BLE sniffer guide

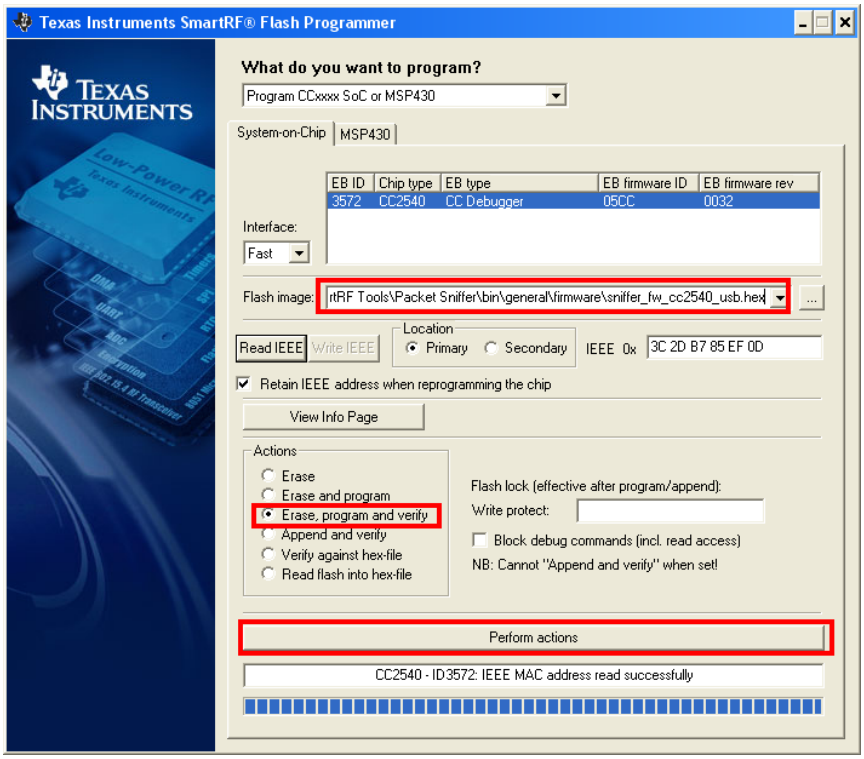
Bluetooth Low Energy Wiki Main Page [1]

Introduction

The TI Packet Sniffer can be used to look at everything that goes on between two BLE devices over the air, and is as such a good tool for debugging or just learning about Bluetooth Low Energy applications.

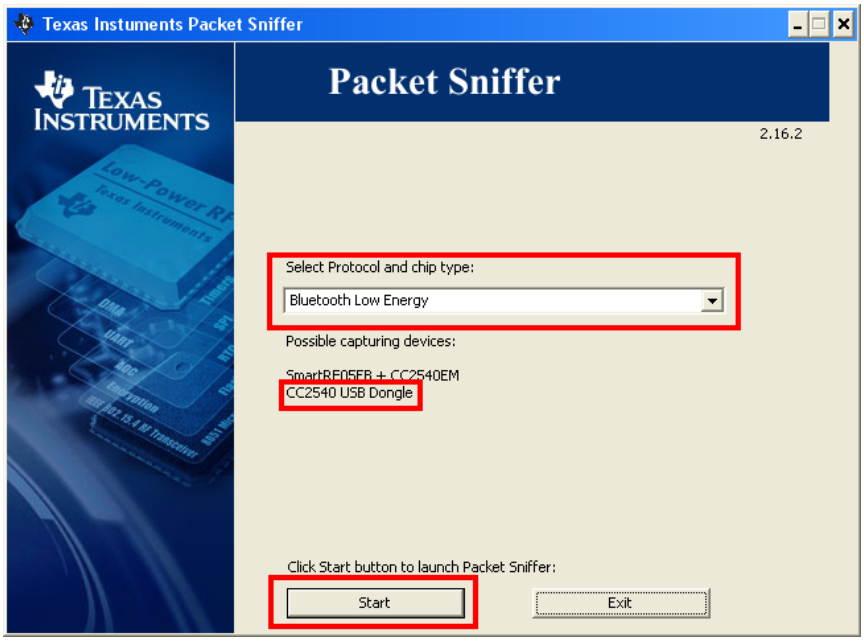
Installation and setup, using a CC2540 USB dongle as sniffer hardware

1. Download and install the SmartRF Packet Sniffer from [2]
2. Using SmartRF Flash Programmer, program the CC2540 USB dongle with the image found in `\program files\Texas Instruments\SmartRF Tools\Packet Sniffer\bin\general\firmware\sniffer_fw_cc2540_usb.hex` after installation.



Using flash programmer

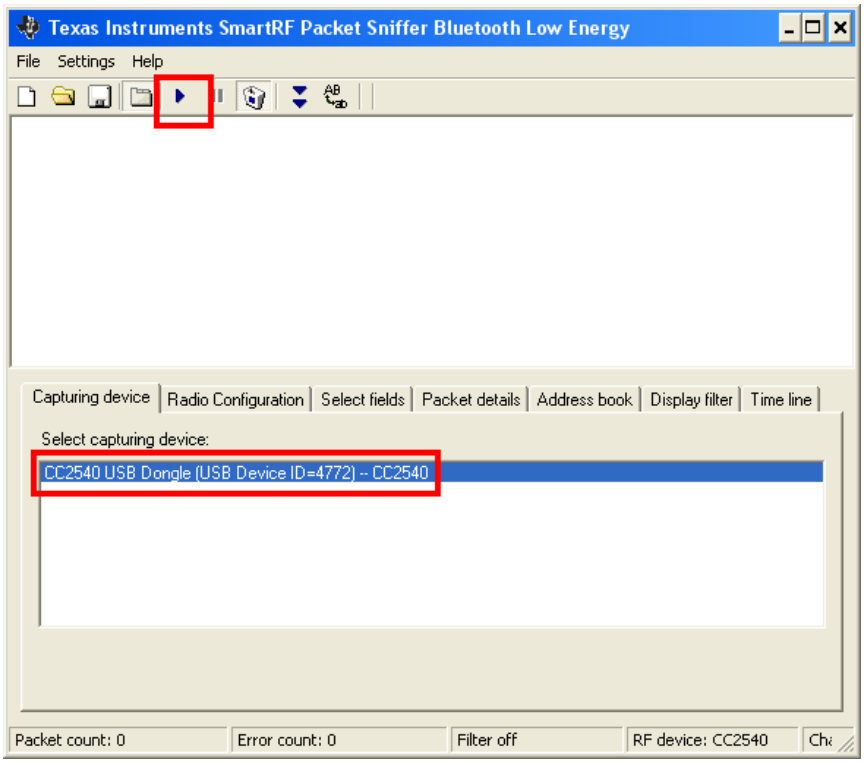
3. Start the sniffer, select Bluetooth Low Energy and press Start



Starting the sniffer in BLE mode

Using the sniffer

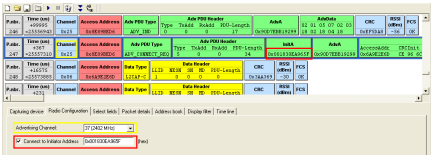
To start sniffing, select the now programmed USB dongle, and press the play button.



Starting packet aquisition

The received packets will be parsed according to the packet format laid out in the Bluetooth 4.0 Core Specification[3] Volume 6, Part B, chapters 2.1, 2.3 and 2.4.

Radio configuration pane



Radio configuration

In the radio configuration pane you can

- Specify which initiator IEEE address' connection you want to follow in the case that there are multiple BLE devices active (red ring). Otherwise the first detected connection establishment will be followed. You will still see all advertisement data.
- Specify which advertisement channel you want to listen to (yellow).

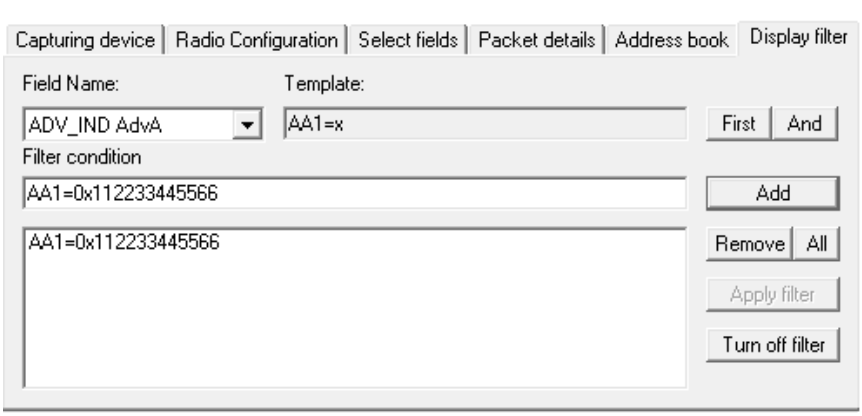
Address book

TODO

Display filter

Filter on Unique Advertiser

Choose "ADV_IND AdvA" and press button "First", then add the address where x is, so the line says ex. AA1=0x112233445566. Then press "Add" followed by "Apply filter".



Packet Sniffer Filtering Advertiser

You should now only see advertiser with address 0x112233445566.

Timeline

TODO

Packet types

According to the state the device is in, different communication channels are applicable.

- Advertising channel: 37 (2402MHz), 38 (2426 MHz) and 39 (2480 MHz)
- Data channel: 0-36 (2404-2478 MHz) excluding (2426 MHz)

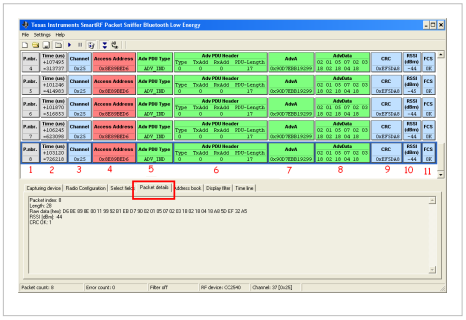
The advertising channel and data channel allow different Protocol Data Unit (PDU) types

PDU Types

Channel	State	PDU Type	Explanation	Core spec chapter
Advertising	Advertising	ADV_IND	Connectable undirected advertising event. Contains AdvA and AdvData.	6.B.2.3.1.1 // 6.B.4.4.2.3 // 3.C.11 // 3.C.18.1 (payload)
		ADV_DIRECT_IND	Connectable directed advertising event. Contains AdvA and InitA	6.B.2.3.1.2 // 6.B.4.4.2.4
		ADV_NOCONN_IND	Broadcast. Contains AdvA and AdvData	6.B.2.3.1.3 // 6.B.4.4.2.6
		ADV_SCAN_IND	Connectable directed advertising event. Scannable.	6.B.2.3.1.4 // 6.B.4.4.2.5
	Scanning	ADV_SCAN_REQ	Request for more information from LL in scanning state. ScanA, AdvA.	6.B.2.3.2.1 // 6.B.4.4.2.5
	Advertising	ADV_SCAN_RSP	Response.	6.B.2.3.2.2 // 6.B.4.4.3.2
	Initiating	CONNECT_REQ	Sent by initiator to establish a connection	6.B.2.3.3.1 // 6.B.4.4.4
Data	Data	LLID field is 1 or 2. Empty PDUs allow the slave to respond with any PDU.	General data	6.B.2.4 // 6.B.4.5
	Control	LLID field is 3. PDU can not be emtpy	Control data, see core spec	6.B.2.4.2 // 6.B.4.5

Advertisement packets

You will immediately start receiving captured advertisement packets, given that a peripheral is advertising. Fields 1,2,3,4 and 9,10,11 are common to all captured packets.



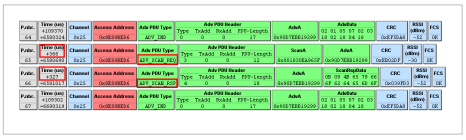
Explanation for advertisement packet fields.

Field #	Source	Explanation	Core spec chapter
1	Sniffer	Packet number as logged by the sniffer	
2	Capture device	Time in microseconds since last packet was received and absolute time	
3	Capture device	Radio channel data was captured on	6.B.1.4.1
4	Air	Bluetooth spec specified address for advertising and scan response	6.B.2.1.2
5	Air	Type of advertisement packet	6.B.2.3
6	Air	Header	6.B.2.3
7	Air	Advertiser IEEE address	6.B.2.3
8	Air	Advertisement data. In this example it's capabilities and three UUIDs the device provides.	6.B.2.3 / 3.C.11 / 3.C.18.1
9	Air	Precalculated CRC checksum	6.B.2.1.4
10	Capture device	Received signal strength indicator.	
11	Capture device	Field Control Sequence. If OK, the checksum is correct	

The advertisement fields are further explained in 6.B.2.3 on page 2202 of the BT core spec.

Scan request / response

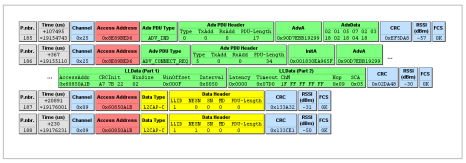
Scan request and response are two other types specified in 6.B.2.3, and look like the image below in the sniffer. The example below is of Active scan, and a sequence diagram is found in 6.D.4.2.



Here we can see that immediately following an advertisement indication (366µs), in the same advertisement event when the peripheral goes into RX mode, another device sends a scan request, which is then immediately answered by the peripheral device. The scan response in this instance is "Keyfobdemo"

Connection establishment

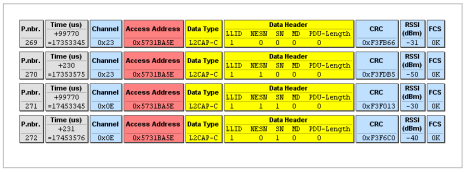
Connection establishment is initiated by the initiator (sic) on the peripheral RX slot of an advertisement event. The message format of the connection request is described in 6.B.2.3.3 in the Bluetooth core spec[3], and a message sequence diagram can be found in 6.D.5.1.



Here we see that Bluetooth LE connection establishment is pretty fast. Packet #185 shows an advertisement event peripheral TX slot, #186 shows connection request in the peripheral RX slot in the same event. Now the link is established. This is followed 20ms later by the first Central device initiated connection event's TX slot in #187, followed by a peripheral answer in #188 in the same connection event.

Empty connection events

After connection establishment we are in the connected state as defined by 6.B.4.5 in the BT Core spec. The data header is defined in 6.B.2.4 and is summarized below.



P.nbr.	Time (us)	Channel	Access Address	Data Type	Data Header					CRC	RSSI (dBm)	FCS
					LLID	NESN	SN	MD	PDU-Length			
269	+99770 =17353345	0x23	0x5731BA3E	L2CAP-C	1	0	0	0	0	0xF3FB66	-31	OK
270	+230 =17353575	0x23	0x5731BA3E	L2CAP-C	1	1	0	0	0	0xF3FDB5	-50	OK
271	+99770 =17453345	0x0E	0x5731BA3E	L2CAP-C	1	1	1	0	0	0xF3F013	-30	OK
272	+231 =17453576	0x0E	0x5731BA3E	L2CAP-C	1	0	1	0	0	0xF3F6C0	-40	OK

Data header

Field	Long name	Explanation	Core spec chapter
LLID	Link Layer ID	0x1 = Data PDU; continued fragment or emtpy, 0x2 Data PDU Start of fragmented data or complete message, 0x3 Control PDU.	6.B.2.4 / 6.B.4.5
NESN	Next expected sequence number	1-bit, used with SN for ack/nack	6.B.2.4 / 6.B.4.5.9
SN	Sequence number	1-bit, used with NESN for ack/nack	6.B.2.4 / 6.B.4.5.9
MD	More Data	Used to indicate whether more data is coming. See table in spec.	6.B.4.5.6
PDU Length	Length of payload + MIC in octets.	PDU Length is maximum 27 octets. MIC 4 octets if present.	6.B.2.4

In this example we can see that the central device has SN = NESN indicating new data, and the peripheral device responds with ACK (SN!=NESN because it expects next packet).

Read request, read response

TODO

Write request, write response

TODO

References

[1] http://processors.wiki.ti.com/index.php/Category:BluetoothLE
[2] http://www.ti.com/tool/packet-sniffer
[3] http://www.bluetooth.org/docman/handlers/downloaddoc.ashx?doc_id=229737

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