3GPP Proficient ANDSF-Assisted Wi-Fi Regulator for Mobile Data Offloading

BHANUTEJA SOMAROUTHU
Bapurao Deshmukh College of Engineering
Branch-CSE

Abstract:

This paper presents a strategic solution to mobile data offloading between 3GPP and non-3GPP access networks. As mobile data traffic is increasing rapidly, many 3G operators face massive challenges in managing the huge amount of mobile data traffic. Thus, mobile data offloading to non-3GPP access networks in 3G-access networks is necessary. In this paper, we propose a novel ANDSF-assisted Wi-Fi control method based on user's high-level motion states, such as walking, driving, and recognizing whether the user is stationary or not, to avoid unnecessary Wi-Fi scanning and connections. The proposed method is compared to a client-based Wi-Fi connection manager, which performs periodic Wi-Fi scanning. According to the performance results, the proposed mechanism shows significant performance improvement in terms of efficient Wi-Fi control and connectivity with 3G and WiFi.

Keywords: *ANDSF, Component, EPC, Mobile Data offloading, Handover, Wi-Fi*

1. Introduction

According to the latest Cisco Visual Networking Index report [1], monthly global mobile data traffic will exceed 10 exabytes by 2016; Asia, in particular Japan, South Korea, Indonesia, and China, will account for 40% of that amount. Furthermore, the continuous advent of mobile services and the high speeds of mobile connections are the major factors in the growth of mobile data traffic.

Today, mobile users frequently use many smartphone/tablet applications, such as social networking applications, location based service applications, and mobile messengers, to communicate with application servers and peers. It will be unlikely to change mobile user trends for the use of such applications, and the traffic volume will be increase even more. Thus, growing mobile data traffic brings the requirements of mobile infrastructure improvement and a new wireless technology, such as Long Term Evolution (LTE) [2] to fulfill mobile user demand. Mobile network operators (MNOs) might have several approaches to deal with the mobile data traffic explosion. The approaches are additional spectrum acquisition, existing 3G network upgrades such as a multichannel assignment, LTE deployment, and alternative networks, such as Wi-Fi. Since all the approaches, except the fourth one, are dependent on MNO policy, thus we limit the discussion to an alternative network as a solution for mobile data offloading between 3GPP and non-3GPP access networks in this paper.

The solutions for mobile data offloading can be categorized into two solutions, such as a client-based solution and a server-based solution. Various Wi-Fi connection managers that are the applications for connecting the Wi-Fi more easily and quickly are available on user equipment

(UE), and it can be a client-based solution for mobile data offloading. However, with the client-based solution, it is impossible for the MNO to gain visibility and control over Wi-Fi traffic and the user experience for better mobile traffic management. In addition, most Wi-Fi connection managers always require turning on a Wi-Fi interface on the UE, and thus it can cause unnecessary Wi-Fi scanning. Therefore, a number of unnecessary Wi-Fi connections might be established.

Recently, ANDSF has been specified in 3GPP standards 23.402 [3] and 24.312 [4] as a server-based solution. The ANDSF is an entity within an Evolved Packet Core (EPC) to assist user equipment (UE) in discovering non-3GPP access networks and provide UE with rules and operator policies to connect to the non-3GPP access networks. However, the ANDSF server needs to acquire the current geographical location of the UE to provide discovery information, which is a list of available Wi-Fi networks near by the UE's current location. Thus, it can also cause an unnecessary energy drain on the UE owing to its power intensive location sensing and the synchronizing operations between the ANDSF server and the UE.

To address the problems of unnecessary Wi-Fi scanning and improve the energy efficiency of the ANDSF operation, we propose a novel ANDSF-assisted Wi-Fi control method by considering the user's motion states. Since the limitation of Wi-Fi coverage, the most efficient use of Wi-Fi is in a stationary state. Thus, we propose a new method of detecting motion states, such as walking and driving, and of recognizing whether the user is stationary or not in a short period time. The aim of the proposed method is to avoid unnecessary Wi-Fi scanning and unnecessary Wi-Fi connections while users are moving. The performance of the ANDSF system that employs the proposed method is compared to a client-based Wi-Fi offloading solution that performs periodic Wi-Fi scanning without considering the motion states. The remainder of the paper is organized as follows. Section II discusses the limitations of the client-based Wi-Fi offloading approach. Section III describes the proposed efficient ANDSF-assisted Wi-Fi control method. Section IV evaluates the performance of the proposed method. Finally, Section V concludes the paper.

2. Limitations of Client-Based Wi-Fi Offloading Approach

This section analyzes a client-based solution for mobile data offloading. In particular, we highlight the problems of unnecessary Wi-Fi scanning and unnecessary Wi-Fi connections with the client-based solution for mobile data offloading.

A. Client-based Wi-Fi Connection Manager

Recently, various Wi-Fi connection managers have become available in smart phone application markets, such as Google Play. Most Wi-Fi connection managers perform Wi-Fi scanning at regular intervals between 1 second and 60 seconds. However, this approach can cause unnecessary Wi-Fi scanning, and thus a number of unnecessary Wi-Fi connections might be established. To confirm this inefficient Wi-Fi scanning and to find the reason why users turn off the Wi-Fi interface, we did some simple user experience tests. As the first test, we turned on the Android Wi-Fi connection manager and listened to Internet radio (NHK Radio World) for 5 minutes while walking around in Tokyo with passing several Wi-Fi hotspot zones. During the 5 minutes, the device switched six times between 3G and Wi-Fi, and 49.6% (Total: 1,986,627 bytes) of the traffic was downloaded through the Wi-Fi access network as shown in Fig. 1.

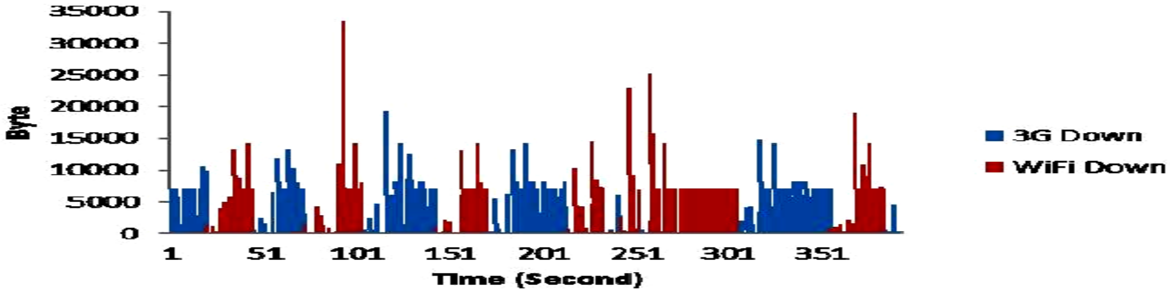

Fig. 1. Received traffic with Android Wi-Fi connection manager

Although, almost 50% of the traffic is offloaded through the Wi-Fi access network, it leads to a bad user experience since the Internet radio service was interrupted and delayed many times due to frequent switching between 3G and Wi-Fi. Fig. 2 shows the received Internet radio traffic without the Android Wi-Fi connection manager. In this test, we turned off the Android Wi-Fi connection manager and confirmed that there was no interruption to the Internet radio reception. Therefore, it is clear evidence as to why users turn off the Wi-Fi interface.

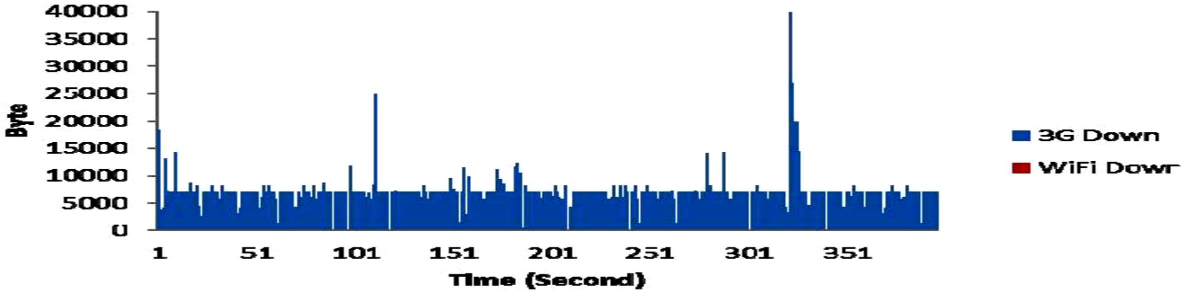

Fig. 2. Received traffic without Android Wi-Fi connection manager

B. ANDSF-assisted Wi-Fi Control

To allow UE to know where and how to choose a non-3GPP access network, such as Wi-Fi, the Technical Specification 23.402[3] defines the ANDSF. In addition, to assist UE in discovering non-3GPP access networks, the ANDSF server provides ANDSF information, which is represented by the ANDSF Management Object described in Technical Specification 24.312[4]. The ANDSF information includes discovery information, which is a list of Wi-Fi access networks available to the UE based on the UE current location and selection rules, which is a list of prioritized rules that control which Wi-Fi access networks should be used based on the UE current location. The exchange of ANDSF information can be triggered by the client pull mode or the server push mode. The initial client pull mode occurs after the UE establishes a 3G connection. At this point, the UE should provide location information (geographical location or base station ID) and request ANDSF information from the ANDSF server. Then, the ANDSF server processes this request by sending a prioritized list of Wi-Fi access networks for the UE current location. A client pull mode also occurs when the UE moves to another location. Thus, according to the ANDSF system, when the UE moves to another location, the UE needs to retrieve ANDSF information by using the pull method from the ANDSF server every time. However, in the case of the user motion state of walking and driving, remaining within the 3G coverage area is much better than Wi-Fi access due to the limitations of Wi-Fi coverage. As a result, with the current ANDSF system, intensive ANDSF information retrievals will be accrued. To confirm this inefficient ANDSF information retrieval, we tested the ANDSF information retrieval operation by using the ANDSF server and client developed according to the TS 24.402 and the TS 24.312. Fig. 3 shows the cumulative ANDSF information retrieval traffic and the time for policy retrieval attempts for 44 minutes. We measured the ANDSF information retrieval traffic while riding on a train and walking. In the test result, the ANDSF information was retrieved 33 times between the ANDSF server and the client, and the cumulative ANDSF information retrieval traffic increased as shown in Fig. 3. As we pointed out before, a ANDSF information retrieval operation while the user is moving is not necessary since it can cause unnecessary energy drain on the UE owing to its power intensive location sensing and the ANDSF information retrieval operations between the ANDSF server and the client.

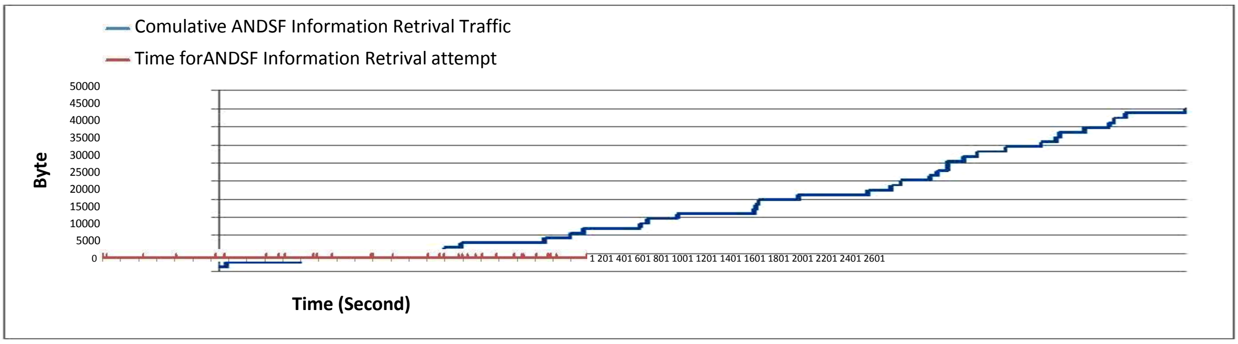

Fig. 3. Cumulative ANDSF Information Retrieval Traffic

3. ANDSF-Assisted Wi-Fi Control for Mobile Data Offloading

In this section, the proposed ANDSF-assisted Wi-Fi control method is described.

A. Discussion on ANDSF Limitations and Alternatives

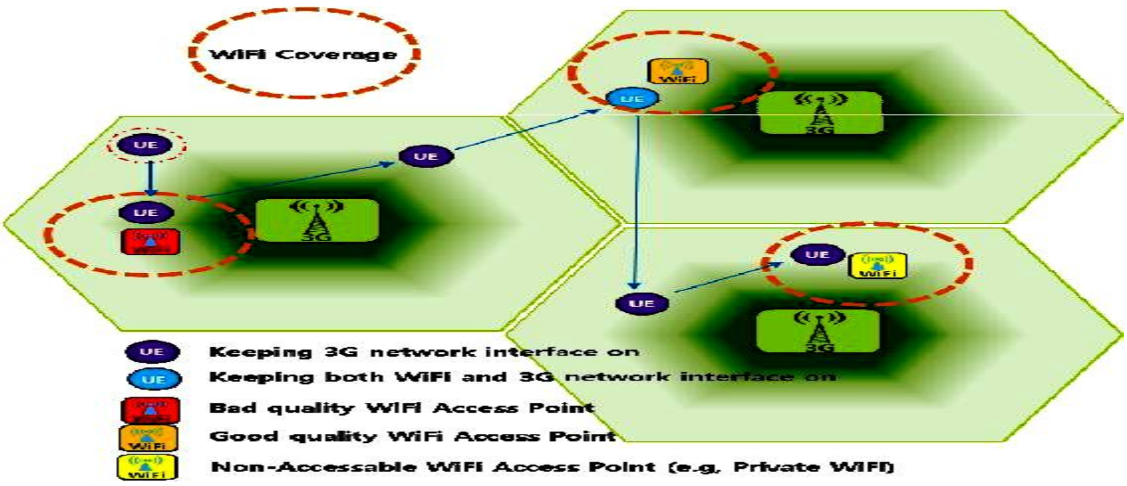

Fig. 4. The ideal case of Wi-Fi Control

The ideal case of Wi-Fi control is to turn on the Wi-Fi interface automatically when the user is stationary, which provides good quality Wi-Fi as shown in Fig. 4. In Fig. 4, the three different types of Wi-Fi are installed in each place and only the orange color coded Wi-Fi is acceptable to the user. This Wi-Fi information can be delivered by the ANDSF server, which is one of the benefits of the server-based mobile data offloading solution compared to the client-based solution. To achieve this, the following requirements should be fulfilled. At first, the UE needs the latest ANDSF information, including good quality Wi-Fi information, when the UE is ready to access the Wi-Fi network. Thus, the most appropriate time for the policy retrieval is not when the UE moves to another location but when the UE is stationary. Second, the UE needs a new function to detect the user's high-level motion state of walking or driving and recognizing whether the user stationary or not in a short period. Current positioning technologies can be used for detecting the user's high-level motion states but GPS [5] is extremely power hungry due to its power intensive location sensing, and the Wi-Fi-based positioning method [6] always needs to keep turning on the Wi-Fi interface, which can also cause an unnecessary energy drain on the UE, as well as unnecessary Wi-Fi scanning. To address these problems, we propose a new user high-level motion detection and tracking method based on 3G/4G(CDMA, WCDMA, LTE) RSSI (received signal strength indicator) variation. With the user's high-level motion detection, periodic 3G/4G RSSI measurement by the UE is a natural and essential behavior; thus, the energy drain by periodic RSSI measuring is unavoidable among the total energy consumption. We measured the 3G RSSI and BSID variations while moving and remaining in one location, respectively, using three different types of smartphones (HTC ISW13HT, Sony Xperia acro HD, and Kyosera Urbano). Fig. 5 and Fig. 6 show the 3G RSSI/BSID variations in the moving state and the stationary state, respectively.

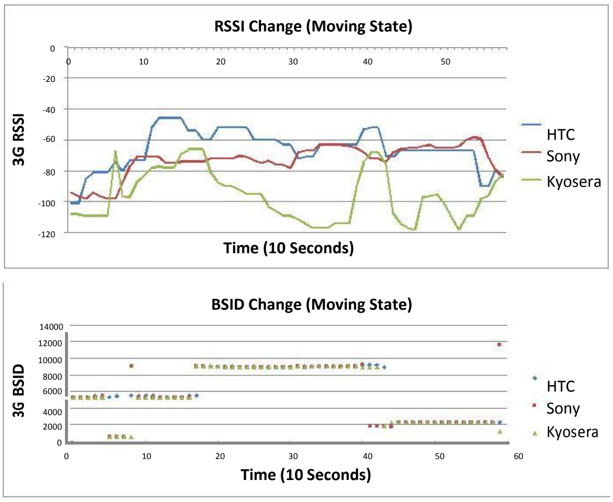

Fig. 5. 3G RSSI/BSID Variation of Moving State

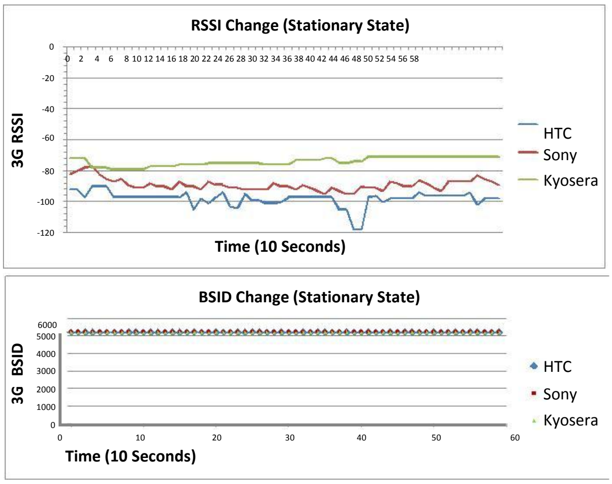

Fig. 6. 3G RSSI/BSID Variation of Stationary State

In Fig. 5, the 3G RSSI/BSID changes irregularly during the measurement time period. In contrast, there are relatively low variations in 3G RSSI values as shown in Fig. 6. With this analysis, we confirm that the RSSI/BSID variations can be used to decide whether a user is stationary or not.

B. Proposed Automatic Wi-Fi Control Mechanism

To improve Wi-Fi control in terms of avoiding unnecessary ANDSF information retrieval and unnecessary Wi-Fi scanning, we propose a method for automatic Wi-Fi control that consists of the following steps: 3G RSSI/BSID measuring during a given time interval; decision on the user's motion state using 3G RSSI/BSID variations; prevention of duplicated Wi-Fi scans in the same place; ANDSF policy retrieval; and selective Wi-Fi connections based on Wi-Fi RSSI. The first step is the decision on the user's motion state using 3G RSSI/BSID variations. To turn on the Wi-Fi interface automatically when a user is stationary only, the UE needs to observe the variations in 3G RSSI/BSID during given time intervals as shown in Fig. 7.

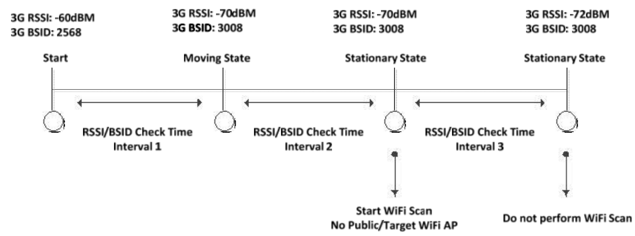

Fig. 7. An example of decision on user's motion state

For each 3G RSSI/BSID checkpoint time, the UE compares current 3G RSSI/BSID values with the previous 3G RSSI/BSID values. If both 3G RSSI/BSID variations are within the acceptable 3G RSSI variation threshold, the UE detects the current motion state as stationary (Line 2 in Fig. 8). The second step is prevention of duplicated Wi-Fi scans in the same location (Line 4 in Fig. 8). Fig. 7 shows an example of the Wi-Fi scanning rule. Although the UE is stationary after check time interval 3, it does not perform a Wi-Fi scanning. The reason is that in comparison to the previous result (Check Time Interval 2), the 3G BSID is unchanged, and the 3G RSSI variations of the previous 3G RSSI value and the current 3G RSSI value are within the range of the acceptable 3G RSSI variation (ex. ±2 dBM) so that the UE detects that the user is stationary. Here, since there were no available Wi-Fi APs in the previous Wi-Fi scan results (Check Time Interval 2), the UE should not perform a Wi-Fi scan after Check Time Interval 3. The third step is the ANDSF policy retrieval (Line 15 in Fig. 8). If the UE detects that it moves to another location and is then stationary, the UE requests the ANDSF policy for the current location, which is at least a different ANDSF policy retrieval method compared to the current ANDSF system. The final step is the Wi-Fi scanning and connection considering the Wi-Fi RSSI. If the Wi-Fi RSSI is under the predefined Wi-Fi RSSI threshold, the UE terminates the Wi-Fi connection according to the proposed algorithm.

R_C : Current Measured 3G RSSI
R_P: Previous Measured 3G RSSI
R_T: Acceptable 3G RSSI Variation Threshold between R_C and R_P B_C: Current Measured 3G BSID
B_P: Previous Measured 3G BSID

1: Measuring 3G RSSI/BSID variation during given time interval;
2: **IF** R_C - R_P within R_T and B_C = B_P ***// Decision on User s motion state***
3: User motion state: stationary detected;
IF R_p - R_{P-1} within R_T and B_p = B_{P-1} ***//***
4: ***Prevention of duplicated WiFi scan***
5: Check Previous WiFi scan result;
6: **IF** Available WiFi exists
7: Turn ON WiFi Interface;
Perform WiFi Connection
8: considering WiFi RSSI;
9: **ELSE**
10: *RP = RP-1*
11: R_C = NULL
12: *Bp = BP-1*

        END
ELSE
    Request ANDSF Information; ***// Start ANDSF policy retrevial***
    IF Available WiFi exists in vicinity of UE
        Turn ON WiFi Interface;
        Perform WiFi Connection considering WiFi RSSI;
    ELSE
        RP = RP-1
        R_C = NULL
        Bp = BP-1
    END
ELSE
RP = RP-1
R_C = NULL
Bp = BP-1
END

Fig. 8. Algorithm for automatic Wi-Fi control method

4. Performance Evaluation

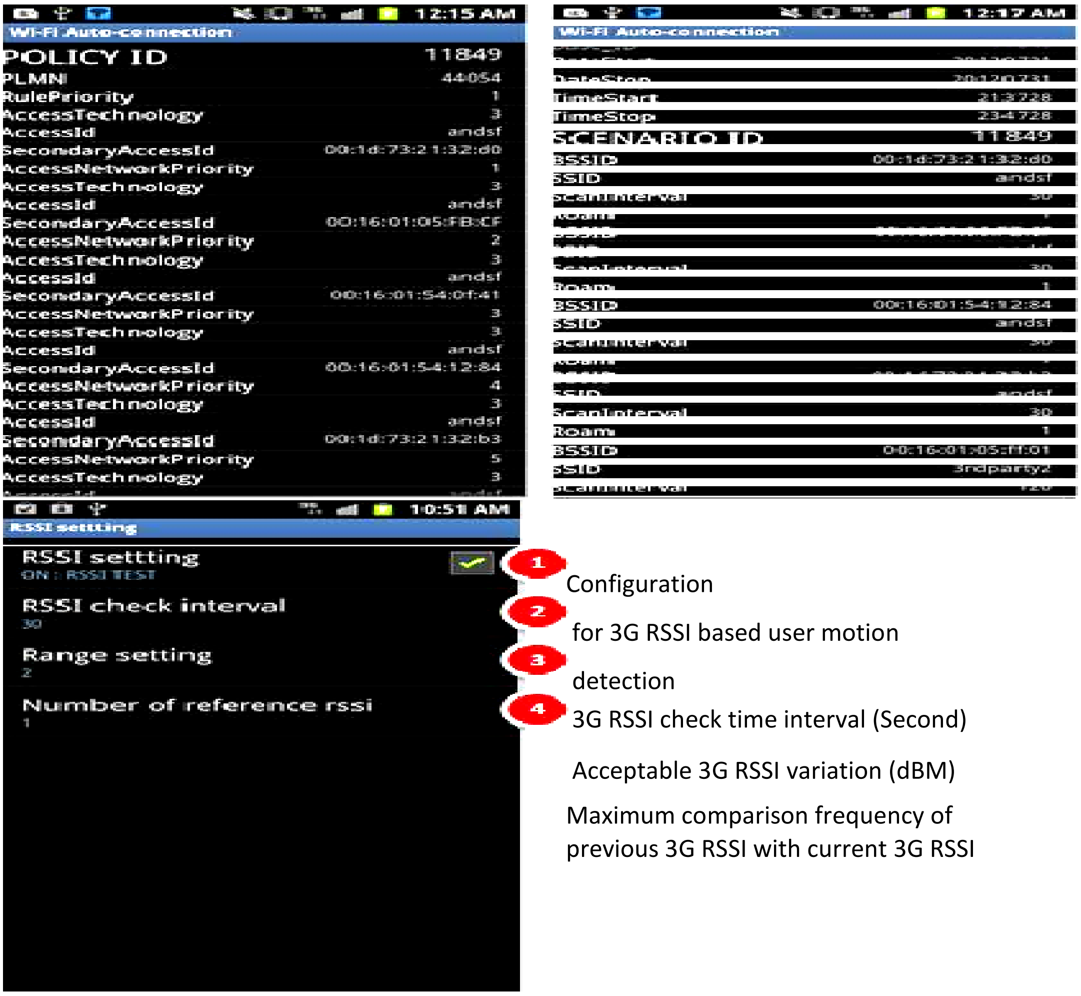

Fig. 9. ANDSF Information and User's motion detection function

To evaluate the performance of the proposed automatic Wi-Fi control method, we developed a prototype of the ANDSF server and client running the Android OS. The performance of the proposed method was compared to the Android Wi-Fi connection manager, which is a client-based Wi-Fi offloading solution that performs periodic Wi-Fi scanning.

Fig. 9 shows the ANDSF policy delivered by the ANDSF server and the user's motion detection function running on the Android OS. An ANDSF policy consists of the policy ID, including relevant parameters, such as a prioritized access network list and the validity period for the policy and scenario ID, including a list of available Wi-Fi information in the vicinity of the UE.

To validate the proposed automatic Wi-Fi control method and find the most appropriate values (3G RSSI check interval, and acceptable 3G RSSI range) for user motion detection, the proposed method was evaluated in terms of the number of Wi-Fi scans and the time cost for the Wi-Fi connection in a real environment with a fixed period of 10, 20, 30, 40, 50, and 60 seconds respectively.

Figure 10. Route for Wi-Fi scan and connection test (Ikebukuro in Tokyo)

Table 1. Time cost for Wi-Fi connections (3G RSSI check interval from 10 to 30 seconds)

Interval Time	3G RSSI_10			3G RSSI_20			**3G RSSI_30**		
RSSI Range	1	2	3	1	2	3	1	**2**	3
1st	28	19	20	59	49	49	349	**69**	40
2nd	43	30	19	89	39	49	99	**40**	40
3d	59	20	29	69	50	44	159	**43**	39
4h	49	29	42	49	49	29	279	**40**	39
5th	29	50	49	30	29	30	39	**73**	39
6h	34	39	18	49	69	63	279	**69**	99
7h	29	19	40	29	49	29	69	**39**	69
8th	31	25	53	89	30	29	69	**39**	40
9h	49	39	20	70	29	79	39	**39**	39
10h	19	30	20	109	49	30	40	**69**	39
Average	37	30	31	64.2	44.2	43.1	142	**52**	48.3

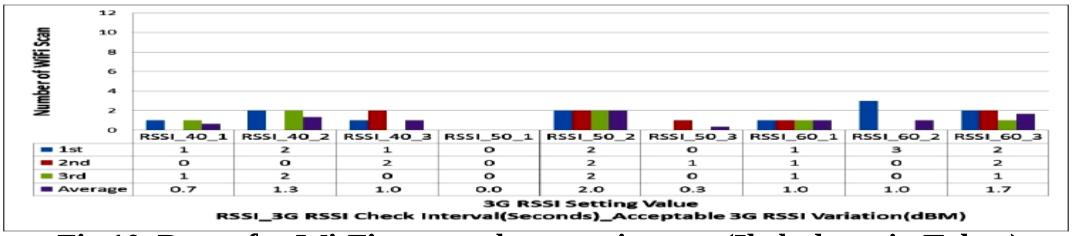

Fig.10. Route for Wi-Fi scan and connection test (Ikebukuro in Tokyo)

For the number of Wi-Fi scan tests, we moved along the selected route as shown in Fig. 10 in order to confirm how many times Wi-Fi scans were performed while we were moving. In addition, the time cost for the Wi-Fi connection was also tested in a location that provided a good quality of Wi-Fi in the Ikebukuro area.

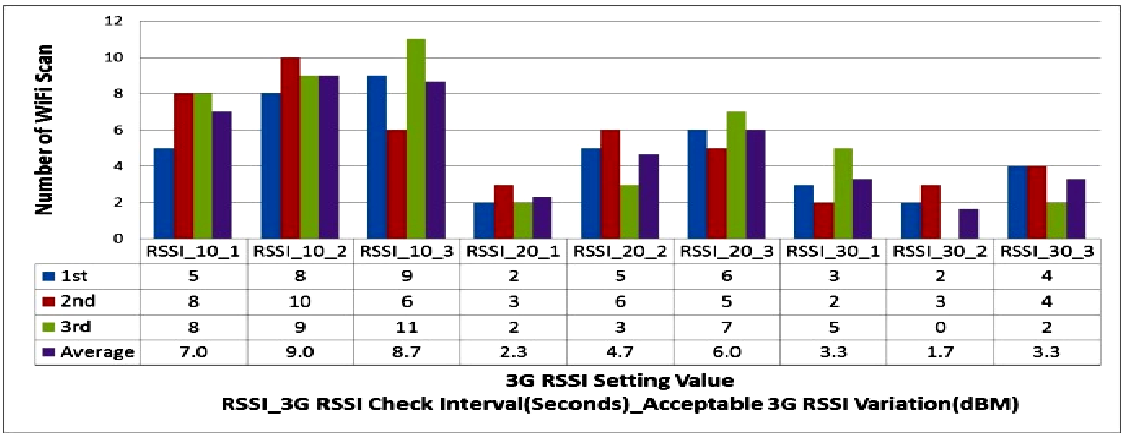

Fig. 11. Number of Wi-Fi scan test results (3G RSSI check interval from 10 to 30 seconds)

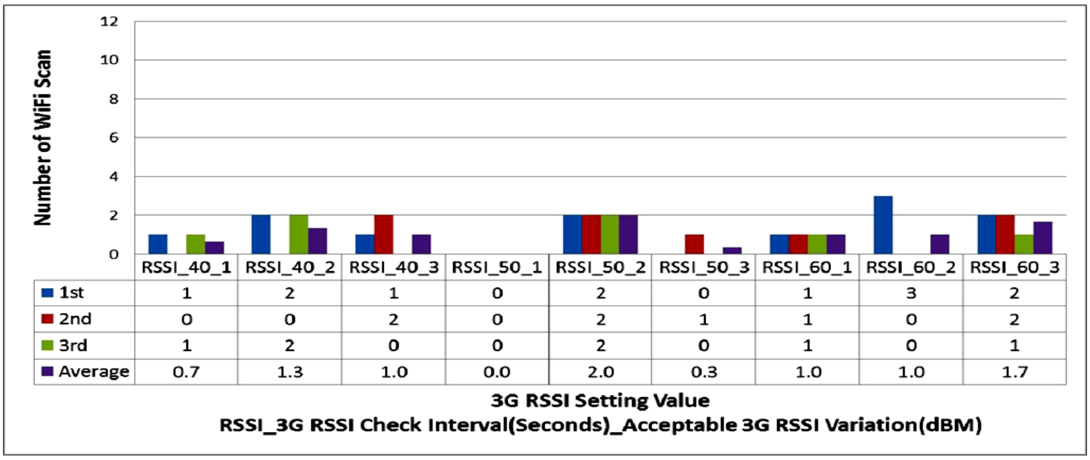

Fig. 12. Number of Wi-Fi scan test results (3G RSSI check interval from 40 to 60 seconds)

Table 2. Time cost for Wi-Fi connections (3G RSSI check interval from 10 to 30 seconds)

Interval Time	3G RSSI_40			3G RSSI_50			3G RSSI_60		
RSSI Range	1	2	3	1	2	3	1	2	3
1	89	49	89	410	59	159	189	70	310
2nd	89	50	130	260	59	109	130	144	129
3d	49	90	90	320	170	59	130	129	70
4h	89	49	129	-	-	-	-	-	-
5th	209	89	49	-	-	-	-	-	-
6h	50	50	49	-	-	-	-	-	-
7h	210	89	49	-	-	-	-	-	-
8th	59	60	49	-	-	-	-	-	-
9th	169	49	49	-	-	-	-	-	-
10h	49	89	49	-	-	-	-	-	-

Fig. 11 and Fig. 12 show the results of the number of Wi-Fi scan tests. With this result, we confirmed that the number of Wi-Fi scans decreased and the time cost for the Wi-Fi connection increased by increasing the 3G RSSI check interval time as shown in Table 1 and Table 2. Considering the above results, we decided that the 3G RSSI check interval time was 30 seconds and the acceptable 3G RSSI
variation was ±2 dBM for the configuration values of the proposed automatic Wi-Fi control method since the combination of these two values had good performance compared to the others.

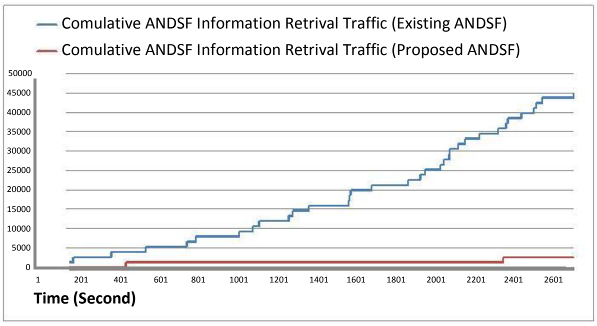

Fig.13. Cumulative Policy Retrieval Traffic

To verify the efficient ANDSF information retrieval operation of the proposed ANDSF-assisted system, the cumulative ANDSF information traffic was measured while riding on a train and walking for 44 minutes as shown in Fig. 13. Since the ANDSF information retrieval, only starts when the UE detects the motion state as stationary, a number of unnecessary ANDSF policy retrievals are not ever going to happen while users are moving. Thus, the intensive ANDSF information requests will be decreased dramatically compared to the existing ANDSF system.

Table 3. Average results of Wi-Fi scans and connection in Fig. 14

Number Of Wi-Fi Scan		Number of Wi-Fi Connection	
Android CM	Proposed CM	Android CM	Proposed CM
8.1	2.5	8.6	0.3

To verify the efficient Wi-Fi scanning and connection of the proposed automatic Wi-Fi control method, the proposed method was compared to the Android Wi-Fi connection manager, which performed periodic network scanning. The 10 tests were performed in the Ikebukuro area as shown in Fig. 10. According to the performance evaluation results, the proposed method, the number of Wi-Fi scans and connections was fewer than the number from the Android Wi-Fi connection manager. Table 3 shows the average results of Wi-Fi scans and connections.

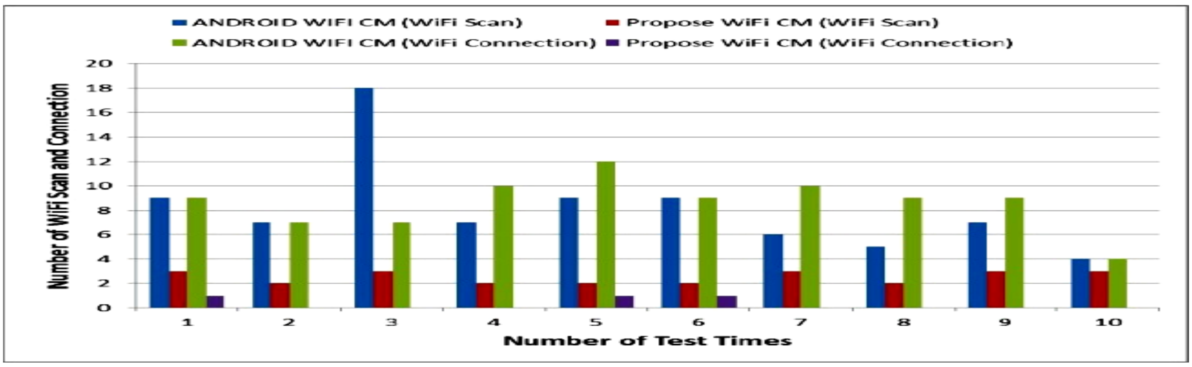

Fig. 14. Comparison of a number of Wi-Fi scans and connections

Table 4 shows the average results of Wi-Fi scans and connections on the train. We also evaluated the proposed method with the Android Wi-Fi connection manager while riding on the train for around one hour.

Table 4. Average results of Wi-Fi scanning and connection on the train

Number Of Wi-Fi Scan		Number of Wi-Fi Connection	
Android CM	Proposed CM	Android CM	Proposed CM
180	17	17	3

This is a result of the fact that the proposed automatic Wi-Fi control method can reduce the number of unnecessary Wi-Fi scans and connections while the user is moving so that it can prevent an unnecessary energy drain on the UE owing to its frequent Wi-Fi scanning.

5. Conclusion

In this paper, we proposed a novel automatic Wi-Fi control method in order to decide when a Wi-Fi scan and the ANDSF policy retrieval should be performed by the UE. Performance results confirmed that the number of unnecessary Wi-Fi scans and ANDSF information retrievals were dramatically reduced. Therefore, the proposed automatic Wi-Fi control method can lead to user experience enhancement, and thus mobile data offloading through Wi-Fi can be realized.

References

1. 3GPP TS 23.402, “Architecture Enhancement for Non-3GPP Accesses (Release 11),” December 2011.
2. 3GPP TS 24.312, "Access Network Discovery and Selection Function (ANDSF) Management Object (MO) (Release 11)," December 2011.
3. Cisco, Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011–2016, February 2012.
4. Jeongyeup Paek, Joongheon Kim, Ramesh Govindan, "Energy-efficient rate-adaptive GPS-based positioning for smartphones," MobiSys 2010, June 2010.
5. Muntean, V.H., Marius Otesteanu, "WiMAX versus LTE - An overview of technical aspects for Next Generation Networks technologies," ISETC 2010, November 2010.
6. Place lab: A privacy-observant location system. http://www.placelab.org/.