works with
BY SILICON LABS
VIRTUAL CONFERENCE

SILICON LABS

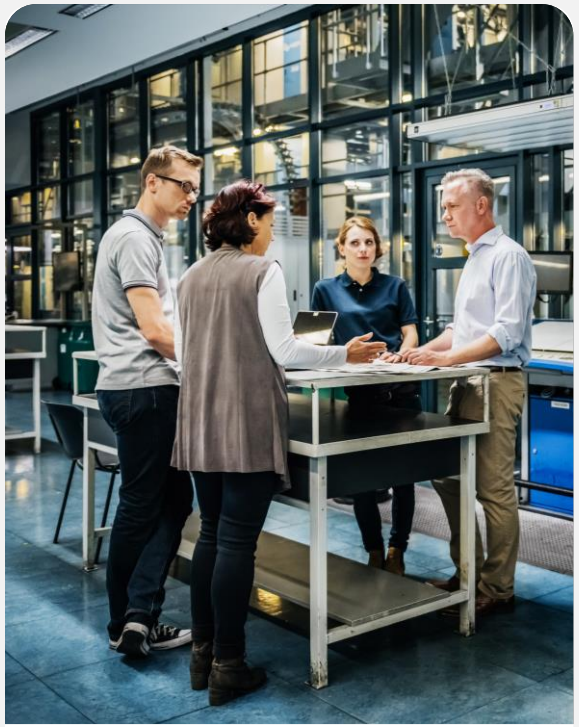
WSN-300: Building Large Scale Smart City Networks with Wi-SUN

WSN-300: Building Large Scale Smart City Networks with Wi-SUN

5 min	What is Wi-SUN?
10 min	Wi-SUN FAN Specification
5 min	Mesh vs Long-Range Protocols Comparison
10 min	Silicon Labs Wi-SUN Solution
15 min	Large Network Simulation
10 min	Break
35 min	Wi-SUN CoAP Hands-on Session
10 min	Q&A

What is Wi-SUN?

Wi-SUN, Wireless Smart Ubiquitous Network



INITIAL PROBLEM

Proprietary Protocols

Lack Of Interoperability

Non-IP Based

Limited Security

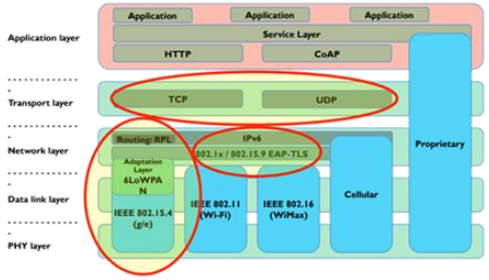
WI-SUN ALLIANCE

Silicon Labs Promoter Member

46 Countries

300+ Members

100+ Million Devices Deployed



FAN SPECIFICATION

OPEN Standards Based

Interoperable

IPv6/6LoWPAN

Mandatory Security

FSK, OFDM

CERTIFICATION

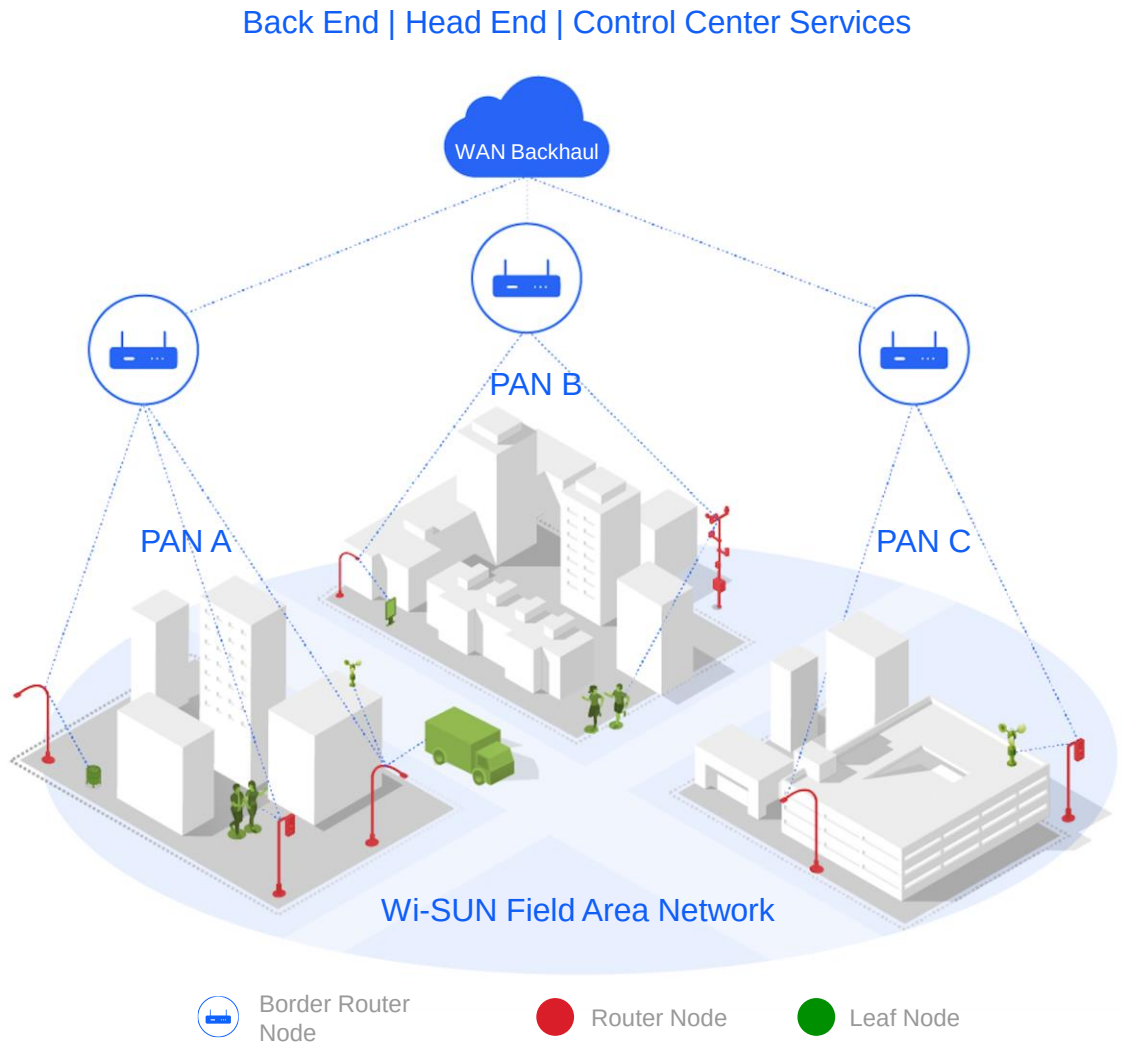
PHY Certification

FAN Profile Certification

6 Independent Test Houses

~50 FAN Certified Products

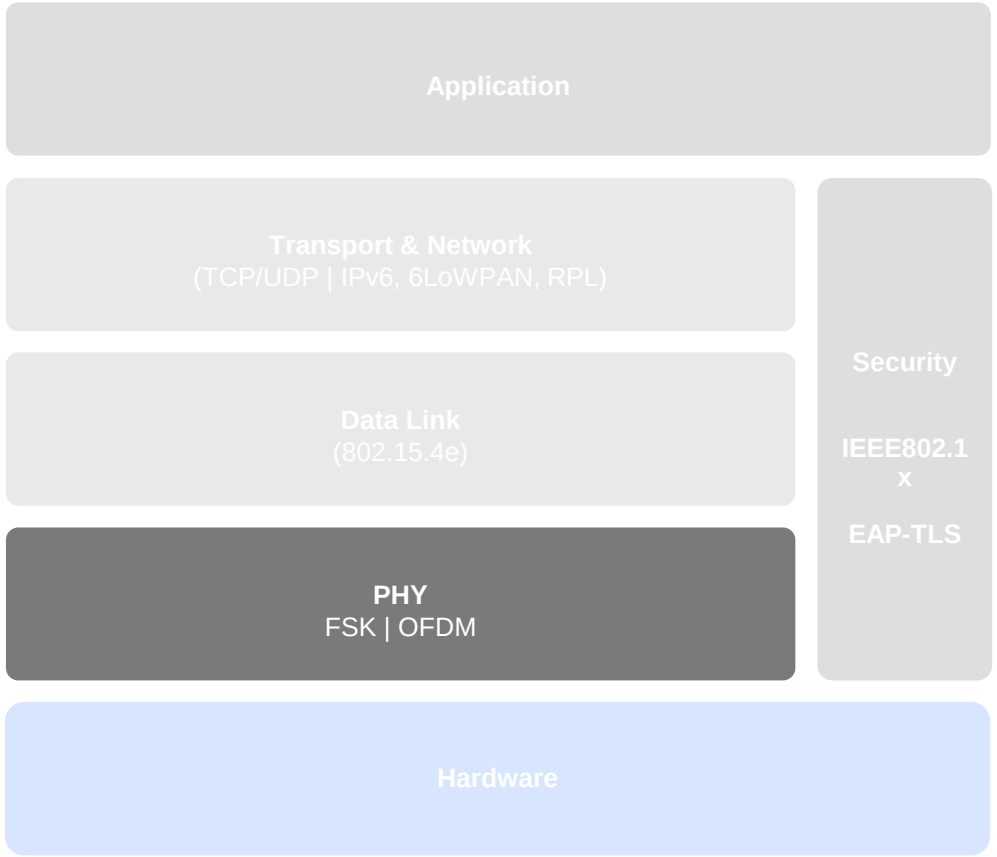
Wi-SUN Solution Keywords



- **Border Router**
  - Provides WAN connectivity
  - Maintains source routing tables
  - Node authentication and key mgmt.
  - Disseminate PAN wide information such as broadcast schedules
- **Router Nodes**
  - Upward and downward packet forwarding within a PAN
  - Services for relaying security and address management protocols
- **Leaf Nodes**
  - Discover and join a PAN
  - Battery powered devices
  - Send/receive IPv6 packets

Wi-SUN FAN Specification

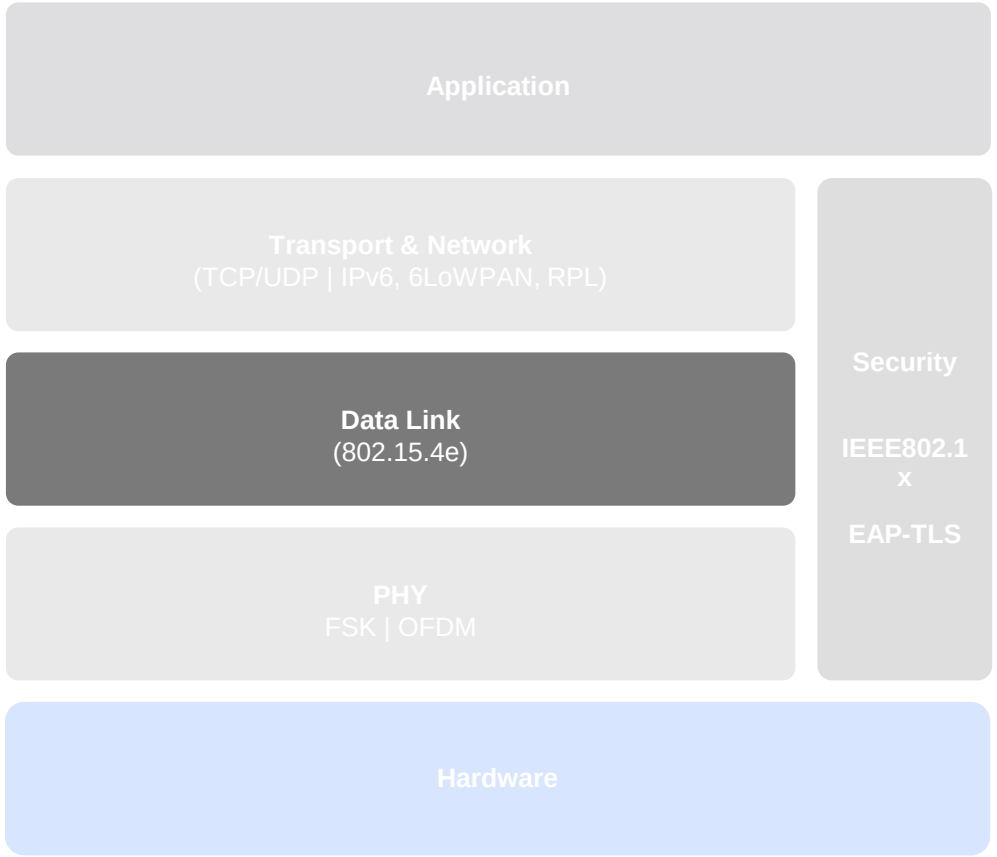
Wi-SUN PHY Layer



Globally available large selection of 802.15.4g based PHY modulations and data rates

- **Specification:**
  - 802.15.4g
    - PHY amendments to 802.15.4 for the Wireless Smart Ubiquitous Networks
    - 802.15.4u - 865 – 867 MHz India band
    - 802.15.4v - 870–876 MHz, 915-921 MHz Europe bands,
      - 902-928 MHz band in Mexico,
      - 902-907.5 MHz and 915-928 MHz bands in Brazil,
      - 915-928 MHz band in Australia and New Zealand
- **Customers have the option to use modulations like**
  - FSK – ubiquitously deployed modulation in smart infrastructure
  - OFDM – high throughput low latency PHY for next generation products
- **FAN 1.0 supports – FSK only**
- **FAN 1.1 supports – FSK, OFDM**

Wi-SUN Data Link Layer



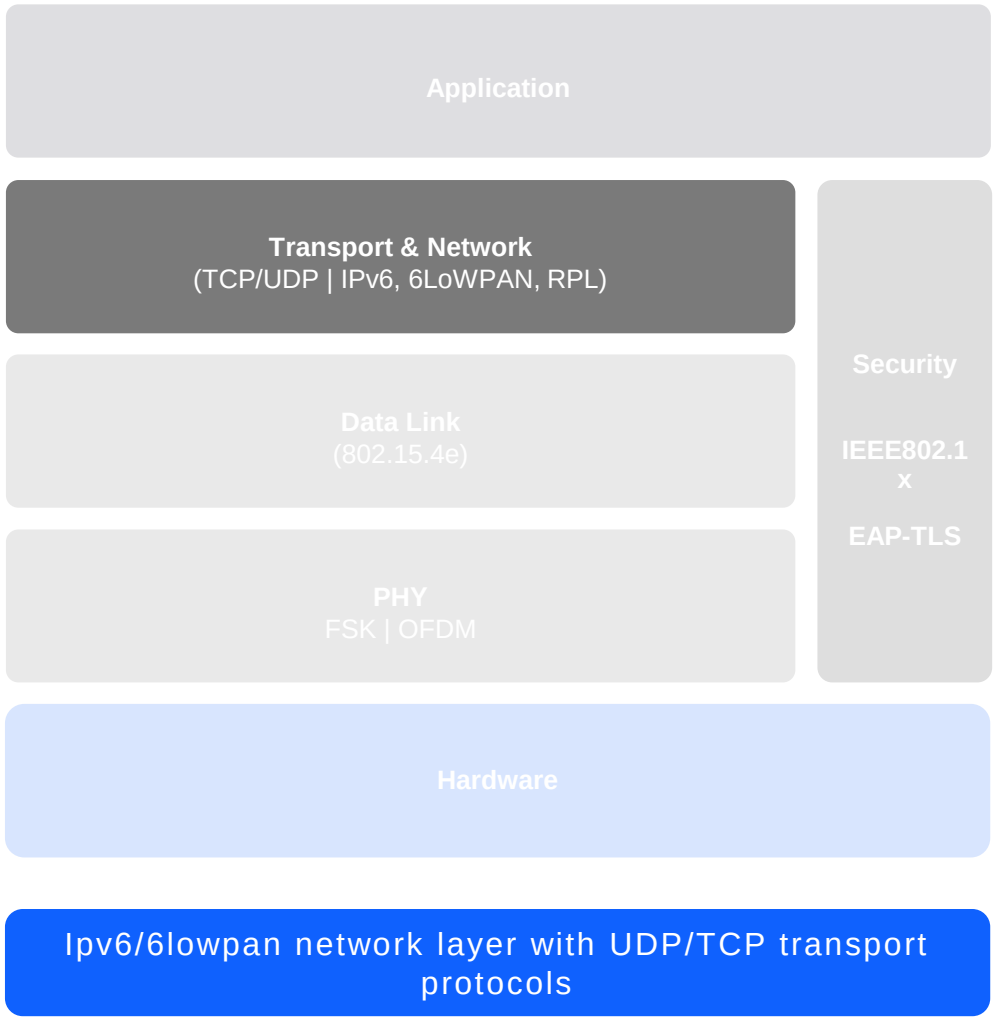
802.15.4e MAC with frequency hopping mechanism and CSMA/CA

- **Specification:**

  Two sub layers, an LLC sub-layer & a MAC sub-layer

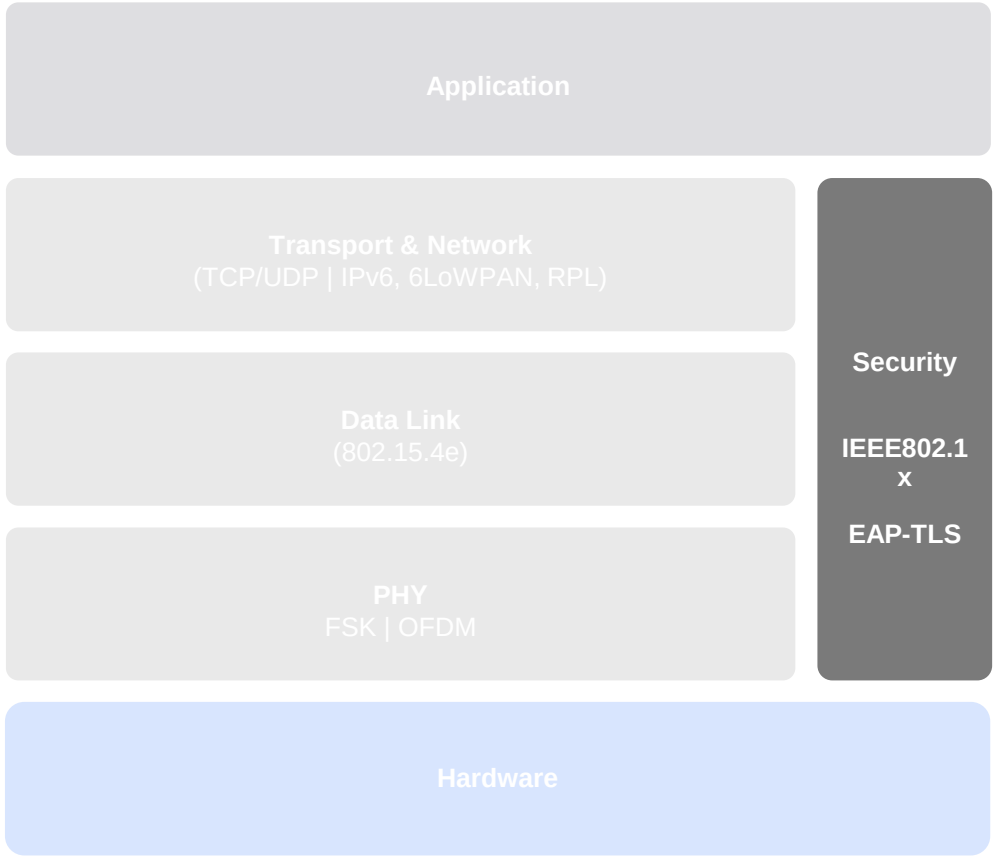
  - LLC sub-layer
    - Upper sub-layer, defines software processes that provide services to network layer protocol
    - Allows access to different types of media defined by lower layers *(15.4, 802.11, 802.3 based media)*
  - MAC Sub-layer
    - Lower sub-layer, defines media access processes performed by the hardware
    - Frequency Hopping
      - The MAC sub-layer supports neighbor synchronized channel hopping for both unicast and broadcast frame transmissions.
      - Unicast and broadcast synchronization information is exchanged between neighbors but there is no dependency upon PAN-wide time synchronization.
      - A fixed channel mode of operation is supported for situations in which channel hopping is not desired
  - 802.15.4e expands the MAC layer feature to fix MAC reliability, unbounded latency, and multipath fading issues
  - Supports Carrier Sense Multiple Access/Collision Avoidance

Wi-SUN Network & Transport Layers



- **Specification:**
  - Uses Adaptation Layer 6LoWPAN between MAC & Network layer
  - IPv6 based network layer with unicast & multicast
  - Uses RPL as the primary routing protocol
  - Transport layer
    - UDP (mandatory), TCP (optional)
- **Why 6LoWPAN?**
  - It defines IPv6 data encapsulation over a 15.4 low power, memory constrained radio link
  - It is needed to efficiently transmit IPv6 packets over low power and lossy networks (LLNs)
  - 6LoWPAN provides
    - header compression, fragmentation & reassembly, stateless auto-configuration
- **RPL (Ripple)**
  - Routing protocol for low power lossy networks
  - RPL is optimized for large networks upstream data flow

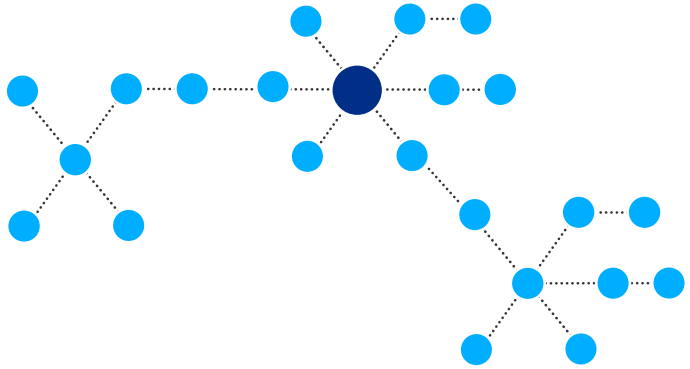
Wi-SUN Security Layer



Public Key Infrastructure Framework With Authentication Through Certificate-based Programming

- **Access control is based upon**
  - Public key infrastructure [PKI]
  - Modeled after Wi-Fi security framework (IEEE 802.1X and IEEE802.11i)
- **Each Wi-SUN device uses two X.509 certificates**
  - They are signed by an official Certification Authority (CA)
  - The device certificate is used to authenticate the device to an authentication server
  - The CA root certificate is used by the device to verify the authentication server
- **Authentication uses EAP-TLS protocol over EAPOL.**
  - Authentication results in Pairwise Master Key (PMK)
  - A unique key shared between the border router and the device.
- **Frame Security**
  - FAN nodes MUST implement AES-CCM 128b based Frame Security

Wi-SUN FAN 1.0 vs FAN 1.1



Border Router Node FAN 1.0

WI-SUN FAN 1.0

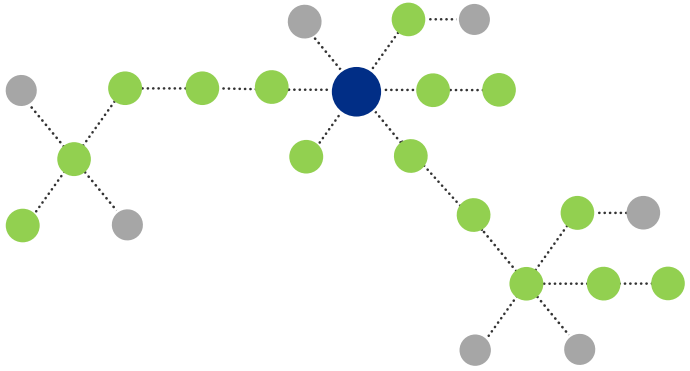
Deploy a mesh network with up to several thousands of connected nodes

Native IPv6 communication through 6LoWPAN

Based on FSK PHYs (up to 300 kbps)

Interoperable

Secure



Border Router Node FAN 1.1 Sleepy Node

WI-SUN FAN 1.1

Enable battery powered devices in the network (water/gas metering, smart city sensing…)

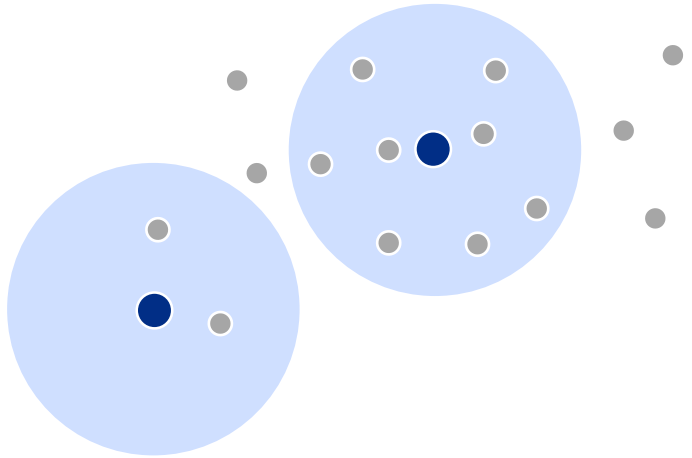
Additional regions supported (Japan, Brazil, EU…)

Introduction of OFDM PHYs (up to 2.4 Mbps)

Modulation and data rate negotiation between nodes to make use of the different PHYs

Mesh vs Long-Range Protocols Comparison

Mesh Network vs Long-Range IoT Protocols

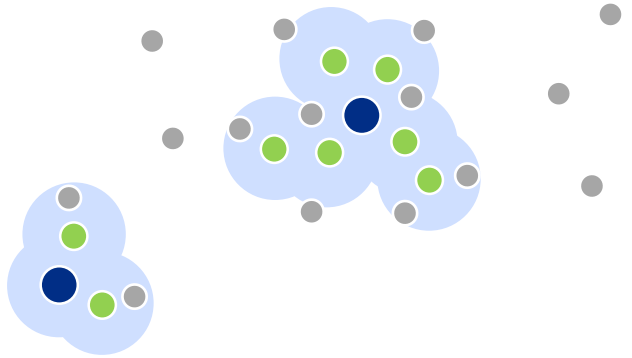


LONG-RANGE IOT PROTOCOL

Star topology (LoRa, Sigfox, NB-IoT…)

Base station able to cover several km² with a data rate which can go below 1 Kbps

One isolated device requires a new base station implantation



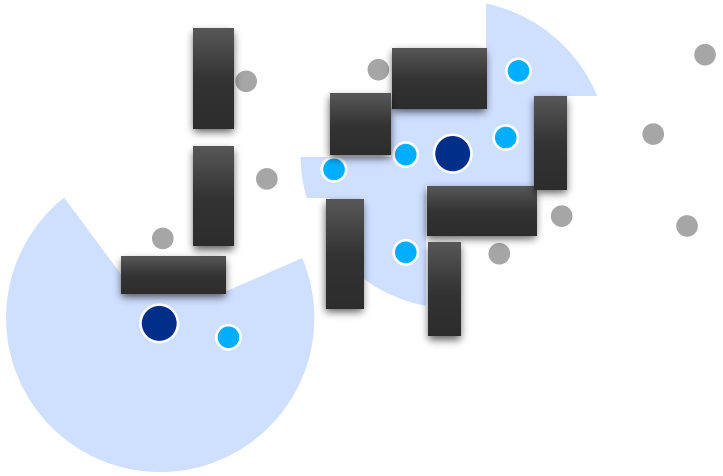
MESH NETWORK PROTOCOL

Mesh topology (Wi-SUN/Thread/Bluetooth Mesh…)

Device range is around 700-800m in the lowest data rate (50 Kbps FSK)

Due the higher data rate used, the battery life of the devices is extended for similar use cases

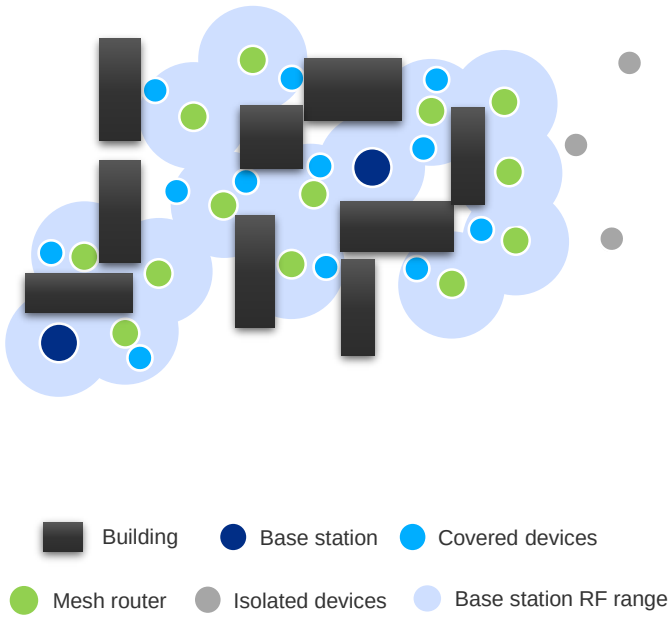
Mesh Network vs Long-Range IoT Protocols



LONG-RANGE IOT PROTOCOL

Star topology includes expensive base stations

In an urban environment or RF challenging layout, deploying enough base stations to cover the entirety of an area is tedious.



MESH NETWORK PROTOCOL

Mesh topology is more flexible

Mesh routers can be deployed on grid powered devices (electric meters, streetlights…)

Having a complete RF coverage of such an area becomes possible

Silicon Labs Wi-SUN Solution

Silicon Labs Wi-SUN FAN Solution

HARDWARE & PHY

WSTK + EFR32FG12 Radio Boards

Certified Wi-SUN PHYs

Certified Wi-SUN FAN stack

SIMPLICITY STUDIO 5

Wi-SUN stack provided as **library**

FreeRTOS or Micrium OS (using CMSIS-RTOS V2)

Radio Configurator

Energy Profiler

PTI/Network Analyzer

SAMPLE APPLICATION

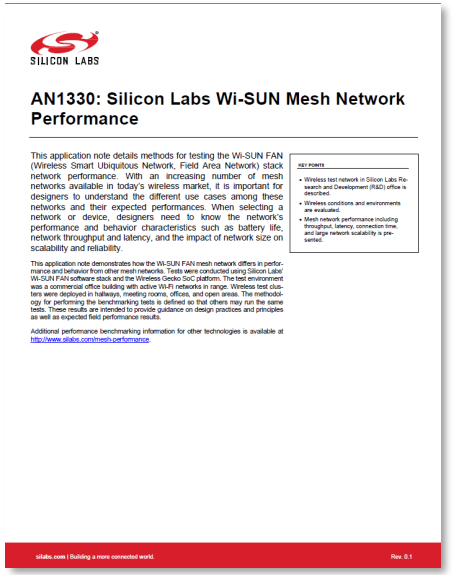
Wi-SUN command-line interface

Wi-SUN POSIX UDP/TCP socket

CoAP-based Meter/Collector

Empty/template project

Border Router demonstrations in **binary format**



DOCUMENTATION

Online Wi-SUN stack API documentation

Readmes embedded inside Studio 5

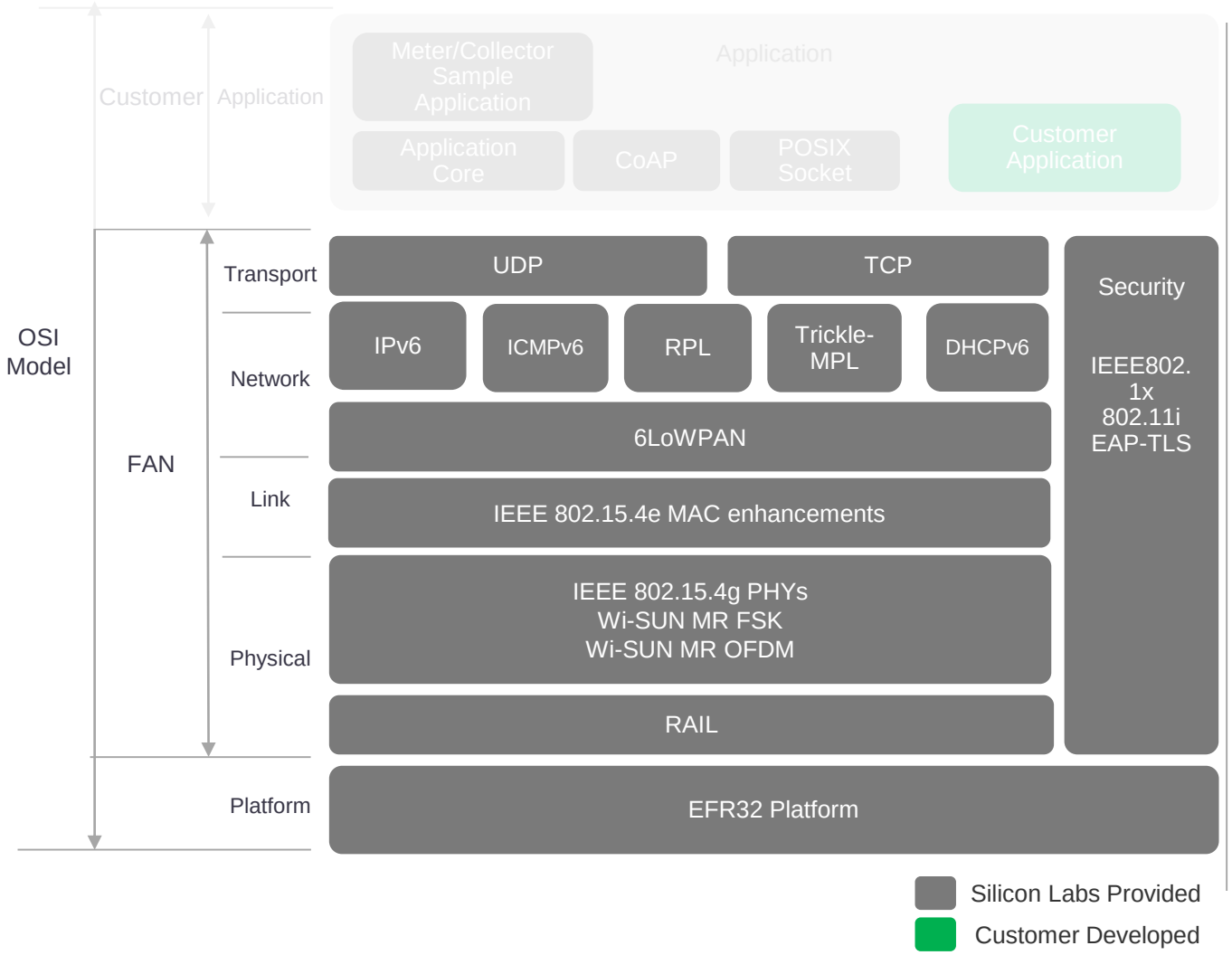
QSG181: Wi-SUN Quick-Start Guide

UG495: Wi-SUN Developer's Guide

AN1330: Wi-SUN Network Performance

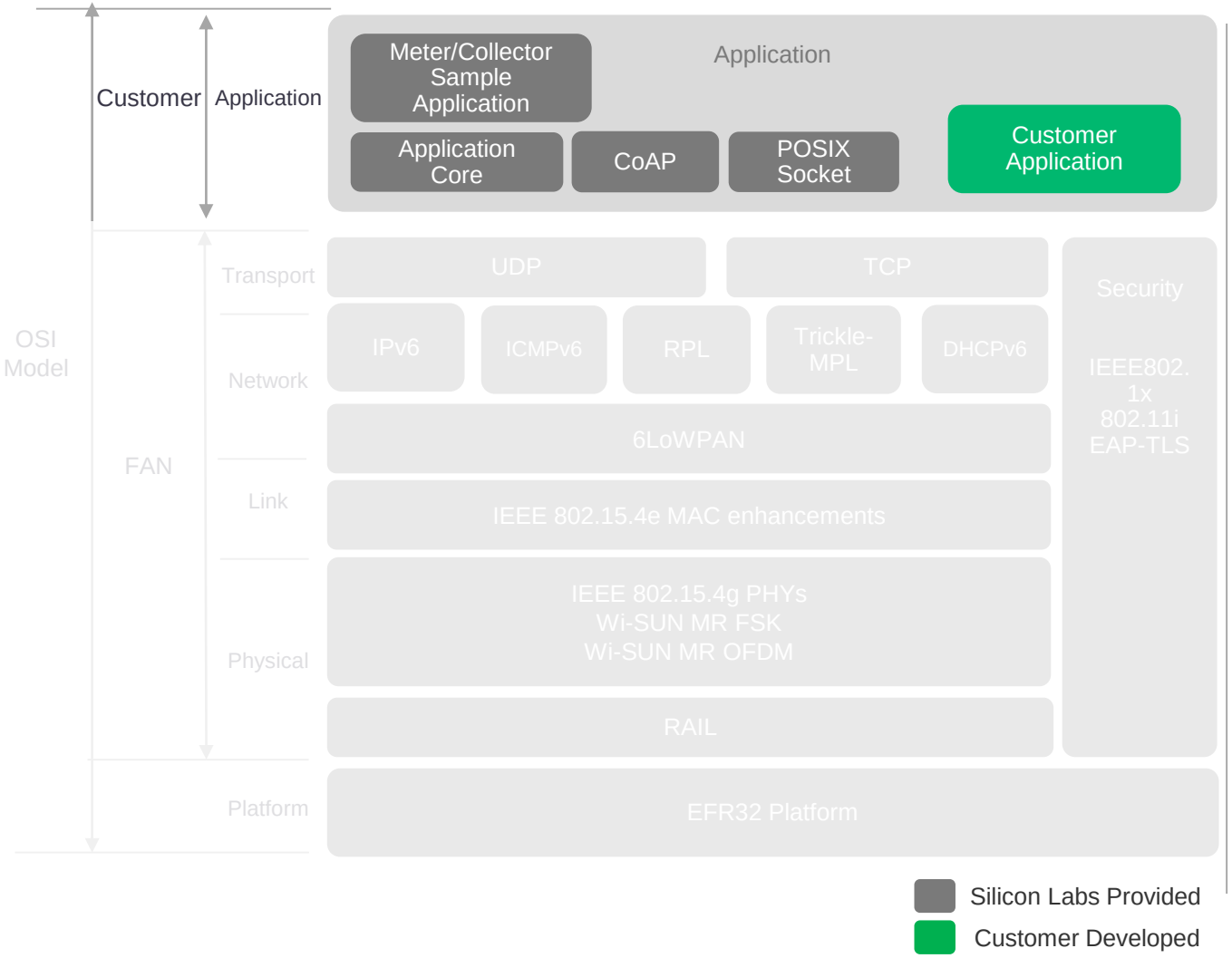
AN1332: Wi-SUN Network Configuration

Stack Architecture



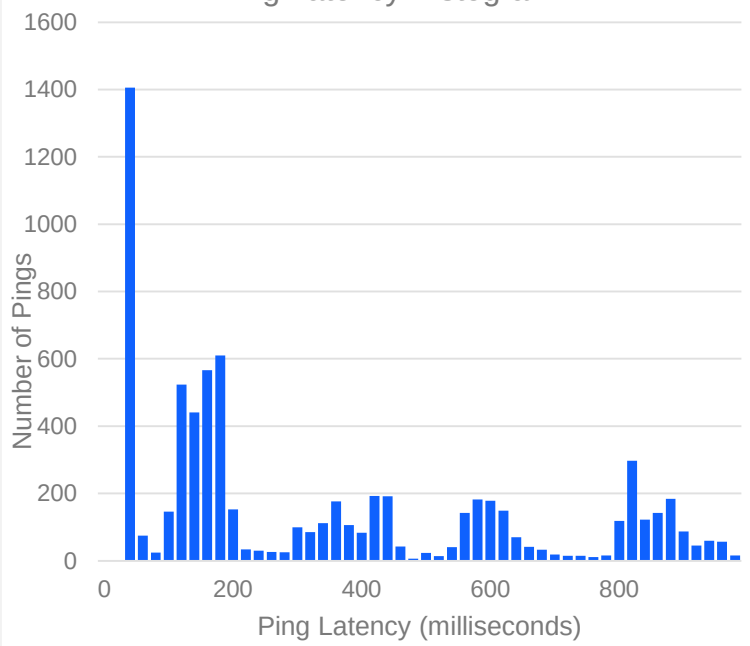
- **Protocol Suite (IPv6)**
  - UDP (TCP optional)
  - 6LoWPAN Adaptation + Header Compression
  - DHCPv6 for IP address management
  - Routing using RPL & Trickle
  - ICMPv6
  - Unicast and Multicast forwarding
- **Security (802.1x)**
  - EAP-TLS/PKI Authentication
  - 802.11i Key Management
  - AEC-CCM 128b Encryption
- **MAC (802.15.4e)**
  - Frequency Hopping
  - CSMA-CA
- **PHY (802.15.4g)**
  - FSK (xG12) modulations, data rates, and regions
  - OFDM Support coming with EFR32FG25

Application Layer



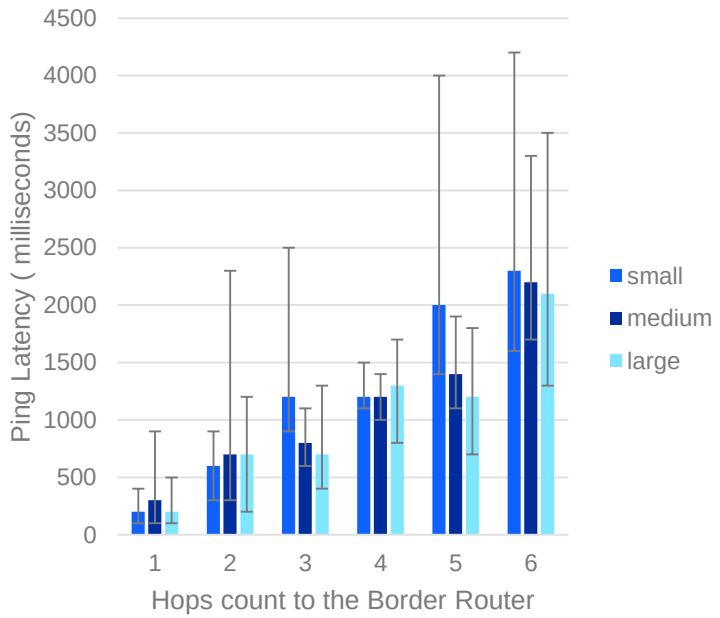
- **Application layer is not part of the Wi-SUN specification**
  - The technology is applicable to several different verticals, challenging to have a common app layer
- **Prevalent application layers**
  - Smart metering
    - DLMS & Smart Energy 2.0
  - Street lighting
    - uCIFI - uCIFI is defining a unified data model on IoT networks and open-source sub-GHz mesh
  - Parking, smart city applications
    - Other partners
  - General purposes
    - CoAP, MQTT, LwM2M…

Wi-SUN Stack Performance



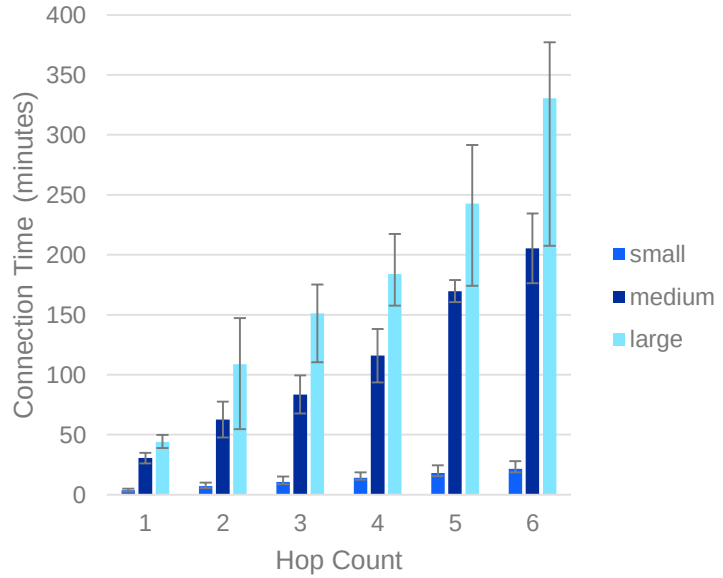
POINT-TO-POINT LATENCY

- **Wi-SUN frequency hopping scheme is the source of the latency**
- **Investigating performance improvements**



HOP IMPACT ON LATENCY

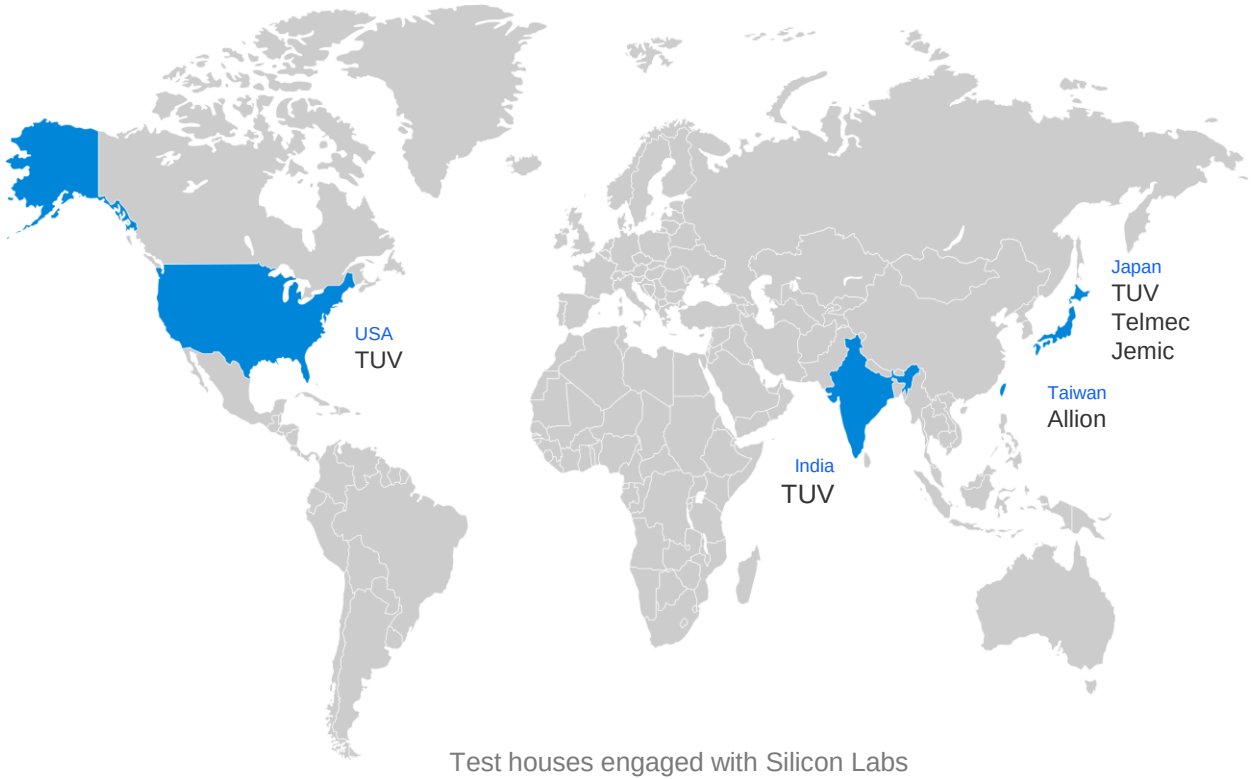
- **Latency scales with the number of hops travelled by the packet**
- **Network size settings have an impact on the ping latency**



CONNECTION TIME

- **Wi-SUN Connection time is significant compared to home & consumer protocols**
- **Allow the protocol to easily scale in size while avoiding RF collisions**

Certification Status



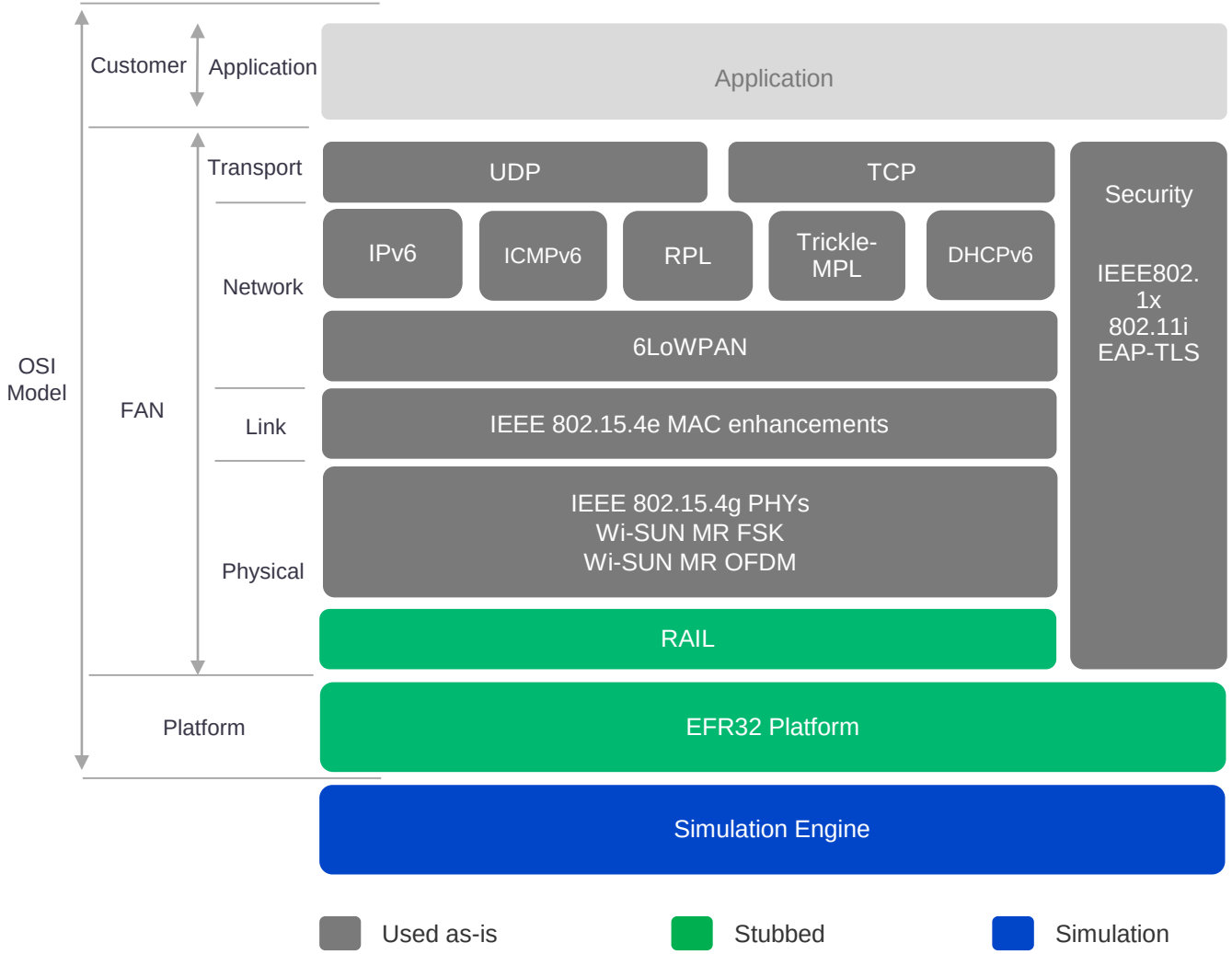
Test houses engaged with Silicon Labs

PHYs	Frequency / Region	Test House
FG12 – FSK 50kbps	902-928MHz North America & Brazil	TUV USA
FG12 – FSK 150kbps	902-928MHz North America & Brazil	TUV USA
FG12 – FSK 100kbps	902-928MHz North America & Brazil	TUV USA
FG12 – FSK 50kbps*	863-875MHz Europe & India	TUV India
FG12 – FSK 150kbps*	863-875MHz Europe & India	TUV India
FG12 – FSK 100kbps *	863-875MHz Europe & India	TUV India
FG12 – FAN 1.0	Global	Allion Labs

* ongoing

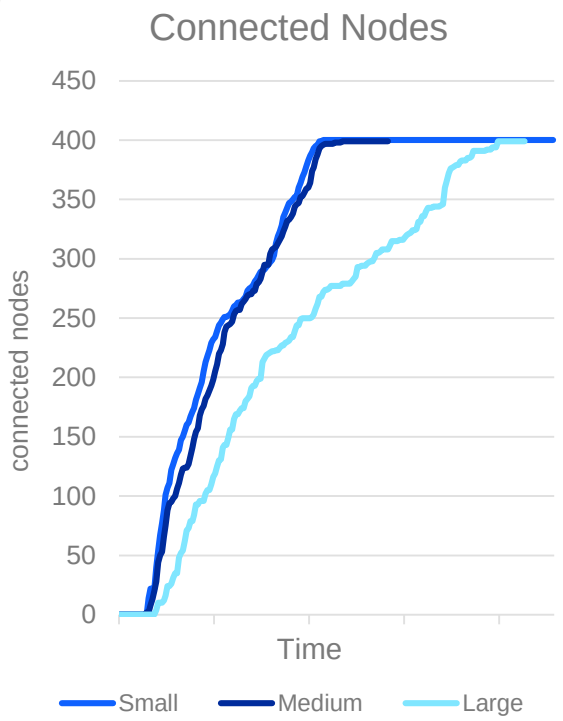
Large Network Simulation

Simulation Overview



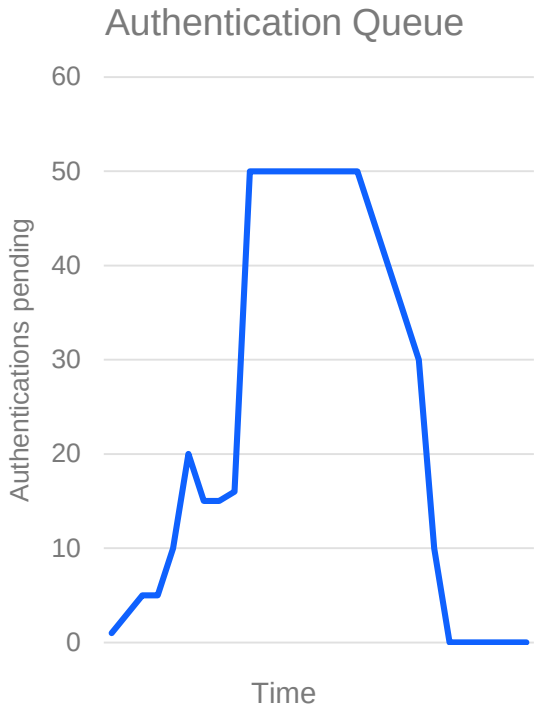
- **Flexibility**
  - Large network simulation up to several thousands of nodes
  - Can handle a wide variety of topologies
  - Deterministic or random
- **Key points**
  - Internal tool based on an open-source solution
  - Each node of the network is running a complete stack instance
  - Used for non-regression testing
  - Used to evaluate the stack, performance, and generates statistics
  - Extended debug capabilities
- **Known limitations**
  - Low-level models not qualified
  - Does not simulate processing time

Simulation Outputs



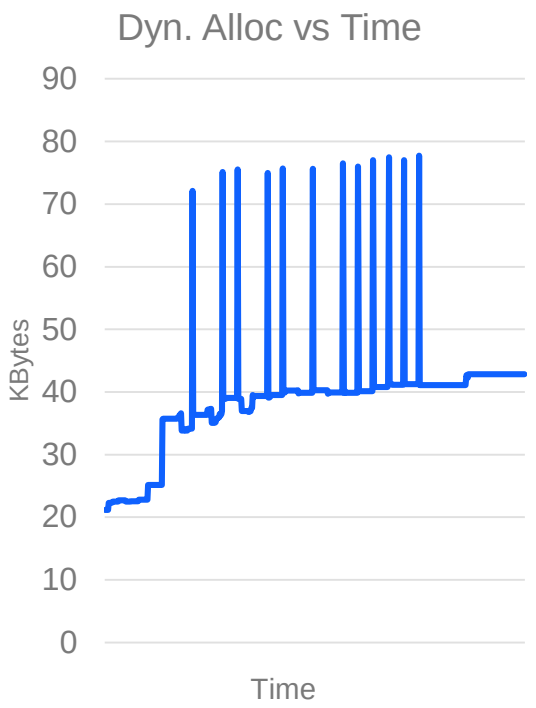
NETWORK

- Connection pace
- Collisions
- Channel occupancy



STACK

- Internal queues
- State machines transitions



HW & PLATFORM

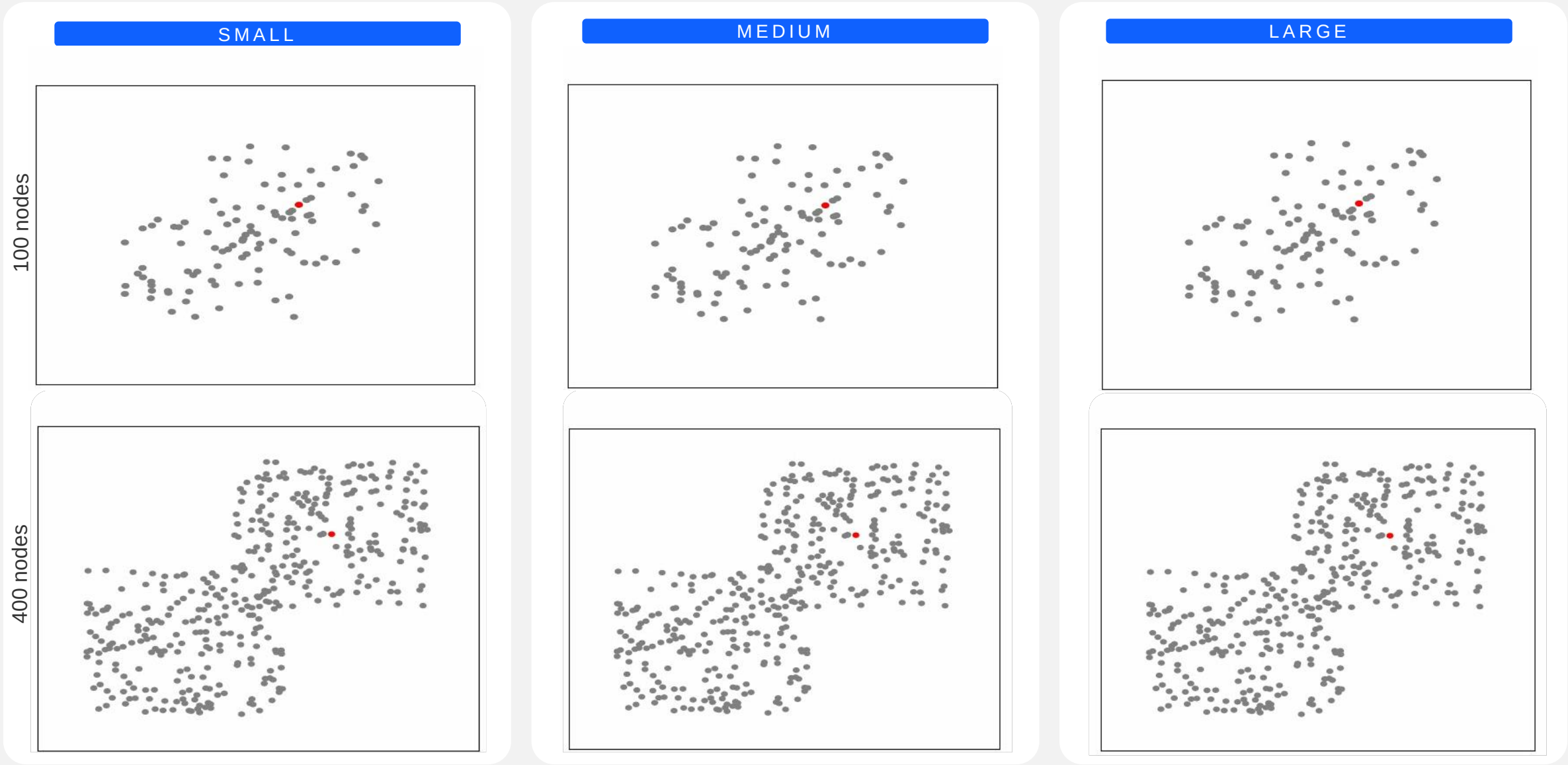
- Memory usage
- Radio status
- Power consumption

```
20.376480  00::00:01 PAN Advertisement Solicit…
24.681520  00::00:04 PAN Advertisement, Routin…
30.310080  00::00:04 PAN Configuration
57.506281  00::00:02 Key (Request)
57.523561  00::00:04 Acknowledgment
57.523561            Listening to channel 20
57.537682  00::00:04 Request, Identity
57.537682            Radio Idle
57.538642  00::00:02 Acknowledgment
57.545323            Listening to channel 20
57.548283  00::00:02 Response, Identity
57.558524  00::00:04 Acknowledgment
57.570725  00::00:04 Request, TLS EAP (EAP-TLS)
57.571685  00::00:02 Acknowledgment
57.581326  00::00:02 Client Hello
57.597486  00::00:04 Acknowledgment
57.610000            Radio Idle
57.740970  00::00:04 Request, TLS EAP (EAP-TLS)
57.741930  00::00:02 Acknowledgment
```

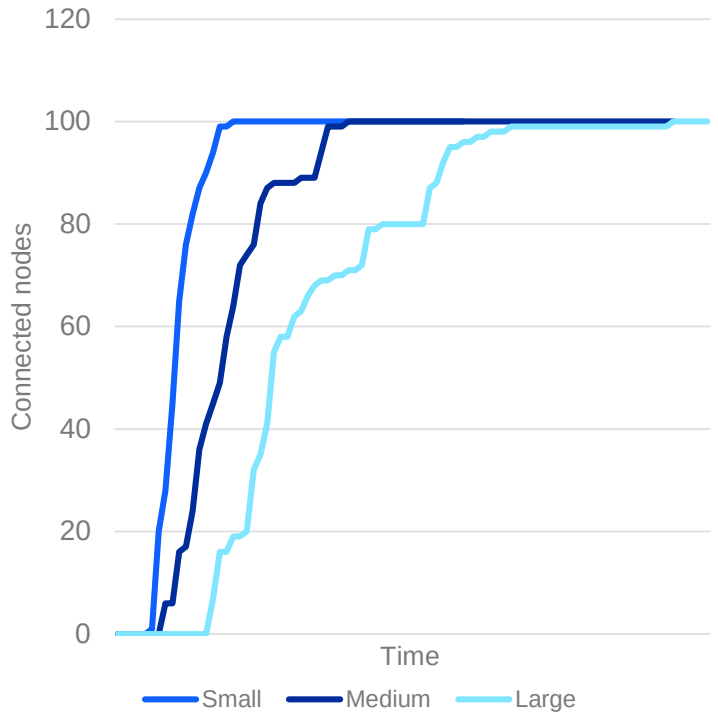
WIRESHARK PCAP

- Network packets
- Radio/stack information
- API requests

Network Connection

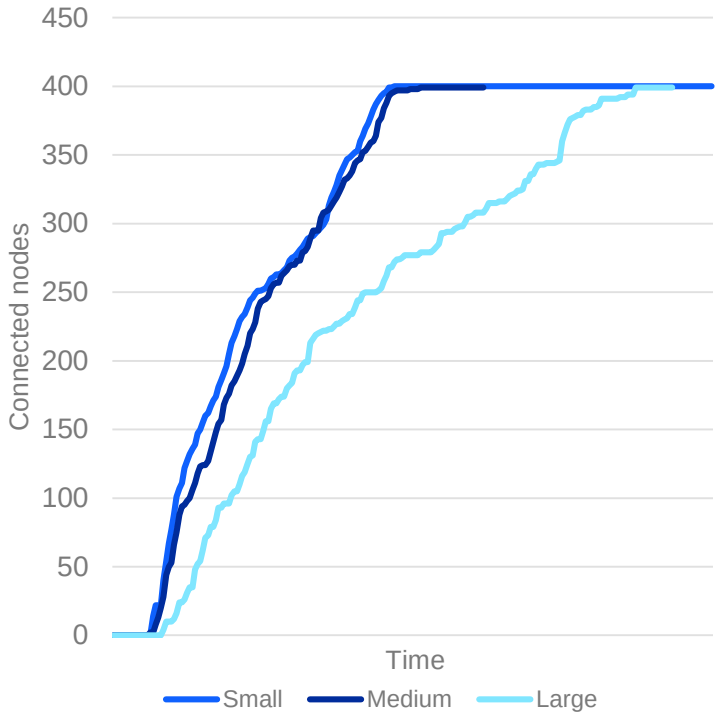


Network Connection



100 NODES

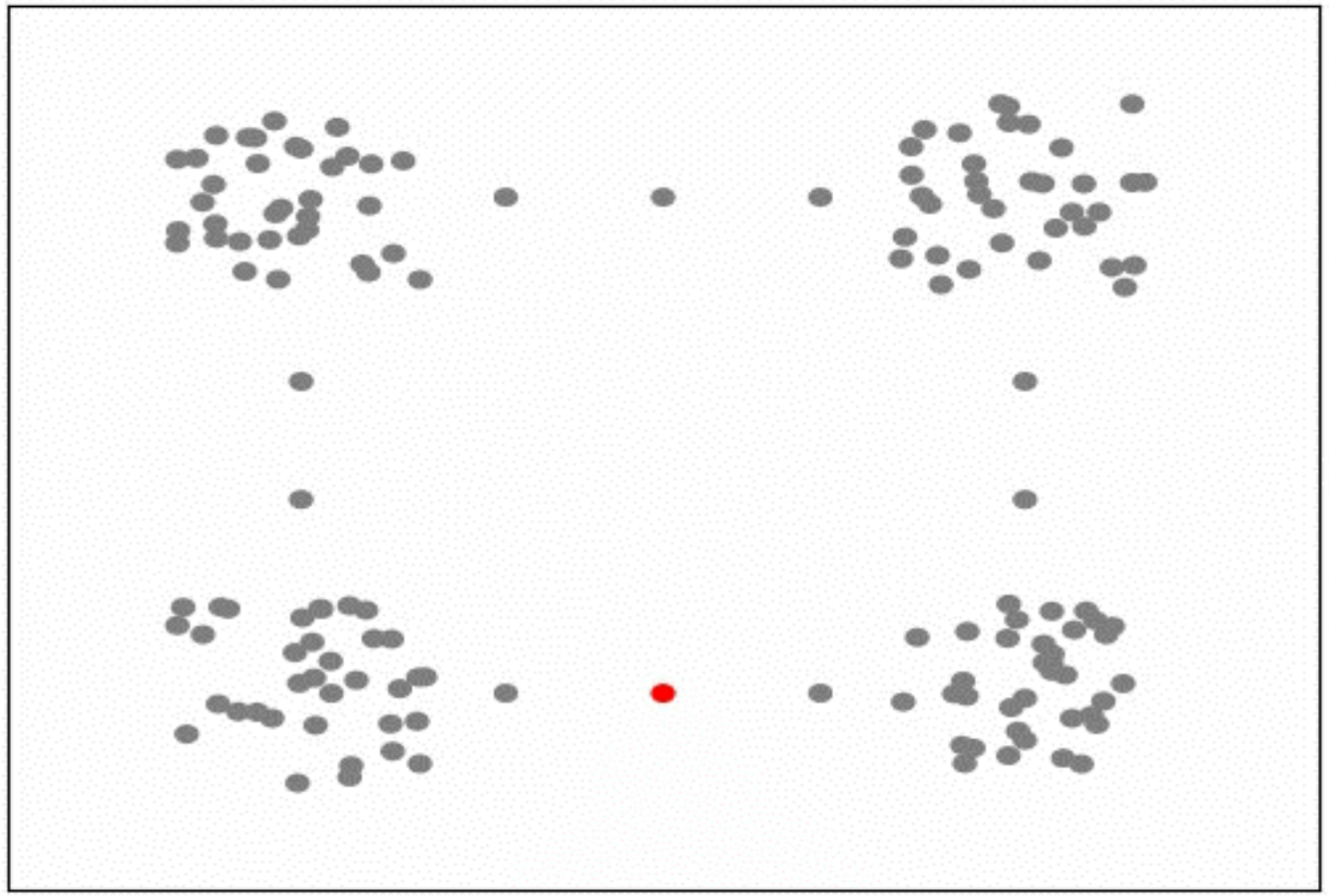
- “Small” network size setting recommended
- Topology impacts connection times



400 NODES

- “Medium” network size setting recommended
- Connection time inflexion point between “small” and “medium”
- Better network performance with “medium” configuration compared to “small”

Network Recovery



- **Four islands linked by four bridges**
  1. Sent connection requests
  2. Unoptimized connections
  3. Optimized connections
  4. Removed the bridge on the right
  5. Fast network recovery
  6. Optimized connections
- **40 minutes to recover**


Questions?
Wi SUN

Wi-SUN CoAP Lab

Silicon Labs Delivers the Wi-SUN Foundation

Applications & Device Management

Grid intelligence | Distribution automation | Municipal infrastructure | Cloud database management | Enterprise efficiency | ... ...

SECURITY

Stack (L2-L4)

Wi SUN **FAN 1.0** — Line powered, FSK modulations

Wi SUN **FAN 1.1** — Battery powered, OFDM modulations

Wi SUN **FAN 2.0**

... ...

SECURITY

Hardware

EFR32xG Series 1

EFR32xG12
1 MB / 256 kB
2.4/sub-GHz

EFR32xG13
512 kB / 64 kB
2.4/sub-GHz

EFR32xG Series 2

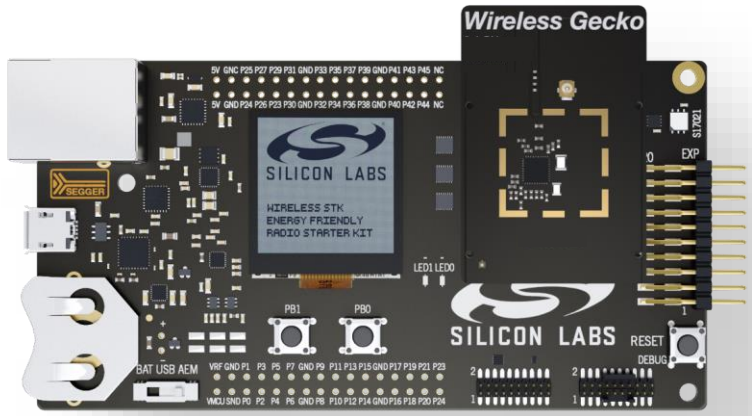
EFR32xG21
1 MB / 96 kB
2.4GHz

EFR32xG22
512 kB / 32 kB
2.4GHz

Coming

CUSTOMER FOCUSED ON CREATING AND MONETIZING VALUE ON THE APPLICATION LAYER

Getting Started with Wi-SUN and xG12 SoCs



Wi-SUN/MG12 SoC Starter Kit
SLWSTK6007A

- Build your Wi-SUN mesh with the Wi-SUN starter kit
- Border router demo in binary format. Backhaul connectivity possible using a Raspberry or a Linux host

Content

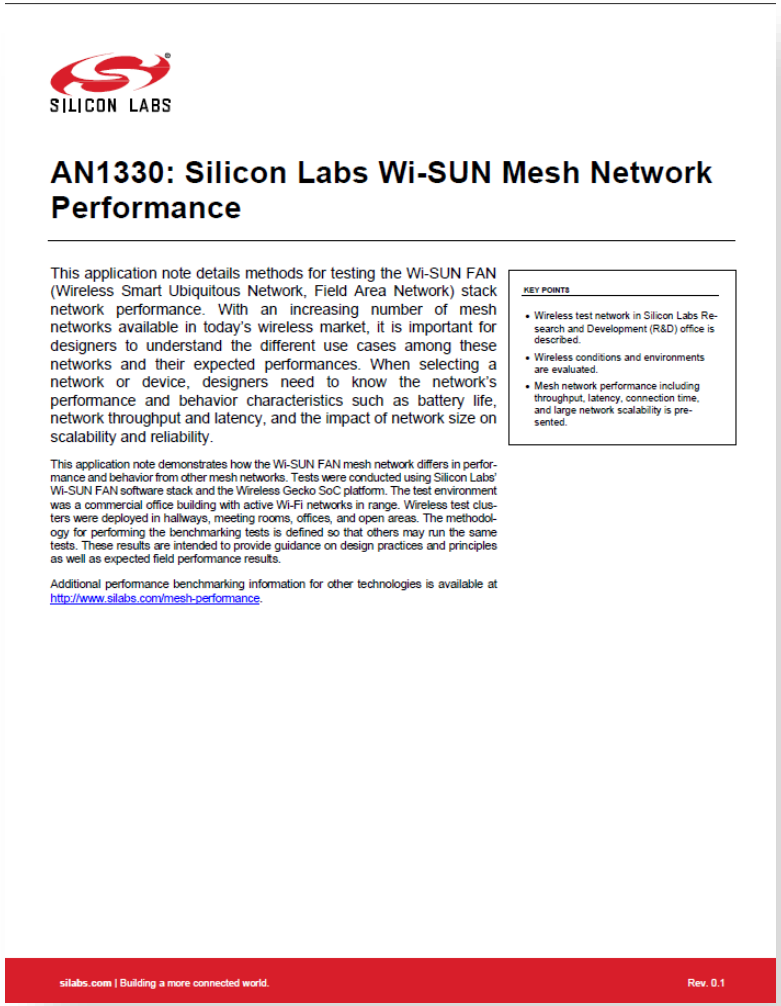
SLWSTK6007A	3x BRD4001A WSTK main boards 3x BRD4170A 2400/868-915 MHz 19 dBm Radio Boards 1x debug adapter board + 1x flat cable SMA Antenna

Other supported radio boards

SLWRB4163A **SLWRB4254A**	2400/868 MHz 10 dBm Radio Boards
SLWRB4164A **SLWRB4253A**	2400/915 MHz 19 dBm Radio Boards
SLWRB4172A	2400/490 MHz 19 dBm Radio Boards

Wi-SUN SDK Collaterals

- **Sample applications**
- **Available documentation**
  - Sample Application readmes
  - AN1330
  - AN1332
  - UG495
  - QSG181
  - Stack documentation on docs.silabs.com
- **Community**
  https://community.silabs.com/s/topic/0TO1M000000qHc6WAE/wisun
- **Support ticket**
  http://www.silabs.com/support



SILICON LABS

AN1330: Silicon Labs Wi-SUN Mesh Network Performance

This application note details methods for testing the Wi-SUN FAN (Wireless Smart Ubiquitous Network, Field Area Network) stack network performance. With an increasing number of mesh networks available in today's wireless market, it is important for designers to understand the different use cases among these networks and their expected performances. When selecting a network or device, designers need to know the network's performance and behavior characteristics such as battery life, network throughput and latency, and the impact of network size on scalability and reliability.

KEY POINTS

- Wireless test network in Silicon Labs Research and Development (R&D) office is described.
- Wireless conditions and environments are evaluated.
- Mesh network performance including throughput, latency, connection time, and large network scalability is presented.

This application note demonstrates how the Wi-SUN FAN mesh network differs in performance and behavior from other mesh networks. Tests were conducted using Silicon Labs' Wi-SUN FAN software stack and the Wireless Gecko SoC platform. The test environment was a commercial office building with active Wi-Fi networks in range. Wireless test clusters were deployed in hallways, meeting rooms, offices, and open areas. The methodology for performing the benchmarking tests is defined so that others may run the same tests. These results are intended to provide guidance on design practices and principles as well as expected field performance results.

Additional performance benchmarking information for other technologies is available at http://www.silabs.com/mesh-performance.

silabs.com | Building a more connected world. Rev. 0.1

Flash and Start the Border Router

1. Run the standard border router demo
2. Discover the CLI commands
3. Configure the Wi-SUN PHY
4. Start the border router

Create and flash the CoAP Meter Project

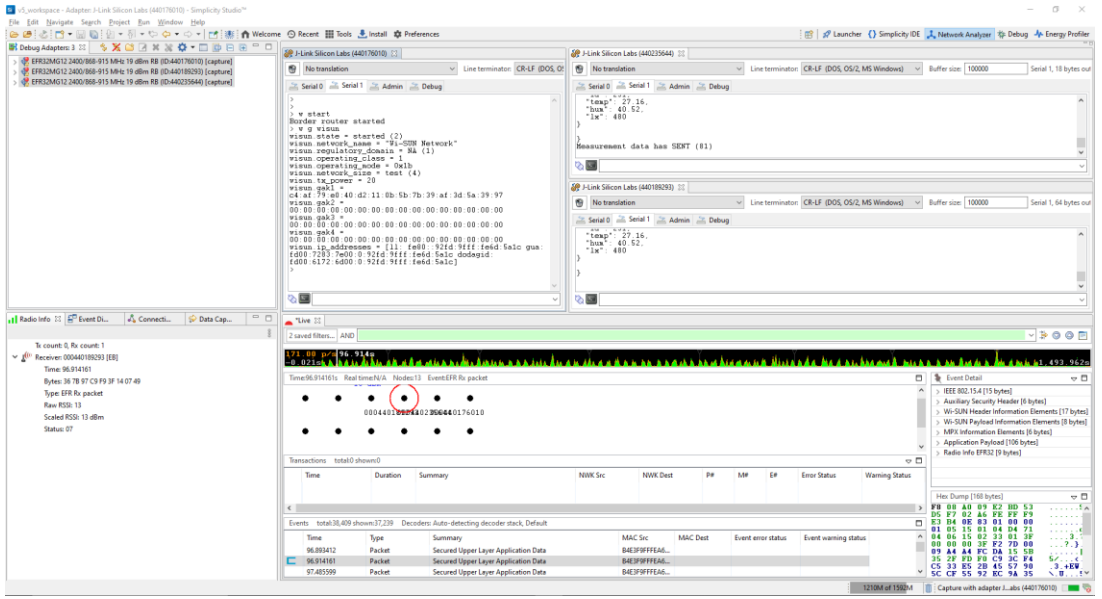
1. Create the project
2. Compile and flash the project
3. Configure the node through the CLI
4. Wait for the connection to complete

Create and flash the CoAP Collector Project

1. Create the project
2. Compile and flash the project
3. Configure the node through the CLI
4. Wait for the connection to complete
5. Register the CoAP Meter
6. Look at the CoAP Collector retrieving sensor data from the Meter

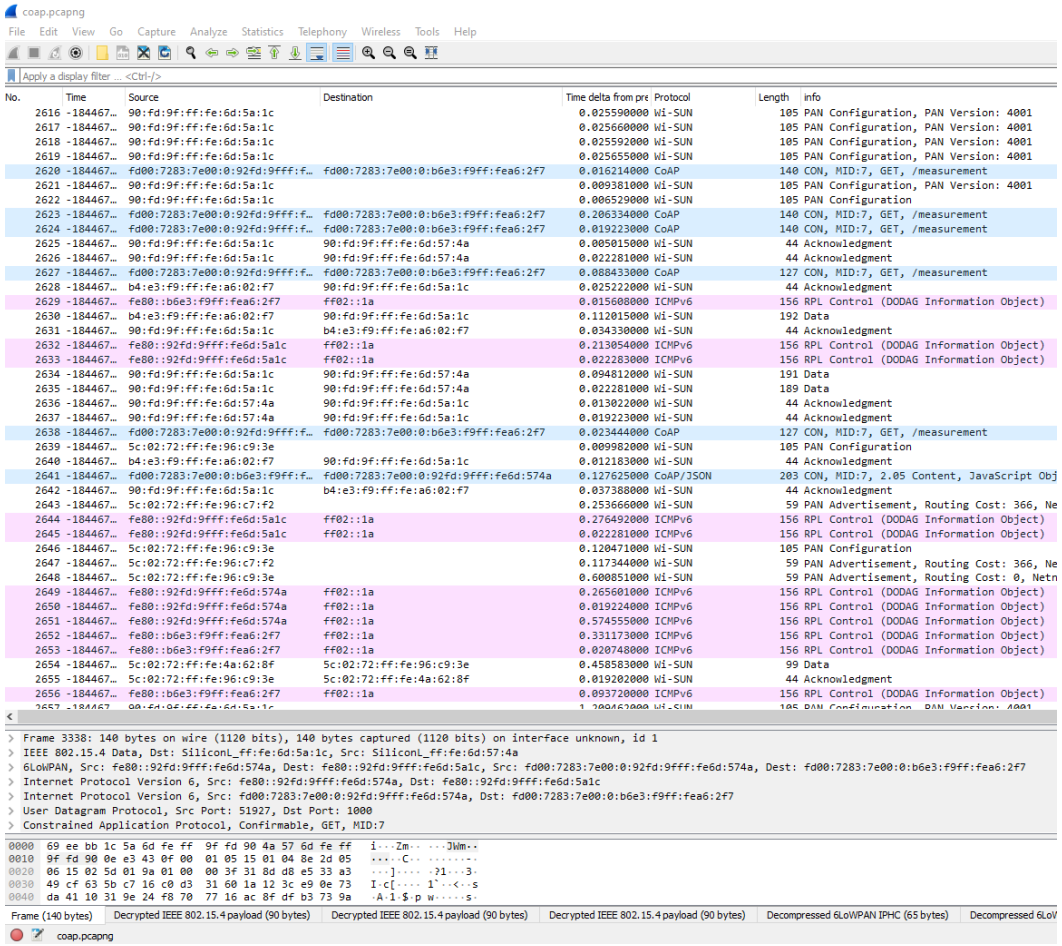
Use PTI and the Network Analyzer to trace the Wi-SUN Traffic

1. Start a capture on the 3 EFR32FG12s
2. Look at the Network Analyzer
3. Analyze the traffic and Wi-SUN headers



Export to Wireshark

1. Export the trace to Wireshark
2. Decrypt the traffic using the BR GAK key
3. Change CoAP default UDP port
4. Look at the decrypted traffic
5. Analyze it



Going further with Wi-SUN

- **GSDK 3.2 release Wi-SUN sample applications**
- **Documentation (QSG, UG and ANs)**
- **Other Works With sessions**

- Wi-SUN FAN Technical Overview
- Tech Talk: Understand the Benefits of Wi-SUN for Long Range Industrial Applications
- QSG181: Silicon Labs Wi-SUN SDK Quick-Start Guide
- UG495: Silicon Labs Wi-SUN Developer's Guide
- AN1330: Silicon Labs Wi-SUN Mesh Network Performance
- AN1332: Silicon Labs Wi-SUN Network Setup and Configuration

Session ID	Session Name
WSN-101	Introduction to Wi-SUN, It's markets and the Alliance
SMC -102	Smart City Network Management in the Cloud Using Pelion
SMC-103	Why Wi-SUN is Ideal for Smart Street Lighting?
WSN-300	Building Large Scale Smart City Networks with Wi-SUN

works with
BY SILICON LABS
VIRTUAL CONFERENCE

SILICON LABS

Thank You

Wi SUN