Resource Management of Next Generation Networks using Cognitive Radio Networks

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1. Introduction

Network resource management is a vastly wide subject that has been studied extensively in many different networks. This chapter studies resource management with respect to cognitive radio networks.

More specifically, this chapter discusses resource management in cognitive radio networks in multimedia enabled Next Generation Networks. At the time of this writing, an emerging multimedia platform being developed is the IP Multimedia Sub-System (IMS). We use the IMS architecture to show how cognitive radio technologies may be incorporated in Next Generation Networks to support multimedia platforms. This is a new area of focus, and we anticipate increase in interest in this area as cognitive radio technologies become a reality. This chapter proposes several resource management scenarios, and highlights open research areas in regards to resource management in cognitive enabled Next Generation Networks.

Delivery of content by cognitive radio technologies will be critical to the successful implementation of cognitive radios in next generation networks. Current trends show that Next Generation Networks will be dominated by multimedia traffic. It is therefore of importance to determine how and where in the architecture of Next Generation Networks cognitive radio technologies will be most effective. Since cognitive radio technologies use white spaces that appear randomly in already assigned spectrum, the manner in which the white space is used is critical to Quality of Service, QoS of the traffic being transported.

The IP Multimedia Subsystem (IMS) is seen as the answer to the much talked-about convergence of data and telecommunication services. The original IMS design was by the 3rd Generation Partnership Project (3GPP) (3GPP TS 23.221, 2007) for delivering IP Multimedia services to end users, using telecommunication infrastructure. 3GPP is a collection of Telecommunication companies. The group's development of the IMS is seen as a way for core network carriers not losing their customers to the fast developing Internet technology.

Cognitive radio technology hopes to make use of unused licensed spectrum, as the secondary user, without interfering with the primary user. While most work has concentrated on predicting of white space in spectrum by a cognitive radio, the concurrent access of multiple cognitive radios still needs more work. Some proposals have proposed cooperation amongst cognitive radios. Should there be hundreds of even thousands of cognitive radios seeking white space conflict resolution should not be a time consuming endeavour. While a solution can be reached in conflict resolution, the appearance of the white space is random, and accessing it should be as soon as it appears.

It should also be expected that primary spectrum users will prefer to have control as to ***how, when*** and ***which*** cognitive radios access white space in their spectrum. The how: Primary users should be able to determine the rate of transmission in the accessed white space. When: Should the cognitive radio find the white space, how long should it wait before accessing it, and when to exit the white space. Which: Depending on individual behaviours of cognitive radios, primary users should be able to accept or reject a request for access to white space on its spectrum. By addressing the how, when and which concerns of the primary users, management of several cognitive radios in different networks should be more feasible.

The use of cognitive radios in IMS NGN architectures can then be classified as an optimization problem. For optimization, the question would be: At what transmission rate, for how long and which channel/s should a cognitive radio use without interfering with primary bandwidth user/s for best QoS?

The Resource Admission and Control Sub-System, RACS, module in the TISPAN architecture may offer a solution for both fast access of the white space, and managing it as a resource amongst several cognitive radios. We develop our proposal from the TISPAN IMS architecture.

We propose a framework for cognitive radio based resource admission and control based on the RACS architecture that allows for end users to use cognitive radios to search for temporarily unused licensed spectrum. The proposed framework allows for resource admission schemes to operate without need for the primary users to adapt their network usage as a result of spectrum access by secondary users. The framework reduces the need for sensing spectrum usage by primary users, by using capabilities of the RACS to specify a preferable period in which to search for spectrum and on which channels, thereby reducing spectrum sensing time. The major cognitive requirement of the radio will be in predicting when and where the white spectrum will appear within the allotted time period of sensing, and how long it will last.

We consider a scenario in an access network with several wireless communication networks, e.g WLAN, UMTS, GPRS CDMA etc. We assume that each of these technologies has an end-to-end coverage of the communicating users/servers, or connects to an core network technology that can communicate with one of the end users/servers.

The next section reviews some recent work in Next Generation Networks, we then discuss resource management in IMS (Section 3). In Section 4 we discuss traffic engineering issues in IMS enabled networks. In Section 5 we highlight some open research questions in cognitive radio networking in Next Generation Networks with respect to IMS, and propose a framework of resource management in Section 6. Future work on this research and conclusion to this chapter follow in Sections 7 and 8.

2. Recent Developments in Resource Management

This section highlights developments in resource management in cognitive radio networks and next generation wireless networks. Since the area of resource allocation in terms of white space, in cognitive radio networks has not yet been explored by the research community, this section serves as a back ground for resource management in cognitive radio networks. Books on giving comprehensive treatment of resource management in wireless networks can be found in (Cardei et al.,2005) and (Li & Pan, 2006) and citations in this section.

2.1 Resource Management Next Generation Wireless Networks

Resource management is concerned with maintaining a specified QoS in a network, and therefore also concerned with the admission control of new users into a network. The aim of resource management in next generation wireless networks is to allow for the most users into the network without compromising QoS of existing, or already committed resources and predicting future use.

Most work in NGN resource management in wireless networks has been concerned with mobility, and how to maintain connectivity and QoS across networks seamlessly. Over provisioning in wireless networks amounts to wasting of bandwidth. Studies on optimal provisioning of bandwidth have used decision theory (Haas et al., 2000), Game theory (Lin, 2004). Optimal provisioning proposals have had to take into account the rapid change in bandwidth usage of multimedia traffic.

Recent resource provisioning schemes have therefore been adaptive in nature (Nasser & Bejaoui, 2006; Chandramathi, 2008; Lu & Bigham, 2007; Sheu &Wu, 2006; Dharmaraja et al.,2003; Hu &Sharma, 2003). We will not detail the contributions of each of the above references on adaptive schemes since they generally attempt to do the same thing in a similar manner. It is however important to have an understanding of the schemes since resource allocation in cognitive radio networks will need to be as dynamic if not more, to accommodate as many users in a randomly short time period of allocated white space.

In (Haas et al., 2000), a problem formulation of admission control, while maintaining QoS is done using a decision theory approach. Assuming that the network providers provide the utilities and probabilities needed for the decision theory approach, Markov Decision Process is the used to make a decision for admission control. Authors assert that by using the utility and probabilities, it is possible to derive locally optimal policies that fall within the probability measures and utility functions. This would then allow for a trade-off between two contradicting requirements of desired QoS and spectrum utilisation.

Game theory approaches are either cooperative or non-cooperative schemes. Resource management in wireless networks is however modelled as non-cooperative game between the end user and the service provider. This is typically due to their contradicting requirements. For instance, end users want fast access to the network, which requires more bandwidth, while service providers want as many users as possible to maximise of profit. One such proposal is introduced in (Lin, 2004), where a resource management framework that attempts to maximise profits, while taking into account QoS requirements is proposed.

Decision theory and game theory approaches in current network resource management schemes and designs for Next Generation Networks will lay foundation for cognitive network based resource management schemes.

While QoS is important, there have been several publications that have alluded to the importance of the end-user's experience (Mellouk, 2008), (Markaki et al. 2007) while using a service as opposed to traditional QoS. Sometimes referred to as Quality of Experience, QoE, the user's perception of QoS maybe more important than the actual QoS. For example, a user may not mind inter-packet delays while downloading a file, but would rather be concerned with the duration of it takes to download the whole file. It will therefore be important to model user perceptions. In NGN networks, users will be able to choose from several available networks. It will therefore be important to understand user perceptions of a network will be important for network operators, as this will determine how they provision QoS in their networks so as to satisfy their users. In (Pal et al., 2005) a user irritation is modelled using Sigmoid functions. The authors classify users according to how much they pay. Although this method of categorizing is being used in current networks, the modelling of user irritation will be an important aspect for resource management in NGNs.

2.2 Resource Management for Cognitive Radio Networks

Resource management has so far been concerned with spectrum sensing at the physical layer and MAC layer resource allocation on a particular radio. These works have included spectrum sensing, spectrum mobility, spectrum sharing and power control and results from these works have brought about understanding of each of the individual problems. While most work has been directed to solving either of the challenges in cognitive radios separately, it may not be entirely realistic to develop the solutions independent of each other because they are interdependent. For example; a scheme for spectrum sharing may allocate several secondary users to white space on the same channel. The presence of several secondary users will degrade the channel quality, and power control schemes will have to optimise power of the radios to achieve the required QoS of their application, else migrate to another channel using a spectrum mobility scheme. Developments in resource management of white space in cognitive radio networks are now being presented by researchers.

A multi-user resource allocation scheme for delay sensitive application in (Shiang & Schaar, 2009) proposed. The work takes into account time delay restrictions of certain applications, note that it would take it would take too long for global information about the whole network to be learnt. The work therefore employs a multiagent-learning scheme for optimal learning. The approach of designing cognitive radio schemes with applications in mind will prevent the problem of over provisioning of resources.

A distributed scheduling and resource allocation scheme is proposed in (Bazerque , et al.,2008) which allocates power to users so as to maximise the weighted average rate of individual users. The scheme provides a good starting framework for cognitive radio networking. Some of the critical assumptions made in (Bazerque , et al.,2008) such as fairness being defined as guaranteeing minimum requirements for primary users and use of the OFDMA scheme limit the scheme in being used different networks using different modulation schemes as well as asserting limitations to primary users.

3. Resource Management in the IP Multimedia Sub-System

This section details resource management in the RACS. The RACS is responsible for allocating resources. The RACS is made up of Access-Resource and Admission Control Function, ARACF, and Service-based Policy Decision Function, SPDF, shown in Fig. 1. The

two are joined by the Rq interface, which is used for QoS resource reservation information exchange between the SPDF and A-RACF.
In the IMS architecture, an Application Function (AF), that contains multimedia applications being accessed, requests for resource reservations based on the required QoS of the application. The SPDF receives these requests and makes policy decisions, based on the specific access network it is located in. The policy decisions made are then transferred to the ARACF through the Rq interface. The ARACF then implements the resource reservation and admission control.

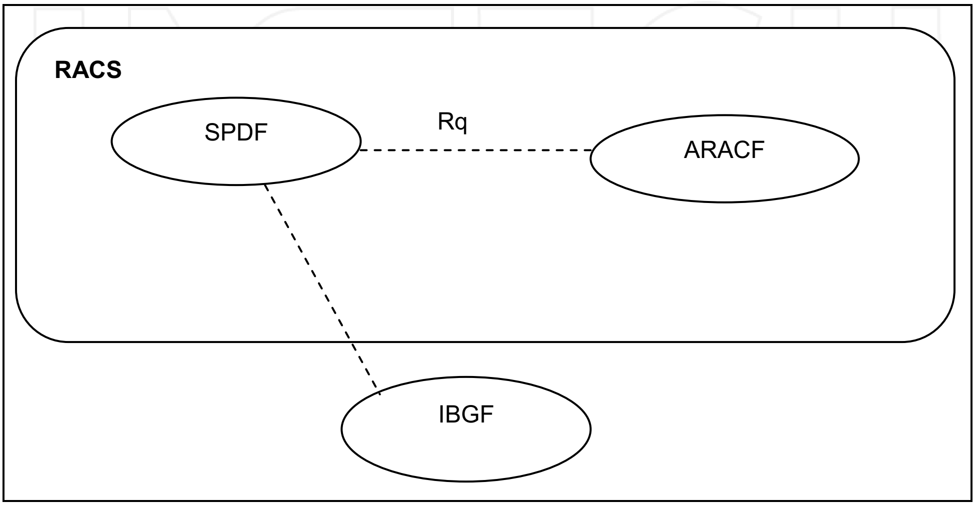

Fig. 1. The RACS architecture based on the TISPAN specification

The communication between the SPDF and ARACF elements is not limited to elements within the same network. One SPDF and ARACF can communicate between several ARACF elements in the same or different networks.
The RACS, a TISPAN NGN specification is meant to provide resource reservation, admission, and policy control to access and core networks. The scope of the RACS is within a given access network to the ingress node of a core network. The RACS therefore has communication interfaces between itself and access nodes, Resource Control and Enforcement Functions (RCEF) and Boarder Gateway Functions (BGF) in the transport layer. The current RACS specification does not take into account the integration of cognitive radio technology at the access nodes and core ingress nodes. The use of cognitive radio technology will allow wireless communication devices to access channels assigned to different access networks and technologies, making it possible for RACS to have access to resources of more than one network. It would also be possible to have several RACS communicate as a result. The RACS can therefore have scope of end-to-end resources across several networks. With available information of the resources available across several networks, better routing strategies would be possible.

4. Traffic engineering issues

While IMS seeks to improve user experience and increase services provided, several issues are still being addressed to make it compatible with existing technologies.

- Increase in Core Traffic

The ease with which services will be deployed in IMS will lead to a tremendous increase in traffic, especially in the core networks. While the strain on current networks due to the growth of the Internet is already a matter of great concern (Willinger, et. Al. 1995) to carrier networks, the implementation of IMS will exacerbate the situation. Increase in core network traffic needs much more efficient signalling schemes than those in current core networks, if QoS for all IMS traffic is to be satisfied.

- Increase in rapidly variable traffic

While to-date, the nature of network traffic has changed significantly from the time voice traffic, traffic characteristics (Willinger, et. al.,1995) will further change due to increased multimedia traffic. The current change of traffic from Poisson modelled traffic to Self-Similar traffic (Willinger, et. Al., 1995) has either led to increased over-provisioning of resources in the network, or reduced QoS. Multimedia traffic is variable in nature, and will thus increase the variance of traffic in the core network. To effectively handle the increased variance of traffic in the core network will require more resource efficient transport protocols, efficient routing schemes and robust Traffic Engineering (TE) solutions.

- Communication across different technologies

For true convergence, where end users can access different services across different networks, probably with different technologies, cognitive radio technologies would have to be used. Cognitive radio technologies would allow for traffic from different technologies to be routed seamlessly. In addition, although different networks with different technologies will co-exist, they will be viewed as one network from the end-user’s point view. It our view that communication networks will range from sensor networks, personal area networks to metropolitan networks, all of which have the ability to have IMS applications running on them. Cognitive radio technology will therefore be key to the interoperability of the different technologies.

Specific to the IMS platform, there will be a need for a customised signalling protocol that caters for the following scenarios:

- Several IMS providers

An IMS provider need not be a Telco. Several IMS providers utilising the same IP core can exist on a given network. And an end-user need not be subscribed to a particular network hosting a service in order to access services on its network. Rather, a User Equipment (UE) should be able to specify to access which application service regardless of which network it is on. On a large scale traffic management of the above scenario will pose signalling and routing challenges for core networks. Service Level Agreements (SLA) are needed between the IMS provider and the associated Telco. Appropriate signalling for resource reservation schemes, based on traffic type and length of route to be taken, would have to be used.

- IMS specific application management

Seamless mobility has recently been a key area of research, with some successes and yet some issues still outstanding. With the advent of IMS, an application will (may) have to be accessible in another network should a user move to another network. In addition, should the same application be available in the network moved into, it should be possible to handover the service from one IMS provider to another. The reason for the application handover would be to maintain the required QoS and/or optimise network resource utilisation. Delay, Jitter and packet loss would change depending on the movement of the end-user. Before the hand-over from one network to another and/or one IMS provider to another, packet routing would have to be re-optimised, based on the new network's status. The re-optimisation of routing would require efficient route discovery schemes across different networks. A generic signalling scheme across heterogeneous networks would be most ideal in such a scenario.

- Different Grades of Service agreements across networks

Across different networks and network types, there will be different Grades of Service (GoS) imposed. Currently internetwork traffic generally experiences poorer end-to-end QoS. Core networks should be able to determine which traffic is more urgent. Traditionally, the network with the lowest capacity or lowest Grades of Service (GoS) would limit the end-to-end QoS, and therefore be a bottleneck the communication. However, NGN IP core networks will be packet based. It will therefore be possible to route a stream of traffic through different routes and even networks, thereby improving end-to-end QoS. Synchronisations of IMS traffic through different routes and networks, and still remain within the strict delay, Jitter and packet loss requirements will be a signalling protocol challenge. To be able to synchronise packets in different networks will require a common signalling protocol between networks, which we propose should be generic in nature.

4. Open Research Areas

The following are open research areas with respect to resource management of cognitive radio networks in Next Generation Networks.

- Signalling protocol:

Current signalling protocols are not appropriate for cognitive radio enabled networks. A signalling protocol in a cognitive radio enabled network should enable the network to:

1. prevent collisions among radios
2. enable cooperation amongst cognitive radios
3. allow for cognitive radios to use available white spaces as efficiently as possible

Traffic behaviour and how access of white spaces by cognitive radios affect traffic modelling
Traffic behaviour has changed significantly from the times of voice communication using the Poisson model. The Poisson model was true for a long while, until telecommunication traffic began including data and multimedia traffic. Recently, traffic has changed from the Poisson model, to bursty traffic, exhibiting self-similar characteristics (Willinger, et. Al 1995). The inclusion of cognitive radios accessing white spectrum will without a doubt have a significant effect on the behaviour of traffic.
While the Poisson model was used for a long while as the traffic model of communication networks long after traffic had changed its behaviour to bursty, we propose that modelling of wireless traffic taking into account access by cognitive radios should be done concurrently with the development of cognitive radio technology. This will go along way in developing adequate resource management methodologies for cognitive radio enabled networks.

- Routing

Cognitive radio networking will not involve end to end resource reservation, due to the dynamic nature of the white spaces. Reservations will most probably only be possible on a link per link basis. Resources for secondary traffic will therefore have to be sought and reserved at every node. This has to be done while maintaining QoS of traffic being transmitted. The choice as to which node traffic should be routed to will depend on how the routing algorithm predicts utilization of a given node or network. Intuitively, secondary traffic should be transmitted into a network with the least utilisation however, delay tolerances of the traffic being transported should not be violated.

- Billing methodology

NGN networks promise single billing for all network access. A billing methodology is still to be developed for cognitive radio enabled networks. Cognitive radio enabled networks will have to develop a billing methodology for the end user so that the user gets billed once. Billing is made difficult by the fact that traffic maybe routed in multiple networks before reaching its destinations. The different SLA in different networks will also complicate accurate billing in cognitive radio networks.

- Classification and priotising of media types and users

Classification of traffic has been done in many traffic engineering solutions. Classification of traffic typically considers parameters such as: delay tolerance, media type, destination, and loss tolerance. In cognitive radio enabled networks, those parameters will have to be used with respect to the characteristics of a particular available white space.
Work needs to be done as to how to classify white spaces that are available randomly, and how to select the most suitable traffic depending on the characteristics of the white space.

5. Proposed Solutions to Some Open Research Areas

In NGNs where end user devices are proposed to have cognitive capabilities, we propose that the RACS controls end user device access to transport networks within its scope. This will be done by giving end user devices time limits within which to make transmissions. Fig. 2 illustrates the proposed architecture. We assume that the two communicating devices are within scope of each of the networks. The control over the use of spectrum by the cognitive radio limits one cognitive radio per time period, thereby reducing conflict in spectrum use by other cognitive radios. This method also lets networks know which cognitive radios are using its spectrum, as well as their individual behaviours. Knowing behaviour of individual radios would allow networks to blacklist any malicious users.

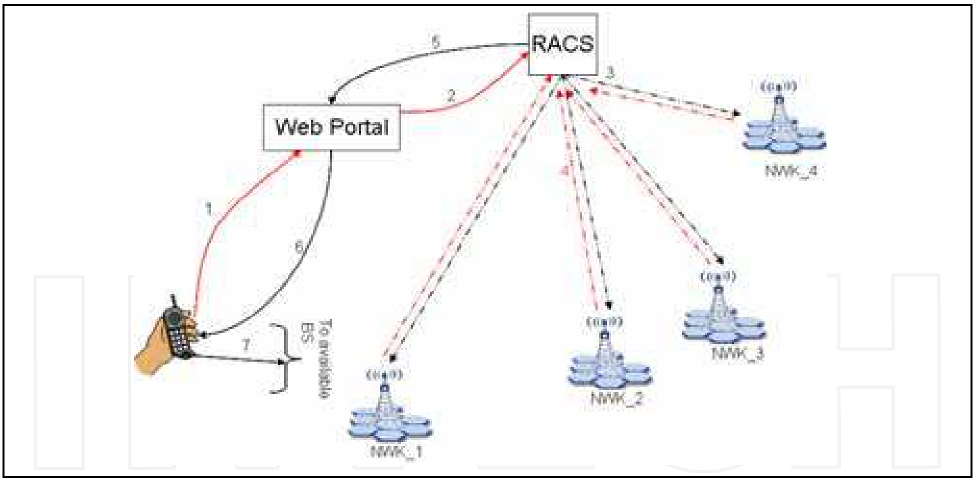

Fig. 2. Proposed use of the RACS for resource allocation in a cognitive radio network

We classify requests from cognitive radio to the Web Portal as Cognitive Radio Requests (CRR) to differentiate them from other bandwidth requests to the RACS. While in normal resource requests, the RACS reserves bandwidth, for CRRs, the RACS instead allocates a time period in which the cognitive radio should have finished or stopped its access to the licensed spectrum.

The sequence of events is as follows:

1. The end user notifies and requests use of licensed spectrum through the web portal.
2. The RACS gets updates from the Web Portal for all requests submitted.
3. For CRRs the RACS sends requests to the base stations within its scope and requests for spectrum access by a cognitive radio.
4. For all networks that accept spectrum access by the cognitive radio, they retain identification of the cognitive radio, and also specify a time period for access to the RACS.
5. The transmission period from each of the networks that accepted CRRs are sent to the Web Portal.
6. The cognitive radio retrieves the information regarding its request.
7. After determining the most optimised transmission solution, the EU transmits in the specified time period in the unused spectrum.

The cognitive radio must send as much data as possible without breaching the time period allocated to it, and without interfering with existing or future spectrum use by primary users. If the time period expires before the cognitive radio finishes transmission, it must request for a new transmission period again.

We deduce two scenarios from the proposed scheme shown in Fig. 3 and 4.

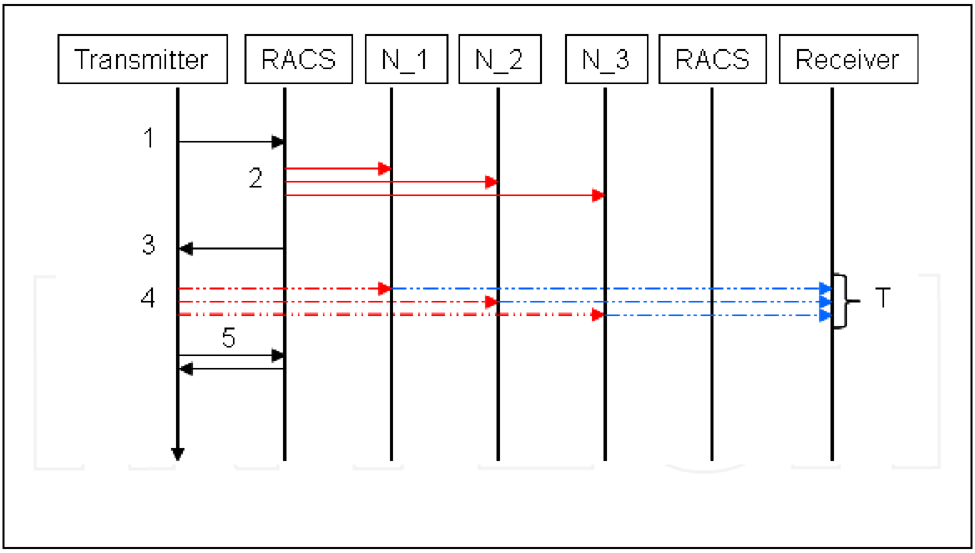

Fig. 3. A signalling mechanism that extends the scope of RACS in a cognitive radio network

The scenario in Fig. 3 is suitable for real time application, and would take the least time compared to the scenario in Fig. 4. After transmitting, the cognitive radio informs the RACS through the Web Portal.

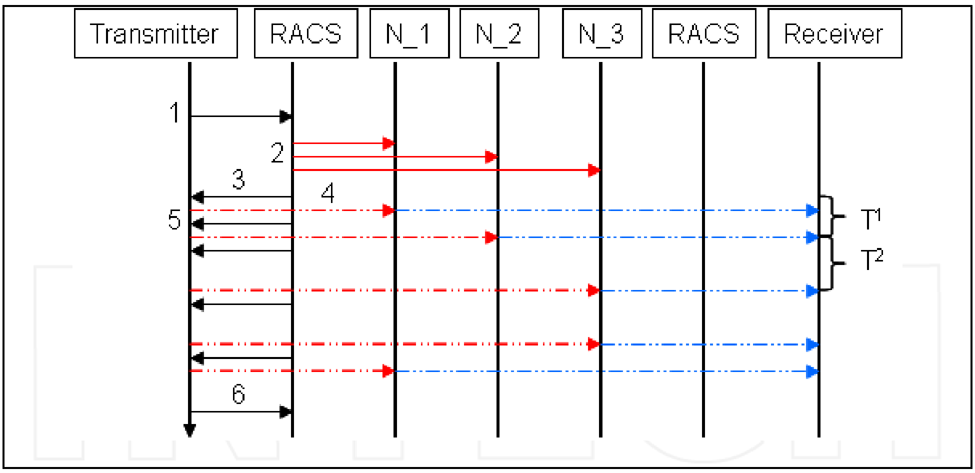

Fig. 4. A more dynamic signalling scheme extending the RACS' scope

The second scenario shown in Fig. 4 requires more signalling and slower than the scenario in Fig. 3. Instead of transmitting to as many networks as accepted, the cognitive radio transmits in the network with the best of two factors: transmitting time period, i.e largest, and least loaded network. However, after each transmission, the cognitive radio must request for new transmission periods. As a result the inter-transmission times vary. The

scheme is therefore not suitable for real time applications. When the cognitive radio finishes transmitting, it must inform the RACS through the Web Portal.
Generally, two main factors to be considered in an NGN cognitive radio based reservation scheme are; number/ types of available networks and capacities of available channels in networks. Since different networks differ in transmission rates temporarily free spectrum gaps in different networks will accommodate different rates of transmission. The greater the number of available networks, the greater the probability of accessing free spectrum. By available networks, we refer to networks that accept cognitive radios to transmit on their spectrum for a specified period.

- Cases for Multiple Cognitive Radio Requests

Partitioning the available transmission times across all the networks to all the available cognitive radios is critical in avoiding conflict during transmission times, and reducing spectrum sensing time. We identify three scenarios in multiple cognitive radio networks:

1. *Scenario* 1: For every cognitive radio request from the Web Portal, give all available transmission time to the first cognitive radio and queue other requests while the first one transmits.
2. *Scenario* 2: Allow the first cognitive radio to take all resources, and reduce transmission times with increase in other cognitive radio requests.
3. *Scenario* 3: For every request, a cognitive radio must identify the RACS through the Web Portal, which predefines a transmission time less than maximum to accommodate future requests.

A. Scenario 1

Scenario 1 would be synonymous with a First in First Out FIFO queuing system for requests. Since each request represents a session from a cognitive radio, priority is then given to the first session over the.

B. Scenario 2

Scenario 2 is a more dynamic type resource reservation scheme. While the first request is given all available transmission times, the allocation of transmission times will be reduced as more requests are allocated, and increased as more resources become available.

C. Scenario 3

In this scenario, the cognitive radio request identifies the type of media and the minimum required transmission rates.

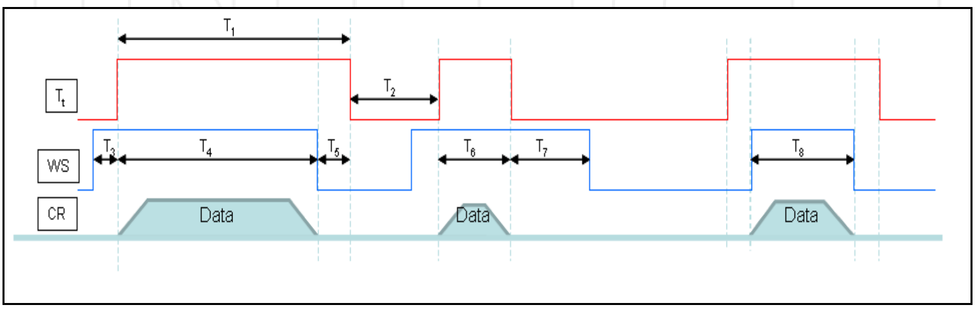

Fig. 5. Determining the transmission slot in case of one cognitive radio

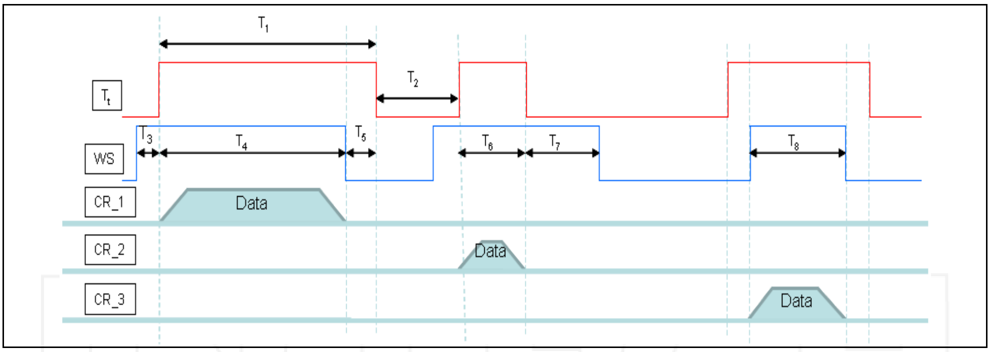

Fig. 6. Determining the sharing of time slots in a cognitive radio network

Fig. 5 and 6 show the relationships between the time allowed for by each network for CRs to use their spectrum T_t, the existence of the white spectrum in a given channel WS and transmission times of the CRs. The CRs can only transmit during the allocated transmission times, and when the white spectrum is available. Fig. 5 shows a simple case the first request being served first. And Fig. 6 shows a case where the all requests share available transmission times depending on priority settings in the RACS.

- Determining the transmission time T_t

Consider an access network with N_{nwk} total number of wireless networks, each with n_i channels. For each network and channels, the primary user specifies the time periods Tc for CRs to access the spectrum on given on a channel c. During the Tc the RACS gives permission to specified CRs to transmit data. The CRs then use spectrum sensing to identify white spectrum WS. The CRs then select appropriate transmission times t_{Tt} within both network time periods T_c and white space estimated times WS.

The reservation can be abstracted as an optimisation problem in (1) and (2).The objective functions f(t) and f(x) maximise transmission times and data rates of the cognitive radios. The distinction between transmission times and data rates is due to the different data rates in different network technologies and quality of channels, as such it is taken as a separate function. The RACS receives information of the number of networks and channels per network, Nc that allows access for CRs. Depending on the reservation queuing scheme at the network portal, CRs access the available network channels n_c. A CR in network channel n_i, then determines a transmission time t_{Tt} in the white space and transmission period T_C. Transmission in each white space is restricted to one CR to prevent interference from other CRs. Each request is processed according to a priority, p, given to it by the RACS.

- Maximizing the utility function for transmission time t_{Tt}

The aim is to maximize the transmission periods T_t, in a network of cognitive radios while taking into account the QoS requirements of each of the sessions in each channel n_{ic}. QoS is taken into account by the priority parameter p.

Priority P depends on the following:

- Time of request
- Position in queue
- Type of session, either beginning or session already in session
- Delay and jitter tolerance
- Packet loss tolerance

The transmission times t_{Tt} must be within the transmission periods T_C for the given channel n_{ic}. The $t_{Tt_{start}}$ and $t_{Tt_{stop}}$ are the starting and end times for Tt.
The selection of a network channel N_{NWKi} depends the quality of the channel, data rates that can be achieved, and network coverage.

$$\max\ f(t) = \sum_{i_{NT}=1, T_t, p=0}^{i_{NT}=n_c, T_t \le T_C, \; p=p_{\max}} U_t(n_{ic}, t_{Tt}, P) \tag{1}$$

$$subject \quad to :$$

$$t_{Tt_{stop}} \le T_C - T_t \qquad t_{Tt} \in T_t$$

$$t_{Tt_{stop}} > t_{Tt_{start}}$$

$$n_c \ge 1,\ N_{NWK} \ge 1,\ n_{ci} \in N_{NWKi} \ ,\ i \ge 1$$

- *Maximizing the utility function for data rates in a cognitive radio networks.*

The aim is to maximize the overall data rate in a cognitive radio network with several cognitive radios and several networks with several channels allowing access to their white space. The data rate will depend on the quality of the channel, modulation scheme used on the particular network and loss probability on a given network. At the start of a session, before assignment to a particular channel, the expected amount of data for the session must be estimated, type of data being transmitted, and the delay and jitter tolerance requirements for the session.

$$\max\ f(x) = \sum_{\substack{i_{NT}=1, D_{\min}, \\ r_{CRi}=r_{CR\,\min}}}^{\substack{i_{NT}=n_{ic}, D_{\max}, \\ r_{CRi}=r_{CR\,\max}}} U_D(r_{CRi}, D, n_{ic}) \tag{2}$$

$$subject \quad to :$$

$$D\min \le D \le D\max$$

$$D_1 = r_{CRi} * t_{Tt}$$

$$D = \sum_{i=1}^{i=n_c} D_i = \sum_{i=1}^{i=n_c} r_{CRi} * t_{Tt}$$

$$R_{CR} = \sum_{CRi=1}^{CRi=N_{CR}} r_{CRi} = \sum_{CRi=1}^{CRi=N_{CR}} r_{CRi} * n_{ci}$$

The amount of data D to be transmitted for a given session, ranges from a minimum acceptable data D_{min} for the specific session to meet QoS requirements, to the maximum amount of data D_{max} allowed by the primary user. R_{CR} is the total transmission rate of a cognitive radio, with r_{CRi} being the individual transmission rates per channel.

- Challenges of the Proposed Design

As with most broad proposals, new design challenges surface. We identify the following challenges: Network security, signalling packet overhead and the installation of the proposed cross layer modules.

1. Network security

The proposed signalling scheme shares network resource and traffic information in all connected networks, which maybe a concern to network operators.

2. Signalling packet overhead

Because different networks may use different protocols, signalling packets from one network may need headers that are installed and/or removed at ingress/egress nodes.

6. Future Research

Future work in this area will involve developing a resource management scheme that will take into account QoS requirements of multimedia traffic in the IMS. Due to the location of the RACS in IMS networks, the RACS will be well suited to provide the necessary information required for optimization of resource use by secondary users without interfering with transmission of primary users.

7. Conclusion

Cognitive radio networking should be developed with QoS in mind. By designing schemes that take into account traffic characteristics, better and more dynamic schemes will be developed. This work has highlighted some of the challenges involved in designing cognitive radio enabled networks in Next generation networks. A general framework for developing a resource management scheme for IMS based networks has been introduced.

8. References

3GPP TS 23.221, 2007. 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Architectural requirements (Release 7) http://www.tech-invite.com/

Bazerque, J., Giannakis, G .B. (2008) Distributed Scheduling and Resource Allocation for Cognitive OFDMA Radios, Published online: 23 July 2008, DOI 10.1007/s11036-008-0083-z

Cardei, M., Cardei, I., &Du, D., (2005) Resource management in wireless networking Edition: 2, illustrated Published by Springer, 2005 ISBN 0387238077, 9780387238074 695 pages.

Chandramathi S., Raghuram S.P.P., Srinivas V.S., Satyajit S. H., (2008). Dynamic bandwidth allocation for 3G wireless systems--A fuzzy approach, Applied Soft Computing, Volume 8, Issue 1, January 2008, Pages 274-284, ISSN 1568-4946, DOI: 10.1016/j.asoc.2007.01.006.

Dharmaraja S., Trivedi K. S., Logothetis D. (2003) Performance modeling of wireless networks with generally distributed handoff interarrival times, Computer Communications, Volume 26, Issue 15, Recent Advances in Computer Communications networking, 22 September 2003, Pages 1747-1755, ISSN 0140-3664, DOI: 10.1016/S0140-3664(03)00044-6.

Haas, Z., Halpern, J. Y., Li, L., & Wicker, S. B. (2000). A decision-theoretic approach to resource allocation in wireless multimedia networks. In Proceedings of the 4th international Workshop on Discrete Algorithms and Methods For Mobile Computing and Communications (Boston, Massachusetts, United States, August 11 - 11, 2000). DIALM '00. ACM, New York, NY, 86-95. DOI= http://doi.acm.org/10.1145/345848.345870

Hu, F & Sharma, N. K. (2003). Multimedia call admission control in mobile networks: a dynamical reservation-pool approach, Computer Networks, Volume 43, Issue 3, 22 October 2003, Pages 263-288, ISSN 1389-1286, DOI: 10.1016/S1389-1286(03)00271-8.

Lin, H. (2004). Game Theory Based Resource Management Framework for Revenue Maximization and Differentiated Services in Competitive Wireless Data Networks, PhD dissertation, Dept. of Computer Science and Eng., Univ. of Texas at Arlington, Dec. 2004.

Li, W. & Pan, Y. (2006) Resource Allocation in Next Generation Wireless Networks Edition: illustrated Published by Nova Publishers, 2006 ISBN 1594545839, 9781594545832 346 pages.

Lu, N & Bigham, J. (2007). On utility-fair bandwidth adaptation for multi-class traffic QoS provisioning in wireless networks, Computer Networks, Volume 51, Issue 10, 11 July 2007, Pages 2554-2564, ISSN 1389-1286, DOI: 10.1016/j.comnet.2006.11.012.

Markaki, O.; Charilas, D.; Nikitopoulos, D. (2007) Enhancing Quality of Experience in Next Generation Networks Through Network Selection Mechanisms, Date: 3-7 Sept. 2007, Pages: 1 – 5, Digital Object Identifier 10.1109/PIMRC.2007.4394198

Mellouk, A. (2008) Quality of Service Mechanisms in Next Generation Heterogeneous Networks, ISBN: 978-1-84821-061-5, December 2008, Wiley-ISTE.

Nasser, N. & Bejaoui, T. (2006). Adaptive resource management for cellular-based multimedia wireless networks. In Proceedings of the 2006 international Conference on Wireless Communications and Mobile Computing (Vancouver, British Columbia, Canada, July 03 - 06, 2006). IWCMC '06. ACM, New York, NY, 641-646. DOI= http://doi.acm.org/10.1145/1143549.1143677

Pal, S, Chatterjee, M., & Das, S. K.(2005) A Two-level Resource Management Scheme in Wireless Networks Based on User-Satisfaction. ACM SIGMOBILE Mobile Computing and Communications Review, 9(4):4–14, 2005.

Sheu, T. & Wu, Y. (2006) A preemptive channel allocation scheme for multimedia traffic in mobile wireless networks, Information Sciences, Volume 176, Issue 3, 6 February 2006, Pages 217-236, ISSN 0020-0255, DOI: 10.1016/j.ins.2004.12.002.

Shiang, H. & van der Schaar, M. (2009). Distributed Resource Management in Multihop Cognitive Radio Networks for Delay-Sensitive Transmission, Vehicular Technology, IEEE Transactions on Volume 58, Issue 2, Feb. 2009 Page(s):941 - 953

Shih, D & Lin, Z. (2003) “Bandwidth saturation QoS provisioning for adaptive multimedia in wireless/mobile networks”, Published by Elsevier Science B.V. 2003

Wang, J. & Chiang, S. (2004) Adaptive channel assignment scheme for wireless networks, Computers & Electrical Engineering, Volume 30, Issue 6, September 2004, Pages 417-426, ISSN 0045-7906, DOI: 10.1016/j.compeleceng.2004.05.004.

W. Willinger, et. al. (1995), “Self-similarity through high-variability: Statistical analysis of Ethernet LAN traffic at the source level,” Proceedings of SIGCOMM '95, pp 100--113, Boston, MA, 1995.

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Cognitive radio is a hot research area for future wireless communications in the recent years. In order to increase the spectrum utilization, cognitive radio makes it possible for unlicensed users to access the spectrum unoccupied by licensed users. Cognitive radio let the equipments more intelligent to communicate with each other in a spectrum-aware manner and provide a new approach for the co-existence of multiple wireless systems. The goal of this book is to provide highlights of the current research topics in the field of cognitive radio systems. The book consists of 17 chapters, addressing various problems in cognitive radio systems.

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