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A new multi-rat scheduling algorithm for heterogeneous wireless networks

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ABSTRACT

The concept of heterogeneous wireless networks (HWNs) is based on the coexistence and interoperability of different types of radio access technologies (RATs) such as long term evolution (LTE) and wireless local area network (WLAN) in a unified wireless heterogeneous platform. Guaranteeing the quality of service (QoS) is an important issue for the next generation wireless networks which are characterized by providing different types of services. To schedule different types of service in HWN, distinct scheduling algorithms have been studied intensively in the literature. Thus in our research work, we focus on a common scheduling algorithm for the HWN where the traffic streams are classified into different categories, and each category has its own set of QoS parameters such as data rate and delay. In this article, we propose a new dynamic scheduling algorithm for HWN. The proposed solution introduces a new approach in scheduling packets while maintaining performance in wireless networks. The scheduling scheme is mainly based on transmission links' condition from the media independent handover (MIH) module, type of call (handoff call prioritization) and classes of service. In order to study the performance of the proposed scheme, we use simulation analysis and compare the performance of our scheme with a competing reference scheme called NSA (new scheduling algorithm) for wireless mesh networks in order to reveal its ability to adapt to the specific service and channel conditions. Simulation results show that under large number of users, the proposed algorithm has lower packet loss and blocking calls ratio while offers allowable average packet delay.

1. Introduction

Next generation wireless networks (NGWN) is expected to be heterogeneous networks which integrate different RATs such as 3GPP's LTE and WLAN. Therefore, the coexistence of distinct RATs in the same area has necessitated common radio resource management (CRRM) to enhance QoS provisioning as well as to provide efficient radio resource utilization. CRRM is defined, in Sabbagh et al. (2012), as a platform to gather information from the base stations (BS) or access point (AP) of different RATs, and to control the resource allocation of all BSs to optimize the overall system performance. HWN present different characteristics in terms of radio resources and mobility management and QoS provisioning. The issues of seamless mobility and end-to-end QoS guarantee for the users should be carefully addressed while developing interworking schemes (Zarai et al., 2010). The interworking between different wireless access networks has been a hot research topic in recent years. Most of the researchers mainly focus on interworking between WLAN and 3G cellular. Following the 3GPP approach, CRRM strategies are considered to jointly manage the radio resources belonging to multiple RATs in an efficient way. In this work we adopt the CRRM architecture introduced by the 3GPP and used in Gelabert et al. (2005), Sabbagh et al. (2012), Zarai et al. (2010).

New wireless devices contain multiple RATs. This sort of equipment carries multiple interfaces belonging to different RATs such as laptops which are equipped with Wi-Fi, Bluetooth, WiMAX and smartphones that are provided with Wi-Fi and 2.5G/3G (BlackBerry, iPhone, and Google Android). Each RAT was designed independently. Since these different technologies have to act as complementary to each other, integration of these networks will enable the mobile users to be connected to the best available access technology depending on their requirements. This interoperability of HWN will, however, lead to heterogeneities in access. A common infrastructure to interconnect the HWN will be needed in order to meet the requirements of mobile users. The management of QoS in the infrastructure of the HWN implies the presence of specific scheduling mechanisms. In fact, in packet networks, link scheduling is an important mechanism to realize QoS as it directly controls packet delay (guarantee a particular metric value for instance, delay under 150 ms for real time traffic). Although the scheduling has a vital role in attributing priorities in

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a queue, most of the scheduling algorithms presented in literature propose methods which do not consider all the metrics that have an effect in the priority decision such as the dynamic aspect of the channel conditions, interference, type of calls and classes of service.

The provision of QoS to real-time communication streams is a key requirement in emerging broadband packet-switched networks. The management of QoS from the beginning to the end implies the presence of specific scheduling mechanisms. However, in some works such as (Kampeas et al., 2012) and (Liu et al., 2007), authors ignore the influence of the transmission link conditions, which can affect the performance when the difference of link qualities between RANs becomes evident. The well deployed cellular networks and WLANs will both be included along with other wireless access networks such as WMNs which consist of dedicated nodes called mesh routers that relay the traffic generated by mesh clients over multi-hop paths. In this article, we consider an interworking of WMNs with WLAN and LTE.

In this article, the proposed scheduling is influenced by the link condition, type of calls and classes of service that can exploit information from the MIH functions module and provide guarantee on delays. We then study a competing algorithm and evaluate its performance using simulation and compare it to our proposed scheme.

The remainder of this article is organized as follows. Related works of this research and different types of scheduling schemes are summarized in Section 2. Section 3 describes the details of our proposed scheduling scheme and the considered network architecture. In order to highlight the contribution developed in the previous sections, various simulation experiments are run and their results are presented in Section 4. Finally, Section 5 summarizes the main findings of this work.

2. Related works

The integration of heterogeneous wireless networks is bringing about revolutionary changes in the Internet by providing better quality of experience (QoE) assurance for users of wireless services. This recent concept called QoE is introduced in Jason et al. (2014) and Quadros et al. (2013). The QoE is an essential indicator for network evaluation, especially with multimedia applications. It represents perception experienced by the user. In Quadros et al. (2013), the authors propose a modular architecture called QoEH and to maximize the QoE of wireless clients in IEEE 802.11 and 802.16 systems.

In the literature, several recent researches focus on heterogeneous wireless networks. In Jason et al. (2014), the authors present a deep review of different studies of QoS/QoE in HWNs. The authors classify these works according to function within an HWN. This categorization included handover, RAT and AP selection, MAC control, scheduling, topology, power control and routing. They identify many open problems related to mobility of users in HWNs.

WLAN has been a topic of research for several years. The case study of WLAN is presented in Ernst et al. (2014) where the authors propose a novel NS3 simulation module which provides support for multi-channel Wi-Fi AP selection. The proposed solution allows user devices to scan several non-interfering channels and select the best AP according to IEEE 802.11 criteria. In Ernst et al. (2014), the authors study the problem of access point (AP) selection in wireless networks. They compare and classify the different approaches proposed in the literature. Then, they propose a utility-based AP selection method for IEEE 802.11 wireless networks. The proposed method is a passive approach that it requires no modification to the AP.

A comparative study of scheduling algorithms for real-time task was proposed in Kaladevi and Sathiyabama (2010). The authors classify the scheduling algorithm in two types: fixed priority scheduling and dynamic priority scheduling. The rate monotonic (RM) and deadline monotonic (DM) are fixed priority scheduling schemes. The RM tasks with smaller periods get higher priorities. The DM tasks are assigned priorities according to their deadline. The task with the shortest deadline is assigned the highest priority. The dynamic priority scheduling contains:

- *The earliest deadline first (EDF) algorithm*: This maintains a list of waiting packets to be executed. This list is sorted by deadline with the first packet having the earliest deadline. The priority of each packet is decided based on the value of its deadline. The task with nearest deadline is given highest priority and it is selected for execution.
- *The least laxity first (LLF)*: It is a dynamic scheduling method. For every task ready to run at the given moment the difference S between the time until deadline D and the remaining computation time C is computed. This difference, called slack or laxity, can be seen as an inverted priority value. The task with the smallest S-value is the one to be executed next. Whenever a task other than the currently running one has the smallest slack a context switch will occur.

In Kampeas et al. (2012), authors propose a novel method, based on the point process approximation, to analyze the expected capacity of scheduled multi-user MIMO systems. They show that the strength of this approximation is in facilitating the asymptotic analysis of the capacity of such systems in different non-uniform scenarios, where users are either inherently non-uniform or are forced to act this way due to QoS constrains. Given the number of users, they set a high capacity threshold such that only a small fraction of the users will exceed it. In each slot, the users estimate their own capacity. If the capacity seen by a user is greater than the capacity threshold, he transmits in that slot. Otherwise, the user keeps silent in that slot. They derive the expected capacity when applying QoS to the users. The expected capacity is estimated when working with a single user in each slot in the above non-uniform environment.

In Garcia et al. (2006), authors propose a dynamic resource allocation (DRA) that takes into account both QoS requirements and channel status for each user. The DRA is a combinational problem where radio resources of each RAT have to be allocated to different users at each frame subject to certain restrictions in terms of QoS and the total amount of available resources. The proposed algorithm is applied in a wireless heterogeneous network to schedule the downlink transmissions of a delay-constrained service. The authors, when calculating the optimum solution of the scheduling algorithm, do not consider the delay in the intermediate nodes and the number of nodes in the path from the source to the destination which are necessary to estimate the end-to-end delay and the remaining delay before the expiration of the packets deadlines.

The authors, in Cui et al. (2011), proposed a scheduling algorithm for HWN that guarantee QoS for the real-time traffic types. They began by developing a utility function to represent the degree of satisfaction of performing a packet scheduling in terms of avoiding wasting resource provided. The utility function is developed based on joint consideration of fairness. To find the optimal solution of the scheduling model, the authors used Hopfield neural network. A generic link layer (GLL) is introduced. It is located between layer 2 and layer 3. The proposed GLL is composed of QoS classifiers, FIFO queues and packet classifier. The proposed algorithm schedules the packet to a RAT which provides higher bit rate as much as possible. The authors do not consider handoff calls when classifying users' packets to be scheduled. The quality of channel is not considered in this scheduler. In Liu et al. (2007), the authors propose a scheduling algorithm called SABLC based on the link condition, aiming to supporting the QoS and improving the whole network throughput in HWN. They estimate the expected delay of packet through all the available paths taking into consideration the packet loss ratio and the bandwidth. Then they schedule the packet in the link that provides the minimum predicted delay. The authors, in this work, do not consider the call type (handoff or new call) and the service class (real or non-real-time traffic).