

A New Economic History-Based Algorithm for Network Selection in the Heterogeneous Wireless Networks

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Abstract

Nowadays, with the development of technology in the telecommunications systems, next generation networks in a heterogeneous environment with different technologies such as WiFi, WiMax and UMTS are developed and integrated schemes can provide different class of services for users, anywhere and anytime. In the networks, network selection as an important mechanism affects in heterogeneous network performance in term of users' quality of service and efficiency. In this paper, an autonomic network selection algorithm is proposed based on utility function included quality of service (QoS) metrics, power consumption and price utilizing past experience of user's delivered service. Since, different networks in the studied environment have a different dynamic pricing policy, such as discount-based usage, residence time of the users according to network coverage, user velocity and user preference are considered in the proposed algorithm as a network selection criteria to maximize user's utility. Simulation results show that proposed algorithm improves obtained utility by users compared with other method and performance parameter number of handoffs decreases.

Keywords: Handoff, Heterogeneous Network, Mobility Management, Reputation

1. Introduction

The fourth generation heterogeneous mobile communication network refers to a complex hierarchical system, including different radio access technologies such as Long Term Evolution (LTE), UMTS, IEEE 802.16 WiMAX, IEEE 802.11 WiFi compatible systems¹⁻³. In this heterogeneous environment, it is expected which always best connected (ABC) concept is supported for users as a most important challenges. To provide best connected features for users, mobility management should be considered and studied. Mobility management has two parts of location management and handoff management⁴. In the location management, the location of the user is updated and its packets are forwarded to its new location. In the handoff management, the user can connect to different networks during service reception, seamlessly, while keeping the active connection.

Handoff management has three elements containing algorithms, decision metrics and execution processes which enable users to receive services while moving in the networks. Handover process can be done in three phases: Handoff initiation, Network election, Handoff execution.

In the handoff initiation phase, handoff is triggered according to different conditions such as received signal strength or quality of service of running application. In the network selection phase, the decision is made to find the best network among candidate networks based on context information e.g. user, network and terminal conditions and requirements. After the proper network is selected, handoff execution phase is activated and interface reconfiguration and relating signaling to connect to a new network is initiated.

Different algorithms were proposed for decision making in the handoff management. The recent methods

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during recent years can be classified in the four categories: RSS-Based, cost-function based, multiple decision criteria based, and intelligent based algorithms. In the RSS-based algorithms, decision making in the handoff process is done related to received signal strength. In these algorithms, the network with higher signal strength is selected among available networks in the coverage area⁵. The position of users related to network location can be obtained from RSS of access point which may be used in the handover process as decision metric. For example RSS I used to find locations which networks are overlapped and found optimum time for handoff according to arrival angle to the network^{6,7}.

In the cost function based algorithms, a function presenting handoff cost is defined according to effective parameters in the handoff performance such as quality of service metrics (bandwidth, delay and jitter) and service cost. In these algorithms, the goal is to find networks which minimize the cost function. The output of cost function defines which network is better to be selected⁸.

Multi attribute decision making (MADM) based methods refer to making preference decisions which were used for network selection according to different context metrics. They can be used in the cases that different criteria is available in the decision making for different alternatives. Some MADM algorithms which were applied for network selection are analytic hierarchy process (AHP), simple additive weighting (SAW), and technique for order preference by similarity to ideal solution (TOPSIS)⁹. However, MADM methods suffer from abnormality. It means that the ranking of candidate networks changes when low ranking alternatives are removed from the candidate list, which can make the selection problem inefficient¹⁰⁻¹². Intelligent based algorithms¹³ were used to deal with imprecise measurement of handoff parameters such as fuzzy based algorithms.

By considering future conditions in the decision algorithms as reputation, performance of handoff can be improved. Reputation was used in the different scenarios and environment such as ad-hoc networks and peer-to-peer networks which users have interaction with each other¹⁴. Also, some works have been studied in the wireless networks that reputation is considered as level of service delivery to users¹⁵, generally, or based on cooperative game theory¹⁶.

Based on our knowledge, in none of previous works, reputation concept is considered for network selection in the autonomic structure which environment includes

various networks with different pricing policies. In this paper, an autonomic network selection algorithm based on users' experience is explored in such that decision making is done related to future of network condition and proposed user's utility function in the heterogeneous network which pricing policies may change dynamically. In the proposed utility function, service quality, energy consumption and price according to user's preference for network selection are considered. Also, since pricing is dynamic in the network, resident time of user in the network is considered for selecting network which affects monetary cost of a service and results an increasing user utility.

The remaining of paper is organized as follow: in the next section, system model is described. Section III describes autonomic concept and algorithm for handoff management. In this section, network selection algorithm, reputation concept and effect of dynamic pricing in the utility function are presented. Then, in the section IV, simulation results and comparison are discussed. Finally, a conclusion is presented in section V.

2. System Model

It is assumed that there are various networks with different technologies which are at the disposal of multiple operators to provide different classes of service for the users. In the heterogeneous environment with the coverage of A , H UMTS cellular networks, M Wireless local area networks are placed which are managed by k different operators ($k \in \{1, 2, \dots, K\}$) as shown in Figure 1. The UMTS and WLAN networks are represented by UMTSh and WLANm respectively; where h ($h \in \{1, 2, \dots, M\}$) indicate the network indexes.

Here, it has been assumed that the UMTSs cover the whole area. Other networks have own coverage levels, which have been randomly placed throughout the area. Wi-Fi and the Universal Mobile Telecommunications System (UMTS) are in a loosely coupled manner. Each network is connected to an IP-core network, directly, which has different characteristics such as QoS, price policy.

It is assumed that users are mobile with multiple interfaces and can receive service from different networks. Handoff is user controlled-network assisted. To improve performance of handoff decision, a server as reputation management is considered in the network that users report their satisfaction from networks to the server.

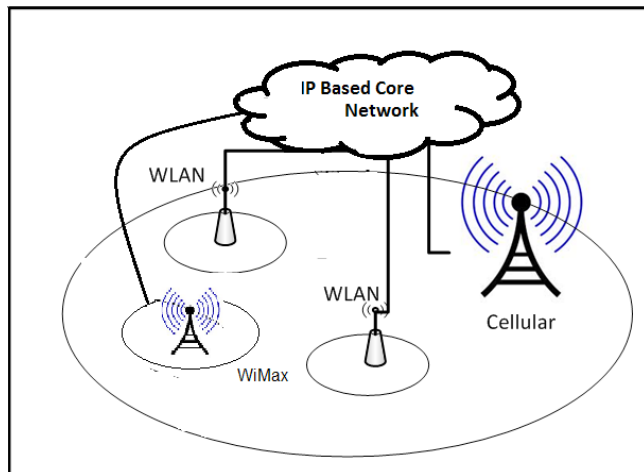


Figure 1. Used network model.

3. Proposed Handoff Algorithm

The proposed handoff algorithm in the heterogeneous network is described in this section which is managed by autonomic terminal related to network conditions, environment, and terminal and user preferences. The handoff process is studied in two sub sections. In the first sub-section, autonomic computing and using the autonomic concept in the proposed handoff are presented. In sub-section two, network selection based utility and past experience is presented by considering residence time of users.

3.1 Autonomic Computing

Autonomic computing (AC) was presented based on autonomic nervous system by IBM, firstly. In the recent years, different works have been done in the information technology and data networks using autonomic computing¹⁷. AC can be used for intelligent control and decision-making without any human, user or admin intervention. As a result, less cost is imposed to system and more complex tasks can be executed. Therefore, system resources are utilized optimally and network is able to be responsible faster to changes in user requirements or business objectives.

Used autonomic scheme for a terminal is presented regarding to autonomic IBM model as shown in Figure 2. It has a control loop adapt system behavior, according to monitoring of its condition and external environment. Functions using in an autonomic terminal are monitoring, analysis, planning and execution. In the monitoring function, network environment is monitored by using

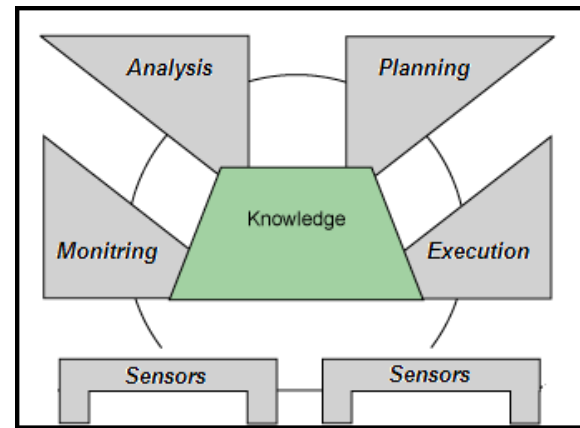


Figure 2. Control-loop model for autonomic managing.

different sensors. In the analysis function, system condition is studied according to received data from monitoring function. Then, system situation is reported to planning function. Planning function makes decisions based on predefined policies and incoming interrupts from other functions. Selected action from planning function is forwarded to execution function. In the execution function, manageable elements are reconfigured to adapt current status of system to optimum system. The four proposed modules for autonomic handoff in the terminal are presented as follows:

- Monitor/Analysis module (MAM): this module is used for monitoring environment and analyzing current conditions.
- The planning module (PLM): in this module, decisions are made for under management elements based on received information from MAM module.
- Execution Module (EM): this module is used to execute selected policies.
- Knowledge Module (KM): KM module uses the database to save and restore obtained data from network and environment conditions, predefined and selected policies by PLM.

In the proposed autonomic handoff management, MAM module monitors terminal characteristics (energy consumption, RSS), performance metrics related to running services and condition of networks. In such cases that environment, terminal or network conditions change, interruption messages containing handoff triggering or network selection are generated in this module. According

to operator policies, user preferences and received data from MAM and KM modules, new decisions such as running network selection module and handoff triggering is made. Module KM holds the reputation of networks, user positions, service characteristics, network conditions and user preferences as well as predefined and previous taken policies. In the EM module, selected policies from PLM are executed, including managing network interface to connect new selected network.

3.2 Network Selection Algorithm

Here, in the heterogeneous environment, the users select the best networks from different candidate networks in related to application requirement, network conditions and user and operator preferences (price and energy). Network selection in the handoff module is activated in two cases: first, the user is in the coverage a network with higher utility in compared with the current network. Second, the obtained utility of the user becomes lower than the threshold value.

Since there are various metrics for choosing best network, here, utility concept is used¹⁸⁻¹⁹ as a utility function to model users' benefit from selected network. Proposed utility function describes the level of user satisfaction from each network providing service. We define a utility function based on quality of service, price and energy consumption as the following:

$$U_u = k_1 \cdot U_b - k_2 \cdot C^{ik}(v_j, f, s) \quad (1)$$

Where,

$$U_b = (f_q - w \cdot f_p)^{q_1} \cdot f_E^{q_2} \cdot f_{rss}^{q_3}$$

$$C^{ik}(v_j, s) = (k_v \cdot C_s)$$

$$C_s = \begin{cases} c_s & s = 1 \\ 1 & s = 2 \end{cases} \quad 0 < c_s < 1$$

Where, the parameter U_b is obtained utility by user from selected network. Weights q_1, q_2, q_3 are used to model user's preference for surplus, energy consumption and signal strength, respectively. $C^{ik}(v_j, Hoff, s)$ is handoff cost. Value C_s depends on service type. For un-resumable sessions (e.g. receiving un-splittable files), value C_s is equal to 1 and for other services (e.g. downloading splittable files), $0 < c_s < 1$. Parameter k_v is increasing function related to user's velocity. Handoff costs e.g. signaling, call dropping and connection transfer from network i to network k are considered in the utility function by

$C^{ik}(v_j, Hoff, s)$. Because, if total utility U_u (used for ranking networks) is only related to U_b , some problems such as ping-pong effect due to closing to network utility U_b to each other may be occurred. So we consider cost function of handoff in the utility function for network ranking and handoff triggering.

3.3 Utility Function U_b

Utility function U_b includes signal quality f_{rss} , quality of service f_q , monetary cost f_p and energy consumption f_E . Function f_{rss} is used to model signal quality in term of received signal strength. It is an increasing function and help terminal to select proper network. In some cases that user is located at cell border, f_{rss} is very low and causes U_b decreases to values near threshold value U_{th} and network selection module will be activated.

Function f_q is defined to model level of user's satisfaction which depends to quality of service metrics including bandwidth, delay and packet loss. The function is related to user's location and network condition. To contribute past behavior of networks and past experience of users into the utility function, network reputation $\mathfrak{R}^i$ for network i is considered when function f_q is calculated as equation (2):

$$f_q^i = U_q^i \cdot \mathfrak{R}^i(ps) \quad (2)$$

Where $\mathfrak{R}^i(ps)$ is reputation of network for the user in the position ps and U_q^i is obtained utility by user from service q . Reputation factor $\mathfrak{R}^i(ps)$ can be calculated by using received and aggregated data, information and reported utilities of other users in the reputation manager. Function U_q^i is defined based on bandwidth (BW), delay (L) and packet loss (PLS) of delivered service in the equation (3) as following:

$$U_q^i = f(BW, L, PLS) \quad (3)$$

Function f_p describes the monetary cost function of a service from a candidate network which is increasing function with price. f_p depends on pricing policies in the networks. In the paper, it is assumed that different networks are managed with various admins with two static and dynamic (volume pricing or time pricing) pricing and Incentive plans such as discount related to usage volume or time. In this regards, monetary cost function is defined for network i and application type j with Eq. (4) as the following:

$$f_p^{i,j} = U(L^i, T_{res}^i, V_{app}^j, C_j) \quad (4)$$

where, parameters L^i , T_{res}^i , V_{app}^j and C_j are load of network i , residence time of user in the network and usage volume for application type j and fixed monetary cost of service j .

In the cases that pricing is dynamic it is assumed that dynamically is relating to user's usage volume and network conditions (e.g. load) during service reception. For example some networks calculate service price based on volume usage and some incentive plans are considered. i.e. service price is related to usage volume or connection time of users. So, users are encouraged to connect to networks for more times to use discount from admin and decrease monetary cost and increase their utility. In the Eq. (5), pricing policies used in the paper is shown. As presented, monetary cost $Cost_j^i$ from network i for service class j is included fixed cost $Cost_{0j}^i$, congestion cost $Cost_{Cj}^i$ and discount $Disc_j^i$.

$$Cost_j^i = Cost_{0j}^i + Cost_{Cj}^i - Disc_j^i \quad (5)$$

where,

$$Cost_{0j}^i = T_{app}^j * P_0^{C_j} \\ Disc_j^i = T_{app}^j * \Delta P_2^{T_{app}^j} Cost_{Cj}^i = \sum_{i=1}^n \tau(n) . \Delta P_1^{L^i, daytime}(n) \quad (6)$$

where, $P_0^{C_j}$, $\Delta P_1^{T_{app}^j}$, $\Delta P_2^{L^i, daytime}$ are fixed price, Discounted pricing based on connection time and congestion price for service class j , respectively. Parameter T^i is minimum of user's residence time in the network (T_{res}^i) and remaining time for service completion (T_{app}^i).

3.4 Reputation Factor $\Re^i$

In the cases that there are different alternative networks to be selected, using evaluation method by considering past experience for network behavior, service quality and expected obtained utility can have benefits. In this regards, score function for networks as reputation can be defined which affects in the decision making for network selection phase. Since the goal is to maximize user's utility, network score are defined according to effective parameters in the user's utility.

Here, daytime, user location and application type is considered in calculating reputation factor for each network. There is a reputation manager in the network core that users report their delivered utility from each network related to daytime, application and their location. Daytime is considered because, there are some times that a network is congested and cannot provide some class of

services. Also, some locations in the network coverage may exist that user cannot receive service from that network but in the other positions, the network provides good quality service. Or, some networks may behave unlike the contract with users to guarantee its services.

Each of the explained issues can affect network selection and as a results, handoff performance and satisfaction of service delivery. Therefore, taking into account past experience tailored to users location and network status can provide better services to the users and decrease handoff number and unnecessary handoffs. The average of reputation of network i based in past experience of users for a delivered service can be calculated to Eq. (7) as follows:

$$\Re^i = \frac{\text{Offered Utility}}{\text{Delivered Utility}} \quad (7)$$

4. Simulation Results

In this section, the proposed algorithm for handoff is evaluated in the heterogeneous environment. Simulation is done by using MATLAB software which utilizes practical parameters for modeling networks. Simulation environment contains one cellular network, one WiMax network and three WLAN which are connected together by IP network core. WLAN networks and WiMax are covered by cellular network, totally. In Table 1 and 2 network characteristics, simulation parameters and application requirement are shown in details. Simulation is done for users that arrive in the networks and receive service, randomly, based on poison distribution with arrival rate (λ). Connection time is assumed based on exponential distribution with normalized mean (μ).

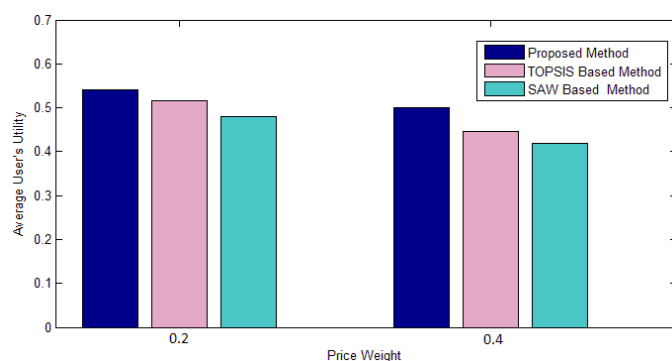
Figure 3 shows average obtained utility by user versus price weight for random arrival rate between 1–15 and mean departure rate 1 for proposed handoff algorithm, TOPSIS-based and SAW based methods. It can be seen from figure that users which use proposed algorithm for handoff management have more utility and get more benefits. It is due to, in the network selection phase, reputation of networks related to daytime and user location are considered during service reception. Also, we can see in Figure 3 that by increasing price weight the difference between the two utility values is more. It is due to as described in section III, proposed algorithm considers residence time of users in the network coverage and so adapt its decision to get more utility from networks which

Table 1. Network characteristics used in the simulation.

Network	Bitrate (kbps)	Delay (ms)	Loss per 10 ⁶ (byte)	Power consumption	Price	
					P0	K2
UMTS	384	200	200	1.2	10	0
WLAN 1	2000	50	20	5	4	0
WLAN 2	3000	100	40	5	5	0.1
WLAN 3	1000	150	100	4	5	0.1
Wimax	2000	100	200	4	7	0.7

Table 2. Application Requirements used in the simulation.

	Bandwidth (Kbps)	Delay(ms)	Packet loss
Service Requirements	100	150–400	2%

**Figure 3.** Average obtained utility by users versus price weight.

propose discount to users for usage volume. For example, a user is receiving service from network i . If another network j discovered, based on proposed algorithm, staying in the current network to get discount is calculated and according to final utility from comparing receiving utility from two network decision to handoff is made. But in the SAW and TOPSIS-based handoff algorithm, future utility and user residence time to get discount is not considered and decisions is made for handoff based on current condition.

Table 3 shows ranking abnormality for different handoff decision methods. Abnormality in the MADM methods means that ranking changes when lower ranking alternatives are removed. As seen in the Table 3, in the proposed method and SAW based method there is not

abnormality but the ranking of TOPSIS method changes when the bottom ranked networks are removed because of depending decision matrix on other attributes of other alternative. For example for all candidate networks, network 3 is elected as top-ranked network by TOPSIS method as well as proposed algorithm. But when network 1 is removed from candidate networks, proposed algorithm selects network 1 as top-ranked but TOPSIS method selects network 2 as top-ranked.

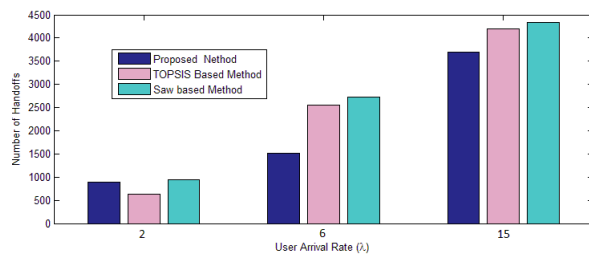
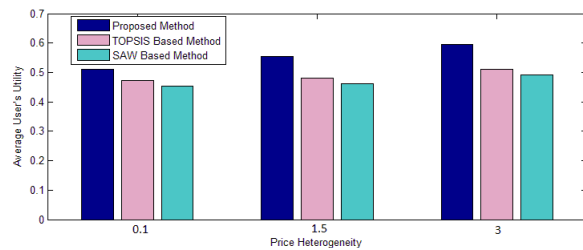
Number of handoffs during connection time of users are shown versus different arrival rates from 1–15 in Figure 4. As shown, number of handoffs are less in the proposed algorithm compared with other methods. It is due to in the other methods decision for network selection is made only based network characteristics. But in the proposed algorithm, for handoff decision, residence time of user in the network coverage also is considered to get discount from network if possible and so for each discovered network handoff may not be triggered. Another reason is that terminal utilizes past utility that it or others were obtained in the past. So, for each discovered network handoff may not triggered because unlike proposed network characteristics, user may not get its required services and should handover to another user. But considering history of service reception can help user to predict future utility that it can obtained. Therefor handoff number and unnecessary handoff could decrease.

Figure 5 shows average utility of user for different selection algorithms versus price heterogeneity. As shown, when the monetary cost of provided services by networks increases and price heterogeneity increases in the network, difference between utility values and average obtained utility of proposed algorithm is more that SAW and TOPSIS based method. It is due to proposed algorithm consider residence time of user and its chance to utilize discount proposed by networks more but others only consider current characteristics of network.

Table 3. Ranking abnormality for different methods.

Network 1 (UMTS)			Network 2 (WLAN 1)			Network 3 (WLAN 2)			Network 4 (WLAN 3)			Network 5 (WiMax)		
T	S	PU	T	S	PU	T	S	PU	T	S	PU	T	S	PU
0.24	0.34	0.33	0.71	0.78	0.50	0.72	0.57	0.52	0.46	0.29	0.46	0.25	0.33	0.41
R #5	R #3	R #5	R #2	R #1	R #2	R #1	R #2	R #1	R #3	R #5	R #3	R #4	R #4	R #4
–	–	–	0.86	0.91	0.50	0.85	0.70	0.52	0.51	0.45	0.46	0.16	0.5	0.41
			R #1	R #1	R #2	R #2	R #2	R #1	R #3	R #4	R #3	R #4	R #3	R #4
–	–	–	0.74	0.91	0.50	0.83	0.70	0.52	0.7	0.45	0.46	–	–	–
			R #2	R #1	R #2	R #1	R #2	R #1	R #3	R #3	R #3			
–	–	–	0.77	0.96	0.50	0.22	0.75	0.52	–	–	–	–	–	–
			R #1	R #1	R #2	R #2	R #2	R #1						

*T: TOPSIS, S: SAW, PU: Proposed Utility, R: Rank


Figure 4. Number of handoffs versus user arrival rate.

Figure 5. Utility ratio of TOPSIS algorithm to proposed algorithm versus price heterogeneity in the network.

5. Conclusion

During recent years, by developing different wireless networks and mobile terminals, selecting proper candidate available network to receive service is important issues to improve service quality and provide continuous service, anywhere and at any time. So, in this article, a history aware handoff algorithm according to user, terminal and network conditions has been proposed in the heterogeneous networks based on knowledge of users by considering economic aspects of delivered service. Decision in the user centeric decision algorithm for hand-off management is made based on defined utility function

including service quality, price and energy consumption to address decision for multi metric decision making problem. Also in the proposed algorithm, since pricing policies in the network are dynamic and depends on users' usage volume, residence time of users has been considered in the network selection phase for available candidate networks according to network coverage, user velocity and user preference. Simulation results show the proposed algorithm improves obtained utility by users in compared with other methods TOPSIS, performance parameters in term of number of handoffs by considering user's residence time in the heterogeneous pricing environment and past experience received service according to networks' behavior.

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