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Efficient Bandwidth Allocation in Wireless Network using Whale Optimization Algorithm

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ABSTRACT:

Efficient bandwidth allocation is important when providing connection and satisfactory quality of service (QoS) to users in wireless networks. To optimize the available bandwidth, conventional allocation techniques are been opt for Artificial Intelligence (AI)-based techniques to enable automatic and efficient bandwidth allocation to users. This paper presents Whale Optimization Algorithm (WOA) approach for optimum bandwidth allocation in wireless network. WOA, a swarm intelligence AI technique, has been successful in optimization solution for several engineering problems. The allocation was based on bandwidth reservation scheme such that bandwidth is always available for upcoming users after distributing bandwidth to current users. The focus is on bandwidth allocation to real-time traffic to improve performance requirement. The performance analysis was discussed in terms of bandwidth connection probability with consideration to available bandwidth and number of real-time users in the network. The simulation results show WOA-based bandwidth allocation gives good optimization manages the limited available bandwidth of the network.

KEYWORDS: Bandwidth allocation, Quality of service, Swarm intelligence, Whale optimization algorithm, Wireless network.

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1. INTRODUCTION:

Bandwidth allocation is the sharing of bandwidth to users in a network (Afzal *et al.,* 2019; Alalibo *et al.,* 2020). Unlike wired network where users have dedicated wires for connection, wireless network encountered various challenges which include bandwidth availability and its fair allocation to users to get satisfactory quality of service (QoS) requirements for the heterogeneous applications (Farid *et al.*, 2013; Alalibo *et al.,* 2020). Packets generated by these applications must be treated by the network according to specific parameters (Enoch *et al.,* 2019; Alalibo *et al.,* 2020). Limited bandwidth can affect the network performance and the users' experience. Some researchers such as Huang *et al.* (2019), Lin and Sou (2019), He *et al.* (2018), Huang *et al.* (2018), Lei *et al* (2018), Umashankar and Ramakrishna (2017), Chen *et al.* (2017), Ekpenyong and Udoh (2014), and, Afzal *et al.* (2019), in recent years have proposed various AI-based techniques for optimization of limited resource and bandwidth allocation in wireless networks. They performed optimal bandwidth allocation with QoS management in cellular IP network using particle swarm optimization (PSO), Differential evolution (DE) and genetic algorithm (GA) were compared, and DE gave a better result in bandwidth allocation for RTUs by reducing connection/call dropping probability (CDP) to improve QoS requirements. In wireless sensor network, Wang *et al.* (2018) made use of modified WOA with reversed learning to optimize the coverage of nodes.

In this paper, we proposed the Whale Optimization Algorithm (WOA) for optimal bandwidth allocation. The bandwidth allocation scheme conformed to the research of Afzal *et al.* (2019) based on the bandwidth reservation technique proposed by Chang and Chen (2003). Real-time users (RTUs) made use of unutilized available bandwidth, or unused bandwidth reserved for non-real-time user (NRTUs) when the originally assigned bandwidth is insufficient for real-time activities. This process is done in a way that free bandwidth is always available for upcoming users in the network, thus however RTUs are denied additional bandwidth if all

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reserved bandwidth has been assigned to them. The study is an effort for WOA to make the best use of the available bandwidth provided in the wireless network. The performance analysis was carried out in terms of probability of connection for RTUs.

2. MATERIALS AND METHODS:

This section presents the details of the WOA method and the bandwidth allocation technique implemented in MATLAB.

2.1 Whale Optimization Algorithm

Whale Optimization Algorithm (WOA) is a meta-heuristic evolutionary and swarm intelligence method that makes use of the bubble-net foraging behavior of humpback whales that prey on krill or school of small fish close to the sea surface (Mirjalili & Lewis, 2016). The preys indicate the possible solutions and the positions of whales or search agents evolve to discover better positions by means of exploitation and exploration approaches. In the exploitation phase, the whales locate prey and use bubble-net method or spiral encircling method to encircle and feed. There is 50% probability (p) of the whales choosing any of the methods to change position when encircling prey as shown in (1). Exploration phase, expressed in (2), is used by the whales for random search for prey in global space and random whales, not the best whales, are used to update positions.

$$Z(t+1) = \begin{cases} Z^*(t) - A \cdot D & ; if\ p < 0.5 \\ D^{\#} \cdot e^{bq} \cdot \cos(2\pi q) + Z^*(t) ; if\ p \geq 0.5 \end{cases} \quad (1)$$

$$Z(t+1) = Z_R - A \cdot D \quad (2)$$

Where:
$Z^*(t)$ = the location vector of prey (best solution) at iteration t
$Z(t)$ = current position of search agents at t
D = the distance between $Z(t)$ and $Z^*(t)$.
C, A = coefficient vectors
p = a random number between 0 and 1

2.2 Bandwidth Allocation

The proposed scheme was adapted to use bandwidth reservation scheme for bandwidth allocation in Afzal *et al.* (2019) and Chang and Chen (2003). The assumption was that the network users consist of RTUs and NRTUs and the total bandwidth B is distributed for real-time traffic, non-real-time traffic, and free bandwidth. Initially the bandwidth is distributed fairly to the users such that there is reserved bandwidth to new users as shown in (3). For service requirement, the bandwidth limitation is $B_i^{max} \geq B_i \geq B_i^{min}$, where B_i^{max} and B_i^{min}, indicate the maximum and minimum bandwidth allocated to i-th user respectively. If the initial allocated bandwidth is insufficient to perform real-time operations, i.e. $B_{iH} < RQ_B$ then, the network allocates free bandwidth as shown in (4), or reserved non-real-time bandwidth as shown in (5), to the RTUs to satisfy the QoS requirements. This process should be carried out in such a way that there must be a bandwidth reserve for new users who come to the network. However, when it is not possible to get extra bandwidth, then the real-time users' request will be denied.

$$B_T = B_f + \sum_{i=0}^{m} B_{iH} N_{iH} + \sum_{j=0}^{n} B_{jL} N_{jL} \quad (3)$$

$$RQ_B = B_{iH} + \frac{B_f}{N_{iH}} \quad (4)$$

$$RQ_B = B_{iH} + \frac{50\%\ of\ B_L}{N_{iH}} \quad (5)$$

Where:
B_T = Total bandwidth
B_f = Free bandwidth
B_{iH} = Bandwidth for i-th RTU
N_{iH} = Number of RTUs
B_{iL} = Bandwidth for j-th NRTU
N_{jL} = Number of NRTUs
RQ_B = Required bandwidth for real-time task completion

2.3 WOA-Based Bandwidth Allocation

The WOA method for bandwidth allocation was implemented using MATLAB codes. The objective (fitness) function used by WOA for the optimization is shown in (6) and (7). The performance analysis focus on the bandwidth Approval probability (BAP) and bandwidth rejection probability (BRP) which indicate the network to accept and reject additional bandwidth request from RTUs respectively. For good optimization, BAP > 0.5 and BRP < 0.5

$$BAP = \frac{B_f + \left(B_H/_{N_H}\right) + \left(B_L/_{N_L}\right)}{B_T} \quad (6)$$

$$BRP = 1 - BAP \quad (7)$$

Table 1 shows the basic parameters defined for the WOA-based optimization. The values of RTUs, NRTUs and maximum available bandwidth were varied to produce results for the performance analysis.

Table 1: Key Parameters

Parameter	Value
Search agents size	9
Maximum Iteration	100
Total Bandwidth *Bt* **(Mbps)**	60
Available Bandwidth $[B_i^{min} - B_i^{max}]$	10 – 50
Number of RTUs $[N_H^{min} - N_H^{max}]$	1 – 8
Number of NRTUs $[N_L^{min} - N_L^{max}]$	1 – 8
Probability	0.5

3. RESULTS AND DISCUSSION:

The WOA-based bandwidth allocation focuses on managing the available bandwidth between RTUs and NRTUs such that there is always free bandwidth for upcoming users in the network. The RTUs' demands for bandwidth do not overshadow the network. The optimization criteria for performance analysis should show fitness values to be BAP > 0.5 and the BRP < 0.5, with regards to available bandwidth and number of RTUs. The simulated results show that the values of BAP and BRP are affected by the increase in the number of RTUs.

From Figures 1 and 2, the average value of BAP is decreasing while the value of BRP is increasing due to the increasing number of RTUs from 1 to 8 and to the available bandwidth increasing from 10 Mbps to 50Mbps at interval of 10. In both cases, the values of BAP and BRP are within the criteria for good optimization. Real-time activities generate large quantity of data which require bandwidth to complete, therefore, the available bandwidth is considered as limited resources, so it tends to affect the network performance and QoS requirements for users on a network. In the optimization process, the WOA method allocated B_i^{min} to users regardless of the value of B_i^{max}. Therefore The WOA make the best use of B_i^{min} for allocation and it manages limited bandwidth and assign to both users, while some free bandwidth are set aside for users that will join the network.

Figures 3 to 6 show the optimization fitness plots at maximum iteration (Max_iter) of 100. The plots indicate the BAP results for 1 RTU and 8 RTUs when maximum available bandwidth is set at 10 Mbps and 50 Mbps respectively. The 'best score obtained' represents the BAP.

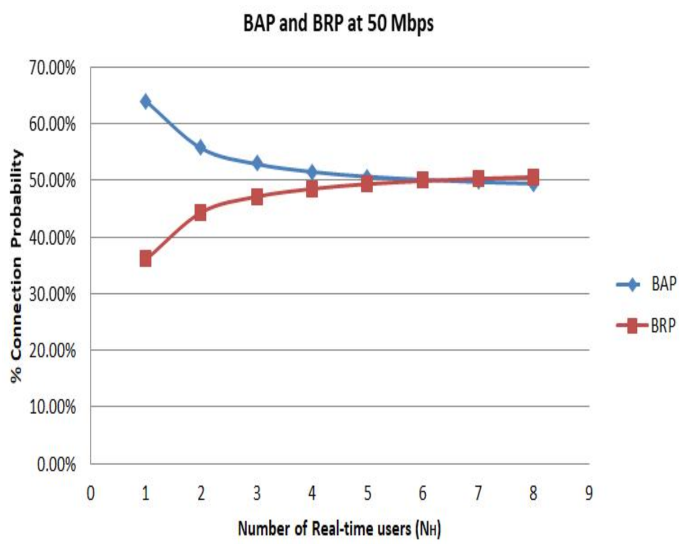

Figure 1: BAP and BRP for optimization focusing on the number of RTUs

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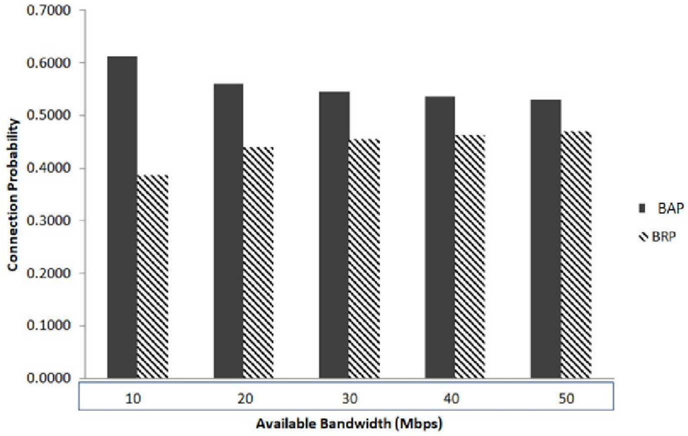

Figure 2: BAP and BRP for optimization focusing on available bandwidth

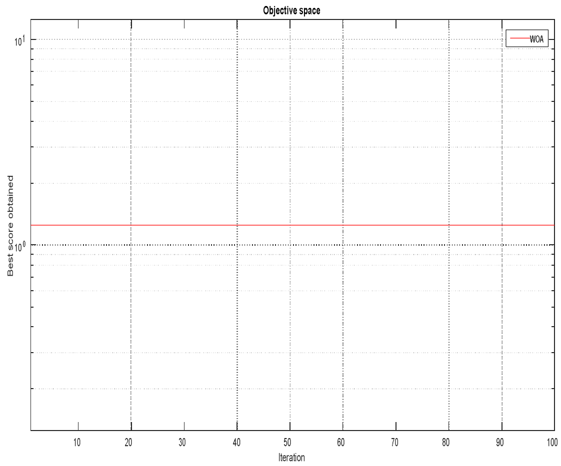

Figure 3: WOA Fitness response with Max_iter of 100, max bandwidth of 10Mbps for 1 RTU

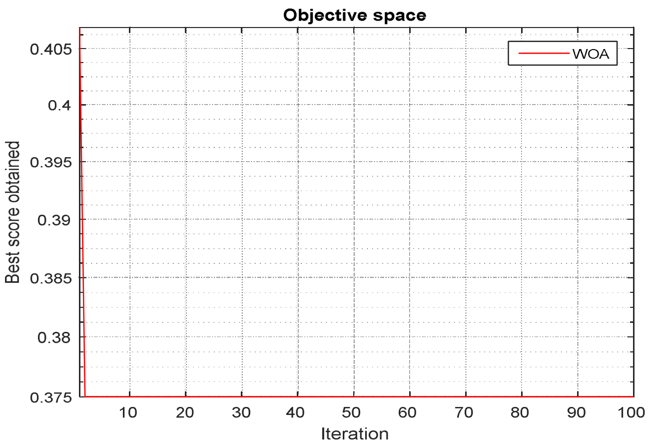

Figure 4: WOA Fitness response with Max_iter of 100, max bandwidth of 10Mbps for 8 RTUs

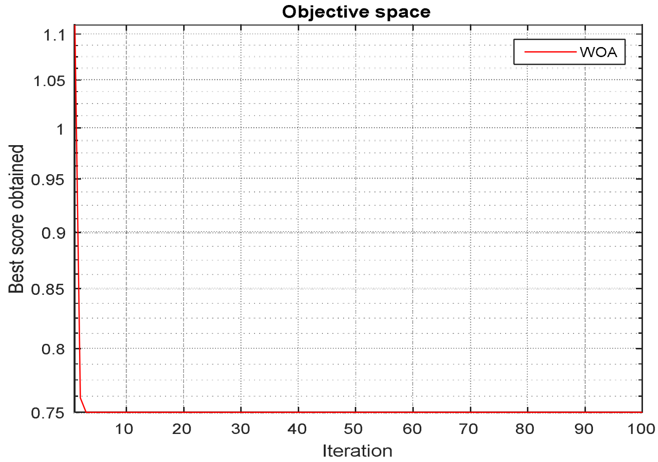

Figure 5: WOA Fitness response with Max_iter of 100, max bandwidth of 50Mbps for 1 RTU

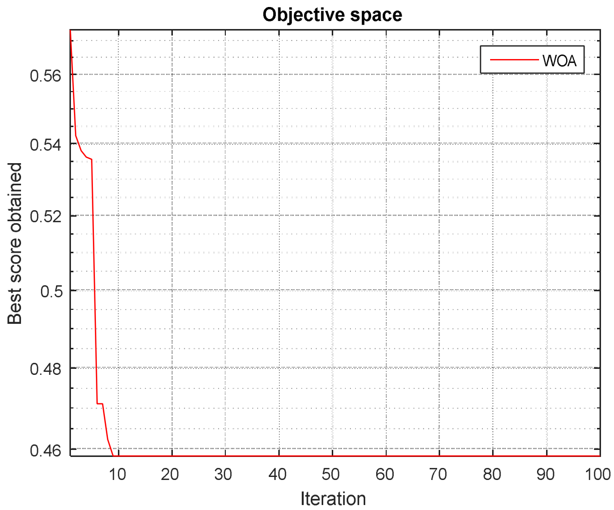

Figure 6: WOA Fitness response with Max_iter of 100, max bandwidth of 50Mbps for 8 RTUs

4. CONCLUSION:

Bandwidth allocation has a vital role in providing adequate connections to users in a wireless network. In the study bandwidth is distributed such that there is balance in bandwidth demand from RTUs and NRTUs while preserving bandwidth for upcoming users. The simulation results for available bandwidth and number of RTUs showed that the BAP and BRP give probability of approximately 0.5. This indicated that proposed WOA-based technique utilized the minimum available bandwidth to provide good optimal bandwidth allocation.

Future study can explore the WOA incorporated with other swarm intelligence method such as Artificial Bee Colony, PSO, Bat algorithm and other variant of WOA to improve bandwidth allocation.

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