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Analysis of a New Approach to Admission Call Control

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Abstract

This study presents a new method of managing call admission in wireless networks using a resource reservation technique. The system under study comprises a defined number of operating devices, standby units, and technicians assigned to repair failed devices. In this method, the failure and repair of devices are assumed to follow an exponential distribution. Whenever a device fails, a standby unit replaces it to maintain seamless functionality, and the failed device is forwarded to a technician group for restoration. The core idea revolves around optimizing the use of limited network resources while ensuring continuous service and minimizing call blocking. To mathematically model the system, transient state equations were developed. These equations are solved using a numerical method known as the fourth-order Runge-Kutta technique. The proposed approach demonstrates improved performance measures, including lower call blocking rates and better resource utilization. This study contributes to network performance optimization in environments where equipment reliability and user demands are dynamically changing. By simulating real-world network behavior, this model proves effective in improving Quality of Service (QoS) without compromising user satisfaction.

Keywords: Operating devices spares, queue length, Runge-Kutta technique, transient analysis, device failure and recovery modeling

INTRODUCTION

The rapid advancement of mobile communication technologies has significantly transformed the way people communicate and access information. In the past, wireless communication networks were primarily used for basic voice communication. However, with the emergence of smartphones, mobile applications, and the growing demand for internet access, these networks have evolved into sophisticated systems that support a wide range of multimedia services. Today's mobile networks are expected to handle not just voice calls, but also high-quality video streaming, online gaming, real-time conferencing, file transfers, and cloud-based applications.

To accommodate these complex services, modern wireless networks have transitioned to Internet Protocol (IP)-based architectures. These networks are designed to manage data traffic more efficiently and to support a variety of user demands simultaneously. However, this evolution also brings new challenges, especially when it comes to managing the flow of data and ensuring reliable communication under high traffic conditions. The need to deliver continuous, high-quality service has placed enormous pressure on the available network resources, making effective resource management more important than ever [1–3].

One of the most pressing problems in mobile communication networks is *network congestion.* As

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the number of users and the volume of data increase, the available communication channels or bandwidth can quickly become saturated. This congestion can lead to degraded service quality, increased call drops, and a higher number of rejected calls. The situation becomes even more complex in *heterogeneous wireless environments,* where different types of devices, applications, and user requirements coexist. In such environments, each call or data session may have different bandwidth and latency requirements, which makes efficient resource allocation a difficult task [4–7].

Another key factor that affects network performance is *user mobility*. In mobile networks, users often move between different coverage areas or cells while they are engaged in a call or data session. When a user moves from one cell to another, the network must transfer the call or session to the new cell without any disruption, a process known as a *handoff*. If the target cell does not have enough free resources, the ongoing call may be dropped, which negatively affects the user experience. Hence, call admission and handoff management are critical components of network operation [8–10].

To tackle these issues, this study introduces a *new approach to Call Admission Control (CAC).* The proposed method focuses on resource reservation and system behavior under device failures. It ensures that new calls are admitted into the network only when sufficient resources are available to handle them without affecting the quality of existing calls. The method dynamically evaluates the network load and either accepts or rejects new call requests based on the real-time capacity of the network. This process helps prevent overloading and ensures that the system continues to operate efficiently under varying traffic conditions [11–13].

The ultimate goal of the proposed CAC mechanism is *to reduce the probability of call blocking, improve resource utilization, and maintain a high level of service quality (QoS).* This model not only supports efficient call management but also introduces mechanisms for handling device failures and recovery, which adds resilience to the network infrastructure. By addressing these challenges, the proposed approach offers a more reliable and user-centric solution for managing mobile communication networks in today's data-driven world [14–17].

LITERATURE REVIEW

Over the years, many strategies have been developed for Call Admission Control (CAC) to optimize the management of network resources and improve the overall user experience in mobile communication networks. These strategies aim to reduce call blocking probabilities, enhance resource utilization, and ensure uninterrupted service. Each approach has its own strengths and challenges, with the selection of a suitable CAC strategy often depending on the specific needs and constraints of the network environment. Below, we review some of the most widely used CAC strategies, categorized by their methodologies and effectiveness [18–21].

Guard Channel Schemes (GC)

Guard Channel (GC) schemes are one of the earliest and most popular approaches in CAC design. These schemes reserve a specific number of channels solely for *handoff calls,* ensuring that users who are already engaged in a call can maintain their connection even if they move from one cell to another [22–25]. The primary goal of these schemes is to guarantee uninterrupted service by preventing handoff calls from being blocked due to a lack of available channels. Several variants of the Guard Channel schemes have been proposed:

- *Cutoff Priority Schemes:* In these schemes, a portion of the available channels is set aside for handoff calls. Whenever a channel is released, it is returned to the common pool of channels, allowing both new calls and handoff calls to use it. This strategy balances the needs of both types of calls but does not prioritize one over the other in terms of availability.
- *Fractional Guard Channel Schemes:* This variant allows new calls to be admitted with a certain probability, which decreases as the network becomes more congested. The probability of admission for new calls depends on factors such as the number of busy channels in the system.

The fractional guard approach improves efficiency by enabling new calls when network resources are available while still ensuring that handoff calls are prioritized.

- *Rigid-Division Schemes:* These schemes strictly divide the channels into two distinct groups: one dedicated to new calls and the other reserved exclusively for handoff calls. While this method simplifies resource allocation, it can lead to inefficient use of network resources, especially when the demand for handoff calls is lower than expected.

Queuing Priority (QP) Schemes

Queuing Priority (QP) schemes focus on managing call admission based on the availability of free channels. When no channels are available, new calls are typically placed in a queue while waiting for a channel to become free. However, the handling of handoff calls in this scheme varies depending on the specific policy:

- *New Calls Queued, Handoff Calls Blocked:* In this approach, new calls are queued when all channels are occupied, while handoff calls are blocked if no resources are available. This policy ensures that users who are already in a call are prioritized over new call attempts.
- *Handoff Calls Prioritized:* In this version, handoff calls are prioritized over new calls. When the system is at full capacity, new calls may be queued while handoff calls are immediately granted access to available channels. This approach ensures that ongoing calls are not dropped, which is particularly important for users in motion.
- *All Calls Queued with Reordering:* This policy attempts to balance fairness by queuing both new and handoff calls and reordering them as necessary. The queueing strategy may involve setting priorities for each type of call, ensuring that the system remains fair while still maintaining service quality.

CDMA and Orthogonality Challenges

Code Division Multiple Access (CDMA) is a widely used technology in mobile communication, where multiple users share the same frequency spectrum by being assigned unique codes. In an ideal CDMA system, the codes used by different users are orthogonal, meaning they do not interfere with each other. However, in real-world conditions, *multipath interference* and non-ideal propagation conditions lead to a reduction in the orthogonality of the codes. As a result, interference between users occurs, which affects the quality of service and makes it more challenging to manage call admission effectively.

To address this issue, network designers must find ways to mitigate interference while still admitting new calls. Managing downlink interference in CDMA systems is a critical aspect of ensuring that the system can support both high user density and varying levels of service demands. Techniques such as interference, cancellation and power control are commonly employed to improve the overall network performance, but they add complexity to the admission control process.

Resource Optimization Techniques

Recent advancements in network management have introduced *dynamic bandwidth allocation* and *predictive admission control* methods, which aim to optimize resource usage even further. These techniques rely on advanced algorithms, including *machine learning* and *pattern recognition,* to predict future network conditions based on historical data and real-time traffic patterns. By forecasting the demand for network resources, these methods can make proactive decisions about admitting or rejecting calls before congestion occurs, thus reducing the likelihood of call blocking.

While these approaches are highly effective in theory, they can be computationally expensive and challenging to implement in real-time systems. Predictive algorithms require large amounts of data and processing power, which may not be feasible in all network environments. As a result, there is still a strong need for simpler and more practical CAC models that can be easily deployed without the need for extensive computational resources.

In summary, while numerous CAC strategies have been proposed and tested in mobile networks, each comes with its own set of trade-offs. Guard Channel schemes are effective in prioritizing handoff calls but can lead to inefficient resource utilization in some cases. Queuing Priority schemes introduce flexibility in handling congestion, though the management of queued calls can complicate network performance. CDMA systems face unique challenges due to interference, requiring more complex admission control strategies. Finally, resource optimization techniques offer promising improvements but face challenges related to implementation complexity and real-time requirements.

Given these challenges, the need for simpler, more efficient CAC models remains. The proposed approach in this study aims to strike a balance between effectiveness and feasibility, offering a robust solution to the problem of call admission in modern mobile networks.

MODEL DESCRIPTION

This study proposes a structured method to reserve resources for call management. The system uses a combination of operational devices, standby units, and repair technicians. The key assumptions are:

- There are M operational devices in normal use.
- There are S standby devices, ready to replace failed ones.
- Failed devices are repaired by R technicians on a First-Come-First-Serve (FCFS) basis.
- Device failure and repair rates follow exponential distributions.
- Once repaired, a device is as good as new and returns to service.

This model is inspired by real-world scenarios where hardware failures can affect ongoing calls. It ensures that if an operating device fails, it is instantly replaced by a standby device, ensuring continuity of service. The failed unit is queued for repair, reducing downtime.

The model allows for dynamic resource replacement and restoration, simulating a resilient and self-healing network environment.

FEATURES OF THE PROPOSED SCHEME

This approach presents several advantages over traditional CAC systems:

1. *Traffic Awareness:* It adapts to varying traffic conditions and services.
2. *Layer Compatibility:* Can integrate with other CAC policies as a modular enhancement.
3. *Buffer Impact Analysis:* Helps examine how buffer size affects call blocking.
4. *Maximized Bandwidth Utilization:* Ensures all available resources are effectively used.
5. *Reduced Signaling Overhead:* Less communication between base stations is needed.
6. *Centralized Control:* The base station manages call admission, termination, and bandwidth allocation.

These features collectively ensure that network performance remains stable even in high-traffic situations.

RESULTS AND DISCUSSION

To evaluate the effectiveness of the proposed model, numerical simulations were carried out using the fourth-order Runge-Kutta method. The results showed the following:

- *Lower Call Blocking Probability:* The new method effectively reduced the chances of call rejection, especially during peak hours.
- *High Resource Utilization:* Standby devices ensured minimal idle time, leading to better resource efficiency.
- *Improved Service Continuity:* Failed devices were replaced instantly, preventing call drops.
- *Scalability:* The system performed well even as the number of users increased.
- *Repair Queue Efficiency:* Technicians were able to handle failed devices efficiently, minimizing backlog.

In comparison with other CAC mechanisms, our model demonstrated a balance between complexity and performance. It does not rely on advanced prediction algorithms, making it easy to implement in existing networks.

Additionally, the system showed resilience in scenarios involving frequent device failures. The dynamic repair and replacement process helped maintain consistent service quality.

CONCLUSION

The increasing demand for uninterrupted mobile communication calls for efficient call admission strategies. Our proposed resource reservation model provides a simple yet effective solution to this problem. It ensures seamless communication by managing operating and standby devices along with a dedicated repair team.

By reserving resources and replacing failed units in real-time, this approach reduces call blocking and improves overall network efficiency. It is suitable for integration with other CAC methods and offers flexibility for various traffic types.

Furthermore, the model ensures that Quality of Service remains high even when devices fail or traffic spikes occur. The use of exponential failure and repair distributions offers realistic modeling, while the Runge-Kutta method ensures accurate numerical results.

This work opens up new possibilities for implementing resilient and self-managing communication systems. Future research can explore the use of AI to further optimize resource allocation and fault recovery.

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