IEEE P802.11
Wireless LANs

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| Mesh high PHY rate airtime link metric |
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Abstract

This document provides suggested changes to solve a concern raised in REVmd comment collection (CID 109).

The concern is on scaling problem of the airtime link metric for mesh operation.

# Comment:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CID** | **PP.LL** | **Comment** | **Proposed Change** | **Suggested Resolution** |
| 109 | 2319.16 | [Background]802.11s introduced mesh procedures. As a part of the mesh procedures, path selection protocol and path selection metric are used to determine a mesh path over multiple hops. Path selection protocol and path selection metric are replacable module, and active path selection protocol and active path selection metric are signalled through Active Path Selection Protocol Identifier field and Active Path Selection Metric Identifier field in the Mesh Configuration element (see 9.4.2.98). For path selection metric, Airtime link metric is defined in clause 14.9, as the default path selection metric.[Problem]The current Airtime link metric cannot express high PHY rate link appropriately due to significant quantization error.Roughly speaking, the Airtime link metric is a channel occupancy time to transmit 1,024 octet data expressed in 0.01 TU. If we assume VHT80 Nss=4, 400ns GI, MCS=8, 1.56Gbps for PHY rate, the payload of the data consumes only 2 OFDM symbols, which is smaller than the unit of the Airtime link metric (0.01TU=10usec). Even with VHT80 Nss=2, 400ns GI, MCS6, 585Mbps, payload airtime value is rounded to the unit. This means the metric value cannot express high PHY rate link appropriately, which results in non-ideal mesh path selection. Also, the Airtime link metric uses 1,024 octet data to measure the airtime, which is quite small if we consider MPDU aggregation which is typical for 802.11n and 802.11ac transmission. Therefore, it is preferable to define a better metric expression that suites with high PHY rate links. | Add another Path Selection Metric, "High PHY rate airtime link metric" that scales to higher bandwidth links considering 802.11n and 802.11ac usage. To minimize the impact to the specification, the new Active Path Selection Metric shall work with existing Active Path Selection Protocol, HWMP. Only change the metric module. In particular:a) Assign a new Active Path Selection Metric Identifier in 9.4.2.98.3,b) Add new clause describing "High PHY rate airtime link metric" right after 14.9 (Airtime link metric),c) Change MIB variable description relating to dot11MeshActivePathSelectionMetric,d) Add another row to PICS table.Commenter is willing to provide resolution text based on 11/16-823. Indeed, the changes to the spec is minimal, and does not break any existing operation. | REVISED:Adopt changes proposed in doc11-17/1448r0. |

# Discussion:

### **1. Overview of the problems and proposed resolution**

1. Problem 1:
The currently defined airtime link metric is designed for 802.11a/b/g PHY. When mesh STA uses higher PHY rate, i.e., HT rate or VHT rate, the metric value suffers from significant quantization error and mesh STAs cannot determine efficient end-to-end path.
2. Problem 2:
The currently defined airtime link metric does not consider MPDU/MSDU aggregation for the metric calculation. As such, calculated metric value contains over weighted overheads when mesh STA uses HT or VHT PHY.
3. Proposed resolution:
Define a new path selection metric that scales to higher PHY rate and considers aggregation factor, “high PHY rate airtime metric”. It uses the same rationale for the metric representation as the currently defined airtime link metric: effective airtime occupancy to transmit 1024 octet data.
4. Impact to the rest of the specification:
As the path selection metric is defined as replaceable module, it is easy to add another metric as a part of the specification. The new path selection metric works with existing path selection protocol, and does not make further impact to rest of the mesh procedures.

### **2. Problem1: Unit of the metric**

Metric is a value used to determine a best end-to-end path (route) when mesh STAs try to establish an active path. Airtime link metric is designed to reflect how much airtime would be consumed to transmit a certain amount of data. Comparing the value, mesh STAs pick up a most efficient path among candidate paths, so that the total amount of airtime consumed to transfer data would be minimized. Naturally, airtime link metric value is represented as a function of PHY rate of the link.

Airtime link metric specified by 802.11s is intended for relatively low PHY rates defined by 802.11a/b/g, up to 54Mbps. If we use the airtime link metric for HT or VHT STAs, the metric value cannot express the airtime usage properly, due to quantization error. As a result, mesh STAs cannot determine efficient path (route).

To mitigate the problem, it is proposed to define a high PHY rate airtime metric utilizing x1024 finer resolution (0.01usec unit) to express high PHY rate links. Comparison between the current airtime metric and proposed high PHY rate airtime metric is shown in the following table (overhead portion is not included in the calculation below).

|  |  |  |
| --- | --- | --- |
|  | Current metric | **Proposed new metric** |
|  | Airtime link metric | High PHY rate airtime metric (0.01usec unit) |
| Airtime to transmit 1024 octet over 1Mbps PHY | 800 | 819,200 |
| Airtime to transmit 1024 octet over 585Mbps PHY | 1 = round(1.367) | 1,400 = round(1400.34) |
| Airtime to transmit 1024 octet over 1.56Gbps PHY | 1 = round(0.512) | 525 = round(525.13) |
| Airtime to transmit 1024 octet over 1.73Gbps PHY | 0 = round(0.461) | 473 = round(472.70) |
| Airtime to transmit 1024 octet over 6.93Gbps PHY | 0 = round(0.115) | 118 = round(118.21) |

Downside of the x1024 finer resolution is that the metric value becomes x1024 time larger number and may hit the ceiling easier. It should be noted that mesh STAs accumulate metric value over multiple hops linearly.

However, the Metric value is represented with 4 octet in length, and should have enough room to represent the value with x1024 times finer resolution.

Comparison on “how many hops the metric value can be accumulated” is shown in the following table assuming 1Mbps link metric (overhead portion is not included in the calculation below).

|  |  |  |
| --- | --- | --- |
|  | Current metric | **Recommended new metric** |
|  | Airtime link metric | High PHY rate airtime metric (0.01usec unit) |
| Max. number of hops with 1Mbps PHY | 5,368,709 hops | 5,242 hops |

Even with proposed x1024 times finer resolution. 4 octet is long enough to accommodate >5,000 hops which is more than plenty.

### **3. Problem2: Aggregation factor**

HT STAs and VHT STAs use MPDU aggregation and/or MSDU aggregation to reduce overhead. However, the airtime link metric does not consider MPDU/MSDU aggregation for the metric calculation. As a result, calculated metric value will be dominated by overly represented overhead portion when it expresses high PHY rate link. As such, mesh STAs cannot make reasonable distinction of the efficiency of the link based on the PHY rate.

To mitigate the problem, it is proposed to include aggregation factor to weaken the presence of the overhead portion, depending on the aggregation capability of the STA. In particular, it is proposed to define channel access overhead constant *O* to become *O/n* , where *n* is the typical number of MSDUs transmitted in a single frame.

### **4. Summary of the proposed changes**

It is proposed to define a new path selection metric in parallel with the current airtime link metric. Brief summary of the proposed changes are as follows:

* Add high PHY rate airtime link metric in parallel with current airtime link metric
* Define the high PHY rate airtime link metric as follows:
	+ Use the same rationale for the metric representation: effective airtime occupancy to transmit 1024 octet data
	+ Use x1024 finer resolution to express high PHY rate links to mitigate quantization error,
	 i.e., in units of 0.01 usec instead of 0.01 TU
	+ Take aggregation factor into consideration to calculate overhead portion appropriately.

In particular, the following changes are proposed.

1. Define a new Active Path Selection Metric Identifier for high PHY rate airtime link metric
2. Change subclause 14.9 (Airtime link metric) to 14.9 (Path selection link metric), add a new subclause 14.9.1 (General), and move contents of 14.9 (Airtime link metric) to a new subclause 14.9.2 (Airtime link metric).
3. Make editorial changes to subclause describing airtime link metric (14.9.2)
4. Add a new subclause describing high PHY rate airtime link metric (14.9.3)
5. Make changes to cross references to subclause 14.9
6. Amend PICS table to accommodate the new metric definition
7. Amend MIB variable to express the new metric definition

As discussed, the path selection metric is defined as replaceable module. The addition of the new metric does not make further impact to the rest of the mesh procedures, and new path selection metric works with existing path selection protocol. It will be an implementation choice if mesh STA uses airtime link metric or uses high PHY rate airtime link metric, while recommending to use high PHY rate airtime link metric for HT STAs and VHT STAs.

# Proposed changes:

Apply the following changes.

Corresponding changes to D0.2 are indicated in the following text with “Track Changes” on, to clarify the direction to the editor. Please update the part indicated by the “Track Changes” only.

***To REVmd Editor: Change 4.3.20.5.10 as follows:***

* Mesh path selection and forwarding

Mesh path selection enables path discovery over multiple instances of the wireless medium within a mesh BSS. The overview of the mesh path selection framework is described in 14.8 (Mesh path selection and metric framework). The hybrid wireless mesh protocol (HWMP) is defined as the default path selection protocol for the mesh BSS. HWMP provides both proactive path selection and reactive path selection. The details of HWMP are described in 14.10 (Hybrid wireless mesh protocol (HWMP)). The path selection protocol uses link metrics in the assessment of a mesh path to the destination. The details of link metrics are described in 14.9 (Path selection link metric). The airtime link metric is the default link metric. It is defined in 14.9.2 (Airtime link metric). If a mesh STA’s PHY entity is capable of transmitting frames with PHY rate higher than 54Mbps, it is recommended that the mesh STA uses high PHY rate airtime link metric, which is defined in 14.9.3 (High PHY rate airtime link metric).

***To REVmd Editor: Insert a new row representing value of 2 in Table 9-218 in subclause 9.4.2.98.3.***

**9.4.2.98.3 Active Path Selection Metric Identifier**

The Active Path Selection Metric Identifier field indicates the path metric that is currently used by the active

path selection protocol in the MBSS. Table 9-218 (Active Path Selection Metric Identifier field values)

provides the path selection metric identifier values defined by this standard.

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| --- |
| Table 9-218—Active Path Selection Metric Identifier field values |
| Value | Meaning |
| 0 | Reserved |
| 1 | Airtime link metric defined in 14.9.2 (Airtime link metric) (default path selection metric) |
| 2 | High PHY rate airtime link metric defined in 14.9.3 (High PHY rate airtime link metric) |
| 3–254 | Reserved |
| 255 | Vendor specific(The active metric is specified in a Vendor Specific element) |

When the Active Path Selection Metric Identifier field is 255, the active path metric is specified by a Vendor

Specific element that is present in the frame. The content of the Vendor Specific element is beyond the

scope of this standard. (See 9.4.2.26 (Vendor Specific element).)

***To REVmd Editor: Change the last paragraph in 9.4.2.100 as follows:***

* Mesh Link Metric Report element

…

The Link Metric field indicates the value of the link metric associated with the mesh link between the peer mesh STA transmitting the Mesh Link Metric Report and the neighbor mesh STA receiving the Mesh Link Metric report. The length and the data type of the Link Metric field are determined by the active path selection metric identifier (see 9.4.2.98.3 (Active Path Selection Metric Identifier)). The length and the data type for the airtime link metric are given in Table 14-5 (Parameters of the airtime link metric for extensible path selection framework) in 14.9.2 (Airtime link metric). The length and the data type for the high PHY rate airtime link metric are given in Table 14-7 (Parameters of the high PHY rate airtime link metric for extensible path selection framework) in 14.9.2 (Airtime link metric).

***To REVmd Editor: Change subclause 14.8 (Extensible path selection framework) as follows:***

* Extensible path selection framework

This standard allows for alternative and flexible implementations of path selection protocols and metrics.

A mesh STA may include multiple protocol implementations (that is, the default protocol, vendor-specific protocols, etc.) as well as multiple metric implementations, but only one path selection protocol and only one path selection metric shall be used by a mesh STA at a time.

As described in 14.2.3 (Mesh profile) and 14.2.7 (Candidate peer mesh STA), mesh STAs use the Mesh Configuration element (9.4.2.98 (Mesh Configuration element)) to announce the active path selection protocol and active path selection metric of the MBSS. This allows a neighbor mesh STA to identify if it should become a member of the MBSS and how it should establish mesh peerings with its members. This standard does not force an existing MBSS that is using a protocol other than the default protocol to switch to the default protocol when a new mesh STA requests mesh peering establishment. While it is possible, in principle, to implement such behavior, an algorithm to coordinate such reconfiguration is beyond the scope of this standard.

Path selection protocol and path selection metric are identified by a unique identifier as defined in 9.4.2.98.2 (Active Path Selection Protocol Identifier) and 9.4.2.98.3 (Active Path Selection Metric Identifier), respectively. Also, each path selection protocol and each path selection metric specifies the following:

* Data type of metric values
* Length of the metric field
* Operator for aggregation of link metrics to a path metric; the symbol  is used to identify an arbitrary operator for aggregation
* Comparison operator for determining a better or worse path; how this is performed depends on the actual comparison operator
* Initial value of the path metric (path selection metric only)

The standard defines HWMP as a default path selection protocol (see 14.10 (Hybrid wireless mesh protocol (HWMP))). The standard defines airtime link metric as a default path selection metric (see 14.9.2 (Airtime link metric)) and high PHY rate airtime link metric as a path selection metric for mesh STAs capable of transmitting frames with PHY rate higher than 54 Mbps (see 14.9.3 (High PHY rate airtime link metric)). Default path selection protocol and default path selection metric shall be implemented on all mesh STAs.

***To REVmd Editor: Change subclause 14.9 (Airtime link metric) as follows:***

* Path selection link metric

14.9.1 General

This subclause defines a default link metric that may be used by a path selection protocol to identify an efficient radio-aware path. A default link metric, airtime link metric, is described in 14.9.2 (Airtime link metric). Another link metric, high PHY rate airtime link metric, is described in 14.9.3 (high PHY rate airtime link metric). It is recommended that a STA uses high PHY rate airtime link metric when its PHY entity is capable of transmitting frames with PHY rate higher than 54Mbps.

The extensibility framework allows this metric to be overridden by other path selection metric as specified in the mesh profile.

14.9.2 Airtime link metric

This metric is used when dot11MeshActivePathSelectionMetric is airtimeLinkMetric (1) (see 14.2.3 (Mesh profile)).

Airtime reflects the amount of channel resources consumed by transmitting the frame over a particular link. This measure is approximate and designed for ease of implementation and interoperability.

The airtime for each link is calculated as follows:

where

*O* and *Bt* are constants listed in Table 14-4 (Airtime cost constants for airtime link metric)

input parameter *r* is the PHY data rate (in Mb/s). It represents the estimated data rate at which the mesh STA would transmit a frame of standard size *Bt* based on current link conditions; its estimation is dependent on local implementation of rate adaptation

input parameter *ef* is the frame error rate for the test frame size *Bt*. It is the probability that when a frame of standard size *Bt* is transmitted at the PHY data rate *r*, the frame is corrupted due to transmission error; its estimation is a local implementation choice. Failures due to exceeding Mesh TTL should not be included in this estimate as they are not correlated with link performance

The airtime link metric shall be encoded as an unsigned integer in units of 0.01 TU.

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| --- |
| * Airtime cost constants for airtime link metric
 |
| Parameter | Recommended value  | Description |
| *O* | Varies depending on PHY | Channel access overhead, which includes frame headers, training sequences, access protocol frames, etc. |
| *Bt* | 8192 | Number of bits in test frame |

Table 14-5 (Parameters of the airtime link metric for extensible path selection framework) gives the parameters of the airtime link metric for the extensible path selection framework.

|  |
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| * Parameters of the airtime link metric for extensible path selection framework
 |
| Parameter | Notes |
| Path Selection Metric ID | See Table 9-218 (Active Path Selection Metric Identifier field values) in 9.4.2.98.3 (Active Path Selection Metric Identifier) |
| Data type | Unsigned integer, 0 metric value < 4 294 967 296 |
| Length of metric field | 4 octets |
| Operator for metric aggregation | addition (+) |
| Comparison operator | *less than, equal to, greater than* as used with integers* metric *a* is *better than* metric *b* iff *a* < *b*
* metric *a* is *equal to* metric *b* iff *a* = *b*
* metric *a* is *worse than* metric *b* iff *a > b*
 |
| Initial value of path metric | 0 |

An example of the airtime link metric is shown in S.5 (Airtime link metric usage example).

14.9.3 High PHY rate airtime link metric

This metric is used when dot11MeshActivePathSelectionMetric is highPHYRateAirtimeLinkMetric (2) (see 14.2.3 (Mesh profile)).

Airtime reflects the amount of channel resources consumed by transmitting the frame over a particular link. This measure is approximate and designed for ease of implementation and interoperability.

The airtime for each link is calculated as follows:

where

*O, n,* and *Bt* are constants listed in Table 14-6 (Airtime cost constants for high PHY rate airtime link metric)

input parameter *r* is the PHY data rate (in Mb/s). It represents the estimated data rate at which the mesh STA would transmit a frame of standard size *Bt* based on current link conditions; its estimation is dependent on local implementation of rate adaptation

input parameter *ef* is the frame error rate for a MSDU length of size *Bt*. It is the probability that when a MSDU of standard size *Bt* is transmitted at the PHY data rate *r*, the MSDU is corrupted due to transmission error; its estimation is a local implementation choice. Failures due to exceeding Mesh TTL should not be included in this estimate as they are not correlated with link performance

The high PHY rate airtime link metric shall be encoded as an unsigned integer in units of 0.01 μs.

|  |
| --- |
| Table 14-6 -- Airtime cost constants for high PHY rate airtime link metric |
| Parameter | Recommended value  | Description |
| *O* | Varies depending on PHY | Channel access overhead, which includes frame headers, training sequences, access protocol frames, etc. |
| *n* | Varies depeding on implementation | Number of MSDUs aggregated in a single data frame. It represents the number of MSDUs that the mesh STA would transmit in a typical data frame; its estimation is dependent on local implementation of the A-MSDU and A-MPDU construction |
| *Bt* | 8192 | Number of bits in test frame |

Table 14-7 (Parameters of the high PHY rate airtime link metric for extensible path selection framework) gives the parameters of the airtime link metric for the extensible path selection framework.

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| Table 14-7 -- Parameters of the high PHY rate airtime link metric for extensible path selection framework |
| Parameter | Notes |
| Path Selection Metric ID | See Table 9-218 (Active Path Selection Metric Identifier field values) in 9.4.2.98.3 (Active Path Selection Metric Identifier) |
| Data type | Unsigned integer, 0 metric value < 4 294 967 296 |
| Length of metric field | 4 octets |
| Operator for metric aggregation | addition (+) |
| Comparison operator | *less than, equal to, greater than* as used with integers* metric *a* is *better than* metric *b* iff *a* < *b*
* metric *a* is *equal to* metric *b* iff *a* = *b*
* metric *a* is *worse than* metric *b* iff *a > b*
 |
| Initial value of path metric | 0 |

***To REVmd Editor: Change the row representing MP10 in the table in B.4.21.1 (General mesh support) in Annex B as follows:***

* Mesh protocol capabilities

**B.4.21.1 General mesh support**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  MP9.5 | Frame transmission to a mesh STA in deep sleep mode | 14.14.7 (Power save support), 14.14.9 (Mesh peer service periods)(Ed) | MP9:M | Yes  No  N/A  |
| \*MP10 | Link metric computation | 14.9 (Path selection link metric) (Ed) | CFMBSS(#6573):M | Yes  No  N/A  |
| MP10.1 | Airtime link metric computation | 14.9.2 (Airtime link metric)(Ed) | MP10 (#6573):M | Yes  No  N/A  |
| MP10.2 | High PHY rate airtime link metric computation | 14.9.3 (High PHY rate airtime link metric)(Ed) | MP10: O(#6573) | Yes  No  N/A  |
| \*MP11 | Link metric reporting | 14.8.3 (Link metric reporting)(Ed) | CFMBSS(#6573):M | Yes  No  N/A  |

***To REVmd Editor: Change the MIB definition of dot11MeshActivePathSelectionMetric in Annex C as follows:***

* MIB Detail

dot11MeshActivePathSelectionMetric OBJECT-TYPE

 SYNTAX INTEGER {

airtimeLinkMetric (1),

highPHYRateAirtimeLinkMetric (2),

vendorSpecific (255)

}

 MAX-ACCESS read-write

 STATUS current

 DESCRIPTION

 "This is a control variable.

 It is written by an external management entity.

 Changes take effect for the next MLME-START.request (MDR)primitive.

 This attribute specifies the active path selection metric."

 DEFVAL { airtimeLinkMetric }

 ::= { dot11MeshSTAConfigEntry 13 }

# Reference:

[1] Draft P802.11REVmd\_D0.2.

[2] 11-17/927 “REVmd Working Group Comments for MAC ad-hoc”

[3] 11-16/823, “CID 8028 – High throughput airtime link metric”