Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/23302
DOI URL: http://dx.doi.org/10.21474/IJAR01/23302

CONFERENCE PAPER

PRIORITIZING THE MIGHTY 6G NETWORK WITH ARTIFICIAL INTELLIGENCE METHODOLOGIES: TECHNOLOGICAL PERSPECTIVE

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Manuscript Info

Manuscript History
Received: 8 February 2026
Final Accepted: 10 March 2026
Published: April 2026

Key words:-
5G, 6G, Artificial Intelligence (AI), Resource Allocation, Machine Learning (ML).

Abstract

The use of modern technologies like 5G and the vision of a 6G network is being created possible by the major change of worldwide connectivity that was caused by the growth of wireless networks for communication. Ultra-high data speeds, huge device connectivity, and ultra-low latency applications are anticipated to be supported by these networks. The effective distribution of scarce network resources, such as bandwidth, power, and spectrum, is still a major problem. Conventional methods of allocating resources are frequently rule-based, static, and unable to adjust to quickly shifting network conditions. Artificial Intelligence (AI), in particular Machine Learning (ML), Deep Learning (DL), and Reinforcement Learning (RL), offers clever and flexible ways to dynamically enhance the use of resources. An extensive analysis of AI-based resource allocation methods, their uses in 5G and 6G networks, their benefits, drawbacks, and potential future research areas are presented in this paper.

Introduction:-

The rapid evolution of wireless communication has significantly transformed global connectivity, leading to the deployment of advanced technologies such as 5G and the vision of 6G. These next-generation networks are designed to support ultra-high data rates, massive device connectivity, and ultra-low latency applications, enabling emerging services such as smart cities, autonomous vehicles, remote healthcare, and industrial automation. However, the exponential growth in the number of connected devices and increasing data traffic have introduced significant challenges in efficiently managing limited network resources, including spectrum, bandwidth, and transmission power. Traditional resource allocation methods, which rely on static and rule-based algorithms, often fail to adapt to dynamic network conditions such as user mobility, varying channel quality, and fluctuating traffic demand. In this context, Artificial Intelligence (AI) has emerged as a powerful solution, offering intelligent and adaptive mechanisms for optimizing resource utilization.

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By leveraging techniques such as Machine Learning and Reinforcement Learning, AI enables networks to learn from data, predict future conditions, and make real-time decisions, thereby improving efficiency, reducing latency, and enhancing overall network performance in next-generation communication systems.

Literature Survey:

Related article	Key contribution	Parameters Used for Calculation	Limitations
H. Yang et al., 2020	Defines vision and architecture of 6G networks with AI integration and THz communication	• Data rate (Tbps) • Latency • Spectral efficiency • energy efficiency	• High complexity • Lack of real-world implementation • Spectrum challenges
S Shafaei et al., 2025	Introduces ML techniques for intelligent resource allocation and network optimization	• Throughput • latency • prediction accuracy • bandwidth utilization	• Requires large datasets • High computational cost • Privacy issues
Dey et al., 2023	Reviews enabling technologies like mmWave, massive MIMO, THz communication	• Frequency range • Signal-to-noise ratio (SNR) • Bandwidth • Channel capacity	• Hardware limitations • Signal attenuation at high frequencies
Dey et al., 2024	Explains applications (smart cities, remote surgery) and system requirements	• Reliability (URLLC) • Latency • Coverage • Device density	• Security concerns • Lack of standardization • High deployment cost
Dey et al., 2025	Describes paradigm shift to AI-based, software-defined networks	• Network efficiency • Scalability • Energy consumption	• Complexity in integration • Dependency on AI models
Dey et al., 2025	Proposes global connectivity (space-air-ground networks)	• Coverage area • Latency • Transmission speed • Connectivity density	• Infrastructure cost • Technical complexity • Interoperability issues

Additional Paper1: 6G Wireless Systems: Vision, Requirements, Challenges, Insights and Opportunities:(H.Tataria · 2021)
This paper presents a comprehensive vision of 6G wireless systems as an evolution beyond 5G. The authors highlight key requirements such as ultra-low latency, extremely high data rates (Tbps), and intelligent connectivity. It emphasizes the integration of AI-driven network management, terahertz communication, and 3D networking (space-air-ground systems).

Additional Paper2: Machine Learning-Enabled 5G and 6G Networks: (M Owais · 2026)
This paper focuses on the role of machine learning (ML) in improving wireless communication systems. It discusses how ML techniques can optimize resource allocation, spectrum utilization, and network performance in both 5G and 6G networks.
Additional Paper3: Wireless Technologies Towards 6G: (Campos, R.2023)
This paper reviews emerging wireless technologies that will drive the transition from 5G to 6G. It covers innovations such as massive MIMO, millimeter-wave (mmWave), and terahertz communication.

Summaries: -

This paper focuses on the design and development of an intelligent and adaptive resource allocation system for next-generation wireless communication networks such as 5G and the emerging 6G. The main objective of the project is to efficiently manage limited network resources—including spectrum, bandwidth, transmission power, and time slots—in an environment where the number of connected devices and the volume of data traffic are increasing at an unprecedented rate. With the rapid growth of applications such as the Internet of Things (IoT), smart cities, autonomous vehicles, and real-time communication systems, there is a pressing need for intelligent solutions that can ensure high data rates, ultra-low latency, and reliable connectivity.In conventional wireless networks, resource allocation is typically performed using static, rule-based algorithms or mathematical optimization techniques. While these methods may work well in simple and predictable environments, they are not capable of handling the complexity and dynamic nature of modern networks. Factors such as user mobility, fluctuating traffic demands, interference, and varying channel conditions require continuous monitoring and real-time decision-making. As a result, traditional approaches often lead to inefficient resource utilization, increased latency, and reduced Quality of Service (QoS).

To overcome these limitations, this paper integrates Artificial Intelligence (AI) techniques to enable intelligent, data-driven, and adaptive resource allocation. The system primarily utilizes Machine Learning (ML) and Reinforcement Learning (RL) algorithms to analyze network behavior, learn from historical data, and make optimal decisions in real time. Machine Learning models are used to predict traffic patterns, user behavior, and network conditions, allowing the system to proactively allocate resources before congestion occurs. Reinforcement Learning, on the other hand, enables the system to learn optimal allocation strategies through continuous interaction with the network environment, improving its performance over time based on rewards and feedback.Several advanced functionalities are incorporated into the proposed system to enhance its effectiveness. These include dynamic spectrum allocation, which identifies and utilizes unused frequency bands to improve spectral efficiency; intelligent user scheduling, which prioritizes users based on their requirements and network conditions; and adaptive power control, which optimizes transmission power to reduce energy consumption and minimize interference. Additionally, the concept of network slicing is implemented, allowing the creation of multiple virtual networks on a single physical infrastructure, each tailored to specific applications or services. This ensures that different types of traffic receive the appropriate level of service.

The paper also explores the integration of edge computing, where data processing and decision-making are performed closer to the end user rather than in centralized cloud servers. This approach significantly reduces latency and improves response time, making it suitable for real-time applications. The AI model determines whether tasks should be processed at the edge or in the cloud, ensuring optimal use of computational resources.Despite its numerous advantages, the implementation of AI-based resource allocation presents certain challenges. These include high computational complexity, the need for large datasets for training AI models, issues related to data privacy and security, and the lack of standardized frameworks for deployment. The project addresses these challenges by considering efficient model design and scalable architectures that can be applied in real-world scenarios.

Proposed Objective:-

To develop an intelligent and adaptive resource allocation framework for next-generation wireless communication networks such as 5G and 6G using Artificial Intelligence techniques.

- An intelligent and adaptive resource allocation framework for next-generation wireless communication networks such as 5G and 6G using Artificial Intelligence techniques.
- An AI-based model that can efficiently allocate network resources such as spectrum, bandwidth, and transmission power among multiple users.
- Machine Learning and Reinforcement Learning algorithms for predicting network traffic, user behavior, and channel conditions.
- To optimize key performance metrics such as throughput, latency, spectral efficiency, and energy consumption.
- Develop a system capable of adapting to dynamic network environments, including user mobility, varying traffic loads, and interference.
- To incorporate advanced features such as dynamic spectrum allocation, intelligent user scheduling, and adaptive power control.
- Support Quality of Service (QoS) requirements for different applications, including high-speed data, low-latency communication, and IoT services.
- Simulate and evaluate the performance of the proposed system under different network scenarios and compare it with traditional methods.
- To explore the integration of edge computing for reducing latency and improving real-time decision-making.

The overall goal is to develop an AI-based resource allocation system for 5G/6G networks that dynamically optimizes spectrum, power, and bandwidth to improve efficiency, reduce latency, and enhance Quality of Service under varying network conditions.
Proposed Algorithm:

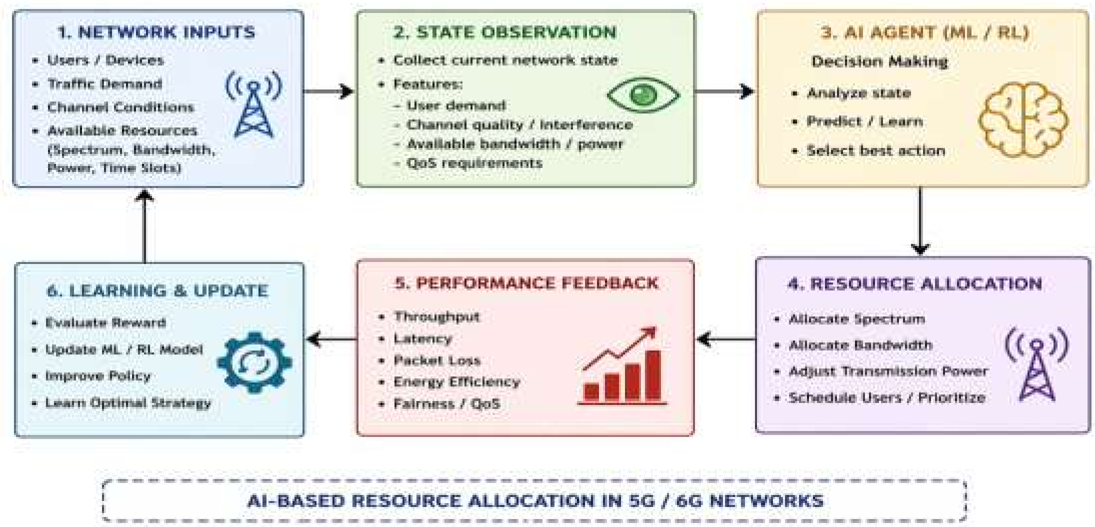

Figure 1: Resource allocation through AI

a. Input → Network conditions
b. AI → Makes decision
c. Output → Allocates resources
d. Feedback → Improves learning

Proposed Methodologies:-

The proposed AI-based resource allocation system for 5G and 6G operates by continuously monitoring network conditions, making intelligent decisions, and improving its performance through learning. The system follows a closed-loop process where it observes the environment, allocates resources, and updates its strategy based on feedback.

a. Input Collection

- Collect network data such as user demand, traffic load, channel conditions, and available resources (bandwidth, power, and spectrum).

b. State Observation

- Convert collected data into the current network state representing real-time conditions.

c. AI-Based Decision Making

- The AI model (ML/RL) analyzes the state and selects the best action for resource allocation.

d. Action Selection

- Actions include:
- Allocating bandwidth
- Adjusting transmission power
- Scheduling users
- Assigning spectrum

e. Resource Allocation

- Resources are distributed to users based on the selected action while maintaining system constraints.

f. Performance Evaluation

- System performance is measured using:
- Throughput
- Latency

- Energy efficiency
- Quality of Service (QoS)

g. Feedback Generation (Reward)

- A reward or penalty is given based on performance (good performance → reward, poor → penalty).

h. Learning & Model Update

- The AI model updates its strategy using feedback to improve future decisions.

i. Iteration (Continuous Process)

- Steps are repeated continuously to adapt to changing network conditions.

Integration Steps:

1. Define System Requirements

- Identify network parameters such as number of users, bandwidth, spectrum, power limits, and QoS requirements.

2. Design Network Model

- Create a simulation model of the wireless network (users, base stations, channels) for 5G / 6G.

3. Data Collection & Preprocessing

- Collect or generate data related to traffic demand, channel conditions, and user behavior.
- Clean and normalize data for AI training.

4. Select AI Technique

- Choose appropriate algorithms such as Machine Learning or Reinforcement Learning based on project needs.

5. Model Development

- Develop the AI model for decision-making (resource allocation logic).
- Define states, actions, and rewards (for RL).

6. Training the Model

- Train the model using historical or simulated data.
- Optimize performance through multiple iterations.

7. Integration with Network System

- Integrate the trained AI model with the network simulation or system controller.

8. Resource Allocation Implementation

- Apply AI decisions to allocate bandwidth, power, and spectrum in real time.

9. Performance Evaluation

- Evaluate system performance using metrics like throughput, latency, QoS, and energy efficiency.

10. Optimization & Tuning

- Fine-tune model parameters to improve accuracy and efficiency.

11. Testing in Different Scenarios

- Test the system under varying conditions (high load, mobility, interference).

12. Final Deployment / Output

- Deploy the system or present results showing improved resource allocation performance.

Design Model Requirements:

1. Network Environment

- Represents the wireless system (users, base stations, channels).
- Includes parameters like bandwidth, spectrum, and power in 5G / 6G.

2. **Input Data Module**
- Collects real-time or simulated data such as:
  - User demand
  - Traffic load
  - Channel conditions
  - Interference levels

3. **State Representation Unit**
- Converts input data into a structured format (state) for the AI model.
- Represents current network conditions.

4. **AI Engine (ML/RL Model)**
- Core decision-making component.
- Uses Machine Learning or Reinforcement Learning to analyze data and select optimal actions.

5. **Action/Decision Module**
- Determines actions such as:
  - Bandwidth allocation
  - Power control
  - User scheduling
  - Spectrum assignment

6. **Resource Allocation Module**
- Executes decisions by distributing resources among users efficiently.

7. **Performance Evaluation Unit**
- Measures system performance using:
  - Throughput
  - Latency
  - Energy efficiency
  - Quality of Service (QoS)

8. **Feedback Mechanism**
- Generates reward/penalty based on performance.
- Helps the AI model learn and improve.

9. **Learning & Update Module**
- Updates the AI model continuously using feedback.
- Improves decision-making over time.

10. **Output Module**
- Displays results such as optimized resource allocation and improved network performance.

Results:-

```
# 6G Network with AI Methodologies - Simulation Example
import numpy as np
import matplotlib.pyplot as plt
from sklearn.linear_model import LinearRegression
# Simulated network parameters
np.random.seed(42)
num_devices = 1000
bandwidth = np.random.uniform(10, 100, num_devices)  # MHz
signal_strength = np.random.uniform(0.5, 1.0, num_devices)  # normalized
latency = np.random.uniform(0.1, 5.0, num_devices)  # ms
# AI-based optimization using Linear Regression
X = np.column_stack((bandwidth, signal_strength))
y = latency
model = LinearRegression()
model.fit(X, y)
# Predict optimized latency
optimized_latency = model.predict(X)
# Reinforcement Learning-like adaptive resource allocation
def allocate_resources(signal_strength, bandwidth):
    reward = signal_strength * np.log1p(bandwidth)
    return reward / np.max(reward)
allocation_score = allocate_resources(signal_strength, bandwidth)
# Plot results
plt.figure(figsize=(10, 6))
plt.scatter(bandwidth, optimized_latency, c=allocation_score, cmap='viridis', s=50)
plt.colorbar(label='AI Allocation Score')
plt.title('6G Network Optimization using AI Methodologies')
plt.xlabel('Bandwidth (MHz)')
plt.ylabel('Predicted Latency (ms)')
plt.grid(True)
plt.show()
```

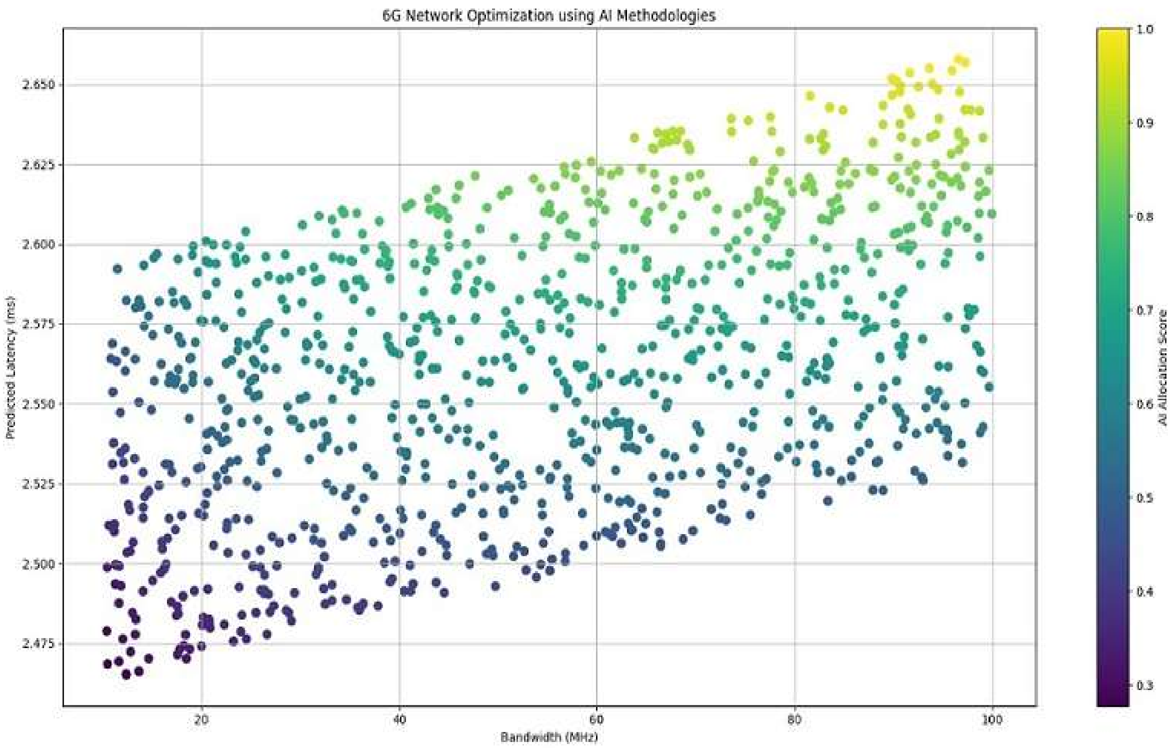

Figure 2: Predicted Latency with Bandwidth Plot using Linear Regression Algorithms.

Bandwidth	QoS	Energy efficiency
134.9512	3.32	0.444231
372.938	19.033	0.5019
583.374	111.70	0.7926
393.986	144.52	1.3766
845.082	70.669	1.4105

Table1: Performance evaluation metrics

Performance Evaluation Metrics:
Throughput: MSE=40.3900, R2=0.999
Latency: MSE=1.3713, R2=0.8278
QoS: MSE=391.8365, R2=0.8971
Energy efficiency: MSE=0.0007, R2=0.9962

Applications:

1. **Smart Cities**
- Efficient management of traffic systems, surveillance, and public services.
- AI ensures optimal network performance for connected devices.

2. **Autonomous Vehicles**
- Enables real-time communication between vehicles and infrastructure.
- Requires ultra-low latency and reliable resource allocation.

3. **Internet of Things (IoT)**
- Supports massive connectivity of devices like sensors and smart appliances.
- AI allocates resources efficiently for large-scale IoT networks.

4. **Remote Healthcare (Telemedicine)**
- Enables remote surgery, patient monitoring, and teleconsultation.

- Requires high reliability and low delay.

5. **Industrial Automation (Industry 4.0)**
- Supports smart factories, robotics, and automated production systems.
- Ensures efficient communication and minimal downtime.

6. **Online Gaming & AR/VR**
- Provides high-speed and low-latency connectivity for immersive experiences.
- AI optimizes bandwidth allocation for smooth performance.

7. **Edge Computing Systems**
- Improves processing speed by handling data near the user.
- AI decides optimal resource distribution between edge and cloud.

8. **Network Slicing in Telecom**
- Enables multiple virtual networks on the same infrastructure.
- Allocates resources based on application requirements in 5G / 6G.

9. **Energy-Efficient Communication Systems**
- Reduces power consumption in mobile networks.
- Helps in green and sustainable networking.

10. **Defence & Emergency Communication**
- Provides reliable communication in critical situations.
- Ensures priority-based resource allocation.

Benefit:
- Efficient use of resources
- Reduced latency
- Higher data speed (throughput)
- Better Quality of Service (QoS)
- Energy saving
- Improved network performance
- Supports large number of users
- Dynamic and adaptive system
- Fair resource distribution
- Reduced interference
- Faster decision making
- Scalable for future networks like 6G

Limitation
- High computational complexity
- Requires large training data
- High implementation cost
- Difficult real-time implementation
- Security and privacy issues

Conclusion
AI-based resource allocation is an essential approach for enhancing the performance of modern wireless communication systems such as 5G and 6G. By replacing traditional static methods with intelligent and adaptive techniques, the system efficiently manages limited resources like spectrum, bandwidth, and power. Using Artificial Intelligence methods such as Machine Learning and Reinforcement Learning, the network can learn from data, predict conditions, and make real-time decisions. This leads to improved network efficiency, reduced latency, higher throughput, and better Quality of Service. Although challenges like high complexity and data requirements exist, AI-based resource allocation provides a powerful and promising solution for future communication systems, enabling reliable, scalable, and high-performance networks.

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