IEEE P802.11
Wireless LANs

Updated Submission Template for TGa - revision 2

Date: April 22, 1998

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Abstract

This document readdresses the submission template for TGa. This document is based on documents 97/96r1, 98/57 on inputs from March 98 plenary meeting, and on comments from proposers following the first revision of 98/156. This document is to be agreed by the proposers to serve as an official template.

The performance data per 98/156 was submitted by the proposers by 12 April 1998.

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

Company	**Lucent Tech. + NTT**	**BreezeCom + NEC**	**RadioLAN**
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 30 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	list all, specify which are mandatory	list all, specify which are mandatory	list all, specify which are mandatory
Channel Spacing			
Center Frequencies	list for lower, middle and upper U-NII bands	list for lower, middle and upper U-NII bands	list for lower, middle and upper U-NII bands
Power Levels	list per channel	list per channel	list per channel
CCA threshold			
Clock Rate accuracy			
Carrier Frequency accuracy			
Waveform implementation accuracy specification method			
Implementation Complexity	gates, MIPS, mW @ given technology etc. as judged appropriate by proposer	gates, MIPS, mW @ given technology etc. as judged appropriate by proposer	gates, MIPS, mW @ given technology etc. as judged appropriate by proposer

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						
LT+NTT 10 Mb						
LT+NTT 15 Mb						
LT+NTT 20 Mb						
LT+NTT 30 Mb						
Br+NEC 21 Mb						
Br+NEC 25 Mb						
Br+NEC 42 Mb						
Br+NEC 50 Mb						
RadioLAN 10 Mb						
RadioLAN 20 Mb						
RadioLAN 20+RS						

Per-Rate Performance Summary

Performance in Noise and Multipath

Attach in a Word file the graphs of PER for the following scenarios:

1) PER vs. Received Power, one graph for all rates, in a AWGN channel
2) PER vs. Received Power, Exponential Profile Rayleigh Fading channel, one graph (with all rates) for each of the delay spread values T_{RMS} = 25 nsec, 50 nsec, 100 nsec, 150 nsec, 250 nsec
3) PER vs. Received Power, Exponential Profile Rayleigh Fading channel, one graph (with all delay spread values T_{RMS} = 25 nsec, 50 nsec, 100 nsec, 150 nsec, 250 nsec) for each of the rates.
4) Attach one graph (with all rates) of PER vs. T_{RMS} without additive noise, covering a range of 10 nsec to 500 nsec
5) Attach one graph (with all rates) of PER vs. RMS phase noise (without thermal noise), for 1000 byte packet length.
6) Attach one graph (with all rates) of PER vs.CCI (without thermal noise), for 1000 byte packet length. The CCI is defined as 10 log((interferer power)/(desired power)), i.e. smaller CCI means less interference.
7) Attach one graph (with all rates) of PER vs.ACI (without thermal noise), for 1000 byte packet length. The CCI is defined as 10 log((interferer power)/(desired power)), i.e. smaller ACI means less interference. Set the Backoff according to U-NII regulations.

The carrier frequency shall be offset by the maximum allowed amount (include Tx and Rx sides) according to the proposed text. The PER data will include the intended acquisition procedure performance.

The Received Power is defined as -174 dBm/Hz + (NF=10 dB) + 10log(Bit_Rate) + Eb/No. For example, at 20 Mbit/s, at Eb/No=12 dB, Pr= -174 dBm/Hz +10dB +73dBHz +12 dB = -79 dBm. The tentative 10 dB noise figure addresses both actual noise figure and implementation degradation, so as to serve a comparison basis.

Bring the graphs for each data rate supported by the proposed PHY, for packet lengths of 64 and 1000 bytes.

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						
LT+NTT 10 Mb						
LT+NTT 15 Mb						
LT+NTT 20 Mb						
LT+NTT 30 Mb						
Br+NEC 21 Mb						
Br+NEC 25 Mb						
Br+NEC 42 Mb						
Br+NEC 50 Mb						
RadioLAN 10 Mb						
RadioLAN 20 Mb						
RadioLAN 20+RS						

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						
LT+NTT 10 Mb						
LT+NTT 15 Mb						
LT+NTT 20 Mb						
LT+NTT 30 Mb						
Br+NEC 21 Mb						
Br+NEC 25 Mb						
Br+NEC 42 Mb						
Br+NEC 50 Mb						
RadioLAN 10 Mb						
RadioLAN 20 Mb						
RadioLAN 20+RS						

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

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					
LT+NTT 10 Mb					
LT+NTT 15 Mb					
LT+NTT 20 Mb					
LT+NTT 30 Mb					
Br+NEC 21 Mb					
Br+NEC 25 Mb					
Br+NEC 42 Mb					
Br+NEC 50 Mb					
RadioLAN 10 Mb					
RadioLAN 20 Mb					
RadioLAN 20+RS					

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					
LT+NTT 10 Mb					
LT+NTT 15 Mb					
LT+NTT 20 Mb					
LT+NTT 30 Mb					
Br+NEC 21 Mb					
Br+NEC 25 Mb					
Br+NEC 42 Mb					
Br+NEC 50 Mb					
RadioLAN 10 Mb					
RadioLAN 20 Mb					

RadioLAN 20+RS					

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						
LT+NTT 10 Mb						
LT+NTT 15 Mb						
LT+NTT 20 Mb						
LT+NTT 30 Mb						
Br+NEC 21 Mb						
Br+NEC 25 Mb						
Br+NEC 42 Mb						
Br+NEC 50 Mb						
RadioLAN 10 Mb						
RadioLAN 20 Mb						
RadioLAN 20+RS						

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						
LT+NTT 10 Mb						
LT+NTT 15 Mb						
LT+NTT 20 Mb						
LT+NTT 30 Mb						
Br+NEC 21 Mb						
Br+NEC 25 Mb						
Br+NEC 42 Mb						
Br+NEC 50 Mb						
RadioLAN 10 Mb						
RadioLAN 20 Mb						
RadioLAN 20+RS						

Timing and Overhead related parameters

Attach verbal explanation of the assumptions taken for each parameter

Parameter	**BreezeCom + NEC**	**Lucent Tech. + NTT**	**RadioLAN**
aSlotTime			
aCCATime			
aRxTxTurnaroundTime			
aTxPLCPDelay			
aRxTxSwitchTime			
aTxRampOnTime			
aTxRFDelay			
aSIFSTime			
aRxRFDelay			
aRxPLCPDelay			
aMACProcessingDelay			
aTxRampOffTime			
aPreambleLength			
aPLCPHdrLength	for each mode, if applicable	for each mode, if applicable	for each mode, if applicable
aMPDUDurationFactor	for each mode, if applicable	for each mode, if applicable	for each mode, if applicable
aAirPropagationTime			
aCWmin			
aCWmax			

Compute throughput penalty according to appendix F

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								
LT+NTT 10 Mb								
LT+NTT 15 Mb								
LT+NTT 20 Mb								
LT+NTT 30 Mb								
Br+NEC 21 Mb								
Br+NEC 25 Mb								
Br+NEC 42 Mb								
Br+NEC 50 Mb								
RadioLAN 10 Mb								
RadioLAN 20 Mb								
RadioLAN 20+RS								

Descriptive Document to be Enclosed

TBD; needs to address all the questions regarding algorithms, implementation suggestions, reasoning for parameters, etc. etc.

Appendix A: Baseline Channel Model - Exponentially Decaying Rayleigh Fading Channel

The following channel model was agreed to be a baseline model for comparison of modulation methods. It's convenience is in its simple mathematical description and in the possibility to vary the RMS delay spread. The channel is assumed static throughout the packet and generated independently for each packet.

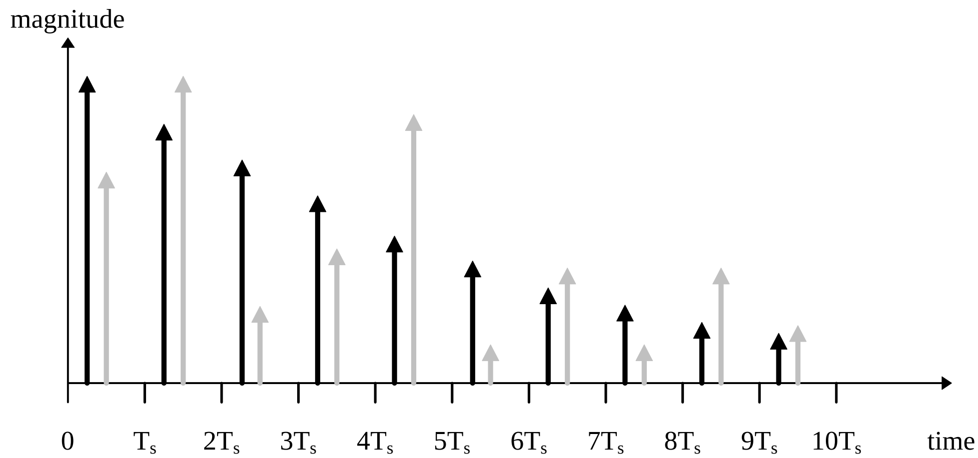


Fig 1: Channel impulse response; black illustrates average magnitudes, grey illustrates magnitudes of a specific random realization of the channel; the time positions of black and grey samples are staggered for clarity only.

The impulse response of the channel is composed of complex samples with random uniformly distributed phase and Rayleigh distributed magnitude with average power decaying exponentially.

$$h_k = N(0,\tfrac{1}{2}\sigma_k^2) + jN(0,\tfrac{1}{2}\sigma_k^2)$$
$$\sigma_k^2 = \sigma_0^2 e^{-kT_s/T_{RMS}}$$
$$\sigma_0^2 = 1 - e^{-T_s/T_{RMS}}$$

where $N(0,\tfrac{1}{2}\sigma_k^2)$ is a zero mean Gaussian random variable with variance $\tfrac{1}{2}\sigma_k^2$ (produced by generating a $N(0,1)$ r.v. and multiplying it by $\sigma_k/\sqrt{2}$), and $\sigma_0^2 = 1 - e^{-T_s/T_{RMS}}$ is chosen so that the condition $\sum \sigma_k^2 = 1$ is satisfied to ensure same average received power.

The sampling time T_s in the performance assessment shall be no longer than the smaller of 1/(signal bandwidth) or $T_{RMS}/2$ (as per motion approved in Nov97 meeting). The number of samples to be taken in the impulse response should ensure sufficient decay of the impulse response tail, e.g. $k_{max}=10T_{RMS}/T_s$.

Appendix B: Phase noise generation for a simulation

The phase noise process to be used for comparison of robustness with respect to it was agreed to be a white Gaussian process filtered with single-pole low pass filter. The rationale for using this model is a typical behaviour of phase-locked microwave oscillators. The model ignores the phase noise contribution of the reference crystal oscillator, which typically affects very low offset frequencies and is easily tracked by carrier tracking loops in the receiver. The corner frequency of the LPF was agreed to be 50 KHz, assuming it is a representative value for a large-step synthesizer.

a) generate initial sample of the process. This takes account for infinite past not being simulated.

$$x_0 = N(0,1)$$

b) Assume simulation time step T_s. Generate next samples of a unity-variance LPF process with an IIR approximation to LPF:

$$x_{k+1} = x_k + \alpha(\beta N(0,1) - x_k)$$
$$\alpha = 2\pi F_c T_S$$
$$\beta^2 = (2/\alpha) - 1$$

c) convert the unity-variance LPF process to phase noise with a chosen φ_{RMS} by computing $\exp(j\varphi_k) = \exp(j\varphi_{RMS} x_k)$. Multiply the complex transmitted signal with the phase noise process.

d) simulate with several values of φ_{RMS}. Search for a value causing PER=10%.

In the performance table state the phase variance in decibells as $10\log\varphi^2_{RMS}$

Appendix C: Power Amplifier Model

The power amplifier model is to be used for assessing performance with respect to adjacent channel interference and regulatory acceptance. The model is based on Rapp's model with parameter P=2.

Let the simulation be conducted at complex baseband, and let the saturated power of the amplifier be $P_{SAT} = |v_{SAT}|^2$. Then the output of the amplifier will be computed sample by sample as

$$v_{OUT} = v_{IN} \Big/ \left(1 + \left(|v_{IN}|/v_{SAT}\right)^{2P}\right)^{1/(2P)}, \qquad P = 2.$$

Allow sampling rate sufficiently high to represent properly the frequency band of interest, including the adjacent channel of the regulatory boundary.

State in the performance table the backoff as the ratio of average power at the output during the data portion to the saturated power:

$$Backoff = -10\log\left(Avg\left(|v_{OUT}|^2\right) \Big/ P_{SAT}\right)$$

Note: P=1 describes better the rate of decay of sidelobes at large backoffs; however, the P=2 describes better the behaviour at powers close to saturation. In March 98 it was agreed to use the P=2 value for comparison.

Appendix D: Backoff Requirements and Link Budget

The out of band emissions, as related to regulatory requirements, affect the PA backoff requirements, and consequently the power efficiency of the transmitter. The proposers are required to address five cases:

1) The LB (low band) U-NII requirement - use full low band power (30 mW for Br+NEC and LT+NTT, 50 mW for RadioLAN), state how much backoff is required to withstand the -27 dBc requirement at band edge.

2) The MB (middle band) U-NII requirement - use full middle band power (150 mW for Br+NEC and LT+NTT, 250 mW for RadioLAN), state how much backoff is required to withstand the -34 dBc requirement at band edge.

3) The restricted band requirement - use full low band power (30 mW for Br+NEC and LT+NTT, 50 mW for RadioLAN), state how much backoff is required to withstand the -46dBm/MHz requirement at band edge (derived from -40 dBmi/MHz requirement and an assumption of 6 dBi antenna)

4) The restricted band requirement - use full middle band power (150 mW for Br+NEC and LT+NTT, 250 mW for RadioLAN), state how much backoff is required to withstand the -46dBm/MHz requirement at band edge.

5) Instantaneous DC power consumption limited transmitter and restricted band requirement - assume power amplifier with 250 mW saturated power. State how much backoff is required to withstand the -46dBm/MHz requirement at band edge, taking into account that backoff reduces the transmitted power.

In the cases where performance degradation rather that regulatory requirement dominates the required backoff, state the performance dominated number.

The link budget table compares two scenarios: regulatory power restriction and DC power consumption restriction combined with regulatory out-of-band requirement. In link budget calculation the sensitivity in AWGN is tentatively used, in order not to involve an arbitrary assumption about delay spread.

1) Regulatory power restriction: take the maximum low band power (30/50 mW) and compute the difference between Pt and Pr (e.g. Pt=15 dBm, Pr=-79 dBm, Loss=Pt-Pr=15-(-79)=94 dB).

2) Regulatory power restriction: take the maximum midband power (150/250 mW) and compute the difference between Pt and Pr (e.g. Pt=22 dBm, Pr=-79 dBm, Loss=Pt-Pr=22-(-79)=101 dB).

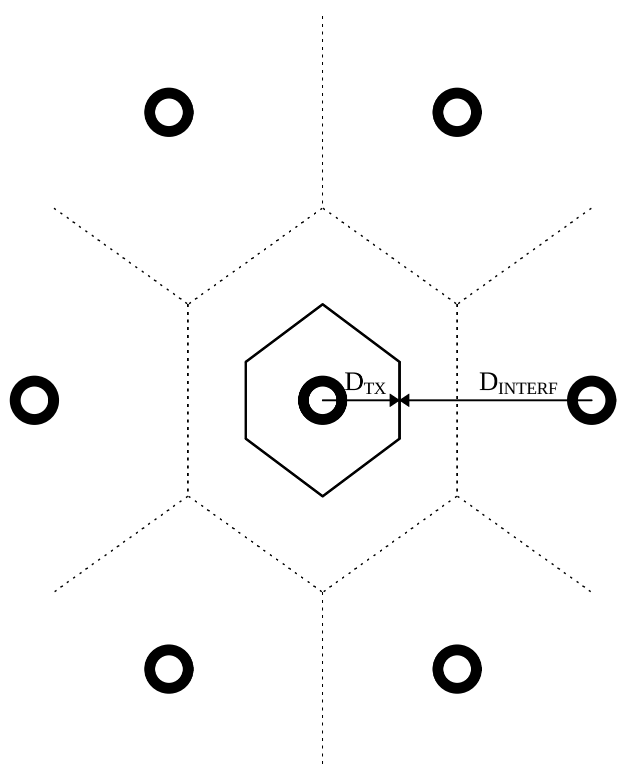
3) DC power consumption restriction combined with regulatory out-of-band (U-NII) requirement - assume power amplifier with saturated power of 250 mW (this should be representative of a station with DC consumption restrictions). Find the backoff required to pass the U-NII requirement (-34 dBc), and compute Loss=Psat-Backoff-Pr. For example, Backoff=6 dB, Pr=-79 dBm, then Loss=(24 dBm-6 dB)-(-79)=97 dB.

4) Same, with restricted band regulation taking precedence (-46 dBm/MHz, assuming -40 dBmi/MHz and 6 dB antenna). For example, at 7 dB backoff 24-7=17 dBm is transmitted, giving spectral density of 6 dBm/MHz (for 12.5 MHz bandwidth); same 7 dB are sufficient for (-46 dBm/MHz)- (6 dBm/MHz) = -52 dBc requirement at band edge. Now, loss budget is (17 dBm)-(-79 dBm) = 96 dB.

Appendix E: Interference Limited Aggregate Rate

This part addresses the capacity per cell which might be achieved in dense, interference limited environment.

The following figure illustrated APs operating at same frequency (there might be other APs in between using other frequencies). The dotted lines divide the area into regions closest to a given AP. The solid line hexagon roughly illustrates a region in which a station heard its own AP sufficiently strong relative to adjacent AP's transmissions to survive in presence of it. The assumption is that only one AP at a time (the closest one) interferes. The distance ratio formula uses CCI value for nonfading, undistorted by multipath transmissions, which is certainly a simplifying assumption, however it is a convenient number for comparison.



Assume that the propagation behaves as

Loss [dB]= A -K log(D),

where one table uses value K=20 (typical of free space or unobstructed indoor environment), and another one uses K=35 (typical of obstructed indoor environment).

Then from tolerable CCI (use the 1000 byte value) we can compute the tolerable Interferer-to-Transmitter "Distance Ratio"

CCI [dB] = K log (D_{TX}/D_{INTERF})

DR=(D_{INTERF}/ D_{TX}) =10^(-CCI / K)

From that we can compute the "Area Ratio" as the ratio between the Coverage Area and the Cell Area

AR=$A_{COVERAGE}/A_{CELL} = 4/(1+(D_{INTERF}/ D_{TX}))^2$

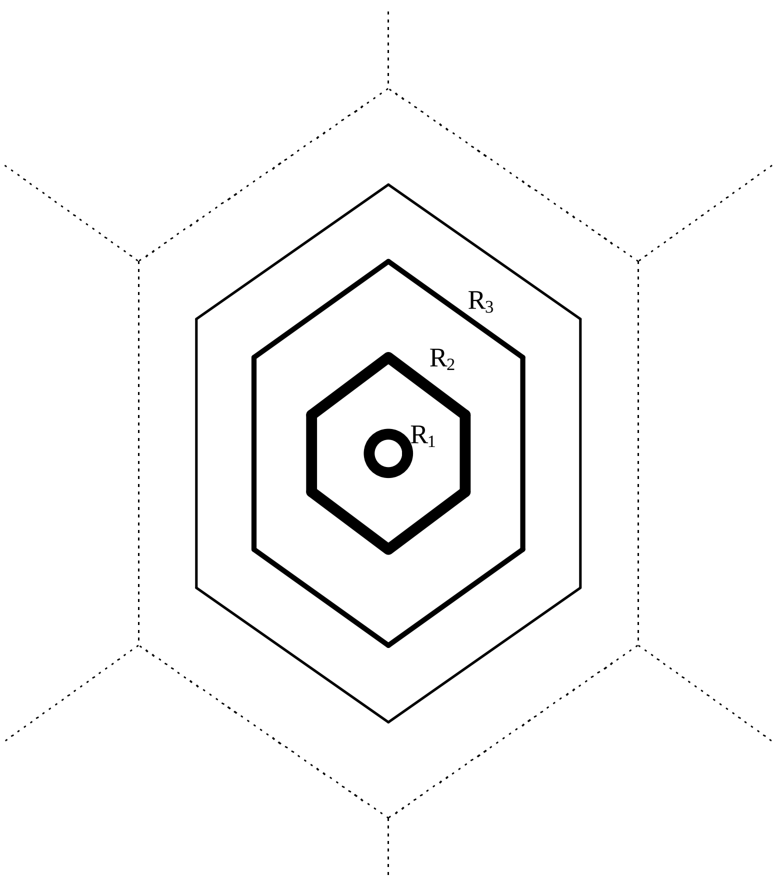
Now compute the "Aggregate rate per AP, single rate" as

R* $A_{COVERAGE}/A_{CELL}$

The computation of "Aggregate rate per AP, multirate" involves all the rates that are intended to be used in same area simultaneously. Assume R1>R2>R3, then AR1<AR2<AR3. Compute

Total Rate=R3*(AR3-AR2) + R2*(AR2-AR1) + R1*AR1

This can be demonstrated by the following drawing:



The drawing illustrates a situation in which in sub-areas closer to the AP higher rates are used.

Finally, compute the “Multirate Multifrequency Aggregate Rate” as

(Multirate Multifrequency Aggregate Rate)= (Multirate Aggregate Rate)*Nchannels,

where Nchannels are taken as the number of channels in the 200 MHz low+middle band.

Of course, this computations are for comparison only, there are many simplifying assumptions - no fading, only one interfering cell at a time, CCA which operates on C/I rather than signal strength, ability to determine exactly at which rate to operate etc.

Example: R1=40 Mb/s, R2=25 Mb/s, R3=40 Mb/s, CCI1=-16 dB, CCI2=-10 dB, CCI3=-6 dB. From that:

DR1=10^(16/35) = 2.86	AR1=4/(1+2.86)^2 = 0.27	Eff. Rate= 40*0.27=10.8 Mb/s
DR2=10^(10/35) = 1.93	AR2=4/(1+1.93)^2 = 0.46	Eff. Rate= 25*0.46=11.5 Mb/s
DR3=10^(6/35) = 1.48	AR3=4/(1+1.48)^2 = 0.65	Eff. Rate= 20*0.65=13.0 Mb/s

(Multirate Aggregate Rate)= 40*0.27+25*(0.46-0.27)+20*(0.65-0.46)=10.8+4.75+3.8=19.35 Mb/s

Now, assume there are 8 channels; then

(Multirate Multifrequency Aggregate Rate)= (Multirate Aggregate Rate)*Nchannels= 19.35*8=154.8 Mbit/s

Appendix F: Protocol Overhead Efficiency

This part addresses the throughput penalty incurred by the protocol overhead. The “efficiency” is computed as

Eff. =(1500B MPDU duration) / (DIFS+ Backoff +(1500B packet duration) + SIFS+ (ACK packet duration))

where Backoff=slot*CWmin/2, CWmin=15

The duration includes all the headers. The “Efficiency” will be computed both for ACK at basic rate and at same-as-data rate.