Group-to-Group Bidirectional Wi-Fi Direct Communication with Two Relay Nodes*

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ABSTRACT

The current capabilities of mobile phones in terms of communication, processing and storage, enables its use to form autonomous networks of devices that can be used in case of collapse or inexistent support from a communication infrastructure. In this paper, we propose a network configuration of nodes that provides high-speed bidirectional device-to-device communication, with symmetrical data transfer rates, in Wi-Fi Direct multi-group scenarios, without using performance hindering broadcasts.

Keywords

Mobile Networking, Device-to-Device Communication, Autonomous Networks, Wi-Fi Direct, Android.

1. INTRODUCTION

Usually smartphone communications rely on Access Point (AP) based paradigm. However, with the increase in smartphone capabilities regarding communication, computing and storage, we can now explore their use in a device-to-device (D2D) communication scenario forming autonomous networks, i.e., networks without infra-structure dependence. From all the D2D communication technologies available on mobile devices, we are interested on Wi-Fi because it supports a wide geographical coverage area and high transfer rates (TR). In addition, Wi-Fi was recently complemented with Wi-Fi Direct (WFD) [1] to support ad hoc group formation, facilitating the discovery, authentication and message (msg) routing between neighboring devices.

As we aim to support the usage of WFD in medium and large-scale scenarios with high-speed bidirectional IP D2D links in Group-to-Group (G2G) communications without support from a network infrastructure, we, in this paper, advance the current state of the art by proposing a network configuration of nodes that: (i) supports symmetrical data TR at high Wi-Fi speeds across groups (without using broadcasts); (ii) needs less hops to forward msgs between groups; (iii) needs less IP routing nodes; (iv) needs less number of nodes per geographical area; and (v) provides a more balanced resource usage.

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2. CURRENT G2G D2D NETWORKS

WFD is a protocol that enables device-to-device communication in groups of nodes. Each group has one node with the role of Group Owner (GO) that acts like a Wi-Fi AP, providing the DHCP service and MAC msg rooting for all the other nodes in the group, called clients. WFD also provides node discovery, negotiation to select the GO and an authentication mechanism. Each GO supports connections from other WFD nodes (P2P client) and legacy Wi-Fi clients if authentication information is provided. In multi-group scenarios, as stated by Casseti et. al. [2], Android devices currently have the following limitations, although not prohibited by the WFD standard: (i) a device can't play the role of P2P client in one group and GO in another; (ii) a device can't behave as the GO of two or more groups; and (iii) a device can't behave as client in two or more groups. To the best of our knowledge only the works of Casseti et. al. [2] and Duan et. al. [3] addressed G2G communication with WFD, and the latter only supports unidirectional communication. To support bidirectional communication between groups, Casseti et. al. propose the use of both the WFD P2P interface and the normal Wi-Fi interface, where the GO of one group communicates with its clients through the P2P interface and communicates with another group using the Wi-Fi interface, as is the case of GO2 and GO3 in Figure 1. From now on we call this configuration GOCR (1 GO and 1 CR).

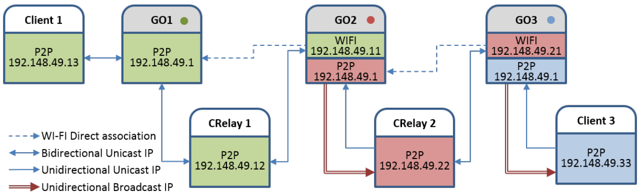

Figure 1: A GOCR configuration with 3 groups

In Android devices all the Group Owners assign to them-

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selves the IP address 192.168.49.1/24 and both the P2P clients and the legacy Wi-Fi clients will have IP addresses in the same network. Because all GOs have the same address they cannot exchange msgs directly, so they have to send the msgs to a relay client, which forwards them to the other GO. Considering the case, depicted in Figure 1, of GO3 sending one IP msg to GO2: (i) G03 sends an IP msg to the relay client 2 (CR2) in a bidirectional unicast link; and (ii) the CR2 forwards the msg to the GO2 in a unidirectional unicast link. The IP msg from GO3 to CR2, travels at the physical MAC layer as two msgs: one from GO3 to GO2 and another from GO2 to CR2. The IP msg from CR2 to GO2 is sent by a unidirectional unicast link, due GO2 cannot send unicast msgs through its P2P interface. Because, in Android devices that use both interfaces, as all unicast msgs are sent to the same network address, they are sent through the priority interface, the Wi-Fi interface [2]. For the case of GO2 sending a msg to GO3: (i) GO2 has to send a broadcast msg to CR2; and (ii) CR2 forwards the msg to GO3 in the bidirectional unicast link. The broadcast is necessary, as it is the only way for the GO2 to send any msg in its P2P interface. The use of Wi-Fi broadcasts hinders the communication speed because of its TR of 6Mbps instead of the normal Wi-Fi unicast TR of 54Mbps, as can be seen in the results of Casseti's work [2]. To send a msg, in Fig. 1, from Client 3 (C3) to Client 1 (C1) it's needed 5 IP msgs, a total of 8 MAC msgs, as seen in Fig. 2 (R2L: right to left flow). From C1 to C3 it has the same number of msgs, but 2 of the IP msgs are broadcasts, as shown in Fig. 2 (L2R).

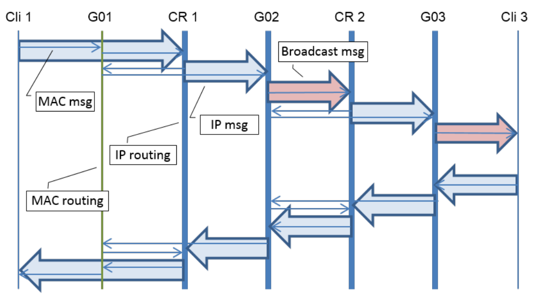

Figure 2: GOCR: L2R) C1 to C3; R2L) C3 to C1

3. G2G D2D WITH 2 RELAY NODES

The GOCR backbone requires that the routing path goes through the GOs and because they use the two interfaces, the communication in one direction must use broadcasts. Exploring the following facts: (i) any node, not only the GOs, can use both interfaces (but can only communicate in one direction at unicast speed); and (ii) the GOs could be withdrawn from the IP path of the backbone. We propose a backbone, which we call GO2CR, with two relay nodes (CR) between each two GOs, being that the relay nodes have to be in range of both GOs and each one provides routing of IP msgs only in one direction, connecting its interfaces WFD e WF symmetrically to the neighboring GOs to create a bidirectional path. Figure 3 illustrates the use of this backbone configuration in a scenario comprising three groups and consequently four relay nodes. In such scenario one msg from C1 to C3 has the following steps: (i) C1 sends an IP msg to the outbound Client Relay of its group CR12, which results, at MAC level, in one msg from C1 to GO1, and another from GO1 to CR12; (ii) CR12 forwards the IP msg to CR32, which results in one MAC msg from CR12 to GO2, and another from GO2 to CR32; and (iii) CR32 forwards the msg to C3 in one IP msg, which results in one MAC msg from CR32 to GO3, and another from GO3 to C3. Totalizing 3 IP and 6 MAC msgs as seen in Figure 4 (left). In the opposite direction, a msg from C3 to C1, will take a symmetrical path, but passing through CR23 and CR21 as shown in Figure 4 (right).

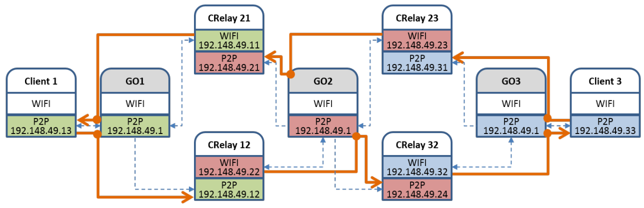

Figure 3: A GO2CR configuration with 3 groups

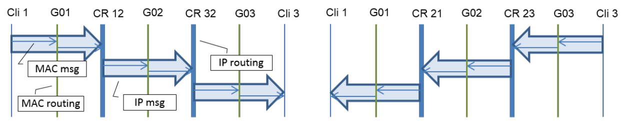

Figure 4: GO2CR: left) C1 to C3; right) C3 to C1

In terms of scaling up to increase coverage area, the GO2CR configuration requires 1 GO and 2 CR to extend the Wi-Fi coverage by two Wi-Fi range distance (WFR), while the GOCR requires 1 GO and 1 CR to extend one WFR. Therefore, the rate of nodes needed to extend the range by one WFR is better in GO2CR, as it needs an average of 1.5 nodes while GOCR needs 2 nodes.

4. CONCLUSIONS

From the identified characteristics, we can conclude that GO2CR: (i) can communicate between groups in symmetrical bidirectional high communication speed, without broadcasts; (ii) needs less number of hops to forwards msgs between groups, as it only needs 1 IP / 2 MAC msgs while GOCR needs 2 IP / 3 MAC msgs; (iii) needs less number of routing nodes (RN), as in one direction it only needs 1 RN per traversed group, while GOCR needs 2; (iv) needs less number of nodes per geographical area, as it needs an average of 1.5 nodes for each WFR while GOCR needs 2 nodes; and (v) balances recourse usage better, as it uses the GOs for routing msgs at physical level and CRs to route at IP level, but one CR only forwards to one side, while in GOCR all the msgs have to be routed by all the GOs and their CRs.

5. REFERENCES

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