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An improved consumer goods market model-based vertical handoff decision algorithm

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Abstract: Seamless mobility support in a heterogeneous roaming environment is one of several challenging issues for next-generation wireless network, and handoff decision is an important and intelligent part of seamless handoff process. In this paper, an improved game theory-based vertical handoff decision algorithm is presented. The proposed algorithm formulates the relationship between mobile nodes and heterogeneous access networks as a special consumer goods market model, and formulates the relationship among candidate access networks as cooperative game process. The simulation experimental results show that the proposed network selection algorithm is able to achieve the load balancing well, and make the networks obtain larger payoff.

Keywords: heterogeneous wireless networks, game theory, vertical handoff decision, network selection, consumer goods market model

Classification: Wireless circuits and devices

References

[1] J. Cnairan and F. Zhu, "Vertical handoffs in fourth-generation multinetwork environments," *IEEE Wirel. Commun.*, vol. 11, no. 3, pp. 8–15, 2004.

[2] M. Kassar, B. Kervella, and G. Pujolle, "An overview of vertical handover decision strategies in heterogeneous wireless networks," *Comput. Commun.*, vol. 31, no. 10, pp. 2607–2620, 2008.

[3] E. Stevens-Navarro and V. W. S. Wong, "Comparison between vertical handoff decision algorithms for heterogeneous wireless networks," *Proc. Veh. Technol. Conf.*, Australia, pp. 947–951, 2006.

[4] E. Stevens-Navarro, Y.-X. Lin, and V. W. S. Wong, "An mdp-based vertical handoff decision algorithm for heterogeneous wireless networks," *IEEE Trans. Veh. Technol.*, vol. 57, no. 2, pp. 1243–1254, 2008.

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[5] D. Niyato and E. Hossain, "Dynamics of network selection in heterogeneous wireless networks: An evolutionary game approach," *IEEE Trans. Veh. Technol.*, vol. 58, no. 4, pp. 2008–2017, 2009.
[6] J. Antoniou and A. Pitsillides, "4g converged environment: Modeling network selection as a game," *Proc. Mob. Wirel. Commun. Summit*, Budapest, pp. 1–5, 2007.
[7] J. Antoniou, V. Papadopoulou, V. Vassiliou, and A. Pitsillides, "Cooperative user-network interactions in next generation communication networks," *Comput. Netw.*, vol. 54, no. 13, pp. 2239–2255, 2010.
[8] X.-W. Liu, X.-M. Fang, X. Chen, and X.-S. Peng, "A bidding model an cooperative game-based vertical handoff decision algorithm," *J. Netw. Comput. Appl.*, vol. 34, no. 4, pp. 1263–1271, 2011.
[9] E. Altman, T. Boulogne, R. Elazouzi, T. Jimenez, and L. Wynter, "A survey on networking games in telecommunications," *Comput. Oper. Res.*, vol. 33, no. 2, pp. 286–311, 2006.
[10] M. Felegyhazi and J.-P. Hubaux, "Game theory in wireless networks: A tutorial," Switzerland, 2006.
[11] D. E. Charilas and A. D. Panagopoulos, "A survey on game theory applications in wireless networks," *Comput. Netw.*, vol. 54, no. 18, pp. 3421–3430, 2010.
[12] W.-Y. Zhang, *Game theory and information economics*, Shanghai People's Publishing House, 1996.
[13] Z.-S. Xu, "An overview of methods for determining owa weights," *Int. J. Intell. Syst.*, vol. 20, no. 8, pp. 843–865, 2005.

1 Introduction

The next-generation wireless network is also envisioned as a convergence of different wireless networks such as Wireless Fidelity (Wi-Fi), Worldwide Inter operability for Microwave Access (WiMAX) and Universal Mobile Telecommunications System (UMTS) [1]. While Mobile Nodes (MNs) roam between heterogeneous access networks, vertical handoff may take place. Handoff decision is an important and intelligent part of seamless handoff process, which is used to determine whether and how to perform the handoff by evaluating and selecting the most appropriate access network [2].

Traditional handoff decision algorithms are usually based on the received signal strength (RSS). However, in a heterogeneous roaming environment, mobile nodes will benefit from different network characteristics that cannot be compared directly. Simple additive weighting (SAW) is one of the multiple attribute decision making (MADM) algorithms which are used in handoff decision [3]. Game theory is an effective mathematical theory to deal with models for studying interaction among decision makers [4, 5]. In [6, 7], the network selection is modeled as a non-cooperative game between access networks to maximize their payoffs. In [8], the competition between mobile nodes and heterogeneous access networks is formulated as a multi-tenderee bidding model; at the same time, the competition among heterogeneous access networks is formulated as a cooperative game process to seek for larger total payoff. However, it requires all mobile nodes simultaneously to move

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into the overlap coverage areas of heterogeneous access networks. In addition, it cannot ensure that every network could obtain larger payoff. To further improve the universal performance of the proposed algorithm in [8], an improved consumer goods market model-based vertical handoff decision algorithm is presented in this paper.

The rest of the paper is organized as follows. An improved consumer goods market model-based vertical handoff decision algorithm is discussed in section 2. Section 3 shows experimental studies for verifying the proposed handoff decision algorithm. Section 4 provides conclusion.

2 The handover decision algorithm

Generally, in heterogeneous networks environment, multiple mobile nodes are often sequential, not simultaneous, within the overlap coverage areas of multiple WiMAX BSs and multiple Wi-Fi Access Points (APs). There exists the competition between MNs and multiple heterogeneous access networks which might be formulated as a special consumer goods market model, and we define it as a game $G = \{P, S, U\}$, where P is the set of players, S corresponds to the strategy space of players, U expresses the benefit set of players [9, 10]. In this game, we have $U = \{u_1(s), u_2(s)\}$, where $u_1(s)$ denotes the payoff set of all MNs and $u_2(s)$ denotes the payoff set of all access networks on the strategy profile s. Furthermore, we define $u_1(s) = \{u_{11}(s), u_{12}(s), \cdots, u_{1n}(s)\}$, where $u_{1i}(s), i = 1, 2, \cdots, n$, means the payoff of MN i on the strategy profile s. If a MN has no request to access a network, then the payoff of the MN is equal to 0. If a MN selects a target network and requests accessing it, then the payoff function of the MN is a mixed set of ordered weighted operator, which is defined as follows.

$$u_{1i}(s) = \prod_{j=1}^{n} d_j^{w_j} \tag{1}$$

where w_j is the weight value of position obtained by the weighting method of the normal distribution [11], d_j is the jth largest data in a set $\{n\psi_1 a_1, n\psi_2 a_2, \cdots, n\psi_n a_n\}$, n is a balance factor, ψ_j is the weight value of the nth property value obtained by analytic hierarchy process (AHP) algorithm, a_n is the nth property value. The payoff function of all heterogeneous access networks is defined as follows.

$$u_2(s) = u_2'(s) + \triangle u_2'(s) \tag{2}$$

where $u_2'(s)$ is the current payoff of all access networks, $\triangle u_2'(s)$ is the newly added payoff of all access networks while one of the networks is selected by a MN and connected to, which is defined as

$$\triangle u_2'(s) = V \times S \times \frac{B_{available}}{B_{required}} \tag{3}$$

where V is a variable and denotes the expense paid by the newly accessed MN, B means bandwidth, the motivating factor $\frac{B_{available}}{B_{required}}$ indicates the capability that the access networks could meet the MNs' bandwidth requirements. S is a conditional value. If $((\frac{B_{available}}{B_{required}} > 1)\&(\frac{D_{available}}{D_{required}} < 1)\&(\frac{J_{available}}{J_{required}} <$

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$1)\&(\frac{L_{available}}{L_{required}} < 1))$ is true, S is equal to 1, otherwise, S is equal to 0, where D denotes network delay, J denotes network jitter, L denotes packet loss rate, $\frac{D_{available}}{D_{required}}$, $\frac{J_{available}}{J_{required}}$ and $\frac{L_{available}}{L_{required}}$ indicate the capabilities that the access networks could meet the MNs' delay, jitter and packet loss rate requirements, respectively.

A consumer goods market model usually consists in some number of repetitions of some base game (called a stage game) [12]. In each stage game, we should consider not only the game between the MNs and the networks, but also the cooperative game among the candidate networks. In each stage game, each network as a game player acts cooperatively in order to seek for larger total payoff, and tries to achieve load balancing well, which depends on the differences of the network utility between any two of the players [8]. If any one is larger than a value ξ defined by experience in a stage game, or the equilibrium is not achieved, then the next stage game continues to be played, as well as all players cooperatively adjust their strategies in the direction of the agreement. The details on how to adjust the strategies in the direction of the agreement is described as follows. According to the consumer goods market model [13], the game player with higher network utility will increase the price in order to decrease the chance of being selected as target network by mobile nodes; on the contrary, the player with lower network utility will decrease the price in order to increase the probability of being selected as target network by mobile nodes. In this way, networks finally achieve the load balancing after finite stages, and obtain larger total payoff.

3 Experimental results

Our experimental environment is two typical handoff scenarios [8]. According to ITU-G.114, the QoS parameter values of various traffic classes are shown in Table I.

Table I. QoS parameter values of various traffic classes

Parameter	Traffic Class	Value
Bandwidth	VoIP	21 Kbps~106 Kbps
	Video	120% bandwidth of one video stream
Delay	VoIP	<150 ms
	Video	<200~300 ms
Jitter	VoIP	< 30 ms
	Video	< 30 ms
Loss Ratio	VoIP	<1%
	Video	<1%

We compare the proposed algorithm with SAW in network utility. In SAW, the network utilities of WiMAX BS, AP-1, AP-2 and AP-3 are 0.92012, 0.87133, 0.87782 and 0.86323. While with the proposed algorithm, they are 0.88066, 0.88666, 0.88446 and 0.87927 that are more approximate. Furthermore, the standard deviation of it with the proposed algorithm is only 0.00294, much smaller than 0.01270 with SAW.

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If non-cooperative manner is used among candidate access networks, each network could choose selfishly the best strategy to maximize its own payoff. On the contrary, if cooperative manner proposed in this paper is used among candidate access networks and suppose the game is repeated enough times, each network could select different strategies and sacrifice the immediate benefits for obtaining long-term larger benefits. Moreover, a quasi-cooperative manner is designed in which cooperation is only used among part of candidate access networks (i.e. WiMAX BS, AP-1 and AP-2). To compare the difference of the long-term benefits brought to the networks by the three manners, suppose that 50 MNs with different traffic classes are sequentially moving into the overlap coverage areas of a WiMAX BS and three Wi-Fi APs in three times. Each time the number of mobile nodes is 20, 20 and 10, respectively. After finite stages (In this example, it lasts 40 rounds or times), networks finally achieve the network load balancing. The standard deviations of network utilities with non-cooperative and quasi-cooperative manner are 0.01454 and 0.00449, respectively; however, that with the proposed algorithm is only 0.00294. It further implies that the traffic load could be equitably distributed across available APs and BSs, and the heterogeneous wireless networks could provide better sustainable services to MNs.

Each network payoff with cooperative, non-cooperative and quasi-cooperative manner, respectively, is shown in Fig. 1. When the first 20 MNs sequentially move into the overlap coverage areas of a WiMAX BS and three Wi-Fi APs, some networks with non-cooperative manner, such as WiMAX BS and AP-1, could obtain larger payoff than them with cooperative or quasi-cooperative manner. However, after the 32th MN moves into the overlap coverage areas and accesses a network, each network with cooperative manner could obtain larger payoff than it with non-cooperative or quasi-cooperative manner. It further implies that each network could select different strategies and sacrifice the immediate benefits for obtaining long-term larger benefits by cooperative manner.

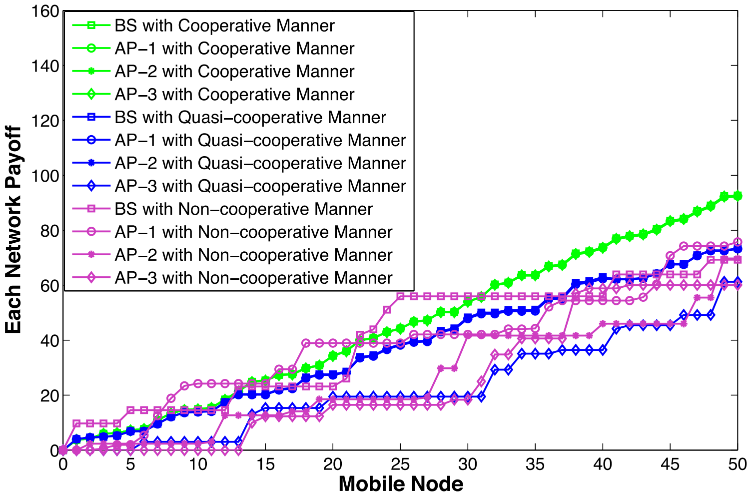

Fig. 1. Each network payoff with cooperative, non-cooperative and quasi-cooperative manner

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The total payoffs of networks with quasi-cooperative, cooperative, and non-cooperative manner, respectively, are shown in Fig. 2. As the amount of MNs that move into the overlap coverage areas of heterogeneous networks and access networks increases, there is a gradual growth for the network total payoff, regardless of whether we use cooperative manner or not. However, the growth rate of network total payoff with cooperative manner is greater than that with other manners.

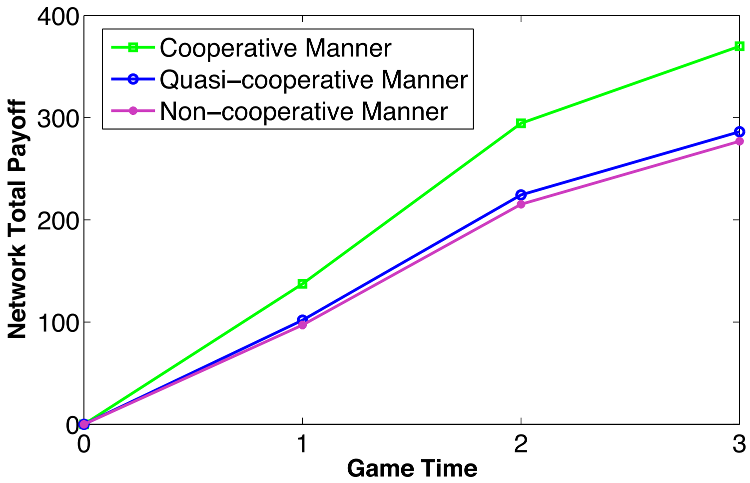

Fig. 2. Network total payoffs with cooperative, non-cooperative and quasi-cooperative manner

4 Conclusion

When mobile nodes move into the overlap coverage areas of heterogeneous access networks, how to select an appropriate network would be still a clear challenge. Because game theory is an effective mathematical theory to deal with models for studying interaction among decision makers, the game between mobile nodes and heterogeneous access networks could be formulated as a special consumer goods market model, and the game among heterogeneous access networks could be formulated as a cooperative game process. The experimental results show that the proposed algorithm can not only achieve load balancing well, but also make every network obtain larger payoff.

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