FLEXIBLE BASE STATIONS AND ASSOCIATED MANAGEMENT FUNCTIONALITY IN THE B3G WORLD

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ABSTRACT

Management functionality in the wireless B3G will have to solve complex problems, due to the existence of versatile options for satisfying stringent requirements, under difficult environment conditions. The introduction of Flexible Base Stations (FBSs) in the B3G world is a direction for achieving efficient management, exploiting the reconfiguration capabilities in software and hardware level. In this paper, the FBS architecture and the management functionalities are described. Furthermore, the efficiency gained through te use of the management functionalities on FBSs will be shown from indicative results.

1. INTRODUCTION

In the context of Beyond 3rd Generation (B3G) wireless communication systems, the coexistence of several different networks like UMTS, LTE [1], WiMAX [2], WLANs [3] will provide several solutions in order the users to be served with the best possible QoS level [4]. However, several problems may be raised like interference, waste of resources, inefficient load balancing etc, because of the parallel operation of many Radio Access Technologies (RATs) at the same time. In order to solve problems like those mentioned above an efficient management scheme is more than necessary.

The management functionalities should take into account a great amount of input like context information (user distribution, user and resources profiles, policies, network capabilities and spectrum resources) in order to provide feasible network configurations. The target is to enable users to be served with the maximum possible QoS level exploiting all network resources capabilities while keeping the operational cost for Networks Operators (NOs) under certain thresholds. In order this target to be achieved, management functionalities should be enhanced with optimization procedures in order the network to be able to adapt properly to the environment changes that may derive from several problems like hot spots, malfunctions, security threats etc.

Pointing towards this direction, Flexible Base Stations (FBSs) provide one of the most important means towards achieving the flexibility described above. FBSs are capable to reconfigure themselves allocating resources dynamically amongst different Radio Access Technologies (RATs), with respect to the decisions of the network management functionality. FBSs provide the following software enabled reconfigurations: a) change of spectrum used for a RAT, b) change RAT keeping the same spectrum and c) change both RAT and spectrum. Exploiting the above FBSs capabilities the management functionalities are able to propose optimum network reconfigurations for proper network adaptation.

Our work presents an approach for the overall optimization procedure, exploiting FBSs software and hardware capabilities. In section 2 a high level description of FBS will be given. In section 3 the management functionality will be presented in detail while in section 4 an indicative scenario will be presented exhibiting the efficiency of FBSs and the associated management functionality.

2. FLEXIBLE BASE STATION DESCRIPTION

To enable the concept of an FBS as outlined above, significant technical enhancements of mobile base station implementations are required. The base station needs to support multiple frequency bands and air interfaces in parallel in a very flexible manner. Operational bands/standards shall be dynamically adjusted. For required enhancements mainly three areas can be distinguished:

- Operational and control functions,
- Baseband processing modules,
- Transceiver module(s).

The basic architecture of a FBS is shown in Figure 1.

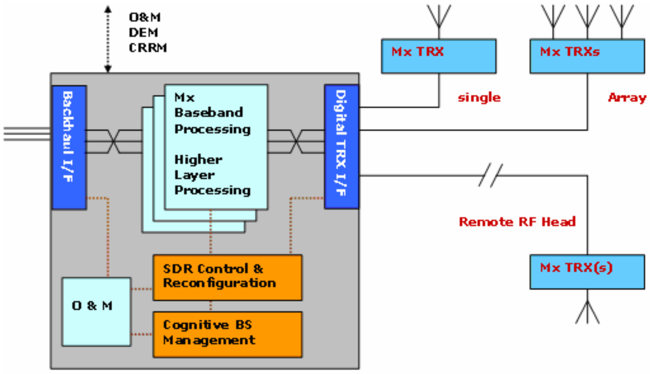

Figure 1: Flexible Base Station architecture

Backhauling to the fixed network is assumed to be based on an all-IP network interface, for transport (user plane) and for signaling (control plane, O&M, reconfiguration plane). Legacy Radio Resource Management functions, e.g. as for LTE, etc. have to be extended by self-learning, self-organizing mechanisms for joint resource optimization. Joint optimization will be achieved by inter-working with neighboring base stations where the context information of infrastructure resources of the subjacent access networks is obeyed while the decisions of FBS configuration and traffic distribution are provided by the management functionalities.

An SDR Control & Configuration function will enable flexible reconfiguration of the base station by means of adequate HW and SW changes. A SW framework will effectively support mapping of signal processing SW on to processing resources as required by the actual configuration. Mx-Transceivers connected via high-speed digital interfaces (e.g. according to CPRI industry standard [5]) can be implemented locally or as remote RF heads, serving single or multi-antenna configurations. Targeted flexibility requires enhanced antenna networks reconfigurable to the appropriate frequency bands for GSM, UMTS, LTE and WiMAX as well as a combined design for FDD and TDD modes.

3. MANAGEMENT FUNCTIONALITY DESCRIPTION

One of the most important characteristics of a B3G environment is the reconfiguration capability of the network resources in order to be properly adapted to the network environment conditions. Flexible base stations can be reconfigured through software enabled reconfigurations including changes like the operating RAT and/or frequency band. Furthermore, mobile terminals have also reconfiguration capabilities in order to be aligned with the allocated base station configuration. Figure 2 depicts a typical wireless network segment (i.e., subset of the overall infrastructure) of a NO in the B3G era. It comprises several access points, respectively, which can operate a specific RAT, or others with software-defined-radio capabilities [6]. These last elements have the ability to change the RAT operated on their transceivers, by activating the appropriate software on the hardware (one RAT can be operated at a time).

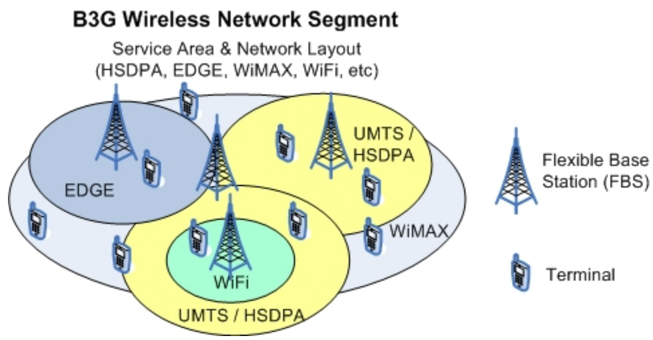

Figure 2: B3G wireless network segment

Figure 3 provides the overall description of the management functionality for B3G wireless network segments. It takes as input information that is classified as context, profiles and policies. Output is produced by applying optimization functionality [7].

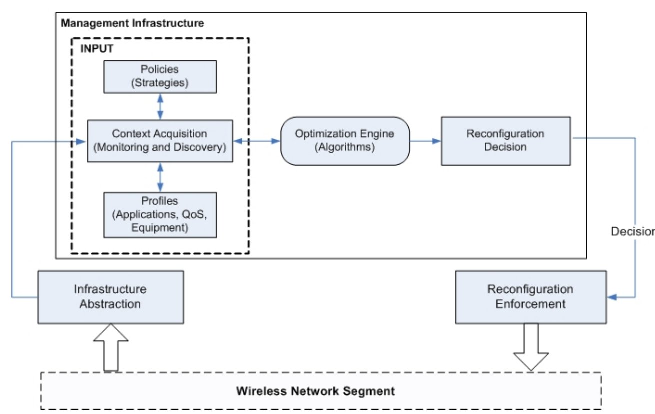

Figure 3: B3G management infrastructure

The management infrastructure has interfaces with the network segment through two components called infrastructure abstraction and reconfiguration enforcement. The former provides -level information, expressed in a high level manner, on the infrastructure. This information is used for perceiving the context encountered in the network segment. The reconfiguration enforcement module proceeds to the implementation of the actions dictated by the management system. The input as well as the optimization procedure and reconfiguration decision is described below.

Context. This component reflects the status of the elements of the network segment, and the status of their environment. Essentially, each element uses monitoring and discovery (sensing) procedures. Monitoring procedures provide, for each network element of the segment, and for a specific time period, the traffic requirements, the mobility conditions, the configuration used, and the QoS levels offered. Discovery procedures provide information on the QoS that can be achieved by alternate configurations. Context information will be used from the system not only to update network KPIs and address possible problems but also to provide the current view of the service area that can be translated to a well-specified pattern.

Profiles. This component provides information on the capabilities of the elements and terminals of the segment, as well as the behavior, preferences, requirements and constraints of users and applications. Essentially, this part designates the configurations that will be checked for network elements and terminals. For users this part designates the applications required, the preferred QoS levels and the constraints regarding costs. This information is necessary during the optimization procedure in order to decide the most appropriate configuration considering current context information.

Policies. The optimized decisions of the management functionalities should not only be feasible from technological perspective but also have to be aligned with NO's policies and strategies. Policies information designates rules and functionality (optimization and negotiation algorithms) that should be followed in context handling. Sample rules can specify allowed (or suggested) QoS levels per application, allocations of applications to RATs and assignments of configurations to transceivers.

Optimization. The optimization procedure which is responsible to produce a feasible network configuration after all aforementioned information about context, profiles and policies are taken into account, can be based on various techniques as discussed in [7]. In general, the strategy should find the best configurations that maximize an objective function, which takes into account the user satisfaction, resulting from the allocation of applications to QoS levels, the cost at which QoS levels are offered, and the cost of the reconfigurations.

The target of this procedure is to find the configuration that maximizes the following objective function:

$$\sum_{i \in U_t} \left[u_{s_i, q_i} - c_{s_i, q_i}\left(l_i, r_{t_i}\right) \right]$$

where u_{s_i,q_i} is the utility volume of user i experiencing service s_i at QoS level q_i and $c_{s_i,q_i}\left(l_i, r_{t_i}\right)$ is the reconfiguration cost for user i experiencing service s_i at QoS level q_i while being in location l_i and served by transceiver t through RAT r_t. The term "utility" borrowed from economics [8] presents the degree of user satisfaction gained from the consumptions of network resources. From this point, it is quite easy to understand that as the objective function increases, users are experiencing services at higher QoS levels while the overall reconfiguration cost is the minimum possible.

Decision. The decision of the optimization procedure includes three allocation sets that should be applied to the service area. The first allocation set is the allocation of RATs to the available FBSs in the service area. Thus, several transceivers may need to change their operating RAT and/or frequency band. The second set is the allocation of traffic load (reflected by user services) to the transceivers. One of the most important aspects of the optimization procedure is load balancing. Thus, traffic load is uniformly distributed to transceivers according to their operating RAT characteristics like range, capacity, etc. The last set is the allocation of QoS levels to user services. The optimization procedure will exploit RATs capabilities in terms of capacity and range in order the user requested services to be delivered with the maximum possible QoS level.

4. RESULTS

An indicative scenario will be presented in order to facilitate the efficiency of the management functionalities combined with FBS capabilities. The FBS capabilities are the following:

- Three available transceivers on FBS
- Three supported RATs: UMTS, WLAN, WiMAX
- RAT activation and deactivation
- Frequency reconfiguration
- User reallocation

Furthermore the offered services are data service and audio service. The audio service will be served in constant QoS level (16Kbps) while data service can be offered to several QoS levels (64 Kbps, 128 Kbps, 256 Kbps, 384 Kbps, 512 Kbps, 1024Kbps) according to network resources and user profiles.

Three phases are considered for the scenario. During phase 1 the users in the service area will be served by the FBS and no reconfiguration action will be triggered. In phase 2 the load will be gradually increased (e.g. more users enter in this cell) and a reconfiguration action will take place. Finally in phase 3, the decision from management functionalities will be implemented by the FBS in order to adapt to the high load environment.

The initial configuration of the FBS is depicted in the following table:

Table I: FBS configuration during phase 1

Transceiver	RAT	Frequency band
1	UMTS	f1
2	UMTS	f2
3	UMTS	f3

According to the scenario, more sessions were activated or users have entered in the service area and the traffic load was increased. Thus, in phase 2, the user percentage per service is 40% for users experiencing data services and 60% for users experiencing audio services. Due to the high load conditions, which are reflected by the KPIs monitored by the management functionalities, the reconfiguration procedure is triggered. The decision that the management functionality reached is depicted in the following table:

Table II: FBS configuration in phase 3 (reconfigured)

Transceiver	RAT	Frequency band
1	UMTS	f3
2	WiMAX	f2
3	WLAN	f1

The changes that the FBS implemented are the following:

- Transceiver 1 changed the frequency band in which it was operating while the RAT was kept the same
- Transceiver 2 kept the same frequency band however the operating RAT was changed in WiMAX
- Transceiver 3 changed both RAT and frequency band

Due to the fact that new RATs were activated with higher capacity compared with UMTS, the total available capacity of the FBS was increased. The decision imposes that users of data services, which are located to the edge of the service area, will be served by UMTS RAT while users close to the FBS will be served with WLAN. WiMAX will serve users located outside the range of WLAN. The percentage of user allocation to QoS levels are depicted in Figure 4.

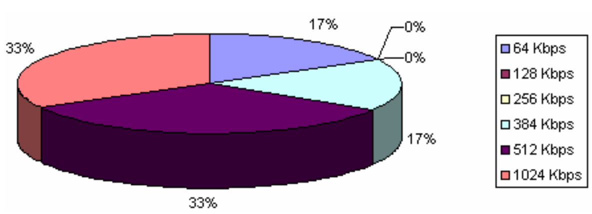

Figure 4: User percentage allocation to QoS levels

As a result of the above new user allocation to QoS levels, the satisfaction of the users will be increased. This is reflected by the objective function values depicted in Figure 5.

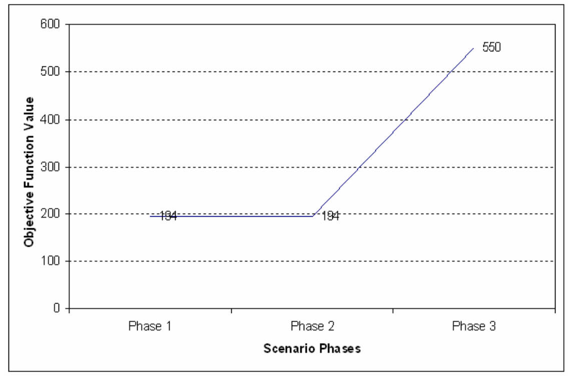

Figure 5: Objective function evolution

5. CONCLUSIONS

In this paper the need for efficient solutions for complex problems derived from B3G network segments was addressed. FBSs' reconfiguration capabilities on operating RATs and frequency bands provide to the management functionalities the means, in order to achieve proper network adaptation to the environment changes. Indicative results show the important gains in terms of user satisfaction and resources exploitation. Further research in this area will enable us to store information on the problems addressed in the past and the actions needed to solve them. In this way future problems of the service area will be solved faster and in a more efficient manner.

6. REFERENCES

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7. ACKNOWLEDGMENT

This work was performed in project E3 which has received research funding from the Community's Seventh Framework programme. This paper reflects only the authors' views and the Community is not liable for any use that may be made of the information contained therein. The contributions of colleagues from E3 consortium are hereby acknowledged.