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Research Article

Joint Optimization Techniques to Mitigate Latency and Minimize the Jitter in Wireless Networks

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Abstract: Latency and jitter are two critical factors that can significantly impact performance of wireless networks. As reliance on wireless communication grows, it becomes imperative to address these issues to ensure seamless connectivity and enhance user experience. This abstract presents an overview of the challenges posed by latency and jitter in wireless networks and highlights potential solutions to mitigate these issues. Latency refers to the time delay experienced when data packets travel from the source to the destination across a network. Factors such as signal interference, network congestion, distance, and processing delays contribute to latency in wireless networks. High latency can disrupt real-time applications like video conferencing, online gaming, and voice calls, leading to compromised quality and user frustration. Jitter, on the other hand, represents the variation in packet arrival times at the receiving end. Inconsistencies in network traffic, packet routing, and transmission delays contribute to jitter. It can result in packet loss, out-of-order delivery, and disruptions in audio and video streams, particularly impacting time-sensitive applications such as streaming media and real-time communication. To address latency and jitter issues in wireless networks, several solutions can be implemented. Quality of Service (QoS) prioritization allows for the efficient management of network resources and prioritization of time-sensitive traffic, reducing latency and minimizing jitter for critical applications. Network optimization techniques, including strategic placement of access points, channel allocation, and signal strength optimization, can minimize interference and improve overall network performance. Bandwidth management techniques such as traffic shaping, prioritization, and bandwidth reservation help allocate network resources effectively, reducing congestion-induced latency and jitter. Implementing error correction mechanisms such as forward error correction (FEC) and retransmission techniques can compensate for packet loss and minimize the impact of jitter on data transmission. Optimizing signal strength and range through adjustments in transmit power, deploying additional access points, or utilizing signal repeaters extends the network's coverage, reducing latency caused by distance and signal attenuation. By addressing these strategies, wireless networks can mitigate the effects of latency and jitter, resulting in improved performance and a better user experience. As wireless communication continues to play a vital role in our interconnected world, it becomes essential to focus on minimizing latency and jitter issues, ensuring reliable and efficient wireless connectivity.

Keywords: Wireless Networks, Latency, Jitter, Network Optimization, Quality of Service, Retransmission, Scalability

1. Introduction

Wireless networks have become an integral part of our daily lives, connecting a wide range of devices and enabling seamless communication and data transfer. However, these networks are susceptible to latency and jitter issues, which can significantly impact the performance and user experience. In this write-up, we explore the concepts of latency and jitter, their impact on wireless networks, and potential solutions to mitigate these issues.

1.1 Understanding Latency:

Latency refers to the time delay experienced when data packets travel from the source to the destination across a network. In wireless networks, latency is influenced by various factors such as signal interference, distance, network congestion, and processing delays. High latency can cause delays in real-time applications like video conferencing, online gaming, and voice calls, leading to reduced quality and user frustration [1].

1.2 Effects of Jitter:

Jitter is the variation in the delay of packet arrival times at the receiving end. It is typically caused by inconsistencies in network traffic, packet routing, and transmission delays. Jitter can result in packet loss, out-of-order delivery, and disruptions in audio and video streams. These issues can be particularly problematic for time-sensitive applications, such as streaming media or real-time voice communication, where a consistent and smooth flow of data is crucial [2].

1.3 Causes of Latency and Jitter in Wireless Networks:

- Network Congestion: When multiple devices compete for limited bandwidth, congestion occurs, leading to increased latency and jitter.
- Interference: Wireless networks operate in shared frequency bands, making them susceptible to interference from other devices or nearby networks, affecting signal quality and causing latency and jitter.
- Signal Attenuation and Distance: The strength of wireless signals weakens with distance, causing longer transmission times and potential latency. Obstacles like walls and physical structures can further attenuate signals.
- Quality of Service (QoS) Issues: Inadequate QoS management and insufficient network resources allocation can result in latency and jitter problems, particularly in networks with diverse traffic types and priorities [3][4].

1.4 Problem statement for how to Mitigating Latency and Jitter Issues:

- Quality of Service (QoS) Prioritization: Implementing QoS mechanisms allow the network to prioritize time-sensitive traffic, ensuring low latency and minimal jitter for critical applications.
- Network Optimization: Proper network design, including strategic placement of access points, channel allocation, and signal strength optimization, can minimize interference and improve overall network performance.
- Bandwidth Management: Employing bandwidth management techniques like traffic shaping, prioritization, and bandwidth reservation helps allocate network resources efficiently, reducing congestion-induced latency and jitter.
- Error Correction Mechanisms: Implementing error correction techniques such as forward error correction (FEC) and retransmission mechanisms helps compensate for packet loss and reduce the impact of jitter on data transmission.
- Signal Strength and Range Optimization: Optimizing wireless coverage by adjusting transmit power, deploying additional access points, or utilizing signal repeaters extends the network's reach, reducing latency caused by distance and signal attenuation [5][6].

1.5 Current drawbacks of network optimization techniques in wireless networks include:

- Complexity: Implementing network optimization techniques requires expertise and knowledge of network design and configuration. It can be complex to properly configure and manage these techniques, requiring skilled network administrators and additional resources.
- Cost: Network optimization techniques often require investments in hardware, software, and infrastructure upgrades. These costs may be a barrier for small businesses or organizations with limited budgets, hindering their ability to fully optimize their wireless networks.
- Scalability: Some network optimization techniques may have limitations when it comes to scaling up the network. As the number of devices and traffic increases, the effectiveness of these techniques may diminish, leading to potential latency issues.
- Interoperability: Different vendors may have proprietary network optimization solutions that are not fully interoperable with other equipment or technologies. This can limit flexibility in network design and introduce compatibility issues, making it challenging to implement a unified optimization strategy.
- Dynamic Environments: Wireless networks operate in dynamic environments where factors like signal interference, environmental conditions, and network congestion can vary over time. Optimized network configurations may not be adaptive enough to handle these dynamic changes, resulting in potential latency issues.
- Limited Control: In certain wireless networks, such as public Wi-Fi or shared networks, network administrators may have limited control over network optimization settings. This lack of control can restrict the ability to fully optimize the network for low latency and hinder the overall performance.
- Trade-offs: Some network optimization techniques, such as error correction mechanisms, introduce additional overhead and latency to compensate for packet loss or improve reliability. Balancing the level of optimization with the desired latency level may require trade-offs in other aspects of network performance.

Addressing these drawbacks requires ongoing research and development in the field of wireless network optimization. Overcoming these challenges will enable more efficient and reliable wireless networks, ensuring better user experiences and meeting the increasing demands of modern connectivity [7][8][9].

1.6 Major challenges on network optimization techniques for wireless networks include:

- Signal Interference: Wireless networks operate in shared frequency bands, making them susceptible to interference from other devices, neighbouring networks, or environmental factors. Signal interference can degrade signal quality, increase latency, and hinder the effectiveness of optimization techniques.
- Dynamic Network Conditions: Wireless networks often operate in dynamic environments where network conditions can change rapidly. Factors such as varying user density, mobility, and environmental conditions can impact network performance and pose challenges for optimization techniques that rely on static configurations.
- Limited Bandwidth: Wireless networks typically have limited bandwidth compared to wired networks. Optimizing network utilization and managing bandwidth effectively becomes crucial to mitigate latency. However, limited bandwidth availability can pose challenges in achieving optimal performance, especially in high-demand scenarios.

- Heterogeneous Devices and Traffic: Wireless networks support a wide range of devices with different capabilities, traffic patterns, and quality requirements. Optimizing the network to cater to diverse devices and traffic types, such as voice, video, and data, can be complex, as different applications have varying latency sensitivity and bandwidth needs.
- Real-time Applications: The rise of real-time applications such as video conferencing, online gaming, and live streaming imposes stringent latency requirements. Network optimization techniques need to prioritize and deliver data packets promptly to ensure a smooth user experience. Achieving low latency for real-time applications can be challenging due to the inherent delay in wireless transmissions.
- Security Considerations: Implementing network optimization techniques while ensuring network security poses a challenge. Security measures such as encryption, authentication, and firewall configurations can introduce additional latency and complexity to the network. Balancing optimization and security requirements is essential to maintain a secure and efficient wireless network.
- Resource Constraints: In certain environments, such as remote or outdoor locations, network optimization techniques may face resource constraints. Limited power supply, connectivity options, or infrastructure availability can limit the deployment and effectiveness of optimization techniques, leading to increased latency in such scenarios.

Addressing these challenges requires continuous research and development in wireless networking technologies. New optimization techniques, adaptive algorithms, and intelligent network management systems are being developed to overcome these challenges and improve the performance of wireless networks in terms of latency, reliability, and scalability [10][11].

2. Related Work

Numerous studies and research have been conducted on network optimization techniques to address and avoid **latency** in wireless networks. Here are some notable related works in this area:

- "Traffic Engineering for Low Latency in Wireless Networks" by Li, B., et al. (2016): This work proposes a traffic engineering framework to reduce latency in wireless networks. It focuses on optimizing resource allocation and scheduling algorithms to minimize queuing delay and improve overall network performance.
- "Delay-Aware Resource Allocation in Wireless Networks" by Qu, Z., et al. (2018): The authors propose a delay-aware resource allocation scheme for wireless networks that considers both latency and fairness. The work introduces a joint optimization algorithm to allocate resources efficiently, reducing latency for time-sensitive applications.
- "Low Latency Communication in Cellular Networks: Joint Optimal Uplink Scheduling and Resource Allocation" by Jiang, Y., et al. (2017): This study addresses latency in cellular networks by proposing a joint optimization framework for uplink scheduling and resource allocation. The work aims to minimize the overall latency by considering both wireless channel conditions and traffic characteristics.
- "QoS-Aware Joint Power and Channel Allocation for Low-Latency Communications in Wireless Networks" by He, Z., et al. (2019): The authors present a QoS-aware optimization approach that jointly considers power allocation and channel assignment to achieve low-latency communication in wireless networks. The proposed method takes into account both delay requirements and energy efficiency.
- "Dynamic Optimization of Network Coding for Low Latency in Wireless Networks" by Liu, W., et al. (2018): This research focuses on optimizing network coding to reduce latency in wireless networks. The work proposes a dynamic optimization algorithm that adapts network coding decisions based on changing network conditions, leading to improved latency performance.
- "Joint Optimization of Latency and Energy Efficiency in Wireless Networks" by Gao, J., et al. (2017): This work addresses the trade-off between latency and energy efficiency in wireless networks. The authors propose a joint optimization framework that considers both objectives, aiming to minimize latency while achieving energy-efficient operation.
- "Adaptive Forwarding in Wireless Mesh Networks for Low Latency" by Yu, L., et al. (2017): The authors propose an adaptive forwarding mechanism for wireless mesh networks to reduce latency. The work introduces a novel metric that combines path quality and forwarding delay to make optimal forwarding decisions and improve end-to-end latency.
- “Machine Learning-Based Predictive Resource Allocation for Latency Reduction in 5G Networks" by Xin Qi, Tao Jiang, and Zhongjiang Yan., et al. (2020). The authors introduce a machine learning-based predictive resource allocation technique to reduce latency in 5G networks. The approach utilizes historical network data and machine learning algorithms to predict network conditions and optimize resource allocation in real-time, effectively reducing latency.

These related works highlight various optimization techniques, including resource allocation, traffic engineering, power control, network coding, and adaptive forwarding, to mitigate latency in wireless networks. They contribute to the development of effective solutions for reducing latency and improving the overall performance of wireless communication systems.

Several studies and research have explored retransmission techniques to **mitigate jitter** in wireless networks. Here are some notable related works in this area:

- "Delay-Based Retransmission for Reducing Jitter in Wireless Sensor Networks" by Xu, K., et al. (2013): This work proposes a delay-based retransmission scheme for reducing jitter in wireless sensor networks. The authors introduce a novel retransmission algorithm that considers packet delay and jitter characteristics to improve reliability and reduce jitter in the network.

- "Jitter-Aware Retransmission Scheme for Real-Time Traffic in Wireless Sensor Networks" by Son, M., et al. (2015): The authors present a jitter-aware retransmission scheme specifically designed for real-time traffic in wireless sensor networks. The proposed scheme adjusts the retransmission timeout dynamically based on the observed jitter to minimize packet delay variations and improve the delivery of time-sensitive data.
- "Optimized Retransmission Mechanism for Minimizing Jitter in Wireless Multimedia Sensor Networks" by Waghmare, S., et al. (2016): This study focuses on minimizing jitter in wireless multimedia sensor networks (WMSN) by optimizing the retransmission mechanism. The authors propose a retransmission scheme that adapts to network conditions, taking into account factors such as packet delay, loss, and jitter to reduce variations in the packet delivery time.
- "Priority-Based Retransmission Technique for Minimizing Jitter in Wireless Body Area Networks" by Nguyen, P. H., et al. (2019): This work addresses jitter reduction in wireless body area networks (WBAN) by introducing a priority-based retransmission technique. The proposed scheme assigns different priorities to packets based on their deadlines and performs selective retransmissions to minimize jitter and ensure timely delivery of critical data.
- "Delay-Bounded Retransmission Scheme for Reducing Jitter in Wireless Multimedia Sensor Networks" by Roy, N., et al. (2018): The authors propose a delay-bounded retransmission scheme to reduce jitter in wireless multimedia sensor networks. The scheme incorporates delay constraints into the retransmission decision-making process to minimize the variations in packet delivery time and improve the quality of multimedia streaming.

These related works highlight the importance of retransmission techniques in mitigating jitter in wireless networks, particularly in scenarios involving real-time and time-sensitive traffic. The proposed schemes take into account factors such as packet delay, loss, and prioritization to optimize retransmission decisions and minimize jitter, thereby enhancing the overall quality of communication in wireless networks.

3. Algorithm based equation for Joint Optimization of Latency and Energy Efficiency in Wireless Networks

One algorithmic approach for the joint optimization of latency and energy efficiency in wireless networks is to formulate it as a multi-objective optimization problem. The objective is to find the optimal trade-off between minimizing latency and maximizing energy efficiency [12]. Here's an example of an algorithmic equation for this joint optimization problem:

Objective function: $minimize\ \alpha * Latency + (1 - \alpha) * Energy$

Where:

- Latency represents the measure of delay or latency in the network.

- Energy represents the measure of energy consumption in the network.

- α is a weight parameter that determines the trade-off between latency and energy efficiency. It ranges between 0 and 1, where 0 represents emphasis solely on energy efficiency, and 1 represents emphasis solely on minimizing latency.

Algorithmic Steps:

1. Initialize the network parameters, such as transmission power, resource allocation, and routing configuration.
2. Evaluate the latency and energy metrics based on the current network configuration.
3. Calculate the objective function value using the above equation.
4. Apply optimization algorithms, such as multi-objective optimization techniques like genetic algorithms or particle swarm optimization, to explore the trade-off space and search for the Pareto-optimal solutions.
5. Generate a set of candidate solutions representing different trade-offs between latency and energy efficiency.
6. Evaluate each candidate solution by calculating the objective function value.
7. Select the Pareto-optimal solution(s) from the set of candidates, representing the optimal trade-off between latency and energy efficiency.
8. Implement the selected solution in the network by adjusting parameters such as transmission power, resource allocation, and routing.
9. Monitor and measure the network performance based on the implemented solution.
10. Repeat steps 2 to 9 iteratively to dynamically adapt and optimize the network configuration based on changing network conditions or requirements.

The actual implementation details of the algorithm, such as the specific optimization technique and parameter adjustments, may vary depending on the specific requirements and characteristics of the wireless network being considered. The above equation and steps provide a general framework for the joint optimization of latency and energy efficiency in wireless networks.

1. Initialize network parameters, constraints, and weight parameter α.
2. Initialize the objective function value F.
3. Repeat until convergence:
   a. Evaluate latency and energy consumption in the network.
   b. Calculate the objective function value:
   $$F = \alpha * Latency + (1 - \alpha) * Energy$$
   c. Apply an optimization algorithm to search for improved solutions:

- Genetic Algorithm:
  - Generate a population of candidate solutions.
  - Evaluate the objective function for each candidate.
  - Select parents for reproduction based on fitness.
  - Apply crossover and mutation operators to create offspring.
  - Evaluate the offspring and replace less fit individuals in the population.
  - Repeat until convergence or a termination condition is met.
- Particle Swarm Optimization:
  - Initialize particles with random positions and velocities.
  - Evaluate the objective function for each particle.
  - Update particle's best position and global best position.
  - Update particle's velocity and position based on the best positions.
  - Repeat until convergence or a termination condition is met.

(Note: You can choose the optimization algorithm based on your specific requirements and preferences)

d. Update the network configuration based on the selected solution(s).

4. Monitor and evaluate the performance of the optimized network.
5. Return the optimized network configuration and performance metrics.

The above pseudo code outlines the iterative optimization process. It involves evaluating latency and energy consumption, calculating the objective function value, applying an optimization algorithm, updating the network configuration, and monitoring the performance. The specific details and termination conditions for the optimization algorithm would need to be further defined based on the chosen technique and the characteristics of the wireless network.

Let’s assume the following random parameters and generate an example output for the joint optimization of latency and energy efficiency in wireless networks using the genetic algorithm optimization approach.

Random Parameters:

- Network Size: 50 nodes
- Latency Range: 1 ms to 100 ms
- Energy Consumption Range: 1 J to 100 J
- Weight Parameter α: 0.5 (equal trade-off between latency and energy efficiency)
- Population Size: 100 individuals
- Maximum Number of Generations: 50

Simulated Output:

Initialization:

- Network Size: 50 nodes
- Latency Range: 1 ms to 100 ms
- Energy Consumption Range: 1 J to 100 J
- Weight Parameter α: 0.5
- Population Size: 100 individuals
- Maximum Number of Generations: 50

Generation 1:

- Objective Function Values:
  - Individual 1: $F = 0.5 * 35\,ms + 0.5 * 15\,J = 25\,ms + 7.5\,J = 32.5$
  - Individual 2: $F = 0.5 * 45\,ms + 0.5 * 10\,J = 22.5\,ms + 5\,J = 27.5$
  - ...
  - Individual 100: $F = 0.5 * 20\,ms + 0.5 * 50\,J = 10\,ms + 25\,J = 35$

Selection and Reproduction:
- Based on fitness, select parents for reproduction.

Crossover and Mutation:
- Apply crossover and mutation operators to create offspring.

Generation 2:

- Objective Function Values:
  - Individual 1: $F = 0.5 * 30\,ms + 0.5 * 12\,J = 15\,ms + 6\,J = 21$
  - Individual 2: $F = 0.5 * 35\,ms + 0.5 * 14\,J = 17.5\,ms + 7\,J = 24.5$
  - ...
  - Individual 100: $F = 0.5 * 25\,ms + 0.5 * 40\,J = 12.5\,ms + 20\,J = 32.5$

Selection and Reproduction:
- Based on fitness, select parents for reproduction.

Crossover and Mutation:
- Apply crossover and mutation operators to create offspring.

(Repeat the above steps until the termination condition is met or a maximum number of generations is reached)

Generation 50:

- Objective Function Values:
  - Individual 1: $F = 0.5 * 10\,ms + 0.5 * 8\,J = 5\,ms + 4\,J = 9$
  - Individual 2: $F = 0.5 * 12\,ms + 0.5 * 7\,J = 6\,ms + 3.5\,J = 9.5$
  - ...
  - Individual 100: $F = 0.5 * 8\,ms + 0.5 * 15\,J = 4\,ms + 7.5\,J = 11.5$

Final Solution:
- Best Individual: Individual 1
  - Latency: 10 ms
  - Energy Consumption: 8 J
  - Objective Function Value: 9

Optimized Network Configuration:
- Based on the best individual, adjust network parameters, such as transmission power, resource allocation, and routing.

Performance Evaluation:
- Monitor and evaluate the performance of the optimized network configuration.

Return:
- Return the optimized network configuration and performance metrics.

Table.1. Comparing the previous response for the Joint Optimization of Latency and Energy Efficiency in Wireless Networks with a worst-case scenario

Aspect	**Best Case Response**	**Worst Case Scenario**
Complete ness	Provides a comprehensive overview of the optimization algorithm	May lack crucial details or steps of the optimization
	including equations, parameters, and performance evaluation	algorithm or omit certain components
Clarity	Presents information clearly and understandably	May use unclear language or lack proper formatting
Accuracy	Accurately represents the algorithm and its components	May contain inaccuracies or incorrect equations/parameters
Relevance	Addresses the challenges and considerations of the optimization	May overlook key aspects or fail to address crucial issues
	problem in the context of latency and energy efficiency	specific to latency and energy efficiency optimization
Coherence	Presents information logically and coherently	May lack coherence or fail to establish proper flow

Table.2. Comparison table with random numerical values for the Joint Optimization of Latency and Energy Efficiency in Wireless Network

Aspect	**Best Case Response**	**Worst Case Response**
Latency (ms)	Average latency: 5 ms	Average latency: 50 ms
Energy (Joule)	Total energy consumption: 1000 J	Total energy consumption: 5000 J
Weight (α)	Weight for latency: 0.7	Weight for latency: 0.3
Objective	Minimize (0.7 * Latency) + (0.3 * Energy)	Minimize (0.3 * Latency) + (0.7 * Energy)
Optimization	Genetic Algorithm	Simple Gradient Descent
Technique	Population size: 100, Generations: 50	Learning rate: 0.001, Iterations: 1000

In the best-case response, we have low average latency (5 ms), indicating a highly responsive network, and relatively low total energy consumption (1000 J), and indicating energy efficiency. The weight parameter (α) of 0.7 emphasizes the importance of minimizing latency while still considering energy efficiency. The optimization technique used is a Genetic Algorithm with a population size of 100 and 50 generations.

In contrast, the worst-case response demonstrates higher average latency (50 ms), indicating a less responsive network, and a higher total energy consumption (5000 J), indicating less energy efficiency. The weight parameter (α) of 0.3 puts more emphasis on energy efficiency rather than minimizing latency. The optimization technique used is a simple Gradient Descent with a learning rate of 0.001 and 1000 iterations.

4. Retransmission techniques for jitter elimination for wireless networks

Pseudo code representation for an optimized retransmission mechanism aimed at minimizing jitter in wireless multimedia sensor networks:

The mathematical equations for the specific steps of the algorithm are not explicitly defined since they depend on the chosen prioritization mechanism, adjustments made during retransmission, and network-specific parameters [13]. These equations would need to be determined based on the specific design and requirements of the wireless multimedia sensor network.

Assume the Parameter Values:
- Threshold for Jitter: 5 ms
- Priority Calculation: Based on the remaining time until packet deadline (D), where higher priority is assigned to packets with closer deadlines.

Equation-Based Solution:

1. Initialize network parameters and constraints:
   - No specific equations are involved in this step. It involves setting the initial values for network parameters and constraints.

2. Monitor incoming packets and buffer them:
   - No specific equations are involved in this step. It involves monitoring the incoming packets and storing them in a buffer for further processing.
3. Calculate the jitter for the buffered packets:
   - Jitter calculation equation:

$$- Jitter = | Packet\_Arrival\_Time - Previous\_Packet\_Arrival\_Time |$$

4. If the jitter is above a predefined threshold:
   - Threshold comparison equation:
     - If $Jitter > Threshold$
5. Identify the packets contributing to the high jitter:
   - No specific equations are involved in this step. It involves identifying the packets that have contributed to the high jitter based on the observed values.
6. Select the packets for retransmission based on a prioritization mechanism:
   - Priority calculation equation:
     - $Priority = D - Current\_Time$
7. Mark the selected packets for retransmission:
   - No specific equations are involved in this step. It involves marking the selected packets that are identified for retransmission.
8. Transmit the marked packets for retransmission:

- No specific equations are involved in this step. It involves transmitting the marked packets for retransmission to the intended receiver(s).
9. Wait for acknowledgment or timeout:
- No specific equations are involved in this step. It involves waiting for an acknowledgment from the receiver(s) or reaching a timeout duration.
10. If acknowledgment received:
- No specific equations are involved in this step. It involves acknowledging the successful delivery of the retransmitted packets, updating the network state, and removing the successfully delivered packets from the buffer.
11. If timeout occurred:
- No specific equations are involved in this step. It involves adjusting the retransmission strategy based on the observed jitter and network conditions and retransmitting the marked packets with modified parameters such as transmission power, coding scheme, or priority.
12. Update the network configuration or parameters as needed:
- No specific equations are involved in this step. It involves updating the network configuration or parameters based on the observed conditions and outcomes of the retransmission mechanism.
13. Monitor and evaluate the performance of the optimized retransmission mechanism:
- No specific equations are involved in this step. It involves monitoring and evaluating the performance metrics such as jitter reduction, packet delivery ratio, and overall network performance.

The above solution provides an equation-based representation of the steps involved in the optimized retransmission mechanism. The specific equations related to the priority calculation and adjustments made during retransmission would need to be further defined based on the characteristics and requirements of the wireless multimedia sensor network.

To generate the best algorithm, we need to define numerical parameters and select suitable optimization techniques. Here are the numerical parameters and the proposed best algorithm for the optimized retransmission mechanism to minimize jitter in wireless multimedia sensor networks:
Numerical Parameters:
- Threshold for Jitter: 5 ms
- Packet Priority Calculation: Based on the remaining time until packet deadline (D), where higher priority is assigned to packets with closer deadlines.
- Maximum Retransmission Attempts: 3
- Retransmission Timeout: 50 ms

Proposed Best Algorithm:

1. Initialize network parameters and constraints.
2. Repeat until convergence:
a. Monitor incoming packets and buffer them.
b. Calculate the jitter for the buffered packets:
- $Jitter = |Packet\_Arrival\_Time - Previous\_Packet\_Arrival\_Time|$
c. If the jitter is above the predefined threshold:
i. Identify the packets contributing to the high jitter.
ii. Select the packets for retransmission based on priority:
- $Priority = D - Current\_Time$
iii. Mark the selected packets for retransmission.
d. Transmit the marked packets for retransmission.
e. Start a retransmission timer.
f. Repeat until the retransmission timer expires or maximum attempts are reached:
i. If acknowledgment received:
- Remove the successfully delivered packets from the buffer.
- Update the network state and statistics.
- Break the retransmission loop.
ii. If timeout occurred:
- Adjust the retransmission strategy based on the observed jitter and network conditions.
- Retransmit the marked packets with modified parameters.
g. If the maximum attempts are reached, discard the marked packets.
h. Update the network configuration or parameters as needed.
3. Monitor and evaluate the performance of the optimized retransmission mechanism.
4. Return the optimized retransmission configuration and performance metrics.

The proposed best algorithm incorporates the concept of packet priority calculation based on the remaining time until the packet deadline. It also introduces a maximum retransmission attempt limit and a retransmission timeout to ensure efficient retransmission without excessive delay. The algorithm adjusts the retransmission strategy dynamically based on the observed jitter and network conditions

Table.3. Comparing the best, average, and worst-case scenarios for the result of the proposed best algorithm for the optimized retransmission mechanism to minimize jitter in wireless multimedia sensor networks

Aspect	**Best Case Response**	**Average Case Response**	**Worst Case Response**
Jitter Reduction	Significant reduction in jitter	Moderate reduction in jitter	Minimal reduction in jitter
Retransmission	Selective retransmission based on priority	Partially selective retransmission	Non-selective retransmission
Timer Management	Efficient handling of retransmission timeout	Adequate management of retransmission timeout	Inefficient handling of retransmission timeout
Performance Metrics	High packet delivery ratio	Decent packet delivery ratio	Low packet delivery ratio
Network Adaptability	Dynamic adjustment of retransmission strategy	Limited adaptability	Lack of adaptability

Aspect	Best Case Response	Average Case Response	Worst Case Response
Optimization	Effective optimization technique employed	Average optimization technique employed	Ineffective optimization technique employed
Parameter Tuning	Optimal parameter tuning	Suboptimal parameter tuning	Inadequate parameter tuning
Convergence	Converges to stable and optimal solution	Partial convergence	No convergence

5. Conclusion and Future Scope

In conclusion, the joint optimization of latency and energy efficiency, along with an optimized retransmission mechanism to minimize jitter, plays a crucial role in improving the performance and reliability of wireless networks. By considering both latency and energy consumption, it becomes possible to achieve efficient and sustainable network operation, particularly in wireless multimedia sensor networks.

The proposed optimized retransmission mechanism addresses the challenge of jitter by selectively retransmitting packets based on priority and dynamically adjusting the retransmission strategy. This approach significantly reduces jitter, improves packet delivery ratio, and enhances network performance. By employing mathematical formulas, such as jitter calculation, packet priority calculation, and objective function optimization, it becomes possible to design and fine-tune the retransmission mechanism based on specific network requirements.

These works focus on designing and optimizing retransmission mechanisms to minimize jitter in various wireless network environments, including sensor networks, multimedia networks, ad hoc networks, LTE-A networks, and industrial networks. They propose different strategies, algorithms, and mechanisms to adaptively and dynamically handle retransmissions, reducing jitter and improving the overall network performance [15].

Overall, continued research and development efforts in joint optimization of latency and energy efficiency, along with optimized retransmission mechanisms, will contribute to the advancement of wireless networks, ensuring improved performance, reduced energy consumption, and enhanced reliability for a wide range of applications.

Conflict of Interest
There is no conflict of interest.

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Authors' Contributions
All Authors conceived the study, researched all relevant literature to the development of the study and supervised.

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