

# A Seamless Handover Method Using IEEE 802.21 and NTMobile for Android Smartphones

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**Abstract**—Smartphones usually experience problems in the form of both connection interruption and communication interruption time when switching between networks during communication. These problems reduce the convenience of using a smartphone. We propose a method based on a seamless handover system through cooperation with NTMobile (Network Traversal with Mobility), which realizes mobility by enabling switching between networks during communication. Our method additionally relies on the use of IEEE 802.21, which is the technology that facilitates network switching. The introduction of this method solves the problems associated with connection interruption and communication interruption time, thereby enhancing the convenience of using a smartphone.

## I. INTRODUCTION

The increasing popularity of Android smartphones has led to an increase in the opportunity presented by using these smartphones to switch between networks such as Wi-Fi and LTE. However, if network switching occurs during communication, smartphones often experience problems in the form of connection interruption because of changes in the IP address and communication interruption time because of the network connection process. We proposed NTMobile [1] that realizes mobility by enabling switching between networks during communication. In this paper, we propose a method based on a seamless handover system without adding any modification to network equipments by cooperating with NTMobile and IEEE 802.21 [2]. We implement IEEE 802.21 by using the ODTONE (Open Dot Twenty One) [3], which is the open source implementation of IEEE 802.21. However, ODTONE lacks the functionality of IEEE 802.21, and this prompted us to develop the required IEEE 802.21 functionality as well as the function that enables cooperation with ODTONE. We have implemented a prototype system on a Android smartphone, and evaluated the IEEE 802.21 functions of ODTONE.

## II. PROPOSED METHOD

An NTMobile node (NTM node) has two kinds of IP addresses: a real IP address assigned by a real network and a virtual IP address. The virtual IP address remains unchanged even when the NTM node switches networks. It realizes mobility by enabling switching between networks during communication. However, the introduction of NTMobile alone does not solve the problem of communication interruption time. Therefore, we propose a method based on a seamless handover system to introduce cooperation with both NTMobile and IEEE 802.21.

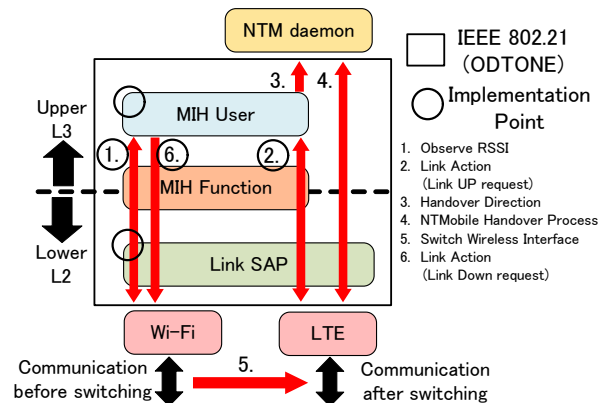


Fig. 1. Proposed Method.

Fig. 1 shows the overview of our proposed method. Usually, the NTM daemon, which performs NTMobile functions when NTMobile is used, observes the routing table and detects the handover between networks. However, because the NTM node could not perform the handover process in advance, communication interruption time occurred during the handover process. In the proposed method, we reconsider the handover detection process. Our solution involves using the functionality of IEEE 802.21 to reduce the communication interruption time by executing the handover process in advance. MIH User, which is the handover management function of IEEE 802.21, observes the state of connection constantly. For example, if the Wi-Fi signal strength is lowered, the MIH User transmits the connection indication to the LTE interface before disconnecting from Wi-Fi. After the MIH User confirmed that it had connected to the LTE network, it indicates the NTMobile handover process (preparation of connection to correspondent node) to the NTM daemon, and when it becomes an LTE connection using NTMobile, the NTM node switches the network from Wi-Fi to LTE. Accordingly, it is possible to realize a seamless handover via the NTM node.

## III. IMPLEMENTATION

We implement IEEE 802.21 by using the ODTONE. The implementation required us to modify both the MIH User of ODTONE and the NTM daemon. We implemented the handover direction, which is the cooperation function of NTMobile and IEEE 802.21 (3. Handover Direction) and the NTMobile handover process (4. NTMobile Handover Process)

by using the UNIX domain socket. Furthermore, we implemented ODTONE and NTMobile on an Android smartphone to evaluate the IEEE 802.21 function of ODTONE and the cooperation function between NTMobile and ODTONE. However, because the MIH User and Link SAP, which is the function that enables connection to interfaces of ODTONE, lacks functions of IEEE 802.21, such as the observation of signal strength (1. observe RSSI) and link up and link down requests to the interface (2. and 6.Link Action), we were unable to realize seamless handover. Because ODTONE lacks the functions of IEEE 802.21, we implemented the functions of IEEE 802.21 on the MIH User and the Link SAP of ODTONE. The empty circles in Fig. 1 show the points that were implemented to ODTONE. We implemented the Link Get Parameters message, which is the observation signal strength, and the Link Action message, which is a link up and link down request to the interface with the MIH User. In the Link Get Parameters message, we implemented the message to transmit the observation indication of signal strength to the Link SAP and to check the value of the signal strength at the MIH User. In the Link Action message, we implemented the message to transmit the connection indication to the Link SAP. MIH User uses the list of access points received from the Link SAP and the signal strength from the Link Get Parameters to decide the destination network and transmits the Link Action to the Link SAP. Furthermore, once the networks have been switched, we implemented a message to transmit the disconnect indication to the Link SAP to disconnect the network before connection. We implemented Link SAP by modifying `sap_80211_linux`, which is the Link SAP program of ODTONE. However, because `sap_80211_linux` can only be used for a Wi-Fi interface, we plan to modify it to enable it to be used on both LTE and Wi-Fi interfaces.

#### IV. EVALUATION

We implemented ODTONE on a commercially available Android smartphone (Google Nexus 6 Android 6.0.1), and evaluated our system. Because cooperation between NTMobile and ODTONE has already been shown to succeed, in this paper, we confirmed that IEEE 802.21 functions with ODTONE. In addition, `sap_80211_linux` was developed to function only on a Wi-Fi interface, we used this evaluation to confirm the handover to the Wi-Fi network. Fig. 2 shows the evaluation environment, which we used to evaluate the IEEE 802.21 functions of ODTONE. An Android smartphone was used to execute ODTONE. This involved moving the smartphone from an area outside the Wi-Fi range to an area covered by Wi-Fi. In this way, we evaluated whether the Link Action message performed normally and enables connection to the network. Fig. 3 shows the ODTONE logs on the Android smartphone. Window 1 presents the log of the MIH User, Window 2 shows the log of the MIH Function, which is the transmission function of IEEE 802.21 between the MIH User and the Link SAP, and Window 3 contains the log of the Link SAP. Window 1 confirmed that the Link SAP started the process of scanning the list of access points (1. Search

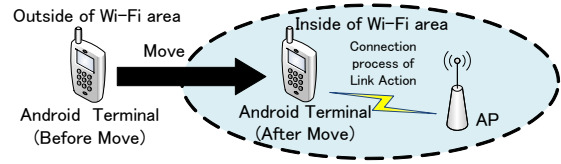


Fig. 2. Evaluation environment.

The screenshot shows three terminal windows with red boxes and numbers highlighting key log entries:

- Window 1 (MIH User):**
  - 3. Detect the AP
  - 4. Send Link Action
  - 8. Connection Success
- Window 2 (MIH Function):**
  - 2.5.7. Intermediary between MIH User and Link SAP
- Window 3 (Link SAP sap\_80211):**
  - 1. Search AP
  - 6. Connection Process

Fig. 3. Operation Verification on the Android terminal.

AP), and Window 3 (3. Detect the AP) shows that the MIH User received the list of access points from the Link SAP via the MIH Function. Moreover, we confirmed that the MIH User transmitted the Link Action message to the Link SAP by receiving the list of access points shown in Window 3 (4. Send Link Action message). Window 3 (6. Connection Process) also shows that the Link SAP executed the connection process to the Wi-Fi network. After the connection process of the Link SAP, we confirmed that it succeeded to connect to the Wi-Fi network as shown by the Link Action message in Window 1 (8. Connection Success) and the Wi-Fi status icon.

#### V. CONCLUSION

In this paper, we proposed a method based on a seamless handover system involving cooperation between NTMobile and IEEE 802.21 on an Android smartphone. In addition, we evaluated the cooperation function of ODTONE and NTMobile, and we implemented the IEEE 802.21 functions to ODTONE and evaluated it on an Android smartphone. As a result, we confirmed that it is possible to achieve cooperation between NTMobile and ODTONE, and that IEEE 802.21 functions execute on an Android smartphone. Hereafter, we plan to complete implementation of the Link SAP and perform an evaluation of the communication interruption time when switching networks by our proposed method. On the other hand, it is possible that power consumption of the battery is increased by our proposed method. Therefore, We also plan to evaluate a power consumption of the battery after completing the implementation.

#### REFERENCES

- [1] K. Kamienuo, et al., "Implementation and evaluation of ntmobile to achieve ip mobility in ipv4 and ipv6 networks," *IEEE GCCE 2012*, 2012, pp. 125–129.
- [2] IEEE 802.21 standard, "local and metropolitan area networks - part 21: Media independent handover services", 2009.
- [3] D. Corujo, et al., "Using an open-source ieee 802.21 implementation for network-based localized mobility management," in *IEEE Communications Magazine*, vol. 49, no. 9, 2011, pp. 114–123.



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## 1. Introduction

### The Demands for mobile communication is increasing

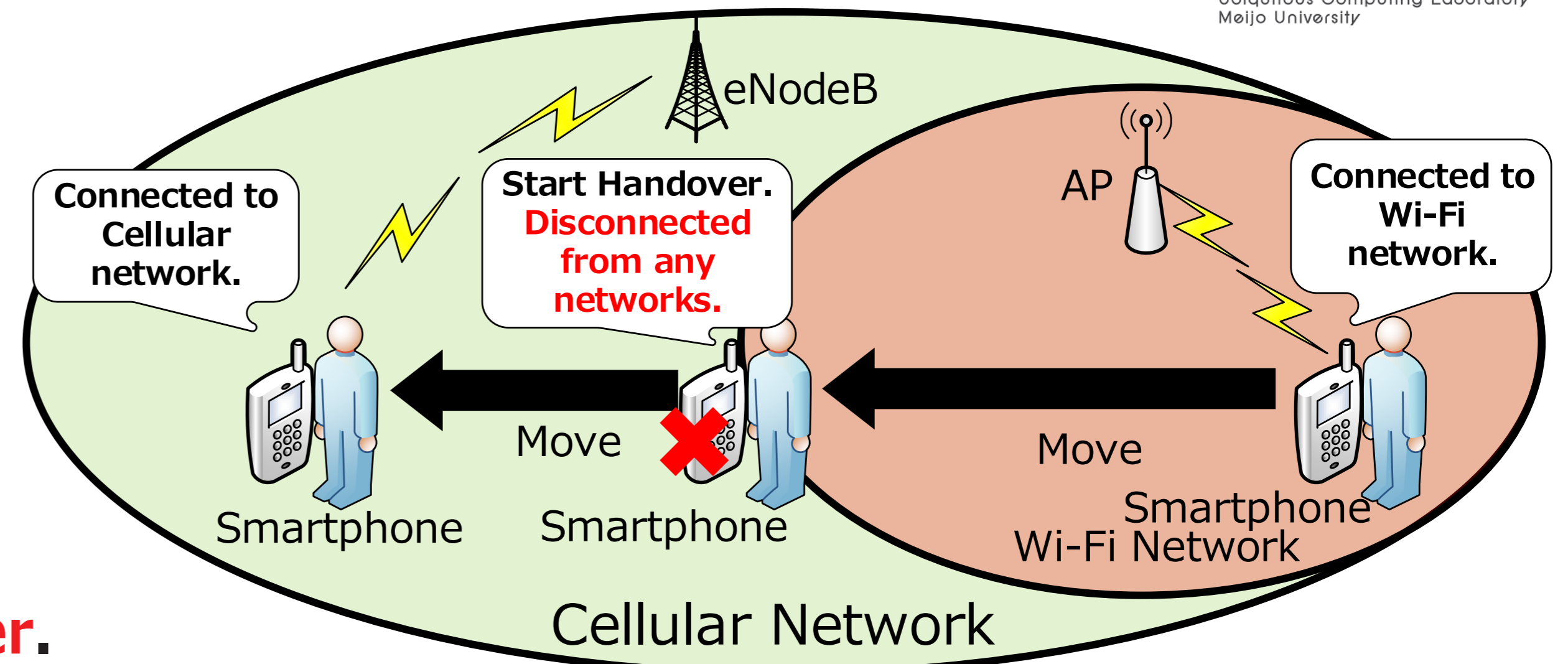
- Fast spreading smartphones and tablets.
- Switching between Wi-Fi and cellular networks.

### Problems by switching networks during communication

- Connection interruption from the change of IP address.
- Communication interruption time due to the switching process.

Current Android smartphones **cannot support a seamless handover.**

It is a **problem for real time communication** such as VoIP.



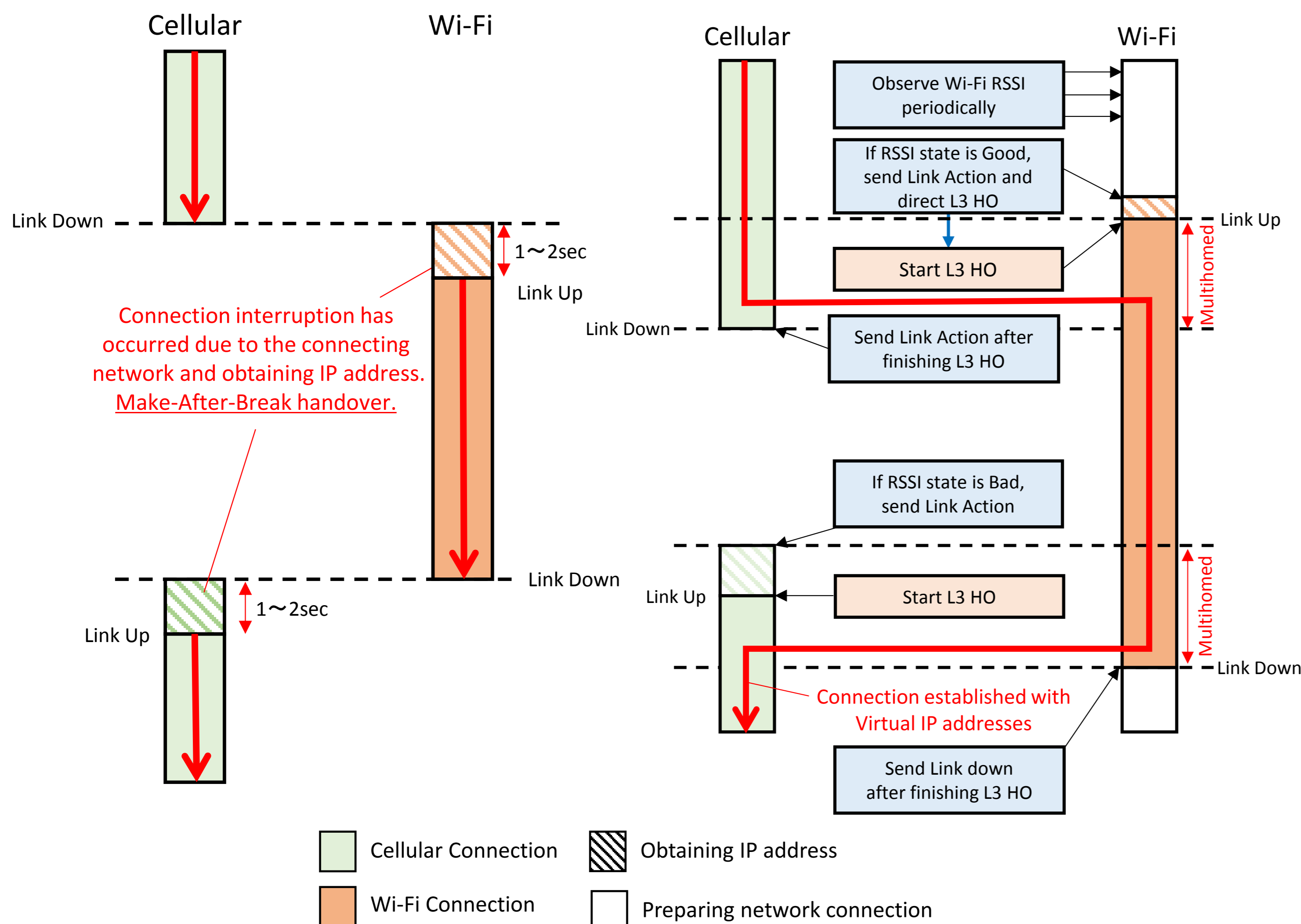
Current handover method on Android Smartphone

## 2. Proposed Method

### Changing the handover process from Make-After-Break to Multihomed Make-Before-Break.

### Modifying only terminal side

- Using Network Traversal with Mobility (NTMobile) for L3 handover.



Normal handover process

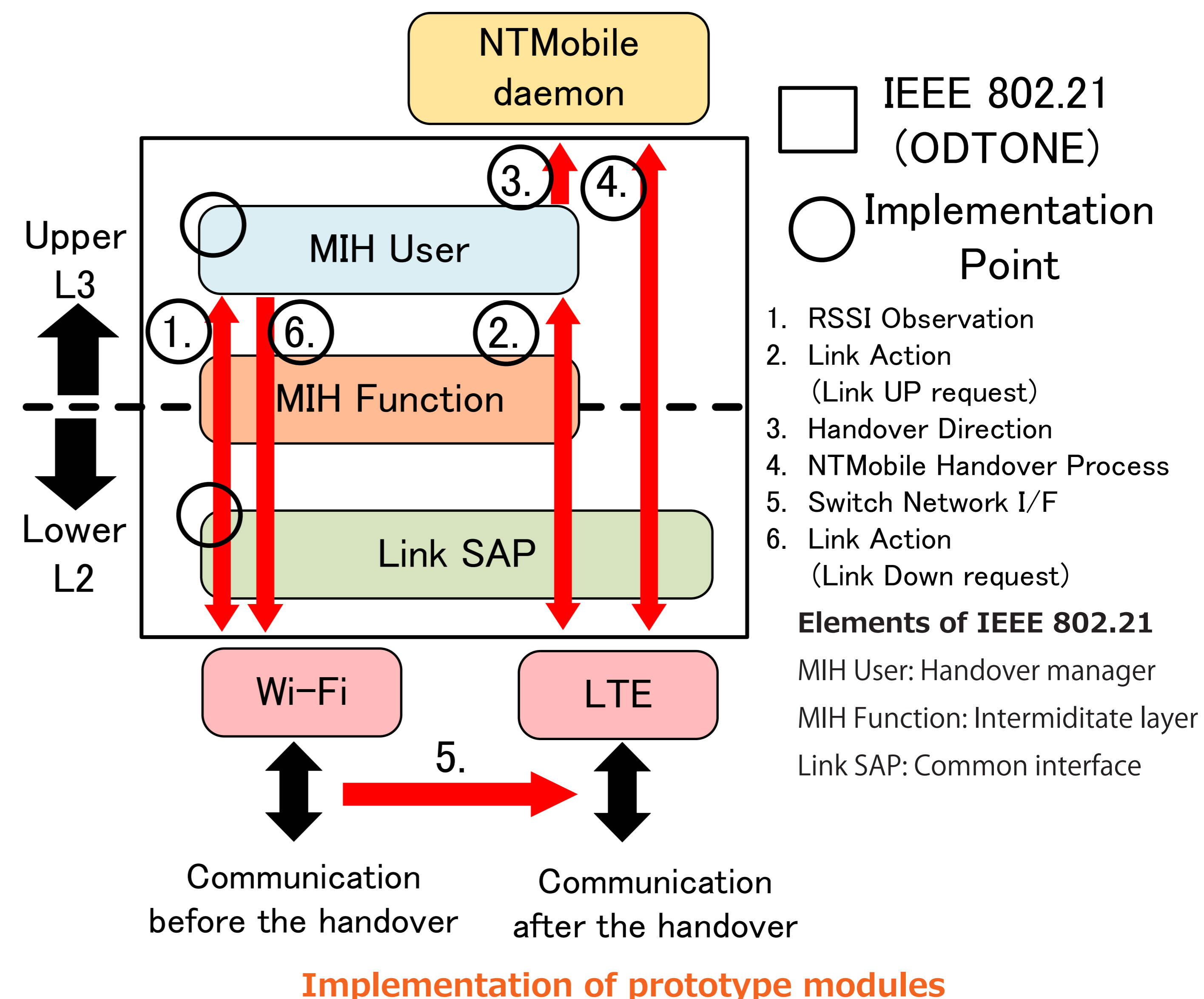
Proposed method handover process

## 3. Implementation

### Cooperation function of NTM daemon and ODTONE

- Only Wi-Fi related functions in IEEE 802.21.

### Modifying the connectivity service in Android OS



Implementation of prototype modules

## 4. Verification

### Verification using Android smartphone

- Check status of network I/Fs when connecting to Wi-Fi network.
- Smartphone can connect to cellular network.

```

root@hammerhead:~# ip link show wlan0
21: wlan0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP mode DORMANT qlen 1000
    link/ether 8c:3a:e3:17:2e:0c brd ff:ff:ff:ff:ff:ff
root@hammerhead:~# ip link show rmnet0
2: rmnet0: <> mtu 1500 qdisc pfifo_fast state DOWN mode DEFA
    ULT qlen 1000
    link/[530]
    
```

Original Android OS

Original Android disconnected from cellular network forcibly.

Wi-Fi state is UP  
Cellular state is DOWN

```

root@hammerhead:~# ip link show wlan0
21: wlan0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP mode DORMANT qlen 1000
    link/ether 8c:3a:e3:17:7a:50 brd ff:ff:ff:ff:ff:ff
root@hammerhead:~# ip link show rmnet0
2: rmnet0: <UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UNK
    NOWN mode DEFAULT qlen 1000
    link/[530]
    
```

Modified Android OS

Modified Android can connect both networks.

Wi-Fi state is UP  
Cellular state is UP

### Verification of IEEE 802.21 functions

- Check the operation when handover to Wi-Fi.
  - Observation of Wi-Fi RSSI.
  - Sending a Link Action message (Link UP request) to Wi-Fi I/F.

Verification of ODTONE on Nexus 6.

2.5.7. Intermediary between MIH User and Link SAP

Android smartphone could connect to Wi-Fi network according to the direction from ODTONE.

## 5. Future Work

- Evaluation the proposed method after completing the implementation
- Consideration of other handover triggers.
  - User settings, link speed, packet jitter and so on.