Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Traffic Model for 802.16 TG3 MAC/PHY Simulations**
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Re:	This contribution contains the Traffic Models to be used for simulating the performance of proposed MAC/PHY's in IEEE 802.16 Task Group 3
Abstract	This contribution describes traffic models that provide typical self-similar traffic for data applications and interrupted Poisson (or on-off) models for streaming media applications for a point-to-multipoint fixed wireless WAN application. The contribution specifies the traffic models for various proto-typical cases. It also provides a definition of what MAC/PHY performance metrics to calculate as a means of characterizing the performance of the MAC/PHY.
Purpose	The contribution describes a traffic model to be used for characterizing performance of MAC/PHY proposals for consideration as components of the common air interface standard for IEEE 802.16 TG3.
Notice	
Release	
Patent Policy and Procedures	

Traffic Model for 802.16 TG3 MAC/PHY Simulations

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Traffic Model for 802.16 TG3 MAC/PHY Simulations

1 Introduction

This contribution defines a traffic model that generates traffic for a point-to-multipoint, fixed-wireless WAN. The model generates traffic in one direction of flow only. To obtain a two-way traffic flow a summation of two independent models is necessary. The summation of the two one-way models can represent both symmetric and asymmetric traffic with respect to the forward and reverse directions from the central point-to-multipoint hubs to individual and remote subscribers.

The contribution contains the following three major sections:

- A model for generating one-way traffic for a single subscriber unit s WAN traffic to or from the point-to-multipoint hub
- A description of proposed set of WAN traffic scenarios for characterizing the performance of a common air interface proposal under different traffic conditions
- A set of parameters to calculate when using the model for characterizing the performance of a candidate MAC/PHY air interface when using the proposed traffic scenarios

To generate the traffic for a set of subscriber units all sharing a common point-to-multipoint hub, each subscriber unit would need a pair of traffic generation models. One model for the forward traffic to the subscriber and another for the reverse traffic from the subscriber unit. Thus, for a set of 25 subscriber units serviced by a single hub, the traffic generation model consists of the summation of 25 pairs (forward/reverse) of traffic generators.

Figure 1-1: Example Network Scenario

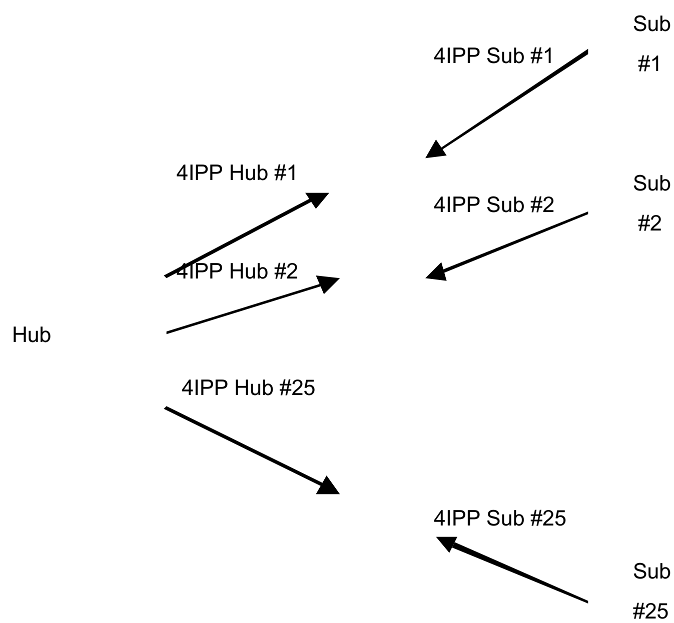


Figure 1-1 shows the traffic flows over a common point-to-multipoint hub with 25 subscribers.

To present a mix of traffic to the hub the set of subscribers may be a mix of different types. For example, some of the subscribers could be residential users while others may be small business or SOHO users. The mix of different categories of subscribers is specified in the simulation scenarios specified in later sections of this document.

The traffic characteristics of each type of subscriber is also specified in later sections of the document. The traffic characteristics include a combination of HTTP/TCP, FTP, voice, and streaming video activity. Different user types have different mixes of the traffic as well as different volumes of traffic. The subscriber classes and their associated traffic characteristics are specified in later sections of this document.

Note that the basic assumption for all models made here is: The call level behavior is NOT modeled at all, only packet level behavior is captured. There are two reasons for doing that: A). Modeling of both call level and packet level will make the simulation too complicated to be executed within reasonable time frame. B). Only packet level behavior is more relevant to MAC/PHY performances, call level behavior is more of up layers concern.

The next sections define each of the traffic models — HTTP/TCP, FTP, voice over IP, and streaming video. Each traffic model is scaled for specific data rates for later use in the simulation scenarios. The scenarios are specified in later sections within this document.

2 Description of the HTTP/TCP and FTP Model

The traffic model generates self-similar traffic found in Ethernets and on the Internet. The model has been proven to accurately predict measured traffic for both Ethernet and Internet traffic. The model is based on an Interrupted Poisson Process (IPP). To generate the self-similar traffic a superposition of 4IPPs has been found to be a good model to use. See reference 1 [Andersen] for details. Each Interrupted Poisson Process generates traffic between the hub and the subscriber unit.

The model simulates the traffic associated with the link between the LAN and a Router as shown in the following figure. The model does NOT simulate the traffic that stays on the LAN which does not exit the LAN to the router. To simulate the traffic destined for the router from the LAN, the model has an on time when it is generating packets to the router and it has an off time when the packets are going from one device on the LAN to another device on that same LAN segment. Since the model only simulates one direction of the traffic, a second simulation model is required for the traffic coming from the router to the LAN.

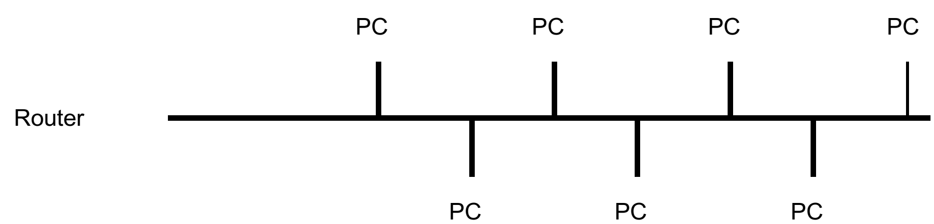
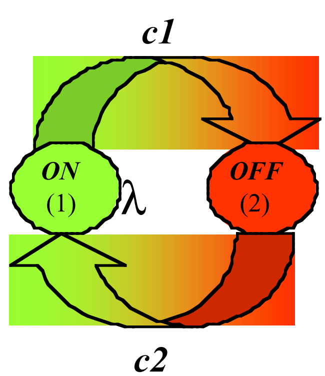


Figure 2-1: Example Subscriber Scenario

The traffic in the above figure simulates the traffic to and from the point-to-multipoint hub and the remote subscriber unit as the router represents the hub and the LAN represents the subscriber unit.

2.1 Application of the 4IPP model to fixed, wireless, point-to-multipoint WANs

The model is a superposition of four Interrupted Poisson Process (4IPP) in which each IPP spans a distinct time frame in order to generate the self-similar traffic found in Ethernet and Internet traffic. The following figure defines each of the normalized Interrupted Poisson Processes. The Interrupted Poisson Process has two states — ON and OFF. During the ON state, the Interrupted Poisson Process generates _ packets/unit-of-time. During the OFF state, the Interrupted Poisson Process does not generate packets. The transition probability rate, c1, is the number of transitions from the ON state to the OFF state per unit-of-time. The transition probability rate (1-c1) is the number of transitions from the ON state to the ON state per unit-of-time. The transition probability rate, c2, is the



number of transitions from the OFF state to the ON

Figure 2-2: Normalized IPP Model

state per unit-of-time. The mean dwell or sojourn time in state 1 (ON time) is 1/c1 (unit-of-time), and the mean dwell time in state 2 (OFF time) is 1/c2 (unit-of-time). The long-term mean probability of being in the ON state is c2/(c1 + c2), and for the OFF state is c1/(c1 + c2). Thus, the parameters c1, c2 and _ characterize the Interrupted Poisson Process.

The normalization factor in the IPP model in Figure 2-2 is that transition probability rates are scaled such that the transition probability rates emanating from any one state sum to 1, i.e. c1 + (1-c1) = 1. When the IPP model is used (as will be seen in a later section), the transition probability rates will be scaled from normalized unit-of-time to seconds to realize a given data rate and packet size (e.g. 4 Mbps and 192-byte-packets of simulated subscriber LAN traffic).

To model the self-similar traffic found in Ethernet and Internet traffic samples, four Interrupted Poisson Processes are superimposed. Each of the four processes has different c1, c2 and _ parameters to represent 4 different time scales found in the self-similar traffic. The following figures graphically demonstrate these different time scales that are represented by the different values of c1, c2 and _. The packet traffic is reasonably well modeled by using just 4 Interrupted Poisson Processes if the parameters of each Interrupted Poisson Process are appropriately chosen.

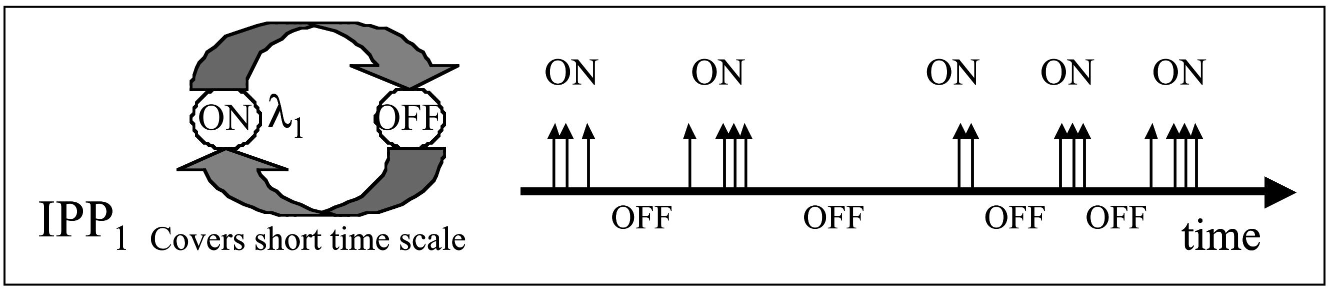
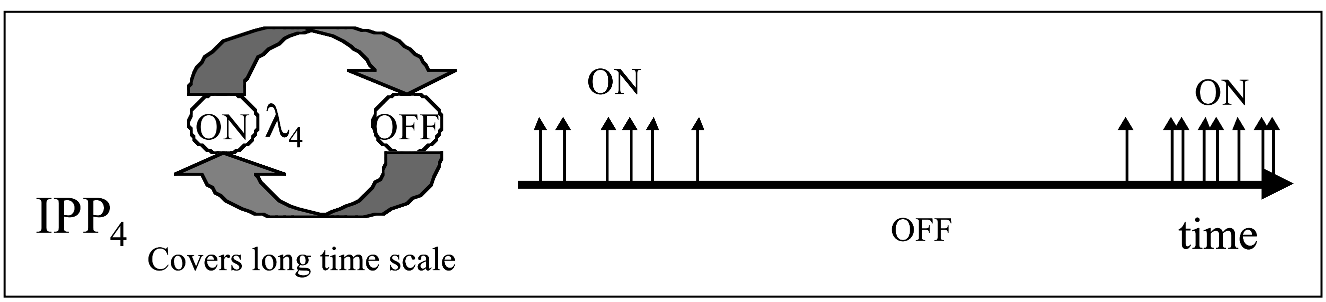


Figure 2-3: Short-term IPP Component

The above figure shows the packets being generated over a short time scale. The following figure shows the packets being clustered at a longer time scales. The 4IPP model superimposes 4 different time scales to generate an accurate



representation of traffic for Ethernet and Internet.

Figure 2-4: Long-term IPP Component

2.2 Basic assumptions of the model

The basic model assumes the following construction of traffic between each fixed subscriber unit and the central point-to-multipoint hub. The subscriber unit uses a 4IPP model to determine the traffic the subscriber unit sends to the hub. The hub uses a 4IPP model to determine the traffic the hub sends to that same subscriber unit. Thus, a point-to-multipoint hub with 25 subscribers has 25 4IPP generators for the traffic to the subscriber units (forward) and another 25 4IPP generators for the traffic to the hub (reverse).

The model also assumes that the traffic from both the hub and the subscriber unit originates from a LAN that connects to the subscriber unit or the hub. In the case of the subscriber unit the subscriber unit is assumed to connect to a router on the subscriber premises LAN. On the hub side, the traffic arriving at the hub from the packet data network is assumed to originate from some server farm that has a LAN that connects to the router that routes the traffic to this hub. In either case, it is assumed that only a small fraction of the traffic (e.g. approximately 10% if symmetric traffic is assumed) goes over the air interface from these LANs with the remainder of the LAN traffic remaining local to that LAN.

Another assumption of the model is the fact that the maximum average Ethernet traffic or average throughput is about 40% of the LAN maximum capacity. Hence, a 10 Mbps Ethernet handles 4 Mbps of average traffic as its maximum average traffic. For the symmetric traffic case, the model assumes both directions of the traffic originate from a 10 Mbps LAN operating at an average 4 Mbps in which the average data rate is the same in both forward and reverse directions.

The scaling of the model parameters involves two steps. First, an intermediate set of 4IPP parameters is derived for internal LAN traffic reflecting a 40% ON state [time ratio of ON/(ON+OFF)] commensurate with 4 Mbps/10 Mbps. The second step recognizes that only about 10% of the internal LAN traffic exits the LAN as external traffic, flowing over the air interface of the point-to-multipoint radio system. This leads to an external traffic 4IPP model that is ON about 4% of the time (one-tenth that of the hypothetical internal traffic model construct). As stated above, for symmetric traffic, this model is used for each direction of traffic to/from a subscriber unit (two models for each subscriber unit).

For a 10:1 ratio of forward-to-reverse asymmetric case (which can be a reasonable model for individuals at the subscriber premises primarily accessing the web), we start with the assumption that the hub traffic to the subscriber unit is the same as the model described above; i.e., a 10 Mbps LAN with 40% peak load (4 Mbps) bursting packets to that subscriber 4% of the time, or 400 kbps in the forward direction. However, in keeping with the 10:1 asymmetry premise, the subscriber unit would only be sending external traffic packets in the reverse direction at a rate of 40 kbps. If it is assumed that the subscriber also has a 10 Mbps LAN with 4 Mbps average internal LAN traffic (like the hub forward traffic to this subscriber), then this 10:1 asymmetry premise means that the external reverse traffic model at the subscriber unit is ON only about 0.4% of the time.

For a 4:1 ratio of forward-to-reverse traffic, the hub model would assume, as before, a 10 Mbps LAN operating at 40% peak load (4 Mbps average data rate) having only 10% of the traffic exiting the LAN towards the subscriber unit (ON about 4% of the time). The reverse channel subscriber unit traffic model would send packets to the hub only about 1% of the time.

For all of the symmetric and asymmetric scenarios described above, a fundamental assumption about the nature of the internal 10 Mbps LAN traffic at both ends of the air interface has been kept constant to preserve the high-speed packet characteristics in both directions of traffic flow. Only the time ratios of ON/(OFF+ON) have been adjusted to equivalently divert shorter- or longer-windowed bursts of external traffic, depending on the desired (a)symmetry.

The parameters that define these models for a set of subscribers will be described in a later section of this contribution.

3 Description of the HTTP/TCP and FTP traffic simulation model

3.1 Basic 4IPP parametric model.

The parameters in the following table define the basic 4IPP model. These parameters are chosen to match self-similar traffic that has a Hurst parameter of 0.9. The Hurst parameter is the measure of correlation of the present packet with the previous packet. The Hurst parameter of 0.9 matches the traffic measure at both Telcordia Technologies and at the Lawrence Berkeley Labs. The parameters were derived from reference 2 [Andersen].

Each row of the table describes one of the four IPPs. The second column contains the _ value for the average packets per unit of time. The third column contains parameter c1 that determines the transition probability rate of going from the ON state (bursting packets over the air link) to the OFF state. Column three contains the parameter c2 that determines the transition probability rate of going from the OFF state (packets stay within the LAN and do not go over the air interface) to the ON state. The last column contains the total average packets for the sum of the ON and OFF times. The last row of the last column contains the average packet rate per unit of time for the superposition of all 4 IPPs combined.

The parameters of the model are shown in Figure 3-1 below

source_i	_i IPP in ON state (pkts/unit-of-time)	c1i (transition probability rate from ON to OFF) transitions/ unit-of-time	c2i (transition probability rate from OFF to ON) transitions/ unit-of-time	*Averaged over both ON and OFF states (pkts/unit-of-time)*
IPP#1	**2.679**	4.571E-01	3.429E-01	*1.1480*
IPP#2	**1.698**	1.445E-02	1.084E-02	*.7278*
IPP#3	**1.388**	4.571E-04	3.429E-04	*.5949*
IPP#4	**1.234**	4.571E-06	3.429E-06	*.5289*
			4IPP Average Rate (pkts/unit-of-time) =	***3.00***

Figure 3-1: Basic 4IPP Model – HTTP/TCP and FTP

Note that this is an approximation of HTTP/TCP and FTP traffic from aggregated point of view, it s not the individual application specific model, it is accurate as long as the aggregate traffic is a concern.

3.2 Scaling of the model: internal vs. external traffic

The 4IPP model of the previous section must be scaled to give the appropriate data rate for the test cases stated in a following section of the contribution. For example, the model must be scaled, as an intermediate step, to generate a 4 Mbps data rate for internal LAN traffic. From the Telcordia and Lawrence Berkeley Labs data, the average packet size is 192 bytes or 1536 bits. Thus, the packets per second for a 100 kbps data rate is 100,000/1536 = 65.104 packets per sec. All of the parameters of the basic model in Figure 3-1 must be scaled by:

65.104 packets per sec / 3 packets per unit-of-time = 21.7014 unit-of-time per sec

to insure the average packets/sec becomes 65.104 for the superposition of all 4IPPs.

The 100 kbps 4 IPP internal LAN traffic model (intermediate step) then becomes as shown in Figure 3-2.

source_i	_i IPP in ON state (pkts/sec)	c1i (transition probability rate from ON to OFF) transitions/ sec	c2i (transition probability rate from OFF to ON) transitions/ sec	*Averaged over both ON and OFF states (pkts/sec)*
IPP#1	**58**	9.920E+00	7.442E+00	24.920
IPP#2	**37**	3.136E-01	2.352E-01	15.795
IPP#3	**30**	9.920E-03	7.442E-03	12.911
IPP#4	**27**	9.920E-05	7.442E-05	11.479
			4IPP Average Rate (pkts/sec) =	***65.104***

Figure 3-2: 100 kbps 4IPP Model

Then the internal LAN traffic model must be scaled appropriately to model external traffic, which is a fraction of the 100 kbps internal LAN traffic. This modeling step can be thought of as using a time-window to divert a portion of the internal traffic as external traffic. Scaling the ON/(ON+OFF) time by the desired factor results in time-windowed bursts of packets. This preserves the high-rate nature of the traffic while a burst is ON but scales down the overall average load by shortening the average burst duration (see reference [Leland and Wilson]). The ON time should be decreased while the OFF time is increased by the same amount in order to preserve the average duration of the overall ON-OFF period. For external traffic of 50 kbps, the ON time is reduced by a factor of 2 from the 100 kbps ON time. Similarly, for external traffic loads of 25 kbps or 10 kbps, the ON time is reduced by a factor of 4 or 10, respectively, from the 100 kbps ON time. Asymmetric traffic loads can then be modeled using an X kbps external traffic model in the forward direction and a Y kbps external traffic model in the reverse direction for each subscriber unit.

The 4 IPP model for 50 kbps external traffic then becomes as shown in Figure 3-3 below when the ON time window is scaled down by a factor of 2 from the 100 kbps internal traffic model.

source_i	_i IPP in ON state (pkts/sec)	c1i (transition probability rate from ON to OFF) transitions/ sec	c2i (transition probability rate from OFF to ON) transitions/ sec	*Averaged over both ON and OFF states (pkts/sec)*
IPP#1	**29**	4.960E+00	3.721E+00	12.460
IPP#2	**18**	1.568E-01	1.176E-01	7.897
IPP#3	**15**	4.960E-03	3.721E-03	6.456
IPP#4	**13**	4.960E-05	3.721E-05	5.739
			4IPP Average Rate (pkts/sec) =	***32.552***

Figure 3-3: 50 kbps External Traffic 4IPP Model

The 4IPP model for 25 kbps external traffic then becomes as shown in Figure 3-4 below when the ON time window is scaled down by a factor of 4 from the 100 kbps internal traffic model.

source_i	_i IPP in ON state (pkts/sec)	c1i (transition probability rate from ON to OFF) transitions/ sec	c2i (transition probability rate from OFF to ON) transitions/ sec	*Averaged over both ON and OFF states (pkts/sec)*
IPP#1	***15***	2.480E+00	1.860E+00	6.230
IPP#2	***9***	7.840E-02	5.881E-02	3.949
IPP#3	***8***	2.480E-03	1.860E-03	3.228
IPP#4	***7***	2.480E-05	1.860E-05	2.870
			4IPP Average Rate (pkts/sec) =	***16.276***

Figure 3-4: 25 kbps External Traffic 4IPP Model

These would be the values for 10 kbps External Traffic 4IPP Model

source_i	_i IPP in ON state (pkts/sec)	c1i (transition probability rate from ON to OFF) transitions/ sec	c2i (transition probability rate from OFF to ON) transitions/ sec	*Averaged over both ON and OFF states (pkts/sec)*
IPP#1	***6***	9.920E-01	7.442E-01	2.492
IPP#2	***4***	3.136E-02	2.352E-02	1.579
IPP#3	***3***	9.920E-04	7.442E-04	1.291
IPP#4	***3***	9.920E-06	7.442E-06	1.148
			4IPP Average Rate (pkts/sec) =	***6.5104***

Figure 3-5: 10 kbps External Traffic 4IPP Model

These would be the values for 8.3333 kbps External Traffic 4IPP Model

source_i	_i IPP in ON state (pkts/sec)	c1i (transition probability rate from ON to OFF) transitions/ sec	c2i (transition probability rate from OFF to ON) transitions/ sec	*Averaged over both ON and OFF states (pkts/sec)*
IPP#1	***5***	8.267E-01	6.201E-01	2.077
IPP#2	***3***	2.613E-02	1.960E-02	1.316
IPP#3	***3***	8.267E-04	6.201E-04	1.076
IPP#4	***2***	8.267E-06	6.201E-06	0.957
			4IPP Average Rate (pkts/sec) =	***5.425***

Figure 3-6: 8.3333 kbps External Traffic 4IPP Model

These would be the values for 3.125 kbps External Traffic 4IPP Model

source_i	_i IPP in ON state (pkts/sec)	c1i (transition probability rate from ON to OFF) transitions/ sec	c2i (transition probability rate from OFF to ON) transitions/ sec	*Averaged over both ON and OFF states (pkts/sec)*
IPP#1	***2***	3.100E-01	2.325E-01	0.779
IPP#2	***1***	9.800E-03	7.351E-03	0.494
IPP#3	***1***	3.100E-04	2.325E-04	0.403
IPP#4	***1***	3.100E-06	2.325E-06	0.359
			4IPP Average Rate (pkts/sec) =	***2.0345***

Figure 3-7: 3.125 kbps External Traffic 4IPP Model

These would be the values for 2 kbps External Traffic 4IPP Model

source_i	_i IPP in ON state (pkts/sec)	c1i (transition probability rate from ON to OFF) transitions/ sec	c2i (transition probability rate from OFF to ON) transitions/ sec	*Averaged over both ON and OFF states (pkts/sec)*
IPP#1	***1***	1.984E-01	1.488E-01	0.498
IPP#2	***1***	6.272E-03	4.705E-03	0.316
IPP#3	***1***	1.984E-04	1.488E-04	0.258
IPP#4	***1***	1.984E-06	1.488E-06	0.230
			4IPP Average Rate (pkts/sec) =	***1.3021***

Figure 3-8: 2 kbps External Traffic 4IPP Model

4 Description of Individual Subscriber Internet model

The model is based on an Interrupted Poisson Process (IPP). The IPP represents one user Internet source. Each IPP generates traffic between the hub and the subscriber unit.

4.1 Application of the IPP to BWA

The generic model represents a single user interacting with the Internet. The assumption is that the single user has an active dialogue with some set of Internet applications in which there is much more downlink traffic than up link traffic.

4.2 Assumption of the model

The generic model is derived from the HTTP/TCP and FTP model in that it is a special case of this model. Again this is an approximation of aggregation of HTTP/TCP and FTP traffic, it's not the individual application specific model, that's why we call it "Internet" traffic in general later on.

4.3 Application of the model

The basic model describes the behavior of the traffic when a call has been established. When the behavior of a subscriber includes multiple media applications including voice, a voice call or multiple voice calls may or may not be active at any point in time. For the purposes of this simulation, since voice traffic cannot be delayed, the voice traffic has priority over any data traffic and has the same priority as any streaming video traffic that can be classified to the BWA as such.

5 Description of Individual Subscriber Internet traffic simulation model

5.1 Basic IPP model

The parameter in following table defines the basic IPP model. The parameters of the model are shown in Figure 5-1 below.

source_i	_i IPP in ON state (pkts/unit-of-time)	c1i (transition probability rate from ON to OFF) transitions/ unit-of-time	c2i (transition probability rate from OFF to ON) transitions/ unit-of-time	*Averaged over both ON and OFF states (pkts/unit-of-time)*
IPP#2	**1.698**	1.445E-02	1.084E-02	*.7278*
			IPP Average Rate (pkts/unit-of-time) =	***.7278***

Figure 5-1: Basic IPP Model – Individual Subscriber Internet

5.2 Scaling of the model

To scale the model for different traffic conditions for the single user the parameters of Figure 5-1 are scaled as shown in the following figures.

source_i	_i IPP in ON state (pkts/unit-of-time)	c1i (transition probability rate from ON to OFF) transitions/ unit-of-time	c2i (transition probability rate from OFF to ON) transitions/ unit-of-time	*Averaged over both ON and OFF states (pkts/unit-of-time)*
IPP#2	**22.79**	.1940	.1455	*9.77*
			IPP Average Rate (pkts/unit-of-time) =	***9.77***

Figure 5-2: 15 kbps IPP Model - Individual Subscriber Internet

source_i	_i IPP in ON state (pkts/unit-of-time)	c1i (transition probability rate from ON to OFF) transitions/ unit-of-time	c2i (transition probability rate from OFF to ON) transitions/ unit-of-time	*Averaged over both ON and OFF states (pkts/unit-of-time)*
IPP#2	**2.279**	.0194	.01455	*.7278*
			IPP Average Rate (pkts/unit-of-time) =	***.977***

Figure 5-3: 1.5 kbps IPP Model - Individual Subscriber Internet

6 Description of voice model

The model is based on an Interrupted Deterministic Process (IDP). One IDP represents one packet voice source. Each IDP generates traffic between the hub and the subscriber unit.

6.1 Application of the IDP to BWA

The IDP model is similar to IPP model, except that the packet interval is fixed rather than exponentially distributed during on time (e.g. 8 Kbps packet voice with packet size of 66 bytes arriving every 20 ms during the talk-spurt, no packet is generated during the silent-period).

6.2 Assumption of the model

The generic model is derived from the reference [Kuczura] and typical 8 Kbps packet voice application. It is also applicable to other packet voice ranging from 5.3 Kbps to 64 Kbps generated by vocoder with voice activity detector.

6.3 Application of the model

The basic model describes the behavior of the traffic when a call has been established. When the behavior of a subscriber includes multiple media applications including voice, a voice call or multiple voice calls may or may not be active at any point in time. For the purposes of this simulation, since voice traffic cannot be delayed, the voice traffic has priority over any data traffic and has the same priority as any streaming video traffic that can be classified to the BWA as such.

7 Description of voice traffic simulation model

7.1 Basic IDP model

The parameter in following table defines the basic IDP model. These parameters are chosen to match the most cited voice model mentioned above with on period of 352 ms, and off period of 650 ms profile.

Source_i	Λ (pkts/unit-of-time)	C1	C2	Average (pkts/unit-of-time)
IDP#1	1.000	5.682E-2	3.076E-2	***0.351***

Figure 7-1: Basic IDP model for single voice

Note that during on time the packet is generated with constant interval. The on time and off time is still exponentially distributed like IPP.

7.2 Scaling of the model

Assume G.729 is our target model. The unit-of-time is 20ms. All of the parameters of the basic model in Figure 7-1must be scaled by:

1000 ms / 20 ms = 50 unit-of-time per sec

Source_i	Λ (pkts/sec)	C1	C2	Average (pkts/sec)
IDP#1	50.000	2.841	1.538	***17.561***

Figure 7-2: IDP model for one G.729 voice conversation

The average packet size is 66 bytes or 528 bits. The average data rate is:

17.565 pkts/sec * 528 bits = 9.3 Kbps.

The number of IDP needed for the subscriber can be obtained by:

Number of IDP = Total bandwidth of the voice users / 9.3 Kbps

The model needs to be stacked up for 2 and 4 concurrent voice. These are shown in the two following figures.

Source_i	Λ_i (pkts/sec)	C_{1i}	C_{2i}	Average (pkts/sec)
IDP#1	50.000	2.841	1.538	***17.561***
IDP#2	50.000	2.841	1.538	***17.561***
			2IDP Average Rate (Packets/sec) =	***35.122***

Figure 7-3: 2 IDP model for two G.729 voice conversations

Source_i	Λ_i (pkts/sec)	C_{1i}	C_{2i}	Average (pkts/sec)
IDP#1	50.000	*2.841*	*1.538*	***17.561***
IDP#2	50.000	*2.841*	*1.538*	***17.561***
IDP#3	50.000	*2.841*	*1.538*	***17.561***
IDP#4	50.000	*2.841*	*1.538*	***17.561***
			4IDP Average Rate (Packets/sec) =	***70.244***

Figure 7-4: 4 IDP model for four G.729 voice conversations

8 Description of streaming video model

The model is based on two Interrupted Renewal Process (IRP). 2IRP represent one packet video source. Each 2IRP generates traffic between the hub and the subscriber unit.

8.1 Application of 2IRP to BWA

The 2IRP model is similar to 4IPP model, except that the sojourn time is Pareto distributed rather than exponentially distributed (e.g. MPEG packet video with 25 frames per second has a local Hurst parameter ranging from 0.73 to 0.93).

8.2 Assumption of the model

The generic model is derived from the reference [Subramanian et al] and the 17100 MPEG frames of Star Wars movie trace. It is also applicable to any other variable bit rate packet video.

9 Description of video traffic simulation model

9.1 Basic 2IRP model

The parameter in following table defines the basic 2IRP model. These parameters are chosen to match the most cited video trace in past 10 years (two-hour Star Wars movie).

Source_i	λi (pkts/unit-of-time)	α1i	α2i	Average (pkts/unit-of-time)
IRP#1	***44.95***	***1.14***	***1.22***	26.74
IRP#2	***61.90***	***1.54***	***1.28***	23.78
			2IRP Average	***50.52***

Figure 9-1: Basic 2IRP model for single Video

Note: The sojourn time follows Pareto distribution: P(X≥x)=(x/unit-of-time)$^{-\alpha ji}$. Note that the average sojourn time is _ji/(_ji -1) (unit-of-time), this is different from exponential distribution. During on time, the packet interval time is still exponentially distributed like IPP.

9.2 Scaling of the model

Assume MPEG is our target model. The unit-of-time is 40 ms, corresponding to 25 frames per second setting. The unit-of-time is included in the Pareto distribution, thus the four Pareto parameters are not to be scaled. But the Packet rates of the basic model in Figure 9-1 must be scaled by:

1000 ms / 40 ms = 25 unit-of-time per sec

Source_i	λi (pkts/sec)	α1i	α2i	Average (pkts/sec)
IRP#1	***1123.80***	***1.14***	***1.22***	668.49
IRP#2	***1547.50***	***1.54***	***1.28***	594.51
			2IRP Average	***1263.00***

Figure 9-2: 1.9 Mbps 2IRP model for MPEG Video

The packet size is 188 bytes or 1504 bits. The average data rate is 1263 pkts/sec * 1504 bits = 1.9 Mbps. The number of 2IRP needed can be obtained by:

Number of 2IRP = Total bandwidth of the video users / 1.9 Mbps

Source_i	λi (pkts/sec)	α1i	α2i	Average (pkts/sec)
IRP#1	***112.380***	***1.14***	***1.22***	66.849
IRP#2	***154.750***	***1.54***	***1.28***	59.451
			2IRP Average	***126.300***

Figure 9-3: .19 Mbps 2IRP model for MPEG Video

10 Subscriber class definitions

Each subscriber generates multiple types of traffic. The four categories of traffic are HTTP/TCP, FTP, voice, and streaming video. Each category of traffic has its own characteristic traffic model as defined in the above section. The HTTP/TCP and the FTP traffic use the 4IPP model. The voice over IP traffic uses the IDP model and the streaming video uses the 2IRP model. This is shown in Figure 10-1.

Traffic Type	Traffic Model
Small/Medium Business HTTP/TCP	4IPP
Small/Medium Business FTP	4IPP
Individual Subscriber Internet	IPP
Voice	IDP
Video	2IRP

Figure 10-1: Traffic Model for Each Traffic Category

The traffic mix for each class of subscriber defines the class. For example, the individual subscriber is characterized by a relatively even mix of categories of traffic but with a lower overall average data rate. The traffic for each subscriber class is shown in Figure 10-2. The entries in this table show the parameters for traffic assumptions associated with nominal usages in the year 2001.

Traffic Type	Forward/Reverse Ratio	Individual Subscriber	Small Business SOHO	Medium Business
HTTP/TCP	**8:1 (2:1 Med)**	N/A	25/3.125 kbps	100/50 kbps
FTP	**5:1 (3:1 Med)**	N/A	10/2 kbps	25/8.33 kbps
Internet	**9:1**	15/1.5 kbps	N/A	N/A
Voice	**1:1**	9.3 kbps	18.6 kbps	37.2 kbps
Video	**10:1**	1.9/.19 Mbps	1.9/.19 Mbps	1.9/.19 Mbps

Figure 10-2: Traffic Mix for Subscriber Class

Each subscriber traffic model is a combination of the four traffic types. Both the forward and reverse direction of the traffic each has four traffic components — HTTP/TCP, FTP, voice and streaming video - and, hence, the traffic in each direction is a sum of the four models.

Traffic Type	Forward/Reverse Ratio	Individual Subscriber	Small Business SOHO	Medium Business

HTTP/TCP	**8:1 (2:1 Med)**	N/A	Figure 3-4/Figure 3-7	Figure 3-2/Figure 3-3
FTP	**5:1 (3:1 Med)**	N/A	Figure 3-5/Figure 3-8	Figure 3-4/Figure 3-6
Internet	**9:1**	Figure 5-2/Figure 5-3	N/A	N/A
Voice	**1:1**	Figure 7-2	Figure 7-3	Figure 7-4
Video	**10:1**	Figure 9-2/Figure 9-3	Figure 9-2/Figure 9-3	Figure 9-2/Figure 9-3

Figure 10-3: Specific Models for Subscriber Scenarios

11 System simulation scenarios

The traffic model generates the simulation cases for characterizing the PHY/MAC behavior. The following simulation cases establish the simulation scenarios for a single radio link from a point-to-multipoint hub to multiple remote subscriber units. The simulation scenarios do not cover the case in which there is a cellular like network of multiple hubs reusing the same carrier frequencies or the case of a single hub with multiple sectors in which some of the sectors may be reusing the same carrier frequencies. The simulations for such networking scenarios may be too complex and too computationally intensive. However, the RF channel model should simulate a cellular arrangement of cells and not the isolated single sector case.

The simulation scenarios consist of four different traffic models as shown in the following. (The scenarios were heavily influenced by contribution IEEE 802.16.3p-01/27 from Randall Schwartz.) The first scenario (No. 1 — 2001) is primarily a residential situation in which voice and Internet traffic are the focus. The individual subscriber does not have any video traffic. Thus, to simulate the individual subscriber in the forward direction the Figure 5-2 values describe the Internet traffic and the Figure 7-2 values describe the voice traffic. The traffic for the individual subscriber is the sum of the two traffic models, i.e. 15 kbps for Internet and 9.3 kbps for voice for a total average data rate of 24.3 kbps. For the reverse direction the Figure 5-3 values describe the Internet traffic and the Figure 7-2 values describe the voice traffic. The reverse direction traffic is the sum of the two, i.e. 1.5 kpbs for Internet and 9.3 kbps for voice for a total of 10.8 kbps.

The first scenario also includes the small business subscriber that does not include a stream video. The small business subscriber has forward direction traffic described by Figure 3-4 for the HTTP/TCP traffic, Figure 3-5 for the FTP traffic and **Figure 7-3** for the voice traffic for a total average data rate of 53.6 kbps. The reverse direction traffic for the small business subscriber is described by Figure 3-7 for the HTTP/TCP traffic, Figure 3-8 for the FTP traffic, and **Figure 7-3**for the voice traffic for a total average data rate of 23.725 kbps.

Test Scenario	Mix of Subscribers		
	Individual Subscriber	Small Business SOHO	Medium Business
No. 1 - 2001	95% Internet & Voice	5% HTTP/TCP, FTP & Voice	0%
No. 2 - 2001	65% Internet & Voice	20% HTTP/TCP, FTP & Voice	15% HTTP/TCP, FTP & Voice
No. 3 - 2004	95% Internet, Voice, & Video	5% HTTP/TCP, FTP, Voice & Video	0%
No. 4 - 2004	65% Internet, Voice, & Video	20% HTTP/TCP, FTP, Voice & Video	15% HTTP/TCP, FTP, Voice & Video

Figure 11-1: Mix of subscribers for Simulation Scenarios

Note that the percentage is counted by number of subscribers. In test scenario No. 1 — 2001 the ratio of individual subscriber to small business must be 20 to 1, i.e. 95% of the subscribers are individuals and 5% are small business.

In addition, the voice traffic must have priority over the HTTP/TCP, FTP and Internet traffic. This derives from the fact that voice cannot have more than roughly 20-40 msecs in variation over the end-to-end circuit of which the fixed wireless access link is but one segment of the end-to-end circuit. This is also true for the streaming video traffic. This priority scheme must be used on all test scenarios. For scenarios No. 3 and No. 4 which incorporate both voice and streaming video, the system must carefully manage the voice and video packets. The video packets are much larger than the voice packets and could potentially delay voice more than the nominal jitter allowed depending on the data rate allocated to the individual subscriber.

11.1 Simulation results (System performance)

The simulation results establish the system performance as characterized by the number of subscribers, the mean and standard deviation of the forward and reverse data traffic and the mean and standard deviation of the delay in the forward and reverse direction. To obtain the performance of a system of 20 subscribers, the simulation would have one traffic model for each subscriber to generate the traffic towards the hub from each of the 20 subscribers in the reverse direction. It would also have 20 traffic models at the hub, one for generating the traffic to each subscriber in the forward direction. The traffic in the forward direction is the sum of all the 20 hub models and the traffic in the reverse direction is the sum of all 20 subscriber models.

11.1.1 Maximum number of subscribers

The maximum number of subscribers the system can support is defined in terms of the delay. Since the traffic grows as the number of subscribers grows, the mean delay increases as the number of subscriber increase. The maximum number of subscribers N is defined as the operating point at which the (N+1)th subscriber first meets the following inequality for either the forward direction or else the reverse direction for HTTP/TCP and/or FTP traffic only:

Mean delay for N+1 subscribers > 4 x (Mean delay for N subscribers)

or the:

Mean delay > 100 msec

whichever occurs first. The choice of numbers results from a maximum mean delay (200 ms) for the radio link and for staying away from the operating point at which the delay grows very rapidly.

11.1.2 Mean and standard deviation of subscriber data rate and delay

To characterize the performance of the system, the MAC/PHY must be characterized by calculating entries in the following pair of graphs and tables. The two graphs and tables use the 3 test scenarios specified above. The first graph and table pair shows the mean and standard deviation of the forward and reverse data rate as well as the sum of the means of the two. The table also includes the maximum number of subscribers that system can support using the criteria stated in the previous section for the specified data rates. The graph must include a plot for both the mean and the standard deviation. The data rate being shown on these graphs is the subscriber data rate and does not include any of the overhead or coding introduced by the radio system itself. The mean data rate does NOT include any errored packets. The simulation scenarios assume that the data delivered to the external system is error free. This is a requirement placed on the operation of the radio system.

If the radio system drops late or errored voice and video packets or drops HTTP/TCP & FTP packets for any reason, the results must be captured in separate average data rate graphs and tables that show the mean and standard deviation for each of these classes of data traffic.

The simulation scenarios can assume infinite length buffers to exclude any buffer overflow issues for simplicity of simulation.

The second graph and table shows the mean and standard deviation of the delay in both the forward and reverse directions of traffic as well as the maximum number of subscribers for that delay. For the graph a separate plot must be done for voice, video and HTTP/TCP & FTP as well as the mean and standard deviation for each. The delay is measured from the time the first bit is received from and the time the first bit is delivered to the interface of the external equipment connected to the radio system excluding the transmission time from the antenna of the transmitter to the antenna of the receiver. For example, if the radio system connects to Ethernet on both ends of the radio link, the delay would be the time from the first subscriber bit is received from the Ethernet at the transmit end to the time the first subscriber bit is delivered to the Ethernet at the receive end. Thus, the delay would include all the interleaving, coding, modulation, demodulation, decoding, de-interleaving, retransmission of error frames, queuing, contention, etc.

All of the simulation scenarios use the channel model specified by the IEEE 802.16.3 channel model ad hoc. The channel model used in the simulation scenarios must be stated on the results.

If the radio system has multiple modes of operation, the configuration of the system used to generate the results must be stated. The configuration stated must completely define the operating mode of the system. The same operating mode of the radio system must be used for generating all performance data. If a system proponent wishes to use multiple configurations of the radio system, multiple sets of performance data may be reported. If a system proponent wishes to report results for additional traffic scenarios, they are encouraged to do so.

DATA RATE RESULTS

Figure 11-2: Plot of Data Rate (Mean/Standard Deviation) Results

Plot both the mean and the standard deviation on the above graph. Plot a separate graph for lost or dropped data for voice, video, and HTTP/TCP & FTP traffic, respectively.

Test Scenario	**Maximum Number of Subscribers**	**Forward Data (bits/sec) (Hub to Sub)**		**Reverse Data (bits/sec) (Sub to Hub)**	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
No. 1					
No. 2					
No. 3					
No. 4 (Optional)					

Figure 11-3: Data Capacity of the Fixed Radio System

Generate a separate table for lost or dropped data for voice, video and HTTP/TCP & FTP, respectively.

Note that the test scenario No.1 to No.3 are mandatory test sets, the test scenario No.4 is optional.

DELAY RESULTS

Figure 11-4: Plot of Delay (Mean/Standard Deviation) Results

Plot both the mean and the standard deviation for each of the voice, video and FTTP/TCP & FTP delay on the above graph.

Test Scenario	Maximum Number of Subscribers	Forward Direction Delay (ms) (Hub to Sub)		Reverse Direction Delay (ms) (Sub to Hub)	
		Mean	Standard Deviation	Mean	Standard Deviation
No. 1					
No. 2					
No. 3					
No. 4 (Optional)					

Figure 11-5: Delay Performance of the Fixed Radio System

Generate a separate table for each traffic type - voice, video and HTTP/TCP & FTP, respectively.

Note that the test scenario No.1 to No.3 are mandatory test sets, the test scenario No.4 is optional.

12 References

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