Project	**IEEE 802.20 Working Group on Mobile Broadband Wireless Access** <http://grouper.ieee.org/groups/802/20/>
Title	**Guidelines for Link-System-Interface**
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Re:	The link-system-interface for the simulation specification.
Abstract	This document proposes principles and criteria of the link-system-interface to be used for the simulation in evaluating MBWA.
Purpose	Discuss and adopt.
Notice	
Release	
Patent Policy	

1. Introduction

In IEEE 802.20 Evaluation Criteria (Ver 07)[1] the interface between the link level simulation and the system level simulation is still not defined yet. The current state of discussion is reflected in the following paragraphs [1]

"
The group discussed 2 potential solutions to the link-system interface:

Proposal a: Use actual link curves:

In this option, link curves are produced for each of the coding, modulation and channel model combinations. However, it was pointed out that the channel models currently being specified in the channel modeling correspondence group are based on a stochastic approach and therefore results in infinite combinations making this approach impractical. Therefore, if the link curve approach is to be used, we need to have a small set (4-5) of discrete channel models.

Proposal b: Specify a methodology for link-system interface:

Using this option, a single AWGN curve (or a small set of curves) is used as reference. The deviations ("fudge factors") from this reference curve for different coding, modulations and channel model realizations are determined based on some analytical formula.

It was also pointed out that the group may not need to specify any link-system interface at all. It can be left to individual proposals to justify and validate the link-system interface used in the simulations."

This contribution advocates the first approach and provides some guidelines for its specification.

In the system level simulation, at each given time slot the SNR of the observed radio link is computed. Using this SNR value the system level simulator will derive the FER value for a given data packet at the given time. The FER is provided by the link level simulation as a function of SNR for each given packet format and a set of parameters. The parameters impacting FER(SNR) include channel model parameters, antenna parameters, data frame size, and receiver specific parameters. Let denote all these parameters except SNR by $\{x1, x2, x3, ...\}$. For a given set of parameters $\{x1, x2, x3, ...\}$ the system level simulation computes at every time instant t the signal-to-noise ratio SNR=SNR(t) and, using this as argument, to determine the function value FER(SNR) via a link curve

$$FER(SNR \mid x1, x2, x3, ...),$$

that is generated for the same set of parameters $\{x1, x2, x3, ...\}$ by a sufficient experiment of a link level simulation. In order for the link level simulation and the system level simulation to be consistent, following issues have to be resolved:

1. The definition of SNR(t) as function of time. This should provide physically solid and mathematically consistent formula for the computation of SNR(t) over a given time interval. As different radio interface is designed based on different physical principles, it is not possible to have a universal definition of SNR(t) that applies to every radio interface. Not only the space-time-frequency structure, but also the receiver structure determines the definition of SNR(t). This requires the SNR(t) definition to be specified case by case. In order for all definitions to be comparable, guidelines or criteria are necessary

2. The parameter list $\{x1, x2, x3, ...\}$ contain channel model, frame size, and other transceiver specific variables. The list used by the link level simulation is supposed to be used by the system level simulation as well, as far as applicable. In most cases the parameters in the link level list is a subset of the parameter of the system level list. In order to compare different proposals, a common list of parameters have to be specified for the link level simulation, and this list has to be kept within a reasonable size, so that the simulation is feasible at all. Parameters that are proposal specific, such as number of antennas, power control step, power control error, time error, frequency error, etc. can only be dealt with case by case.

3. FER(SNR) is the statistics of the error performance as a function of SNR. A common procedure for inferring the long term statistics and the short terms statistics have to be specified, so that the results can be comparable. In some technologies SNR is not computed by the measured value of one received instance (at given time, frequency and space), but consists of a combination of measured values from multiple received instances. Methods for evaluating the statistics in such a situation need to be specified and used consistently in the link level and system level simulations.

In the sequel these issues will be discussed. .

2. Criteria for SNR

It is assumed that the signal is received frame-wise in time and each frame consists of a number of consecutive symbols. Each received symbol at base band consists of two additive parts

$$r(t) = s(t) + n(t)$$

where the signal $s(t)$ carries the information and depends on the channel model and the transceiver design, $n(t)$ is the received additive white Gaussian noise, possibly, plus the colored noise, and both are functions of time t. The term AWGN refers to all possible non-signal power sources that can be modeled in the link level simulation by an AWGN process, while the colored noise refers to all non-signal power sources that cannot be modeled by an AWGN process. Although the expression for s(t) , and for n(t), may be different for different air-interfaces and different receiver designs, they are assumed of being zero mean in the link level simulation

$$E\{s(t)\} = E\{n(t)\} = 0 \,,$$

where E{x} refers to the expectation of x.

The signal-to-noise ratio is evaluated in the simulation by

Equation 1

$$SNR(t) = \frac{\sum_{\tau=t}^{t+T-1} h[s^2(\tau)]}{\sum_{\tau=t}^{t+T-1} g[n^2(\tau)]}$$

for some well defined functions h[x] and g[x], where T is the symbol duration and t is the reference time for a given symbol. The frame SNR is then the average of the symbol SNR over a frame of symbols, when a frame consists of multiple symbols. For different air-interfaces and receiver design the functions h[x] and g[x] are different. A properly defined set of s(t), n(t), h[x], g[x] satisfies the following requirement for the AWGN channel:

Equation 2

$$\frac{E\{h[s^2(\tau)] \mid \tau \in [t, t+T]\}}{E\{g[n^2(\tau)] \mid \tau \in [t, t+T]\}} = \frac{1}{E\{n^2(t)\}}$$

This is the relation between the short term SNR and the long term SNR, as the right hand of the above equation is the long term SNR and is in fact independent of t. We propose to evaluate SNR for each base band symbol as defined in Equation 1 and recommend Equation 2 as a criterion for the definition of SNR in Equation 1. The precise expression of h[x], and of g[x], may not be identical for the system level and the link level simulation, though both refer to the same physical quantity. Therefore, Equation 2 should be checked for SNR defined for the system level simulation as well as for SNR defined for the link level simulation.

3. Criteria for FER(SNR)

There are two issues here:

3.1 FER for different channel models.

Let the first parameter in list $\{x1, x2, x3, ...\}$ indicate the channel model, i.e.

Equation 3

$$FER(SNR \mid x1, x2, ...) = FER(SNR \mid f(t), n(t), ...)$$

where $f(t)$ is the fading process and $n(t)$ is the AWGN process. In case $f(t) \equiv 1$., the frame error rate depends only on $n(t)$ and is, as a result of channel coding per frame, a function of the AWGN power. There are attempts to derive Equation 3 from

$$FER(SNR \mid 1, n \ (t), ...)$$

by means of approximations, i.e. extrapolate FER of fading channel from the FER of AWGN channels. But none of those approaches possesses generality applicable to different air-interfaces and to SNR values beyond a limited range. This is because the function FER (SNR) as well as its dependence on the fading process is non-linear. As a simulation model of a complex system already contains numerous approximations, additional approximation of the final statistics FER should be avoided as much as possible. Therefore, <u>we propose to simulate each channel model verbatim</u>, i.e. an FER for AWGN channel is simulated using simulated AWGN channel and an FER for fading channel is simulated with the corresponding simulated fading channel.

3.2 FER with SNR Combining

In case a proposal requires a combination of SNRs' from different time instants, a link curve such as

$$FER(SNR(t1) + SNR(t2) + ... \mid x1, x2, ...)$$

needs to be determined, where $t1 < t2 < t3, ...$ are consecutive time instants. There are also attempts to use analytical model to map this function to a reference function

$$FER(SNR1 \mid x1, x2, ...)$$

with an appropriate $SNR1$. Again, due to the same reason mentioned above, none of those attempts are really successful. <u>We propose to simulate the link curve for each individual combination instead of using any analytical models.</u>

4. Channel Model

In [1] a methodology is defined to generate a useful fading process based on physically measurable parameters. In order to accommodate the statistic nature of the fading process, many parameters have to be generated in cascade order due to the nested dependence of the physical phenomena. This makes the model very impracticable. Particularly for link level simulation, where many samples are required for a single curve to achieve the desired confidence, a parameter list with many random numbers would require prohibitive simulation time to achieve required confidence. One could think some intermediate parameterization of the random variables, but that would redirect the difficulty to another equally time consuming task. In order to achieve useful link curves with reasonable efforts, we propose to select fixed parameters to replace the random variables in [1] down to the path level and chose a common subset of available channel models from [1] for the use by the link level simulation.

The following table from [2] can serve as a starting point:

Models		case-i		case-ii		case-iii		case-iv		case-v	
PDP		Modified Pedestrian-A		Vehicular-A		Pedestrian-B		Typical Urban (optional)		Vehicular-B (optional)	
Doppler Spectrum		Classical; Optional: Path#1 = Rician (K=6)		Classical;		Classical		Classical		Classical	
Number of Paths		1) 4+1 (LOS on, K = 6dB) 2) 4 (LOS off)		6		6		11		6	
Relative Path power (dB)	Delay (ns)	1) 0, 2) -∞ ,	0	0	0	0	0	-4.0	0	-2.5	0
		1) -6.51, 2) 0,	0	-1.0	310	-0.9	200	-3.0	100	0	300
		1) -16.21, 2) -9.7	110	-9.0	710	-4.9	800	0	300	-12.8	8900
		1) -25.71, 2) –19.2	190	-10.0	1090	-8.0	1200	-2.6	500	-10.0	12900
		1) -29.31, 2) -22.8	410	-15.0	1730	-7.8	2300	-3.0	800	-25.2	17100
				-20.0	2510	-23.9	3700	-5.0	1100	-16.0	20000
								-7.0	1300		
								-5.0	1700		
								-6.5	2300		
								-8.6	3100		
								-11.0	3200		

Speed (km/h)		1) 3 2) 30, 120	30, 120, 250	3, 30, 120,	3, 30, 120	30, 120
Mobile Station	Topology	0.5λ	0.5λ	0.5λ	0.5λ	0.5λ
	PAS	1) LOS on: Fixed AoA for LOS component, remaining power has 360 degree uniform PAS. 2) LOS off: PAS with a Laplacian distribution, RMS angle spread of 35 degrees per path	RMS angle spread of 35 degrees per path with a Laplacian distribution Or 360 degree uniform PAS	RMS angle spread of 35 degrees per path with a Laplacian distribution	RMS angle spread of 35 degrees per path with a Laplacian distribution Or 360 degree uniform PAS	RMS angle spread of 35 degrees per path with a Laplacian distribution Or 360 degree uniform PAS
	DoT (degrees)	0	22.5	-22.5	22.5	22.5
	AoA (degrees)	22.5 (LOS component) 67.5 (all other paths)	67.5 (all paths)	67.5 (all paths)	22.5 (odd number paths), -67.5 (even number paths)	67.5 (all paths)
Base Station	Topology	Reference: ULA with 0.5λ-spacing or 4λ-spacing or 10λ-spacing				
	PAS	Laplacian distribution with RMS angle spread of 2 degrees or 5 degrees, per path depending on AoA/AoD				
	AoD/AoA (degrees)	50^o for 2^o RMS angle spread per path 20^o for 5^o RMS angle spread per path				

Table 1 Summary of Link Level Channel Model Parameters

As this approach implies a mapping of a set of variables onto one of its proper subsets, a modified channel model of [2] for the link level simulation is necessary, which would be an approximation of the channel model used by the system level simulation. For instance, in the link level simulation the sub-path AoD/AoA can be chosen from a given look-up table representing a deterministic distribution compliant with the given probability distribution.

<u>We propose to use a set of channel models with fixed parameters down to the path level and a simplified channel model for the link level simulation.</u>

5. FER Curves

Given the sets of parameters to be used by the link level simulation and system level simulation, the link curves can be ordered in a matrix, where the row indicates the number of the frame formats and the column indicates parameter such as the channel classes. Using this kind of matrix the system level simulation can read the link curve for the given SNR for the corresponding parameters.

	Frame Format 1	Frame Format 2	Frame Format 3	Frame Format 4
Scenario 1	**FER(SNR)**	**FER(SNR)**	**FER(SNR)**	**FER(SNR)**
Scenario 2	**FER(SNR)**	**FER(SNR)**	**FER(SNR)**	**FER(SNR)**
Scenario 3	**FER(SNR)**	**FER(SNR)**	**FER(SNR)**	**FER(SNR)**

Table 1: Example of a FER template

This provides a way to categorize the parameters in the parameter list, where the frame format, i.e. the frame size by the appropriate definition, is distinguished from the other parameters in the list. The actual template for FER(SNR) to be generated in reality may require multiple dimensional matrix, when the relevant parameters are more than 2. Nevertheless, by proper selection of parameters, the size of the template can be limited to a manageable size. Therefore, we propose to use the above template to indicate link curves generated for the given scenarios and frame formats.

6. Recommendation

We propose a set of guidelines to the link-system-interface for the simulation that includes

- Criteria for the definition of the short term SNR
- Simulation of FER using simulated fading channels instead of extrapolation of AWGN link curve
- Simulation of FER for combined SNR instead of extrapolation of a reference link curve via analytical models
- Use a finite subset of channel models with fixed parameters down to the path level
- Use a matrix template to indicate FER curves generated by the link level simulation.

7. Reference

[1] IEEE C802.20-04/21: IEEE 802.20 Evaluation Criteria (Ver 07)

[2] IEEE C802.20-03/92: Channel Models for IEEE 802.20 MBWA System Simulations