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Research Article

Network Access Control for Location-Based Mobile Services in Heterogeneous Wireless Networks

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Recent advances in information communication technology and software have enabled mobile terminals to employ various capabilities as a smartphone. They adopt multiple interfaces for wireless communication and run as a portable computer. Mobile services are also transferred from voice to data. Mobile terminals can access Internet for data services anytime anywhere. By using location-based information, improved mobile services are enabled in heterogeneous networks. In the mobile service environment, it is required that mobile terminals should efficiently use wireless network resources. In addition, because video stream becomes a major service among the data services of mobile terminals in heterogeneous networks, the necessity of the efficient network access control for heterogeneous wireless networks is raised as an important topic. That is, quality of services of the location-based video stream is determined by the network access control. Therefore, this paper proposes a novel network access control in the heterogeneous wireless networks. The proposed method estimates the network status with Naïve Bayesian Classifier and performs network access control according to the estimated network status. Thus, it improves data transmission efficiency to satisfy the quality of services. The efficiency of the proposed method is validated through the extensive computer simulation.

1. Introduction

Nowadays, mobile terminals adopt multiple network interfaces such as cellular, WiFi, and Bluetooth. They are widely used as smartphones and enable various services in heterogeneous networks. Services for the mobile terminals are changing to data-based services from circuit-based services. In the data-based services, there exist web services, online game, video streaming, and so on. Among them, demand for high quality video streaming is increased. Video traffic will be occupied by 75% of total mobile data traffic in 2020 [1]. Particularly, the growth of location-based video services is expected. The demand of this mobile service user causes mobile terminals to find better network connection for better services. Operating systems for the mobile terminals such as android of google and iOS of apple support controlling multiple network interfaces. Application services provide various services using the multiple network interfaces. Thus, users can use data services that they want, through various network interfaces of mobile terminals, anytime anywhere.

Over the Top (OTT) services are mobile TVs which provide video contents over mobile Internet. Using location-based information of mobile terminals, video clip for advertisement can be provided to service users. Through the location-based video service, marketing effects can be maximized. In this mobile service environment, because 4G LTE networks are widely spread and public WiFi networks are increased, communication environments for mobile Internet are improved. However, data traffic of the high quality videos grows very fast and radio resources to serve the data traffic are gradually lacking. Thus, OTT service providers are interested in exploiting multiple networks to connect Internet. The OTT services mainly employ cellular and WiFi network as shown in Figure 1. For their quality of services, OTT service providers take network access control between cellular and WiFi network into account. Several researches for

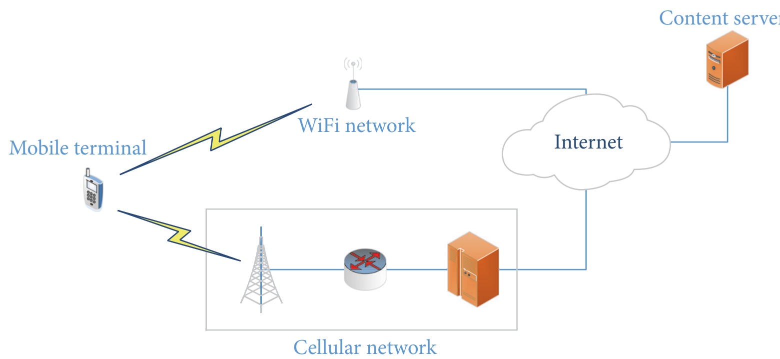

Figure 1: Network system architecture for the OTT services.

the OTT services approached efficient usage of the cellular and WiFi network to improve the quality of services and user satisfaction.

In OTT services, 98% of video traffic uses Hypertext Transfer Protocol (HTTP) to transmit data traffic [2, 3]. It is possible that a mobile terminal requests video traffic in byte-range by HTTP Range Requests [4–7]. Media content servers transmit video traffic in the requested byte-range. Through the HTTP Range Requests, requesting data in byte-range according to the network interface is enabled. That is, mobile terminal chooses a target network and can receive video traffic in the requested bytes by a media player. Because the HTTP Range Requests technology deals with data traffic as a byte block (i.e., chunk), segmentation and assembly of data traffic are available. Thus, it can be used to change network interfaces during video streaming and to adjust traffic load of network interfaces in a mobile terminal.

Multimedia applications of mobile services employ multiple wireless networks and thereby selecting the network interface in a mobile terminal according to the wireless channel status is crucially affected on the quality of services. In case of cellular network, it provides connectivity in wide area; however, it shows fluctuation in data rate. WiFi network has the weak point in aspect of providing seamless connectivity. Therefore, efficient network control between cellular and WiFi [8] is required, and providing services by recognizing the network status and efficient controlling network interfaces is raised as an important challenge.

According to user policies, network interfaces of mobile terminals can be diversely exploited. If the goal of users is cost effective service, WiFi network can be preferentially selected to provide video streaming. Relatively, if the goal is seamless connectivity, cellular network can be selected by priority [9–11]. In this paper, however, the network interface for a streaming service is determined according to the quality of services (i.e., content rate of a media player in a mobile terminal) instead of the characteristics of wireless networks. Moreover, not only is the network switched between cellular and WiFi network, but also the simultaneous usage of cellular and WiFi network is solved. The Naïve Bayesian Classifier, which is based on statistics of successful transmission rate and signal strength in a mobile terminal, is exploited to be aware of channel status of wireless networks. The method to select the proper network interface according to the channel status is proposed in order to satisfy the quality of services of a media player. By learning using the Naïve Bayesian Classifier, the proposed method is expected to improve the estimation accuracy of the network status and efficient decision for network interface selection can be carried out from that.

The remainder of paper is organized as follows. Section 2 discusses the related work on network selection method specific to heterogeneous wireless networks. The proposed network access control method for heterogeneous wireless networks is presented in Section 3. Section 4 presents the performance evaluation. Finally, Section 5 concludes the paper.

2. Related Work

OTT services such as mobile TV become widely spread and location-based services are added to the OTT services in order to provide improved services and to maximize business effect of service providers. They are served by heterogeneous wireless networks which consist of cellular and WiFi. The heterogeneous wireless networks focus on the efficient network selection to provide the best services for mobile terminals. There are two types of network selection methods (i.e., terminal-side selection and network-side selection). In the terminal-side network selection, a terminal classifies several elements such as mobility, traffic, and cost. Then, it assigns scores to the elements. According to the characteristics of given services, the terminal combines the scores and applies the combined score to the network selection [12]. In the network-side selection, Common Radio Resource Management (CRRM) module, which is a network device, manages radio resources of whole wireless networks. It selects a network for mobile terminals and assigns proper radio resources to the mobile terminals [13–16]. In the network selection, if a network is selected only according to elements of user preference, the change of network status cannot be adaptively reflected. Thus, the elements of network status should be considered to choose a network for a given service.

There are several policies to select the proper networks: the network selection policy to maximize performance of mobile terminals, the network selection policy to minimize usage of the cellular traffic, and the network selection policy

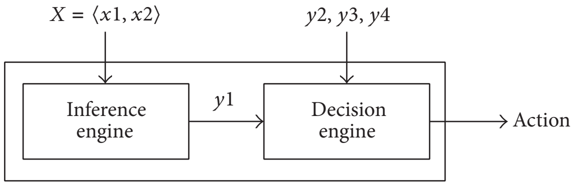

Figure 2: Architecture of the proposed network access control.

to conserve energy consumption of mobile terminals [9]. In the first policy, a mobile terminal monitors data rate of wireless networks and compares the data rates per the given time. Then the mobile terminal selects a network with bigger data rate. In the second policy, if WiFi network is available, a mobile terminal chooses the WiFi. However, when the signal strength of the WiFi is less than a certain threshold, the mobile terminal changes the WiFi network to cellular network. In the last policy, a mobile terminal uses cellular network at first. Then if traffic usage is larger than a certain threshold, it changes the cellular network to WiFi network. In general, a mobile terminal in the cellular network consumes more energy to exchange data traffic than the WiFi network. Thus, to reduce consumed energy in the mobile terminal, the amount of traffic usage in the cellular network should be restricted.

When the channel status of wireless networks is frequently changed, data rates of the wireless networks are the crucial factor for the efficient data transmission. Mobile terminals should satisfy the required data rates of services. In [8], the method combining the bandwidth of both cellular (LTE) network and WiFi network for services was proposed.

Existing methods in heterogeneous wireless networks to select a network in a mobile terminal considered user preference, amount of data usage, data rate, and so on. However, these methods cannot reflect both buffer status of media players and the network status. In addition, they cannot provide stable data reception and cause service problems such as media pause. Thus, in this paper, in order to be aware of the network status, Naïve Bayesian Classifier, which is based on statistics of data rate, is exploited. Through the classifier, the network status can be estimated. Then, according to the estimated network status and buffer status for a media player, the mobile terminal selects the proper network. In addition, the mobile terminal can use both cellular and WiFi networks simultaneously. In proposed method, the mobile terminal can provide the proper data transmission for its services.

3. The Proposed Radio Access Control

The proposed method consists of the inference engine and the decision engine. The inference engine estimates network status using Naïve Bayesian Classifier. The decision engine decides behaviors for the network access control. The proposed method is periodically operated for the network access control. Figure 2 represents the architecture of the proposed network access control.

The inference engine manages statistics data for successful transmission rate (x_1) and signal strength (x_2) in WiFi networks. It estimates the network status of WiFi networks through the Bayesian Inference with the statistics data. The estimation of WiFi status is for the network status that services are available. Then, according to the result of the estimation (y_1), the decision engine performs the network access control with buffer status of a media player (y_2), stability of the WiFi network (y_3), and system status for incoming/outgoing traffic (y_4).

3.1. WiFi Status Estimation in the Inference Engine. The inference engine employs Naïve Bayesian Classifier. The Naïve Bayesian Classifier is based on the Bayes rule and it is a widely used supervised learning algorithm (supervised learning is widely applied to wireless networks to estimate the variance of wireless resources and network environment [17–23]). It is used to estimate the most possible state from probability by the a priori statistic information. Therefore, the more the training data by experience, the better the decision accuracy. The probability of the most possible state can be obtained by the Bayes rule. The Naïve Bayesian Classifier calculates the posterior probability of each state and chooses the state with the largest probability. It is represented as

$$\begin{aligned} v &= \arg\max_{Y} P(Y \mid X) = \arg\max_{Y} \frac{P(X \mid Y) P(Y)}{P(X)} \\ &= \arg\max_{Y} P(X \mid Y) P(Y). \end{aligned} \quad (1)$$

In the Naïve Bayesian Classifier, when attributes X are given, the probability of available states Y can be calculated. By the Bayes rule, $P(Y \mid X)$ is represented as $P(X \mid Y)P(Y)/P(X)$. However, because the Naïve Bayesian Classifier wants to find the largest probability for Y, only $P(X \mid Y)P(Y)$ is considered.

$$\begin{aligned} P(Y \mid X) &= P(x_1, x_2, \ldots, x_n \mid Y) P(Y) \\ &= P(x_1 \mid Y) P(x_2 \mid Y) \cdots P(x_n \mid Y) \\ &= \prod_{i=1}^{n} P(x_i \mid Y). \end{aligned} \quad (2)$$

Then, the Naïve Bayesian Classifier becomes as

$$\begin{aligned} v &= \arg\max_{Y} P(X \mid Y) P(Y) \\ &= \arg\max_{Y} \prod_{i=1}^{n} P(x_i \mid Y) P(Y). \end{aligned} \quad (3)$$

At first, the proposed network access control method estimates the network status of WiFi through the inference engine. The inference engine employs the Naïve Bayesian Classifier of (3) and exploits successful transmission rate (x_1) and strength of reception signal (x_2) as attributes. State variable Y for WiFi has 0 and 1 as its value. $Y = 0$ means the network status of WiFi is bad and $Y = 1$ means the network status of WiFi is good. If there exists m training set as a priori statistic information, the probabilities for WiFi state Y in the inference engine can be represented as

$$P\left(x_i \mid Y=1\right)=\frac{\sum_{j=1}^{m} 1\left\{x_i^{(j)}=1,\ y^{(j)}=1\right\}}{\sum_{j=1}^{m} 1\left\{y^{(j)}=1\right\}},$$
$$P\left(Y=1\right)=\frac{\sum_{j=1}^{m} 1\left\{y^{(j)}=1\right\}}{m}, \quad (4)$$

$$P\left(x_i \mid Y=0\right)=\frac{\sum_{j=1}^{m} 1\left\{x_i^{(j)}=1,\ y^{(j)}=0\right\}}{\sum_{j=1}^{m} 1\left\{y^{(j)}=0\right\}},$$
$$P\left(Y=0\right)=\frac{\sum_{j=1}^{m} 1\left\{y^{(j)}=0\right\}}{m}. \quad (5)$$

Equation (4) represents the probability of WiFi with good status and (5) represents the probability of WiFi with bad status. The inference engine applies the probability values of (4) and (5) to (3) and then it estimates the WiFi status. In (4) and (5), the indicator function $1\{\cdot\}$ counts 1 if the given condition is satisfied.

If the inference engine has no a priori information, it cannot estimate the WiFi status because $P(X \mid Y)$ is 0. In this case, $P(Y \mid X)$ is also 0 so the network estimation cannot be performed. To avoid this case, the inference engine applies Laplace smoothing. The Laplace smoothing adds 1 to the numerator of (4) and (5) and adds k to the denominator of (4) and (5). The value k represents the number of states of Y. In this paper, because Y has 0 (bad) or 1 (good) as the WiFi status, k becomes 2. Then, when the Laplace smoothing is applied, (4) and (5) become

$$P\left(x_i \mid Y=1\right)=\frac{\sum_{j=1}^{m} 1\left\{x_i^{(j)}=1,\ y^{(j)}=1\right\}+1}{\sum_{j=1}^{m} 1\left\{y^{(j)}=1\right\}+2},$$
$$P\left(Y=1\right)=\frac{\sum_{j=1}^{m} 1\left\{y^{(j)}=1\right\}+1}{m+2},$$
$$P\left(x_i \mid Y=0\right)=\frac{\sum_{j=1}^{m} 1\left\{x_i^{(j)}=1,\ y^{(j)}=0\right\}+1}{\sum_{j=1}^{m} 1\left\{y^{(j)}=0\right\}+2},$$
$$P\left(Y=0\right)=\frac{\sum_{j=1}^{m} 1\left\{y^{(j)}=0\right\}+1}{m+2}. \quad (6)$$

From (3) and (6), the WiFi network status can be estimated and the status value of the WiFi is used as an input parameter for the decision engine. The decision engine performs network access control using the estimated network status value and other system parameters. Table 1 shows an example of training data for learning. The inference engine maintains transmission rate and signal strength as training data and obtains the most possible probability using the maintained data.

Table 1: Training examples to predict network status.

APs	Transmission rate	Signal strength	Network status
1	120 kbps	−80 dBm	Bad
1	125 kbps	−83 dBm	Bad
1	110 kbps	−81 dBm	Bad
1	131 kbps	−78 dBm	Bad
2	2431 kbps	−52 dBm	Good
2	2105 kbps	−48 dBm	Good
2	2254 kbps	−56 dBm	Good

3.2. Wireless Network Selection in the Decision Engine. The decision engine determines behaviors for the network selection using several statuses information such as WiFi status (y_1), buffer status (y_2), WiFi stability (y_3), and system status (y_4), which are as shown in Figure 2. It considers whether WiFi is good or not, data in the buffer is sufficient or not, WiFi is stable or not, and reception data rate for the network is greater than data consumption rate in the buffer or not.

The decision engine controls the network access through the behavior decision table and it is represented in Algorithms 1 and 2. The WiFi status is estimated by the inference engine and the buffer status is obtained from a media player. In the proposed method, the buffer status is defined by three steps: high, normal, and low. The thresholds for the buffer of each step are represented as THRD_H, THRD_M, and THRD_L. The network stability is determined by the history of the network status. The decision engine manages history of the connected WiFi networks. If the ratio of good status is greater than the ratio of bad status in the history information, the network can be considered as stable. Otherwise, the network is considered as unstable. The system status is described with the variables, μ and λ. μ is content bit rate of a media player. λ is reception data rate of the connected network. The buffer is filled according to the data rate and the media player consumes data in the buffer according to the content bit rate.

In the proposed method, mobile terminals control the network access according to Algorithms 1 and 2 when they are connected to a WiFi network. Mobile terminals only connect to cellular network without any WiFi connections and they search for available WiFi networks and try to connect to them.

When the connected WiFi is good, if the amount of data in the buffer is sufficient (high step), the decision engine does not perform any operations. However, if the amount of data in the buffer is insufficient, the network access control will be performed according to stability and system status. In normal step of the buffer, mobile terminals search for another WiFi and try to migrate to the WiFi network. In low step of the buffer, if the WiFi is stable and μ is less than or equal to λ, it means incoming data in the buffer is greater than or equal to outgoing data. Thus, mobile terminals simultaneously use both cellular and WiFi until the amount of data in the buffer satisfies THRD_M. If μ is greater than λ, it means incoming data in the buffer is less than outgoing data. Thus, mobile terminals simultaneously use both cellular and WiFi until the amount of data in the buffer satisfies THRD_H and then the mobile terminals search for another WiFi and migrate to the WiFi network. If WiFi is unstable in low step of the

```
Decision-For-Network-Access-Control (y1, y2, y3, y4)
μ ← y4 · μ
λ ← y4 · λ
If y1 is good then
    If y2 is normal then
        If y3 is stable then
            If μ > λ then
                Find another WiFi
            End if
        Else
            If μ > λ then
                Find another WiFi and then migrate to the WiFi
            End if
        End if
    Else if y2 is low then
        If y3 is stable then
            If μ ≤ λ then
                Use cellular and WiFi simultaneously until the buffer meets THRD_M
            Else
                Use cellular and WiFi simultaneously until the buffer meets THRD_H
                Find another WiFi and then migrate to the WiFi
            End if
        Else
            If μ ≤ λ then
                Use cellular and WiFi simultaneously until the buffer meets THRD_H
                Find another WiFi and then migrate to the WiFi
            Else
                Find another WiFi and then migrate to the WiFi
                Or transfer to cellular
            End if
        End if
    End if
End if
```

Algorithm 1: Decision algorithm for network access control: good WiFi status.

buffer, when μ is less than or equal to λ, mobile terminals simultaneously use both cellular and WiFi until the amount of data in the buffer satisfies THRD_H and then the mobile terminals search for another WiFi and migrates to the WiFi network. When μ is greater than λ, the mobile terminal only uses cellular network or finds another WiFi network to migrate to it.

In case that WiFi status is bad and the amount of data in the buffer is sufficient, mobile terminals keep the current WiFi connection or search for another WiFi network according to the network stability. If the amount of data in the buffer is an intermediate level and the connected WiFi is stable, mobile terminals search for another WiFi network or migrate to the discovered WiFi network according to the system status. If WiFi is unstable and the reception data rate for data transmission (λ) is greater than or equal to the content bit rate (μ), mobile terminals simultaneously use both cellular and WiFi to fill the buffer until THRD_M. In case that the reception data rate is less than the content bit rate, mobile terminals simultaneously use both cellular and WiFi to fill the buffer until THRD_H. When the amount of data in the buffer is insufficient and the connected WiFi is stable, if the reception data rate is greater than or equal to the content bit rate, mobile terminals simultaneously use both cellular and WiFi to fill the buffer until THRD_H. If the reception data rate is less than the content bit rate, mobile terminals try to migrate to another WiFi network or transfer to cellular network. In case that the connected WiFi is unstable and the reception data rate is greater than or equal to the content bit rate, mobile terminals also try to migrate to another WiFi network or transfer to cellular network. However, if the reception data rate is less than the content bit rate, the mobile terminals do not use WiFi network. They just transfer to cellular network.

4. Performance Evaluation

4.1. Network Model. Mobile terminals include multiple network interfaces to access cellular and WiFi network. They move according to the network model as shown in Figure 3. That is, the mobile terminals move from cellular area to WiFi1 area and then they move from WiFi1 area to WiFi2 area. In WiFi2 area, the mobile terminals move to cellular area. The mobile terminals continuously move to these network areas. Each WiFi area is maintained for VISITING_TIME and the cellular area is maintained for VISITING_TIME/2. In this

```
Decision-For-Network-Access-Control (y1, y2, y3, y4)
μ ← y4 · μ
λ ← y4 · λ
If y1 is bad then
  If y2 is high then
    If y3 is unstable then
      Find another WiFi
    End if
  Else if y2 is normal then
    If y3 is stable then
      If μ ≤ λ then
        Find another WiFi
      Else
        Find another WiFi and then migrate to the WiFi
      End if
    Else
      If μ ≤ λ then
        Use cellular and WiFi simultaneously until the buffer meets THRD_M
      Else
        Use cellular and WiFi simultaneously until the buffer meets THRD_H
      End if
    End if
  Else if y2 is low then
    If y3 is stable then
      If μ ≤ λ then
        Use cellular and WiFi simultaneously until the buffer meets THRD_H
      Else
        Find another WiFi and then migrate to the WiFi
        Or transfer to cellular
      End if
    Else
      If μ ≤ λ then
        Find another WiFi and then migrate to the WiFi
        Or transfer to cellular
      Else
        Transfer to cellular
      End if
    End if
  End if
End if
```

Algorithm 2: Decision algorithm for network access control: bad WiFi status.

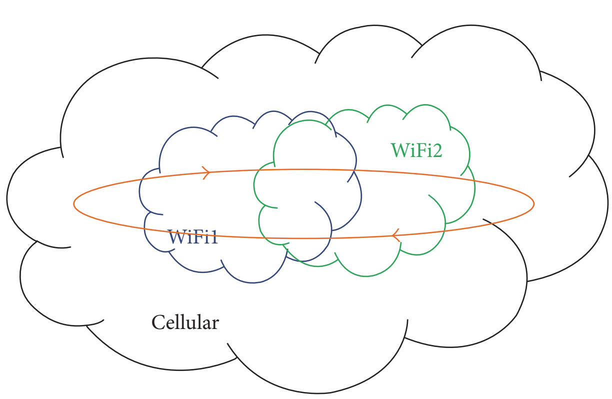

Figure 3: Network model.

network model, the mobile terminals monitor the status of the connected network and periodically perform the network access control.

4.2. Channel Model. The status of wireless channel for WiFi network can be divided into two categories which are denoted as good and bad. The status change of wireless channel can be modeled by Markov Chain. When probability of the status change from good to bad is p and probability of the status change from bad to good is q, the wireless channel can be modeled as Figure 4.

Then, Figure 3 is represented as

$$P = \begin{pmatrix} 1-p & p \\ q & 1-q \end{pmatrix}. \qquad (7)$$

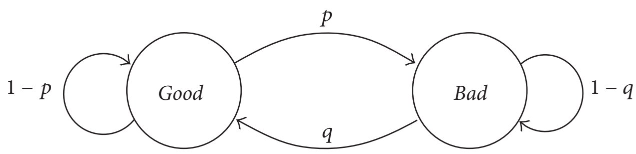

Figure 4: WiFi channel model.

When limiting probability [24] is applied to the Markov channel model, the probabilities of good or bad status can be obtained. The probabilities of the good and bad status are represented as

$$P\{X = \text{Good}\} = \frac{q}{p+q},$$
$$P\{X = \text{Bad}\} = \frac{p}{p+q}. \quad (8)$$

Then, the probability of successful data transmission is represented as

$$P_s = (1 - \text{PER})\, P\{X = \text{Good}\}, \quad (9)$$

where the Packet Error Rate (PER) for the WiFi network is set to 1%.

In general, signal strength in WiFi networks is frequently changed due to channel environments such as interference. However, cellular network provides better wireless conditions. Thus, in this paper, the channel condition of cellular network is always assumed as good.

4.3. Simulation Environments. The simulator for performance evaluation is implemented with the SMPL library [25]. It is an event-driven simulation library using C language. The period of simulation is set to 50000 sec. A mobile terminal moves according to the network model in Section 4.1 and data rates of the wireless networks are set to 10 Mbps in cellular, 1 Mbps in WiFi1, and 5 Mbps in WiFi2. The VISITING_TIME in the simulation is set to 300 sec and the WiFi channel is changed per 120 sec according to the channel model in Section 4.2.

In WiFi2, the channel parameter p follows the uniform distribution between 0.1 and 0.2 and the parameter q follows the uniform distribution between 0.7 and 0.9. Signal strength of the WiFi network is randomly determined between −65 and −45 in good channel condition. In bad channel condition, the signal strength is randomly determined between −85 and −65. In WiFi1, the parameter p follows the uniform distribution between 0.2 and 0.4 and the parameter q follows the uniform distribution between 0.7 and 0.8. In good channel condition, the signal strength is randomly determined between −75 and −55. In bad channel condition, the signal strength is randomly determined between −90 and −75. In the WiFi networks, the network condition is assumed as good if P_s is greater than 0.8. If P_s is less than 0.7, the network condition is assumed as bad.

When the mobile terminal is in the WiFi networks, it monitors network per 5 sec and adds the training set (i.e., network information) of the network. At that time, the mobile terminal estimates the network status using the inference engine and then performs network access control using the decision engine. For WiFi networks, if the ratio of good channel is greater than the ratio of bad channel, it is assumed the network is stable. Otherwise, the network is assumed as unstable.

Table 2: Simulation parameters.

Parameters	Value
VISITING_TIME	300 sec
WiFi1 data rate	1 Mbps
WiFi2 data rate	5 Mbps
Cellular data rate	10 Mbps
CHANNEL_INTERVAL	120 sec
NET_MONITOR_INTERVAL	5 sec
THRD_H	6 MB
THRD_M	4 MB
THRD_L	1/1.5/2 MB
BUFFER_SIZE	8 MB
SIMULATION_TIME	50000 sec

When the mobile terminal moves, the streaming service is provided for the mobile terminal. A media player of the mobile terminal has 2 Mbps as CONTENT_RATE and data in the buffer is consumed according to the rate. The buffer size is 8 MB. If the whole buffer is filled with data, the mobile terminal will not request data to the media server. If the buffer is empty, the streaming service cannot be provided and the media player is in PAUSE status. The buffer parameter THRD_H is set to 6 MB and THRD_M is set to 4 MB. THRD_L is set to 1 MB, 1.5 MB, and 2 MB, respectively. Table 2 represents the simulation parameters for performance evaluation.

The proposed method is compared with the buffer-based network access control and no network access control. The buffer-based network access control is classified by two cases. (1) In the first case, network switching between WiFi and cellular networks occurs according to the buffer status. If the amount of data in the buffer is less than or equal to THRD_L, the mobile terminal releases the connection of WiFi and uses the only cellular network. If the amount of data in the buffer is greater than THRD_L, the mobile terminal tries to access the available WiFi networks. (2) In the second case, bandwidth aggregation between WiFi and cellular networks occurs according to the buffer status. If the amount of data in the buffer is less than or equal to THRD_M, the mobile terminal simultaneously exploits both cellular and WiFi networks. If the amount of data in the buffer is greater than THRD_H, the mobile terminal only uses WiFi network.

4.4. Simulation Results. For performance evaluation, the proposed method is compared to buffer-based network access control methods and no network access control. The pause counts of a media player in the streaming service and the amount of data traffic usage in WiFi and cellular network are measured through the computer simulation. Table 3 and

Table 3: Simulation result: pause counts.

	Proposed	Buffer 1	Buffer 2	None
Number of pauses	0	0	0	17109

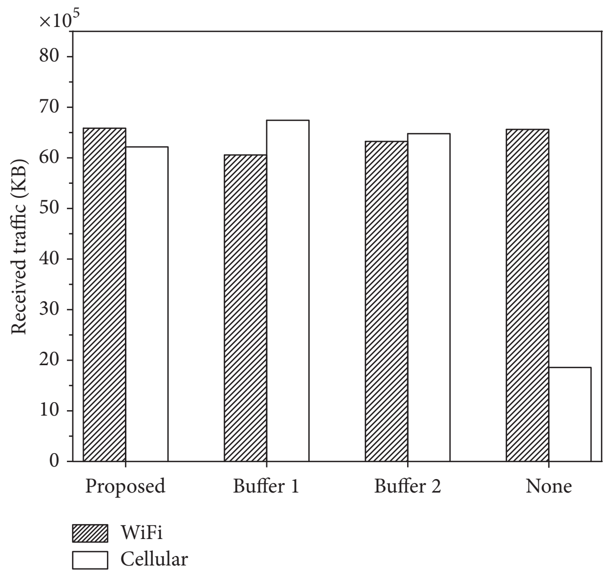

Figure 5: Simulation result: received traffic at the mobile terminal.

Table 4: Simulation result according to THRD_L: pause counts.

	1 MB	1.5 MB	2 MB
Number of pauses	103	4	0

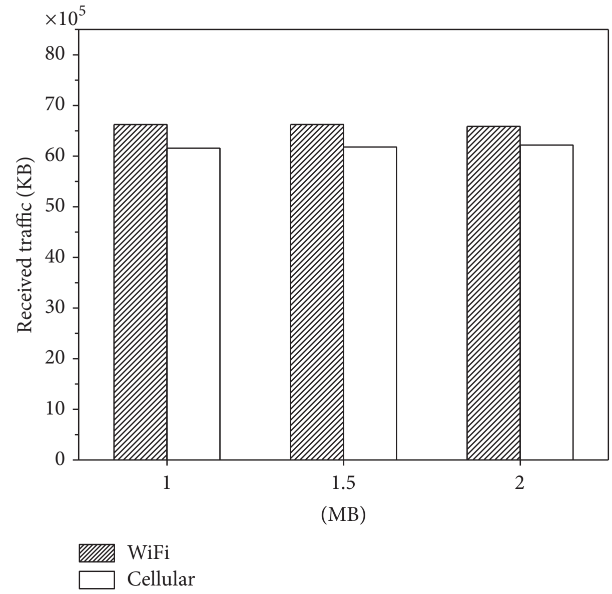

Figure 6: Simulation result according to THRD_L: received traffic at the mobile terminal.

Figure 5 show the simulation results when the lowest buffer threshold (THRD_L) is 2 MB.

Table 3 represents pause counts and Figure 5 shows received traffic through cellular and WiFi networks at the mobile terminal. In Table 3 and Figure 5, "Proposed" indicates the proposed method and "None" indicates no network access control. "Buffer 1" is the first case of the buffer-based method and "Buffer 2" is the second case of the buffer-based method. As shown in Table 3, by applying the network access control, the pause counts of the media player can be largely reduced. As shown in Figure 5, when the network access control is applied, received traffic of cellular network is greatly increased. By exploiting the cellular network when the WiFi is not good, usage of the cellular network is increased while the user experience is improved. That is, users can be served seamless streaming services without any pauses. The "Buffer 1" method disconnects from WiFi and uses the cellular network when the WiFi is bad and the amount of data in the buffer is not sufficient. In this case, the amount of traffic usage of the cellular network is the largest. The "Buffer 2" method exploits both the WiFi and the cellular network when the WiFi is bad and the amount of data in the buffer meets THRD_M. Thus, it can increase usage of WiFi network. However, the proposed method considers more factors to access wireless networks. The proposed method includes buffer status, WiFi status, network stability, data rate of networks, and content bit rate of the media player. Through the proposed method, usage of WiFi networks is maximized and usage of cellular network is minimized while seamless streaming service is provided. According to the results, it is verified that the proposed method is more efficient in aspect of data offloading (data offloading means usage of complementary networks such as WiFi instead of cellular networks). Data offloading rate of "Proposed" is 51%. "Buffer1" and "Buffer2" are 47% and 49%, respectively.

Table 4 represents pause counts and Figure 6 shows received traffic through cellular and WiFi networks at the mobile terminal according to the lowest threshold of the buffer (THRD_L). The proposed method selects different behaviors in the network access control according to the buffer status. In the decision engine, the proposed method has several actions according to the parameters when the amount of data in the buffer is lower than the threshold, THRD_L. Thus, the results according to the change of the lowest threshold of the buffer are shown in Table 4 and Figure 6.

When the lowest threshold of the buffer is reduced, pause counts of the media player are increased as shown in Table 4. The difference of WiFi traffic and cellular traffic is increased as shown in Figure 6: the differences are 467,456 KB, 445,440 KB, and 369,664 KB when THRD_L is 1 MB, 1.5 MB, and 2 MB, respectively. That is, the WiFi traffic is increased and the cellular traffic is decreased. The reason is that the behaviors for network access control are lately performed when the amount of data in the buffer meets the lowest threshold of the buffer under the bad WiFi condition. Thus, more pause counts occur when the lowest threshold is reduced: the pause counts are 103, 4, and 0 when THRD_L is 1 MB, 1.5 MB, and 2 MB, respectively. Therefore, the threshold value should be determined according to the goal of the designed system. If the goal of the system is to maximize WiFi usage, the lowest threshold of the buffer should be minimized and if the goal of the system is to improve user experiences, the threshold value should be increased. By adjusting the threshold value according to the system goal, network access control can be tuned.

As shown in Table 3, Figure 5, Table 4, and Figure 6, if the mobile terminal does not perform the network access control in heterogeneous wireless networks, good user experiences cannot be provided. In addition, the network access control by considering only the buffer status is difficult to control the network access accurately. Thus, as the proposed method, various elements should be considered for the efficient network access control.

5. Conclusion

Mobile data services provide various business opportunities. The location-based mobile data services are increased. Particularly, the growth of the location-based video services is expected. In addition, recent advances in mobile applications have enabled mobile terminals to use multiple network interfaces. Mobile operating systems support controlling an individual network interface. Application protocol such as HTTP Range Requests provides transmitting a data block as a chunk in total data size. Therefore, network access control is available. Controlling network access according to the network status affects quality of services of the mobile applications. In case of the mobile terminal such as smartphones, applications provide services over both cellular and WiFi networks. The cellular network provides stable network connectivity in wide area. However, the cellular network takes high costs. Although the WiFi network takes no costs, it has limitation of the network coverage and its network status is frequently changed. In addition, video traffic has the largest portion in total mobile traffic. If users are served video streaming services while they are moving, maintaining the quality of services is very important. However, the quality of services is not guaranteed in the only WiFi network. Therefore, it is significant that the mobile terminal performs the network access control in heterogeneous wireless networks according to the network status.

In general, the network access control is based on the amount of data in the buffer but this case is difficult to accurately control the network access. The proposed method performs the network access control by considering the network status such as current status and stability by the network history. It also reflects the buffer status to decide the behaviors for the network access control. Through the inference engine based on Naïve Bayesian Classifier, the proposed method estimates the WiFi network status. The estimated results (i.e., the history information of WiFi networks) and the buffer status are reflected to decide the behaviors for the network access control. Therefore, the proposed method can provide the efficient network access. As the results, the proposed method can guarantee quality of the seamless services. In addition, because the proposed method increases the usage of the WiFi networks, the costs for network usage can be reduced. Although this paper uses the fixed buffer parameters, the parameters can be varied according to network status. This point can be applied to the proposed approach as future works.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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