

ZIGBEE IMPLEMENTATION IN RAILROAD MODEL

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Abstract

Control over cable or wireless network gains popularity over last decade. Low cost alternatives like ZigBee were developed as a substitute for specialized industrial networks. ZigBee is one of the most popular wireless networks in control today, because of its properties. We have used ZigBee wireless network to control speed and other elements of model railroad produced by Tillig. We have used m-files and Simulink environment for construction of ZigBee's communication packets. This model can be beneficial in teaching process.

1 Introduction

Networked control systems (NCS) have been in attention for many researchers for the past ten years. NCSs are one type of distributed control systems where sensors, actuators, and controllers are interconnected by communication networks. Cheaper but very popular networks like ZigBee have been developed as substitutes of the industrial applications like PROFINET or IWLAN [1,2].

Modern education of engineers requires not only theoretical knowledge but also practical experience. Both of these requirements we could fulfil with Matlab environment with practical models. MATLAB is a high-level technical computing language. Add-on toolboxes extend the MATLAB environment to solve particular classes of problems. Matlab provides good sets of commands and blocks that we could use for networked control systems.

We have modified model railroad so that we could control speed and direction of trains by ZigBee technology. We have used Matlab for creating data packets and send them by serial port to our devices. We would like to describe steps needed to construction of our model and communication through Matlab environment in this paper.

2 Tillig TT model railroad

TILLIG Modellbahnen GmbH & Co. KG (Tillig) is a German company specialized on railroad models. Most of the models are in TT scale that stands for Table Top. TT scale has scale ratio of 1:120 and 12mm gauge size is between H0 (1:87) and N (1:160) scales. TT model railroads are popular mostly in Europe. Tillig produces more than 150 locomotives, over 200 wagons and easy setup starter track systems for beginners in TT scale, which are mostly replicas of European railways. Example of TT scale model railroad is shown in figure 1. Our goal was to build simple railroad model and control it with ZigBee technology [3].



Figure 1 TT scale model railroad [4]

3 ZigBee

ZigBee is the only standards-based wireless technology designed to address the unique needs of low-cost, low-power wireless sensor and control networks. ZigBee can be used almost anywhere, is easy to implement and needs little power to operate. They should be used in many applications like building automation, remote control, health care, home automation and many others [5].

We have used XBee DigiMesh 2.4, 1mW from MaxStream and DFR0050 DFRobot Xbee USB adapter from DFRobot for connection to PC in our experiments. Software X-CTU, from DIGI International, creates during installation USB serial port (COM) that we used with our USB adapter. X-CTU software could be used to set parameters directly to connected module as shown in figure 2 [6].

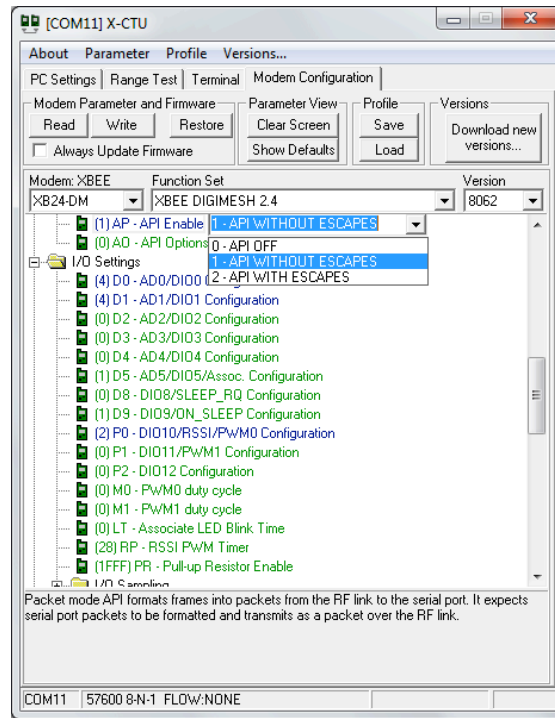


Figure 2 Parameters setting with X-CTU software

4 Hardware implementation

Power supply hardware implementation has been changed to control the train through ZigBee module. Most of the Tillig TT railroad track models are supplied with DC voltage from railroad track. DC voltage is connected through collectors to the small DC motor. We have changed this connection by inserting ZigBee module and control electronics. Power supply was disconnected from DC motor and connected to the input of control circuit. The control circuit sets magnitude of voltage and direction of the train by PWM module, according to properties on ZigBee module. Output from the circuit is then connected to the DC motor. This implementation is shown in figure 3.

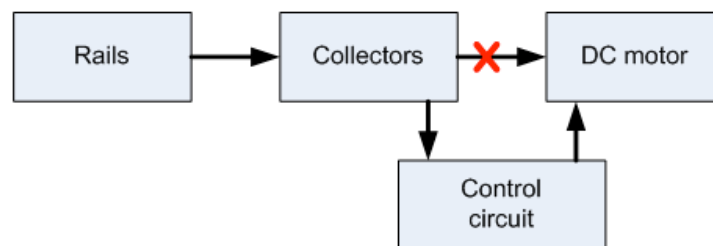


Figure 3 Schematic diagram of power supply of the DC motor

Power supply within range of 2.8 - 3.7V has to be connected to ZigBee module, before we could start the communication. DC voltage supply of Zigbee module is connected through stabilizer

with output of 3.3V in control circuit. We have used pins 20, 19, and 6 (digital output DO-0, digital output DO-1 and PWM signal). Logical unit switches output polarity depending on DO-0 and DO-1 states. Logical unit is also supplied from stabilizer with output of 5V. H-bridge is connected after logical unit and provides power supply to the DC motor. Simplified schematic diagram is shown in the figure 4.

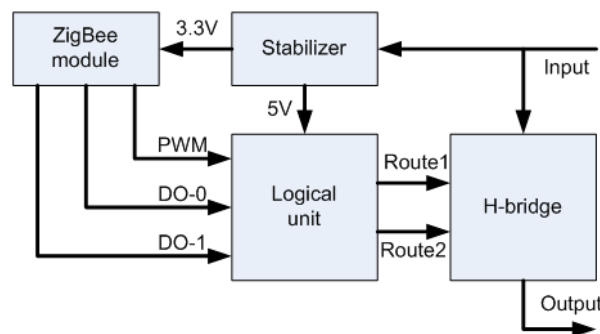


Figure 4 Schematic diagram of control circuit

5 Matlab implementation

We have decided to use Matlab to change the output values of ZigBee module. Three pins are used for controlling speed and direction, as we have mentioned before. PWM output has interval of values between 0-1023 (0-0x3FF) and this interval ensures smooth change of train speed. Direction should be set by two digital outputs. States of motions are described in table 1.

Tab. 1 State of motions

Output/State	Forward	Backward	Total Stop	Stop
DO-0	1	0	1	X
DO-1	0	1	1	X
PWM (M0)	X	X	X	0

The X character means any value in table 1. Forward and backward motion is decided by digital outputs and value of PWM signal. When both digital outputs have set value to logical 1, motion is stopped no matter of PWM signal value (this is done by hardware). If value of PWM signal is 0, train stops, but will move again in same direction, when another PWM value is set again. This is beneficial because we do not need to set API frame for direction again.

ZigBee modules are often used as data transmitters, so we had to use other methods for changing parameters. Specialized API frames have been used for this task. API Frames are series of hexadecimal values, which identify devices and contain data in defined structure. In our case we had to create Remote AT Command request, which is shown in figure 5. Structure of API Frame is in device manual.

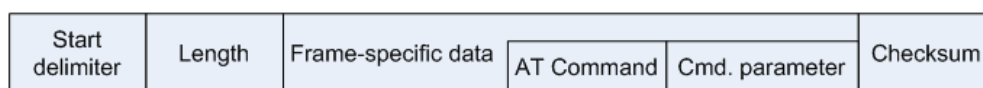


Figure 5 API Frame

5.1 M-files

First implementation used Matlab m-files. First step was to create object of serial port, which can be done by command *serial()*. Object must be saved to variable for later usage in other commands. We can also set properties to port object with *set()* command. Communication through port can be opened with *fopen()* command and closed with *fclose()* command. Data should be send with help of formatted (*fprintf()*, *fscanf()*) or binary (*fwrite()*, *fread()*) input and output. ZigBee module uses only

binary coded data. Next listing is example of simple communication with module using Matlab command.

```
>>port=serial('port_name');
>>set(port,'Timeout',.2);
>>fopen(port);
>>data=API_FRAME;
>>fwrite(port,data);
>>response=fread(port,dataLength);
>>fclose(port);
```

Several functions have been created to work with API Frames in Matlab. One set of functions code data to API Frames and other decode data from API Frames. GUI application in Matlab has been created for better work with commands. We can open and close ports, set speed and directions for our trains or stop movement with Total Stop button in this application. Parts of API Frames are displayed in GUI also.

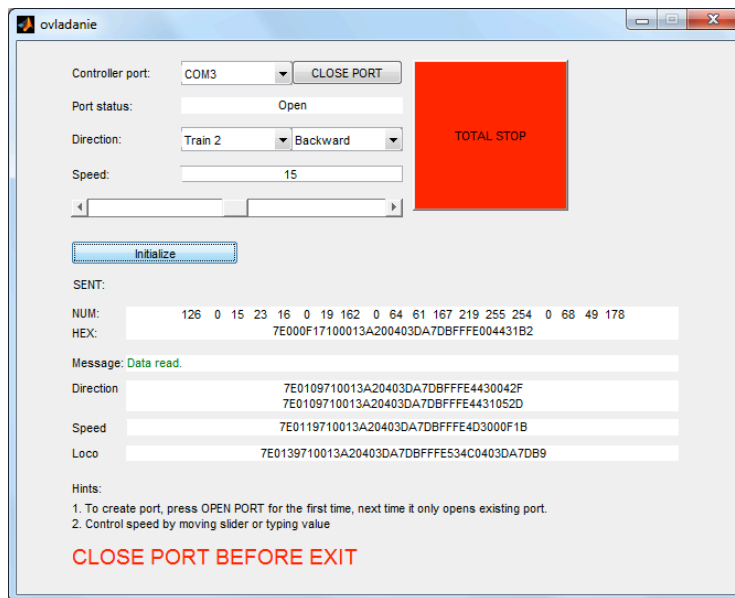


Figure 6 GUI application

5.2 Simulink

We have sent commands using Simulink also. Simulink diagram consists of blocks that are creating API frames. The inputs in schematic diagram are speed of our train and flag for simulation stop. Speed is processed by block *ACCELERATION* for smoother acceleration. Corrected speed and train address are sent to blocks for generation of the API frames for PWM, DO-0 and DO-1. Frames are connected to block *To Instrument* that ensures data transmission. Whole schematic diagram is shown in figure 7.

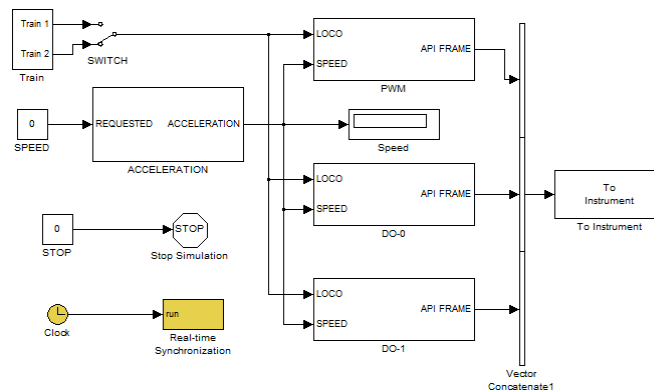


Figure 7 Simulink schematic diagram

Schematic that creates API frame for PWM output is shown in figure 8. Data are sent with sample time of 0.15s. Simulation can be stopped through the stop flag. Simulink control is cyclic so data frames are sent permanently (packet dropouts are therefor no problem), but it could be sometimes disadvantage.

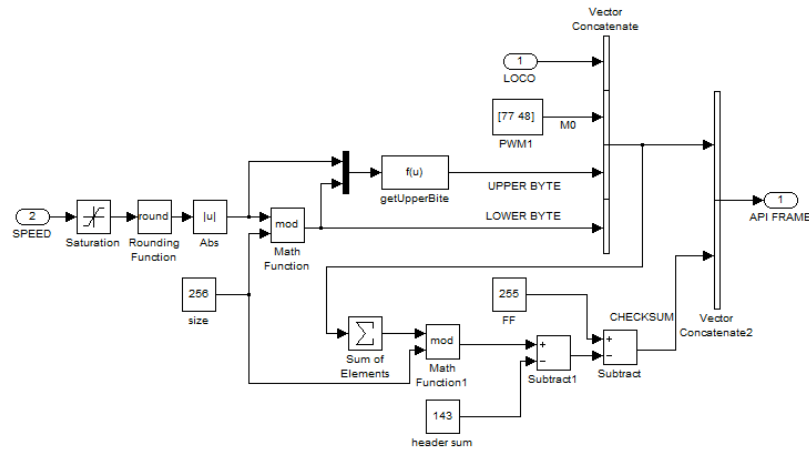


Figure 8 Block for PWM API frame

6 Conclusion

We have described TT model railroad in which we control speed and direction of train through ZigBee module. Communication between ZigBee modules in Matlab was possible through serial port. Standard ZigBee API Frame was used to change parameters of the ZigBee modules. Firstly we have sent packets with standard Matlab commands (within M-files) and then we have sent them using Simulink blocks.

We have created simple railroad track model and we were able to communicate between multiple ZigBee modules and change their configuration. ZigBee should control train model speed and other parts of the railroad track model like cross switch or decouplers. The model can be used in teaching process of control, event-driven systems, communications, optimization and many others.

Acknowledgement

This work has received support from the Slovak Scientific Grant Agency through the grant VEGA-1/0592/10. It has been supported by the project Req-00048-001 too.

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