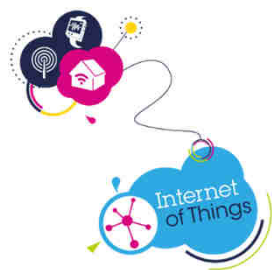




BlueNRG-MESH

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

Raffaele RIVA



Technology Tour 2019

Boston, MA | November 5



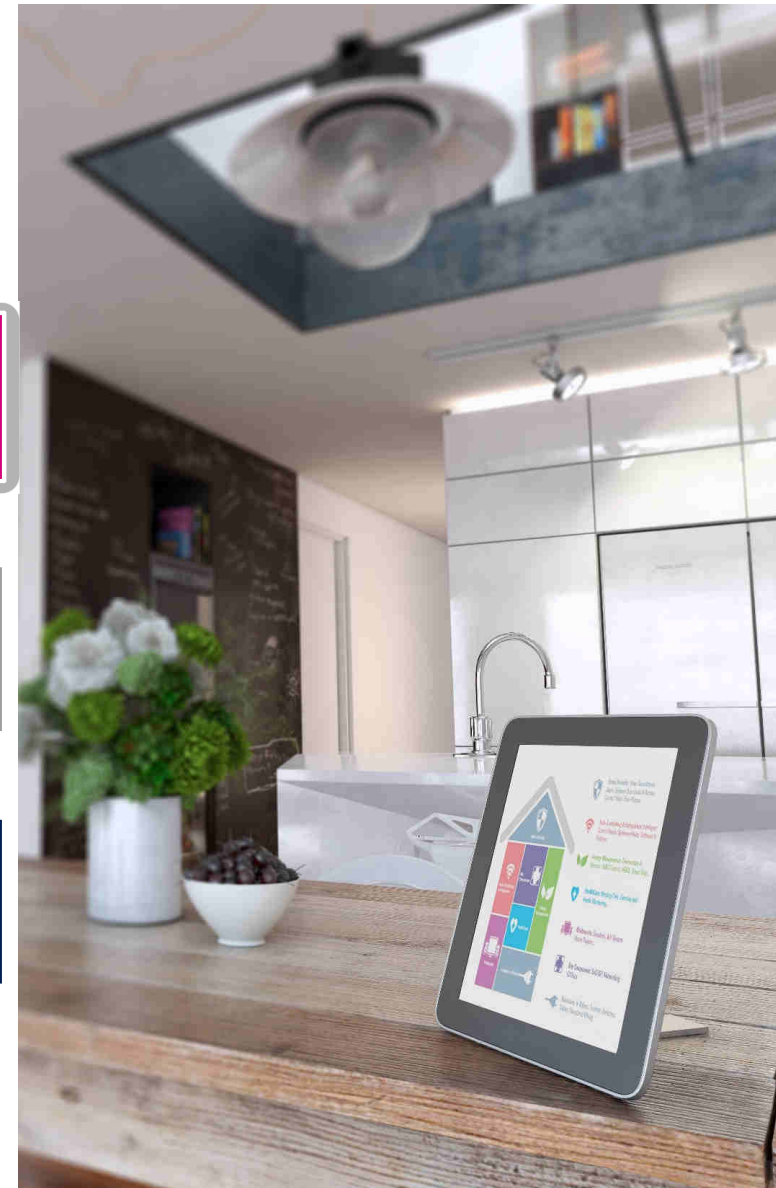
BlueNRG-Mesh



Bluetooth Mesh Basics

BlueNRG-Mesh SDK Solution

Getting started with BlueNRG-Mesh



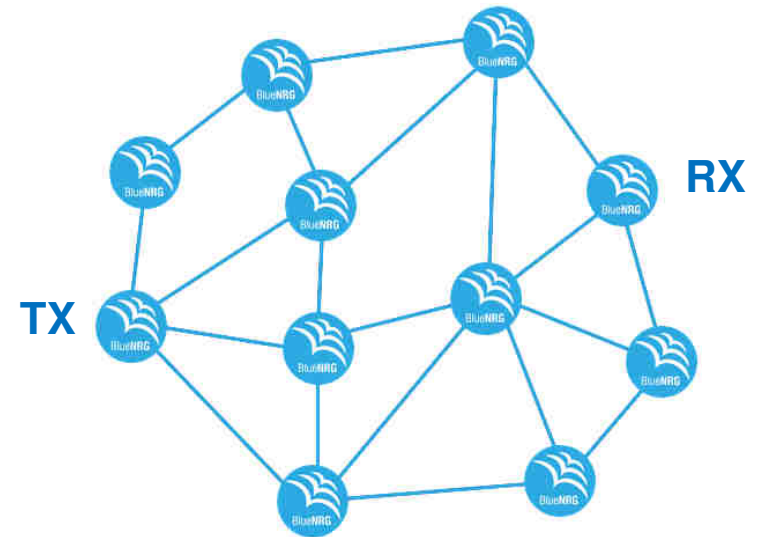
What is the BLE Mesh?

3

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)**.



BLE MESH: Backed up by Industry Leaders

4



companies supporting the launch
of Bluetooth mesh networking

3M

AIR
CABLE

ARM



cortet™
by CEL



SILVAIR



Bluetooth
5



Extending Bluetooth Capabilities

5

The Bluetooth Mesh network topology optimizes the power consumption.

PAIRING one-to-one



**1 MASTER with
Up to 8 SLAVES**



DATA TRANSFER

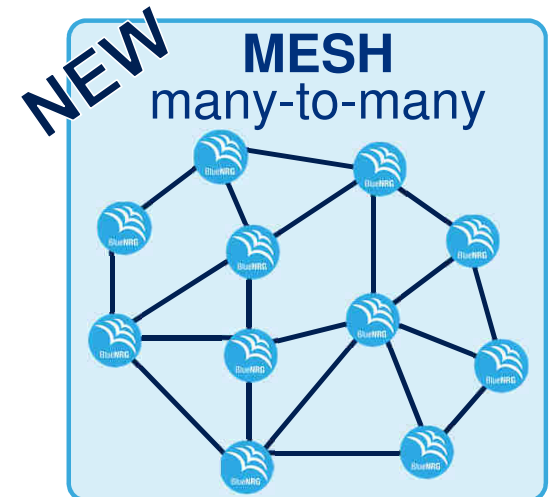
- Sports & fitness devices
- Health and wellness devices
- Peripherals and accessories

BROADCASTING one-to-many



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

6

The Bluetooth SIG MESH extends the capabilities of Bluetooth Smart chips to answer **more and more complex applications.**

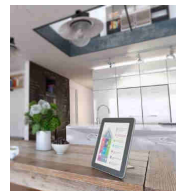
The protocol has been developed with the **Smart Lighting industry** in mind.

- 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


Smart Home/Building




Smart Things




Smart Industry



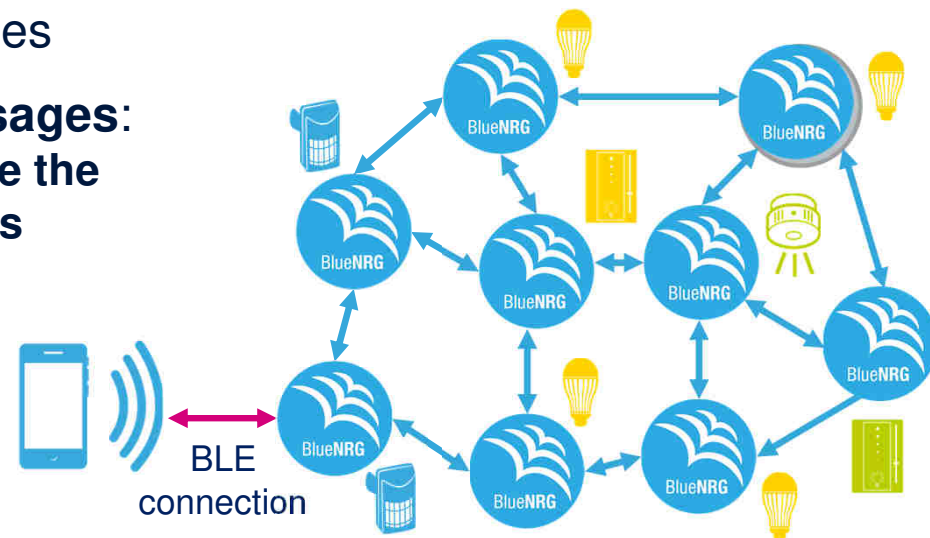
Bluetooth® Mesh Topology

Managed Flooding

7

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

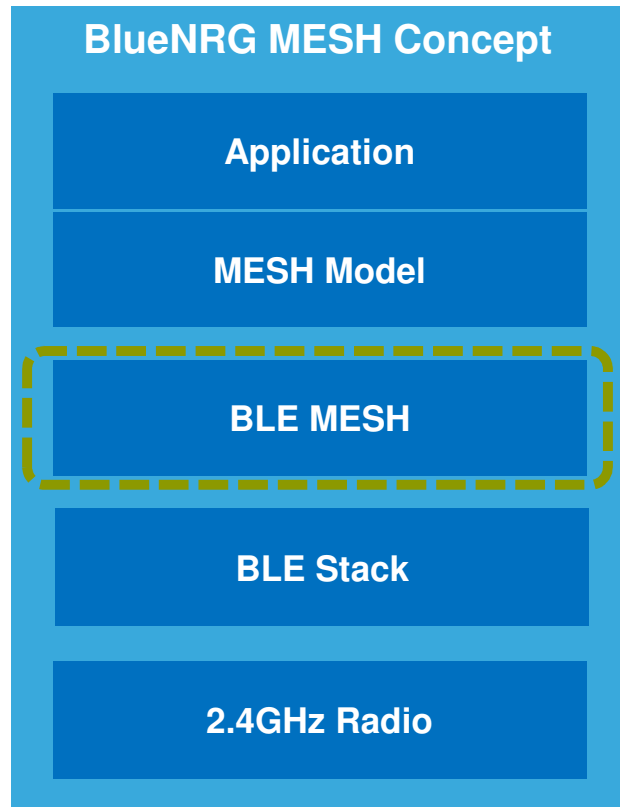
- **Message relay** extends the communication range (Multi-hop data transmission)
- **No single point of failure**
 - does not require any centralized operation nor coordination
 - dynamic self healing
- **Direct communication** between contiguous nodes
- **Rules to restrict** devices from **re-relaying 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





Bluetooth MESH vs BLE Stack

8



- 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



Security, Attacks and Protection

9

- 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

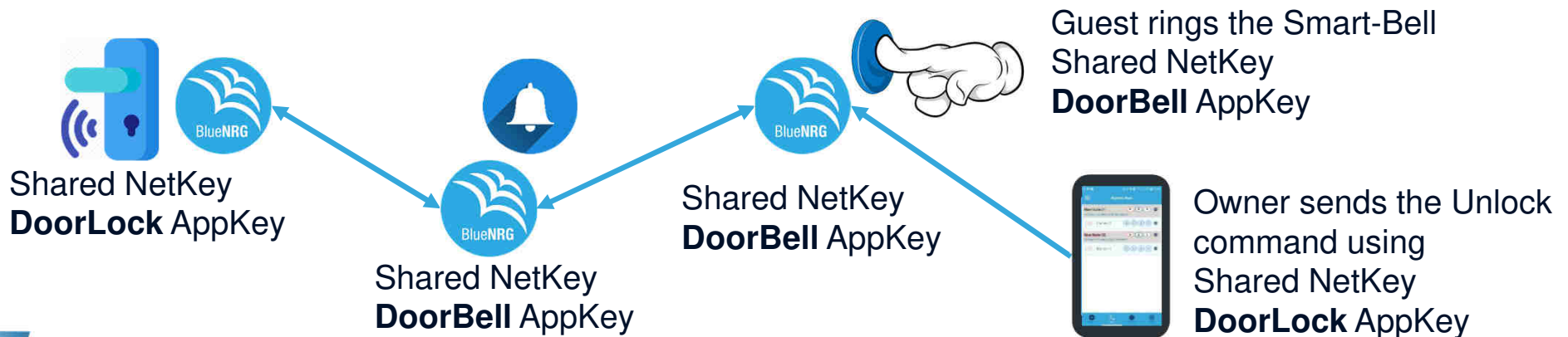
10

- **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?

11

- 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**

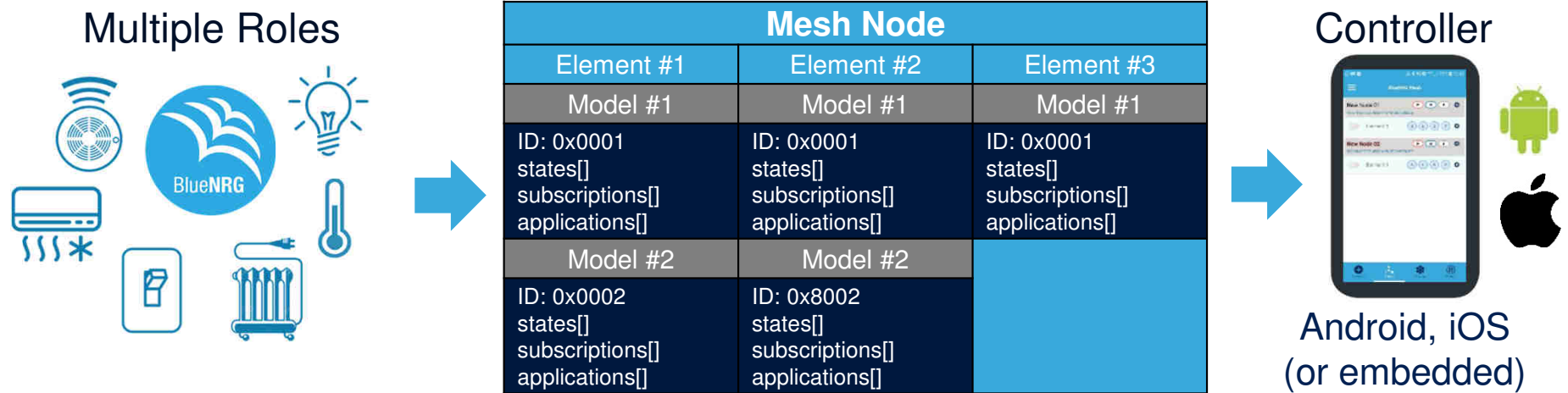


Bluetooth® Mesh for Smarter Devices

12

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**



- **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

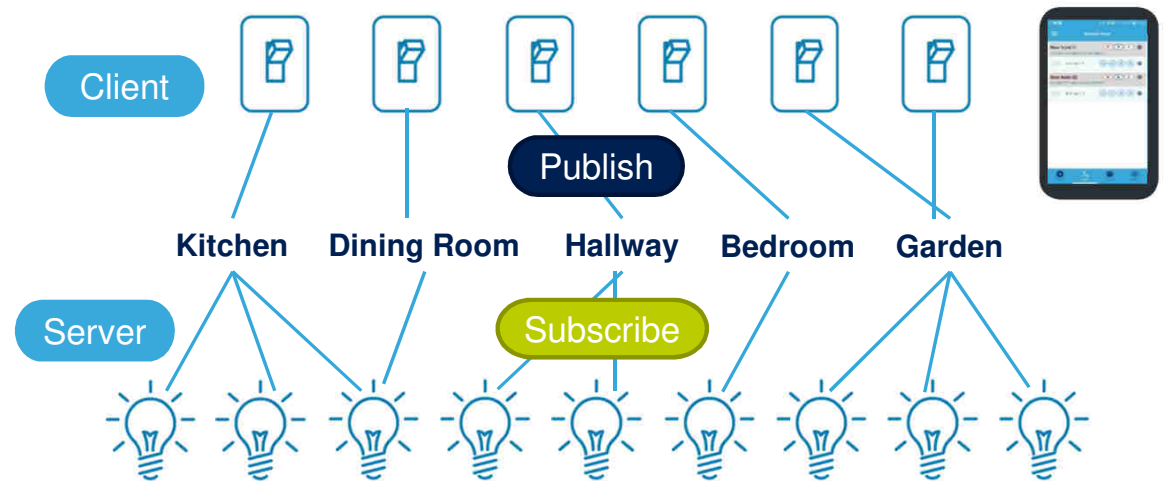
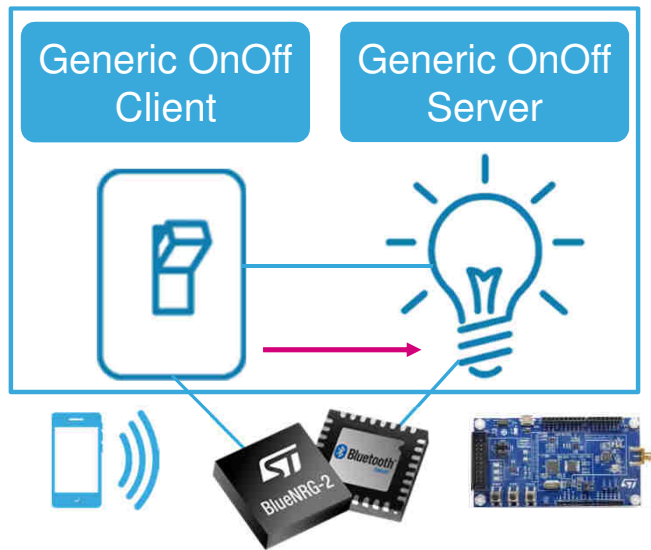
- **Models:**

- 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

13



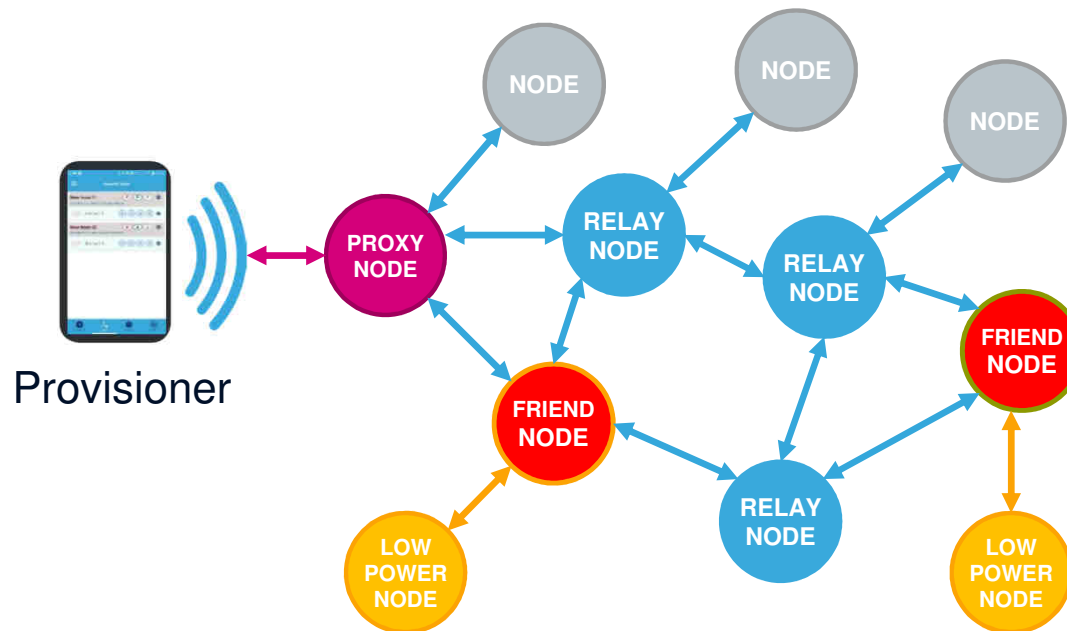
- Publish: send a message to unicast /virtual /group address
 - A **Client** device (e.g. Switch/Smartphone) can **publish messages** (e.g. ON/OFF control) and a **Server** device (e.g. a light bulb) can **subscribe** and be **notified** of new command arrival.
 - Also, a Client can **publish** a message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

Bluetooth® Mesh Network Topology

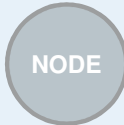
Nodes Types

14

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.



- Expose the interface for Smartphone/ Tablet to interact with a mesh network



- Simple leaf node whom you don't want to relay messages (Weak nodes or Resource constrained nodes)



- Able to retransmit received messages
- Enable multiple "hops" in the network



- Battery operated devices
- Primarily send but Rarely receive messages
- No need 100% duty cycle: mostly sleep

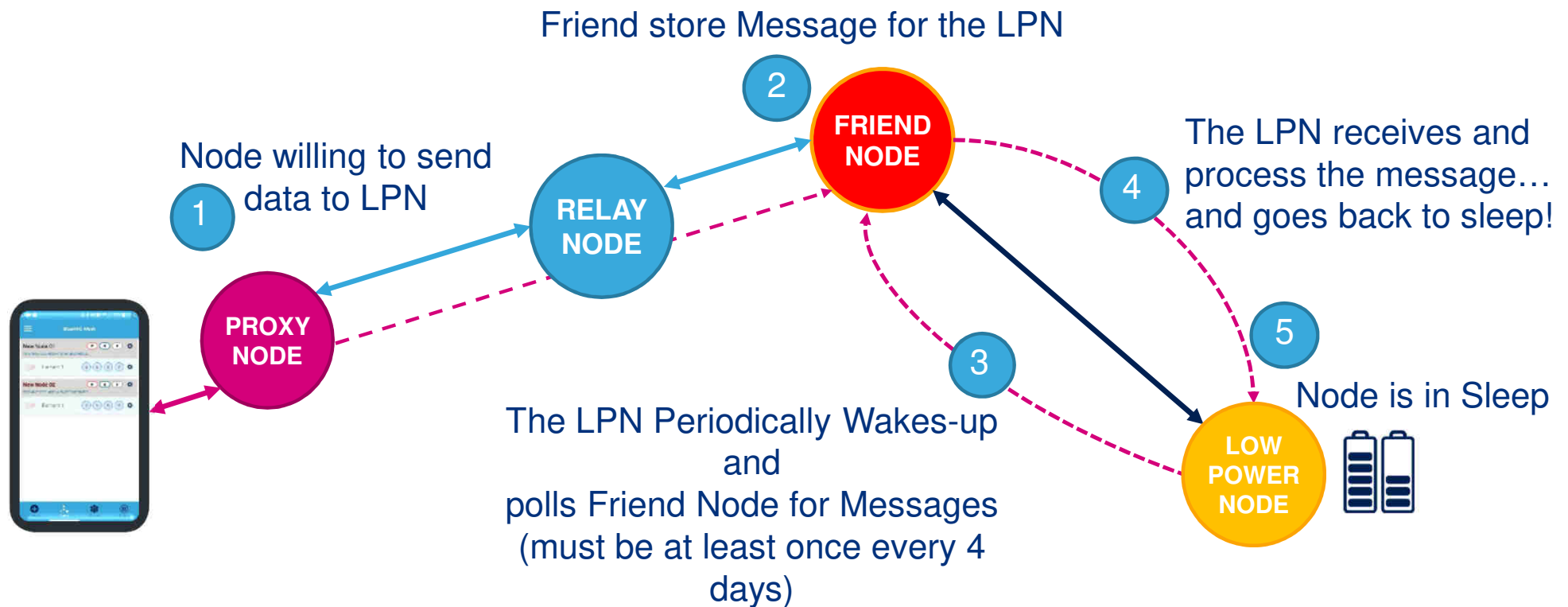


- Stores messages addressed to LPNs and delivers them whenever the LPN polls for "waiting messages"

Bluetooth® Mesh Entities

Low Power & Friendship Node

15



BlueNRG-Mesh

Bluetooth Mesh Basics



BlueNRG-Mesh SDK Solution

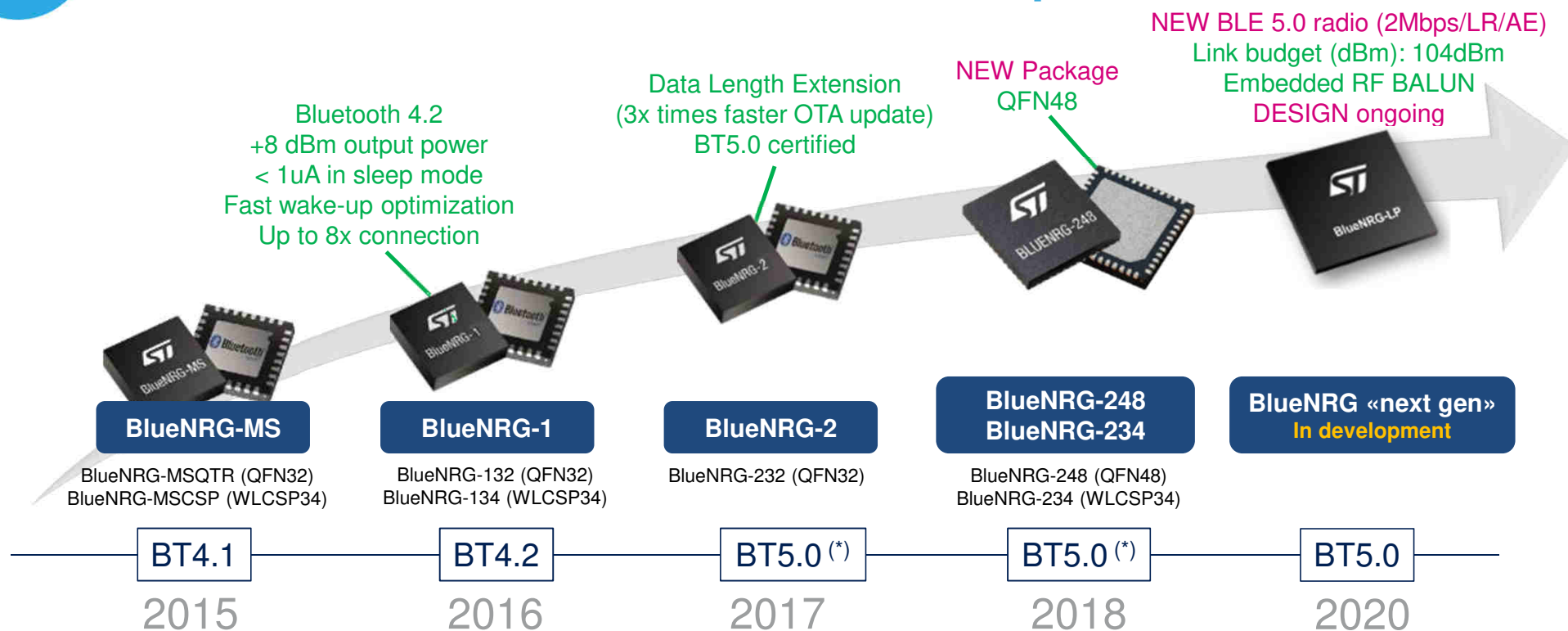
Getting started with BlueNRG-Mesh





BlueNRG chipset evolution

17



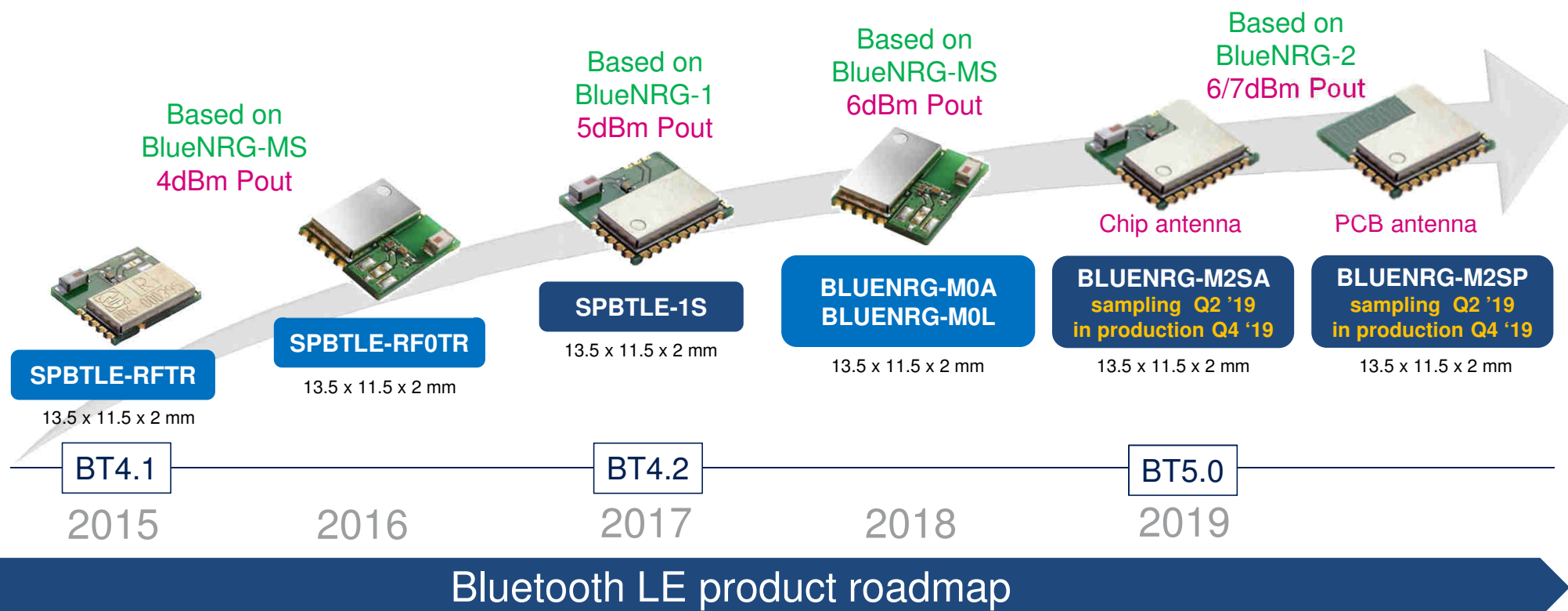
Bluetooth LE product roadmap

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



BlueNRG Modules Portfolio

18



NETWORK PROCESSOR

SoC PROCESSOR



- SDK
 - **Firmware, Android and iOS app sources**
 - www.st.com/blemesh

• ST BLE Mesh app on Store

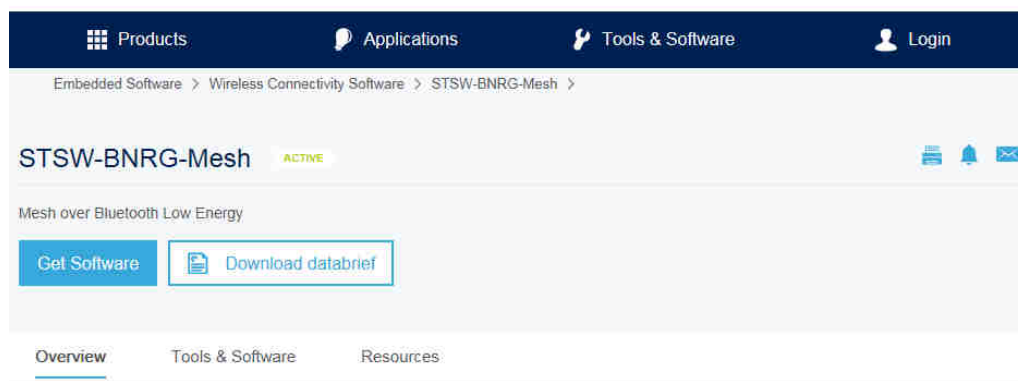


- BlueNRG-mesh community forum
 - <http://community.st.com/blemesh>



STSW-BNRG-Mesh

19



BlueNRG-Mesh is a software solution for connecting multiple BLE (Bluetooth low energy) devices in Mesh networks for Internet of Things (IoT) solutions. It enables true two-way communication between Bluetooth-enabled devices in powerful, secure, integrated and range-extending Mesh networks.



The solution is compatible with the ST BlueNRG product family range.

Bluetooth SIG Certification

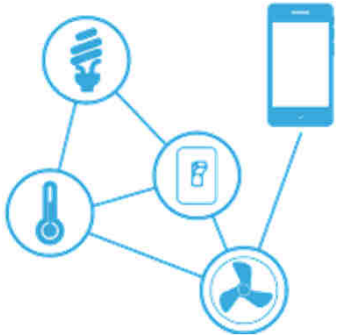
20

- **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**



Bluetooth Qualification
Certified
BlueNRG-Mesh
QDID: 116029

BlueNRG-Mesh in Numbers



Hop latency
30 ms avg

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

BLE Mesh 1.0 SIG
certified

Provisioning procedure
10-15 seconds average

**Mesh Library
Memory footprint**
55.2 KB Flash
5.3 KB RAM



Message Payload
8 bytes unsegmented
64 bytes segmented

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

Compatible with both
BLE 4.X or 5.0



BlueNRG-Mesh Roadmap

22

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



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>



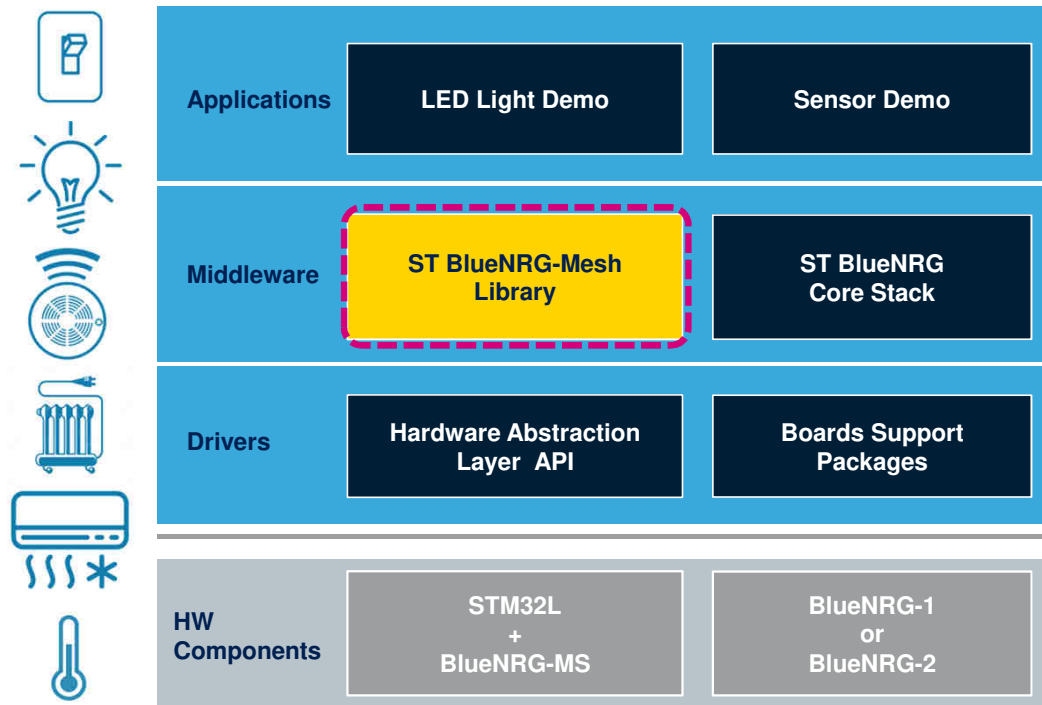
Available on SoC and network processor

BlueNRG-MESH SDK

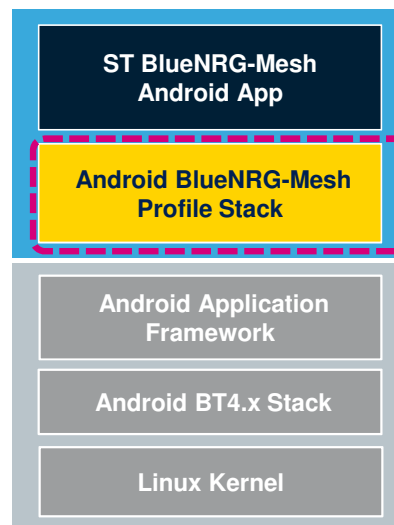
for Embedded, Android and IOS

23

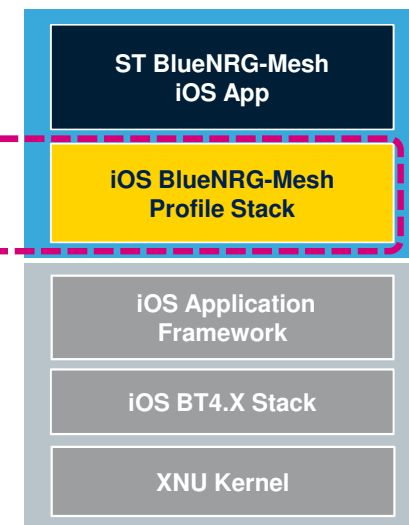
SDK SW Packages: STSW-BNRG-Mesh
and X-CUBE-BLEMESH1



 Android SDK



 iOS SDK

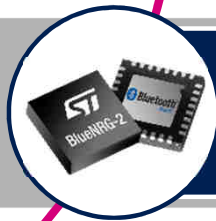


BlueNRG-Mesh

Bluetooth Mesh Basics

BlueNRG-Mesh SDK Solution

Getting started with BlueNRG-Mesh



BlueNRG-MESH SDK

Hardware Platform Support

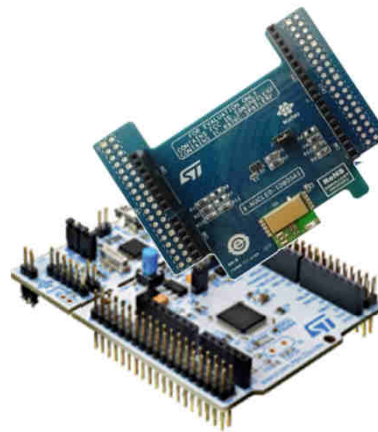
25



STEVAL-IDB007V2
BlueNRG-1

STEVAL-IDB008V2
STEVAL-IDB009V1
BlueNRG-2

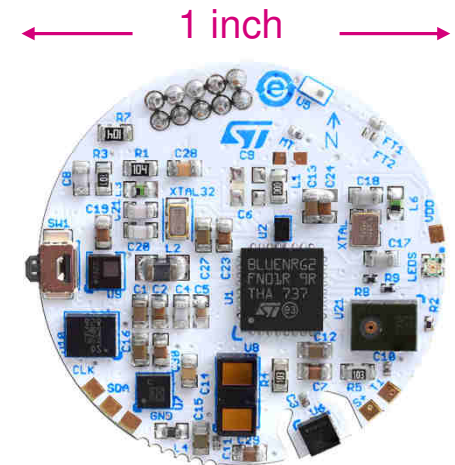
SW Package: STSW-BNRG-Mesh



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



STEVAL-BCN002V1B

aka «BlueTile»

BlueNRG-2

SW Package: STSW-BNRG-Mesh



BlueNRG-MESH SDK

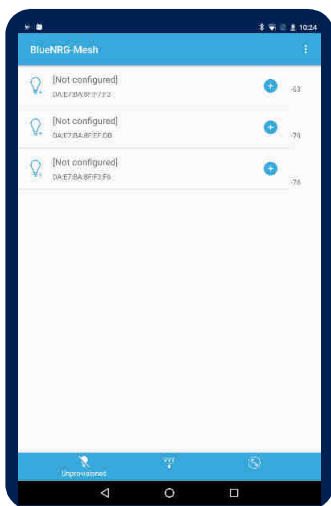
Software Platform Support

26

BlueNRG-Mesh App



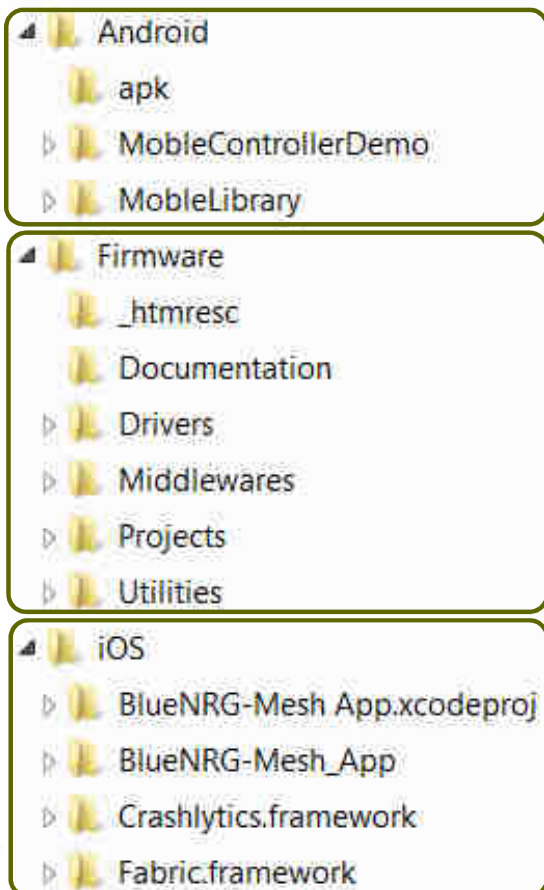
**ST BLE Mesh app
for Android and iOS**



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>

Contents of STSW-BNRG-Mesh Package



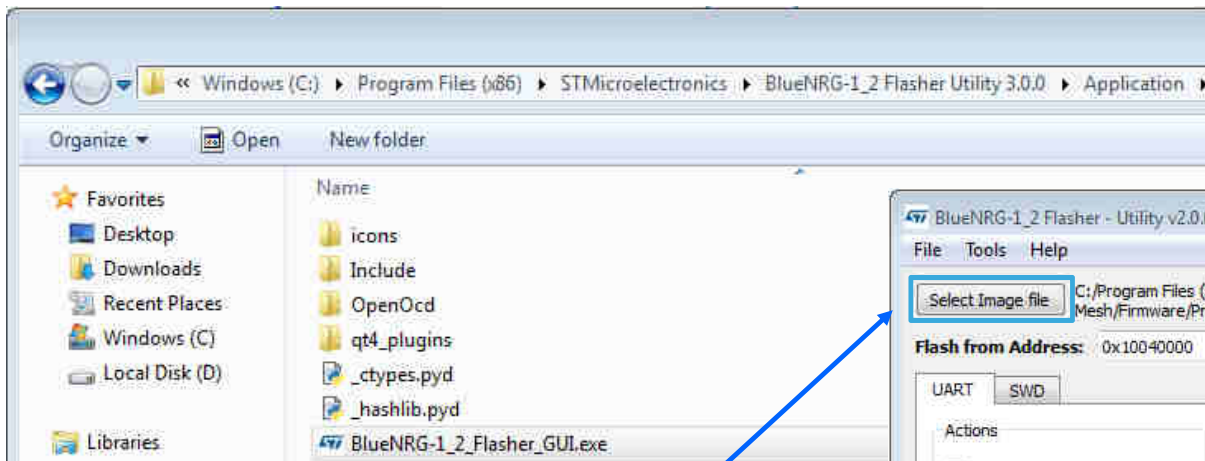
- ST BLE Mesh Android SDK
 - **App Source Code for Android Studio**
 - Mesh Library
 - APK
- Firmware SDK
 - **Examples for BlueNRG-1, BlueNRG-2**
 - **Middleware** folder with **libraries** for **Mesh** and **BLE** communication
 - **Drivers** folder with **HAL** and **drivers** for supported **boards**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



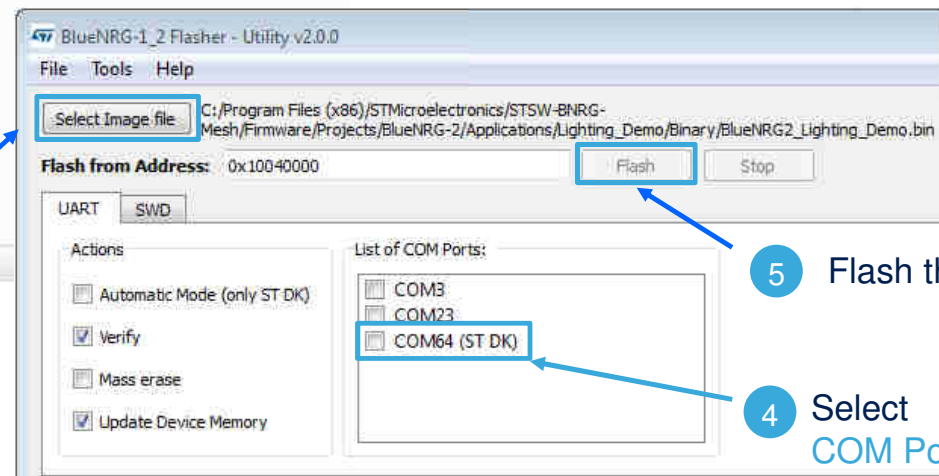
STSW-BNRGFLASHER for BlueNRG-1/2

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"**



- 5 Flash the Board

- 4 Select COM Port

- 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



ST BLE Mesh: Provisioning of the Nodes

29

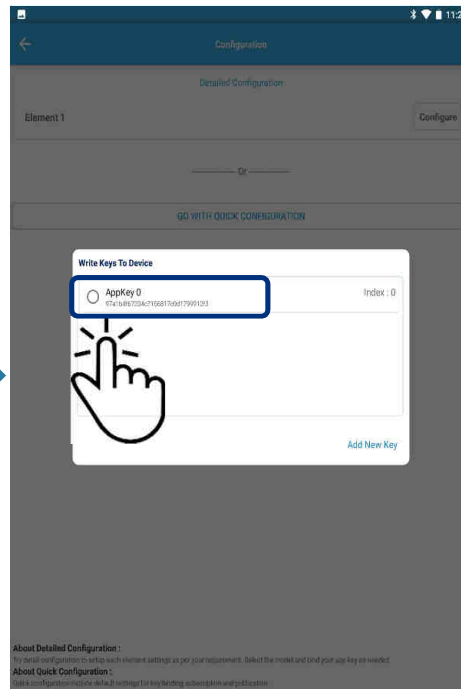
Provisioning



Before the provisioning the ones listed are called **“devices”**

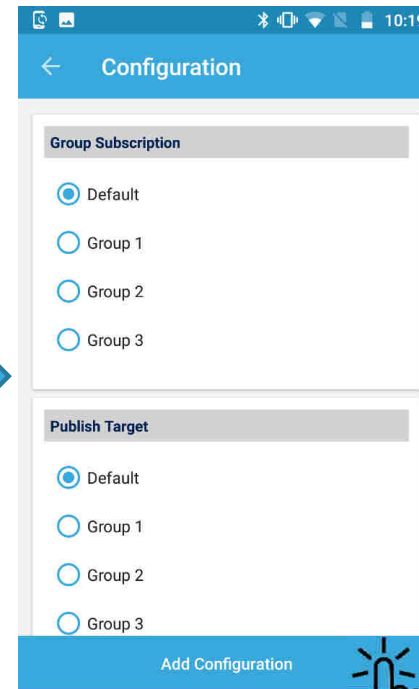


AppKey Select



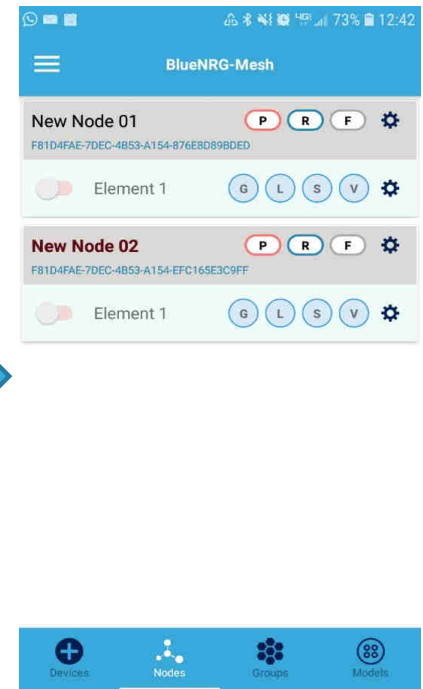
Select the default Application Key or Add a New one

Address Configuration



The Node can be added to a specific group of elements

List of provisioned Nodes



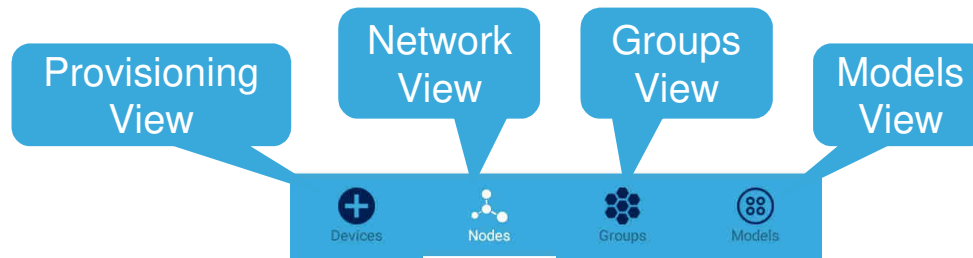


ST BLE Mesh: Nodes List Tab Features

30

The screenshot shows the 'BlueNRG-Mesh' app interface. It displays two nodes: 'New Node 01' and 'New Node 02'. Each node has a list of elements, with 'Element 1' being the first. Callouts highlight the following features:

- Element inside the node:** Points to 'Element 1' under 'New Node 01'.
- Proxy, Relay and Friend roles are supported:** Points to the 'P', 'R', and 'F' role buttons for 'New Node 01'.
- Proxy Node indicated with the name in bold:** Points to the bold text 'New Node 02'.
- Models Supported: Generic, Lighting, Sensor, Vendor:** Points to the 'G', 'L', 'S', and 'V' model buttons for 'New Node 02'.

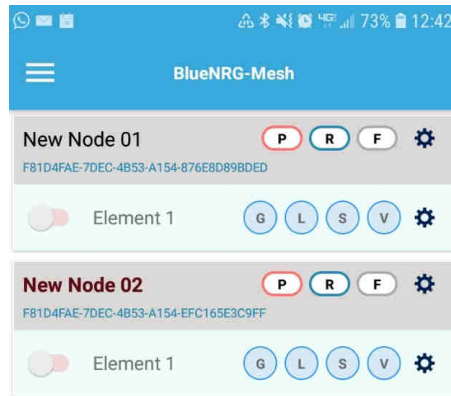




ST BLE Mesh: Models Selection

31

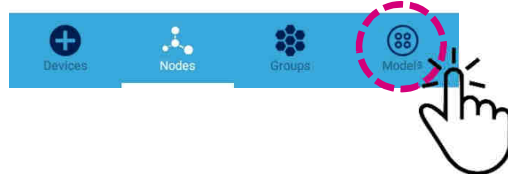
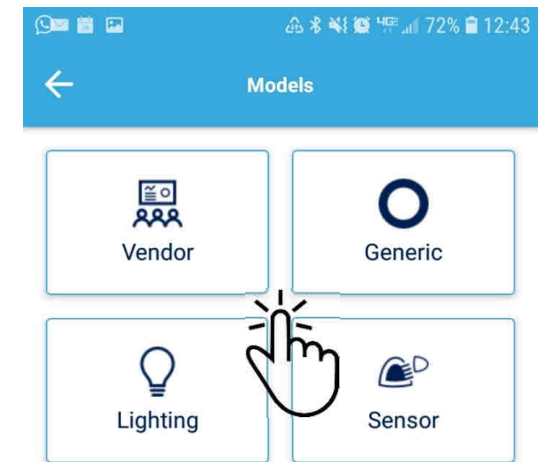
Nodes List



Models selection

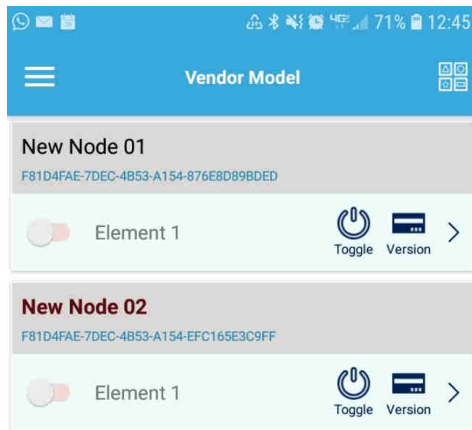
- Different screen for each mesh model
- Send model specific commands
- Selected choice is saved

Model Selection





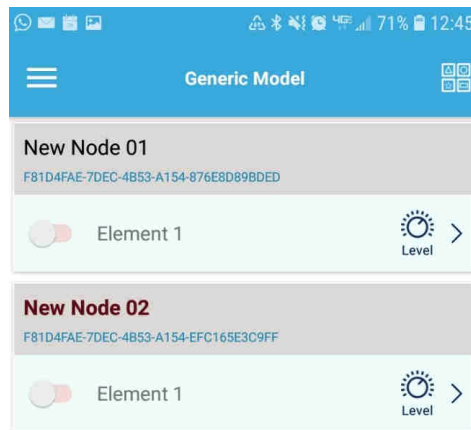
Vendor Model



- Supported Commands
 - Vendor on/off
 - Version query
- * **Vendor model allows for transmitting custom payload.**



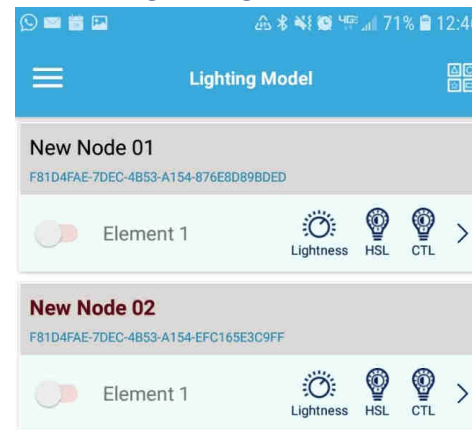
Generic Model



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



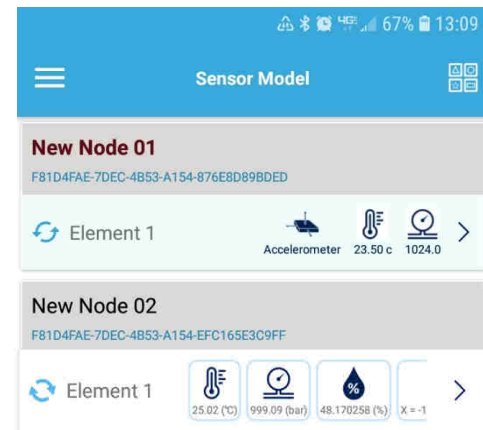
Lighting Model



- 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

33

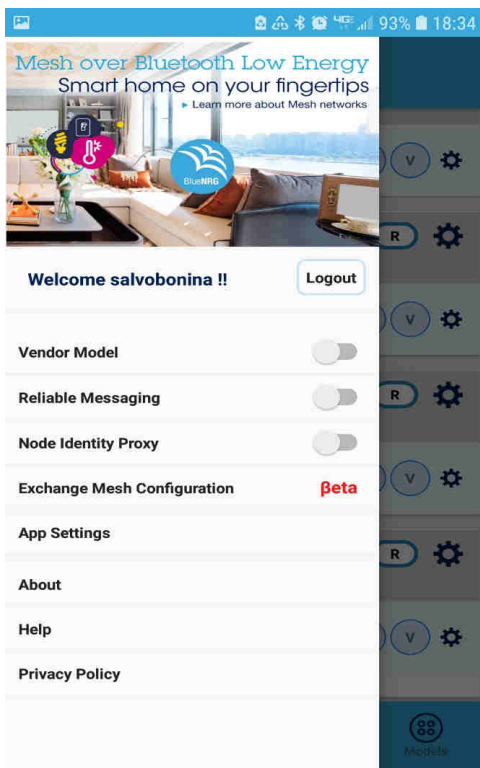
- **Stores security info & parameters** to operate in a mesh network
- Shared in **JSON** format.
- Allows another Smartphone to manage and control the mesh network.
- Two ways to share
 - **Via email** – Instantly share network with another smart phone
 - **Via Cloud** – Our mesh cloud web app allows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



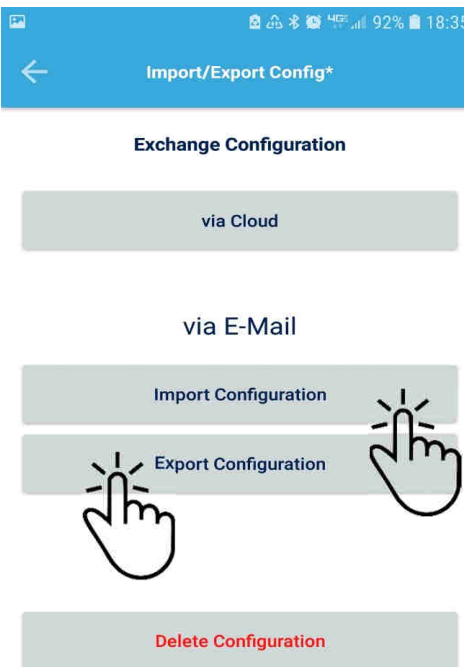
Exchange Provisioning DB Configuration via email

34

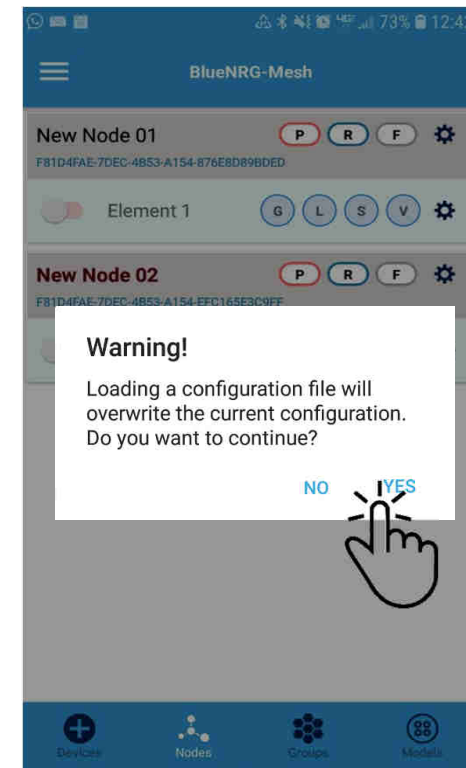
Settings



Import/Export Configuration



Replace current configuration



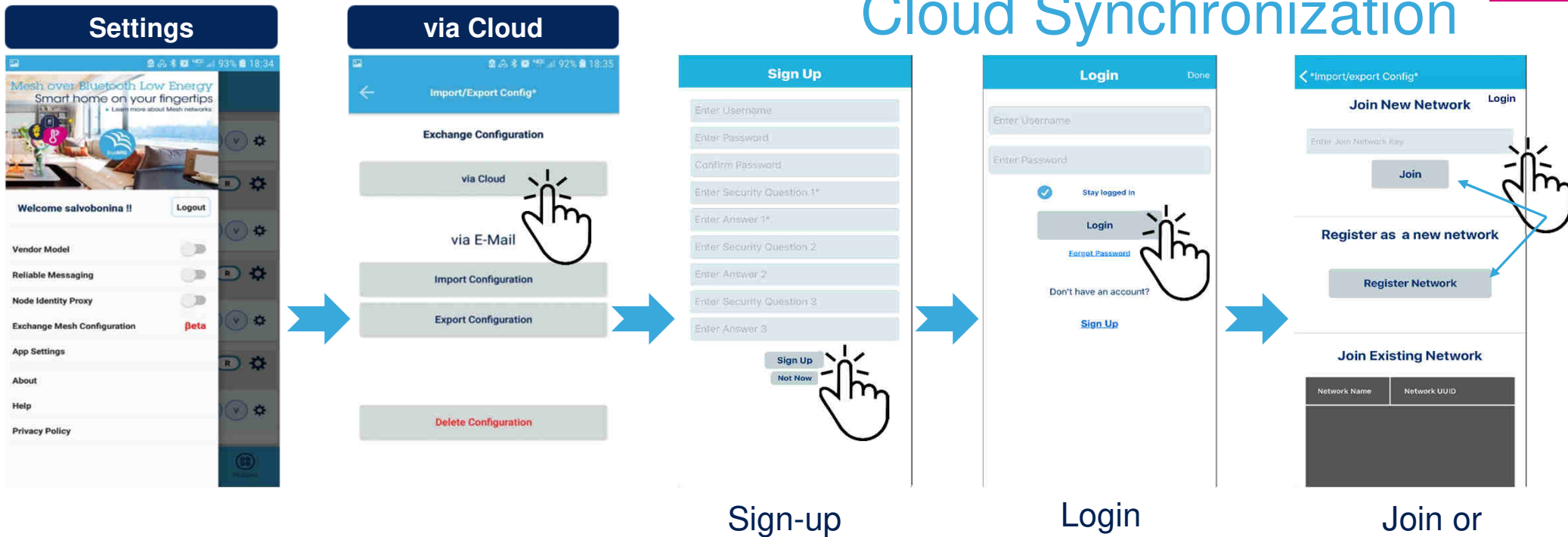
**Export Configuration on one Smartphone.
Import Configuration on another Smartphone.**

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



Exchange Provisioning DB Configuration via Cloud Synchronization

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Cloud Network scenarios

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

STSW-BNRG-Mesh Documentation

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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

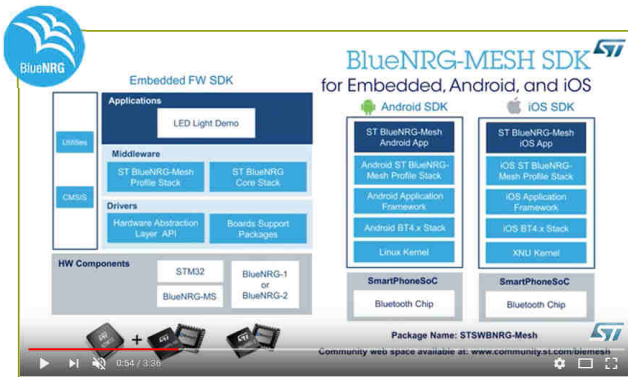
UM2295 - Getting started with the ST BlueNRG-Mesh embedded firmware

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



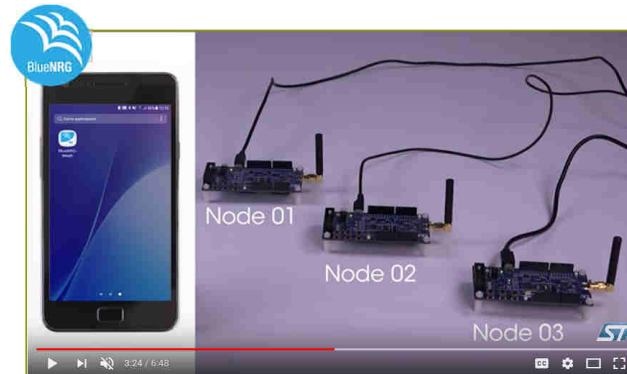
BlueNRG-Mesh SDKs – Videos

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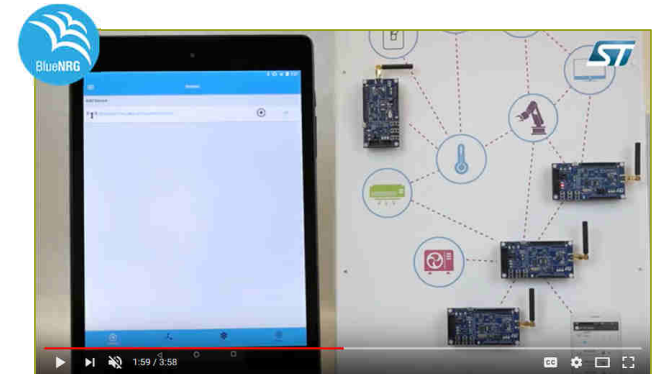
Introduction to BlueNRG-MESH

<http://www.youtube.com/watch?v=NMeHUAiaPxl>



Getting started with BlueNRG-Mesh

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



BlueNRG-MESH: Provisioning & Transfer

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

BlueNRG-Mesh Additional Resources

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- **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

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- 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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