

# NEW LEARNING MODELS USING MATLAB AND ZIGBEE

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## Abstract

**Real world models have been proven useful in learning process. ICII FEEIT SUT in Bratislava started project called “The use of ZigBee technology in control” with support of Tatra Banka foundation. In this project we have aimed to build learning models for students using ZigBee technology. Model railway implements XBee as control devices for all subsystems. Second learning module implements XBee for data exchange with several peripherals.**

## 1 Introduction

Learning is important and many times lifelong process in our lives. Our society demand from us knowledge and skills to improve quality of our lives, work, society and economy. Education institutes prepare students to fulfill these requirements. Improvement and modernization of the universities courses should be our priority. There are many modern methods and technologies for learning but most of them have one in common today – computers [1].

One of the most used environments for technical computing is Matlab [2]. Matlab is not only exploited in computations but also in learning process. Real world models can improve quality of learning process despite the advantages of learning through simulation. With models students have to deal with problems that doesn't occur in simulation. Another benefit is that students can see changes they made and how changes affect the models. In this paper we present two new learning models.

## 2 ZigBee

ZigBee is the only standards-based wireless 802.15.4 technology designed to address the unique needs of low-cost, low-power wireless sensor and control networks. The ZigBee standard employs 64 bit (IEEE) and short 16 bit addresses. The short address supports over 65 535 nodes per network. ZigBee is a multiple access network with CSMA/CA access method where the preferred topologies are the mesh and star. Mesh topology enables flexible network configuration and provides redundancy in the available routes. The star topology is necessary for RF (Reduced Function) devices, as they are not capable of routing [3,4].

ZigBee is designed for applications that need to transmit small amounts of data while being battery powered so the architecture of the protocols and the hardware is optimized for low power consumptions of the end device. It provides long battery life. The ZigBee security architecture includes security mechanisms to protect transmitting data. There are number of publications devoted to the study of ZigBee technology and their implementation in real applications. ZigBee found usage in many applications like building automation, remote control, health care, home automation and many others [5].



Figure 1: Xbee module

### 3 Xbee controlled model railway

Model railway started as a simple demonstration of Xbee technology. At first stage it was only simple circuit with one train. After we have solved how to control it, we have expanded model to big railway with multiple stations and trains. It is controlled within Matlab application.

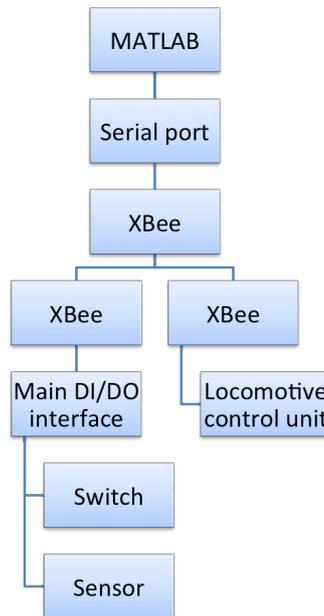


Figure 1: Schematic of control structure

#### 3.1 Railway

Railway is model in TT scale (1:120), which is optimal scale for table railways. It contains one main and three minor stations. In full size it is over three meters long and eighty centimetres wide. There are seventeen switches and twenty sensors. [6]

#### 3.2 Trains

We have four remotely controlled locomotives and eleven train cars. Each train is designed to fit on one station track. Train cars include freight container transports, cistern, cargo and coal transport cars. Control electronics is placed on the roof of locomotives. Standard direct power supply to engine is removed and is connected to the control electronics. Logical circuit processes two digital outputs and PWM output from Xbee. Output is then amplified by half h-bridge and connected to engine. Thanks to this, engine rotation depends on Xbee outputs and not on polarity of track. Thanks to PWM range from zero to 1023, changing speed can be very smooth.

#### 3.3 Sensors

Sensors on track are positioned on each end of every station track. Construction is purely mechanical and contains no electric elements except wires. Main idea is using common electric ground for whole track. Digital inputs of Xbee in disconnected state are keeping logical one status with pull up resistors. When train drives over the sensor section, it connects common ground to digital input of Xbee. Device detects change of state at input and sends API frame containing new state of inputs to computer. All sensors are programmed to send data directly to main control Xbee connected to computer.

#### 3.4 Switches

All switches are controlled by one digital output each. Logical circuits and timers create impulse for switch in requested direction every time the logical value at the Xbee output changes. Switches cannot be connected to the power source for more than few seconds, or their coils will burn. That is why we create only half-second impulse of direct current, which behaves as alternating current in this case. It is enough to activate electromagnet in switch.

### 3.5 Control

Whole communication is based on API frames. With this frames the locomotives and switches are controlled and data from sensors are transferred to control system. Data are collected and processed in Matlab GUI. GUI reads data from serial port in cycle every fifty milliseconds and sends command data only on status change. Data traffic is kept at very low level. Main cycle reads data from serial port, then decodes all sensor statuses and checks if any train arrived to its destination. If yes, it engages algorithm to create next route. After creating new route, train is allowed to drive again.

All trains can be operated in two modes. First mode is automatic, when after arriving to the station, program finds next empty route and sends train there. Only user interaction is to set direction of train and if it can drive or not. Second mode is targeted, when user gives train a target track. Program uses Dijkstra algorithm to create shortest route to target in last used direction.

Visualization of railway is also provided. Each train is marked by different color. Empty tracks are green and each blocked track is marked by train's color. When track is blocked by one train and reserved by another, in visualization it is filled with dashed lines of both colors.

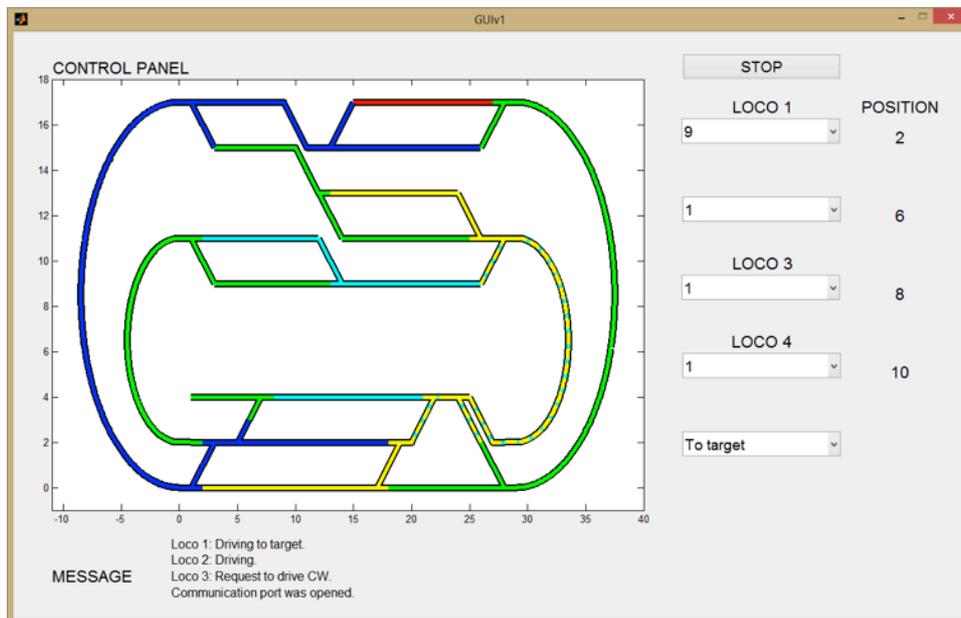


Figure 2: GUI interface

### 3.6 Map

For navigation tasks, program includes special data structure containing map of whole railway. This structure is universal and can be used for mapping any configuration of railway. It is also possible to block some tracks on map to simulate different situations with parked trains in stations. Program can process even dead end tracks and switches in cascade. Only visualisation map must be programmed manually for now.

## 4 XBee development kit

XBee development kit tries to implement wireless standard ZigBee in learning process through XBee wireless modules. XBee development kit with HMI is out of box solution. It prevents students from any unnecessary electrical connections with the XBee module, and also speeds up the learning process.

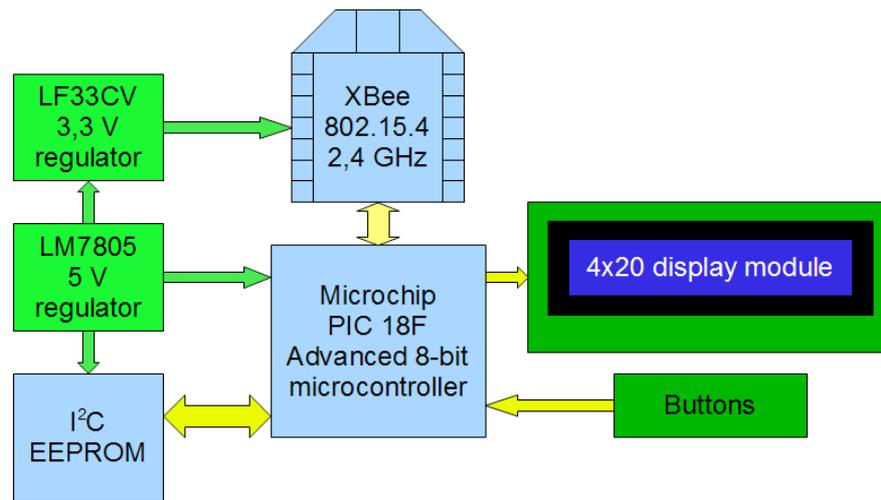


Figure 3: Block diagram of development kit

#### 4.1 Development kit electrical connection

It contains XBee module mounted in socket, which is connected to Microchip PIC 18F microcontroller via USART. 4x20 display module and three buttons creates the whole HMI. Display is connected with four-wire data bus and three more control signal I/O's. Buttons are connected to PORTB external interrupt pins. Whole solution is powered using external 7,5 V adapter and stabilized by two monolithic voltage regulators LM7805 for 5 volts and LF33CV for 3,3 volts required for the XBee. Although the PIC 18F has 8 kB of flash memory, we added an additional 8 kB of I<sup>2</sup>C EEPROM memory, for example for storing text strings, or user data presets. [7]

All components are through-hole type and they are mounted on single sided printed circuit board with display connector and power connector (however, there was afterthought, so we added few SMD capacitors for decoupling the power lines both 3,3 V and 5 V). Display is connected via flat cable, buttons and LEDs are connected with twisted pair instead. To use this module for custom application or project, some pins of the XBee module were cabled to the back panel connector.

#### 4.2 Sensors

An example board will be available in the future to prove the function of the module. It will consist of phototransistor, photoresistor and trim pot for analog input demonstration. Another possibility is direct current motor in full H bridge connection for pulse width modulation testing. Few LED's will be placed on the front panel for custom, as well as custom configurable buttons.

#### 4.3 Control

This development module provides three control capabilities. First is wireless control from MATLAB interface, where can students learn how to use API frames to tele-control the XBee with specified destination address. MATLAB uses graphical user interface with buttons and feedback elements. These button press, or slider tuning is then interpreted to XBee via API frames, which are assembled automatically using special function after every press or change. As a transmit module we use XBee with USB converter (FT232 chip), as the receiver module we use XBee in development kit, which is switched to API frame mode.

Second, but not the last, is manual control via HMI (display module and buttons). For those who prefer embedded system control, we provided 8-bit PIC 18F series microcontroller, which can be programmed in C language. This kind of control uses AT commands, which represent the present-type control via cable UART interface of directly connected XBee modules. The last possibility of control is provided HMI. This menu can be used to find out info about XBee module (serial numbers of address, signal strength, channel), or to control the outputs of the XBee module and PWM duty cycle.

## 4.4 Future plans

In the near future, digital input's and outputs will be isolated using optocouples for better electrical resistance. Possible electrical damage od analog inputs from external sources will be suppressed by metal oxide varistors, diode bridge and some other safety components, which would make this module much more resistant to voltage spikes. XBee pins will be available through COM port connector type.

## 5 Conclusion

In this paper we wrote about new learning models developed with ZigBee technology and Matlab environment. The main benefit is that ZigBee technology is fully capable of replacing serial links with the wireless transfer. Matlab provides known environment to students, therefor solving task is easier for them. Model railway is using XBee as control devices for locomotives motion, switches and for monitoring traffic by sensors. Model provides fun and interesting platform for students and control task. Learning module implements XBee module for data exchange with display module, buttons and user selectable peripheries. This model provides modular platform and students could select area of interest that they want to explore and work on. Over all, designed models aims to improve education process with models that are real and not simulation only. Students can improve their skills in process control, event-driven systems, communications and optimization.

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