BlueNRG-MESH

Overview of the BlueNRG-MESH SDK for the ST Bluetooth Low Energy SOCs

Salvo Bonina

STMicroelectronics

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Technology Tour 2019

Minneapolis, MN | October 24

BlueNRG-Mesh

Bluetooth Mesh Basics

BlueNRG-Mesh SDK Solution

Getting started with BlueNRG-Mesh

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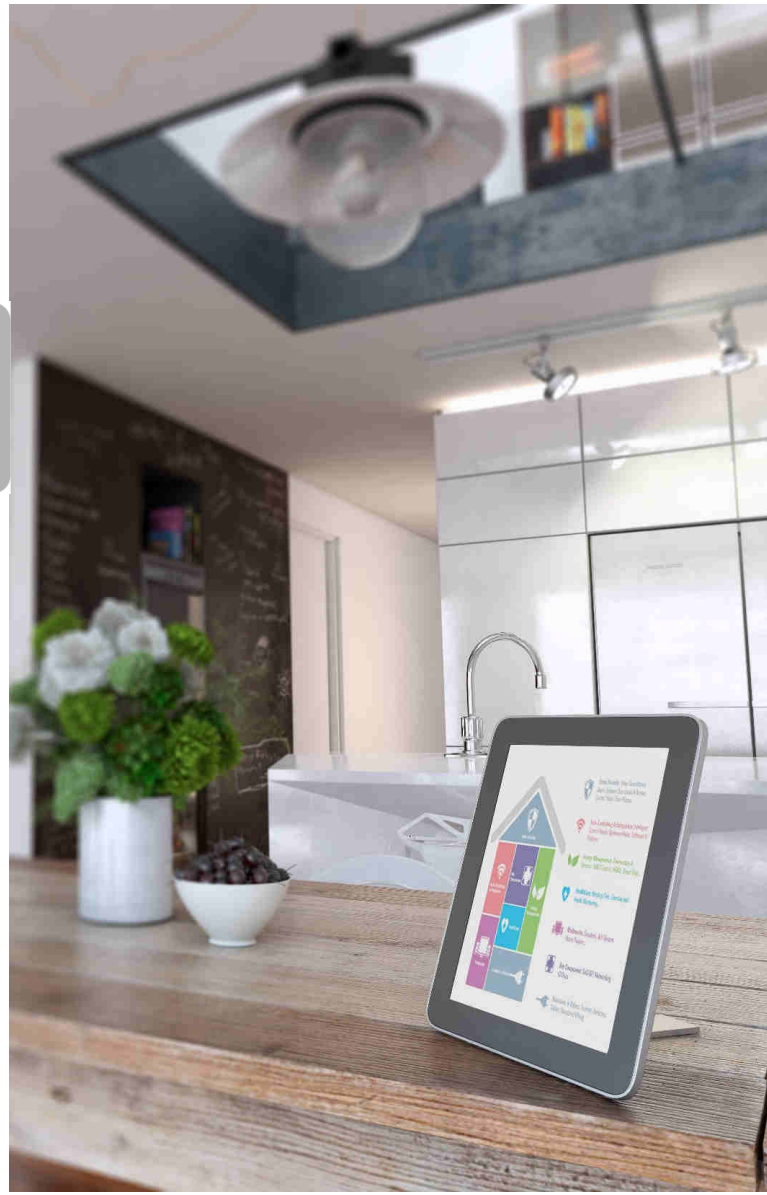
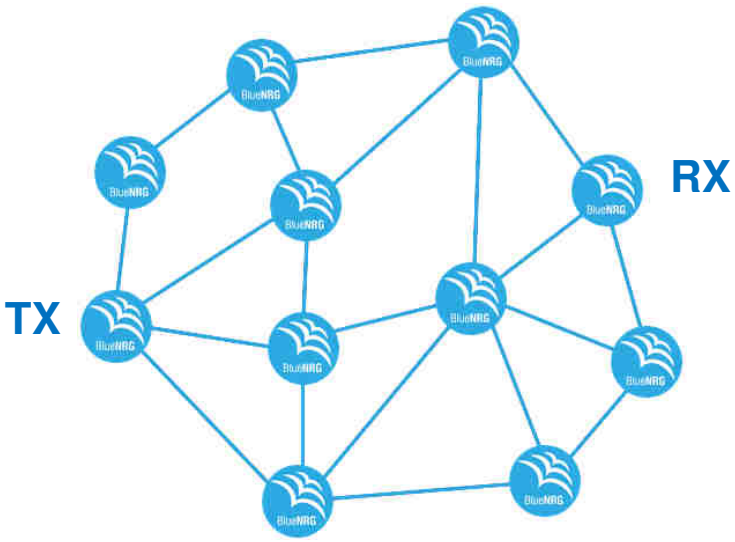


What is the BLE Mesh?

July 18, 2017 - Bluetooth SIG Announces Mesh Networking Capability

Brings proven, **global interoperability** and the mature, **trusted ecosystem of Bluetooth technology** to industrial-grade device networks

- A standard network protocol to **extend the communication range** with a **mesh network topology** between several nodes over multiple hops when there is not direct reachability between two nodes.
- The BLE Mesh is standardized by the **Bluetooth Core** also known as **Special Interest Group (SIG)**.



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BLE MESH: Backed up by Industry Leaders

Bluetooth® companies supporting the launch of Bluetooth mesh networking

3M, AIR CABLE, ARM, BeON home, cortet™ by CEL, CYPRESS, dialog SEMICONDUCTOR, ElectricBench, ERICSSON, FULHAM, Gooee, Gunitech, hellohub, Imagination, muRata INNOVATOR IN ELECTRONICS, QUALCOMM, SILICON LABS, SILVAIR, smart and green, life.augmented, TOSHIBA Leading Innovation, TRLink, WISILICA

BlueNRG

Bluetooth 5

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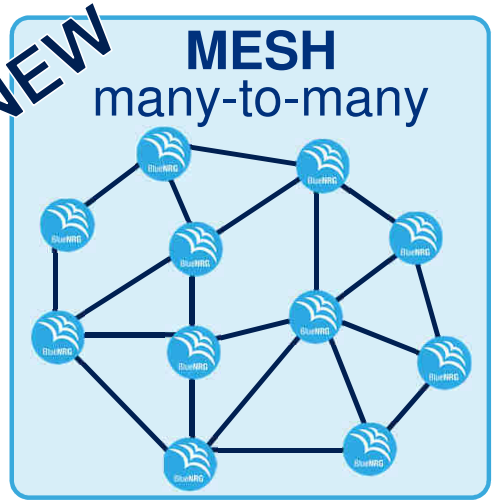
Extending Bluetooth Capabilities

The Bluetooth Mesh network topology optimizes the power consumption.



DATA TRANSFER

- Sports & fitness devices
- Health and wellness devices
- Peripherals and accessories

LOCALIZED INFORMATION

- Point of interest beacons
- Item finding beacons
- Way finding beacons

LARGE DEVICE NETWORKS

- Building automation
- Wireless sensor networks
- Asset tracking

Signal range depends on RF output power

Coverage extended by relaying messages over multiple hops

Bluetooth® Mesh Applications

The Bluetooth SIG MESH extends the capabilities of Bluetooth Smart chips to answer **more and more complex applications**.
The protocol has been developed with the **Smart Lighting industry** in mind.

- Lighting
  - Interface to major light IOs (DALI, PWM, etc.)
- Smart Home and Building automation
  - Heater/Fan control
  - Temperature / Shutter control
- Smart Industry
  - M2M control
- Wireless sensor networks
- Asset Tracking

Source : Bluetooth® SIG

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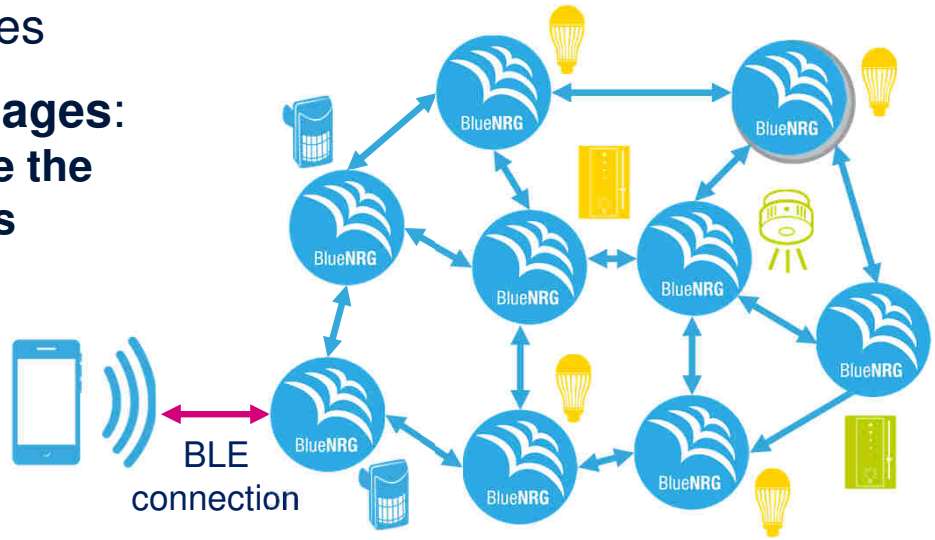
Bluetooth® Mesh Topology

Managed Flooding

The Bluetooth Mesh network mechanism is based on a **managed flooding protocol**

- **Message relay** extends the communication range (Multi-hop data transmission)
- **No single point of failure**
  - does not require any centralized operation nor coordination
  - dynamic self healing
- **Direct communication** between contiguous nodes
- **Rules to restrict** devices from **re-relaying messages**:
  - Messages contain a **Sequence Number** to **optimize the network usage and protect against replay attacks**
    - Reject messages already received
  - **TTL** (Time To Live) method:
    - Limit the number of times a message is relayed



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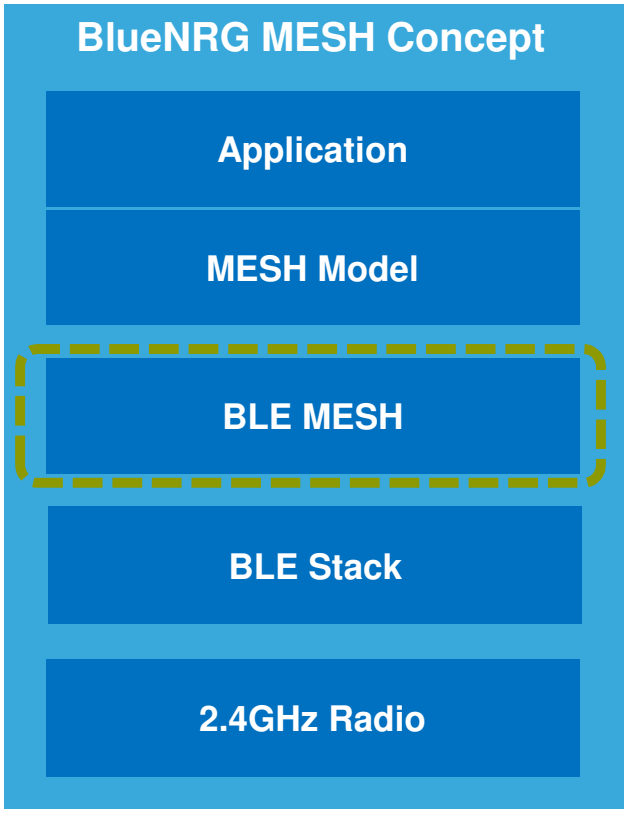
Bluetooth MESH vs BLE Stack



- Bluetooth Mesh runs on top of the BLE Stack
- It is not linked to BLE 5.0
- It is backward compatible with BLE 4.x

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Security, Attacks and Protection

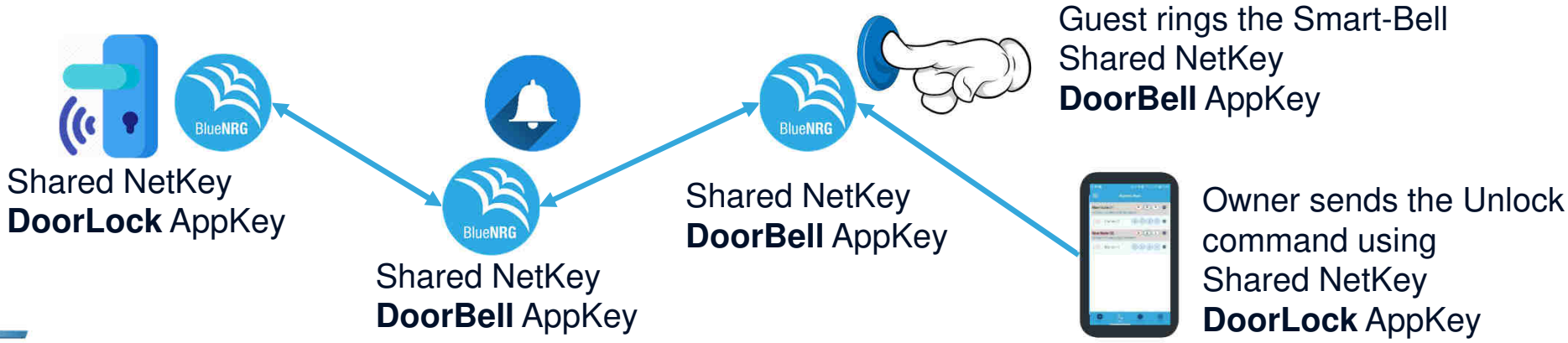
- The Mesh security uses a privacy mechanism called **obfuscation** through **AES** to encrypt the **header** information.
- **Message payload** is **encrypted twice**. Once with an Application or device key and the second time with a Network key.
- Mesh security **protects the network against** third-party interference and monitoring: Replay/Eaves Dropping **attacks**.
- Nodes can be removed from the network securely, preventing trash-can attacks, by erasing the security keys stored in the flash memory.

Security in the Bluetooth Mesh: Keys

- **Device Key**: Never transmitted over air
  - **Unique key for each single device**, only known by the Provisioner (i.e. Smartphone) and the device, used for provisioning, configuration and key management.
- **Network Key**: Provided by Provisioner
  - Shared across all Nodes in the network, allows a node to decrypt message's header and to relay messages throughout a network
- **Application Key**: Provided by Provisioner
  - **Different applications have a different "Application key"** used to **encrypt/decrypt messages payload (application data).**

Why Do You Need Both Network Key and Application Key?

- The NetKey provides security/authentication for all communication at network layer
- The AppKey protects the application data. Messages can be relayed by any nodes in the network without being able to read or change the application data.
- We can't have a compromised **Door Bell** allow anybody to unlock **Door Lock**



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Bluetooth® Mesh for Smarter Devices

How Node Features are Exposed – Two Entities: Elements and Models

Using Elements and Models helps **exchange messages** between a BLE device and a Smart Application (Controller) for simple **control and monitoring applications**

Multiple Roles

Mesh Node		
Element #1	Element #2	Element #3
Model #1	Model #1	Model #1
ID: 0x0001 states[] subscriptions[] applications[]	ID: 0x0001 states[] subscriptions[] applications[]	ID: 0x0001 states[] subscriptions[] applications[]
Model #2	Model #2	
ID: 0x0002 states[] subscriptions[] applications[]	ID: 0x8002 states[] subscriptions[] applications[]	

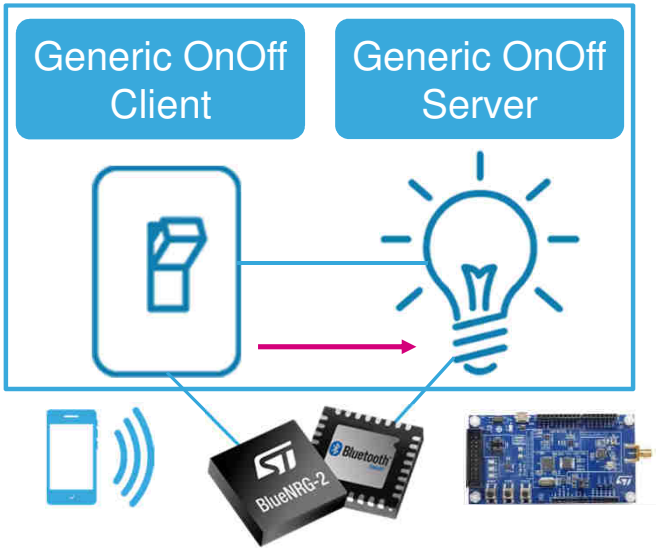
Controller

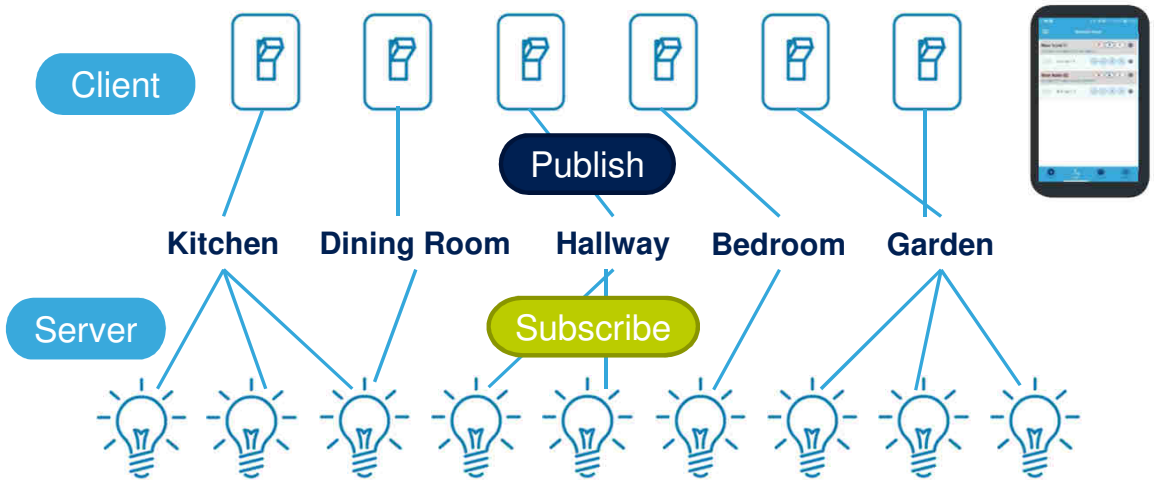
Android, iOS
(or embedded)

- **Elements**:
  - define the **functionalities** of a single node, i.e. a light fixture may have two lamps, each of them is a **separate element** independently controlled. Each element contains models
- **Models:**
  - represent specific **Services** and define a set of **States and Messages** supported by the element; (i.e. a lamp supports the **Lighting** model for On/Off Control or Dimming

The Mesh Messaging Model

Publish and Subscribe Paradigm





- Publish: send a message to unicast /virtual /group address
  - A **Client** device (e.g. Switch/Smartphone) can **publish messages** (e.g. ON/OFF control) and a **Server** device (e.g. a light bulb) can **subscribe** and be **notified** of new command arrival.
  - Also, a Client can **publish** a message to a **multicast address** (i.e. **Group**), and **multiple nodes** can **subscribe** to such specific address.

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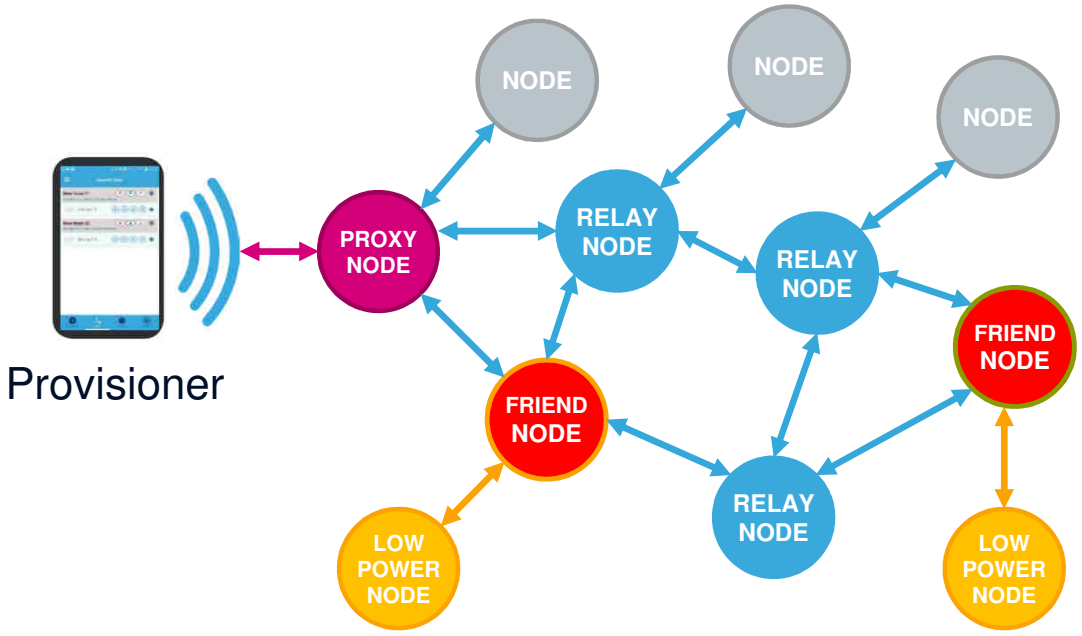
Bluetooth® Mesh Network Topology

Nodes Types

To stay efficient, the BLE Mesh takes advantage of a **managed flooding network** mechanism.
Compared to routed protocols, it is **much more simpler** to deploy.



- **PROXY NODE**
  - Expose the interface for Smartphone/ Tablet to interact with a mesh network
- **NODE**
  - Simple leaf node whom you don't want to relay messages (Weak nodes or Resource constrained nodes)
- **RELAY NODE**
  - Able to retransmit received messages
  - Enable multiple "hops" in the network
- **LOW POWER NODE**
  - Battery operated devices
  - Primarily send but Rarely receive messages
  - No need 100% duty cycle: mostly sleep
- **FRIEND NODE**
  - Stores messages addressed to LPNs and delivers them whenever the LPN polls for "waiting messages"

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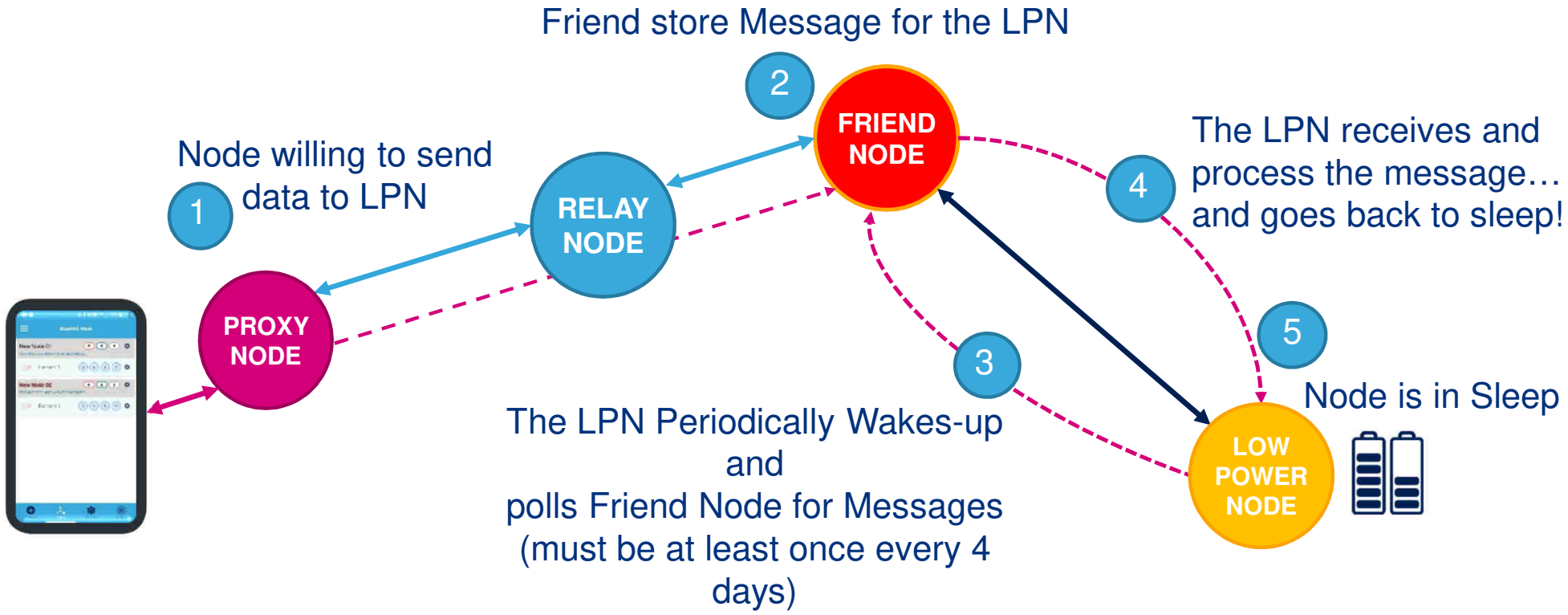
Bluetooth® Mesh Entities

Low Power & Friendship Node



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BlueNRG-Mesh

Bluetooth Mesh Basics

BlueNRG-Mesh SDK Solution

Getting started with BlueNRG-Mesh

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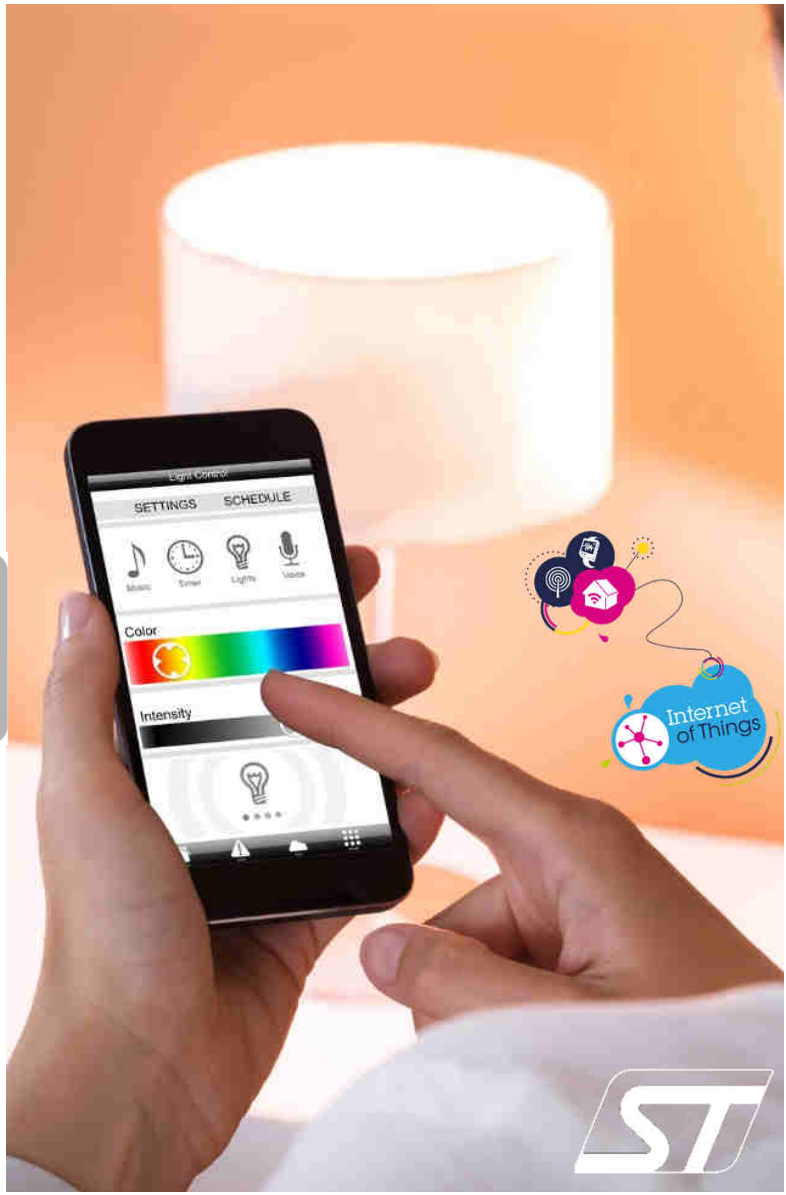
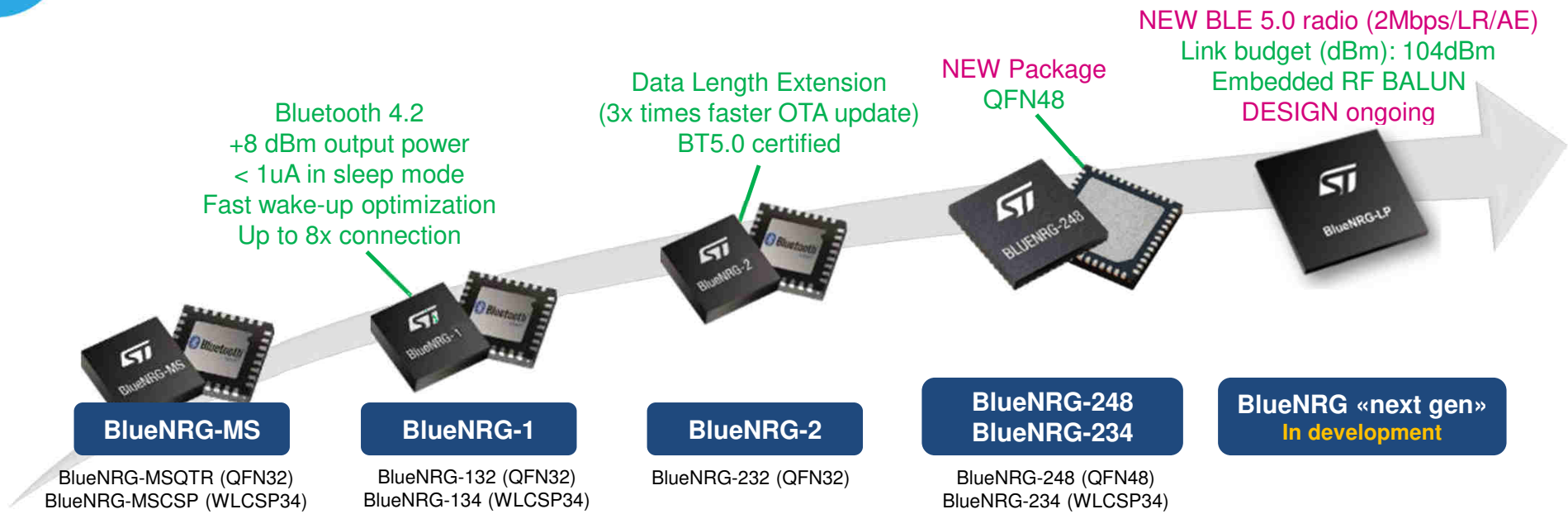


BlueNRG Chipset Evolution



BlueNRG-MS	BlueNRG-1	BlueNRG-2	BlueNRG-248 BlueNRG-234	BlueNRG «next gen» In development
BlueNRG-MSQTR (QFN32) BlueNRG-MSCSP (WLCSP34)	BlueNRG-132 (QFN32) BlueNRG-134 (WLCSP34)	BlueNRG-232 (QFN32)	BlueNRG-248 (QFN48) BlueNRG-234 (WLCSP34)	
BT4.1	BT4.2	BT5.0 (*)	BT5.0 (*)	BT5.0
2015	2016	2017	2018	2020

Bluetooth LE product roadmap

(*) Certified for BLE 5.0. It does not support other optional BLE 5.0 features like 2 Mbit/s, Long Range and Advertising Extensions.

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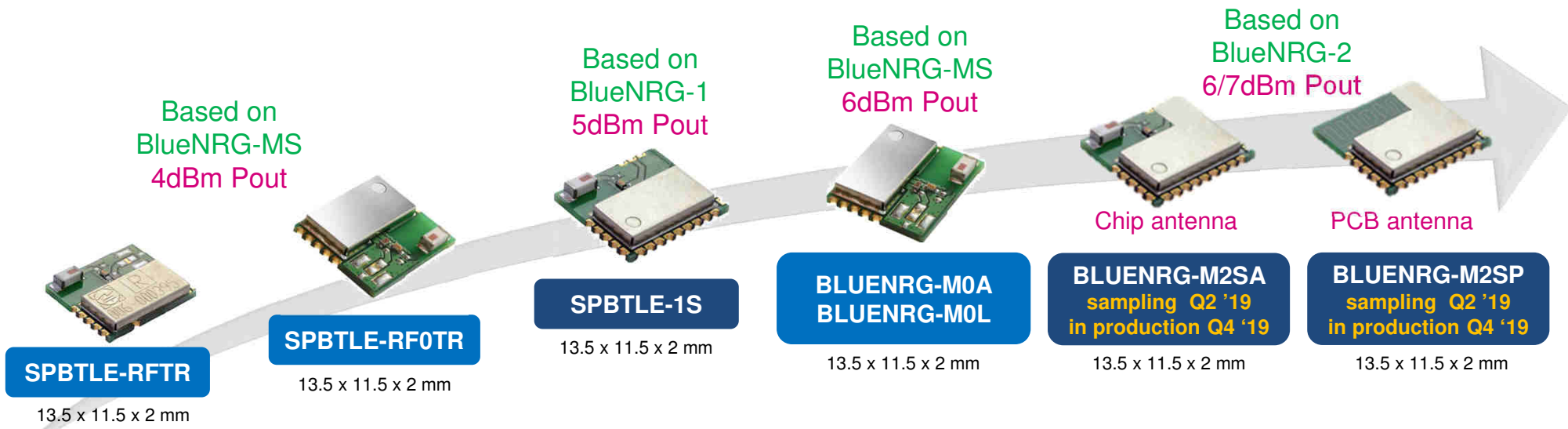
BlueNRG Modules Portfolio



Bluetooth LE product roadmap

NETWORK PROCESSOR

SoC PROCESSOR

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STSW-BNRG-Mesh

- SDK
  - **Firmware,** Android and iOS **app sources**
  - **www.st.com/blemesh**
- ST BLE Mesh app on Store

Download on the App Store

GET IT ON Google play

- BlueNRG-mesh community forum
  - **http://community.st.com/blemesh**

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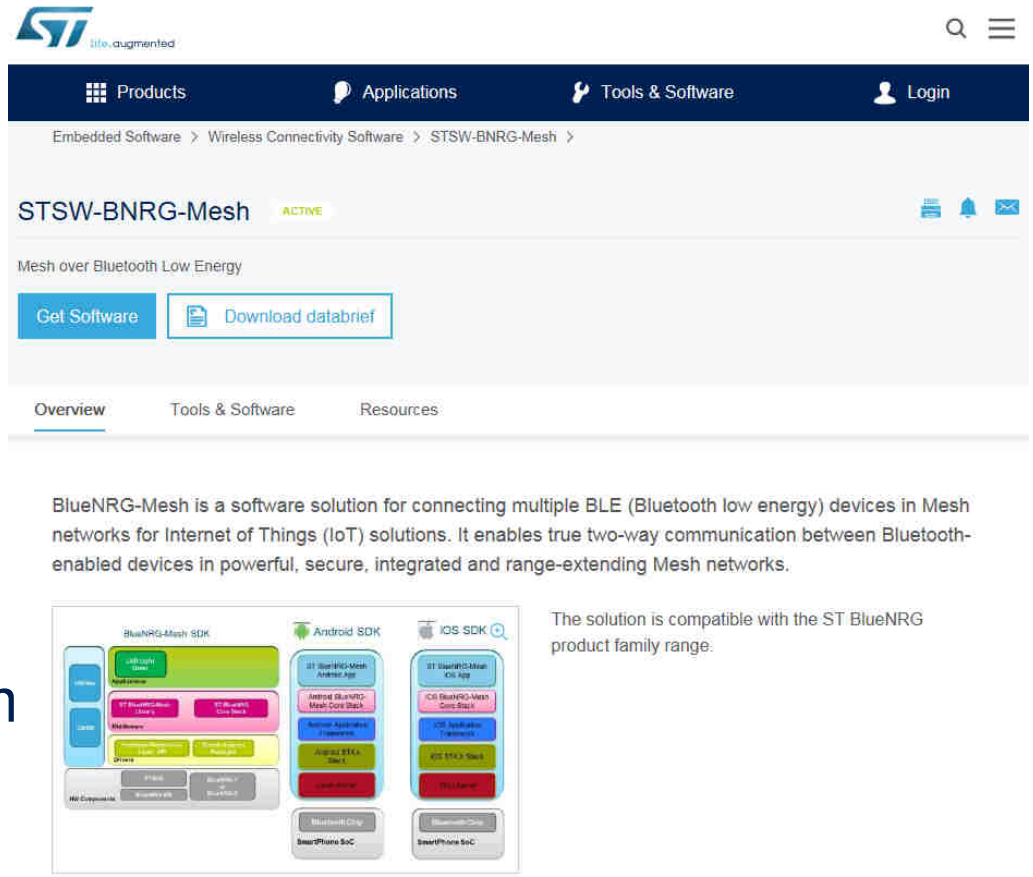

Bluetooth SIG Certification

- Mandatory Features
  - **FW library compliant** to the **SIG specs v1.0**
  - Role: Node (Features: Proxy, Relay)
  - Bearer: Advertising, GATT
  - Provisioning: PB-GATT
  - Provisioning Protocol: Provisioning Server
  - Foundation Mesh Models: Configuration Server, Health Server

- Optional Features
  - **Friend Node**
  - **Low Power Node**
- ST Additional Features
  - **Models: Generic, Lighting, Sensor, Vendor, Time & Scene**
  - Light Intensity control (i.e. Dimming) using PWM control
  - **Provisioning information sharing** between mobile Phones/Tablets (Android and iOS) **via JSON file by eMail & Cloud Synchronization**

https://launchstudio.bluetooth.com/ListingDetails/65504

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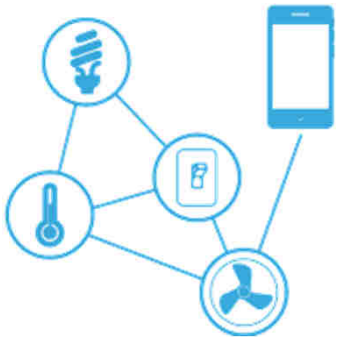

BlueNRG-Mesh in Numbers

Power consumption
7 mA average
(with no LPN/ Friendship)

Hop latency
30 ms avg

BLE Mesh 1.0 SIG certified

Provisioning procedure
10-15 seconds average

Message Payload
8 bytes unsegmented
64 bytes segmented

Mesh Library Memory footprint
55.2 KB Flash
5.3 KB RAM

Network size
Max 32767 nodes for a single network
Max network diameter of 126 hops

Compatible with both BLE 4.X or 5.0

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BlueNRG-Mesh Roadmap

STSW-BNRG-Mesh v1.05.000
X-CUBE-BLEMESH1 v1.0.0

- Friendship & Low Power
- Health Model
- Lighting Model
- Key-refresh
- IV Update procedure
- Database transfer (via Cloud)
- BT Mesh v1.0 Profile Certification
  QDID 116029
- Base for X-CUBE-BLEMESH1 v1.0.0

STM32 Open Development Environment

STSW-BNRG-Mesh v1.06.000
X-CUBE-BLEMESH1 v1.1.0

- Performance Optimization
- Generic Model
  - Server: OnOff, Level
  - Client: OnOff, Level
- Lighting Model
  - Server: Lighting HSL
- Android & iOS supporting HSL Model
- CID & PID Configuration
- Static OOB Provisioning

STSW-BNRG-Mesh v1.07.000
X-CUBE-BLEMESH1 v1.2.0

- **Sensors Model**
- **Lighting Model**
  - Client
- **Time and Scene Model**
  - Empty wrappers
- **PB-ADV – Provisioning over advertising**

STSW-BNRG-Mesh v1.08.000
X-CUBE-BLEMESH1 v1.3.0*
FP-SNS-BLEMESH1 v1.1.0*
* Partially supported

- **Multiple App Keys (up to 2 keys)**
- **Model data/states saving into flash**
- **Models Added: Generic PowerOnOff Server and Setup, Generic Default Transition Time, Light LC Server** (Mode, OM, Light OnOff),
- **Light LC Controller state machine for Occupancy/Ambient Lux Level sensor**
- **Output/Input OOB, Public Key OOB Provisioning**
- **Vendor Model moved to appl layer**
- FW example for STEVAL-BCN002V1B and STEVAL-BLUEPLUG1

STSW-BNRG-Mesh v1.09.000
X-CUBE-BLEMESH1 v1.4.0
FP-SNS-BLEMESH1 v1.2.0

- Multiple Network Keys
- **Embedded Provisioner**
- **BT Mesh v1.0 Server Models Certification**

August 2018

November 2018

March 2019

August 2019

November 2019

http://www.st.com/blemesh

http://community.st.com/blemesh

https://itunes.apple.com/us/app/bluenrg-mesh/id1348645067

https://play.google.com/store/apps/details?id=com.st.bluenrgmesh

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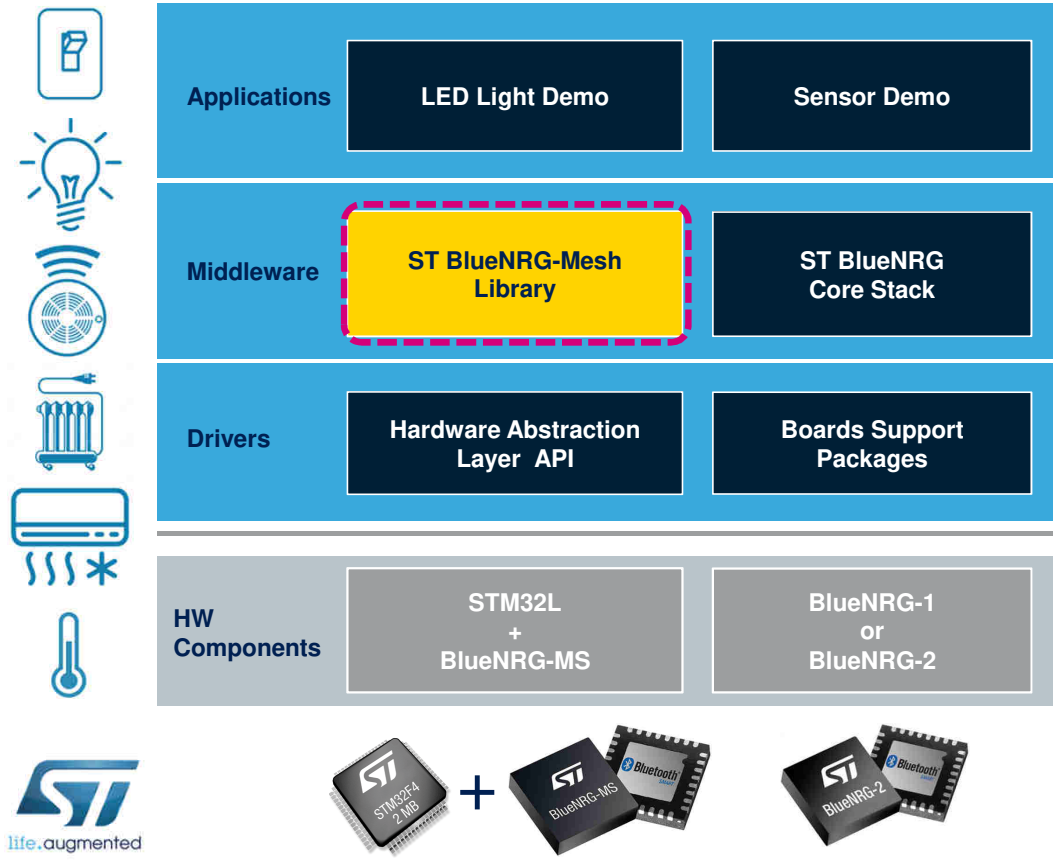
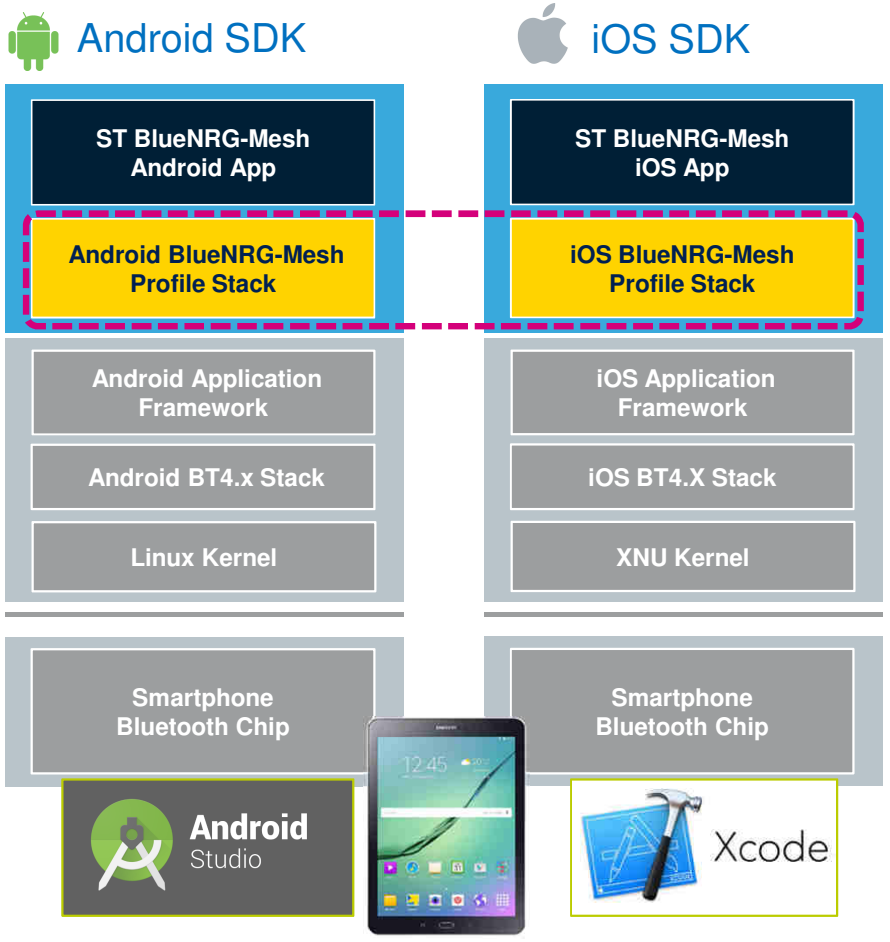
BlueNRG

Available on SoC and network processor

BlueNRG-MESH SDK
for Embedded, Android and IOS

SDK SW Packages: STSW-BNRG-Mesh and X-CUBE-BLEMESH1





BlueNRG-Mesh

- Bluetooth Mesh Basics
- BlueNRG-Mesh SDK Solution
- Getting started with BlueNRG-Mesh

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BlueNRG-MESH SDK

Hardware Platform Support

PLATFORMS

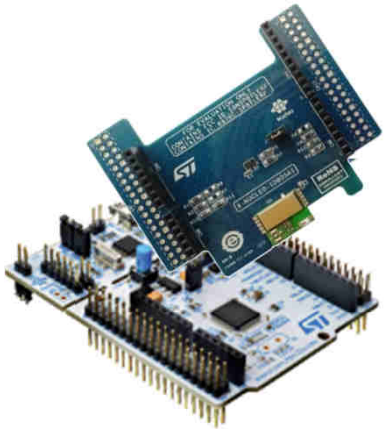
STEVAL-IDB007V2

BlueNRG-1

STEVAL-IDB008V2
STEVAL-IDB009V1

BlueNRG-2

SW Package: STSW-BNRG-Mesh



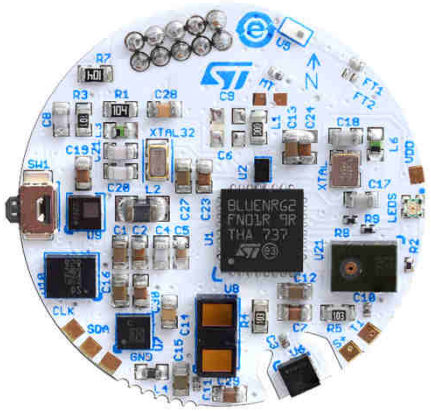
Nucleo-L1/L4/F3/F4 + X-Nucleo-IDB05A1 + X-NUCLEO-IKS01A2

BlueNRG-MS +
STM32L1 or STM32L4 or STM32F3 or STM32F4

SW Packages: X-CUBE-BLEMESH1 and FP-SNS-BLEMESH1

STM32 Open Development Environment

1 inch



STEVAL-BCN002V1B

aka «BlueTile»

BlueNRG-2

SW Package: STSW-BNRG-Mesh

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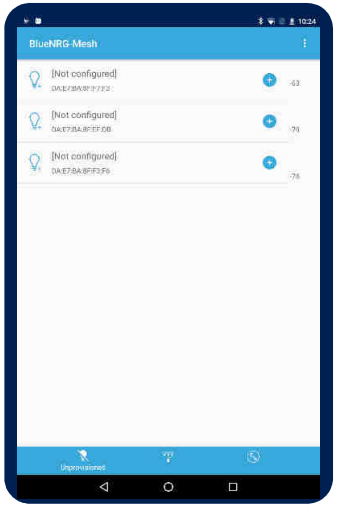
BlueNRG-MESH SDK

Software Platform Support

BlueNRG-Mesh App

ST BLE Mesh app for Android and iOS



BlueNRG Platform SW

- **STSW-BNRG-Mesh**
  - Mesh over Bluetooth Low Energy for **BlueNRG-1** and **BlueNRG-2**
  - https://www.st.com/content/st_com/en/products/embedded-software/wireless-connectivity-software/stsw-bnrg-mesh.html
- **X-CUBE-BLEMESH1**
  - Mesh over Bluetooth low energy software expansion for **STM32Cube**
  - https://www.st.com/en/embedded-software/x-cube-blemesh1.html
- **Application Example: FP-SNS-BLEMESH1**
  - **STM32Cube function pack** for IoT node with BLE Mesh connectivity and **Sensor model example**
  - https://www.st.com/en/embedded-software/fp-sns-blemesh1.html

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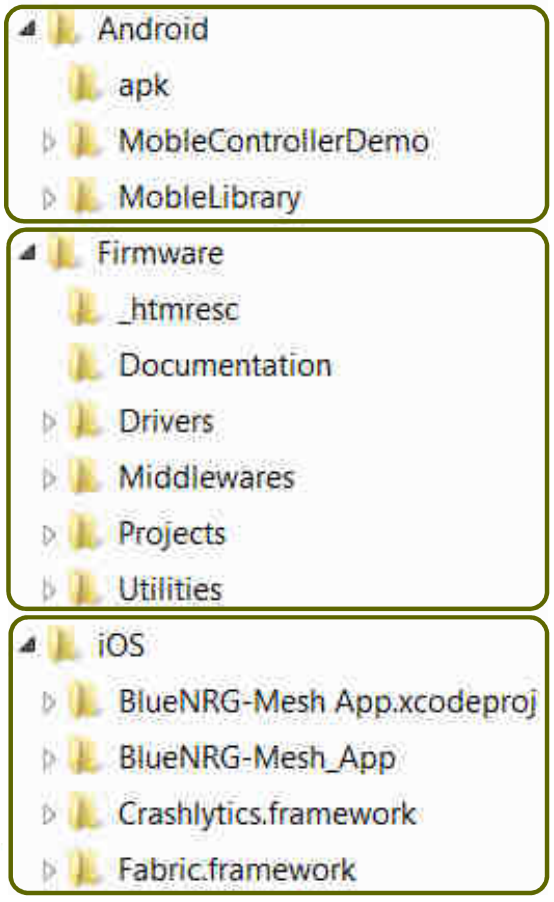
Contents of STSW-BNRG-Mesh Package



- ST BLE Mesh Android SDK
  - **App Source Code for Android Studio**
  - Mesh Library
  - APK
- Firmware SDK
  - **Examples for BlueNRG-1, BlueNRG-2**
  - **Middleware** folder with **libraries** for **Mesh** and **BLE** communication
  - **Drivers** folder with **HAL** and **drivers** for supported **boards** and **components**
  - **Doxygen Documentation**
- ST BLE Mesh iOS SDK
  - **App Source Code for Xcode**
  - Mesh Library in Object code

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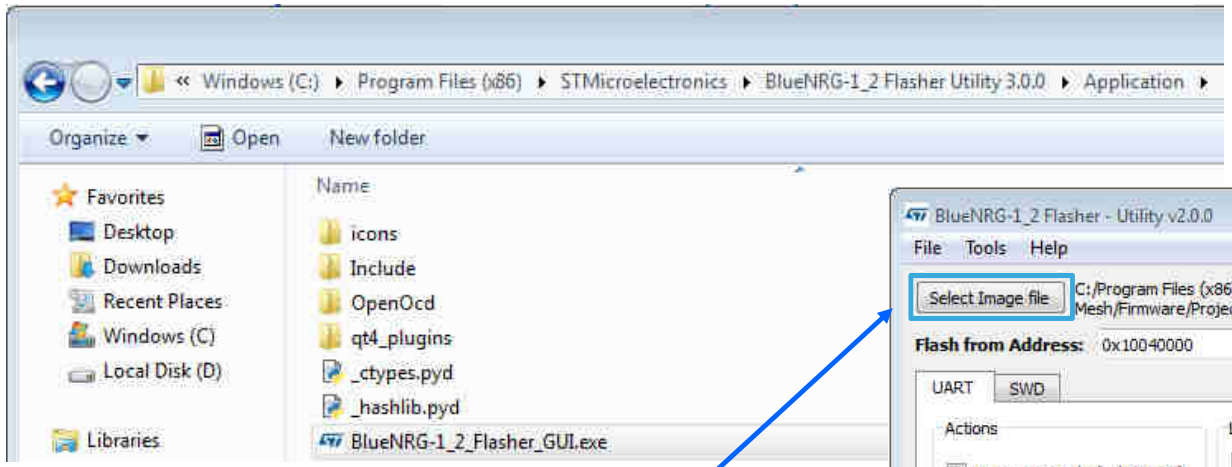
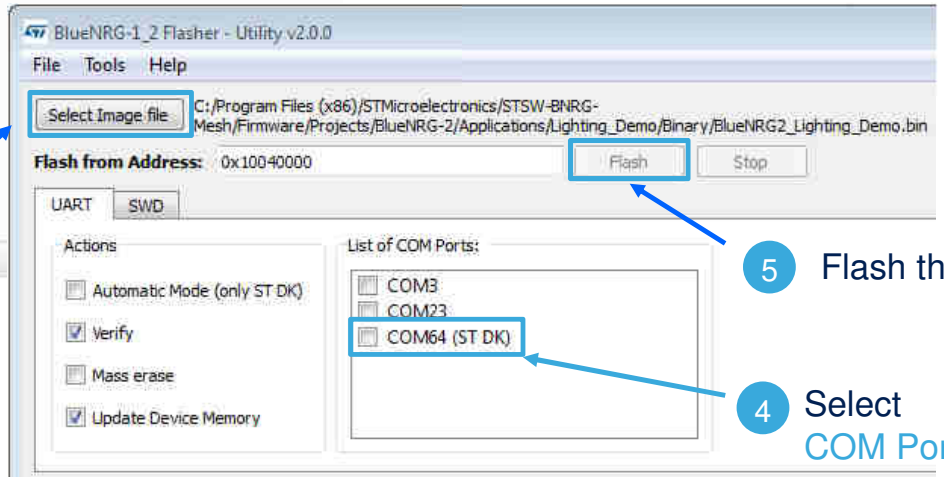
STSW-BNRGFLASHER for BlueNRG-1/2

Program in Just Few Seconds: Using Binaries

1 Open the **BlueNRG Flasher Utility**: Double click on **BlueNRG-1_Flasher_GUI.exe**





2 Click "**Select Image file**"

4 Select COM Port

5 Flash the Board

3 Go to .\STSW-BNRG-Mesh\Firmware\Projects\BlueNRG-1\Applications\Lighting_Demo\Binary
.\STSW-BNRG-Mesh\Firmware\Projects\BlueNRG-2\Applications\Lighting_Demo\Binary
And select the file BlueNRG1_Lighting.bin or BlueNRG2_Lighting.bin depending on the platform in use
STEVAL-IDB007V2 STEVAL-IDB008V2

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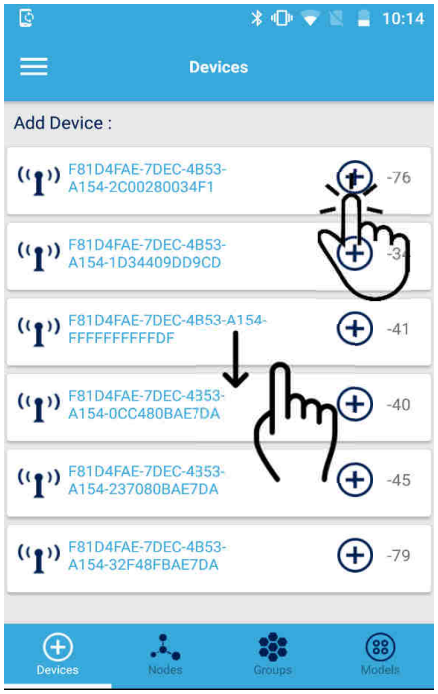
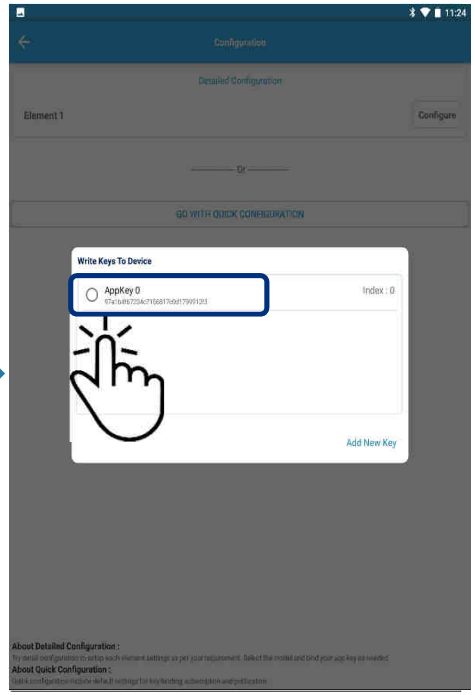
ST BLE Mesh: Provisioning of the Nodes

Provisioning



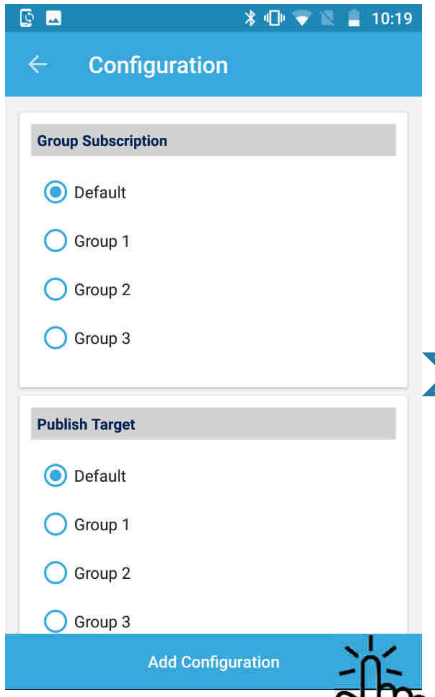
Before the provisioning the ones listed are called "**devices**"

AppKey Select



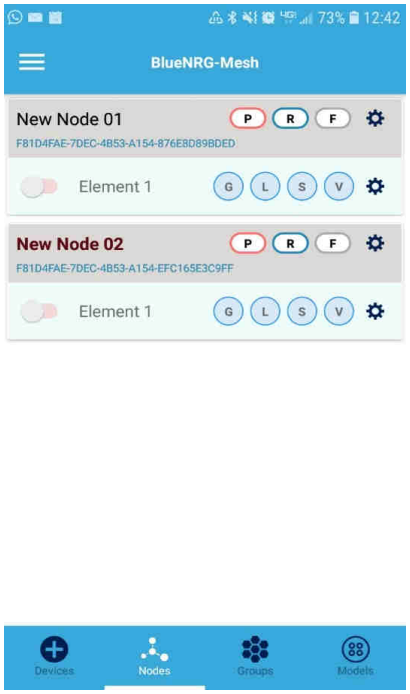
Select the default Application Key or Add a New one

Address Configuration



The Node can be added to a specific group of elements

List of provisioned Nodes



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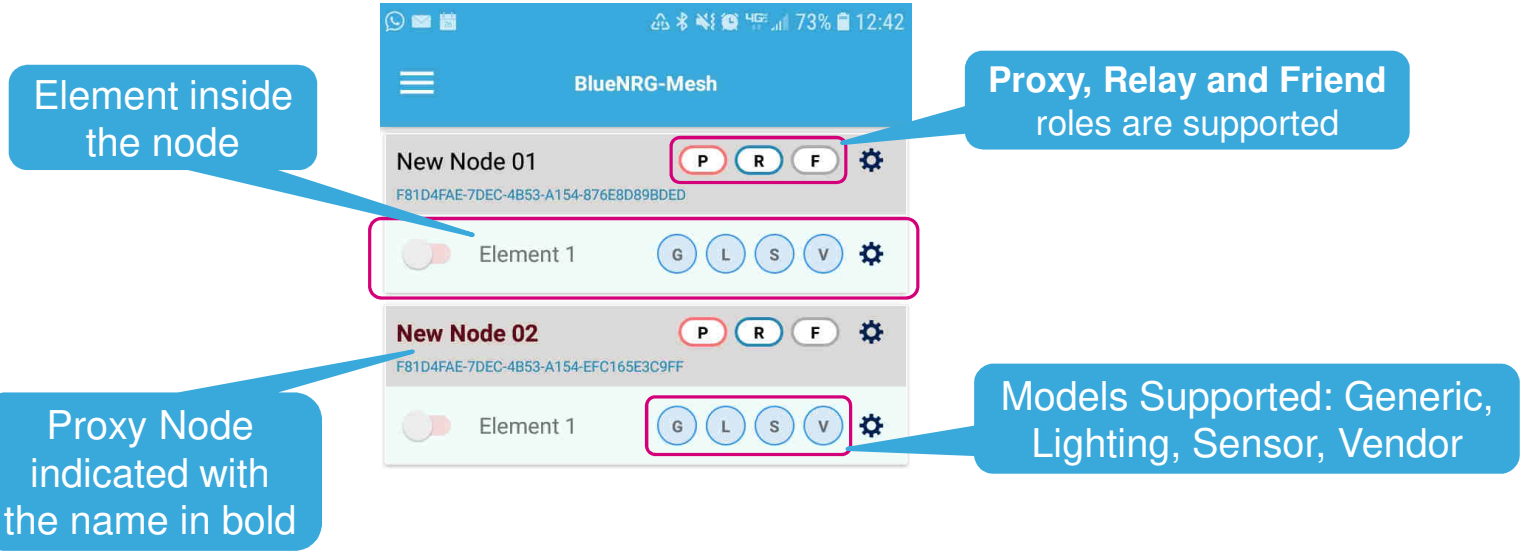
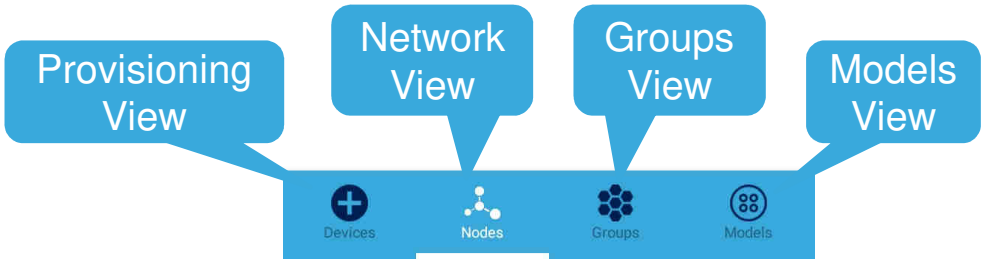
ST BLE Mesh: Nodes List Tab Features





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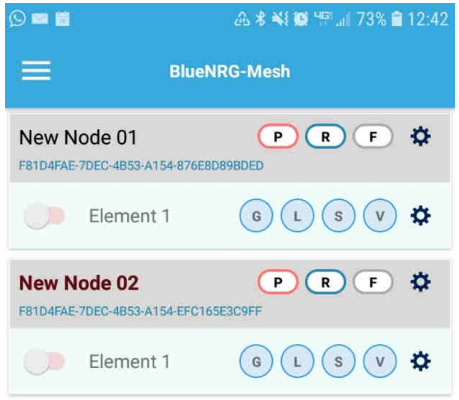
ST BLE Mesh: Models Selection

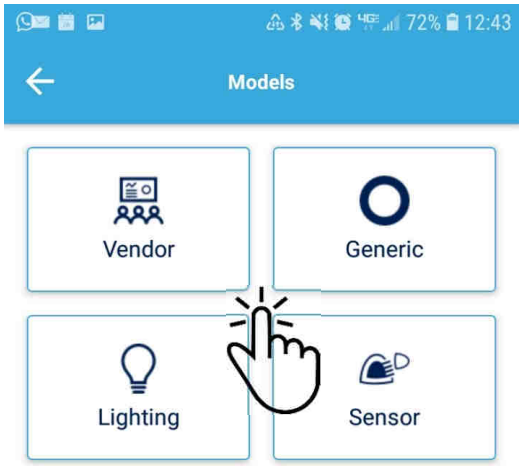
Nodes List

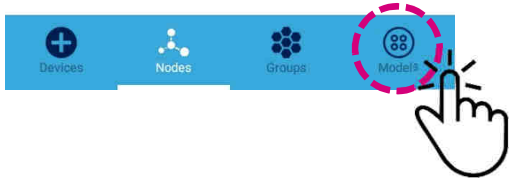


Models selection

- Different screen for each mesh model
- Send model specific commands
- Selected choice is saved

Model Selection





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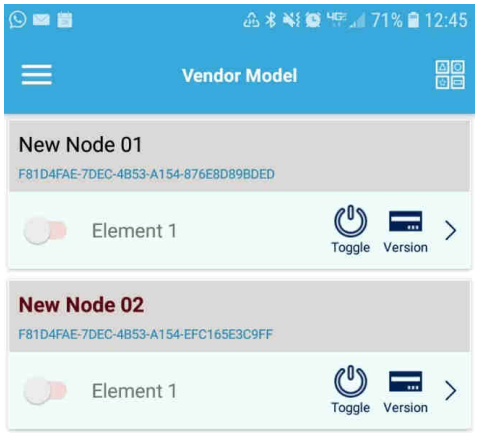
ST BLE Mesh: Models Selection

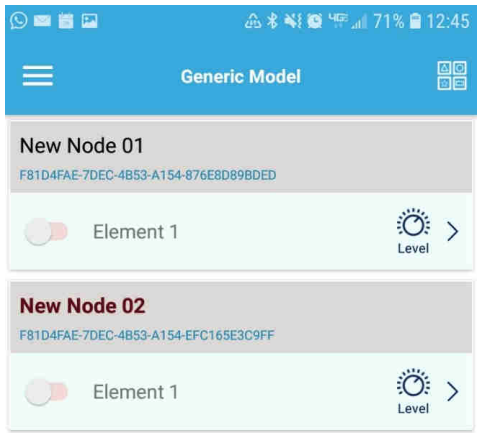
Vendor Model



- Supported Commands
  - Vendor on/off
  - Version query

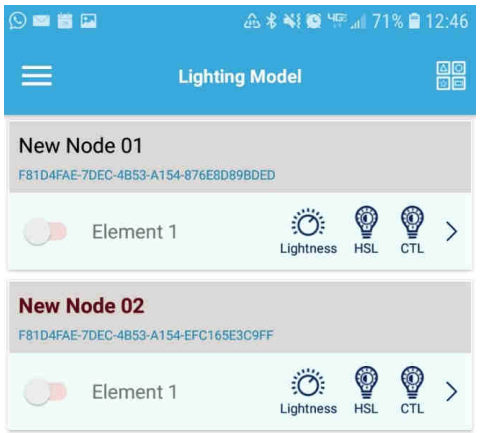
* **Vendor model allows for transmitting custom payload**.

Generic Model



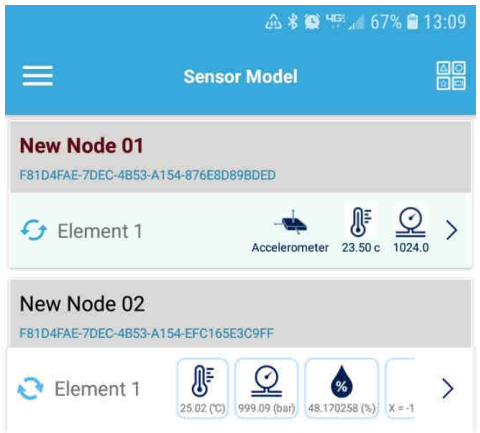
- Supported Commands
  - **Generic on/off**: for device supporting On/Off feature
  - **Generic level**: Manage state of an element in a **16-bit signed integer**

Lighting Model



- Supported Commands
  - **Light lightness**
  - **Hue, Saturation,** Lightness
  - **CTL (Color temperature),** Lightness

Sensor Model



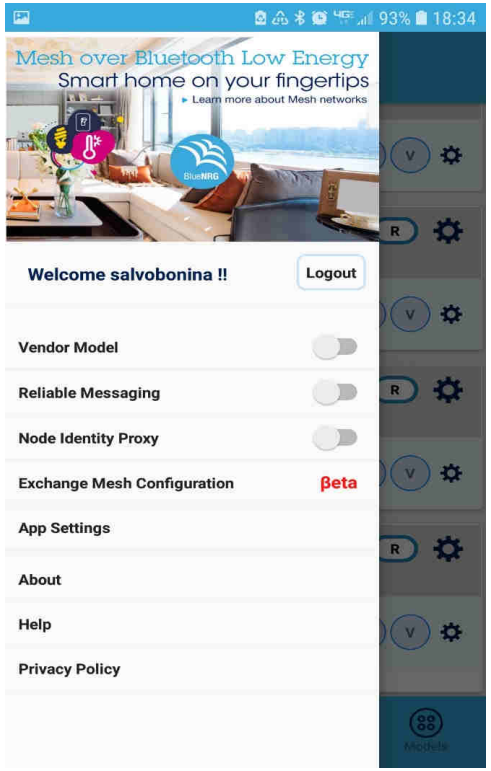
- Supported Commands
  - **Sensor Get**: i.e. Acceleration, MAG & Gyro, Temperature, Humidity, Pressure
  - **Sensor Cadence Set**

Network Configuration Database

- **Stores security info & parameters** to operate in a mesh network
- Shared in **JSON** format.
- Allows another Smartphone to manage and control the mesh network.
- Two ways to share
  - **Via email** – Instantly share network with another smart phone
  - **Via Cloud** – Our mesh cloud web app allows sharing between multiple phones.
- **Interoperable** on both iOS and Android **ST BLE Mesh** apps

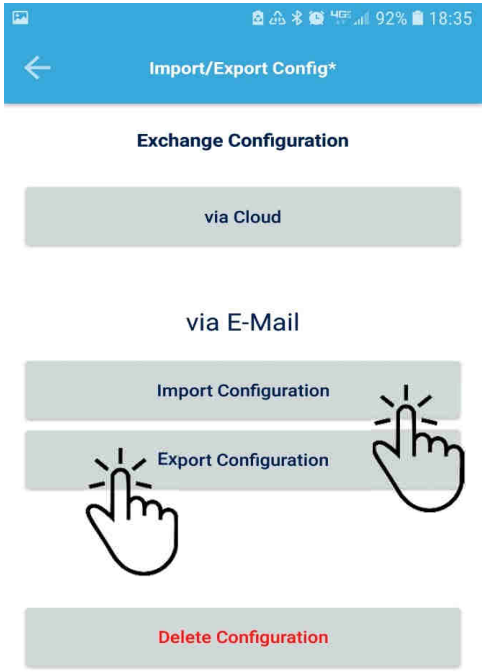
Exchange Provisioning DB Configuration via email

Settings



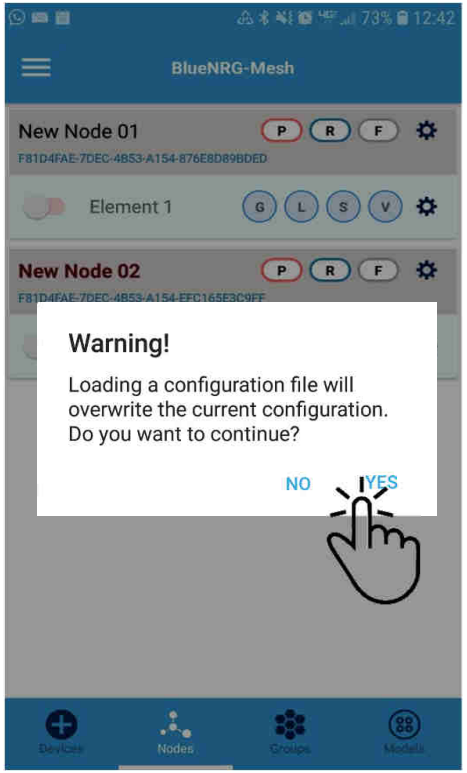
Next Panel

Import/Export Configuration



Import Configuration

Replace current configuration



Export Configuration on one Smartphone.
Import Configuration on another Smartphone.

To import on iPhone/iPad, save the email attachment with “Save to Files” –> On My iPhone/iPad -> “BlueNRG_Mesh”

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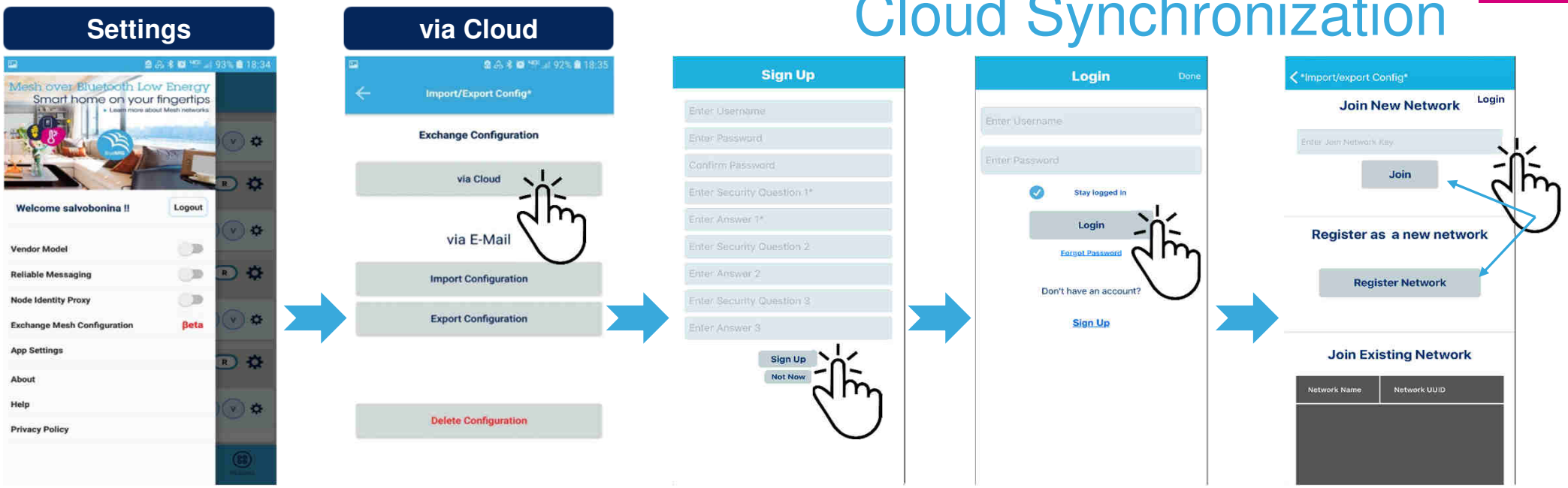
Exchange Provisioning DB Configuration via Cloud Synchronization



Sign-up

Login

Join or Register a new network

Cloud Network scenarios

- Register a New Network
- (Re) Join an Existing Network (pre-registered by you)
- Join a New Network (by invitation)

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STSW-BNRG-Mesh Documentation

AN5285 - STSW-BNRG-Mesh Friend and Low Power features (NEW!)

- **How to enable low power operations, in agreement with Bluetooth Mesh Profile v1.0 and Friendship concept**

UM2290 - BlueNRG Mesh Android API guide for Mesh over Bluetooth low energy
UM2417 - BlueNRG Mesh iOS API guide for Mesh over Bluetooth low energy

- **Start developing Bluetooth Low Energy Mesh applications on Android devices**
- Network creation
- List un-provisioned nodes
- Provision a new node
- Send unicast/broadcast commands
- Save/Restore network configuration
- Register/Un-register callbacks

UM2180 - Getting started with the ST BLE Mesh Android application (*)
UM2361 - Getting started with the ST BLE Mesh iOS application (*)

(*) Differences due to available control and libraries to design the App Unified User Interface available since v1.05.000

- **Provision, un-provision, and control nodes in Bluetooth Low Energy Mesh network**

UM2295 - Getting started with the ST BlueNRG-Mesh embedded firmware

- **Start developing Bluetooth Low Energy Mesh applications on available platforms**
- Core functionality for secure provisioning and communication
- Smart Light sample application

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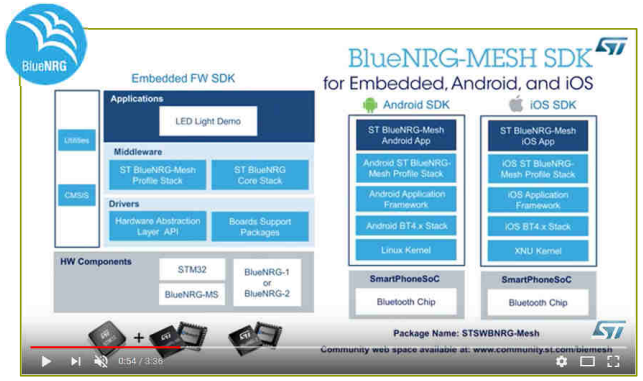
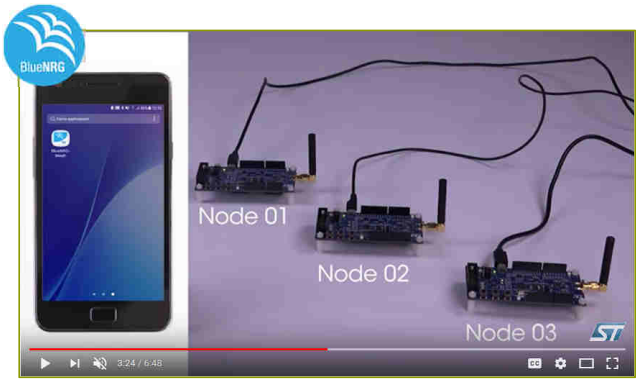
BlueNRG-Mesh SDKs – Videos



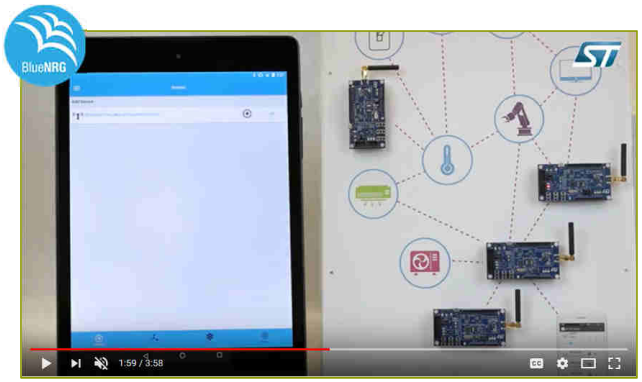
Introduction to BlueNRG-MESH

http://www.youtube.com/watch?v=NMeHUAlaPxI



Getting started with BlueNRG-Mesh

http://www.youtube.com/watch?v=MV5M5AHMuU0



BlueNRG-MESH: Provisioning & Transfer

www.youtube.com/watch?v=8ocXQmQa-dA

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BlueNRG-Mesh Additional Resources

- **Bluetooth SIG website:** Bluetooth Mesh deep dive from the official
  - Bluetooth Mesh specification
  - Bluetooth Mesh overview
  - Bluetooth Mesh FAQ
- **BlueNRG-Mesh SDK** available (firmware, mobile app for Android, iOS):
  - www.st.com/blemesh
- **BlueNRG-mesh community forum**
  - http://community.st.com/blemesh
- **ST BLE Mesh Android application** available on **Google Play Store**:
  - https://play.google.com/store/apps/details?id=com.st.bluenrgmesh&hl=en
- **ST BLE Mesh iOS application** available on the **Apple iTunes App Store**:
  - https://itunes.apple.com/us/app/bluenrg-mesh/id1348645067?mt=8

Conclusion: BlueNRG-Mesh

- A SIG certified BLE Mesh library running on ST's BlueNRG SoC series
- Multiple evaluation platforms: BlueNRG evalkit, Nucleo kit and BlueTile
- Easy-to-use SDK, providing Firmware, Android and iOS app source code
- Customers already shipping ST BlueNRG-2 with BlueNRG-Mesh in high volume!

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BlueNRG