STSW-BNRG-Mesh Friend and Low Power features

Introduction

The STSW-BNRG-Mesh library supports all of the following features in a Mesh node:

1. **Relay**: to forward received network PDUs on advertising or GATT bearer, if the Proxy feature is enabled
2. **Proxy**: to forward received network PDUs between GATT and advertising bearers
3. **Friend**: can perform duties such as scanning for other associated nodes that are usually Low Power mode
4. **Low Power**: consumes much less power as the node usually does not perform any scanning

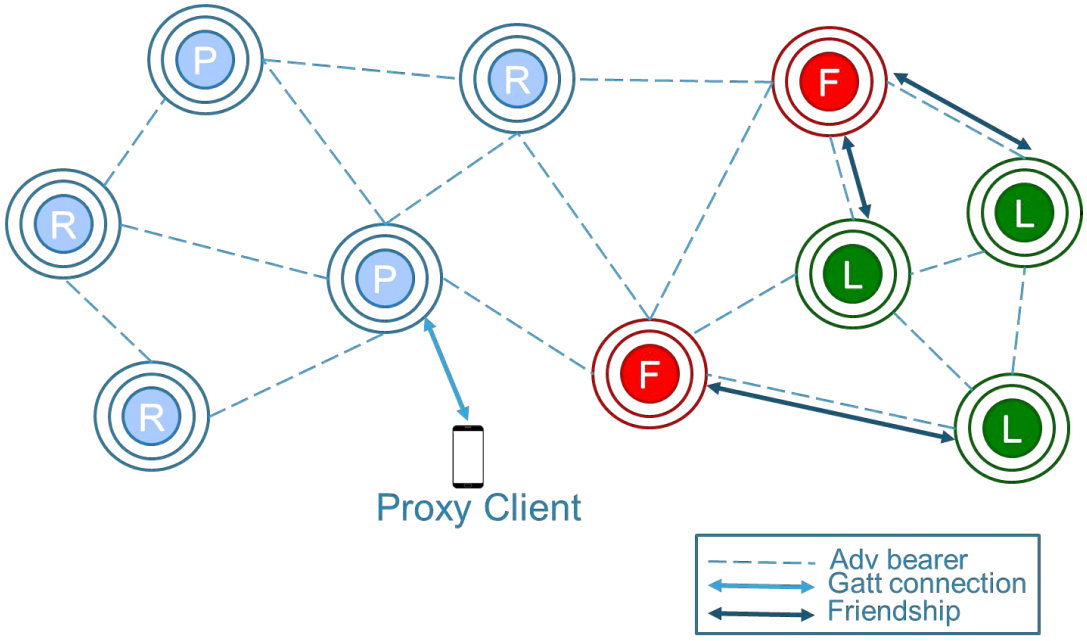
A typical Bluetooth Mesh node radio should always be in scanning mode to avoid missing packets over the air, but this kind of operation is not supported by many devices due to continuous energy requirements.

To enable low power operation, Bluetooth Mesh Profile v1.0 defines the concept of Friendship.

In a Mesh network, a Low Power feature-enabled Mesh node (LPN) offloads its packet receiving (scanning) duty to an adjacent Friend feature-enabled Mesh node (FN). The LPN is not always scanning and remains inactive (or sleeps) for most of its life cycle, significantly reducing its energy requirements. Nodes running on batteries or energy harvesting techniques usually support the Low Power feature.

Once connected to each other, the FN and LPN are considered friends and their connection is known as a Friendship. At least one FN must be in the direct radio range of an LPN to establish Friendship.

Figure 1. STSW-BNRG-Mesh network connecting Relay, Proxy, Friend and Low Power nodes



1 Overview

The BlueNRG-Mesh embedded firmware for BlueNRG-1 and BlueNRG-2 features:

1. Low Power support (as described in Mesh Profile Specification v1.0, Section 3.6.6.4, available at https://www.bluetooth.com/specifications/mesh-specifications) by STSW-BNRG-Mesh library provided with SDK to handle Low Power node interoperability with Friend node and vice versa;
2. Reduced power consumption and low power mode operation of BlueNRG-1 and BlueNRG-2 devices by calling the `BlueNRG_Sleep` API.

1.1 Configuration

1.1.1 Friend node

Friend feature support is enabled by defining `ENABLE_FRIEND_FEATURE` in *mesh_cfg_usr.h*.

To set the number of possible Low Power nodes (LPN) that can be associated with a Friend node (FN) is defined by `FN_NO_OF_LPNS`.

The number of LPNs that can be associated with a Friend node is limited: for each FN-LPN pair, the FN has to allocate memory (about 1 k) and radio time. By increasing `FN_NO_OF_LPNS`, memory usage is consequently increased and has be chosen as required by the application.

The following parameters are fixed inside the FN and cannot be changed:

- FN receive window size: 50 ms (for BlueNRG-1 and BlueNRG-2)
- FN subscription list size: 4
- FN max. no. of messages: 16

1.1.2 Low Power node

Low Power feature support is enabled by defining `ENABLE_LOW_POWER_FEATURE` in *mesh_cfg_usr.h*.

Note: A Low Power feature-enabled node does not support any other feature: all the other features should be undefined.

Table 1. LPN configurable parameters

LOW_POWER_NODE_PARAMS	Min. value	Max. value	Comments
LPN_RSSI_FACTOR_LEVEL(1)	0x0	0x3	To prioritize Friend Offer with RSSI link: 0x0 – 1 0x1 – 1.5 0x2 – 2 0x3 – 2.5
LPN_RECIVE_WINDOW_FACTOR_LEVEL(1)	0x0	0x3	To prioritize Friend Offer with receive window factor: 0x0 – 1 0x1 – 1.5 0x2 – 2 0x3 – 2.5
LPN_MINIMUM_QUEUE_SIZE_LOG(2)	0x1	0x7	Minimum packets queue size required by Low Power node: 0x1 – N = 2 0x2 – N = 4 0x3 – N = 8 0x4 – N = 16 0x5 – N = 32 0x6 – N = 64 0x7 – N = 128
LPN_RECEIVE_DELAY(3)	0x0A	0xFF	Receive delay after sending Friend Poll (ms)
LPN_POLL_TIMEOUT(3)	0x00000A	0x34BBFF	Poll timeout value after which Friendship ceases to exist if no Friend Poll has been received by FN within this duration (100 ms)
LPN_RECEIVE_WINDOW_SIZE(3)	0x0A	0xFF	Maximum received window size acceptable for Low Power node (ms)

LOW_POWER_NODE_PARAMS	Min. value	Max. value	Comments
LPN_SUBSCR_LIST_SIZE	0x01	0x05	FN subscription list (min.) size capability required by LPN
LPN_FRIEND_REQUEST_FREQUENCY	0x00	0xFF	Time after which LPN periodically sends Friend Request in search of a probable Friend node if no FN exists (100 ms)
LPN_FRIEND_POLL_FREQUENCY	0x00000A	0x34BBFF	Time after which LPN periodically sends Friend Poll to receive its packets if a FN exists (100 ms).
LPN_MINIMUM_RSSI	-127	-60	Minimum RSSI required by Low Power node. Used only for accepting/rejecting Friend Offer
LPN_NO_OF_RETRIES	0x02	0x0A	Retries made by the LPN before termination of Friendship or Friendship establishment procedure

1. *See Mesh Profile Specification v1.0, Section 3.6.6.3.1.*
2. *See Mesh Profile Specification v1.0, Section 3.6.5.3.*
3. *See Mesh Profile Specification v1.0, Section 3.6.6.1.*

1.1.3 BlueNRG_Sleep API

The `BlueNRG_Sleep` API includes the following parameters:

1. `SleepModes sleepMode`: sleep mode to be used (it should be `SLEEPMODE_WAKETIMER`). In this mode, low speed clock remains active in sleep mode. This mode is used to wake up BlueNRG-1 and BlueNRG-2 using the system virtual timers 0.
2. `uint8_t gpioWakeBitMask`: GPIOx to be used for wakeup
3. `uint8_t gpioWakeLevelMask`: GPIO level (high or low) to be used for wakeup

1.2 Demo setup based on STSW-BNRG-Mesh

The following demo based on STSW-BNRG-Mesh has been set up using one board as a Friend node and two boards as Low Power nodes.

1.2.1 Low Power node setup

Step 1. Enable Low Power feature (by defining `ENABLE_LOW_POWER_FEATURE` macro in *mesh_cfg_usr.h* file and un-defining Relay, Proxy and Friend features).

Step 2. Configure LPN parameters.

Note: Change only if required otherwise skip this step (use example parameters defined in mesh_cfg_usr.h).

Table 2. Low Power node example parameters

LOW_POWER_NODE_PARAMS	Value
LPN_RSSI_FACTOR_LEVEL	1
LPN_RECIVE_WINDOW_FACTOR_LEVEL	1
LPN_MINIMUM_QUEUE_SIZE_LOG	2
LPN_RECEIVE_DELAY	150 ms
LPN_POLL_TIMEOUT	2000 (*100 ms)
LPN_RECEIVE_WINDOW_SIZE	55 ms
LPN_SUBSCR_LIST_SIZE	2
LPN_FRIEND_REQUEST_FREQUENCY	50 (*100 ms)
LPN_FRIEND_POLL_FREQUENCY	25 (*100 ms)
LPN_MINIMUM_RSSI	-100
LPN_NO_OF_RETRIES	10

Step 3. Start virtual timer (timer number 0 is used in `BlueNRG_Mesh` for `BluenrgMesh_sleepTime`) to ensure the device wakes up after `BluenrgMesh_sleepTime` duration.

Note: Change only if required otherwise skip this step (already implemented in function `Appli_LowPowerProcess`).

Step 4. Configure `BlueNRG_Sleep` parameters:

- sleepMode: `SLEEPMODE_WAKETIMER` for BlueNRG-Mesh
- gpioWakeBitMask - `WAKEUP_IO13` (PUSH1 button on STEVAL-IDB007V2 or STEVAL-IDB008V2 evaluation boards)
- gpioWakeLevelMask - `WAKEUP_IOx_LOW`

Note: Change only if required, otherwise skip this step (already implemented in function `Appli_LowPowerProcess`).

Step 5. Generate and flash binary in board 1 and board 2.

Note: The LED corresponding to GATT connection does not switch on in the LPN.

1.2.2 Friend node setup

Step 1. Enable Friend feature, defining `ENABLE_FRIEND_FEATURE` macro in *mesh_cfg_usr.h* file.

Step 2. Enable Relay and Proxy features if required.

Step 3. Un-define `ENABLE_LOW_POWER_FEATURE`.

Step 4. Generate and flash binary in board 3.

Step 5. Provision the three boards with the default parameters, using BlueNRG-Mesh Android or BlueNRG-Mesh iOS app (subscribe and publish to default group).

1.2.3 Demo operation

Table 3. STSW-BNRG-Mesh demo default configuration

Board	Node	Group subscription list	Publication address
1	LPN1	Default	Default
2	LPN2	Default	Default
3	FN	Default	Default

After provisioning, it might take a few seconds for Friendship to be established between FN and LPNs.
In this demo, the FN establishes Friendship with LPN1 and LPN2.

Any packet targeted to LPN1/LPN2 or to a group address subscribed by LPN1 or LPN2 is put in queue by the FN that forwards packets to LPN1/LPN2 as soon as it receives a Friend Poll from the respective LPN.

The LPN is free to send packets (generate traffic) any time.

Table 4. LPN LED status

LED[1]	Status	Result
Yellow	ON	BlueNRG-1 or BlueNRG-2 device is running
Yellow	OFF	BlueNRG-1 or BlueNRG-2 device is in sleep mode
Blue and yellow	ON	LPN received LED on command
Blue and yellow	OFF	LPN received LED off command

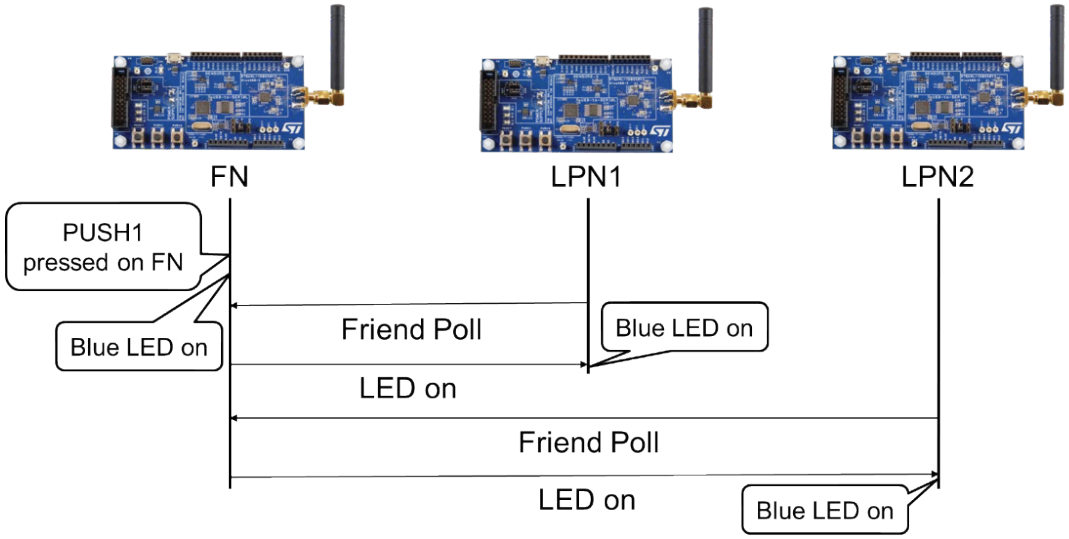
1. *Both yellow and blue LEDs turn on and off simultaneously to achieve the result described in the last column.*

1.2.3.1 *Pressing PUSH1 button on the Friend node*

By pressing [**PUSH1**] button on the Friend node:

1. FN publishes a LED ON command to the default group and the FN blue LED immediately turns on (when the FN belongs to the default group).
2. FN forwards a LED ON command to the LPNs subscribed to the default group. As soon as the FN receives poll from an LPN, it sends LED ON to the respective LPN.
3. The Blue LED on the LPNs starts blinking along with the yellow LED. As soon as the device goes into low power mode, both LEDs turn off.

Figure 2. Message sequence and corresponding LED behavior when pressing FN PUSH1 button

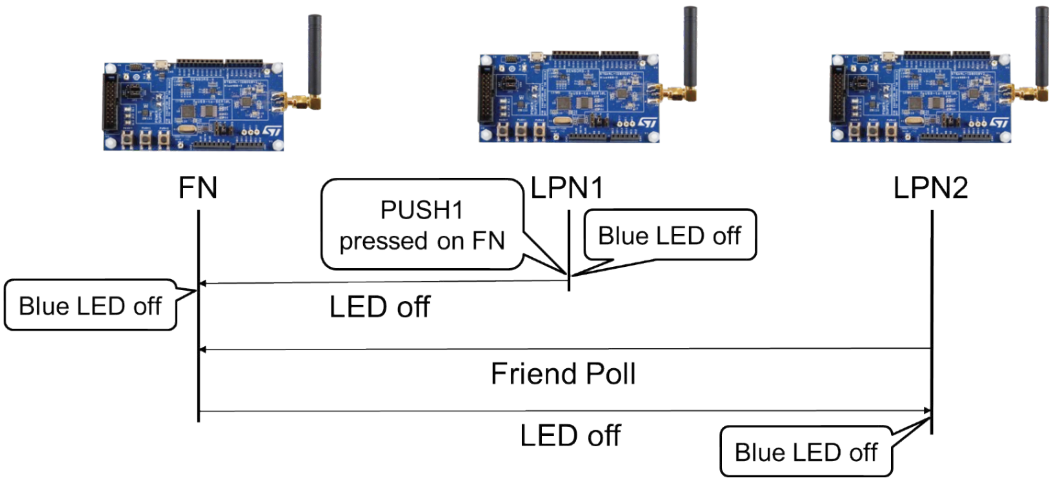


1.2.3.2 *Pressing PUSH1 button on LPN1*

By pressing [**PUSH1**] button on LPN1:

1. LPN1 publishes an LED OFF command to the default group. The LPN1 blue LED stops blinking (when LPN1 belongs to the default group). LPN1immediately forwards LED OFF command to the default group.
2. FN receives an LED OFF command (as it is subscribed to the default group) and the FN blue LED turns off.
3. FN also sends an LED OFF command to LPN2 (subscribed to the default group) as soon as FN receives poll from LPN2.
4. LPN2 blue LED stops blinking.

Figure 3. Message sequence and corresponding LED behavior when pressing LPN1 PUSH1 button



2 LPN parameters and energy consumption profile

The following images show the graphs related to energy consumption upon different responses to LPN parameter requests.

Figure 4. Friend request periodically sent by LPN with no response

Figure 5. Friend request followed by Friend establishment

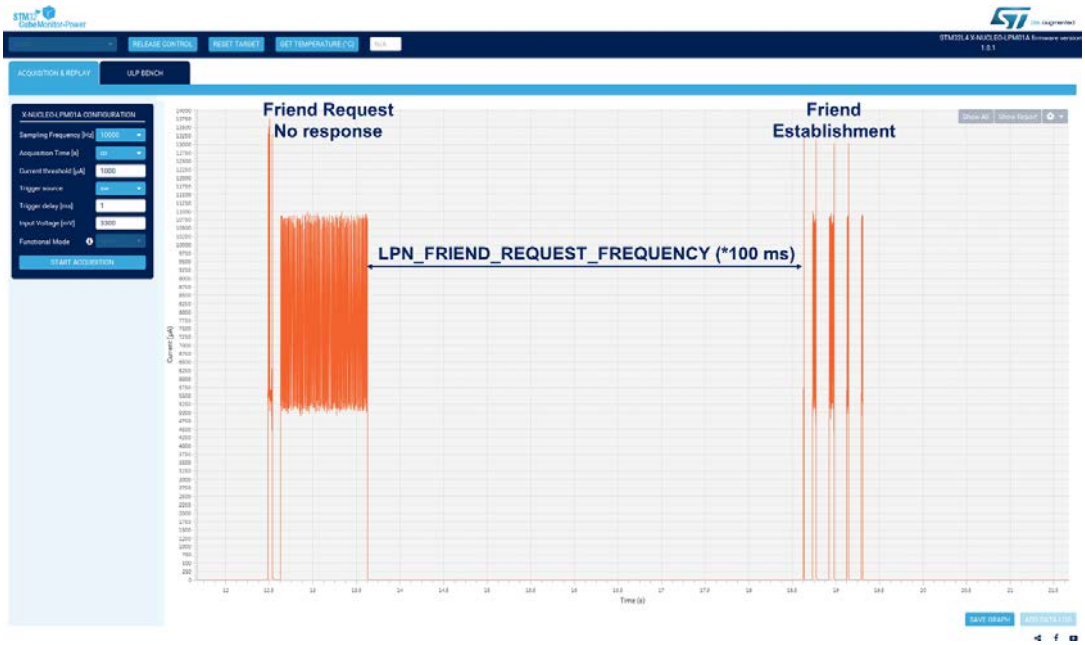
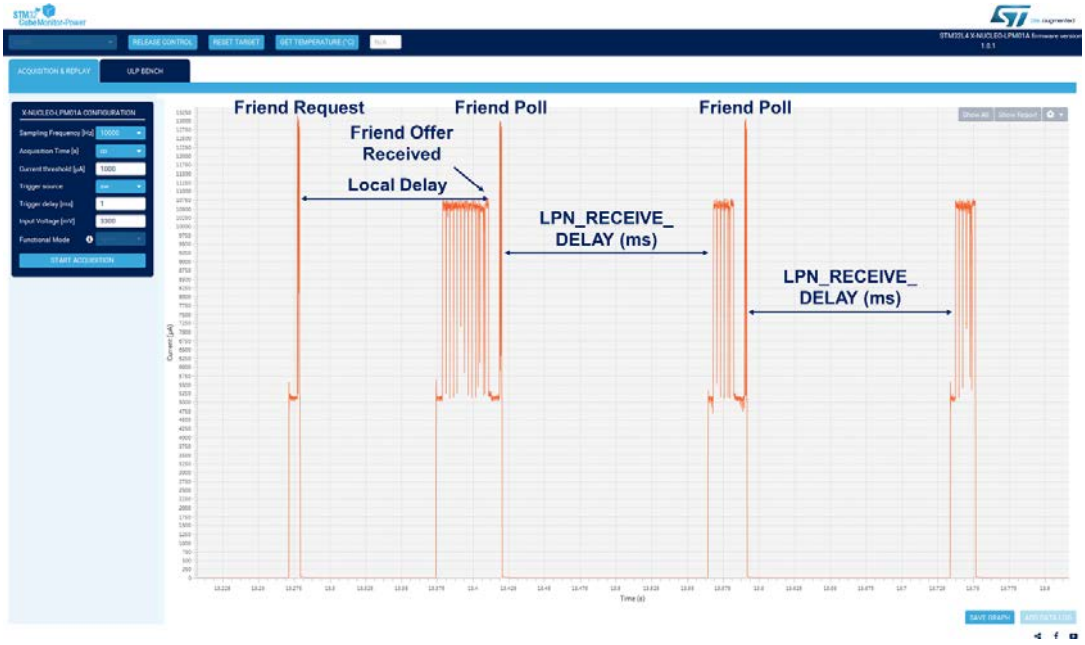


Figure 6. Friend establishment sequence



See Mesh Profile Specification v1.0, Section 3.6.6.3.1 for Local Delay.

Figure 7. Friend establishment procedure followed by Friend Poll after LPN_FRIEND_POLL_FREQUENCY

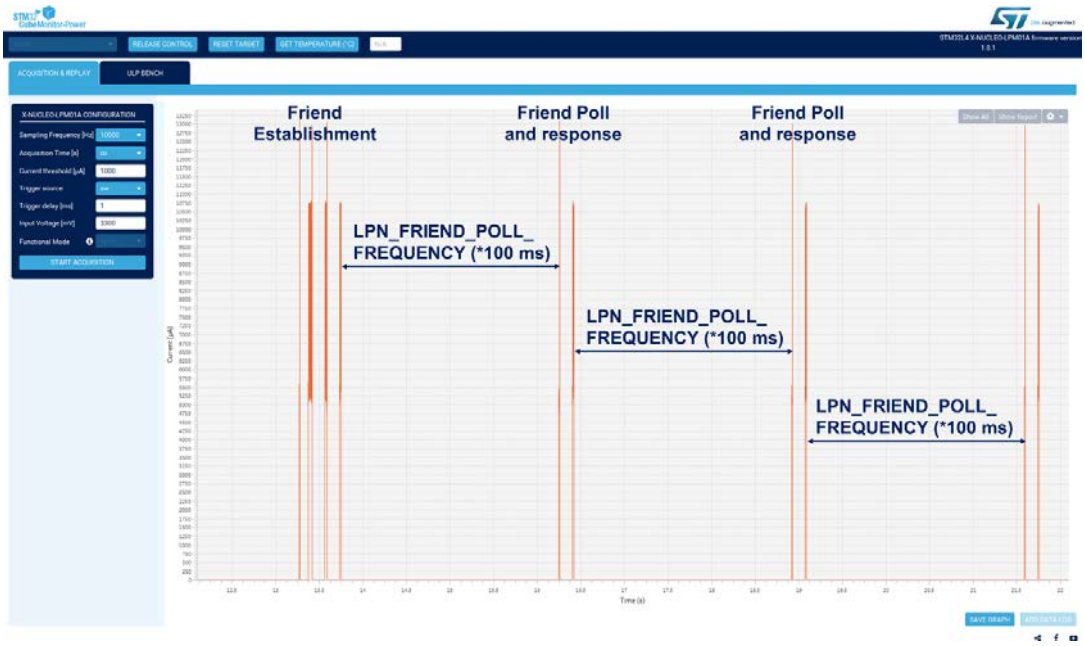
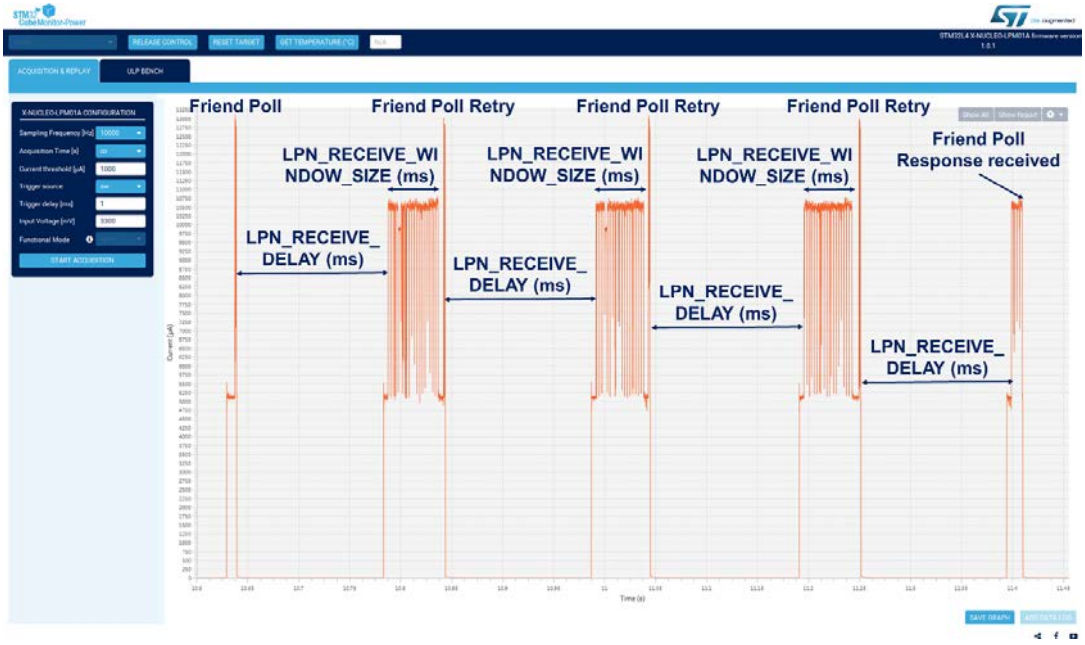
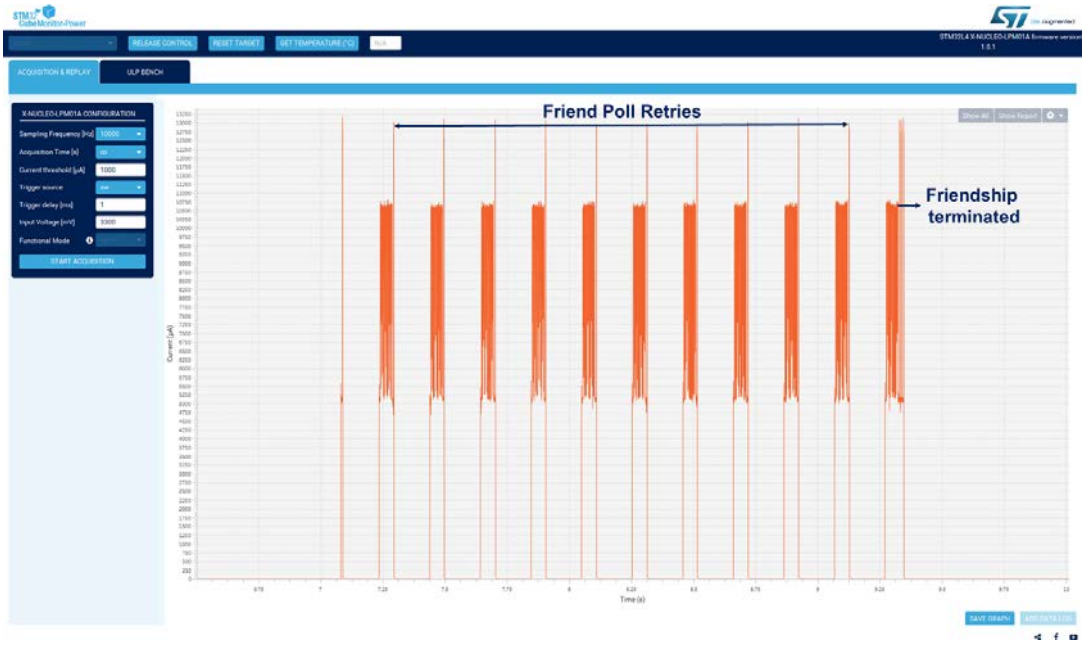


Figure 8. Friend Poll retry if no response received



If no response is received for Friend Poll, LPN keeps sending Friend Poll requests until a response is received by the FN. The LPN terminates Friendship if Friend Poll retry count reaches `LPN_NO_OF_RETRIES`.

Figure 9. Friend Poll retries for LPN_NO_OF_RETRIES and Friendship termination



3 Customization

`BluenrgMesh_sleepTime` represents duration of time (in ms) for which no activity is scheduled by the STSW-BNRG-Mesh library.

If `BluenrgMesh_sleepTime = 0`, the device does not enter sleep mode, otherwise start a virtual timer (virtual timer 0 is used for Mesh in the sample application) for `BluenrgMesh_sleepTime` and call `BlueNRG_Sleep`.

Additional virtual timer configuration might be necessary for the requirements of different applications used with BlueNRG-Mesh.

In any case, the maximum sleep duration time should not exceed 5242879 ms.

Different parameters described in Section 1.1.2 Low Power node can also be optimized to best suit the target application.

Note: Interrupts are disabled during sleep mode; therefore, it is mandatory to update `Clock_Time` (after device wakeup) to compensate for sleep duration.

Revision history

Table 5. **Document revision history**

Date	Version	Changes
07-Feb-2019	1	Initial release.

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