} \in \mathbb{C}^{N_l x1}$ for $l = 1,....,L$, such that $w^T P^{(0)} \leq \bar{P}^{(1)}$, and $\|u_l^{(0)}\| = 1$, $\|v_l^{(0)}\|=1$ for all l.
Iteration index n=1.
Iterate:

1: Initialize Algorithm 1 with $(P^{(n-1)}, \mathbb{U}^{(n-1)}, \mathbb{V}^{(n-1)})$.
Use a total power constriants of $\bar{P}^{(n)}$ and run Algorithm1 till convergence to within a tolerance ϵ.
Store the solution in $(P^{(n)}, \mathbb{U}^{(n)}, \mathbb{V}^{(n)})$.

2: If $\bar{P} = \bar{P}^{(n)}$, exit the iteration. Otherwise update the power constraints as follows.
$\bar{P}^{(n+1)} = \min\{\bar{P}^{(n)} + \bar{P}_\delta, \bar{P}\}$.

3: Update $n \leftarrow n+1$ Repeat from step 1.
Output: $(P^{(n)}, \mathbb{U}^{(n)}, \mathbb{V}^{(n)})$.

Algorithm 3: Worst Outage Probability Minimization:

1) Update power $P(k+1)$:

$p_l(k+1) = -\log(1-O_l(p(k)))p_l(k) \forall l$.

2) Normalize $P(k+1)$:

$$P(k+1) \longleftarrow \frac{p(k+1).\ \bar{P}}{1^T p(k+1)} \text{if } \mathcal{P} = \{P \mid 1^T P \leq \bar{P}\}.$$

$$P(k+1) \longleftarrow \frac{p(k+1).\ \bar{P}}{\max_j \mathcal{P}_j(k+1)} \text{if } \mathcal{P} = \{P \mid p_t \leq \bar{p} \forall l\}.$$

$$P(k+1) \longleftarrow \frac{p(k+1).\ \bar{p}}{\max_j \mathcal{P}_j(k+1)} \text{if } \mathcal{P} = \{P \mid p_t \leq \bar{p} \forall l\}.$$

Algorithm 4: Total Power Minimization:

$p_l(k+1) = \min\{-\log(1-O_l(P(k)))\ p_l(k) / \alpha_l, \bar{p}\} \forall l$.

Algorithm 5: Adaptive Outage-based Power Control (AOPC):

1)Update the auxiliary variable $z(k+1)$:

$z_l(k+1) = -\log(1-O_l(z(k)))\ z_l(k) \forall l$.

2) Normalize $z(k+1)$:

$z(k+1) \longleftarrow z(k+1) .\bar{p} / \max_j z_j(k+1)$

3) Update the transmit power $P(k+1)$:

$$p_l(k+1) = \min\left\{\frac{-\log\left(1-O_l(p(k))\right)p_l(k)}{\max\{\alpha_l, -\log(1-O_l(z(k)))}, \ \bar{p}\right\} \forall l.$$

4.5 Project Flow Diagram:

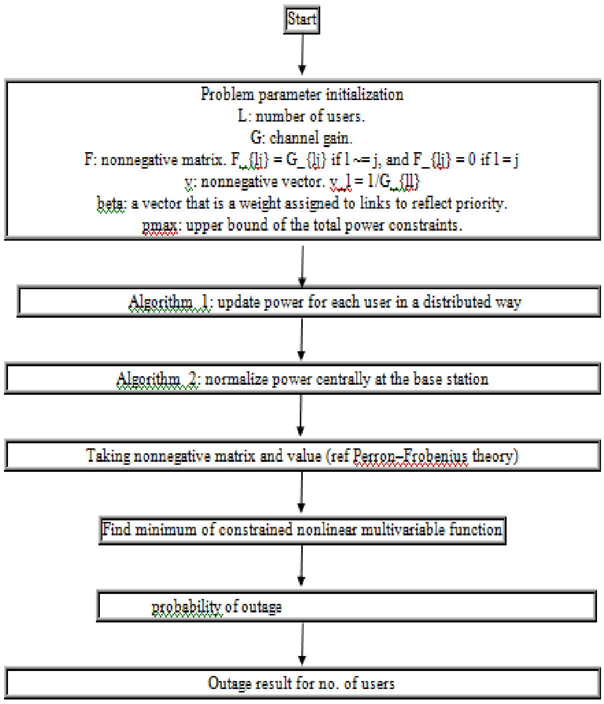


Fig 4 : Implemented network diagram

5. RESULT:

Here we are analyzing of SINR for SIMO MISO and MIMO downlink system and comparing the all of them with respect to Energy per Bit to noise ratio vs bit error rate and Power vs SINR.

Comparison for various numbers of users :

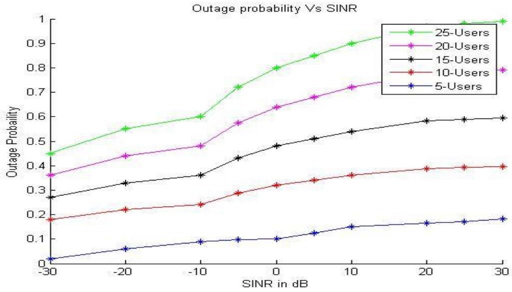


Fig 5 Comparison Of Sinr Vs Outage Probability For Various Nos. Of Users.

5.1. Output in Tabular from:

The graph shows that as the number of user increasing in a MIMO power control downlink system the outage probability also increases as compared to SINR. Mathematically we will get the answers which are shown in the tables number respectively Table no:1, Table no: 2, Table no: 3, Table no: 4, Table no: 5.

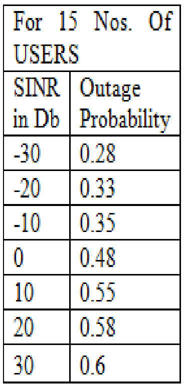
Table no:1

For 5 Nos. Of USERS	
SINR in dB	Outage Probability
-30	0.02
-20	0.06
-10	0.08
0	0.1
10	0.146
20	0.162
S30	0.181

Table no:2

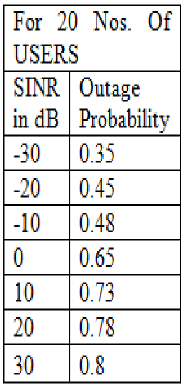
For 10 Nos. Of USERS	
SINR in dB	Outage Probability
-30	0.16
-20	0.22
-10	0.23
0	0.33
10	0.36
20	0.38
30	0.4

Table no: 3



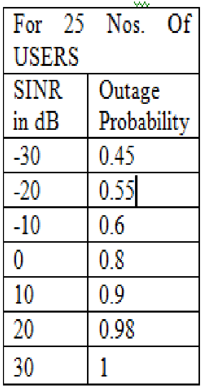
For 15 Nos. Of USERS	
SINR in Db	Outage Probability
-30	0.28
-20	0.33
-10	0.35
0	0.48
10	0.55
20	0.58
30	0.6

Table no: 4



For 20 Nos. Of USERS	
SINR in dB	Outage Probability
-30	0.35
-20	0.45
-10	0.48
0	0.65
10	0.73
20	0.78
30	0.8

Table no:5



For 25 Nos. Of USERS	
SINR in dB	Outage Probability
-30	0.45
-20	0.55
-10	0.6
0	0.8
10	0.9
20	0.98
30	1

For 5 numbers of users when SINR is -30dB the occurred outage probability is 0.02
when SINR is 0dB the occurred outage probability is 0.1
when SINR is +30dB the occurred outage probability is 0.181
For 10 numbers of users when SINR is -30dB the occurred outage probability is 0.16
when SINR is 0dB the occurred outage probability is 0.33
when SINR is +30dB the occurred outage probability is 0.4
For 15 numbers of users when SINR is -30dB the occurred outage probability is 0.28
when SINR is 0dB the occurred outage probability is 0.48
when SINR is +30dB the occurred outage probability is 0.6
For 20 numbers of users when SINR is -30dB the occurred outage probability is 0.35
when SINR is 0dB the occurred outage probability is 0.65
when SINR is +30dB the occurred outage probability is 0.8
For 25 numbers of users when SINR is -30dB the occurred outage probability is 0.45
when SINR is 0dB the occurred outage probability is 0.8
when SINR is +30dB the occurred outage probability is 0.1

6. CONCLUSIONS

As MIMO plays a key role in the analysis of SINR with various downlink systems, We obtained a MIMO system that is approximately three times more the capacity of MISO and SIMO. Therefore, under high Signal-to-Interference-Noise Ratio (SINR) conditions, the capacity of the Multiple Input Multiple Output (MIMO) system grows proportionally with the quantity of antennas employed at both the transmitting and receiving ends. It is deduced that as the number of users rises, the likelihood of outage also escalates. Consequently, our examination of the MIMO max-min weighted SINR problem entailed a thorough investigation into its optimality attributes. More precisely, two situations have been pinpointed where this nonconvex issue can be effectively resolved: (i) when the channels exhibit rank-one characteristics, and (ii) when the network operates within the low Signal-to-Noise Ratio (SNR) domain. An algorithm is put forward that converges towards the optimal solution in both of these scenarios. Motivated by the parametric continuity of the issue in the power constraint, we developed an initialization strategy for our (usually) suboptimal solution, which we hope would enhance its performance. It is easy to extend the suggested parametric search initialization approach to the MIMO total power minimization issue, and it performs better than random initialization. The worst outage probability problem and its certainty-equivalent margin counterpart are found to have a close relationship. This relationship can be used to determine relevant bounds and the rate of convergence. The topic of minimizing total power without age specification limitations and meeting its feasibility requirement is tackled. A dynamic algorithm is proposed that minimizes the total power in a heterogeneous network by adapting its outage probability specification. This enabled the seamless management of outage unfeasibility in a decentralized fashion while ensuring maximum fairness in terms of the most unfavorable outage probability. The paper introduces an algorithm for adjusting the desired power to base stations in the downlink. The utilization of novel power control algorithms is anticipated to yield improved outcomes in both the downlink and uplink. Addressing the outage probability for users across remaining tiers poses a significant challenge as well.

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