QoS-Aware Network Selection for Seamless Multimedia Service

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Abstract—In heterogeneous wireless environments which change dynamically, the optimal network selection problem is one of the key issues. This paper proposes a network selection scheme based on the required bandwidth, which estimates the bandwidth required to satisfy the quality of service (QoS) requirements of the target service. Required bandwidth can be estimated from the signal strength of each access path and the QoS requirements such as delay, packet loss, burst size, etc. Simulation results show that the proposed scheme can achieve higher throughput or lower cost or lower power consumption according to the user preference, which outperforms the signal strength based network selection schemes.

I. INTRODUCTION

Network selection in a heterogeneous wireless environment is typically addressed in the literature by using either a network-centric or a user-centric approach. With the network-centric approach, a centralized controller decides which network to access. However, this approach comes with significant communication overhead. On the other hand, with a user-centric approach, the user or mobile terminal selects the access network. This approach can achieve low implementation complexity and low communication overhead. Therefore, this paper focuses on the user-centric and multi-connection approaches.

A number of network selection schemes have been proposed recently. A decision process for a network assisted network selection mechanism that combines non-compensatory and compensatory multiple attribute decision making (MADM) algorithms has been proposed in [1]. And a cost function based network selection strategy has been presented in [2]. And an interface selection scheme based on the bandwidth estimation has been proposed in [3].

However, all the mentioned works above did not consider the case that a mobile terminal connects to two or more networks simultaneously. In that case, the mobile terminal must determine whether it will connect to a single access network or multiple access networks. If it is determined that the mobile terminal will connect to the multiple access networks, the mobile terminal has to determine whether it will achieve a diversity gain or a multiplexing gain. These aspects were not taken into account in the existing network selection schemes. Moreover, the QoS requirements of the target application services and the effects of received signal strength were not considered in the existing works. Therefore, in this paper, we propose a QoS-aware multi-network selection scheme for multi-homed mobile terminals in the heterogeneous wireless environments.

II. REQUIRED BANDWIDTH-BASED NETWORK SELECTION

The required bandwidth can be estimated from the received signal strength of each access path and the QoS requirements such as delay, packet loss, burst size, etc. Therefore, the QoS requirements and the signal strength can be reflected in network selection by employing the required bandwidth as one of the selection criteria. The network selection criteria also include the access cost and the power consumption rate. And the user preference is used to calculate the weighting factor of each criterion. The overall procedure of the proposed scheme is represented in Fig. 1. The detailed descriptions will be given in the following sections.

A. Network Selection Criteria

1) Cost: The cost of using a particular access network is an important factor in a user-centric approach.
2) Power Consumption: Since the majority of power consumption is related to the radio interfaces, selecting an access network which consumes less power than other networks is one of the key goals of this work.

3) Required Bandwidth: Each access network has distinctive characteristics such as data rate, modulation and coding scheme, spectral efficiency, bandwidth, and so on. And each service has its own QoS requirements such as delay, jitter, packet loss, etc. Thus, we introduce a quantitative factor which is calculated from the characteristics of access networks and the QoS requirements of the application services.

4) User Preference: Some users may prefer the cheaper access network with a moderate QoS level rather than the access network which guarantees high QoS level with high cost. On the other hand, some users may prefer the access network with a high QoS level regardless of the access cost. Therefore, in this work, weighting factors are determined according to the user preferences.

B. Effective Data Rate

We define effective data rate as the data rate required to satisfy the QoS requirements of target service. Different application services correspond to different QoS requirements, such as delay bound, data rate, packet loss ratio bound, etc. Effective data rate of the path \( i \) can be obtained as

\[
ER_i = g \times s_i \times (1 - L),
\]

where \( g \) is the required data rate considering delay bound, peak data rate, mean data rate, and burst size. And \( s_i \) is the number of transmission required to transmit a packet successfully, and \( L \) is the packet loss ratio bound. Because the constant bitrate (CBR) voice applications always transmit packets at the peak rate, \( g \) of the CBR voice applications can be expressed as

\[
g = R_{peak},
\]

where \( R_{peak} \) is the peak data rate which is one of the QoS requirements. Since the variable bitrate (VBR) voice applications transmit packets only during talk-spurt duration, \( g \) of the VBR voice applications can be calculated as

\[
g = \frac{\lambda}{\lambda + \alpha} R_{peak},
\]

where \( \lambda \) is the talk-spurt duration and \( \alpha \) is the silence duration.

Since the video streaming applications can be modeled as a dual bucket model [4], [5], \( g \) of the video streaming applications can be obtained as

\[
g = \frac{R_{peak}}{1 + D \times B^{-1} \times (R_{peak} - R_{mean})},
\]

where \( D \) is the delay bound, \( R_{mean} \) is the mean data rate, and \( B \) is the bucket size which can be calculated as

\[
B = \frac{\sigma \times (1 - R_{mean})}{R_{peak}},
\]

where \( \sigma \) is the maximum burst size.

Since the other best effort applications usually requires mean data rate, \( g \) of the other best effort applications can be obtained as

\[
g = R_{mean}.
\]

And \( s_i \) is obtained as

\[
s_i = \frac{1 - p_{i+1}}{1 - p_i},
\]

where \( p_i \) is the probability of packet loss determined by signal strength of the path \( i \), and \( l \) is the maximum number of retransmissions.

C. Spectral Efficiency

Since each path has different signal to noise ratio (SNR), appropriate modulation and coding scheme (MCS) level is different and result in different spectral efficiency. High SNR enables the mobile terminal to use high MCS level, which requires small resources.

D. Required Bandwidth

Required bandwidth is simply calculated by dividing the effective data rate by the spectral efficiency. When the mobile terminal connects to multiple networks simultaneously to achieve diversity gain, mobile terminal will receive the same packet streams from the multiple different paths. Thus the probability of packet loss is reduced as

\[
p = \prod_{i=1}^{N} p_i.
\]

where \( N \) is the number of paths connected.

When the purpose is multiplexing gain, the mobile terminal will connect to multiple path, and each path will carry its own packet streams distinctively. Therefore, the total data rate \( (R_{total}) \) at the mobile terminal is as follows

\[
R_{total} = \sum_{i=1}^{N} R_i,
\]

where \( R_i \) is the data rate of the path \( i \). And the packet loss probability is calculated as

\[
p = \sum_{i=1}^{N} \left( p_i \times \frac{R_i}{R_{total}} \right).
\]

E. Normalization

The values for each of the attributes are normalized because each attribute has different magnitude. Normalized values can be calculated as follows.

\[
v_{normalized} = \frac{v_{ij}}{\sqrt{\sum_{i=1}^{N} v_{ij}^2}},
\]

where \( v_{ij} \) is the value of \( j \)th attribute on the path \( i \).
\( A_{\text{cost}} + A_{\text{power}} + A_{\text{RBW}} = 1, \) \hspace{1cm} (12)

where \( A_{\text{cost}}, A_{\text{power}}, \) and \( A_{\text{RBW}} \) are the user preferences of cost, power consumption, and required bandwidth, respectively.

\section*{G. TOPSIS Ranking}

Euclidean distances from the weighted values of each path to the best and worst values are calculated. Finally, the path which is closest to the best value and farthest from the worst value will be selected using technique for order preference by similarity to ideal solution (TOPSIS) \cite{6}.

\section*{III. PERFORMANCE ANALYSIS}

This section presents the simulation results to highlight the benefits of the proposed access network selection scheme. OPNET Modeler was used to simulate typical network selection schemes based on the signal strength, and the proposed network selection scheme.

\subsection*{A. Simulation Scenarios}

1) \textbf{Scenario 1 (Best One)}: An access network which has the greatest SNR is selected. Multi-connection is not considered in this scenario.

2) \textbf{Scenario 2 (Best Two - Diversity)}: If the highest SNR is reduced below the threshold value, the access network which has the second highest SNR is selected as a secondary path to achieve a diversity gain.

3) \textbf{Scenario 3 (Proposed - Diversity)}: This scenario uses proposed required bandwidth-based network selection scheme. The access network is determined according to the result of TOPSIS ranking as described in section II-G. If the ranking of a multi-connection path is higher than a single-connection, the multi-connection with diversity gain is selected. In this scenario, users are divided into three classes by the user preference: the \textbf{Cost First Users} prefers low cost to low power consumption and high QoS, and the \textbf{Power First Users} prefers low power, and the \textbf{QoS First Users} prefers high QoS.

4) \textbf{Scenario 4 (Best Two - Multiplexing)}: If the highest SNR is reduced below the threshold value, the access network which has the second highest SNR is selected as a secondary path to achieve a multiplexing gain.

5) \textbf{Scenario 5 (Proposed - Multiplexing)}: Proposed network selection scheme is used in this scenario. Like scenario 3, users are divided into three classes. The difference is that the purpose of this scenario is to accomplish multiplexing gain.

\subsection*{B. Simulation Settings}

Fig. 2 represents the network model used in our simulation. There are 2 LTE eNodeBs, 2 LTE Home eNodeBs, and 2 WLAN APs. And the mobile terminal moves with a speed of 3km/h. The mobile terminal uses FTP download service during 30 minutes. Wireless channel models and simulation parameters are summarized in Table. I \cite{7, 8, 9}. The cost of LTE eNB is set to 1$ per 10 MBytes, and the cost of LTE HeNB and WLAN is set to 0.1$ per 10 MBytes.

\subsection*{C. Performance Metrics}

1) \textbf{Cost}: Sum of the costs of selected access networks for whole simulation time.

2) \textbf{Power Consumption}: Sum of the power consumed by selected access networks for whole simulation time.

3) \textbf{Throughput}: Sum of the size of received packets which are successfully downloaded for every second.

\subsection*{D. Simulation Results}

Fig. 3 shows the cost of diversity mode in each scenario. The cost of scenario 3. Cost is much lower than other scenarios as intended. The other scenarios do not show clear differences. The power consumption of diversity mode in each scenario is
represented in Fig. 4. The scenario 3. Power shows the least power consumption as expected. However, the difference is small because power consumption rates of considered access networks are similar. The power consumption of scenario 2 is the greatest since it selects multi-connection whenever the SNR is below the predefined threshold value.

The average throughput of each scenario is shown in Fig. 5. The scenario 3. Cost and the scenario 3. Power have much lower throughput than other scenarios because the primary goal of these scenarios are not throughput. However, the scenario 3. QoS shows slightly higher throughput than scenario 1 and 2. As shown in Fig. 5, the throughput of multiplexing mode (scenario 4 and 5) is about 20% higher than diversity mode. And the throughput of scenario 5 is about 1.3% higher than that of the scenario 4.

IV. Conclusion

In this paper, we proposed a QoS aware network selection scheme which is based on the estimation of the required bandwidth. The QoS requirements of the application services and the condition of wireless channel can be reflected in network selection by employing the required bandwidth as one of the attributes. The proposed scheme also support multi-connection selection considering user preferences. The simulation results have shown that the proposed network selection scheme can achieve a trade-off between the QoS and the cost or the power consumption. Therefore, the proposed scheme can provide the users with an efficient way to configure network selection strategy according to the user preference. In addition, required bandwidth can be used in other MADM-based network selection algorithms.

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