# Simulation Model for WLAN and GSM interoperating

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*Abstract* — **This paper presents a finite state machine model of a mobile station supporting simultaneously both GSM voice communications and data transmissions in an IEEE 802.11b WLAN network.**

## I. INTRODUCTION

Increasing competitiveness in the wireless industry combined with the rapid pace at which technology is evolving challenges equipment vendors to find new and better ways to reduce product development costs. Also, the demand for a multitude of wireless applications leads to the need of having different technologies on the same mobile terminal.

Sharing internet access, transmitting voice over WLANs, managing manufacturing and inventory are only a few of the most common applications motivating the rapid growth of the WLAN technology. There is no doubt about the wide usage of the GSM voice services and the utility of mobile station supporting simultaneously both GSM voice communications and data transmissions in an IEEE 802.11 WLAN network. While terminals implementing WLAN and GSM on separated chips are already used, the power consumption, dimensions and costs are the main arguments for implementing both GSM and WLAN on the same chip.

Based on this idea, we developed a simulation model as a finite state machine for a mobile terminal supporting simultaneously both GSM voice communications and data transmissions in an IEEE 802.11b WLAN network and we integrated this model in a simple IEEE 802.11b WLAN network to monitor the dual WLAN and GSM station behavior.

In elaborating the model of the dual station we had to take into account the following statements: (1) The terminal cannot communicate (send or receive) simultaneously in both of the networks because it has only one transmitter and one receiver both connected to one single antenna. Thus, the simultaneous communication in both of the networks is only apparent to the user: in fact, it is interleaved in disjoint time slots. (2) Because GSM is a TDMA standard and the mobile terminal has to fulfill specific tasks (receive, transmit or measure) in time slots prescribed by network, unconditional priority is given to the GSM communication. There is however one exception, which is the Beacon receiving in the 802.11b network, which blocks, if necessary, any GSM operation.

The WLAN and GSM interoperation schematic is shown in Fig. 1 where the WLAN packets are placed between GSM slots.

## II. SYSTEM MODEL

The 802.11 LAN is based on a cellular architecture, where the system is subdivided into cells. Each cell is controlled by a station called Access Point (AP). The functionality of a WLAN is assured by the Medium Access Control (MAC) layer, which can be constructed as a set of diverse services to accomplish information exchange, power control, synchronization and power control.

The *basic access mechanism*, called the Distributed Coordination Function (DCF) is basically a Carrier Sense Multiple Access with Collision Avoidance mechanism and it is used together with a Positive Acknowledge (ACK) scheme [1]. DCF works by a station willing to transmit data, senses the medium first. If the medium is busy, then the station defers its transmission to a later time, but if the medium is free for a specified time (called Distributed Inter Frame Space (DIFS)), the station transmits. The receiving station then checks the CRC of the received packet and sends an acknowledgement (ACK) packet. This receipt indicates to the transmitting station that there were no collisions detected. If the sender does not receive ACK, then it retransmits the last fragment [2], [3].

In order to reduce the probability of two mobile stations (STA) colliding because they cannot hear each other, the standard defines a *Virtual Carrier Sense mechanism*: a STA wanting to transmit a packet first transmits a short control packet called Request To Send (RTS), which includes the duration of the following transaction (that is the packet and the respective ACK), the destination STA responds (if the medium is free) with a response control packet called Clear to Send (CTS), which includes the same duration information [1]. All STAs receiving either the RTS and/or the CTS, set their Virtual Carrier Sense indicator (called Network Allocation Vector – NAV), for the given duration, and use this information together with the Physical Carrier Sense when sensing the medium [2].

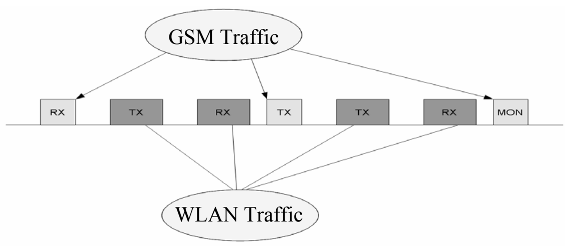


Figure 1. WLAN and GSM time interopperation

The diagram from Fig. 2 shows how the RTS/CTS mechanism works for station *A* as a transmitter and station *B* as a receiver and the NAV settings for their neighbors [2].

Bit error rates on wireless systems ($10^{-5}$-$10^{-6}$) are substantially higher than wire-line systems ($10^{-12}$). Thus, large blocks may approach the number of bits where the probability of a block error occurring may be extremely high. To reduce the possibility of this happening, large blocks may be *fragmented* by the transmitter and *reassembled* by the receiver node. While there is some overhead in doing this – both the probability of an error occurring is reduced and, in the event of an error, the re-transmission time is also reduced [1].

802.11 Specifications require for a Data volume to be transmitted to be split in units denoted as MAC Service Data Unit (MSDU) and allow for every MSDU to be split in smaller units denoted as MAC Protocol Data Unit (MPDU) [5]. The transmission of an MSDU consists in successive transmissions of its MPDUs. Every MPDU transmission should be acknowledged by the receiving part. The Short Inter Frame Space (SIFS) time intervals separate the receiving of an MPDU and the transmission of its ACK as well as the receiving of an ACK and the transmission of the next MPDU. The unacknowledged MPDUs are retransmitted after an AckTimeOut waiting time.

In good propagation conditions the transmission of an MSDU is a continuous succession of the sequence MPDU–SIFS–ACK–SIFS. The transmission of a second MSDU is allowed only after applying the basic access procedure. This way a STA having a huge volume of data to send is not allowed to block the channel for a too long period of time.

There are defined some types of *inter frame spaces*, illustrated in Fig. 3, in order to provide different priorities to stations [3]: (1) Short Inter Frame Space (SIFS) is used to separate transmissions belonging to the single dialog (Fragment-ACK) and it is the minimum inter frame space. There is, at most, one single station to transmit at any given time, therefore giving it priority over all other stations. (2) Point Coordination IFS (PIFS) is used by the Access Point to gain an access over the medium before any other station. The value is SIFS plus one slot time. (3) Distributed IFS (DIFS) is the inter frame space used for a station willing to start a new transmission, which is calculated as PIFS plus one slot time.

*Backoff* is a well-know method used to resolve contention between different stations waiting to access the media [2]. This method requires each station to choose a random number between 0 and a given limit (CW – Contention Window), and wait this number of slot times before accessing the medium. The slot time is defined as a way a station will always be capable of determining if another station has accessed the medium at the beginning of the previous slot. It reduces the collision probability by half. Each station listens to the network, and the first station to finish its allocated number of slot times begins the transmission. If any other station hears the first station talk, it stops counting down its backoff timer. When the network is idle again, it resumes the countdown.

The 802.11 standard [5] defines an *exponential backoff algorithm* which must be executed in the following cases: when the station senses the medium before the first transmission of the packet, and the medium is busy; after each retransmission; and, after a successful transmission. The only case when this mechanism is not used, is when the station decides to transmit a new packet and the medium has been free for more than DIFS.

On a WLAN infrastructure, the stations are kept *synchronized* by all the STAs updating their clocks according to the AP's clock, using the following mechanism: the AP periodically transmits frames called Beacon frames. These frames contain the value of the AP's clock at the moment of transmission. The receiving STAs check the value of their clocks at the moment the signal is received, and correct it to keep in synchronization with the AP's clock. Beacon frames are intended to be transmitted at regular time intervals (BP – Beacon Period), but the transmission of a particular Beacon could be delayed if the medium is busy at the intended moment (TBTT – Target Beacon Transmission Time) [5].

In mobile applications, *battery power* is an important resource. This is the reason why the 802.11 standard directly addresses the issue of *power saving* (PS) and defines a mechanism which enables STAs to go into sleep mode for long periods of time without losing information, as exemplified in Fig. 4. The main idea behind the PS mechanism is that the AP maintains a continually updated record of every STA working in PS mode, and buffers the packets addressed to it until the STA either specifically request the packets by sending a polling request (PsPoll message) or it changes its operation mode.

As part of its Beacon frames, the AP also transmits information (TIM – Traffic Indication Map) about which PS STAs have MSDUs buffered at the AP. The STAs wake up in order to receive the Beacon frame. If there is an indication that there is an MSDU buffered at the AP waiting for delivery, then the STA stays awake and sends a PS Poll message to the AP to get this MSDU. Some Beacon frames, regularly distributed in time, are followed by multicast and broadcast messages. These Beacon frames are denoted as DTIMs (Delivery TIM).

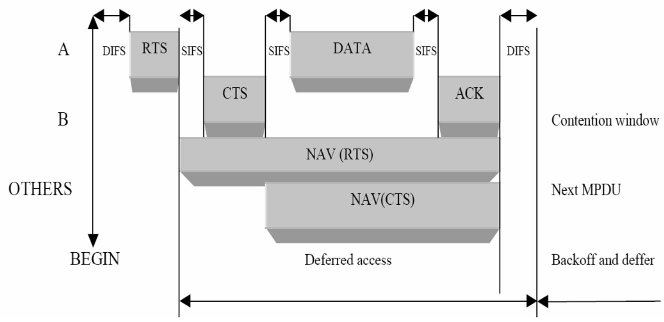


Figure 2. NAV state for the RTS/CTS mechanism

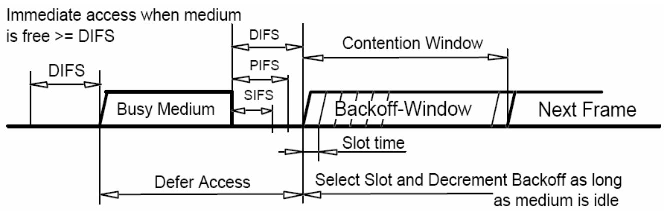


Figure 3. A schematic of the access medium

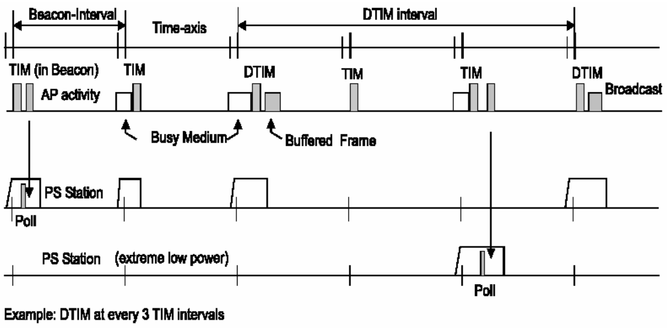


Figure 4. Power management of one STA

## III. Simulation Model

The main state diagrams of the modeled Power-Saving Station (Ps_STA) are presented in the followings. The initial state of a normal Ps_STA is DOZE. There are two conditions for exiting (wake-up) this state:

A. First is if the STA has to wake up to listen to the network activity and there are two situations: (1) When approaching a TBTT scheduled for wake-up (according to STA Listen Interval): a waiting state (WaitBcBMData) is activated and the channel state is monitored. The STA transits to RECEIVE state any time the channel becomes Busy. When exiting this state the packet is checked for errors. If there are errors in receiving it the STA discards the packet and returns to the WaitBcBMData state in order to receive the next packet. When the received packet is valid (FCS=1) its type is established through successive conditional transitions. If the packet is Beacon, its TIM part is analyzed to check for possible data stored in the AP having the STA as the final destination. (2) When approaching a DTIM beacon: at DTIM moments, the STA continues to wait after the Beacon for the scheduled broadcast data.

In both cases, if the received packet is of type Data STA checks for its final destination discarding it if the STA is not the intended destination or interpreting it, otherwise. If the Data are intended for the STA it stores the information, waits for a SIFS time and sends an ACK. If the received packet is an ACK the STA waits for a SIFS time and sends the next packet (MPDU) if there are still Data to transmit (Dts=1) or returns to DOZE state (Dts=0). Dts is an internal parameter used to indicate the application has still data to be transmitted by the STA. The transition to DOZE state is postponed if there are still Data to receive from the AP (DtR=1).

When the TIM element in the Beacon signals the existence of an MSDU having the STA as the destination (DtR=1) the STA sends a PsPoll message. This message is sent after a DIFS time if it is the only STA to receive a message, or by activating the back-off procedure if there are messages waiting for more than one STA. If, after a scheduled waking-up, neither a Beacon, nor an expected broadcast data packet is received, the STA returns to the WaitBcBMData state until these events happen.

B. The second condition for the station to wake up is the need to transmit data from a higher-level application, that is transmission of an MSDU (Dts=1). These moments are randomly generated following an exponential distribution. The basic access procedure is activated for the transmission of the first MPDU and successive SEND-SIFS-ACK-SIFS transitions are used until the entire MSDU is sent towards AP. The STA waits for an ACKTimeOut time for an ACK. It repeats the transmission of the last MPDU if the waiting time is longer than this.

Based on the GSM standard features [4] and aiming at using a worst case analysis the following rules were adopted in building the GSM part of a mobile transceiver (Dual Station).

There are 4 possible operational states for an MS (Mobile Station): SEND, RECEIVE, MEASURE and SILENT. While in SEND state the MS transmits towards its own BS on the allocated frequency and time Slot. During the RECEIVE state the MS receives the information transmitted by the BS (Base Station) on the allocated frequency and time Slot. In the MEASURE state the MS tunes itself to the frequencies broadcast by the network and takes measurements of the local electromagnetic field strength. Finally, the SILENT state is the time period when the MS has no task to fulfill.

While engaged in a call (CA=1) and the discontinuous transmission feature is not activated (DTX=0) the time evolution of the MS states is the one presented in Fig. 5 and it is almost the same as the standard specifies. The only difference is that the transmitting Slot does not occur at exactly 3 Slots after the beginning of a receiving Slot, but earlier with a Ta (timing advance) time. This timing advance Ta is needed for the compensation of the propagation delay and it is used for a precise superposition of the MS's transmissions at the BS level. In order for all transmissions associated with a time Slot to arrive at the BS precisely at the beginning of the given Slot it is mandatory for the MSs at a greater distance from the BS to begin their transmissions earlier than MSs positioned at a smaller distance from the same BS. According to the GSM Specifications the timing advance is a multiple of the bit period (which is approx. 3.69μs). The maximum value of the multiple is 63 and so, the maximum value of the timing advance is approx. 232ms. Obviously the minimum value of the timing advance is 0.

The time and duration of the mandatory measurements during a call in progress are implementation dependent of both the network and the mobile terminal. The network requests the mobile terminal to take periodic measurements on the frequency pilot of their own cell and, also, on frequency pilots of all the neighboring cells. We considered for the simulation that the measurement window lasts for a time Slot duration (approx. 577μs) and it is randomly positioned around the center of the time interval separating a transmitting Slot and the next receiving one. The time offset is no greater than half of Slot.

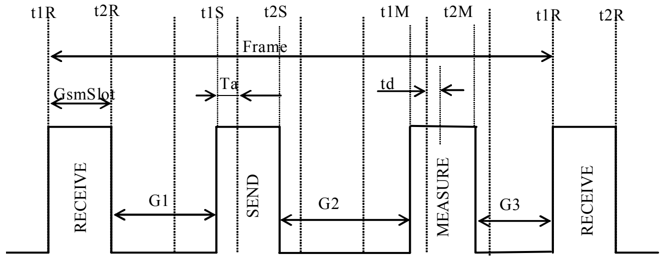


Figure 5. GSM state sequence when CA = 1 and DTX = 0

When the DTX feature is activated the mobile terminal remains in its SILENT state during the allocated transmitting Slots, except for the 8 specified Slots in the Frames no. 52-59 in a group of successive 4 Traffic Multiframe.

While in idle mode the MS stays in its SILENT state most of the time, except for the 4 no. 0 Slots in the Frames included in its Paging group.

The Ps_STA part of the Dual STA has to have some supplementary features in order to interact with the GSM part. As the GSM standard is a pure implementation of the TDMA concept mobile terminals has to obey all the control commands it receives from the network like to transmit and to receive on the frequency channel and the time slot allocated by the network. As a consequence a dual terminal has to treat its tasks in the GSM network with greater priority than the ones in the WLAN. The sole exception is the receiving of the Beacon, which has absolute priority on all the events in GSM part.

The reason of implementing this exception is that after loosing a Beacon due to a simultaneous GSM task the Dual station continues to wait the Beacon all the time interval until the next Beacon, thus blocking all its traffic activity in the WLAN network. This has a great negative influence on its throughput and on its power saving efficiency. Loosing a slot or even two successive slots in GSM network has no other consequence than stealing a very small part of the voice traffic with little effect on its intelligibility.

The absolute priority given to GSM events means that any WLAN activity could be interrupted in the following situations: MPDU transmission, ACK transmission, PS Poll transmission, RTS transmission, Backoff, Receive, Waiting states. This behavior is obtained in the model by setting a variable (ExitGsm) anytime a WLAN state is abnormally terminated. The GSM part of the Dual STA contains, also, an extra state (GsmBusy) as compared to a normal STA in order to take into account this new feature.

In Fig. 6 is presented an example of 16ms of activity in the simulated network, while the Beacon Period is set to 10ms. The diagrams represent the codified states of the AP, Ps_STA and DualSTA (including WLAN and GSM), where in the WLAN diagrams values of 20 to 30 signifies Tx states (30 – Beacon B, 27 – Broadcast Message BM, 28 – RTS, 29 – CTS, 25 – Ps-Poll, 26 – MPDU Data, 24 – ACK), values of 10 to 20 means Rx states (13 – Beacon B, 12 – Broadcast Message BM, 18 – RTS, 19 – CTS, 15 – Ps-Poll, 16 – MPDU Data, 14 – ACK) and values from -5 to 10 are codes for Waiting states (-5 – Idle/Doze, -3 – GSMBusy, 0 – BackOff, 1 – SIFS, 3 – DIFS, 4 – WaitData), while in the GSM diagram, 0 means SILENT, 1 – RECEIVE (Rx), 2 – MEASURE (Mon) and 3 – SEND (Tx).

It may be observed in the example considered that there is 1 MSDU formed by 6 MPDUs transmitted from the Dual_STA to the WLAN Ps_STA trough AP and the Ps_STA transmits to the Dual_STA via AP 1 MSDU formed by IV MPDUs. The WLAN part of Dual_STA is interrupted and delayed by the GSM activity, which has greater priority. Also, during the GSMBusy state, the Ps_STA takes control over the WLAN channel and when the DualSTA resumes from GSMBusy, it has to monitor and wait for the channel to become idle.

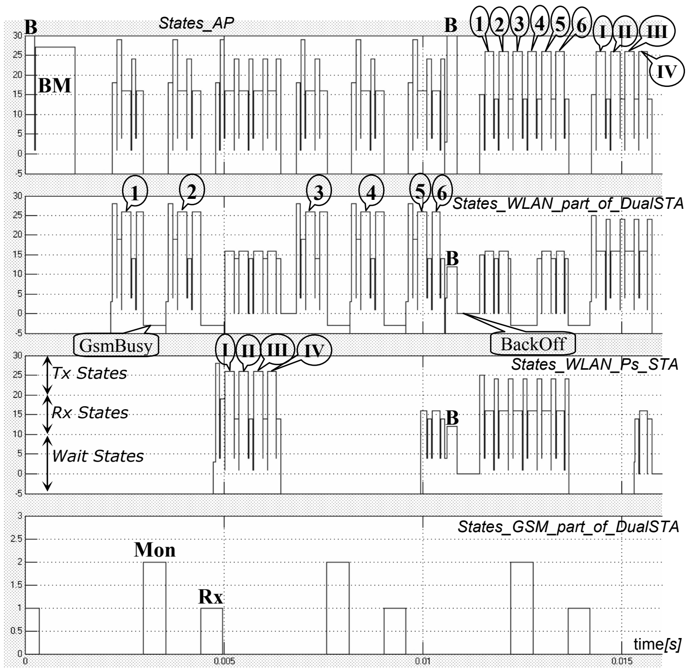


Figure 6. An example of activity in the simulated network

One can observe that the MPDU transmission interrupted by GSM is not acknowledged and that particular MPDU is retransmitted. Also the first Beacon is followed by a Broadcast Message and the second is delayed until the AP finishes the receiving of the MPDUs transmitted by one STA at the TBTT moment. After receiving the Beacon (at 11ms), because both stations have data to receive, they enter in competition for the channel, using the BackOff mechanism. First station that sends a PsPoll message gains control over the channel, receive its corresponding data from the AP, while the other station waits its turn to use the channel and receive its data from AP.

## IV. Conclusions and Future Work

The simulation model developed using Simulink Stateflow is of great help in studying the opportunity of using a Dual Station including both WLAN and GSM standards on a single chip. The throughput and the delay in transmissions are relevant for such a DualSTA implementation and both may be determined, and then analyzed, using our simulation model. But this analyze suppose a lot of simulations with different parameters and this is just our next future work.

## References

[1] J. Heiskala, J. Terry, "OFDM wireless LANs: A theoretical and practical guide", SAMS Publishing, 2002.

[2] P. Nedeltchev, "Wireless Local Area Networks and the 802.11 Std.", http://www.cisco.com/warp/public/784/packet/jul01/pdfs/whitepaper.pdf, 2001.

[3] Ph. Belanger, W. Diepstraten, "802.11 tutorial. 802.11 MAC entity: MAC basic access mechanism, privacy and access control", http://grouper.ieee.org/groups/802/11/Tutorial/MAC.pdf, 1996.

[4] 3GPP TS 45.002 V6.6.0 (2004-04) - "Technical Specification Group GSM/EDGE: Multiplexing and multiple access on the radio path".

[5] IEEE 802.11, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, ANSI/IEEE Std. 802.11, 1999.

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