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A Novel Joint Radio Resource Management with Radio Resource Reallocation in the Composite 3G Scenario

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Abstract: Joint Radio Resource Management (JRRM) is the envisaged approach to optimize the radio resource usage of the heterogeneous wireless networks. In particular, this study proposes a novel Joint Radio Resource Management framework with the Radio Resource Reallocation function to improve the radio resource efficiency. Radio Resource Reallocation entity is introduced to the JRRM framework which dynamically reallocates the ongoing sessions of different Radio Access Networks to achieve better radio resource utilization. In order to realize Radio Resource Reallocation, we build the system model of the composite 3G scenario and investigate the Radio Resource Reallocation approach based on Integer Programming. Simulation results demonstrate that the proposed JRRM with Radio Resource Reallocation function can improve the radio resource efficiency and perform better than that without Radio Resource Reallocation function.

Key words: JRRM, session reallocation, heterogeneous networks, integer programming, branch-and-bound procedure

INTRODUCTION

Joint Radio Resource Management (JRRM) is one of the promising approaches that can efficiently manage the radio resources in the heterogeneous networks scenario (Giupponi *et al*., 2008). JRRM refers to the set of functions that are devoted to manage the available radio resources of the composite Radio Access Networks (RAN) (Moessner *et al*., 2006). The main point of JRRM is to satisfy users' service requests through the most proper RAN. Several factors are considered in JRRM including the service support capabilities, traffic loads of different RANs, Quality of Service (QoS) requirement of the service request, movement speed of the user, the link measurements of available RANs and so on. The access selection in JRRM is a key enabler to properly manage radio resource which allocates connections to specific RANs at session initiation (Giupponi *et al*., 2005). The traffic loads of available RANs play an important role in the access selection. It would be better to allocate sessions to the RANs with lower traffic loads which can provide better QoS to the users (Ramirez *et al*., 2006; Saker *et al*., 2009). The traffic loads varies all the time with the allocation and release of the radio resources. The access selections for the sessions may not keep always the most suitable. New service requests may be blocked by the unsuitable access selections of the ongoing sessions. So we propose a novel JRRM with Radio Resource Reallocation function. The Radio Resource Reallocation entity will reallocate the ongoing sessions when new service requests are harmed by the ongoing ones to achieve always the most efficient radio resource allocation.

JOINT RADIO RESOURCE MANAGEMENT

JRRM is investigated by the European Smart User Centric Communication Environment (SCOUT) project and further studied within the European End-to-End Reconfigurability (E^2R) project. The JRRM concept is intended to achieve an efficient usage of the joint pool of the radio resources available belonging to a variety of RANs in a certain service area. JRRM scheme usually comprises three main radio resource management functions: Radio Access Technology (RAT) and cell selection (i.e., the functionality set to decide the RAT and cell the mobile has to be attached to at session start), bit rate allocation (i.e., the functionality set to decide the most suitable bit rate or bandwidth for each RAT and accepted user) and admission control (i.e., the functionality set to decide whether a request to set-up a

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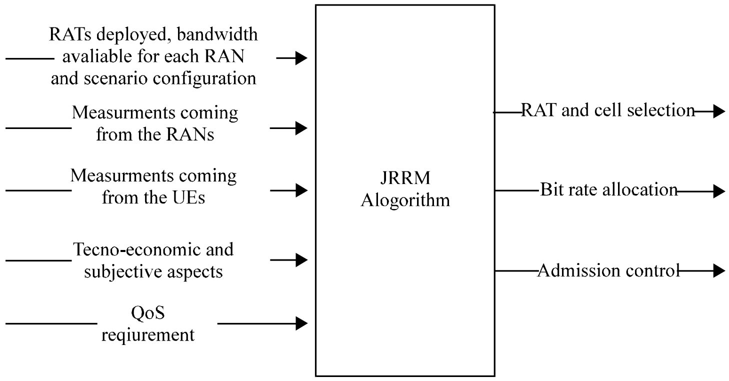

Fig. 1: Preliminary framework for a general JRRM algorithm

connection can be accepted in the heterogeneous network scenario or not as well as the RAT that the connection will use) (Agusti *et al*., 2004). The preliminary framework for a general JRRM algorithm is depicted in Fig. 1.

The inputs available for JRRM decisions are mainly: (1) RATs deployed, bandwidth available for each RAN and scenario configuration (e.g., base station maximum transmitted power level, service supporting capability, etc.); (2) Measurements coming from the different RANs (e.g., traffic load levels) as well as measurements coming from the User Equipments (UEs), such as the received power levels, the path loss; (3) Techno-economic and subjective aspects, including operator policies which may prevail the use of certain RANs in front of others for different reasons (e.g., commercial strategies, radio network ownership, etc.) as well as subscriber profiles and user preferences (e.g., considering QoS versus cost) (Perez-Romero *et al*., 2008).

JRRM WITH RADIO RESOURCE REALLOCATION

JRRM allocates connections to specific RANs at session initiation considering the traffic loads of different RANs. When a session is admitted, the corresponding radio resource will be allocated according to the QoS requirement and the occupied radio resource will be released at the session end, so the traffic load situation is changing all the time. Although the access selection for the session is suitable for the traffic load situation at the session initiation, it might become unsuitable and affect the QoS of the following sessions when the traffic load situation changes. If the ongoing connections are reallocated through vertical handover when the previous access selection becoming unsuitable, it will alleviate and even eliminate the adverse impact with improving the radio resource utility and the overall QoS of the networks.

We proposed a novel JRRM with Radio Resource Reallocation function which can dynamically change the traffic loads of different RANs in the heterogeneous scenario to achieve better radio resource utilization. The main idea of the proposed JRRM scheme is that when there is not enough radio resource for the user waiting to access the networks, Radio Resource Reallocation function will be started to optimize the radio resource utility and suitable radio resource may become available for the waiting user's service request.

The framework of JRRM with Radio Resource Reallocation is shown in Fig. 2. Different from the conventional JRRM, the proposed JRRM will start Radio Resource Reallocation algorithm when there is not enough radio resource to meet the user's service request, while the conventional JRRM will reject the user's service request directly. The Radio Resource Reallocation algorithm will conduct whether there is enough radio resource available for the user if reallocating the ongoing sessions through vertical handover to alter the available radio resource distribution. If so, execute the radio resource reallocation and return the new traffic loads of different RANs to the JRRM algorithm to select the suitable RAN for the user to access. Otherwise, the user's service request has to be rejected because of radio resource deficiency.

The Radio Resource Reallocation is actually a progress of radio resource optimization which corrects the suboptimum radio resource allocation during the conventional JRRM and maximizes the overall capacity of the composite RANs. So we investigate a Radio Resource Reallocation algorithm based on Integer Programming.

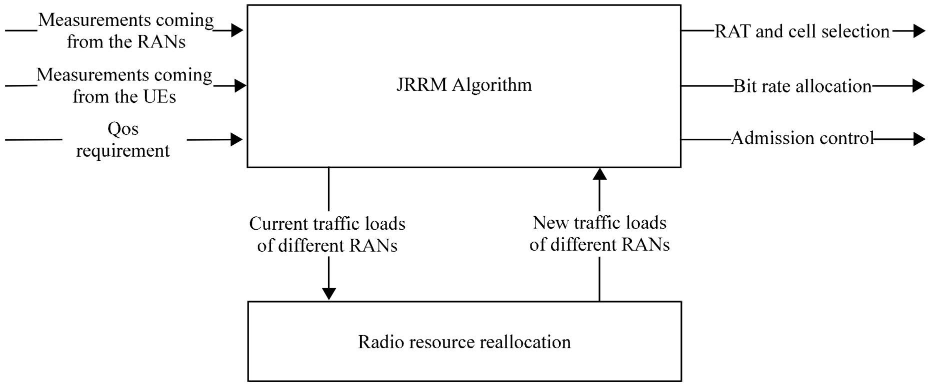

Fig. 2: The framework of JRRM with Radio Resource Reallocation function

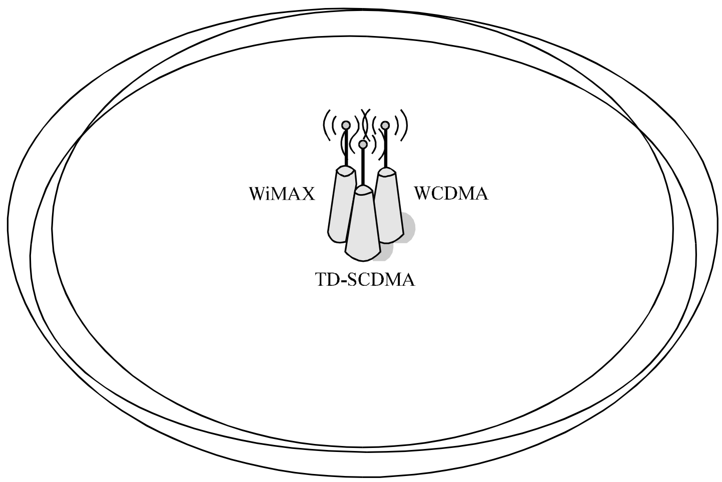

Fig. 3: The composite 3G scenario

RADIO RESOURCE REALLOCATION ALGORITHM BASED ON INTEGER PROGRAMMING

System model: In this study, we consider the heterogeneous scenario comprising WCMDA, TD-SCDMA and WiMAX. In this scenario, the cell coverage of each RAN is almost the same as shown in Fig. 3 and the base stations of different RANs are co-sited. Users are all located within the multi-RAT overlapped scenario.

Here S is denoted as the service type set, s is a specific kind of service. R is the RAN set, r is a single RAN. The overall sessions of service s is C_s, $s \in S$, the sessions of service s distributed in RAN r is $c_{s,r}$, $s \in S$, $r \in R_s$, R_s is the set of RANs supporting service s. $c^{\circ}_{s,r}$, $s \in S$, $r \in R$ is denoted as the current session distribution. The required spectrum bandwidth of service s through RAN r is $b_{s,r}$, $s \in S$, $r \in R_s$. For WCMDA, TD-SCDMA and WiMAX differ from each other by spectrum efficiency and service supporting capability, R_s $\forall s \in S$ and $b_{s,r}$ $\forall r \in R_s$ are not quite the same. There kinds of services are considered here, including voice, video conversation and 384kbps data service. So there are the following descriptions:

$$S = \{voice, video\_conversation, 384kbps\_data\} \quad (1)$$

$$R = \{WCDMA, TD-SCDMA, WiMAX\} \quad (2)$$

$$R_{voice} = \{WCDMA, TD-SCDMA\} \quad (3)$$

$$R_{video\_conversation} = \{WCDMA, TD-SCDMA\} \quad (4)$$

$$R_{384kbps\_data} = \{WCDMA, TD-SCDMA, WiMAX\} \quad (5)$$

$$b_{voice,TD-SCDMA} = \frac{1}{2} b_{voice,WCDMA} \quad (6)$$

$$b_{video\_conversation,TD-SCDMA} = b_{video\_conversation,WCDMA} \quad (7)$$

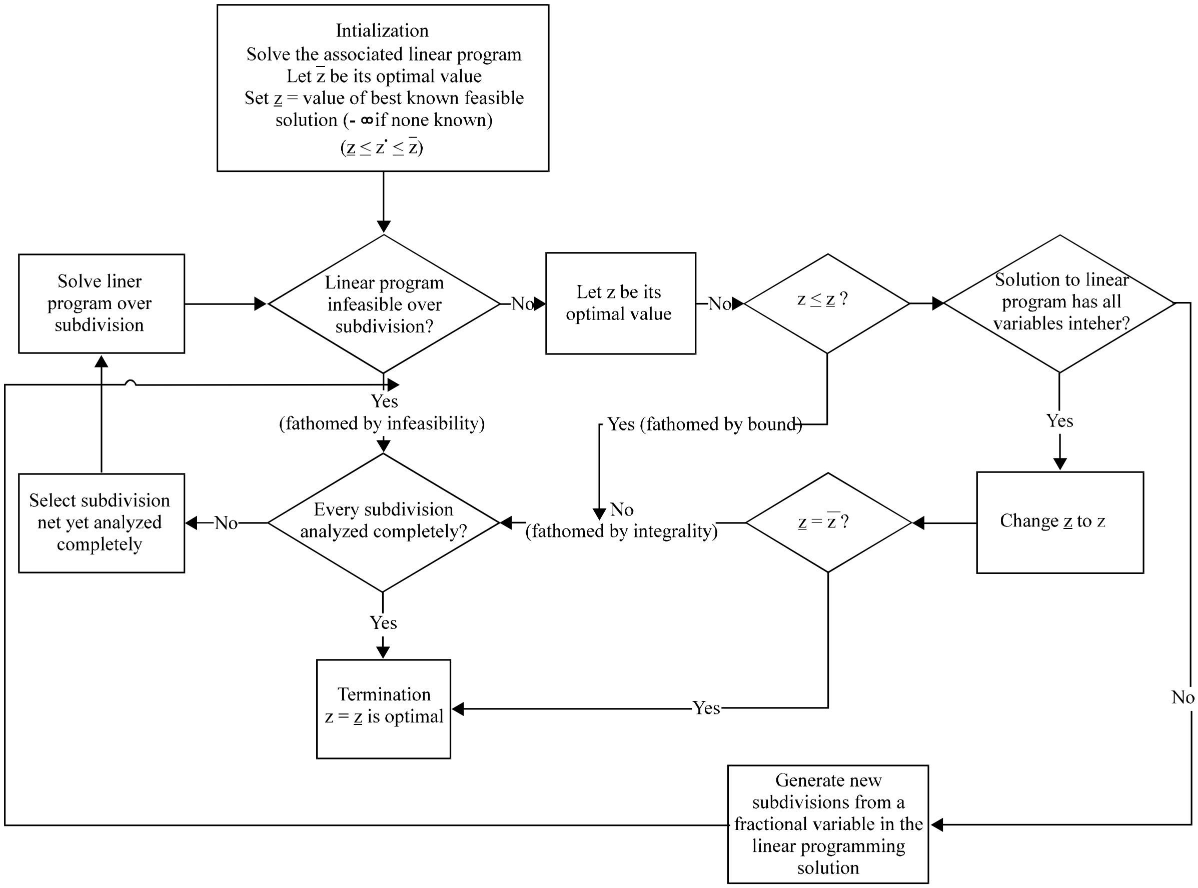

Fig. 4: The flow chart of branch-and-bound procedure

$$b_{384kbps\_data,WiMAX} = \frac{1}{3} b_{384kbps\_data,TD-SCDMA} = \frac{1}{3} b_{384kbps\_data,WCDMA} \quad (8)$$

We set the overall spectrum bandwidth of each RAN as constant Sp_r, $r \in R$ and C'_s, $s \in S$ including the service request of the current user waiting to access the network. If there exists the feasible solutions for the following problem:

$$\begin{cases} \min\left(\sum_{\forall r \in R} \sum_{\forall s \in S} (b_{s,r} \times c_{s,r})\right) \\ \sum_{\forall r \in R_s} c_{s,r} = C'_s \ \forall s \in S \qquad (*) \\ \sum_{\forall s \in S} (b_{s,r} \times c_{s,r}) \le Sp_r \ \forall r \in R \end{cases}$$

the current user's service request can be satisfied through reallocating the ongoing sessions to alter the available radio resource distribution; otherwise, the current user's service request has to be rejected because of radio resource deficiency. Solving problem *, we can acquire the optimal solution $c'_{s,r}$, $s \in S$, $r \in R_s$ with the highest spectrum efficiency. Comparing $c'_{s,r}$, $s \in S$, $r \in R$ and $c^{\circ}_{s,r}$, $s \in S$, $r \in R_s$, the vertical handover execution plan can be obtained and sessions are chosen to execute vertical handover according to the plan. Finally, the current user's service request is admitted and the suitable RAN to access is selected.

Problem * is an integer programming problem, because the variables $c_{s,r}$, $s \in S$, $r \in R$ are all integer and the constraints $\sum_{\forall r \in R_s} c_{s,r} = C'_s \ \forall s \in S$ $\sum_{\forall s \in S} (b_{s,r} \times c_{s,r}) \le Sp_r \ \forall r \in R$ and the objective function $\sum_{\forall r \in R} \sum_{\forall s \in S} (b_{s,r} \times c_{s,r})$ are all linear. In the mathematical programming, the branch-and-bound procedure is the most common algorithm used in practice to solve the integer-programming problem.

Branch-and-bound Procedure: Branch-and-bound is essentially a strategy of divide and conquer. The feasible region is partitioned into more manageable subdivisions and then, if required, the subdivisions are further partitioned. In general, there are different ways to divide the feasible region and as a consequence there are different kinds of branch-and-bound algorithms. For historical reasons, the technique that will be described next usually is referred to as the branch-and-bound procedure as shown in Fig. 4.

The essential idea of branch-and-bound is to subdivide the feasible region to develop bounds $\underline{z} < z^* < \bar{z}$ on z^*. For a maximization problem, the lower bound $\underline{z}$ is the highest value of any feasible integer point encountered. The upper bound is given by the optimal value of the associated linear program or by the largest value for the objective function at any subdivision. After considering a subdivision, we must branch to (move to) another subdivision and analyze it. Also, if either (I) The linear program over subdivision L_j is infeasible; (II) The optimal linear-programming solution over subdivision L_j is integer; or (III) The value of the linear-programming solution z^j over subdivision L_j satisfies $z^j \le \underline{z}$ (if maximizing), then there is no need to subdivid L_j.

In the above cases, integer-programming terminology says that L_j has been fathomed (To fathom is defined as to get to the bottom of; to understand thoroughly. Here, fathomed might be more appropriately defined as understood enough or already considered.). Case (I) is termed fathoming by infeasibility, (II) fathoming by integrality and (III) fathoming by bounds (Bradley *et al*., 1977).

In this study, we use the MATLAB toolbox YALMIP (Lofberg, 2004) to solve the integer programming problem which is a free MATLAB toolbox to model and solve optimization problems. As most of the mathematical programming solvers, branch-and-bound procedure is applied in YALMIP.

SIMULATION AND DISCUSSION

Here, the proposed JRRM with Radio Resource Reallocation is evaluated by simulation and the results are analyzed. The scenario shown in Fig. 3 is still considered as a typical scenario in the simulation. Each of the RANs in this scenario has 10 MHz spectrum bandwidth. Terminals can support multiple air interfaces with multi-homing capabilities. The voice and video conversation traffic are modeled according to Poisson scheme. The 384 kbit/sec data service is considered as FTP service according to the ON/OFF model and ON and OFF periods are both with Pareto distribution. The simulation time is set to 43200 sec and the overall blocking probability is calculated and recorded during the simulation. Finally, the simulation results are acquired as shown in Fig. 5.

The simulation results show that the proposed JRRM with radio resource Reallocation can decrease the blocking probability and improve the overall spectrum efficiency. With the number of users increasing, the blocking probabilities of the proposed and conventional JRRM both increase. However, the blocking probability of the proposed JRRM increases slower and which is always lower than the blocking probability of the conventional JRRM.

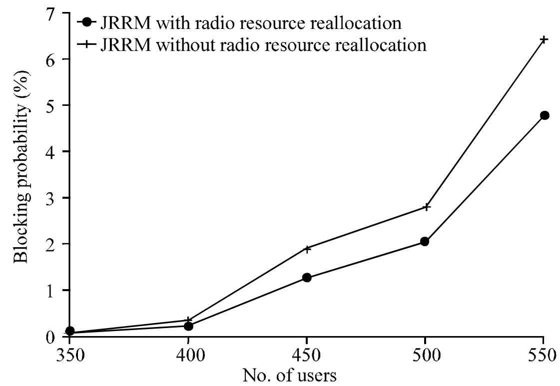

Fig. 5: Blocking probability against the number of total users

The major difference between the proposed and conventional JRRM is the Radio Resource Reallocation function. JRRM with Radio Resource Reallocation can correct the suboptimum radio resource allocation during the conventional JRRM and maximizes the overall capacity of the composite RANs. Radio Resource Reallocation can dynamically change the traffic load situation in the heterogeneous scenario to achieve optimal radio resource utility and better access environment for the users waiting to access the networks. For the above reasons, the proposed JRRM can decrease the blocking probability and improve the overall radio resource efficiency.

CONCLUSION

In this study, we have presented a novel JRRM with Radio Resource Reallocation function. Radio Resource Reallocation dynamically reallocates the ongoing sessions of different Radio Access Networks to achieve better radio resource utilization and correct the suboptimum radio resource allocation. We also investigate the algorithm based on Integer Programming to realize the Radio Resource Reallocation. Simulation results prove that the proposed JRRM with Radio Resource Reallocation can decrease the blocking probability and promote the overall radio resource efficiency.

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