Extending the Scope of the Resource Admission Control Subsystem (RACS) in IP Multimedia Subsystem Using Cognitive Radios

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Abstract— This paper highlights issues relating to signaling of IMS traffic, and how a truly seamless converged network may be achieved using cognitive radio technology. In this paper we propose implementation of the Resource Admission Control Subsystem (RACS) in IMS using cognitive radios to achieve the required flexibility in resource allocation across different networks. Our proposed model enables the RACS to have an extended 'view' of available networks and resources. The end result is that the scope of the RACS is greatly increased, and resource reservation and QoS management by the RACS is also greatly increased.

***Index Terms*—Traffic Engineering; Cross Layer; Cognitive Radio, IP Multimedia Subsystem (IMS)**

I. Introduction

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) for delivering IP Multimedia services to end users, using telecommunication infrastructure. 3GPP is participated by many Telecommunication companies. The group's development of the IMS is seen as a way for core network carriers to not lose their customers to the fast developing Internet technology.

At present, all communications and services that can be offered by a carrier company, are available over the Internet, at a much cheaper rate and sometimes free, for example Voice over IP (VoIP). The setback to getting services over the Internet is that it offers no QoS assurances. In this regard, the carrier companies, with QoS assurances, aim to provide IP multimedia services over their networks using IMS. Telecommunications and Internet converged Services for Advanced Networks (TISPAN), a European telecommunications standardisation body is working with 3GPP in developing a standard for IMS. The RACS, discussed in this paper, is a TISPAN specification.

IMS promises to greatly improve the end user experience when accessing Multimedia and other data services. Users should be able to access all available services from any network, from any device that is connected to a network. This will mean a one bill system for all services will be possible.

Many issues in IMS are still unresolved, with no published results showing how many of the promised abilities will perform. Some of the issues include: How handover from different terminals will happen, how QoS will be maintained, how seamless roaming will be accomplished across different IMS providers and networks, and how unified billing will be accomplished.

In this paper, we specifically look at the Traffic Engineering (TE) challenges that may be presented by IMS traffic and how developments in cognitive radio technology will affect core network TE challenges. In next generation networks, core networks will be IP based, with most traffic being multimedia traffic, the overall behaviour of aggregated core network traffic will therefore be different from today's network traffic. TE solutions will therefore have to be adapted to this change in behaviour.

Though IMS is set to be a standalone subsystem, abstracting the underlying layers, we argue that, for SIP to be able to offer or guarantee the QoS promised to the users, knowledge of the state of the layers 1 2 and 3 will be essential. In addition, seamless migration of users from one network to another with no disruption in services would require a mobile device to be able to communicate with different communication protocols, which would require cognitive radio technology. In our solution, we propose the use of signalling traffic in a cross-layer model using cognitive radio technology, to effectively coordinate resource reservation and routing in the core network, while maintaining the desired QoS requirements.

Cognitive radio technology is an evolution of Software Defined Radios (SDRs). Cognitive radios are intended to improve the efficiency of bandwidth use, and therefore allow for secondary bandwidth usage. With the RACS in NGN subsystems being intended for resource reservation in both access and core networks, there will be a need to interact cognitive radio enabled base stations in the access and core networks with the RACS. In addition, cognitive radios will be used to access several networks and/or technologies, which will in-turn require the RACS to coordinate resource reservation with other networks. The current RACS scope therefore needs to be extended in order to cater for future cognitive radio enabled base stations and devices. The RACS

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will need to not only know the resources available, but also the type of resource and its behaviour. A signalling scheme for this information is needed. Currently work by the Next Step In Signalling (NSIS) group are working on a signalling standard for IMS.

The next section discusses the need of a new signalling scheme (section II), we then discuss some of the issues surrounding traffic engineering in networks with IMS (section III). Section IV briefly describes the RACS and its scope. In section V we detail a proposed generic cognitive radio cross layer signalling scheme for IMS traffic. In section VI we briefly highlight some work in Cognitive radio technology and a proposed model for the cognitive radio in Section VII. Section VIII gives our conclusion.

II. Need For Customised Core Signalling For IMS Traffic

A. *There will be 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.

B. *IMS 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.

C. *Different Grades of Service agreements across networks*

Across different networks and network types, there will be different Grades of Service (GoS) imposed. Currently inter-network 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.

III. 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. We identify three issues that will arise upon implementation of IMS:

1) *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 [2] 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.

2) *Increase in rapidly variable traffic*

While to-date, the nature of network traffic has changed significantly from the time voice traffic, traffic characteristics [2] will further change due to increased multimedia traffic. The current change of traffic from Poisson modelled traffic to Self-Similar traffic [2] 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.

3) *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.

IV. RACS AND ITS DEFINED SCOPE

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.

V. A COGNITIVE RADIO CROSS LAYER SIGNALLING PROTOCOL

Qos Negotiations in IMS with the transport layer are critical for the fulfilment of the QoS assigned to the end-user. These negotiations, in terms of signalling, must then be translated on a network level, then link layer and finally to the physical layer. However, the abstraction of the lower layers to the IMS makes it impossible for the lower layers to have information of the QoS requirements of a particular session or sessions. As a result, lower layers would treat all multimedia services coming to them in the same manner.

Because of the expected number of services, most of them being multimedia services, efficient transmission on the lower layers will have to be realised.

We propose, for fast and efficient coordination of service delivery in the IMS, cross layer signalling in the design of the IMS architecture to allow for faster and more efficient data transfer in the Link layer. We base our cross layer design on one proposed in [3] to facilitate the signalling. Fig 4 shows the proposed cross layer design, while

The cross layer design would be located in the cognitive radio, allowing for signalling across different technologies. The proposed Cross-Layer Manager (XLM) would typically be implemented at the ingress/egress nodes of all core networks. It should therefore be feasible for the cross layer managers to communicate with the IMS provider, and the core network. In a full implementation of the cross layer manager, all XLM modules exchange information on the state of the corresponding core networks. The proposed ingress/egress node would imply that core network operators would have to mind QoS of traffic being routed in their networks. We see this as a possible future trend as core network operators move to make themselves key players in TE developments and management.

A. *Cross Layer Implementation in the IP Core*

Fig. 1 shows the modified version of a cross layer design proposed in [3]. The cross layer manager contains the Decision Engine (DE), QoS Manager (QM) and the Link Information Manager (LIM). The functions of the three blocks in the Cross Layer Manager are varied from the original design to suite signalling with the IMS modules.

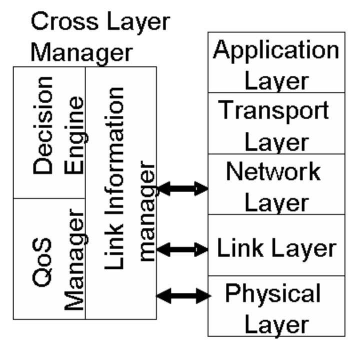

Fig.1. A cognitive radio Cross layer design for interaction between the Transport, Network and Link Layers. The cross layer design allows for more information about the Network and Link Layers.

The LIM is responsible for sending signalling packets into the core networks. The LIM gathers information about the status of the networks within its reach. Information gathered may include: Node and link load status, types of networks available, other available IMS systems and information about broken links or new links. All information from the LIM is passed to the DE. The DE also gets information from the Service-based Policy Function (S-PDF) in the RACS and MRF in the IMS. Traffic Engineering principles are then carried out in the DE to determine the most appropriate networks and routes for a given type of service. User QoS requirements must be interpreted into networks' GoS for the DE to appropriately select the most preferable networks and routes. The QM has is responsible for converting QoS requirements to GoS parameters.

Fig. 2 shows the interaction of the components presented in the cross layer model, while Fig 3 shows the proposed implementation. The proposed XLM will be located at the access node to an access network. The RACS and MRF will have interfaces to the XLM, which will communicate resource availabibility and behaviour across several spectrum. We believe this would result in better reource management.

Due to the existence of secondary users in cognitive radio based networks, the DE in the XLM will make decisions on whether to allow accept the secondary user, and then inform the RACS and the MRF of the new user. The DE in the XLM determines when to terminate resources to the secondary users, when a primary or higher priority user requests for the resources. Before terminating the connection to the secondary user, the XLM must inform the RACS and MRF of the procedure.

The nature of resource reservation is therefore flexible and continuous. For the DE we propose the use of a Bayesian decision mode for resource modelling and decision making.

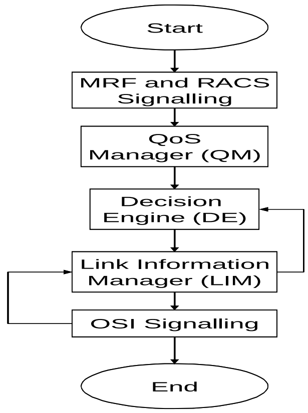

Fig.2. Functional design of interaction between the OSI Layers cross layer design.

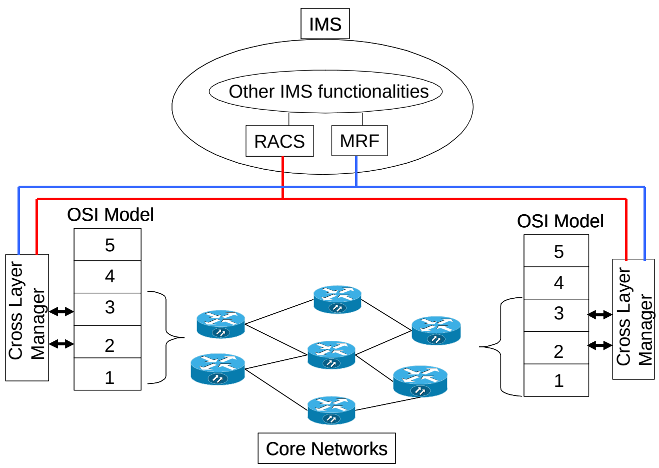

Fig.3. A combination of the cross layer model with IMS. The RACS and MRF communicate with the Cross Layer manager to ensure adequate resource allocation, and more intelligence for IMS during resource allocation.

VI. Cognitive Radio Related Work

Cognitive Radio is a term that was coined by Mitola in his PhD dissertation. Since then, a lot of research has been done and many challenges in the field have come to surface. The development has been made possible by the rapid development in programmable integrated circuits. Our research will concentrate on three main areas in Cognitive Radio technology; study of the Physical Layer, MAC Layer and addition of intelligence to the MAC layer to enable learning. Increasingly, research is being done to understand how a network of cognitive radios can be managed.

Cognitive Radio Networking requires the integration of relevant layers in the OSI layered model, in order to implement a cognitive radio networks. To realize the full potential that cognitive radio brings to networking, cross-layer design optimization principles and Artificial Intelligence have to be adopted. Cross-layer design optimization allows for communication across layers, while Artificial Intelligence allows for learning and decision support based on the channel conditions and the parameters obtained from other layers.

Works on cross layer optimization and Artificial Intelligence in [6, 7] propose technology specific apporoaches. In [6], a cross layer implementation using fuzzy logic systems is proposed. The work interacts the Physical and MAC and Application Layers. The simulation results show that the Physical layer and MAC layer are able to adapt to the Quality of Service demands of the Application layer. The results do not however take into account cognitive radio technology. A study done in [7] also proposes a technology specific cross-layer approach, and therefore suffers the same limitations as [7]. An ideal cross-layer implementation would be a generic learning scheme that is not technology specific. In [8] a cross layer approach that incorporates cognitive radio and not entirely technology specific is proposed. The proposal has specifies current and legacy technologies, but in addition, extensions of current technologies are made. Therefore, technological developments of a technology would not obsolete the module. However, the proposal is still not generic, and there are no provisions made for learning a completely new technology. Such an attempt is made in [9]. In [9], a Biological Cognitive Radio that uses genetic algorithms is proposed. Though generic, the proposed solution does not take into account the cross-layer optimization needed for optimal use of cognitive radio. Work in [10] recognizes the fact that cross-layer optimization is essential for the implementation of cognitive radios. Fuzzy Logic is proposed to meet the artificial intelligence requirements of cognitive radios, including learning at the MAC layer.

VII. Proposed Resource Modeling and Management Methodology

We argue that it is important for all wireless stations to collectively contribute to the optimal performance of the network as a whole. There are two incompatible game theory philosophies [4]: The first philosophy dictates that a player's preferences are modeled by their utility functions. In which case, all players are kept happy for optimal performance. The second philosophy dictates that each player involved in the game seek to maximize their utility functions.

There has been work to propose that end user devices listen to the spectrum and decide on the most suitable channel, while other work has proposed a centralized control manager. Our work proposes a distributed control mechanism of bandwidth allocation by the base stations.

We propose the use of a universal signaling channel, we call, the primary channel. Each channel in a given spectrum is proposed to have a separate signaling channel dedicated for control and monitoring of the channel. These we call secondary channels. The primary channel signals information about the state of the spectrum, and QoS expectations. Based on the information from the primary channel, the end user device or base station decides on the most appropriate channel to use. Fig 4 shows the functional flow chart of the proposed model.

In a Cognitive Radio Network, secondary users would need to know the following aspects of the network, with respect to their needs:

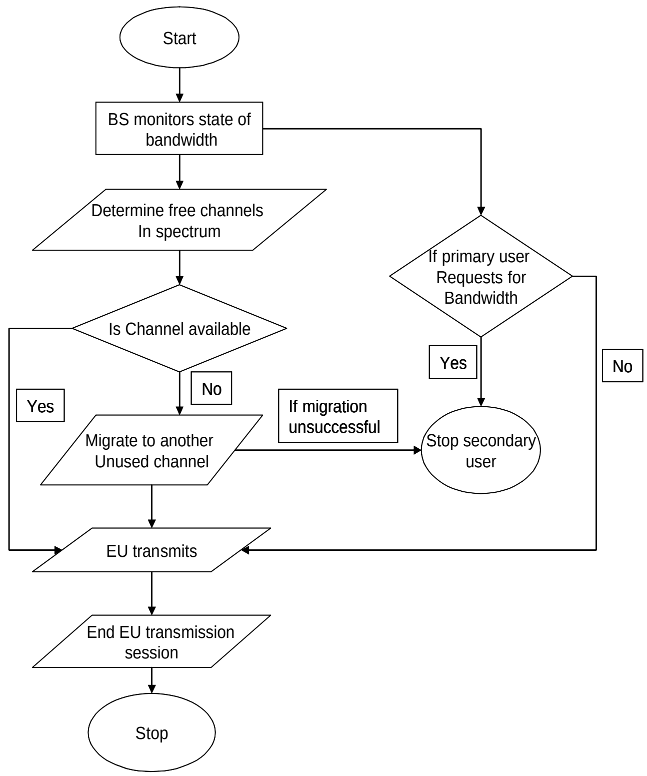

Fig.4. A functional flow chart of the allocation and secondary and primary channels.

1) What is the QoS supported by a given channel at a given time, transferring certain media?
2) What is the average time, in a given unit time, is available for transmission?
3) Given conditions of available networks, how much data can be accommodated?

There have been two extreme methods of Cognitive Radio implementation in literature. One proposes a centralized management scheme, while the other proposes a decentralized management scheme. It is less complex to design a centralized management scheme compared to a decentralized one. Decentralized based proposals assume that the end-user devices will continually scan frequencies, learn from previous behavior, and determine the most appropriate transmission time and period. While the centralized based proposals assume that the allocation of all transmission times and periods are centrally controlled.

The centralized and decentralized proposals assume a universal control channel. For a decentralized system, when a device decides to transmit in a given time period, it has to alert all other secondary bandwidth users. A centralized system does not consider that the different networks with different technologies are independent of each other.

The complexities involved in introducing a universal signaling channel are significant, since all current communicating technologies do not support such a scenario. The proposals for both centralized and decentralized systems are therefore not “legacy” compatible.

However, both centralized and decentralized methods have advantages that are applicable to a network with Cognitive Radios. We propose the use of an overlay network of Cognitive Radios over the existing technologies, with which we introduce the concept of Cognitive Networking. The Cognitive Radios will see each all the different participating networks as one network. In this approach, each participating network will offer information regarding its Physical, MAC and Network Layer characteristics. Information gained from the Physical, MAC layers, and other Network Layers would enable routing of Secondary traffic through the networks, and even be able to cater for QoS.

By using the overlay model, it is possible to avoid the need of a universal control channel. Instead each network can choose a control channel of its choice. This would also imply that Cognitive Radio end users would have to listen on a given channel depending on the network they are in, or which network they want to communicate with.

To coordinate the traffic monitoring, admission and control mechanisms and new routing strategies there is a need to use Artificial Intelligence.

VIII. Conclusions

The introduction of IMS has brought about many possibilities of communication to the end user. It has however also brought about several challenges that need to be addressed. It is also clear that the traditional roles of the core network operators will have to change to accommodate the efficient operation of IMS.

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