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Radio Resource Management in Heterogeneous Networks, Functional Models and Implementation Requirements

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ABSTRACT

The scope of this paper is to provide a detailed description of the selected architecture and the functionalities considered for the AROMA project. This project focuses on a heterogeneous radio access network which includes several Radio Access Technologies (RAT) , namely; UMTS Terrestrial Radio Access Network (UTRAN), GSM/EDGE Radio Access Network (GERAN), and Wireless Local Area Network (WLAN). The corresponding Common Core Network (CN) is considered to provide and satisfy different kind of services, thus, different identified services have different QoS, then, so the goal is to study and analyze some algorithms, that best fit in the network in order to enable quality of service (QoS) based on the service demand in the network. Radio Resource Management (RRM) refers to a group of algorithms that are collectively responsible for efficiently utilizing the radio resources within a RAT to provide services with an acceptable level of QoS. Mainly, at present, Radio Resource Management (RRM) algorithms are implemented independently in each RAT. In the meanwhile, The Common RRM (CRRM) strategy, has been proposed in the literature to coordinate radio resources utilization among a number of RATs in an optimized way. This paper analyze CRRM solutions with particular attention on implementations. Starting from an analysis of the state of the art, the most interesting solutions have been critically analyzed and then some in depth investigations on some of the identified solutions have been performed.

Keywords

Common Radio Resource Management (CRRM), Heterogeneous Wireless Networks, Radio Access Technology (RAT)

1. INTRODUCTION

Recently, it is clear the wide deployment of several coexistence radio access technologies (RATs), such deployment for wireless scenarios introduces a new dimension to improve and utilize the performance and the efficiency when several radio access technologies are deployed together in comparison to the scare available radio resources.
Several RATs reflect the heterogeneity concept, where this scenario is composed of different Radio Access Network (RAN) each RAN interfacing a Common Core Network (CN). RANs can consist in different cellular networks, e.g. Universal Terrestrial Radio Access Network (UTRAN) either Frequency Division Duplexing (FDD) or Time Division Duplexing (TDD), GSM EDGE Radio Access Network (GERAN), as well as other public non-cellular broadband wireless hotspots, e.g. WLAN IEEE 802.11g or IEEE 802.11n [3]. Typically, The infrastructure of core network is divided into the Packet Switch (PS) and Circuit Switch (CS) domains. The CM provides access to external networks such as Public Switched Telephone Network (PSTN) or the Internet. Recently, the mentioned external networks include other public and private Wireless Local Area Networks (WLANs) providing an interface for terminals to access to the core network services. For more details refer to figure 1.

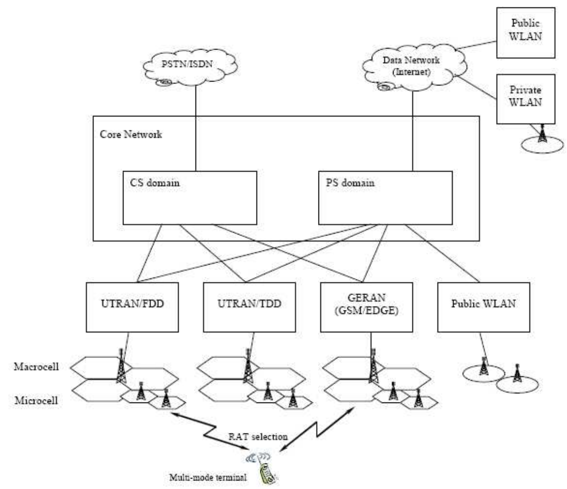

Fig. 1: heterogeneous network environment

Mobile and wireless radio access networks differ in their radio coverage, air interference methods [6], access techniques, offered services, price [2] and ownership. It is worth to mention that we focus in our study just on common radio resource management in heterogeneous networks only for 3G technologies and earlier mobile and wireless access techniques. For systems and scenarios where differ-

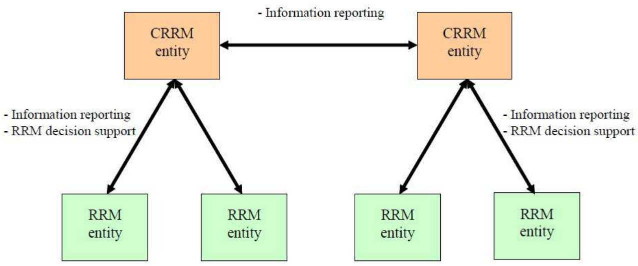

Fig. 2: CRRM functional model

ent access technologies can be deployed and coordinate together is referred as Beyond 3G (B3G) systems (i.e. 4G, LTE, and WiMax); in order to achieve gain of such B3G networks, the available radio resources must be managed in a proper way. This trend introduces a new algorithms for managing the radio resources, that take into considerations the overall available resources offered by several RANs, such algorithms from the common perspective is called as Common Radio Resource Management (CRRM) algorithms, briefly the concept of CRRM uses a two-tier Radio Resource Management (RRM) model [5], including of RRM and CRRM entities as clarified in figure 2. Generally, Common Radio Resource Management (CRRM) involves a set of functions that are engineered to achieve a coordinated and efficient utilization of the available radio resources in complex scenarios that are including heterogeneous networks. More in details, CRRM policies should guarantee to meet the network operator's goals in terms of Quality of Service (QoS) and network coverage extension while increasing the overall capacity as high as possible.
The scope of this study is to analyze CRRM solutions with particular attention on implementations. Starting from an analysis of the state of the art, the most interesting solutions have been critically analyzed and then some in depth investigations on some of the identified solutions have been performed.

2. RESEARCH METHODOLOGY

The methodology followed to carry out this research paper focused on the following steps:

(1) Read and analyse accurately some research articles and technical available reports which report several CRRM solutions.
(2) Investigate about the CRRM-algorithms and related work on the explicit subject, in order to derive the important features, requirements and architecture that can be used for implementing and modelling the CRRM-algorithms.
(3) Using some software tools (models-simulator) already developed in TiLab SpA [9] in order to model the behaviour of the system when CRRM solutions are applied; analytical models are based on Markovian Chain.
(4) System modelization permits to analyse the QoS and system performance for the desired CRRM algorithm.

3. RELATED WORK

Recently, different strategies of of Radio Resource Management (RRM) are independently implemented in each RAT. Since each RRM strategy [1] just only take into considerations the situations and conditions on only one RAT, thus none of the RRM strategy is suitable of heterogeneous networks. CRRM strategy, is also known as Joint RRM (JRRM) or, Multi-access RRM (MRRM), just strategies has be proposed in order to coordinate and optimize the utilization of different RATs. Many strategies has been proposed for CRRM, i.e. in [10] the results shows that CRRM has much better performance in networks in comparisons to that networks without CRRM, such performance gain is valid for networks with either real time (RT) and non-real time (NRT) services, in different terms, mainly capacity gain and blocking probability of the call [4].
The author in [7] proposed a Common RRM (CRRM) algorithm to jointly manage radio resources among different radio access technologies (RATs) in an optimized way. Moreover, a survey on the Common Radio Resource Management has been further analyzed in [11].

4. CRRM IMPLEMENTATION

The main factor for selecting suitable CRRM strategy and implementing its mechanism is depending on the functionalities associated to the CRRM, which determines and define the interaction between both RRM and CRRM entities. such interaction control is used for decision support and reporting the information between different network entities. It is important to note that, in all CRRM strategies, the trade-off between the any strategy gain and the typical network delay and signaling overhead must be considered.
Interworking architecture:

(1) **GERAN/UTRAN interworking**: To establish a network connection between UTRAN and GERAN, both the Base Station Controller (BSC) and Radio Network Controller (RNC) must be connected to the same 3G CN, in particular to the Serving GPRS Support Node (SGSN) via the Iu interfaces (such interface is shown in 3).
(2) **3GPP/WLAN internetworking**: WLAN deployments use a different network architecture from the architecture that is used by 3GPP system, whereas both UMTS and GSM/EDGE use 3GPP system networking architecture. Thus, desired internetworking solution should consider both none technical and technical aspects. Thus, for supporting both CRRM and RRM functionalities, the APC (Access Point Controller), that is responsible for managing the radio resources utilized by the access points where the WLAN users are connected to, should be equipped with similar functionalities of the BSC and the RNC for both the GERN and UTRAN, as depicted in figure 3.

CRRM can be implemented as:

(1) **New separate node**: CRRM entity can be implemented as a new separate node of the network (CRRM server). Furthermore, the CRRM server defines an open interface to facilitate internetworking between the CRRM node as well as the devices where RRM entities reside (i.e. APC, RNC and BSC). Such open internetworking interface is a common method generally is deployed in order to reduce or even remove the interoperability issues that are may introduce when different vendors components and equipments are interconnected. In most cases, such approach will boost both the cost and the time needed during any potential future upgrade tasks. More importantly, this approach will ensure that all the functionalities are centralised.
(2) **Integrate CRRM between existing nodes**: CRRM functionalities can be integrated into existing nodes (integrated CRRM), in this case CRRM/RRM communications details not required to be defined in-priori and this detailed will depend on vendor implementation. The main advantage of this approach

Short name	Category	Sub-category	Involved RATs	Desired Scenarios
Radio quality based inter-working mechanisms	CRRM	RRM strategies for VoWLAN and capacity estimation	UTRAN-R99, GERAN	Theoretical 2G-3G co-site
CRRM perceived throughput	CRRM	RRM strategies for combined usage of 2G, 3G and WLAN systems	GERAN, UTRAN R99 / R5 / R6, 802.11 a/b/g	Theoretical hot-spot urban
Coverage-based CRRM for Voice Traffic	CRRM	Coverage-based CRRM	Heterogeneous UMTS/GERAN	Realistic multi-floor building
CRRM Cost Function	CRRM	CRRM strategies for BS selection	UMTS-R99, UMTS-R5 and WLAN	Theoretical hot-spot urban
MPLS based mobility management and IP QoS	CRRM	Mobility management and QoS	LTE UTRAN	Specific defined scenario
Fittingness factor algorithm	CRRM	RAT selection strategies	UTRAN R99, HSDPA, HSUPA, GERAN, can be extended also to WLAN, etc.	Theoretical 2G-3G co-site
Common congestion control	CRRM	Inter-RAT RRM	UTRAN R99, GERAN	Theoretical 2G-3G co-site
Opportunistic CRRM	CRRM	RAT selection strategies	UTRAN R99, HSPA, and WLAN	Theoretical hot-spot main road

Table 1. : Overview of different CRRM solutions.

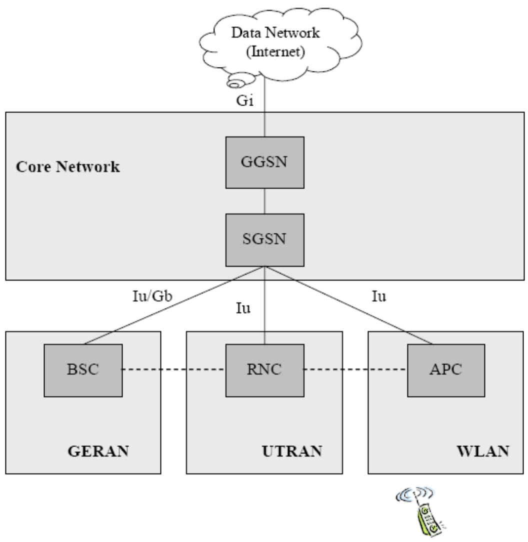

Fig. 3: WLAN/3GPP architecture

is that the system performance can be achieved without introducing additional delay, where the delay is important aspect especially for call setup, handover and channel switching.

5. OVERVIEW OF CRRM SOLUTIONS

The following group of CRRM algorithms come from IST-AROMA project [8]. These algorithms have been read and analysed carefully as an important task toward achieving the knowledge and requirements to model and implement CRRM algorithms and to evaluate them.
briefly, we provide a description about the studied CRRM algorithms.

(1) **CRRM perceived throughput**: Total data transmission delay times (connection setup, radio bearer establishment, TCP transmission etc) is used to calculate perceived user throughput for data transmissions. 2G, 3G and WLAN systems are analysed with different radio capabilities and with tight or loose WLAN coupling. Centralised CRRM algorithms are evaluated to analyse the total system throughput using different radio access capabilities and different operator policies / CRRM algorithms.

(2) **Coverage-based CRRM for Voice Traffic**: The coverage-based CRRM concept for hybrid FD/TDMA and CDMA cellular systems, which intend to improve system efficiency by taking advantage of the complementary characteristics of FD/TDMA and CDMA systems, i.e. FD/TDMA is able to offer a rather static coverage and capacity while the coverage and capacity trade-off in CDMA is much more straightforward. This scheme has shown great potential to improve voice capacity in the heterogeneous environment.

(3) **Multiprotocol Label Switching (MPLS) based mobility management and IP QoS**: A framework for QoS architecture with the MPLS-based micromobility presented. The simulation platform includes the following functionalities: DiffServ and MPLS for the user-plane forwarding, QoS-enabled Open Shortest Path First (QOSPF) for the routing, bandwidth broker for the resource reservation and admission control and IP micro-mobility for the intra-domain mobility management.

(4) **Fittingness factor algorithm**: It consists in a new generic framework for developing CRRM strategies in heterogeneous scenarios was presented. It captures the different degrees of

heterogeneities that can be found in the network (including RAT and terminal capabilities as well as the suitability of one or another RAT depending on the current interference, path loss and load conditions) by means of the so-called fittingness factor of one cell in one RAT. From this metric, new RAT selection schemes both at the session initiation and during the connection lifetime have been defined.

(5) **Common congestion control**: This algorithm addresses how to solve congestion situations in UTRAN/GERAN networks by means of executing vertical handover procedures between both RATs and RAT-specific procedures, like bit rate reduction in UTRAN.

(6) **Opportunistic CRRM**: Opportunistic CRRM is intended for services without stringent delay constraints. It is based on the concept that these services allow waiting until the coverage area of a high speed RAT (e.g. WLAN, High Speed Packet Access (HSPA), etc.) is found instead of making use of RATs with continuous coverage (e.g. GERAN, UMTS) with a more reduced bit rate.
In Table 1, we present a brief comparison between the earlier algorithms under study in terms of Short name, Category, Subcategory, Involved RATs and Desired Scenarios.

6. CONCLUSIONS AND FUTURE WORK

This paper has described emerging heterogeneous network scenarios with a mix of RATs (e.g. GERAN, UTRAN and WLAN) utilizing a common core network functionality. A functional model for having a common management of the pool of radio resources has been outlined. in the telecommunications field. This scenario arises the need for network functionalities (i.e. CRRM solutions) devoted to mange the pool of resources offered by different RATs to get benefit of the specific characteristics of each RAT with the aim of increasing the network capacity and improving the QoS. While the proper selection of CRRM- algorithm reflect the gain that can be obtained from the heterogeneous scenarios. this paper. outlines the potential levels of coordination in the radio resource management decisions in the identified functionalities. Finally, the requirements in terms of interworking capabilities and considerations about the physical CRRM implementation have been detailed.

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