Mobile Network Configuration for Large-scale Multimedia Delivery on a Single WLAN

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***Abstract*—We report performance measurements and analyses of a variety of wireless networks to arrive at an appropriate network structure configuration for smooth multimedia streaming service with a variety of smart devices in a single wireless network environment. Unlike the usual infrastructure network, configurations such as the IEEE 802.11 ad hoc network and the Wi-Fi direct network use direct connections between devices without going through a wireless AP. Therefore, these configurations prevent concentrating traffic at the wireless AP. We generated three types of wireless network performance measurements and arrived at a suitable network for multimedia streaming service using a variety of smart devices. The wireless network was configured in a structure for efficient multimedia streaming service in a single wireless LAN environment, and subsequently, the network performance was measured.**

Keywords—media streaming; ad hoc network; Wi-Fi Direct; video delivery

I. Introduction

Provision of Internet services is spreading because of the rapid proliferation of non-PC devices, such as smart mobile devices, the spread of cloud computing, and emerging standards, such as N screen, that share content among multiple devices and platforms [1].

Using Miracast [2] techniques, part of N screen technology, it is possible to share multimedia content (music, pictures, and video) with multiple devices simultaneously. However, using these techniques to share content on multiple devices in an environment with a single wireless LAN is limited by the traffic generated. For example, multimedia streaming in a single wireless LAN environment, such as a conference room or a classroom for a meeting or class, to perhaps 30 or more devices while providing smooth multimedia streaming service is difficult because a large amount of traffic is concentrated on the wireless LAN.

To solve the problem, one may consider a wireless ad hoc network configuration that enables a one-to-one connection among devices instead of an Infrastructure network. Unlike Infrastructure network configurations, ad hoc networks connect devices with each other, independent of wireless access points (APs), to transfer data directly between devices. This method of connection can resolve the problems of concentrated traffic on a wireless AP.

However, the Android OS, which accounts for a large share of smart device operating systems, does not support the IEEE802.11 ad hoc network standard for security reasons. The configuration of such a network is therefore not easy, needing administrator privileges to configure rooting. An alternative to using similar techniques is Wi-Fi Direct. Wi-Fi Direct can be used to transfer data through a direct connection among smart devices within this new standard announced by the Wi-Fi Alliance. Wi-Fi Direct can be used without a wireless AP. Most android OS devices currently support Wi-Fi Direct.

This study uses a variety of smart devices and laptops for performance measurements of infrastructure networks, ad hoc networks and Wi-Fi Direct networks and presents an analysis of the results. Based on these results, wireless network structures are configured to overcome the traffic limitation in a single wireless network environment when multimedia streaming, and the resulting performance is measured.

The remainder of this paper is organized as follows. Section 2 describes related work, and Section 3 describes the construction and standards of wireless networks. Section 4 describes the performance measurement of each type of wireless network and analyzes the results. Section 5, based on the results of Section 4 in a single wireless LAN environment, determines a wireless network suitable for multimedia streaming and performance measurement of a multiple-connection wireless network whose results can be analyzed. In Section 6, a wireless network structure is configured to overcome the traffic limitations of a single wireless network environment in which multiple devices are engaging in multimedia streaming, and the resulting performance is measured. Finally, in Section 7, we conclude the paper.

II. Related Work

Existing research on wireless environments focusses on the high-speed transfer rates and quality assurance of multimedia rather than on the constraints of traffic when multiple devices invoke multimedia streaming.

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TABLE 1. ROUTING TABLE OF THE CONFIGURATION OF AN AD HOC NETWORK

Destination	Gateway	Genmask	Flags	Metric	Ref	use	Iface
192.168.49.0	*	255.255.255.0	U	0	0	0	eth 0

R. AlTurki et al. [3] report work on supporting video streaming over ad hoc networks and present an analysis using the OPNET simulation environment. They then evaluate the performance of a video streaming application over ad hoc networks by simulating a few scenarios while varying video quality, network size, and 5 different routing protocols. The simulations demonstrate that it is possible to stream fairly good quality video over medium sized ad hoc networks. However, they do not consider multicast because they assume that each application requires a unique connection. They note that a network with 9 nodes can support up to 800 Kbps of multimedia traffic (reasonably high-quality video) at 100% throughput. A network with 25 nodes could support up to 200 Kbps of traffic (medium quality video) with 80% throughput. However, the throughput in larger networks decreases rapidly with over 80% packet losses for fairly small traffic rates.

H. Yoon et al. [4] propose Decentralized cOllaborative Media content Streaming (DOMS) that realizes flexible media content sharing by exploiting collaborative segment-based streaming among Wi-Fi devices via temporarily-established direct links. The prototype devices show improved sharing performance by supporting twice as many concurrent devices compared with conventional non-collaborative streaming at target media quality.

T. Hwang et al. [5] proposed the Enhanced Adaptive Fast Replica (EAFR) method to be able to transfer content by distributing the network traffic effectively using the transport bandwidth of the Digital Living Network Alliance (DLNA); a proxy is not used in the transmission path.

Z. Fu et al. [6] describe the design and implementation of a transmission control protocol (TCP)-friendly transport protocol for ad hoc networks. The key novelty of their design is to perform multi-metric joint identification for packet and connection behaviors based on end-to-end measurements. Their NS-2 simulations show significant performance improvement over wired TCP-friendly congestion control and TCP with explicit-link-failure-notification support in ad hoc networks.

S. Lee et al. [7] describe a hop-based priority (HBP) technique using 802.11e for ensuring good Quality of Service (QoS) of a multimedia streaming service. Multimedia streaming data packets are assigned a higher priority after every hop. This assignment can minimize the contention between the previous packet and the next packet. However, when many random routes exist, some routes have a lower priority than others at the cross-route node and cannot obtain a channel.

These research studies mostly consider the transfer of content between a few devices. Research is insufficient on a single wireless LAN environment using multiple devices transferring content simultaneously. Such an environment with multiple devices has a problem in that performance is not guaranteed because of traffic restrictions. Thus, in this paper, we measure the performance of each wireless network and then identify the appropriate wireless network when streaming multimedia to multiple devices

III. WIRELESS NETWORK CONSTRUCTION AND STANDARDS

This Section describes the construction of a standard wireless network, such as an ad hoc network; it also describes how to configure the network prior to the experiment, limiting the number of Wi-Fi Direct connection devices, and how to configure the wireless LAN standard when connecting between devices to support the wireless LAN.

A. IEEE 802.11 Ad Hoc Networks Configuration

IEEE 802.11 ad hoc networks are not supported on android devices because of security issues. There are two ways to configure an ad hoc network with android devices.

First, it is possible to replace the IEEE 802.11 ad hoc network with a wpa_supplicant file [8]; this file supports the IEEE 80211 ad hoc network configuration in obtaining administrator privileges on android devices through rooting. A wpa_supplicant file is supported in wireless LAN security standards on android devices. It is not easy to use multimedia streaming by configuring ad hoc networks in this way because of rooting issues and changes to system files.

Secondly, an ad hoc network can be configured through a hotspot using tethering. This method has the advantage that it does not need to be routed to when configuring the network. However, devices not supporting tethering cannot configure ad hoc networks.

We tried to check the routing table of a configuration using tethering in an ad hoc network to confirm the group owner of the connected devices. In this circumstance, the Group Owner is the device that created the hot spot for configuring the ad hoc network. This process should confirm whether traffic passes through the Group Owner when communicating between connected devices. If it passes through the group owner, traffic is concentrated at the group owner, such as an infrastructure network. This means that the ad hoc network was not properly connected.

Table 1 is the Routing table for an ad hoc network configured using tethering. The Gateway is expressed as the * symbol when the destination is 192.168.49.0. This means that the destination is reached directly, without going through an intermediate point when communicating over the internal network. Therefore, the network configuration using tethering is an ad hoc network.

TABLE 2 DEVICES FOR THE PERFORMANCE MEASUREMENT OF WIRELESS NETWORKS

Device name	Manufacturer	CPU	Operating System	RAM	Wireless LAN Specification
Galaxy Note 10.1	Samsung Electronics	ARM Holdings Cortex-A9 Architecture 1.4GHz Quad Core	Android 4.1.2 Jellybean	2GB DDR2 SDRAM	802.11 a/b/g/n
Galaxy Tab 7.0	Samsung Electronics	1GHz Single Core	Android 2.3.6 Gingerbread	512MB DDR SDRAM	802.11 a/b/g/n
Optimus LTE2	LG Electronics	Qualcomm Krait 200 Architecture 1.5GHz dual core	Android 4.1.2 Jellybean	2GB LPDDR2 RAM	802.11 a/b/g/n
Xnote Z2	LG Electronics	Intel Mobile Core2 Duo T5600 (Merom)	Ubuntu 12.04.3 LTS	1GB DDR2 PC2-5300	802.11 a/b/g
iPad	Apple	1GHz dual-core ARM Cortex-A9	iOS 7.04	1GB LPDDR2 SDRAM	802.11 a/b/g/n

B. Restriction of the Number of Connection of a Wi-Fi Direct Group

When creating a Wi-Fi Direct group for more than 2 devices, the group might have restrictions imposed by the device manufacturer and by the performance of the group owner. The Group Owner is a device that can control and manage a group.

The number of devices in the group for this experiment was 5 units plus the group owner.

C. Wireless LAN Restrictions when Supporting a Wireless Network Connection among Devices

Wireless LAN technology has been established as a set of 802.11x standards. The wireless standard most mobile devices currently support is IEEE 802.11n. The IEEE 802.11n standard is a revision to improve the bandwidths of IEEE 802.11g and IEEE 802.11a. By using a channel bandwidth of 40 MHz, IEEE 802.11n provides up to 600 Mbps maximum data transfer rate. In contrast, the maximum data transfer rate of IEEE 802.11g is 54 Mbps [9].

To use the IEEE 802.11n standard between two devices, the following two conditions must be satisfied. First, both devices must support IEEE 802.11n. Second, it is necessary to set the WPA2-PSK security mode and to use the AES encryption algorithm. Our experiment satisfies these conditions.

IV. WIRELESS NETWORK PERFORMANCE MEASUREMENTS

In this Section, we configure an Infrastructure network, Wi-Fi Direct and an ad hoc network; we then measure their performance and compare the results. We use these results to discuss network configurations suitable for multimedia streaming.

A. Experimental Environment

1) Devices and wireless LAN standards for experiment

The devices used for this experiment are shown in Table 2. These devices are not able to represent the all smart devices. However the validity of the experimental results increased by using the Samsung Galaxy Note and the LG Optimus in the Android OS devices, which market share is high. The wireless LAN standards of the experiment were in IEEE 802.11 mode among all devices except the laptop; the laptop used IEEE 802.11g mode. The ad hoc network configuration used the IEEE 802.11g mode because of the security issue. The laptop used a wireless LAN card supporting the IEEE 802.11n standard; we configured the security mode for tethering for the ad hoc network. It was possible to connect in IEEE 802.11n mode.

2) Measurement Methods

We measured the Round Trip Time (RTT) with ping and bandwidth with iperf for our performance measurement of each wireless network.

Each device sent 10 pings to the IP address of its server to measure the mean value and average deviation for each RTT measurement. Default values were used for all parameters except for the number of pings.

Bandwidth measurements used iperf to capture the TCP transfer rate for packets from the client device to the server. The server had better performance when the devices were interconnected because the network performance did not impact the device performance. This experiment transmitted TCP packets for 10 seconds from the client device to the server device, after which the bandwidth was measured from the sizes and numbers of packets transferred. All parameter values were defaults except for the packet transfer time and the settings of the client and server.

3) The Wireless Network Configuration for Performance Measurement

. We configured wireless networks for performance measurements of an infrastructure network, an ad hoc network and a Wi-Fi Direct network. The performance of the infrastructure network was measured with public AP and private AP. A number of devices connected to the public AP that were not participating in the experiment. This method was used to study the effect of the number of devices connected to the wireless AP on the performance of the network. Ten or more devices not used in the experiment were connected to the public AP. In contrast only four connected devices to the private AP were used in the experiments.

The configuration of the IEEE 802.11 ad hoc network was to create a hotspot with the group owner tethered. The other devices were connected to the group owner.

Only the Samsung Galaxy Note 10.1 and Optimus LTE2 support Wi-Fi Direct. Therefore, we measured Wi-Fi Direct performance using only these two devices.

B. Experimental Results

Figure 1 is a graphic representation of the RTT and bandwidth measurement results for the wireless networks. Performance values were similar using the Wi-Fi Direct and IEEE 802.11 ad hoc networks and lower in the network Infrastructure configuration. In case RTT, the transmission delay time of the latter was higher than that of the IEEE 802.11 ad hoc network and Wi-Fi Direct, which transmitted directly between devices because the infrastructure network transmits the ping between devices via the wireless AP, i.e., the number of hops increases. In case bandwidth, performance may be degraded due to channel interference in the vicinity of the wireless AP and beaconing. Additionally, a lower performance value was measured for the infrastructure network than for the directly connected devices. When a packet is received by the wireless AP, it is processed for such purposes as packet filtering (for security problem) before being transmitted to its destination. Therefore, the performance decline in the network Infrastructure scenario. Furthermore, the RTT value increases when many devices are connected to the wireless AP; its processing speed slows down due to its tasks in security management, such as packet filtering and network management.

The result is that the IEEE 802.11 ad hoc and Wi-Fi Direct networks are more stable when streaming multimedia than the infrastructure network. The IEEE 802.11 ad hoc and Wi-Fi Direct networks, in contrast to the infrastructure network, are unaffected by processing delays because their traffic does not pass through the wireless AP. However, configuring the IEEE 802.11 ad hoc network is not easy. In contrast, most Android devices support Wi-Fi Direct, facilitating an easy setup. Thus Wi-Fi Direct is more suitable for multimedia streaming.

V. Performance Measurement of Multiple Devices Using Wi-Fi Direct

In this Section, we describe performance measurements with an increasing number of devices connected by Wi-Fi Direct and discuss the results. The method for measuring the performance was the same as that described in Section 4.

A. Experimental Environments

1) Devices for the experiment and the wireless LAN standards

The Samsung Galaxy player 5.8 was used in this experiment. Its CPU is an ARM Holdings Cortex-A9 architecture 1 GHz dual-core, and its operating system is Android 4.0.4 (“Ice Cream Sandwich”). Memory was 1GB EER 2 SDRAM; wireless standards supported are IEEE 802.11a/b/g/n. The maximum number of connected devices

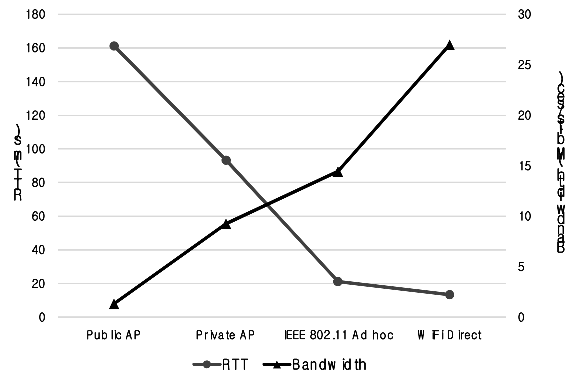

Fig. 1. Performance measurement of wireless network

is 5, except for the group owner when this device creates a group.

We used the IEEE 802.11n mode because it supports higher throughput than IEEE 802.11g. Wi-Fi Direct supports WPA2-PSK/AES security standards, and the devices used for this experiment supported the IEEE 802.11n mode.

2) Method of Measurement

RTT and bandwidth were measured while increasing the number of devices connected to the group owner, one at a time; the changes in performance were measured as a function of the number of devices. When RTT and bandwidth were measured, the group owner acted as a server; devices that participated in the group (except the group owner) were clients. The client devices sent a TCP packet and pinged the server simultaneously. The Group Owner examined the throughput when it received a TCP packet and pinged the equipment simultaneously. The environment to measure bandwidth and RTT was the same as that described in Section 4.

B. Experimental Results

Figures 2 show the measurements of RTT and bandwidth with multiple devices using Wi-Fi Direct. For RTT, an average value of approximately 26ms was maintained despite increasing the number of connected devices. This number is similar to the Wi-Fi Direct RTT measurement results described in Section 4. Because devices in Wi-Fi Direct connect directly, the path of the RTT measurement of

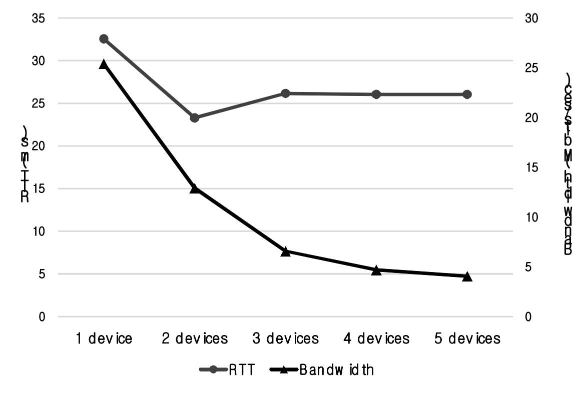

Fig. 2. Performance measurement of connecting multiple devices using Wi-Fi Direct

Wi-Fi Direct is the same. Therefore, the number of devices does not affect the RTT value.

However, bandwidth values decrease in inverse proportion to the increasing number of devices. Wi-Fi Direct devices use the same channel.

Configuring a network using Wi-Fi Direct for the smooth use of multi-media streaming with multiple devices is almost impossible because of the problem of bandwidth reduction due to the use of the same channel. Therefore, wireless network structure configuration is required to solve this bandwidth problem.

VI. Wireless Network Configuration for Multimedia Streaming and Its Measured Performance

In this Section, a wireless network structure is suitably configured for multimedia streaming, and its performance is measured.

A. *Wireless Network Configuration for Multimedia Streaming*

Progress in streaming is difficult when using only a single wireless network and multiple devices. Wi-Fi Direct restricts the number of device connections; therefore, it is difficult to connect multiple devices. Additionally, when using an infrastructure network, traffic is concentrated at the wireless AP; therefore, using the infrastructure network for streaming is difficult. Hence, we have combined Wi-Fi Direct with an infrastructure network for smooth multimedia streaming.

Figure 3 shows the network configuration. Six devices are connected using Wi-Fi Direct as a single group; this is for implementing multimedia streaming to these groups. For example, using five Wi-Fi Direct groups at once supports multimedia streaming to 30 units. The Wi-Fi Direct group owners are then configured in an infrastructure network using a wireless AP. With the network configured in this way, communication is possible between a Wi-Fi Direct group owner and every other device by exchanging multimedia data using the infrastructure network; the Group Owner of each group transmits multimedia data it receives to its group.

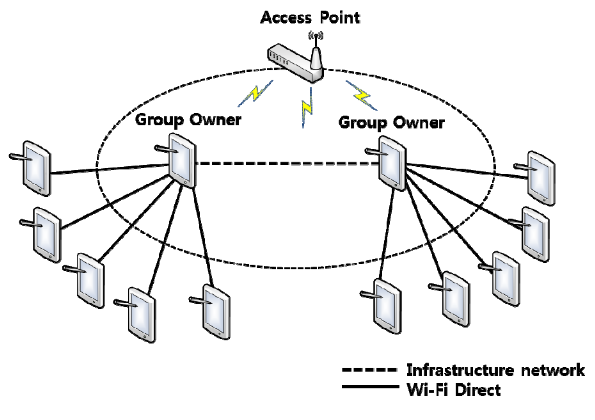

Fig. 3. Wi-Fi direct and Infrastructure network configurated for multimedia streaming

B. *Performance Measurements*

The experimental environment was configured, and its performance was measured using the network structure already presented.

We used the Samsung Galaxy player 5.8, Samsung Galaxy note 10.1 and a Samsung note 10.1, 2014 edition (Galaxy 2014 for brevity) in this experiment. The Galaxy 2014 specifications are as follows. The CPU was an ARM Holdings Cortex-A15 architecture 1.3 GHz quad-core and ARM Holdings Cortex-A7 architecture 1.3 GHz quad core, the operating system was Android 4.3 Jelly bean, and memory (RAM) was 3GB LPDDR3 SDRAM; the wireless standards supported were IEEE 802.11a/b/g/n/ac. The limiting number of connected devices was 7, except for the group owner, when groups were created using this device. The specification of the Galaxy Player 5.8, the experimental equipment of Section 5, and the specifications of the Samsung Galaxy note 10.1 are listed in Table 1.

The Wi-Fi Direct network was configured using the Samsung Galaxy player 5.8 and Samsung Galaxy 2014. In this scenario, the Galaxy 2014 was the group owner. Improved performance was expected from the group owner in the Wi-Fi Direct network configuration because the impact of the devices on network performance was removed. Here, the Galaxy 2014 that was also connected to the wireless AP could be used in the infrastructure network. However, the Galaxy player was not connected to the wireless AP; therefore, its infrastructure network configuration was not possible. The infrastructure network was configured by connecting a Samsung Galaxy note 10.1 to the wireless AP to which the Samsung Galaxy 2014 was connected. At this time, the wireless AP was connected only to the Samsung Galaxy 2014 and to the Samsung Galaxy note 10.1.

The environment to measure bandwidth and RTT was the same as the performance measurement environment described in Section 4. When RTT and bandwidth were measured, the Samsung Galaxy 2014 was a server, and the other devices were clients. When using a multimedia streaming environment configuration, both Wi-Fi Direct and infrastructure networks was configured, and the Galaxy 2014 was part of both. Thus, the measurement of performance is required when TCP packets and pings are focused on this device.

C. *Results of the Experiments*

Figures 4 and 5 are the measured performance results using the combination of a Wi-Fi Direct and infrastructure network. The RTT and bandwidth of the Wi-Fi Direct configuration had measured values similar to those reported in Section 5, with five devices connected to the group owner.

However, when the infrastructure network was configured, the RTT value measured was significantly lower and comparable to that reported in Section 4. The reason for this result is that TCP packets for measuring bandwidth pass through the wireless AP. Because the wireless AP manages security, such as packet filtering, the maximum TCP throughput is reduced. Wi-Fi Direct device groups and the infrastructure network connect using the same channel;

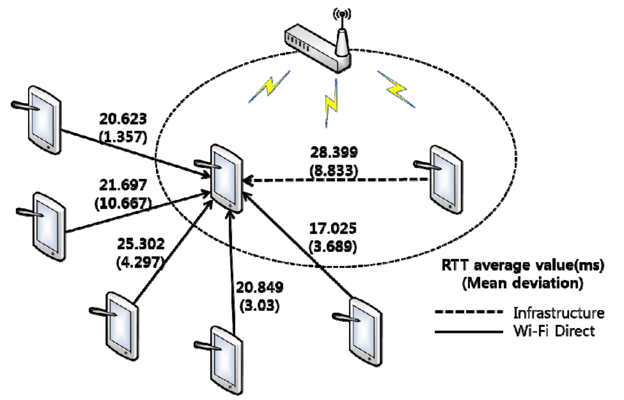

Fig. 4. The performance measurement of a network structure for multimedia streaming: RTT

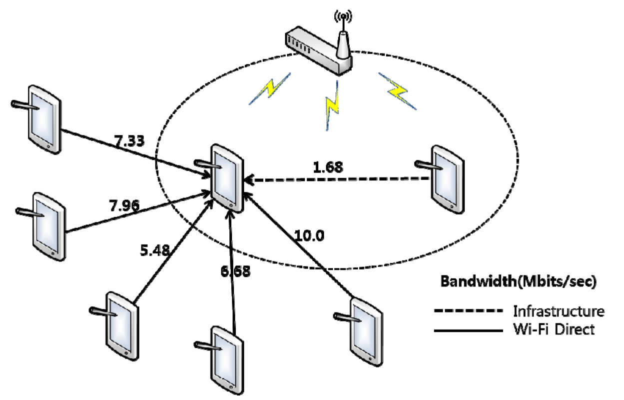

Fig. 5. The performance measurement of a network structure for multimedia streaming: Bandwidth

therefore, the bandwidth declines. Additionally, performance may be degraded due to channel interference and beaconing.

Configuring a mobile network using this topology for the smooth use of multimedia streaming with multiple devices is almost impossible because of the limitation of network traffic processing performance of the wireless AP between group owners. However, it can be solved using a high performance wireless AP. Therefore, this topology is appropriate for large-scale multimedia delivery on a single WLAN.

VII. Conclusion

As smart devices become disseminated and more popular, N screen technology that provides content to multiple screens is spreading. However, the issues of traffic limits that arise when using multiple devices simultaneously has not yet been resolved. In particular, techniques to increase traffic are insufficient when multimedia streaming is used on multiple devices. Therefore, we need to measure the performance of the wireless network in configurations that can overcome the traffic limitations and can allow for multimedia streaming.

Wireless networks were configured using an infrastructure network, an ad hoc network, and a Wi-Fi Direct network. The performance of these configurations was measured for RTT and bandwidth. The performance of the ad hoc and Wi-Fi Direct networks were similar; both had higher performance than an infrastructure network. However, ad hoc networks are not easy to configure. It is easy, however, to conduct multimedia streaming by configuring the network using Wi-Fi Direct.

We looked for a change in performance when using Wi-Fi Direct to connect to multiple devices. We found similar RTT values, but bandwidth was inversely proportional to the number of devices. This result indicates that configuring a network for multimedia streaming to multiple devices is not a smooth process. Furthermore, Wi-Fi Direct restricts the number of connected devices depending on the manufacturer and performance. Thus, the configuration of the network is difficult using multiple devices.

We have proposed a method to configure a network for multimedia streaming using both Wi-Fi Direct and an infrastructure network. We created a number of separate Wi-Fi Direct groups, each of whose group owners were configured in an infrastructure network. We measured the performance of this network structure through RTT and bandwidth measurements. The RTT and bandwidth of Wi-Fi Direct was similar to that described in Section 5, in which Wi-Fi Direct had 5 devices connected to the group owner. When an infrastructure network was added, the measured RTT value was similar to the measured performance results provided in Section 4. In contrast, the bandwidth were significantly lower. However, it can be solved using wireless AP of high performance. Therefore, this topology is used for large-scale multimedia delivery on a single WLAN.

References

[1] C. Yoon, H. Lee and W. Ryu, "Classification of N-Screen Services, Scenarios and its Standardization," ICACT Transactions on Advanced Communications Technology, vol.2, pp.214-222, May 2013.

[2] "Wi-Fi Certificated Miracast: Extending the Wi-Fi experience to seamless video display," Wi-Fi Alliance, Jan. 2013.

[3] R. AlTurki and R. Mehmood "Multimedia Ad hoc Networks: Performance Analysis," in Proc. UKSIM European Symposium on Computer Modeling and Simulation, pp.561-566, Sep. 2008.

[4] H. Yoon and J. Kim, "Collaborative Streaming-based Media Content Sharing in WiFi-enabled Home Network," IEEE Transactions on Consumer Electronics, vol.56, no.4, pp.2193-2200, Nov. 2010.

[5] T. Hwang, H. Park, E. Paik, and J. Chung, "EAFR-Based DLNA Proxy for High-Quality Video Distribution in Extended Home Space," IEEE Transactions on Consumer Electronics, vol.57, no.1, pp.120-125, Feb. 2011.

[6] Z. Fu, X. Meng, and S. Lu, "A Transport Protocol for Supporting Multimedia Streaming in Mobile Ad Hoc Networks," IEEE Journal On Selected Areas In Communications, vol.21, no.10, pp.1615-1626, Dec. 2003.

[7] S. Lee and C. Yoo, "Hop-Based Priority Technique Using 802.11e for Multimedia Streaming," IEEE Transactions on Consumer Electronics, vol.56, no.1, pp.48-53, Feb. 2010.

[8] Linux WPA/WPA2/IEEE 802.1X Supplicant, Available: http://hostap.epitest.fi/wpa_supplicant

[9] O. O. Olusegun and C. E. Tan, "TCP Throuput Efficiency Enhancement In IEEE 802.11n Network," in Proc. International Conference on Information Technology in Asia, Jul. 2013.