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THIS SPEC IS OBSOLETE

Spec No: 002-14849

Spec Title: AN214849 - AIRTIME QUEUE FAIRNESS

Replaced by: NONE

AN214849

Airtime Queue Fairness

Associated Part Family: CYW43XX

This document provides information on the Cypress airtime queue fairness (ATF) feature. The ATF feature was implemented to address the impact of slow data rate transfers on high data rate transfers. Data transfers that use a low PHY rate take longer to transmit over the air than those using a high PHY rate. Prior to ATF feature implementation, the fairness goal was equal frame numbers per transfer. This resulted in longer duration (slower rate) packets holding up shorter duration (higher rate) packets. When using TCP, this hold-up effect causes the round-trip time of high-rate transfers to go up significantly.

The ATF feature optimizes throughput, particularly during times when airlink traffic exceeds capacity. It does this by adding the capability of only transmitting packets that meet per-destination airtime usage targets.

1 About This Document

1.1 Cypress Part Numbering Scheme

Cypress is converting the acquired IoT part numbers from Broadcom to the Cypress part numbering scheme. Due to this conversion, there is no change in form, fit, or function as a result of offering the device with Cypress part number marking. The table provides Cypress ordering part number that matches an existing IoT part number.

Table 1. Mapping Table for Part Number between Broadcom and Cypress

Broadcom Part Number	Cypress Part Number
BCM43XX	CYW43XX
BCM4360	CYW4360
BCM4331	CYW4331

1.2 Acronyms and Abbreviations

In most cases, acronyms and abbreviations are defined upon first use. For a more complete list of acronyms and other terms used in Cypress documents, go to: http://www.cypress.com/glossary.

2 IoT Resources

Cypress provides a wealth of data at http://www.cypress.com/internet-things-iot to help you to select the right IoT device for your design, and quickly and effectively integrate the device into your design. Cypress provides customer access to a wide range of information, including technical documentation, schematic diagrams, product bill of materials, PCB layout information, and software updates. Customers can acquire technical documentation and software from the Cypress Support Community website (https://community.cypress.com/)

3 ATF Hardware and Software Requirements

The ATF feature works on all Broadcom CYW43XX devices as long as AMPDU is enabled. It is only available in Broadcom driver versions 6.37.x and higher.

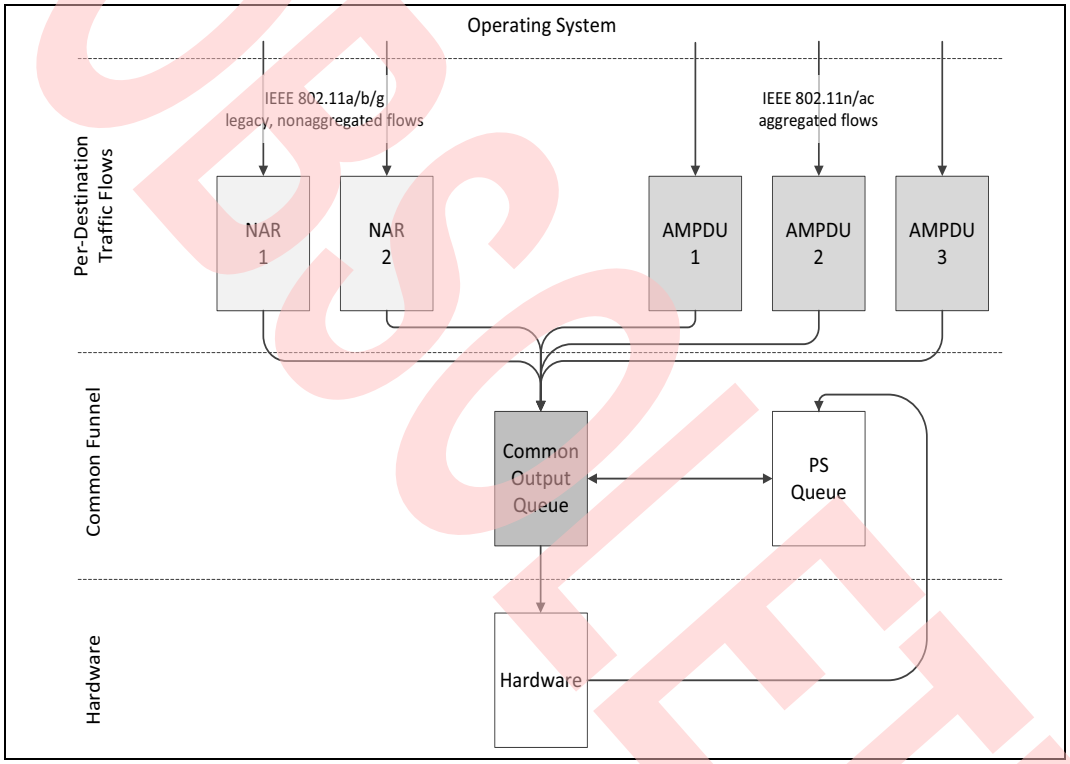
4 Introduction

The ATF feature was implemented to address the impact of slow data rate transfers on high data rate transfers. Data transfers that use a low PHY rate take longer to transmit over the air than those using a high PHY rate. Prior to ATF feature implementation, the fairness goal was equal frame numbers per transfer. This resulted in longer duration (slower rate) packets holding up shorter duration (higher rate) packets. When using TCP, this hold-up effect causes the round-trip time of high-rate transfers to go up significantly.

The ATF feature optimizes throughput, particularly during times when airlink traffic exceeds capacity. It does this by adding the capability of only transmitting packets that meet per-destination airtime usage targets.

Figure 1 shows the WLAN driver queueing diagram.

Figure 1. WLAN Driver Queueing



The current CYW43XX WLAN driver releases packets of per-destination Aggregated MAC Protocol Data Unit (AMPDU) and Nonaggregated (NAR) transmit flows to a common queue with the goal of equalizing the number of transmitted packets across flows. NAR transmissions use lower PHY rates and, therefore, take more time to transmit.

By striving to transmit equal numbers of packets across flows, the NAR flows tend to usurp the transmit channel during times when the capacity of the airlink is exceeded, thus blocking channel access to AMPDU flows.

There is no scheduler in the current driver for controlling access to the common queue. Each AMPDU and NAR flow contributes to traffic independently, which does not present an issue until the traffic to be transmitted exceeds the available bandwidth. When the traffic exceeds the available bandwidth, each AMPDU and NAR flow contributes to congestion and all services get affected in an uncontrolled and unpredictable manner. This is magnified during a TCP transfer because the round-trip time on a high-speed transfer goes up significantly when there is a simultaneous slow-speed transfer.

The airtime fairness (ATF) feature is implemented to address the issue where low-speed data transfers impact high-speed data transfers, specifically during instances when channel bandwidth is momentarily being exceeded.

The ATF solution adds a per-destination airtime target to the already existing packet number target. The ATF traffic scheduler uses the per-destination airtime targets to balance airtime usage across flow destinations. Doing this helps to optimize the throughput of each flow.

5 ATF Implementation

The ATF feature does the following to overcome airlink domination by low-rate links:

- It estimates the airtime usage of each packet using packet lengths, PHY rates, and any packet protection mechanisms such as CTS-to-self. See Packet Airtime Estimation on page 3.
- It saves the packet airtime in a packet tag.
- It sums the per-packet airtime estimates of each flow's enqueued packets to calculate a per-destination airtime usage.
- It releases the packet of a flow to the common queue (that is, it enqueues a flow's packet) if the following conditions are met:
  - The per-destination packet count does not exceed 256.
  - The per-destination airtime usage of the flow does not exceed a preconfigured threshold.
- After a packet is transmitted, it adjusts the per-destination airtime usage of the associated flow by subtracting the estimated airtime of the transmitted packet (which is stored in the packet tag of the packet).

6 Packet Airtime Estimation

The packet airtime is calculated using packet lengths, the best available PHY rates, and any packet protection mechanisms such as CTS-to-self.

An 802.11 packet comprises a header, payload, and trailer. Each of these packet elements affects the per-packet airtime estimation.

Airtime is estimated assuming the largest PDU from the maximum PDU (max_pdu) tunable in the driver for a particular chipset. The actual implementation estimates the airtime of a 1500 byte data frame, averages the estimate out over the max_pdu frames, and adds the header and trailer airtime estimates.

6.1 Header

The airtime associated with the header is the IEEE 802.11 contention/backoff time plus the DCF (distributed coordination function) interframe space (DIFS) time.

- The backoff time, which is a function of the minimum contention window (CW_{min}), is:
- $CW_{min}/2$ + one slot time (9 µs for a short slot and 20 µs for a long slot).
- The DIFS time is:
- SIFS time (16 µs) + two slot times.

6.2 Payload

The airtime associated with the payload is the transmit time of the data frame and the PLCP header.

- The data-frame transmit time is:
- frame length (in bits)/estimated rate (bps) + SIFS (16 µs).
- The PLCP header time is a function of the modulation type. The following constants are the default PLCP header times used in the ATF code.

```
#define AIRTIME_PLCP_DSSSLONG_US  192
#define AIRTIME_PLCP_CCKSHORT_US 96
#define AIRTIME_PLCP_OFDM_US 20
#define AIRTIME_PLCP_HTGF_US 24
#define AIRTIME_PLCP_HTMM_US 32
#define AIRTIME_PLCP_VHT_US 32
```

6.3 Trailer

The airtime associated with the trailer is (ACK or Block ACK) + (SIFS) and optionally (RTS + SIFS) or (CTS + SIFS).

7 ATF IOVARs

The following IOVARs pertain to the ATF feature.

7.1 ampdu_atf_us

Type: uint32
Default: 4000

This value is the allowed per-destination airtime usage for AMPDU flows in microseconds.

7.2 atf

Type: Boolean
Default: False

This value enables or disables the ATF feature. The IOVAR can be changed only when the driver is in a down state.

7.3 nar_atf_us

Type: uint32
Default: 4000

This value is the allowed per-destination airtime usage for NAR flows in microseconds.

7.4 nar_transit_limit

Type: uint32
Default: 64

The maximum number of packets enqueued to the common queue for transmission. This number represents the limit to the number of packets passed to the transmit modules at lower layers. The default value achieves fairness among all aggregated and nonaggregated flows. Choosing a value lower than the AMPDU transit limit favors aggregated traffic, and choosing a higher value favors nonaggregated traffic. A value that is too small will block (starve) nonaggregated traffic, whereas a value that is too large will block aggregated traffic.

8 Throughput with ATF on and ATF Off

Figure 2 and Figure 3 show the effectiveness of the ATF feature. The data used to create the figures was collected using a Cypress dual-band router (a CYW4360 at 5 GHz and a CYW4331 at 2 GHz) and two clients with the same chipsets running the Chariot high-performance script. The test setup was cabled and TCP downstream (AP to STA) traffic was used with STA RSSI levels of –45 dBm, –55 dBm, –65 dBm, and –75 dBm.

Figure 2. Throughput Results with ATF Off

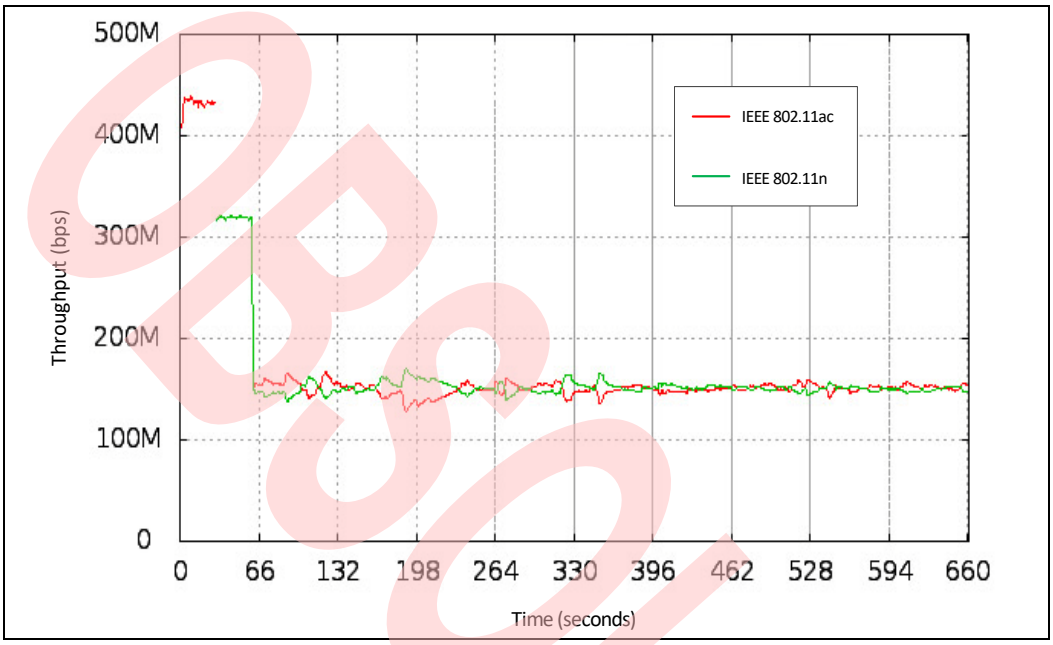
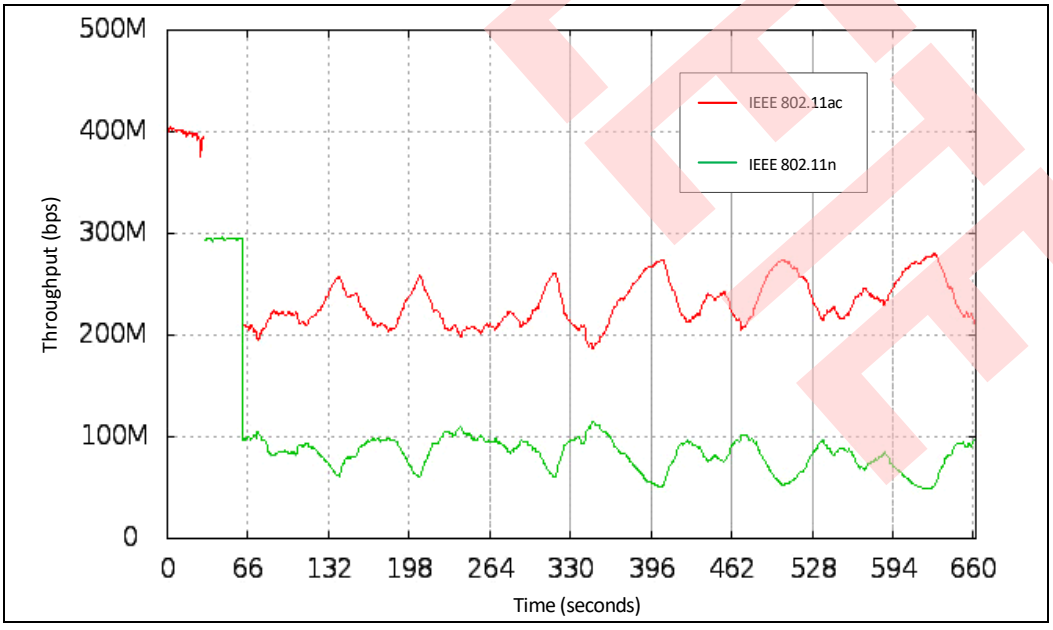


Figure 3. Throughput Results with ATF On



Document History Page

Document Title: AN214849 - Airtime Queue Fairness Document Number: 002-14849				
Rev.	**ECN No.**	**Orig. of Change**	**Submission Date**	**Description of Change**
**	–	–	08/15/2013	43XX-AN1600-R Initial release
*A	5445689	UTSV	09/27/2016	Updated About This Document: Added “Cypress Part Numbering Scheme”. Updated to Cypress template.
*B	5836731	AESATP12	08/01/2017	Updated Cypress Logo and Copyright.
*C	6650468	KEMA	08/08/2019	Obsolete document. Completing Sunset Review.

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