Performance Analysis of Call Admission Control Strategies in LTE-Advanced Networks

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Abstract: Call Admission Control (CAC) plays a crucial role in ensuring efficient resource allocation and maintaining Quality of Service (QoS) in LTE-A (Long-Term Evolution-Advanced) networks. This study presents a performance analysis of different CAC strategies, including Guard Channel, Threshold-Based, Bandwidth Reservation, Priority-Based, and Utility-Based CAC mechanisms, to evaluate their impact on blocking probability, dropping probability, throughput, and resource utilization. A mathematical modeling approach is employed to characterize the dynamic interaction between incoming call requests, available resources, and network congestion. Using queuing theory and analytical modeling, this study investigates how each CAC strategy affects network efficiency under varying traffic loads. Simulation results demonstrate that while Guard Channel CAC effectively reduces call dropping probability, it increases new call blocking, whereas Utility-Based CAC provides a balanced trade-off between resource utilization and QoS. The findings highlight the importance of selecting an optimal CAC strategythat can enhance LTE-A network performance, minimize congestion, and improve overall system reliability.

Keywords: Call Admission Control (CAC), LTE-Advanced (LTE-A), Quality of Service (QoS), resource allocation, blocking probability, dropping probability, throughput, resource utilization

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1. Introduction:

Long-Term Evolution-Advanced (LTE-A) networks require effective resource management to ensure Quality of Service (QoS) for different traffic types. Call Admission Control (CAC) strategies play a crucial role in managing system resources efficiently by deciding whether to accept or reject incoming calls based on available network resources. This study develops a mathematical model for different CAC strategies and analyzes their impact on LTE-A network performance. Performance analysis of CAC strategies involves evaluating key metrics such as blocking probability, handover failure rate, resource utilization, and user throughput under varying traffic loads and network conditions. Various CAC schemes, including threshold-based, priority-based, and QoS-aware algorithms, have been developed to balance resource allocation between real-time and non-real-time applications. Advanced techniques like fuzzy logic, machine learning, and game theory-based CAC are increasingly explored to enhance decision-making adaptability in dynamic network environments. A comprehensive performance analysis of these strategies help to optimize network efficiency, improve user experience, and ensure seamless connectivity in next-generation mobile communication systems.

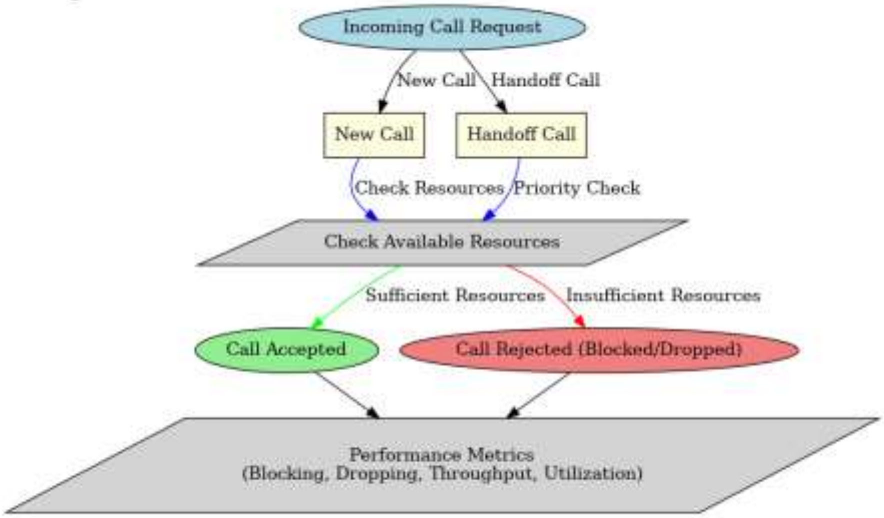


Figure 1: Flowchart of Call Admission Control (CAC) Process in LTE-Advanced Networks

The figure (1) illustrates the Call Admission Control (CAC) process in LTE-Advanced Networks using a flowchart. The process begins with an Incoming Call Request, which can be either a New Call or a Handoff Call. These calls undergo a resource check or priority check before proceeding to the Check Available Resources stage. If sufficient resources are available, the call is accepted (indicated by a green oval). If resources are insufficient, the call is rejected (blocked or dropped, shown in red). The outcomes of call acceptance or rejection contribute to performance metrics, which include blocking, dropping, throughput, and utilization. The figure visually represents decision-making in CAC to ensure optimal network performance while managing resource allocation effectively.

Belghith et al. (2016) demonstrated that adaptive CAC mechanisms can significantly improve Quality of Service (QoS) by efficiently handling both new calls and handoff calls under varying traffic conditions. Radhia et al. (2016) highlighted that prioritization strategies help in reducing call dropping probability, especially for handoff calls, but may lead to a slight increase in blocking probability for new calls.Al-Qahtani (2017) introduced a user classification-based CAC strategy incorporating adaptive resource reservation to balance the trade-off between new call acceptance and ongoing call continuity. Their approach dynamically adjusted bandwidth allocation based on network congestion levels, significantly reducing call dropping probability while maintaining efficient resource utilization. Maharazu et al. (2017) effectively prioritized real-time traffic, ensuring low latency for voice and video calls while maintaining acceptable throughput levels for non-real-time applications.Maharazu et al. (2018) integrated real-time and non-real-time traffic management techniques, optimizing resource allocation based on speed, location, and service priority. The results demonstrated a significant reduction in call dropping probability for high-mobility users, thereby enhancing the overall QoS in vehicular environments.Yese et al. (2019) provided insights into emerging trends, emphasizing that AI and fuzzy logic-based CAC mechanisms offer promising solutions for adaptive and dynamic resource allocation.Umar et al. (2019) proposed a QoS-Aware Call Admission Control (QA-CAC) scheme that utilized traffic prediction models to improve call acceptance rates while minimizing network congestion. Their model achieved better fairness in bandwidth allocation across different service categories, making it suitable for heterogeneous LTE-A environments.Umar et al. (2020) reinforced the idea that hybrid CAC strategies that integrate resource reservation, priority-based scheduling, and dynamic bandwidth allocation tend to offer the most balanced performance in terms of QoS and network efficiency.Umar et al. (2021) further refined this approach by developing an Enhanced Adaptive CAC scheme with bandwidth reservation, tailored for highly congested LTE networks. Their model outperformed traditional CAC strategies by dynamically adjusting the reservation threshold based on real-time traffic conditions, thereby reducing congestion effects and improving network efficiency. Abdulazeez et al. (2022) confirmed that adaptive and AI-driven CAC strategies are crucial for next-generation LTE-A networks, where traffic demand and mobility patterns vary dynamically.

2. LTE-A Network Model: LTE-A networks consist of evolved NodeBs (eNBs) that allocate radio resources to different users. The key resources in LTE-A networks include:

(i)Bandwidth (B)

(ii)Power (P)

(iii)Transmission time interval (TTI)

(iv) Modulation and Coding Scheme (MCS)

The total system bandwidth B_{Total} is shared among various users, where the CAC scheme ensures optimal utilization while maintaining predefined QoS constraints.

3. Call Admission Control (CAC) Strategies: The CAC strategies considered in this study include:

(i) Guard Channel (GC) Scheme: In the Guard Channel (GC) scheme, a fraction of the total bandwidth is reserved for handoff calls. The state probability for a system with Nchannels is modeled as:

$$P_n = \frac{\frac{(E)^n}{n!}P_0}{\sum_{k=0}^{G-1} \frac{(E)^k}{k!} + \sum_{k=G}^{N} \frac{(E)^k}{k!}} \quad (1)$$

where,

$E = \frac{\lambda}{\mu}$is the offered load,

$G$is the number of reserved guard channels,

λandμ are the arrival and service rates, respectively.

The blocking probability for new calls is:$B_{new} = \sum_{n=G}^{N} P_n$

while the dropping probability for handoff calls is:

$$D_{handoff} = P_N \quad (2)$$

(ii)Threshold-Based Scheme: The threshold-based CAC model ensures admission only when the available resources exceed a defined threshold T. The probability of accepting a call is:

$$P_{accept} = P(R_{available} > T) \tag{3}$$

where,$R_{available}$ represents the remaining network resources after serving existing calls.

(iii) Bandwidth Reservation (BR) Scheme: In this scheme, a portion B_r of the total bandwidth is reserved for high-priority traffic:

$$B_{available} = B_{Total} - B_r \tag{4}$$

The acceptance probability for a new call is given by:

$$P_{New} = P\left(B_{available} > B_{req}\right) \tag{5}$$

(iv) Priority-Based CAC: The priority-based CAC strategy differentiates between different traffic classes such as:

- Real-time (RT) services (e.g., voice, video streaming)
- Non-real-time (NRT) services (e.g., file downloads, web browsing)

Using queuing models, the service rate for class iii can be given as:

$$\mu_i = \frac{1}{E[T_i]} \tag{6}$$

where, $E[T_i]$ is the expected service time for class i. The priority queueing model ensures that real-time traffic is served before non-real-time traffic.

(v)Utility-Based CAC: The utility-based CAC aims to maximize a utility function U, defined as:$U = \sum_{i=1}^{M} \quad \omega_i U_i(R_i)$ (7)

where:

$\omega_i$is the weight assigned to traffic type i,

$U_i(R_i)$is the utility function for resource allocation R_i.

The CAC decision is made by solving the optimization problem:

$$max U \text{ subject to} \sum \quad R_i \leq B_{Total} \tag{8}$$

4. Performance Metrics: The impact of different CAC strategies is evaluated based on:

(i) Call Blocking Probability (B): Call blocking probability is the likelihood that a new call request is denieddue to insufficient resources (e.g., bandwidth or channels).

$$B = \frac{Number\ of\ blocked\ new\ calls}{Total\ numbers\ of\ new\ call\ requests} \tag{9}$$

For Erlang-B formula (without queuing), assuming a system with N channels and an offered traffic load A (in Erlangs):

$$B = \frac{\frac{A^N}{N!}}{\sum_{k=0}^{N} \frac{A^k}{k!}} \tag{10}$$

(ii) Call Dropping Probability (D): Call dropping probability is the probability that an ongoing call is droppeddue to resource unavailability.

$$D = \frac{Number\ of\ dropped\ ongoing\ calls}{Total\ numbers\ of\ ongoing\ calls\ (handoff + accepted\ new\ calls)} \tag{11}$$

For systems with Guard Channel CAC, where G guard channels are reserved for handoff calls:

$$D = B \times P_h \tag{12}$$

where,P_h is the proportion of handoff calls in the network.

(iii) Throughput (T): Throughput is the total successful data transmission rate in Mbps or bps.

$$T = R_{success} \times (1 - B) \tag{13}$$

where,

$R_{success}$is the total available bandwidth for accepted calls.

$(1 - B)$represents the fraction of calls that are admitted.

(iv) Resource Utilization (U): Resource utilization is a measure of how efficiently the available bandwidth is used:

$$U = \frac{Total\ allocated\ bandwidth\ for\ active\ users}{Total\ available\ Bandwith} \tag{14}$$

Alternatively, in terms of traffic load A:

$$U = \left(\frac{A}{B_{Total}}\right) \times (1 - B) \tag{15}$$

where,B_{Total} is the total system bandwidth.

5. Results and Discussion:

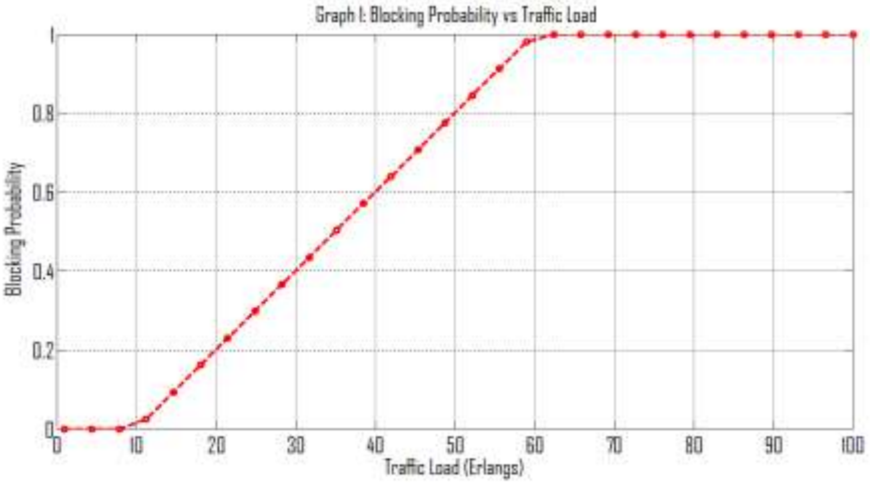
Table 1: System Parameters

Parameters	**Symbol**	**Value**
Total Available Channels	N	50
Guard Channels for Handoff Calls	G	10
Total Bandwidth	B_{Total}	20 Mbps
Traffic Load Range	A	1 to 100 Erlangs (varied)
Handoff Call Proportion	P_h	0.2 (20%)
Maximum Throughput	$R_{success}$	20 Mbps

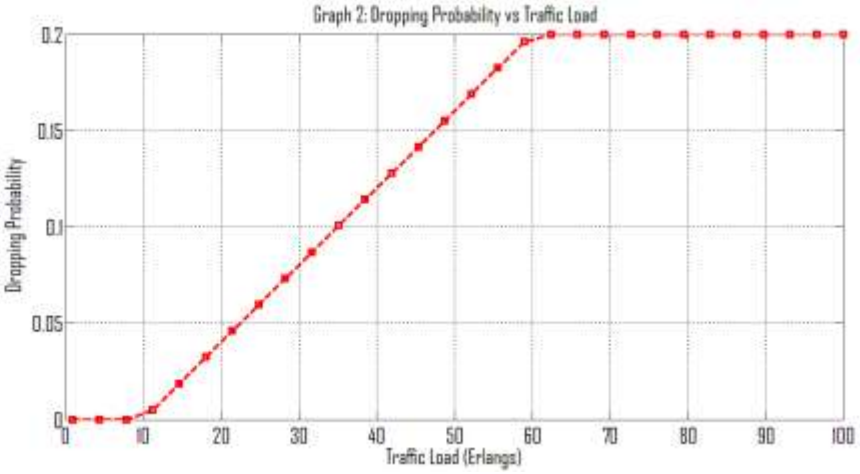
Table 2: CAC Performance Analysis

Traffic Load (Erlangs)	Blocking Probability	Dropping Probability	Throughput (Mbps)	Resource Utilization
1	0	0	20	0.05
4.413793103	0	0	20	0.220689655
7.827586207	0	0	20	0.39137931
11.24137931	0.024827586	0.004965517	19.50344828	0.54811415
14.65517241	0.093103448	0.01862069	18.13793103	0.664536266
18.06896552	0.16137931	0.032275862	16.77241379	0.757650416
21.48275862	0.229655172	0.045931034	15.40689655	0.827456599
24.89655172	0.297931034	0.059586207	14.04137931	0.873954816
28.31034483	0.366206897	0.073241379	12.67586207	0.897145065
31.72413793	0.434482759	0.086896552	11.31034483	0.897027348
35.13793103	0.502758621	0.100551724	9.944827586	0.873601665
38.55172414	0.571034483	0.114206897	8.579310345	0.826868014
41.96551724	0.639310345	0.127862069	7.213793103	0.756826397
45.37931034	0.707586207	0.141517241	5.848275862	0.663476813
48.79310345	0.775862069	0.155172414	4.482758621	0.546819263
52.20689655	0.844137931	0.168827586	3.117241379	0.406853746
55.62068966	0.912413793	0.182482759	1.751724138	0.243580262
59.03448276	0.980689655	0.196137931	0.386206897	0.056998811
62.44827586	1	0.2	0	0
65.86206897	1	0.2	0	0
69.27586207	1	0.2	0	0
72.68965517	1	0.2	0	0
76.10344828	1	0.2	0	0
79.51724138	1	0.2	0	0
82.93103448	1	0.2	0	0

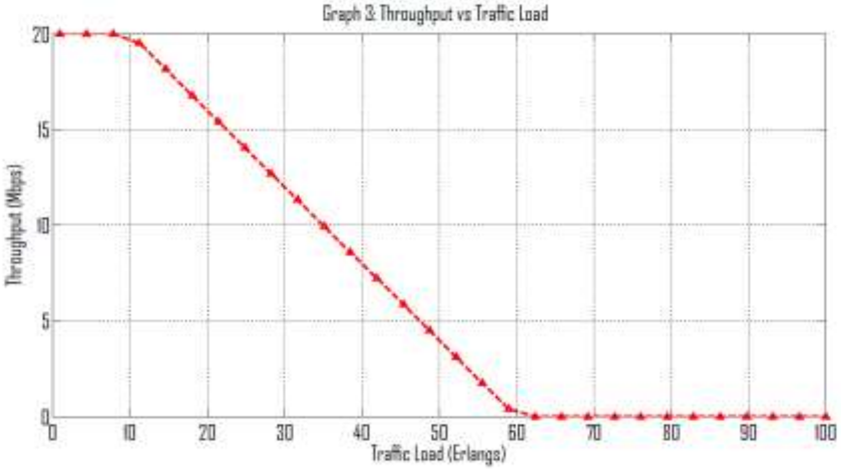
86.34482759	1	0.2	0	0
89.75862069	1	0.2	0	0
93.17241379	1	0.2	0	0
96.5862069	1	0.2	0	0
100	1	0.2	0	0



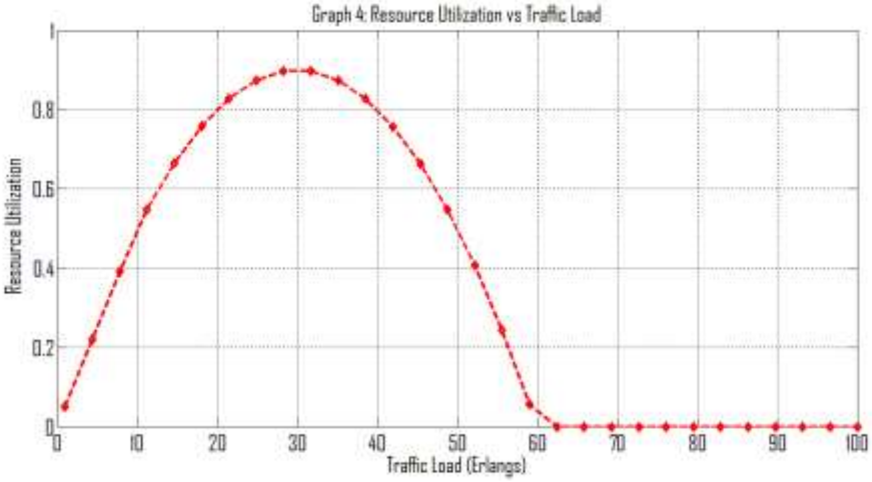
The graph (1) illustrates the Blocking Probability vs. Traffic Load (Erlangs) in a Call Admission Control (CAC) model. As the traffic load increases, the blocking probability initially remains low, indicating that most incoming calls are being accepted due to sufficient available network resources. However, after reaching a certain threshold (around 50 Erlangs), the blocking probability increases significantly and approaches 1 (100%), meaning that almost all incoming calls are being blocked due to resource saturation. This behavior reflects the capacity limits of the network: when available channels are fully occupied, any additional call requests are denied. The graph highlights the importance of efficient resource management in LTE-Advanced networks to minimize call blocking and ensure better Quality of Service (QoS), especially under high traffic conditions.



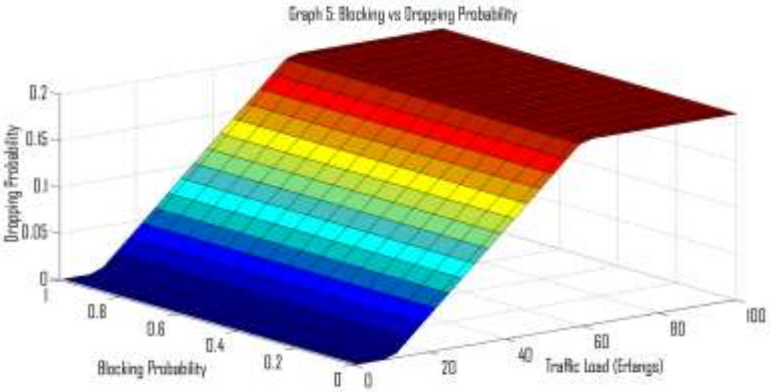
The graph (2) illustrates the Dropping Probability vs. Traffic Load (Erlangs) in a Call Admission Control (CAC) model for an LTE-Advanced network. Initially, when the traffic load is low, the dropping probability remains close to **zero**, indicating that ongoing calls are rarely dropped due to sufficient network resources. As the traffic load increases beyond a certain threshold (around 50 Erlangs), the dropping probability starts rising steadily and eventually plateaus at 0.2 (20%). This indicates that approximately 20% of ongoing calls are dropped when the network reaches its capacity limits, which is likely due to resource exhaustion and prioritization of new or handoff calls. The graph emphasizes the impact of network congestion on call continuity and highlights the importance of efficient resource management strategies to minimize call drops and ensure better Quality of Service (QoS), especially in high-traffic conditions.


Graph 3: Throughput vs Traffic Load

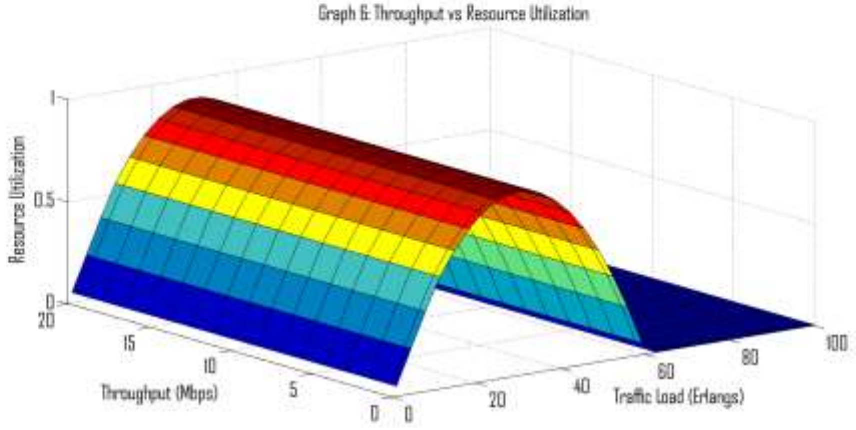
The graph (3) illustrates the Throughput vs. Traffic Load (Erlangs) **in a** Call Admission Control (CAC) model for an LTE-Advanced network. Initially, at low traffic loads, the throughput remains at its maximum capacity of 20 Mbps, indicating that the network can efficiently handle all incoming call requests without congestion. However, as the traffic load increases beyond 10 Erlangs, the throughput begins to decrease steadily. This decline is due to increasing call blocking and resource constraints as more users attempt to access the network. Around 50 Erlangs, the throughput drops significantly, approaching **zero**, indicating that the network is fully saturated, and most call requests are either blocked or dropped due to insufficient resources. This behavior demonstrates how excessive traffic load negatively impacts network performance and emphasizes the need for efficient resource allocation strategies to maintain higher throughput and better Quality of Service (QoS) in high-traffic conditions.


Graph 4: Resource Utilization vs Traffic Load

The graph (4) illustrates the Resource Utilization vs. Traffic Load (Erlangs) in a Call Admission Control (CAC) model for an LTE-Advanced network. At low traffic loads, resource utilization starts at a low value and increases steadily as more users connect to the network. Around 30 Erlangs, resource utilization reaches its peak (close to 0.9), indicating that the network is efficiently utilizing its available bandwidth and resources to serve active users. However, beyond this point, resource utilization starts to decline rapidly. As the traffic load exceeds 50 Erlangs, resource utilization drops significantly and approaches zero. This decline occurs because the network becomes fully saturated, leading to a high call blocking probability, where new calls are rejected and resources remain underutilized. This behavior highlights the impact of network congestion and emphasizes the importance of dynamic resource allocation strategies to optimize utilization while maintaining high Quality of Service (QoS).



The 3D graph (5) illustrates the relationship between Blocking Probability, Dropping Probability, and Traffic Load (Erlangs) in a Call Admission Control (CAC) model for an LTE-Advanced network. The x-axis represents Blocking Probability, the y-axis represents Dropping Probability, and the z-axis represents Traffic Load. Initially, at low traffic loads, both blocking and dropping probabilities are close to zero, indicating that most call requests are successfully admitted into the system. As the traffic load increases beyond a critical point (around 50 Erlangs), the blocking probability rises significantly, leading to a corresponding increase in dropping probability. The graph shows that at higher blocking probabilities (above 0.8), the dropping probability plateaus around 0.2 (20%), meaning that a portion of ongoing calls is dropped when network congestion reaches extreme levels. This visualization highlights how network congestion severely impacts call continuity, and emphasizes the need for efficient resource management strategies to reduce call dropping and improve Quality of Service (QoS) in high-traffic conditions.



The 3D graph (6) illustrates the relationship between Throughput, Resource Utilization, and Traffic Load (Erlangs) in a Call Admission Control (CAC) model for an LTE-Advanced network. The x-axis represents Throughput (Mbps), the y-axis represents Resource Utilization, and the z-axis represents Traffic Load. Initially, at low traffic loads, throughput remains at its maximum capacity (20 Mbps) and resource utilization steadily increases as more users access the network. As the traffic load continues to rise, resource utilization peaks at around 30–40 Erlangs, indicating that the network is operating at its most efficient level. However, beyond this threshold, network congestion leads to a rapid decline in throughput and resource utilization, as blocking probability increases and fewer new calls are admitted. At very high traffic loads (above 60 Erlangs), throughput approaches zero, and resource utilization declines to minimal levels due to excessive call blocking and service degradation. This graph highlights the trade-off between throughput and resource utilization, demonstrating the importance of efficient network management to maintain high system performance under varying traffic conditions.

6. Concluding Remarks: This study provides a comprehensive performance analysis of Call Admission Control (CAC) strategies in LTE-Advanced (LTE-A) networks, focusing on their impact on blocking probability, dropping probability, throughput, and resource utilization. The results demonstrate that CAC mechanisms play a crucial role in optimizing network performance by efficiently managing available resources and ensuring Quality of Service (QoS). While Guard Channel CAC effectively reduces call dropping probability, it increases blocking probability for new calls. Conversely, Utility-Based and Adaptive CAC schemes provide a more balanced trade-off between QoS and resource utilization, ensuring improved network efficiency under varying traffic loads. The findings highlight the importance of dynamic and intelligent CAC mechanisms, including those based on machine learning and fuzzy logic, to enhance LTE-A network performance and adapt to real-time traffic fluctuations. Future research should explore AI-driven CAC models to further optimize network admission policies, reduce congestion, and enhance user experience in next-generation wireless networks.

REFERENCES

1. Abdulazeez A., Umar M.M., Orduen S.Y., Mohammed A. (2022): “Performance evaluation of call admission control schemes in 3gpp long term evolution networks”, *European Journal of Electrical Engineering and Computer Science*, 6(4):1-8.
2. Al-Qahtani S. (2017): “Users’ classification-based call admission control with adaptive resources reservation for LTE-A networks”, *Journal of King Saud University-Computer and Information Science*, 29(1):103-115.
3. Belghith A., Turki N., Cousin B., Obaidat M.O. (2016): “Efficient bandwidth call admission control in 3GPP LTE networks”, *IEEE Global Communications Conference (GLOBECOM), Washington DC*, 1251-1258.
4. Maharazu M., Zurina M.H., Azizol A., Abdullah M. (2017): “An adaptive call admission control with bandwidth reservation for downlink LTE Networks”, *IEEE Access*, 10986-10994.
5. Maharazu M., Zurina M.H., Azizol A., Abdullah M. (2018): “Call admission control for real-time and non-real-time traffic for vehicular LTE downlink networks”, *Lecture Notes in Electrical Engineering*, 425:46-53.
6. Radhia K., Kais M., Aymen B., Lotfi K. (2016): “An efficient call admission control scheme for LTE and LTE-A networks”, *International Symposium on Networks, Computers and Communications (ISNCC), YasmineHammamet*, 1-6.
7. Umar M.M., Mohammed A., Abdulazeez A., Yese S.O. (2020): “Study on call admission control schemes in 3GPP LTE Networks”, *Science in Information Technology Letters*, 1(2):6-67.
8. Umar M.M., Mohammed A., Roko A., Tambuwal A.Y., Abdulazeez A. (2021): “Enhanced adaptive call admission control scheme with bandwidth reservation for LTE networks”, *International Journal of Mobile Computing and Multimedia Communications*, 12(1):23-42.
9. Umar M.M., Mohammed A., Roko A., Tambuwal A.Y., Abdulazeez A. (2019): “QoS-Aware call admission control (qa-cac) scheme for LTE networks”, *IEEE 15th International Conference on Electronics Computer and Computation (ICECCO)*, 1-5.
10. Yese S.O., Abdulhakeem A., Mohammed A., Umar M.M., Yeldu Z.Y. (2019): “A survey on call admission control schemes in LTE”, *International Journal of Computer Science and Engineering Survey*, 10(4/5):1-20.