Product Overview

TI Wi-SUN® FAN Stack - Software Overview

ABSTRACT

The TI Wi-SUN® software overview describes the overall Wi-SUN® FAN software content and supporting ecosystem from Texas Instruments based on the TI Wi-SUN® FAN 1.0 implementation. The document provides a high level overview of the features and capabilities of the Wi-SUN® FAN software without specific details. For further information on APIs and implementation details, see the Wi-SUN® Developers Guide and the SIMPLELINK-LOWPOWER-F2-SDK.

Table of Contents

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1 Acronyms

This product overview uses the following acronyms:

- BR - border router
- CA- certificate authority
- CLI - command-line interface
- CoAP - constrained application protocol
- FAN - field area network
- GTK - group transient key
- IETF - internet engineering task force
- IPv6 - internet protocol version 6
- NWP - network processor
- OAD - over-the-air download
- PKI - public key infrastructure
- PMK - pairwise master key
- PTK - pairwise transient key
- RFC - request for comments
- RN - router node (also mentioned as embedded router)
- RTOS - real time operating system
- UDP - user datagram protocol

2 Overview

Wi-SUN® is a standards-based mesh network with frequency hopping. The Wi-SUN® Alliance (wi-sun.org) has more than 300 members from 46 countries, with 100M+ devices deployed world-wide. Wi-SUN® supports IPv6 protocol suite and standards based multilayer security. The standard supports multiple data rates and frequency bands to meet different regulatory requirements world-wide. Applications include smart grid and smart city applications, with certified products enabling multi-vendor interoperability.

TI's Wi-SUN® FAN 1.0 is based on the open source IETF RFC components integrated on top of the Wi-SUN® compliant TI 15.4 Stack. A Network Interface is provided either as the TI Wi-SUN FAN Spinel Client Interface or the TI wfantund Linux network interface. Customers typically develop applications on top of IPv6 using UDP as the transport layer.

TI's Wi-SUN® FAN v1.0.0 design is optimized for a small memory footprint to fit embedded devices, in addition to optimizations for low-power operation. Integration and testing of the software stack is done in tagged, certified releases.

Table 1. Software Overview

Component	Version
TI Wi-SUN® FAN	1.0
Distribution	Included in SDK8.30 for CC13x2 and CC13x4 devices as library code
IDE support	CCS v 12.8 or CCS 1.5 for Microsoft® Windows® 10, Linux®, and macOS®
Compiler support	TI Clang 3.2.2 LTS
RTOS support	TI-RTOS, Free RTOS
Supported devices	Border router: CC1312R7, CC1352P7, CC1314R10, CC1354R10, CC1354P10 Router nodes: CC1312R, CC1312PSIP, CC1352R, CC1352P, CC1312R7, CC1352P7, CC1314R10, CC1354R10, CC1354P10
Recommended development kits	Border router: Personal Computer (PC) host + CC1352P7 LaunchPad™ Development Kit or CC1354P10 LaunchPad™ Router nodes: CC1352P LaunchPad™ or CC1354P10 LaunchPad™

TI has certified multiple FAN profiles with the Wi-SUN® Alliance to be used on CC13x2x as well as CC13x4x10 devices. Not every devices support all of the FAN profiles due to constraints of the internal memory of the device. Table 2 lists the Wi-SUN® FAN profiles with the corresponding certificate and the certificate for the PHYs that can be used with the respective device.

Table 2. Wi-SUN® Certifications for FAN Profiles and PHYs

Wi-SUN® Certificate	FAN profile	Corresponding PHYs
WSA0272	FAN profile (router) for CC13x2R or CC13x2P	WSA0260 WSA0262 (800MHz)
WSA0273	FAN profile (router) for CC13x2R7 or CC13x2P7	WSA0261 WSA0263 (800MHz)
WSA0278	FAN profile (border router) for CC13x2R7 or CC13x2P7	WSA0261 WSA0263 (800MHz)
WSA0313	FAN profile (router) for CC13x4R10 or CC13x4P10	WSA0311 WSA0312
WSA0314	FAN profile (border router) for CC13x4R10 or CC13x4P10	WSA0311 WSA0312

3 Reference Examples

The SimpleLink™ SDK incorporates a number of examples for the different roles in a Wi-SUN® FAN. Not every role and example is available for every device. This is due to the memory requirements of some roles. Lower memory devices are therefore not be able to be used as a border router role. A list of examples with the corresponding capable devices is listed in Table 3 and Table 4.

Table 3. Code Examples Included in the SDK

Application	Usage
ti-wisunfan-pyspinel	Python interface module to control a NWP from a Linux or Microsoft® Windows® 10 PC. Public on TI GitHub
ti-wisunfantund	Linux network interface to control a NWP from Linux as a network interface. Public on TI GitHub
ns_br ns_br_src*	Border router in NWP configuration controlled over UART with TI-defined API (based on SPINEL interface layer).
ns_node ns_node_src*	Router node in NWP configuration controlled over UART with TI defined API (based on SPINEL interface layer).
ns_coap_node ns_coap_node_src*	Embedded router node example with CoAP server.
ns_coap_oad_offchip ns_coap_oad_offchip_src*	Embedded router node example with off-chip Over-the-Air-Download capability and CoAP server.
ns_coap_oad_onchip ns_coap_oad_onchip_src*	Embedded router node example with on-chip Over-the-Air-Download capability and CoAP server.
*the src examples include the nanostack source code	

Table 4. Memory Usage With Reference Examples Running on Select TI Devices

SDK examples	Occupied FLASH [kB]	Occupied RAM[kB]	Supported Devices
ns_br	367	122	CC1312R7, CC1352P7, CC1352R7, CC1354P10, CC1354R10
ns_node	310	64	CC1312R, CC1312PSIP, CC1352R, CC1352P, CC1352P7, CC1352R7, CC1354P10, CC1354R10
ns_coap_node, ns_coap_oad_offchip	310	60	CC1312R7, CC1352P7, CC1352R7, CC1354P10, CC1354R10
ns_coap_oad_onchip	310	61	CC1354P10, CC1354R10

For on-chip OAD the FLASH is split into 2 application slots each of 344kB.

The memory footprint is based on using the TIRTOS7 and TICLANG compiler. It is possible that the footprint varies when using FreeRTOS or another compiler. See summary of memory sizes of each device in the wireless MCU overview on TI.com

4 RF Protocols – Wi-SUN® PHYs

Wi-SUN® supports a number of frequencies and data rates to enable world-wide coverage and address different application needs. Major frequency bands used are 902 to 928 MHz for North America, 863MHz to 876MHz for Europe and 920MHz to 928MHz for Japan. Further details and information about frequency plan and channels is available to Wi-SUN® alliance members.

Table 5. Wi-SUN® PHYs and TI Support Overview

Symbol Rate (ksymbol/s)	Modulation Index	Wi-SUN® Mode	Frequency Bands	Regulatory Compliance Targets
50	0.5	#1a	EU	EN300 220
	1.0	#1b	NA, BZ, JP	FCC 15.247
100	0.5	#2a	EU	EN300 220 FCC 15.247
	1.0	#2b	NA, BZ, JP	ARIB STD-108
150	0.5	#3	EU, NA, BZ, JP	FCC 15.247 ARIB STD-T108
200	0.5	#4a	NA, BZ	FCC15.247
	1.0	#4b	JP	ARIB STD-T108
300	0.5	#5	NA, BZ, JP	FCC15.247 ARIB STD-T108

5 Software Block Diagram

Table 6. Overview of Software Layers and TI Implementation

Layer	Wi-SUN® FAN	TI Router and Border Router
NWP	Not Defined	Based on open source SPINEL interface.
Security	EAP-TLS, 802.11i, 802.1X	Based on open source components.
Transport Layer	UDP	
Network Layer	IPv6	
	ICMPv6	
	RPL	
	6LoWPAN	
Data Link Layer	Frequency hopping MAC	Based on TI 15.4 Stack.
PHY Layer	IEEE 802.15.4g	Based on TI 15.4 Stack.

The Wi-SUN® FAN protocol is defined up to the Transport Layer and the TI stack supports UDP as the transport layer.

6 Network Topology and Features

TI's Wi-SUN® FAN 1.0 supports the following device types and designs:

- Border router
  - Based on TI CC13x2x7 series (704KB) and CC13x4x10 series (1MB) memory devices in Network Processor (NWP) mode requiring a Host Processor for providing backhaul connectivity
  - Supports UART communication through a TI defined NWP interface (based on SPINEL interface layer)
- Router node in NWP mode
  - Supported in both TI CC13x2xx series (352 KB), CC13x2x7 series (704 KB) and CC13x4x10 series (1MB) devices
  - Supports UART communication through a TI defined NWP interface (based on SPINEL interface layer)
- Embedded router node

- Based on TI CC13x2x7 series (704KB) and CC13x4x10 series (1MB) memory devices
- Provides an example implementation based on CoAP Application
- Over-the-Air Download (OAD) functionality with off-chip memory for CC13x2x7 series (704KB) and on-chip memory for CC13x4x10 series (1MB)

A network can consist of a variety of the aforementioned devices and roles in a Wi-SUN® FAN. One possible network architecture that displays all of the roles is visualized in Figure 1.

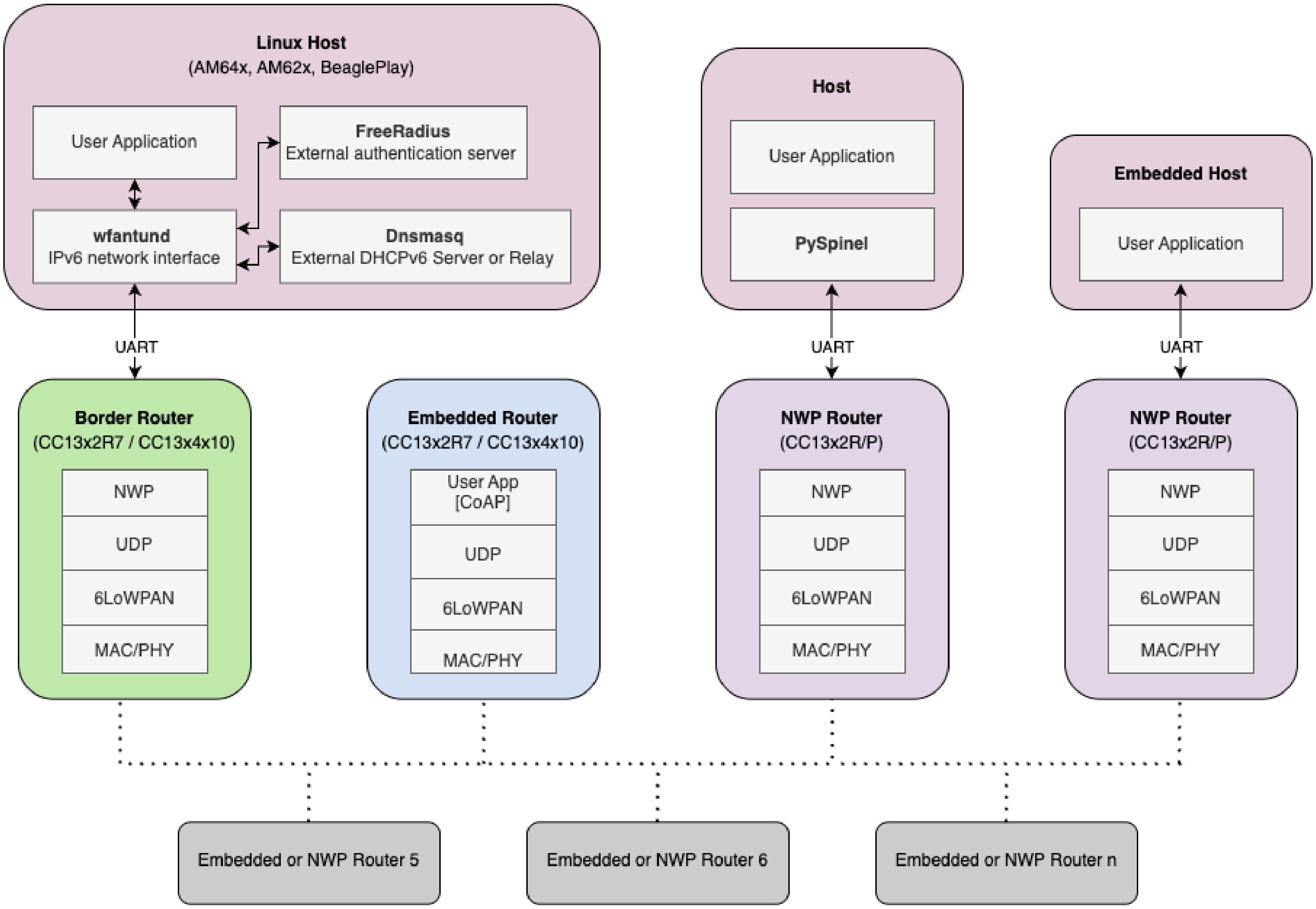

Figure 1. Available Network Architectures With Border Router and Routers Using NWP Implementation and Embedded Routers

The network associated with a border router is called a PAN. Multiple PANs can be connected through a WAN Backhaul to extend the network coverage. This backhaul is not part of the Wi-SUN® FAN specification.

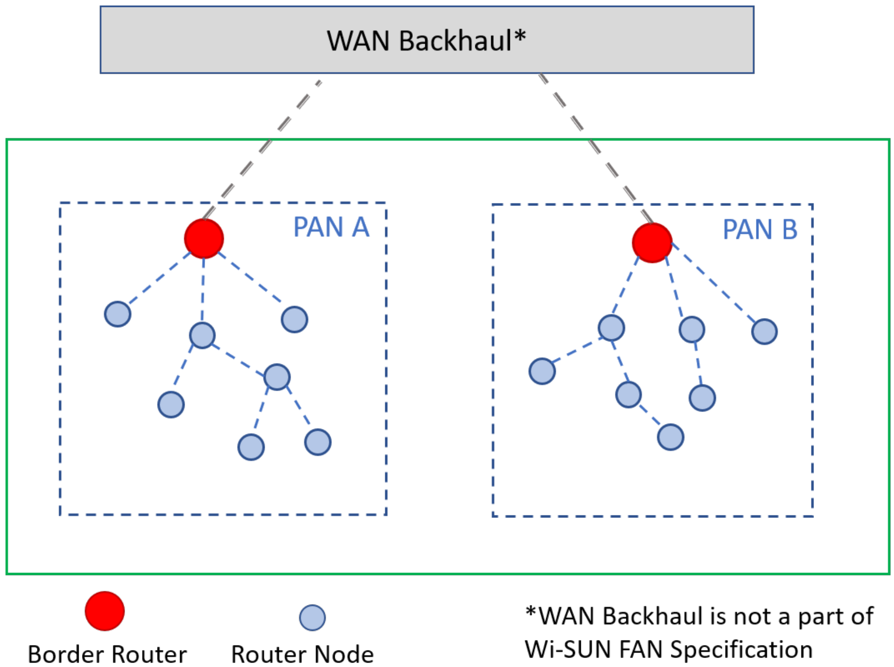

Figure 2. Wi-SUN® Network Topology Consisting of Two PANs

Wi-SUN® FAN 1.0 standard supports up to 24 hops. The network size is limited by border router RAM, in addition to application use-case details. TI recommends using up to approximately 100 nodes per border router for devices with 144KB RAM. Multiple border routers can be used to scale the network as shown in this figure. TI devices with larger memory can support larger networks.

7 Security

TI's Wi-SUN® FAN v1.0.0 design supports best-in-class network security based on the IEEE 802.1x specification:

Table 7. Security Enablers in TI Wi-SUN® FAN v1.0.0

Category	Security Enabler
Wi-SUN® FAN 1.0 security specification	IEEE 802.11i key WAN Management
	IEEE 802.1x for authentication and encryption
	AES-128 encryption
	ECC based key exchange and signature verification
	True random number generation for security protocols
	IEEE802.1AR defined X.509 certificates

Figure 3 summarizes key aspect of the key exchange mechanism:

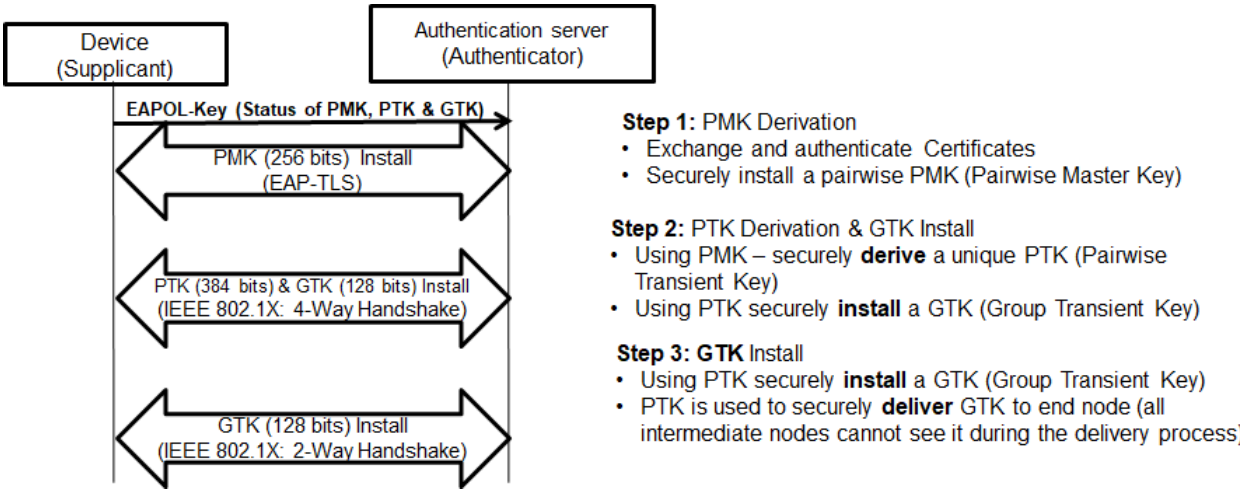

Figure 3. Security Key Exchange Mechanism in Wi-SUN®

7.1 Certificate Management

TI recommends obtaining a unique certificate for each device. Customers can either use their own PKI infrastructure or work with Global Sign (a Wi-SUN® Alliance Partner - wi-sun.org/cyber-security-certificates).

7.2 Key Exchange Process

The following list is an overview of the security key exchange process:

- A unique Pairwise Master Key (PMK) and Pairwise Transient Key (PTK) is established between Device and Border Router
- A PTK is used to securely install a GTK (Group Transient Key) to individual devices
- A GTK is used by devices to encrypt MAC payload packets using AES-128 CCM* as defined in IEEE 802.15.4
- Network management defines the lifetime for different keys and performs key management
- Lifetime of PMK, PTK , and GTK are typically in descending order (default value: 4, 2 and 1 month respectively)

This stack release supports default test certificates (compiled into code for field trials).

8 Performance and Test Data

This performance test is run with a 100-node mesh network using 5-hop network topology.

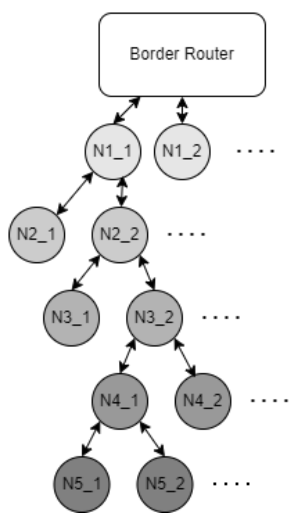

Figure 4. Network Topology for the 100-Node Mesh Network Test

8.1 Latency Test

The border router *pings* each device periodically one by one. The ping packet size is 50 bytes; ping interval is 2 seconds with a ping response timeout of 30s. The test is run for 24 hours.

Table 8. 100-Node Mesh Network Test Data

Test Parameter	Hop 1	Hop 2	Hop 3	Hop 4	Hop 5
End-to-end delay [ms]	265	353	477	645	773
Average packet error rate (PER) [%]	0.00046	0.0017	0.0029	0.0029	0.0091

8.2 Join-time Test

The average join delay is tested with a 100-node network with the 5-hop architecture as shown in Figure 4. Every hop incorporates a different number of router nodes. Table 9 lists average join delay per hop. This delay is defined by the average time it takes from powering up the devices until 100% of the nodes in one hop have joined the network.

An out-of-the-box network with 2-3 nodes joins in a few minutes after powering up. The exact join time is dependent on the network profile, multiple timing factors and the desired data rate. Configure these settings in SysConfig.

Table 9. 100-Node Mesh Network: Join Delay per Hop

Hop	Number of Routers per Hop	Average Join Delay (Minutes)
Hop 1	34	3
Hop 2	16	6
Hop 3	17	7
Hop 4	17	8
Hop 5	16	10

8.3 OAD Test

The OAD tests were conducted with an image size of 352256 Bytes using different block sizes and 50kbps PHY. The results vary depending on the number of hops that the data has to travel to the destination. OAD was tested for a maximum hop count of 2. Consider these values to be taken in a mostly noise-free environment. Heavy traffic leads to repeating packets, which increases the total download duration.

Table 10. Wi-SUN® OAD Performance

Number of Hops	Block Size (B)	Download Duration (Minutes)
1	128	8:30
1	512	3:31
1	1024	3:01
2	128	15:56
2	1024	4:34

9 Out-of-box Experience

This stack release is intended for initial development of a Wi-SUN® network. This release provides the following out-of-box experience:

- Setup a border router by using PCs communicating with a NWP border router over a CC1352x7 or CC1354x10 series device (a reference implementation is provided)
- Compile router notes (even in a NWP model) as a self contained solution that can join a network when powered on and respond to an IPv6 ping
- Perform field testing by pinging individual devices without building a customer application
- Build customer applications on a separate host and communicate with a router over a NWP interface using UART

- Host a simple CoAP server over a router device through an embedded router node example based on CC13x2x7 and CC13x4x10 series devices
- Reference Python scripts that provide examples for interacting with out-of-box CoAP server resources
- wfantund host application integrating the border router and/or the router node as native IPv6 interface for Linux with separate IPv6 adress for border router and host
- Develop single-chip custom applications over Wi-SUN® stack using the embedded router node example as reference

Start by going to the CC1352P7 Product Folder.

10 Training

As part of the SimpleLink™ Academy TI provides training material for the Wi-SUN® FAN implementation including hands-on examples using the CC13x2R7 and CC13x4R10 LaunchPads. The examples are split into three parts:

1. Fundamentals to Wi-SUN® FAN: This training guides the user on how to create a simple Wi-SUN® FAN using one border router connected to a host PC running PySpinel CLI to control the network. Basic serial commands to start the network and ping connected nodes are explained.
2. Over-the-Air Download: This training explains the concept of OAD using Wi-SUN®, the memory layout necessary for saving multiple images and how to setup the OAD environment and perform the download.
3. CoAP Messaging: This training is intended to introduce fully embedded router nodes to transmit CoAP messages between the BR and RN. Examples are given for confirmable and non-confirmable CoAP messages. An example for an EV charger application sending status information to the BR is given.

Find these trainings through the links above or on dev.ti.com.

11 Tools

11.1 Code Composer Studio™ IDE

Latest release per October 2023 is v12.8.0 or v1.5. Link to Code Composer Studio™: www.ti.com/tool/CCSTUDIO.

11.2 SysConfig

The SysConfig Utility is a software tool which provides a Graphical User Interface for configuring pins, peripherals, radios, subsystems, and other components for TI devices. Results output as C header and code files that can be imported into software development kits (SDKs) or used to configure custom software.

11.3 Packet Sniffer

Latest release per April 2025 is v1.11.0. Link to Packet Sniffer 2: Download link

- Wi-SUN® PHY modes supported: #1a, #1b, #2a, #2b, #3, #4a, and #4b
- Packet sniffer is single channel only, but multiple boards can be used to sniff multiple channels

11.4 TI Wi-SUN® FAN Spinel

The TI Wi-SUN® FAN Spinel CLI exposes the configuration and management APIs running on a TI Wi-SUN® FAN Network Processor (NWP) via a command line interface. This tool is primarily suitable for manual experimentation with controlling TI Wi-SUN® FAN NWP instances and is not meant for expanding into production grade driver software for TI Wi-SUN® FAN NWP devices. A detailed guide on how to use the TI Wi-SUN® FAN NWP Interface can be found here: NWP Interface Guide.

This tool is helpful for the following purposes:

1. As a path for automated testing and performing field trials with TI Wi-SUN® FAN NWP running on TI SimpleLink™ devices.
2. As a simple debugging tool for NWP builds of TI Wi-SUN® FAN stack.

Public on TI GitHub

11.5 TI wfantund – User-Space Network Interface Driver

The wfantund provides a native IPv6 network interface to a connected TI Wi-SUN® FAN border router that is operating in NWP mode. The repository (public on TI GitHub) provides software to run on a Linux host with a Wi-SUN® FAN NWP connected over UART. wfantund also offers the possibility to visualize the network topology graphically with the use of a webapp as shown in Figure 5. This webapp is also part of the wfantund GitHub reposit.

Features of wfantund include:

Enables host to embedded device, host to host and multicast IPv6 communication

- Provides a native IPv6 interface to an NCP with the configuration option of separate IPv6 addresses for host and NCP

Supports External Authentication and/or DHCPv6 Servers

- Configures the host to route authentication and DHCP traffic up through wfantund (examples for FreeRADIUS and Dnsmasq).

Allows to test network performance

- Supports iperf bandwidth measurement to calculate network throughput via the TUN interfaces created by wfantund
- Supports ping latency testing

Web application

- Show all devices with IPv6 adress and nick names
- Perform Over-the-Air-Download of new firmware
- Visualize network architecture and link quality
- Send COAP commands to all router nodes to toggle LEDs
- Ping devices

Reference cross compilation support is provided for the TI AM64x platform as well as the BeaglePlay board.

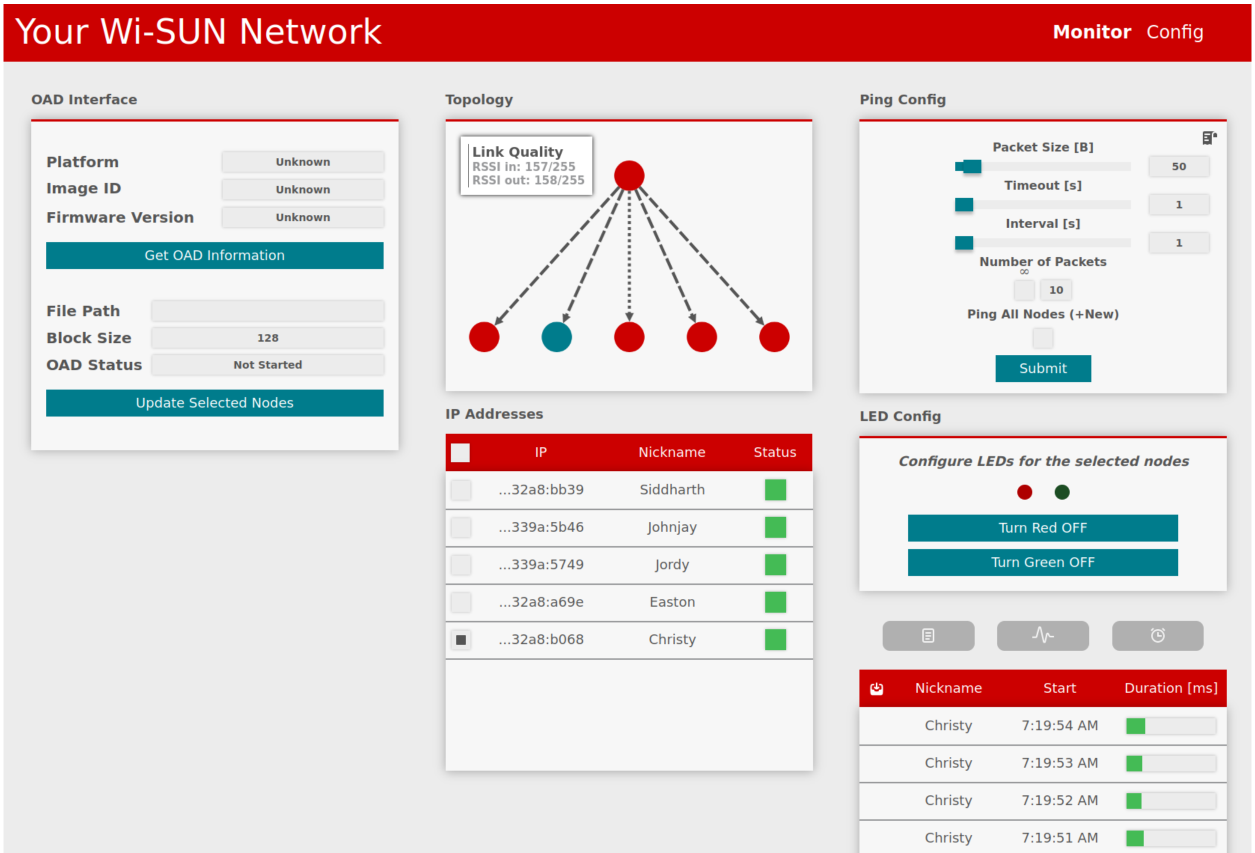

Figure 5. FAN Visualization in wfantund Webapp

12 Known Limitations

This version is tested with a 100-node network.