IEEE P802.11
Wireless LANs

Multirate is broken

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Abstract

The multirate mechanism currently described in 802.11 allows implementations to be created that are not interoperable for PHYs other than the current FH and DS PHYs. The main reason for this is due to the fact that the BSS basic rate set is incorrectly defined. We have studied the multirate mechanism, with the view of implementing it with the new high-speed PHY, and found that the basic concept is sound but some details need to be modified to provide the correct behaviour. This paper provides a description of the issues and suggested changes to the 802.11 standard.

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2 The Problems and Suggested Solutions

The purpose of the 802.11 multirate mechanism was to allow implementations that support multiple data rates to perform dynamic rate switching with the objective of improving performance. There are two aspects to the multirate mechanism. The first is the definition of the BSS basic rate set, which is the set of rates that all stations in a BSS must be able to receive and transmit frames at. The other is the support for optional rates and the specification of the rate of the Control Response Frame when a frame is sent at an optional rate. Due to the various editing passes at the standard both aspects of the multirate mechanism exhibit unintended operation. Some operational scenarios best demonstrate the issues and the suggested solutions.

2.1 Scenario 1

Assume that the BSS is configured for 1, 2 and 5.5 Mb/s as rates in the BSS basic rate set. It should be noted that the standard does not have any restrictions on what rates can be in the BSS basic rate set.

Upon receiving a 5.5 Mb/s frame the receiving STA is supposed to check the PHY mandatory rates (clause 9.6) to determine the rate that the control response frame is to be sent at. This set is not defined in the standard, and in fact the mandatory rates are different for receive and transmit for the IR PHY, and may be different for future PHYs.

We believe that the reference to the PHY mandatory rates is a remnant of an incomplete edit where all other references were changed to BSS basic rate set rates. This problem can be resolved by removing the reference to PHY mandatory rates.

2.2 Scenario 2

Assume that the BSS is configured for 1 and 2 Mb/s as rates in the BSS basic rate set. Upon receiving a 1 Mb/s frame the receiving STA would be required to transmit the control response frame at 2 Mb/s if we remove the reference to PHY mandatory rates as suggested in the solution to the problem described in scenario 1.

We believe that the intended mode of operation for the multirate mechanism is for an STA to transmit the control response frame at the same rate as the received frame if that rate is in the BSS basic rate set. This problem can be resolved by requiring that the response be sent at the highest rate in the BSS basic rate set that is less than or equal to the rate of the received frame.

2.3 Scenario 3

Assume that the BSS is configured for 1, 2 and 5.5 Mb/s as rates in the BSS basic rate set. Upon receiving a 5.5 Mb/s frame the multirate mechanism requires that the receiving STA respond with a 5.5 Mb/s control response frame. However, the definition of BSS basic rate set only requires that STAs be able to receive at all the rates in the set and transmit at one of the rates.

This problem can be overcome by requiring that all STAs in a BSS be able to receive and transmit at all the rates in the BSS basic rate set.

2.4 Scenario 4

The descriptions and use of the PHY characteristic aMPDUDurationFactor are inconsistent in the standard. The definition in clause 10.4.3.2 specifies it as an integer. However, the value assigned it in clause 14.9 is 1.03125. Additionally the description of its use in 10.4.3.2 assumes it is a real number.

This problem can be overcome easily by normalizing the value with an integer so that the effect of discarding a fractional component will be less than 1 μs. We suggest using 65536 as the normalizing factor since the maximum length of a frame is approximately 18.5 ms and implementations involving 65536 are easy.

2.5 Scenario 5

No mechanism is provided in the standard for an MLME on one STA to discover the rates supported by a remote STA. The Join and Start primitives allow the MLME to specify what data rates it can receive via the OperationalRateSet parameter but there is no complementary mechanism for it to receive an indication as to the receive capabilities of the remote STA.

This is not an insurmountable problem since the rate switching mechanism is not specified and trial and error could be used to discover the capabilities of the remote STA. However, a mechanism that allowed the MLME to discover the receive capabilties of a remote STA would greatly simplify the rate switching mechanism. This could be accomplished by adding a service primitives to retrieve the receive capabilities of remote STAs, and it would not effect existing implementations since the service primitive interface is not an exposed interface.

3 Changes to the 802.11 Standard Document

The following is a list of changes required to the current 802.11 standard document to support multirate operation as modified by the above recommendations. Changes are also needed to the state machines to incorporate the text changes described here.

The black text is the original text from the standard document. The text marked with revision marks depicts the changes required to support the revised multirate mechanism.

3.8 basic service set (BSS) basic rate set:

The set of data transfer rates that all the stations in a BSS will be capable of using to receive and transmit frames from/to the wireless medium (WM). The BSS basic rate set data rates are preset for all stations in the BSS.

7.3.2.2 Supported Rates element

The Supported Rates element specifies the ~~rates~~ values in the Operational-Rate-Set parameter as described in the MLME_Join.request and MLME_Start.request primitives. The information field is encoded as 1 to 8 octets where each octet describes a single supported rate ~~in units of 500 kbit/s~~.

Within Beacon, Probe Response, Association Response, and Reassociation Response management frames, each supported rate belonging to the ~~BSSBasicRateSet~~ BSS basic rate set, ~~as defined in 10.3.10.1,~~ is encoded as an octet with the msb (bit 7) set to 1 (e.g., a 1 Mbit/s rate belonging to the ~~BSSBasicRateSet~~ BSS basic rate set is encoded as X'82'). Rates not belonging to the BSS basic rate set~~BSSBasicRateSet~~ are encoded with the msb set to 0 (e.g., a 2 Mbit/s rate not belonging to the BSS basic rate set~~BSSBasicRate Set~~ is encoded as X'04'). The msb of each Supported Rate octet in other management frame types is ignored by receiving STAs.

The BSS basic rate set~~BSSBasicRateSet~~ information in Beacon and Probe Response management frames is delivered to the management entity in an STA via the BSSBasicRateSet parameter in the MLME_Scan.confirm primitive. It is used by the management entity in an STA ~~STAs in order~~ to avoid associating with a BSS if ~~they~~ the STA ~~do not support~~cannot receive and transmit at all the data rates in the ~~BSSBasicRateSet~~BSS basic rate set. See Figure 36.

9.2 DCF

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The medium access protocol allows for stations to support different sets of data rates. All STAs shall be able to receive and transmit at all the data rates ~~in the aBasicRateSet~~specified in the ~~-~~BSSBasicRateSet parameter of the MLME_Join.request and MLME_Start.request primitives ~~and transmit at one or more of the aBasicRateSet data rates~~. To support the proper operation of the RTS/CTS and the Virtual Carrier Sense mechanism, all STAs ~~shall~~

must be able to detect the RTS and CTS frames. For this reason the RTS and CTS frames shall be transmitted at one of the rates in the BSS basic rate~~aBasicRateSet rates~~. (See Clause 9.6 for a description of multirate operation).

Data frames sent under the DCF shall use the Frame Type Data and Subtype Data or Null Function. Stations receiving Data Type frames shall only consider the frame body as the basis of a possible indication to LLC.

9.6 Multirate support

Some PHYs have multiple data transfer rate capabilities that allow implementations to perform dynamic rate switching with the objective of improving performance. The algorithm for performing rate switching is beyond the scope of this standard, but in order to ensure coexistence and interoperability on multirate-capable PHYs, this standard defines a set of rules that shall be followed by all STAs.

All Control frames shall be transmitted at one of the rates in the ~~BSSBasicRateSet~~ BSS basic rate set ~~(see 10.3.10.1), or at one of the rates in the PHY mandatory rate set~~ so that they will be understood by all STAs in the BSS.

All frames with multicast and broadcast RA shall be transmitted at one of the rates included in the ~~BSSBasicRateSet~~BSS basic rate set, regardless of their type or subtype

Data and/or management MPDUs with a unicast immediate address shall be sent on any supported data rate selected by the rate switching mechanism (whose output is an internal MAC variable called MACCurrentRate, ~~defined in units of 500 kbit/s,~~ which is used for calculating the Duration/ID field of each frame). A STA shall not transmit at a rate that is known not to be supported by the destination STA, as reported in the supported rates element in the management frames. For frames of type Data+CF-ACK, Data+CF-Poll+CF-ACK and CF-Poll+CF-ACK, the rate chosen to transmit the frame must be supported by both the addressed recipient STA and the STA to which the ACK is intended.

~~In order to~~To allow the transmitting STA to calculate the contents of the Duration/ID field, the responding STA shall transmit its Control Response frame (either CTS or ACK) at the highest rate in the BSS basic rate set that is less than or equal to the the rate of ~~at the same rate as~~ the immediately previous frame in the frame exchange sequence (as defined in 9.7)~~, if this rate belongs to the PHY mandatory rates, or else at the highest possible rate belonging to the PHY rates in the BSSBasicRateSet.~~

The time required to transmit a frame, for use in the Duration/ID field, can be calculated using the following equation:

Frame duration = aPreambleLength + aPLCPHeaderLength +
(8 x MPDU length x aMPDUDurationFactor) /
(MACCurrentRate x 32768)

10.3.3.1.2 Semantics of the service primitive

The primitive parameters are as follows:

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MLME-JOIN.request     (
                        BSSDescription,
                        JoinFailureTimeout,
                        ProbeDelay.
                        OperationalRateSet
)
```

Name	Type	Valid Range	Description
BSSDescription	BSSDescription	N/A	The BSSDescription of the BSS to join. The BSSDescription is a member of the set of descriptions that was returned as a result of a MLME-SCAN.request.
JoinFailureTimeout	integer	greater than or	The time limit, in units of beacon intervals,

		equal to 1	after which the join procedure will be terminated
ProbeDelay	integer	N/A	Delay (in μs) to be used prior to transmitting a Probe frame during active scanning
OperationalRateSet	set of integers	1 through 127 inclusive (for each integer in the set)	The set of data rates ~~(in units of 500kbit/s)~~ that the STA desires to use for communication within the BSS. The STA must be able to receive at each of the data rates listed in the set. ~~The OperationalRateSet~~ This set is a superset of the ~~BSSBasicRateSet~~ BSS basic rate set advertised by the BSS.

10.3.10.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-START.request (
SSID,
BSSType,
BeaconPeriod,
DTIMPeriod,
CF parameter set,
PHY parameter set,
IBSS parameter set,
ProbeDelay.
CapabilityInformation,
BBSBasicRateSet,
OperationalRateSet
)

Name	Type	Valid Range	Description
SSID	octet string	1 - 32 octets	The SSID of the BSS.
BSSType	Enumeration	INFRA-STRUCTURE, INDEPEN-DENT	The type of the BSS.
Beacon Period	integer	greater than or equal to 1	The Beacon period of the BSS (in Kμs).
DTIM Period	integer	As defined in Frame Format	The DTIM Period of the BSS (in Beacon Periods)
CF parameter set	As defined in Frame Format	As defined in Frame Format	The parameter set for CF periods, if the BSS supports CF mode. aCFPPeriod is modified as a side effect of the issuance of a MLME-START.request primitive.
PHY parameter set	As defined in Frame Format	As defined in Frame Format	The parameter set relevant to the PHY.
IBSS parameter set	As defined in Frame Format	As defined in Frame Format	The parameter set for the IBSS, if BSS is an IBSS.
ProbeDelay	integer	N/A	Delay (in μs) to be used prior to transmitting a Probe frame during active scanning
CapabilityInformation	As defined in Frame Format	As defined in Frame Format	The capabilities to be advertised for the BSS.
BSSBasicRateSet	set of integers	1 through 127	The set of data rates ~~(in units of 500 kbit/s)~~

		inclusive (for each integer in the set)	that must be supported by all STAs that desire to join this BSS. The STA that is creating the BSS must be able to receive and transmit at each of the data rates listed in the set.
OperationalRateSet	set of integers	1 through 127 inclusive (for each integer in the set)	The set of data rates ~~(in units of 500 kbit/s)~~ that the STA desires to use for communication within the BSS. The STA must be able to receive at each of the data rates listed in the set. ~~The OperationalRateSet~~ This Set is a superset of the BSS basic rate set~~BSSBasicRateSet~~ advertised by the BSS.

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm(
aSlotTime,
aSIFSTime,
aCCATime,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

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aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the wireless medium. This duration factor is normalized such that for the DS PHY its value is 65536. The total time to transmit a PPDU over the air is the following equation rounded up to the next integer μs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor x 8 x PSDU length (octets))/~~data rate~~(MACCurrentRate x 32768)). The total time (in μs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength +

		((aMPDUDurationFactor x 8 x *N*)/~~data rate~~(MACCurrentRate x 32768))] + 1, where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamblePLCP Header.

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