Service-Adaptive Fuzzy Multi Criteria Based Intelligent Vertical Handover Decision Algorithm for Heterogeneous Wireless Networks

V. Anantha Narayanan, A. Rajeswari and V. Sureshkumar

Abstract The next-generation wireless networks should be interoperable with other communication technologies to offer the best connectivity to the users.

But providing such interworking is a key challenge. Currently, existing decision engines are simple, proprietary, and have no support for profile-based service, and handover is only based on the received signal strength which is not intelligible enough to make handoff decision. The proposed decision algorithm gains intelligence by combining fuzzy logic system, multiple attribute decision making, and context-aware strategies. It synchronizes the user schedule and usage pattern through software agent for making handover at appropriate time. The performance analysis shows that the proposed algorithm efficiently uses the network resources by switching between 3G and Wi-Fi based on the user schedule. It is observed that average handover delay for the experiment is 25–35 ms under good RF conditions, running time of algorithm is around 1 ms, and it reduces the call dropping rate (<0.006), blocking probability (<0.00607), as well as unnecessary handover in heterogeneous networks.

Keywords Vertical handover · Fuzzy logic · Multiple attribute decision making · Context awareness · Software agent · User schedule

---

V.A. Narayanan (✉) · V. Sureshkumar
Department of CSE, Amrita Vishwa Vidyapeetham, Coimbatore, India
e-mail: veluananthu@gmail.com

V. Sureshkumar
e-mail: sureshkumarvcse@gmail.com

A. Rajeswari
Department of ECE, Coimbatore Institute of Technology, Coimbatore, India
e-mail: rajeswari.ece.cit@gmail.com

L.P. Suresh et al. (eds.), *Artificial Intelligence and Evolutionary Algorithms in Engineering Systems*, Advances in Intelligent Systems and Computing 324,
DOI 10.1007/978-81-322-2126-5_33

1 Introduction

A number of proposals have been made for vertical handover decision algorithms. This section reviews most of the algorithms with their significance. Qualcomm [1] designed a connectivity engine that uses dual-stack mobile IP for sending selected IP traffic to particular interface with support of simultaneous 3G and Wi-Fi access. But the decision engine is based on received signal strength which has already been proved as a not an intelligent solution. This bottleneck is addressed in proposed approach using multiple attribute decision-making algorithms. Akyildiz et al. [2] made a survey on mobility management techniques for next-generation IP-based wireless systems. The survey has all protocols to provide mobility management at different layers. Its review deals mostly with the algorithms used for decision making and its significance. This significance of each algorithm helps to fine-tune the proposed algorithm to obtain intelligence to the algorithm. Ning et al. [3] proposed fuzzy clustering-based group vertical handover decision by combining traffic of users and the status of available networks. Fuzzy clustering method assists user to choose best network with reduced handover-blocking probability. Grishaeva and Voropayeva [4] proposed fuzzy logic-based vertical handover decision algorithm to increase the quality of service and transparent mobility.

Even though these methods choose appropriate time for handover, it fails to use context awareness for choosing appropriate network. Buburuzan [5] presented a new handover model derived from the IEEE 802.21 standard which allows the seamless integration of broadcast technologies in a wireless heterogeneous environment. But it leads to major changes in the core architecture of cellular–WLAN architecture. The proposed algorithm applies decision algorithm over the cellular–UMTS integration architecture which does not require any change in the core architecture. Chen et al. [6] proposed a scheme based on bandwidth, dropping probability, and cost parameters as the metrics for the network selection function. These values are placed in target-visiting network to reduce the processing delay. The metrics collected are not stable in nature due to rapidly changing RF conditions. It requires frequent distribution of the distribution of the metrics collected, which increases the network traffic. The proposed algorithm handles this problem by processing the collected information locally in mobile terminal itself.

Kirsal et al. [7] proposed a Markov model for cellular/WLAN integration based on the policies. This model clearly differentiates requests originating in the cellular system, from requests being handed over from WLAN to cellular system. This ensures that calls handed over from WLAN to cellular are not handed over back to the WLAN. But the prediction of user movement of this algorithm makes it complicated to deploy in mobile terminal. The proposed algorithm reduces unnecessary handover and call dropping probability by using multiple attribute decision-making algorithms. Kassar et al. [8] and Mehbodniya et al. [9] presented an idea to eliminate the imprecision of data in the work of Ling et al. [10] by combining fuzzy logic with multiple attribute decision making. It includes received signal strength, QoS parameters, and mobile velocity attributes with analytic hierarchy process as a weighting scheme. This algorithm works fine in indoor environmental conditions, but not for outdoor due to rapidly changing RF conditions. The proposed algorithm handles this problem by taking context-aware strategies in decision-making algorithm.

Ekiz et al. [11] proposed fuzzy logic–analytic hierarchy process-based handover decision algorithm with received signal strength as the handover parameter. But it is proven that the decision only based on the received signal strength is not intelligent enough. This triggers unwanted handover which causes poor quality of service faced by the user. Ekiz et al. [12] proposed vertical handover decision based on the fuzzy inference system and clustering method, and they have shown that their proposed method enables fast handover between heterogeneous network users. But it fails to use context awareness for choosing appropriate network, and it does not adopt based on the service.

The proposed algorithm combines fuzzy logic system with multiple attribute decision making (FMADM) and context-aware strategy for including the current status of the target network and the application network resource requirements into consideration. It synchronizes the user schedule and usage pattern for making handover at appropriate time without any processing to reduce the load on the decision engine. The multiple attributes for making handoff and application network resource requirements are collected using the software agent to reduce the processing time of decision engine.

2 Service-Adaptive FMADM-Based Decision Algorithm

The proposed algorithm (Fig. 1) uses multiple attributes from the network for intelligent vertical handover decision making. These multiple attributes are collected using software agents for reducing the workload on the decision engine. The software agent is a program that acts on behalf of another software program (decision engine) to retrieve and to process information. Once the software agent identifies the new network, it starts to collect the information that is required to make handover decision. Sometimes, the discovered network may offer poor service quality. At that case, processing of information from the discovered network is useless. To avoid such a problem, the software agent checks the received signal strength, service quality, and service/network load on the discovered network. This process helps to avoid the processing of poor-connectivity network. The software agent also collects the usage pattern, preferred network interface of user through learning to make an intelligent solution. Sometimes, the discovered network may have good received signal strength, and service quality.

But there may be a chance that all channels are occupied. If the decision engine makes the handover to that network, then it leads to poor connectivity to the user. This can be avoided by using a software agent that transmits load on the network at every beacon of network. The collected information using software agents, user schedule, and usage pattern are assigned with predefined weights and then passed

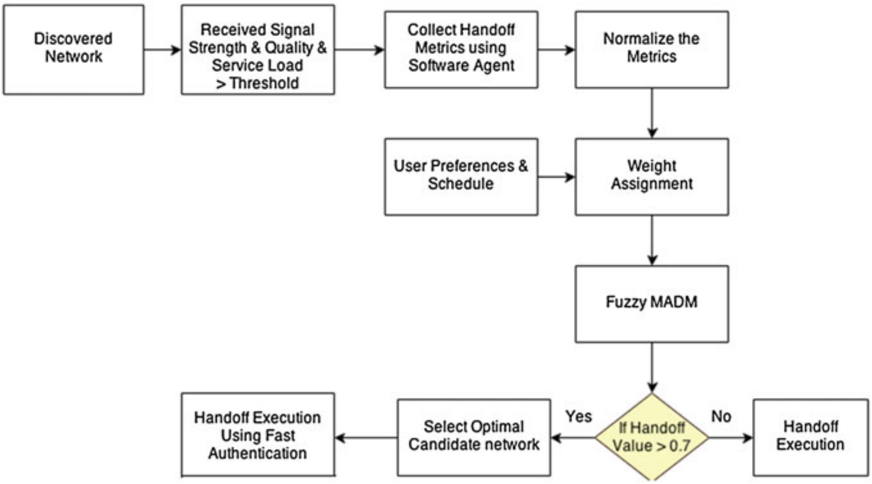


Fig. 1 Working flow of intelligent vertical handoff decision algorithm

into fuzzy-based multiple attribute decision-making algorithm. The collected information from different network is converted into common scale (out of 10 scales), and these collected values are analog in nature. But the analog values cannot be processed by the fuzzy logic systems, and it should be converted into linguistic values (fuzzification/aggregation) on the basis of predetermined membership functions. Then, the linguistic values are fed into a fuzzy inference engine. The inference engine applies IF-THEN rules to obtain fuzzy decision sets (activation). The output fuzzy decision sets include linguistic values like strongly yes, yes, uncertain, no, and strongly no. This output fuzzy sets are combined into a single fuzzy set (accumulation) and defuzzified into analog values using defuzzifier by applying center of gravity method (COG).

COG: $U = \int_{\text{Min}}^{\text{Max}} u\,\mu(u)\mathrm{d}u / \int_{\text{Min}}^{\text{Max}} \mu(u)\mathrm{d}u$, where U, u, p, μ, Min, and Max refers the result of defuzzification, output variable, number of singletons, membership function after accumulation, lower limit for defuzzification, and upper limit for defuzzification, respectively. Handover decision is based on the defuzzified value to choose the appropriate time and the most suitable access network according to user preferences. If the candidate network gets handoff probability greater than 0.7 (optimal value), then decision algorithm applies “make before break handover” and does the regular fast authentication and mobile IP registration. Once the selected network interface becomes active, the decision algorithm seamlessly routes the traffic to the selected interface with minimum packet loss.

3 Results and Analysis

The proposed approach has been implemented in Ubuntu-based machine for measuring accurate efficiency and effectiveness of the proposed algorithm. The decision algorithm uses common parameters to support integration of all high-data rate technologies. But currently, most of the mobile phones and laptop machines have the support for only Wi-Fi and 3G connectivity. So for implementation, only these two technologies have been taken into account.

3.1 Weight Assignment

The proposed algorithm uses signal strength, quality of service, service cost, power requirements, mobile velocity, location information, data rate, network latency, user preferences, and security. This collected information using software agents, user schedule, and usage pattern has to be assigned with predefined weights before passing into fuzzy-based multiple attribute decision-making algorithm. The service from the cellular and WLAN operators is classified into real-time and non-real-time services, and optimal weights are assigned using trial and error method.

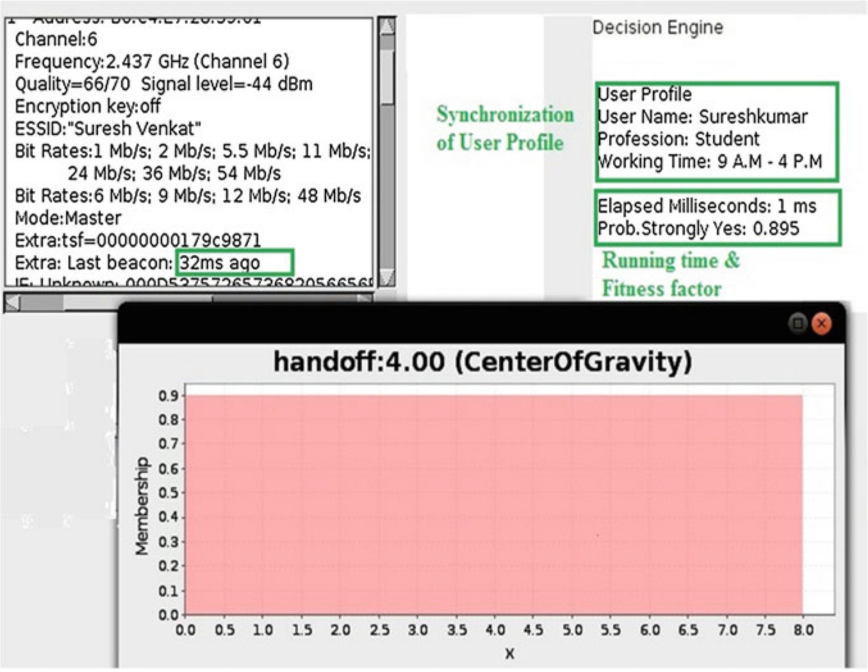
Handoff value (UMTS_Non-Real time) = 0.148 * (Remaining battery capacity) + 0.095 * (Received signal strength) + 0.098 * (Link quality Indication) + 0.092 * (Data rate supported) + 0.082 * (Network latency) + 0.088 * (Service cost) + 0.213 * (Mobile velocity) + 0.222 * (Network coverage) + 0.026 *(Security).

Handoff value (WLAN_Real time) = 0.154 * (Remaining battery capacity) + 0.085 * (Received signal strength) + 0.168 * (Link quality Indication) + 0.126 * (Data rate supported) + 0.092 * (Network latency) + 0.108 * (Service cost) + 0.153 * (Mobile velocity) + 0.082 * (Network coverage) + 0.032 * (Security).

Figure 2 shows the user profile for the student and user preference and probability to make handover to the particular candidate network. In decision engine text area, it clearly shows that running time of this algorithm to make decision is around 1 ms. This running time is relatively less when compared to other approaches.

3.2 Device Interoperability

The proposed approach uses software-defined networking to handle the device interoperability. The decision engine manages the network services through lower level of functionality by decoupling the wireless access technology into control plane and data plane.



```
Channel:6
Frequency:2.437 GHz (Channel 6)
Quality=66/70  Signal level=-44 dBm
Encryption key:off
ESSID:"Suresh Venkat"
Bit Rates:1 Mb/s; 2 Mb/s; 5.5 Mb/s; 11 Mb/s;
          24 Mb/s; 36 Mb/s; 54 Mb/s
Bit Rates:6 Mb/s; 9 Mb/s; 12 Mb/s; 48 Mb/s
Mode:Master
Extra:tsf=00000000179c9871
Extra: Last beacon: 32ms ago
```

User Profile
User Name: Sureshkumar
Profession: Student
Working Time: 9 A.M - 4 P.M

Elapsed Milliseconds: 1 ms
Prob.Strongly Yes: 0.895

Fig. 2 User profile synchronization, running time, and fitness factor

The control plane selects the interface to route the traffic, and the data plane will route the traffic into the selected interface. To support interoperability between devices, most of the data card has been studied and common dialing, redialing, and disconnect features are extracted. These features are coded using scripts and used in the decision engine to obtain handoff metrics independent of devices. This novel approach in the proposed approach helps to support different data cards including Huawei E303C, Huawei E303U, Huawei E3121, Huawei E355S, Huawei E173, Huawei E 303, Huawei E303S, and Reliance CDMA data cards on most of the carriers.

Figure 3 shows that when number of handover increases, the packet loss (<0.022 %) and round trip time (deviation (<2.5 ms)) also increase due to high signaling loads. Call dropping and blocking probability are the most important factor in traffic usage during the handover. The experiment was conducted with total number of 500 calls (Table 1); the calling rate was 20/h, and call holding time was 120 s. It was observed that the total number of blocked call was 3 and dropped call was 2.

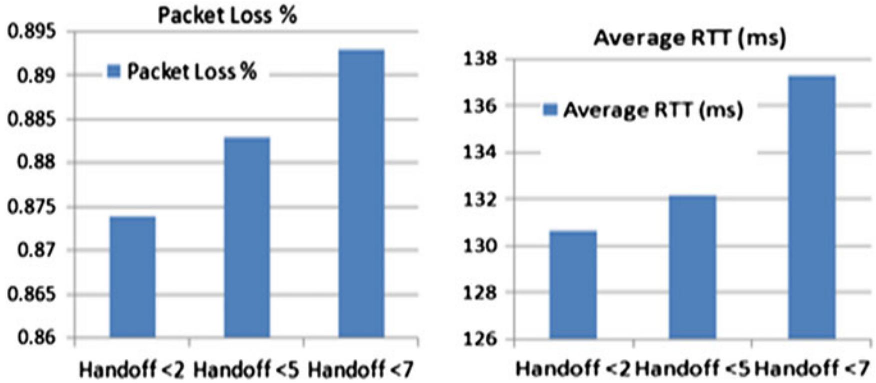


Fig. 3 Packet loss and average round trip time (RTT) analysis

Table 1 Call blocking probability and drop call rate

Number of handoffs	Blocking probability in busy hours with handover	Drop call rate in busy hours with handover
Handoff <3	3/494	3/500
Handoff <5	3/494	3/500
Handoff <7	2/500	4/500

Blocking Probability = (Number of lost calls)/(Total number of offered calls) and Drop call rate = (Number of dropped calls/(No of call attempts), Blocking Probability in busy hours = (3/494) = 0.00607 and Drop call rate in busy hour = (2/500) = 0.004

4 Conclusion

The proposed intelligent vertical handoff decision algorithm uses a software agent to collect and process handoff information to reduce the load on the decision engine, and the user profile is given as the input to the decision engine to reduce the processing time. The reduction in the computational time reduces the handover delay and power required to compute handover decision. The proposed approach uses novel scheme to handle device interoperability by splitting control plane from the data plane. The performance analysis shows that the effectiveness of proposed algorithm in terms of minimal packet loss (<1 %), running time (1 ms), average round trip time (<137 ms), and efficient resource utilization is based on the application requirements, and the proposed approach fulfills QoS requirements of audio, video, and data in terms of packet loss and handover delay during the handover as recommended by Cisco Systems. It is observed that average handover delay for the experiment is 25–35 ms, and the proposed intelligent decision algorithm reduces the call dropping rate (<0.006), call blocking probability (<0.00607), as well as unnecessary handover in heterogeneous networks. The proposed algorithm uses predefined weights to choose the target network. If unsupervised learning algorithm is used to adapt automated weighting, then decision will perform better, and this work has been taken for the future work.

Acknowledgments We are highly indebted to the authorities of Mobile and Wireless Networks Research Laboratory of CSE department of Amrita Vishwa Vidyapeetham for providing necessary hardware resources and test bed for carrying out this research work.

References

1. Qualcomm Technology, 3G/LTE Wi-Fi Offload Framework: Connectivity Engine (CnE) to Manage Inter-System Radio Connections and Applications (2012)
2. I.F. Akyildiz, J. Xie, S. Mohanty, A survey of mobility management in next-generation all-IP-based wireless systems. Wirel. Commun. **11**(4), 16–28 (2004)
3. L. Ning, Z. Wang, Q. Guo, K. Jiang, Fuzzy clustering based group vertical handover decision for heterogeneous wireless networks, in *Wireless Communications and Networking Conference (WCNC)*, *2013 IEEE*, vol. 7(10) (IEEE, 2013), pp. 1231–1236
4. A.D. Grishaeva, V.Y. Voropayeva, Development of the vertical handover algorithm for heterogeneous wireless networks, in *23rd International Crimean Conference on Microwave and Telecommunication Technology*, vol. 8(14) (2013), pp. 480–481
5. T. Buburuzan, Performance evaluation of a handover model for integrating mobile broadcast technologies within heterogeneous networks, in *IEEE 13th International Symposium* (2009), pp. 603–607
6. J. Chen, Z. Wei, Y. Wang, L. Sang, D. Yang, A service-adaptive multi-criteria vertical handover algorithm in heterogeneous wireless networks, in *Personal Indoor and Mobile Radio Communications* (2012), pp. 899–904
7. Y. Kirsal, E. Ever, G. Mapp, O. Gemikonakli, Enhancing the modeling of vertical handover in integrated cellular/WLAN environments, in *Advanced Information Networking and Applications (AINA)* (2013), pp. 924–930
8. M. Kassar, B. Kervella, G. Pujolle, An overview of vertical handover decision strategies in heterogeneous wireless networks. Comput. Commun. **31**(10), 2607–2620 (2008)
9. A. Mehbodniya, F. Kaleem, K.K Yen, F. Adachi, A fuzzy MADM ranking approach for vertical mobility in next generation hybrid networks, in *Ultra Modern Telecommunications and Control Systems and Workshops* (2012), pp. 262–267
10. Y. Ling, B. Yi, Q. Zhu, An improved vertical handover decision algorithm for heterogeneous wireless networks. Wirel. Commun. Netw. Mob. Comput. **1**(3), 12–14 Oct 2008
11. L. Ekiz, C. Lottermann, D. Ohmannm, T. Tran, O. Klemp, C. Wietfeld, C.F. Mecklenbrauker, Potential of cooperative information for vertical handover decision algorithms, in *Intelligent Transportation Systems. 16th International IEEE Conference*, vol. 6(9) (2013), pp. 455–460
12. M.T. Ekiz, M.L. Hossain, M.A. Kabir, M.T. Rahman, S. Salekin, S.S. Alam, A.F. Mitul, Vertical handover decision using fuzzy logic in a heterogeneous environment, in *2013 International Conference on Informatics, Electronics and Vision (ICIEV)*, vol. 17(18) (2013), pp. 1–3