Efficient Decision Based Spectrum Mobility Scheme for Cognitive Radio Based V2V Communication System

Atta-ur-Rahman
Department of Computer Science, College of Computer Science & Information Technology, Imam Abdulrahman Bin Faisal University (IAU), P.O. Box 1982, Dammam, Saudi Arabia
Email: aaurrahman@iau.edu.sa

Abstract —Efficient spectrum decision and spectrum mobility schemes for cognitive radio based inter vehicle communication (IVC) system have been anticipated in this research. Cognitive Radio has four main functions, spectrum sensing, spectrum management, spectrum mobility and spectrum sharing. At high speed of vehicles performing spectrum decision and spectrum mobility is not an easy task for cognitive radio. Spectrum mobility is very frequent in IVC due to extremely mobile nature of vehicles and unpredictable radio frequency channel. A proficient white space optimization technique is a basic requirement to perform in time spectrum decision and spectrum mobility. Genetic Algorithm (GA) is considered as one of the best optimization techniques for white space optimization. But at high vehicular speed simple genetic algorithm (GA) has been botched to perform optimization. To anticipate this problem, we have already proposed Memory Enabled Genetic algorithm (MEGA) in our previous work. In this research work we have further improved the convergence time of MEGA by manipulating the generation gap, crossover and mutation operator of MEGA. Simulation results proved that improved memory enabled genetic algorithm (IMEGA) is 0.522 ms faster than MEGA. Simulation results revealed that using our proposed spectrum decision and spectrum mobility schemes are more efficient cognitive radio based vehicular networks.

Index Terms—V2V communication, genetic algorithm, cognitive radios, spectrum mobility, MEGA, IMEGA

I. Introduction

Inter-Vehicle Communication (IVC) system is a part of Intelligent Transport Systems (ITS). ITS is an active research area [1]. Every year in road accidents average 1.2 million people lost their lives and about 50 million people get injured [2]. IVC system enables vehicles to share their location and speed to evade the fenders-benders as well as very deadly crashes [4]. Safe vehicle movement requires powerful intelligent transport system. Intelligent transport system makes the communication effective and smooth. It helps to reduce accidents. With the growth of population, vehicles are increasing consistently in the world. The life of human has become more insecure due to road accidents. Road accidents are the 9th major reason of human death. This enormous death ratio can be minimized by setting up new IVC system, which pre-alerts the vehicles from the possible fenders-benders. Cognitive Radio (CR) is considered as a best remedy to solve the extensive bandwidth demand of vehicles. The concept of cognitive radio was introduced by Joseph Mitola III. CR (Cognitive Radio) is such a remarkable system to make networks so intelligent that they can take decision by their own. Cognitive radio works like a human brain (thinking, understanding, remembering, perceiving, decision making etc.). When embed these processes in radio it becomes CR (cognitive radio) [6]. Unlike other communication networks CR takes decision by its own according to the requirements. Cognitive radio comprises of four main capabilities like sensing, management, sharing and mobility [4]. Cognitive radio is considered as a suitable solution for V2V communication system [7]-[9]. The focus of this research work is suggesting efficient spectrum decision and spectrum mobility scheme for cognitive radio based V2V communication system.

Mobility management is one of the most challenging research areas for vehicular networks [3]. Spectrum decision and spectrum mobility are inter-depending procedures. Due to varying mobile nature of IVC networks in which vehicles are communicating with each other, decision time to choose optimized white space should be in milliseconds. According to the research if driver knows three seconds before the accident happen, accident can prevent [11]. It means the decision time should be minimum. Normally secondary user requests same QoS only when the white space under his utilization lost due to some reasons such as primary user activation or weakness of signals' powers. In such conditions, our proposed technique will perform efficiently. Our technique can save the time as well as human lives. In our previous work we have proposed memory enabled genetic algorithm to make GA capable to operate in real time applications like runtime white space optimization in cognitive radio based vehicular networks [12]. The technique is based on integration of memory into GA. MEGA can save and continuously update optimized white spaces against the QoS, rather than waiting for GA to access optimized white space again and again. The user will wait only for the first time for a application. On the backend the GA will perform its task continuously and will update the white spaces after particular time in the memory. When the user request for white space, MEGA get white space from memory immediately rather than wait for GA execution. The major drawback of GA

Manuscript received March 20, 2018; revised August 21, 2018.
Corresponding author email: aaurrahman@iau.edu.sa
doi:10.12720/jcm.13.9.498-504

is that, it is not suitable for fast response. It is too slow for run time applications such as IVC. Many researchers do not prefer GA for run time applications.

As a summary, the problem can be formulated as the spectrum decision time plays and critical role in cognitive radios and must be as minimum as possible. Moreover, to decrease the spectrum decision time of cognitive radio, conventional MEGA needs significant improvement. So, in the proposed work spectrum decision time has been improved by reducing convergence time of MEGA. In proposed IMEGA the generation gap parameter and mutation operator have been manipulated. The results proved that IMEGA is 0.522ms better than MEGA.

Rest of the paper is organized as follows. Section 2 contains the discussion about the parameters used in the proposed scheme, section 3 highlights he proposed scheme itself. Results are presented in section 4 while section 5 concludes the paper.

II. Parameters in Proposed Scheme

We have reported our new research scheme, to decrease the drawbacks of GA and memory enabled GA. We proposed improved memory enabled genetic algorithm (IMEGA) in cognitive radio. Cognitive radio site is a concept introduced by researchers inside the vehicle capable of performing basic cognitive radio functions [1]. Cognitive system monitor (CSM) is working as brain of cognitive cycle. In this research work we have only focused on spectrum management according to the users QOS. CSM automatically initiate Multi-RAT scanners to scan different available spectrums from environment and then using sensing capabilities it will record the available whitespaces in pool. Here we introduce improved memory enabled GA. The logic behind this idea is to save execution time of GA by minimizing generation gap crossover and mutation rate. When the user or application request for same QoS as requested in vary previous time.

Rather than waiting for QoS request from user the GA will continue the optimization of white spaces based on last requested QoS. The GA will save and rapidly update these white spaces in the memory. We consider only few parameters in this research. The parameters we have used are Frequency band, Power, BER (Bit Error Rate) and modulation scheme [34]. Some other parameters are also possible in advance level research such as Bandwidth, Spectrum efficiency, Noise ratio and interfaces etc. The Genetic Algorithm starts with chromosomes structural definition. As mentions earlier we keep the size of chromosome small for simplicity and avoid the complexity. The chromosome will contain four gens here in our research these genes will refer to as parameters. These genes of individual chromosome play a major role in decision making. The four parameters have been considered in this research for optimization using Genetic Algorithm. Namely:

- Frequency
- Power
- BER (Bit Error Rate)
- Modulation scheme

A. Frequency

The frequency band range we have considered in our research is from 0 to 10MHz. Although it can be different such as can be from 0 to 5 or 0 to 20. The size of a single step for the frequency band in our research is 10 KHz [57]. If this step is available for every application under transmission then we can easily calculate that how many users can be setup in this room of space. By considering 10 KHz as a step size we have total 1000 frequency band in the range from 0 to 10MHz. This also means that the maximum number of chromosomes we can consider in initial population generated randomly should be less than or equal to 1000. The number of bits to represent the first gene chromosome gene (Frequency band) are 10 because 10 bits can represent the all decimal number we have considered in our research from 0 to 999. The representation of frequency band into bits will help us in GA operations such as when we will apply mutation operator. There will be a check as well after mutation when we will convert back to decimal numbers because it can cross the limit we have mentioned. The step size of 10 KHz can represent 1000 decimal numbers in the range of frequency band we have specified in our research. The first step represents the frequency band from 0 to 10 KHz and will be denoted by a decimal number 0. Similarly, the second step will represent the frequency band from 11-20 KHz and will be refer to decimal '1'. This series of steps continue till end limit such as 999 in our research. The last decimal number will be 999 and represent the frequency band 9.99 MHz to 10MHz. There will be a check on random number generation in initial population so that there will be no number greater than limit specify such as 999.This check also apply on the QoS of SUs they request.

B. Power

The second gene of chromosome we have considered in our research is power. The communication parameters refer to genes in our research. The power parameter associated with signal strength that an application need for transmission. Lack of power parameter in communication can leads to poor quality and useless in the most cases. The power can increase the signal strength and as resultant the probability of successful communication without errors increases as well. The range of power parameter in our research is from -30dBm to +30dBm [57]. The step size for power we have considered here is 1. This implies that we have total 61 decimal numbers in our power limits which can represent the power perimeters. The referring process of decimal number is almost same as was in frequency parameter. Here the most bottom power range within limit is -29dBm to -30dBm and the decimal number 0 will represent this limit. Similarly, the next range will be from

- 28dBm to -29dBm and this will represent by a decimal number 1. The last and highest power range in our research is +30dBm and this will represent by a decimal number 60. To represent these decimal numbers, we require 26 (6 bits) for mutation operator. There will be a check on power input so that the user can't request power which can't be mapped in the specified limits of power. This check also controls the initial population generated randomly so that there is no any random number over these limits.

C. Bit Error Rate (BER)

Another and placed at third number in the structure of chromosome in our research is BER (Bit Error Rate) parameter. It is the average of invalid or bits with errors in a transmission. BER have great relationship with the type of application going to be transmitted. Reliability is greatly associated with this parameter. Some application requires reliability and known as error sensitive application where these applications require low BER, Voice over IP is an example of these kinds of applications. Some other application can compromise on BER because they need high bandwidth and have less reliable. Video streaming is the example of these kinds of applications [60]. The range of BER (Bit Error rate) we are going to consider in our research is from 10^-1 to 10^-8. The step size will be 10^-1 and represent by a decimal number. According to specified limits on BER we can get total 8 decimal numbers to represent BER within these limits. The decimal number 0 will represent the 10^-1. Similarly, the decimal number 1 will represent the 10^-2 and continue up to 8.

D. Modulation Scheme

The fourth and last gene in the structure of chromosome we have considered in our research is modulation scheme. We have considered only four modulation schemes in our research for maintaining simplicity although other might be possible as well. The modulation schemes we have considered in our research are GMSK, BBPSK, 16QAM and QPSK. According IEEE 802.11n standard the supported range of modulation schemes are from PSK-64 QAM [25]. To perform mutation operator in GA, we need to convert this gene into binary value as well. So only two bits can represent this limit of modulation scheme. We used decimal values instead of binary conversion.

TABLE I: CHROMOSOME STRUCTURE

Sr	Gene	Limit
1	Frequency (F)	0-999
2	Power (P)	0-60
3	BER (B)	0-7
4	Modulation Scheme (M)	0-3

As shown in Table I, the first gene in chromosome structure is frequency and can be denoted as F with limits from 0 to 999. This gene requires Total 10 bit for binary representation. The second one is power and can be denote as P with limits from 0 to 60. This gene requires total 6 bits for binary representation. The gene BER has been placed at number three in the structure of chromosome and can simple denote as BER. The limits for BER are from 0 to 7, means any number between these limits for this gene will be allowed. This gene requires Total III bit for binary representation. The fourth and last gene in the chromosome structure is modulation scheme having limits from 0 to 3 and is denoted by M. This gene requires Total II bits for binary representation. By calculating together all bits we have total 21 bits need to represent the chromosome into binary number for operators such as mutation.

III. PROPOSED IMPROVED MEGA

Different modification in GA has been investigated. Like SGA-CSM, SGA-SCM, SGA-CM and SGA-MCS. In these modifications, many researchers change the GA operators sequence to improve the performance of SGA. Very big generation gap reduces the performance [63] so we need some accurate values of generation gap, crossover rate 0.85 and mutation 0.1 [63]. Generation gap is most important parameter of GA regarding performance of GA. In our proposed improved MEGA, we improved the convergence time of MEGA by manipulating the generation gap, crossover and mutation operator. Simulation results proved that improved memory enabled genetic algorithm (IMEGA) is 0.522 ms faster than MEGA. Fig-1 shows the proposed algorithm.

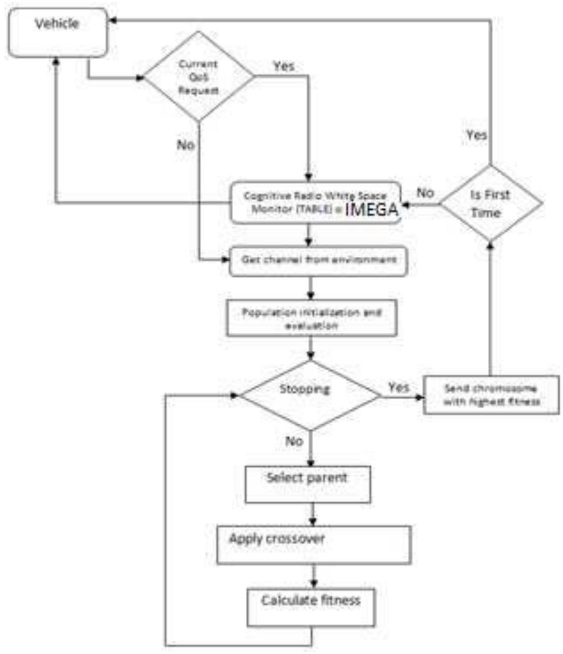

Fig. 1. Flowchart of IMEGA Processing

Reasons like moving vehicle can drop signal power than it can pick already optimized white space from memory within much less time than wait for GA to perform operation [57]. The above figure is the incremental figure of the Genetic Algorithm. Here we have added a memory to the algorithm which will contain few previous results rather than destroying them.

After calculating the fitness of individual gene in the chromosome, the next step is to combine these individual's fitness to access the total fitness of chromosome. The total fitness of chromosome can be access by the sum of fitness of these four genes in the chromosome. Each gene is contributing one of fourth part in overall fitness of the chromosome's fitness. This fitness can calculate through following equation [57]. The chromosome with highest fitness will refer to the worst chromosome to the optimal solution and the chromosome with the lowest fitness refers to the most suitable and best chromosome. GA and its variants has been used in variety of application in Communication systems [68]-[74].

IV. Results

We have performed 150 tests and results with SGA, MEGA & IMEGA. By performing 150 tests we measured convergence time of SGA, MEGA and IMEGA in milliseconds. We also calculated their mean and standard deviation as shown in table-II. It is apparent from the table entries that proposed scheme has the fastest convergence rate compared to existing schemes SGA and MEGA.

TABLE II: Convergence Time Comparison

Test 1 (F=10, P=60, B=4, M=2)			
Sr. No.	**SGA**	**MEGA**	**IMEGA**
1	1647	1.338	0.44
2	1654	1.186	0.905
3	1669	1.087	0.042
4	1645	1.191	0.617
5	1666	1.306	0.979
Mean	1656.2	1.2291	0.5964
Std. Dev.	10.895	0.1149	0.3787
Test 2 (F=999, P=30, B=7, M=3)			
Sr. No.	**SGA**	**MEGA**	**IMEGA**
1	1646	1.2319	1.048
2	1654	1.2812	0.583
3	1662	1.2299	0.532
4	1653	1.257	0.562
5	1655	1.2443	0.595
Mean	1654	1.2489	0.6642
Std. Dev.	7009	0.0211	0.2161
Test 3 (F=498, P=10, B=1, M=1)			
Sr. No.	**SGA**	**MEGA**	**IMEGA**
1	1654	1.218	0.618
2	1646	1.449	0.592
3	1646	1.067	0.526
4	1661	1.332	0.627
5	1660	1.262	0.687
Mean	1653	1.266	0.61
Std. Dev.	7.2664	0.1409	0.0585

Fig. 2, Fig. 3 and Fig. 4 show the convergence rates of SGA, MEGA and proposed IMEGA in terms of time elapsed. The experiment was conducted for ten diverse tests. Like three tests given in Table-II. From the graphs, it is apparent that proposed scheme converges much faster than the other schemes. Fig. 5 shows all the schemes in the same scale.

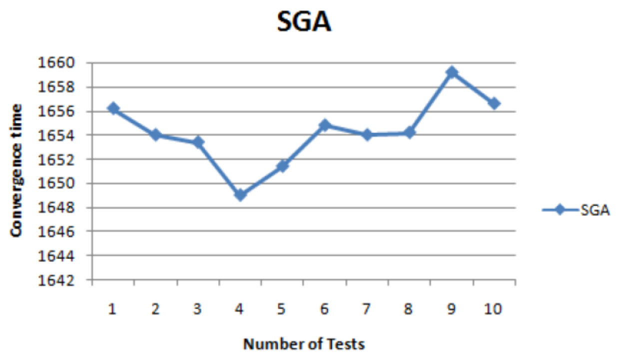

Fig. 2. Convergence time (ms) of SGA

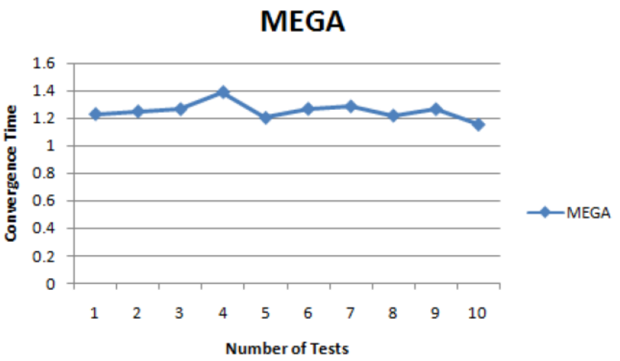

Fig. 3. Convergence time (ms) of MEGA

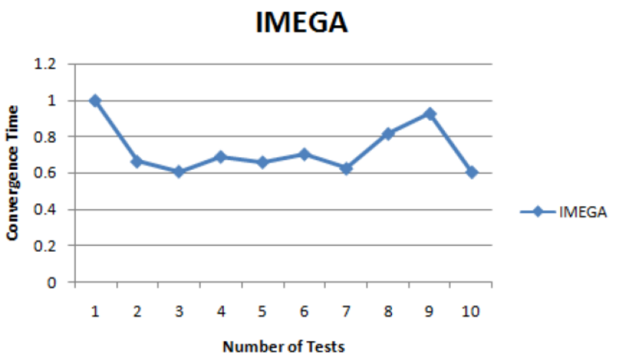

Fig. 4. Convergence time (ms) of proposed IMEGA

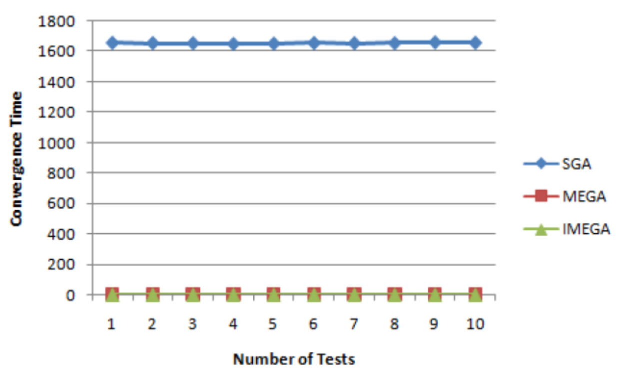

Fig. 5. Convergence time (ms) comparison

Fig. 6 shows the comparison of MEGA and proposed IMEGA for ten tests with random parameters and chromosome/genes lengths. This figure can better highlight the performance of proposed scheme in terms of convergence time. The difference is significant. The maximum difference noted is 0.7ms for fourth test. However, for all the test cases, proposed scheme outperforms.

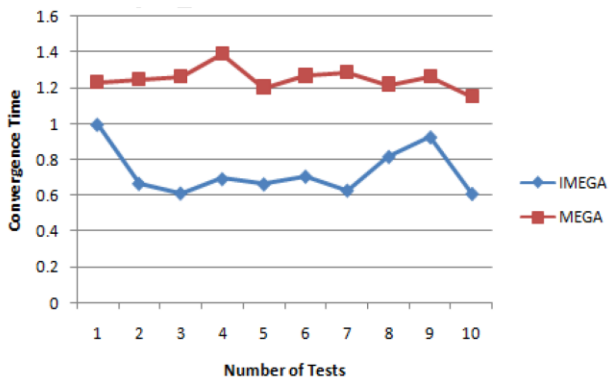

Fig. 6. Convergence of MEGA and IMEGA

V. Conclusions

Different modification in GA has been investigated. Like SGA-CSM, SGA-SCM, SGA-CM and SGA-MCS. In these GA modifications researcher change the GA operators sequence to improve the performance of SGA. Very big generation gap reduces the performance [63]. So we need some accurate values of generation gap, crossover rate 0.85 and mutation 0.1 [63]. Generation gap is most important parameter of GA regarding performance of GA. In our proposed improved MEGA, we use two approaches to improve the performance. First, we minimize the generation gap 0.05. Second approach is to save the conversion time by using crossover rate 80% and mutation rate 0%. Results show that our proposed scheme is 0.522% faster than previous scheme. Proposed scheme can be effective on finding suitable solution. When we decrease crossover rate we get good convergence time but we may put limit on solution range. We may lose solutions that are closer to user request. We may bound on local solutions rather than global by eliminating mutation operation. But in IVC system time matters a lot so we need fast response to make smooth communication.

References

[1] S. Tsugawa, "Inter-vehicle communications and their applications to intelligent vehicles: an overview," in *Proc. Intelligent Vehicle Symposium*, June 17-21, 2002, pp. 564-569.

[2] F. H. Somda, H. Cormerais, and J. Buisson, "Intelligent transportation systems: a safe, robust and comfortable strategy for longitudinal monitoring," *Intelligent Transport Systems*, vol. 3, no. 2, pp. 188-197, June 2009.

[3] Y. S. Chen, C. H. Cho, and I. You, and H. C. Chao, "A cross-layer protocol of spectrum mobility and handover in cognitive LTE networks," *Elseivier*, September 27, 2010, pp. 1-31.

[4] European Road Safety Council: '2010 on the Horizon', 3rd Road Safety PIN report, 2009.

[5] C. Passmann, C. Brenzel, and R. Meschenmoser, "Wireless vehicle to vehicle warning system," in *Proc. SAE 2000 World Congress*, 2002.

[6] F. K. Jondral, "Software-defined radio: basics and evolution to cognitive radio," *Eurasip Journal on Wireless Communications and Networking*, vol. 2005, pp. 275–283, August 2005.

[7] D. Raychaudhuri, "Adaptive wireless networks using cognitive radios as a building block," *ACM MobiCom 2004 Keynote Speech*, Philadelphia, Sept. 2004.

[8] D. K. H. L. Irick, "Collaborative spectrum sensing in cognitive radio vehicular ad hoc networks: Belief propagation on highway," in *Proc. IEEE 71st Vehicular Technology Conference*, May 16-19, 2010, pp. 1-5.

[9] X. Wang, Z. Li, P. Xu, Y. Xu, X. Gao, and H. H. Che, "Spectrum sharing in cognitive radio networks –an auction based approach," *IEEE Transactions on Systems, Man, and Cybernetics, Part B*, vol. 40, no. 3, pp. 587-596, 2010.

[10] M. J. Kaur, M. U. ddin, and H. K. Verma. "Performance evaluation of qos parameters in cognitive radio using genetic algorithm," *World Academy of Science, Engineering and Technology*, vol. 70, pp. 957-961, 2010.

[11] L. Chen, S. Iellamo, M. Coupechoux, P. Godlewski, "An auction framework for spectrum allocation with interference constraint in cognitive radio networks," *Wireless Network*, vol. 17, pp. 1355–1371, May 20, 2011.

[12] J. Garvey. (2008). Car crash warning system could prevent the accident waiting to happen. [Online] Available: http://www.gizmag.com/car-crash-warning-system couldprevent-the-accident-waiting-to-happen/8610/

[13] Y. Zeng, Y. C. Liang, Z. Lei, S. W. Oh, F. Chin, and S. Sun, "Worldwide regulatory and standardization activities on cognitive radio," in *Proc. 5th IEEE Symposium on New Frontiers in Dynamic Spectrum*, April 2010, pp. 1–9.

[14] J. F. Hauris, "Genetic algorithm optimization in a cognitive radio for autonomous vehicle communications," in *Proc. IEEE International Symposium on Computational Intelligence in Robotics and Automation Jacksonville*, FL, USA, June 20-23, 2007.

[15] J. Mitola, "Cognitive radio: An integrated agent architecture for software defined radio," *Doctor of Technology, Royal Inst. Technol. (KTH)*, Stockholm, Sweden, 2000.

[16] D. Niyato and E. Hossain, "A game-theoretic approach to competitive spectrum sharing in cognitive radio networks," in *Proc. IEEE Wireless Communications and Networking Conference (WCNC'07)*, Hong Kong, March 2007.

[17] IEEE 802.22Working Group, "IEEE 802.22 D1: Draft standard for wireless regional area networks," March 2008.

[18] H. Liu, B. K. Machari, and Q. Zhao, "Negotiation game for multichannel access in cognitive radio networks," in *Proc. Cogent Workshop*., Beijing, China, 2008.

[19] M. S. El-Nasr, J. Yen, and T. Ioerger, "FLAME – a fuzzy logic adaptive model of emotions," Automous Agents and Multi-Agent Systems.

[20] Multi-agent Q-Learning of Channel Selection in Multi-user Cognitive Radio Systems: A Two by Two Case Husheng Li.

[21] K. A. Maria and R. A. Zitar, "Emotional agents: A modeling and an application," *Information and Software Technology*, vol. 49, pp. 695–716,14 August 2006

[22] IEEE 1900. [Online]. Available: http://www.ieeep1900.org

[23] J. Hu, C. Guan, M. Wang, and F. Lin. (2006). Model of Emotional Agent. PRIMA 2006. [Online]. 4088, pp. 534-539. Available: http://www.springerlink.com/content/l117571x8u060787/.

[24] C. X. Wang, X. Hong, H. H. Chen, and J. Thompson, "On capacity of cognitive radio networks with average interference power constraints," *IEEE Transactions on Wireless Communications*, vol. 8, no. 4, pp. 1620-1625, 2009.

[25] Lee. McCauley, Stan. Franklin, Architecture for Emotion, ACM, New York, 1998.

[26] S. Haykin, "Cognitive radio: brain-empowered wireless communications," *IEEE Journal on Selected Areas in Communications*, pp. 201–220, Feb. 2005.

[27] G. Lee, P. Faratin, S. Bauer, and J. Wroclawski, "A user-guided cognitive agent for network service selection in pervasive computing environments," in *Proc. Second IEEE Annual Conference on Pervasive Computing and Communications*, 2004.

[28] S. Deb, VikramSrinivasan, and RiteshMaheshwari, "Dynamic spectrum access in DTV whitespaces: Design rules, architecture and algorithms," in *Proc. 15th Annual International Conference on Mobile Computing and Networking (Mobi- Com'09)*, New York, NY, USA, 2009, pp. 1–12.

[29] C. Stevenson, G. Chouinard, Z. Lei, W. Hu, S. Shellhammer, and W. Caldwell, "IEEE 802.22: The first cognitive radio wireless regional area network standard," *IEEE Communications Magazine*, vol. 47, no. 1, pp. 130–138, January 2009.

[30] M. Sherman, A. N. Mody, R. Martinez, C. Rodriguez, and R. Reddy, "IEEE standards supporting cognitive radio and networks, dynamic spectrum access, and coexistence," *IEEE Communications Magazine*, vol. 46, no. 7, pp. 72–79, July 2008.

[31] A. Stirling, "White spaces – the new Wi-Fi?" *International Journal of Digital Television*, vol. 1, no. 1, pp. 69–83, 2010.

[32] H. Jiang, J. M. Vidal, and N. Michael, "EBDI: An architecture for emotional agents," in *Proc. 6th International Joint Conference on Autonomous Agents and Multi Agent Systems*, 2007.

[33] P. Piggin and K. L. Stanwood, "Standardizing WiMAX solutions for coexistence in the 3.65 GHz band," in *Proc. 3rd IEEE Symposium on New Frontiers in Dynamic Spectrum*, Oct. 2008, pp. 1–7.

[34] B. R. Steunebrink, M. M. Dastani, and J. J. C. Meyer, "The OCC model revisited," in *Proc. 4th Workshop on Emotion and Computing - Current Research and Future Impact*, Psaderborn, Germany, 2009.

[35] V. Blaschke, T. Renk, and F. K. Jondral, "A cognitive radio receiver supporting wide-band sensing," in *Proc. IEEE International Conference on Communications Workshops*, 2008.

[36] M. Mitchell, *An Introduction to Genetic Algorithms*, The MIT Press, 1998.

[37] J. Koza. Genetic Programming. [Online]. vol. 1. Available: www.genetic-programming.org

[38] H. Lu and G. G. Yen, "Multiobjective optimization design via genetic algorithm," in *Proc. International Conference on Control Applications*, 2001, pp. 1190-1195.

[39] D. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*, Addison-Wesley, 1989.

[40] C. Carlos, "An updated survey of GA-based multiobjective optimization techniques," *ACM Computing Surveys*, vol. 32, no. 2, pp. 109-143, June 2000.

[41] M. Petrova and P. Mähönen, *Cognitive Resource Manager: A Cross Layer Architecture for Implementing Cognitive Radio Networks*, 2007, pp. 397-422.

[42] S. Haykin, "Cognitive radio: Brain-Empowered wireless communications," *IEEE JSAC*, vol. 23, no. 2, pp. 201–20, Feb. 2005.

[43] S. Kirkpatrick, C. D. Gelatt, and M. P. Vecchi, "Optimization by simulated annealing," *Science*, vol. 220, no. 4598, pp. 671-680, May 1983.

[44] J. Luo and J. P. Hubaux, *A Survey of Inter-Vehicle Communication*, CH-1015 Lausanne, 2004.

[45] A. de Baynast, P. Mahonen, and M. Petrova, "ARQ-based cross-layer optimization for wireless multicarrier transmission on cognitive radio networks," *Computer Networks*, vol. 52, no. 4, pp. 778-794, March 2008.

[46] T. R. Newman, B. A. Barker, A. M. Wyglinski, A. Agah, J. B. Evans, and G. J. Minden, "Cognitive engine implementation for wireless multicarrier transceivers," *Wiley Journal on Wireless Communications and Mobile Computing*, vol. 7, no. 9, pp. 1129-1142, November 2007.

[47] G. J. Klir and B. Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications*, Prentice Hall PTR, 1995.

[48] D. Reichardt, M. Miglietta, L. Moretti, P. Morsink, and W. Schulz, "CarTALK 2000 safe and comfortable driving based upon inter-vehicle-communication," in *Proc. Intelligent Vehicle Symposium*, vol. 2, pp. 545-550, 2002

[49] IEEE Intelligent Vehicle Symposium. (2002). [Online]. Available: http://www.cartalk2000.net.

[50] M. E. Bratman, *Intention, Plans, and Practical Reason*, Harvard University Press, Cambridge, MA, 1987.

[51] M. Toda, editor. *Man, Robot and Society*, Martinus Nijhoff Publishing, Boston, MA, 1982.

[52] J. Bates, "The role of emotion in believable agents," *Communications of the ACM*, vol. 37, no. 7, pp. 122–125, 1997.

[53] N. Frijda and J. Swagerman, "Can computers feel? Theory and design of an emotional system," *Cognition and Emotion*, vol. 1, no. 3, pp. 235–257, 1987.

[54] T. Siddique, "Spectrum optimization cognitive radio networks using genetic algorithms," M.S Electrical Eng. thesis, Blekinge Institute of Technology, Sweden, 2010.

[55] A. R. Damasio, *Descartes' Error: Emotion, Reason, and the Human Brain*, Avon Books, New York, 1994.

[56] T. Y. Byun, "An performance measurements of inter-vehicle communication system over wireless WANs," *International Journal of Control & Automation*, vol. 3, no. 3, September 2010.

[57] T. W. Rondeau, B. Le, and C. J. Rieser, "Cognitive radios with genetic algorithms: Intelligent control of software defined radios," 2006.

[58] J. F. Hauris, "Genetic algorithm optimization in a cognitive radio for autonomous vehicle communications," June 2007.

[59] F. Riaz, S. Ahmed, I. Shafi, F. Iqbal, and M. Ibrahim, "White space optimization using memory enabled genetic algorithm in vehicular cognitive radio," in *Proc. 11th IEEE International Conference on Cybernetic Intelligent System*, Limeric, Ireland, August 23-24, 2012.

[60] S. Kumar, G. Sing, Vibhakarpattak, and K. Chandra "Spectrum management for cognitive radio based on genetics algorithm," vol-7, August 2010.

[61] D. Thierens, *Scalability Problems of Simple Genetic Algorithms*, Unecht, Netherland.

[62] S. Khan, Y. Peng, E. Steinbach, M. Sgroi, and W. Kellerer, "Application-Driven cross-layer optimization for video streaming over wireless networks," *IEEE Communications Magazine*, vol. 44, no. 1, pp. 122-130, January 2006.

[63] H. Lu and G. G. Yen, "Multiobjective optimization design via genetic algorithm," in *Proc. International Conference on Control Applications*, Sep. 2001, pp. 1190–1195.

[64] K. Deb, A. Pratap, S. Agarwal, and T. Meyarivan, "A fast and elitist multi objective genetic algorithm: NSGA-II," *IEEE Transactions on Evolutionary Computation*, vol. 6, no. 2, pp. 182–197, Apr. 2002.

[65] M. Angelova, P. Melo-Pinto, and T. Pencheva, "Modified simple genetic algorithms improving convergence time for the purposes of fermentation process parameter identification," *Wseas Transactions on Systems*, vol. 11, no. 7, pp. 2224-2678, July 2012.

[66] H. J. Liu, Z. Wang, S. Li, and M. Yi, "Study on the performance of spectrum mobility in cognitive wireless network," in *Proc. 11th IEEE Singapore International Conference on Communication Systems*, 2008.

[67] P. Benko, G. Malicsko, and A. Veres, "A large-scale, passive analysis of end-to-end TCP performance over GPRS," in *Proc. Twenty-Third Annual Joint Conference of the IEEE Computer and Communications Societies*, March 7-11, 2004, pp. 1882-1892.

[68] J. H. Holland, *Adaptation in Natural and Artificial Systems*, The University of Michigan Press, 1975.

[69] Atta-ur-Rahman, I. M. Qureshi, and A. N. Malik, "Adaptive resource allocation in OFDM systems using GA and fuzzy rule base system," *World Applied Sciences Journal*, vol. 18, no. 6, pp. 836-844, 2012.

[70] Atta-ur-Rahman, I. M. Qureshi, M. T. Naseem, M. Z. Muzaffar, "A GA-FRBS based rate enhancement scheme for OFDM based hyperlans," in *Proc. 10th IEEE International Conference on Frontiers of Information Technology*, Islamabad, Pakistan, December 17-19, 2012, pp. 153-158.

[71] Atta-ur-Rahman and I. M. Qureshi, "Optimum resource allocation in OFDM systems using FRBS and Particle swarm optimization," in *Proc. Nature and Biologically Inspired Computing*, North Dakota, USA, 2013, pp. 174-180.

[72] Atta-ur-Rahman, I. M. Qureshi, A. N. Malik, M. T. Naseem, "Dynamic resource allocation for OFDM systems using DE and fuzzy rule base system," *Journal of Intelligent & Fuzzy Systems*, vol. 26, no. 4, pp. 2035-2046, 2014.

[73] Atta-ur-Rahman, "Applications of softcomputing in adaptive communication," *International Journal Control Theory and Applications*, vol. 10, no. 18, pp. 81-93, 2017.

[74] Atta-ur-Rahman, I. M. Qureshi, A. N. Malik, and M. T. Naseem, "A real time adaptive resource allocation scheme for OFDM systems using GRBF-Neural networks and fuzzy rule base system," *International Arab Journal of Information Technology*, vol. 11, no. 6, pp. 593-601, 2014.

[75] Atta-ur-Rahman, "Applications of hybrid intelligent systems in adaptive communications," in *Modeling, Analysis and Applications of Nature-Inspired Metaheuristic Algorithms*, 1st, Chapter: 10, 2017, pp. 183-217.

Atta-ur-Rahman is currently working at Department of Computer Science, College of Computer Science and Information Technology, Imam Abdulrahman Bin Faisal University (Former University of Dammam), Dammam, KSA as Assistant Professor. Before that he was Associate Professor and Deputy Director at BIIT (Pakistan) where he served for 11 years. Dr. Atta has completed his BS degree in Computer Science from University of The Punjab, Lahore, Pakistan; MS degree in EE from International Islamic University, Islamabad, Pakistan and PhD degree in Electronic Engineering from ISRA University, Islamabad Campus, Pakistan in years 2004, 2008 and 2012, respectively. His research interests include digital signal processing, information and coding theory, digital image watermarking, wireless/digital communication, AI and soft/evolutionary computing.