AN APPLICATION FUZZY ID3 TO WIRELESS LAN ACCESS POINT OPTIMAL LOCATION PROBLEM

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Abstract : Although wireless LAN is useful in its small size and mobility, how optimally wireless LAN points (APs) are located is important. In this paper, we propose the APs' optimal location method using fuzzy ID3. We discuss how to formulate the method for setting AP optimal location and show the effectiveness of this method by illustrating the examples of AP optimal locations.

Keywords : Wireless LAN, Fuzzy ID3, Fuzzy Rules

1. Introduction

Recently, as the performance of wireless LAN [1, 2] has improved, wired LAN system has rapidly been replaced by wireless LAN system. Although wireless LAN is useful in its small size and mobility, the connection region of transmitted radio wave is strongly affected by other electric devices, consumer products, and differences in size and type of the room. Therefore, how optimally APs are located is important. This is called AP optimal location problem. For example, if some PCs and APs are located within a room, the number of PC, which can connect to an AP, needs to be limited. Moreover, these PCs must be located within the connection region of AP, and wherever a PC is situated, it must be connected to the AP all the time. Under these subjects, it is necessary to ensure that PCs are located within important connection region in order to minimize the number of AP by locating them at the optimal region. To solve this problem, it is possible to utilize the mathematical programming. However, we only find the information of whether PC can be connected or not. Moreover, the connection region of AP is uncertain, and the knowledge of security experts cannot be utilized. To overcome these situations, we propose the AP's optimal location method applying the knowledge of security experts.

Quinlan [3] has proposed ID3 algorithm, which acquires the production rules from given data. When input and output data are given to ID3, an attribute is selected where average mutual information is maximized, data sets are divided by the attribute, and finally if-then rule of tree structure is organized. Fuzzy ID3 [4–8] is a powerful method to acuire the structures of fuzzy decision trees from given data using formulates average mutual information and membership functions. On the other hand, Hayashi et al. [9] has formulated fuzzy AND operator by t-norm operator [10] with parameters, and proposed learning-type fuzzy ID3 that can determine attributes by tuning AND operator [11]. The AND operator is adjusted to the extent that the average mutual information is maximized.

In this paper, the algorithm for AP optimal location is proposed. First, each connection region of AP is estimated by using fuzzy ID3, and the overall connection regions are fixed by utilizing knowledge of security experts among the acquired fuzzy rules. Next, whether several AP connection regions occupy the room is judged, either access or unaccess. Moreover, whether there are any AP connection regions which cover the frequently-PC-situated region ($FPSR$) is judged. Finally, AP is shifted to the improved evaluation index, where AP connection region which cover the $FPSR$ is most widened and the number of AP is minimized. As a result, optimal locations of APs are determined. We formulate the algorithm for determining AP optimal locations, and show the usefulness of the AP optimal location method through introducing an example.

2. Algorithm of Fuzzy ID3 with Learning

Fuzzy ID3 is a powerful method for acquiring fuzzy rules. Let $s,\ s = 1, 2, \cdots, W$ be an index of data and $j,\ j = 1, 2, \cdots, N$ be an index of membership functions. When the data set D in which we have the data, $f_{si},\ i = 1, 2, \cdots, M$ with the class k, its grade for the class, γ_s and the membership functions are obtained, the fuzzy rules are obtained using the following steps.

[Step 1] Calculate the entropy $H(D)$ of all data D.

$$H(D) = -\sum_{k=1}^{U}\left(\frac{\sum_{s\in\psi_k}\gamma_s}{\sum_{s=1}^{W}\gamma_s}\log_2\frac{\sum_{s\in\psi_k}\gamma_s}{\sum_{s=1}^{W}\gamma_s}\right). \quad (1)$$

where ψ_k is a set of the data with the class k.

[Step 2] Select a attribute, i, temporarily and calculate the conditional entropy $H(D|i)$.

$$H(D|i) = -\sum_{j=1}^{N} g_j \sum_{k=1}^{U} G_{jk}\log_2 G_{jk} \quad (2)$$

where

$$g_j = \frac{\sum_{s=1}^{W}\mu_{F_{ij}}(f_{is})}{\sum_{j=1}^{N}\sum_{s=1}^{W}\mu_{F_{ij}}(f_{is})} \quad (3)$$

$$G_{jk} = \frac{\sum_{s\in\psi_k}\gamma_{js}^{new}}{\sum_{s=1}^{W}\gamma_{js}^{new}} \quad (4)$$

$$\gamma_{js}^{new} = \gamma_{js}^{old} \otimes \mu_{F_{ij}}(f_{is}), \quad (5)$$

and the initial value of $\gamma_{js}^{old} = 1$.

The operator $\otimes$ is the t-norm connective [10] with parameter $p > 0$ as follows:

$$x \otimes y = 1 - ((1-x)^p + (1-y)^p - (1-x)^p(1-y)^p)^{1/p}. \quad (6)$$

By changing the parameter p, t-norm connective expresses the various AND operators.

[Step 3] Calculate the average mutual information, $H(i,p) = H(D) - H(D|i,p)$.

[Step 4] Select the optimal attribute i^* and the optimal parameter p^* using a learning algorithm, e.g., the golden section method [9], the descent method and so on.

$$(i^*, p^*) = \{(i,p)|\max_{i,p} H(i)\}. \quad (7)$$

[Step 5] If the stopping condition is satisfied, then the process for adding some sub-trees under the membership function j is stopped. If all of the processes for adding sub-trees are stopped, the algorithm is terminated.

[Step 6] If the condition is not satisfied, repeat it from step 2 to step 5.

After the algorithm is terminated, the fuzzy rules in equation is obtained and class degree o_{tk} is calculated as follows:

$$o_{tk} = \frac{\sum_{s\in\psi_k}\gamma_{ts}}{\sum_{s=1}^{R}\gamma_{ts}}. \quad (8)$$

3. A Method of Wireless AP Optimal Location

The devices for Wireless LAN access point easily and continuously enable lap top computers to connect to the Internet wherever the PC is placed. In general, there are the following prerequisite conditions to connect with PC.

1) All PCs must be connected to AP.
2) All APs must be safely located excluding a PC without permitting to connect to the Internet.
3) The number of PC which can be connected to AP is limited.
4) The connection region for PC to connect with AP is limited, but the connection region becomes uncertain because of transmitted radio wave interfered by object reflection and size of the room, and security.
5) Since PC is available for various purposes, the PC is not fixed in one area, and their locations are not evenly distributed.

AP optimal location problem is to maximize the following purposes of locating AP considering above five subjects;

1) To minimize the number of AP.
2) To maximize the PC's multiple connection rates where PC is located in $FPSR$, which means the frequently-PC-situated region.

To solve above subjects and purposes, it is possible to apply mathematical programming, however, generally, the connection distance of AP cannot be fixed due to the PC's operating environment and security problems. Moreover, we only find the information of whether PC can be connected or not. Therefore in this paper, we propose the AP's optimal location method applying the knowledge of security experts.

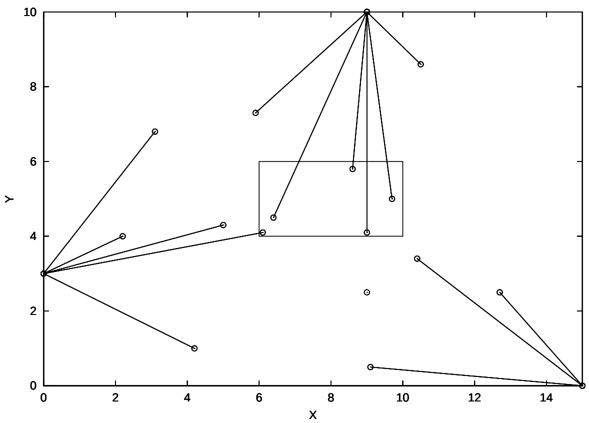

Figure 1: Location of Wireless LAN Access Point

Now, we assume that there is a room as shown Figure 1. We here treat this problem of AP location as two dimensional, not three dimensional. Our purpose is to find out the AP optimal location in this room. Let the location of AP be $ap_i = (x_i, y_i)$, $i = 1, 2, \cdots, m$, the location of PC be $pc_j = (x_j, y_j)$, $j = 1, 2, \cdots, n$, and the distance between ap_i and pc_j be $f(ap_i, pc_j)$. Also, let the connection distance of AP be a radius R, the connection region of ap_i be $F(ap_i)$, upper limit of the number of connected PC be T, and $FPSR$ be I. Moreover, let $FPSR$ be a rectangle in the middle, and the location probability of PC in $FPSR$ be $Prob_L(x, y) = 1/3$. Also, locate AP which is $m = 3$ at random on the wall, defining the connection region from each AP as $R = 6.5$. Locate PC at random, which is $n = 15$, and let the connected number of PC in each AP be $T = 10$. Each location of AP is expressed as follows;

$$ap_1 = (0.0, 3.0) \quad ap_2 = (9.0, 10.0) \quad ap_3 = (15.0, 0.0).$$

In this location, one PC cannot connect from all APs.

The Figure 2 shows the diagram of AP optimal location algorithm. First, the location of PC and $FPSR$, which is L, are determined at (a). In (b), the initial location of AP is determined, and the location of AP shifted to the next step is also determined. The distance between AP and PC is calculated at (c). In (d), whether the number of connected PC at each AP exceeds the upper limit T is judged. In (e), it

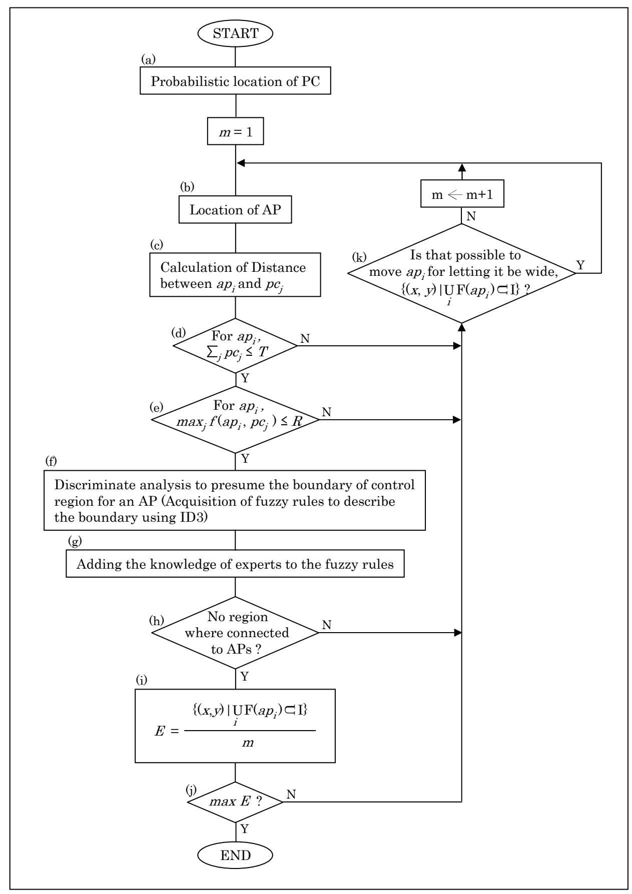

Figure 2: Flowchart for Location of Wireless LAN Access Point

is judged whether PC is located out of the connection region R for each AP. After these conditions are judged, each connection region of AP is estimated at (f) by using fuzzy ID3. In fuzzy ID3, the coordinate $pc_j = (x_j, y_j)$ for PC is an attribute variable, and when the PC is connected, the value of output class is categorized as 'access'. If the PC is not connected, the value of output class is categorized as 'unaccess'. Besides, the golden section method is applied for determining of the optimal attribute i^* and the optimal t-norm parameter p^*. Applying the fuzzy ID3 to the input/output data, fuzzy rules which describe the connection region of AP are obtained. In (g), the knowledge of security experts is used to adjust the fuzzy rules, and more optimized fuzzy rules are determined. In the next (h), the connection region of AP is estimated by using above obtained fuzzy rules. Also, whether there are any regions that cannot be connected overall is judged. If such region exists, the following multiple connection region K within $FPSR$, which is identical with I, is first calculated.

$$K = \{(x,\ y) | \cup_i F(ap_i) \subset I\}. \tag{9}$$

In the next (k), whether each AP can be shifted to the direction where region K is increased is judged. If it is possible for AP to be shifted, APs are shifted by the following equations:

$$x^{new} = S_x(x^{old}) \tag{10}$$

$$y^{new} = S_y(y^{old}) \tag{11}$$

where, $S_x(\ )$ and $S_y(\ )$ are the shifted function for removing APs to new positions. For example,

$$S_x(x) = x + \triangle x \tag{12}$$

$$S_y(y) = y + \triangle y. \tag{13}$$

If it is impossible for APs to be shifted, m, which is the number of AP is incremented. On the other hand, if no connection region exists, calculate the following density, which is the multiple connection regions per one PC, and shift the location of AP to the direction where the index E is increased.

$$E = \frac{K}{m}. \tag{14}$$

Finally the optimal location is determined.

Now, let's determine the optimal location of AP by using the algorithm for optimal location. The algorithm starts from the initial location of AP as described in the Figure 1. Let m be 3, $n = 15$, $R = 6.5$, and T be 10. The probability of PC location is 1/3 in $FPSR$, which is L. The location of PC is determined at (a), and the initial location of AP is determined at (b). The conditions for the connection region R and T, the number of connected PC, are judged in accordance with the steps from (c) to (e). Figure 1 shows that one PC is unable to access from every AP. However, since the minimum distance to AP is 6.5, and the connection region is $R = 6.5$, the connection region becomes uncertain. Therefore, we decide that this PC is out of recognition, and we should proceed to the next step. In (f), assuming $\delta = 0.8$, $\zeta = 0.1$, the fuzzy ID3 is used. Then, the first connection region of AP is estimated. The following fuzzy rules are obtained by adding the knowledge of security experts at (g).

If X are F_1 to F_3 $\text{and}_{\text{p}^*\to 0}$ Y are F_1 to F_9,
then $Access(1.0)$, $Unaccess(0.0)$.
If X is F_4 $\text{and}_{\text{p}^*\to 0}$ Y are F_1 to F_8,
then $Access(0.96)$, $Unaccess(0.04)$.
If X is F_5 $\text{and}_{\text{p}^*=0.13}$ Y is F_5,
then $Access(0.84)$, $Unaccess(0.16)$.
If X is F_5 $\text{and}_{\text{p}^*=0.13}$ Y is F_6,
then $Access(0.33)$, $Unaccess(0.67)$.
If X is F_6,
then $Access(0.11)$, $Unaccess(0.89)$.
Else $Access(0.0)$, $Unaccess(1.0)$.

We got six rules and the AND operators are learned by t-norm connective. Since the parameter values p^* of the first rule and the second rule are converged to zero, the connection strength of locations, X and Y, is very strong because of t-norm definition. On the other hand, the parameter values p^* of the third and the forth rules are 0.13, and the connection region of locations, X and Y, combine weakly.

Figure 3 shows the estimated connection region. The dot meshing area shows the connection region. From the fuzzy rules, the connection regions estimated by the third and the forth rules are obviously weak for connecting with PCs. Figure 4 shows the whole connection region of three APs. We find that there are three blank non-connection regions in which PC is not connected with any APs. At (h) of Figure 2, whether there are any non-connection regions is judged, so x, y for AP is shifted to the direction where K calculated by Eq. (9) improves as $\triangle x = 0.1$, $\triangle y = 0.1$. Afterward, the algorithm is repeated. The connection region is shown in Figure 5, where three sets of APs are integrated after shifting those sets of APs for 31st times.

$$ap_1 = (0.0, 3.0) \quad ap_2 = (9.0, 10.0) \quad ap_3 = (12.0, 0.0).$$

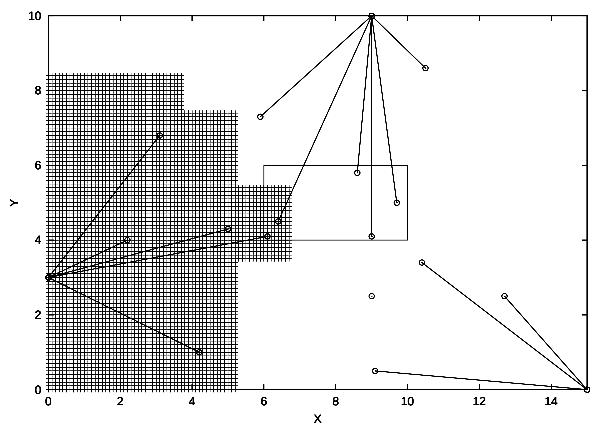

Figure 3: Area of the First Wireless LAN Access Point

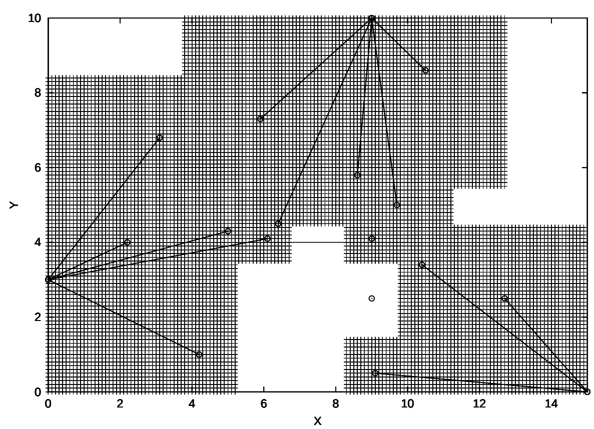

Figure 4: Area of All Wireless LAN Access Point at the First Step

Comparing Figure 4 with Figure 5, we find out that the non-accessible three regions become smaller, and PC, which is not connected in Figure 4 can now connect to AP because ap_3 is shifted. In addition to this, while the index E of Eq. (14) for Figure 4 is calculated to $E = 4.0$, the index E for Figure 5 is calculated to $E = 5.5$. Therefore, the value of $FPSR$ is improved.

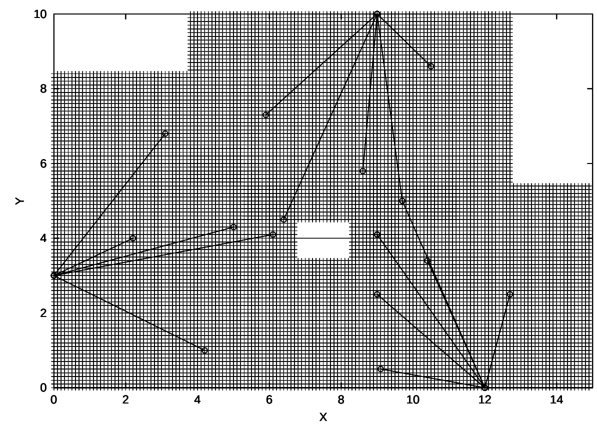

Figure 5: Area of All Wireless LAN Access Point at the 31th Step

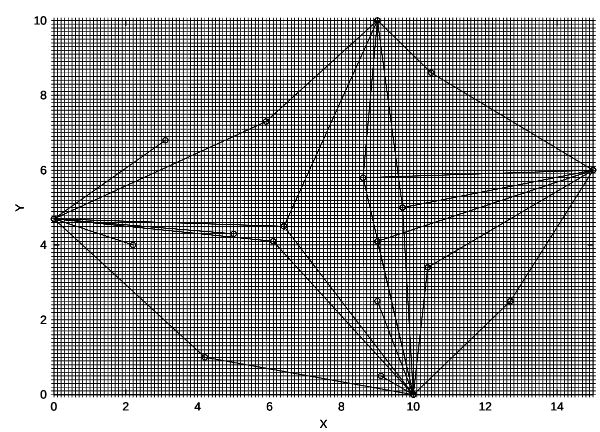

Figure 6: Area of All Wireless LAN Access Point at the Last Step

Figure 6 shows all connection regions of 87th times. At 87th times, all connection areas are accessible, and the value of $FPSR$ is obtained as $E = 7.875$, which was the maximum among the values of E. As the value of E becomes maximum, the algorithm is terminated at (j) of Figure 2. In total, four sets of APs are located by adding one more new AP. The following locations of AP are expressed. As a result, All PCs connect with AP, and all connection areas are accessible, satisfying the condition of $R = 6.5$ and $T = 10$. Therefore, these AP locations are optimized for PCs.

$$ap_1 = (0.0, 4.7) \quad ap_2 = (9.0, 10.0)$$
$$ap_3 = (10.0, 0.0) \quad ap_4 = (15.0, 6.0).$$

4. Conclusions

We proposed the method of locating optimal Wireless LAN access points using fuzzy ID3. This method enables us to estimate the connection region for PCs and the location for APs by adding the knowledge of security experts to the if-then rule.

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