Qualcomm Research

Band-Steering for Dual-Band Wi-Fi Access Points

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Table of Contents

Introduction

In this paper, we discuss QualcommTechnologies, Inc.'s (QTI) Band-Steering solution for a dual-band Wi-Fi Access Points environment.

Most newer commercially available Wi-Fi Access Points and clients have dual-band Wi-Fi support (i.e., 2.4GHz and 5GHz) to provide more capacity and higher data rates in wireless networks. In a typical dual-band Wi-Fi environment, a dual-band AP can be configured to broadcast the same SSID on both the bands thereby enabling the Wi-Fi clients to roam between the two bands without changing its IP address.

When a user turns on Wi-Fi, the Wi-Fi client device scans the environment and chooses a band to associate with the AP. Dual-band Wi-Fi clients will see both, the 2.4GHz and 5GHz bands available but can only associate with one band at a time. Normally, a client discovers the nearby APs by sending out Probe Requests on each channel of both the supported bands. After receiving the Probe Responses, the client decides on which band and AP (SSID, channel) to associate with. Generally, clients do not take into account the load on the band they are associating with. Also, most clients tend to stick to the band they are already associated with no matter how poor the signal gets thereby impacting medium efficiency. Over time, the load on the bands can become severely imbalanced, thereby significantly deteriorating user experience. Furthermore, the system capacity cannot be fully or optimally utilized as clients stick to poor links while a better link may be available on the other band.

The current client-centric dual-band Wi-Fi environment has the following problems, leading to poor overall network performance.

1) Current Wi-Fi clients use simplistic metrics (e.g. downlink RSSI) to decide which band to associate with. They do not take into account the load on each band, and will associate with a band even if it is overloaded, as long as the RSSI value is good enough to connect.
2) Once associated, the Wi-Fi client may continue to stick to that same band even though it could be better served by the other band.
3) Currently there are no widely deployed or standardized ways for an AP to steer Wi-Fi clients to a specific band.

An AP with QTI's Band-Steering solution will steer Wi-Fi clients to the best band based in changing signal and load conditions to achieve load balancing across 2.4GHz and 5GHz bands, higher overall system capacity and a better user experience.

Dual-band Wi-Fi Environment

QTI's Band-Steering Solution for Dual-Band APs

In QTI's Band-Steering solution, a dual-band AP will steer the Wi-Fi clients between the 2.4GHz and 5GHz bands to ensure that both bands are optimally utilized and that clients are connected to the best band based on their signal conditions on the respective bands. All computations are done by the AP and the solution does not require any changes to the Wi-Fi clients or Wi-Fi standards.

A dual-band AP using QTI's Band-Steering solution will make steering decisions based on inputs such as:

- Wi-Fi Client capabilities: Is the client dual-band?
- RSSI on current band: Is the current link good enough?
- RSSI on target band: Can client connect to the target band? Is target band good enough?

- Medium utilization on current and target bands: Is load balancing needed?
- Steering history: Is the client steering-friendly? Has client been steered too often?

The AP may steer the clients before and after association depending on the situation. The focus of our solution is on addressing the following issues:

Sticky Wi-Fi Clients:

1) Many Wi-Fi clients tend to stay connected on 5GHz band (that they first associate on) despite the RSSI on that band getting low and the RSSI on 2.4GHz band being much better. This behavior not only deteriorates that client's performance, but will impact the overall network since that sticky client will occupy more medium time for lower data rates due to their low MCS.

2) Many Wi-Fi clients once connected to 2.4GHz will tend to stay on 2.4 GHz even when they are very close to the AP with a strong 5GHz RSSI. This behavior is sub-optimal as in these scenarios, the client can be better served by the 5GHz band while at the same time reducing the load on the 2.4GHz band.

Solution: Clients on 2.4GHz will be steered to 5GHz when the 5GHz band is good enough to accommodate the client and provide better throughput for that client. Clients with poor 5GHz links are moved to 2.4GHz for better range.

Load Balancing:

Even when a band is overloaded, new unassociated clients may still associate with the overloaded band simply based on stronger RSSI, thereby worsening the overload condition and overall performance, while already associated clients continue to stay on the overloaded band and see their performance degrade further.

Solution: Idle clients on an overloaded band are steered to the other (non-overloaded) band. Additionally, pre-association steering is performed whereby unassociated clients are steered to the lesser loaded band, as their RSSI on that band is sufficient.

Steering Constraints

Based on extensive testing, it was found that some Wi-Fi client devices may not behave well if they are steered during traffic exchange. This behavior is a combined effect of the client's and application's reaction to being steered. Some applications may not recover gracefully from a re-association of the Wi-Fi connection. As a result, only idle clients are steered.

Dynamic Monitoring

Since radio conditions, client activity, client location and mobility are constantly changing, the AP needs to dynamically track and monitor the clients and the load on each band, evaluating whether any clients need to be steered and whether new clients should be blocked from a specific band due to overloaded conditions. Once the AP decides it needs to steer a client, it activates the steering mechanism and monitors the clients to detect when they are idle and then executes the steering decision.

The Steering Mechanism

To start steering a client, the AP first disassociates with the client on a particular band, and then blocks that client from re-associating on that band for a period of time. Once disassociated, the client will briefly try to re-associate with the AP on the same SSID and on the same band as the last association before scanning for other AP or band options. Most Wi-Fi clients scan both bands by sending Probe Requests and estimate the downlink signal strength from the Probe Responses which also indicate the AP's readiness to re-associate.

Since this scanning and re-association behavior is completely client implementation dependent, some clients may steer faster than others. Some clients may

not steer, but may keep trying to re-associate with the original (blocked) band or just choose to disassociate from Wi-Fi altogether and attempt to re-associate only when they have packets to send.

Care needs to be taken at the AP to prevent such steering-unfriendly clients from getting blocked at the AP, in which case user intervention may be needed to restore the Wi-Fi connection. User intervention can be as simple as toggling the Wi-Fi on/off. Clearly such user interventions are not desirable. Therefore, the design errs on the conservative side. If a client cannot be steered or a steering attempt fails, the AP will let the client re-associate with the original band as opposed to risking the client being blocked from the AP for an extended period of time. Since the client is only steered when idle, there will be no interruption to the user traffic.

Conclusion

QTI's Band-Steering solution for the AP significantly enhances overall network performance in a dual-band Wi-Fi environment. By monitoring the RSSI of Wi-Fi clients on each band and the load on each band, the AP can make smart steering decisions to achieve optimal load balancing across multiple bands, while having Wi-Fi clients associate on the best serving band at any time, given dynamically changing signal and load conditions. By carefully executing the steering mechanism, the AP can avoid user data interruption and can accommodate for Wi-Fi clients that are not steering-friendly, thus minimizing or eliminating any user intervention.

Future Work

The current Band-Steering solution works on a single AP. This solution will be extended to handle multiple APs so as to achieve load balancing across multiple bands and multiple APs, while steering W-Fi clients to the best serving band on the best serving AP. Such a solution will also provide optimal coverage with the use of Wi-Fi Range Extenders (RE). When multiple dual-band APs and REs are part of a Wi-Fi network, the selection of best serving AP/Band for the clients and the steering decision will be need to handle multiple possible end-to-end data paths, multiple hops as well as consider overall network impact of the selected path and steering decision.

QTI's solution will be extended to use the steering mechanism from IEEE 802.11v BSS Transition Management Request, which is currently being certified as part of Wi-Fi Alliance Multi-band Operations (MBO) and Optimized Connectivity Experience (OCE) working groups. With a standards-based steering mechanism our solution can be extended to steer Wi-Fi clients dynamically to achieve even further performance enhancements. For example, steering clients while in-traffic may become possible so the AP can steer an active client on a sub-optimal band with excessive medium utilization. Also, inputs such as QoS and traffic characteristics can be taken into account to enhance overall network performance and user experience.