Blocking Performance Comparison for Guard Channel and Fractional Guard Channel Policy in Wireless Cellular Networks

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***Abstract*—A wireless network is a collection or group of devices that communicate through radio frequencies to send and receive data. Utilization of limited resources and quality of service improvement are the major concerns for wireless cellular networks. One major constraint in achieving the desired quality of service is call blocking. In cellular networks, blocking happens when a base station cannot assign a channel to a mobile user due to the absence of available channels. There are two kinds of blocking. The first is called new call blocking, which refers to the blocking of new calls. Handoff call blocking occurs when an ongoing call is interrupted because the user moves, and no available channels can accommodate the call in the new location. In cellular networks, channel management is specifically designed to minimize the effects of blocking during peak traffic periods. The focus of this work is a comparative analysis of blocking performance between two channel allocation policies: the Guard Channel Policy (GCP) and the Fractional Guard Channel Policy (FGCP). The analysis includes the blocking probabilities for new and handoff calls through simulations while increasing the steady traffic. Furthermore, we aim to analyze and test both these policies in our project. In conclusion, we will determine which policy is the best under the Channel Reservation Technique.**

***Index Terms*—handoff call, new call, handoff call dropping probability, new call blocking probability.**

I. INTRODUCTION

Cellular networks are always based on the concept of dividing the service area into smaller regions known as cells, each served by a base station which takes care of the communication between mobile devices and the core network. Cellular networks remain the backbone of today's modern wireless communications that enable mobile users to communicate seamlessly across large geographical areas. The architecture of cellular networks supports wide-ranging applications from voice calls to high-speed data services and is designed in such a way that reliable communication can be achieved when users switch between different cells, a process known as handoff or handover..

Key Elements of a Cellular Network:

Base Stations (BS): Each cell in the network contains a base station that manages communication with the mobiles. The base station will allocate free radio channels to be used for the calls and data sessions.

Mobile Switching Centers (MSC) It is a central hub that connects multiple base stations and thus acts as an interface between the cellular network and other telecommunication networks like the PSTN.

Mobile devices. Devices operated by users, such as smart phones or tablets, that connect to the network via the base stations.

Handoff Process: When a mobile device switches from one cell to another, the next cell base station assumes the active call or data session without dropping, thereby completing the seamless handoff for the user.

Call Admission Control Policies:

Several Call Admission Control policies are designed to try and mitigate the problem of call blocking by prioritizing traffic and efficiently allocation resources. Some common policies include

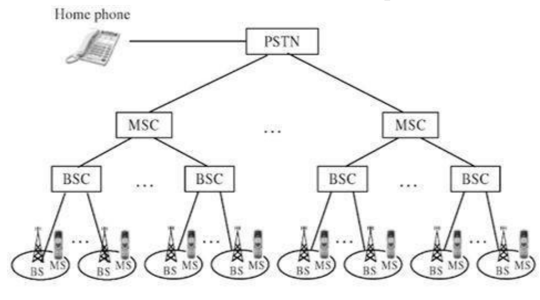


Fig: cellular system infrastructure

A.Guard Channel Policy(GCP):

Carries a fixed number of channels for hand-off calls to avoid decrease blocking probability, causing potential resource under utilization during low traffic.

B.Fractional Guard Channel Policy(FGCP):

The fractional guard channel policy in cellular networks allocates a portion of channels as reserved for high-priority calls, reducing call blocking for these users. It improves call quality and reduces interference by balancing call prioritization and resource utilization.

II. LITERATURE SURVEY

"Performance analysis of fractional guard channel policies in mobile cellular network" was published by juse luis Vazquez-Avila,Felipe A.cuez-perez and luerro ortigoza Guerrero and this paper helps in analysing the fractional guard channel policies by using recursive formulas for the new call blocking and handoff failure probabilities for fractional guard policies in cellular network are derived.

"On optimal call admission control in cellular network" was published by Ramachandran Ramjee a, Don Towsley a and Ramesh Nagarajan b. The paper focuses on minimizing new and handoff call blocking probabilities in cellular networks. The paper develops simple and efficient algorithms for determining optimal parameters for these policies.

"Performance Analysis of the Guard Channel Scheme with Self-Similar Call Arrivals in Wireless Mobile Networks" was published by Geyong Min and Xiaolong Jin. The study suggests that optimizing the number of guard channels can significantly improve the balance between new and handover call handling, enhancing overall network efficiency.

The paper by D. Hong and S. S. Rappaport (1986) introduces a "traffic model for cellular networks and proposes the Guard Channel (GC) policy, which prioritizes handoff calls by reserving dedicated channels. Using Markov chain analysis, the study evaluates call blocking probabilities and shows that prioritizing handoff calls reduces call drops while slightly increasing new call blocking. The findings highlight the importance of optimal guard channel allocation for balancing network efficiency and Quality of Service (QoS).

The paper by Youssef Iraqi and Raouf Boutaba (2005) analyzes handoff and call dropping probabilities in wireless cellular networks, emphasizing the trade-off between resource allocation and Quality of Service (QoS). The study concludes that efficient handoff prioritization strategies, such as guard channels and adaptive resource reservation, can significantly reduce call drops while maintaining network performance. Their findings highlight the need for dynamic resource management to adapt to varying traffic conditions and mobility patterns.

III. METHODOLOGY

A.Guard Channel Policy:

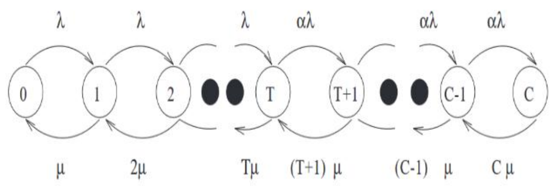


Fig 1: State transition diagram (Guard Channel policy)

The GC policy operates by reserving a predetermined number of channels for handoff calls, ensuring that ongoing calls are less likely to be dropped during cell transitions. This approach maintains a balance between accepting new calls and preserving resources for handoff scenarios.

Algorithmic Process: Guard Channel Policy

The GC policy can be implemented through the following step-by-step process:

Step 1: Initialization

Define the total number of channels, denoted as "C," available in the cell.

Set a threshold "T" such that "$C - T$" channels are reserved exclusively for handoff calls.

Step 2: Call Arrival

When a call (new or handoff) arrives, check the current channel occupancy.

Step 3: New Call Handling

If the number of occupied channels is less than "T," accept the new call.

If the number of occupied channels is greater than or equal to "T," reject the new call.

Step 4: Handoff Call Handling

If a handoff call arrives and there are available channels, accept the handoff call. If no channels are available, reject the handoff call.

Step 5: Channel Release

When a call (new or handoff) completes, release the occupied channel.

Formulas for calculating handoff call blocking probability and new call blocking probability in Guard Channel Policy:

Steady-State Probability:

$$P_j = \begin{cases} \frac{p^j}{j!} P_0, 0 \leq j \leq T , \\ \frac{p^j \omega^j - \tau}{j!}, \ T < j \leq C , \end{cases}$$

Normalizing constant(P0):

$$P_0 = \frac{1}{\sum_{j=0}^{T} \frac{p^j}{j!} + \sum_{j=T+1}^{C} \frac{p^j \omega^{j-T}}{j!}}$$

Blocking Probabilities:

Handoff Blocking Probability:

$$B_h(C, \beta) = P_C$$

New Call Blocking Probability:

$$B_h(C, \beta) = \sum_{j=0}^{C} (1 - \beta_{j+1})\, P_j, \beta_{C+1} = 0$$

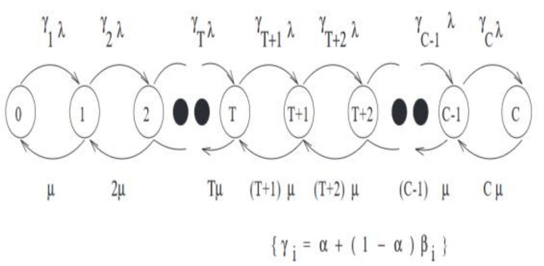
Note:

$$\beta_i = 1{,}1 \leq i \leq T$$

$$\beta_i = 0, T + 1 \leq i \leq C$$

B.The Fractional Guard Channel Policy:

The Fractional Guard Channel (FGC) policy operates by dynamically controlling the admission of new calls based on current channel occupancy, ensuring higher priority for handoff calls while optimizing resource utilization. Unlike the Guard Channel policy, FGC uses a probabilistic approach for admitting new calls when the channel occupancy exceeds a threshold.



Algorithmic Process: Fractional Guard Channel Policy:

Step 1: Initialization

Define the total number of channels, denoted as C, available in the cell.

Set a threshold "T" where $C - T$ channels are prioritized for handoff calls using probabilistic admission for new calls.

Step 2: Call Arrival

When a call (new or handoff) arrives, check the current channel occupancy, denoted as j.

Step 3: New Call Handling

If $j < T$, accept the new call.

If $T \leq j < C$, accept the new call with probability

If $j = C$, reject the new call.

Step 4: Handoff Call Handling

If a handoff call arrives and there are available channels ($j < C$), accept the handoff call.

If no channels are available ($j = C$), reject the handoff call.

Step 5: Channel Release

When a call (new or handoff) completes, release the occupied channel.

Formulas for calculating handoff call blocking probability and new call blocking probability in Fractional Guard Channel Policy:

Steady-State Probability:

$$P_j = \frac{p^j \prod_{i=1}^{j} \gamma_i}{j!} P_0, 0 \leq j \leq C$$

Normalizing constant(P0):

$$P_0 = \frac{1}{\sum_{j=0}^{C} \left(p^j \prod_{i=1}^{j} \gamma_i / j! \right)}$$

And

$$\gamma_i = \alpha + (1 - \alpha)\beta_i, \quad 1 \leq i \leq C$$

Blocking Probabilities:

Handoff Blocking Probability:

$$B_h(C, \beta) = P_C$$

New Call Blocking Probability:

$$B_n(C, \beta) = \sum_{j=0}^{C} \left(1 - \beta_{j+1}\right) P_j, \beta_{C+1} = 0$$

Note:

$$\beta_i = 1, 1 \le i \le T$$

$$\beta_i = 0, T + 1 \le i \le C$$

Simulation Setup:

The simulations are conducted using Python and Google Colab, with different traffic scenarios analyzed:

• Low Traffic: Minimal channel occupancy, leading to fewer blocked calls.

• High Traffic: Higher channel occupancy and increased blocking probabilities.

Key parameters:

• New Call Arrival Rate (λ1)

• Handoff Call Arrival Rate (λ2)

• Total Number of Channels (C)

• Service Rate (MU)

• Threshold Channel (T)

Traffic Scenarios: Traffic scenarios ranged from low to high, simulating conditions of minimal to maximum channel utilization.

Performance Metrics: The study evaluates:

• New Call Blocking Probability (Bn): Likelihood of blocking a new call request.

• Handoff Call Blocking Probability (Bh): Likelihood of dropping a handoff call.

• Overall Channel Utilization: Percentage of channels actively in use

IV.RESULTS AND DISCUSSION

Graphs show the relationship between variable quantities, typically two variables. In this project, we will visualize and summarize the policies by comparing the Guard Channel Policy and the Fractional Guard Channel Policy using graphs. We will plot graphs based on different parameters, resulting in a total of twelve graphs:

1.Four graphs for the performance of the Guard Channel Policy.
2. Four graphs for the performance of the Fractional Guard Channel Policy.
3. Four comparative graphs by overlaying the results from both policies to facilitate direct comparisons.

These visualizations will help us understand the performance differences between the two policies, highlighting the key metrics and trends that influence their effectiveness in managing channel allocation.

Guard Channel Policy:

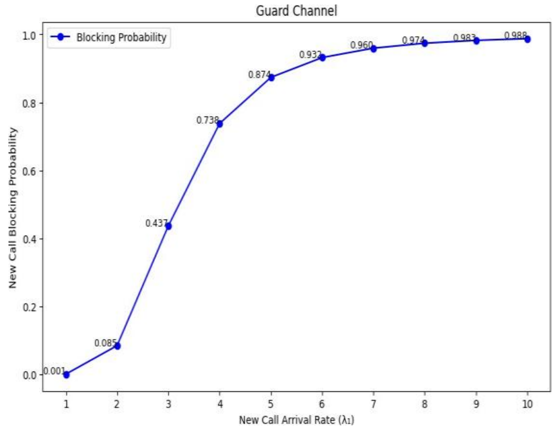


Figure 1: This graph illustrates the relationship between the new call arrival rate (λ_1) and the new call blocking probability under the Guard Channel Policy. As the arrival rate of new calls increases, the blocking probability also rises. Initially, the blocking probability is very low when the call arrival rate is minimal. However, it sharply increases as the traffic load grows, reaching near saturation at higher arrival rates. This behavior highlights the limited capacity of the system and the effectiveness of the Guard Channel Policy in reserving channels, which may lead to higher blocking probabilities for new calls under heavy traffic conditions.

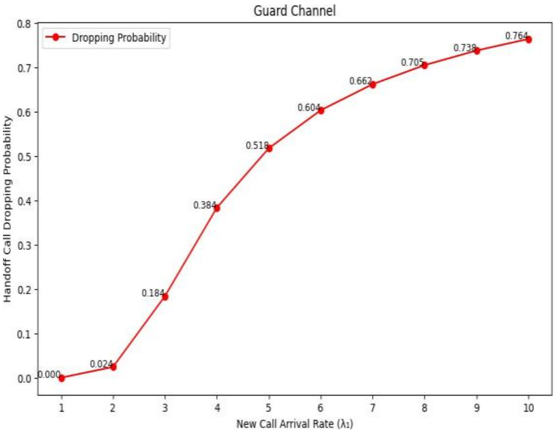


Figure 2: This graph illustrates the relationship between the new call arrival rate (λ_1) and the handoff call dropping probability under the Guard Channel Policy.

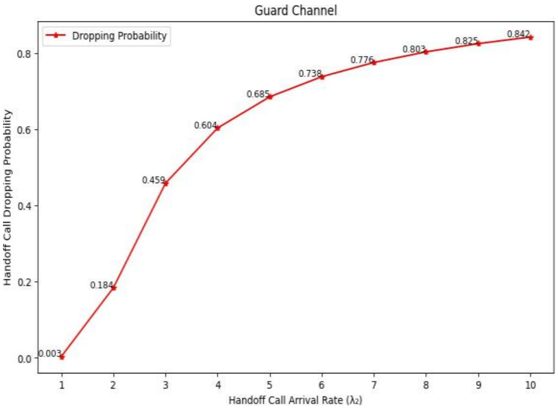


Figure 3: This graph illustrates the relationship between the handoff call arrival rate (λ_2) and the handoff call dropping probability under the Guard Channel Policy.

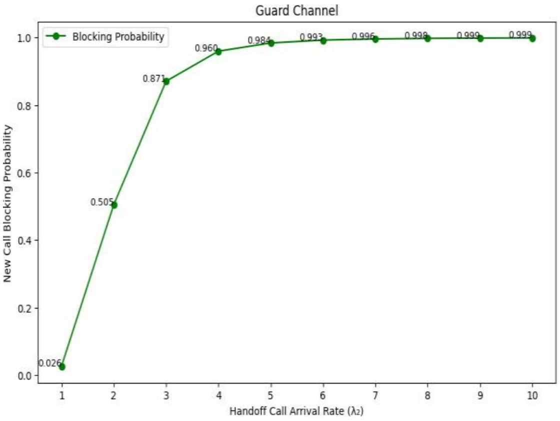


Figure 4: This graph illustrates the relationship between the handoff call arrival rate (λ_2) and the new call blocking probability under the Guard Channel Policy.

Fractional guard Channel Policy:

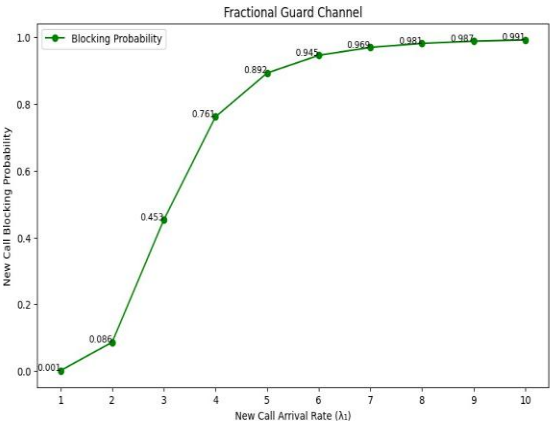
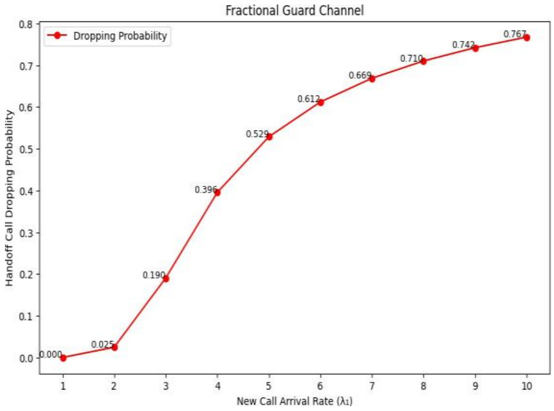


Figure 5: This graph illustrates the relationship between the new call arrival rate (λ_1) and the new call blocking probability under Fractional Guard Channel Policy.



Sd Figure 6: This graph illustrates the relationship between the new call arrival rate (λ_1) and the handoff call dropping probability under Fractional Guard Channel Policy.

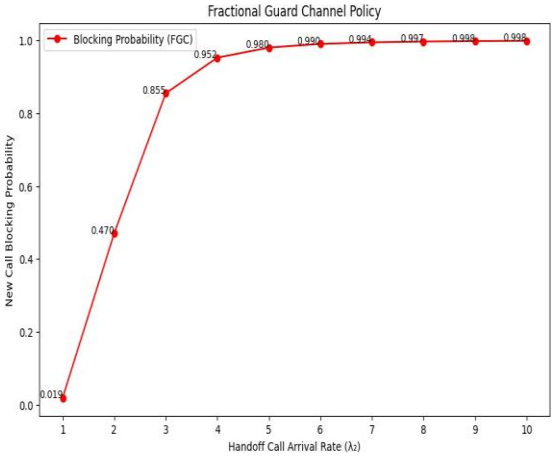


Figure 7: This graph illustrates the relationship between the handoff call arrival rate (λ_2) and the new call blocking probability under Fractional Guard Channel Policy.

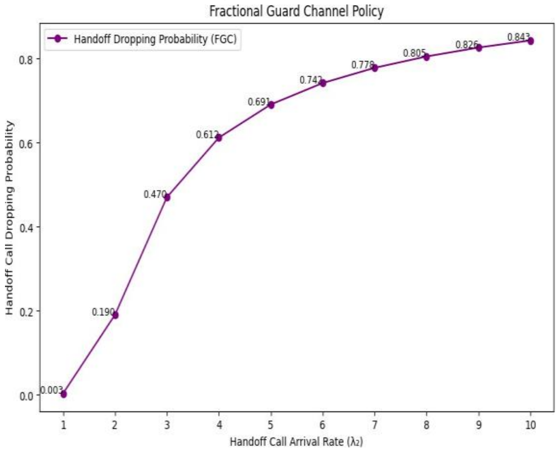


Figure 8: This graph illustrates the relationship between the handoff call arrival rate (λ_2) and the handoff call dropping probability under Fractional Guard Channel Policy.

Comparison of graphs between guard and the fractional guard channel policy:

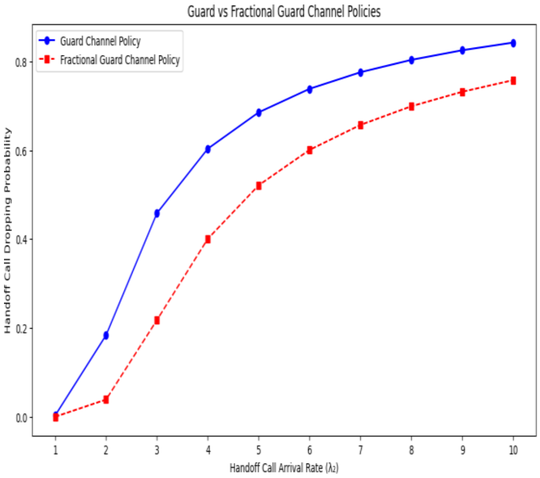


Figure 9: The graph illustrates the performance comparison between the Guard Channel Policy and the Fractional Guard Channel Policy in terms of handoff call dropping probability as a function of the handoff call arrival rate (λ2).

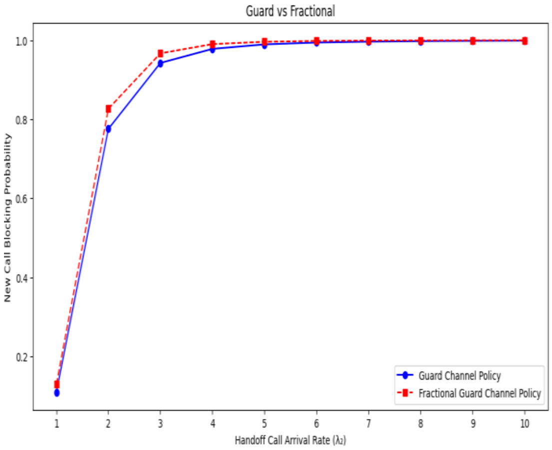


Figure 10: The graph illustrates the performance comparison between the Guard Channel Policy and the Fractional Guard Channel Policy in terms of new call blocking probability as a function of the handoff call arrival rate (λ2).

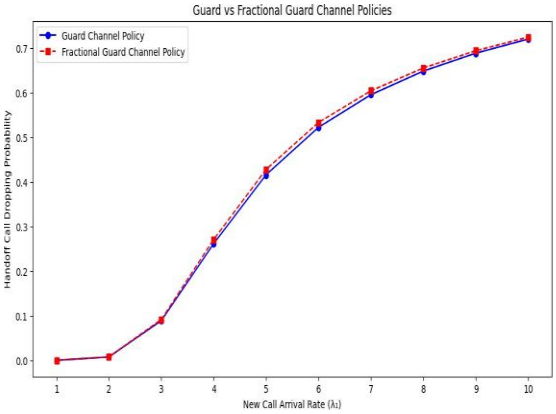


Figure 11: The graph illustrates the performance comparison between the Guard Channel Policy and the Fractional Guard Channel Policy in terms of handoff call dropping probability as a function of the new call arrival rate (λ1).

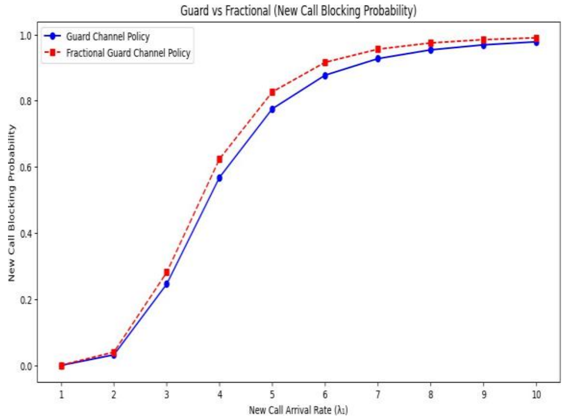


Figure 12: The graph illustrates the performance comparison between the Guard Channel Policy and the Fractional Guard Channel Policy in terms of new call blocking probability as a function of the new call arrival rate (λ1).

V. CONCLUSION

This study concludes that the Fractional Guard Channel Policy is the superior call admission strategy for wireless cellular networks. By dynamically adjusting channel allocations based on traffic conditions, FGCP minimizes blocking probabilities and enhances resource utilization. It outperforms the traditional Guard Channel Policy, particularly under high traffic conditions, making it the optimal choice for modern cellular networks.

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