



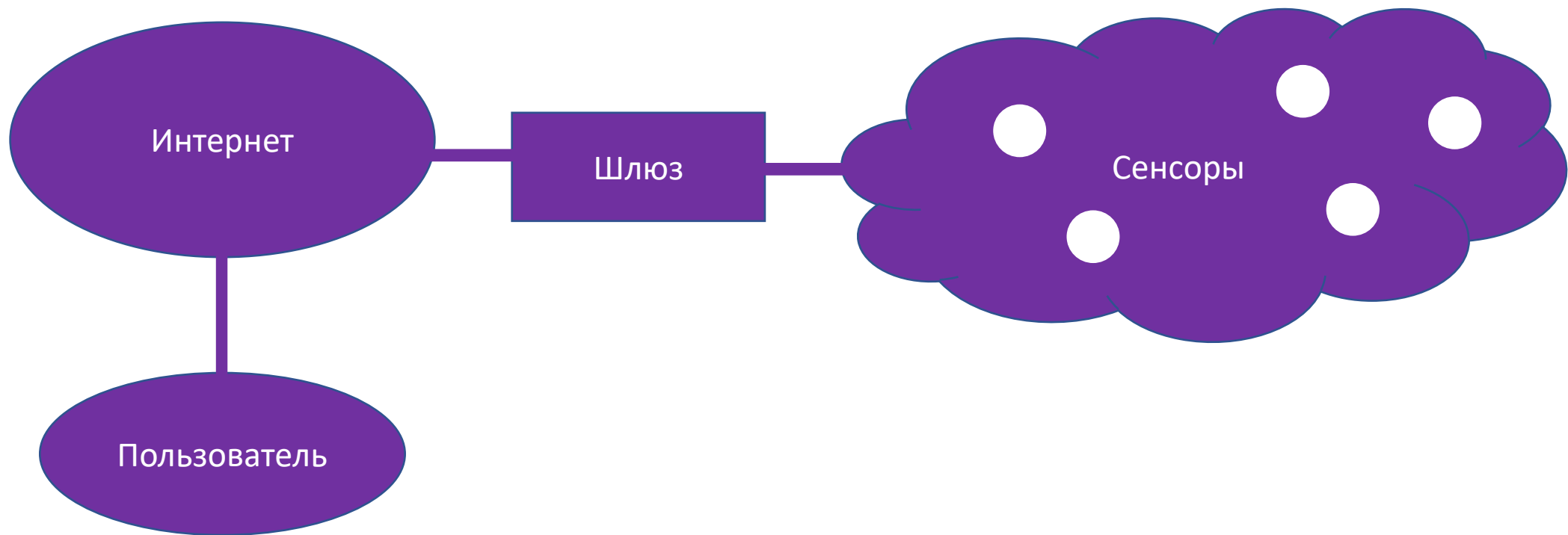
Практическое введение в ZigBee

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Исследовательский центр Samsung

23.07.2021

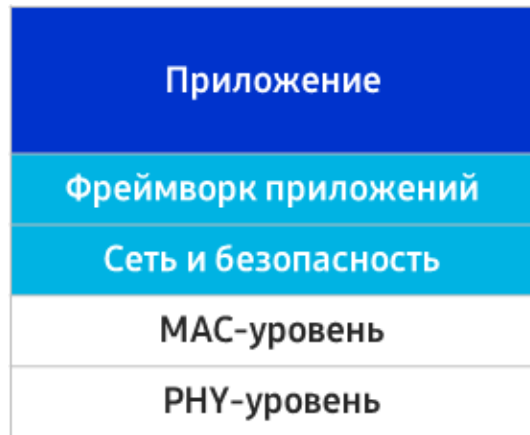
Беспроводные сенсорные сети



Спецификация 802.15.4

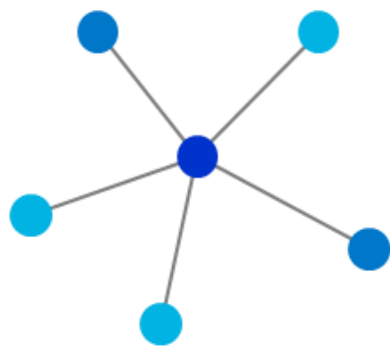
- Маленький размер пакета
- Низкая скорость передачи данных
- Топологии «звезда» и «ячеистая сеть»
- Низкое энергопотребление устройств
- Низкая стоимость устройств
- Большое количество устройств
- Местоположение устройства заранее неизвестно
- Устройства ненадежны
- Режим длительного сна для устройств

Немного про ZigBee

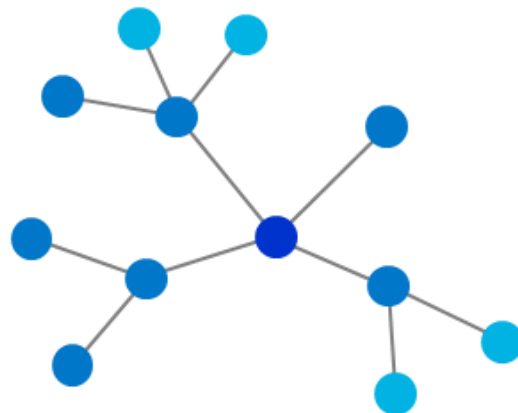


- Приложение
- ZigBee-стек
- Железо

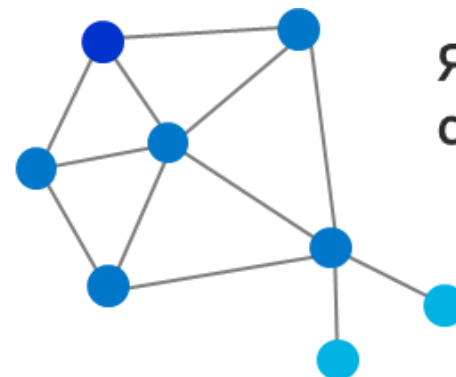
Топологии сетей ZigBee



Звезда



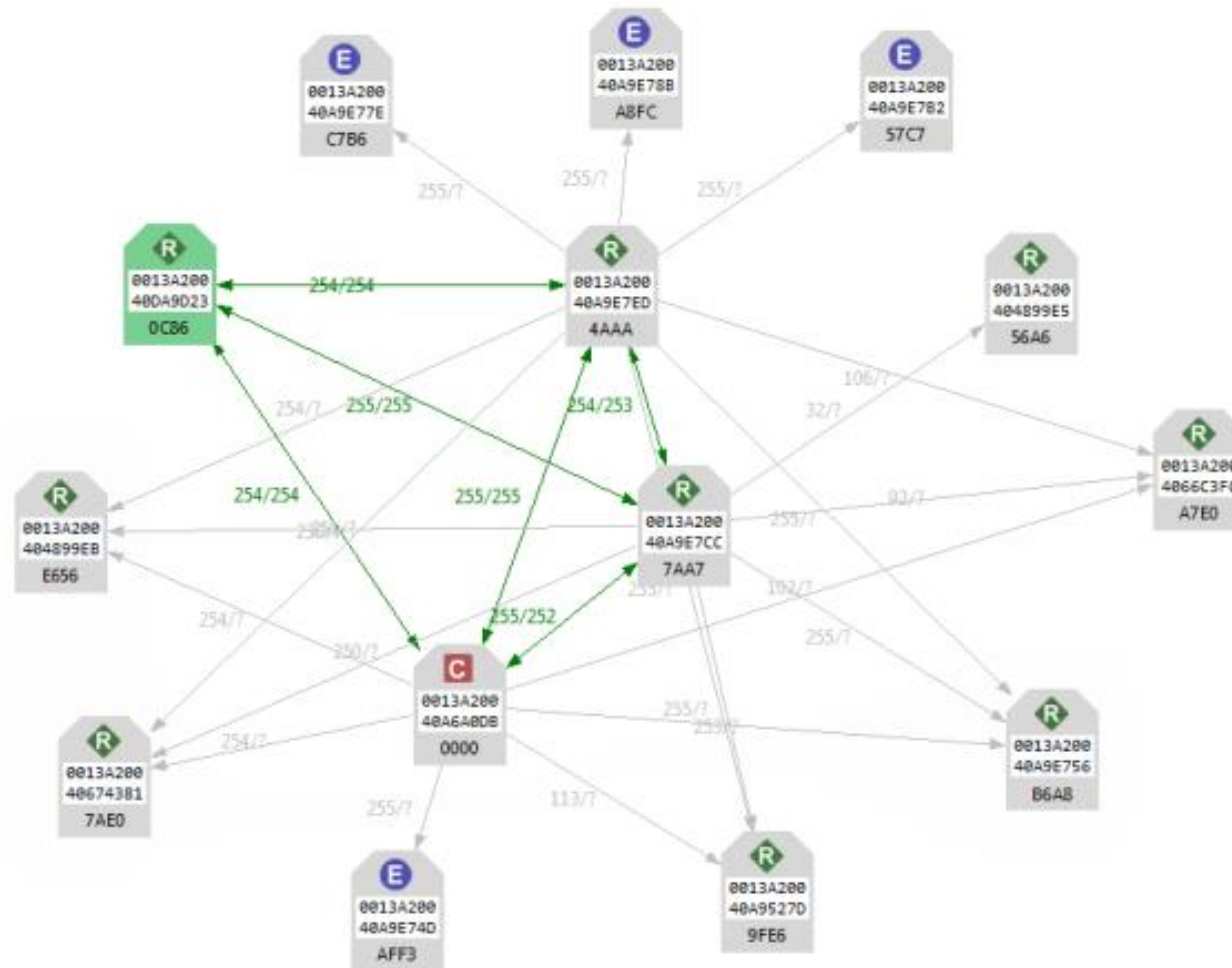
Дерево



Ячеистая
сеть

- Координатор
- Роутер
- Лист

Пример сети ZigBee



ZigBee в «Умном доме»



Пример: IKEA TRÅDFRI



Пример: Philips Hue



Пример: Aeotec SmartThings Hub

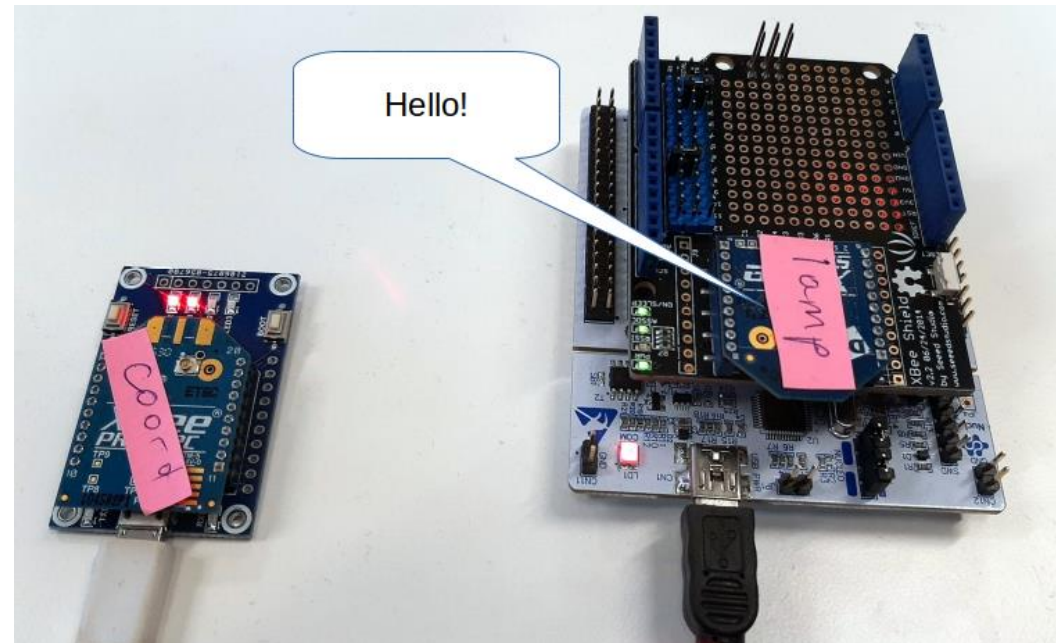


История со взломом лампочек через квадрокоптер



Сценарий практикума

1. Конфигурируем XBee-модуль
2. Объединяем модули в сеть
3. Соединяем модуль и плату микроконтроллера
4. Получаем данные
5. Отправляем данные
6. Делаем простой MQTT-шлюз



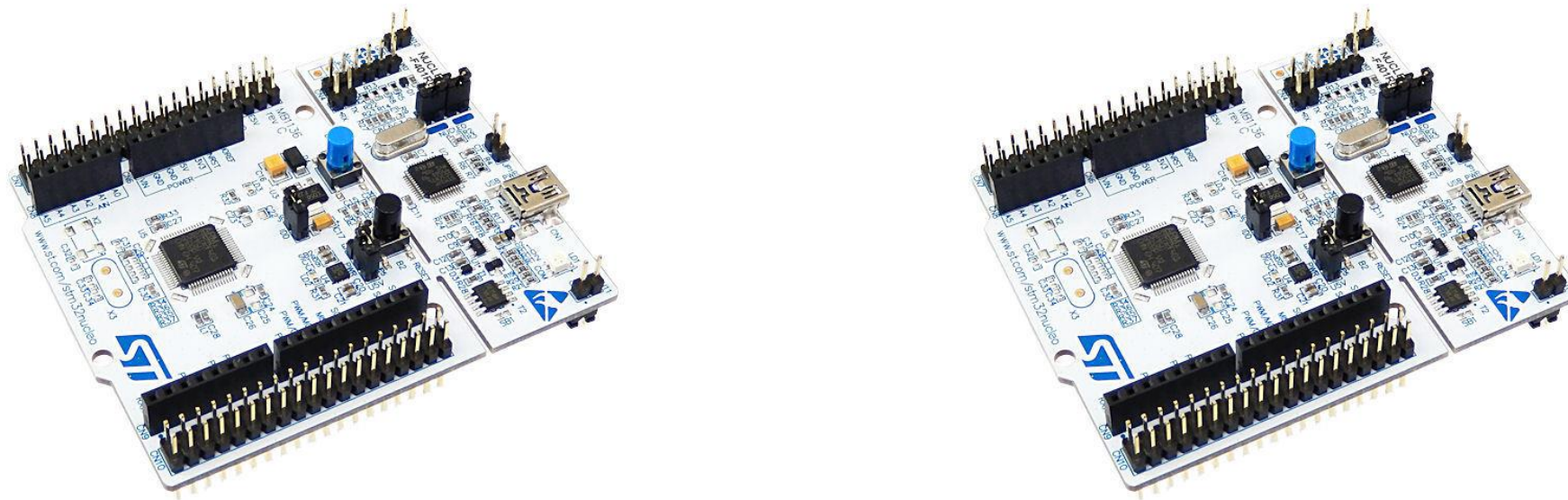
С чем работаем: XBee-модули



С чем работаем: USB-XBee адаптер



С чем работаем: платы микроконтроллера



С чем работаем: Хвее-шилд



Разница между ZigBee и XBee?

- ZigBee – протокол
- XBee – модуль производства компании Digi
 - Форм-фактор
 - API
 - Реализует протоколы: WiFi, ZigBee, DigiMesh
- Нас интересуют модули XBee, реализующие ZigBee-интерфейс

Форм-фактор



MBees



Bluetooth

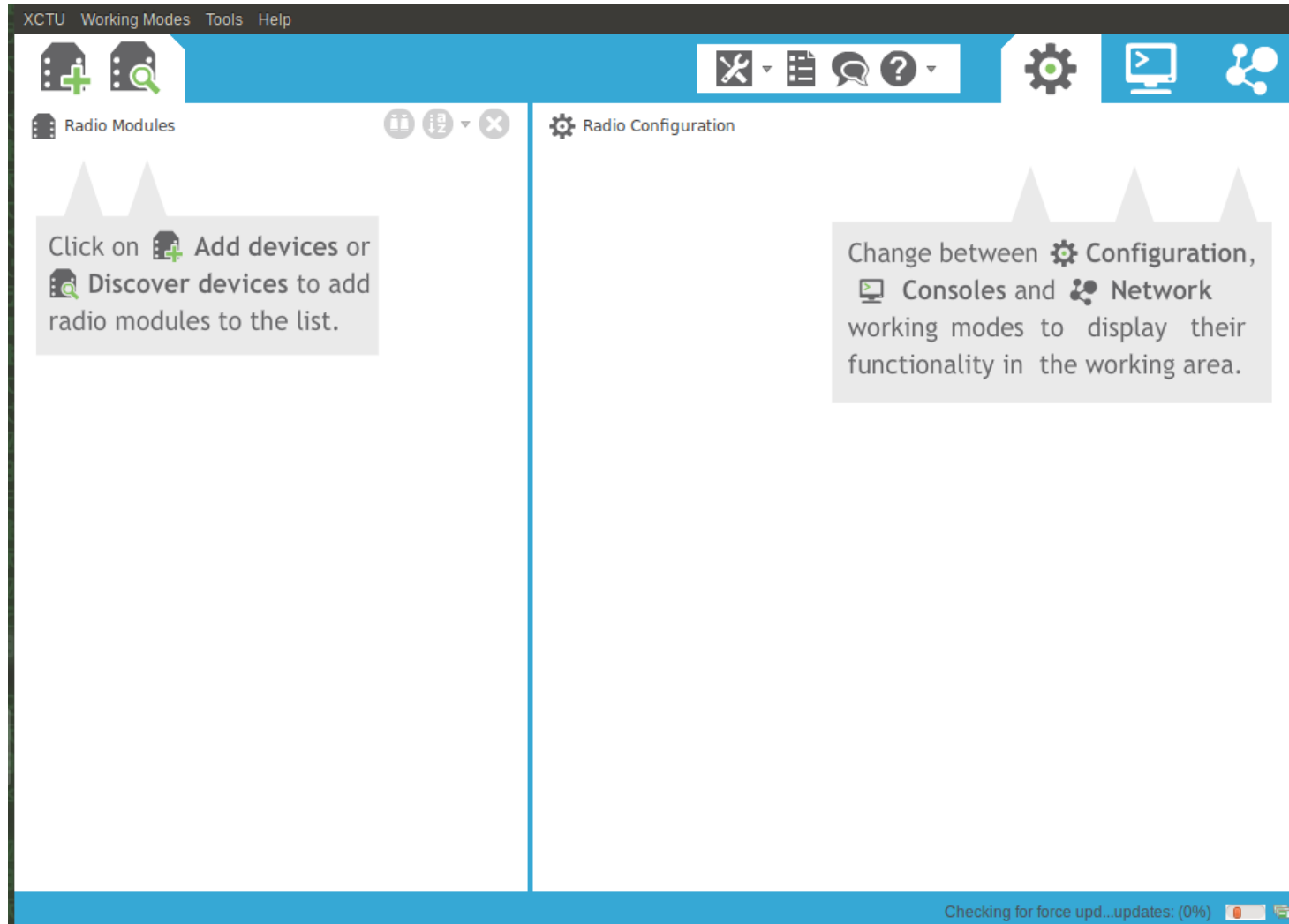


WiFi



LoRa


Программа Digi XCTU




Успешное добавление модуля

Discovering radio modules...

Search finished. 1 device(s) found

 1 device(s) found ⌛ Stop

Devices discovered:

<input checked="" type="checkbox"/>		Port: /dev/ttyUSB0 - 115200/8/N/1/N - AT Name: MAC Address: 0013A20041632E86
-------------------------------------	--	--










Select all Deselect all

Your device was not found? [Click here](#)

Cancel Add selected devices

Конфигурируем модуль: ID сети

▼ **Networking**
Change networking settings











i ID PAN ID	<input type="text" value="42"/>			 
i SC Scan Channels	<input type="text" value="7FFF"/>	Bitfield		 
i SD Scan Duration	<input type="text" value="3"/>	exponent		 
i ZS ZigBee Stack Profile	<input type="text" value="0"/>			 

Конфигурируем модуль: роль











i CH Operating Channel	17			
i NC Number of Remaining Children	14			
i CE Coordinator Enable	Enabled [1]			
i DO Device Options	0	Bitfield		
i DC Device Controls	0	Bitfield		

▼ Addressing
Change addressing settings

Конфигурируем модуль: режим

i RO Packetization Timeout	<input type="text" value="3"/> x character times	 
i D6 Pin 16 - DIO6/nRTS Configuration	Disable [0]	 
i D7 Pin 12 - DIO7/nCTS Configuration	Disable [0]	 
i AP API Enable	API enabled [1]	 
i AO API Output Mode	Native [0]	 

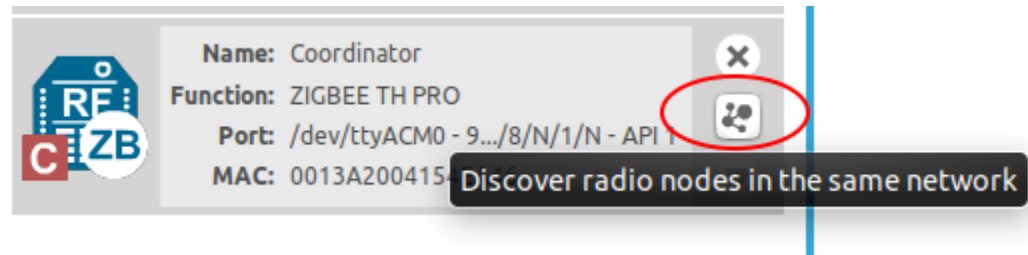
Конфигурируем модуль: название

i DH Destination Address High	<input type="text" value="0"/>	 
i DL Destination Address Low	<input type="text" value="0"/>	 
i NI Node Identifier	<input type="text" value="Coordinator"/>	 
i NH Maximum Hops	<input type="text" value="1E"/>	 
i BH Broadcast Radius	<input type="text" value="0"/>	 

Записываем настройки

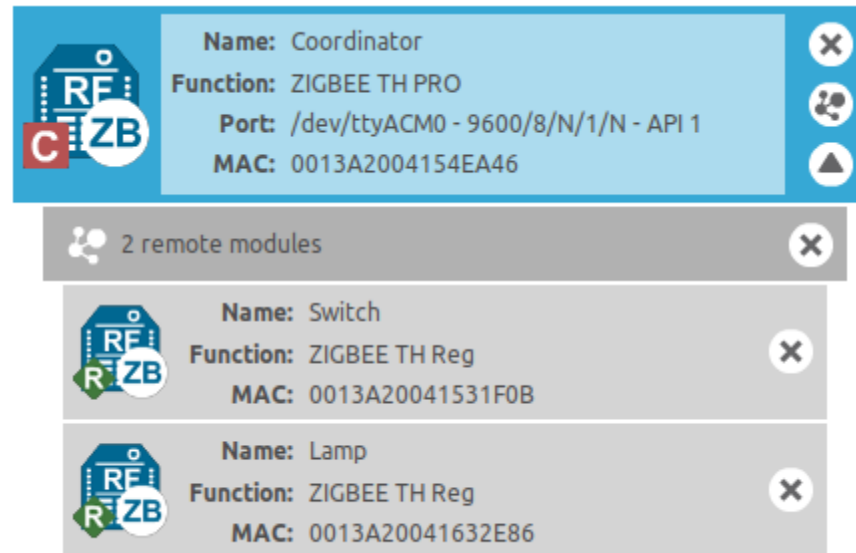
The screenshot displays a configuration interface for a device. At the top, a toolbar contains several icons: a circular arrow for 'Read', a pencil for 'Write' (circled in red), a factory icon for 'Default', a download icon for 'Update', and a person icon for 'Profile'. Below the toolbar, the device information is shown: 'Product family: XB24C', 'Function set: ZIGBEE TH Reg', and 'Firmware version:'. A 'Networking' section is partially visible, with the text 'Change networking settings'. A modal dialog box titled 'Writing radio module settings...' is overlaid on the interface. It features a progress bar, the text 'Writing radio module settings...', 'Exiting command mode', and a 'Stop' button with a red 'X' icon. The background interface shows a search bar labeled 'Param...' and various configuration fields, including 'Bitfield' and 'exponent'.

Объединяем модули в сеть



Name: Coordinator
Function: ZIGBEE TH PRO
Port: /dev/ttyACM0 - 9.../8/N/1/N - API 1
MAC: 0013A200415...

Discover radio nodes in the same network



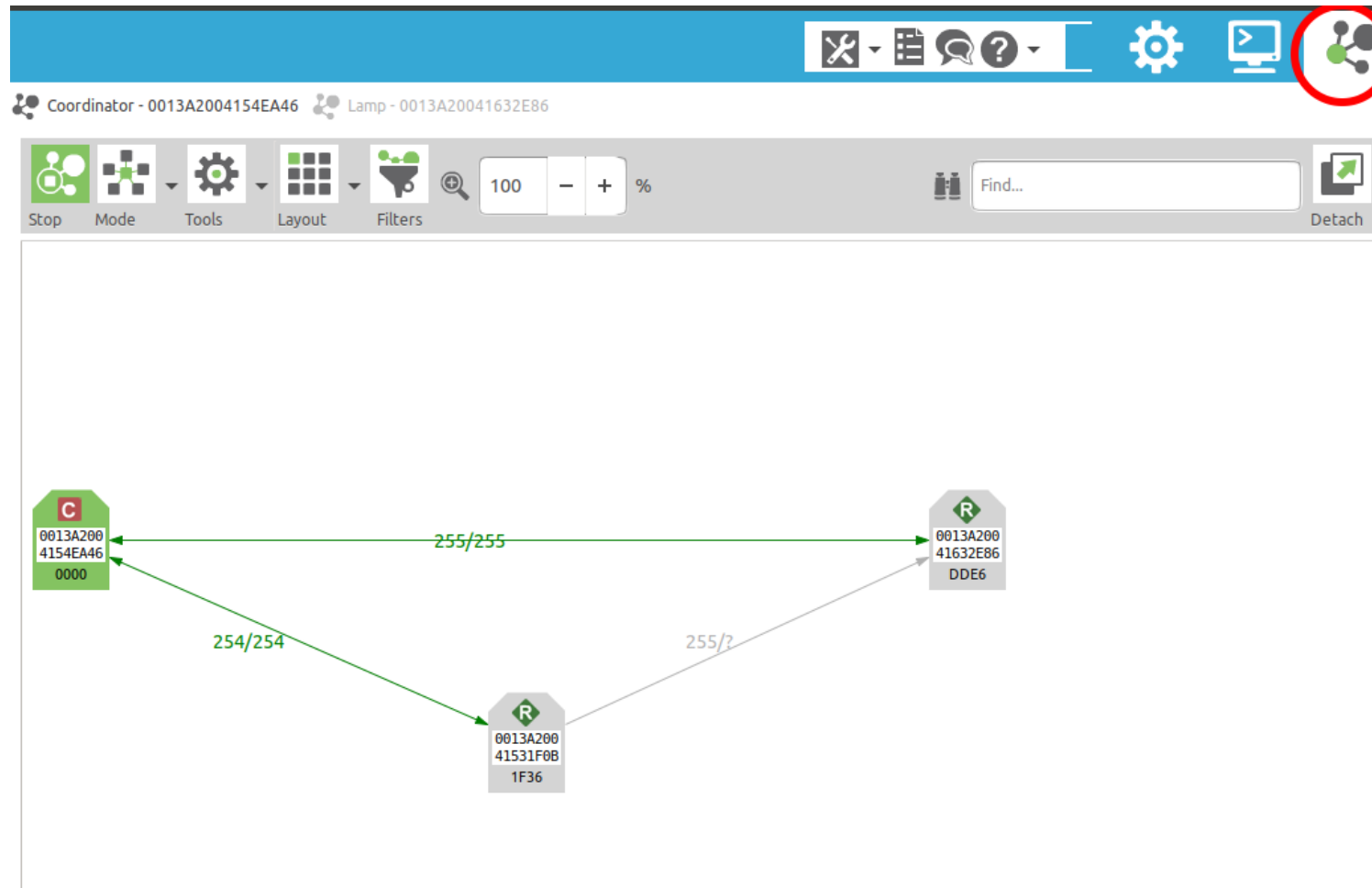
Name: Coordinator
Function: ZIGBEE TH PRO
Port: /dev/ttyACM0 - 9600/8/N/1/N - API 1
MAC: 0013A2004154EA46

2 remote modules

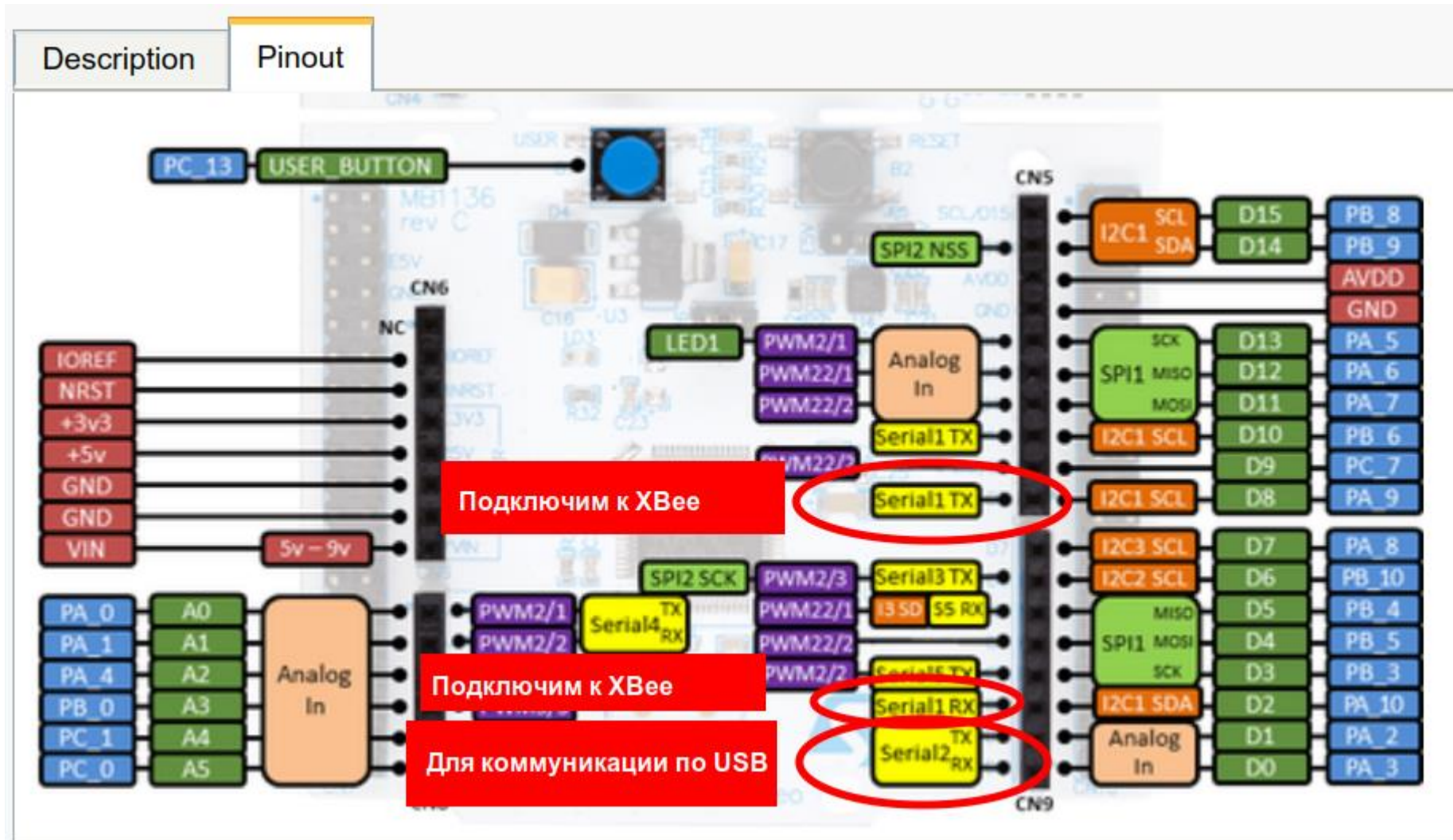
Name: Switch
Function: ZIGBEE TH Reg
MAC: 0013A20041531F0B

Name: Lamp
Function: ZIGBEE TH Reg
MAC: 0013A20041632E86

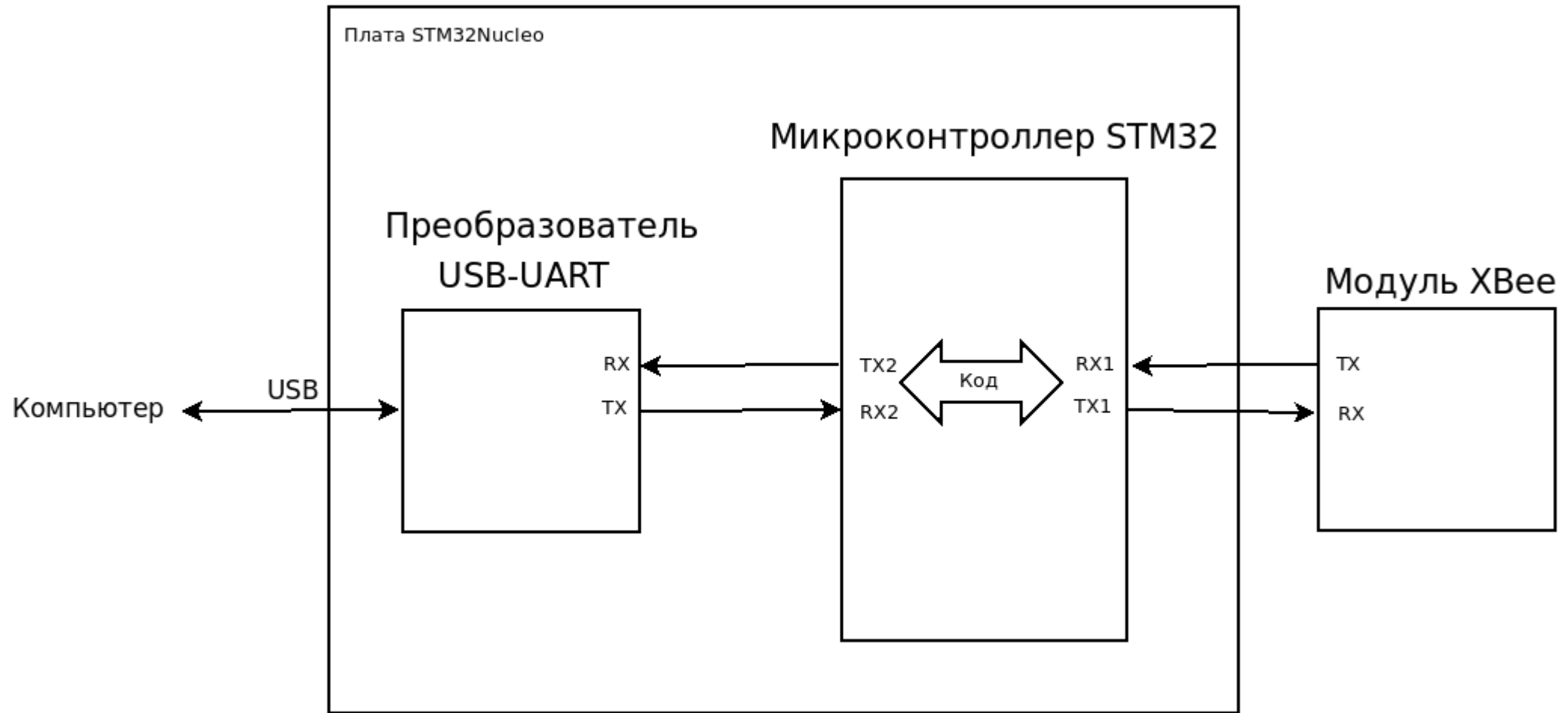
Карта сети



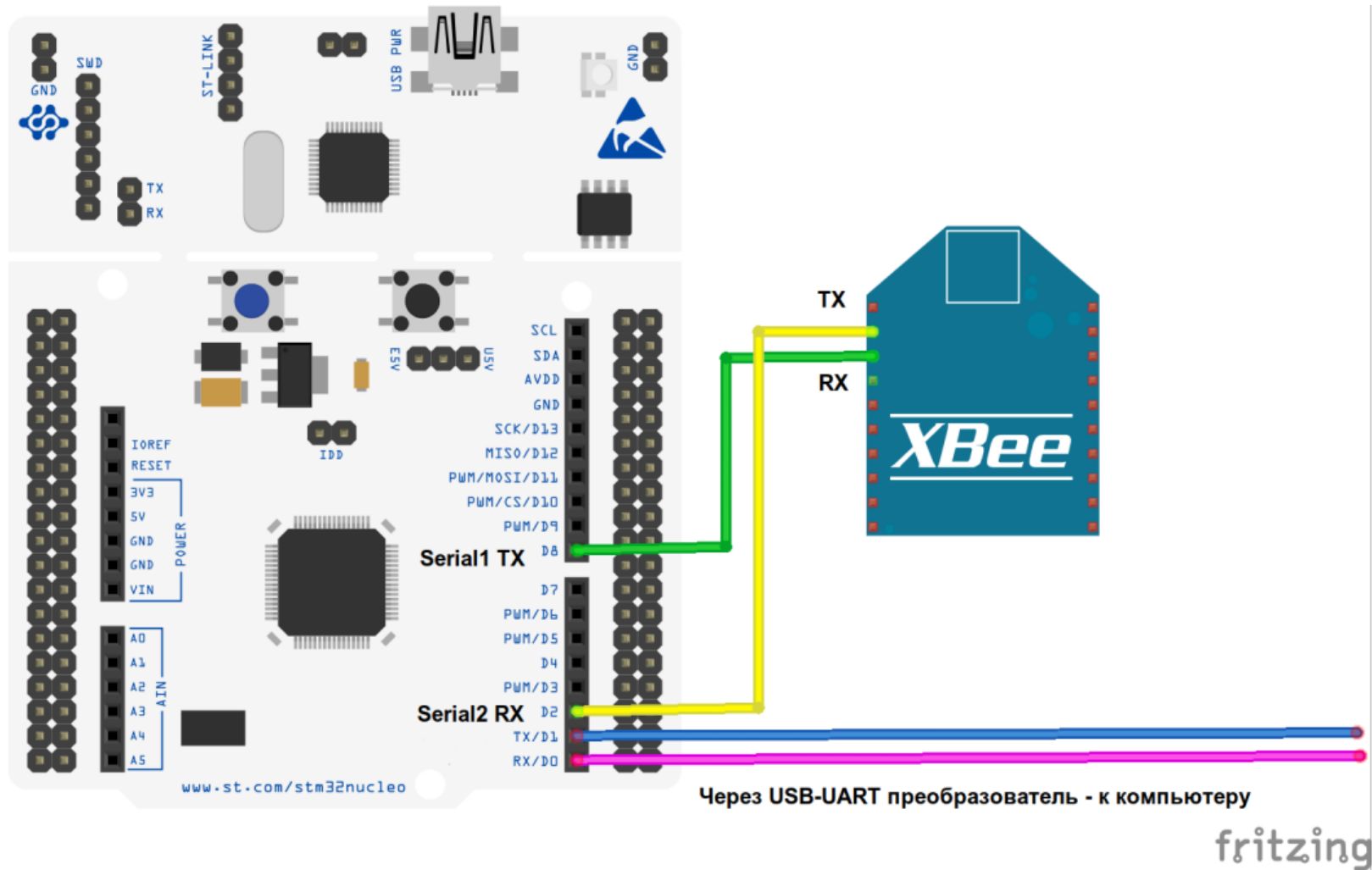
Подключаем к микроконтроллеру



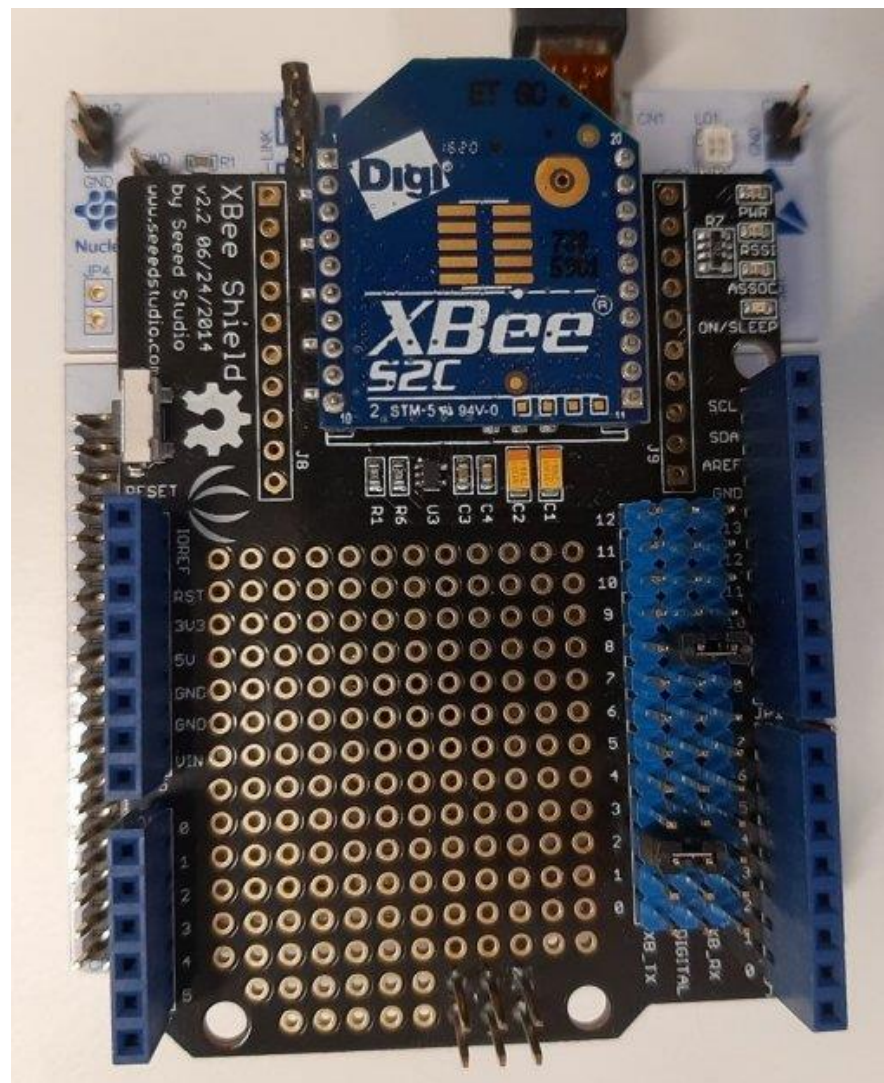
МК как мост между XBee и ПК



МК как мост между XBee и ПК



МК как мост между XBee и ПК



Код Serial Bridge

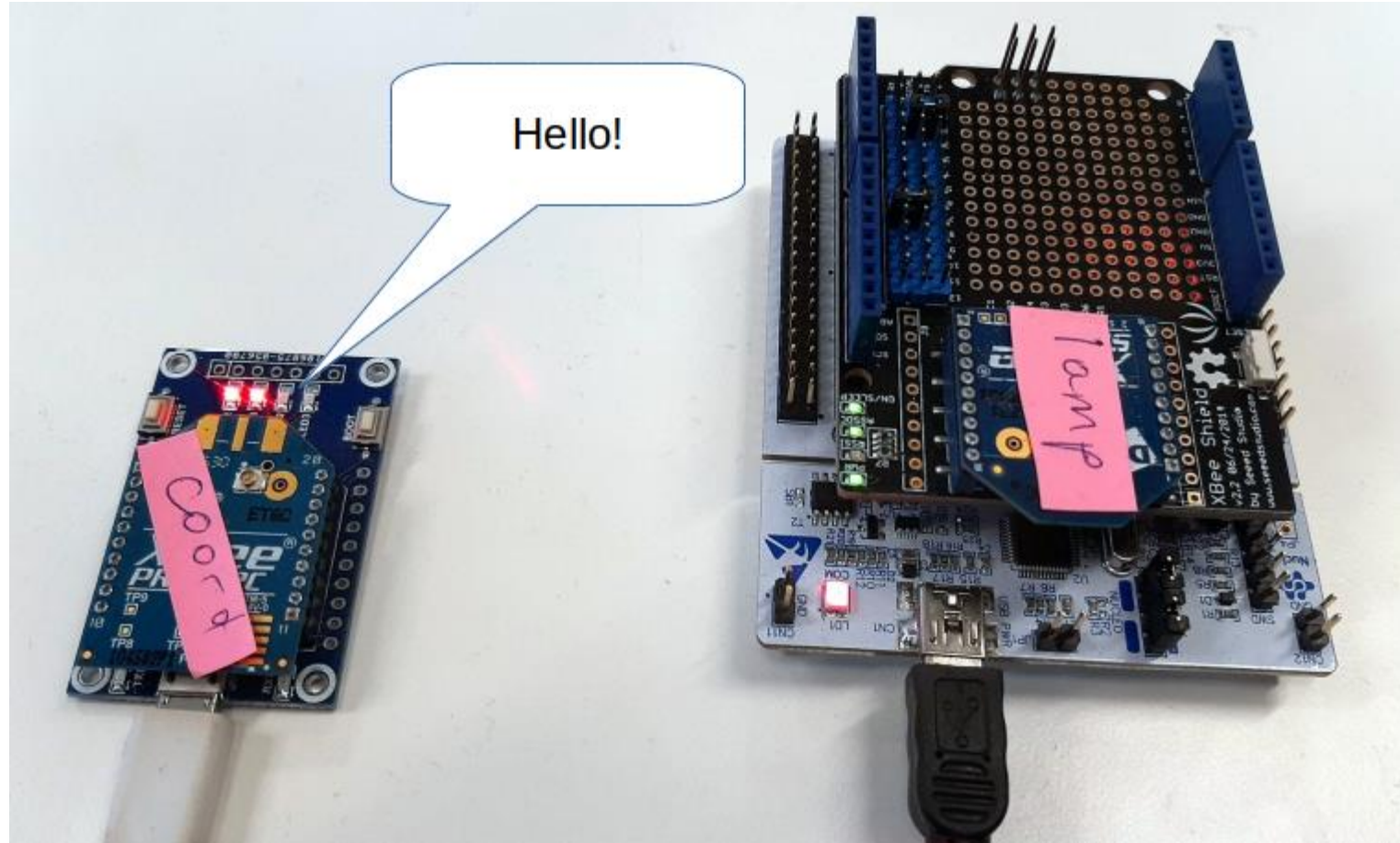
```
#include "mbed.h" // Make a serial bridge from a serial I/O device on mbed to the PC
```

```
Serial pc(USBTX, USBRX); // tx, rx  
Serial device(PA_9, PA_10); // tx, rx
```

```
// Defaults to 9600 baud on each device - use .baud(baudrate) to change
```

```
int main()  
{  
    pc.printf("Hello!");  
    while(1)  
    {  
        if(pc.readable())  
            device.putc(pc.getc());  
        if(device.readable())  
            pc.putc(device.getc());  
    }  
}
```


Пример: Получение данных



<https://os.mbed.com/teams/Digi-International-Inc/code/XBeeLib/wiki/Receiving-Data-from-other-module>

Фикс библиотеки для S2C модулей



https://os.mbed.com/users/maiorfi/code/XBeeLib_Fixed/

Указываем выводы в config.h

```
//#define RADIO_TX NC /* TODO: specify your setup's Serial TX pin connected to the XBee module DIN pin */  
//#define RADIO_RX NC /* TODO: specify your setup's Serial RX pin connected to the XBee module DOUT pin */
```



```
#define RADIO_TX PA_9  
#define RADIO_RX PA_10
```

```
//#define DEBUG_TX NC /* TODO: specify your setup's Serial TX for debugging */  
//#define DEBUG_RX NC /* TODO: specify your setup's Serial RX for debugging (optional) */
```



```
#define DEBUG_TX USBTX  
#define DEBUG_RX USBRX
```

Запуск примера в консоли

```
GtkTerm - /dev/ttyACM0 9600-8-N-1
File Edit Log Configuration Controlsignals View Help
Sample application to demo how to receive unicast and broadcast data with the XBeeZ
B

mbed Digi International Inc., XBeeLib v1.1.2
mode: 01
HV: 2e43
VR: 4060
ADDR64: 0013a200:41632e86
ADDR16: dde6
Waiting for device to join the network: OK
.....
```

Serial Console

Serial Console

This tool allows you to communicate with your XBee devices without having to add them to the list of radio modules.

Close **Configure** **Record**

CTS CD DSR DTR RTS BRK

Tx Bytes: 0
Rx Bytes: 61

/dev/ttyUSB0 - 9600/8/N/1/N

Console log

```
00 00 00 03 00 00 00 00 03 00 00 00 00 03 00 00 00 00
03 00 00 00 00 03 00 00 00 00 03 00 00 00 00 03 00 00
00 00 03 00 00 00 00 03 00 00 00 00 03 00 7E 00 07 8B
07 00 56 00 00 00 AA
```

Send packets

Name	Data
------	------

Send a single packet

Send selected packet

Send sequence

Transmit interval (ms): 500

Repeat times: 1

Создание пакета

Add a data packet to the list

i Enter the name of the data packet to be added to the list.

Packet name

ASCII **HEX**

7E 00 19 10 01 00 00 00 00 00 00 FF FF FF FE 00 00 48 65 6C 6C 6F
20 58 42 65 65 21 5A

Byte count: 29

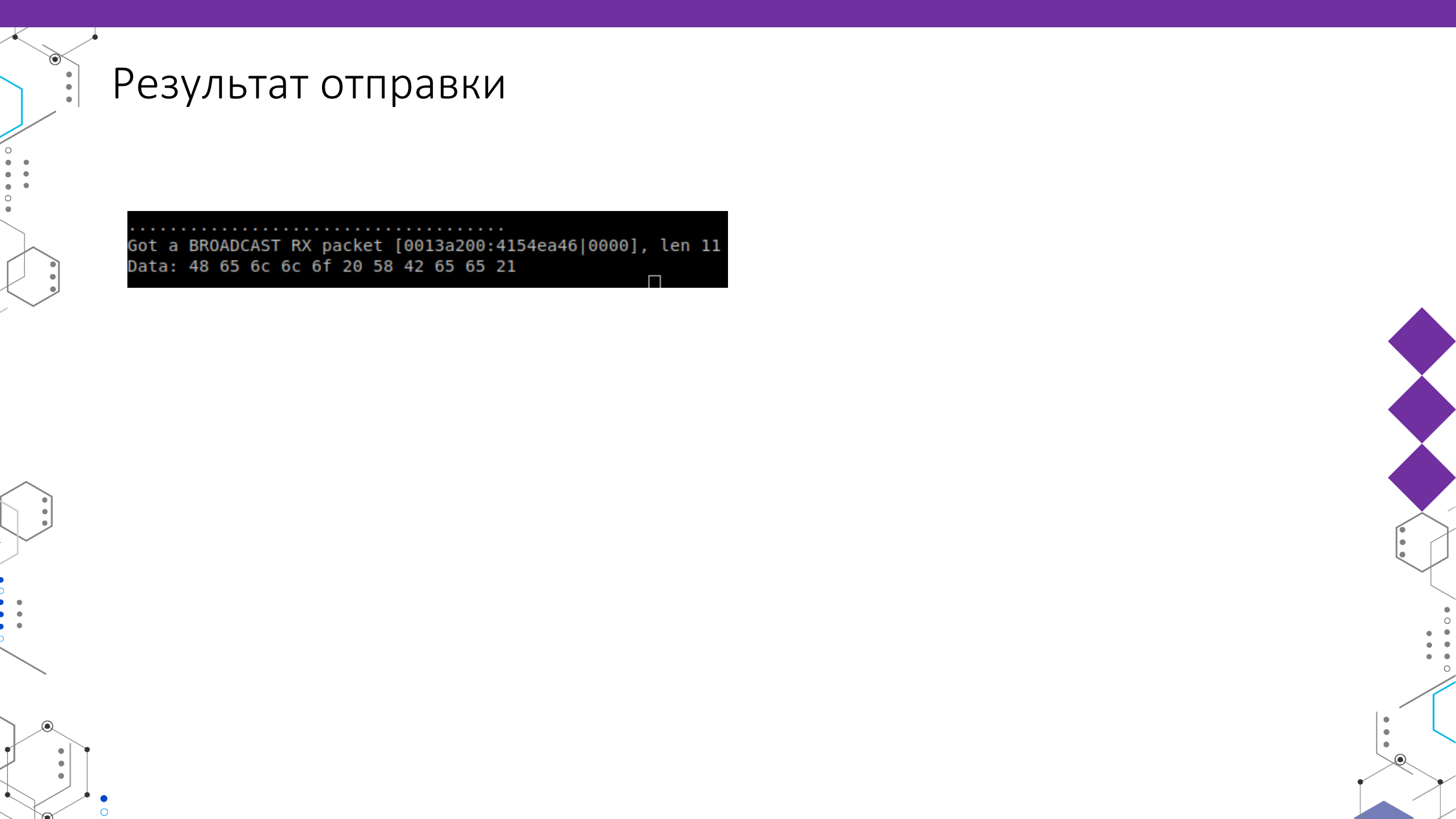
Cancel Add packet

Посылаем пакет:

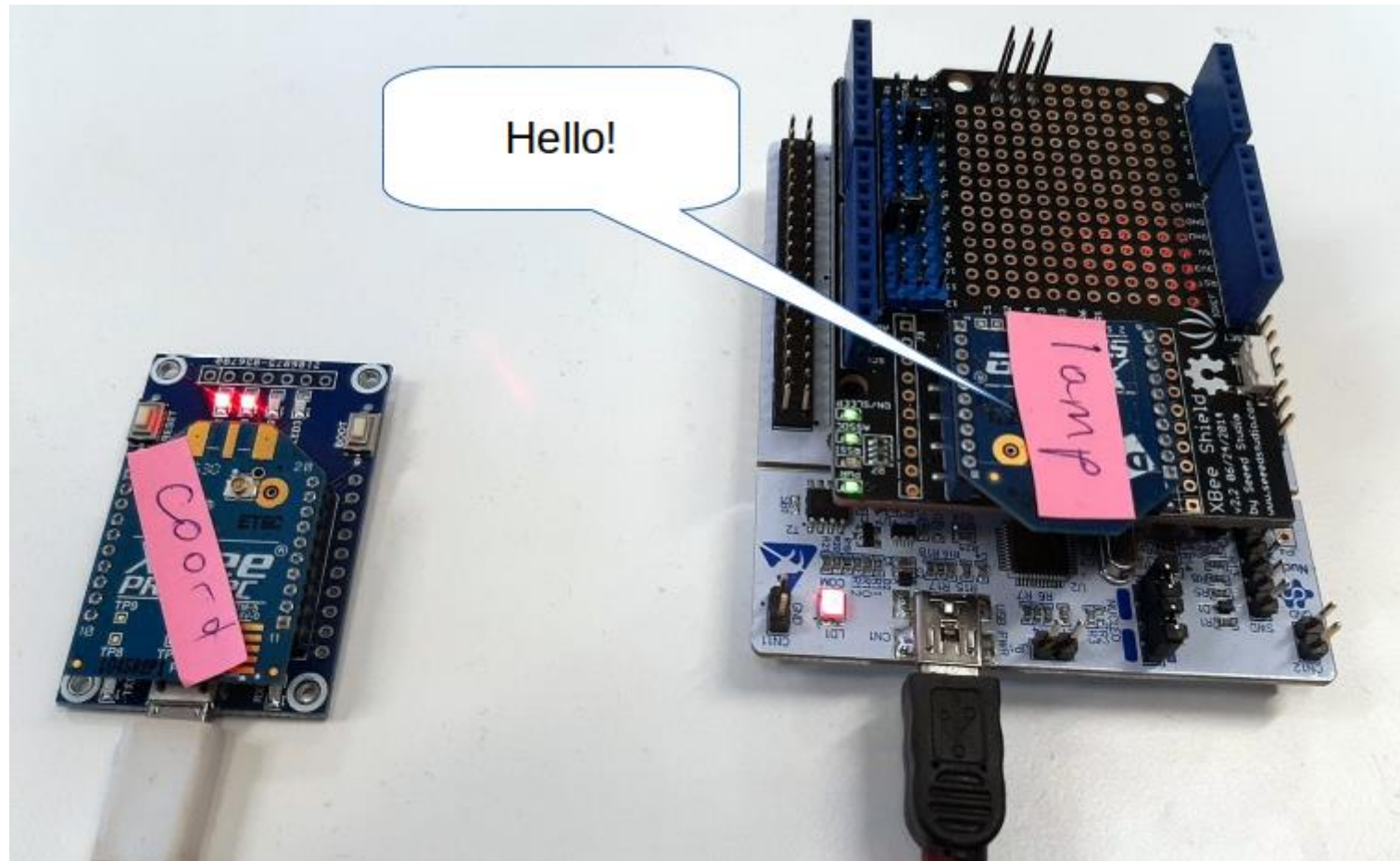
7E 00 19 10 01 00 00 00 00 00 00 FF FF FF FE 00 00 48 65 6C 6C 6F 20 58 42 65 65 21 5A

Результат отправки

```
.....  
Got a BROADCAST RX packet [0013a200:4154ea46|0000], len 11  
Data: 48 65 6c 6c 6f 20 58 42 65 65 21
```



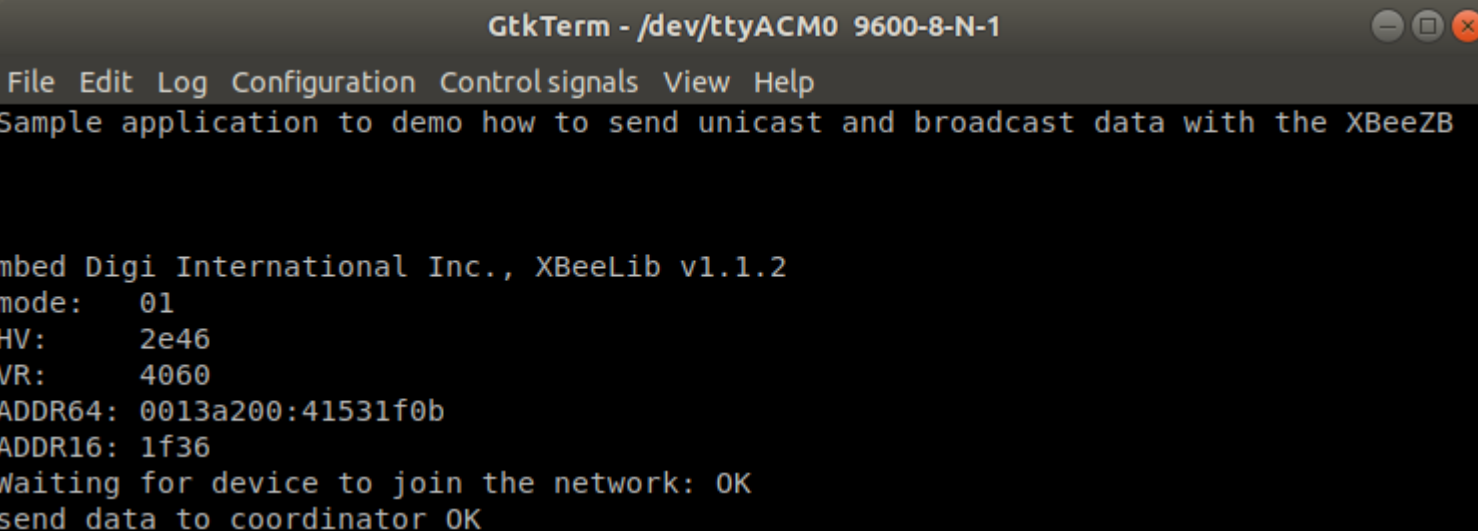
Пример: отправка данных



https://os.mbed.com/teams/Digi-International-Inc/code/XBeeZB_Send_Data/

Пример

```
send_data_to_coordinator(xbee);  
//send_broadcast_data(xbee);  
//send_data_to_remote_node(xbee, remoteDevice);  
//send_explicit_data_to_remote_node(xbee, remoteDevice);
```



```
GtkTerm - /dev/ttyACM0 9600-8-N-1  
File Edit Log Configuration Controlsignals View Help  
Sample application to demo how to send unicast and broadcast data with the XBeeZB  
  
mbed Digi International Inc., XBeeLib v1.1.2  
mode: 01  
HV: 2e46  
VR: 4060  
ADDR64: 0013a200:41531f0b  
ADDR16: 1f36  
Waiting for device to join the network: OK  
send data to coordinator OK
```

Сетевая консоль

Coordinator - 0013A2004154EA46 - 0013A20041632E86

Close Record Detach

CTS CD DSR DTR RTS BRK

Tx frames: 14
Rx frames: 28

Frames log

	ID	Time	Length	Frame
←	30	18:19:13.461	7	Transmit Status
←	31	18:19:13.651	98	Explicit RX Indicator
→	32	18:19:13.651	22	Explicit Addressing Command Frame
←	33	18:19:13.652	7	Transmit Status
←	34	18:19:13.826	98	Explicit RX Indicator
→	35	18:19:13.826	22	Explicit Addressing Command Frame
←	36	18:19:13.828	7	Transmit Status
←	37	18:19:13.942	48	Explicit RX Indicator
←	38	18:19:13.942	7	Transmit Status
→	39	18:19:14.015	22	Explicit Addressing Command Frame
←	40	18:19:14.145	45	Explicit RX Indicator
←	41	18:19:14.147	7	Transmit Status

Frame details

Информация о пакете

Coordinator - 0013A2004154EA46

Close Record Detach

CTS CD DSR DTR RTS BRK

Tx frames: 0
Rx frames: 1

Frames log

ID	Time	Length	Frame
← 0	14:26:31.280	42	Explicit RX Indicator

Frame details

Explicit RX Indicator (API 1)

```
7E 00 2A 91 00 13 A2 00 41 53 1F
0B 1F 36 E8 E8 00 11 C1 05 01 73
65 6E 64 5F 64 61 74 61 5F 74 6F
5F 63 6F 6F 72 64 69 6E 61 74 6F
72 16
```

Start delimiter

7E

Coordinator - 0013A2004154EA46

Close Record Detach

CTS CD DSR DTR RTS BRK

Tx frames: 0
Rx frames: 1

Frames log

ID	Time	Length	Frame
← 0	14:26:31.280	42	Explicit RX Indicator

Frame details

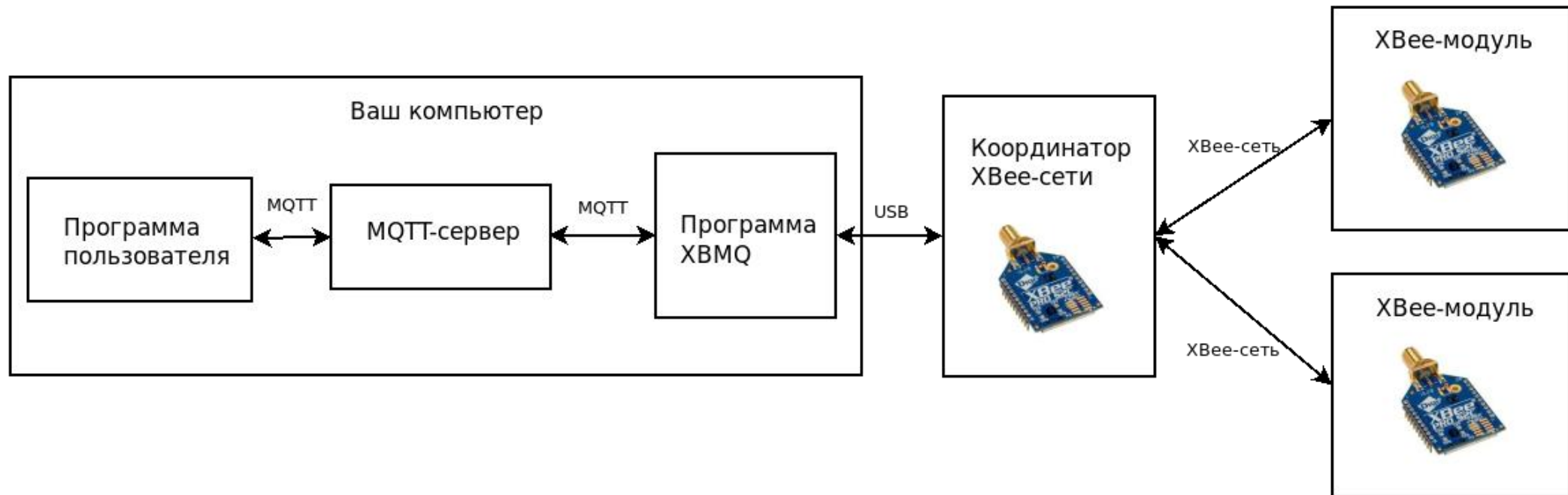
01

RF data

ASCII HEX

```
send_data_to_coordinator
```

Пример: MQTT-шлюз



Программа XBMQ

<https://github.com/angryelectron/xbmq-java>

```
git clone https://github.com/angryelectron/xbmq-java  
ant dist  
nano dist/xbmq.properties
```

```
#  
# Xbmq Properties.  
#  
#port = /dev/ttyUSB0  
#baud = 9600 #rootTopic = ab123  
#broker = tcp://test.mosquitto.org:1883  
#username = user #password = password
```



```
port = /dev/ttyUSB0  
baud = 9600  
rootTopic = ab123  
broker = tcp://127.0.0.1:1883  
username = user  
password = password
```

Запуск xbmq

./dist/xbmq.sh

The screenshot displays the xbmq web interface. At the top, there are 'Connect' and 'Disconnect' buttons. Below this, there are tabs for 'Publish', 'Subscribe', 'Scripts', 'Broker Status', and 'Log'. The 'Subscribe' tab is active, showing a search bar with a '#' symbol and a 'Subscribe' button. To the right of the search bar are buttons for 'QoS 0', 'QoS 1', 'QoS 2', 'Autoscroll', and a settings icon. The main area shows a list of messages with columns for topic names and QoS values. The messages are as follows:

Topic	QoS
#	7
ab123/0013A2004154EA46/log	2
#	QoS 0
ab123/0013A2004154EA46/log	3
#	QoS 0
ab123/0013A2004154EA46/online	4
#	QoS 0
ab123/0013A2004154EA46/online	5
#	QoS 0
ab123/0013A2004154EA46/log	6
#	QoS 0
ab123/0013A2004154EA46/0013A20041531F0B/dataOut	7
#	QoS 0
ab123/0013A2004154EA46/0013A20041531F0B/dataOut	7
#	QoS 0
22-10-2019 14:22:20.51740806	QoS 0

At the bottom of the interface, there is a 'Topics Collector (0)' section with 'Scan', 'Stop', and a settings icon. A dark box at the bottom of the message stream contains the text 'send_data_to_coordinator'.