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A Cognitive Access Selection approach for Heterogeneous Wireless Networks Based on Fuzzy Logic

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Abstract. At present, lots of work focus on spectrum allocation of wireless networks, and pay little attention about optimization network access. In this paper, we propose a cognitive access selection approach of heterogeneous wireless networks based on fuzzy logic. By means of established access selection factors and its membership functions(MFs), we can access optimal network using presupposition fuzzy rules according to service types. Finally, simulation experiments shown the approach is effective.

Introduction

Various wireless network forms existing simultaneously and complementing reciprocally induce high complexity and heterogeneity of current network environment. Nevertheless, network access technology becomes a bottleneck and impedes the development of network technology since lacking of dynamic and self-adaptive modulation ability. Motivated by such problems, the concept of cognitive is considered as a key and attracts much attention.

Cognitive is a psychology word, it has been introduced into the research of network technology to make network possess intelligence in recent years. The proposal of cognitive networks[1], cognitive radio[2] and cognitive radio networks[3] shows cognitive becoming a hotspot in the field of network respectively. Recently, the research of cognitive related has stepped into practical stage. IEEE 802.22 work group has proposed a first cognitive related standard, trying to make use of spectrum reserved for TV. For cognitive radio network access technology, since cognitive radio proposed in [4], the research of spectrum access for cognitive radio has sparked much achievement. Viewing from the existed literature, it is concluded that current research for cognitive access in heterogeneous network is weakness and inefficiency. Thereby, it is necessary to continue studying this issue for researchers.

In this paper, we present a cognitive access architecture(CAA) and cognitive access process model (CAPM) for heterogeneous wireless networks, and using fuzzy logic to realize the optimal accession. The rest of this paper is organized as follows. We design CAA and CAPM in detail, analyzes the rationality of the architecture and model in section 2. Section 3 exploits fuzzy logic realized the access selection process. Simulation experiments are given in section 4 to verify our thoughts. Finally, section 5 concludes the paper and discusses future work.

Cognitive Access Architecture and Cognitive Access Process

Considered a scenario as follows. A mobile terminal(MT) is covered by several wireless networks, and each wireless network has different network attributes, such as some networks have higher security, and others have wider bandwidth, each wireless network has accessed IP core network and can provide minimum access service. According to traditional network access technology, the MT will select the network that has strongest signal level as its access network. Nevertheless, it's not a perfect solution. For example, if the data to be transferred is confidential, the MT access a network with strongest signal level but lower security, it will cause serious consequences of disclosure. Therefore, we should consider not only the characteristics of MTs, but also the attributes of access networks, then, select the optimal access networks in terms of full consideration for all network elements.

A significant characteristic of current heterogeneous wireless network access is terminals can select access network flexibly. Exploit various network access technology, intelligent multi-terminals can realize seamless connection and cooperation effectively on platforms of different network. When terminals access network, network allocates bandwidth self-adaptively and indicates the optimal routing so as to achieve optimum communication effects. Comparing to traditional wireless network, current heterogeneous wireless network has higher bandwidth and data transmission rate, can support broadband service such as real-time video and HD video. IEEE 802.16 work group makes 802.16 and 802.16e standards to orient fixed access pattern and mobile access pattern for terminals. These measures meet service requirements partially, and the architectures is shown as Fig.1.

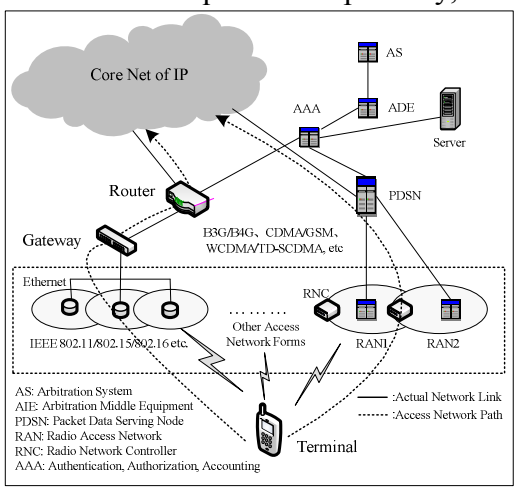

Fig .1. Wireless Network Access Architecture

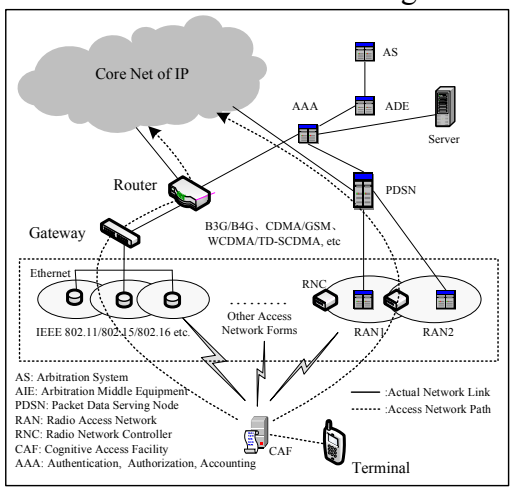

Fig .2. Cognitive Access Architecture

Current heterogeneous wireless network access architecture includes terminal(single or multi-mode), access network, authentication system and core net of IP. Multi-Terminal can select different access network which is IEEE 802.1x, RAN and some other network access forms.

Although Multi-Terminal can select access network flexibly, it still has such problems to solve as follows: 1,Spectrum awareness. It refers to spectrum sensing, spectrum management, spectrum mobility, spectrum sharing. These elements decide if it has available spectrum to access.2 Network physical properties awareness. Network attributes include network bandwidth, network load, quality of link, network delay, etc. These elements have a major impact on quality of access. 3 Network overall properties awareness. Overall properties of network are estimation for various network elements. It includes network safety, credibility, timeless, etc. Terminals can select the optimal access network according to its data attributes transferred and overall properties of network. 4 Terminal overall properties awareness. Overall properties of terminal can be decided by the rate of terminal movement and properties of data transmission, it's a prerequisite to access appropriate network.

Compared to Fig.1, heterogeneous wireless network cognitive access architecture can select the optimal access network form according to each network physical properties, overall properties and terminal overall properties. Cognitive Access Facility (CAF) is a key component between terminal and access networks. The aim of CAF is to decide which network can be access optimally in terms of external environment and internal policy.

Access Decision Making Based on Fuzzy Logic

Fuzzy Logic and Membership Function

Fuzzy Set Theory differs from traditional set theory in that partial membership is allowed. For example, an element can belong to a set only to a certain degree. This degree of membership is commonly referred to as the membership value and is represented using a real value in [0, 1], where 0 and 1 correspond to full non-membership and full membership, respectively. Formally, a fuzzy set A is in a universe U is defined by the membership function A: U→[0,1], so that for each $u \in U$ its grade of membership to the set A is given by $A(u)$. Fuzzy inference is an important part of fuzzy logic,

commonly used inference form includes Mamdani inference and Takagi-Sugeno inference, the difference of the two is that the output of Mandani is an accurate value, and the output of Takagi-Sugeno inference is polynomial of input vector. In this paper, we use Mamdani inference form to implement reasoning.

In this paper, network elements we should consider including bandwidth, time-delay, network load, terminal factors we consider moving rate, and service types we consider voice service, video service, streaming media service, background service and interactive service. We use MF to depict the fuzzy degree through parameter value. We define the universe of all access factors as follows:

Table 1. Universe of All Access Factors

Network Factor	*Terminal Factor*
$[N_i^l, N_i^h]$	$[T_j^l, T_j^h]$
$1 \le i \le 3$	$j = 1$

Where l represents access factor can select min value in the universe, and h is the max value in the universe. At present, popular MF choices include the triangular, trapezoidal, Gaussian, and Cauchy MFs[5]. In this paper, we use Gaussian MF to represent access factor fuzzy degree. The function represents as follows:

Network side MF:

$$\psi_1(n;\alpha_n,\sigma_n) = \exp\left(-\frac{1}{2}\left(\frac{n-\alpha_n}{\sigma_n}\right)^2\right) + f_n(n) \tag{1}$$

Terminal side MF:

$$\psi_2(t;\alpha_t,\sigma_t) = \exp\left(-\frac{1}{2}\left(\frac{t-\alpha_t}{\sigma_t}\right)^2\right) + f_t(t) \tag{2}$$

Where α represents the center value of curves, and σ decides width or narrow degree of the curve. α and σ can be optimized by intelligent optimal algorithms such as swarm algorithm and genetic algorithm. $f(x)$ is the adjustment function, it makes $\psi(x)$ reach 0 or 1.

Fuzzy Inference Process

According to access factors mentioned, we can adopt fuzzed measures as follows:

Fuzzy sets {'N', 'M',' 'W'} represent {'narrow', 'medium', 'wide'} of bandwidth. Fuzzy sets {'S', 'M',' 'B'} represent {'small', 'medium', 'big'} of network delay. Fuzzy sets {'L', 'M',' 'H'} represent {'low', 'medium', 'high'} of network load. Fuzzy sets {'S', 'M',' 'F'} represent {'slow', 'medium', 'fast'} of terminal moving rate. Fuzzy sets {'L', 'B', 'M', 'G', 'B'} represent {'less', 'bad', 'medium', 'good', 'better'} of network access degree.

The reasoning form likes this: IF service type is voice service, and bandwidth is 'W', and network delay is 'S', and network load is 'L', and terminal moving rate is 'S', the network access degree is 'B'. Fuzzy inference rules are established as shown in Table 2.

Table 2. Fuzzy Inference Rules

	Network Bandwidth	***Network Delay***	***Network Load***	***Moving Rate***	***Service Types***	***Access Degree***
Rule$_1$	W	S	L	S	VoS	B
Rule$_2$	M	M	M	M	SMS	M
…	…	…	…	…	…	…
Rule$_x$	N	B	H	B	IS	L

In table 2, we will have $3^4 \times 5 = 405$ rules, and they include all the conditions of access factors variation. So, according to these rules, we can find the optimal access network for each service type in any case.

Experimental Results

Experiments Scenario

In this paper, we use OPNET-Modeler[6] network simulation tool to put up network simulation platform. On the hexagonal cellular topology, runs IEEE 802.11a, 802.11b, 802.15, 802.16, TD_LTE and LTE_FDD wireless access network. In the access environment, six access network are covered each other, that is to say, terminals can access any networks at the same time. Terminals entering follow a Poisson's distribution, and the running track follows random walking model. Scenario setting is shown as Fig.3.

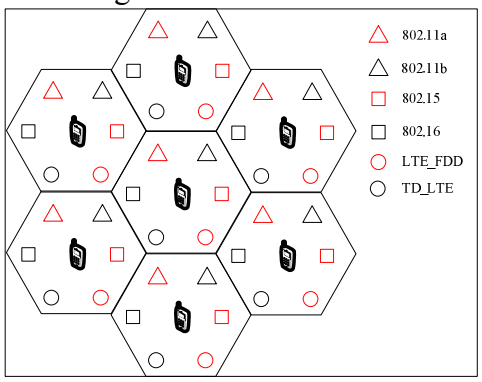

Fig .3. Wireless Access Environments

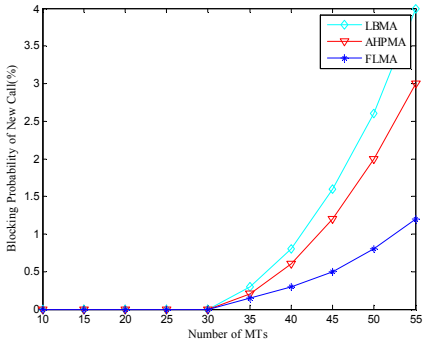

Fig.4 .Blocking Probability Curve

Experiment Results and Its Analysis

We run Multi-Access Selection Algorithm Based on Load Balance(LBMA), Multi-Access Selection Algorithm Based on Analytic Hierarchy Process(AHPMA), and Multi-Access Selection Algorithm Based on Fuzzy Logic(FLMA) mentioned in this paper, respectively. By comparing blocking probability, dropping probability, average of throughput of new calls with the increase of mobile terminal number, and the results are shown as follows.

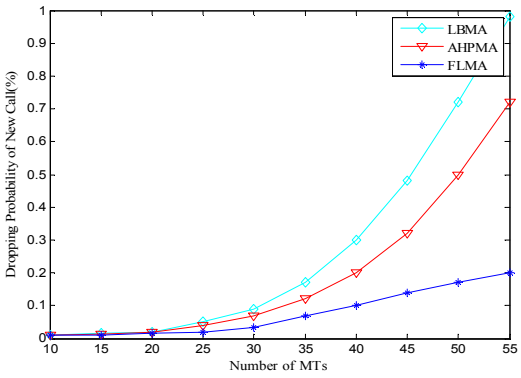

Fig.5. Dropping Probability Curve

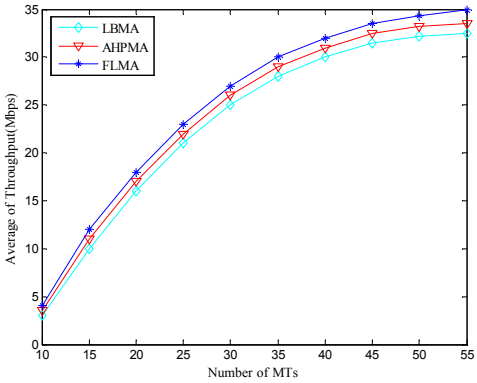

Fig.6. Average Throughput Curve

Fig.4 compares blocking probability of LBMA, AHPMA and FLMA. As it showing, when the number of MT increasing to 30, blocking probability begins to increase. When the number of MT increased to 55, the blocking probability using LBMA and AHPMA come to 4% and 3% respectively, and the blocking probability using FLMA only reaches to 1.2%. Comparing to LBMA and AHPMA, blocking probability has an obvious decreased. Fig.5 shows variation trend of dropping probability among LBMA, AHPMA, and FLMA. When the number of MT increased to 25, the dropping probability is closed, but when the number of MT continued increased, LBMA and AHPMA have a faster increasing rate, and although FLMA increasing as well, the tendency increased at a relatively slow rate. This is because FLMA can analysis the network situation in real-time, if the available bandwidth decreased or network delay increased, access fuzzy rule will changed, it can adjust balance of access networks automatically. Fig.6 shows the average of throughput to the three methods, it's easy to see that the effect among three approaches is changed little, FLMA doesn't have much advantages. We consider that its because the three approaches can obtain a load balance effect, so the result is so closed.

Conclusions and Future Work

In this paper, we propose a cognitive multi-access selection approach for heterogeneous wireless network. On the base of access selection architecture, we construct an access selection model based on MDE., and we use fuzzy logic to make access decision. In order to select the optimal access network, we consider several access factors of network side and terminal side. Experiment results show the approach we proposed is more advantageous than LBMA and AHPMA.

The approach we proposed in this paper still has some problems. First, since we consider much access factors, it leads to much fuzzy rules, decreased the rate of access. Second, the parameters of MFs should be optimized according to the variation of network environment, and this problem we have not discussed in the paper. So, our future work is to improve and overcome these problems, and set up an efficient and self-adaptation access system.

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References

[1] Y Li, L Cong, L Zuhao, H Wenyu. Heuristic Spectrum Assignment Algorithm in Distributed Cognitive Networks[C]. 2010 6th International Conference on Wireless Communications Networking and Mobile Computing, (2010)

[2] V Marojevic, N Vucevic, X Reves, Gelonch A. Integrated Resource Management in Cognitive Radio[C], 16th Mobile and Wireless Communications Summit, (2007)

[3] S Wang, H Zheng. A resource management design for cognitive radio ad hoc networks[C]. IEEE Military Communications Conference, (2009)

[4] N,Nie, C Comaniciu. Adaptive channel allocation spectrum etiquette for cognitive radio networks[C]. 2005 First IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks, (2005)

[5] D Ramot, M Friedman, G Langholz., A Kandel. Complex fuzzy logic[J]. IEEE Transactions on Fuzzy Systems, vol 11 (2003)

[6] S J Habib, P N Marimuthu. Optimized capacity planning and performance measurement through OPNET Modeler[C]. 2010 International Conference on Computer Applications and Industrial Electronics, (2010)