Survey of Soft Computing Techniques for Joint Radio Resource Management

Prakash B Metre[1], K. R. Radhika[1], Gowrishankar[1]
[1]B.M.S. College of Engineering,
Bangalore, INDIA
prakash.metre@ieee.org, radhikakr@ieee.org

Abstract—**Ever changing requirements of the mobile devices has posed significant challenges on existing cellular network systems. The Next Generation Wireless Networks (NGWN) will be heterogeneous which will have different Radio Access Technologies (RATs) operating together. Radio Resource Management (RRM) is one of the key challenges in NGWN. Joint Radio Resource Management (JRRM) is one of the RRM technique plays instrumental role in ensuring the desired Quality of Service (QoS) to the users working on different applications which are having the diversified nature of QoS requirements to be fulfilled by the wireless networks. Soft computing is one promising field which is strongly believed to enhance the capability of the existing methods for JRRM. The objective of this paper is to bring out the best features of soft computing techniques for JRRM in NGWN to enhance capability of existing methods, which integrates the different RRM strategies using soft computing techniques for NGWN and observe how JRRM would properly work together with soft computing techniques in heterogeneous scenario to perform better than the existing techniques.**

Keywords- Call admission control , Call blocking probablity, Heterogeneous wireless Networks, Radio resource management.

I. INTRODUCTION TO JRRM

Deployments of latest networks begin to spread throughout the world. Today emerging multimedia application has many requirements in terms of quality of service. Users always want to be best connected anywhere, and anytime. To satisfy these demands, a variety of access technologies are available like Wireless Fidelity (WiFi), Worldwide Interoperability for Microwave Access (WiMAX), and Cellular networks. This has made it difficult for service provider to select the best network for requesting services and to control the quality level of ongoing connections. Thus, the resource management is used to prevent overloaded or underutilized networks to satisfy users are indispensable [2]. In such a scenario the operator has full control on all single radio access technologies (RAT) involved and will be motivated to use the JRRM techniques for optimized usage of radio resources of different RATs [7]. JRRM concepts and algorithms have to meet requirements of viewpoint of overall network performance, the individual user's point of view and the operator's point of view. JRRM solutions should integrate all these aspects. RRM is the system level control of co-channel interference and other radio transmission characteristics in wireless communication systems, for example cellular networks, wireless networks and broadcasting systems. RRM involves strategies and algorithms for controlling parameters transmit power, channel allocation, data rates, handover criteria, modulation scheme, and error coding scheme. RRM concerns multi-user and multi-cell network capacity issues, rather than point-to-point channel capacity. Traditional telecommunications research-education often dwells upon channel-source coding with a single user in mind. Though it is not possible to achieve the maximum channel capacity when several users and adjacent to base stations share the same frequency channel. Efficient dynamic RRM schemes increase the system capacity in an order of magnitude, which often is considerably more than what is possible by introducing advanced channel coding and source coding schemes. Defining RRM framework in the context of Heterogeneous Wireless Network (HWN) is a difficult task as there is tradeoff between user satisfaction and network resource utilization. RRM is especially important in systems limited by co-channel interference rather than by noise, for example cellular systems and broadcast networks homogeneously covering large areas, and wireless networks consists of many adjacent access points that reuse the same channel frequencies. RRM framework is composed of one or all of the following functionalities.

- Resources monitoring is the phase in which information is gathered. This data comes from users, networks, or both. Collecting information varies from one decision mechanism to another, it is considered as input for making decisions.
- Decision making is the phase in which decisions are made. Most of time, these decisions are made at the network operator for which we call it network-centric approach, however, they are also be made at user terminals (user-centric approach), or some time decisions are made by the collaboration between both sides (collaborative approach).
- Decision enforcement is the phase in which decisions are enforced/executed. In user-centric approach, this phase is done by ensuring that connection request to a selected network is successful. Despite, if it is not, user will try backup solution until the last one. If there is no more solution to try and user still cannot get connection, it will have to go back to monitoring step and wait for new condition.

These actions are related to each other and invoked at different level of users' connection process.

RRM in the next generation wireless access system will have features and requirements that are quite distinct from current systems, mostly designed for non-heterogeneous and non-shared networks. Such features include radio resource sharing which is considered as one of the main future issues of RRM as network evolves towards 4G. These features have an

978-1-4673-1520-3/12/$31.00 ©2012 IEEE

impact on system design in general and on RRM in particular. In general, radio resources of 3G and beyond are managed using various schemes that are grouped in three main sets [3]. The first set includes frequency/time resource allocation schemes such scheduling. The second set consists of power allocation and control schemes, which control the transmitter power of the terminals and the base stations. The third set comprises call admission control, and base station assignment as shown in fig. 1. Generally, RRM in mobile heterogeneous network consists of 3 steps information harvesting, decision making, and decision enforcement [11].

1. Information harvesting at this stage, information about user and network are gathered, this information is important factor for making decision. First users' information is collected at user terminals level then is propagated up through Access Points (AP) and Access Routers (AR) levels for having more information about cell condition and network conditions respectively

2. Decision making at this stage, decisions are made. Decision is made at user terminals in case they have possibility to choose their point of attachment or at access routers for controlling local networks. Consequently, the decision point depends essentially on where the control has been placed.

3. Decision enforcement at this stage, decision is enforced. Several mechanisms are used to ensure that decisions made in step 2 are appreciated. Admission control is one of the enforcement mechanisms and it is used to filter access according to the decision. In several cases, it is adopted in decision making (step 2) to screen candidate networks by comparing required service and availability on the present networks. Instead of performing the management of radio resources independently for each RAT, one form of overall and global management of the pool of radio resources is used. Joint or Common radio resource management is the process to manage the allocation and de-allocation of radio resources within a single or between different radio access systems [4, 5]. It reveals that more efficient usage of available radio resources effectively achieved.

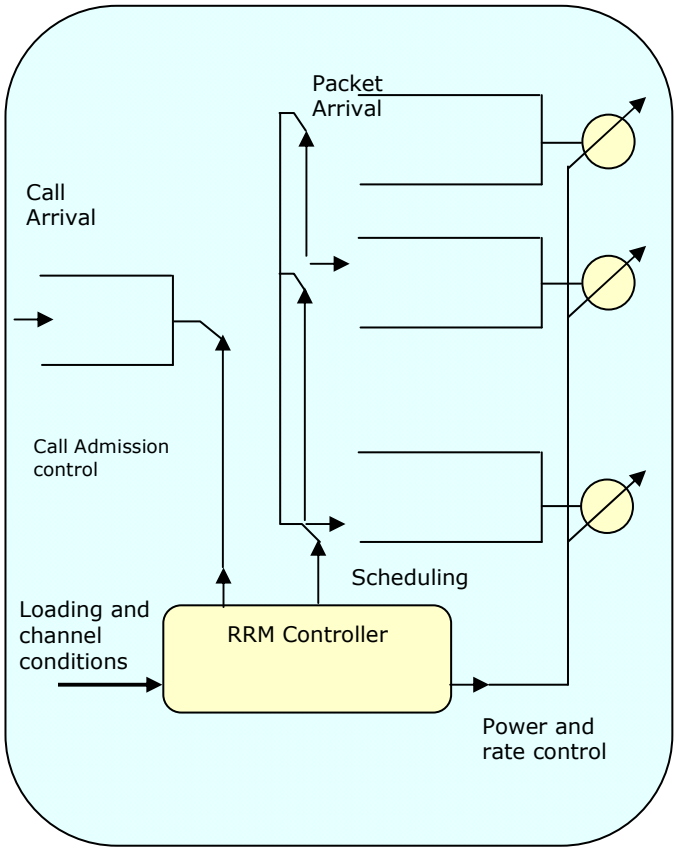

Figure 1. Abstract RRM Model

The few simulation results show that the blocking probability improves when different considerations are taken into account [31]. There is need for JRRM policies so that the total available radio resources are efficiently distributed among active users in order to maximize the system revenue and provide the QoS levels demanded by users/services in multimedia environments [30].

II. INTRODUCTION TO SOFT COMPUTING

Soft Computing is a new multidisciplinary field that was proposed by Dr. Lotfi Zadeh, whose goal was to construct new generation Artificial Intelligence, known as Computational Intelligence [32]. Soft computing deals with imprecision, uncertainty, partial truth, and approximation to achieve practicability, robustness and low solution cost. Soft computing in its latest incarnation as the fusion of the fields Fuzzy Logic, Neuro-computing, Evolutionary, Genetic Computing, and Probabilistic Computing. The main goal of Soft Computing is to develop intelligent machines and to solve nonlinear and mathematically un-modeled system problems. Soft computing techniques, which emphasize gains in understanding system behavior in exchange for unnecessary precision, have proved to be important practical tools for many contemporary problems [29].

The applications of Soft Computing have proved two main advantages. First, it made solving nonlinear problems, in which mathematical models are not available, possible. Second, it introduced the human knowledge cognition, recognition, understanding, learning, and others into the fields of computing. Applying above steps resulted in the possibility of constructing intelligent systems like autonomous self-tuning systems, and automated designed systems.

Components of soft computing include

- Neural networks
- Fuzzy systems
- Evolutionary computation, including
    - Evolutionary algorithms
        - Genetic algorithms
        - Differential evolution
    - Metaheuristic and Swarm Intelligence
        - Ant colony optimization
        - Bees algorithms
        - Bat algorithm
        - Cuckoo search
        - Harmony search
        - Firefly algorithm
        - Artificial immune systems
        - Particle swarm optimization
- Ideas about probability including
    - Bayesian network
- Chaos theory

Soft computing techniques exploit the given tolerance of imprecision, partial truth, and uncertainty for a particular problem. Genetic Algorithm and Particle Swarm Optimization Techniques have emerged as potential and robust optimization tools in recent years. Advantage of this feature is used for resource management.

III. FUZZY LOGIC

The concept of Fuzzy logic has been extensively applied in characterizing the behavior of nonlinear systems. The nonlinear behavior of the system effectively captured and represented by a set of Fuzzy rules [18]. Many engineering and scientific applications including time series are not only nonlinear but also non-stationary. Such applications cannot be represented by simple Fuzzy rules, because fixed number of rules describe time invariant systems only and cannot take in to account the non-stationary behavior. Recently, a new set of Fuzzy rules have been defined to predict the difference of consecutive values of non-stationary time series [19]. The Advantages of Fuzzy Logic approach [20] are Easy to understand and build a predictor for any desired accuracy with a simple set of Fuzzy rules, no need of mathematical model for estimation and fast estimation of future values Due to the less computational demand. The Limitations of Fuzzy Logic approach is, it works on Single step prediction and fuzzy logic does not have learning capability.

IV. NEURAL NETWORKS

The neural networks are low-level computational elements that exhibit good performance when they deal with sensory data. Applied to the situation where there is sufficient observation data available. The Neural network method is used in any problem of control, prediction and classification. Neural Networks are able to gain this popularity because of the commanding capacity that they have in modeling exceptionally complex nonlinear functions. Neural networks have a biggest advantage in terms of easy to use which is based on training-prediction cycles. Training the neural networks plays crucial role in the system usage of neural networks. The training pattern that contains a predefined set of inputs and expected outputs is used to train the neural networks. Next, in prediction cycle, the outputs are supplied to the user based on the input values. To make the neural networks to behave like a physical system or predict or control the training set used in the training cycle shall consist of enough information representing all the valid cases [21, 22, 23].

Neural Networks are flexible soft computing frameworks for modeling a broad range of nonlinear problems [24].

One significant advantage of the neural network based approach over other classes of nonlinear models is that NNs are universal approximation tools that approximate large class of functions with a high degree of accuracy [25]. This approximation power of Neural Network model comes from several parallel processing elements, called as 'neurons'. No prior assumption of the model form is required in the model building process. Instead, the network model is largely determined by characteristics of the data. Single hidden layer feed forward network is the most widely used model for prediction and forecasting of time variant functions. The model is characterized by a network of three layers of simple processing unit connected by non-cyclic links. The architecture of feed-forward neural network is shown [28].

V. EVOLUTIONARY COMPUTATION

Evolutionary computation is a general stochastic search Methodology. Evolutionary computation is becoming popular as it often gives satisfactory results for various optimization problems in different areas. The computation intelligence based CAC use evolutionary approaches like Genetic Algorithm (GA), fuzzy logic and Artificial Neural Networks (ANN). Majority of the computational intelligence based CAC algorithms incorporate fuzzy logic, fuzzy neural and fuzzy MCDM methods. There are very few works reported on the usage of Artificial Neural Networks in CAC [7]. Genetic algorithm is the most popular evolutionary algorithm.

VI. SWARM INTELLIGENCE

Ant colony optimization and Bees algorithm are most popular techniques in swarm intelligence. The Swarm Intelligence based Resource Allocation Algorithm (SIRAA) divides all cognitive radios in a network into sub-networks to reduce the scanning time of each cognitive radio communicates among themselves to get a global view of spectrum availability and their characteristics. The cognitive radios then compute respective bid values and send to the base station. The base station uses binary Particle Swarm Optimization technique for optimal allocation of channels to these radios by maximizing the total bid value [6].

VII. FUZZY NEURO SYSTEM

The Fuzzy Neuro System (FNS) is one of the soft computing techniques that combine the best features of neural networks and fuzzy logic for intelligent computation. FNS is especially suitable to take decisions from imprecise information as it is the case when optimizing JRRM parameters from real network indicators. FNS helps to take intelligent decisions in consideration with different parameters transmit power, channel allocation, data rates, handover criteria, modulation schemes, and error coding schemes [12]. The FNS approach overcome measurement error, mobility and traffic model uncertainty, and provide effective means of describing the behavior of the systems that are too complex and not easy to tackle mathematically [13, 14].

Few important results attained by different authors are listed in Table 1. The results reveal to have intelligent and efficient JRRM technique. Soft computing is one promising field which is strongly believed to enhance the capability of the existing methods for JRRM that integrates the different RRM strategies using soft computing techniques for NGWN.

TABLE 1. SURVEY RESULTS

Year	Field	S/Results
2011	Heterogeneous wireless networks	6% improvement in utility of the MNO compared to JCAC [9].
2010	Wireless networks	FNCAC reduces the 20% of call blocking/dropping probability compared to other methods [28].
2010	Wireless networks	Proves that performance of RRM techniques has direct impact on each user's individual performance and on the overall network performance [2].
2010	Heterogeneous wireless networks	User-centric JCAC improves load distribution among available RATs [4].
2007	Heterogeneous wireless networks	oCSR out performs both traditional disjoint guard channel scheme and non-optimized J RRM scheme [18].
2004	Heterogeneous wireless networks	Adaptive multimedia out performs the non-adaptive approach in terms of lower handoff dropping probability and call blocking probability [20].

CONCLUSION

In this paper, the performance of existing systems is compared. Though, considerable research has been done for JRRM in NGWN. Many research results have opened up new challenges and issues for JRRM [8, 9, 10]. There is a need for a system that should have radio access strategy implementing JRRM over a complex heterogeneous wireless network composed by several realistic RATs and proposes several users equipped with multimode terminals are able to simultaneously connect to the available RATs. In this paper, we present a comprehensive survey on JRRM in NGWN. The goal is to provide a better understanding of resource management in this type of environment.

REFERENCES

[1] Saraee, H.; Matinkhah, S.M.; Khorsandi, S.; , "Cooperative joint radio resource management in wireless heterogeneous networks," Computer Networks and Distributed Systems (CNDS), 2011 International Symposium on , vol., no., pp.111-115, 23-24 February 2011

[2] Pillekeit, A.; , "Influence of information aging in self organizing joint radio resource management systems," Wireless Communication Systems (ISWCS), 2010 7th International Symposium on , vol., no., pp.726-730, 19-22 September 2010

[3] Lucas-Estañ, M.C.; Gozálvez, J.; , "Real-time computational performance of advanced JRRM policies in B3G heterogeneous wireless systems," Wireless Conference (EW), 2010 European , vol., no., pp.564-571, 12-15 April 2010

[4] Falowo, O.E, "Joint call admission control algorithm for reducing calls locking/dropping probability in heterogeneous wireless networks supporting multihoming", GLOBECOM Workshops (GC Wkshps), pp.611-615, IEEE, December 2010

[5] Serrador, A.; Carniani, A. ; Corvino, V. ; Correia, L.M, "Radio access to heterogeneous wireless networks through JRRM strategies", Future Network and Mobile Summit, pp.1-8, June 2010

[6] Ramesh Babu H.S., Gowrishankar, Satyanarayana P.S, "Call Admission Control performance model for Beyond 3G Wireless Networks", International Journal of Computer Science and Information Security, vol. 6, No. 3, 2009

[7] Ramesh Babu H.S., Gowrishankar, Satyanarayana P.S, "Call Admission Control for Next Generation Wireless Networks Using Higher Order Markov Model", CCSE Computer and Information Science vol. 3, No. 1, February 2010

[8] Ding Zhe, Xu Yubin, Sha Xuejun, Cui Yan, "A Novel JRRM Approach Working together with DSA in the Heterogeneous Networks ", vol.1, IFITA '09, May 2009

[9] Andreas Klein, Christian Lottermann, Christian Mannweiler, Joerg Schneider, and H.D. Schotten Chair for Wireless Communications and Navigation, " A Novel Approach for Combined Joint Call Admission Control and Dynamic Bandwidth Adaptation in Heterogeneous Wireless Networks" , pp.1-8, NGI, 2011

[10] TIAN JinFeng, ZHENG XiaoYing, HU HongLin, & YOU XiaoHu, "A survey of next generation mobile communications research in China", Chinese science Bulletin, vol.56 pp..272875-2888, September 2011

[11] Olabisi E. Falowo, and H. Anthony Chan, "Admission Control Scheme for Heterogeneous Wireless Networks", University of Cape Town, South Africa, 2009

[12] Hung-yu Wei; Izmailov, R.; , "Channel-aware soft bandwidth guarantee scheduling for wireless packet access," Wireless Communications and Networking Conference, 2004. WCNC. 2004 IEEE , vol.2, no., pp. 1276- 1281, vol.2, 21-25 March 2004

[13] Joseph Mitola III, "Cognitive radio architecture evolution: annals of telecommunications", pp.419-441, vol.64, issiue.7 Springer, France 2009

[14] Haykin, S.;, "Cognitive radio: brain-empowered wireless communications," Selected Areas in Communications, IEEE Journal on , vol.23, no.2, pp. 201- 220, February 2005

[15] Sneha K. Kasera, Ramachandran Ramjee, Sandra Thuel and Xin Wang, "Congestion Control Policies for IP-based CDMA Radio Access Networks", vol.23, issiue.2, pp.201-220, IEEE 2003

[16] C M Chin, C M Tan and M L Sim, "Future trends in radio resource management for wireless communications", BT Technology Journal, vol 24 , pp.103-110, issiue. 2, April 2006

[17] Lu Yanhui Zhang Yuqiong Yang Shouyi Mu Xiaomin, "Modeling Radio Resource Management In Cognitive Radio System Based On OFDMA Using Colored PETRI NET1", Journal Of Electronics (CHINA), Vol.27 issiue.5, September 2010

[18] Chunming Liu; Chi Zhou; Niki Pissinou; Kia Makki; , "Resource Management in the Next-Generation Integrated WLAN / 3G Cellular Networks," Wireless Communications and Networking Conference, 2007.WCNC 2007. IEEE , vol., no., pp.3341-3346, 11-15 March 2007

[19] Liljana Gavrilovska, and Vladimir Atanasovski, "Spectrum Sensing Framework for Cognitive Radio Networks", vol.59, pp.447-469, issiue.3, Springer Netherlands, Aug 2011

[20] Xin Gang Wang, Geyong Min, John Mellor and Khalid Al-Begain, "A QoS-Based Bandwidth Management Scheme In Heterogeneous Wireless Networks", I.J. of Simulation Vol.5, issiue pp.9-17, september 2004

[21] Vanem, E.; Svaet, S.; Paint, F.; , "Effects of multiple access alternatives in heterogeneous wireless networks," Wireless Communications and Networking, 2003. WCNC 2003. 2003 IEEE , vol.3, no., pp.1696-1700 vol.3, 20-20 March 2003

[22] O. E. Falowo and H. A. Chan, "Adaptive Bandwidth Management and Joint Call Admission Control to Enhance System Utilization and QoS in Heterogeneous Wireless Networks," EURASIP Journal on Wireless Communications and Networking, July 2007

[23] Perez-Romero, J.; Sallent, O.; Agusti, R.; Karlsson, P.; Barbaresi, A.; Wang, L.; Casadevall, F.; Dohler, M.; Gonzalez, H.; Cabral-Pinto, F.; , "Common radio resource management: functional models and implementation requirements," Personal, Indoor and Mobile Radio Communications, 2005. PIMRC 2005. IEEE 16th International Symposium on , vol.3, no., pp.2067-2071 vol. 3, 11-14 September 2005

[24] C. Liu, "System Design and Resource Management in the Next-Generation Integrated WLAN / 3G Cellular Networks," dissertation, Florida International University, 2006

[25] Ahmed, M.H.; , "Call admission control in wireless networks: a comprehensive survey," Communications Surveys & Tutorials, IEEE , vol.7, no.1, pp.49-68, 2005

[26] Y. Fang and Y. Zhang, "Call admission control schemes and performance analysis in wireless mobile networks," IEEE Transactions on Vehicular Technology, vol.51, No.2, pp.371-382, March 2002

[27] Falowo, O.E.; Chan, H.A.; , "Fuzzy Logic Based Call Admission Control for Next Generation Wireless Networks," Wireless Communication Systems, 2006. ISWCS '06. 3rd International Symposium on , vol., no., pp.574-578, 6-8 September 2006

[28] Ramesh Babu H.S, Gowrishankar, Satyanarayana P.S, "An Intelligent Call Admission Control Decision Mechanism for Wireless Networks", Journal of computing, volume 2, issue 4, April 2010

[29] Feng Han; Yingzhuang Liu; Guangxi Zhu; , "A Cross-layer Resource Allocation Scheme with Guaranteed QoS in Multiuser OFDM Systems," Communication Technology, 2006. ICCT '06. International Conference on , vol., no., pp.1-4, 27-30 November 2006

[30] Lucas-Estan, M.; Gozalvez, J.; , "On the Real-Time Hardware Implementation Feasibility of Joint Radio Resource Management Policies for Heterogeneous Wireless Networks," Mobile Computing, IEEE Transactions on , vol.PP, no.99, pp.1-14, 2011

[31] Suleiman, K.H.; Chan, H.A.; Dlodlo, M.E.; , "Issues in Designing Joint Radio Resource Management for Heterogeneous Wireless Networks," Wireless Communications, Networking and Mobile Computing (WiCOM), 2011 7th International Conference on , vol., no., pp.1-5, 23-25 September 2011

[32] M. Nikravesh, F. Aminzadeh, and L. A. Zadeh, Eds., Soft Computing and Intelligent Data Analysis in Oil Exploration, Developments in Petroleum Science, 51, Amsterdam; Boston: Elsevier, 2003

AUTHORS

Prakash B Metre received Bachelor of Engineering degree in Computer Science and Engineering from Visvesvaraya Technological University, Belgaum and M.Tech in Networking and Internet Engineering from Visvesvaraya Technological University, Belgaum. He is currently working as Asst. Professor in Department of Computer Science and Engineering, B.M.S. College of Engineering, Bangalore-560 019, INDIA. He is pursuing his Ph.D in the field of "A Novel Soft Computing Technique for Joint Radio Resource Management for Next Generation Wireless Networks".

Dr. K.R. Radhika received Bachelor of Engineering degree in Information Science and Engineering from Bangalore University and ME in computer Science and Engineering from Bangalore University and Ph.D from Visvesvaraya Technological University Belgaum. She is currently working as Professor in Department of Information Science and Engineering, B.M.S. College of Engineering, Bangalore-560 019 INDIA. Her research area is "Soft computing techniques".

Dr.Gowrishankar received Bachelor of Engineering degree in Computer Science and Engineering from Mysore University and ME in computer Science and Engineering from Visvesvaraya Technological University and Ph.D from Visvesvaraya Technological University Belgaum. He is currently working as Professor and Head Department of Computer Science and Engineering, B.M.S.College of Engineering, Bangalore-560 019, INDIA. His research area is "Efficient vertical Hand-off systems".