WILEY | Hindawi

Research Article

A Network Selection Scheme Based on the Analytic Hierarchy Process for Marine Internet

Liang Zhou [ID],[1] **Sheng-Ming Jiang,**[2] **and Tao Yan** [ID][1]

[1]*Computer Center, Shanghai Sixth People's Hospital, Shanghai 201306, China*
[2]*College of Information Engineering, Shanghai Maritime University, Shanghai 201306, China*

Correspondence should be addressed to Liang Zhou; lzhou@shmeea.cn and Tao Yan; tyan@shmeea.cn

The marine Internet technology has been proposed to exploit abundant communication and network resources available in the ocean in order to provide more cost-effective and handy network services therein. Basically, the marine Internet architecture is based on heterogeneous large-scale dynamic wireless, which consists of different types of networks such as satellite networks, coastline networks, and ship ad-hoc networks etc. These networks are different in terms of networking cost, capacity, and performance as well as availability and reliability. This imposes challenges for network selection, especially when there is no guarantee on the availability and reliability of network resources in oceans, which is different from network selection in terrestrial environments. Thus, this paper studies a network selection scheme by jointly considering the above uncertainty of network resources based on the analytic hierarchy process (AHP) for marine Internet. The proposed scheme is evaluated through a simulation study on the EXata platform, in comparison with the Simple Additive Weighting and the Multiplicative Exponent Weighting schemes. The simulation results show that the proposed scheme yield better performance.

1. Introduction

There are abundant resources in the ocean. Many countries, especially major powers, have made a huge investment on the ocean, and it is necessary to develop marine Internet technology. In [1], a structure of marine Internet is proposed in 2013. As shown in Figure 1, there are multiple access networks may be available for selection, which include coastline networks (CLN), ship ad hoc networks, high-altitude communication platforms (HAP), underwater wireless ad hoc network (UWAN), and satellite networks [1]. How to select the target network in the marine Internet where multiple access networks coexist? The general idea of solving such problems is to propose a mathematical algorithm to assign weights to each index and to calculate the comprehensive utility value of each index corresponding to the candidate network through the utility function. Finally, the best solution with the largest utility value is selected.

The common algorithms for setting weights are Simple Additive Weighting (SAW) [2], Multiplicative Exponent Weighting (MEW) [3, 4], and Technique for Order Prefer-

ence by Similarity to an Ideal Solution (TOPSIS) [5–7]. These algorithms are relatively simple to implement, but not very accurate and have low sensitivity to user preferences. In the marine Internet scene, users are sparsely distributed mainly on ships, users are unevenly distributed, and different users have different preferences. This imposes challenges for network selection, especially when there is no guarantee on the availability and reliability of network resources in oceans, which is different from network selection in terrestrial environments.

So, the access method in the marine Internet is a brand new research topic. Therefore, this paper proposed an algorithm based on the analytic hierarchy process (AHP) [4, 5] to select the target network.

2. Network Selection Model Based on the Analytic Hierarchy Process

The analytic hierarchy process (AHP) is an effective method to solve complex multicriteria decision-making problems [5]. In this paper, we use AHP to deal with access selection
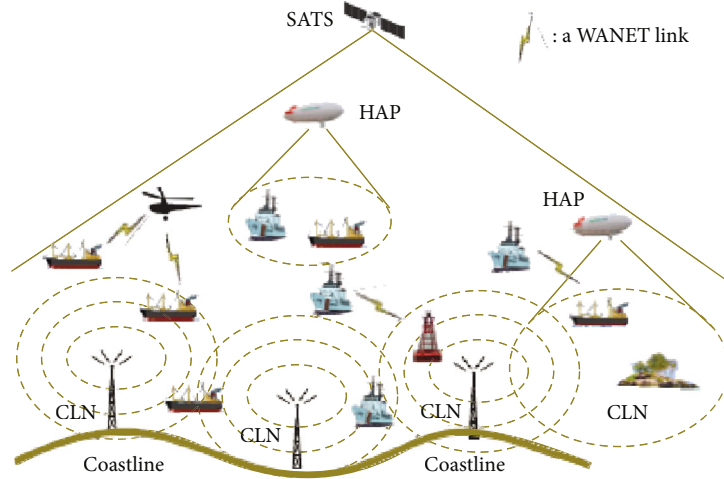
FIGURE 1: A structure of marine Internet [1].

problems in the marine Internet environment. We take several important factors as indicators. Some users pay attention to cost, some focus on network quality, some pursue high bandwidth, and some focus on real-time, and different applications have different requirements of network performance. Considering the above factors, when using the AHP algorithm to establish a hierarchical model, the criteria layer considers user preferences, and the subcriteria layer considers the application requirements.

2.1. Hierarchical Model of Network Selection Based on User Preference. As shown in Figure 2, we propose two modes, QoS (quality of service) priority mode and price priority mode. We select the *QoS* level, the *network available load*, the *price*, and *accessibility* as the network performance indicators in the above modes.

In the QoS priority mode, users prefer an access network with superior performance and are less sensitive to price. Under this strategy, the priority of the three network attribute indicators is QoS level > network load > price. In the price priority mode, the user cares more about the cost and is less sensitive to the network performance. The priority of the three network attribute indicators is price > QoS level > network load. Different from the terrestrial Internet, the accessibility of the network is uncertain. Here, we introduce a parameter of accessibility probability, which is expressed by ρ. the value of ρ should be set according to the specific scenario. As shown in Figure 3, the accessibility probability can be calculated by Eq. (1). Take WANET as example, the accessibility probability is $A1/A0 = 0.8$.

$$\rho = \frac{\text{Coverage area of the ntework}}{\text{Total area of the scene}}. \qquad (1)$$

At first, we establish 2 decision matrices in two modes, set the relative importance of each of the indicators, and the digital product of the diagonal of the matrix is 1, as shown in Table 1.

For ease of description, α is used to indicate the QoS level, β indicates the available load, γ indicates the price, ρ indicates the possibility of access to the network, and the value depends on the experience of the decision maker. It can be adjusted appropriately to suit the specific requirements of the algorithm.

Next, a hierarchical single rank and consistency check is performed on the decision matrix. The maximum eigenvalues of both matrices are 4, and the CR values are all 0, indicating that the setting of the matrix conforms to the consistency requirement. Then, the weights of the indicators in the two modes are obtained and normalized. The calculated values are all four decimal places as shown in Eq. (2).

$$\begin{cases} W_{\text{QoS}} = \{\omega_\alpha, \omega_\beta, \omega_\gamma, \omega_\rho\} = \{0.4082, 0.1020, 0.0816, 0.4082\} \\ W_{\text{Price}} = \{\omega_\alpha, \omega_\beta, \omega_\gamma, \omega_\rho\} = \{0.1538, 0.0769, 0.6154, 0.1538\} \end{cases}. \qquad (2)$$

2.2. QoS Hierarchical Model Based on Service Type. Different applications have different requirements for network service quality. Currently, 3GPP classifies applications into four major categories based on QoS requirements, such as conversation, streaming media, interactive, and back-end services [7]. Therefore, we use the QoS as the target layer of the criterion layer to establish a QoS hierarchical model based on service types. The quasilateral layer is divided into conversational classes (for convenience of description, the following diagrams are represented by T_1), streaming media (T_2), interaction (T_3), and background (T_4). Subordinate sublayers include delay, jitter, packet loss rate, and transmitted rate (represented by α_1, α_2, α_3, α_4) [6, 10–14]. The network performance indicators between the decision matrixes are set as shown in Table 2.

Then, based on the AHP algorithm flow, it is calculated that the maximum eigenvalues corresponding to the decision matrices corresponding to the four service types are 4, 4, 4, and 4, respectively. The four decision matrices pass the consistency check; then, the QoS subitems are calculated. The
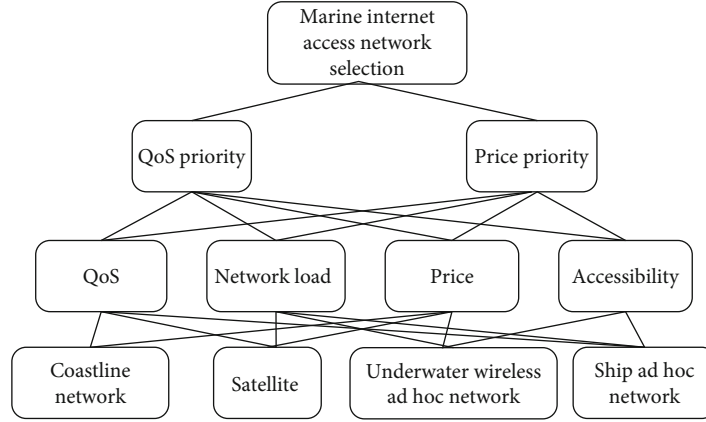
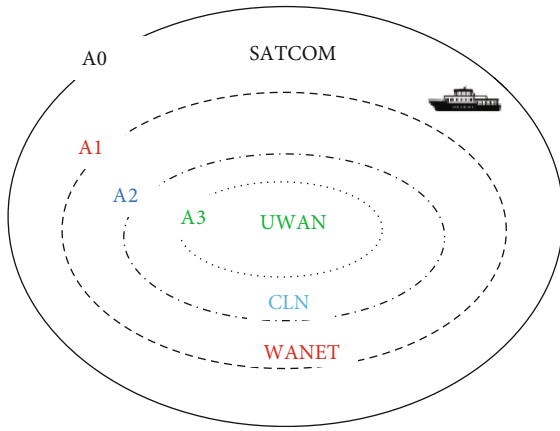Figure 2: The hierarchical model based on the user's preferred access network.

Figure 3: Accessibility of the networks.

Table 1: The decision matrix under different strategies.

(a) QoS priority

QoS priority	α	β	γ	ρ
QoS level (α)	1	4	5	1
Load (β)	1/4	1	5/4	1/4
Price (γ)	1/5	4/5	1	1/5
Accessibility (ρ)	1	4	5	1

(b) Price priority

Price priority	α	β	γ	ρ
QoS level (α)	1	2	1/4	1
Load (β)	1/2	1	1/8	1/2
Price (γ)	4	8	1	4
Accessibility (ρ)	1	2	1/4	1

parameters are based on the weights of different service types. We can see Table 2 for details.

$$W_{\text{QoS\_i}} = \left\{ \omega_{Q_{\alpha 1}}, \omega_{Q_{\alpha 2}}, \omega_{Q_{\alpha 3}}, \omega_{Q_{\alpha 4}} \right\}, \tag{3}$$

where $i \in \{T_1, T_2, T_3, T_4\}$. Among them, the corresponding weight of the parameters is shown in Table 3.

2.3. Ranking the Total Order and Calculating the Weight. After analysis, we draw an overall multilevel hierarchical model based on the network selection problem in Figure 4. In the model, the target layer includes two modes, QoS priority and price priority, which represent different preferences of users; the middle criteria layer is QoS, network available load, and price factor, and the weight of the corresponding target layer is shown in Eq. (2). The subcriterion layer below includes delay, jitter, packet loss rate, and rate, and the same weights for different service types are different. The decision layer is an alternative access network set.

Then, use the single-level sorting weight of each level to calculate the level of total sorting weights. Combining Eqs. (2) and (3), according to the calculation method of hierarchical total ordering, the hierarchical total ordering of each indicator under different user preference patterns and different service types is obtained, i.e., delay (α_1), jitter (α_2), the rate of packet loss (α_3), transmit rate (α_4), and price (γ) are based on weight vector in different situations:

$$W_1 = \left\{ \omega'_{\alpha 1}, \omega'_{\alpha 2}, \omega'_{\alpha 3}, \omega'_{\alpha 4}, \omega'_{\beta}, \omega'_{\gamma}, \omega'_{\rho} \right\}. \tag{4}$$

The weight vectors for different scenes are shown in Eqs. (5) and (6).

QoS priority:

$$\begin{cases} T1 : W_{C1\_T1} = (0.2065\ 0.1033\ 0.0689\ 0.0295\ 0.1020\ 0.0816\ 0.4082) \\ T2 : W_{C1\_T2} = (0.0227\ 0.0907\ 0.1134\ 0.1814\ 0.1020\ 0.0816\ 0.4082) \\ T3 : W_{C1\_T3} = (0.1670\ 0.0186\ 0.1670\ 0.0557\ 0.1020\ 0.0816\ 0.4082) \\ T4 : W_{C1\_T4} = (0.0291\ 0.0291\ 0.1750\ 0.1750\ 0.1020\ 0.0816\ 0.4082) \end{cases}$$

$$\tag{5}$$

Table 2: Judgment matrices based on various application types.

(a) Conversational class-T_1

	α_1	α_2	α_3	α_4
Delay (α_1)	1	2	3	7
Jitter (α_2)	1/2	1	3/2	7/2
Packet loss rate (α_3)	1/3	2/3	1	7/3
Transmitted rate (α_4)	1/7	2/7	3/7	1

(b) Streaming media class-T_2

	α_1	α_2	α_3	α_4
α_1	1	1/4	1/5	1/8
α_2	4	1	4/5	1/2
α_3	5	5/4	1	5/8
α_4	8	2	8/5	1

(c) Interactive class-T_3

	α_1	α_2	α_3	α_4
α_1	1	9	1	3
α_2	1/9	1	1/9	1/3
α_3	1	9	1	3
α_4	1/3	3	1/3	1

(d) Background application-T_4

	α_1	α_2	α_3	α_4
α_1	1	1	1/6	1/6
α_2	1	1	1/6	1/6
α_3	6	6	1	1
α_4	6	6	1	1

Table 3: The QoS (α) weights of different service types.

Type of service	α_1	α_2	α_3	α_4
T_1	0.5060	0.2530	0.1687	0.0723
T_2	0.0556	0.2222	0.2778	0.4444
T_3	0.4091	0.0455	0.4091	0.1364
T_4	0.0714	0.0714	0.4286	0.4286

Price priority:

$$\begin{cases} T1 : W_{C2\_T1} = (0.0778\ 0.0389\ 0.0259\ 0.0111\ 0.0769\ 0.6154\ 0.1538) \\ T2 : W_{C2\_T2} = (0.0086\ 0.0342\ 0.0427\ 0.0683\ 0.0769\ 0.6154\ 0.1538) \\ T3 : W_{C2\_T3} = (0.0629\ 0.0070\ 0.0629\ 0.0210\ 0.0769\ 0.6154\ 0.1538) \\ T4 : W_{C2\_T4} = (0.0110\ 0.0110\ 0.0659\ 0.0659\ 0.0769\ 0.6154\ 0.1538) \end{cases}$$
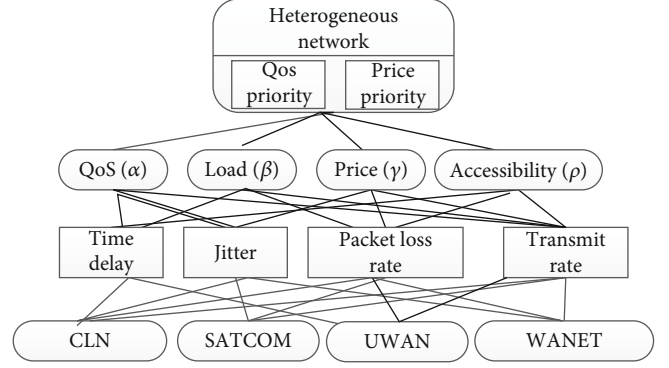(6)

Figure 4: Network selection hierarchy model.

After the layer model is built up, we should first calculate the weight of the single layer and then calculate the total weight of the hierarchy.

3. Simulation and Analysis

In order to verify the performance of the proposed access selection method (AHP), we simulated AHP on the EXata platform [14–18], comparing it with the SAW [19] and MEW algorithm [7, 19–28]. The simulation scenario follows a real ship distribution with 30 ships, and the moving speed of ship follows the random moving model.

The basic parameters of the scene are set as described in Table 4 [6, 14]. CBR is used to simulate the streaming traffic.

Suppose users (ships) move in the overlapped area of 4 types of networks as satellite (SAT), coastline network (CLN), wireless ad hoc network (WANET), and underwater acoustic network (UWAN), seven attributes are considered to trigger a network selection, including end-to-end delay (D), [29] packet jitter (J), packet loss rate (PL), data transmission rate (R), network load (L), price (P), and accessibility probability (A). Table 5 shows the values of such attributes. Some parameters are positive indicators [30–34], and the bigger the better, such as data transmission rate, network load, and accessibility probability; some parameters are negative, and the smaller the better, such as end-to-end delay, packet jitter, packet loss rate, and price; so, these parameters need to be normalized [35–39]. For positive parameters, the normalization formula is

$$z_i = \frac{x_i}{x_{\max}},$$
(7)

where $i = 1,2,3, \cdots n$, $x_{\max}$ is the maximum of x_i. For negative parameters, the normalization formula is

$$z_i = \frac{x_{\min}}{x_i},$$
(8)

where $i = 1,2,3, \cdots n$, $x_{\min}$ is the minimum of x_i.

All normalized parameters are as reported in Table 6. The data can form a matrix $R_{(4\times6)}$; then, according to Eq. (5) and

TABLE 4: Parameters of the scenario.

Simulation parameters	Values
Number of ships	30
Ships' movement model	Random
Speed of ships	6~13 m/s
Simulation time	30 s
Application type	CBR
Data packet size	512 bytes
Maximum number of packets	100

TABLE 5: Network parameters.

Networks	D (ms)	J (ms)	PL (%)	R (mbps)	L (%)	P	A
SAT	689	0.1	0.01	0.42	95	2000	1
CLN	73	0.8	6.5	22	85	3	0.2
WANET	69.5	11	13	10	90	1	0.8
UWAN	75	10	12	0.4	75	2	0.1

TABLE 6: Normalized parameters.

Networks	D	J	PL	R	L	P	A
SAT	0.1009	1	1	0.0191	1	0.0005	1
CLN	0.9521	0.125	0.0015	1	0.8947	0.3333	0.2
WANET	1	0.0091	0.0008	0.4545	0.9474	1	0.8
UWAN	0.9267	0.01	0.0008	0.0182	0.7895	0.5	0.1

TABLE 7: AHP weights in the QoS priority mode.

Networks	T_1	T_2	T_3	T_4
SAT	0.7038	0.7201	0.7138	0.7206
CLN	0.4392	0.4146	0.4174	0.4067
WANET	0.7257	0.6109	0.6974	0.6138
UWAN	0.3551	0.1875	0.3182	0.1927

FIGURE 5: Comparison of throughput.

Eq. (6), the weight of each network (v) in different applications can be calculated as

$$v = R \bullet W. \tag{9}$$

Then, we calculate the weight of each network in 4 different applications in 2 modes as reported in Tables 7 and 8.

As shown in Figure 5, we choose the QoS priority mode, the simulation time and packet size remain the same. With the decrease of the packet transmission rate, the total number of packets is decreasing, and the total throughput of the two links shows a downward trend. After the transmission interval becomes 0.8 seconds, the trend becomes gentle, and the effect of the packet transmission rate on the throughput per unit time gradually decreases. AHP's throughput per unit time is always the highest. This is because AHP chooses the ad hoc network and coastline networks, which have a higher throughput than the satellite one, which is selected by SAW and MEW. Therefore, AHP's data processing capability is superior than those of SAW and MEW.

As shown in Figure 6, the end-to-end delay of the SAW algorithm is always the highest, followed by the MEW, and the AHP is the lowest. Since the packet size and the total number are the same, the transmission distance is the main variable. Although the AHP chooses to go through multihop ship networks, the data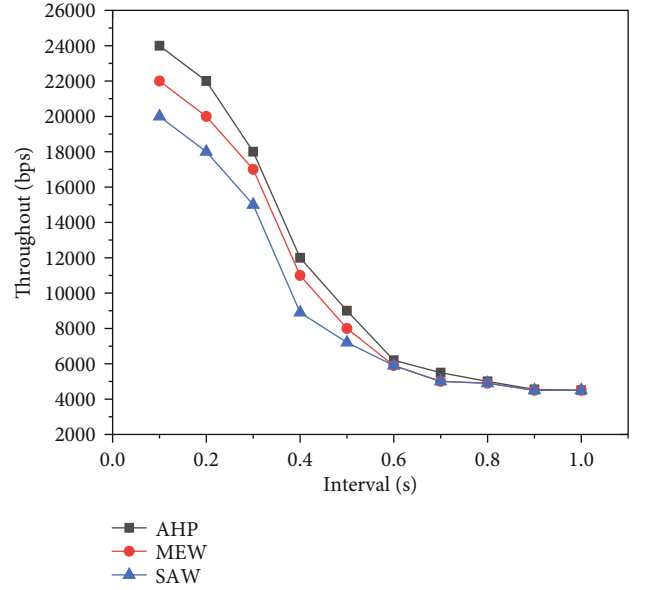 exchange between ships increases the time delay, but the satellite communication systems chosen by SAW and MEW have larger delays. As the data packet transmission rate decreases, the end-to-end delays of SAW remain basically stable, basically maintaining at 0.29 seconds. Because the satellite height is very high, the transmission distance of the SAW algorithm mainly consists of the satellite communication transmission path, and the transmission delays are mainly affected by satellite systems, while satellite communications are characterized by high but stable delays.

Figure 7 shows the jitter of the three algorithms. The packet loss rate of AHP is always higher than that of SAW and MEW. The movement of nodes in the ship's ad hoc network leads to unstable link status, which results in an increasing packet loss rate. Compared with ad hoc and land-based networks, satellite communications have greater stability. With the decrease of the data packet sending rate, the packet loss rate of all three algorithms showed a decreasing trend and reached the minimum when the data sending interval was 1 second. MEW is the highest point of the packet loss rate when the data transmission interval is 0.8 s. The movement of the node causes the network topology to change, causing the original link to be disconnected, resulting in packet loss.

In terms of the delay, jitter, and throughput, the advantages of AHP are higher than SAW and MEW significantly.
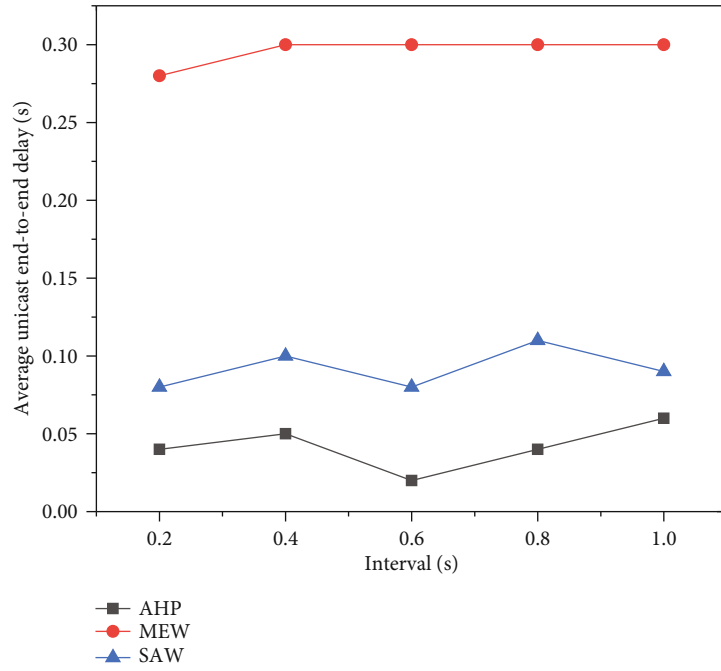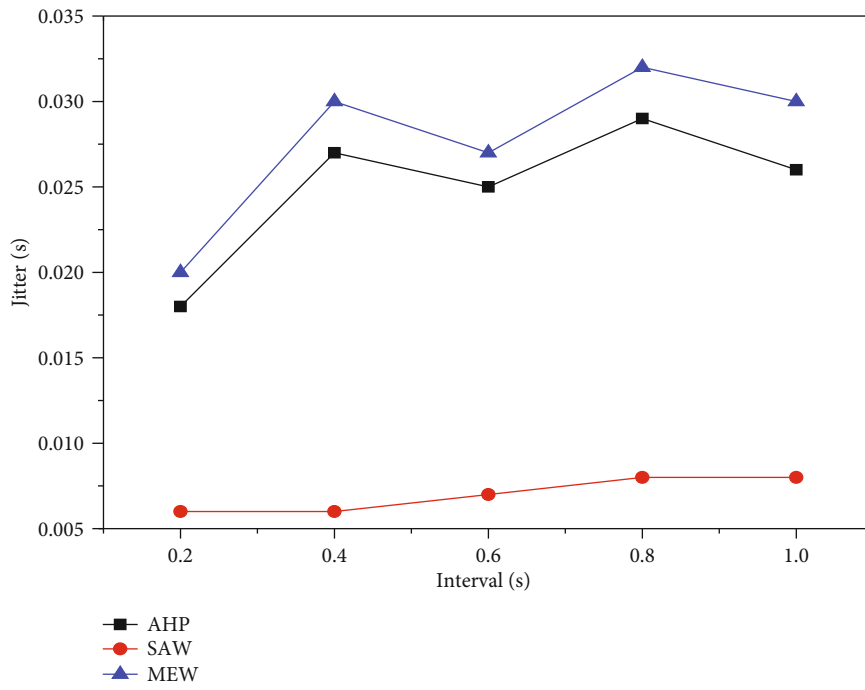
Figure 6: Comparison of end-to-end delay.

Figure 7: Comparison of jitter.

TABLE 8: AHP weights in price priority mode.

Networks	T_1	T_2	T_3	T_4
SAT	0.3039	0.3101	0.3077	0.3103
CLN	0.3947	0.3855	0.3865	0.3825
WANET	0.8945	0.8513	0.8839	0.8524
UWAN	0.4565	0.3934	0.4426	0.3953

4. Conclusion

In order to adapt to the coexistence of multiple access networks in the marine Internet, this paper considers the different preferences [40] of users and the different requirements of different services on network performance. It proposes an access network selection algorithm in marine Internet based on AHP: using two modes of the AHP algorithm to select parameters for the network and import the accessibility probability. Firstly, establish a hierarchical model, sort out the affiliation relationships between the indicators, calculate the utility value of each access network, sort the results, and select the access network with the largest effect value as the handover target. The algorithm is simulated on EXata. Performance analysis shows that the AHP-based algorithm outperforms SAW and MEW in several respects, so AHP can be used in the marine Internet for access network selection.

Data Availability

The data used to support the study are available within the article.

Conflicts of Interest

The author(s) declare(s) that they have no conflicts of interest.

Acknowledgments

References

[1] S. Jiang, "On the marine internet and its potential applications for underwater inter-networking," in *8th ACM International Conference on Underwater Networks and Systems*, 2013.

[2] I. Kaliszewski and D. Podkopaev, "Simple additive weighting—a met model for multiple criteria decision analysis methods," *Expert Systems with Applications*, vol. 54, no. 1, pp. 28–33, 2016.

[3] L. Zhou and S. Jiang, "A composite weight based access network selection algorithm in marine Internet," in *Second IFIP TC 12 International Conference, ICIS 2017*, pp. 435–444, Shanghai, 2017.

[4] L. Zhu, *MEW Algorithm for Vertical Handoff Algorithm in Heterogeneous Wireless Networks*, Nanjing University of Posts and Telecommunications, 2012.

[5] T. L. Saaty, "Decision-making with the AHP: why is the principal eigenvector necessary," *European Journal of Operational Research*, vol. 145, no. 1, pp. 85–91, 2007.

[6] S. Lin, S. Shen, and A. Zhou, "Approach based on TOPSIS and Monte Carlo simulation methods to evaluate lake eutrophication levels," *Water Research*, vol. 87, p. 116437, 2020.

[7] K. Savitha and C. Chandrasekar, "Trusted network selection using SAW and TOPSIS algorithms for heterogeneous wireless networks," *International Journal of Computer Applications*, vol. 26, no. 8, pp. 22–29, 2011.

[8] T. Wakabayashi, K. Itoh, T. Mitamura, and A. Ohuchi, "A framework of an analytic hierarchy process method based on ordinal scale," in *IEEE International Conference on Fuzzy Systems*, pp. 355–360, New Orleans, LA, USA, USA, 1996.

[9] H. L. Jia, *Research on Access Selection and Admission Control in Heterogeneous Wireless Networks*, Zhejiang University, Hangzhou, 2007.

[10] Q. F. Lv, *Research on Network Selection Algorithm Based on Entropy Method and Network Analytic Hierarchy Process*, Inner Mongolia University, Huhehaote, 2013.

[11] V. K. Varma, S. Ramesh, K. D. Wong, M. Barton, G. Hayward, and J. A. Friedhoffer, "Mobility management in integrated UMTS/WLAN networks," in *IEEE International Conference on Communications*, pp. 1048–1053, 2003.

[12] M. Buddhikot, G. Chandranmenon, S. Han, Y. W. Lee, S. Miller, and L. Salgarelli, "Integration of 802.11 and third-generation wireless data networks," *Physica C Superconductivity*, vol. 1, no. s 3–4, pp. 503–512, 2003.

[13] E. Allers, J. J. Wright, K. M. Konwar et al., "Diversity and population structure of marine group a bacteria in the northeast subarctic Pacific Ocean," *The ISME journal*, vol. 7, no. 2, pp. 256–268, 2013.

[14] Telecommunications, "SCALABLE releases new versions of QualNet and EXata modeling and simulation products," *Journal of Engneering*, vol. 1, p. 60, 2017.

[15] J. Wen, *The Improvement Study of MP-OLSP in the Ship Network*, South China University of Technology, Guangzhou, 2014.

[16] S. M. Jiang, *Fostering Marine Internet with Advanced Maritime Radio System Using Spectrums of Cellular Networks*, IEEE ICCS, Shenzhen, China, 2016.

[17] M. H. Yaghmaee and D. A. Adjeroh, "Priority-basedrate controlfor service differentiation and congestion control in wirelessmultimedia sensor networks," *Computer Networks*, vol. 53, no. 11, pp. 1798–1811, 2009.

[18] M. Stemm and R. H. Katz, "Vertical Handoffs in Wireless Overlay Networks," *Mobile Networks and applications*, vol. 3, no. 4, pp. 335–350, 2015.

[19] S. Ajay Biswas, S. Datta, and S. B. G. Majumdar, "Application of Vikor based Taguchi method for multi-response optimization: a case study in submerged arc welding (SAW)," in *Proceeding of the international Conference on Mechanical Engineering 2009 (ICME 2009)*, Dhaka, Bangladesh, 2009.

[20] R. Tawil, G. Pujolle, and O. Salazar, "Vertical handoff decision schemes for the next generation wireless networks," in *Wireless Communications and Networking Conference*, pp. 2789–2792, 2008.

[21] R. Tawil, G. Pujolle, and J. Demerjain, "Distributed handoff decision scheme using MIH function for the fourth generation wireless networks," in *3rd International Conference on Information and Communication Technologies: From Theory to Applications*, pp. 1–6, Damascus, Syria, 2008.

[22] L. Wang and G. S. Kuo, "Mathematical modeling for network selection in heterogeneous wireless networks-a tutorial," *IEEE Communications Surveys & Tutorials*, vol. 15, no. 1, pp. 271–292, 2013.

[23] U. Paul and O. E. Falowo, "Efficient RAT-selection for group calls using intuitionistic fuzzy TOPSIS in heterogeneous wireless networks," *2017 IEEE AFRICON IEEE*, 2017.

[24] F. Bari and V. Leung, "Multi-attribute network selection by iterative TOPSIS for heterogeneous wireless access," in *IEEE Consumer Communication and Networking Conference*, pp. 808–812, Las Vegas, NV, USA, 2007.

[25] F. Bari and V. C. M. Leung, "Automated network selection in a heterogeneous wireless network environment," *IEEE Network*, vol. 21, no. 1, pp. 34–40, 2007.

[26] R. Trestian, O. Ormond, and G. M. Muntean, "Game theory-based network selection: solutions and challenges," *IEEE Communications surveys & tutorials*, vol. 14, no. 4, pp. 1212–1231, 2012.

[27] A. Sgora, P. Christos, and D. D. Vergados, "Network selection in a WiMAX–WiFi environment," *Pervasive and Mobile Computing*, vol. 7, no. 5, pp. 584–594, 2011.

[28] Y. Wei, Y. Hu, and J. Song, "Network selection strategy in heterogeneous multi-access environment," *The Journal of China Universities of Posts and Telecommunications*, vol. 14, Suppl, pp. 16–20, 2007.

[29] E. Stevens-Navarro and V. Wong, "Comparison between vertical handoff decision algorithms for heterogeneous wireless networks," in *2006 IEEE 63rd vehicular technology conference*, pp. 947–951, Melbourne, Vic., Australia, 2006.

[30] Q. Song and A. Jamalipour, "A network selection mechanism for next generation networks," in *IEEE International Conference on Communications*, pp. 1418–1422, Seoul, South Korea, 2005.

[31] M. Drissi and M. Oumsis, "Multi-riteria Vertical handover comparison between Wimax and wifi," *Information*, vol. 6, no. 3, pp. 399–410, 2015.

[32] J. Fu, J. Wu, J. Zhang, L. Ping, and Z. Li, "Novel AHP and GRA based handover decision mechanism in heterogeneous wireless networks," in *International Conference on Information Computing and Applications*, vol. 2, pp. 213–220, Berlin, Heidelberg, 2010.

[33] L. Sheng-mei, P. Su, M. Zheng-kun, M. Qing-min, and X. Ming-hai, "A simple additive weighting vertical handoff algorithm based on SINR and AHP for heterogeneous wireless networks," in *International Conference on Intelligent Computation Technology and Automation ICICTA'2010*, pp. 347–350, Changsha, China, 2010.

[34] M. Lahby, C. Leghris, and A. Adib, "A hybrid approach for network selection in heterogeneous multi-access environments," *The Proceedings of the 4th IFIP International Conference on New Technologies, Mobility and Security (NTMS)*, 2011, pp. 1–5, Paris France, 2011.

[35] A. Sgora, D. Vergados, and P. Chatzimisios, "An access network selection algorithm for heterogeneous wireless environments," in *The IEEE symposium on Computers and Communications*, pp. 890–892, Riccione, Italy, 2010.

[36] L. Sheng-mei, P. Su, and X. Ming-hai, "An improved TOPSIS vertical handoff algorithm for heterogeneous wireless networks," in *The Proceedings of the 12th IEEE International Conference on Communication Technology (ICCT)*, Nanjing, China, 2010.

[37] M. Lahby, C. Leghris, and A. Adib, "An intelligent network selection strategy based on MADM methods in heterogeneous networks," *The International Journal of Wireless and Mobile Networks (IJWMN)*, vol. 4, no. 1, pp. 83–96, 2012.

[38] M. Lahby and A. Adib, "Network selection mechanism by using MAHP/GRA for heterogeneous networks," in *The Proceedings of the Sixth Joint IFIP Wireless and Mobile Networking Conference (WMNC)*, Dubai, United Arab Emirates, 2013.

[39] M. Lahby, C. Leghris, and A. Adib, "An enhanced-TOPSIS based network selection technique for next generation wireless networks," in *The Proceedings of the 20th International Conference on Telecommunications (ICT 2013)*, Casablanca-Morocco, 2013.

[40] I. Chamodrakas and D. Martakos, "A utility-based fuzzy TOPSIS method for energy efficient network selection in heterogeneous wireless networks," *Applied Soft Computing*, vol. 11, no. 4, pp. 3734–3743, 2011.