PROCEEDINGS OF SCIENCE

Research of Wireless Network Coverage Self-Optimization Based on Node Self-Adaption Model

Bojian Xu[1]
International School
Beijing University of Posts and Telecommunications
Beijing, 100000,China
Email: m15501121368@163.com

Wenzhi Chen[2]
International School
Beijing University of Posts and Telecommunications
Beijing,100000, China
*Email:*m15501121368@163.com

This paper points that nowadays, the widely disseminated wireless network with base stations and founds the Node Self-Optimization Model which treats stations as research objects in order to enable the BSs (base stations) to regulate the signal transmitting power by themselves; at meanwhile, under the analysis of actual wireless signals' transmitting conditions, an unique Path-Loss Model with probability factor which has never been considered before has been established, in this sense, the proper power value for BS which is able to meet certain coverage can be educed more accurately through calculation so that the wireless network's coverage-shortage problem can be solved thoroughly. In addition, for the optimization of BSs' power by using efficiency of the whole network, we introduce the coverage overlapping ratio as a building block of designing macro power regulating arithmetic and then find the Redundancy-Optimization Algorithm. In comparison with the conventional power configuration of BSs, the utilization of this algorithm is able of declining the coverage redundancy and thus increasing the overall power by using the efficiency effectively.

ISCC 2015
18-19, December, 2015
Guangzhou, China

[1]Bojian Xu
[2]Wenzhi Chen

1. Introduction

Nowadays, the wireless network has been integrated with the human's life, from TD-LTE wide area communication with high data rate to the WLAN with the core of routers[1]. The wireless network is almost everywhere; however, the extensive existence of wireless network fails to always provide users with high-speed and stable communication and furthermore there is nearly no relevant research that can solve the problem thoroughly[2] . In our daily life[3], we may often face the situation that our phones can't detect the signal of a certain WiFi or the signal is too weak to support network services; therefore, the best signal covering range which is able of supporting every mobile terminal (MT) to communicate smoothly and provides by BS ought to be explored deeply. Consequently, we initially founded the Node Self-Adaption Model which can make BSs regulate the coverage range intelligently; furthermore under the premise of enough covering range, the overall power-saving arithmetic is put forward, which would exert effect of saving natural resources[4].

2.Node Self-Adaption Model

2.1 Model Background

In the wireless network base station, the source of signals and the foundation of communication can be found. In fact, excluding some special occasions, there is nearly no difference between BSs within a certain region; therefore, in this model, the base stations can be treated as identical nodes. Conventionally, the main duty of BS is transmitting signals and the emitting power has to be set by people; as a result, it's difficult to realize coverage self-optimization. However, in the Node Self-Adaption Model, the self-regulation of BS's transmitting power can be achieved via interaction between BS and MT [5][6].

2.2 Maintaining the Integrity of the Specifications

Under the Node Self-Adaption Model, all BSs' transmitting power will not be regulated by people, on the contrary, it will be controlled by a server. Suppose p_0 be the smallest receiving power for MT which is able to support the fundamental communication and it likes a kind of threshold. When MT connects with a certain BS, MT's signal receiving power can be sent to the server through current network in real time then the server would analyze and deal with the accepted data, which is followed by the transmitting power regulating on that BS until it can meet the needed communication of client. (The process is illustrated in Fig. 1)

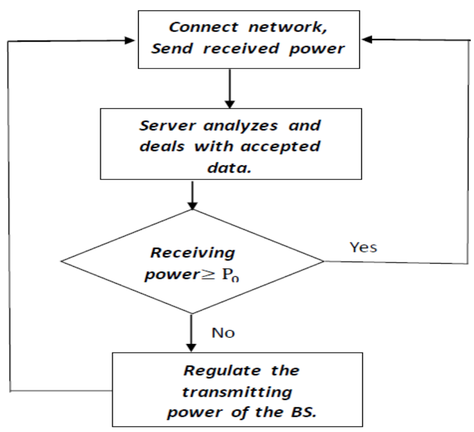

Figure 1: Process of the Model

3. Establishment of Self-Optimization

3.1 Path-Loss Model Under Coverage

In the Node Self-Adaption Model mentioned above, the server has to regulate BS's signal transmitting power; but the wireless communication problems faced by MT are always caused by the formation of coverage dead zone, resulting from the insufficient BS transmitting power. Hence the determination of regulated power that provides by the server that is able to meet necessary coverage needs to be discussed more deeply.

Based on the actual situation, the coverage range of a single BS can be approximately regarded as a circle with radius: r and the value of r is almost determined by the transmitting power of the BS. During the process of signal propagating, the power loss would increase with longer distance between MT and the signal center. In this case, the path-loss can be expressed as:

$$P_L \propto \left(\frac{d}{d_0}\right)^i \tag{3.1}$$

Among the expression, d is the signal propagating distance. d_0 is a reference distance and in wireless channel the value of d_0 can be set as 1m. Exponent i is relevant to the signal propagating environment and the further discussion of i is as follows.

When the height of BS's antenna is fixed, the value of i is estimated to 2 in free space; however, unquestionable signal may be affected by obstacle probably during propagating and the impediment would make i bigger. Suppose $p(d)$ be the probability of being impeded during propagating and it is related to d. In addition, α represents the attenuation of signal amplitude caused by obstacle. In this sense:

$$i = 2 + 2\,p(d) * \ln\alpha \tag{3.2}$$

Furthermore, when the transmitting power of BS is constant, the average signal receiving power of MT will logarithmically decay with distance. As a result, the signal receiving power of MT can be expressed as (in decibel) :

$$P_r = P_C - P_L(d_0) - 10\left(2 + 2\,p(d) * \ln\alpha\right) * \ln\left(\frac{d}{d_0}\right) \tag{3.3}$$

In the equation, P_C is the transmitting power of BS [7]. $P_L(d_0)$ is the power loss for the reference point which is d_0 meters away from the coverage center and it is always measured in reality.

3.2 Optimized Power Value for Coverage-Shortage

By utilizing the Path-Loss Model, the optimized power value for solving wireless network coverage-shortage problem can be determined by calculation. Under the premise of MT, it is able of detecting the current network signal while considering the condition that MT's receiving power fails to support the communication as demanded.

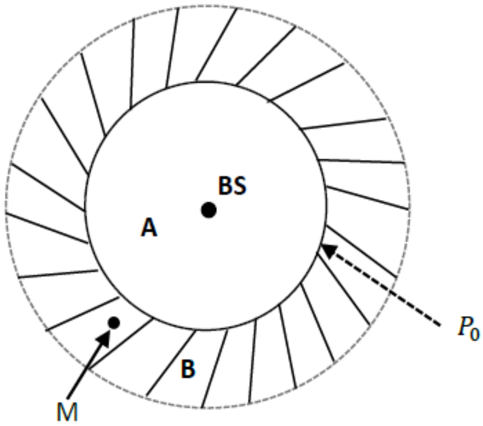

Figure 2: Picture based on Path-loss model

As shown in Fig. 2, the mobile terminal M is located at the shaded area B. In order to provide M with normal communication, it is necessary to enlarge the efficacious coverage area of BS (the efficacious coverage area of the BS is A). Assuming that the receiving power of M be P_M, then on the basis of computing and the Path-Loss Model, new radius of coverage after power regulation can be reached:

$$r = d_0 * \frac{e^{P_C - P_M - P_L(d_0)}}{10\left(2+2\,p(r)*\ln\alpha\right)} \tag{3.4}$$

In this representation, the value of $p(r)$ is determined by actual condition. With the calculated value: r, we could draw the regulated BS power which is able to meet the coverage:

$$P_R = P_0 + \frac{1+p(r_0)*\ln\alpha}{1+p(r)*\ln\alpha} * (P_C - P_M) \tag{3.5}$$

Among the expression, P_R is the BS power after regulation. P_C is BS's original transmitting power. $p(r_0)$ is the probability of being impeded under the original coverage range. What's more, in order to avoid the signal coverage marginal effect and simplifying calculation, we leave out the reference power $P_L(d_0)$. Then BS can just employ the calculated power: P_R to meet the coverage needs [8][9].

4.Coverage Redundancy Self-Optimization

4.1 Coverage Overlap Ratio

In the wireless network, as the coverage range of BS is estimated to be a circle, the overlap regions between several base stations are unavoidable; however, too much coverage redundancy will not only result in the power waste but also exacerbate the signal interference between adjacent BSs. Consequently, it is principal to optimize overall power deployment of base stations.

In the Node Self-Adaption Model, suppose all base stations inside of a certain region constitute a node set: ξ. Define coverage overlap ratio as the proportion of the whole overlapping area and efficacious coverage area of all nodes, recording as D then [10]:

$$D = \frac{R_1 + R_2 + R_3 + \ldots + R_n - R_1 \cup R_2 \cup R_3 \cup \ldots \cup R_n}{R_1 \cup R_2 \cup R_3 \cup \ldots \cup R_n} = \frac{\sum_{i=1}^{n} R_i - \bigcup_{i=1}^{n} R_i}{\bigcup_{i=1}^{n} R_i} \tag{4.1}$$

In the expression, R_i is the coverage area of one of the nodes. $\bigcup_{i=1}^{n} R_i$ is the efficacious coverage of all nodes in ξ. The value of D can reflect coverage redundancy extent and the lower D is the higher power by using efficiency of the network.

4.2 Coverage Redundancy Optimization Algorithm

In order to improve the power utilizing efficiency of ξ, under the premise of providing enough coverage for all mobile terminals, descending coverage overlapping area can effectively reduce the value of D. As Fig. 3 shows the shaded parts: C_1 and C_2 which represent the overlapped area of adjacent nodes. Then diminish the weights of C_1, C_2 in $\bigcup_{i=1}^{n} R_i$ to reduce coverage redundancy.

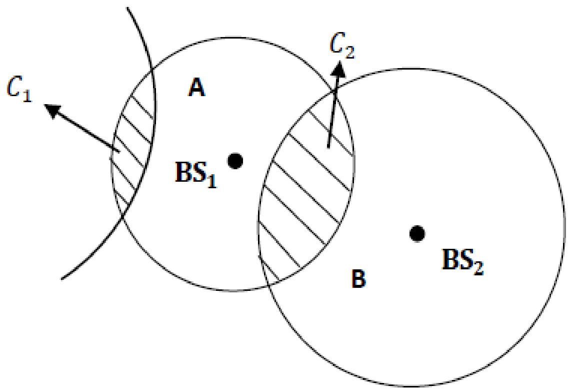

Figure 3: Picture-based on Coverage Redundancy

Based on on the Node Self-Optimization Model, we designed Algorithm [11]:

Firstly, choose one node from ξ randomly and name it as O, then find all adjacent nodes of O and their transmitting powers through the server, form the power set $\{p_1, p_2, p_3, ..., p_n,\}$: and coordinate set: $\{(x_1, y_1), (x_2, y_2), (x_3, y_3), \ldots (x_n, y_n)\}$ (In the actual cellular network, the value of n is 6). After that, with the assistance of distance formula between two points, it is able to get the distances between O and other nodes, form the set: $\{d_1, d_2, d_3, \ldots, d_n\}$.

According to the Path-Loss Model, the set of coverage radiuses of O and its adjacent nodes can be obtained by calculation: $\{r_0, r_1, r_2, r_3, \ldots, r_n\}$. Then choose one of O's neighbor: O_1 randomly and compute its coverage radius: r_i also the physical distance between O_1 and O: d_i. Afterwards, compare d_i with $(r_i + r_0)$: If $d_i > (r_i + r_0)$, then the transmitting power of O_1 needs to be increased so as to enlarge its coverage radius and realize $d_i = ({}'r_i + r_0)$. If initially $d_i = (r_i + r_0)$, then the power of O_1 should be kept unchanged. If $d_i < (r_i + r_0)$, we define this circumstance as 'shadow' and further optimizing about this is needed.

At the moment of optimizing the coverage overlap, the optimization of coverage shortage also needs to be considered and guaranteed. In this case, the circumstance of 'shadow' has to be subdivided. Upon receiving the power formula provided in Path-Loss Model, it's easy to compute the signal transmitting distance when the losing power is P_0 (threshold value) and record it as: R_0. Then if $(r_i + r_0) - R_0 < d_i$, the power of O_1 has to be increased until physical distance equals to the subtraction of coverage radiuses and threshold distance. On the contrary, if $(r_i+r_0)-R_0>d_i$, then the power has to be decreased until both sides are equal. Finally, if $(r_i+r_0)-R_0=d_i$, the power of O_1 remains unchanged.

After the process of O_1 mentioned above, another adjacent node of O_1 would be chosen randomly, named as O_2. If O_1 satisfies the condition of 'shadow', regulate the power of O_2 and realize $d_j=(r_j+r_0)$. If O_1 does not satisfy 'shadow', regulate the power of O_2 and realize $(r_j+r_0)-R_0=d_j$.

Do the same process mentioned above for all O's adjacent nodes and finally guarantee that every other one ought to have the power value to be calculated after 'shadow' process [12].

4.3 Algorithm Preliminary Verification

For the purpose of putting forward the Coverage Redundancy Optimization Algorithm, which just provides a feasible solution for improving the wireless network coverage by using efficiency, it has not been put into practice; in this case we just give simple verification of this arithmetic here with the assistance of geometric illustration.

Firstly, we consider the condition that there are three base stations inside a local wireless network. Three initial power values which are randomly generated by computer are set to O_2, O_1 and O respectively (in reality, the transmitting power values for different base stations are not identical commonly). In this case, based on the algorithm, the geometric figure of this network is shown in Fig. 4. Inside of it, O_2, O_1 are two adjacent nodes of O and T is the intersection of O_2 and O; furthermore, with the algorithm and through calculation, the power utilization efficiency can be improved to 97.4% after simulation.

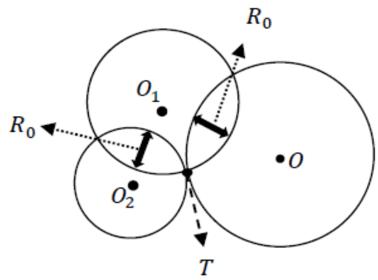

Figure 4: Three Base Stations

The illustration mentioned above is only able to partly show the strength of the provided algorithm and for wireless network with more than three BSs. Through simulation, the outcomes are all over 96.2%; but recent researches on this topic can hardly achieve the figure over 95.0%. [13] Hence this result indicates the significance of saving power resource of the Redundancy-Optimization arithmetic as well as the stability of this arithmetic to some extent; however, in fact, the power utilization efficiency in real life is considerably lower than this value due to specific environments at different places; therefore, further practical testing is still indispensable before it is employed in real life and certain modifications for the algorithm when facing diverse situations are also necessitated.

5. Conclusion

In this paper, the Node Self-Adaption Model and the Path-Loss Model are firstly established, providing wireless network coverage-shortage optimization with more feasible and precise solution; at meanwhile, in order to reduce the coverage redundancy and optimize the overall power utilization efficiency of the base stations in a certain region, the two models are utilized thoroughly and the favorable algorithm is designed. Under the premise of meeting the coverage needs, the provided coverage redundancy optimization process is helpful in solving the overlapping problem and is tested theoretically, which will be more efficacious in practice. Although the whole researching procedure is still in theory, it is meaningful for improving the coverage capability of wireless network in the future.

References

[1] L.Roelens, S. Van Den Bulcke, W. Joseph, G. Vermeeren, L. Martens, *Path loss model for wireless narrowband communication above flat phantom*, Electronics Letters, vol.42,2006, n1, pp10-11

[2] M. Zhou, Y. Sun, Y. B. Xu, Z.A. Deng, W. X. Meng, *WLAN indoor location method based on artificial neural network*, High Technology Letters, vol.16, n3, p227-234, September 2010

[3] T. Bin, L. Zi, G.L. Wang, W. S. Zhang, *How wireless power charging technology affects sensor network deployment and routing*, Institute of Electrical and Electronics Engineers Inc. June 21,pp438-447, 2010, ICDCS 2010 – 2010

[4] X.Y. Zhang , J. Tang, M. Li , *The design of mobile terminal security management system based on digital certificate*, 3rd International Conference on Advanced Engineering Materials and Architecture Science, Trans Tech Publications Ltd, vol. 651-653, 2014, pp 1976-1979.

[5] B. Shen, X.M. Gu, C.D. Yang, J.H. Zhao, R.H. Yuan, *Non-standard parts management based on Browser\Server*, 2014 International Conference on Advances in Materials Science and Information Technologies in Industry, Trans Tech Publications, vol.513-517, 2014, pp 2424-2427.

[6] J.Z. Wang, G.F. Yin, X.B. Hu, T. Chen, *Implementing method of remote cooperative design system based on browser/server model*, Jisuanji Jicheng Zhizao Xitong/Computer Integrated Manufacturing Systems, vol.6, 2000, pp 52-55+60.

[7] Y.H. Yang , Y. P. Sun, D.Y. Shen, Y.G. Xie, *study of the pass loss models based on measurement and simulation*, 2012 International Conference on Mechanical Engineering and Intelligent Systems, Trans Tech Publications, vol.195-196, 2012, pp 678-683.

[8] H. Wu, B. Chen, L. Guan, W. Le, *Quantitative evaluation and optimized selection of power supply reliability enhancement measures*, Dianli Zidonghua Shebei/Electric Power Automation Equipment, vol.35, n 5, pp 126-130, 2015, May 10.

[9] Y. Jing, Z. Fu , M. Qi , J. Wang, *Prediction research based on the optimized BP neural network for coal calorific value*, 2012 Spring World Congress on Engineering and Technology, May 27, 2012 - May 30, 2012.

[10] R. Han, C. Feng, H. Xia, Y. Wu , *Coverage optimization for dense deployment small cell based on ant colony algorithm*, IEEE Vehicular Technology Conference, 2014-November, November, November 24, 2014, 2014 IEEE 80th Vehicular Technology Conference.

[11] J. Jia, J. Chen, G. Chang, LinLiang Zhao, GuangXing Wang, *Kongzhi yu Juece/Control and Decision*, vol.22, n 11,2007,pp 1289-1292+1301

[12] J. Hu, Xiufang Feng, *A coverage optimization scheme for wireless sensor networks*, Journal of Computational Information Systems, vol.9, n20, pp 8325-8332, 2015, October 15

[13] Y. Zheng, Lombard, Anthony, Kellermann Walter, *An improved combination of directional BSS and a source localizer for robust source separation in rapidly time-varying acoustic scenarios*, IEEE Computer Society, p58-63, 2011