November 2019

# Quick Wireless Local Area Network Rate Control

Nihar Jindal

Sriram Sundararajan

# Quick Wireless Local Area Network Rate Control

**Abstract:**

This publication describes techniques for determining a data rate at which an electronic device on a wireless local area network should transmit to another wireless local area network device. The electronic device conducts a data rate search by transmitting multiple short packets, or probes, each at a different rate over a trial period to determine a data rate for future transmissions. The packets are transmitted one after the other to the access point and may or may not carry meaningful data. The data rate search can be further informed by a transmission history of the electronic device, smart search algorithms, searching multiple input/multiple output (MIMO) streams, searching guard intervals, and searching across multiple bands. A candidate set of data rates can be tried multiple times to get accurate estimates for the data rates before a data rate is selected for transmission.

**Keywords:**

Wireless local area network (WLAN), 802.11, access point, WiFi, data rate, data rate search, maximum data rate, modulation and coding scheme, MCS, signal quality, bandwidth, orthogonal frequency-division multiple access (OFDM), modulation symbol, probe packet, MAC Protocol Data Unit (MPDU), acknowledgment (ACK), multiple input-multiple output (MIMO), guard interval length, cyclic redundancy check (CRC), binary search, candidate set

**Background:**

A wireless local area network (WLAN), such as those based on the IEEE 802.11 standard, more commonly known as "wireless LAN" or "WiFi," is commonly used by a variety of electronic devices for wireless network communications. An electronic device's data rate is a critical factor that determines the efficiency and battery consumption of the electronic device because the data rate determines the air time required to transmit a given payload of data. Maximum data rates can span multiple orders of magnitude; for example, for 802.11ac they can be as low as 7.2 Megabit per second (Mbps) or as high as 867 Mbps. It is important to be at the maximum data rate supported on a WLAN connection in order to maximize efficiency during data transmission.

A maximum data rate (modulation and coding scheme (MCS)) that is supported by a WLAN connection with an access point depends on many factors. Factors that affect the MCS of a transmitting electronic device include signal quality (*e.g.*, distance/obstacles between the electronic device and access point), propagation environment (*e.g.*, reflections), interference at the access point, plus other factors (*e.g.*, transmit power, bandwidth). As a result, the MCS can be difficult to accurately determine.

In some implementations, an electronic device selects its data rate based on trial and error. The electronic device can maintain a history of the data rates of previous transmissions (*e.g.*, how many successes and failures (or packet error rate) for every data rate that has been tried). The electronic device receives a positive acknowledgement (ACK) for every successful packet transmission and records ACKs. These statistics may be limited to a time window (*e.g.*, 10 seconds). For example, a transmitting electronic device may determine that an 867 Mbps data rate has a 50% packet error rate, a 780 Mbps data rate has a 40% error rate, a 650 Mbps data rate has a 10% error rate, and a 550 Mbps data rate has a 2% error rate. These statistics may lead the electronic device to choose a 650 Mbps data rate for future transmission. The trial and error approach is most effective in a static environment when factors such as interference, the environment, or distance between the electronic device and the access point remains constant.

In a dynamic environment, where the above-mentioned factors change, a transmitting electronic device may make several unsuccessful transmissions of packets of data at too high of a data rate. This wastes airtime of the WLAN network and battery of the electronic device. The electronic device is forced to periodically try lower and higher data rates than the current one. The electronic device may transmit packets at one data rate for 1 millisecond or longer, which is relatively slow. When the electronic device receives a reply, there may be errors due to rate-independent decisions (*e.g.*, burst of interference) that ideally would not affect the data rate selected by the electronic device. The 802.11ax WLAN standard introduces orthogonal frequency-division multiple access (OFDMA) which allows a user to be scheduled on different portions of a bandwidth. The access point might sometimes schedule an electronic device higher or lower in a bandwidth and the access point will only have limited history of rates per position in the bandwidth. Using a trial and error method with an access point that uses OFDMA can lead to inaccurate transmission rates. Therefore, it is desirable to improve the data rate search procedure conducted by a transmitting electronic device to achieve greater accuracy and efficiency.

**Description:**

This publication describes techniques to improve a WLAN data rate search conducted by a transmitting electronic device in order to determine a data rate (wireless transmit rate) that the electronic device should use to communicate with an access point. The WLAN data rate search can be improved by transmitting multiple short packets at different rates with packets composed of non-data frames. The data rate search is further improved by including spatial streams, modifying a guard interval length, and performing a data rate search across multiple bands.

An electronic device, such as a smartphone, includes a WLAN data rate search application. The electronic device, having a wireless connection to an access point of a wireless network, performs operations under the direction of the WLAN data rate search application to determine a data rate for communication with an access point. The operations include: communicating to a WLAN radio to transmit packets at different rates, processing responses from one or more access points, using smart search algorithms to optimize a data rate search, determining a data rate the electronic device should use to communicate with the access point, and, in response, communicating the data rate information to other applications on the electronic device.

Figure 1, below, illustrates an example computing device and elements of the computing device that supports a WLAN data rate search application.

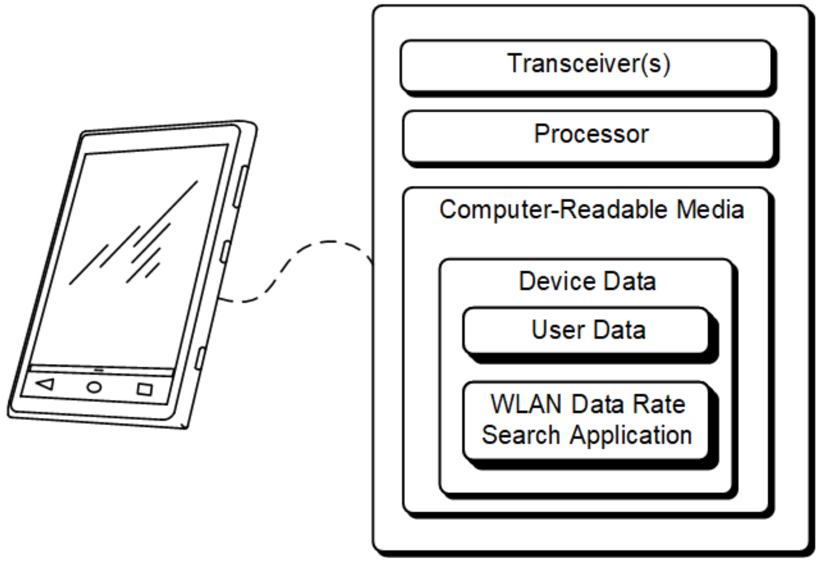
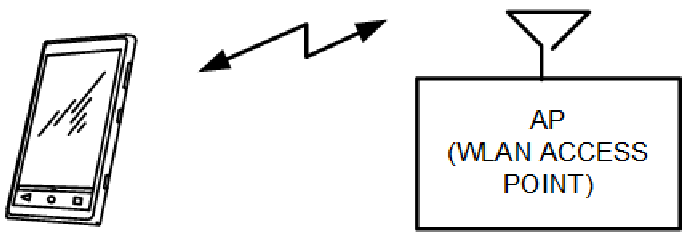



**Figure 1**

As illustrated, the electronic device is a smartphone. However, other electronic devices (*e.g.*, a tablet, a laptop computer, a wearable device, or the like) can also support the WLAN data rate search application described in this publication. The electronic device includes a processor(s) and transceiver(s) (*e.g.*, wireless local area network (WLAN) transceiver) for transmitting data to and receiving data from an access point of a wireless network. The electronic device also includes a computer-readable medium (CRM). The CRM includes device data. The device data includes user data, multimedia data, applications (*e.g.*, a WLAN data rate search application), and/or an operating system of the computing device, which are executable by the processor(s) to enable determining a data rate for WLAN communication by the electronic device. While the WLAN data rate search application could be stored within the CRM, other implementations can include any combination of firmware, hardware, and/or software

The device data includes executable instructions of a WLAN data rate search application that can be executed by the processor(s). The WLAN data rate search application represents functionality that communicates to one or more WLAN radios to transmit packets at different rates, process responses from one or more access points, use smart search algorithms to optimize a search, and determine a data rate the electronic device should use to communicate with the access point.

The electronic device may transmit many short packets (*e.g.*, one modulation symbol, one Orthogonal Frequency Division Multiplexing (OFDM) symbol), each at different rates. These short packets can be referred to as probe packets and they may or may not contain real data. The probe packets are transmitted one after another to minimize time spent on transmission. In an embodiment, a probe packet sent at a particular MCS can be as short as forty-four micro-seconds. The electronic device must allow for idle periods and for scheduled ACK according to the 802.11 family of standards. Example timing values for two packet transmissions at different data rates are pictured in Figure 2.




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| IDLE 16 | Probe Packet 1 at Rate 1 44 | IDLE 16 | ACK 24 | IDLE 16 | Probe Packet 2 at Rate 2 44 | IDLE 16 | ACK 24 |

Example Probe Packets for WLAN Data Rate search in microseconds

**Figure 2**

The sum of the above micro-seconds for each IDLE, Probe Packet, IDLE and ACK computes to requiring roughly one hundred micro-seconds for an electronic device to transmit at a particular data rate. One hundred micro-seconds per data rate allows the electronic device to send packets at ten different data rates over the course of 1 millisecond. The electronic device receives an acknowledgement (ACK) from an access point for every successful transmission.

The electronic device may use smart search algorithms to optimize a data rate search. For example, the search may be a binary search that starts with a middle data rate and if that data rate is successful, packets may be sent at a higher data rate at 75% of the maximum rate, and so on. In another example, the electronic device may use the results of a previous rate search as a starting point for a current rate search. In a third example, the electronic device may tailor the data rate selection by trying a final candidate set of the data rates multiple times to get accurate estimates for the data rates. In a fourth example of optimizing a search, the device may try packets of different bandwidth (*e.g.*, 20/40/80/160 MHz) during the data rate search. For example, if part of a bandwidth (*e.g.*, the upper 40 MHz of a 80 MHz channel) has high interference, then by probing different bandwidths the electronic device can determine that a portion of the channel (*e.g.*, the lower 40 MHz) can support a higher data rate than the full 80 MHz. The data rate of the channel will scale down proportional to the bandwidth, but the signal is more robust at a lower bandwidth.

The data rate search includes antenna configurations that use spatial multiplexing such as multiple-input, multiple-output (MIMO) to transmit multiple streams of data at the same time with different antennas. The data rate search includes probing a guard interval length. For a device operating on 802.11ac standard, there are two options for a guard interval length and for 802.11ax there are three options for guard interval lengths. A longer guard interval may be beneficial if there is a physically large area to reduce interference. The data rate search may be performed across multiple bands (*e.g.*, 2.4 GHz and 5 GHz) if multiple bands are available. One band may be selected for future transmissions.

The data rate search may be performed periodically, such as every second, or it may be used as an augmentation to a status quo trial and error approach. In a first example, the electronic device may use a trial and error approach to choose its data rate and periodically perform a data rate search to optimize the data rate. In a second example, if it has been over a threshold time value since a last transmission, the history is stale so a rate search should be performed. In a third example, the electronic device may use a trial and error approach to choose its data rate and monitor the connection for failures. If failures occur at the current data rate, the electronic device can perform a rate search to determine an improved connection.

A rate search can be optimized farther than current standardization of 802.11. Currently under 802.11 standards, aggregated frames are a long frame composed of different sub-frames (*i.e.*, MAC Protocol Data Unit (MPDU)) transmitted at a same data rate. A receiver on an electronic device sends a bitmap in a block ACK indicating which of those sub-frames were successfully decoded by an access point. Each MPDU has a cyclic redundancy check (CRC) for error detection. However, a rate search could be performed faster if the MPDUs were sent at different data rates in the long frame. The system would signal to the receiver what the data rate (*i.e.*, MCS) of each sub-frame are and the receiver can send a bitmap in a block ACK indicating which of those sub-frames were successful. This approach requires less overhead and is more efficient.

**References:**

[1] Patent Publication: US20140269655A1. Dynamic Rate Control In WiFi Systems. Priority Date: March 14, 2013.