The Development of Baseband and LMP Layers in Bluetooth

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Abstract

The current paper describes an aspect for development of Baseband and LMP layers defined in Bluetooth 1.1 standard specification for implementation purposes.
The structure of developed unit consist: control module which manages all other modules in the system, an interface module for interaction with L2Cap and LMP layers, separated modules for data reception and transmition, a module for interface purposes with radio chip, a clock generation module, frequency hopping sequence module, module for implementation of LMP structure.
The development of that unit has been done with "top-down" methodology of design. By this way the time for development was generally shorter. Each module of the design was described and developed with hardware description language – VHDL. Using this contemporary method of design allows being mineralized the risk of error in development and easy integration of some components in future works. The design has been orientired for Xilinx's FPGA XCV600E-4 platform by test purposes. Also the module has been fully simulated to check its functionality. The final version has been successfully implemented and tested in Xilinx's FPGA chip.

1. INTRODUCTION

The Bluetooth Radio system is operating at 2.4 GHz and has a very low power consummation. This is very convenient for integrating those devices in various mobile system and personal networks. Bluetooth is used for communication purposes between two or more devices in range 10-20 m.

Two or more units transferred information form piconet. Multiple piconets with overlapping coverage form a scatternet. There are two types of Bluetooth devices: master and slave. A unit is master if it is an originator and arbiter in a given piconet. The master device, define the frequency hop sequence and all data transfers in the piconet.

Each slave device must to be synchronized with master's clock. Each piconet has no more than seven active slave devices and many others may remain locked in so called parked state. The access for all these devices is controlled by the master device.

A channel in Bluetooth is represented by a pseudo-random hopping sequence. The hopping sequence changes its value regularly and can be decoded only from a device which is a member of current piconet. The hopping sequence is unique for each piconet and is derived from Bluetooth address of master device. The maximum transfer rate defined in Bluetooth 1.1 standard is 1 Ms/s. All units in a piconet have been synchronized with the master's clock and hopping sequence.

Time-Division Duplex scheme is used for data transmission. The channel is divided into time slots, each 625 us in length (Figure 1). The time slots are numbered according to Bluetooth clock of the piconet master from 0 to 2^{27}-1. The master device may transmit in all even numbered time slots, while a slave device in odd numbered slots, but only if it was addressed from mater device.

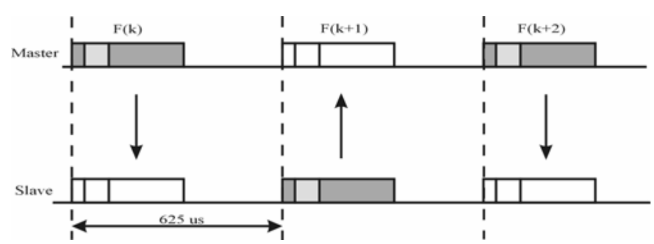

Fig.1 Data Transmition in Bluetooth

Each Bluetooth device must to have an integrated part for decoding of data, for choosing hopping sequence and others basic operations. The layer in Bluetooth who carry all these operations is Baseband. This layer has interface part with radio chip, link layer and user layer. The LMP layer manages all dedicated and security packet in Bluetooth. This layer generates and process' these dedicated messages and responses needed for establishment general parameters of the connection. Figure 2 shows the basic structure of a Bluetooth device. Packets transmission on reception may have two directions: HOST-L2CAP-BASEBAND-Radio chip or contrariwise. In that direction are send user data packets that doing to be send or receive.

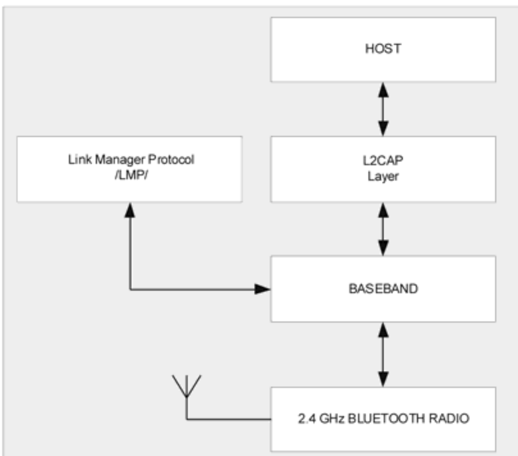

Fig. 2 Structure of Bluetooth device

The second primary direction for data packets is LMP-BASEBAND-Radio chip or contrariwise. This data channel is used for dedicated and control messages. These data packets are not accessible for others higher layer by security reasons.

2. DEVELOPMENT OF BLUETOOTH'S BASEBAND LAYER

The Baseband module has been developed according to standard Bluetooth and the design has been chosen with standard generic architecture. The main advantage in the architecture is that some basic management functions are performed by an external microcontroller. The structure is shown on Figure 3.

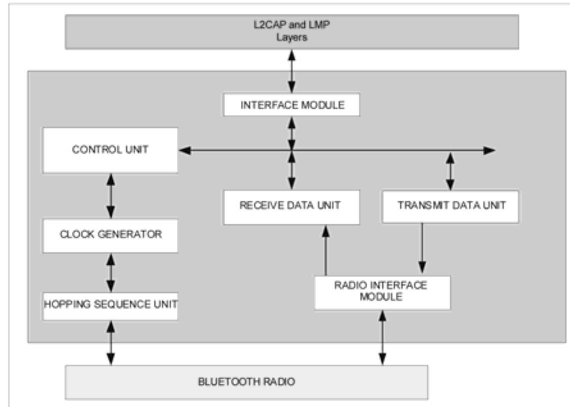

Fig.3 Structure of Baseband layer

The necessary condition is microcontroller to have system clock at least 10 MHz. An exception is only several internal for these layer computation processes, which are performed at 30 MHz. The microprocessor firmware is located in flash memory and it is recommended to have some initialization program (Boot Program).

When data must to be received from the Bluetooth air, the microcontroller must to initialize the receiver module and to control its work. After the packet has been received, the module generates an interrupt for this event.

2.1. Development of Frequency Hopping Sequence module

This module has the primary function to calculate the hopping sequence. The output from this module is a radio chip input and its value is equal to Изходът на модула за честотна синхронизация е вход в радио чипа и стойността на този изход е the difference in main frequency of 2.4 GHz.

The Bluetooth clock signal, which is used for internal logic switching is equal to 10 MHz, but for division modules at 79 and 23 the clock is 30 MHZ. The structure schematic is shown at Figure 4.

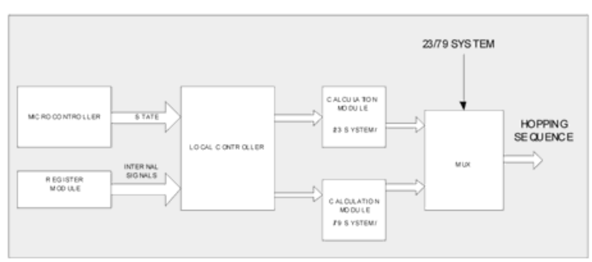

Fig. 4 Structure of Frequency hopp selection module

The entire module was separated at many small modules, but calculation controller manages the main input signals. After the generation of these input parameters the value of frequency hopping sequence is calculated. The output depends on the chosen system.

2.2. Transmit module

The transmitter module is shown at Figure 5.

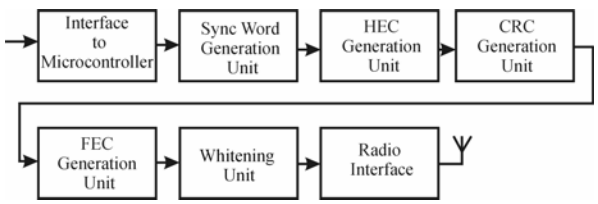

Fig. 5 Transmitter module flow chart

The direction of the data to be transmit is shown with arrows. The different stages of data operations are shown as different modules.

The transmit module consist of the following processes to be performed:

- Interface module for communication with control system.
- Generation of synchro word.
- Generation of checking code for header error detection
- Fast error correction module
- Cyclic redundancy check module
- Radio interface

Depending on the type of the packet that to be sending in the air, different processes may be performed. An example is the packet send with synchronous link. In case of this type of packet the cyclic redundancy check is never performed.

2.3. Data reception module

The structure of the receiver module is shown on Figure 6. The data must to be received first from radio chip and after that depending on the decoded type of the received packet may be performed different data decoding and corrections.

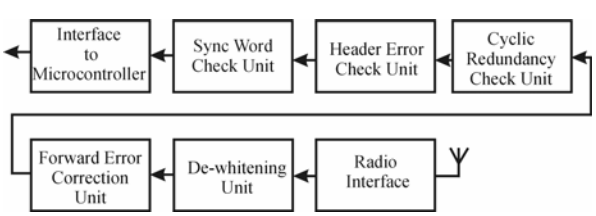

Fig.6 Receiver module flow chart

2.4. Bluetooth clock module.

Fig. 7 Structure of Bluetooth clock signal

The internal Bluetooth clock signal determines the critical periods and switches between some general events in Bluetooth messages. By definition the internal Bluetooth clock signal is generating in Baseband layer and is used for determining the times for packet receiving and transition. This clock signal represents 27 bits counter register with frequency 3.2 kHz. There are four important periods about each Bluetooth system: 312.5 μs, 625 μs, 1.25 ms and 1.28 s. These periods respond to CLK0, CLK1, CLK2 and CLK12. This is shown at figure 7. Data transmission from master to slave starts in even time slot always, i.e. CLK0 and CLK1 are both logical zeros /'0'/.

2.5. Link Manager Protocol Layer module

LMP is the logical layer which manages all dedicated packet transfers between devices in a Bluetooth piconet. Depending on these control messages is possible to change current configuration's device, use of some special working modes and disable of the device from piconet. In LMP registers are stored all data for global settings and parameters of that device. An example is support of maximum time slots per packet, some time intervals on dedicated data transmission and so on. The transmission of all LMP messages is performed in one time slot. Decoding of the layer that must receive that packet (LMP or L2CAP) has been done in Baseband layer during decoding the first two bits in payload header. The general task is the development of the generic Bluetooth module which supports all mandatory functions for implementing Bluetooth device. The structure of the LMP message is shown on Figure 8.

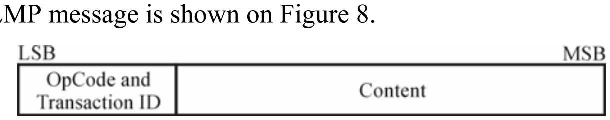

Fig. 8 Structure of LMP message

LMP layer receive this message from Baseband layer and generates a response. If the message consist of a parameter which can not to be performed, than the response consist of the value of unsupported parameter and the reason for it's discarding. For an example if the parameter is unsupported then the reason in this case is "unsupported LMP feature" and so on. In case of that message consists a correct request then are send required parameters of connection or device. The structure of LMP layer is shown at Figure 9.

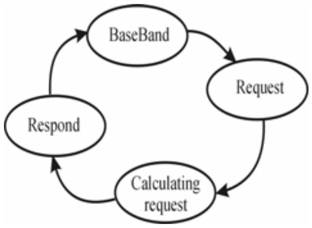

Fig. 9 Structure of LMP layer

4. SIMULATION REZULTS

Some synthesis results from frequency hopping selection module are shown below on Figure 10.

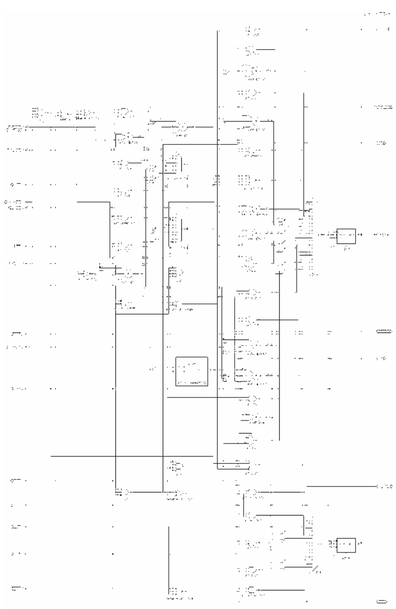

Fig. 10 Frequency hopping sequence module

Its post- synthesis simulation is shown on Figure 11.

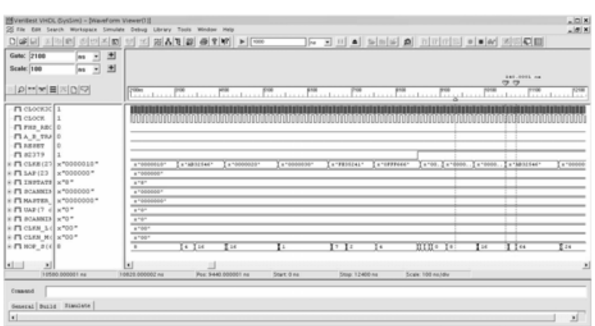

Fig. 11 Hop selection simulation results

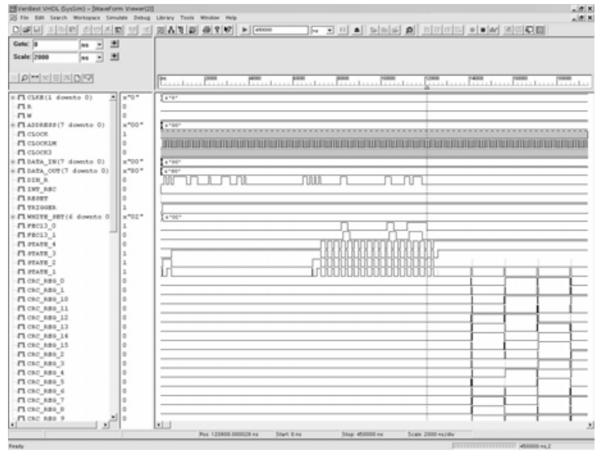

Fig. 12 Post synthesis simulation of data receive module

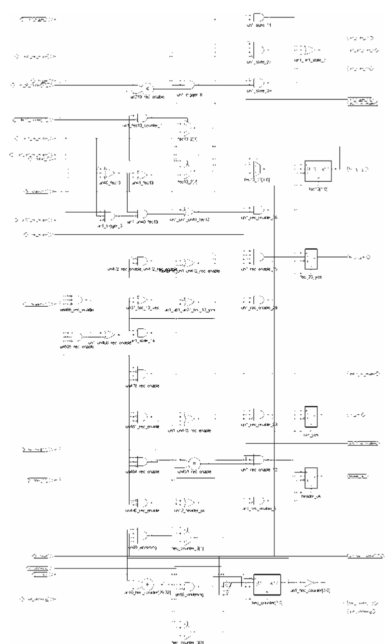

Fig. 13 Synthesis of data receive module

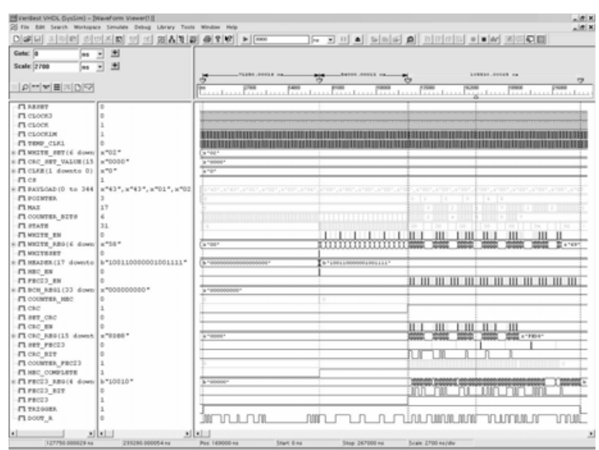

Fig. 14 Post synthesis simulation of transmission module

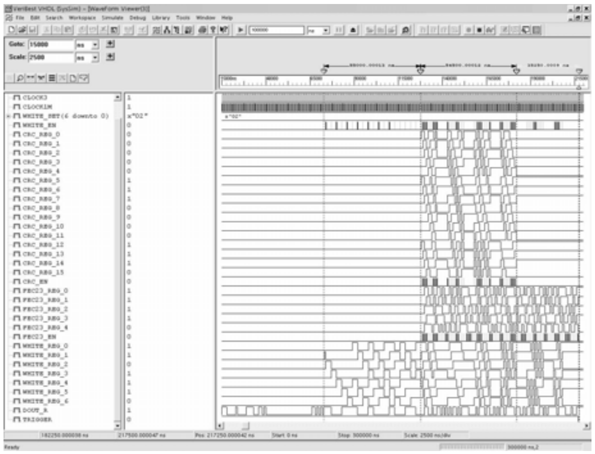

Fig. 15 Post synthesis simulation of transmission of a packet

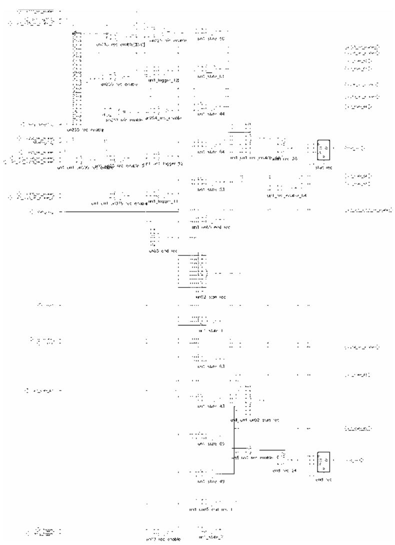

Fig. 16 Synthesis of transmission module

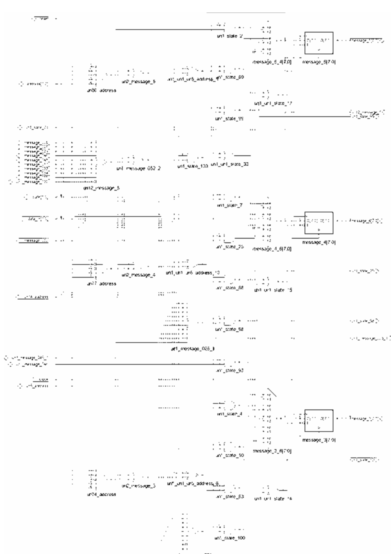

Fig.17 Post synthesis simulation of LMP module

5. COMPARISON OF THE REZULTS

The simulation results are fully functional according to Bluetooth 1.1 specification. These simulations proved the validation of the developed module which realizes the required minimum for creation of Bluetooth device. The developed device uses speed optimized processes for their fast calculation. To prove its functionality has been performed post synthesis simulations. The final version has been successfully implemented and tested in Xilinx's FPGA chip.

6. CONCLUSION

The main task of this work is to be developed a universal digital module which to be useful for easy integration in device that support Bluetooth 1.1 standard. An example for practical use of this module can be its integration in a system with microcontroller and radio chip for realization of a personal home Bluetooth network.

The method chosen in development of this module is top-down, because this method allows mineralizing the time for development of the design. For description of Bluetooth module has been used hardware description language - VHDL. Because a good time characteristics and developer testing reasons has been chosen programmable logic for test platform. The chosen logic was Xilinx's FPGA–XCV600E-4.

This project was making by ECAD Lab (http://ecad.vmei.acad.bg) in the Technical University-Sofia, Bulgaria.

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