Microarea Selection Method Based on Service Diffusion Process for Broadband Services

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***Abstract*— Wired/wireless information communication networks have been expanded in order to meet the demand for broadband services as an information and communication technology (ICT) infrastructure. Since the installation of such ICT infrastructures requires a large amount of time and money for expansion, the decision how to select the installation area is a key issue. Low-usage facilities can cause problems for business in terms of investment efficiency. Moreover, it takes time to select areas because of the need to consider how to estimate the potential demand, and how to manage the installation of infrastructures for thousands of municipal areas across the nation. In this paper, we propose an efficient microarea selection method for use during the life cycle of broadband services. The method is constructed with consideration of consumer segmentation, and each type of consumer behaviour as the broadband service propagation model.**

Keywords-data mining; area marketing; demand forecast; decision support system; algorithm.

I. INTRODUCTION

Fibre-to-the-home (FTTH) is an ultra-high-speed, wired, broadband access infrastructure, provided in Japan since 2002. Such an ICT infrastructure provides a variety of technologies and circumstances for corporate activity. Although the FTTH coverage rate for 2014 with respect to the total number of households nationwide was about 98% [1], the customer rate using FTTH in the coverage areas was still only 43%. As for wireless broadband access, long-term evolution (LTE) for high-speed wireless access has been provided since December 2010. The LTE coverage rate for the population was more than 90%, and the customer rate was about 42% in 2014 [2]. The other high-speed wireless access, worldwide interoperability for microwave access (WiMAX), which has been provided since 2009, had a coverage rate of greater than 90%, and the total number of customers was about 7 million in 2014.

Since the infrastructure installation is very expensive, business management is strongly affected when the facility usage is low. Therefore, strategic and economical installation is necessary for ICT infrastructures, such as broadband and wireless access facilities. Such installations strongly depend on how we estimate the potential demand in different areas; therefore, an efficient estimation method is urgently required.

The goal of providing an area with ICT services is to determine the investment order of areas, as ICT infrastructure installation per area is both more effective and less expensive than on-demand installation. If we can come up with an efficient method, it will have a lasting impact on enterprise business.

In this paper, we propose a microarea selection method that is simple to use compared with trade analysis [3]. Our target is ICT infrastructure installation during the life cycle which covers both early and late stages of broadband services. The proposed method is based on consumer segmentation, on each type of consumer behaviour as in the broadband service propagation model, and is verified with the service penetration of WiMAX services. Section II introduces related works. The trend of demand of WiMAX in Japan is described in Section III. Section IV is devoted to the hypothesis of the service diffusion and its model. Section V describes an efficient method for the selection of microareas. Simulation results and discussions are presented in Section VI. Section VII concludes this paper.

II. RELATED WORKS

Determining the target area for marketing, such as which area to focus on in terms of sales activities, and which area to install the facility in, is based on trade analysis. In fact, the setting up of a convenience store is decided by demographic data and field surveys. The geographic information system (GIS) [4] is an effective tool for area-related decision making. An empirical study using GIS for trade analysis has been previously [5] reported. These approaches are effective for deciding whether a store should be set up in a given area.

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For the application of these methods to ICT infrastructure installation, it is necessary to spend a large amount of time selecting areas, because the installation has little effect from the viewpoint of network externality [6] if it is carried out in one area rather than in several areas simultaneously nationwide.

In order to select the areas, we need to first consider the potential demand. Previous research [7]-[9] has focused on a macrodemand forecast to provide facility installation principles, not to specify installation areas. There has been one study on microarea forecasting [10]. It describes only the guidelines for microarea forecasting by using multiple regression analysis.

In order to proceed with microarea marketing, we focused on the diffusion mechanism of the ICT infrastructure. It seems to be diffused in accordance with service reputation in areas where ICT infrastructure has been provided as a trial. Therefore, who pushes forward service diffusion is an important question. An innovative early adopter in the technology lifecycle is characterized as an information source affecting acquaintances from the viewpoint of innovative diffusion [11]. The innovative early adopter is generally reckoned as a person who gets stimulated with many contacts through his/her mobility. It is difficult to identify each person in an area from the viewpoint of the technology life cycle (e.g., who is an early adopter).

Concerning the diffusion of the broadband infrastructure facilities at the moment, the framework of microarea marketing is based on commuting flows in terms of considering human behaviour [12]. Such a flow-based microarea selection method has been developed and compared to the population-based method, which is a simple application of the population order [13]. However, the application of this method is limited to only the early stage of area penetration. Therefore, it is necessary to construct a microarea selection method that is applicable throughout the life cycle (from early to late stage) of broadband services.

III. TREND OF DEMANDS FOR WIMAX IN JAPAN

WiMAX is a wireless broadband access service that has been in place in Japan since 2009. The total demand is increasing, with about 20 billion customers existing in 2015 as shown in Fig. 1. The demand increases at a consistent rate until 2014, and then increases sharply from 2014 to 2015. This is because service by mobile virtual network operator (MVNO) was introduced in mid 2013. MVNO is defined as a network service operator that does not have a network facility itself, but rather borrows the facility from a real network operator. Therefore, newcomers to MVNO have features for value-added services, such as character brand gadgets, rich content of video, and so on. Customers have many options of network operators through SIM-free terminals. MVNO*1 represents the demand excluding real mobile network operators, while MVNO*2 represents the demand including the results of real mobile network operators as MVNO. These results show that the effect by MVNO*1 is small for the total demand, while the total demand is almost the same with MVNO*2. Considering these results, customers who have already been WiMAX users do not change their service to MVNO, this is because the total demand is almost the same as those of MVNO*2. Therefore, new customers tend to choose their MVNO in terms of pricing compared to 2013.

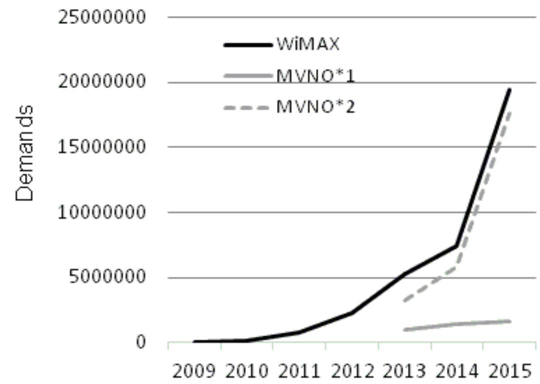

Figure 1. Demand for WiMAX in Japan.

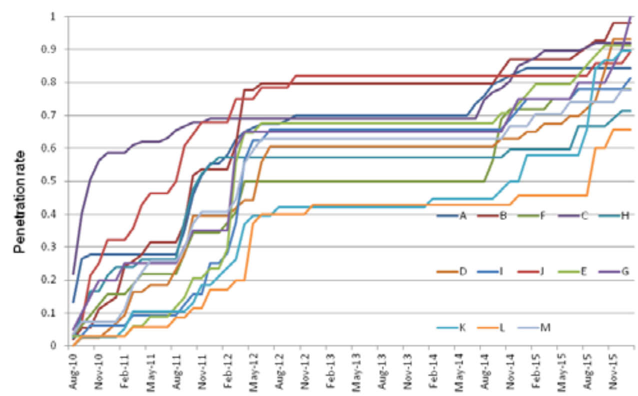

Figure 2. Trend of number of microareas for WiMAX.

Fig. 2 shows the trend of penetration microareas for WiMAX since August 2010. The microarea is defined as the municipal area in this study. The vertical axis is the penetration rate of WiMAX services, meaning the ratio of the number of microareas for a WiMAX facility installed against the total number of microareas in the prefecture. Thirteen prefectures were taken and defined as A to M. The graph shows that many microareas were selected, and that the facilities were installed from 2010 to 2012. This time interval corresponds to the early stage of WiMAX diffusion. The demand grew inside the areas from 2012 to 2014 this is because the number of installed microareas did not change. Since late 2014, the number of installed microareas has increased. This situation corresponds to the appearance of MVNO, and this means that the customers who are interested in the price of services are major factors.

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IV. Hypothesis of Service Diffusion and its Model

We made a hypothesis of service diffusion in early stage on the basis of personal behaviour [13]. Since face-to-face communication with friends/acquaintances is the key of broadband service diffusion, it is absolutely necessary to introduce the concept of innovation diffusion [11]. There are five types of consumers, namely the innovator, early adopter, early majority, late majority, and the laggard. In particular, an early adopter who is trend-conscious, and collects information and makes decisions by himself/herself plays an important role. It is widely known that an early adopter has a considerable influence on general consumers as an opinion leader. This implies that he/she sends interesting information to his/her acquaintances. If an individual (especially early majority) has many contacts with early adopters, the possibility that he/she will demand the service is high [14], as shown in Fig. 3 (a). Since face-to-face communication is effective in the diffusion of broadband services, the mobility of an early adopter will probably induce broadband service diffusion through contacts with many individuals. Therefore, we assumed a commuting flow that includes early adopters in the service diffusion process, as shown in Fig. 3 (b).

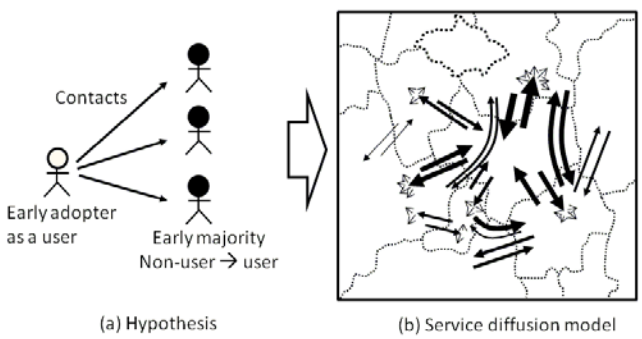

Figure 3. Mechanism of service diffusion in early stage.

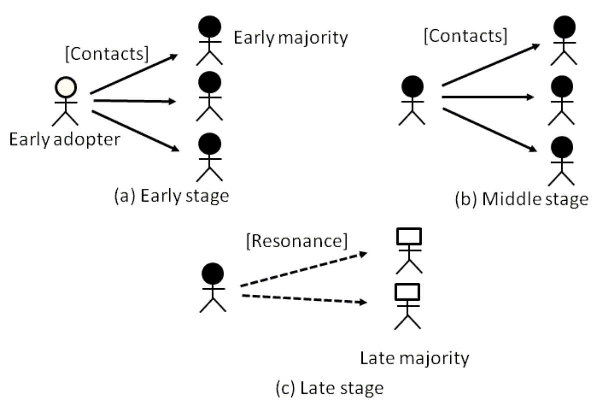

Figure 4. Relationship between service diffusion and customer segmentation.

Next, we explain the mechanism from early to late stage according to the trend as shown in Fig. 2. The early stage of service diffusion corresponds to the time interval between 2010 and 2012. The penetration rate grew with a steep slope, for which the mechanism has already been explained in the previous study. The middle stage of service diffusion corresponds to the time interval between 2012 and 2014. In that stage, there were no increases of the number of installed microareas. This means that the early majority affected by early adopters made contact with others of the early majority in the same microarea, as shown in Fig. 4 (b). As a result, the demand increased inside a microarea of the middle stage. The penetration rate increased in all areas during the late stage of service diffusion after 2014. The new type of services provided by MVNO started in that stage, where there is potential demand from the late majority. The late majority tends to be skeptical of the service, price-oriented and follow the early majority after the service has sufficiently penetrated the field. Therefore, the late majority is not affected by contact with the early majority, but rather by resonance [15] with early majority, as shown in Fig. 4(c).

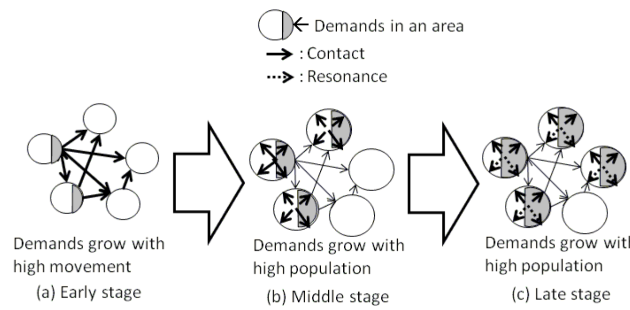

Figure 5. Mechanism of potential demand diffusion.

The next step was to obtain the mechanism of potential demand diffusion as shown in Fig. 5. Our hypothesis at the early stage for service diffusion is that the demand grows with high movement among microareas (Fig.5 (a)). Therefore, the microarea is selected by in- and outflows of commuters in a microarea. Since the possibility of growing potential demand exists inside a microarea during the middle and late stages, the effect of population in microareas becomes great when compared with that of movement among microareas (Fig. 5(b)).

V. Microarea Selection Algorithms

The population-based algorithm is defined as the method that selects areas by the application of the population order; therefore, areas with a large population tend to be selected. The flow-based algorithm is defined as a method that selects areas on the basis of the inflows and outflows among areas. To analyse inflows and outflows among areas, we introduced the representation of a graph model with an area as a node, and the commuting flow among areas as a link. In particular, a link has an arrow to consider the direction of commuting flows; therefore, areas with a large inflow/outflow tend to be selected. According to the mechanism described in the previous section, the mixed algorithm is constructed so that the flow-based algorithm is used in the low penetration rate while the population-based algorithm is used in the high penetration rate.

Let $G = (N, L)$ be a graph, where N denotes a finite set of nodes ($i \in N$) and L represents a set of links ($l_{ij} \in L$).

For any l_{ij}, there exists a function f: $L \rightarrow N_0$ (non-negative integer) such that $f(l_{ij}) = z_{ij}$ for $l_{ij} \in L$. For any n_i, there exists a function g: $N \rightarrow M_0$ (non-negative integer) such that $g(n_i) = u_i$ for $n_i \in N$.

The procedure for the mixed algorithm is as follows;

- Step 1: Let $c = 1$ be a counter with an initial value '1', and $n(k)$ be a k-th element of the array where $k = 1, 2, \cdots$. Let "p" as the number of selected areas by WiMAX evolution under the penetration rate (40%), Set $N_t \leftarrow N$.
  Sort links according to flow values $f(l_{ij})$ in N_0 in the descending order: assign threshold values α and β.
  Sort nodes according to population values $g(n_i)$ in M_0 in the descending order.
- Step 2: If $p \geq c$, then the following steps are performed (flow-based algorithm):
  - Step 2-1: Define a set K ($\subset L$) = arg max $f(l_{ij})$, and denote $f(l^*_{ij}) = z_d \in N_0$ for $l^*_{ij} \in K$.
  - Step 2-2: If there is a node 'm' $\in N_t$ whose *in-degree* exceeds α, then select node 'm', and set $n(c) \leftarrow m$, $c \leftarrow c+1$, and replace N_t with $N_t \backslash \{n(c)\}$ and replace L with $L \backslash K$.
  - Step 2-3: If there is a node 'm' $\in N_t$ whose *out-degree* exceeds β, then select node 'm', and set $n(c) \leftarrow m$, $c \leftarrow c+1$, and replace N_t with $N_t \backslash \{n(c)\}$ and replace L with $L \backslash K$.
- Step 3: If $|N| \geq c$, then the following steps are performed (population-based algorithm):
  - Step 3-1: If there is a node 'm' $\in N_t$ whose $g(n) = \max g(n_i)$, then select node 'm', and set $n(c) \leftarrow m$, $c \leftarrow c+1$, and replace N_t with $N_t \backslash \{n(c)\}$.

VI. SIMULATION RESULTS

A. Classification of prefectures

The 33 prefectures are considered as representative of prefectures in terms of size. Since employee fluidity (as commuting flows) depends on the area selected especially in the early stage [13], the attributes of prefectures are considered to be 'number of employees in own microarea', 'inflow of employees among microareas', and 'outflow of employees among microareas'. We classified the prefectures into the following five categories in terms of employee fluidity according to the correspondence analysis shown in Fig. 6. The vertical axis represents the occurrence ratio of the in- or outflow among the microareas in the prefecture. The horizontal axis represents the staying ratio of employees in their own microareas.

- Group 1: areas with large inflow; Aichi (A)
- Group 2: areas with large in- and outflows; Ibaraki (B) and Shiga (F)
- Group 3: areas with large outflow; Saitama (C) and Nara (H)
- Group 4: areas with little in- and outflows; Niigata (D), Okayama (I) and Hiroshima (J)
- Group 5: balanced areas of average in- and out-flow; Kagawa (E), Ishikawa (G), Yamagata (K), Tokushima (L) and Fukui (M)

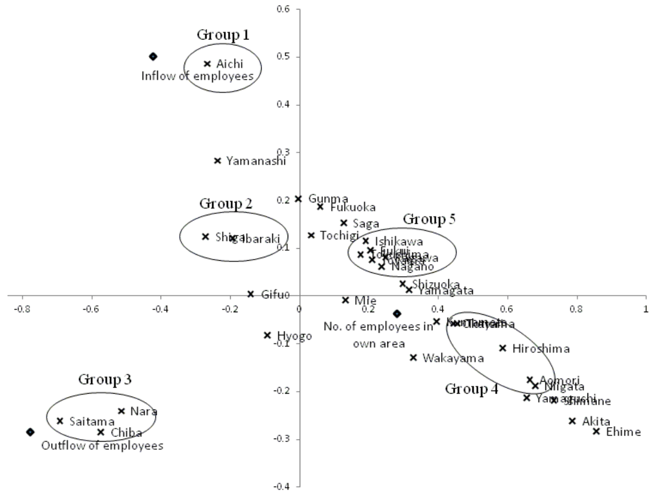

Figure 6. Correspondence analysis of employee fluidity.

B. Comparison with algorithms

In this section, we compare and evaluate the population-based, flow-based and mixed algorithms. To determine the difference in results depending on region, thirteen prefectures were considered among five groups (A to M).

TABLE I. COMPARATIVE RESULTS

Prefecture (Area no.)	Group	Population -based algorithm	Flow-based algorithm	Mixed algorithm
A (83)	1	<u>0.94</u>	0.92	<u>0.94</u>
B (54)	2	<u>0.79</u>	<u>0.79</u>	<u>0.79</u>
F (32)	2	<u>0.80</u>	<u>0.80</u>	<u>0.80</u>
C (87)	3	<u>0.93</u>	0.91	<u>0.93</u>
H (42)	3	<u>0.97</u>	0.93	<u>0.97</u>
D (43)	4	<u>0.82</u>	<u>0.82</u>	<u>0.82</u>
I (32)	4	<u>0.92</u>	0.88	<u>0.92</u>
J (28)	4	<u>0.91</u>	0.86	<u>0.91</u>
E (34)	5	0.81	<u>0.89</u>	0.81
G (20)	5	<u>0.81</u>	<u>0.81</u>	<u>0.81</u>
K (38)	5	0.81	<u>0.87</u>	0.81
L (35)	5	0.87	<u>0.91</u>	0.87
M (27)	5	0.86	<u>0.90</u>	0.86

Table 1 shows the concordance ratio comparison among the three algorithms. The penetration rate is calculated as the ratio of the number of areas, where WiMAX has been introduced by the provider (WiMAX evolution), to the number for all areas in the given prefecture. The Table 1 results are when the penetration rate was 80% in each prefecture. $\alpha = \beta = 1$ are taken in the flow-base algorithm because of the optimization analysis in the early stage [13]. The concordance ratio (CR) of the number of selected areas between WiMAX evolution and each algorithm is defined by the following equation.

CR = (Number of selected areas matching WiMAX evolution areas /Number of WiMAX evolution areas). (1)

The underlined values indicate the highest CR at each prefecture. Although the CR by flow-based algorithm is sometimes the highest, the CR by population-based algorithm is always the highest for Groups 1 to 4. Employee fluidity well explains the behaviour in the early stage as applying the flow-based algorithm, while the resonant effect well explains the demand increase by population in the late stage as applying the population-based algorithm. Therefore, the mixed algorithm is for use in accordance with the penetration rate for Groups 1, 2, 3 and 4 during the life cycle of the services. However, the CR by flow-based algorithm is always superior to that by population-based algorithm for Group 5. It is better to use the flow-based algorithm for the whole penetration rate.

C. Consideration for microarea characteristics

In this subsection, we consider the differences between Group 5 and the other groups in order to apply the proposed algorithm. The differences of population between areas are focused and analysed. Figs. 7 and 8 show the relationship between population in a microarea, and ranking of microareas for four prefectures (B, C, J and K). The target microareas exclude the microareas which were selected by WiMAX evolution when the penetration rate was lower than 40% in each prefecture.

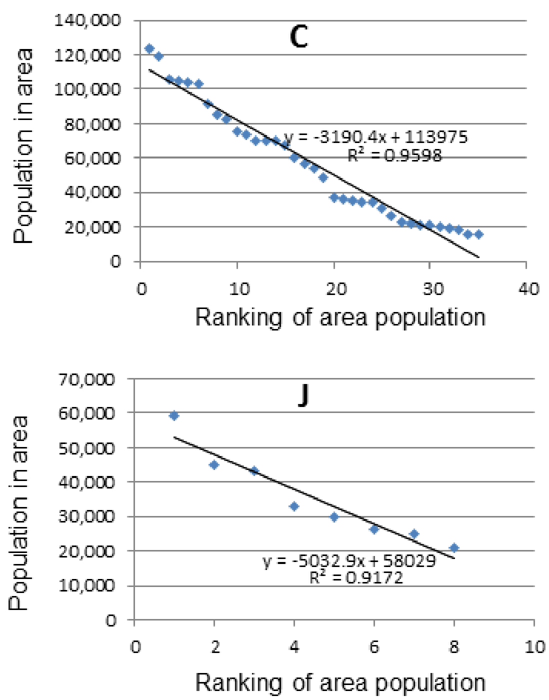

Figure 7. Relationship between population in area and its ranking (C and J).

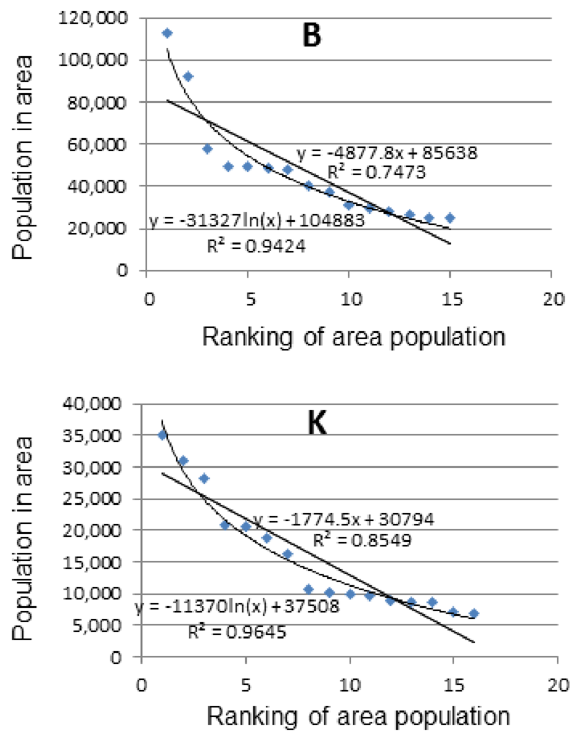

Figure 8. Relationship between population in area and its ranking (B and K).

The results showed that the approximation by regression line fits into the scatter diagram in C (Group 3) and J (Group 4) in Fig. 7, while it does not fit in B (Group 2) and K (Group 5) in Fig. 8. Instead, the diagram fits into logarithmic regression curves in B and K. It is understandable that the population difference is small for low-ranking microareas in B and K, and the effect of fluidity is greater than that of population-based algorithm. The results are significant for Group 5, while the same results (CRs between three algorithms) are obtained for Group 2.

VII. CONCLUSIONS

It is tremendously important to select an area in which an ICT infrastructure is introduced in order to ensure quick and economic development of an advanced information society. Area selection strongly depends on the potential demand, and one of the main features of the ICT infrastructure is network externality; therefore, a huge amount of time and labour is required to select specified areas from among a large number of candidate areas.

In this paper, we proposed an efficient area selection method based on a service diffusion model. We evaluated the method using real field data from 13 prefectures, and we obtained the application of flow-based and population-based algorithms during the life cycle of the services.

Our future work will analyse the more detailed features of area category, in addition to evaluate the proposed method for the rest of prefectures. Furthermore, we intend to apply the method to other information network infrastructures, such as FTTH, LTE, and energy management services.

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