

**IEEE P802.11  
Wireless LANs**

**TGa Comparison Matrix per 98/156r2**

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**Abstract**

This document concentrates the results as submitted by the three proposers on April 12, 1998 with updates done until April 29. The submissions were per tentative template 98/156 draft 2 as distributed among the proposers on April 8, 1998, while the updated data reflects an updated template 98/156r2. The data was compiled into single document by Naftali Chayat (NC) and undergone some editing. The main changes were bringing data to a common format (for example when different proposers used I/C or C/I), and reducing the amount of data in the tables, whenever multiple options were covered.

The template was revised through a process of email discussions, which was quite difficult due to time zone differences and sometimes lack of agreement of what should go in. For example, "link budget in multipath" table was not included because of disagreement at what delay spread should the comparison be conducted. I would like to thank all the proposers for the participation in this process.

The full data, including graphs, is in documents 98/165+166 (Lucent+NTT), 98/167r1 (BreezeCom+NEC) and 98/168 (RadioLAN). Please refer to the template document 98/156r2 for explanation of the conditions and methods of computation. Some of the data in this Matrix differs from the contents of the documents as it was revised by the proposers.

Follows a short summary of the three proposals being considered by the committee.

<b>Company</b>	<b>Lucent Tech. + NTT</b>	<b>BreezeCom + NEC</b>	<b>RadioLAN</b>
Modulation method	OFDM DBPSK, DQPSK or 16-QAM in each subcarrier	Offset Quadrature Modulation (OQPSK/OQAM)	Differential Pulse Position Modulation (16-DPPM, 4-DPPM)
Pulse shaping features	48 subcarriers out of 64	50% Square-Root Raised Cosine	50% Square-Root Raised Cosine
Error Correction Coding	Convolutional K=7, R=1/2 or R=3/4 Inter-carrier interleaving	Hamming (31,26) with interleaving, uncoded option	Uncoded, option for Reed Solomon (15,13) coded with interleaving
Rates supported	5 Mbit/s (DBPSK, R=1/2) 10 Mbit/s (DQPSK, R=1/2) 15 Mbit/s (DQPSK, R=3/4) 20 Mbit/s (16-QAM, R=1/2) 30 Mbit/s (16-QAM, R=3/4)	21 Mbit/s (OQPSK, coded) 25 Mbit/s (OQPSK, uncoded) 42 Mbit/s (OQAM, coded) 50 Mbit/s (OQAM, uncoded)	10 Mbit/s (4-DPPM) 20 Mbit/s (16-DPPM) 20 Mbit/s (16-DPPM, coded)
Number of channels in U-NII band	5 in 100 MHz, 10 in 200 MHz 15 MHz channel spacing	4 in 100 MHz, 9 in 200 MHz 20 MHz channel spacing	3 in 100 MHz, 7 in 200 MHz 28 MHz channel spacing
Applicable documents	97/92, 97/123, 97/137, 98/02, 98/03, 98/12, 98/71r1, 98/72, 98/73, 98/74,	98/76r1, 98/109, 98/144	97/145r1, 98/38, 98/75, 98/132, 98/133

**TGA Performance Template****General Description, Parameters Common for all Rates**

Parameter	BreezeCom + NEC	Lucent Tech. + NTT	RadioLAN
Data Rates Supported	20.9677 Mbit/s (mand), 25.0000 Mbit/s (mand), 41.9355 Mbit/s (opt), 50.0000 Mbit/s (opt), Next rates are covered by the definition but are virtually impractical: 62.9032 Mbit/s, 75.0000 Mbit/s, 83.8710 Mbit/s, 100.0000 Mbit/s	30, 20 (mandatory), 15 (mandatory), 10, 5 Mbit/s	10 Mbps uncoded 20 Mbps, uncoded 20 Mbps, coded (optional)
Channel Spacing	20 MHz	15 MHz	28 MHz
Center Frequencies	lower band: 5170, 5190, 5210, 5230, 5250 MHz middle band: 5270, 5290, 5310, 5330 MHz upper band: 5745, 5765, 5795, 5815 MHz	Lower band : 5170, 5185, 5200, 5215, 5230 MHz Middle band : 5270, 5285, 5300, 5315, 5330 MHz Upper band : 5745, 5760, 5775, 5790, 5805 MHz	<b>10-Channels Plan:</b> Lower: 5166 MHz, 5194 MHz, 5222 MHz, 5250 MHz Middle: 5278 MHz, 5306 MHz, 5334 MHz Upper: 5747 MHz, 5775 MHz, 5803 MHz
Power Levels	Lower band: 30 mW Middle band: 150 mW Upper band: 600 mW (derived from 12.5 MHz)	5150 - 5250 MHz : 30mW 5250 - 5350 MHz : 150mW 5725 - 5825 MHz : 600mW	<b>10-Channels Plan:</b> Lower: 50 mW Middle: 250 mW Upper: 1000 mW
CCA threshold	-82 dBm (suggested)	-78 dBm	-77 dBm
Clock Rate accuracy	10ppm	40 ppm maximum	100 ppm
Carrier Frequency accuracy	10 ppm (60 kHz)	40 ppm maximum	100 ppm
Waveform implementation accuracy specification method	RMS residual ISI when optimizing with respect to slack parameters – frequency, phase and timing offset, and a short equalizer	Insensitive	Per Waveform Mask
Implementation Complexity	<u>Breeze estimate:</u> 100-200 Kgates, depending on equalizer length. The power consumption for the implementation with 8 tap forward filter is expected to be 300 mW with equalizer adaptation and 200 mW without adaptation along the packet. (based on 0.25 micron process) <u>NEC estimate:</u> 40kgate for simple receiver	Hardware size : 158 k gates (Baseband) Power consumption @ 0.35 $\mu$ m technology 30 Mbit/s : 146 mW 20 Mbit/s : 113 mW 15 Mbit/s : 104mW 10 Mbit/s : 86mW 5 Mbit/s : 72 mW (Full duty cycle)	The complexity of the RF transmitter, the RF receiver, and the baseband processor for L-PPM is rather low. The receiver is non- coherent and therefore quite simple. The baseband processor will be a single-chip Silicon integrated circuit implemented in either high-speed CMOS, or BiCMOS. The DC power consumption is quite

	100kgate for complex receiver		efficient due to the pulsed nature of this system, with a low duty cycle. We believe this to be the simplest and most readily achievable approach as compared to the other five proposals.

**Per-Rate Feature Summary**

Proposal and Rate	ECC method	Interleaving method	Suggested minimal sensitivity	Suggested Adjacent Channel rejection	Suggested Alternate Channel rejection	Implementation Accuracy
LT+NTT 5 Mb	R=1/2, Convolutional	6x8	-84dBm (differential)	23dB (differential)	50dB (differential)	Not sensitive by skipping the center subcarrier
LT+NTT 10 Mb	R=1/2, Convolutional	12x8	-81dBm (differential)	21dB (differential)	49dB (differential)	as above
LT+NTT 15 Mb	R=3/4, Convolutional	12x8	-78dBm (differential)	17dB (differential)	46dB (differential)	as above
LT+NTT 20 Mb	R=1/2, Convolutional	24x8	-75dBm (coherent)	15dB (coherent)	50dB (coherent)	as above
LT+NTT 30 Mb	R=3/4, Convolutional	24x8	-72dBm (coherent)	11dB (coherent)	50dB (coherent)	Not sensitive by skipping the center subcarrier
Br+NEC 21 Mb	Hamming (31,26,3)	8 bit depth row-col	-77 dBm	18 dB	30 dB	-20 dB residual ISI
Br+NEC 25 Mb	none	none	-75 dBm	18 dB	30 dB	-20 dB residual ISI
Br+NEC 42 Mb	Hamming (31,26,3)	16 bit depth row-col	-67 dBm	8 dB	20 dB	-30 dB residual ISI
Br+NEC 50 Mb	none	none	-65 dBm	8 dB	20 dB	-30 dB residual ISI
RadioLAN 10 Mb	None	None	-77	20	35	Not sensitivite
RadioLAN 20 Mb	None	None	-75	18	30	Medium Sensitivity to Implementation accuracy
RadioLAN 20+RS	Reed-Solomon (15, 13)	Depth 4	-73	18	30	Medium Sensitivity to Implementation accuracy

**Per-Rate Performance Summary**

**Performance in Noise and Multipath**

The Received Power is defined as  $-174 \text{ dBm/Hz} + (\text{NF}=10 \text{ dB}) + 10\log(\text{Bit\_Rate}) + \text{Eb/No}$ . For example, at 20 Mbit/s, at Eb/No=12 dB,  $\text{Pr} = -174 \text{ dBm/Hz} + 10\text{dB} + 73\text{dBHz} + 12 \text{ dB} = -79 \text{ dBm}$ .

Proposal and Rate	Pr [dBm] at PER=10%, AWGN, 64b	Pr [dBm] at PER=10%, AWGN, 1000b	Trms at PER=10%, noise free, 64b	Trms at PER=10%, noise free, 1000b	Pr [dBm] @ 20%, with Trms @ 10%, 64b	Pr [dBm] @ 20%, with Trms @ 10%, 1000b
LT+NTT 5 Mb	-90.6 dBm	-89.6 dBm	> 500 ns	> 500 ns	-86.1 dBm*1	-83.1 dBm*1
LT+NTT 10 Mb	-87.5 dBm	-86.3 dBm	> 500 ns	460 ns	-78.2 dBm	-74.1 dBm
LT+NTT 15 Mb	-84.6 dBm	-83.5 dBm	320 ns	240 ns	-71.6 dBm	-68.5 dBm
LT+NTT 20 Mb	-83.0 dBm	-81.0 dBm	300 ns	225 ns	-75.0 dBm	-71.0 dBm
LT+NTT 30 Mb	-79.2 dBm	-77.2 dBm	175 ns	150 ns	-69.2 dBm	-66.2 dBm
Br+NEC 21 Mb	-83.5 dBm	-82.5 dBm	182 nsec (Br) 175 nsec (N8) 120 nsec (N4)	174 nsec (Br) 175 nsec (N8) 120 nsec (N4)	-72 dBm	-71 dBm
Br+NEC 25 Mb	-81.5 dBm	-80 dBm	167 nsec (Br) 175 nsec (N8) 120 nsec (N4)	164 nsec (Br) 175 nsec (N8) 120 nsec (N4)	-72 dBm	-71 dBm
Br+NEC 42 Mb	-76 dBm	-75.5 dBm	83 nsec	75 nsec	-66 dBm	-66 dBm
Br+NEC 50 Mb	-74 dBm	-73 dBm	77 nsec	73 nsec	-66 dBm	-65 dBm
RadioLAN 10 Mb	-88 dBm	-85 dBm	200 nsec	180 nsec	-72 dBm	-71 dBm
RadioLAN 20 Mb	-84 dBm	-81 dBm	150 nsec	140 nsec	-69 dBm	-68 dBm
RadioLAN 20+RS	-83 dBm	-80.5 dBm	140 nsec	130 nsec	-68 dBm	-68 dBm

**Notes:**

- 1) (by L+N) PER never exceed 10% with  $T_{rms}$  of 25 - 500 ns. PER of 20% is assumed instead at  $T_{rms}$  of 500 ns
- 2) (by NC) In Breeze+NEC the (Br) denotes performance with (8+23 DFE), the (N8) denotes performance with (8+16 PMA-MLSCE), and (N4) with (4+16 PMA-MLSCE). This data is brought in full because it represents different implementation approaches.

**Performance in Interference**

Proposal and Rate	AWGN Sensitivity @NF=10 dB, no degr. [dBm]	CCI immunity [dB]	ACI immunity [dB]	CW jammer immunity [dB]	Narrowband Gaussian noise immunity [dB]	Phase noise tolerance, [dBc]
LT+NTT 5 Mb	-89.6 dBm	-3.1dB	23.8dB	0.9 dB	-5.5 dB	-8.0 dBc
LT+NTT 10 Mb	-86.3 dBm	-6.6dB	21.3dB	-7.7dB	-9.6dB	-12.5dBc
LT+NTT 15 Mb	-83.5 dBm	-9.4dB	17.8dB	-15.2dB	-13.5dB	-14.1dBc
LT+NTT 20 Mb	-81.0 dBm	-12.3 dB	16.5 dB	-15.7 dB	-14.3 dB	-11 dB
LT+NTT 30 Mb	-77.2 dBm	-16.5 dB	12.5 dB	-20.9 dB	-19.4 dB	-12.5 dB
Br+NEC 21 Mb	-82.5 dBm	-9 dB	22.5 dB (2 dB OBO)	-9 dB	-12 dB	-12.5 dBc
Br+NEC 25 Mb	-80 dBm	-10 dB	20.5 dB (2 dB OBO)	-11 dB	-14.5 dB	-14 dBc
Br+NEC 42 Mb	-75.5 dBm	-16 dB	14 dB (4 dB OBO)	-17 dB	-19 dB	-17.5 dBc
Br+NEC 50 Mb	-73 dBm	-17 dB	11.5 dB (4 dB OBO)	-19 dB	-21 dB	-19.5 dBc
RadioLAN 10 Mb	-85 dBm	-6.5 dB	20 dB	-9 dB	-6 dB	5 dBc
RadioLAN 20 Mb	-81 dBm	-8 dB	18 dB	-10 dB	-9 dB	7 dBc
RadioLAN 20+RS	-80.5 dBm	-8.5 dB	18 dB	-11 dB	-10 dB	8 dBc

**Note:** (by NC) Original L+N data contains both 64 and 1000 byte data; here only 1000 byte data is presented. In all submissions, I inverted the sign of immunity values whenever required to bring them to common notation.

**PA Backoff and Link Budget (see Appendix D for explanation)**

**Backoff**

Proposal and Rate	Backoff [dB] @LB Pmax (LB U-NII regulations)	Backoff [dB] @MB Pmax (MB U-NII regulations)	Backoff [dB] @LB Pmax (restricted regulations)	Backoff [dB] @MB Pmax (restricted regulations)	Backoff [dB] @Psat=250 mW, (restricted regulations)
LT+NTT 5 Mb	5 dB	5 dB	5.2 dB	8.2 dB	6.3 dB
LT+NTT 10 Mb	5 dB	5 dB	5.2 dB	8.2 dB	6.3 dB
LT+NTT 15 Mb	5 dB	5 dB	5.2 dB	8.2 dB	6.3 dB
LT+NTT 20 Mb	5 dB	5 dB	5.2 dB	8.2 dB	6.3 dB
LT+NTT 30 Mb	5 dB	5 dB	5.2 dB	8.2 dB	6.3 dB
Br+NEC 21 Mb	2 dB	2 dB	5.5 dB	7.5 dB	6 dB
Br+NEC 25 Mb	2 dB	2 dB	5.5 dB	7.5 dB	6 dB
Br+NEC 42 Mb	4 dB *1	4 dB *1	6.5 dB	8.5 dB	7 dB
Br+NEC 50 Mb	4 dB *1	4 dB *1	6.5 dB	8.5 dB	7 dB
RadioLAN 10 Mb	0	0	0	0	0
RadioLAN 20 Mb	0.5	0.5	0.5	0.5	0.5
RadioLAN 20+RS	0.5	0.5	0.5	0.5	0.5

Note: (by Br+NEC) The backoff at 42/50 Mb/s with U-NII regulations is dominated by performance degradation rather than by the regulatory restrictions.

**Link Budget, AWGN sensitivity**

Proposal and Rate	AWGN Sensitivity @NF=10 dB, no degr. [dBm]	Loss [dB] @LB Pmax	Loss [dB] @MB Pmax	Loss [dB] at @Psat=250 mW, (MB U-NII regulations)	Loss [dB] at @Psat=250 mW, (restricted regulations)
LT+NTT 5 Mb	-89.6 dBm	104.4 dB (30 mW)	111.4 dB (150 mW)	108.6 dB	107.3 dB
LT+NTT 10 Mb	-86.3 dBm	101.1 dB	108.1 dB	105.3 dB	104.0 dB
LT+NTT 15 Mb	-83.5 dBm	98.3 dB	105.3 dB	102.5 dB	101.2 dB
LT+NTT 20 Mb	-81.0 dBm	95.8 dB	102.8 dB	100.0 dB	98.7 dB
LT+NTT 30 Mb	-77.2 dBm	92.0 dB	99.0 dB	96.2 dB	94.9 dB
Br+NEC 21 Mb	-82.5 dBm	97 dB (30 mW)	104 dB (150 mW)	104 dB	100.5 dB
Br+NEC 25 Mb	-80 dBm	94.5 dB	101.5 dB	101.5 dB	98 dB
Br+NEC 42 Mb	-75.5 dBm	90 dB	97 dB	95.5 dB	92.5 dB
Br+NEC 50 Mb	-73 dBm	87.5 dB	94.5 dB	93 dB	90 dB
RadioLAN 10 Mb	-85 dBm	102 dB (50 mW)	109 dB (250 mW)	102 dB	109 dB
RadioLAN 20 Mb	-81 dBm	98 dB	105 dB	97.5 dB	104.5 dB
RadioLAN 20+RS	-80.5 dBm	97.5 dB	104.5 dB	97 dB	104 dB

Note: (by NC) Original L+N data contains both 64 and 1000 byte data; here only 1000 byte data is presented.

Interference Limited Aggregate Rate (see Appendix E for explanation)

Indoor (35 log(distance ratio)) propagation model:

Proposal and Rate	CCI immunity [dB]	D2/D1, Interferer to Transmitter dist. ratio, indoor	Fraction of Area covered, indoor	Aggregate rate per AP, single rate, indoor	Aggregate rate per AP, multirate, indoor	Aggregate rate per AP, multirate, multichannel indoor
LT+NTT 5 Mb	3.1	1.23	0.807	4.04	4.04	44.4 (11 ch)
LT+NTT 10 Mb	6.6	1.54	0.618	6.18	7.13	78.4
LT+NTT 15 Mb	9.4	1.86	0.490	7.36	9.58	105.4
LT+NTT 20 Mb	12.3	2.25	0.380	7.59	11.48	126.2
LT+NTT 30 Mb	16.5	2.96	0.255	7.65	14.03	154.3
Br+NEC 21 Mb	9 dB	1.807	0.507	10.6 Mbit/s	10.6 (1 rate)	95.4 Mbit/s
Br+NEC 25 Mb	10 dB	1.931	0.465	11.6 Mbit/s	12.5 (2 rates)	112.5 Mbit/s
Br+NEC 42 Mb	16 dB	2.865	0.268	11.2 Mbit/s	17.0 (3 rates)	153 Mbit/s
Br+NEC 50 Mb	17 dB	3.06	0.243	12.1 Mbit/s	18.9 (4 rates)	170 Mbit/s
RadioLAN 10 Mb	6.5	1.534	0.623	6.23	6.23	43.62
RadioLAN 20 Mb	8	1.693	0.552	11.03	11.75	82.24
RadioLAN 20+RS	8.5	1.749	0.529	10.58	11.75	82.24

Free Space (20 log(distance ratio)) propagation model:

Proposal and Rate	CCI immunity [dB]	D2/D1, Interferer to Transmitter dist. ratio, free space	Fraction of Area covered, free space	Aggregate rate per AP, single rate, free space	Aggregate rate per AP, multirate, free space	Aggregate rate per AP, multirate, multichannel free space
LT+NTT 5 Mb	3.1	1.43	0.678	3.39	3.39	37.3 (11 ch)
LT+NTT 10 Mb	6.6	2.14	0.406	4.06	5.42	59.6
LT+NTT 15 Mb	9.4	2.95	0.256	3.84	6.70	73.7
LT+NTT 20 Mb	12.3	4.12	0.153	3.05	7.46	82.1
LT+NTT 30 Mb	16.5	6.68	0.068	2.03	8.14	89.5
Br+NEC 21 Mb	9 dB	2.818	0.274	5.76 Mbit/s	5.76 (1 rate)	51.8 Mbit/s
Br+NEC 25 Mb	10 dB	3.162	0.231	5.77 Mbit/s	6.68 (2 rates)	60.1 Mbit/s
Br+NEC 42 Mb	16 dB	6.31	0.075	3.15 Mbit/s	7.95 (3 rates)	71.5 Mbit/s
Br+NEC 50 Mb	17 dB	7.08	0.061	3.06 Mbit/s	8.44 (4 rates)	76.0 Mbit/s
RadioLAN 10 Mb	6.5	2.11	0.413	4.13	4.13	28.9
RadioLAN 20 Mb	8	2.51	0.324	6.49	7.37	51.6
RadioLAN 20+RS	8.5	2.66	0.298	5.97	7.37	51.6

**Timing and Overhead related parameters**

Parameter	BreezeCom + NEC	Lucent Tech. + NTT	RadioLAN
aSlotTime	7.4 μs	6 μs	3
aCCATime	3.0 μs	< 4 μs	1.2
aRxTxTurnaroundTime	1.4 μs	8.8 μs	1
aTxPLCPDelay	0.4 μs	<< 1 μs	0.2
aRxTxSwitchTime	0.4 μs.	<< 1 μs	0.1
aTxRampOnTime	0.4 μs.	Not applicable	0.5
aTxRFDelay	0.4 μs.	< 8.8 μs	0.2
aSIFSTime	13.4 μs	13 μs	5
aRxRFDelay	1.0 μs.	4 μs	0.2
aRxPLCPDelay	7.0 μs.	7 μs	0.2
aMACProcessingDelay	2.0 μs	< 2 μs	0.5
aTxRampOffTime	0.4 μs.	Not applicable	1.5
aPreambleLength	12.8 μs	19 μs	12.8
aPLCPHdrLength	3.2 μs	4 μs (for 30 Mbit/s) 5 μs (for 20 Mbit/s) 6 μs (for 15 Mbit/s) 7 μs (for 10 Mbit/s) 12 μs (for 5 Mbit/s)	4.8
aMPDUDurationFactor	1.0000 (25, 50 Mbit/s) 1.1923 (21, 42 Mbit/s)	(coding rate) <sup>-1</sup>	1
aAirPropagationTime	0.8 μs	< 1 μs	0.3
aCWmin	15	15	15
aCWmax	1023	1023	512

**Throughput penalty (ratio of MPDU duration to transaction duration)**

Proposal and Rate	1500B MPDU duration (μsec)	DIFS + backoff (μsec)	1500B packet duration	SIFS	ACK packet duration, same rate	ACK packet duration, basic rate	Efficiency, ACK at same rate	Efficiency, ACK at basic rate
LT+NTT 5 Mb	2400	70	2478.2	13	54.2	30.2	0.91764	0.92614
LT+NTT 10 Mb	1200	70	1249.4	13	39.8	30.2	0.87451	0.88067
LT+NTT 15 Mb	800	70	841.4	13	35.0	30.2	0.83385	0.83805
LT+NTT 20 Mb	600	70	635.0	13	30.2	30.2	0.80192	0.80192
LT+NTT 30 Mb	400	70	433.4	13	30.2	30.2	0.73180	0.73180
Br+NEC 21 Mb	572.8	83.7	601.28	13.4	22.1	22.1	0.795	0.795
Br+NEC 25 Mb	480	83.7	506.88	13.4	20.5	22.1	0.769	0.767
Br+NEC 42 Mb	286.4	83.7	308.64	13.4	19.9	22.1	0.673	0.669
Br+NEC 50 Mb	240	83.7	261.44	13.4	18.3	22.1	0.639	0.630
RadioLAN 10 Mb	1200	30.5	1221.6	5	32.8	32.8	0.9303046	0.9303046
RadioLAN 20 Mb	600	30.5	620	5	25.6	32.8	0.8809279	0.8717129
RadioLAN 20+RS	600	30.5	620	5	25.6	32.8	0.8809279	0.8717129