Fast Location-based Association of Wi-Fi Direct for Distributed Wireless Docking Services

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***Abstract*—This paper proposes a novel method of faster association in the Wi-Fi Direct specification to support various wireless docking services in future wireless networking. Wireless docking can be one of the most prominent services in the future because various real-time multimedia streaming applications will be based on this service. Even though the Wi-Fi Direct specifies a neat architecture to support these environments, the delay from the association process may severely deteriorate the network performance. To solve this problem, we propose a faster method of Wi-Fi Direct association by allowing mobile clients to share information of their Group Owner (GO) with each other. Location and channel information is also utilized to locate and quickly associate with GOs. The performance of the proposed scheme is evaluated using the NS-3 simulator, showing that the association delay can be reduced as much as 75%.**

Keywords:Wi-Fi Direct, Wireless Docking Services, Location-based Association

I. INTRODUCTION

The concept of future networking such as Internet of Things (IoT) now looks into the world with every electronic device equipped with wireless communication modules, being connected with each other for unattended automation and services. Following this movement, systems such as distributed wireless docking [1] is becoming one of the most promising services for establishing and maintaining connectivity between various consumer devices. Distributed wireless docking is a *1:N* connection between a host and multiple devices that interact with each other in a peer-to-peer (P2P) direct communication basis. Via distributed wireless docking, various services can be realized with simple control of electronic devices using smartphones.

Several technologies have been proposed for standardization in device-to-device (D2D) communication. Of them all, Wi-Fi Direct [2] has gained the most interest as a means of direct communication between consumer devices in local proximity of each other to support spontaneous service provision to users. Wi-Fi Direct establishes a WLAN [3] based connection between service providers and users with data rates now exceeding more than 1Gbps.

Using the Wi-Fi Direct, various future wireless docking services can be realized. For example, imagine a scenario with mass mobility within groups of people, such as mobile exhibitions, school activities, and military exercises and tactical maneuvers. In these scenarios, multiple leader devices (like mobile access points) co-exist with a far more number of client devices that need to be constantly associated with each other. Depending on the mobility, client devices can dock with different leader devices by re-association and handover processes. Through this connection, various services can be provisioned to the clients without frequently losing connection. Wi-Fi Direct supports the ideal network architecture for these services, as it provides methods of instantaneous group formation between Group Owners (GOs) and client devices.

However, Wi-Fi Direct may also pose some problems in the wireless docking environments that can negatively affect the performance of the network. One of the biggest issues is the association process for establishing a connection between hosts and client devices. In the case of mobile wireless docking environment explained above, the association process needs to be attempted for every new leader device or GO that a client device meets. The total delay and control packet exchange overhead induced from this process can negatively affect the Quality-of-Service (QoS) of various applications.

In this paper, we propose an enhancement scheme to reduce the delay induced in the association process of Wi-Fi Direct. We design a so-called “client-aided search” of GOs where the mobile clients can share the information of GOs that they have associated with in the past. To accurately account for the location of GOs, some location-based searching is also used. Thus, with the proposed scheme, channel and location information of multiple group owners can be shared by the client devices, which can successfully reduce the delay in the forthcoming association process. We verify the performance of the proposed scheme via the NS-3 simulator [4], and show that the overall association time can be reduced enough to provide faster services.

II. BACKGROUND

Wi-Fi Direct is an industrial specification for the usage of IEEE 802.11 WLAN standard for various P2P/D2D communication services and applications [5]. Using the Wi-Fi Direct technology to construct a WLAN-based D2D system can become a great sidekick to existing broadband communications for providing various future mobile services. The main functions of Wi-Fi Direct consist of device and service discovery, group formation, and power management, and P2P data delivery. Here, we only discuss the characteristics

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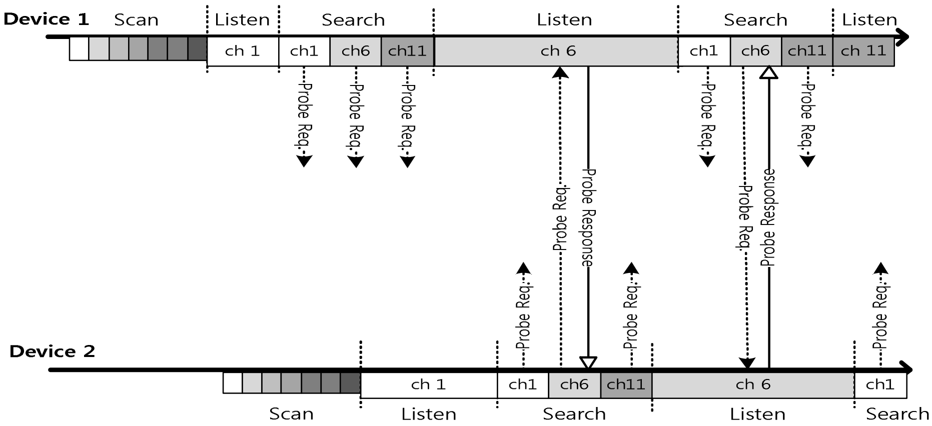


Figure 1. Device Discovery Process in Wi-Fi Direct[2]

and problems of the device discovery and the group formation procedures, which are most relevant to the scope of our work.

A. The Association Process in Wi-Fi Direct

The Wi-Fi Direct device discovery process is used to search for and locate the devices that are intending to participate in a specific service. The device that turns on the Wi-Fi Direct mode initiates scan, listen, and search phases to find other WLAN-based D2D-enabled devices in the currently used frequency. The specification is based on the 2.4-GHz frequency used in 802.11b/g/n, but it can also be extended in the future to 5.0 GHz, which is used in 802.11a/n/ac, and the TV white spaces used in 802.11af.

In the scanning process, the device periodically switches its channel and transmits a probe request message in each channel. If the channel of another WLAN-based D2D device is timely matched with the scanning device at a specific moment, the probe request can be received by another device, which can respond with a probe response. After scanning, the device enters the listen-search phase, in which the default channel is listened to and the mainly used channels of the frequency (e.g. social channels of 2.4 GHz) are searched for. The example in Fig. 1 shows how two devices with Wi-Fi Direct capabilities progress through their device discovery process to discover each other. The time spent in each channel during the scan, listen, and search phases can vary, making the discovery process between two devices completely blind and random.

Once the devices share the probe messages, the association process is initiated to establish P2P connection and select a Group Owner (GO). This is done by the devices sharing association messages in the channel that they used to share the probe messages. The role of GO is given to a single device, which becomes responsible for transmission of periodical beacon messages for maintaining connection with group clients.

In contrast to traditional ad hoc networks, devices in Wi-Fi Direct create a virtual topology called a group. In a group, multiple devices associate and elect a Group Owner (GO), which acts as a Soft AP, while other devices become clients. To elect a GO, each node is given an intent value ranging from 0 to 15. This intent value is compared between the devices, and the device with the highest intent value becomes the GO. After the formation, data transmission can be initiated through the channel that is selected at the device discovery. In the wireless docking environment, this group formation process can be effectively used to create 1:N docks between the GO and client devices to provide various services and applications.

B. Problems of the Wi-Fi Direct Association

The problem of the association process in Wi-Fi Direct is that the scan, listen, and search processes may consume considerable amount of time. Two devices attempting a peer discovery can share probe messages only if a search phase and a listen phase is met on the same channel. However, these phases are randomized; as each listen phase of a device can vary from a random multiplier of 100 time units. Therefore, two devices could attempt multiple discoveries before actually synchronizing their channels, which could consume time in scales of seconds. In the wireless docking environments where a client may frequently change its association with multiple GOs in the network, this may cause considerable problems in service provisioning due to the association delay.

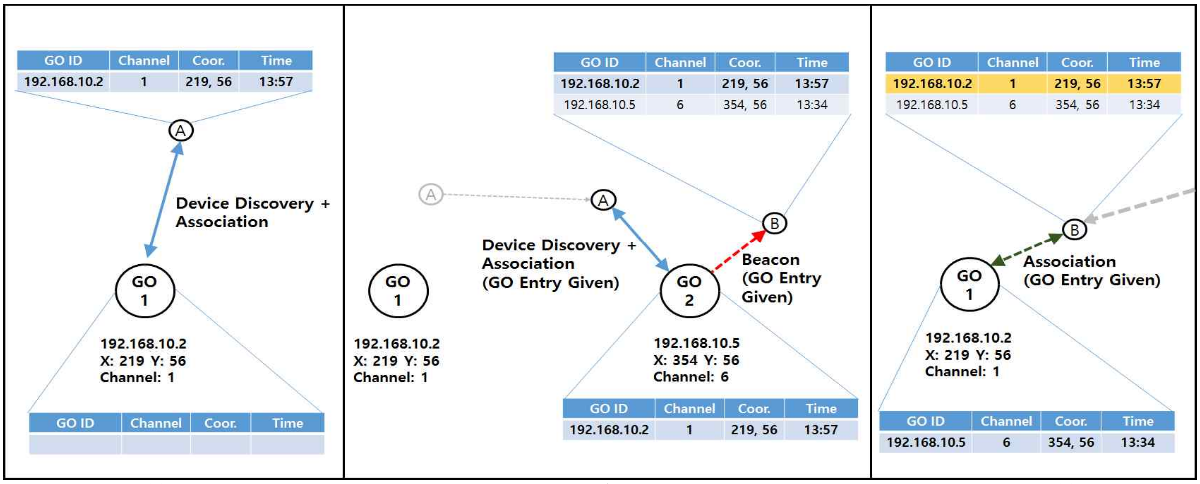
Much of the related work in enhancing the performance of the Wi-Fi Direct has been focused on power management [6][7]. On the other hand, there is currently little work on solving the problem of reducing the association time of Wi-Fi Direct devices. Therefore, novel schemes must be proposed to solve the association and group formation problem in Wi-Fi Direct, especially in wireless docking environments.

III. THE PROPOSED SCHEME

The main objective of the proposed scheme is to reduce the overall time consumed from the association process between host and multiple devices in the distributed wireless dock. The whole association process can be divided into three steps: 1) Modified GO association, 2) GO information sharing, and 3) Fast association.

A. Modified Group Owner(GO) Association

When a client needs to associate with a GO without any information about it, the client must initiate a new discovery and association process. In our modified GO association, some additional information will be inserted into the association control packets to allow faster association in the latter processes.



(a) (b) (c)

Figure 2. Example Operation of the Proposed Scheme

After a successful device discovery as shown in Fig. 1, a GO and clients share association messages through the channel used by the GO. In the sharing process, the location information of the GO is given to the client. As there are no traditional fields in the association packet to add location information, the P2P attribute field in the P2P Information Element in Wi-Fi Direct frame format (Refer to [2]: chapter 4.1.1) is utilized. The format of P2P attribute field provides a variable field length for adding information in the P2P header. For defining the P2P attribute, an attribute ID needs to be designated for the periodic data. Since there are more than 200 reserved IDs, we define and select a specific attribute ID, for example ID = 100, to act as the carrier of data interval information. Using this P2P attribute format provided by the specification, GO can successfully provide its location information to any client that intends to associate with the GO. As for gaining the actual location information, we assume that Global Positioning System (GPS) [8] can be easily used to acquire them. As most Wi-Fi Direct enabled devices such as smartphones, notebooks, and tablets also have GPS by default, we believe that this assumption is valid.

Once the location information is received by the client device, it will store the overall information of the GO in its GO entry list, as shown in Table Ⅰ. The GO entry list will maintain the IP address, the channel information used, the (x,y) coordinates, and the timestamp of the updated entry so that it can be provided to other GOs when needed. Note that only the information of GOs would be inserted into the GO entry list.

B. *Group Owner Information Sharing*

When a mobile client moves away from the vicinity of the currently associated GO, they become disconnected and the client can find another GO to associate with. However, in this process, the client will not remove the information of the disconnected GO from its GO entry list. Instead, when the client associates with a new GO, it will transmit its GO entries to the GO so that information of other GOs in the network can be shared. Also, in return, GO provides the list of its own GO entries to the currently associated client so that information of the GOs can be acquired by clients as well. When the GO entries are shared between clients and GOs, a timestamp field is used to update the most recent information of a GO so that redundant entries can be aggregated.

TABLE I. SAMPLE OF GO ENTRY LIST (KEPT BY A CLIENT)

GO ID	Used Channel	Location Coordinates	Timestamp
192.168.10.2	1	X:219, Y: 56	2013/12/03 13:57
192.168.10.5	6	X: 354, Y: 56	2013/12/03 10:38

For the group client to share its GO entry list with the currently associated GO, it must also utilize the P2P attribute field in addition to the associable control packet. However, to differentiate the ID that is used for carrier of data interval information, a different attribute ID can be used, for example ID = 110. On the other hand when GO needs to give its entry list to the clients, it will piggyback the GO entry list to its periodical beacon, also with a different attribute ID.

As the GO entry list of all clients and GO are frequently shared between each other, the size of GO entry list must be carefully controlled. This is because if the size of GO entry list becomes too large, this in turn causes considerable overhead in the network. To control the size of the GO entry list, for example, entries with location coordinates that are too far from the current location can be deleted. In addition, actual limit to the size of the GO entry can also be used to control it. For example, if the size of one GO entry is total 15 bytes (4 byte IPv4 address + 1 byte channel + 4 byte coordinate + 5 byte timestamp), a 60 byte limit can effectively reduce the transmission size of GO entries to 4.

In addition, if mobility is also given to the GO, then the location coordinate information in the GO entry list can quickly become obsolete. If wrong information is shared by GOs and clients due to mobility of the GO, then this in turn may cause more overhead in the network. Therefore, the timestamp should be observed by each client and GO, and any entries should be deleted if the timestamp becomes too old that it may become wrong information. Although empirical values can be given to control the timestamp of the GO entries, specific values depending on the network environment should be derived to control the association process more accurately.

C. Fast Association

Through the exchanging of GO entry list, clients can obtain information of other GOs that it has not yet associated with in the past. Therefore, the time for device discovery and association can be substantially decreased. When the client wants to newly associate with a GO that is in its vicinity, it will check its GO entry list and transmit an association message to the GO that is closest to itself using the GO's channel. The GO can receive this message as the channel is already matched between the GO and the client through the GO entry list. As a result, association can be quickly done between the new GO and the client, because the device discovery does not need to be attempted to search for the GO.

D. Example Operation of the Proposed Scheme

Fig. 2 describes an example operation of the proposed scheme when there are two group owners and two client devices in the network. As seen in Fig. 2 (a), when a client has no information about a GO, it has no choice but to initiate device discovery and search for a GO nearby. When client device A successfully finds the GO1, it initiates association and adds an entry about GO1 in its GO entry list.

When device A moves away from GO1 and approaches towards the vicinity of GO2, it begins a new device discovery and finds GO2 to associate with. This can be observed in Fig. 2 (b). In this process, GO2 and device A share the GO entry list, and therefore GO2 learns about the information of GO1. This information is then forwarded to device B through the periodical beacon transmitted by GO1. Device B, which was yet associated with GO2, now acquires information about GO1 without having to associate with it before.

Fig. 2 (c) shows that, when client device B moves away from GO2 and enters the vicinity of GO1, it can initiate the association process immediately without the device discovery. GO can receive device B's association request and respond back, successfully associating without discovery delay. Also, GO entry list is shared between the two devices, so that this information can be utilized by other devices in the near future.

TABLE II. SIMULATION PARAMETERS

Parameter	Value
MAC	WLAN 802.11
PHY	802.11g OFDM 54Mbps
Radio	2.4GHz 13 channels
Traffic	Constant Bit Rate
Data Rate	800 Kbps
Topology	1-36 Wi-Fi Direct GOs with 5 Wi-Fi Direct Clients
	5 Wi-Fi Direct GOs with 10-60 Wi-Fi Direct Clients

Through the sharing of the GO information via mobility of client devices, devices can conveniently dock with GOs quickly and with less overhead. As a result, considerable delay from the association process can be reduced, as well as any transmission interference that may result from the process.

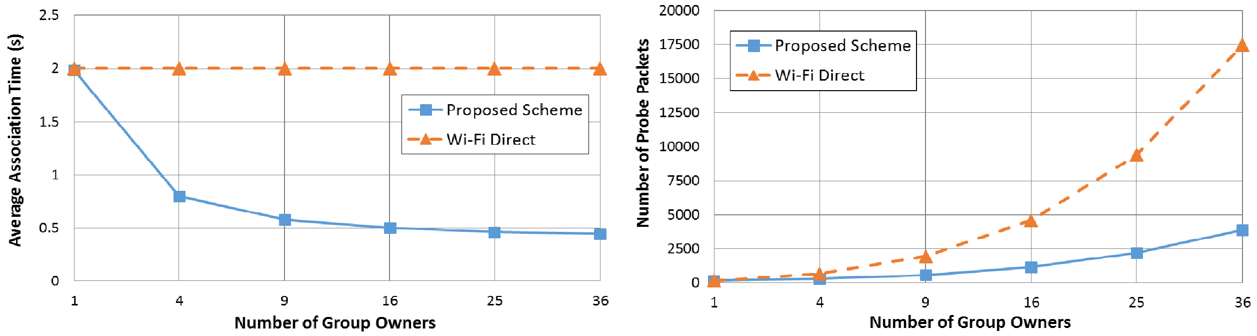
IV. PERFORMANCE EVALUATION

We evaluate the performance of the proposed scheme using the NS-3 simulator [4]. Simulation parameters are shown in Table Ⅱ. There are two scenarios of the simulation. One is that the number of GOs increases and the other is that the number of clients increases. This environment is configured to emulate a large-scale wireless docking environment, where a large number of GOs and clients can be deployed in a single network. Each client in the network performs device discovery and the association procedure for all the GOs that are in its vicinity. As a certain client sequentially associates all the GOs, the clients can be used to pass the GO entry list to various GOs in the network. After associating with several GOs, clients gain the GO entry list containing information of all GO entries.

The two parameters that will be compared are the average association time and number of probe packets. Average association time represents the average time spent on associating with a single GO. The number of probe packets calculates the total amount of control overhead that occur in the association process. Fig. 3 presents the performance of the proposed scheme when the number of GO is increased in the network. Fig. 3 (a) shows the average association time when one client associates one GO. In the traditional Wi-Fi Direct association scheme, the association time is similar regardless of the number of GOs in the network. This is because each client performs the device discovery process every time to associate with each GO. On the other hand, in the proposed scheme, average association time decreases because the sharing of GO entry list enables clients to skip the device discovery process and proceed directly to association. Therefore, proposed scheme can guarantee fast association between GO and client compared to the existing Wi-Fi Direct association process.

Fig. 3 (b) shows the increase in the number of probe packets. As the device discovery process is always initiated every time an association request is attempted in the traditional Wi-Fi Direct, control packet overhead is huge. On the other hand, in proposed scheme, because the number of performing device discovery is few, the number of probe packets is also reduced. As a result, reduced number of control packet overhead allows the proposed scheme to utilize the bandwidth for other vital data transmission instead.

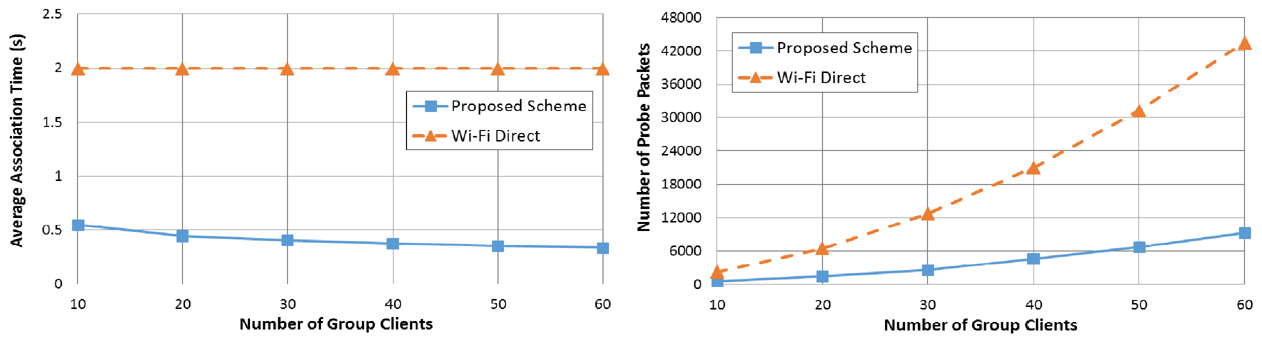
Fig. 4 shows the performance of the proposed scheme when the number of group clients are increased in the network. Fig. 4 (a) shows that as the number of group clients increase, the chance that the GO entry list is shared between the GOs also increase. Therefore, average association time for each group client can actually decrease, as shown in the graph for the proposed scheme. On the other hand, in the traditional Wi-Fi Direct association scheme, clients perform the device discovery process every time to association with each GO, so the average association time is unaffected by the increase of group clients.



a) Average Association Time by varying number of group owners

(b) Number of Probe Packets by varying number of group owners

Figure 3. Evaluation of Proposed Scheme when the number of GOs are increased



(a) Average Association Time by varying number of group clients

(b) Number of Probe Packets by varying number of group clients

Figure 4. Evaluation of Proposed Scheme when the number of group clients are increased

Fig. 4 (b) shows the number of total probe control packets that is generated in a single network when the number of group clients increase. In the traditional Wi-Fi Direct association, the probe packet overhead severely increases because each group clients attempts its own probing and association processes. On the other hand, the proposed scheme can reduce the probe and association process for some mobile group clients, because the sharing of GO entry list can remove the probing process and allow quicker connection to the GOs without generating additional control overhead.

In overall, we can conclude that the proposed scheme can guarantee a fast association between GO and client by decreasing the number of device discovery attempts, because client gain a GO entry list through a GO. Moreover, by decreasing the number of probe packets, the available bandwidth can increase.

V. Conclusion and Future Work

As interest of the distributed wireless docking is increasing, Wi-Fi Direct technology is becoming a prominent means to support P2P direct communication in distributed wireless docking environments. However, when a GO attempts to connect with multiple devices in the docking scenarios, the association process of Wi-Fi Direct can cause delay and QoS deterioration. Therefore, we propose an enhanced association scheme in Wi-Fi Direct to provide faster and more efficient association between Wi-Fi Direct devices. Simulation conducted via NS-3 shows that our proposed scheme can reduce association time and control packet exchange overhead by at most 75%. For future works, we will model the proposed scheme in a more realistic environment using actual linux-based smartphone testbed. Furthermore, we must also consider delays and overheads that can be induced from the group formation stage and increase the performance of Wi-Fi Direct.

Acknowledgment

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References

[1] T. Laine, A. Bacioccola, J. Suumaki, "Wireless docking with out-of-band initiation," U.S. Patent 8 462 734, Jun. 11, 2013.

[2] Wi-Fi Alliance, P2P Technical Group, Wi-Fi Peer-to-Peer (P2P) Technical Specification v1.1, 2010.

[3] IEEE P802.11™-2012, Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications, IEEE, 2012.

[4] Ns-3 documentation, http://www.nsnam.org/docs/release/3.14/doxygen/index.html.

[5] Wi-Fi Alliance, http://www.wi-fi.org.

[6] K. Lim, W. Jung, H. Kim, J. Han, Y.-B. Ko, "Enhanced Power Management for Wi-Fi Direct," in IEEE Wireless Communications and Networking Conference, Apr. 2013.

[7] D. Camps-Mur, X. Perez-Costa, S. Sallent-Ribes, "Designing energy efficient access points with Wi-Fi Direct," *Computer Networks*, 55, pp. 2838-2855, 2011.

[8] S. Hwang, D. Yu, "GPS Localization Improvement of Smartphones Using Built-in Sensors," International Journal of Smart Home, Vol. 6, No. 3, Jul. 2012.