

Artificial Intelligence-Enabled Wireless MIMO-OFDM Systems in Biomedical and Drug Delivery Applications: A Narrative Review

Shamna A R*

^{1*}Professor, Electronics and Communication Engineering, Musaliar College of Engineering, Trivandrum,
Email ID: shamnav83@gmail.com,
Orcid ID :0009-0004-6097-1447

Abstract

The convergence of artificial intelligence and advanced wireless communication systems has significantly transformed biomedical engineering, particularly in the development of innovative drug delivery technologies. With the growing demand for precision medicine and real-time patient monitoring, intelligent and connected healthcare systems have become increasingly important. Wireless communication frameworks such as multiple-input multiple-output orthogonal frequency division multiplexing offer high data rates, improved reliability, and efficient spectrum utilisation, making them highly suitable for biomedical applications. This narrative review aims to explore the integration of artificial intelligence-enabled multiple-input multiple-output orthogonal frequency division multiplexing systems and their potential applications in drug delivery and healthcare. The review is based on recent literature from biomedical, pharmaceutical, and communication domains to provide a comprehensive understanding of this interdisciplinary field. The findings indicate that artificial intelligence significantly enhances signal processing, resource optimisation, and real-time monitoring capabilities in biomedical systems. These advancements support the development of smart drug delivery systems, implantable medical devices, wearable monitoring technologies, and telemedicine platforms. Artificial intelligence-driven approaches enable precise drug administration, improved patient monitoring, and efficient healthcare delivery. In conclusion, the integration of artificial intelligence with wireless communication systems presents a promising pathway for developing personalised, efficient, and intelligent drug delivery solutions, thereby advancing the future of modern healthcare systems.

Keywords: Artificial Intelligence, MIMO-OFDM, Drug Delivery, Wireless Systems, Smart Healthcare

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1. Introduction

Drug delivery technologies have evolved significantly over the past few decades and have moved to the most recent varieties, which cease to be the most common types of dosage but sophisticated mechanisms that offer specific and targeted therapeutic action. Traditional drug delivery techniques are associated with undesirable side effects such as failure to deliver drugs site-specifically, low bioavailability, systemic bio-adverse effects. The difficulties are addressed by innovating modern-day drug delivery methods which are capable of enhancing health care properties, including drug stability, bioavailability and therapeutic effects with the aid of nanocarriers, liposomes as well as polymer-based systems (Patra et al., 2018). This can be done with such sophisticated systems to ensure the precise control of the drug release profiles to increase the capability of the patient to comply or respond to treatment effectively. Focused and regulated drug delivery systems has been critical in the recent pharmaceuticals since it ensures that the therapeutic agents reach the target site of action. This practice with a focus decreases the side effects and maximizes the effectiveness of the drugs, particularly in the management process of the chronic and complex diseases. Incorporation of smart technologies in drug delivery systems has also contributed to the emergence

of personalised medicine, in which the treatment options are based on the specific characteristics of the patient (Panchpuri et al., 2025). These are the developments that are necessary in enhancing clinical outcomes and minimising medical expenses.

The introduction of intelligent healthcare systems has changed the paradigm of biomedical engineering because of the use of highly developed computational technologies and real-time monitoring devices (Rajkomar et al., 2019). One of the enablers of this shift is artificial intelligence (AI), which provides such features as data-driven decision-making, predictive analytics, and automation. Pharmaceutical development and the design of drug delivery have shown large-scale applications of AI, such as machine learning and deep learning, to make the formulation process optimal and improve therapeutic performance (Vora et al., 2023; Colombo, 2020). Moreover, AI-based systems can facilitate the early detection of the disease, treatment planning and constant monitoring of the patients, which helps to make healthcare delivery more efficient (Esteva et al., 2019; Topol, 2019).

Another essential part of the modern healthcare system is reliable wireless communication, especially to the implantable and wearable medical devices that need constant transfer of data. Wireless technologies can be

*Author for Correspondence: shamnav83@gmail.com

used to monitor and control drug delivery systems in real-time and thus allow timely medical intervention. New technologies, like wireless on-demand drug delivery systems, can enable a third party to control the release of the drugs through innovation and methods of better treatment and convenience to patients (Mirvakili and Langer, 2021). Among other wireless communication technologies, multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) has been attractive because of high data rate, strength, and efficient spectrum utilisation; it is reasonable to apply it in biomedical applications.

Even though these developments have been made, there is still a substantial gap in the overall integration of artificial intelligence, wireless communication systems, and drug delivery technologies. Although separate areas have been well researched, their use in combination in biomedical engineering and pharmaceuticals remains very new. This gap can be used to emphasise the necessity of a systematic review that could investigate the potential of AI-enabled wireless systems to improve drug delivery and healthcare applications.

Thus, the aim of this review is to offer an overview of the application of artificial intelligence to wireless MIMO-OFDM systems and the integration of these systems with biomedical engineering, especially drug delivery. The review will speak about basic principles, main uses, issues, and prospects of the future, therefore providing some understanding about the evolution of intelligent and connected healthcare systems.

2. Fundamentals of AI and Wireless MIMO-OFDM Systems

2.1 Artificial Intelligence in Healthcare

Machine learning (ML) and deep learning (DL) methods have become an innovative instrument of artificial intelligence (AI) in healthcare. ML allows the systems to pick patterns in data and make inferences, whereas DL uses multi-layered neural networks to represent and analyse complex data (Goodfellow et al., 2016; Shrestha and Mahmood, 2019). These methods are commonly used in diagnoses, disease prediction, and making decisions in clinical settings, which are very useful in making the health system more accurate and efficient. The use of AI also promotes automation in medical imaging, patient monitoring, and individual treatment plans (Ponnusamy et al., 2022). Moreover, AI combined with communication systems improves real-time data analysis and smart healthcare provision, and the recent

developments emphasise the increased importance of deep learning in intelligent wireless healthcare systems (Mao et al., 2018).

2.2 Basics of MIMO-OFDM Systems

Multiplexing wireless communication systems, like multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM), are important in contemporary healthcare practice. MIMO is designed to have multiple antennas on both the transmitter and receiver side to enhance the data throughput and reliability, whereas OFDM uses more than one subcarrier, which is orthogonal to break down the signal to enhance the spectral efficiency (Daniels et al., 2009). MIMO plus OFDM offer high data rates, resistance to interference and use of bandwidth effectively, thus it is appropriate in biomedical communication systems. Also, machine learning devices have been utilised more frequently to improve the performance of wireless networks such as channel estimation and signal detection (Jiang et al., 2016; Sun et al., 2019). The performance of the physical layer can also be advanced by deep learning techniques that allow adaptation and data-driven communication strategies (O'Shea and Hoydis, 2017), and neural network-based techniques are used more and more often in the design and optimisation of intelligent wireless networks (Chen et al., 2017).

2.3 Relevance to Biomedical and Drug Delivery Systems

The introduction of AI-based MIMO-OFDM systems is specifically applicable to the biomedical and drug delivery field, where quality and real-time communication are critical. Wearable and implantable medical devices, including insulin pumps and biosensors, need to be constantly linked to transmit data and control it. In such systems, AI methods make it easier to allocate resources intelligently and adaptively communicate, which makes them energy-efficient and reliable (Hu et al., 2021). Additionally, the distributed machine learning systems can also facilitate decentralised data processing within healthcare networks to enhance the scale and responsiveness. These innovations help with tracking in real-time, with the administration of drugs remotely, and with customised healthcare solutions, showing the significance of wireless systems based on AI in contemporary pharmaceuticals (Zhang et al., 2019).

Table 1: Comparison of AI Techniques Used in Biomedical Communication Systems

AI Technique	Application	Advantages	Key References
Machine Learning (ML)	Disease prediction, signal processing	Efficient pattern recognition, predictive capability	(Jiang et al., 2016; Sun et al., 2019)
Deep Learning (DL)	Medical imaging, wireless signal detection	High accuracy, automatic feature extraction	(Goodfellow et al., 2016; Shrestha & Mahmood, 2019)
Distributed Learning	Healthcare networks, IoT-based systems	Scalability, reduced latency	(Hu et al., 2021)

AI-based Wireless Optimisation	Channel estimation, resource allocation	Improved network efficiency	(Daniels et al., 2009; O'Shea & Hoydis, 2017)
Intelligent Healthcare Systems	Smart monitoring, automation	Real-time decision-making	(Ponnusamy et al., 2022; Zhang et al., 2019)

Table 1, in the summary, has identified that diverse AI methodologies have been used in biomedical communication systems to improve the performance, reliability, and decision-making abilities.

3. AI Integration in Wireless Biomedical Systems

3.1 AI for Signal Processing

AI has played an important role in boosting signal processing in wireless biomedical systems, especially in MIMO-OFDM. Channel estimation is one of the main applications where AI models can be trained to capture the complicated channel properties and closely predict them, enhancing the reliability of the communication (Shamna & Shanthi, 2020b). Neural networks, also known as deep learning methods, have been shown to be more successful in the estimation of channel state information than traditional approaches (Jiao et al., 2021; Wang et al., 2017; Shamna & Shanthi, 2020a). Also, machine learning methods are common applications in multi-user MIMO systems to maximise receive processing and eliminate interference, which improves the performance of the system (Goutay et al., 2021).

Reduction of noise is also another very important factor in biomedical communication, particularly among implantable and wearable devices that are used in a noisy environment. The AI algorithms can help reduce the noise and locate the meaningful signal, improving the quality of the data and the accuracy of its transmission. The methods based on neural networks served to determine patterns and eliminate distortions of the biomedical signals in order to provide reliable monitoring and diagnosis (Sutariya et al., 2013). These inventions focus on the value of AI to boost the efficiency and power of wireless biomedical communication systems.

3.2 AI for Resource Optimisation

Wireless biomedical systems demand effective optimisation of resources and power and bandwidth has to be taken into consideration. The AI methods are important in optimising these resources as they allow making decisions which are adaptive and intelligent. As an example, deep learning has been used to apply hybrid precoding and beamforming to MIMO systems to enhance spectral efficiency and power consumption (Li and Alkhateeb, 2019). These techniques permit active

control of the transmission parameters depending on the environmental characteristics and demands of the system.

In implantable medical devices, battery life is often restricted and power efficiency is especially important. Optimisation methods through AI can be used to minimise the use of energy as resources are efficiently distributed and avoid the transmission of redundant messages. In a similar way, machine learning algorithms can be run to optimise bandwidth by prioritising essential medical information and ensuring effective communication. The methods will help in building efficient and energy-efficient biomedical communication systems with high performance that will facilitate the provision of reliable and sustained healthcare services.

3.3 AI for Real-Time Monitoring and Decision Making

Biomedical systems using AI would involve real-time monitoring and making intelligent decisions, which is crucial to effective medical service provision and medication. Continuous patient monitoring is based on wireless communication to transfer physiological parameters, and the analysis is performed with the help of AI algorithms to identify abnormalities in a timely manner. These systems improve the safety of the patients and facilitate medical procedures in a timely manner.

Moreover, AI-based systems can facilitate smart drug delivery by processing patient-specific information and changing the dose delivery. Nanotechnology coupled with AI has also developed drug delivery systems that allow therapeutic agents to work precisely and controllably (Almansour et al., 2024). The AI models can be used to determine the ideal dosage and the time of delivery of the medication, enhancing the treatment results and decreasing the number of side effects. Also, neural network-based solutions are useful to induce data-driven decisions in the pharmaceutical industry, which increases the effectiveness of drug delivery procedures (Sutariya et al., 2013).

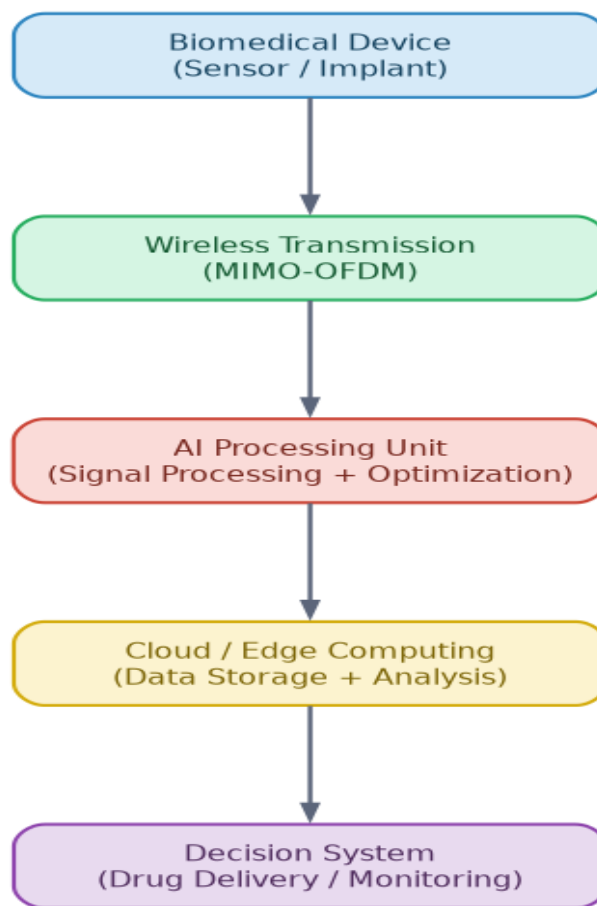


Figure 1: Architecture of AI-enabled MIMO-OFDM Biomedical System

The general structure of an AI-powered MIMO-OFDM biomedical system is shown in Figure 1, which marks the incorporation of AI modules into signal processing, resource optimisation, and decision-making frameworks in wireless communication. This architecture illustrates the transmission, processing and analysis of biomedical devices data in real time to provide intelligent healthcare solutions.

4. Applications in Drug Delivery and Biomedical Engineering

4.1 Smart Drug Delivery Systems

Pharmaceutics: AI-enabled smart drug delivery systems have transformed the current state of pharmaceutics by empowering the precise, controlled and personalised therapeutic intervention. To control drug release systems with AI machines, machine learning algorithms are used to find the optimal dose and timing of a specific medicine based on patient-specific data, including physiological parameters and disease progression (Mutha et al., 2024; Singh and Nishad, 2025). These systems facilitate the effectiveness of therapy and reduce the negative reactions. Moreover, nanoengineered biomaterials in combination with AI can be used to target drugs at the cellular and molecular levels to enhance the treatment outcomes of complex diseases (Mozafari,

2020; Bae et al., 2025). Regulated drug delivery methods are also developing, providing them with better release rates and drug specificity (Adepu & Ramakrishna, 2021).

Another important development is wireless-controlled drug delivery, where additional signals are received remotely and utilised to regulate drug release. These systems allow the on-demand delivery of the drug, which is especially important in the context of the treatment of chronic diseases and implantable therapeutic devices (Mirvakili & Langer, 2021). Nanocarrier systems combined with AI can also improve drug targeting, stability, and release kinetics, which cannot be measured with traditional delivery systems (Alshawwa et al., 2022; Shinde et al., 2025).

4.2 Implantable Biomedical Devices

The implantable biomedical devices are essential in the continuous monitoring of healthcare and the delivery of drugs. Neural implants, pacemakers, and insulin pumps are devices that are based on wireless communication systems to transfer and control real-time data. AI adds functionality to these devices, predictive analytics, and responsiveness according to patient condition. As an example, insulin pumps are insulated by AI and can

adjust their delivery dynamically by measuring glucose levels to enhance the management of diabetes.

Likewise, pacemakers with artificial intelligence can observe the activity of the heart and adjust the stimulation to achieve optimal functioning. The neural implants, which are applicable in the case of neurological conditions, are characterised by the signal processing and decision-making supported by AI and, therefore, allow for precise stimulation as well as achieve better therapeutic results (Hamet and Tremblay, 2017). New bio-cyber interfaces also combine both biological systems and smart communication networks so that new, advanced targeted drug delivery systems can be implemented (Kamal et al., 2026). Such developments underscore the need to amalgamate AI with wireless systems in order to enhance the efficiency and reliability of implantable medical devices.

4.3 Wearable Systems

The systems of wearable biomedical systems have received a lot of attention because they offer continuous monitoring and drug delivery. These gadgets gather physiological data in real-time, which is subsequently analysed with AI algorithms to identify abnormalities and prescribe treatment measures. The AI-powered wearable devices are especially effective in treating chronic conditions where constant observation is a key to successful treatment.

A combination of the Internet of Things (IoT) technologies and AI also contributes to advanced functions of wearable systems that can facilitate smooth

interaction between gadgets and healthcare professionals. Such systems can allow automated delivery of drugs on the basis of real-time data analysis, which enhances compliance and treatment results in patients (Raikar et al., 2023). Also, wearable technologies developed using AI can be used in early diagnosis and preventive care, eliminating the pressure on health systems.

4.4 Telemedicine and Remote Healthcare

The combination of AI and wireless communication technologies has contributed to the improvement of telemedicine and remote healthcare systems significantly. These systems allow remote monitoring, diagnosis and treatment, thus making healthcare more efficient and accessible. Patient care systems are AI-assisted systems that process big amounts of medical data to make precise and timely suggestions to enhance clinical decision-making (Ahmed et al., 2020).

Wireless communication and AI-based remote drug delivery systems enable healthcare professionals to monitor their patients and readjust their treatment plans remotely. This comes in particularly handy to patients of the isolated or underserved areas. It is also possible to have personalised medicine with the help of AI-based solutions that may suggest certain treatment plans, which are created based on the personal data and make treatment more effective. Development of AI, wireless communication and intelligent drug delivery systems is an important breakthrough in the development of connected and intelligent healthcare systems.

Table 2: Applications of AI-Enabled Wireless Systems in Drug Delivery

Application	Technology Used	Role of AI	Key References
Smart Drug Delivery	Nanocarriers, AI models	Dose optimisation, targeted delivery	(Mozafari, 2020; Bae et al., 2025)
Wireless Drug Delivery	MIMO-OFDM, sensors	On-demand drug release	(Mirvakili & Langer, 2021)
Implantable Devices	Insulin pumps, pacemakers	Real-time monitoring, adaptive control	(Hamet & Tremblay, 2017)
Wearable Systems	IoT, biosensors	Continuous monitoring, automation	(Raikar et al., 2023)
AI-driven Healthcare	ML platforms	Decision support, predictive analysis	(Ahmed et al., 2020; Mutha et al., 2024)
Nanotechnology-based Delivery	Nano-carriers	Controlled release, targeting	(Alshawwa et al., 2022; Shinde et al., 2025)

The use of AI-powered wireless systems in the biomedical and drug delivery field is prevalent, as seen in Table 2, which indicates that AI-powered wireless systems can be used in numerous biomedical and drug delivery projects.

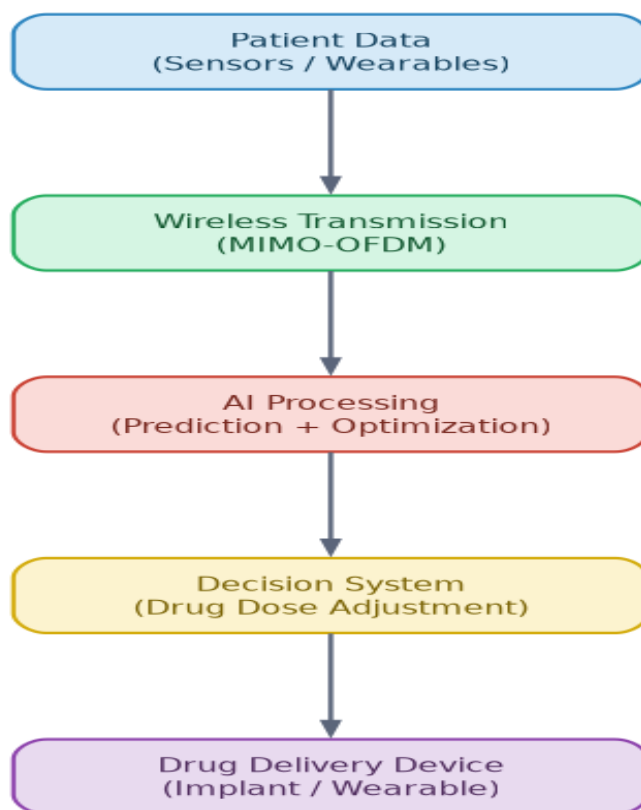


Figure 2: Workflow of AI-Based Smart Drug Delivery

Figure 2 demonstrates the steps of the workflow of AI-based smart drug delivery systems, indicating the combination of data collection, wireless communication, artificial intelligence processing, and decision-making to ensure the best therapeutic effects.

5. Challenges and Limitations

Irrespective of the high levels of development of AI-based wireless biomedical systems, there are a number of challenges and limitations that do not favour their extensive use in drug delivery and health care applications. Among the key issues are those that are associated with the technical challenges, such as latency, interference, and reliability of the system. Environmental factors can cause a degradation of wireless communication systems like MIMO-OFDM, which can impact data transmission and decision-making in real-time. Even by the slightest delay or incorrectness, patient safety is at risk in critical healthcare applications, which is why high-quality and consistent system design is essential.

Another key issue of AI-based healthcare systems is data privacy and cybersecurity. The use of AI and biomedical equipment comes with the gathering and sharing of patient-sensitive information; thus, such systems are prone to cyberattacks and information leaks. Patient confidentiality and trust imply that it is necessary to ensure that the data are stored securely, encrypted, and the privacy regulations are complied with (Choudhry et

al., 2024). Also, biometric and AI-based systems contribute to making the management of security even more complicated, necessitating sophisticated protection measures.

There are also regulatory issues, which are important factors restricting the use of AI in the pharmaceutical and drug delivery. Safety, efficacy, and reliability of the medical devices and drug delivery systems, which are operated by AI, require strict regulations before their approval. Nonetheless, the ever-changing and responsive character of AI models renders a standardised assessment framework challenging to the regulatory authorities (Mak and Pichika, 2019). Such an absence of definite guidelines may slow down the process of creating and commercialising innovative healthcare solutions.

Another notable weakness is integration complexity since the combination of AI algorithms and wireless communication systems with pharmaceutical technologies needs interdisciplinary skills. The technological and biological systems should be well integrated with hardware and software so that the systems can run smoothly. Moreover, the introduction of high-end AI models into biomedical devices with a limited number of resources also presents new issues associated with computational needs and device performance (Mottaghi-Dastjerdi and Soltany-Rezaee-Rad, 2024).

Lastly, the accessibility of the AI-enabled drug delivery systems is curtailed by the problem of cost and scalability. The setup, installation, and maintenance of these systems are very expensive and are not feasible on a large-scale basis of implementation, especially in low-

resource environments. In order to achieve the full potential of AI-driven wireless biomedical systems in the contemporary healthcare setting, it is necessary to address these challenges.

Table 3: Challenges and Potential Solutions

Challenge	Description	Potential Solution	Key References
Technical Issues	Latency, interference, signal reliability	Advanced signal processing, AI optimisation	(Mottaghi-Dastjerdi & Soltany-Rezaee-Rad, 2024)
Data Privacy & Security	Risk of data breaches and cyberattacks	Encryption, secure AI frameworks	(Choudhry et al., 2024)
Regulatory Challenges	Lack of clear approval frameworks	Standardised AI regulations	(Mak & Pichika, 2019)
Integration Complexity	Difficulty in combining AI, wireless, and pharma systems	Interdisciplinary system design	(Mottaghi-Dastjerdi & Soltany-Rezaee-Rad, 2024)
Cost & Scalability	High implementation cost	Cost-effective AI models, scalable infrastructure	(Mak & Pichika, 2019)

In brief, Table 3 summarises that these challenges can be mitigated using specific solutions, such as intensive security measures, regulating the standardisation of regulatory protocols, and an effective system design strategy.

6. Future Perspectives

The future of AI-enhanced wireless biomedical systems has a very great future in revolutionising drug delivery and health care using the better version of technology add-on. The existing development paths that appear to give the greatest promise to the improvement of AI-simulated precision medicine include the customisation of treatment plans in accordance with specific patient information, including genetic, physiological, and lifestyle data. By processing complicated data, AI algorithms can forecast the progression of a disease and provide the most effective treatment, which results in better clinical outcomes.

With the advent of next-generation wireless technologies, especially 5G and the next 6G network, it is presumed that the health care system may be improved even more, allowing the application of ultra-reliable and low-latency communication. The current technologies

will enable the transmission of real-time data collected by biomedical devices, enabling constant monitoring and decision-making. The development is particularly useful in remote healthcare and telemedicine implementation, as immediate action is essential.

Another important direction of development in the future is integration with nanotechnology. AI could have a significant impact on nanocarriers, potentially allowing their use to deliver therapeutic agents with high specificity to the affected tissue by reducing side effects and ensuring that treatment reaches the affected tissues. This strategy helps to increase the effectiveness of drugs and promotes the production of novel treatment forms for complex diseases.

Even the method of personal delivery of drugs is likely to learn a new form as AI will allow modifying the dose based on feedback provided by the patient in real-time. These systems are able to provide a dynamic change in the drug release profiles, resulting in better compliance by the patient and increased therapeutic efficacy. Also, the use of intelligent decision-making systems will contribute to the automation of the healthcare process, the minimisation of the role of human error, and increased clinical efficiency.

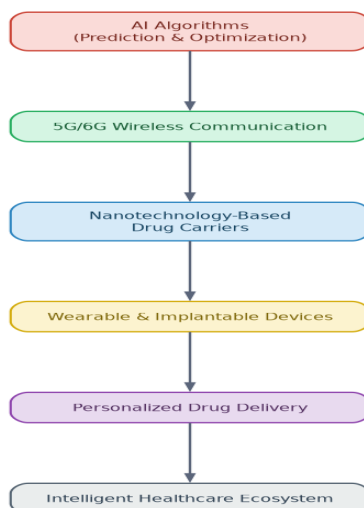


Figure 3: Future Roadmap of AI-Enabled Drug Delivery Systems

The general future map of AI-based drug delivery systems is shown in Figure 3 that demonstrates the coming together of AI, wireless communication, nanotechnology, and healthcare systems. This non-specific solution depicts how the new technologies can integrate with each other to facilitate innovations in drug delivery and biomedical engineering that will enable the development of more effective, customized, and affordable healthcare solutions.

7. Conclusion

This review identifies the revolutionary quality of the artificial intelligence (AI) integration with wireless MIMO-OFDM in technologies of biomedical engineering and drug delivery. The findings indicate that AI has been discovered to significantly optimise valuable functions in AI signal processing, resource management and real-time decision-making, thereby enhancing the efficiency, reliability, and flexibility of the wireless biomedical systems. Applications of smart drug delivery systems, implantable medical devices, wearable monitoring devices, and telemedicine platforms have portrayed great prospects of improving patient care and treatment. Another issue identified in the review is that interdisciplinary integration with the knowledge in the pharmaceutical sciences, biomedical engineering and artificial intelligence and wireless communication technologies is highly essential. The secret to the development of intelligent, patient-centric healthcare systems that will be capable of surmounting complex medical problems is that cooperation. These fields also intersect with each other giving the opportunities to formulate more complex systems, which are more precise and effective in their therapeutic delivery, which are more controlled and targeted and offer more personalised therapies. Subsequently, the further progress in AI and the following generations of wireless communication, 5G and 6G, and application of nanotechnology are most likely to modernize the system of drug delivery in the future. The technologies will

assist in developing highly flexible and personalised solutions in healthcare to improve access and clinical outcomes. In general, intelligent, effective, and integrated healthcare ecosystems in the future are a potential direction in the development of wireless biomedical systems with AI.

References

1. Adepu, S., & Ramakrishna, S. (2021). Controlled drug delivery systems: current status and future directions. *Molecules*, 26(19), 5905.
2. Ahmed, Z., Mohamed, K., Zeeshan, S., & Dong, X. (2020). Artificial intelligence with multi-functional machine learning platform development for better healthcare and precision medicine. *Database*, 2020, baaa010.
3. Almansour, S. S. M., Almasaabi, Y. M. A., Almansour, N. S. M., Alfalakah, M. M., Almansour, S. M. R., Alyami, H. A. M., ... & Almakrami, A. A. A. (2024). Nanotechnology in Drug Delivery Systems: Current Trends and Future Perspectives. *Journal of International Crisis and Risk Communication Research*, 7(S10), 315.
4. Alshawwa, S. Z., Kassem, A. A., Farid, R. M., Mostafa, S. K., & Labib, G. S. (2022). Nanocarrier drug delivery systems: characterization, limitations, future perspectives and implementation of artificial intelligence. *Pharmaceutics*, 14(4), 883.
5. Bae, H., Ji, H., Konstantinov, K., Sluyter, R., Ariga, K., Kim, Y. H., & Kim, J. H. (2025). Artificial intelligence-driven nanoarchitectonics for smart targeted drug delivery. *Advanced Materials*, 37(42), e10239.
6. Chen, M., Challita, U., Saad, W., Yin, C., & Debbah, M. (2017). Machine learning for wireless networks with artificial intelligence: A tutorial on neural networks. *arXiv preprint arXiv:1710.02913*, 9.

7. Choudhry, M. D., Sundarrajan, M., Jeevanandham, S., & Saravanan, V. (2024). Security and privacy issues in AI-based biometric systems. In *AI Based Advancements in Biometrics and its Applications* (pp. 85-100). CRC Press.
8. Colombo, S. (2020). Applications of artificial intelligence in drug delivery and pharmaceutical development. In *Artificial intelligence in healthcare* (pp. 85-116). Academic Press.
9. Daniels, R. C., Caramanis, C. M., & Heath, R. W. (2009). Adaptation in convolutionally coded MIMO-OFDM wireless systems through supervised learning and SNR ordering. *IEEE Transactions on vehicular Technology*, 59(1), 114-126.
10. Esteva, A., Robicquet, A., Ramsundar, B., Kuleshov, V., DePristo, M., Chou, K., ... & Dean, J. (2019). A guide to deep learning in healthcare. *Nature medicine*, 25(1), 24-29.
11. Goodfellow, I., Bengio, Y., Courville, A., & Bengio, Y. (2016). *Deep learning* (Vol. 1, No. 2, pp. 1-800). Cambridge: MIT press.
12. Goutay, M., Ait Aoudia, F., Hoydis, J., & Gorce, J. M. (2021). Machine learning for MU-MIMO receive processing in OFDM systems. *IEEE Journal on Selected Areas in Communications*, 39(8), 2318-2332.
13. Hamet, P., & Tremblay, J. (2017). Artificial intelligence in medicine. *metabolism*, 69, S36-S40.
14. Hu, S., Chen, X., Ni, W., Hossain, E., & Wang, X. (2021). Distributed machine learning for wireless communication networks: Techniques, architectures, and applications. *IEEE Communications Surveys & Tutorials*, 23(3), 1458-1493.
15. Jiang, C., Zhang, H., Ren, Y., Han, Z., Chen, K. C., & Hanzo, L. (2016). Machine learning paradigms for next-generation wireless networks. *IEEE Wireless Communications*, 24(2), 98-105.
16. Jiao, J., Sun, X., Fang, L., & Lyu, J. (2021). An overview of wireless communication technology using deep learning. *China Communications*, 18(12), 1-36.
17. Kamal, I. R., El-Zoghdy, S. F., Mahmoud, M. M., & Soliman, R. F. (2026). Smart Bio-Cyber Interface for Targeted Drug Delivery Based on Internet of Biological Nano-Things. *IEEE Access*.
18. Li, X., & Alkhateeb, A. (2019, November). Deep learning for direct hybrid precoding in millimeter wave massive MIMO systems. In *2019 53rd Asilomar Conference on Signals, Systems, and Computers* (pp. 800-805). IEEE.
19. Mak, K. K., & Pichika, M. R. (2019). Artificial intelligence in drug development: present status and future prospects. *Drug discovery today*, 24(3), 773-780.
20. Mao, Q., Hu, F., & Hao, Q. (2018). Deep learning for intelligent wireless networks: A comprehensive survey. *IEEE Communications Surveys & Tutorials*, 20(4), 2595-2621.
21. Mirvakili, S. M., & Langer, R. (2021). Wireless on-demand drug delivery. *Nature Electronics*, 4(7), 464-477.
22. Mottaghi-Dastjerdi, N., & Soltany-Rezaee-Rad, M. (2024). Advancements and applications of artificial intelligence in pharmaceutical sciences: a comprehensive review. *Iranian journal of pharmaceutical research: IJPR*, 23(1), e150510.
23. Mozafari, M. (Ed.). (2020). *Nanoengineered biomaterials for advanced drug delivery*. Elsevier.
24. Mutha, R. E., Bagul, V. S., Tade, R. S., & Vinchurkar, K. (2024). An overview of artificial intelligence (AI) in drug delivery and development. *AI Innovations in Drug Delivery and Pharmaceutical Sciences; Advancing Therapy through Technology*, 1-27.
25. O'shea, T., & Hoydis, J. (2017). An introduction to deep learning for the physical layer. *IEEE Transactions on Cognitive Communications and Networking*, 3(4), 563-575.
26. Panchpuri, M., Painuli, R., & Kumar, C. (2025). Artificial intelligence in smart drug delivery systems: A step toward personalized medicine. *RSC pharmaceuticals*, 2(5), 882-914.
27. Patra, J. K., Das, G., Fraceto, L. F., Campos, E. V. R., Rodriguez-Torres, M. D. P., Acosta-Torres, L. S., ... & Shin, H. S. (2018). Nano based drug delivery systems: recent developments and future prospects. *Journal of nanobiotechnology*, 16(1), 71.
28. Ponnusamy, V., Vasuki, A., Clement, J. C., & Eswaran, P. (2022). AI-driven information and communication technologies, services, and applications for next-generation healthcare system. *Smart Systems for Industrial Applications*, 1-32.
29. Raikar, A. S., Kumar, P., Raikar, G. V. S., & Somnache, S. N. (2023). Advances and challenges in IoT-based smart drug delivery systems: a comprehensive review. *Applied System Innovation*, 6(4), 62.
30. Rajkomar, A., Dean, J., & Kohane, I. (2019). Machine learning in medicine. *New England Journal of Medicine*, 380(14), 1347-1358.
31. Shamna, A. R., & Shanthi, S. A. (2020a). An approach for reduce distortion and improve system performance of MIMO-OFDM using Wiener Hammerstein equalizer. *Journal of Advanced Research in Dynamical and Control Systems*, 12(Special Issue 4), 390-401.
32. Shamna, A. R., & Shanthi, S. A. (2020b). Performance comparison of MIMO-OFDM using Wiener Hammerstein and CNN equalizers. *Journal of Critical Reviews*, 7(6), 195-201.
33. Shinde, T., Deshmukh, K., Gavali, V., & Deokar, S. (2025). Nano Based Drug Delivery Systems: Recent Developments and Future

Prospects. *International Journal of Scientific Research and Technology*.

34. Shrestha, A., & Mahmood, A. (2019). Review of deep learning algorithms and architectures. *IEEE access*, 7, 53040-53065.
35. Singh, A., & Nishad, R. (2025). A Review Analysis of Drug Delivery System Using Artificial Intelligence. *Biomedical Informatics and Smart Healthcare*, 1(2), 52-66.
36. Sun, Y., Peng, M., Zhou, Y., Huang, Y., & Mao, S. (2019). Application of machine learning in wireless networks: Key techniques and open issues. *IEEE Communications Surveys & Tutorials*, 21(4), 3072-3108.
37. Sutariya, V., Groshev, A., Sadana, P., Bhatia, D., & Pathak, Y. (2013). Artificial neural network in drug delivery and pharmaceutical research. *The Open Bioinformatics Journal*, 7(1).
38. Topol, E. J. (2019). High-performance medicine: the convergence of human and artificial intelligence. *Nature medicine*, 25(1), 44-56.
39. Vora, L. K., Gholap, A. D., Jetha, K., Thakur, R. R. S., Solanki, H. K., & Chavda, V. P. (2023). Artificial intelligence in pharmaceutical technology and drug delivery design. *Pharmaceutics*, 15(7), 1916.
40. Wang, T., Wen, C. K., Wang, H., Gao, F., Jiang, T., & Jin, S. (2017). Deep learning for wireless physical layer: Opportunities and challenges. *China Communications*, 14(11), 92-111.
41. Zhang, Y., Wang, H., & Zhang, X. (2019). Deep learning for wireless communications: A comprehensive survey. *IEEE Commun. Surveys Tuts.*, 21(3), 1-30.