

January 2017 doc.: IEEE 802. 15-17-0039-00-003d-summary-of-results-from-link-level-simulations

Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Summary of Results from TG3d Link Level Simulations

Date Submitted: 16 January 2017

Source: Thomas Kürner, TU Braunschweig

E-Mail: kuerner@ifn.ing.tu-bs.de

Re: n/a

Abstract: This document provides a summary of results from TG3d link level simulations. The results are intended to be included in the draft standard IEEE 802.15.3d or for validation the technical requirements of the standard

Purpose: Discussion document for the TG 3d

Notice: This document has been prepared to assist the IEEE P802.15. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

Release: The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15.

Summary of Results from TG3d Link Level Simulations

Thomas Kürner
TU Braunschweig

Outline

- Basis for the calculations
- Deriving maximum EVM at the transmitter
- Required Receiver Sensitivity
- Achieved maximum link distances

Basis for the calculations

- The following calculations are based on the results from doc. 16/0746r7 “Preliminary Performance of FEC schemes in-TG3d channels”, where required minimum SNR values have been derived using the TG3d channel models:

<https://mentor.ieee.org/802.15/dcn/16/15-16-0746-07-003d-preliminary-performance-of-fec-schemes-in-tg3d-channels.pdf>

EVM

- The draft standard requires numbers for the maximum Error Vector Magnitude (EVM), that shall be measured at a compliant the transmitter
- In the following table it has been assumed that the EVM at the transmitter should be at least correspond to the minimum required SNR for an AWGN channel.

Suggestion for Table 11b-13 Maximum EVM

MCS Identifier	Modulation	FEC Rate	Max. EVM [dB]
0	BPSK	11/15	-3
1	BPSK	14/15	-6
2	QPSK	11/15	-6
3	QPSK	14/15	-9
4	8-PSK	11/15	-11
5	8-PSK	14/15	-14
6	8-APSK	11/15	-11
7	8-APSK	14/15	-14
8	16QAM	11/15	- 13
9	16-QAM	14/15	- 16
10	64-QAM	11/15	- 18
11	64-QAM	14/15	- 22

Receiver Sensitivity

- The receiver sensitivity has to be calculated for each of the defined eight bandwidths.
- A noise figure of 8 dB is assumed for the receiver
- The minimum SNR assumed is the value derived from the simulations of the AWGN channel increased by 3 dB.
- The increase of 3dB is required in order to take into account the additional noise originating from variations of the signal due to the EVM at the transmitter. It is assumed that the noise at the receiver and the EVM at the transmitter are uncorrelated.

Suggestion for Table 11b-14 Reference Sensitivity Levels for MCS for the THz-SC PHY

MCS Identifier	Modulation	FEC Rate	Receiver Sensitivity [dBm] depending on the bandwidth							
			2.16 GHz	4.32 GHz	8.64 GHz	12.96 GHz	17.28 GHz	25.92 GHz	51.84 GHz	69.12 GHz
0	BPSK	11/15	-67	-64	-61	-59	-58	-56	-53	-52
1	BPSK	14/15	-63	-60	-57	-55	-54	-52	-49	-48
2	QPSK	11/15	-64	-61	-58	-56	-55	-53	-50	-49
3	QPSK	14/15	-60	-57	-54	-52	-51	-49	-46	-45
4	8-PSK	11/15	-59	-56	-53	-51	-50	-48	-45	-44
5	8-PSK	14/15	-57	-54	-51	-49	-48	-46	-43	-42
6	8-APSK	11/15	-59	-56	-53	-51	-50	-48	-45	-44
7	8-APSK	14/15	-57	-54	-51	-49	-48	-46	-43	-42
8	16-QAM	11/15	-57	-54	-51	-49	-48	-46	-43	-42
9	16-QAM	14/15	-53	-50	-47	-45	-44	-42	-39	-38
10	64-QAM	11/15	-52	-49	-46	-44	-43	-41	-38	-36
11	64-QAM	14/15	-47	-44	-41	-40	-38	-36	-33	-32

Suggestion for Table 11b-19 Reference Sensitivity Levels for MCS for the THz-OOK PHY

MCS Identifier	Modulation	FEC Rate	Receiver Sensitivity [dBm] depending on the bandwidth							
			2.16 GHz	4.32 GHz	8.64 GHz	12.96 GHz	17.28 GHz	25.92 GHz	51.84 GHz	69.12 GHz
0	OOK	224/240	-62	-59	-56	-54	-53	-51	-48	-47
1	OOK	11/15	-67	-64	-61	-59	-58	-56	-53	-52
2	OOK	14/15	-63	-60	-57	-55	-54	-52	-49	-48

Maximum Achievable Link Distances

- In the following exemplary maximum achievable link distances are calculated based on
 - receiver sensitivity levels for the corresponding channel model
 - sets of Tx output power (P_{Tx}); antenna gain at the transmitter (G_{Tx}) and antenna gain at the receiver (G_{Rx})
 - free-space propagation loss at a carrier frequency of 300 GHz

Link Distance for the AWGN Channel

P_TX=5 dBm; G_Tx=40 dB; G_Rx=40 dB

MCS Identifier	Modulation	FEC Rate	Maximum Link Distance in m							
			2.16 GHz	4.32 GHz	8.64 GHz	12.96 GHz	17.28 GHz	25.92 GHz	51.84 GHz	69.12 GHz
0	BPSK	11/15	3005	2125	1502	1227	1062	867	613	531
1	BPSK	14/15	2050	1450	1025	837	725	592	418	362
2	QPSK	11/15	2134	1509	1067	871	755	616	436	377
3	QPSK	14/15	1441	1019	721	588	510	416	294	255
4	8-PSK	11/15	1213	858	606	495	429	350	248	214
5	8-PSK	14/15	970	686	485	396	343	280	198	171
6	8-APSK	11/15	1213	858	606	495	429	350	248	214
7	8-APSK	14/15	972	687	486	397	344	281	198	172
8	16-QAM	11/15	961	680	481	392	340	277	196	170
9	16-QAM	14/15	648	458	324	264	229	187	132	114
10	64-QAM	11/15	534	377	267	218	189	154	109	94
11	64-QAM	14/15	327	231	163	133	116	94	67	58
0	OOK	224/240	846	691	598	488	345	299	846	691
1	OOK	11/15	1528	1248	1081	882	624	540	1528	1248
2	OOK	14/15	1014	828	717	586	414	359	1014	828

at least 100 Gbit/s achieved by this mode

Link Distance for the AWGN Channel

P_TX=0 dBm; G_Tx=18 dB; G_Rx=18 dB

MCS Identifier	Modulation	FEC Rate	Maximum Link Distance in m							
			2.16 GHz	4.32 GHz	8.64 GHz	12.96 GHz	17.28 GHz	25.92 GHz	51.84 GHz	69.12 GHz
0	BPSK	11/15	10,66	7,54	5,33	4,35	3,77	3,08	2,18	1,88
1	BPSK	14/15	7,27	5,14	3,64	2,97	2,57	2,10	1,48	1,29
2	QPSK	11/15	7,57	5,35	3,79	3,09	2,68	2,19	1,55	1,34
3	QPSK	14/15	5,11	3,62	2,56	2,09	1,81	1,48	1,04	0,90
4	8-PSK	11/15	4,30	3,04	2,15	1,76	1,52	1,24	0,88	0,76
5	8-PSK	14/15	3,44	2,43	1,72	1,41	1,22	0,99	0,70	0,61
6	8-APSK	11/15	4,30	3,04	2,15	1,76	1,52	1,24	0,88	0,76
7	8-APSK	14/15	3,45	2,44	1,72	1,41	1,22	1,00	0,70	0,61
8	16-QAM	11/15	3,41	2,41	1,71	1,39	1,21	0,98	0,70	0,60
9	16-QAM	14/15	2,30	1,62	1,15	0,94	0,81	0,66	0,47	0,41
10	64-QAM	11/15	1,89	1,34	0,95	0,77	0,67	0,55	0,39	0,33
11	64-QAM	14/15	1,16	0,82	0,58	0,47	0,41	0,33	0,24	0,20
0	OOK	224/240	6,00	4,24	3,00	2,45	2,12	1,73	1,23	1,06
1	OOK	11/15	10,85	7,67	5,42	4,43	3,83	3,13	2,21	1,92
2	OOK	14/15	7,20	5,09	3,60	2,94	2,55	2,08	1,47	1,27

at least 100 Gbit/s achieved by this mode

Link Distance for the AWGN Channel

$P_{TX}=0$ dBm; $G_{Tx}=6$ dB; $G_{Rx}=6$ dB

MCS Identifier	Modulation	FEC Rate	Maximum Link Distance in m							
			2.16 GHz	4.32 GHz	8.64 GHz	12.96 GHz	17.28 GHz	25.92 GHz	51.84 GHz	69.12 GHz
0	BPSK	11/15	0,67	0,48	0,34	0,27	0,24	0,19	0,14	0,12
1	BPSK	14/15	0,46	0,32	0,23	0,19	0,16	0,13	0,09	0,08
2	QPSK	11/15	0,48	0,34	0,24	0,20	0,17	0,14	0,10	0,08
3	QPSK	14/15	0,32	0,23	0,16	0,13	0,11	0,09	0,07	0,06
4	8-PSK	11/15	0,27	0,19	0,14	0,11	0,10	0,08	0,06	0,05
5	8-PSK	14/15	0,22	0,15	0,11	0,09	0,08	0,06	0,04	0,04
6	8-APSK	11/15	0,27	0,19	0,14	0,11	0,10	0,08	0,06	0,05
7	8-APSK	14/15	0,22	0,15	0,11	0,09	0,08	0,06	0,04	0,04
8	16-QAM	11/15	0,22	0,15	0,11	0,09	0,08	0,06	0,04	0,04
9	16-QAM	14/15	0,14	0,10	0,07	0,06	0,05	0,04	0,03	0,03
10	64-QAM	11/15	0,12	0,08	0,06	0,05	0,04	0,03	0,02	0,02
11	64-QAM	14/15	0,07	0,05	0,04	0,03	0,03	0,02	0,01	0,01
0	OOK	224/240	0,38	0,27	0,19	0,15	0,13	0,11	0,08	0,07
1	OOK	11/15	0,68	0,48	0,34	0,28	0,24	0,20	0,14	0,12
2	OOK	14/15	0,45	0,32	0,23	0,19	0,16	0,13	0,09	0,08

at least 100 Gbit/s achieved by this mode