Communication Model - Algorithm's Implementation Progress Report

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1 802.11g Standard Description

The major mode of 802.11g is ERP-OFDM. It is essentially running 802.11a in 2.4GHz frequency band. It supports the same data rates as 802.11a: 6,9,12,18,24,36,48 and 54 Mbps. Rates of 6,12 and 24 Mbps are mandatory. On figure 1 the transmission time diagram is depicted. The communication is initialized by sending of RTS message by a transmitter to the receiver. The receiver sends a CTS message to the transmitter it is ready to communicate with. After CTS is granted, the transmitter sends the data frame and waits for the ACK message. The all message transitions are separated by idle intervals such as SIFS, DIFS and CW. We assume that the network consists only of 802.11g stations (nodes). Thus, the parameters of the network we use are as follows, $T_{SIFS} = 10\mu s$, $T_{DIFS} = 28\mu s$, $T_{CW} = 135\mu s$ and a symbol duration is $4\mu s$. Note, that to be 802.11b compatible a higher overhead is required.

Abbreviation and Denotations.

- ERP-OFDM - The extended rate physical orthogonal frequency division multiplexing.

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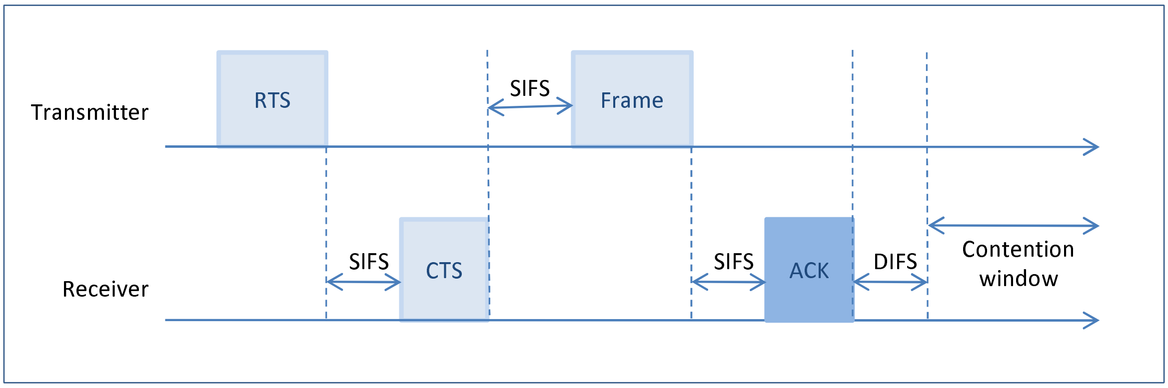

Figure 1: Transmission Time Diagram

- PLCP - Physical layer convergence procedure (mapping of MAC frames onto the medium).
- MCS - Modulation Coding Scheme.
- FCS - Frame check sequence.
- MAC_PSDU - Media access control PLCP service data unit.
- R - Coding rate.
- SIFS -Short inter frame space.
- DIFS -Distribution coordination function inter frame space.
- CW - Contention window.
- PER - Packet error rate.
- SNR - Signal to noise ratio.
- PHY - Physical.
- Payload - The useful information to be transmitted in bits.
- Service - The number of bits in service field.
- Trailer - The number of bits in trailer field.
- MAC_PSDU_SIZE - A size of MAC_PSDU in bits (not codded).
- MAC_H - MAC header in bits (not codded).
- MAC_FCS - MAC FCS in bits (not codded).
- MAC_O - MAC overhead in bits (not codded).
- RTS - Request to send
- CTS - Clear to send
- ACK - Acknowledgment
- T_{phy} - A time to transmit PSDU frame in μs.
- T_P - A time length of PLCP preamble in μs.
- T_H - A time length of PLCP header in μs.
- T_{tr} - A time length of trailer in μs.
- T_{RTS} - RTS time transmission in μs.
- T_{CTS} - CTS time transmission in μs.

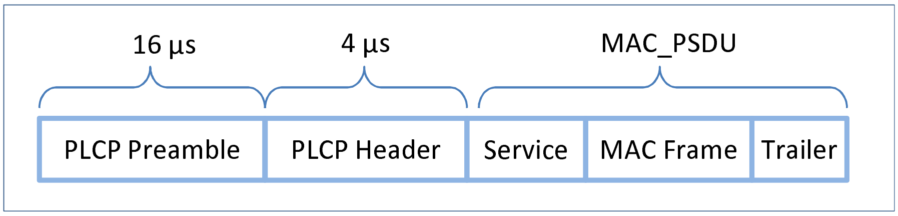

Figure 2: PHY Packet

- T_{ACK} - ACK time transmission in μs.
- T_{MAC_O} - MAC overhead transmission time in μs.
- T_{SIFS} - SIFS transmission time in μs.
- T_{DIFS} - DIFS transmission time in μs.
- T_{CW} - CW transmission time in μs.
- R_{raw} - A raw data transmission rate in Mbps.
- R_{actual} - An actual data transmission rate.
- Edge capacity - An maximal actual rate in the edge in Mbps.

1.1 PHY Layer

On figure 2 the PHY layer packet is depicted. It consists from PLCP Preamble, PLCP header and MAC_PSDU. PLCP preamble consists of synchronization field followed by a frame delimiter. PLCP header consists of information regarding MCS and a few control bits. PLCP header is transmitted by BPSK with $R = 1/2$ and data rate of 6 Mbps - the most reliable MCS. MAC_PSDU consists of service, MAC frame and trailer fields. Service consits from 16 bits and used for the initializations purposes. MAC frame is a payload with additional control bits added on the MAC layer (see subsection 1.2). A trailer consists of 6 tail bits, set to zero, notifying end of field and followed by padding bits, required to complete data blocks to a fixed size. The MAC_PSDU is transmitted with chosen MCS. The time duration to transmit a frame is calculated as follows:

$$MAC\_O = MAC\_H + MAC\_FCS. \tag{1}$$

$$MAC\_PSDU\_SIZE = Payload + MAC\_O + Service + Trailer. \tag{2}$$

$$T_{phy} = T_P + T_H + \frac{MAC\_PSDU\_SIZE}{R_{raw}}. \tag{3}$$

We upper bound the $Service + Trailer$ by 8 μs.

The table 1 represents 802.11g standard MCSs and data raw rates. Note that division of data bits per symbol by data rate is always $4\mu s$ as expected, since duration of symbol is $4\mu s$.

MCS	Data Rate (Mbps) R_{raw}	Modulation and coding rate (R)	Coded bits per carrier	Coded bits per symbol	Data bits per symbol
1	6	BPSK, R=1/2	1	48	24
2	9	BPSK, R=3/4	1	48	36
3	12	QPSK, R=1/2	2	96	48
4	18	QPSK, R=3/4	2	96	72
5	24	16-QAM, R=1/2	4	192	96
6	36	16-QAM, R=3/4	4	192	144
7	48	64-QAM, R=2/3	6	288	192
8	54	64-QAM, R=3/4	6	288	216

Table 1: MCSs and Raw Data Rates

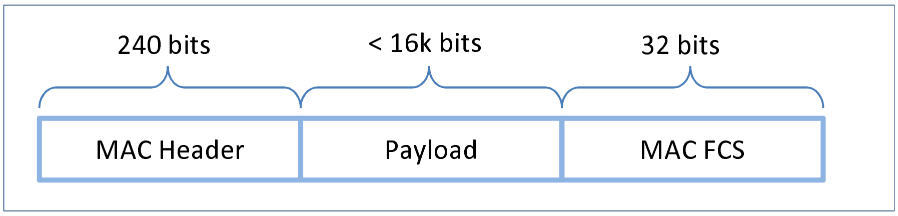

Figure 3: Data MAC Frame

1.2 MAC Layer

On the MAC level we consider the following types of frames: data, ACK, RTS and CTS.

A Data Frame. On the figure 3 a MAC data frame is depicted. A data frame consists of 240 bits of MAC header (addresses and control bits), 32 bits of FCS (a basic check sum code) and a payload to be transmitted. The MAC data frame overhead is 272 bits to be transmitted with chosen MCS.

ACK, RTS and CTS Frames. On figures 4 and 5 RTS, CTS and ACK MAC frames are depicted. These messages have no payload. ACK and CTS frames are of 112 bits each, RTS is of 160 bits. Any MCS can be chosen for their transmission. For simplicity we assume the same MCS for data, ACK, RTS and CTS. Since these messages are short we assume that they are transmitted without errors. With some abuse of notations we use RTS, CTS and ACK to denote the bit length of these frames.

$$T_{ACK} = T_P + T_H + \frac{ACK + Service + Trailer}{R_{raw}}. \tag{4}$$

$$T_{RTS} = T_P + T_H + \frac{RTS + Service + Trailer}{R_{raw}}. \tag{5}$$

$$T_{CTS} = T_P + T_H + \frac{CTS + Service + Trailer}{R_{raw}}. \tag{6}$$

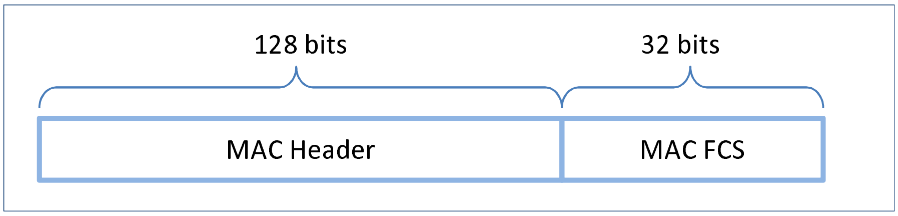

Figure 4: RTS MAC Frame

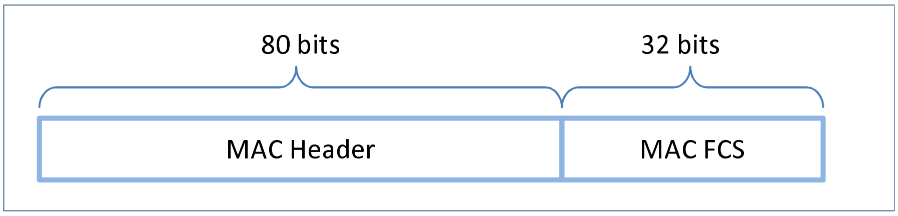

Figure 5: CTS and ACK MAC Frames

MCS Choise. First we calculate the actual transmission rate as follows:

$$R_{actual} = \frac{Payload \cdot (1 - PER)}{T_{phy} + T_{RTS} + T_{CTS} + T_{ACK} + 3 \cdot T_{SIFS} + T_{DIFS} + T_{CW}}. \tag{7}$$

For a given SNR at a receiver we find PER for each MCS. For each pair of PER and MCS we calculate R_{actual}. We choose MCS which provides the highest R_{actual}.

We notice that that there is a high degradation in the actual rate versus raw rate and a payload size.

In figure 6 is depicted a dependence of an actual rate versus a raw rate for 8000 bits of a payload and $PER = 0.1$.

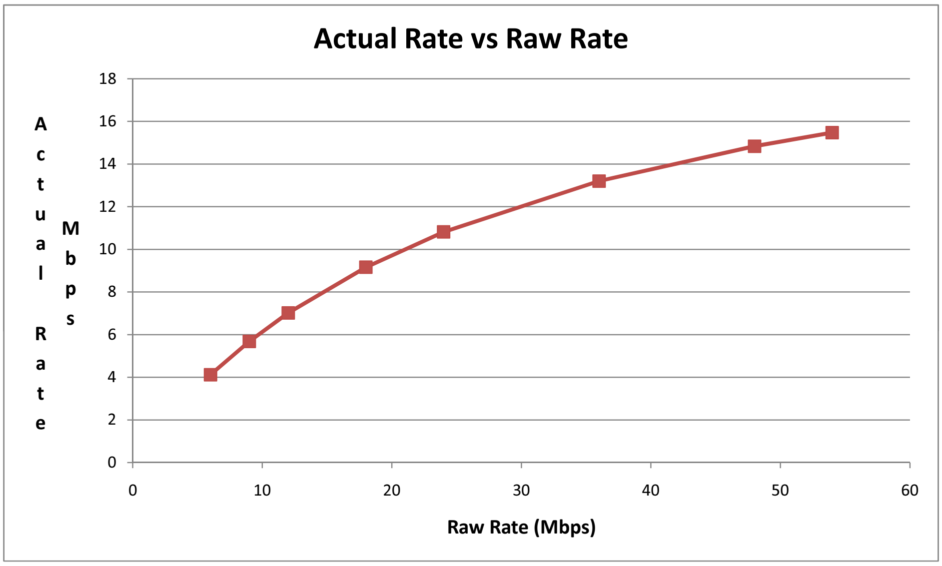

Figure 6: Actual Rate vs Raw Rate

In figure 7 is depicted a dependence of an actual rate versus a payload size for $PER = 0.1$ and

$MCS = 5$ (raw rate of 24Mbps).

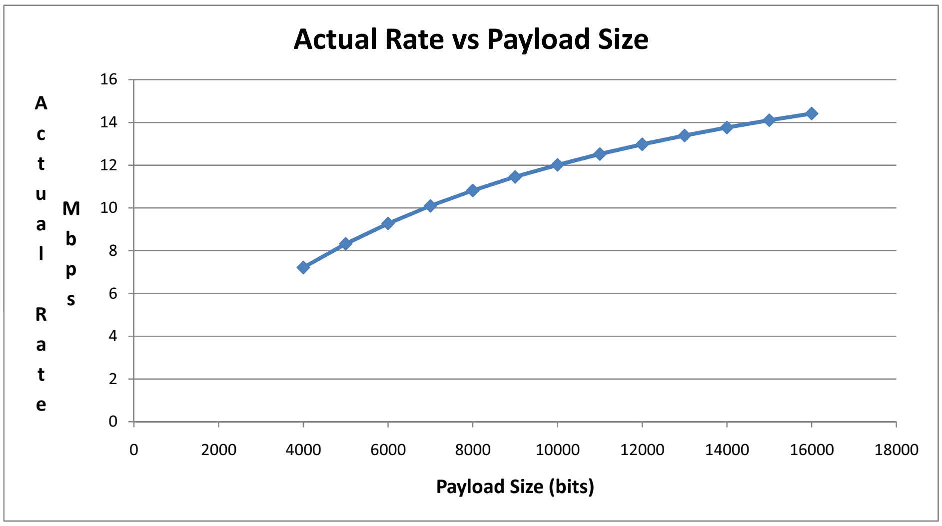

Figure 7: Actual Rate vs Payload Size

2 SNR Calculations

SNR has a crucial role of what MCS index should be used for the transmission. There are a few important factors which defines the receiver's SNR: a transmission power P_{tr}, an transmitter antenna height (h_{tr}) and gain (G_{tr}), a receiver antenna height (h_{rc}) and gain (G_{rc}), a path loss (L) and a noise power at a receiver (N_o). Namely,

$$SNR(db) = P_{tr}(dbm) + G_{tr}(db) - L(db) + G_{rc}(db) - N_o(dbm) \tag{8}$$

The path loss are impacted by the following factors, distance between a transmitter and a receiver in meters (d), transmission frequency in Hz (f), break point distance (d_{bp}) and shadow fading due to large scale obstructions (SF). The formulas we used for large space environment (city square) [3] is

$$\begin{aligned}
&L(d) = L_{FS}(d) + SF, && d \leq d_{bp}\\
&L(d) = L_{FS}(d_{BP}) + 35log_{10}(\frac{d}{d_{bp}}) + SF, && d > d_{bp}\\
&L_{FS}(d) = 20\log_{10}(d) + 20\log_{10}(f) - 147.5\\
&p_{SF}(x) = \frac{1}{\sqrt{2\pi}\sigma_{SF}}\exp(-x^2/2\sigma_{SF}^2)
\end{aligned}$$

For suburban and urban environments the following path loss formula [1] is widely used (it was provided by Elbit as well)

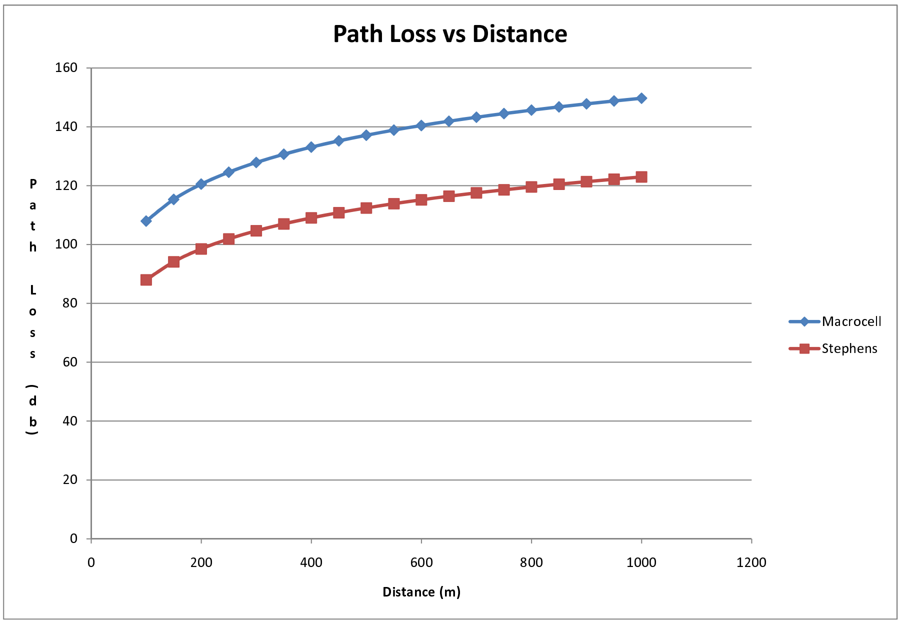

Figure 8: Path Loss vs Distance

$$\begin{aligned} L = &(44.9 - 6.55log_{10}(h_{tr}))log_{10}(\frac{d}{1000}) \\ &+ 45.5 + (35.46 - 1.1h_{rc})log_{10}(f) \\ &- 13.82log_{10}(h_{rc}) + 0.7h_{rc} + C \end{aligned}$$

where h_{tr} is the transmitter's antenna height in meters, h_{rc} the receiver's antenna height in meters, f is the frequency in MHz, d is the distance between the transmitter and the receiver in meters, and C is a constant factor ($C = 0dB$ for suburban environment and $C = 3dB$ for urban environment).

For each SNR value we are interested in what PER is guaranteed. The next table 2 summarize the expected PER versus SNR (meanwhile for 2 MCS indexes).

References

[1] G. Calcev, D. Chizhik, B. Goransson, S. Howard, H. Huang, A. Kogiantis, AF Molisch, AL Moustakas, D. Reed, and H. Xu, *A wideband spatial channel model for system-wide simulations*, IEEE Transactions on Vehicular Technology **56** (2007), no. 2, 389–403.

[2] M.S. Gast, *802.11 wireless networks: the definitive guide*, O'Reilly Media, Inc., 2005.

[3] E. Perahia and R. Stacey, *Next generation wireless LANs: throughput, robustness, and reliability in 802.11 n*, Cambridge University Press, 2008.

SNR(db)	PER	MCS
11	0.08	1
12	0.04	1
13	0.018	1
14	0.013	1
15	0.011	1
16	0.01	1
32	0.063	8
33	0.04	8
34	0.025	8
35	0.016	8
36	0.013	8
37	0.011	8

Table 2: PER vs SNR

[4] L. Villaseñor-González, C. Portillo-Jiménez, and J. Sánchez-García, *A Performance Study of the IEEE 802.11 g PHY and MAC Layers over Heterogeneous and Homogeneous WLANs*, Ing. invest. y tecnol, 45–57.

A Tables Format

In this section we summarize different tables which generator, algorithm and scheduler creates. A communication graph table (see table 3) consists from an edge number, both its nodes i and j, edge capacity and PER. The graph is undirected and defines which nodes can communicate and at what conditions. The delimiter is used to separate the fields in all the tables is comma ",". In the header (first row) of the table the number of edges and nodes will appear.

Edge number	i	j	Capacity	PER	MCS

Table 3: Communication Graph Table

An interference graph (internal for an algorithm part) table (see table 4) consists from an edge number and both its nodes i and j. The graph is undirected and defines which nodes interfere to each other. In the header of the table the number of edges will appear.

Edge number	i	j

Table 4: Interference Graph Table

A coordinates table (see table 5) consists from a node number, its (x,y) at time zero and its velocity (speed and angle). In the header of the table the number of nodes will appear.

A location table (see table 6) consists from a node number and its (x,y) location in the plane.

A requests table (see table 7) consists from stream number, source node, required bandwidth, destinations number and list of destinations. Required bandwidth is a requirement for an actual rate in Mbps.

Node number	X	Y	V	A

Table 5: Coordinates Table

Node number	X	Y

Table 6: Location Table

In the header of the table the number of requests will appear.

Stream number	Source node	Required rate	Number of destinations	List of destinations

Table 7: Requests Table

A scheduler table (see table 8) consists from the time slot number, frequency for communication, transmitter node, stream number, receivers number, receivers list, transmission rate and MCS index. A transmission rate is a flow obtained by the algorithm on the edges between the transmitter and the receivers . MCS index is taken according to the table 1. We assume that the number of frequencies is 3, but the algorithm is capable to get the number of frequencies as a parameter. In the header of this table will appear the number of time slots in 1 second and a payload size. We assume that the same payload size is chosen for all transmissions in the table the header corresponds.

Slot	Frequency	Transmitter	Stream number	Number of receivers	Receivers list	Transmission rate

Table 8: Scheduler Table