

Energy Efficiency Network Selection Method

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Abstract— We propose an energy efficiency network selection method in coexistence with various wireless networks, such as 3G, WiFi and WiMAX. The network selection method considers the parameters of throughput (T), cost (C) and power consumption (P). First, a fuzzy measure for each parameter is determined. And the network is estimated for the evaluation value of each parameter using the fuzzy integrals. Finally, the most appropriate network can be selected, by comparing the assessment results of various wireless networks. Mobile terminal usage time can be extended, by considering the power consumption of the terminal for the selection of a network. And the proposed method can select the optimal network by considering throughput of each network.

Keywords— energy efficiency, wireless, network selection

I. INTRODUCTION

The demand for next generation wireless systems, which support seamless communication, is increasingly accelerated along with the sharp development of mobile terminal and wireless technologies [1]. The wireless network systems consist of integration of various wireless networks to provide high performance. A terminal is also designed to access the various wireless networks. Thus, it has enough access capabilities for the heterogeneous wireless networks.

The mobile terminal selects a single network based on a simple predefined strategy. This strategy usually chooses the WiFi network that provides the largest signal strength. However, the WiFi network with the largest signal strength does not guarantee the best service because it might be congested with many users [2]. Thus, it is necessary that the network selection method consider effective throughput of the network.

The demand for mobile terminal, which supports internet data service, is rapidly increasing. Accordingly, mobile application market is growing with an increase of mobile user [3]. The usage time of mobile terminal is sharply increased due to growing demand for various mobile applications. Therefore, interest in the method of extending usage time has been increased.

In this paper, to solve the above-mentioned problem of network selection strategy, we propose an energy efficiency network selection method based on Fuzzy Integrals which considers cost, throughput and power consumption in the mobile terminal. The method can extend the usage time of

mobile terminal and also select optimal network in heterogeneous wireless network (Figure 1).

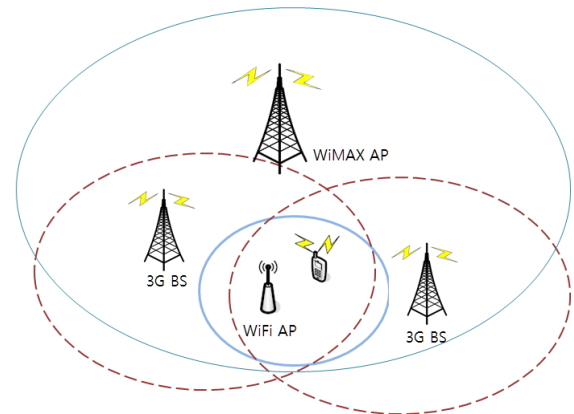


Figure 1. Coexistence with various wireless networks

This paper is structured as follows. Section 2 describes the existing works on the network selection method in coexistence with various wireless networks. In section 3, we present an energy efficiency network selection method. Next, section 4 shows the numerical analysis for the fuzzy value for each network. Finally, we conclude in section 5.

II. RELATED WORKS

To solve the network selection problem, lots of methods have been studied. A type of network selection and handover mechanism with the goal of maximizing QoS is formulated as a Markov Decision Process (MDP). An algorithm based on Reinforcement Learning (RL) is then obtained that selects the best network based on the current network load and the potential future network states. The goals are balancing the number of handovers and the achievable QoS. It is found that the user QoS obtained through the proposed MDP algorithm is comparable to the QoS obtained through the optimum QoS-achieving opportunistic selection algorithm. It is also found that the number of handovers obtained through the MDP algorithm can be fairly reduced, while keeping high QoS [2].

Another deals with a network selection algorithm based on Fuzzy Multiple Attribute Decision Making. The algorithm considers the factors of Received Signal Strength(RSS), Monetary cost(C), Band Width (BW), Velocity (V) and user

preference (P). It obtains the Network selection function (NSF) that measures the efficiency in utilizing radio resources by handing off to a particular network [4].

Another describes a generic decision making process to rank candidate networks for service delivery to the terminal. The proposed mechanism is based on a unique decision process that uses compensatory and non-compensatory multi-attribute decision making algorithms jointly to help the terminal in selecting the top candidate network [5].

Another addresses selection problem of the most valid radio access network when receiving a service request by offering an adaptive and efficient algorithm. It also proposes a Radio Access Network (RAN) selection scheme which can enable seamless communications and adaptive quality of service. The Radio Access Optimisation (RAO) algorithm streamlines the selection process and considers the increased resource utilization and the user contentment [6].

The other proposes network selection module to select network dynamically according to the application type. It uses the network performance parameters to execute the network selection algorithm and application blocking probability of each network to identify the user satisfaction [7]. However, power consumption in the mobile terminal has not been considered in these papers.

III.NETWORK SELECTION METHOD

We proposed an energy efficiency network selection method using fuzzy integrals.

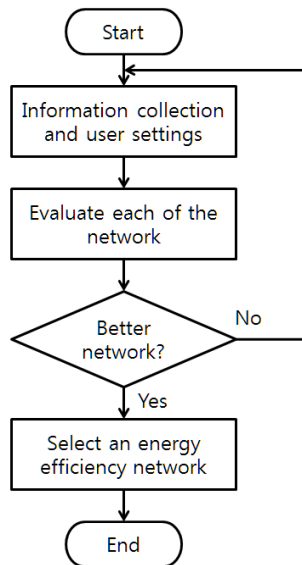


Figure 2. Energy efficiency network selection algorithm

Figure 2 shows energy efficiency network selection algorithm. First, a fuzzy measure for each parameter is determined and information for each parameter is collected. And the network is estimated for the evaluation value using the fuzzy integrals. Finally, by comparing the assessment results of various wireless networks, the energy efficiency

network can be selected. So, usage time of smartphone can be extended.

Let X be a finite index set $X = \{T, C, P\}$. The X consist of throughput (T), cost (C), power consumption (P). A fuzzy measure g defined on X is a set function $g: P(X) \rightarrow [0,1]$, where $P(X)$ is the power set of X , satisfying the following:

$$(i) \ g(\emptyset) = 0, g(T, C, P) = 1$$

$$(ii) \ T \subseteq C \Rightarrow g(T) \leq g(C)$$

A fuzzy measure is a monotone and normalized set function. It needs 2^3 coefficients to be defined, which are the weights of μ for all the different subsets of X .

A. Evaluation criteria and items

The X , which are considered for selecting optimal network, are defined as follows:

Throughput (T) : The average rate of successful data delivery over the network. The normalization function of throughput is given by equation (1).

$$h(T_x) = \begin{cases} 0, T_x > T_{\max} \\ \frac{T_x}{T_{\max}}, 0 \leq T_x \leq T_{\max} \end{cases} \quad (1)$$

T_x is the throughput of the network and $T_{\max}$ is the maximum throughput that can be provided by the network. The normalization function of throughput is plotted in Figure 3.

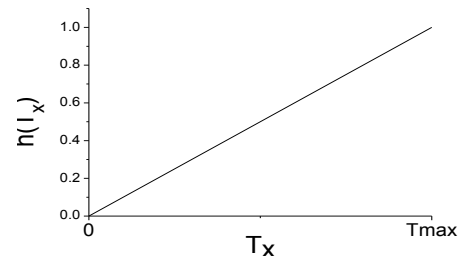


Figure 3. Normalization function of throughput

Cost (C) : The operating expense of the network. The normalization function of cost is given by equation (2).

$$h(C_x) = \begin{cases} 0, C_x > C_{th} \\ 1 - \frac{C_x}{C_{th}}, 0 \leq C_x \leq C_{th} \end{cases} \quad (2)$$

C_x is the operating expense of the network. C_{th} is the threshold cost which user can make a payment. The normalization function of cost is plotted in Figure 4.

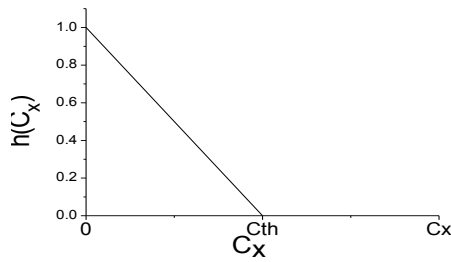


Figure 4. Normalization function of cost

Power consumption (P) : The power consumption in the smartphone by using the network. The normalization function of power consumption is given by equation (3).

$$h(P_x) = \begin{cases} 0, & P_x > P_{th} \\ 1 - \frac{P_x}{P_{th}}, & 0 \leq P_x \leq P_{th} \end{cases} \quad (3)$$

Where P_x is the power consumption of the network. P_{th} is the maximum power which smartphone consume for using the network. The normalization function of power consumption is plotted in Figure 5.

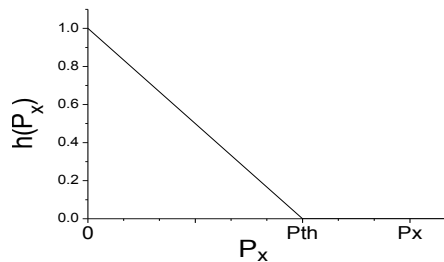


Figure 5. Normalization function of power consumption

The higher evaluation value of throughput, cost and power consumption represents the best network. The evaluation value of throughput is proportional to practical value, the value of cost and power consumption is inversely proportional to actual value. These normalization function values of each parameter are used to obtain the Fuzzy Value.

B. Evaluation method

Fuzzy Integrals used in this paper was defined by Sugeno, as follows:

Let g be a fuzzy measure on X and $h: X \rightarrow [0,1]$ a function. The Sugeno integrals of h with respect to g is

$$\int h \circ g = S_g(h) = \sup_{0 \leq \alpha \leq 1} (\alpha \wedge g(H_\alpha)),$$

where $H_\alpha = \{x \in X \mid h(x) \geq \alpha\}$. H_α is a power set of X which is larger than α . The minimum and maximum operators are denoted by the symbols $\wedge$ and $\vee$, respectively. The sup can be replaced with max.

The algorithm of Fuzzy Integrals by Sugeno can be defined as follows:

Step 1. Determine a fuzzy measure $g(X)$ for all the different subsets of X and an evaluation value for each of the parameter.

Step 2. $h(X_i) \in [0,1]$, $X_i \in X (i = T, C, P)$

$h(X_1) \leq h(X_2) \leq \dots \leq h(X_n)$, $h(X_i)$ is sorted in order from small of X . Then h can be expressed as $H_i = \{X_k \mid k = T, C, P\}$.

Step 3. Create a result set of $h(X_i) \wedge g(H_i)$

Step 4. A Fuzzy Value is maximum value of the result set.

The above-mentioned step1~4 can describe in detail for the first and second procedures of energy efficiency network selection algorithm shown in Figure 2. As user selects the threshold cost and a fuzzy measure, user preference can be considered. And by using Fuzzy Integrals, we can estimate which is the best network.

IV. NUMERICAL ANALYSIS

In this paper, the wireless network technologies, such as WiFi, WiMAX and 3G, are considered. A fuzzy measure considered energy efficiency of the network is assigned as shown Table 1. By considering energy efficiency of the network, we will simply show examples.

TABLE 1. FUZZY MEASURE VALUE FOR EACH NETWORK

Fuzzy Measure	Value	Fuzzy Measure	Value
$g(\{\emptyset\})$	0	$g(\{T\})$	0.3
$g(\{C\})$	0.1	$g(\{P\})$	0.4
$g(\{T, C\})$	0.7	$g(\{C, P\})$	0.8
$g(\{T, P\})$	0.9	$g(\{T, C, P\})$	1

TABLE 2. EVALUATION VALUE FOR EACH NETWORK

Network	Throughput	Cost	Power Consumption	Fuzzy Value
WLAN	0.1~0.4	0.7	0.4	0.4
	0.5			0.5
	0.6			0.6
	0.7~1.0			0.7
WiMAX	0.1~0.35	0.6	0.35	0.35
	0.4			0.4
	0.5			0.5
	0.6~1.0			0.6
3G	0.1~0.3	0.5	0.3	0.3
	0.4			0.4
	0.5~1.0			0.5

Table 2 shows the Fuzzy Value, which is calculated by Fuzzy Integrals. The evaluation value of cost and power consumption is set to a fixed value, and inversely proportional to practical value. The Fuzzy Value is indicated each of the energy efficiency of the network. The Fuzzy Value for each

network is evaluated by Fuzzy Integrals and compared to select the optimal network which considers the three parameters.

Figure 6 shows the Fuzzy Value graph according to throughput. In case of Throughput evaluation value is more than 0.6 and less than 0.4, the mobile terminal selects WiFi network that evaluation value of cost and power consumption is highest. The best network is selected according to throughput evaluation value of the network, because the Fuzzy Value increases in proportion to Throughput evaluation value in the range of 0.4 to 0.6. If the Fuzzy Value is equal, the best network is selected according to one of the parameters, such as throughput, cost and power consumption.

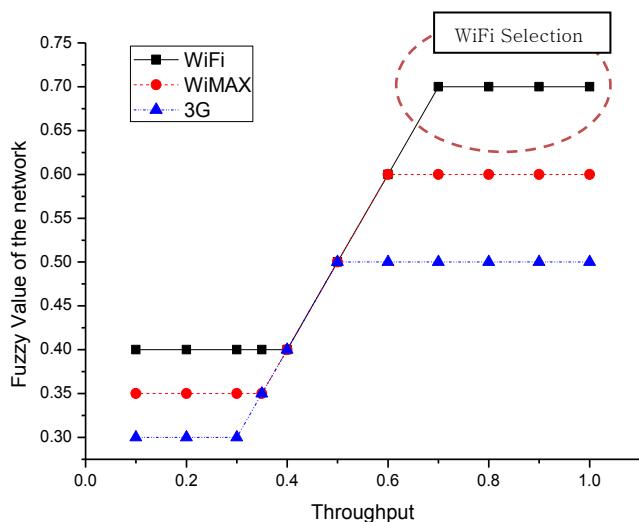


Figure 6. Fuzzy Value according to throughput

WiFi is selected according to the Fuzzy Value considered power consumption, cost and throughput. In this case, even if other network throughput is higher than WiFi, smartphone selects WiFi network. By the selection of the energy efficiency network, the battery life time in the Smartphone can be extended.

V. CONCLUSIONS

This paper proposes the mobile terminal usage time can be extended due to the selection of the optimal network according to throughput, cost and power consumption. As we performed directly Fuzzy Integrals, the Fuzzy Value could be obtained. So, we were able to confirm that any network was selected. In the future, it will be necessary that research of a reasonable valuation method is studied in respect of evaluation item of each network.

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