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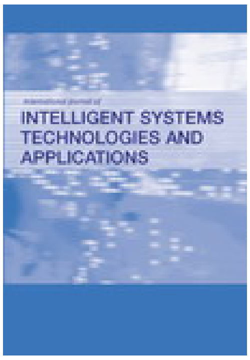

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Access selection in heterogeneous wireless networks based on user preferences

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Abstract: Access selection is an important key in heterogeneous networks, and the design of a new algorithm for decision is not a trivial task. Different aspects must be taken into consideration while designing a new decision algorithm, including both users' requirements (in terms of resources, QoS, user's preferences), and operator policies that aim to maximise the utilisation of its network capacity and to deliver services with acceptable QoS levels for the largest number of customers. Thus, in this paper, we propose a new selection algorithm based on user's preferences. The comparison between the proposed scenarios is given based on several performance indicators. The results show the improvement achieved by increasing the resource utilisation and therefore the overall system capacity.

Keywords: access selection; heterogeneous networks; user preferences; QoS; resource utilisation.

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1 Introduction

The new generation of mobile systems is emerging into a wireless heterogeneous access network composed of various radio access technologies (RATs), capable of hosting multiple interface radio stations, each capable of operating alternately in different radio technologies [e.g., mobile networks, wireless LANs (WLAN), etc.]. These existing technologies will include collaborating modules and will be linked together by a fixed IP backbone (Adamopoulou et al., 2005).

These technologies differ in connection range, power consumption, reliability, security, bandwidth, delay, complexity of implementation, cost to end user, and many other features. Having access networks opens up the possibility of choosing the proper network or of sharing access networks to guarantee that all applications have an adequate quality of service (QoS) (Gustafsson and Jonsson, 2003). Let us say, the applications can be transparently handed off vertically to better access networks, whenever the state of their current connected networks varies. When bandwidth is constrained in an access network, the bandwidth provided by several networks could be combined to sustain broadband services. That will lead to 'always best connected (ABC)' notion, where the users are allowed to stay associated to the network that best outfit their applications requirements. In a multiple access technologies environment, ABC networks are considered as a concept that permits users not only to be always connect but also to access a specific QoS level at a certain cost, or other criteria (Gustafsson and Jonsson, 2003; Fodor et al., 2003). The idea of 'best' is regularly depending on numeral features that are related to both user and application, like device capabilities, user preferences, security, QoS needs of an application, etc., or even additional features related to the network like the available resources and the coverage (Xing and Venkatasubramanian, 2005).

The selection of a radio access network (RAN) is one of the most important facets of the whole process. The key objective, when designing and installing an efficient ABC service system, is to define the parameters of the access selection process and to define a dependent algorithm that uses these parameters to allow the user to being always served by the best connection. Numerous criteria can guide the selection process. Therefore, having mechanisms, to help each user decides which network is best for him, at each moment for every needed application, is an important issue. The decision depends on many QoS parameters (Sgora and Vergados, 2009), which need to be optimised, and this causes the algorithm that will be used for network selection to be a very complex task.

There are already many published works in the field of the optimisation of the selection of access networks. An algorithm for access selection dynamically adapted according to the needs and the preferences of the users is presented in Iera et al. (2006). It is based on an appropriately defined cost function, which simultaneously considers metrics that reflect both objective (i.e., network-related) and subjective (i.e., conditions related to user preferences). This function associates a weight to each cost parameter which is dynamically adapted to user and profile preferences, not only on a per-session basis, but also within the same session.

As many criteria must be taken into account, the problem of selecting an access network is generally considered from the side of multi-criteria analysis, more precisely by applying different multi-attribute decision-making (MADM) algorithms (Niyato and Hossain, 2009). In their work, Dhia et al. (2019) propose a method to improve the selection of RATs and resource allocation in multi-technology wireless networks over a period of time. The optimisation takes into account the services required, the contracts of different users, and users' satisfaction. They also add constraints to deny the session drops and the handovers for static users. The goal of the optimisation is to maximise the overall user's satisfaction and the number of connected users. Guo et al. (2022) design a multi-attribute access selection approach based on the attributes of the fuzzy network. They calculate, at first, the network attribute values by interval hesitant fuzzy theory. Then, they calculate the subjective weights of the network attribute values by the analytical hierarchy process, while the objective weights of the network attributes values are calculated by the entropy method. The integrated weights of both subjective and objective weights are obtained by the method based on the longest geometric distance of the negative ideal solution. At the end, they calculated the scores of the candidate networks by means of grey relational analysis based on the intuitive fuzzy decision matrix.

Wang et al. (2019) introduce artificial intelligence to highly dense heterogeneous networks, and propose a model-driven framework with a combined offline and online method, which is able to achieve fast and optimal network selection through the alliance of machine learning and game theory. Moreover, they implement a user-distributed algorithm based on the proposed framework, which can reduce the number of frequent switches, increase the possibility of profitable switching, and provide individual service.

Liang et al. (2019) designed an algorithm to select shared access and allocate bandwidth in heterogeneous wireless networks. Taking into account the environment in which WiMAX, LTE and WLAN can coexist, the algorithm uses the received signal strength, network load, and user rate requirements as input decision parameters, and adjusts the membership function parameters in a fuzzy five-layer neural network architecture through supervised learning, to obtain the values of score and bandwidth allocation, for each candidate network. The proposed algorithm can enable users to choose the most appropriate network to access, and may modify fuzzy rules and adjust resource usage for different networks based on user preferences.

Li et al. (2017) proposed a 3-Param algorithm for network selection for cognitive radio terminals (CRTs). The factors which are detected by CRTs and the factors which cannot be acquired before, are used by the proposed algorithm to determine the selection of the given network. Montaya et al. (2018) proposed a network-centric strategy to assess and define the RAN in a heterogeneous network system that will be used to host a future session. The sequential decision-making process is used by the authors to design the problem of RAN selection, in which the objective of the optimisation problem is to maximise the discounted long-term reward through the dynamic allocation of arriving sessions to one of the available RANs. Udhayakumar et al. (2018) developed a cost-effective wireless network selection algorithm that was optimised with a modified PSO to improve the heterogeneous wireless environment including UMTS and LTE networks. PSO is an artificial intelligence technology that could be utilised to find a rough solution to reduce or maximise the objective functions.

Liu et al. (2018) proposed a selection algorithm for heterogeneous networks based on objective and subjective synthetic weights. Synthetic weighting is used to reduce information loss. Meantime, the traditional CRITIC algorithm has been enhanced to optimise its performance. Ali et al. (2018) proposed in their work a ranking algorithm to rank heterogeneous networks on the basis of a collection of parameters counting those related to the network, the terminal and some QoS parameters such as packet transmission delay, packet loss rate, jitter and bit rate. Then, they suggest an algorithm for network selection to choose the most appropriate network given several handover scenarios. Finally, they estimate the work proposed for a collection of parameters taking into account different traffic classes.

In their work, Liang et al. (2019) designed an algorithm for combined access selection and bandwidth allocation in heterogeneous wireless networks. Considering the environment in which existing wireless networks may coexist, the algorithm uses network load, received signal strength, and user throughput requirements as input decision parameters for a neural fuzzy network, through supervised learning to acquire the degree and the value of bandwidth allocation to each candidate network. Yu et al. (2019) proposed an algorithm for network selection for multiservice multimode terminals (MMTs) in heterogeneous wireless networks. This algorithm takes into account network attributes, service characteristics, and user preferences. It also uses entropy and fuzzy analytical hierarchy process (FAHP) to respectively compute the weights of the network attributes objectives, and those determined by the properties of the services.

These algorithms use in the selection process many parameters that can be linked to:

1. the network state (network capacity, security level, lack of reliability of a network, availability of a network, signal quality)
2. the QoS provided (delay, bandwidth requirements)

3 the user terminal (energy consumption associated with physical interfaces of the device)

4 user preferences (monetary cost of a session, type of service requested, network operator, type of technology, quality).

The contribution of this work is three-folds:

1 definition of new QoS parameters in heterogeneous networks

2 proposal of a new selection algorithm based on the user's preferences

3 definition of new performance indicators to evaluate the QoS parameters.

Our proposed selection algorithm, based on the user's preferences, can achieve load balancing between networks. We apply the principle of preferences on the service type of the application requested by the user; hence, the same user can have several preferences according to the service type requested. The performance indicators that we use to make the comparison between the proposed scenarios in order to evaluate the QoS parameters are:

1 the rejection rate associated with lack of resources

2 the rejection rate associated with degradation of QoS

3 the occupancy rate of the service type in each network

4 the acceptance rate of users.

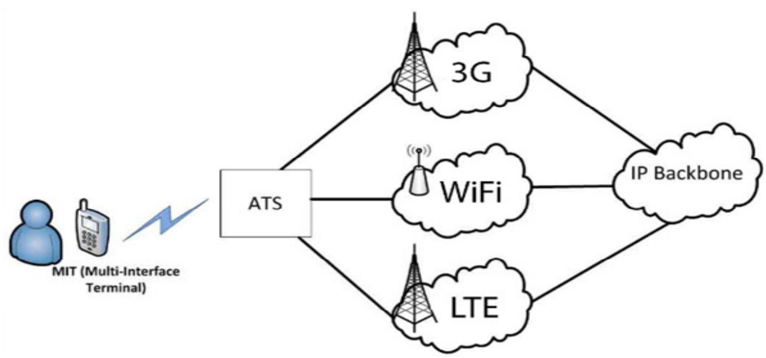
The user preference of user u describes the user's preferred access network and the preference level. Thus, any user should have the ability to set his preference to each of the available networks through an interface provided by its main operator and registered in the ATS. There are three types of preference values: 'high-preference', 'medium-preference' and 'no-preference'. Therefore, a user A, by example, can specify the choice 'high-preference' to the network X. In this case, this user cannot be assigned to any network other than the network X. While, a user B can select the choice 'medium-preference' to the network X. In this case, the network X is considered as the favourite network for the user B if there are enough resources that will meet the requirements of user's B traffic, but the other networks are adequate in the opposite case. Finally, a user C can select the choice 'no-preference' to any network, which is the default choice. Therefore, the ATS can assign to this user any available network that will meet the requirements of his traffic.

The remaining of the paper is organised as follows: Section 2 presents the basic elements of an ABC system, mainly the access technology selector (ATS) module. In Section 3, we explain our new access selection algorithm based on user preferences. In Section 4, we apply the preferences used in the proposed algorithm on the type of service. In Section 5, the simulation parameters are highlighted, then two scenarios were proposed and simulated, therefore their results were discussed and interpreted. A comparison between the different scenarios is also presented and discussed later in this section. Section 6 summarises the comparison between our work and some existing approaches from the literature. Finally, Section 7 concludes our paper and highlights future works.

2 ABC system

The core of the next generation infrastructure is expected to be an IP-based (backbone IP) multiservice network that provides connectivity and transmission over any access technology, including legacy second generation (2G), advanced third generation (3G), long-term evolution (LTE) mobile systems, 5G networks, wireless LANs and future access technologies. This multi-access infrastructure supports users and services with a widespread variety of multiple access (multimode) terminals (MMTs) (Fodor et al., 2004). MMTs for next generation wireless networking (NGWN) have the ability to make two or more different call classes concurrently (Falowo and Taiwo, 2018; Falowo and Chan, 2011, 2012). Thus, from the point of view of QoS and access selection, the main components of the ABC system include the ATS module, the multi-interface (MIT) or Multi-mode Terminal, the access networks of the candidate (the existing RANs), and the IP core network, as shown in ‘Figure 1’. Moreover, the ATS service could be part of any RAN, where it may have direct access to get instantaneously the important network status parameters from it, or it may communicate with specific access technology network through the underlying IP network.

Figure 1 Main elements of an ABC system (see online version for colours)



In the ATS module, the algorithms for access selection decision must be applied to guarantee a better connection of the users in terms of QoS, price and possibly other preferences. These algorithms are expected to improve the combined capacity of the multi-access networks. Examples of algorithms that can be used during the selection process are suggested and discussed in the next section.

3 Access selection based on user preferences

In this section, we present a new selection algorithm based on load distribution according to user preferences. The access preference value, called apv, for user u describes the user’s preferred access network and the preference level. Therefore, we set the access preference value to zero (apv = 0) to users having ‘no-preference’ to any network, so they can be assigned to any access network. The users having ‘high-preference’ to a specific network RANj, will be assigned a value j to their access preference parameter (apv = j, $1 \leq j \leq m$ and $j \in \mathbb{Z}$, where m is the number of existing access networks), in condition that these users cannot be assigned to any access network other than their preferred network RAN_j. The users having 'medium-preference' to an access network RAN_k, will have an apv of negative value equal to –k ($1 \leq k \leq m$), in this case, the access network RAN_k is favourite, but also other access networks are adequate.

We define the following functions:

- *checkResources*(u, RAN_i): tests the resources availability needed by user u in RAN_i.
- *abs*($u.apv$): is the absolute value of the preference of user u.
- *meetQoS*(RAN_i, *user*): tests if RAN_i meets the QoS requirements of user u.
- *Assign*(u_i): is the assignment function represented by Algorithm 1.

We define *dsv* as the dissatisfaction value of each user association, it describes the degree to which this association does not fit the preference of the user to an access network. Therefore, the dissatisfaction value *dsv* of a user u_i associated with an access network RAN_j is defined as shown in (1).

$$dsv = \begin{cases} 0, & apv = 0 \text{ and } Assign(u_i) \neq null \\ 0, & 0 < apv \leq m \text{ and } Assign(u_i) = RAN_j,\ apv = j \\ 0, & -M \leq apv \leq -1 \text{ and } Assign(u_i) = RAN_j,\ apv = -j \\ 1, & -M \leq apv \leq -1 \text{ and } Assign(u_i) = RAN_j,\ apv \neq -j \\ 2, & Assign(u_i) = null \end{cases} \tag{1}$$

The general strategy applied by the algorithm to choose an access network is described as follows:

- The user's preferences are specified by the ATS when the user tries to connect.
- A user of high-preference is assigned directly to its preferred RAN if it provides sufficient free resources and meets the QoS requirements requested by the user. Otherwise, the user request is refused.
- A user with medium-preference is assigned to its preferred RAN if this one provides sufficient free resources and meets the QoS requirements requested by the user. Otherwise, the ATS seeks another RAN providing sufficient free resources and meeting the QoS requirements requested by the user, the selection process starts with the RANs having the largest number of free resources. If no RAN was assigned, the user request is refused.
- A user with no-preference is assigned to any RAN providing free resources and meeting the QoS requirements requested by the user, starting with the RAN that provides the largest number of free resources. If no RAN was assigned, then the user request is refused.

Algorithm 1 Access selection based on user preferences

FUNCTION Assign(*user*): **boolean**

  IF *user.api* > 0 **THEN**

    k = user.api;

    IF checkResources(user, RAN_k) **AND** meetQoS(RAN_k, user) **THEN**

```
        Assign RANk to user;
        dsv = 0;
        RETURN true;
      ENDIF
    ELSE IF user.api < 0 THEN
      k = abs(user.api);
      IF checkResources(user, RANk) AND meetQoS(RANk, user) THEN
        Assign RANk to user;
        dsv = 0;
        RETURN true;
      ELSE
        FOR RANs sorted in decreasing Capacity order
          IF checkResources(user, RANj) AND meetQoS(RANj, user) AND (j ≠ k) THEN
            Assign RANj to user;
            dsv = 1;
            RETURN true;
          ENDIF
        END LOOP FOR
      ENDIF
    ELSE IF user.api = 0 THEN
      FOR RANs sorted in decreasing Capacity order
        IF checkResources(user, RANj) AND meetQoS(RANj, user) THEN
          Assign RANj to user;
          dsv = 0;
          RETURN true;
        ENDIF
      END LOOP FOR
    ENDIF
    dsv = 2;
    RETURN false;
  END FUNCTION
```

4 Preferences according to the type of service

User preference can be set by the user himself and recorded in his profile, or settled by the ATS following a specific configuration by the operator. This preference may be based, not only on the user as a subscriber, but also on the type of service requested by the user, thus a user can have multiple preferences depending on the requested services.

Each network is preferable for a type of service, and can serve it, in terms of QoS and in number of provided resources, better than other types of services. Thus, for example, a Wi-Fi network is not preferable for real time applications like VoIP: if the number of voice users increases in a Wi-Fi network, the QoS decreases remarkably, until a moment where a user cannot continue his call or make new connections. While in an LTE network, QoS is guaranteed at certain level through algorithms used in admission control.

In the following scenarios, we consider a heterogeneous environment composed of two networks: LTE and Wi-Fi, and a number of users trying to find an available network to connect to it. These users are divided into two categories: users connecting to make VoIP calls, so they require a high level of QoS, and others are transferring files and do not require any level of QoS.

Since the preference may be based on the service type of the user, thus we can consider that a user using VoIP has a high preference to LTE network and the user of type data can be considered with a high preference or medium preference to Wi-Fi network, and this depends on the applied scenario.

After all the above, the general strategy used by the algorithm is to choose an access network as follows: a voice user is assigned directly to its high preference network (LTE) in condition that it has available resources and can guarantee the QoS requirements. Otherwise, the user is refused.

For data user, two cases are presented:

- If the user has high preference, he is assigned to its high preference network (Wi-Fi) in condition that it has available resources. Otherwise, the user request is refused.
- If the user has medium preference, he is assigned, as a first choice, to its medium preference network (Wi-Fi) in condition that it has available resources, regardless of QoS levels. If Wi-Fi refuses this user request, then the second choice will be the LTE network.

As described in Fodor et al. (2004) and Furuskär (2003), data users consume greater number of resources than voice users, and since a session of data transfer takes an average time greater than a voice call, thus, a Wi-Fi network becomes saturated more quickly than an LTE network. Therefore, to maximise the overall system capacity, and in the case where the wireless network (Wi-Fi) becomes saturated, data users with medium preference are redirected to the LTE network which has available resources meeting the user requirements.

When a voice user tries to connect to its network of high preference (LTE in our case), the ATS checks the availability of free resources in this network and confirms whether there are resources reserved for users with medium preference to another network (data user in our example). In the case where the network of medium preference of these users (Wi-Fi) provides free resources, then the ATS forces one of the data users to make a vertical handover from the host network (LTE) to his network of medium preference (Wi-Fi). All this is done to ensure that the new voice user will have sufficient level of QoS in its network of high preference.

5 Simulation parameters and applied scenarios

5.1 Simulation platform

For our simulation, we used the 'ABCDecision' simulator, which we have presented in a previous work (Haydar et al., 2010). This simulation platform implements the various modules of an ABC System, such as the ATS, the RANs, and the users. Concerning network simulation, many simulation software are available. Although, most of them (counting the famous simulators such as Opnet, ns-2, J-Sim and OMNeT ++) were initially designed for wired networks. It was only later that it was also expanded to support wireless networks. Additionally, these tools use packet level simulation to analyse the performance of networks and are not particular to develop models for heterogeneous networks. Most of them only simulate two kinds of wireless networks, which requires us to write some complex pieces of code to achieve the required configuration.

5.2 Simulation parameters

Several simulations were conducted to measure the performance of the proposed algorithms and to analyse their impact on maximising the total system capacity. To obtain convincing results, new parameters have been implemented and measured, and several scenarios were simulated while varying the users' arrival rate λ.

We define the following measured parameters:

- The instantaneous occupancy rate of each type of service in each network.
- RejLackRes: The instantaneous rejection rate related to the lack of resources in each network.
- RejLackQoS: The instantaneous rejection rate related to the lack of QoS.
- The instantaneous rate of users who are forced to perform a vertical handover.
- The rate of accepted users in the system.
- The dissatisfaction value for each user association.
- The dissatisfaction preference average (dsa) of a given configuration (set of n users associated to access networks) is calculated as per (2).

$$dsa = \sum_{i=1}^{n} dsv / n \qquad (2)$$

- The instantaneous occupancy of each network in terms of resources for each type of service.

5.3 Scenario 1

In this scenario, we give the voice users a strong preference to LTE network and data users a strong preference to Wi-Fi network. We apply the network access selection algorithm (Algorithm 1). Five values of inter-arrival have been simulated and these values are enumerated in Table 1.

Table 1 Values of simulated inter-arrival rates

Simulation	*1*	*2*	*3*	*4*	*5*
Inter-arrival rate (users/min)	10	20	30	40	50

Figure 2 LTE occupancy for λ = 10 (see online version for colours)

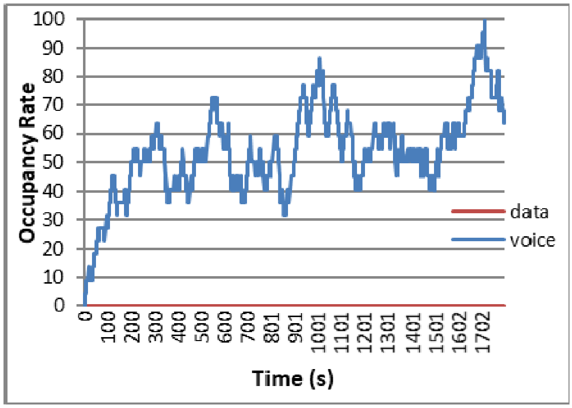


Figure 3 LTE rejection rate for λ = 10 (see online version for colours)

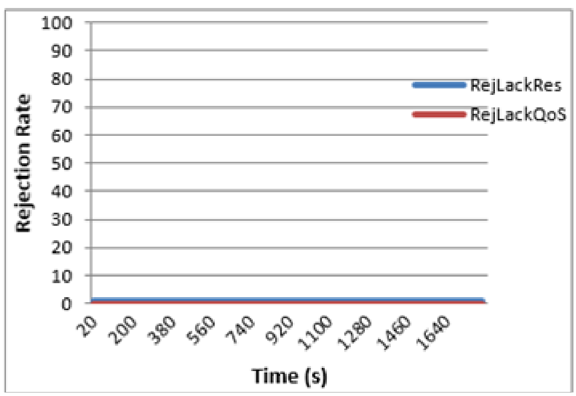
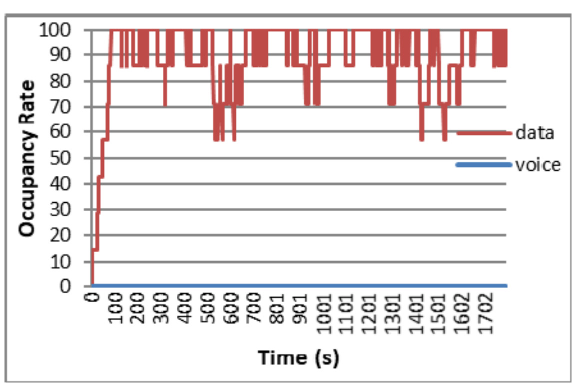


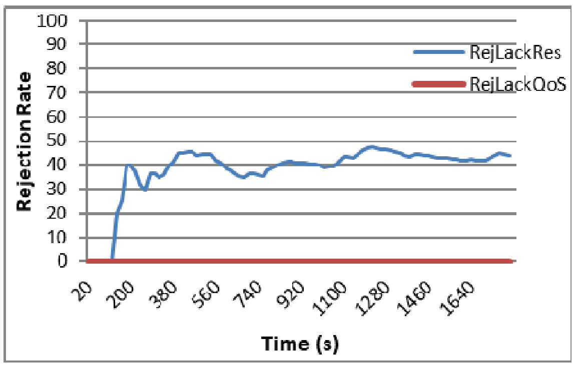
Figure 4 Wi-Fi occupancy for λ = 10 (see online version for colours)



As shown in ‘Figure 2’, where λ = 10, the LTE network does not become saturated, and we always find free resources, as well as the rejection rate due to lack of resources, RejLackRes, is always zero as in ‘Figure 3’. In contrast, the Wi-Fi network is almost saturated all the time 'Figure 4', and the RejLackRes approaches 50% 'Figure 5'. Strong preferences of data users to Wi-Fi network prevent access to LTE network while the latter provides free resources, which affects the rejection rate of those users. As the selection process respects the users' preferences, thus we notice that the rejection rate due to the lack of QoS, RejLackQoS, remains null as in 'Figure 5'.

We use the following main metrics to assess the performance of the suggested algorithm: the instantaneous occupancy rate in both systems, the two instantaneous rejection rates related to lack of resources and to degradation of QoS, and the average rate of accepted users in the system.

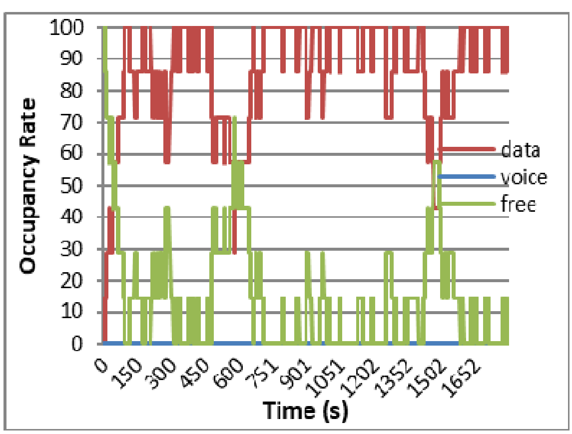
Figure 5 Wi-Fi rejection rate for λ = 10 (see online version for colours)



5.4 Scenario 2

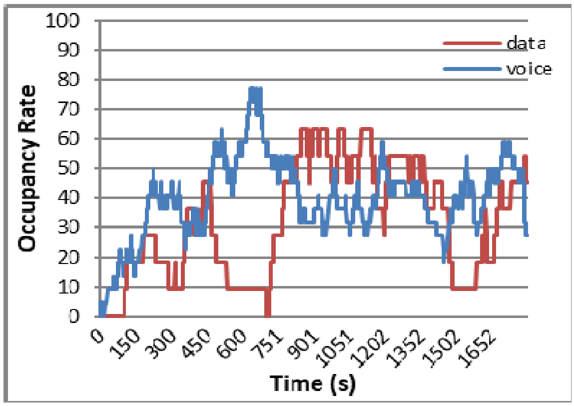
In this scenario, we give voice users a strong preference to LTE network and data users a medium preference to Wi-Fi network. We apply Algorithm 1, so that these users can be assigned to LTE network in case there are not sufficient resources in Wi-Fi.

Figure 6 Wi-Fi occupancy for λ = 10 (see online version for colours)



'Figure 6' and 'Figure 7' show that when Wi-Fi network is saturated, new data traffic is redirected to LTE network. By comparing the results obtained after the implementation of this scenario with those of the previous scenario, we can notice that the rejection rate of users in Wi-Fi network decreases significantly ‘Figure 8’, while the rejection rate in LTE network begins to increase after times t = 520 and t = 800 ‘Figure 9’, but their increases are relatively small regarding the improvement of the acceptance rate of the whole system.

Figure 7 LTE occupancy for λ = 10 (see online version for colours)



But by varying the arrival rate λ, to a value equal to 40 for example, we get different results. As Wi-Fi network is saturated most of the time ‘Figure 10’, and as data users access LTE networks, as there are resources available, without any control on their numbers or their proportions, then those users prevent voice users from accessing, at a given time, their strong preference network LTE, due to the degradation of the provided QoS. In other words, ‘Figure 11’ shows that LTE network becomes saturated by data users, and between t = 500 and t = 1250 no voice users are accessing the network. As ‘Figure 12’ shows the increase in the rejection rate related to lack of resources in Wi-Fi network, ‘Figure 13’ shows the increase in the rejection rate related to QoS degradation, in LTE network, caused by data users.

Figure 8 Wi-Fi rejection rate for λ = 10 (see online version for colours)

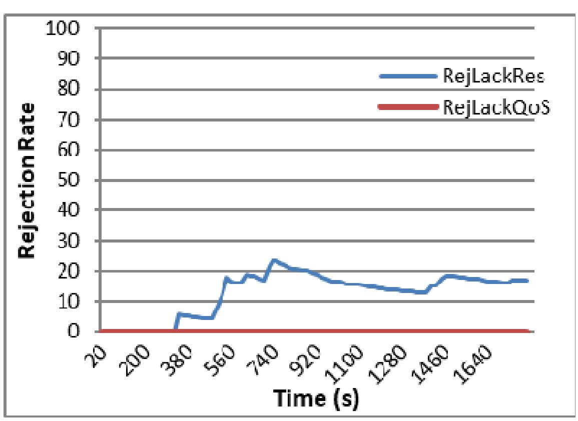


Figure 9 LTE Rejection rate for λ = 10 (see online version for colours)

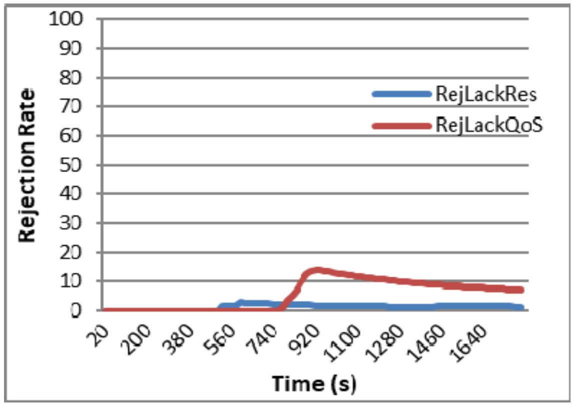


Figure 10 Wi-Fi occupancy λ = 40 (see online version for colours)

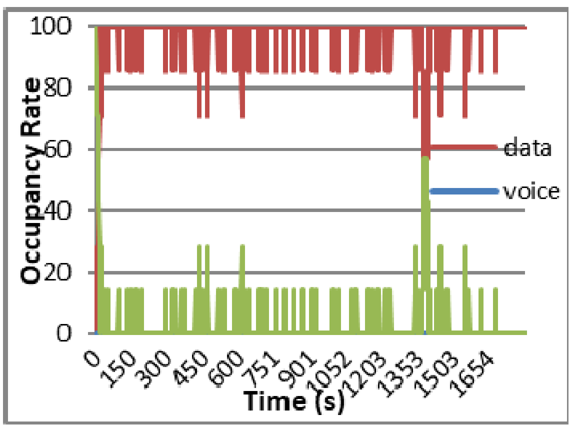


Figure 11 LTE occupancy for λ = 40 (see online version for colours)

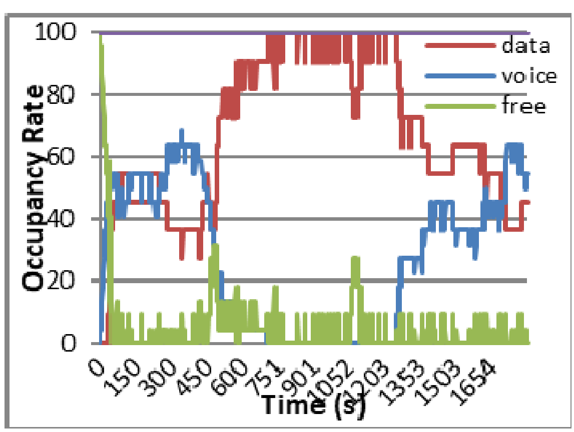


Figure 12 Wi-Fi rejection rate for λ = 40 (see online version for colours)

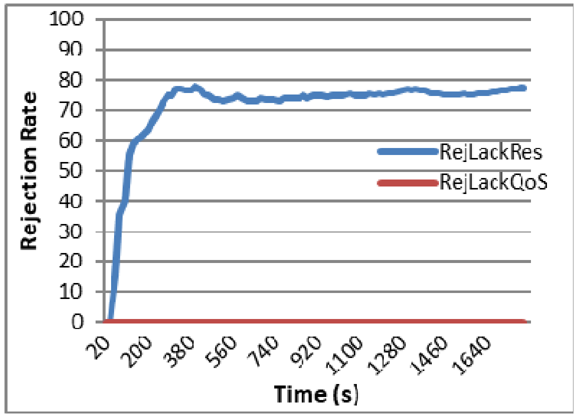


Figure 13 LTE rejection rate for λ = 40 (see online version for colours)

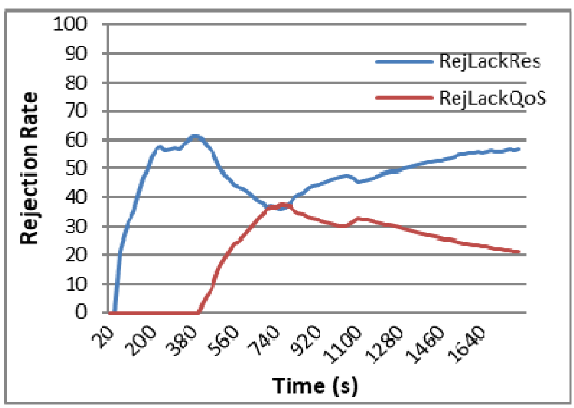
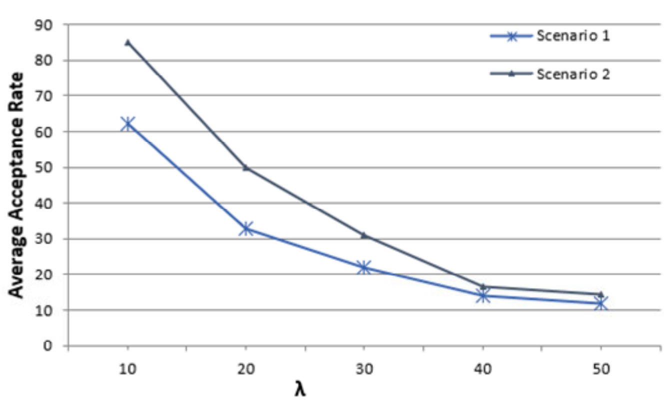


Figure 14 Average acceptance rate in the overall system for the two scenarios in function of λ (see online version for colours)



5.5 Comparison between values of average acceptance rate for the two scenarios

'Figure 14' shows the variation of the average acceptance rate of users in function of λ for different scenarios.

Scenario 1 provides the lowest acceptance rate for all values of λ: which is normal, because data users cannot access LTE network while the latter network provides free resources. Scenario 2 leads to better results than scenario 1 with all values of λ (highest acceptance rate).

5.6 Comparison between values of users' dissatisfaction average for the two scenarios

'Figure 15' shows the variation of users' dissatisfaction average in function of λ. With small values of λ, the dissatisfaction average in the two scenarios are close, this is due to the availability of resources and because most of the users are assigned to their preferred networks. We recall that a low value of dissatisfaction rate indicates that users are satisfied, i.e., that most of them are assigned to their preferred networks and the rejection rate is very small. When users are assigned to networks other than their preferred networks (the rejection rate increases), then we get a high average dissatisfaction rate. When the arrival rate increases, networks become saturated more quickly, and the rejection rate increases. Additionally, scenario 2 shows better dissatisfaction average values than scenario 1, as data users are assigned with medium preferences to Wi-Fi network, there will not be rejected immediately even if there are no resources available on their preferred network, instead they could be assigned to the LTE network, and this operation impacts on decreasing the average dissatisfaction rate.

Figure 15 Users' dissatisfaction average in function of λ (see online version for colours)

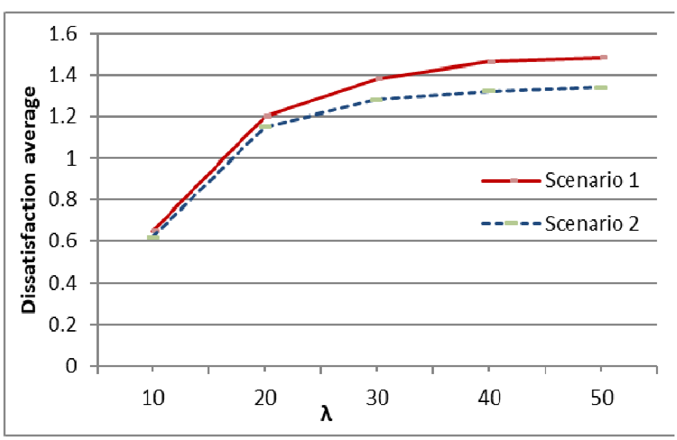


Table 2 Comparison between our work and some existing approaches from the literature

Work	*Candidate networks*	*Approach*	*Load balancing?*	*User satisfaction?*	*Evaluation parameters*	*Simulation/implementation*
Li et al. (2017)	2G, 3G, 4G	3-Param network selection algorithm using fuzzy explore-and-exploit strategy	No	Yes	RSSI, network matching factor (MF) related to user's preference, and number of free channels (FC)	By simulation
Udhayakumar et al. (2018)	UMTS, LTE	PSO (an AI technique) to achieve good QoS	No	No	RSS, bit rate, SNR, throughput, outage and BER	By simulation (NS2)
Ali et al. (2018)	UMTS, WiMAX, WLAN	A ranking algorithm based on user profiles and QoS	No	Yes	QoS (delay, jitter, packet loss ratio, min bitrate), cost, network security, mobile speed and battery power consumption	By simulation (NS2)
Liang et al. (2019)	WiMAX, LTE, WLAN	Selection algorithm based on the fuzzy neural network	No	Yes	Wireless link state (RSS), network performance (load), and user requirements (user service rate requirement)	By simulation (Matlab)
Our approach	LTE, WLAN, 3G	Selection algorithm based on load distribution according to user preferences	Yes	Yes	User preferences related parameters (bitrate per type of service, access preference value, dissatisfaction value), QoS (delay, jitter, packet loss ratio)	By simulation (ABCDecision)

6 Comparison with existing access selection algorithms

In the related work, the most effective and widely used parameters are those related to network capacity, to the QoS and to user preferences. But these algorithms do not consider the problem of load balancing between the various available networks, nor the problem of finding a trade-off between the user satisfaction (in terms of QoS) and the profit of the operator (in terms of maximising the network capacity). These issues are treated in our approach of decision selection that we proposed.

Table 2 summarises the comparison between our work and some existing approaches from the literature that were presented in the introduction section.

7 Conclusions

In this paper, we proposed an access selection algorithm that aims to maximise the overall ability of a system composed of many heterogeneous access networks. This algorithm, which is based on user preferences selection, can be used to maximise the capacity of a heterogeneous system composed of multiple access networks. The user preferences were applied on the type of service of the application required by the user. Two scenarios were discussed and simulated, where the results showed an enhancement on the overall acceptance rate.

In the future work, we aim to add a threshold for each network to limit the user accepted in a time, thus a network will not be saturated when the others still have resources.

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