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Concurrency-Aware Peer-To-Peer Negotiation on Wireless Devices

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Abstract:

This publication describes techniques of optimally establishing peer-to-peer connections between a group of wireless devices. In aspects, the techniques are performed by a Connection Manager implemented on one or more of the wireless devices. The Connection Manager utilizes a selection process to select a wireless device from the group to act as the group owner of the peer-to-peer network. Through the selection process, the Connection Manager selects the wireless device that is most suited to become the group owner. For example, the Connection Manager may select as group owner the wireless device with the highest probability of providing optimal data-exchange (*i.e.*, throughput) among the wireless devices, based on factors including device capabilities and/or the concurrency state of the device. The wireless device selected as group owner then configures the peer-to-peer network.

Keywords:

Peer-to-peer (P2P), connection, group owner, group client, Wi-Fi Direct, channel, multi-channel concurrency (MCC), concurrency state, wireless device, Group Owner Intent parameter, Group Owner (GO) negotiation, wireless local area network (WLAN), Dual Band Simultaneous (DBS), bandwidth, throughput, 2.4 GHz, 5 GHz

Background:

Many applications on wireless devices utilize peer-to-peer networking technology to share information across these devices. Peer-to-peer networking involves two or more peers directly connected to each other for the purpose of data or resource sharing over a network connection.

In an aspect, peer-to-peer networking is implemented utilizing the Wi-Fi Direct standard by two or more devices, or peers, where a handshaking process is used to establish a network connection between the peers. During this handshaking process, the peers negotiate which peer will be the group owner of the network. Each peer has an equally-likely opportunity to be designated the group owner of the network, with the other peers designated as group clients. The decision for which peer is designated group owner is based on a randomly generated parameter value (*i.e.*, a tiebreaker bit) of each peer.

The group owner has the controlling role in configuring the peer-to-peer network by selecting a network frequency and channel. Depending on the network configuration, the data-exchange rate (*i.e.*, throughput) of the network could vary between 50 Megabits per second (Mbps) and 550 Mbps. The choice of which peer becomes the group owner may not be dependent on the device capability nor the concurrency state of the individual device. As a result, the configuration of the peer-to-peer network may not be the most-optimized configuration possible.

Description:

This publication describes techniques of optimally establishing peer-to-peer connections between a group of wireless devices. In aspects, the techniques are performed by a Connection Manager implemented on one or more of the wireless devices. These techniques enable the Connection Manager to intelligently decide which peer would be most suited to become a group

owner of a peer-to-peer network created between the peers. The group owner of the peer-to-peer network configures the network. The peer chosen to be the group owner is the peer with the highest probability of providing optimal data-exchange (*i.e.*, throughput) among the peers. The decision is based on factors including the capabilities of the device (*e.g.*, ability to configure a 5 GHz network, Dual Band Simultaneous (DBS) capability) and/or the concurrency state of the device.

Devices capable of peer-to-peer communications include, but are not limited to, smartphones, tablets, laptop computers, embedded devices, and other electronic devices. The peer-to-peer devices include at least one processor having logic for executing instructions and a computer-readable medium (CRM). The CRM may include any suitable memory or storage device such as random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), non-volatile RAM (NVRAM), read-only memory (ROM), or Flash memory. The CRM includes a Connection Manager. The Connection Manager may be part of an operating system executing at the computing device. In other aspects, the Connection Manager may be a separate component (*e.g.*, an application) executing within an application environment or "framework" provided by the operating system. The Connection Manager may be a peer-to-peer sharing application.

The mobile device, while initiating a wireless network connection with one or more peers, performs operations under the direction of the Connection Manager to negotiate with other peers to determine which peer will be designated as the group owner (GO) of the network. The GO is responsible for configuring the network. The operations include alternatively scanning and listening on a frequency or frequencies for other peers until at least one peer is found, performing a GO negotiation process between the peers, exchanging cryptographic keys, and configuring the peer-to-peer network. These operations are illustrated in Figure 1.

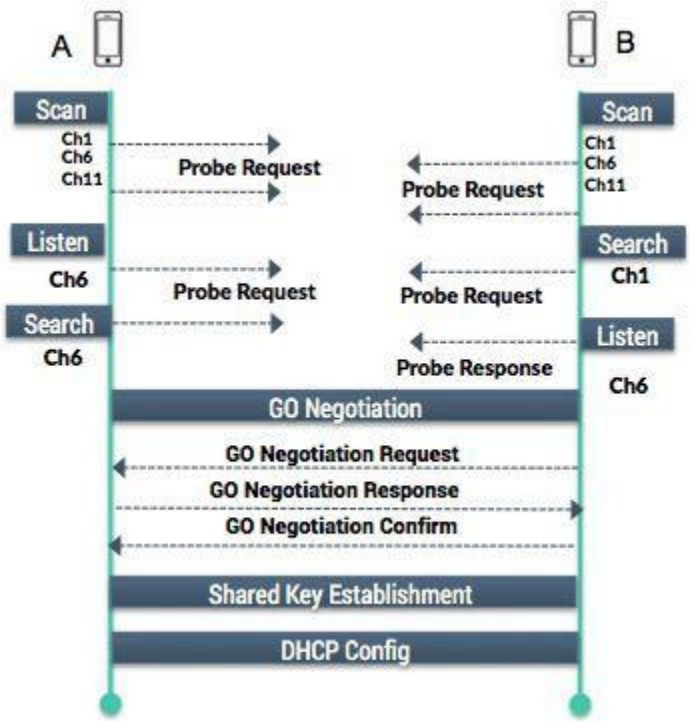

Figure 1

During the GO negotiation, the Connection Manager of device B (CM_B) initiates a GO Negotiation process to establish a peer-to-peer network by sending a GO Negotiation Request to the Connection Manager of device A (CM_A). The GO Negotiation Request includes the current value of a Group Owner Intent parameter (intent value) of CM_B. CM_A compares the intent value of CM_B with its own intent value. If the intent value of CM_B is greater than the intent value of CM_A, CM_A responds, through a GO Negotiation Response, indicating that CM_B should be the group owner. If the intent value of CM_B is less than the intent value of CM_A, CM_A responds, through the GO Negotiation Response, indicating that CM_A should be the group owner. If the intent values are equal, then a separate parameter with a randomly generated value (*i.e.*, tiebreaker bit) of each Connection Manager is compared to determine which one becomes group owner. After CM_A responds to CM_B as to which Connection Manager should be the group owner, CM_B sends a confirmation (GO Negotiation Confirmation) back to CM_A.

The newly established group owner then proceeds with the rest of the operations to configure the peer-to-peer network.

The intent value of a peer is determined by the current network state of the peer. The current network state is chosen from a list or table of possible network states. Each possible network state is assigned a value with a more optimal network state having a greater intent value than a less optimal network state. Possible network states may include "disconnected (D/C) from any network channel," "connected to a channel on the 2.4 GHz band," and "connected to a channel on the 5 GHz band." Figure 2 is a table listing possible network states and assigned values. The table entries take into consideration possible capabilities of the device and possible concurrency states of the device including multi-channel concurrency (MCC) cases. An example of MCC is when a network connection to an access point is on one channel and a peer-to-peer network connection is on a different channel. In MCC cases, the device may timeshare across both network interfaces resulting in less throughput efficiency.

Network State	GO Intent Value
D/C	7
2.4 GHz Non-DBS	1
5 GHz Non-DBS	14
2.4 GHz DBS	10
5 GHz DBS	11

Figure 2

Connection Managers capable of selecting a Group Owner more adaptively during the GO negotiation can reach an optimal group-owner agreement among all the peers participating on the peer-to-peer network. The optimization of the peer-to-peer network throughput may improve by

as much as 200% to 500% when these techniques are employed. Large variations in network performance due to chance are minimized when the group owner negotiation between peers is decided by which peer offers the best network choice instead of only depending on a randomly generated tiebreaker bit.

References:

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