IEEE P802.11  
Wireless LANs

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| Traffic Model Updates to Evaluation Methodology | | | | |
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# Abstract

This document provides traffic model updates to Evaluation Methodology Document [IEEE 802.11-14/571r08](https://mentor.ieee.org/802.11/dcn/14/11-14-0571-08-00ax-evaluation-methodology.docx) in support of mixed traffic modeling for each simulation scenario in Simulation Scenarios Document [IEEE 802.11-14/0980r10](https://mentor.ieee.org/802.11/dcn/14/11-14-0980-10-00ax-simulation-scenarios.docx)

# Problem 1

The underlying dot11ax Traffic Models are presented in the Evaluation Methodology Document [IEEE 802.11-14/0571r8](https://mentor.ieee.org/802.11/dcn/14/11-14-0571-08-00ax-evaluation-methodology.docx).

Traffic Model relevancy (Per each apartment/cubicle/BSS) to specific Simulation Scenarios are TBD for scenario 1~4 in the Simulation Scenarios Document [IEEE 802.11-14/0980r10](https://mentor.ieee.org/802.11/dcn/14/11-14-0980-10-00ax-simulation-scenarios.docx).

Currently the reserved location for the TBD information in the Simulation Scenario document only conveys the potential presence and characterstics of the traffic models.

For simulation purposes it is also necessary to know the specific traffic types that are present for a given Simulation Scenario, and at what frequency of presence among STA in the BSS: Traffic Mix.

Update to the Evaluation Methodology Appendix 2 Traffic Models are required to provide clarity, consistency with the changes needed to the Simulation Scenarios Document, and to correct for Traffic Model omission for HTTP traffic, as part of the Traffic Mix completion in the Simulation Scenario Document.

# Remedy 1

[Modify EVM Appendix 2 Traffic Model Descriptions as:]

# Appendix 2 – Traffic model descriptions

## Wireless Display (lightly compressed video) Traffic Model

Wireless display is a single-hop unidirectional (e.g., laptop to monitor) video application. The video slices (assuming a slice is a row of macro blocks) are generated at fixed slice interval. For example, for 1080p, the slice interval is 1/4080 seconds.

The video slices are typically packetized into MPEG-TS packets in wireless display application. But for 11AX simulation, we will ignore the MPEG-TS packetization process and assume video slices are delivered to MAC layer for transmission directly.

The traffic model for wireless display is modified from [TGad] with modifications below due to the fact that some parameters have dependency on video formats.

1. Parameters
   1. Set **IAT**, **MaxSliceSize** according to video format as Table 4.
   2. Normal distribution parameters
      1. µ = 9.19 Kbytes
      2. σ = 1.350 Kbytes
      3. b = 300 Mbps
2. Algorithm for generating each video slice/packet

* Input: target bit rate in Mbps (**p**)
* Output: slice size in Kbytes (L): At each IAT, generate a slice size L with the following distribution: Normal(µ\*(p/b), σ\*(p/b))
  + - If L > MaxSliceSize, set L= MaxSliceSize

Table 4: Model parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Traffic Model Class Identifier** | **Video format** | **Inter-arrival time (IAT)** | **MaxSliceSize** | **p** |
| WD1 | 1080p60 | 1/4080 seconds | 92.160 Kbytes | 300 |
| WD2 | 1080p60 3D | 1/4080 seconds | 92.160 Kbytes | 450 |
| WD3 | 4K UHD (3840x2160) 60fps | 1/8100 seconds | 184.320 Kbytes | 600 |
| WD4 | 8K UHD (7680x4320) 60fps | 1/16200 seconds | 368.640 Kbytes | 1200 |

Note: the data rate increase from 1080p to higher resolution is not linearly scaling as the uncompressed data rate due to higher redundancy in the images at higher resolution. Similar argument applies to 3D video. A 100% increase is assumed for 4K video as compared to 1080p, and 50% bit rate increase for 3D from 2D video.

### Evaluation metric

* MAC throughput, latency

## Buffered Video Steaming (e.g., YouTube, Netflix) Traffic Model

Unlike wireless display, video streaming is generated from a video server, and traverses multiple hops in the internet before arriving at AP for transmission to STA. It is a unidirectional traffic from the video server to the station, with reciprocal TCP Acknowledgement of the video frames.

Typically, Video streaming application runs over TCP/IP protocol, and video frames will be fragmented at TCP layer before leaving the video server. Since these TCP/IP packets experiences different processing and queuing delay at routers, the inter-arrival time between these TCP/IP packets are not a constant despite the fact that video frames are generated at constant interval at the video application layer.

### STA Layering Model

STA layering model is shown in Figure xx. Both AP and STA generate video frames at application layer. The video traffic goes through TCP/IP layer and then to MAC layer. The TCP protocol used for video streaming simulation is the same as other traffic model.



Figure 5: Traffic layering model

### Video traffic generation

The video traffic from Video Source to Video Receiver is generated as follows:

**Step 1**: At application layer, generate video frame size (bytes) according to Weibull distribution with the following PDF.


f(x;\lambda,k) =
\begin{cases}
\frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1}e^{-(x/\lambda)^{k}} & x\geq0 ,\\
0 & x<0,
\end{cases}

Depending on the video bit rate, the parameters to use are specified in Table 5.

Table 5: Lambda and k parameter for video bit rate

|  |  |  |  |
| --- | --- | --- | --- |
| **Traffic Model Class Identifier** | **Video bit rate** | **lambda** | **k** |
| BV1 | 2Mbps | 6950 | 0.8099 |
| BV2 | 4Mbps | 13900 | 0.8099 |
| BV3 | 6Mbps | 20850 | 0.8099 |
| BV4 | 8Mbps | 27800 | 0.8099 |
| BV5 | 10Mbps | 34750 | 0.8099 |
| BV6 | 15.6 Mpbs | 54210 | 0.8099 |

**Step 2**: AT TCP layer, set TCP segment as 1500 bytes and fragment video packet into TCP segments.

**Step 3**: Add network latency to TCP/IP packets when these segments arrive at AP for transmission. The network latency is generated according to Gamma distribution whose PDF is shown below

f(x;k,\theta) =  \frac{x^{k-1}e^{-\frac{x}{\theta}}}{\theta^k\Gamma(k)} \quad \text{ for } x > 0 \text{ and } k, \theta > 0.

Where

* + k=0.2463
  + theta=60.227

The mean of the latency with the above parameters is 14.834ms. To simulate longer or shorter network latency, scale theta linearly since mean of Gamma distribution is K\*theta

If network latency value is such that the packet arrives at MAC layer after the end of the simulation time, then re-generate another network latency value until the packet arrives at MAC within the simulation window.

The reciprocal TCP Ack to the video traffic, from Video Receiver to Video Source is generated as follows:

Step 1: 40 Byte TCP Ack, inter-arrival interval is equal to 1ms delay from video traffic frame reception at the Video Receiver

### Evaluation metrics

* MAC throughput, latency
* TCP throughput, latency

## Video Conferencing (e.g., Lync) Traffic Model

Unlike buffered video streaming where video traffic is unidirectional and heavily buffered at the receiver, video conferencing is bi-directional video traffic with limited tolerance for latency. Video traffic is generated at each station, sent to AP, traverses the network/internet, reaches another AP, and then is transmitted to its destination STA.

### Station layer model



Figure 6: Video conferencing model

Because the traffic from AP to station has experienced network jitter, it can be modelled the same way as the traffic model of video streaming.

For traffic sent from Station to AP, since the traffic has not experienced network jitter, it is a periodic traffic generation as the first two steps described in video streaming.

### Video traffic generation

Traffic model from AP to station: use the same model as video streaming BV1.

Traffic model from station to AP: use the first two steps in video streaming traffic model BV1

Traffic Model Class Identifier for Video Conferencing is VC

### Evaluation metrics

* MAC throughput, latency

## Application event models

Application event model is used to specify the patterns of the application events, i.e., when to start the applications and how long for each application in the simulation. Different use scenarios may choose different application event models in the simulation.

* Poisson model

Poisson model can be used for random application event pattern where there are many users, each generating a little bit of traffic and requesting network access randomly.

Parameters: TBD

* Hyper-exponential model

Hyper-exponential model can be used for peak event pattern where users requesting network access in big spikes from the mean.

Parameters: TBD

## Multicast Video Streaming Traffic Model

Multicast Video Streaming is unidirectional video traffic from AP to multiple (1 or more) STAs.

The video traffic is generated from a video server, and traverses multiple hops in the internet before arriving at AP for transmission to STAs.

### Station layer model

****

Figure 7: Multicast streaming model

AP generates video frames at application layer.

Because the traffic from AP to stations has experienced network jitter, it can be modelled the same way as the traffic model of video streaming.

The video traffic goes through UDP/IP layer and then to MAC layer. The video traffic is transmitted in the MAC layer as multicast RA addressed frames, NOT multiple duplicate instances of unicast RA addressed frames.

### Video traffic generation

Traffic model from AP to station: use the same steps in video streaming traffic model

We assume bit rate for video streaming 6 Mbps (1080/30p AVC) and 3 Mbps (1080/30p HEVC)

|  |  |  |  |
| --- | --- | --- | --- |
| **Traffic Model Class Identifier** | **Video bit rate** | **Lamda** | **K** |
| MC1 | 3Mbps | 10425 | 0.8099 |
| MC2 | 6Mbps | 20850 | 0.8099 |

**Evaluation metrics**

MAC throughput, latency

## Gaming Traffic Model

First Person Shooter (FPS) is a typical representative game of Massively Multiplayer Online (MMO) game. The FPS traffic model is considered to be a typical gaming traffic model, as it has additional requirements on, for instance, real time delay with irregular traffic arrivals. Gaming is asymmetric, bi-directional single-hop video traffic.

Gaming traffic can be modelled by the Largest Extreme Value distribution. The starting time of a network gaming mobile is uniformly distributed between 0 and 40 ms to simulate the random timing relationship between client traffic packet arrival and reverse link frame boundary. The parameters of initial packet arrival time, the packet inter arrival time, and the packet sizes are illustrated in the Table 6 [13]:

Table 6: Parameters for gaming traffic model

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Component** | **Distribution** | | **Parameters** | | **PDF** |
| **DL** | **UL** | **DL** | **UL** |
| Initial packet arrival (ms) | Uniform | Uniform | a=0,  b=40 | a=0,  b=40 |  |
| Packet arrival time (ms) | Largest Extreme Value | Largest Extreme Value | a=50,  b=4.5 | a=40,  b=6 |  |
| Packet size (Byte) | Largest Extreme Value | Largest Extreme Value | a=330,  b=82 | a=45,  b=5.7 |  |

\* A compressed UDP header of 2 bytes and a IPv4 header of 20 bytes (if use IPv6 here, the header should be 40bytes) has been accounted for in the packet size.

Traffic Model Class Identifier for Gaming is GMG

### Evaluation metrics

MAC throughput, latency

## Virtual Desktop Infrastructure Traffic Model

Virtual desktop infrastructure (VDI) traffic is generated from a server, and traverses multiple hops in the intranet before arriving at AP for transmission to STA. For the transmission from AP to STA, it is asymmetric, bidirectional single-hop traffic between AP and STA. VDI traffic transfers from server to STA/client via AP over TCP/IP protocol. This model describes the attribution of traffic from AP to STA, and VDI application type navigation and feedback traffic from the STA to AP.

The VDI traffic from AP to STA is generated as follows:

**Step 1:** VDI traffic generation

The VDI traffic is generated as shown in Figure xx. At MAC layer, arrival interval of VDI packets is generated according to exponential distribution.



Figure 8: Traffic generation model

Traffic direction specific parameters for packet arrival time are specified in Table 7.

**Step 2**: At MAC layer generate VDI MSDU frame size (in bytes) for uplink and downlink transmission, respectively.

For uplink the packet size is generated according to a Normal distribution. For downlink the packet size is generated with a bimodal Normal distribution. The traffic direction specific PDFs and the packet size parameters are specified in Table 7.

Table 7: Parameters for VDI traffic model

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Component** | **Distribution** | | **Parameters** | | **PDF** |
| **DL** | **UL** | **DL** | **UL** |
| Initial packet arrival (ms) | Uniform | Uniform | a=0,  b=20 | a=0,  b=20 |  |
| Packet arrival time (ms) | Exponential | Exponential |  |  |  |
| Packet size (Byte) | Bimodal Normal | Normal |  |  |  |

Traffic Model Class Identifier for Gaming is VDI

### Evaluation metrics

* MAC throughput
* Latency

**Voice-over-IP (VoIP) Traffic Model**

VoIP service uses the internet protocols to deliver real-time voice packets across networks. VoIP traffic is symmetric, bi-directional between AP and STA. The VoIP traffic comprises periods of active talking and silence, as shown in Figure 1. It can be considered as a simple 2-state noice activity Markov model as shown in Figure 2.



**Figure 1: VoIP traffic profile**



**Figure 2: Two-state voice activeity model**

For VoIP traffic, the VoIP user will always be in either the silence state (State 0) or active talking state (State 1), assuming that the probability of transitioning from state 0 to state 1 is *a*, and the reciprocal transition from state 1 to state 0 is *b*. Hence, the probability of staying in state 0 is 1*-a* and in state 1 is 1-*b*. The state update is assumed to be done at the speech encoder frame rate *R*=1/*T*, where *T* is the encoder frame duration whose typical value is 20ms for active talking state and 160ms for silence state, respectively. VoIP packets are generated at time intervals *iT*+*τ*, where *τ* is the network packet arrival delay jitter, and *i* is the encoder frame index. During the active state, voice packets with fixed size are generated at these time intervals, while the model is updated at regular frame intervals [1].

The detailed parameters of the VoIP traffic model are specified in Table 1. The rate of voice source assumes 12.2 kbps with a 50% voice activity factor. The payload size of active talking state and silence state are 33 byte and 7 byte respectively. Compressed protocol headers including UDP check sum are used in the traffic, which is 3 byte for IPv4 and 5 byte for IPv6. The total voice MSDU frame sizes for active talking state are 36 byte and 38 byte for IPv4 and IPv6 respectively, and for silence state are 10 byte and 12 byte for IPv4 and IPv6 respectively.

Table 1: Parameters for VoIP traffic model

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Distribution** | **Parameters** | **PDF** |
| Source rate | N/A | 12.2 Kbps | N/A |
| Active packet payload size | N/A | 33 byte | N/A |
| Silence packet payload size | N/A | 7 byte | N/A |
| Compressed protocol headers | N/A | IPv4: 3 byte  IPv6: 5 byte | N/A |
| Voice encoder interval | N/A | 20+τ ms | N/A |
| Noise encoder interval | N/A | 160+τ ms | N/A |
| Active/Silence state duration | Exponential | Mean=1.25 second |  |
| Downlink delay jitter | Laplacian | *β*=5.11 ms |  |
| Uplink delay jitter | N/A | 0 | N/A |
| Voice activity factor | N/A |  | N/A |
| a | N/A | 0.016 | N/A |
| b | N/A | 0.016 | N/A |

Traffic Model Class Identifier for VoIP is VOIP

**Evaluation metrics**

MAC throughput, latency

**Local File Transfer (FTP) Traffic Model**

FTP, File Transfer Protocol is a standard network protocol used to transfer computer files from an FTP Source to an FTP Client over a TCP-based network, such as the Internet. FTP traffic is asymmetric, bi-directional with large, fixed-size block data frames in one direction, from an FTP Source to an FTP Client, and TCP ACK responses in the other direction, from the FTP Client to an FTP Source. FTP traffic is modeled as a sequence of file transfers separated by reading time, where reading time is defined as the time between the end of file transmission and the start of the subsequent file transmission. The packet call size is equivalent to the file size (S) and the packet call inter-arrival time is the reading time (D). A typical FTP traffic pattern is shown in Figure 1



**Figure 1 FTP traffic pattern**

The FTP Source traffic generation process is, at first, to create a file using the file size statistics in Table 1 which provides the model parameters for FTP traffic that includes both DL and UL, with either MTU size is 1500 bytes or 576bytes, and then to complete the transfer of the file using a new TCP connection with initial window size W=1, eventually waiting for a reading time until next file transfer.

Based on the results on packet size distribution, 76% of the files are transferred using an MTU size of 1500 bytes and 24% of the files are transferred using an MTU size of 576 bytes. Note that these two packet sizes calculated from the statistical distributions in Table 1 also include a 40 byte IP packet header.

**Table 1: Parameters for FTP traffic model**

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Distribution | Parameters | PDF |
| File  size (S) | Truncated Logonormal | Mean = 2 Mbytes  SD = 0.722 Mbytes  Max = 5 Mbytes | if x > max or x < min, discard and generate a new value for x |
| Reading  time (D) | Exponential | Mean = 180 second |  |

The reciprocal TCP Ack to the FTP traffic, from FTP Client to FTP Source is generated as follows:

Step 1: 40 Byte TCP Ack, inter-arrival interval is equal to 1ms delay from FTP traffic frame reception at the FTP Client

Traffic Model Class Identifier for FTP is FTP

**Evaluation Metrics**

* MAC Throughput, latency

**Web Browsing (HTTP) Traffic Model**

HTTP traffic is governed by the structure of the web pages on the World Wide Web (WWW), and commonly has a bursty profile due to the characteristics of human interaction, where the HTTP traffic pattern is as shown in Figure 2.

HTTP traffic is asymmetric, bi-directional with large, fixed-size block data frames in one direction, from an HTTP Server to an HTTP Client, and HTTP request packet(s) and TCP ACK responses in the other direction, from the HTTP Client to an HTTP Server.



**Figure 2 HTTP traffic pattern**

Packet session represents that web page is being transferred from HTTP Server to HTTP Client, and the reading interval represents the time that Client spending reading the webpage. The amount of information transferred from the Server to Client during the packet session is governed by the web page structure. A webpage is usually composed of a main object and several embedded objects. The total amount of traffic transferred from HTTP Server to HTTP Client is equivalent to the size of the main object and a number of the embedded objects, where the model parameters of HTTP Server traffic are specified in Table 2.

The HTTP Client sends an HTTP request packet, which has a constant size of 350 bytes in order to initiate an HTTP Server traffic event.

From the statistics presented in the literature, a 50%-50% distribution of HTTP versions between HTTP 1.0 and HTTP 1.1 has been found to closely approximate web browsing traffic in the internet. Studies also show that the maximum transmit unit (MTU) sizes most common to the internet are 576 bytes and 1500 bytes (including the TCP header) with a distribution of 24% and 76% respectively.

Thus, the HTTP Server web traffic generation is that, at first, to create an HTML page using the HTML page statistics, with either MTU size is 1500 bytes or 576bytes, and then to download the main and the embedded objects using either HTTP/1.0-burst transport or HTTP/1.1- persistent transport.

**Table 2: Parameters for HTTP traffic model**

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Distribution | Parameters | PDF |
| File  size (S) | Truncated Logonormal | Mean = 10710 bytes  SD = 25032 bytes  Min = 100 bytes  Max = 2 Mbytes  (before truncation) | if x > max or x < min, discard and generate a new value for x |
| Embedded  Object size (SE) | Truncated Logonormal | Mean = 7758 bytes  SD = 126168 bytes  Min = 50 bytes  Max = 2 Mbytes  (before truncation) | if x > max or x < min, discard and generate a new value for x |
| Number of  embedded  objects per  page (Nd) | Truncated  Pareto | Mean = 5.64  Max. = 53  (before truncation) | Subtract k from the generated random  value to obtain Nd  if x > max, discard and regenerate a new value for x |
| Reading  time (Dpc) | Exponential | Mean = 30 sec |  |
| Parsing  time (Tp) | Exponential | Mean = 0.13 sec |  |

I addition to the HTTP request packet from HTTP Client to HTTP Server, the reciprocal TCP Ack to the HTTP traffic, from HTTP Client to HTTP Server is generated as follows:

Step 1: 40 Byte TCP Ack, inter-arrival interval is equal to 1ms delay from HTTP traffic frame reception at the HTTP Client

Traffic Model Class Identifier for HTTP is HTTP

**Evaluation Metrics**

* MAC Throughput, latency

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# Straw poll

Do you agree to modify the Evaluation Methodology document IEEE 802.11-15/571r8 as provided in IEEE 802.11-15/0590r0?

Y:

N:

A: