Applied Soft Computing 37 (2015) 156–165

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

A self-adaptive joint bandwidth allocation scheme for heterogeneous wireless networks

Chenn-Jung Huang [a,b,*], Chih-Tai Guan [b], Heng-Ming Chen [b], Yu-Wu Wang [a], Sheng-Yuan Chien [a], Jui-Jiun Jian [b], Jia-Jian Liao [c]

[a] Department of Computer Science and Information Engineering, National Dong Hwa University, Hualien, Taiwan
[b] Department of Electrical Engineering, National Dong Hwa University, Hualien, Taiwan
[c] Institute of Computer Science and Information Engineering, National Taiwan University, Taipei, Taiwan

ARTICLE INFO

Article history:
Received 16 June 2013
Received in revised form 26 August 2014
Accepted 1 August 2015
Available online 20 August 2015

Keywords:
Heterogeneous network
Bandwidth allocation
Optimization
Hybrid Genetic Algorithm
Local Search
Pareto set

ABSTRACT

Recently, people have been able to connect with different types of networks anytime, anywhere using advanced network technologies. In order to properly distribute wireless network resources among different clients, this work proposed a user mobility prediction algorithm, which takes the coverage of different kinds of base stations, and the volatile mobility of pedestrians, vehicles, and mass transportation, into consideration. In addition, a novel bandwidth utilization optimization technique is proposed in the algorithm to allocate bandwidth more efficiently. The Hybrid Genetic Algorithm, which combines the Genetic Algorithm and local searches to improve the frequency of finding a Pareto set, is used to realize the optimization problem as well. Compared with our previous work and the other four methods in the literature, the simulation results show that our proposed work can achieve desirable performance by network utilization, throughput, and QoS quality in the heterogeneous wireless networks.

1. Introduction

Different radio access technologies (RATs) have their own advantages and limitations. However, the Internet service provider (ISP) can have sufficient capacity not only to achieve the required QoS but also to decrease the cost of the various traffic demands generated by mobile users, if the resources provided by different RATs can be integrated.

Multi-homing techniques have been widely used for balancing the traffic among multiple networks and lowering bandwidth costs over the past few years [1,2]. Goff et al. investigated how parallel transmission and bandwidth aggregation can be handled at different layers of TCP/IP stack [3]. Yousaf et al. [4] presented an architecture that exploits the existence of multiple network interfaces in multi-homed devices and provides vertical handover and bandwidth aggregation services for TCP applications. Performance analysis results given in [3,4] exhibited the feasibility of providing vertical handover service seamlessly, as well as the bandwidth aggregation service with prominent throughput gains while using multiple network interfaces in multi-homed devices.

Joint radio resource management (JRRM) was proposed to ensure the development of efficient, economic and sustainable solutions for managing radio resources and spectra in the context of B3G cognitive wireless heterogeneous systems [5]. JRRM is expected to efficiently manage the allocation and deal location of radio resources among different radio access technologies. However, it was pointed out that JRRM cannot perform smoothly in the heterogeneous wireless network environment [6,7]. Because the mobility of mobile hosts are difficult to predict exactly, and the volatile change of connection capability during switching from one radio access technology to another, there is also the main problem of performance deterioration of the JRRM.

Although Luo et al. [7] provided joint session admission control (JOSAC) and joint resource scheduling (JOSCH) techniques for common radio resource management (CRRM), multi-homing was not supported in the JOSAC. Hasib and Fapojuwo [8] presented an adaptive CRRM project, which considers the variables of user service type, user mobility and location information, and service cost in order to provide stable message communication with the result of minimizing unnecessary vertical handoff decreases in users' call blocking probability, and service cost in the different RATs. Although some CRRM schemes that used multiple attribute decision-making methods for RAT selection in the heterogeneous wireless environment were addressed in the literature [9], they did not take mobility information into account for more

* Corresponding author at: Department of Computer Science and Information Engineering, National Dong Hwa University, Hualien, Taiwan.
E-mail address: cjhuang@mail.ndhu.edu.tw (C.-J. Huang).

http://dx.doi.org/10.1016/j.asoc.2015.08.001
1568-4946/

efficient resource management. Although Huang et al. [10] presented an adaptive joint radio resource management scheme that was inspired by the concept of stem cell regeneration (SCR-JRRM) for strengthening various radio access technologies to adapt to the volatile change characteristics of heterogeneous wireless networks, the initial setting for the parameters of membership function used in the fuzzy inference rules experienced difficulty in achieving the expected bandwidth allocation. Meanwhile, Huang et al. [10] did not take some parameters, such as mobility information and signal strength of connection, into account in the resource management scheme.

Owing to the well-developed digital maps and global position system (GPS) of recent years, researchers have started considering the users' mobility in their resource management. However, most works only considered a single RAN [11,12]. Shenoy et al. [13] integrated the WLAN and cellular network by taking normal user movement and biased user movement patterns into account based on a 2D random walk model proposed by Chiang and Shenoy [14]. However, the result had some limitations due to the assumed transition probabilities between macro cell and microcell. Hasib and Fapojuwo [8] presented a mobility model scheme for heterogeneous wireless networks; however, this method is not suitable for real-time situations because of its complexity of calculation.

Recently, some researchers have applied memetic algorithms in the resource allocation issues. Memetic algorithm is an evolutionary computation with separate individual learning or local improvement procedures to search for optimal solutions. Ghosh et al. [15] proposed a modified Differential Evolution (DE) algorithm to diminish the high peak-to-average power ratio (PAPR) of Orthogonal Frequency Division Multiplexing (OFDM) systems. Islam et al. [16] presented a modified Discrete Differential Evolution (MDDE) algorithm to enhance the converging process in the proposed effective optimization framework for a multi-objective Time Division Multiple Access (TDMA) scheduling problem. M. Nasir et al. [17] proposed an evolutionary multi-objective sleep scheduling scheme for differentiated coverage in wireless sensor networks. S. Sengupta et al. [18] developed a novel multi-objective evolutionary algorithm to optimize the coverage, energy consumption, lifetime and number of nodes maintaining connectivity in wireless sensor networks. Notably, it is not unusual for researchers to adopt GA for solving the optimization problems in the literature. The disadvantage of GA is its slowness compared to other traditional optimization methods. Some studies have thus utilized the Hybrid Genetic Algorithm (HGA) [19] to improve the computation time of finding the global optimum. Quintero and Pierre [20] combined the advantage of both the Genetic Algorithm and the Tabu Search and presented Hybrid Genetic Algorithms with a local refinement strategy to solve the problem of assigning base stations (BSs) under the jurisdiction of suitable radio network controllers (RNCs) in a large-scale universal mobile telecommunications service (UMTS) mobile network.

The aim of this work is to improve the efficiency and fairness of resource allocation in heterogeneous wireless networks. The solution of optimization is obtained by utilizing the Hybrid Genetic Algorithm. By combining the GA and the Local Search, we can decrease the computation complexity largely in order to obtain the optional bandwidth allocation. We also take the transportation types of mobile hosts (MHs) into consideration, and provide a lookup table which records the probability with which a MH moves into the coverage of the specific BS. With the help of the proposed lookup table method, we can quickly predict the probabilities of connectivity with neighboring BSs, and reserve the appropriate amount of bandwidth for possible handoffs without sacrificing the efficiency of bandwidth usage.

The following is the remainder of this paper. Section 2 presents the algorithm for the proposed joint bandwidth allocation scheme. The simulation results are given in Section 3. The conclusion is made in Section 4.

2. The proposed joint bandwidth allocation scheme

Properly distributing wireless network resources among different clients is a popular issue in the field of joint radio resource management. This work manages radio resources with multiple RATs according to our proposed user mobility prediction algorithm, considering the coverage of different kinds of base stations and the volatile mobility of pedestrians, vehicles, and mass transportation. There are three main modules in the proposed system, including the mobility prediction module, the remaining bandwidth estimation module, and the common bandwidth utilization optimization module. The mobility prediction module and a remaining bandwidth estimation module are established at each BS as shown in the lower part of Fig. 1. The global radio resource manager located at the upper part of Fig. 1 consists of a bandwidth utilization optimization module. First, a user collects required parameters, such as the service type, current location, and the signal strength of a MH. When a MH's status changes, the latest MH's status is immediately updated at the BS where the MH resides, and the mobility prediction module will check with a pre-built lookup table to determine whether the handoff will occur. Notably, the functionality of the lookup table is used to reduce computation overhead during the computation of the mobility prediction in real time in the system. If the handoff is predicted to occur, the MH sends out a bandwidth requirement to the nearest BS, and the remaining bandwidth estimation module in the target BS will be activated to determine the amount of remaining bandwidth that can be used by the handoff. In the case that a given BS finds that its bandwidth is going to be inadequate, a bandwidth adjustment coordinator located at the BS will request the common bandwidth utilization optimization module be applied with the Hybrid Genetic Algorithm to overcome the shortcoming of the genetic algorithm in terms of low speed of convergence at its upper level to reallocate the bandwidth for the BSs/APs of different RATs. The results of the bandwidth reallocation will then be sent back to each BS to reassign the bandwidth to the MHs.

2.1. Mobility prediction module

This module is proposed to predict the mobility pattern of MH. There are three cases of mobility prediction according to MHs' moving characteristics, including the low-speed pedestrian's mobility prediction, the fixed-route vehicle's mobility prediction, and the prediction for a MH on a driveway.

2.1.1. Low-speed pedestrian's mobility prediction

The predicted location of a MH may be changed due to the MH's movement. We can predict a user's desired location by detecting and calculating the related data, including the location and the velocity, during each periodical time. The probability that a MH moves to a distance r can be expressed by

$$p(r) = ce^{-ur}, \quad (1)$$

where r is the moved location of the MH, u is the probability distribution function in terms of time, and c is a preset constant.

Because the total probability should be equal to 1, we obtain:

$$\int_0^{\infty} 2\pi r \cdot p(r)dr = 1. \quad (2)$$