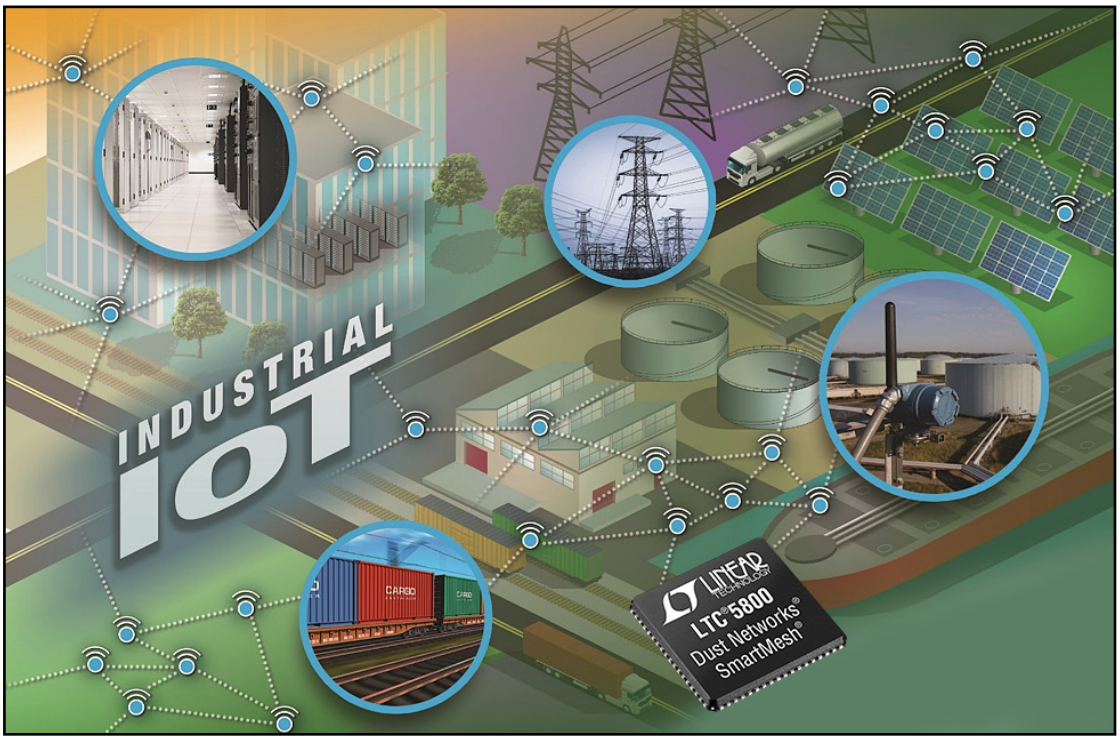
SmartMesh

Wireless Mesh for Tough Industrial IoT Applications

- The Only Network Built for Industrial IoT
- Engineered for Years of Trouble Free Operation
- Complete Networking Software Speeds Time to Market



Linear Technology's Dust Networks® offers the industry's lowest power and most reliable standards-based wireless sensor networking (WSN) products. Dust Networks' SmartMesh® products are field proven, with over 60,000 customer networks deployed in 120 countries. By delivering >99.999% data reliability in tough RF environments, Dust Networks' wireless mesh networks are entrusted by industrial IoT solution providers to deliver critical sensor and control data reliability for many years without requiring intervention.

dust networks®

LINEAR TECHNOLOGY

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SmartMesh Overview

SmartMesh wireless sensor networking products are chips and pre-certified PCB modules, complete with mesh networking software, enabling sensors to communicate in tough Industrial Internet of Things (IoT) environments.

SmartMesh embedded wireless sensor networks deliver >99.999% data reliability and >10 year battery life, making it practical to deploy wireless sensor networks in the most challenging environments:

- **Tough RF Environments,** having extensive metal and concrete, including industrial plants, data centers, commercial building monitoring, bridges, tunnels.
- **Large Area Networks,** such as street parking applications, smart street lighting networks spanning multiple city blocks, commercial irrigation.
- **Dense Deployments,** where thousands of nodes operate within radio range of each other, for instance data centers, utility scale solar farms.
- **Networks on Moving Vehicles,** including rail cars, cargo containers, semi trucks or aircraft.
- **Long, Extended Networks,** including pipelines, mines, tunnels, bridges, fence line and smart street lighting.
- **Remote Monitoring,** where all nodes must be powered by battery or energy harvesting, such as oil fields, agriculture or environmental monitoring.

The Only Network Built for Industrial IoT

Delivers Business-Critical Data in Tough Industrial Environments and Scales with Your Business

- **>99.999% Network Reliability**

  SmartMesh delivers business-critical data when other RF solutions fail. Industrial applications cannot tolerate even a 1% failure rate, which translates to 3.65 days per year of unscheduled downtime.

- **NIST-Certified Encryption Security**

  All data is protected by end-to-end AES 128-bit encryption (message stays secret), message integrity checking (message is unchanged) and message authentication (sender is who they say they are).

- **Scalable >10,000 Nodes**

  SmartMesh's time-synchronized, channel hopping technology eliminates in-network packet collisions. Network optimization algorithms intelligently load-balance data traffic to efficiently route data.

- **Bidirectional Communication for Monitoring and Control**

  Receive sensor data, retrieve log files, configure sensors, control actuators (alarms, locks, valves, HVAC dampers, etc).

- **Up to 10 Messages/Second/Node for Data-Intensive Appications**

  Unlike other wireless solutions, this includes built-in margin for packet retries to sustain the rate even in noisy RF environments.

Video: Reliable Wireless Sensor Network Streamlines Manufacturing Operations

www.linear.com/solutions/7254

Engineered for Years of Trouble Free Operation

Field Proven, Wireless Networks That Are Easy to Install, Expand and Maintain Over Years of Operation

- **>50,000 Installed Networks**

  SmartMesh is field proven, with networks in over 120 countries.

- **>10 Year Battery Life Enables "No-Wires" Installation**

  SmartMesh enables sensors to be placed anywhere information needs to be gathered.

- **No RF Skills Required**

  Installers do not need specialized RF expertise.

- **Worldwide RF License Free Operation**

  Operation at 2.4GHz enables development of one product to serve the global market.

- **Diagnostics Provide Visibility to Network Performance**

  Network self-monitors and self-heals.

- **Built-In Self-Optimization**

  SmartMesh proactively maintains reliability, reduces latency and minimizes power consumption in changing RF conditions.

- **Over-the-Air Software Updates**

  Wirelessly updates software of nodes deployed in the field.

Complete Networking Software Speeds Time to Market

No Wireless Software Stack Development Required

- **No Network Software Stack Development Required**

  Developers can focus on sensor and application development, knowing that SmartMesh automatically maintains the network integrity and quality of service.

- **>1M Node-Hours Network Stack Testing**

  Network software is verified under real-life stress conditions, such as RF interference, heavy data traffic, environmental extremes, and multiple co-located networks.

- **Comprehensive API Simplifies Development**

  Software application programming interfaces (APIs) provide access to network configuration and performance statistics.

- **User-Programmable ARM Cortex-M3**

  SmartMesh IP wireless nodes support On-Chip application software development.

- **Wireless Standards Compliant**

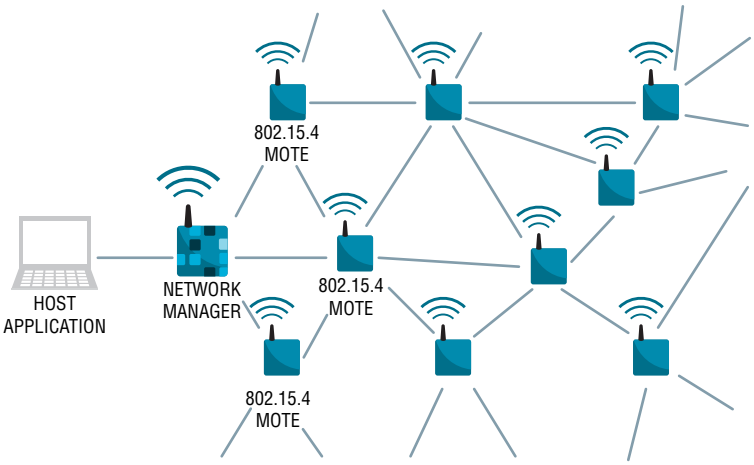
  SmartMesh IP™ is compliant to 6LoWPAN, making sensor data easily cloud-accessible. SmartMesh WirelessHART products interoperate with WirelessHART devices from other vendors.

White Paper: Verifying >99.999% Data Reliability

www.linear.com/docs/52484

SmartMesh Technology

A SmartMesh network consists of a highly scalable self-forming multi-hop, mesh of nodes, known as motes, which collect and relay data, and a network manager that monitors and manages network performance and security, and exchanges data with a host application.



SmartMesh motes and managers are complete wireless sensor network solutions. SmartMesh combines a time-synchronized, channel-hopping link layer with hardware based on Dust Networks Eterna® system-on-chip technology for a complete wireless networking solution with:

- **>99.999% Data Reliability,** superior network reliability
- **>10 Year Battery Life,** place sensors anywhere with lowest cost
- **Encryption, Authentication and Message Integrity Checks,** secured network
- **Complete Wireless Mesh Solution,** no network stack development required

Eterna – Dust Networks' Revolutionary IEEE 802.15.4e System-on-Chip Platform

At the heart of SmartMesh motes and network managers is the Eterna IEEE 802.15.4e system-on-chip (SoC), featuring Dust Networks' highly integrated, low power 2.4GHz radio design, plus an ARM Cortex-M3 32-bit microprocessor running SmartMesh networking software.

SmartMesh Networking

Time Synchronized, Channel Hopping Communications

SmartMesh networks communicate using a Time Synchronized Channel Hopping (TSCH) link layer, a technique pioneered by Dust Networks and a foundational building block of wireless mesh networking standards, such as WirelessHART (IEC62591) and IEEE 802.15.4e. In a TSCH network, all motes in the network are synchronized to within a few microseconds. Network communication is organized into time slots, which enables low power packet exchange, pair-wise channel hopping and full path diversity.

Low Power Packet Exchange

The use of TSCH allows SmartMesh devices to sleep at ultralow power between scheduled communications, typically resulting in a duty cycle of < 1%. The network manager utilizes TSCH to ensure:

- Motes know precisely when to talk, listen or sleep
- No packets collide on the network
- Ultralow power consumption at every node–routing nodes typically consume <50µA

Pair-Wise Channel Hopping

Time synchronization enables channel-hopping on every transmitter-receiver pair for frequency diversity. With a SmartMesh network:

- Every packet exchange channel-hops to avoid inevitable RF interference
- Multiple transmissions can occur simultaneously, increasing network bandwidth
- Networks may be dense and scale without creating debilitating RF self-interference

Full Path and Frequency Diversity

Each device has redundant paths to overcome communications interruption due to interference, physical obstruction or multipath fading. If a packet transmission fails on one path, a mote will automatically retry on the next available path and a different RF channel. Unlike other mesh technologies, no power and time-consuming path rediscovery is required.

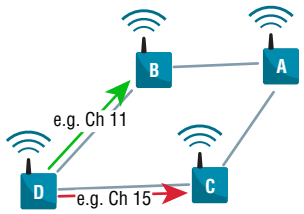


Figure 1 Path and Frequency Diversity
If communication fails on the green arrow, node D retries on the red arrow using another channel

Dynamic Network Optimization

A SmartMesh network always maintains a profile of the RF environment surrounding the entire network with automatic site surveys – each mote tracks relevant performance statistics and periodically sends these statistics to the manager in packets called health reports. The network manager uses this data to proactively optimize network performance to:

- Maintain redundant pathways between motes in changing RF conditions
- Lower system latency by adjusting the routing between motes
- Reduce traffic retries by optimizing for paths with better RF performance
- Reduce overall power consumption

Secure Mesh with 128-Bit Encryption

SmartMesh networks are among the most secure mesh networks available. All traffic in a SmartMesh network is protected by end-to-end encryption, message integrity checking and device authentication. Additionally, the SmartMesh network manager includes applications that enable secure joining of the network, key establishment and key exchange.

Security Feature	Benefit
Device Authentication	Choose from three increasingly strong levels of device authentication
Encryption	Certification 128-bit AES-based encryption with multiple keys ensures privacy and confidentiality of the data
Message Integrity Check (MIC)	Data transmitted is protected by message authentication codes to ensure that it has not been tampered with
Synchronized Key Changeovers	The entire network can be programmed to change over to a new encryption key automatically
Customized Key Rotation	The customer decides how often the network should change keys, balancing extra security with additional network traffic

Choose the Solution That's Right for You

SmartMesh IP

The SmartMesh IP solution is highly scalable and well suited for a wide range of applications. It delivers high reliability and low power consumption even in harsh, dynamically changing RF environments.

Choose SmartMesh IP for:

- Industrial wireless sensor network applications
- Compliance to the 6LoWPAN standard

SmartMesh WirelessHART

SmartMesh WirelessHART offers the lowest power consumption in its class and is the most widely used WirelessHART (IEC62591) standard compliant product available.

Choose SmartMesh WirelessHART for:

- Interoperability with WirelessHART field devices/sensors

SmartMesh IP Products

SmartMesh IP products are wireless chips and pre-certified PCB modules, complete with ready-to-deploy wireless mesh networking software. They are built for IP compatibility, and based on the 6LoWPAN and 802.15.4e standards. The SmartMesh IP product line enables low power consumption and >99.999% data reliability even in harsh, dynamically changing RF environments.

IPv6–based Low–power Wireless Personal Area Network

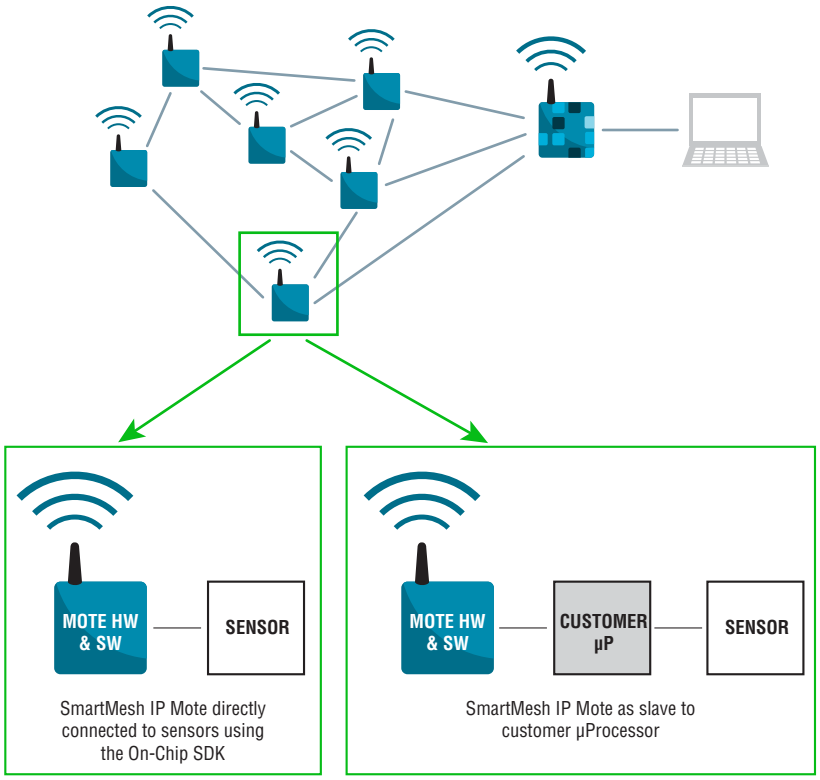
SmartMesh IP Motes

SmartMesh IP Motes are the wireless nodes in a SmartMesh IP network. They connect to sensors/actuators and route data from other motes, yet remain low power.

Each mote can both send and receive messages (supports bidirectional data). Each mote may have a different data reporting rate and the network manager will automatically coordinate individual pair-wise communications to efficiently route the traffic.

Each mote may have a different power supply capability (e.g., line-, battery-, or energy-harvested power). The network manager will load balance traffic accordingly to extend time until the network's first battery replacement.

SmartMesh IP networking software is compiled and fully tested. Motes have an onboard ARM Cortex-M3 processor that supports customer application software using the SmartMesh IP On-Chip Software Developer Kit. Alternatively, a mote may be controlled by an external microprocessor through its serial API interface.



SmartMesh IP On-Chip Software Development Kit (On-Chip SDK)

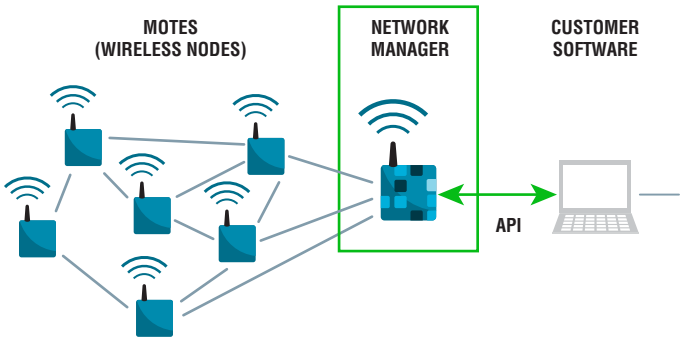
The SmartMesh IP On-Chip Software Development Kit (On-Chip SDK) enables you to develop C-code applications for execution on SmartMesh IP motes. With the On-Chip SDK, users may quickly and easily develop application code without the need of an external microprocessor.

Applications written within the On-Chip SDK may:

- **Read and Control Peripherals -** Via GPIO pins, ADC inputs, UART, SPI Master, I^2C Master, 1-Wire Master
- **Process Data –** such as statistical analysis (on-the-edge of the network), and local decision-making and control
- **Send and Receive Wireless Messages –** through the SmartMesh IP wireless mesh network

SmartMesh IP Managers

SmartMesh IP network managers perform two major functions for the mesh network. First they serve as an Access Point Mote™, connecting the wireless mesh to customer host applications. Second, network managers run sophisticated network management algorithms to maintain performance of the network.



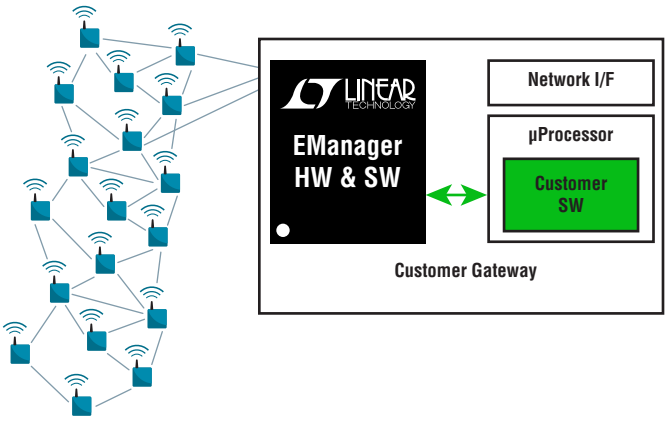
SmartMesh IP network managers come in two versions:

- EManager (supports up to 100 motes)
- VManager™ (supports thousands of motes)

SmartMesh IP EManager

An EManager, or embedded manager, runs as a Manager-on-Chip® where both the access point function and the network management algorithms run on board the SmartMesh IP 802.15.4 hardware (e.g., LTC5800-IPM).

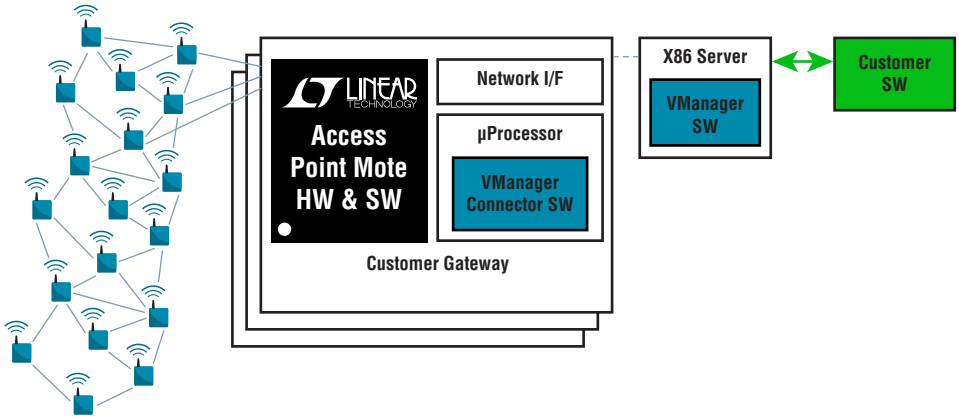
EManagers support up to 100 motes in the network and are ideal for low power gateway operation.



SmartMesh IP VManager

VManager software-based manager and separate Access Point Motes enable:

- Large Networks - thousands of nodes
- Increased Bandwidth through Multiple Access Points
- Hot Failover Gateway Redundancy



VManager software runs on an x86 virtual machine (VM), which can be installed on a variety of hardware platforms, from cloud servers to low power embedded x86-based processors. The VManager software is delivered from Linear Technology as a pre-compiled and tested VM application that may run on VMWare, or Oracle VirtualBox VMs.

One or more Access Point Motes (AP Motes) connect the SmartMesh IP network to the VManager software. An AP Mote™ is the combination of AP Mote software running on SmartMesh IP 802.15.4 hardware (e.g., LTC5800-IPM).

For a short video introduction of VManager visit:
www.linear.com/solutions/7445

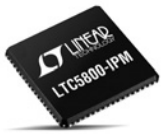
SmartMesh IP Products

Hardware Form Factors

SmartMesh IP 802.15.4 hardware is available in chip package, or as pre-RF-certified printed circuit board assemblies (PCBA). The 802.15.4 hardware's network behavior is defined by the type of SmartMesh IP software loaded onto the hardware (i.e., mote software, network manager software, or access point mote software).

Purchasing the hardware includes rights to download and run the SmartMesh IP embedded software.

Hardware



LTC5800IWR-IPMA

QFN Chip Package
10mm × 10mm

LTC5901IPC-IPMA

Pre-RF-Certified PCB Module
with Chip Antenna
24mm × 42mm

LTC5902IPC-IPMA

Pre-RF-Certified PCB Module
with MMCX Antenna Connector
24mm × 37.5mm

Software

Runs with either:

- SmartMesh IP **Mote** software

  or
- SmartMesh IP **Manager** software

  or
- SmartMesh IP **Access Point** software

Hardware Form Factor[5]	Ordering Part Number	Package (mm × mm)	Antenna Connection	Radio Frequency (GHz)	RF Output Power (dBm)	Receive Sensitivity (dBm)	RF Modular Certifications	Supply Voltage Range (V)
LTC5800	LTC5800IWR-IPMA#PBF I-Grade[1] LTC5800HWR-IPMA#PBF H-Grade[2]	QFN-72 (10 × 10)	QFN Lead	2.4000 to 2.4835	+8, 0[3]	–93[3]	NA	2.1 to 3.76
LTP5901	LTP5901IPC-IPMA#PBF I-grade[1]	Castellated Surface Mount PCBA (42 × 24)	Onboard Chip Antenna	2.4000 to 2.4835	+10, +2[4]	–95[4]	USA, Canada, EU, Japan, Korea, India, Australia, New Zealand, Taiwan	2.1 to 3.76
LTP5902	LTP5902IPC-IPMA#PBF I-Grade[1]	Castellated Surface Mount PCBA (37.5 × 24)	MMCX Antenna Connector	2.4000 to 2.4835	+8, 0[3]	–93[3]	USA, Canada, EU, Japan, Korea, India, Australia, New Zealand, Taiwan	2.1 to 3.76

Notes:
1. I-grade = –40°C to 85°C
2. H-grade = –55°C to 105°C
3. Conducted RF output power/sensitivity
4. Radiated Conducted RF output power/sensitivity
5. Hardware ships unprogrammed; Precompiled mesh networking software delivered electronically via www.linear.com/myLinear

SmartMesh IP Starter Kit

The DC9021B SmartMesh IP Starter Kit provides all the tools for evaluating SmartMesh network performance with respect to your application needs, including high reliability, ultralow power, scalability and ease of installation. This accelerates device integration and application software development.

The DC9021B Starter Kit includes five motes, or nodes (DC9018B-B), to enable you to quickly deploy a multi-hop mesh network in the RF environment specific to your application. The StarGazer evaluation software graphical user interface (GUI) allows you to quickly see the mesh network form, as well as key performance statistics, such as data reliability and latency.

The DC9018B-B Evaluation/Development Mote Modules feature easy-to-probe signal pins. In addition, the starter kit provides access to both manager and mote software application programming interfaces (APIs) over USB to enable application software development.

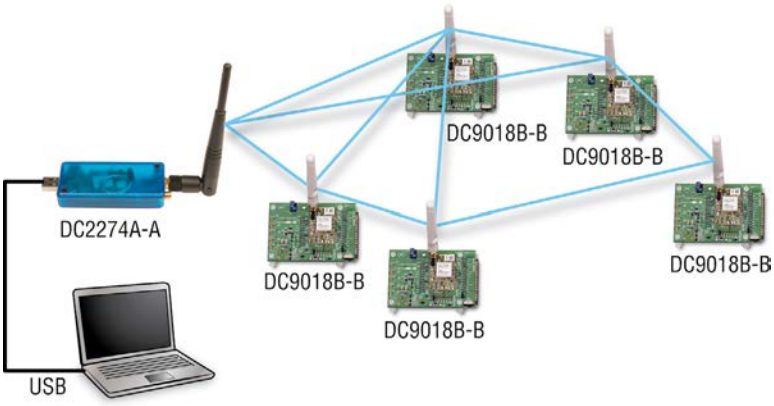
The DC2274A-A USB Embedded Network Manager comes factory-configured as an embedded network manager, where both the wireless-to-wired access point function and the network management algorithms run on board.

The DC2274A-B USB Access Point Mote enables customers to evaluate VManager, which supports thousands of nodes.

For more information visit
www.linear.com/starterkits

DC9021B SmartMesh IP Starter Kit

Part Number	Contents
DC9021B	• One USB Embedded Network Manager (DC2274A-A) • One USB Access Point Mote (DC2274A-B) • Five Evaluation/Development Motes (DC9018B-B) • One Eterna Interface Card (DC9006A), which Includes a DC9004 Adapter Card • One Eterna QuikEval Adapter (DC9005A) • Additional CR2032 Batteries • USB Cables

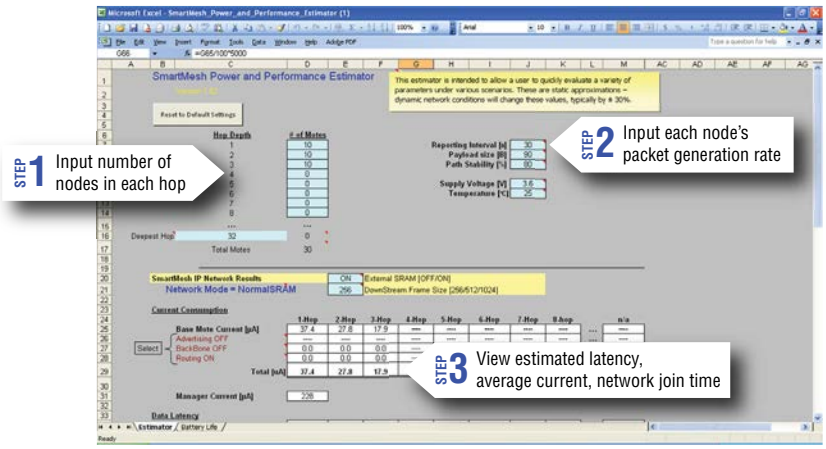


Typical Embedded Manager Setup

SmartMesh Power and Performance Estimator

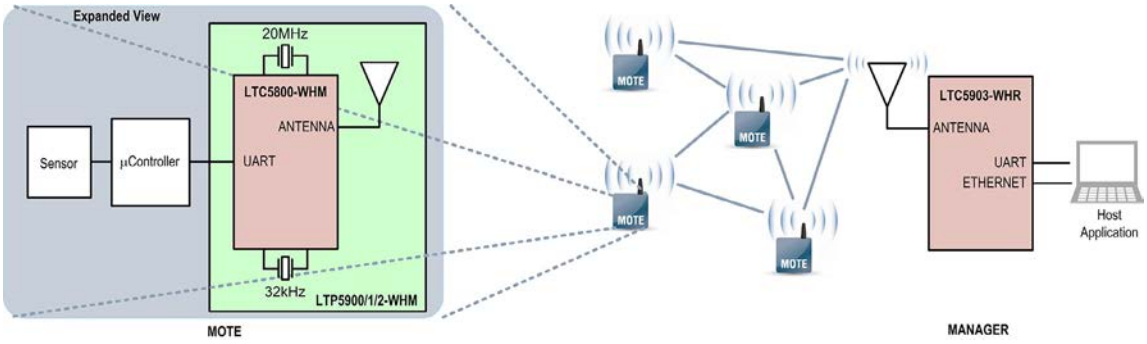
This Excel spreadsheet allows you to specify key parameters of a SmartMesh network (e.g., number of nodes, frequency of data transmission) and provides the associated estimates of power consumption, battery life and data latency. It is an excellent tool for doing "what-if" studies on network performance under various user-driven scenarios.

www.linear.com/docs/42452



SmartMesh WirelessHART Embedded Products

SmartMesh WirelessHART complies with the WirelessHART (IEC62591) standard, offering the lowest power consumption in its class and is the most widely used WirelessHART product available.



802.15.4 Motes **LTC5800-WHM** **LTP5901-WHM** **LTP5902-WHM**

Part Number	Operating Temp Range[1]	Package (mm × mm)	Supply Voltage Range (V)	Antenna Connection	Radio Frequency (GHz)	RF Output Power (dBm)	Receive Sensitivity (dBm)[2]	RF Modular Certifications
LTC5800-WHM	I	QFN (10 × 10)	2.1 to 3.76	QFN Lead	2.4000 to 2.4835	8, 0[3]	–93[3]	NA
LTP5901-WHM	I	Castellated PCBA (42 × 24)	2.1 to 3.76	Onboard Chip Antenna	2.4000 to 2.4835	10, 2[4]	–95[4]	USA, Canada, EU, Australia/New Zealand, India, Japan, Korea, Taiwan
LTP5902-WHM	I	Castellated PCBA (37.5 × 24)	2.1 to 3.76	MMCX Antenna Connector	2.4000 to 2.4835	8, 0[3]	–93[3]	USA, Canada, EU, Australia/New Zealand, India, Japan, Korea, Taiwan

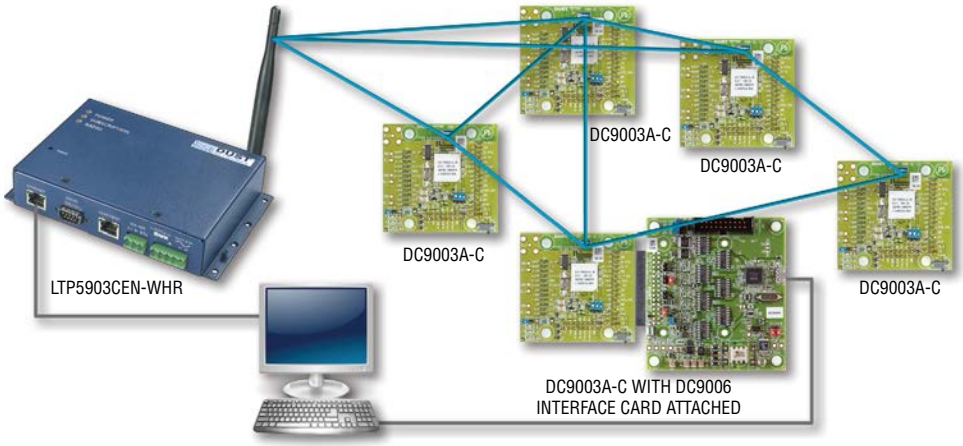
Note 1: I Temperature Grade = –40 to 85°C
Note 2: PER = 1% per IEEE 802.15.4
Note 3: Conducted RF Output Power/Sensitivity
Note 4: Peak Radiated RF Output Power/Sensitivity via Integrated Antenna

Network Managers **LTP5903IPC-WHR**

Part Number	Maximum Network Size	Op. Temp Range	Package (mm × mm)	Supply Voltage Range (V)	Antenna Connection	Radio Frequency (GHz)	RF Output Power (dBm)	Receive Sensitivity (dBm)[2]	RF Modular Certifications
LTP5903IPC-WHR	250 Motes (-WHRB) 500 Motes (-WHRC)	I	Stacked PCBA (102.9 × 55.6)	4.0 to 5.5	MMCX Antenna Connector	2.4000 to 2.4835	8, –2	–91[3]	USA, Canada, EU, Japan

Note 1: I Temperature Grade = –40 to 85°C
Note 2: PER = 1% per IEEE 802.15.4
Note 3: Conducted RF Output Power/Sensitivity

SmartMesh WirelessHART Starter Kit



DC9007 SmartMesh Wireless HART Starter Kit

The DC9007 SmartMesh WirelessHART Starter Kit provides all the tools for evaluating SmartMesh network performance for your application needs, as well as the necessary hardware and software for product development.

The DC9007 Starter Kit includes five motes, or nodes (DC9003A-C), to enable you to quickly deploy a multi-hop mesh network in the RF environment specific to your application. The software graphical user interface (GUI) allows you to quickly visualize the mesh network, and displays key performance statistics, such as data reliability and latency.

Part Number	Description
Starter Kit	
DC9007	SmartMesh WirelessHART Starter Kit – Includes the Following: ● One Packaged Manager (LTP5903CEN-WHR) ● Five Evaluation/Development Motes (DC9003A-C) ● One Eterna Interface Card (DC9006) ● Additional CR2032 Batteries ● Cables
DC9022	SmartMesh WirelessHART Starter Kit (Certified for Japan) Includes the Following: ● One Packaged Manager (LTP5903CEN-WHRB) ● Five Evaluation/Development Motes (DC9018A-C) ● One Eterna Interface Card (DC9006A) ● Additional CR2032 Batteries ● Cables

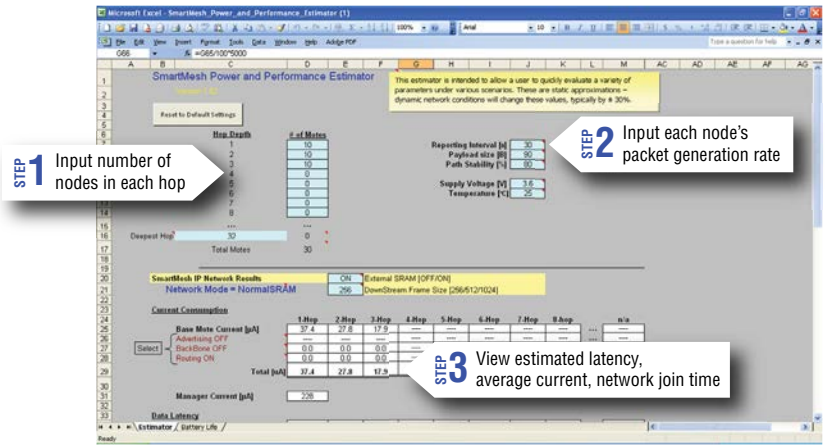
The DC9003A-C Evaluation/Development Mote Modules feature easy-to-probe signal pins. In addition, the starter kit provides access to both manager and mote software application programming interfaces (APIs) to enable application software development.

For more information visit
www.linear.com/starterkits

SmartMesh Power and Performance Estimator

This Excel spreadsheet allows you to specify key parameters of a SmartMesh network (e.g., number of nodes, frequency of data transmission) and provides the associated estimates of power consumption, battery life and data latency. It is an excellent tool for doing "what-if" studies on network performance under various user driven scenarios.

www.linear.com/docs/42452



Dust Networks Applications

Providing low power wireless mesh networks for demanding industrial process automation applications, Dust Networks supports customers that include Fortune 500 companies with solutions for building automation, data center energy management and renewable energy. Over sixty thousand Dust Networks enabled systems are deployed worldwide, securely connecting a variety of smart devices to applications delivering on smarter, greener, more efficient solutions.

Data Center

Manage the data center environment and significantly reduce energy consumption by connecting sensors that monitor and control temperature, pressure and humidity.

Case Study - Vigilent and Dust Networks Reduce Data Center Energy Consumption www.linear.com/docs/41384

Industrial Automation

Lower system and infrastructure costs, use energy and materials more efficiently, improve safety, and guarantee regulatory compliance in factories, refineries and plants.

Case Study – Emerson Process and Dust Networks
www.linear.com/docs/41383

Renewable Energy

Optimize operational efficiencies and equipment uptime for production of electricity in solar farms, wind farms and smart grid distribution infrastructure.

Building Automation

Reduce installation and maintenance costs for lighting control and HVAC systems using wireless mesh for the underlying communications among sensors in commercial buildings.

Remote Monitoring

Enable large-scale environmental monitoring with field-tested products made for harsh weather, challenging RF environments, and long battery life, designed to endure high volume data transmissions.

Case Study – Dust Networks and CITRIS Measure Snow Pack
www.linear.com/docs/41905

Transportation

Improve quality and quantity of data collection with intelligent infrastructure solutions that optimize the use of transportation assets such as city parking spaces, rail system, logistics operations and airport fueling.

Case Study – Streetline Networks and Dust Networks Make Cities Smarter and Happier www.linear.com/docs/41387

Case Study – TDG Technologies and Dust Networks Improve Airport Fueling Safety
www.linear.com/docs/57720

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