Novel Communication System Selection Applying the AHP Algorithm in Heterogeneous Wireless Networks

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Abstract. In this paper, we propose a novel selection policy for a communication system in heterogeneous wireless networks, which applies the analytic hierarchy process (AHP) algorithm by taking into account the mobility of the user terminals. In particular, the AHP algorithm has excellent characteristics of improving overall performance within the existing wireless systems. We certify the performance improvement by applying the AHP through software simulations under the conditions where Wi-Fi and WiMAX are used in the heterogeneous wireless networks.

Keywords: system selection policy, analytic hierarchy process (AHP), heterogeneous wireless networks, performance improvement.

1 Introduction

Considering the lack of frequency resources in wireless networks, it is quite important to efficiently use exiting wireless systems. One solution is to apply multiple systems and adequately select one system, which is generally called a heterogeneous wireless network. Cellular networks, such as WiMAX and cdma2000, support bandwidths over a wide geographical area. On the other hand, the Wi-Fi based on IEEE 802.11 provides bandwidths in a small coverage area of a few thousand square meters around a single access point. In heterogeneous wireless networks, a dynamic network selection mechanism must be developed to determine the appropriate radio access technology for specific situations.

This paper proposes a novel selection policy for a communication system in heterogeneous wireless networks, which applies the analytic hierarchy process (AHP) algorithm by taking into account the mobility of user terminals. In particular, the AHP algorithm offers the excellent characteristics of improving the overall performance within existing wireless systems. We certify the performance improvement by applying the AHP through software simulations under conditions where Wi-Fi and WiMAX are used for the heterogeneous wireless network.

Some related works have been reported on the selection of radio access in heterogeneous wireless networks. Multimode terminal measures the signal to interference noise ratio (SINR) of each radio access and converts them to effective SINR. Then, the

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radio access with maximum effective SINR is selected in [1]. However, the quality of the radio signal like SINR does not always present application quality. Position information can be used for radio selection in [2]. However, when a short distance radio access is included in the heterogeneous wireless network, it is difficult to determine the coverage area from the position. These are classified into single attribute decision making. Another approach is multi attribute decision making (MADM), which uses some parameters simultaneously. Various parameters such as receive signal strength Indication (RSSI), throughput, delay, pricing rules, and user preferences can be treated as input parameters for MADM in [3]. Fuzzy logic and neural networks are proposed for radio selection in [4]. One vital approach is the AHP proposed in [5] [6]. In such work, the effect of AHP is evaluated for only one terminal environment. From a realistic viewpoint, in order to accurately evaluate the selection algorithm, an area simulation with multiple terminals is mandatory. We focus on this point and introduce the area simulation results in this paper.

The rest of the paper is organized as follows: the system selection policy is introduced in Section 2. The AHP-based system selection policy and the simulation model, condition, and results are described in Section 3. Finally, Section 4 concludes this paper.

2 System Selection Policy in Heterogeneous Wireless Networks

2.1 Outline of System Selection Policy

The outline of the system selection policy is shown in Figure 1. The proposed system selection policy works by considering multiple user terminals, which move around the Wi-Fi and WiMAX areas. To select a wireless system, the user terminal's mobility and the result of AHP calculation are used. One of the branches uses AHP calculation to select the communication system. The processes surrounded by the dotted line are described in Section 2.2 and Section 3, respectively.

To realize the proposed system selection policy for actual networks, we decided that the system architecture would consist of a user terminal, sensing node, and location service server as shown in Figure 2. The proposed policy is installed on the user terminal, and this cooperates with the location service server to efficiently search the wireless network. This works on a heterogeneous wireless network where each WiMAX BS (base station) cell overlays several Wi-Fi hot-spot APs (access points).

The sensing node with a GPS module scans the quality information of the Wi-Fi and periodically uploads the information with location information to the location service server. The location service server stores the quality information of the sensing node with location information and holds the table of the Wi-Fi AP location. By using this information, the location service server estimates the position of the AP. The positioning information of the user terminal acquired by the GPS module will be uploaded to the location service server. Then, the location service server will query the database for the corresponding area and reply to the user terminal with the AP allocation information. By receiving the information, the user terminal discovers the potential reachable wireless networks. After discovering the potential reachable wireless networks, the user terminal searches for an appropriate Wi-Fi AP.

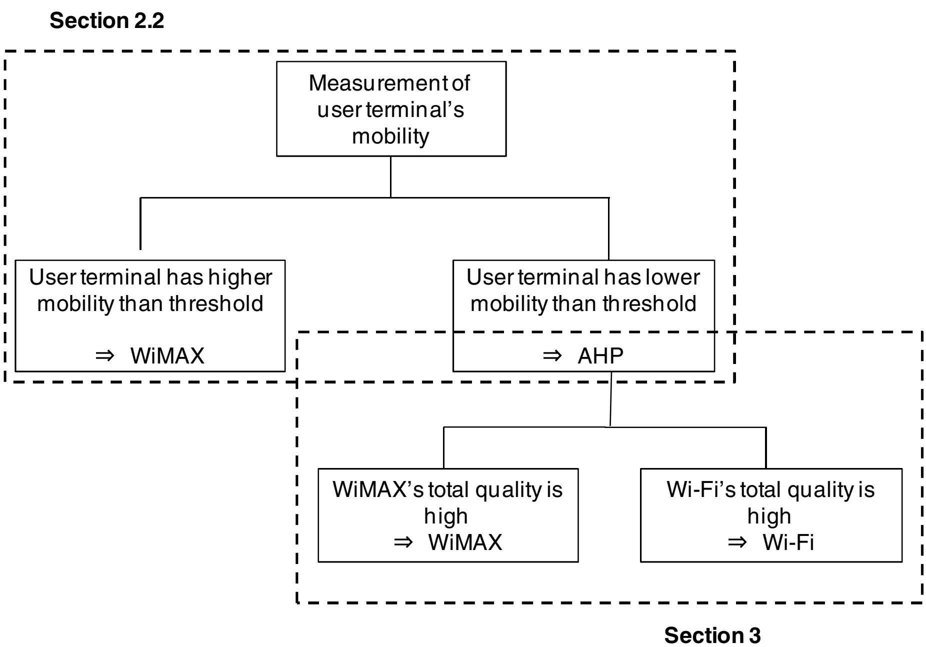

Fig. 1. Outline of the system selection policy

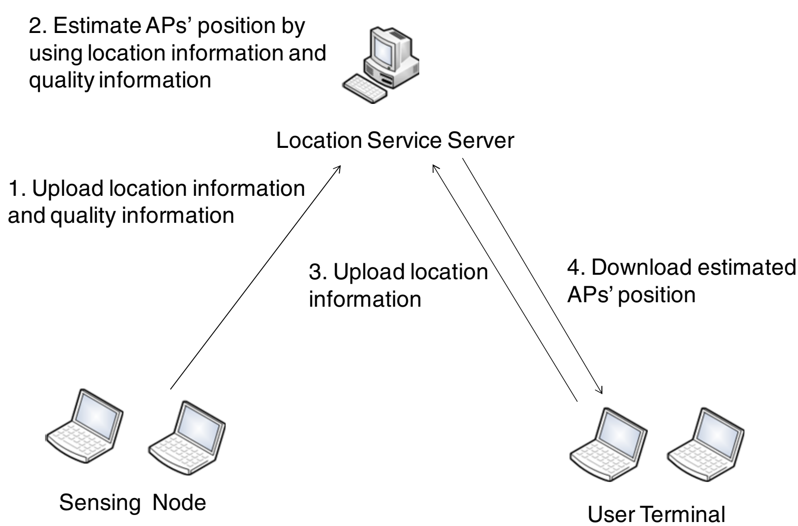

Fig. 2. An example of system architecture

2.2 Consideration of User Terminal's Mobility

In the selection policy we propose, the user terminal with a global positioning system (GPS) module measures mobility. To determine the access communication system, the user's mobility is considered. When the user terminal has higher mobility than the threshold for a certain period, WiMAX is selected because WiMAX coverage is usually broader than Wi-Fi. When the user terminal has lower mobility than the threshold during a certain period, the access communication system will be determined by the calculation of the AHP. The mobility threshold of the user terminal is considered higher than walking speed.

3 Application of AHP Algorithm

3.1 Principle of AHP and Its Feature

This section introduces the AHP-based approach to provide a more efficient system selection solution for user terminals that connect to WiMAX and Wi-Fi networks.

AHP solves complicated tasks by decomposing into a hierarchy of simpler sub-portions. The sub-portions are usually called decision factors and weighted according to relative importance. The solution is given as the bottom decision. AHP selects the solution with the greatest synthesized weight.

Structuring a task as a hierarchy of multiple criteria is the first step in implementing AHP. The task is placed at the top of the hierarchy. The decision factors of the task are identified within the hierarchy. The solution will be placed at the bottom of the hierarchy. In this paper, the task requiring a solution is to make the decision to use Wi-Fi or WiMAX. The decision factors are uplink data rate, round-trip time (RTT), RSSI, and power consumption. The hierarchy for the selection of the wireless system is established as shown in Figure 3.

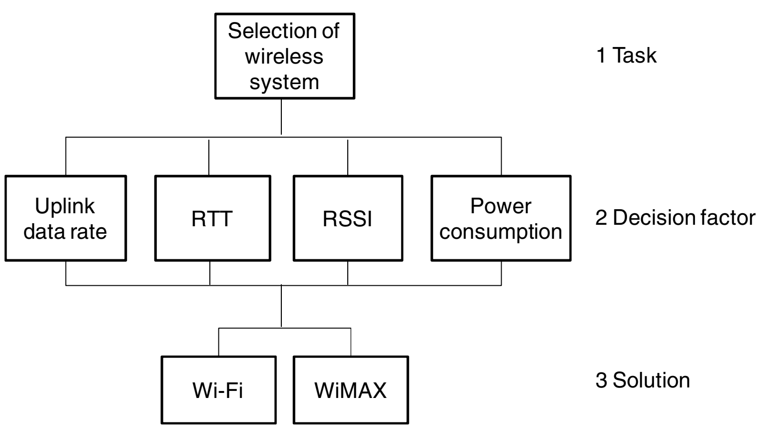

Fig. 3. An example of AHP hierarchy establishment

An example of the AHP matrices is shown in Table 1. The comparison scale uses a range of 1 to 9, each representing entries as follows: 1: Equally important, 3: Moderately more important, 5: Strongly more important, 7: Very strongly more important, 9: Extremely more important. The elements of the AHP matrices might equal 1, 3, 5, 7, 9, 1/3, 1/5, 1/7, 1/9. The elements in Table 1 represent that any delay is considered *very strongly more important* than others with regard to traffic. Each pair in the comparison matrix is solved using the geometric mean method. The weights determined using the geometric mean method and the resulting weights are shown in Table 1. The overall score of an alternative network selection is determined by the score measured in an actual network environment, and the score is computed as the weighted sum of the attribute values.

Table 1. Example of AHP matrices for each traffic class

	UL data rate	RTT	RSSI	Power consumption	Geometric Mean	Importance weights
UL data rate	1	1/9	1	1	0.5773	0.0833
RTT	9	1	9	9	5.1962	0.7500
RSSI	1	1/9	1	1	0.5773	0.0833
Power consumption	1	1/9	1	1	0.5773	0.0833

Different applications may assign different weights to a particular factor. For example, the importance of RTT is different in real time applications compared to non-real time applications, so the applications may assign different weights. The AHP calculation runs periodically to detect changes in the wireless conditions. When the user terminal discovers a wireless network with higher utility than the current network, the user terminal will change the network.

3.2 Simulation for AHP Algorithm

3.2.1 Simulation Model

In this section, we investigate the sensitivity of using quality information in the calculation of AHP for system selection. To see the superiority of selecting the system via AHP, we conducted a simulation. In the simulation, we considered an area where there were three Wi-Fi APs and a WiMAX BS, as shown in Figure 4. The WiMAX BS was placed in the center, and the Wi-Fi APs were placed at distances of 100 m from the WiMAX BS at 120 degrees. In the simulation scenario, dual mode terminals, which were transferring a file, were located at random within a distance of 400 m from the WiMAX BS. The numbers of dual mode terminals were 50, and they were all settled as static.

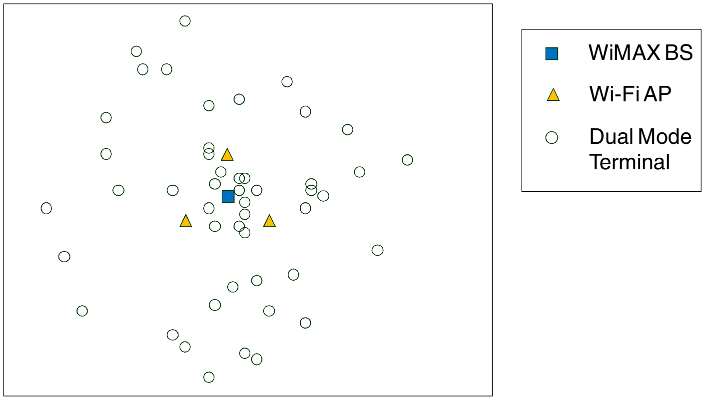

Fig. 4. Example of node's allocation in simulation

3.2.2 Simulation Condition

The condition of the simulation is shown in Table 2. The Wi-Fi and WiMAX frequencies were 2.4 GHz and 2.6 GHz, respectively. The channels of the three Wi-Fi APs were the same. To imitate the movement of the user terminals, the propagation condition for WiMAX, shadowing effect of 4 dB, and the Rayleigh fading effect of 3.6 km/h were given as the fading characteristics as shown in Table 2. The Wi-Fi radio only influenced the distance characteristics. The dual mode user terminal transferred data on average of 2 MB with a maximum of 5 MB. The simulation time was 40 seconds, and the data were taken 10 times. This was done by changing the position of the dual mode terminal.

The AHP matrices used in the simulation are shown in Table 3. The decision factors were uplink throughput and RTT. The importance weights for the uplink throughput and RTT were 0.5, respectively. The uplink throughput and RTT of the simulation were taken every 10 seconds and used for the calculation to select the wireless system.

To investigate the effect of using quality information with AHP, we compared the average application throughput. To compare throughput, four modes were tested as shown in Table 4. The conventional mode is a conventional policy used in smartphones.

Table 2. Simulation conditions

Condition	Wi-Fi	WiMAX
Frequency	2.4GHz	2.6GHz
Shadowing	Not considered	4 dB
Rayleigh	Not considered	3.6km/h

Table 3. The AHP matrices used in the simulation

	Uplink throughput	RTT	Geometric mean	Importance weights
Uplink throughput	1	1	1	0.5
RTT	1	1	1	0.5

Table 4. Four types of system selection modes

Mode	System selection policy
Conventional	Select Wi-Fi whenever it is available for use
AHP	Select wireless system by AHP calculation
Wi-Fi	Select Wi-Fi which is only available
WiMAX	Select WiMAX which is only available

This mode selects Wi-Fi as the wireless system whenever it is available for use. The AHP mode selects wireless systems using AHP. The Wi-Fi mode selects Wi-Fi only, which is the only available system. The WiMAX mode selects WiMAX only, which is the only available system.

3.2.3 Simulation Results

Figure 5 shows the average cumulative distribution function (CDF) application throughput rate of 10%, 50%, and 90% under four different system selection modes. Conventional and Wi-Fi modes take almost the same rate. In conventional mode, it is assumed that all dual mode user terminals selected Wi-Fi. The WiMAX mode shows a rate 1.64 times higher, in a CDF of 90%, compared to the conventional mode. The AHP mode shows a rate 1.33 times higher in a CDF of 50% compared to the conventional mode. And in a CDF of 90%, the AHP mode shows rates 2.37 times higher compared to the conventional mode and 1.4 times higher compared to the WiMAX mode. This shows that the AHP mode, which selects wireless systems using AHP, enables higher throughput than the conventional, Wi-Fi, and WiMAX modes.

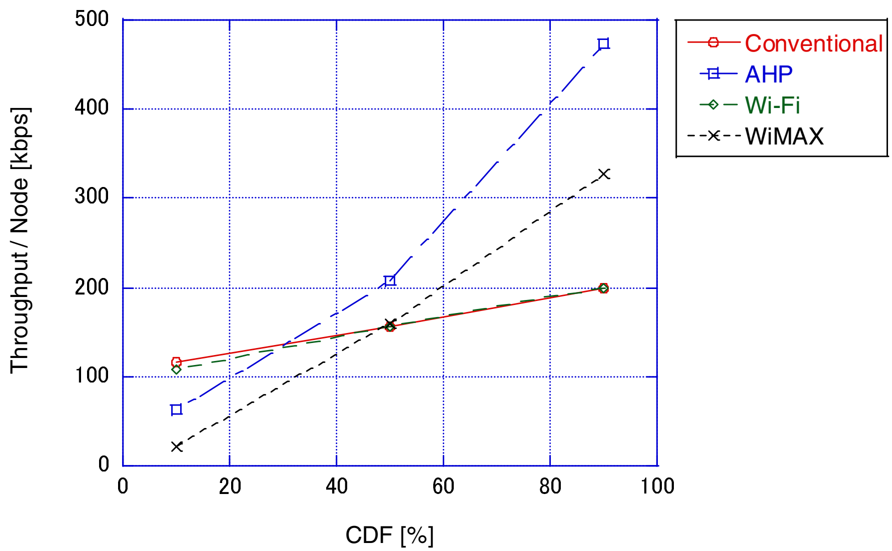

Fig. 5. Average CDF application throughput rate of 10%, 50%, and 90% under four different system selection modes

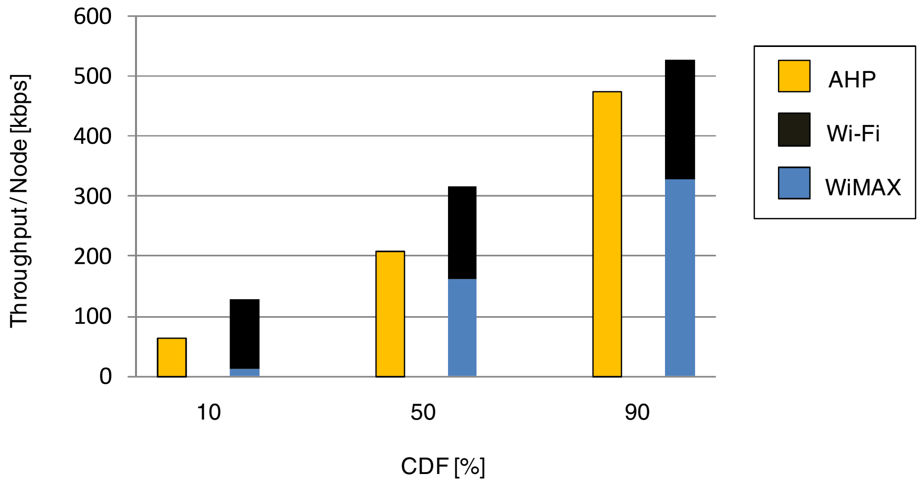

Fig. 6. Comparison of the total application throughput of Wi-Fi and WiMAX modes with AHP mode

Figure 6 shows the comparison of the total application throughput of Wi-Fi and WiMAX modes with the AHP mode. The AHP mode's CDF of 90% average rates is almost 90 percent, compared to the total rate of Wi-Fi and WiMAX modes. The AHP mode's simulation throughput rate is only slightly lower than the simply added rate of Wi-Fi and WiMAX. This shows that the proposed communication system selection policy using AHP is effective.

4 Conclusions

In this paper, we proposed an AHP-based system selection policy for heterogeneous wireless networks that hold Wi-Fi and WiMAX. The proposed system selection policy used AHP by calculating the weights of the various traffic quality parameters. We conducted a software simulation that used uplink throughput and RTT as attributes. The simulation results showed that the proposed policy using AHP provided higher throughput than the conventional policy that chose Wi-Fi when available. For future work, we will conduct a software simulation using other quality information for AHP calculation under various models and conditions.

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