Bandwidth Optimization of Wireless Networks Using Artificial Intelligence Technique

TAMUNO-OMIE JOYCE ALALIBO[1], SUNNY ORIKE[2], PROMISE ELECHI[3]
[1,3]*Department of Electrical Engineering, Rivers State University, Port Harcourt, Rivers State Nigeria*
[2] *Department of Computer Engineering, Rivers State University, Port Harcourt, Rivers State Nigeria*

Abstract- Bandwidth allocation and management play a vital role in satisfying the Quality of Service (QoS) requirements for applications and promote the move to user-centric network models. As bandwidth is a scarce resource, conventional methods for bandwidth allocation are gradually been swapped with artificial intelligence methods for better bandwidth utilization. In this study, the Whale Optimization Algorithm (WOA) was investigated for the provision of optimum allocation of bandwidth in wireless networks. WOA is a recent swarm intelligence method that copies the foraging pattern of humpback whales. In this study, the bandwidth was allocated to real-time users (RTUs) and non-real-time users while reserving bandwidth for future users. The simulations were implemented in MATLAB and the results were discussed in terms of connection probability with a focus on available bandwidth and the numbers of RTUs on the network. From the results, the proposed WOA technique efficiently optimized the bandwidth allocated to users and showed bandwidth management of the small amount of bandwidth.

Indexed Terms- Whale Optimization Algorithm, bandwidth allocation, quality of service, wireless network, connection probability

I. INTRODUCTION

Wireless networks, together with mobile devices, have become indispensable parts of communication aiding the advent of numerous applications and services utilized in industries and organizations. The benefits of wireless networks are indisputable; therefore, continuous development and improvement of algorithms and protocols are necessary for efficient management of the network capacity and functionality [1, 2]. Bandwidth availability is vital for reliable communication in wireless networks. Policies and plans on bandwidth allocation have been made in various wireless communication networks to achieve the full potential of the network [2, 6]. However, the growing numbers of mobile devices and multimedia applications have created competitive networking environment such that bandwidth has become a scarce resource [6]. Real-time users (RTUs) generate more traffic having unique requirements, therefore providing decent Quality of Service (QoS) is a major challenge in wireless networks [3].

This study investigates the Whale Optimization Algorithm (WOA) technique for the delivery of optimal bandwidth allocation in wireless networks. WOA is a swarm-based artificial intelligence (AI) technique that mimics the hunting method of humpback whales [7]. WOA has produced up to 29 benchmark functions and has optimization solutions applied in many engineering areas. Bandwidth allocation, in this context, refers to the distribution or assigning of bandwidth to users in a wireless network. The research simulations have normal bandwidth allocation (NBA) technique and WOA-based allocation technique. The simulation is used to determine the performance analysis for QoS with respect to available bandwidth and the number of RTUs. With the high demand in bandwidth, this research is an effort to effort to optimize the allocation of available bandwidth in wireless networks.

II. BACKGROUND STUDIES

Advancement in wireless technologies has led to the advents of applications, protocols and scenarios that have contributed positively to the endeavours of human activities [2]. Scalable and reliable communication networks are necessary to give support to various aspects of applications, services and transmissions. Some of the recent improvements to aid the efficiency of communication and data delivery across wireless networks include sensor networks, machine-to-machine communications, Internet of things, Millimetre-wave techniques, multiple input multiple output technology, and many more [12]. The mixed networking environments are changing and more focused on user-centric model based on Quality of Experience (QoE), which is determined by QoS provided by the network [3].

The issues of bandwidth availability still linger, thus many studies are gearing towards AI solutions to manage and allocate stingy network resources to give an acceptable level of QoS requirement for applications and services on communication networks [8]. In a bid to optimize the allocation of this limited bandwidth, conventional allocation techniques are been opted for Artificial Intelligence (AI)-based techniques to enable efficient bandwidth allocation in communication networks. Machine language-based algorithms in [8] were proposed to provide optimization agents for effective allocation of resources for the purpose of balancing complexity, performance and to ease problem removal, which reduced problems with resource allocation. In [9], Genetic algorithm (GA) was used to improved network performance and bandwidth allocation during routing as it solved issues related to error rate and network congestion. In [4], differential evolution (DE), particle swarm optimization (PSO) and GA techniques were used to provide optimum bandwidth allocation based on bandwidth reservation scheme to provide satisfactory QoS in a wireless network but DE gave better results. The research in [10] made use of PSO and gauss elimination in wireless sensor network (WSN) for dynamic bandwidth allocation to rectify traffic constraints and nodes' energy limitation. Modified WOA technique in [11] was proposed for optimization of node coverage in WSN, which results in less iteration, higher coverage, improved network ability to search for nodes and increased global search speed. Current research into optimum bandwidth allocation has not included the WOA technique.

III. METHODS

In this study, the method used for bandwidth allocation is adapted from [4] and [5]. Using the bandwidth reservation scheme [5], the assumption is that RTUs and non-real-time users (NRUs) shared the total bandwidth B. The B consists of 3 parts: free bandwidth, bandwidth for real-time traffic and bandwidth for non-real-time traffic. Another assumption is that RTUs have higher bandwidth demand because they generate a huge amount of traffic. When the initially assigned bandwidths are not enough, RTUs are allowed to demand additional bandwidth, which is assigned to them from unused bandwidth reserved for NRUs or unreserved free bandwidth. The RTUs are denied additional bandwidth when NRUs' bandwidth and unreserved free bandwidth are exhausted. The bandwidth allocation is done in a way that free bandwidth for future users joining the network is always available. Since bandwidth is a limited resource for RTUs, WOA method is proposed to optimize bandwidth allocation.

The AI method employed for the optimization of bandwidth allocation is the WOA, a swarm intelligence technique, which mimics the distinctive foraging method of humpback whales called bubble-net attack [7]. In WOA, the prey is possible solutions while the whales are the search agents. The positions of the search agents are updated using the exploration phase and exploitation phase as they move around the prey. In the exploitation phase of WOA, the search agents locate, encircle and feed on prey using either the shrinking encircling approach expressed in (1) or the spiral updating approach expressed in (2). There is 50% chance (p) that the search agents will update their positions using (1) when $p < 0.5$, or (2) when $p > 0.5$. The exploration phase is used to randomly search for prey in a global space and the search agents update their position using random search agents instead of the best search agents as expressed in (3). The flowchart of WOA is shown in fig 1.

$$Y(t+1) = Y^{*}(t) - A \cdot D \quad (1)$$

$$Y(t+1) = D^{\#} \cdot e^{bs} \cdot \cos(2\pi s) + Y^{*}(t) \quad (2)$$

$$Y(t+1) = Y_{R} - A \cdot D \quad (3)$$

Where,
$Y^{*}(t)$ = position of prey at iteration t
$Y(t)$ = current position of search agents at t
Y_R = random position of search agents
D = distance between Y (t) and Y*(t).
C, A = coefficient vectors

b = constant
s = random number between -1 and 1

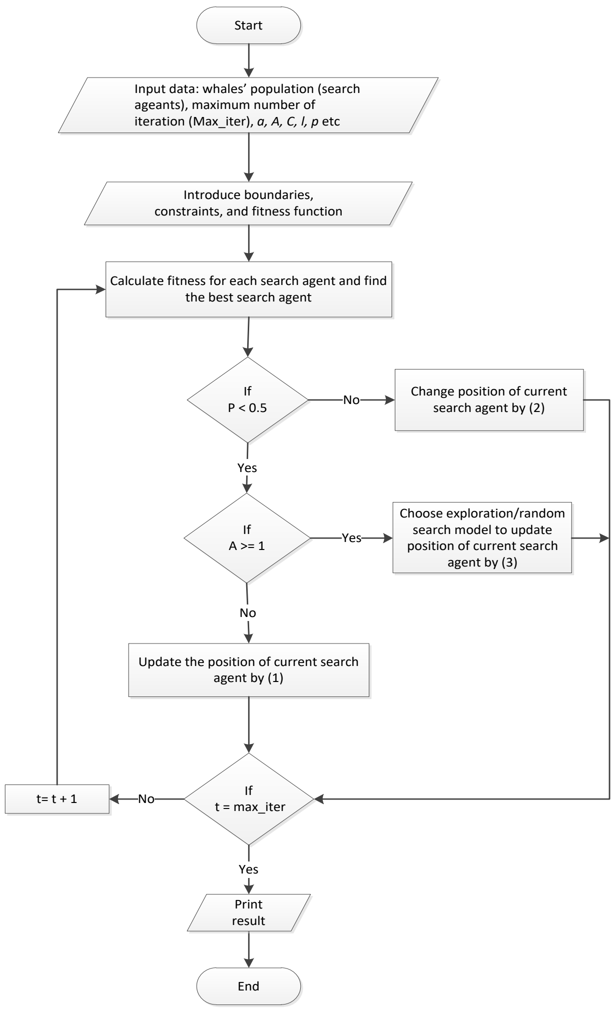

Fig. 1. The flowchart of WOA

IV. SIMULATION PARAMETERS

The objective (fitness) functions for the bandwidth allocation are expressed in (4) and (5). The fitness functions focus on Bandwidth Approval Probability (BAP) and Bandwidth Rejection Probability (BRP). The BAP and BRP indicate the probabilities that the network accepts and rejects the RTUs' requests for additional bandwidth respectively. The simulation results will be discussed in terms of BAP and BRP.For good optimization, results should show BCP > 0.5 and BRP < 0.5.

$$BAP = \frac{B_f + \left(B_H / N_H\right) + \left(B_L / N_L\right)}{B_T} \quad (4)$$

$$BRP = 1 - BAP \quad (5)$$

Where:
B_T = Total bandwidth
B_f = Free bandwidth
B_H = Bandwidth for RTUs
N_H = Number of RTUs
B_L = Bandwidth for NRUs
N_L = Number of NRUs

In this work, the number of RTUs (N_H) and available bandwidth are used as the QoS performance analysis. The number of RTUs and the available bandwidth on a network, among other things, can affect the QoS satisfaction for users. When the number of RTUs increases on a network, the bandwidth demand also increases to extend that the network bandwidth can be insufficient. Therefore the available bandwidth can be considered as a scarce resource that affects the QoS of users.

The simulations were implemented in MATLAB and conducted in two parts: NBA and WOA-based techniques. The results of the simulations are interpreted in terms of BAP and BRP of the RTUs for both techniques. However, in the NBA, the optimization algorithm was not applied. For each N_H, the number of NRUs and maximum available bandwidth (B_i^{max}) were increased at an interval of 1 and 10 respectively. The minimum available bandwidth (B_i^{min}), number of search agents and maximum iteration (Max_iter) were left constant. These parameters are defined in the MATLAB codes. Table 1 shows the key parameters used in the simulations.

Parameter	Value
Search agents size	9
Maximum Iteration	50
Available Bandwidth $[B_i^{min} - B_i^{max}]$	10 – 50
Number of RTUs $[N_H^{min} - N_H^{max}]$	1 – 8
Number of NRUs $[N_L^{min} - N_L^{max}]$	1 – 8
Probability	0.5

Table 1. Key parameters

V. RESULTS AND DISCUSSION

Table 2 shows the average values of BAP and BRP for NBA and WOA-based techniques with respect to available bandwidth. Fig 2 – 3 shows the graphical representation of Table 2 comparing the BAP and BRP for NBA and WOA-based techniques respectively. Table 3 shows the average values of BAP and BRP for NBA and WOA-based techniques with respect to N_H when B_i^{max} = 50 Mbps. Fig 4 - 5 shows the BAP and BRP with focus on N_H for NBA and WOA-based methods respectively. Fig 6 - 8 show the optimization fitness plots at *Max_iter* of 50. The plots indicate the BAP results for 8 RTUs when B_i^{max} = 10, 30 and 50 Mbps respectively. The 'best score obtained' on the graph indicates the BAP value.

From Table 2 and 3, the values of BRP are decreasing and BRP values are increasing as N_H increased from 1 to 8 and available bandwidth increased from 10 to 50 Mbps. It can be seen that the values of BAP and BRP are both within the criteria for good optimization. With respect to available bandwidth, the performance shows the BRP values for WOA method are 38.69% and 47.01% for 10 Mbps and 50Mbps respectively, while for the NBA method, BRP values are 34.71% for 10Mbps and 45.44% for 50Mbps. With respect to N_H, the performance shows the BRP values for WOA method are 36.00% and 50.59% for 1 RTU and 8 RTUs respectively, while for the NBA method, the values are 36.00% for 1 RTU and 45.07% for 8 RTUs. The average BAP and BRP values for the NBA seem to fit the optimization criteria better (see Fig 2 and 3). However, it was observed from the simulations that the NBA method allocated bandwidth to users using the value ofB_i^{max}. But WOA method allocated bandwidth using the B_i^{min} irrespective of what set value for B_i^{max} is. From the results, the network granted more than 50% of additional bandwidth requests from RTUs (i.e. BAP values) using B_i^{max} for NBA method and B_i^{min} for WOA method. Hence, the WOA method gives optimum bandwidth allocation usingB_i^{min}.

In addition, the RTUs did not monopolize the entire bandwidth but NRUs are able to get bandwidth for activities as indicated by the BRP values. The WOA method also provides balance to the bandwidth allocation such that bandwidth are not overused or underused by both users (see Fig 4 and 5). The proposed WOA method can optimally allocate limited bandwidth in wireless networks to users while setting aside some bandwidth for upcoming users in the network.

Available Bandwidth (Mbps)	BAP		BRP	
	NBA	WOA	NBA	WOA
10	0.6529	0.6131	0.3471	0.3869
20	0.6599	0.5598	0.3401	0.4402
30	0.6199	0.5449	0.3801	0.4551
40	0.5581	0.5359	0.4419	0.4641
50	0.5456	0.5299	0.4544	0.4701

Table 2: Average BAP and BRP values for NBA and WOA method with respect to available bandwidth

N_H	NBA		WOA	
	BAP	BRP	BAP	BRP
1	0.6400	0.3600	0.6400	0.3600
2	0.5566	0.4434	0.5566	0.4434
3	0.5289	0.4711	0.5289	0.4711
4	0.5150	0.4850	0.5150	0.4850
5	0.5289	0.4711	0.5066	0.4934
6	0.5262	0.4738	0.5011	0.4989
7	0.5200	0.4800	0.4971	0.5029
8	0.5493	0.4507	0.4941	0.5059

Table 3: Average BAP and BRP values for NBA and WOA with respect to N_H

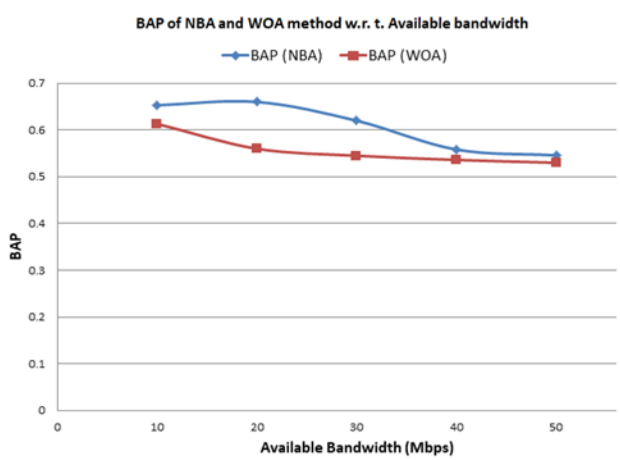

Fig. 2. Comparison of BAP values for NBA and WOA with respect to available bandwidth

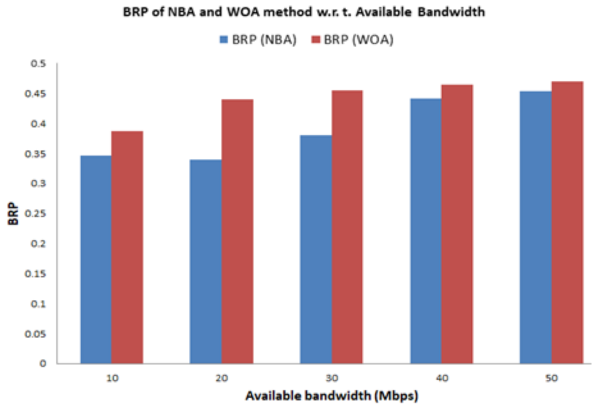

Fig. 3: Comparison of BRP values for NBA and WOA with respect to available bandwidth

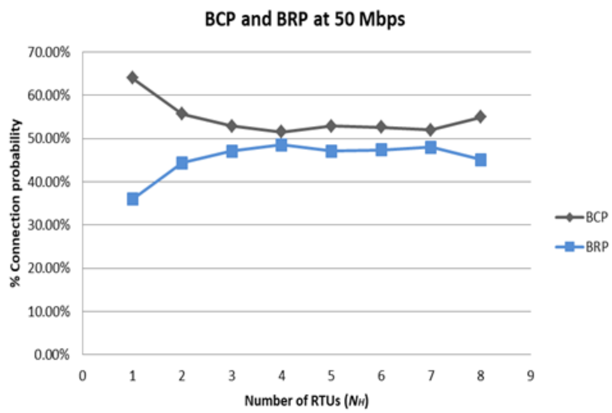

Fig 4: BAP and BRP values for NBA with respect to N_H

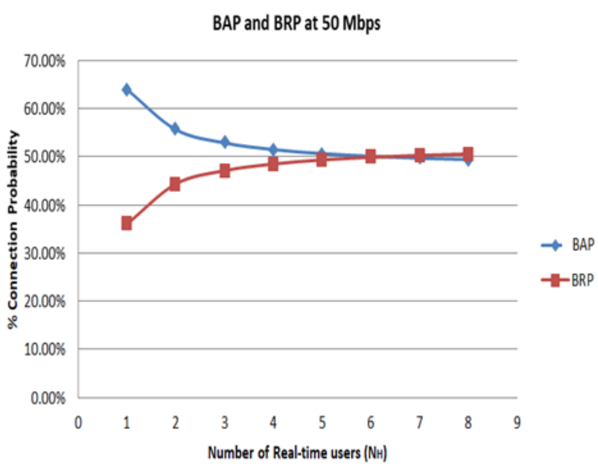

Fig. 5: BAP and BRP values for WOA with respect to N_H

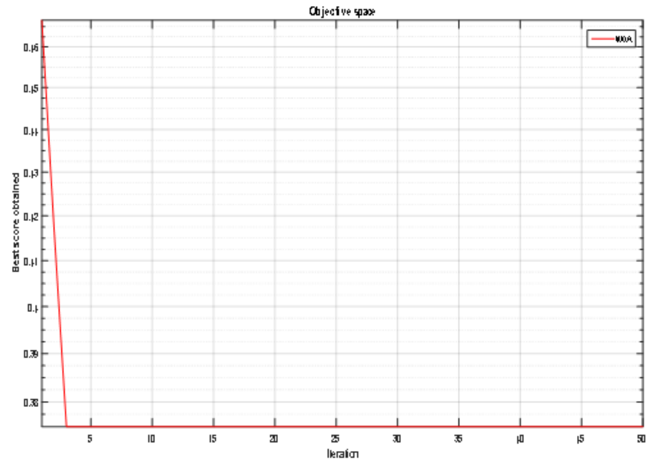

Fig. 6: WOA Fitness response of WOA method for 8 RTUs when *Max_iter* = 50, B_i^{max} = 10Mbps

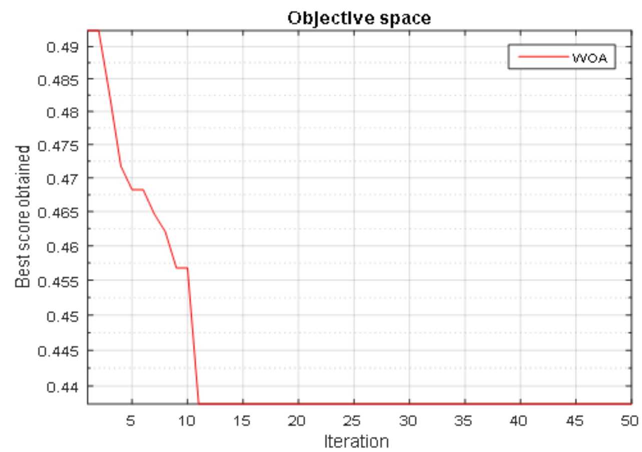

Fig. 7. WOA Fitness response of WOA method for 8 RTUs when *Max_iter* = 50, B_i^{max} = 30Mbps

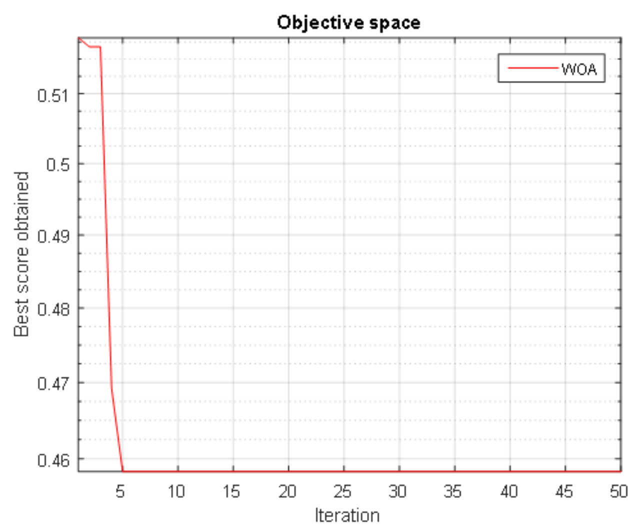

Fig. 8. WOA Fitness response of WOA method for 8 RTUs when Max_iter = 50, B_i^{max} = 50Mbps

VI. CONCLUSION AND RECOMMENDATION

Adequate bandwidth allocation is very significant in a wireless network to achieve a level of QoS that is acceptable especially for RTUs. This paper presented research on WOA technique for optimization of bandwidth allocation in a wireless network. The simulations were implemented in MATLAB. Unlike the NBA method that assigns the maximum available bandwidth to users, the proposed WOA method assigns the minimum available bandwidth to users, regardless of the value of the maximum bandwidth. The WOA method for optimum bandwidth allocation can manage a small amount of bandwidth and balance the distribution among the users in the network while reserving bandwidth for upcoming users. Further study can research the WOA method combined with other AI methods such as PSO, GA, Fish algorithm, and other WOA-variants to enhance bandwidth allocation

REFERENCES

[1] S. Ahmad, R. M. Nadeem, B. Ehsan, M. Ullah and A. B. Siddique, “Wireless networks throughput enhancement using artificial intelligence,” Indian Journal of Science and Technology, vol. 10, no. 26, pp. 1 – 5, 2017.

[2] S. Orike and T. J. Alalibo, “Comparative analysis of computer network protocols in wireless communication technology,” International Journal of Electronics Communication and Computer Engineering, vol. 10, no. 3, pp. 76 – 85, 2019.

[3] F. Farid, S. Shahrestani, and C. Ruan, “Quality of service concerns in wireless and cellular networks,” Communications of the IBIMA, vol. 2013, pp. 1 – 15, 2013

[4] Z. Afzal, P. A. Shah, K. M. Awan, and Zahoor-ur-Rehman, “Optimum bandwidth allocation in wireless networks using differential evolution,” Journal of Ambient Intelligence and Humanized Computing, vol. 10, no. 4, pp. 1401 – 1412, 2019.

[5] J. Chang and H. Chen, "Dynamic-grouping bandwidth reservation scheme for multimedia wireless networks," IEEE Journal on Selected Areas in Communications, vol. 21, no. 10, pp. 1566-1574, 2003

[6] B.I. Bakare and T.J. Alalibo, “Gigabit Fidelity (GI-FI) as future wireless technology in Nigeria,” International Journal of Engineering Science Invention, vol. 7, no. 12, ver.3, pp. 1-6, 2018.

[7] S. Mirjalili and A. Lewis, "The Whale Optimization Algorithm," Advances in Engineering Software, vol. 95, pp. 51-67, 2016.

[8] Y. Shen, Y. Shi, J. Zhang, and K. B. Letaief. (2018) “LORA: Learning to Optimize for Resource Allocation in wireless networks with few training samples,” [online] arXiv preprint arXiv: 1812.07998. Available: https://arxiv.org/abs/1812.07998

[9] P. Akilandeswari, P. Gopikannan, and C. Balasubramanian, “A bandwidth allocation using genetic algorithm to providing solution for optimization problem in wireless mesh network,” International Journal of Innovation and Scientific Research, vol. 25, no. 2, pp. 445 – 456, 2016.

[10] M. L. Umashankar, and M. V. Ramakrishna, “Optimization techniques in wireless sensor networks: A survey,” International Journal of Scientific Research Engineering & Technology, vol 6, no. 7, pp. 704 – 708, 2017.

[11] L. Wang, W. Wu, J. Qi, and Z. Jia, “Wireless sensor network coverage optimization based on whale group algorithm,” Computer Science and Information Systems, vol. 15, no. 3, pp. 569-583, 2018

[12] C. Jiang, H. Zhang, Y. Ren, Z. Han, K. C. Chen, and L. Hanzo, “Machine learning paradigms for next-generation wireless networks,” IEEE Wireless Communications, vol. 24, no. 2, pp. 98-105, 2017.