PE1HVH

MeshCore

Complete Manual

Off-grid mesh communication

Text-based communication via LoRa radio

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1. Introduction: What is MeshCore?

MeshCore is a powerful wireless communication system that operates completely independently of the internet, mobile networks, and other central infrastructure. It combines LoRa radio technology with advanced mesh networks to enable reliable communication over distances of tens of kilometers.

Important: MeshCore is een **text-based communicatiesysteem**. Het is specifiek ontworpen voor het verzenden of tekstberichten, GPS-locaties, telemetrie-data en besturingscommando's. Spraakoproepen of video zijn niet mogelijk vanwege de beperkte bandbreedte of LoRa radio.

1.1 What makes MeshCore unique?

Unlike traditional communication systems, MeshCore does not require a central server or access point. Each device in the network is simultaneously:

- A transmitter and receiver - for direct communication
- A router - that forwards messages for others
- An autonomous computer - that makes decisions without human intervention

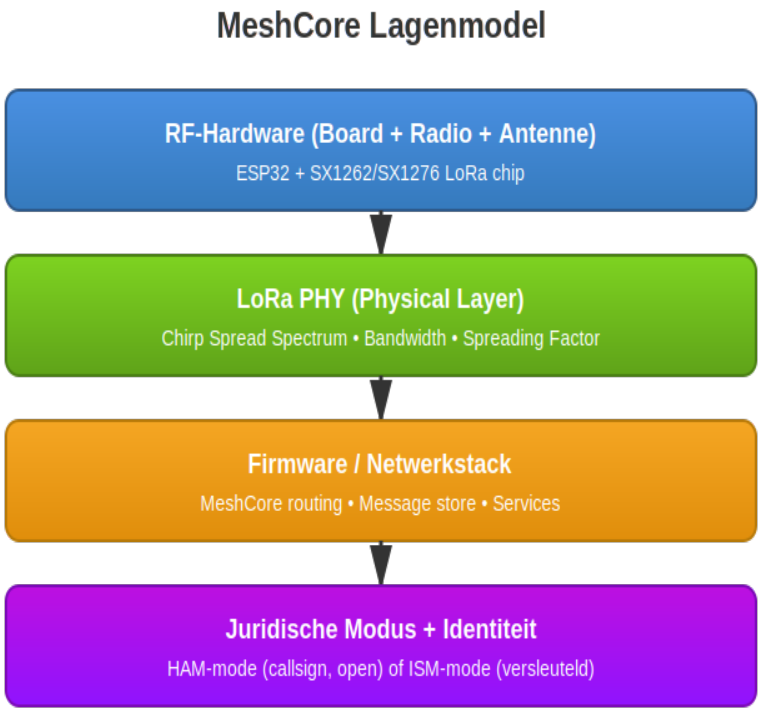
This architecture makes the network extremely robust: if one device fails, the network automatically finds an alternative route.

1.2 Who is MeshCore for?

- Families - who want to communicate with each other during travel or emergencies
- Clubs and associations - such as morse clubs or hiking groups
- Radio amateurs - for digital experiments and emergency communication
- Outdoor enthusiasts - hikers, campers, adventurers

2. Technical Foundation: The Layer Model

MeshCore is built from four strictly separated layers, each with a specific function:



2.1 Layer 1: RF Hardware

The physical foundation consists of a microcontroller (usually ESP32 or nRF52), a LoRa radio chip (SX1262), antenna, and power supply.

2.2 Layer 2: LoRa PHY (Physical Layer)

The modem layer determines how bits are converted to radio signals via Chirp Spread Spectrum (CSS) modulation. Parameters such as bandwidth, spreading factor, and coding rate determine range versus speed.

2.3 Layer 3: Firmware and Network Stack

MeshCore firmware handles routing, message processing, and network management. Each node has its own identity and can forward messages.

2.4 Layer 4: Legal Mode

Determines whether the device operates in HAM mode (70 cm band, no encryption, callsign required) or ISM mode (868 MHz band, encryption on, anonymous possible).

3. Getting Started: First Installation

3.1 Requirements

- MeshCore-compatible hardware (e.g., Heltec V3, T-Deck Plus)
- Antenna for 868 MHz
- Android or iOS phone with MeshCore Companion App
- USB cable for initial configuration

3.2 Step 1: Flash Firmware

Go to flasher.meshcore.co.uk in Chrome or Edge. Select your device, choose 'Companion Radio BLE' firmware, and click Flash.

3.3 Step 2: Connect with the App

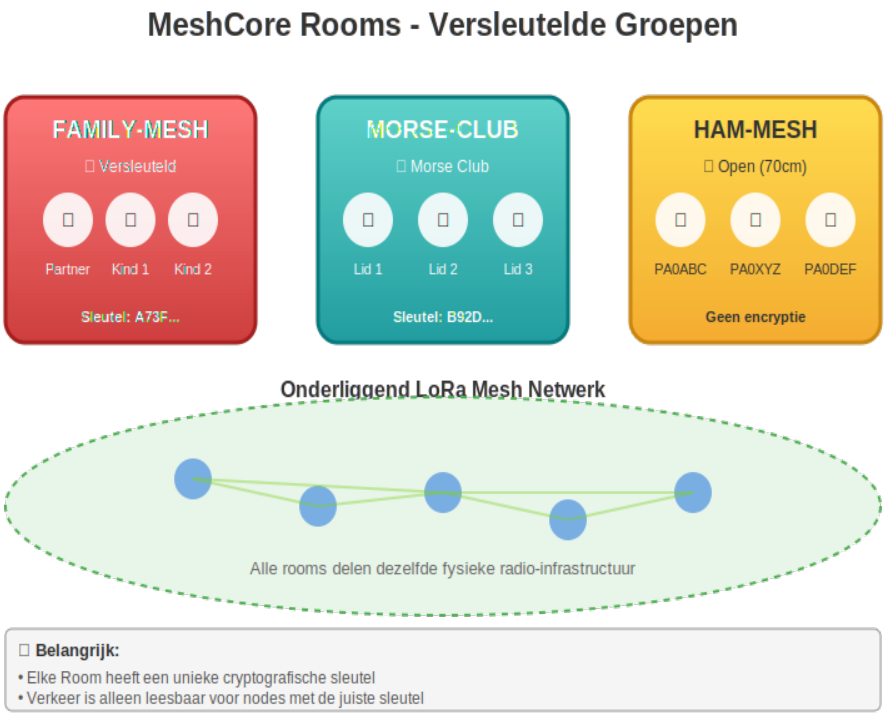
Start the MeshCore Companion App, choose Scan, select your node, and tap Connect. You are now connected.

3.4 Step 3: Configure

Configure: frequency 868.300 MHz, bandwidth 125 kHz, spreading factor SF11, power 14 dBm (EU limit). Encryption is enabled by default.

4. Group Communication: Rooms

MeshCore supports Rooms: separate communication groups within the same mesh network. Each Room has its own participants, its own message stream, and in ISM mode its own cryptographic key.



4.1 Sharing Room Keys

- Via QR code - scan the code with the recipient's phone
- Via BLE - directly from node to node when nearby
- Via mesh - encrypted transmission to known nodes

4.2 Messages Without Connection (Store-and-Forward)

A frequently asked question is: what happens to messages when the node has no connection to the mesh network? MeshCore has a built-in store-and-forward mechanism for this.

How does it work?

When you send a message and the destination is not directly reachable, the node stores the message in its internal memory. The node continues to periodically try to deliver the message. As soon as a route becomes available again, the messages are sent.

Standard versus extended functionality

Standard functionality: Every node has basic buffering for messages in transit through the mesh. This ensures that messages are not lost during temporary route interruptions.
Extended store-and-forward: The full store-and-forward function (longer storage, storing more messages) is part of the Ultra license. This is especially relevant for nodes that function as fixed repeaters or room servers and need to be able to hold messages for extended periods.

Practical limitations

In practice, it usually works out fine, for a few reasons:

- **Short messages:** MeshCore is text-only, so messages are small (tens to hundreds of bytes). Many can fit in memory.
- **Mesh nature:** If one route fails, the network often quickly finds an alternative route via other nodes.
- **Typical usage:** Most people don't send dozens of messages while completely isolated.

When can it become a problem?

- **Node restart:** During a reboot, the queue is lost unless the firmware supports persistent storage.
- **Extended isolation:** If you have no connection for hours or days and send many messages.
- **Memory limitations:** Cheaper boards like the Heltec V3 have less RAM than, for example, a T-Deck.

Practical advice

For normal family or club use, you'll hardly notice it. If you place a node in a remote location that is regularly offline and needs to forward important messages, then the Ultra license with extended store-and-forward is worth it.

5. Privacy and Security: Visibility

5.1 What is always visible?

Each node must broadcast beacons for routing. Other nodes see that a node exists and is active.

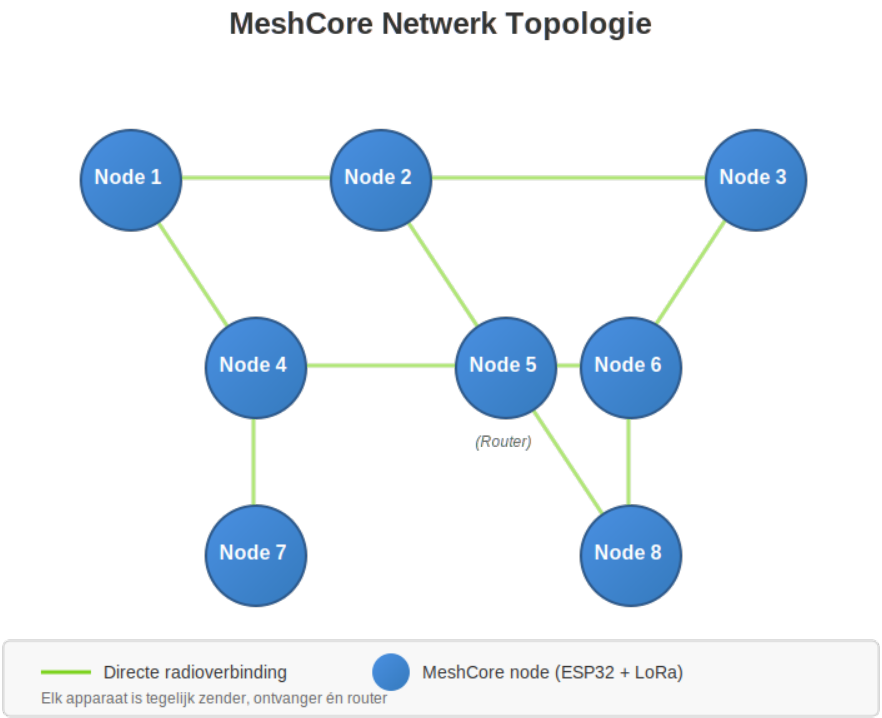
5.2 What is NEVER visible (in ISM mode)?

- Who you communicate with
- Which Rooms you are in
- The content of your messages
- Even the existence of your Rooms

5.3 HAM vs ISM Comparison

Property	HAM Mode	ISM Mode
Frequency	70 cm band (430-440 MHz)	868 MHz band
License	Required (amateur)	Not required
Encryption	Not allowed	Required
Identification	Callsign required	Anonymous possible

6. Practical Applications



6.1 Application 1: Family Mesh

Alle gezinsleden hebben een MeshCore apparaat in Room 'FAMILY-MESH'. Gebruik: korte berichten, GPS-tracking, afspraken tijdens reizen. Werkt zonder mobiel netwerk.

6.2 Toepassing 2: MORSE-CLUB

Clubleden coordineren CW-activiteiten, velddagen en spotmeldingen via een gezamenlijke Room. Leden zien elkaar automatisch op de kaart.

6.3 Application 3: Amateur Radio Mesh

On the 70 cm band with callsigns. Digital QSOs, emergency communication, self-routing repeaters. Each node functions as both station and repeater.

6.4 Application 4: Remote Station

Node on rooftop terrace with good antenna, node inside with BLE to phone. Control your radio infrastructure via your own radio-internet. No TeamViewer, no VPN needed.

7. Advanced Features: Remote Control

MeshCore is not just a chat system. It can be used as a fully off-grid, encrypted command-and-control network for physical devices.

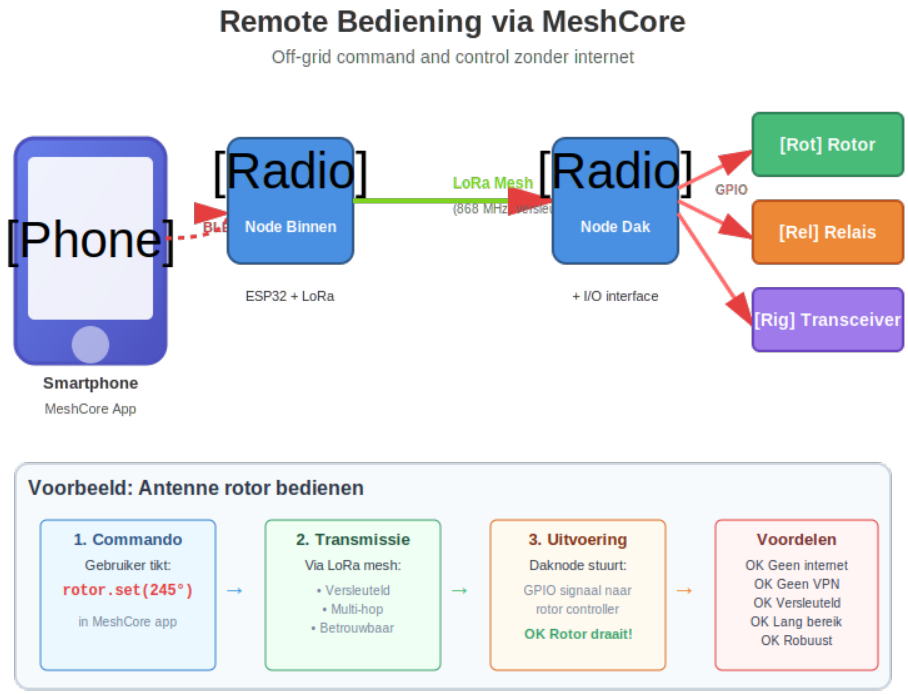
7.1 Technical Overview

Each MeshCore node is simultaneously:

- A LoRa radio - for wireless communication
- A router - for mesh network functions
- A computer (ESP32) - with processing power
- Met I/O interfaces - UART, GPIO, I2C, SPI, USB

This means you can literally connect devices:

- Relays - for switchable power
- Arduinos and Raspberry Pis - for more complex tasks
- Transceivers - via CAT interface
- Sensors - temperature, humidity, air pressure
- Motors and rotors - for antenna direction
- Power switches - for remote on/off



7.2 How does it work?

MeshCore has a service layer on top of the mesh. A node can offer services such as gpio.toggle, rig.set_freq, power.on, status.read. Other nodes can call those services. It's similar to REST over radio, but end-to-end encrypted, without internet, via multiple hops.

7.3 Concrete Example: Rooftop Terrace

Je zet een node bij je antennes op het dak. Die node zit in Room 'REMOTE-MESH' en heeft GPIO verbindingen naar rotor, relais en transceiver CAT. Binnen heb je een andere node. Je tikt 'rotor.set(245)' en het signaal gaat: Phone -> BLE -> node -> mesh -> daknode -> GPIO -> rotor. Geen wifi, geen kabel, geen provider.

7.4 Why is this so powerful?

- Cannot be jammed with a single transmitter
- No central point that can fail
- No cloud needed
- Fully encrypted

- Tens of kilometers range

Summary: MeshCore can be used as an encrypted, off-grid network for remote control and monitoring of physical devices, because each node is simultaneously a radio, router, and control computer.

8. Hardware Overview

MeshCore supports a wide range of hardware devices. This chapter provides an overview of the most popular options with their pros and cons.

8.1 Hardware Categories

- Companion Radios - require smartphone for operation via Bluetooth/USB/WiFi
- Standalone Devices - complete communication devices with keyboard and screen
- Repeaters and Servers - nodes that extend the network

8.2 1. LilyGO T-Deck Plus (€70-80)

Best for: Standalone use without smartphone

Complete standalone solution with ESP32-S3, 2.8 inch LCD color screen, physical QWERTY keyboard, built-in GPS, 2000mAh battery, microphone and speaker. The microphone and speaker are NOT used for real-time voice but for notification tones and possibly future codec-based voice messaging.

Voordelen: Volledig zelfstandig, fysiek toetsenbord, robuuste behuizing, Built-in GPS, externe antenne mogelijk.
Nadelen: Trackball soms gevoelig, reset knop kan per ongeluk ingedrukt worden, firmware minder functies dan app.

8.3 2. Heltec WiFi LoRa 32 V3/V4 (€20-40)

Best for: Budget entry with smartphone

Cheapest way to start with MeshCore. ESP32-S3 with SX1262 LoRa, small 0.96 inch OLED screen, WiFi and Bluetooth. Requires external battery. V4 has more memory and 28dBm transmit power.

Voordelen: Zeer betaalbaar, compact, breed ondersteund, geschikt als companion en repeater.
Nadelen: Vereist smartphone, klein scherm, geen behuizing standaard, USB-C naar USB-C kan problemen geven.

8.4 3. RAK WisBlock RAK4631 (€40-60)

Best for: Energy-efficient and modular solutions

Based on nRF52840 with extremely low power consumption - weeks to months on battery. Modular system expandable with sensors. Ideal for solar-powered installations and IoT projects.

Voordelen: Extreem laag verbruik, modulair, perfect voor solar, professionele kwaliteit.
Nadelen: Duurder, geen WiFi (alleen Bluetooth), complexere setup, minder verwerkingskracht.

8.5 4. Seeed Studio T1000-E (€30-40)

Best for: Compact companion radio with GPS

Extremely compact credit card format with built-in GPS. nRF52840 based for low consumption. Full-fledged MeshCore node that can send and receive text messages via the smartphone app. Door het compacte formaat en de ingebouwde GPS bijzonder geschikt voor tracking-toepassingen.

Voordelen: Zeer compact, ingebouwde GPS, laag verbruik, robuust, volledige MeshCore functionaliteit.
Nadelen: Geen display of knoppen, vereist smartphone voor alle interactie, geen externe antenne mogelijk.

8.6 Hardware Comparison Table

Specification	T-Deck Plus	Heltec V3/V4	RAK4631	T1000-E
Price	€70-80	€20-40	€40-60	€30-40
Communicatie	Text-only	Text-only	Text-only	Text-only
Standalone	**Yes**	No	No	No
Display	**Yes**	**Yes**	No	No
Toetsenbord	**Yes (QWERTY)**	No	No	No
Built-in GPS	**Yes**	No	Optional	**Yes**
WiFi	**Yes**	**Yes**	No	No
Bluetooth	**Yes**	**Yes**	**Yes**	**Yes**
Batterij ingebouwd	**Yes (2000mAh)**	No	No	**Yes**
Battery Life	2-3 days	1-2 days	**Weeks**	**Weeks**
Behuizing	**Yes**	Optional	No	**Yes**
Externe antenne	**Yes (SMA)**	**Yes (IPEX)**	**Yes (U.FL)**	No
Solar mogelijk	**Yes**	**Yes**	**Yes**	No
Microfoon*	Yes*	No	No	No
Speaker*	Yes*	No	No	No
Best for	Standalone	Budget	Solar/IoT	Compact/GPS

*** Microfoon en speaker:** NIET voor realtime spraak. Speaker is voor notificatie-piepjes, microfoon voor mogelijke toekomstige codec-based voice messaging (vergelijkbaar met WhatsApp voice notes).

8.7 Purchase Advice

- T-Deck Plus - voor volledig zelfstandig apparaat zonder smartphone
- Heltec V3/V4 - voor budgetbewuste gebruikers met smartphone
- RAK WisBlock - voor vaste installaties en solar-powered nodes
- T1000-E - voor maximale compactheid met ingebouwde GPS

Note: Always check that the device has the correct frequency for Europe (868 MHz, not 915 MHz).

9. Useful Links and Resources

9.1 Official Websites

- https://meshcore.co.uk/ - Official MeshCore website
- https://github.com/meshcore-dev/MeshCore - GitHub source code

9.2 Web Tools

- https://flasher.meshcore.co.uk/ - Web Flasher for firmware
- https://analyzer.letsmesh.net/ - Packet Analyzer
- https://meshcore.nz/ - Web Companion Client
- https://map.meshcore.dev/ - Official MeshCore map

9.3 Apps

- https://meshcore.co.uk/apps.html - Overview of all apps
- MeshCore Companion App - Android en iOS

9.4 Community

- https://discord.gg/ZVH2ujy9ex - MeshCore Discord server

10. Open Source and Paid Licenses

MeshCore is an open-source project. The core of the software is freely available under the MIT license. This means anyone can download, modify, compile, and use the firmware without paying. Je kunt dus altijd een volledig werkend MeshCore-netwerk bouwen zonder iets te kopen in de MeshCore store.

10.1 What is open source?

The open-source core of MeshCore includes: mesh routing, end-to-end encryption, room systems, basic messaging, and firmware for ESP32/LoRa nodes. This code is freely available on GitHub and anyone can contribute to development.

10.2 MeshCore Ultra Software License

De MeshCore store verkoopt **unlock-licenties voor extra functies** op bepaalde apparaten. De Ultra-licentie (circa £8) activeert extra mogelijkheden op standalone hardware zoals T-Deck, T-Deck Pro, T-Pager, T-Display Pro, T5 en WIO Tracker L1.

Extra features with Ultra license:

- Higher zoom levels on maps
- Remote Repeater profile (node as fixed repeater)
- Room server admin (manage rooms remotely)
- Telemetry node (send/receive sensor data)
- Store-and-forward (store messages and deliver later)

10.3 ESP-NOW / HyperBridge License

Deze licentie ontgrendelt een bridge-functie tussen MeshCore en ESP-NOW, een low-power peer-to-peer protocol of Espressif. Hiermee kun je ESP-NOW sensornodes laten communiceren met het MeshCore-netwerk, ideaal voor sensor-netwerken, telemetrie, domotica en remote monitoring.

10.4 What remains free?

Without any license you have access to:

- Full mesh routing
- Encrypted chat
- Rooms and group communication
- Basic GPS
- LoRa networks

- Custom firmware builds

So you can set up and use family networks, club networks, disaster communication, and off-grid messaging completely free.

11. Abbreviations and Terminology

11.1 Radio and Modulation

Term	Meaning
LoRa	Long Range - modulation technique for long-distance communication with low power
CSS	Chirp Spread Spectrum - the modulation method that LoRa uses
SF	Spreading Factor - determines range vs speed (SF7-SF12), higher = further but slower
BW	Bandwidth - bandwidth in kHz (125/250/500), smaller = more robust but slower
CR	Coding Rate - error correction level (4/5 to 4/8), more redundancy = more reliable
PHY	Physical Layer - the physical radio layer that converts bits to radio signals
dBm	Decibel-milliwatt - unit for transmit power (14 dBm = 25 mW)
EIRP	Effective Isotropic Radiated Power - effective radiated power including antenna
Link Budget	Total signal loss that a connection can tolerate and still be decodable

11.2 Network and Protocol

Term	Meaning
Mesh	Network where each device can forward messages to others
Node	A device/node in the MeshCore network
Hop	One hop between two nodes - messages can make multiple hops
Routing	Determining the best route for a message through the network
Beacon	Periodic signal that a node broadcasts to announce its presence
Room	Encrypted communication group with its own cryptographic key
Room Key	Cryptographic key that gives access to a Room
Node-ID	Unique identification of a node in the network
Repeater	Node that forwards messages to increase range
Telemetry	Measurement data from sensors sent via the network

11.3 Hardware and Connectivity

Term	Meaning
ESP32	Popular microcontroller from Espressif with WiFi and Bluetooth
nRF52840	Nordic microcontroller with ultra-low power consumption and Bluetooth
SX1262	Semtech LoRa radio chip - the newer, more efficient version
SX1276	Semtech LoRa radio chip - older but still used version
MCU	Microcontroller Unit - the central processor of a node
BLE	Bluetooth Low Energy - energy-efficient connection between node and phone
GPIO	General Purpose Input/Output - connection pins for external devices
UART	Universal Asynchronous Receiver-Transmitter - serial communication interface
I2C	Inter-Integrated Circuit - bus for connecting sensors and displays
SPI	Serial Peripheral Interface - fast bus for LoRa chip and SD card
SMA	SubMiniature version A - screw-on antenna connector
IPEX/U.FL	Small click-on antenna connector for internal antennas
GPS/GNSS	Global Navigation Satellite System - satellite navigation for positioning
OLED	Organic LED - type of display used on many MeshCore devices
LiPo	Lithium Polymer - type of rechargeable battery

11.4 Frequencies and Regulations

Term	Meaning
ISM-band	Industrial, Scientific, Medical - license-free frequency band, 868 MHz in Europe
70 cm-band	Amateur radio band 430-440 MHz, license required
HAM	Amateur radio mode - requires license, no encryption allowed
Callsign	Callsign - unique identification for radio amateurs (e.g., PA0ABC)
QTH	Location/position of a radio station (amateur jargon)
QSO	Radio contact between two stations (amateur jargon)
Duty Cycle	Percentage of time that a transmitter may transmit (EU: max 1% on 868 MHz)

11.5 Security and Encryption

Term	Meaning
E2E	End-to-End encryption - only sender and receiver can read messages
Public Key	Public key - can be shared, used to encrypt messages
Private Key	Private key - secret, used to decrypt messages
Key Rotation	Periodic replacement of keys for extra security

11.6 Software and Firmware

Term	Meaning
Firmware	Software that runs permanently on the node
Flashen	Installing or updating firmware on a device
Companion App	Smartphone application to control the MeshCore node
Web Flasher	Browser tool to install firmware without special software
DFU	Device Firmware Update - method to update firmware via Bluetooth
Meshtastic	Alternative firmware for LoRa mesh - not compatible with MeshCore
MIT-licentie	Open-source license that allows free use, modification, and distribution
ESP-NOW	Low-power peer-to-peer WiFi protocol from Espressif for direct communication between ESP devices
Open-source	Software whose source code is publicly available and may be freely used and modified
Store-and-forward	Function where messages are stored until the recipient is reachable

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