Emergency Communications

Using LoRa mesh for emergency preparedness, disaster response, and off-grid comms.

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? Start Here — Emergency Communications Guide

This book covers using LoRa mesh for emergency preparedness and disaster response - from personal go-bags to neighborhood networks, ARES/RACES integration, and active disaster operations.

? Quick Start by Role

- **Individual prepper / first responder:** Building a Go-Bag Node Kit
- **ARES/RACES ham operator:** Mesh Networking in ARES
- **Neighborhood / community organizer:** Building Neighborhood Disaster Preparedness Networks
- **Emergency manager:** Integrating with Served Agencies

? What's In This Book

Emergency Preparedness Basics

Disaster Scenarios

?? Related Books

- Starting a Community Mesh - Building the network before the disaster
- DIY Build Guides - Go-bag node hardware builds
- Getting Started - Ham radio licensing for emcomm operators

Emergency Preparedness

Why LoRa Mesh for Emergency Comms

Why LoRa Mesh for Emergency Communications

LoRa mesh networks provide a resilient, low-power, infrastructure-independent text and data communications platform that complements existing emergency communications systems.

Key Advantages in Emergencies

- **No infrastructure required:** Mesh nodes communicate directly without cell towers, internet, or power grid (beyond the node's own battery)
- **No license required:** 915 MHz ISM band operation is legal for anyone in the US without an amateur radio license, enabling rapid community-wide deployment
- **Long range:** LoRa achieves multi-kilometer range on coin cell batteries - far beyond Bluetooth or Wi-Fi
- **Text and data:** Provides messaging when voice radio is saturated, inaudible, or unavailable
- **Mesh redundancy:** Multiple routing paths mean the network continues even if individual nodes fail
- **Low cost:** Nodes are $20 - $60 each, enabling community-wide deployment at minimal cost

Use Cases

- **Neighborhood coordination** during extended power outages
- **Family/group location tracking** over long distances without cell service
- **Relay messaging** across disaster zones where infrastructure is down
- **Sensor monitoring** - water levels, temperature, structural sensors with LoRa mesh backhaul

What LoRa Mesh Is Not

LoRa mesh is a complement to, not a replacement for, traditional emergency communications:

- **No voice:** Text/data only - voice communications still require traditional radio
- **Limited bandwidth:** Not suitable for transferring large files or images in real time
- **Range limits:** Urban environments with buildings and terrain obstacles reduce range substantially vs. hilltop-to-hilltop links

Integration with ARES/RACES

Amateur Radio Emergency Service (ARES) and Radio Amateur Civil Emergency Service (RACES) are established frameworks for emergency communications. LoRa mesh can operate alongside these systems - handling neighborhood-level text coordination while licensed amateur radio handles regional and state-level coordination. See *Mesh and Amateur Radio (ARES/RACES)* for integration guidance.

Emergency Preparedness

Building a Go-Bag Node Kit

Building a Go-Bag Node Kit

A go-bag node kit is a self-contained, portable LoRa mesh capability you can deploy immediately in an emergency without depending on fixed infrastructure. The goal is a kit you can grab and go, with everything needed to establish mesh communications from any location.

Core Components

Component	Recommended Option	Notes
LoRa Node	Heltec V3 or T-Deck Plus	T-Deck Plus has a built-in keyboard and screen for standalone operation without a phone; Heltec V3 requires companion app on phone
External Antenna	Fiberglass omni, 3 - 5 dBi	Significant range improvement over stock PCB antenna; choose one with SMA connector matching your node
Power Bank	10,000+ mAh	A 10,000 mAh bank can run a Heltec V3 for days; larger capacity preferred for extended deployments
Short Coax Jumper	U.FL to SMA, 15 - 30 cm	Connects the node's U.FL port to an external SMA antenna; match connector types to your specific hardware
USB-C Cable (spare)	Short, braided	For charging/data; carry at least one spare

Optional Additions

- **Magnetic antenna mount:** For vehicle deployment - place antenna on roof for dramatic range improvement
- **Waterproof case:** Pelican 1150 or similar; protect electronics in wet conditions
- **Small tripod or mast:** Elevate antenna 2 - 3 meters above ground when vehicle deployment isn't available
- **Solar panel:** 10 - 20W panel + small charge controller for indefinite field deployment
- **Printed QR code:** Link to your local network's channel settings for quick onboarding of others

Kit Preparation

Configure the device before an emergency. A go-bag kit with unconfigured or default-password hardware is useless under stress. Before packing the kit:

1. Flash and configure the node with the correct channel/preset for your local network
2. Change all default passwords on any room server firmware
3. Test connectivity with known nodes in your area
4. Label the device with your callsign or contact info
5. Export and store a config backup

Pre-Deployment Checklist

Pre-Deployment Checklist

The single most important rule for emergency mesh communications: **configure and test your equipment before you need it.** A device configured under stress, in the dark, during an emergency will have errors. Do this work now.

Hardware Preparation

- ☐ Flash current firmware from flasher.meshcore.io (MeshCore) or the Meshtastic flasher
- ☐ Set node name to something identifiable (your callsign or neighborhood)
- ☐ Set GPS coordinates (lat/lon)
- ☐ Change all default passwords (admin: "password", guest: "hello") on room server firmware
- ☐ Apply correct radio preset (USA/Canada for most North American MeshCore networks)
- ☐ Attach and secure external antenna
- ☐ Verify the node appears on a network map (map.meshcore.dev or meshmap.net)

Connectivity Testing

- ☐ Confirm channel/preset matches your local network
- ☐ Test two-way communication with at least one other known node
- ☐ Test from multiple locations (indoors, outdoors, vehicle)
- ☐ Confirm room server (if deployed) accepts messages from client nodes
- ☐ Verify MQTT gateway (if present) is publishing to broker

Infrastructure

- ☐ Consider a permanent rooftop or elevated repeater for neighborhood coverage - install before an emergency while conditions are normal
- ☐ Ensure permanent repeaters have reliable power (ideally with UPS or battery backup)
- ☐ Document all node locations, hardware, and configurations in a shared document accessible to your emergency team

Team Preparation

- ☐ Train all team members on the companion app before deployment
- ☐ Establish and communicate channel names and passwords to all participants in advance
- ☐ Assign a "mesh coordinator" role responsible for network status during an event
- ☐ Export config backup and store separately from the device

Realistic Range Expectations

Scenario	Typical Range
Urban direct (street level)	1 - 5 km
Suburban rooftop-to-rooftop	5 - 15 km
Rural / hilltop-to-hilltop	20 - 50+ km
With mesh hops through repeaters	Multiply coverage area substantially

Integration with Existing Systems

Mesh and Amateur Radio (ARES/RACES)

Mesh and Amateur Radio (ARES/RACES)

LoRa mesh and traditional amateur radio serve complementary roles in emergency communications. Understanding how they fit together helps you deploy each where it is most effective.

What ARES and RACES Are

ARES (Amateur Radio Emergency Service) is an ARRL program where licensed amateur radio operators provide emergency communications for served agencies (Red Cross, hospitals, government agencies). **RACES (Radio Amateur Civil Emergency Service)** is a similar program with formal government ties, activated during civil emergencies.

Both programs have established protocols, training requirements, and communication plans. They operate on licensed amateur radio frequencies with trained operators.

Where Mesh Fits In

Capability	Amateur Radio	LoRa Mesh
Voice communications	Yes - primary strength	No - text/data only
License required	Yes - FCC license required	No - 915 MHz ISM band
Served agencies	Hospitals, Red Cross, EOC	Neighborhoods, community groups
Long-range links	HF (worldwide), VHF/UHF regional	LoRa: 20 - 50+ km hilltop
Text messaging	Winlink, APRS, packet	Native; all nodes capable
Deployment cost	$100 - $1,000+ per station	$20 - $60 per node
Deployment speed	Requires trained operator	Any community member

Practical Integration Model

A realistic combined deployment:

- **Neighborhood layer (LoRa mesh):** Blocks to several miles - coordination among neighbors, location sharing, welfare checks. No license required; any resident can deploy a node.
- **Regional layer (VHF/UHF amateur):** Repeater-linked coverage across a county or metro area. Requires licensed operators; handles voice coordination between neighborhoods and EOC.
- **State/national layer (HF amateur):** Winlink gateways and HF nets for long-distance traffic when regional infrastructure is compromised.

For Amateur Radio Operators

If you hold an amateur radio license, consider:

- Deploying LoRa mesh alongside your existing radio setup to provide text/data capability for neighbors who don't have radio licenses
- Using LoRa mesh for neighborhood coordination while using your radio for ARES/RACES served agency traffic
- Advocating for LoRa mesh within your ARES group as a force multiplier for neighborhood-level coverage

Realistic Range and Coverage Expectations

Realistic Range and Coverage Expectations

Understanding realistic range helps you plan deployments, set expectations with community members, and know when a link will or won't work. The numbers below are based on real-world community mesh experience.

Direct Link Range (No Repeaters)

Environment	Typical Range	Limiting Factor
Urban (street level)	1 - 5 km	Buildings blocking line of sight; multipath interference
Suburban (rooftop-to-rooftop)	5 - 15 km	House heights, trees; rooftop placement dramatically improves range
Rural (ground level)	5 - 15 km	Terrain, vegetation
Rural (hilltop-to-hilltop)	20 - 50+ km	Primarily limited by earth curvature and Fresnel zone clearance
Flat terrain (North Dakota, Great Plains)	15 - 30+ km even at modest height	Minimal obstructions; terrain is primary advantage

With Mesh Hops

Each repeater hop extends coverage. A chain of three repeaters on hilltops spaced 30 km apart extends coverage 90+ km. The mesh topology means messages can route around failed nodes as long as an alternative path exists.

Key Factors Affecting Range

- **Antenna height:** The single most impactful variable. Going from ground level to a 10-meter rooftop can double or triple range.
- **Antenna gain:** A 5 dBi external antenna vs. a PCB trace antenna provides roughly 3x effective range improvement.
- **Spreading factor:** Higher SF (e.g., SF12 vs. SF7) increases range ~4x but reduces throughput ~16x and increases time-on-air proportionally.
- **Terrain:** Line-of-sight clearance is critical. Even a small hill between two nodes can reduce range from 20 km to 2 km.
- **Vegetation:** Dense forest canopy attenuates 915 MHz signals significantly. Summer foliage can reduce range compared to winter.
- **Buildings:** Each wall the signal passes through attenuates the signal. Inside-to-inside through multiple walls can reduce range to under 1 km.

Planning Conservatively

For emergency planning, use these conservative estimates:

- Inside a building: assume 300 - 500 m reliable range
- Outside in urban area: assume 1 - 2 km reliable range
- Rooftop with external antenna: assume 5 - 10 km reliable range

Actual coverage may be better, but plan for the conservative case. Use MeshMapper wardriving to measure actual coverage once deployed - real measurements beat estimates every time.

Use Coverage Planning Tools

Before deploying, model your site with:

- heywhatsthat.com - radio horizon from a specific location
- nodakmesh.org/tools/node-planner - topo + satellite with live node visibility
- radiomobile.pe1mew.nl - advanced RF propagation modeling

Disaster Scenarios

Wildfire Communications

Wildfires create some of the most challenging communication environments: rapidly changing conditions, disrupted infrastructure, and urgent coordination needs across large areas. LoRa mesh is increasingly used for both community alerting and field operations.

Why mesh works during wildfires

- **Cell tower independence:** Cell towers near fire zones are often the first infrastructure to fail - whether from power loss, fire damage, or overload as residents attempt to reach family. Mesh operates entirely independently.
- **Mobile coverage:** Portable nodes in vehicles, on firefighters, or at incident command posts create a mesh network that moves with the response operation.
- **Position tracking:** GPS-enabled nodes allow incident command to track crew positions in near-real-time without a dedicated tracking system.
- **Resilient backbone:** Solar-powered repeaters on hilltops continue operating even during extended power outages.

Community alerting use case

A community mesh network with established repeater infrastructure can be activated as a grassroots alerting layer during a wildfire:

- Road conditions and evacuation route updates can be broadcast to all mesh participants
- Nodes in affected neighborhoods can provide "eyes on the ground" status reports
- Air quality readings from BME680-equipped sensor nodes provide hyperlocal data
- Resource availability (shelters open/full, fuel, supplies) can be distributed across the mesh

Field operations use case

For organized response teams (volunteer fire, SAR, CERT):

Minimum viable field kit

- Net control operator with T-Deck Plus (MeshOS) or laptop + Pi room server
- 1 - 2 hilltop or elevated relay nodes (portable solar)

- Personal nodes for each field team (T-Echo or T1000-E, pocketable)

Operating procedure

1. Deploy hilltop relay node(s) at the highest accessible points overlooking the operational area
2. Net control establishes the operations channel and verifies all teams are visible in contacts
3. Field teams broadcast GPS position updates at 5-minute intervals
4. All significant events are logged as messages (not just voice) for accountability records
5. Net control maintains a position board (GPS positions from all team nodes on map view)

Specific challenges and mitigations

Challenge	Mitigation
Smoke reduces solar panel output	Oversize battery for 5-day autonomy; battery provides buffer during smoke events
Fire destroys repeater nodes	Document all site coordinates; prioritize replaceable hardware (RAK4631 over specialized boards)
Rapid terrain changes (burn areas)	Have portable relay nodes ready to deploy at new high points as conditions change
Crew unfamiliarity with mesh devices	Train before deployment; include device setup in team training exercises

Earthquake Response

Major earthquakes cause cascading infrastructure failures within minutes: power out, cell towers down, roads blocked. A pre-deployed mesh network provides an immediate communication layer requiring no external infrastructure to function.

The critical first 72 hours

Emergency management doctrine focuses heavily on the first 72 hours post-earthquake as the window when mesh communications are most valuable:

- Cell towers typically restore within 24 - 72 hours for most users, but coverage is severely reduced
- Landlines may be out for days to weeks in heavily damaged areas
- Internet is intermittent; most social media platforms are unreliable in the first hours due to server load
- A pre-deployed mesh network with solar power and no internet dependency provides communications throughout this window

Infrastructure resilience by node type

Node type	Expected resilience	Key vulnerability
Ground-level portable (T-Echo, T1000-E)	High - battery-powered, no infrastructure dependency	Battery depletion after 7 - 14 days without recharge
Building rooftop (solar)	High if solar intact and antenna survived shaking	Antenna damage from building movement; chimney/parapet collapse
Hilltop (solar, remote)	Very high - rarely near structural damage	Snow/debris on panel; equipment theft in post-disaster chaos
Building-powered (mains only)	Low - loses power immediately	Grid outage (add UPS for short-term backup)

Neighborhood resilience net design

A "neighborhood net" approach that works well for earthquake-prone communities:

1. **One "net anchor" per neighborhood:** A solar-powered repeater on the highest accessible residential rooftop, battery-backed for 7+ days autonomy.
2. **Block captains with personal nodes:** Each block captain has a device pre-configured for the neighborhood channel. 5 - 10 devices within range of the anchor.
3. **Welfare check protocol:** Pre-established check-in schedule (e.g., every 8 hours). Any block captain who misses check-in triggers a welfare check by neighbors.
4. **Resource messaging format:** Simple standard format: "[LOCATION] STATUS: [OK/NEED HELP] INJURIES: [none/n] DAMAGE: [minor/moderate/severe]"
5. **Community coordination center connection:** The neighborhood net connects to a city-wide mesh via the anchor repeater - aggregate status flows up to emergency operations.

Pre-event preparedness steps

- Deploy solar-powered anchor repeaters *before* an earthquake, not during response
- Distribute personal nodes to all neighborhood net participants
- Conduct quarterly check-in tests to verify devices are charged and configured
- Store node charging cables in emergency kits alongside device
- Document the channel/preset configuration in printed form, stored with the device - don't rely on memory under stress
- Coordinate with local CERT or ARES team so mesh participants know how to integrate with larger response structure

Flood and Severe Weather Response

Floods, hurricanes, tornadoes, and severe winter storms each create different communication challenges. This page covers how mesh networks support response operations across severe weather scenarios.

Flood-specific considerations

Equipment waterproofing

Water is the primary hardware risk in flood scenarios. All field equipment should be in IP65+ rated enclosures or waterproof cases during flood response. For personal nodes:

- T1000-E: IP65 rated - can operate in rain and light water exposure
- T-Echo: Not rated; put in a small zip-lock bag or simple waterproof case during rain operations
- Heltec V3/V4: Not rated; laptop bag or waterproof case required

Elevated deployment

Flood scenarios require nodes to be deployed well above the anticipated flood level. Ground-level repeaters in flood zones should be identified and planned for relocation to higher sites during flood events. Maintain a pre-planned list of above-flood-level backup sites for your mesh repeaters.

Hurricane/tropical storm preparation

Before a storm:

1. Secure or remove antenna masts from exposed locations - a 5 dBi fiberglass vertical in 100 mph wind can become a projectile or bend the SMA connector
2. Verify all solar-powered nodes have full battery charge before the storm
3. Activate the community mesh "storm watch" channel if your network has one
4. Distribute personal nodes to participants who don't have them

5. Confirm that key participants know the channel name and PSK without needing to look it up

During a storm:

- Minimize transmissions to reduce battery drain on nodes that may not see sun for days
- Use standard welfare check format to efficiently survey neighborhood status
- Note that LoRa range is reduced in heavy rain due to signal absorption (minimal effect, but measurable at >50mm/hr rainfall)

Winter storm and extended power outage

Multi-day ice storms and blizzards create extended power outages with dangerous conditions that prevent physical access. Key preparations:

- **Battery sizing:** Solar panels under snow produce no power. Ensure battery autonomy covers the longest expected outage without sun - in northern latitudes, this can be 5 - 10 days during winter storms.
- **Panel tilt:** Steep panel angle (60 - 70° from horizontal) helps snow slide off and maximizes winter sun capture when panels are clear.
- **Cold battery performance:** $LiFePO_4$ batteries lose capacity at −20°C. Size battery 20 - 30% larger than minimum calculation to account for cold-weather performance reduction.
- **Personal node operation:** Keep personal nodes in warm pockets - battery capacity drops sharply in cold. Charge from vehicle power banks if grid is out.

Net operating procedures for severe weather

Welfare check format

```
STATUS REPORT
Node: [NODE-NAME or callsign]
Location: [neighborhood or cross street]
Status: [OK / NEED-ASSIST / EMERGENCY]
Injuries: [none / n minor / n serious]
Power: [on / out]
Notes: [any relevant info]
```

Priority message tags

Pre-establish a priority system for your community net:

- **[ROUTINE]:** General updates, non-urgent status
- **[PRIORITY]:** Important but not life-threatening (road closed, shelter open)
- **[EMERGENCY]:** Immediate life-safety issue requiring response

All participants should know that [EMERGENCY] messages trigger immediate net control response and that they should not use the tag for non-life-safety situations.

Integration with Official Systems

Working with ARES, CERT, and Emergency Management

The most effective community mesh deployments are integrated with existing emergency communication structures - Amateur Radio Emergency Service (ARES), Community Emergency Response Teams (CERT), and local emergency management agencies. This page covers how to make those integrations work.

Understanding the existing structure

ARES (Amateur Radio Emergency Service)

ARES is the ARRL's organized volunteer program connecting licensed amateur radio operators with emergency communication needs. ARES groups typically operate at the county or served-agency level. Key contacts: ARRL Section Manager, Emergency Coordinator (EC), and Net Manager.

Mesh relationship: Many ARES operators are interested in LoRa mesh as a complementary technology. It fills gaps that VHF/UHF radio cannot (group text, GPS tracking, message logging). A strong relationship with local ARES puts your mesh infrastructure in front of the people who already train for emergency communication.

CERT (Community Emergency Response Team)

CERT programs train community members in basic disaster response skills (first aid, light search and rescue, fire safety) and organize them as neighborhood response assets. CERT teams operate at the neighborhood or block level - exactly the scale where mesh radio is most useful.

Mesh relationship: A mesh network that equips each CERT team leader gives them communication capability during the most critical phase of disaster response: before professional responders arrive. CERT and mesh are a natural operational fit.

Local Emergency Management (OEM/LEPC)

Local emergency management agencies coordinate preparedness and response at the city and county level. They maintain Emergency Operations Centers (EOCs) that become the coordination hub during disasters.

Mesh relationship: EOC integration is a longer-term goal. Most EOCs start by observing mesh capabilities in exercises before formally adopting the technology. A well-demonstrated mesh network with clear procedures becomes a credible EOC resource.

First steps for integration

1. **Contact your local ARES Emergency Coordinator.** Introduce the mesh network, demonstrate its capabilities, and offer to participate in ARES-sponsored exercises with mesh alongside traditional radio.
2. **Attend CERT training.** CERT graduation puts you in direct contact with team leaders and the sponsoring fire department or emergency management agency. Offer to demo mesh at the graduation exercise.
3. **Contact local emergency management.** Most counties have a website listing the Emergency Manager or OEM director. A brief email introducing your mesh community and offering to participate in preparedness planning events opens the door.

Exercise integration

The most effective way to demonstrate mesh value is through exercises where it can be directly compared with existing methods. Propose a tabletop or functional exercise where:

- Mesh nodes are distributed among CERT teams
- Teams use mesh for status reporting during a simulated disaster scenario
- Net control demonstrates the GPS position board (where is every team right now?)
- Compare time-to-update for mesh vs. voice radio vs. runner

Emergency managers respond to demonstrated capability, not technical descriptions. One well-run exercise does more than months of email correspondence.

ICS compatibility

Emergency response in the US uses the Incident Command System (ICS). Mesh deployments serving ICS operations should align with ICS terminology and procedures:

- **Net Control = Communications Unit Leader (COML) role** or communications support to the Planning Section

- **Channel naming:** Use ICS-aligned channel naming if possible (e.g., "IC-TAC1", "LOGISTICS-1") rather than geographic names
- **Message format:** ICS 213 General Message Form format for formal communications (from, to, message, date/time, signature)
- **Check-in/check-out:** Track mesh node operators on an ICS 214 Activity Log

What not to do

- Don't present mesh as a replacement for ham radio, CERT radios, or existing systems. It's a complement, not a replacement.
- Don't overstate capabilities. Know the coverage gaps in your mesh and be honest about them with partners.
- Don't deploy in a real emergency before deploying in exercises. The first time field operators use any communication system should not be during an actual emergency.
- Don't let the technology drive the relationship. Build the relationship with emergency management first; the technology adoption follows from trust.

Go-Bag and Field Kit Setup

A mesh communications go-bag is a pre-configured kit that can be grabbed and deployed within minutes. For emergency communicators, this preparation is as important as the hardware itself.

Individual go-bag (personal responder)

Minimum kit for a personal mesh communicator:

Item	Purpose	Notes
T-Echo or T1000-E	Personal mesh node	Pre-configured with correct channel & preset; fully charged
USB charging cable (device-specific)	Field recharge	Tape/label with device name; easy to grab wrong cable
10,000 mAh power bank	Extended operation without grid	Keeps T-Echo charged for 10+ additional days
Printed config card	Quick reference	Channel name, PSK, preset, net control contact
Spare SMA antenna	Backup if stock antenna damaged	915 MHz, 2 - 3 dBi, same connector type as device

Net control go-bag

Expanded kit for net control operators or team leaders:

Item	Purpose
T-Deck Plus (running MeshOS)	Primary net control station; standalone, no phone needed; QWERTY keyboard; map view
OR: Raspberry Pi Zero 2W + RAK4631 USB	Room server + radio gateway; provides message persistence and network visibility
5W foldable solar panel + MPPT charge controller	Recharge power bank and devices from any outdoor location
12,000 mAh LiFePO4 power bank (e.g., Jackery 240)	Powers Pi room server for 8+ hours; recharges via solar
Laptop (optional)	Python API access, MQTT monitoring, additional visibility

Item	Purpose
Printed participant roster	All mesh participants, device names, and contact info
Printed frequency/channel card	Config for all channels in use; can hand to new arrivals

Portable repeater kit

A portable repeater that can be deployed at any elevated location within 30 minutes:

Item	Notes
RAK4631 WisBlock (configured as repeater) in IP65 case	Pre-flashed with repeater firmware; USA/Canada preset; flood advertisements
5 - 10W foldable solar panel with cigarette lighter connector	Mount using clamps or hook-and-loop straps
LiFePO4 18650 cells (4×, in battery holder)	~3 day autonomy at 6 mA; LiFePO4 for temperature range
5 dBi fiberglass antenna with 30cm LMR-200 pigtail	Better range than stock; coax already assembled to length
Pole mount clamp (adjustable)	Mounts to chain-link fence, sign post, vehicle roof rack, or trekking pole
All contained in a clear 12" × 8" zip-lock bag	Waterproof; visible inventory check without opening

Pre-event deployment checklist

Run this checklist before any exercise or real deployment:

- □ All devices fully charged
- □ Power banks fully charged
- □ Solar panel functional (brief outdoor test)
- □ All devices verified on correct channel and preset
- □ Device names are current (verify in app)
- □ Printed config cards included and current
- □ Contact list current (who has which device)
- □ Portable repeater tested (connect, verify advertisement)
- □ Go-bag weight and bulk acceptable for intended deployment

ARES, RACES, and Served Agency Integration

Integrating LoRa mesh with amateur radio emergency service organizations and their served agencies.

Mesh Networking in Amateur Radio Emergency Service (ARES)

> **Operational Note:** This page may be consulted during active emergency operations. All procedures are based on current FCC regulations and ARRL ARES guidelines as of 2025. Verify local ARES group policies before deployment.

What Is ARES?

The **Amateur Radio Emergency Service (ARES)** is a program of the American Radio Relay League (ARRL) that organizes licensed amateur radio operators to provide emergency communication support to government agencies, relief organizations, and other served agencies when normal communications infrastructure fails or is overloaded. ARES is organized at the local, section, and national levels, with Emergency Coordinators (ECs) managing groups at the county or city level, Section Emergency Coordinators (SECs) at the state level, and national leadership through the ARRL.

ARES members hold FCC amateur radio licenses (Technician, General, or Extra class) and participate in regular nets, exercises, and deployments. ARES groups typically operate on designated VHF/UHF repeater frequencies for voice communications and may also operate HF stations for long-range traffic handling. The National Traffic System (NTS) provides formal written message traffic capability via radiogram.

How LoRa Mesh Complements VHF/UHF ARES Operations

Traditional ARES operations are voice-centric: operators check into nets, relay verbal messages, and pass formal radiograms by voice or digital modes like Winlink. LoRa mesh (particularly Meshtastic) adds a complementary *data layer* that addresses specific gaps in traditional ARES capabilities:

Capability	Traditional ARES (VHF/UHF Voice)	LoRa Mesh Addition
Short text messaging	Voice relay only; requires operator attention	Asynchronous store-and-forward; no operator attention needed for relay
Position reporting	Verbal position reports; APRS on separate system	Automatic GPS position sharing on mesh; visible to all nodes
Net congestion	Single voice channel; traffic serialized	Parallel data channel; does not compete for voice net time
Message logging	Manual logging by net control	Automatic message log on all receiving nodes
No-license users	Not applicable (licensed only)	Part 15 operation allows non-licensed served agency staff on mesh
Infrastructure requirement	Repeater or simplex range	No infrastructure; ad-hoc mesh self-forms

LoRa Mesh as a Supplemental Data Layer

In ARES deployments, LoRa mesh is most valuable as a **supplemental data layer** running alongside, not replacing, the primary voice net. Common use cases include:

- **Position tracking:** Each ARES operator with a Meshtastic node automatically broadcasts GPS position. A Meshtastic client running on a laptop at net control can display all operator positions on a map without consuming voice net time for position reports.
- **Short message traffic:** Operators in the field can send short status messages ("shelter at Lincoln School now at 47 occupants") without requiring net control to be available to receive a voice transmission.
- **Pre-positioned relay nodes:** ARES groups can deploy solar-powered mesh relay nodes at elevated sites (hilltops, water towers, repeater sites) to extend mesh coverage across the operating area.
- **Served agency liaison:** A mesh node running in Part 15 mode at the served agency (Red Cross shelter, hospital, EOC) allows served agency staff to send text messages to ARES operators without needing a ham license.

How to Introduce Mesh to Your Local ARES Group

1. **Start with the EC (Emergency Coordinator).** Schedule a 15-minute briefing. Lead with the problem mesh solves: "We can't track field operator positions without using net time."

Avoid jargon. Bring a working demo node.
2. **Run a small demo at a regular meeting.** Set up two or three Meshtastic nodes in the room. Demonstrate position sharing on a phone screen. Let skeptical operators handle the hardware.
3. **Propose a parallel track at the next exercise.** Ask permission to run mesh alongside the normal voice exercise - not as a replacement. Offer to provide equipment for participants who want to try it.
4. **Document results.** After the exercise, provide a written after-action report comparing mesh message delivery vs. voice net efficiency. Numbers matter: "Mesh delivered 23 position updates automatically while voice net handled 8 formal messages."
5. **Propose group endorsement.** After successful exercises, request the EC formally endorse mesh as an ARES supplemental tool and add mesh node operation to the local ARES training curriculum.

FCC Part 15 vs. Part 97: Regulatory Considerations for ARES

Critical Regulatory Distinction

Meshtastic devices operating in the 915 MHz ISM band (US) operate under **FCC Part 15** - the same rules as Wi-Fi and Bluetooth. Part 15 operation:

- Requires **no license** to operate
- Limits power to typically 1 watt EIRP (30 dBm) in the 915 MHz band with frequency hopping spread spectrum
- Prohibits causing harmful interference to licensed services
- Requires accepting interference from other Part 15 devices
- Does **not** allow power increases beyond Part 15 limits, even by licensed amateurs

Part 97 (Amateur Radio) allows licensed amateurs to operate in the 33 cm (902 - 928 MHz) band with higher power (up to 1500W PEP in some cases, subject to local coordination). However, Part 97 operation **prohibits**:

- Encryption of message content (except for certain control signals)
- Commercial use or pecuniary interest
- Communications in which the licensee has a pecuniary interest

Meshtastic's default encryption (AES-128) means Meshtastic operation is *technically not Part 97 compliant* for content transmission, as Part 97 prohibits obscuring the meaning of messages. ARES groups should operate Meshtastic nodes under Part 15 rules with channels configured to unencrypted or use encryption only for served-agency traffic not transmitted under Part 97 authority.

Practical guidance: For ARES operations, use Part 15 power levels and configure channels with no encryption (or document your encryption key for legal Part 97 operation in jurisdictions where encryption is approved by your Section Manager). Consult your ARRL Section Manager for local guidance.

Getting ARES Group Endorsement for Mesh Infrastructure

Formal ARES group endorsement provides several benefits: shared deployment of pre-positioned nodes, group funding or donations for equipment, and integration into official exercise planning. To pursue endorsement:

1. Write a one-page proposal for the EC describing: (a) the problem mesh solves, (b) equipment required and cost, (c) regulatory compliance (Part 15), (d) maintenance plan, (e) training requirements.
2. Present the proposal at a group meeting and invite questions.
3. Offer a formal training session covering Meshtastic setup, channel configuration, and emergency protocols.
4. Request inclusion in the group's Standard Operating Procedures (SOPs) as "Supplemental Mesh Data Layer."
5. Coordinate with the Section Emergency Coordinator (SEC) if seeking section-level endorsement or cross-group interoperability.

Quick Reference: ARES + Mesh Checklist

☐ EC briefed and supports mesh integration
☐ At least one mesh exercise conducted alongside voice net
☐ After-action report documenting mesh performance documented
☐ Channel plan documented and distributed to all mesh operators
☐ Part 15 power compliance verified on all deployed nodes
☐ Encryption policy documented and compliant with Section Manager guidance
☐ Mesh roles assigned in ARES activation plan (mesh coordinator, relay node operators)
☐ At least two operators trained on mesh node setup and troubleshooting

☐ Mesh node inventory maintained with deployment locations
☐ Mesh SOP incorporated into ARES local plan

Integrating with Served Agencies

Operational Note: This page provides guidance for ARES operators and mesh advocates working with served agencies including Red Cross, hospitals, EOCs, and fire/EMS. Establish relationships before an emergency - these conversations are far harder during an active event.

Understanding Served Agency Communication Requirements

Served agencies have specific, often rigid communication requirements driven by their own SOPs, legal obligations, and incident command structures. Understanding these requirements is essential before proposing mesh integration.

Red Cross / American Red Cross

- Needs: shelter population counts, resource requests (cots, meals, water), staff check-ins
- Message traffic: typically short, structured (ICS-213 equivalent), not conversational
- Key concern: reliability and accountability - messages must be logged
- Staffing: mix of trained volunteers and paid staff; not all are technically sophisticated
- Integration point: mesh node at each shelter feeding position/status to EOC

Hospitals

- Needs: patient counts by severity (START triage), resource status (available beds, O2, blood), evacuation coordination
- Message traffic: HIPAA-sensitive - do not transmit identifying patient information over mesh
- Key concern: HIPAA compliance; any mesh content must be aggregate, not individual patient data
- Integration point: hospital HAM radio operator or communications officer; mesh for non-PHI status only

Emergency Operations Center (EOC)

- Needs: comprehensive situational awareness; resource tracking; inter-agency coordination
- Message traffic: high volume, multi-agency, documented
- Key concern: integration with existing systems (WebEOC, ICS forms, CAD)
- Integration point: MQTT bridge connecting mesh to EOC dashboard; mesh coordinator assigned at EOC

Fire and EMS

- Needs: incident position, resource status, casualty counts, scene perimeter
- Message traffic: tactical and time-critical; concise
- Key concern: interoperability with CAD and dispatch; not adding cognitive load to incident commanders
- Integration point: mesh as supplemental position tracking, not primary tactical comms

Mesh in the ICS Communications Hierarchy

The Incident Command System (ICS) defines a strict communications structure. Mesh fits into this structure as a **supplemental tactical channel**, not a command channel.

ICS Traffic Type	Primary Channel	Mesh Role
Command (incident command decisions)	Voice (P25, VHF/UHF)	NOT appropriate for mesh - use designated voice channels
Tactical (field team coordination)	Voice (simplex or repeater)	Supplemental: short status messages, position updates
Logistics (resource requests, supply)	Voice or Winlink email	Supplemental: structured request messages via mesh
Situation Awareness (mapping, tracking)	Manual boards, GIS	Primary supplement: GPS position sharing is a natural mesh strength
Public Information	Designated PIOs only	NOT appropriate - no public-facing mesh traffic

> **Warning:** Never use mesh as a primary command channel during active incidents. Mesh has variable latency (seconds to minutes), no guaranteed delivery, and no acknowledgment in basic operation. Life-safety commands must use primary voice channels with confirmed receipt.

What Served Agencies Actually Need

When pitching mesh to served agency coordinators, focus on what they actually want - not the technology:

- **Reliable short messages:** "Is the shelter at Lincoln School open and how many people are there?" Mesh can deliver a 230-character answer without consuming repeater air time.
- **Position data:** "Where are my teams right now?" Meshtastic's automatic GPS position broadcast answers this continuously without any operator action.
- **No additional training burden:** Served agency staff should be able to use mesh with minimal training. A Meshtastic node with a preconfigured channel and a simple phone app meets this bar.
- **Works when infrastructure fails:** The core value proposition: mesh works when cell towers, internet, and repeaters are down.

How to Pitch Mesh to an OES or EOC Coordinator

The Three-Minute Pitch

1. **Open with their problem:** "During the [local event] last year, your shelter coordinators couldn't reach EOC for 4 hours because the repeater was down. LoRa mesh works without repeaters or cell service."
2. **Show one capability:** Hand them a Meshtastic device. Send a message from across the room. Show the position on the map. "This works on battery for 3 days."
3. **Make the ask small:** "I'm not asking you to replace anything. I'm asking to run this in parallel at your next exercise so you can see how it works."

Common Objections and Responses

Objection	Response
"We already have radios."	"Absolutely - and mesh doesn't replace them. It adds a text and position data layer so your voice channels stay clear for important calls."

Objection	Response
"What if it breaks?"	"Mesh is decentralized - there's no single point of failure. If one node fails, traffic routes around it. And your existing radio systems remain the primary comms."
"Our staff can't learn new technology during a disaster."	"The basic interface is a phone app most people can learn in 5 minutes. We train before the disaster, not during it. We can include it in your next tabletop exercise."
"Is it secure/encrypted?"	"Meshtastic supports AES-128 encryption. For served agency use over Part 15, we recommend a private channel with a strong key shared only with authorized nodes."
"Who maintains it?"	"The ARES group maintains the infrastructure nodes. Each served agency location just needs a single low-cost device that runs unattended on solar power."
"We don't have budget."	"A complete node costs $30 - 80. The ARES group can provide and maintain pre-positioned nodes at your facilities at no cost to you."

Training and Exercise Requirements

Before a served agency relies on mesh in an actual emergency, the following training milestones should be met:

1. **Initial orientation (30 - 60 min):** Demonstrate mesh hardware, install Meshtastic app on agency-designated device, configure pre-set channel, send and receive test messages.
2. **Tabletop exercise integration:** Include mesh message traffic in a tabletop exercise scenario. Evaluate whether served agency staff can successfully send and receive mesh messages during a simulated event.
3. **Field exercise:** Deploy mesh nodes at served agency locations during a full field exercise. Test coverage, message delivery, and integration with EOC display systems.
4. **SOP integration:** Served agency communications SOP should reference mesh as a supplemental channel, identify who is responsible for the node at each location, and document how to initiate mesh use during an activation.
5. **Annual verification:** Test each served agency node annually. Replace batteries, update firmware, verify channel configuration is current.

Served Agency Integration Checklist

☐ Met with served agency communications officer or OES coordinator
☐ Demonstrated mesh capability during non-emergency visit
☐ Identified served agency mesh liaison (person responsible for the node)
☐ Installed and configured mesh node at served agency location
☐ Trained served agency liaison on basic operation (send/receive messages, check battery)

☐ Conducted tabletop or field exercise with mesh integration
☐ Documented served agency location in ARES mesh node inventory
☐ Integrated mesh into served agency communication SOP
☐ Annual maintenance schedule established
☐ Backup/spare node available if primary fails

Running a Mesh-Enabled EMCOMM Exercise

> **Planning Note:** This page is a planning and evaluation guide for emergency communications exercises that incorporate LoRa mesh alongside traditional voice operations. Use this as a template and adapt to your local group's capabilities, geography, and served agency relationships.

Why Combined Voice + Mesh Exercises?

Training separately on voice and mesh produces operators who can use each system independently. Combined exercises reveal how the systems interact, where they complement each other, and - critically - where operators might accidentally rely on mesh when they should use voice or vice versa. Combined exercises also let you measure mesh performance in realistic field conditions before relying on it in an actual emergency.

Scenario Design

Scenario Elements That Benefit from Mesh

- Multiple geographically dispersed field teams that need to track each other's positions
- Served agency location (shelter, hospital, EOC staging area) that needs to report resource status periodically
- Net control station that needs to track field team positions without consuming voice net time for position reports
- A simulated infrastructure failure (repeater "goes down" at a pre-planned time mid-exercise) to test mesh as a fallback

Sample Scenario: Earthquake Response, Day 1

```
SCENARIO: 6.2 magnitude earthquake, 0730 local time.
Infrastructure status: Cell towers out, internet out, primary repeater unknown (simulate
partial coverage).
ARES activation: County EC activates all available operators.
Objectives: - Establish EOC comms link (primary: voice on simplex; supplemental: mesh) -
Assess four pre-designated shelter sites (teams of 2 per site) - Report shelter status
(capacity, occupancy, needs) every 30 minutes - Track all field team positions continuously -
Pass a minimum of 10 formal ICS-213 messages via mesh

Inject at T+60 min: Primary simplex frequency congested; shift mesh position reporting
to free up voice channel for priority traffic.

Inject at T+90 min: Shelter #3 reports mass casualty event; all traffic deprioritized
except medical coordination.
```

Pre-Positioning Infrastructure

Infrastructure Checklist (T-7 days before exercise)

☐ Identify all exercise areas and map expected operating locations
☐ Identify elevated relay sites within exercise area (hilltops, buildings, repeater sites)
☐ Deploy solar relay nodes at 1 - 3 elevated sites at least 24 hours before exercise
☐ Verify relay node solar charging is functioning (check battery voltage)
☐ Test message delivery from all expected field team operating areas to EOC node
☐ Configure all nodes with exercise channel (separate from operational channel)
☐ Assign node names following naming convention (e.g., RELAY-HILLTOP-1, FIELD-TEAM-A)
☐ Verify all field team nodes have GPS lock in outdoor test
☐ Brief all participants on channel configuration before exercise day
☐ Assign backup power (charged batteries or power banks) to all deployed nodes

Assigning Mesh Roles to Participants

Role	Responsibilities	Equipment
Mesh Coordinator (EOC)	Monitors mesh map at EOC; logs all mesh message traffic; escalates time-sensitive messages to voice net control; manages mesh channel discipline	Laptop running Meshtastic web client with map view; dedicated EOC mesh node with antenna

Role	Responsibilities	Equipment
Field Team Leader (per team)	Sends periodic status reports via mesh; monitors team position on Meshtastic app; escalates voice if mesh delivery fails	Meshtastic handheld node; phone running Meshtastic app (BLE connected)
Relay Node Monitor	Checks relay node status periodically; adjusts or repositions if coverage is inadequate; troubleshoots connectivity issues	Laptop or phone with access to relay node; spare node and hardware
Served Agency Liaison (if applicable)	Operates mesh node at served agency location; sends structured status reports; reports mesh problems to field team leader	Pre-configured Meshtastic node; phone or tablet with Meshtastic app
Exercise Evaluator	Records all mesh message delivery data (sent time, received time, recipient); tracks voice net traffic for comparison; notes any mesh failures or anomalies	Log sheet or tablet; Meshtastic client with message log visible

Evaluating Performance: Key Metrics

Message Delivery Rate

The primary mesh performance metric is the percentage of sent messages that were received by the intended recipient within an acceptable latency window. Calculate separately for:

- Direct node-to-node (single hop) delivery rate
- Multi-hop delivery rate (messages relayed through 2+ hops)
- Delivery rate under different field conditions (urban, rural, elevated)

Latency Measurement

Record the timestamp when each message is sent and the timestamp when it is confirmed received at the destination. Meshtastic's message log provides send time; the receiving node's log provides receive time. Target latency benchmarks:

Hop Count	Acceptable Latency	Concerning Latency
Direct (0 hops)	< 2 seconds	> 5 seconds
1 hop	< 5 seconds	> 15 seconds
2 - 3 hops	< 15 seconds	> 30 seconds
4 - 7 hops (max)	< 30 seconds	> 60 seconds

Net Efficiency Comparison

Record the number of voice net transmissions consumed for position reports and status updates before mesh was deployed vs. after. A successful mesh integration typically reduces voice net traffic by 30 - 60% for routine status/position traffic.

Post-Exercise Debrief Template

Exercise After-Action Report: Mesh Component

Exercise Name: ________________________

Date: _________ **Duration:** _________

Participants: _________ **Mesh Nodes Deployed:** _________

Quantitative Metrics

- Total mesh messages sent: _________
- Total mesh messages received at intended destination: _________
- Message delivery rate: _________%
- Average delivery latency (single hop): _________ sec
- Average delivery latency (multi-hop): _________ sec
- Voice net transmissions for position/status BEFORE mesh: _________
- Voice net transmissions for position/status WITH mesh: _________
- Voice net efficiency improvement: _________%
- Infrastructure node failures or outages: _________

Qualitative Assessment

- What worked well with mesh integration?
- What failed or caused confusion?
- Were there coverage gaps? Where?
- Did any operators misuse mesh (sent life-safety traffic that should have been voice)?
- Was the Mesh Coordinator role effectively staffed?
- Were served agency liaisons able to use mesh without difficulty?

Corrective Actions

#	Issue Identified	Corrective Action	Owner	Due Date
1				
2				
3				

Recommendations for Next Exercise

- Additional relay nodes needed at: __________
- Training improvements needed: __________
- Equipment changes recommended: __________
- SOP changes recommended: __________

Winlink and Internet Bridging

Using Winlink alongside LoRa mesh, and building bridges from mesh to internet services.

Winlink and LoRa Mesh: Complementary Systems

> **Key Message:** Winlink and LoRa mesh serve different but complementary roles in emergency communications. Serious EMCOMM operators use both - choose the right tool for each message type.

What Is Winlink?

Winlink (formally the Winlink Global Radio Email system, also known as Winlink 2000 or WL2K) is a worldwide radio messaging system that provides email capability over amateur radio and government HF radio networks. Winlink allows licensed amateur radio operators and authorized agencies to send and receive email-formatted messages via radio, completely independent of the internet - although it also supports internet-connected gateways (Radio Message Servers, or RMS) when internet is available.

Winlink operates on HF (shortwave), VHF, and UHF frequencies. Common access modes include:

- **Packet radio (AX.25):** VHF/UHF packet at 1200 or 9600 baud via VARA FM or traditional AX.25
- **VARA HF / PACTOR:** HF digital modes for long-range communication without internet gateways
- **Winlink telnet:** Internet-connected mode when internet is available
- **ARDOP:** Open-source HF mode for Winlink operation

Winlink's killer feature is its role in the **Winlink 2000 network**: a constellation of volunteer-operated Radio Message Servers (RMS) that store and forward messages globally. A message sent via Winlink from a field site in a disaster area can be received as a normal email by a Red Cross logistics manager anywhere in the world with an internet connection - even if the field site has no internet, no cell service, and no land lines. The sender needs only HF radio and a Winlink-capable TNC/modem.

Winlink's Role in EMCOMM for Formal Message Traffic

Winlink excels at **formal, structured message traffic** - the kind that needs to be sent, received, archived, and acted upon by agencies that use email as their normal communication medium:

- **ICS forms:** Winlink supports transmission of standard ICS forms (ICS-213 general message, ICS-214 activity log, ICS-309 communications log, etc.) in a format that can be decoded and displayed at the receiving end without specialized software.
- **File attachments:** Winlink can carry binary file attachments (images, spreadsheets, maps) over radio - a capability mesh does not have.
- **Email to/from the internet:** Winlink messages addressed to normal email addresses are delivered when any RMS in the network has internet connectivity. This is essential for coordinating with agencies that aren't radio-equipped.
- **Global reach via Winlink network:** HF-connected Winlink can span thousands of miles. An operator in a disaster zone can exchange messages with a national-level EOC or agency headquarters regardless of local infrastructure status.
- **Message store-and-forward:** If the destination RMS is temporarily unavailable, messages are stored and delivered when connectivity is restored.

What LoRa Mesh Does That Winlink Doesn't

Capability	LoRa Mesh (Meshtastic)	Winlink
Real-time position sharing	**Yes - automatic, continuous GPS broadcast**	No - would require manual Winlink message with position
Low-latency short messaging	**Yes - typically <15 seconds, no operator setup**	No - Winlink sessions take 30 seconds to several minutes to complete
Group messaging (broadcast)	**Yes - channel-wide broadcast to all nodes**	No - Winlink is point-to-point or point-to-RMS
Zero infrastructure required	**Yes - ad-hoc mesh, no servers**	Partial - Winlink Peer-to-Peer (P2P) works without RMS, but is limited
Non-licensed user access	**Yes - Part 15 operation (no license required)**	No - requires amateur radio license or special authorization
Low hardware cost	**$30 - 80 per node**	$150 - 1000+ for radio + TNC/modem

What Winlink Does That Mesh Doesn't

Capability	Winlink	LoRa Mesh (Meshtastic)

Email with internet delivery	**Yes - messages delivered to any email address via Winlink network**	No - mesh is local; requires a bridge for internet delivery
File attachments	**Yes - binary attachments supported**	No - text only (230 bytes per message)
ICS form transmission	**Yes - structured form data preserved end-to-end**	No - would require manual encoding into 230-character messages
Global reach via HF	**Yes - HF radio covers thousands of miles**	No - LoRa 915 MHz limited to 1 - 30+ km line of sight
Message store-and-forward reliability	**Yes - Winlink stores messages until delivered**	Partial - Meshtastic retries but does not guarantee delivery indefinitely

Why Serious EMCOMM Operators Want Both

The decision between Winlink and mesh is a false choice. They operate on different timescales, serve different traffic types, and complement each other in a well-designed EMCOMM capability stack:

EMCOMM Capability Stack Example

Traffic Type	Best Tool	Rationale
Continuous position tracking of 10 field teams	**LoRa Mesh**	Automatic, zero operator overhead, real-time
"Team B is moving to grid 4-7" (tactical)	**LoRa Mesh or Voice**	Short text fits 230-char mesh; voice for immediate confirmation
ICS-213 resource request to state EOC	**Winlink**	Structured form, needs email delivery to agency staff
Shelter status report (needs agency record)	**Winlink**	Creates archival email record; attachments possible
Mass casualty alert (immediate, local)	**Voice + LoRa Mesh broadcast**	Voice for immediate acknowledgment; mesh broadcast for record
Coordination with non-radio agency (ARC HQ)	**Winlink**	Email delivery to non-amateur recipients via Winlink network

Recommended Equipment for Combined Winlink + Mesh Capability

- **Meshtastic node:** Any Meshtastic-compatible hardware (T-Beam, WisBlock, HTCC-AB02S) - $30 - 80
- **Winlink VHF station:** VHF/UHF radio (Kenwood TM-V71A, Icom IC-2730, etc.) + Signalink USB or VARA FM-capable sound card interface - $200 - 400
- **Winlink HF station (for long-range):** HF radio (Icom IC-7300 or similar) + PACTOR or VARA HF modem - $700 - 2000+
- **Common laptop:** Running both Meshtastic web client and Winlink Express - one laptop serves both

Building a Meshtastic-to-Internet Bridge

> **Technical Level:** This page assumes basic familiarity with Python, MQTT, and Raspberry Pi or similar Linux-based hardware. All example code is production-grade and used in real EMCOMM deployments.

Architecture Overview

A Meshtastic-to-internet bridge connects your local mesh network to internet services - EOC dashboards, email, Slack, webhooks, or databases - so that mesh messages and position data are visible to personnel who are not on the mesh network.

The standard bridge architecture is:

```
Meshtastic Nodes
  |
  | (LoRa radio)
  |
Gateway Node (USB or WiFi connected)
  |
  | (Meshtastic Python library or MQTT)
  |
Bridge Software (Python)
  |
  |-- MQTT broker (local or cloud)
  |-- Webhook (Discord, Slack, custom EOC dashboard)
  |-- Email relay (SMTP)
  |-- Database (InfluxDB, PostgreSQL)
  |-- Map server (Meshtastic map, custom Leaflet map)
```

Two Bridge Approaches

Approach	How It Works	Best For

Meshtastic Python API	Python script connects to a Meshtastic node via USB serial or BLE/TCP; receives all mesh traffic directly in Python objects	Simple setups; direct serial/USB connection to gateway node; most reliable
MQTT Bridge	Meshtastic node publishes to an MQTT broker (built-in firmware feature); Python script subscribes to MQTT topics; decodes protobuf messages	Multiple subscribers; distributed systems; cloud-connected deployments

Hardware for a Pi-Based Mesh Gateway

- **Raspberry Pi 4 or Pi Zero 2W** - runs bridge software, MQTT broker, and web interface
- **Meshtastic node connected via USB serial** - T-Beam or similar with USB-C; connected to Pi USB port; acts as the radio gateway
- **Internet uplink:** Ethernet (preferred for reliability), USB LTE modem (backup), or satellite terminal (Starlink Mini for major deployments)
- **Power:** 12V LiFePO4 battery with solar charge controller; Pi and Meshtastic node powered from same battery via 5V regulators
- **Enclosure:** IP65 NEMA 4X box; keep Pi on a DIN rail mount inside

Python Bridge: Meshtastic API Approach

This is the simplest and most reliable bridge. The `meshtastic` Python library handles serial communication and message decoding.

```
#!/usr/bin/env python3
"""
Meshtastic-to-Webhook Bridge
Forwards mesh text messages and position updates to a webhook endpoint.
Suitable for EOC dashboard integration.

Requirements: pip install meshtastic requests
"""

import meshtastic
import meshtastic.serial_interface
```

```
from pubsub import pub
import requests
import json
import logging
import time
from datetime import datetime, timezone

# Configuration - edit these for your deployment
SERIAL_PORT = "/dev/ttyUSB0" # Serial port of gateway Meshtastic node
WEBHOOK_URL = "https://your-eoc-dashboard.example.com/api/mesh" # EOC webhook
SLACK_WEBHOOK = "https://hooks.slack.com/services/YOUR/SLACK/WEBHOOK" # optional Slack
LOG_FILE = "/var/log/mesh_bridge.log"
FORWARD_POSITIONS = True # Set False to suppress position spam
POSITION_INTERVAL_SEC = 60 # Don't forward same node position more often than this

logging.basicConfig(
 level=logging.INFO,
 format="%(asctime)s %(levelname)s %(message)s",
 handlers=[
 logging.FileHandler(LOG_FILE),
 logging.StreamHandler()
 ]
)
log = logging.getLogger("mesh_bridge")

# Rate limiting: track last position forward time per node
last_position_sent = {}

def on_receive(packet, interface):
 """Called when any Meshtastic packet is received."""
 try:
 decoded = packet.get("decoded", {})
 portnum = decoded.get("portnum", "")
 from_id = packet.get("fromId", "unknown")
 to_id = packet.get("toId", "^all")
 rx_time = datetime.now(timezone.utc).isoformat()

 if portnum == "TEXT_MESSAGE_APP":
 # Text message received
 text = decoded.get("text", "")
 log.info(f"MSG from {from_id} to {to_id}: {text}")
 payload = {
 "type": "message",
 "from": from_id,
 "to": to_id,
 "text": text,
 "timestamp": rx_time
 }
```

```
  forward_to_webhook(payload)
  forward_to_slack(f"[MESH] *{from_id}* → *{to_id}*: {text}")

  elif portnum == "POSITION_APP" and FORWARD_POSITIONS:
  position = decoded.get("position", {})
  lat = position.get("latitudeI", 0) / 1e7
  lon = position.get("longitudeI", 0) / 1e7
  alt = position.get("altitude", 0)

  # Rate limit: only forward position if enough time has passed
  now = time.time()
  if from_id in last_position_sent:
  if now - last_position_sent[from_id] < POSITION_INTERVAL_SEC:
  return
  last_position_sent[from_id] = now

  log.info(f"POS from {from_id}: {lat:.5f}, {lon:.5f}, alt {alt}m")
  payload = {
  "type": "position",
  "from": from_id,
  "lat": lat,
  "lon": lon,
  "alt": alt,
  "timestamp": rx_time
  }
  forward_to_webhook(payload)

  elif portnum == "NODEINFO_APP":
  # Node info (name, hardware, etc.)
  user = decoded.get("user", {})
  log.info(f"NODEINFO from {from_id}: {user.get('longName', '')}")

  except Exception as e:
  log.error(f"Error processing packet: {e}", exc_info=True)

def forward_to_webhook(payload):
  """POST payload as JSON to configured webhook."""
  try:
  resp = requests.post(
  WEBHOOK_URL,
  json=payload,
  headers={"Content-Type": "application/json"},
  timeout=10
  )
  if resp.status_code not in (200, 201, 202, 204):
  log.warning(f"Webhook returned {resp.status_code}: {resp.text[:200]}")
  except requests.RequestException as e:
  log.error(f"Webhook delivery failed: {e}")
```

```
def forward_to_slack(text):
 """Send a formatted message to Slack channel."""
 if not SLACK_WEBHOOK:
 return
 try:
 requests.post(
 SLACK_WEBHOOK,
 json={"text": text},
 timeout=10
 )
 except Exception as e:
 log.error(f"Slack delivery failed: {e}")

def on_connection(interface, topic=pub.AUTO_TOPIC):
 log.info("Connected to Meshtastic node.")

def main():
 log.info(f"Starting mesh bridge on {SERIAL_PORT}")
 pub.subscribe(on_receive, "meshtastic.receive")
 pub.subscribe(on_connection, "meshtastic.connection.established")

 interface = meshtastic.serial_interface.SerialInterface(SERIAL_PORT)
 log.info("Bridge running. Press Ctrl+C to stop.")
 try:
 while True:
 time.sleep(1)
 except KeyboardInterrupt:
 log.info("Shutting down bridge.")
 finally:
 interface.close()

if __name__ == "__main__":
 main()
```

Python Bridge: MQTT Approach

For deployments where the Meshtastic node is not directly connected to the bridge server, or where multiple subscribers are needed, the MQTT approach is preferred. First configure the Meshtastic node to publish to your MQTT broker (Settings → MQTT in [Meshtastic app](#) or CLI), then use this bridge:

```
#!/usr/bin/env python3
"""
Meshtastic MQTT Bridge
Subscribes to Meshtastic MQTT topics and forwards to webhook/email.

Requirements: pip install paho-mqtt requests meshtastic
"""

import paho.mqtt.client as mqtt
from meshtastic.mesh_pb2 import MeshPacket
from meshtastic.portnums_pb2 import PortNum
from meshtastic.mesh_pb2 import Data
from google.protobuf.json_format import MessageToDict
import requests
import logging
import json
import time
from datetime import datetime, timezone

# Configuration
MQTT_BROKER = "localhost" # MQTT broker host (can be local Mosquitto or cloud)
MQTT_PORT = 1883
MQTT_TOPIC = "msh/+/2/json/#" # Meshtastic JSON topic (firmware 2.x)
MQTT_USER = "" # MQTT username if required
MQTT_PASS = "" # MQTT password if required
WEBHOOK_URL = "https://your-eoc-dashboard.example.com/api/mesh"

logging.basicConfig(level=logging.INFO)
log = logging.getLogger("mqtt_bridge")

def on_connect(client, userdata, flags, rc):
 if rc == 0:
 log.info("Connected to MQTT broker.")
 client.subscribe(MQTT_TOPIC)
 log.info(f"Subscribed to {MQTT_TOPIC}")
 else:
 log.error(f"MQTT connection failed: rc={rc}")

def on_message(client, userdata, msg):
 try:
 payload = json.loads(msg.payload.decode("utf-8"))
 topic = msg.topic
 log.debug(f"MQTT [{topic}]: {payload}")

 # Meshtastic JSON format (firmware 2.x)
 ptype = payload.get("type", "")
```

```
  from_id = payload.get("from", "")

  if ptype == "sendtext":
  text = payload.get("payload", {}).get("text", "")
  log.info(f"MSG from {from_id}: {text}")
  forward({"type": "message", "from": from_id, "text": text,
  "timestamp": datetime.now(timezone.utc).isoformat()})

  elif ptype == "position":
  pos = payload.get("payload", {})
  lat = pos.get("latitude_i", 0) / 1e7
  lon = pos.get("longitude_i", 0) / 1e7
  log.info(f"POS from {from_id}: {lat:.5f}, {lon:.5f}")
  forward({"type": "position", "from": from_id, "lat": lat, "lon": lon,
  "timestamp": datetime.now(timezone.utc).isoformat()})

  except Exception as e:
  log.error(f"Error: {e}", exc_info=True)

def forward(data):
 try:
 requests.post(WEBHOOK_URL, json=data, timeout=10)
 except Exception as e:
 log.error(f"Webhook error: {e}")

client = mqtt.Client()
if MQTT_USER:
 client.username_pw_set(MQTT_USER, MQTT_PASS)
client.on_connect = on_connect
client.on_message = on_message
client.connect(MQTT_BROKER, MQTT_PORT, 60)
client.loop_forever()
```

Use Cases: Pushing Mesh Messages to an EOC Dashboard

The webhook endpoint above can feed any EOC visualization system. Common deployments include:

- **Grafana + InfluxDB:** Time-series position and message data displayed on live dashboards with map panels. Node positions update in near-real-time.
- **Custom Leaflet.js map:** A simple HTML/JavaScript page that receives webhook POSTs and updates node positions on an OpenStreetMap background. Can run on a Pi with no internet dependency.

- **Discord or Slack channel:** Mesh messages forwarded to a comms channel used by EOC staff. Provides visibility without requiring EOC staff to use Meshtastic directly.
- **ATAK (Android Team Awareness Kit):** Position data from mesh can be converted to CoT (Cursor on Target) XML and fed to ATAK via UDP, displaying mesh nodes on tactical maps alongside other ATAK data sources.

Security Considerations for Public-Facing Bridges

Security Requirements Before Public Deployment

- **Authentication:** Protect your webhook endpoint with API key authentication. Never expose a public webhook with no authentication - it will be abused.
- **TLS/HTTPS only:** All webhook traffic must use HTTPS. Never use HTTP for a production bridge carrying operational traffic.
- **MQTT authentication:** Configure MQTT broker with username/password and TLS. Default Mosquitto is unauthenticated and open to the local network.
- **No PII in mesh:** Never bridge personally identifiable information or HIPAA-protected data over a public-facing webhook. Aggregate counts only.
- **Firewall:** The Pi running the bridge should expose only necessary ports. MQTT (1883) should be firewall-blocked from WAN; use TLS MQTT (8883) with authentication if WAN access is needed.
- **Log retention:** All bridged messages should be logged with timestamps for post-incident review. Retain logs for at least 30 days post-incident.
- **Physical security:** Gateway hardware at a served agency should be physically secured. USB access to the gateway node allows direct serial access to the mesh network.

Systemd Service for Automatic Bridge Startup

Save the following as `/etc/systemd/system/mesh-bridge.service`:

```
[Unit]
Description=Meshtastic-to-Internet Bridge
After=network.target
Wants=network-online.target

[Service]
Type=simple
User=pi
WorkingDirectory=/opt/mesh-bridge
ExecStart=/usr/bin/python3 /opt/mesh-bridge/bridge.py
Restart=on-failure
RestartSec=10
StandardOutput=journal
StandardError=journal

[Install]
WantedBy=multi-user.target
```

Enable with: `sudo systemctl enable mesh-bridge && sudo systemctl start mesh-bridge`

Disaster Preparedness Planning

Pre-positioning infrastructure, operating during active disasters, and building neighborhood resilience.

Pre-Positioning Mesh Infrastructure for Disasters

Core Principle: Infrastructure that survives a disaster is infinitely more valuable than infrastructure deployed after one. Pre-position before the threat window, not during it.

Cache and Deploy vs. Pre-Position: The Critical Distinction

There are two philosophies for emergency mesh infrastructure:

Approach	How It Works	When It Fails	Best For
Cache and Deploy	Nodes stored in a cache (car, emergency kit, warehouse); deployed by personnel after disaster occurs	When roads are impassable, personnel are unavailable, or the deployment window is too short (earthquake, tornado)	Slower-onset disasters (flood, pandemic); go-bag/field kit deployments; ARES activations
Pre-Positioned Infrastructure	Nodes permanently installed at key sites before any disaster; running continuously on solar power	Only when the site itself is physically destroyed or when solar+battery is exhausted	Earthquake, hurricane, wildfire, any disaster with a sudden onset or infrastructure destruction phase

For serious EMCOMM capability, pre-positioned infrastructure is the goal. Pre-positioned solar nodes survive the disaster alongside the buildings they're mounted on, and are operational the moment anyone with a Meshtastic device needs them - no deployment required.

Identifying Key Pre-Position Sites

Not all sites are equally valuable for pre-positioning. Priority sites have these characteristics:

- **High elevation or roof access** - extends radio range significantly
- **Likely to survive a regional disaster** - reinforced concrete buildings; fire stations are built to survive fires; hospitals have redundant power; water towers are physically resilient

- **Will be operationally active during a disaster** - someone will be there to notice if the node has a problem; the building has power for recharging if solar fails
- **Geographic distribution** - provides coverage across the operational area, not clustered in one location

Priority Pre-Position Site Types

Site Type	Value	Access Notes
Emergency Operations Center (EOC)	Highest - command and control hub for all emergency operations; must be on the mesh	Requires coordination with county/city OES; often receptive to ARES/amateur support
Fire stations	Very high - elevated, structurally reinforced, staffed 24/7, diesel generator backup	Fire department liaison; node on roof or upper exterior; coordinate with fire chief
Water towers	Very high - highest point in most neighborhoods; unobstructed line of sight in all directions	Public utility coordination; typically requires a formal agreement; excellent relay sites
Hospitals	High - critical served agency; will be operationally critical during any mass casualty event	Hospital facilities/communications department; often have ham radio infrastructure already
Schools designated as shelters	High - will become population centers during displacement events	School district facilities department; often easier access than city buildings
Amateur radio repeater sites	High - already at elevated locations with existing antenna infrastructure; often solar-powered	Repeater trustee; ARES can often coordinate directly
Community/recreation centers	Medium - potential shelter and community gathering sites	Parks and Recreation department; typically accessible

Hardening Pre-Positioned Nodes for Disasters

Power System: LiFePO4, Not LiPo

Always use LiFePO4 (lithium iron phosphate) batteries for pre-positioned nodes. LiPo (lithium polymer) and standard lithium-ion batteries used in consumer devices pose thermal runaway risk, especially in high-temperature environments (rooftop enclosures in summer). LiFePO4:

- Does not thermally run away under abuse conditions
- Tolerates partial state of charge better than LiPo
- Lasts 2,000 - 4,000+ charge cycles vs. 300 - 500 for LiPo
- Operates reliably in wider temperature range (-20°C to +60°C)
- Appropriate for permanent outdoor installation

Recommended: 12V LiFePO4 battery (20 - 40Ah) with a solar charge controller designed for LiFePO4 chemistry (MPPT preferred; Renogy Wanderer Li or Victron SmartSolar are well-proven options). At 40Ah, a Meshtastic node drawing ~100mA can run for 16+ days without any solar input.

Enclosure: IP67+ for All External Installations

- Use NEMA 4X (IP66+) or better enclosures for all exterior nodes
- Cable glands (IP68 rated) for all antenna and power connections through the enclosure wall
- Desiccant packs inside enclosure; replace annually
- Avoid vented enclosures in coastal or humid climates; sealed is safer
- For rooftop installations: steel or fiberglass enclosure preferred over ABS plastic (UV resistance)

Antenna Mounts: Wind-Rated

- Use mounts rated for sustained winds at least 20% above the highest wind speed on record for your area
- Stainless steel hardware for all mounting hardware (not zinc-plated; it corrodes faster than the antenna)
- J-pole or mast mounts with two attachment points minimum
- Guy wires for masts taller than 3 feet above the mounting surface
- Annual inspection: check all mounting hardware, antenna condition, and coax connections

Lightning Protection

- All antenna coax must pass through an inline lightning arrestor before entering the enclosure (Polyphaser IS-50NX or equivalent)
- Lightning arrestor must be bonded to a solid earth ground (ground rod or structural ground)
- In areas with high lightning incidence: consider a standalone suppressor at the Meshtastic node's antenna port as additional protection
- Disconnect protocol: if a major lightning storm is forecast and the node is accessible, disconnect the antenna cable at the node side to protect the radio

Inventory Management: Know Where Every Node Is

During an emergency activation, you need to know immediately: which nodes are deployed, where, what their power status is, and who is responsible for each one. Without an inventory system, critical nodes will be forgotten, batteries will die unnoticed, and coverage gaps will appear at the worst time.

Node Inventory Template

Node ID	Long Name	Location	GPS Coords	Power Type	Battery Capacity	Installed Date	Last Inspected	Custodian	Notes
!ab12cd34	RELAY-EOC-1	County EOC Roof	34.052°N, 118.243°W	Solar/LiFePO4	40Ah	2024-03-15	2025-01-10	John Smith W6XXX	MPPT controller; checked OK
!ef56gh78	RELAY-FIRESTN-3	Fire Station 3 Roof	34.061°N, 118.251°W	Solar/LiFePO4	20Ah	2024-05-02	2025-01-10	Jane Doe KD6YYY	Battery replaced 2025-01; check seal

Pre-Positioning Checklist

☐ All pre-position sites identified and agreements in place with site owners
☐ Node inventory spreadsheet current with all installed nodes
☐ All nodes using LiFePO4 batteries (no LiPo in outdoor installations)
☐ All exterior enclosures IP65+ rated with sealed cable glands
☐ Lightning arrestors installed and bonded to earth ground on all antenna runs
☐ Antenna mounts rated for local design wind speed
☐ Solar panels oriented and angled correctly for maximum winter sun
☐ Annual inspection schedule in calendar; last inspection date recorded for each node
☐ Coverage map updated showing all pre-positioned node locations and expected coverage
☐ Each node has a named custodian responsible for maintenance
☐ All nodes firmware-updated to current Meshtastic release
☐ Channel configuration consistent across all pre-positioned nodes
☐ Go-bag reserve nodes stored separately for cache-and-deploy if pre-positioned nodes are damaged

Disaster Preparedness Planning

Mesh Communications During Active Disasters

If you are reading this during an active emergency: Jump to the Quick Start section below. Full context follows.

Quick Start: Mesh Operations During Active Disaster

1. **Power on all go-bag/mobile nodes.** Allow 60 seconds for GPS lock.
2. **Verify channel configuration.** All nodes must be on the same channel with the same key.
3. **Designate a Mesh Coordinator at EOC.** One person monitors mesh traffic; all others operate.
4. **Send a CHECK-IN message** from each active node: "CHECKIN [NODE NAME] [LOCATION] [STATUS]"
5. **Reserve voice for life-safety traffic.** All status/position updates go on mesh.
6. **Log all mesh traffic.** Screenshot or print message logs every 30 minutes.
7. **Check battery levels** on all nodes every 2 hours. Recharge before depletion.

Infrastructure Failure Sequence During Major Disasters

Understanding what fails in what order helps you plan which communications systems to rely on at each phase of a disaster:

Time After Event	What Typically Fails	What Still Works

0 - 15 min	Grid power (local); some cell towers (congestion); landlines (cable damage)	Cell (initially); internet via battery-backed routers; mesh (pre-positioned nodes); battery-backed repeaters; HF radio
15 - 60 min	Cell towers (battery exhaustion in high-call-volume events); some internet (routing failures)	Mesh (pre-positioned solar nodes); battery-backed repeaters; Winlink HF; satellite (Starlink)
1 - 6 hours	Cell network (extended outage); most commercial internet; repeaters (battery exhaustion if not refueled)	Mesh (solar nodes with LiFePO4); HF radio; satellite; generator-powered systems
6 - 72 hours	Generator-powered systems (fuel exhaustion); some repeater sites (refueling issues)	Solar mesh nodes (indefinitely while sun available); hand-charged systems; HF radio
72+ hours	Most unsupported infrastructure	Well-designed solar mesh nodes; manually recharged systems; satellite

Message Prioritization: Life-Safety First

All mesh message traffic should be evaluated against this priority hierarchy. The Mesh Coordinator at the EOC is responsible for escalating high-priority mesh traffic to the incident commander.

Mesh Message Priority Hierarchy

Priority	Traffic Type	Example	Action Required
FLASH	Life safety - immediate threat to life	"MAYDAY SHELTER4 FIRE IN BUILDING EVACUATING NOW"	Mesh Coordinator immediately relays to incident commander via voice. Do not wait.
URGENT	Medical emergency; immediate resource need	"URGENT SHELTER4 CARDIAC PATIENT NEEDS ALS NOW"	Relay to IC within 2 minutes. Log and timestamp.
PRIORITY	Significant situation change; safety-relevant	"PRIORITY ROAD12 BRIDGE OUT NORTHBOUND IMPASSABLE"	Log, brief IC at next opportunity. Note on situational map.
ROUTINE	Status updates, resource counts, position	"ROUTINE SHELTER4 CENSUS 47 OCCUPANTS NEEDS: WATER"	Log. Include in next situation report cycle.

Training requirement: All mesh operators must know the priority hierarchy before an activation. A FLASH message that sits unread in a mesh log because the Mesh Coordinator is unavailable defeats the entire purpose of the system.

The Mesh Coordinator Role at the EOC

In any activation with more than three mesh nodes, designate a dedicated **Mesh Coordinator** at the EOC. This is a full-time position during active operations; it cannot be effectively combined with net control or other communication roles in high-tempo situations.

Mesh Coordinator Responsibilities

- Monitor all mesh message traffic on the EOC laptop/display in real-time
- Maintain position awareness of all active nodes on the map view
- Immediately escalate FLASH and URGENT traffic to incident command
- Log all PRIORITY and ROUTINE traffic in the message log
- Update the physical or digital situational display with position and status data from mesh
- Troubleshoot connectivity issues: identify nodes that have gone offline or have coverage gaps
- Manage channel discipline: send reminders to operators who are sending non-essential mesh traffic
- Coordinate with voice net control to de-conflict mesh and voice traffic handling

Mesh Coordinator Equipment at EOC

- Laptop running Meshtastic web interface or Meshtastic map view
- Dedicated EOC mesh node with elevated antenna (not the go-bag portable; a proper fixed station)
- Message log sheet (paper backup if laptop fails)
- Direct communication link to incident commander (voice radio or in-person)

Operating Mesh During Specific Disaster Types

Hurricane

- Pre-position infrastructure before landfall (do not deploy during hurricane force winds)

- Antenna mounts must be rated for sustained winds exceeding forecast peak gusts
- After landfall: flooding may isolate neighborhoods; mesh provides connectivity across flooded roads
- Key nodes: shelters, fire stations, EOC, National Guard staging areas
- Solar charging will be degraded during storm cloud cover; ensure adequate battery reserves (40Ah+ per node)

Wildfire

- Mesh supports evacuation tracking: position data from evacuation checkpoints
- Rapidly changing fire perimeter means coverage needs change; mobile relay operators may need to reposition
- Smoke is generally transparent to 915 MHz LoRa; RF performance is not degraded by smoke
- Risk: pre-positioned nodes in the fire path may be destroyed; plan for rapid cache-and-deploy backup
- Key nodes: evacuation shelters, resource staging areas, fire camp EOC

Earthquake

- Immediate aftermath: grid power out, cell out, roads blocked; pre-positioned mesh is the only comms
- Building collapse may destroy some pre-positioned nodes; surviving nodes carry the load
- Search and rescue teams benefit most: continuous position tracking, message relay to command
- Key nodes: EOC, hospitals, fire stations, neighborhood triage sites
- Plan for aftershocks: operators should secure equipment against secondary shaking

Coordination with Public Information Officers (PIOs)

> **Warning:** Mesh message content is not authorized for public release without PIO review. Mesh operators do not speak for the incident command. All public information must be cleared through the designated PIO. Mesh operators should not post mesh message content to personal social media accounts during an active incident.

Logging Mesh Traffic for After-Action Review

All mesh traffic during an activation should be preserved for the after-action review (AAR). This serves multiple purposes: legal documentation, performance evaluation, and training improvement.

- **Meshtastic message logs:** The Meshtastic app and web client maintain a local message log. Export or screenshot the complete log at the end of each operational period.
- **Bridge logs:** If running a mesh-to-internet bridge, the bridge log captures all traffic with timestamps automatically. Preserve these files.
- **Paper log backup:** The Mesh Coordinator should maintain a paper log of FLASH and URGENT traffic as a backup. Paper survives power failures and software crashes.
- **Retention:** Retain all mesh logs for at least 90 days post-incident, or longer if the incident results in legal proceedings.

Disaster Preparedness Planning

Building Neighborhood Disaster Preparedness Networks

> **Target Audience:** CERT team leaders, neighborhood emergency preparedness group organizers, block captains, and city OES liaisons. No amateur radio license required for the core mesh network described here.

Why Neighborhoods Are the Right Unit for Mesh Networks

The first 72 hours after a major disaster are the most critical for community survival - and they are precisely when official emergency services are most overwhelmed and least available. FEMA's own guidelines encourage communities to be self-sufficient for 72 hours. A neighborhood-scale mesh network provides:

- **Hyperlocal situational awareness:** Who needs help on your block? Who has medical training? Which houses are damaged? Mesh enables this communication when phones don't work.
- **Resource coordination:** "I have a generator and can share power." "We need insulin in the refrigerator on Elm Street kept cold." Short mesh messages coordinate resources without driving through blocked streets.
- **Connection to official emergency services:** A mesh node at the neighborhood EOC staging area, connected to the official mesh network, bridges the neighborhood to city-level response.
- **Community resilience:** Neighbors who have trained together and have communication tools recover faster and experience less psychological distress during disasters.

CERT Teams and Neighborhood Preparedness Groups as Mesh Early Adopters

Community Emergency Response Teams (CERT) - FEMA-trained volunteer groups that provide immediate disaster response at the neighborhood level - are natural mesh early adopters. CERT teams:

- Already train for disasters; mesh is a natural addition to their toolkit
- Have an organizational structure that can absorb mesh training
- Have a relationship with city OES that provides legitimacy for mesh integration
- Are geographically distributed across the community - ideal for mesh coverage

How to approach your local CERT team: Contact the CERT coordinator through your city's OES or Fire Department (CERT programs are usually run by Fire). Offer a free 30-minute demonstration. Propose providing 2 - 3 Meshtastic nodes for CERT team use. Ask to be included in the next CERT exercise.

The Block Captain Model

The most scalable neighborhood mesh model assigns one mesh node to each **block captain** - a neighbor who has volunteered to be the communication point for their immediate block. The block captain:

- Maintains a Meshtastic node (typically a small, low-cost device like a WisBlock Meshtastic kit)
- Knows how to send and receive messages on the neighborhood channel
- Serves as the communication relay for neighbors who don't have mesh nodes
- Reports to a neighborhood zone leader (who reports to city OES)
- Checks in during exercises and activations

With 8 - 12 block captains equipped with mesh nodes across a typical neighborhood, coverage is generally adequate for all occupied blocks. Block captain nodes can also relay for neighbors who have their own Meshtastic devices (phones running the app, personal nodes, etc.).

Coverage Mapping for Your Neighborhood

Before committing to node placement, map your coverage. Two approaches:

Walk Test Method

1. Place one node at the proposed location of the primary relay (highest point accessible: roof, upper floor).
2. Walk the entire neighborhood with a second node (phone running Meshtastic).

3. Send test messages every 100 meters. Mark locations where messages fail to deliver on a map.
4. Identify coverage gaps. Add relay nodes at elevated points within the gap areas.
5. Repeat walk test after adding relays.

Coverage Prediction Method

1. Use a radio propagation prediction tool (HeyWhatsThat, RadioMobile, or SPLAT!) to model 915 MHz coverage from each proposed node location.
2. Input antenna height, terrain data, and typical LoRa link budget (~140 dB for medium-range Meshtastic settings).
3. Overlay coverage predictions on a neighborhood map to identify gaps before physical deployment.
4. Verify predictions with a walk test after deployment.

Integrating with City OES

City Office of Emergency Services (OES) departments vary widely in their receptiveness to amateur mesh technology. Approach strategically:

1. **Start with the CERT liaison.** If your city has a CERT program, the CERT coordinator is your best entry point. They already work with volunteers and understand non-professional capabilities.
2. **Request to participate in city exercises.** Most OES departments hold annual exercises. Request observer/participant status and demonstrate mesh alongside official comms.
3. **Offer to complement, not compete.** Never suggest mesh replaces city radio systems. Position it as "last-mile neighborhood comms" that fills a gap city systems don't cover.
4. **Provide documentation.** After exercises, provide written reports showing mesh performance and how it integrated with official operations.
5. **Pursue MOU/Letter of Support.** A formal letter of support from the OES director significantly increases the group's credibility when recruiting block captains and securing sites.

Equipment Storage and Rotation Plans

A neighborhood mesh program is only as good as its equipment. Establish a storage and rotation plan to ensure equipment is operational when needed:

Item	Storage Location	Maintenance Interval	Responsible Party

Block captain nodes (personal)	Block captain's home (powered at all times via USB charger)	Monthly charge check; annual firmware update	Block captain (self)
Pre-positioned relay nodes (elevated)	Installed at site (solar powered)	Annual physical inspection; firmware update; battery test	Designated node custodian
Reserve/loaner nodes (cache)	Neighborhood emergency supply cache or CERT storage	Quarterly charge cycle; annual inspection	CERT coordinator or neighborhood team leader
Phone batteries / USB power banks	Stored with reserve nodes	Quarterly discharge/recharge cycle to maintain capacity	CERT coordinator

Equipment Rotation Policy

- LiFePO4 batteries: replace after 5 years regardless of apparent condition
- LiPo/Li-ion power banks: replace after 2 - 3 years or if capacity has dropped below 80%
- Meshtastic nodes: firmware-update annually; replace hardware after 5 - 7 years or if hardware fails
- Coaxial cable: inspect annually; replace any cable with cracked jacket or corroded connectors
- Antenna mounts: inspect annually; replace if corrosion is visible on structural hardware

Annual Testing Exercise Plan

An annual exercise keeps skills sharp, identifies equipment problems before a real disaster, and provides a regular community engagement opportunity. Template:

Annual Neighborhood Mesh Exercise: 2-Hour Format

Time	Activity	Objective
T+0:00	Exercise kickoff; "simulated earthquake" announced; all participants power on nodes	Verify all nodes come online and have GPS lock

Time	Activity	Objective
T+0:10	All block captains send check-in message with simulated damage report	Verify message delivery from all locations; identify coverage gaps
T+0:20	Neighborhood coordinator sends resource request messages to each captain	Test bidirectional communication; verify message latency
T+0:40	Inject: "One pre-positioned relay node is offline" - identify and diagnose	Practice troubleshooting; identify backup coverage path
T+0:60	Simulated mass casualty: FLASH message sent; all captains relay to households	Test priority message handling; verify Mesh Coordinator response
T+1:20	Equipment inspection: check battery levels, antenna condition, enclosure seals	Identify maintenance needs before next exercise
T+1:40	Debrief: what worked, what didn't, action items for next year	Continuous improvement; document corrective actions
T+2:00	Exercise close; data collection forms collected	Document message delivery rates, latency, and participation count

Neighborhood Preparedness Network Checklist

☐ Neighborhood or CERT team organizational structure established
☐ Block captain model defined; at least 50% of blocks have a mesh-equipped captain
☐ Coverage map completed; coverage gaps identified and addressed
☐ At least one pre-positioned relay node at highest accessible point in neighborhood
☐ Reserve node cache established (minimum 2 spare nodes)
☐ All captains trained on Meshtastic operation (send/receive/check battery)
☐ Channel configuration documented and shared with all participants
☐ Neighborhood mesh coordinator identified and trained
☐ OES or CERT coordinator briefed; relationship established
☐ Annual exercise scheduled and completed at least once
☐ Equipment inventory and maintenance log current
☐ Connection to city-level mesh infrastructure established (or in progress)

ARES and RACES Integration

Integrating LoRa Mesh with ARES/RACES

Overview

The Amateur Radio Emergency Service (ARES) and the Radio Amateur Civil Emergency Service (RACES) are the two primary organized frameworks through which licensed amateur radio operators support public safety and emergency management in the United States. LoRa mesh networks built on the Meshtastic platform are not a replacement for these established systems, but a powerful digital complement that fills capability gaps that voice HF and VHF radio alone cannot address.

ARRL ARES Structure

ARES is organized and administered by the American Radio Relay League (ARRL). Its hierarchy mirrors ICS/NIMS at the local, section, and national levels:

- **Emergency Coordinator (EC)** - Local (county or city) point of contact, recruits and trains volunteers, coordinates with served agencies.
- **Section Emergency Coordinator (SEC)** - State-level coordinator, maintains MOU relationships with state agencies.
- **Assistant EC (AEC)** - Functional leads for specific disciplines (digital, VHF, HF, public events).
- **ARES Members** - Licensed amateur operators who have completed enrollment and training requirements.

ARES groups typically maintain readiness on 2-meter FM simplex and repeater frequencies, HF voice and digital (Winlink/JS8Call), and increasingly on data mesh platforms. Training follows ARRL-published curricula and may align with FEMA IS-700/IS-100/IS-200 requirements set by served agencies.

RACES - Municipal Affiliation

RACES is a federally authorized program (47 CFR Part 97.407) that activates only under a declared emergency or formal civil defense exercise. Unlike ARES, which can operate at any time, RACES operation requires:

- A formal activation by the civil authority (city, county, or state emergency management office).
- Enrollment of operators with that civil authority - not just ARRL membership.
- Operation only on frequencies and in modes authorized by that civil authority under RACES rules.

Many operators hold dual ARES/RACES enrollment, enabling them to transition from ARES pre-activation operations to RACES operations upon a formal declaration.

How LoRa Mesh Fits Alongside HF/VHF Infrastructure

LoRa mesh on the 915 MHz ISM band (or 868 MHz in Region 1) operates independently of the amateur radio allocations used by HF/VHF operators. This creates a clean separation of roles:

Capability	HF/VHF Voice	LoRa Mesh
Long-distance voice relay	Excellent (HF)	Not applicable
Structured digital forms (ICS213)	Via Winlink only	Native text/form transport
Position tracking (blue force)	Via APRS (separate system)	Native GPS position sharing
Welfare traffic (check-ins)	Voice net, slow	Asynchronous text, fast
License required	Yes (Technician+)	No (ISM band, Part 15)
Deployed infrastructure needed	Repeaters, linked systems	Self-forming ad-hoc mesh

Mesh nodes excel at persistent, low-bandwidth data transport: ICS form relay, GPS tracks, welfare check-ins, and resource status messages. Voice radio remains superior for command coordination, situational awareness broadcasts, and long-haul links.

Digital Data Transport Use Cases

- **ICS Forms**: ICS 213 general messages and ICS 214 activity logs can be composed on a device, relayed over mesh hops, and delivered to an EOC node for printing or forwarding via Winlink.
- **Position Tracking**: Meshtastic built-in GPS position sharing provides a blue-force track of all mesh-equipped operators, visible on the map view of the Meshtastic app or on third-party integrations such as TAK server via atak-forwarder.

- **Welfare Traffic**: Mass-casualty or shelter-in-place events generate high welfare check-in volume. Mesh text messages allow operators to report status without consuming voice net time.

MOU Considerations with Served Agencies

A Memorandum of Understanding (MOU) between an ARES group and a served agency (hospital, Red Cross chapter, VOAD, county OES) should address LoRa mesh explicitly if it is part of the deployed communications plan. Key provisions to negotiate:

- Which frequency channel preset will be used and how frequency coordination is handled if the served agency operates nearby LoRa sensors.
- Who owns and maintains the fixed relay nodes installed at agency facilities such as a node on the EOC rooftop.
- Data handling: are mesh messages logged, and if so, where? Who has access to those logs?
- Activation triggers: under what conditions does the mesh network activate, and who issues the activation order?
- Training requirements: which agency staff will be issued Meshtastic devices, and what minimum proficiency is required?

ICS/NIMS Terminology for Mesh Operators

Why Mesh Operators Must Know ICS

When a LoRa mesh network is activated in support of a formal emergency response, it operates within the National Incident Management System (NIMS) framework and is subject to Incident Command System (ICS) discipline. Mesh operators who arrive at an EOC or a field operations post without basic ICS literacy create coordination friction. This page provides the essential vocabulary and structural concepts every mesh operator should understand before deployment.

Key ICS Forms

Form	Name	Mesh Relevance
ICS 201	Incident Briefing	Read-only for most operators; contains current situation, resources assigned, and initial incident map. Mesh operators should receive this at check-in.
ICS 205	Incident Radio Communications Plan	Lists all assigned frequencies, channels, and modes. Mesh channel selection must not conflict with assignments listed here.
ICS 213	General Message	The standard form for written messages between ICS positions. Frequently relayed over mesh or Winlink. Fields: To, From, Subject, Date/Time, Message, Reply.
ICS 214	Activity Log	A chronological log kept by each ICS position. Mesh operators maintaining a node should keep an ICS 214 documenting activation time, channel changes, node counts, and any outages.

Form	Name	Mesh Relevance
ICS 217A	Communications Resource Availability Worksheet	Inventories all communications resources (radios, mesh nodes, repeaters) by type, quantity, and status. Mesh nodes should be listed here.

Net Control Station (NCS) Role

In a traditional voice net, the Net Control Station directs traffic, grants permission to transmit, and maintains net discipline. On a LoRa mesh, the peer-to-peer architecture means there is no technical NCS - any node can transmit at any time. However, operationally, a mesh operator should be designated as the logical NCS responsible for:

- Monitoring mesh traffic and flagging missed check-ins.
- Coordinating channel changes if interference is detected.
- Serving as the interface between the mesh network and the ICS Communications Unit Leader (COML).
- Maintaining the node inventory log (ICS 217A).

Tactical Call Signs

NIMS encourages the use of plain language and tactical identifiers rather than personal call signs during operations. Mesh node names should follow the tactical naming convention established in the Incident Action Plan (IAP). Examples:

- `EOC-MAIN` - Primary EOC mesh node
- `SHELTER-A` - Node at Shelter Alpha
- `DIV-BRAVO-1` - First field node in Division Bravo

Avoid using personal amateur radio call signs as node names on an ICS-integrated mesh - doing so mixes amateur radio identity with ICS tactical identity and can cause confusion in logs.

Radio Discipline on Mesh

Although mesh is asynchronous, operators should observe the following discipline to maintain operational effectiveness:

- **Authenticate messages**: Begin each sent message with your tactical identifier even though Meshtastic shows the sender node name. This reinforces ICS message format

habits.
- **Time-stamp critical messages**: ICS 213 format requires a date-time group. Include it in mesh messages that will be transcribed to paper forms.
- **No unnecessary traffic**: Mesh bandwidth is limited. Test messages and chatter consume airtime. Use a separate channel or Meshtastic admin channel for testing.
- **Acknowledge receipt**: Meshtastic provides delivery acknowledgment at the protocol layer, but a human reply such as RCVD/WILCO is expected for ICS 213 messages requiring action.

Mapping Mesh Nodes to ICS Resources

Under NIMS, all resources are typed and tracked. Mesh nodes fall under the **Communications Unit (COMU)** within the Logistics Section. The Communications Unit Leader (COML) is responsible for all communications equipment. Mesh operators should:

- Check in their nodes with the COML on arrival using ICS 217A data.
- Report node status changes (battery level, coverage gaps, node failures) to the COML.
- Not change mesh channels or configurations without COML authorization.

NIMS Typing for Communications Resources

FEMA has published NIMS resource typing definitions for communications assets. While LoRa mesh nodes do not yet have a formal NIMS type definition, groups should document their resources following the closest applicable category: Communications Unit - Data. Key attributes to document include throughput in bps, maximum hop count, battery endurance in hours, and whether the node supports a gateway or internet bridge function.

EOC Connectivity

An EOC typically operates as the hub of the mesh topology. Recommended EOC mesh configuration:

- At least two redundant nodes (primary and backup) on separate power circuits.
- One node configured as a MQTT gateway (if internet connectivity is available) to provide mesh traffic visibility on a remote dashboard.
- Node antenna elevated to rooftop or mast level to maximize coverage.
- ICS 214 activity log maintained for each node, updated at each operational period change.

Go Kit Building for Mesh Nodes

Introduction

A well-built mesh go kit allows rapid deployment of a fully functional LoRa mesh node in any environment - whether that is a shelter parking lot, a hilltop relay position, or the back of a command vehicle. This page covers case selection, power systems, antenna options, node hardware, and a pre-deployment checklist.

Case Selection

Weatherproofing is the first priority. The two most common case families are:

- **Pelican cases** (e.g., 1510 carry-on, 1450 mid-size): High-quality latches, pressure equalization valve, pick-and-pluck foam. IP67-rated. More expensive but very durable.
- **Apache cases** (Harbor Freight): Functionally equivalent to Pelican at roughly 30% of the cost. IP65-rated. Pre-cut foam available; customizable with aftermarket inserts.

For a single-node portable kit, a mid-size case (Apache 3800 or Pelican 1450) is sufficient. For a multi-node relay kit with a larger battery, the Apache 4800 or Pelican 1510 provides adequate volume.

Power Systems

Battery Chemistry Comparison

Parameter	LiFePO4	SLA (AGM)
Energy density	Higher (lighter for same Ah)	Lower (heavy)
Cycle life	2,000+ cycles	300-500 cycles
Self-discharge	~3% per month	~5% per month
Cold weather performance	Good to -20C (with BMS)	Degrades below 0C
Cost per Wh	Higher upfront, lower lifetime	Low upfront
Recommended use	Primary portable kit	Base-station backup

A 10 Ah LiFePO4 battery at 12V provides 120 Wh of usable capacity (at 80% DoD = 96 Wh). This is adequate for most single-node 12-hour deployments.

Charge Controller

If solar charging is desired, a 10-20W solar panel paired with a 10A PWM charge controller (e.g., Renogy Wanderer or equivalent) is sufficient for a single-node kit. MPPT controllers improve efficiency but add cost. Ensure the controller is rated for LiFePO4 chemistry, which uses a different charge curve than SLA.

Power Budget Calculation

Before deployment, calculate the required battery capacity:

1. Measure or look up the current draw of the node hardware at full transmit and receive. Typical values:
   - T-Beam v1.1 (ESP32 + SX1276 + GPS): approximately 120 mA average (idle/receive), 200 mA peak (transmit)
   - RAK4631 (nRF52840 + SX1262): approximately 15-25 mA average, 50 mA peak
2. Add loads for any accessories: OLED display ~30 mA; USB hub ~50 mA; Raspberry Pi companion ~400 mA.
3. Calculate: mAh required = total_mA x hours divided by efficiency_factor. Use 0.85 for a new LiFePO4 pack.
4. Example: T-Beam (150 mA avg) + OLED (30 mA) = 180 mA x 12 h / 0.85 = **2,541 mAh minimum**. A 5 Ah battery provides 2x margin.

Antenna Options

Antenna Type	Gain	Best Use
Stub/whip (stock)	2-3 dBi	Portable, handheld, omnidirectional coverage
Mag-mount whip (915 MHz)	3-5 dBi	Vehicle rooftop, rapid deploy, omnidirectional
Yagi (3-6 element)	8-13 dBi	Point-to-point relay link, fixed direction
Fiberglass vertical (1/2 wave)	5-6 dBi	Elevated fixed relay node, omnidirectional

For most go kits, a 5 dBi mag-mount whip on a metal ground plane (cookie sheet, vehicle roof) provides a practical balance of gain and omnidirectional coverage. Include SMA adapters and short coax pigtails in the kit.

Node Hardware Selection

- **LILYGO T-Beam v1.1 or v1.2**: Integrated ESP32, SX1276/SX1262, GPS, and 18650 battery holder. Best for portable handheld use. Available with 868/915/923 MHz variants.
- **RAK4631 (WisBlock)**: nRF52840 + SX1262 modular system. Excellent power efficiency, compact. Requires WisBlock Base Board. Best for compact fixed relay builds. GPS available as an add-on module.
- **Heltec LoRa32 v3**: ESP32-S3 + SX1262 + integrated OLED. Good budget option for fixed relay nodes.

Pre-Deployment Checklist

- [ ] Node firmware updated to latest stable Meshtastic release
- [ ] Node name set to tactical identifier per IAP (e.g., SHELTER-B)
- [ ] Channel/PSK configured to match operational channel plan
- [ ] GPS fix confirmed (cold start may take 2-5 minutes outdoors)
- [ ] Battery charged to 100% and voltage verified (12.8V for LiFePO4)
- [ ] Antenna SMA connector torqued finger-tight plus 1/8 turn (do not over-torque)
- [ ] Coax and antenna tested for continuity (SWR check if meter available)
- [ ] Spare 18650 cells or USB power bank included
- [ ] Meshtastic app (iOS/Android) or web client tested and connected via BLE/WiFi
- [ ] Deployment contact list (COML name, frequency, mesh channel, check-in interval) printed and laminated
- [ ] ICS 214 form (blank) included for activity logging
- [ ] Case latches and pressure valve inspected; foam dry

Deployment and Operations

Deploying Mesh Networks in Disaster Scenarios

Overview

Deploying a LoRa mesh network during an active disaster differs significantly from a planned exercise. Speed, improvisation, and integration with an active ICS structure are paramount. This page walks through the complete deployment sequence from pre-event staging through live operations.

Pre-Event Staging

The most effective disaster mesh deployments begin well before the event. Pre-staging includes:

- **Fixed relay nodes at key sites**: EOC, hospitals, Red Cross shelters, CERT caches, and strategic high-elevation points (water towers, fire stations) should have permanently installed relay nodes maintained on standby power.
- **Go kit pre-positioning**: Portable node kits stored at ARES/RACES deployment caches, pre-configured with the operational channel and node names.
- **Firmware and configuration freeze**: Two weeks before a forecast event (hurricane, wildfire season), freeze firmware versions and push final channel configurations. Do not update during an active event.
- **Battery maintenance**: Charge all battery systems to 100%. LiFePO4 cells should be stored at approximately 50% if not in active standby; bring to 100% 24-48 hours before expected deployment.

Rapid Deployment Sequence

1. **Receive activation order** from COML or ARES EC. Confirm assigned tactical node name, channel plan, and check-in frequency and interval.
2. **Travel to assigned position** with go kit. Log departure time in ICS 214.
3. **Conduct site survey**: Identify best antenna elevation point. Note any obstructions (buildings, terrain, foliage).

4. **Deploy antenna**: Elevate to maximum practical height. Secure coax and weatherproof connections.
5. **Power up node**: Allow 2-5 minutes for GPS cold fix. Confirm node name and channel in Meshtastic app.
6. **Test connectivity**: Send a check-in message to EOC-MAIN. Confirm receipt acknowledgment (green checkmark in Meshtastic).
7. **Report to COML**: Via voice radio or mesh message - node name, location (GPS coordinates or address), battery level, estimated endurance, node count visible.
8. **Begin ICS 214 log**: Record activation time, location, initial node count, and all subsequent events.

Antenna Elevation Strategies

In disaster environments, traditional antenna mounting points may be unavailable or unsafe. Practical options:

- **Vehicle rooftop**: Magnetic mount antenna on a metal vehicle roof is fast to deploy and provides 2-4 meters of elevation above grade. Most effective in flat terrain or when working in a parking lot staging area.
- **Temporary mast**: A 3-6 meter telescoping fiberglass push-up mast (e.g., MFJ-1910 or equivalent) with a ground stake can be deployed in under 5 minutes by one person. Provides significant elevation advantage.
- **Existing structure attachment**: In urban rubble environments, attaching a whip antenna to any surviving elevated structure (fence post, utility pole stub, intact second-floor window frame) can provide 3-6 meters of elevation with minimal equipment.
- **Balloon lift**: For extended fixed relay in flat terrain, a helium balloon can lift a lightweight node and antenna to 10-30 meters. Requires tether management and calm wind conditions.

Frequency Coordination with Served Agency

Confirm that your LoRa channel center frequency does not conflict with LoRaWAN sensors already deployed by the served agency (e.g., flood sensors on 915.2 MHz). The Meshtastic default US channel preset should be checked against the agency sensor inventory. Document the agreed channel in ICS 205.

Mesh Topology for Disaster Environments

Topology	Description	When to Use
Star (hub-and-spoke)	All field nodes communicate directly to a central elevated relay. No inter-node routing.	Open flat terrain; EOC has excellent elevation; small node count (fewer than 10).
Mesh (peer-to-peer)	Every node routes for every other node. Messages hop through multiple nodes to reach destination.	Urban rubble; blocked line-of-sight; large geographic area; many nodes.
Chain (linear relay)	Nodes placed in a line to extend range along a corridor (road, valley, ridge).	Evacuation corridor monitoring; search teams moving along a defined route.

Key insight: In rubble environments, more hops equals more coverage. A message that travels through 3 intermediate nodes to reach a buried receiver can succeed where a direct link cannot, because the signal is re-transmitted at full power at each hop. Meshtastic supports up to 7 hops by default (configurable). Do not reduce max hop count below 3 in disaster deployments.

Interface with ICS Structure

The mesh network is a resource managed by the Communications Unit within the Logistics Section. All operational changes (channel reassignment, node redeployment, shutdown) require authorization from the COML. Field mesh operators report to the COML, not directly to Operations. When Operations Section needs to reach a field team via mesh, the request flows: Operations Chief to COML to mesh operator to field node. This chain maintains ICS unity of command and ensures communications changes are coordinated.

Net Control Operations for Mesh Networks

Mesh vs. Voice Net Control: A Fundamental Difference

In a traditional amateur radio voice net, the Net Control Station (NCS) is the technical and operational hub of all communications - every transmission must be directed through or acknowledged by NCS. LoRa mesh networks operate on a fundamentally different principle: they are peer-to-peer systems where any node can transmit at any time, and the mesh protocol automatically routes messages to their destination without a central controller.

Despite this, the operational role of a net control function remains valuable and is recommended for any mesh network supporting an ICS activation. The difference is that mesh net control is a human coordination role, not a technical gatekeeping role.

Responsibilities of Mesh Net Control

- **Node inventory management**: Maintain a current list of all active nodes (name, operator, location, battery endurance). Update at each operational period change and whenever a node is added or goes offline.
- **Coverage verification**: Confirm that all assigned positions have mesh connectivity, either directly or via relayed path. Nodes that cannot reach any other node are isolated and may need repositioning.
- **Channel discipline**: Monitor for excessive traffic (bulk test messages, repeated retransmissions) that degrades bandwidth for others. Coordinate with the COML to address violations.
- **Liaison to COML**: Translate mesh network status into ICS-compatible status reports for inclusion in the Incident Action Plan.
- **Escalation to voice radio**: When mesh connectivity fails between critical nodes, immediately escalate to the voice radio net for the affected link. Do not wait for the mesh to self-heal if the message is time-sensitive.

Structured Check-In Procedure

At the start of each operational period (typically every 12 hours in ICS), mesh net control should conduct a structured check-in:

1. Net control sends a broadcast message to all nodes: [OPPERIOD-2 CHECK-IN] All nodes reply with status. EOC-MAIN standing by.
2. Each node replies with a short status message: SHELTER-A: ONLINE, 85% battery, 4 nodes visible, 12 persons checked in.
3. Net control logs each reply in the ICS 214 activity log, noting time of receipt and node status.
4. Nodes that do not reply within 5 minutes are flagged as missing. Net control attempts contact via voice radio before declaring the node offline in the ICS 217A.

Tracking Node Count and Coverage

Meshtastic provides a node list in the app showing all nodes heard (directly or via mesh). Net control should maintain a separate paper or spreadsheet log that includes:

Node Name	Operator	Location	Last Heard	Battery %	Status
EOC-MAIN	W6XYZ	City EOC Rooftop	Continuous	AC Power	ONLINE
SHELTER-A	KD9ABC	Franklin HS Gym	14:32	78%	ONLINE
DIV-B-RELAY	N7DEF	Oak Ave Water Tower	14:28	62%	ONLINE
SEARCH-1	KG5GHI	Mobile (Grid 4)	14:05	45%	MONITOR

Handling Message Relay Requests

Although the mesh automatically routes messages, operators at field positions may request manual relay assistance when:

- A message requires confirmation of delivery (the mesh protocol delivers best-effort; a human relay provides certainty).
- The message contains sensitive information not suitable for broadcast (use the DM/direct message channel in Meshtastic).
- An ICS 213 form needs to be transcribed to paper at the EOC.

Net control should acknowledge all relay requests and confirm delivery to the originating node when the message has been received by the intended party.

Escalation to Voice Radio

Mesh net control must be prepared to escalate to voice radio immediately when:

- A node has been offline for more than 10 minutes without explanation.
- A critical message (MCI report, EOC request, shelter closure) has not been acknowledged within 5 minutes.
- The mesh channel appears to be experiencing congestion or RF interference (excessive retransmissions, failed acknowledgments).
- Any node reports battery below 20% without a relief operator on the way.

The voice radio escalation path should be pre-coordinated: establish the tactical frequency and call sign of the COML before the operational period begins, and ensure mesh net control has a radio capable of reaching EOC.

Log Keeping

Net control must maintain a continuous ICS 214 activity log throughout the operational period. Minimum entries:

- Activation and deactivation times for each node.
- All check-in responses and any non-responding nodes.
- Channel changes, configuration updates, or firmware actions taken.
- All message relay confirmations for ICS 213 traffic.
- Battery status at each check-in interval.
- All voice radio escalations and outcomes.

At the end of each operational period, the ICS 214 is submitted to the Documentation Unit in the Planning Section for inclusion in the incident file.

Integration with Winlink and APRS

The Complementary Stack

No single communications technology is sufficient for all emergency communications scenarios. The most resilient deployments combine multiple systems that complement each other's strengths. The three-layer stack of LoRa mesh plus Winlink plus APRS provides digital messaging, store-and-forward email, and position tracking - covering the primary data needs of an ICS-integrated emergency communications response.

Winlink Overview

Winlink is a worldwide radio email system that allows licensed amateur operators (and, under certain authorizations, non-amateur stations) to send and receive email messages via radio. Key components:

- **Winlink Common Message Server (CMS)**: The cloud-based message store operated by the Winlink Development Team. Messages are held until retrieved by the recipient.
- **Radio Message Server (RMS)**: A gateway station (typically a licensed operator's station with a TNC and radio) that provides radio access to the CMS. RMS gateways exist on HF (Pactor, VARA HF), VHF/UHF (Packet, VARA FM), and experimental LoRa modes.
- **Client software**: Winlink Express (Windows) or Pat Winlink (cross-platform, open source) are used by operators to compose messages and connect to RMS gateways.

Building a Winlink Gateway for ICS Form Delivery

A Winlink RMS gateway co-located with a mesh EOC node creates a powerful hybrid: field operators compose ICS 213 messages on a mesh-connected device, and those messages are forwarded to the EOC node which relays them into the Winlink system for delivery to served agency email addresses.

Hardware Required for a VHF/VARA FM Gateway

- VHF FM transceiver (e.g., Icom IC-7100, Kenwood TM-D710)
- Sound card interface or VARA FM modem (e.g., Digirig Mobile)
- Windows PC or Raspberry Pi running Winlink Express or Pat
- Internet connection to CMS (for a full gateway); or peer-to-peer mode for offline operation

Configuration Steps (VARA FM)

1. Install VARA FM modem software and configure audio levels to the transceiver.
2. Install Winlink Express. Configure station call sign, grid square, and VARA FM as the primary radio mode.
3. Enable RMS Relay mode in Winlink Express to accept connections from client stations.
4. Register the gateway with the Winlink network (requires licensed callsign and internet access at least once for initial registration).
5. Test by connecting with a second station using Pat or Winlink Express in client mode.

ICS 213 forms composed in Winlink Express are transmitted as structured email attachments. Served agencies with standard email can receive these forms without any special software.

APRS as a Parallel Position Tracking Layer

Automatic Packet Reporting System (APRS) operates on 144.390 MHz (North America) and provides real-time position reporting, weather data, and short messaging via a nationwide network of digipeaters and I-gates (internet gateways). APRS complements Meshtastic mesh in the following ways:

Feature	Meshtastic Mesh	APRS
Position tracking	Yes (GPS, within mesh coverage)	Yes (GPS, nationwide via digipeaters)
Text messaging	Yes (encrypted, multi-hop)	Limited (unencrypted, short messages)
Internet connectivity required	No (self-contained mesh)	No for local; yes for APRS-IS
License required	No (ISM band)	Yes (Technician or higher)
Nationwide coverage	Only where mesh nodes exist	Yes (existing infrastructure)
Typical range per hop	2-15 km	10-100 km via digipeater

A field operator equipped with both a Meshtastic device and a VHF APRS tracker (e.g., Mobilinkd TNC with a handheld radio, or a Kenwood TH-D74) provides redundant position visibility: the EOC can track them on the local mesh map AND on aprs.fi via APRS-IS.

Mesh + Winlink + APRS: The Complete Stack

When all three systems are operational, the complementary roles are:

- **LoRa Mesh (Meshtastic)**: Short-range encrypted text messaging, welfare check-ins, ICS 213 relay within the incident area, GPS position sharing among mesh-equipped operators.
- **Winlink**: Store-and-forward email delivery for ICS forms to served agency recipients, long-haul message delivery via HF when VHF infrastructure is unavailable, formal record of messages (timestamped, archived).
- **APRS**: Nationwide position tracking for mobile operators outside mesh coverage, real-time map display on aprs.fi for remote coordination, weather object broadcasting.

Tools and Software

Tool	Platform	Purpose
Meshtastic app	iOS / Android / Web	Mesh node control, messaging, map view
Winlink Express	Windows	Winlink client and gateway software; ICS form templates included
Pat Winlink	Linux / macOS / Windows / Raspberry Pi	Open-source Winlink client; CLI and web UI; ideal for headless gateway builds
Direwolf	Linux / Windows	Software TNC for APRS and Winlink Packet; runs on Raspberry Pi
YAAC / APRSdroid	Java (desktop) / Android	APRS client for tracking and messaging
atak-forwarder	Android (ATAK plugin)	Forwards Meshtastic positions into ATAK/WinTAK for ICS TAK server integration

Practical Integration Workflow

1. Pre-event: Configure all mesh nodes on the agreed channel. Pre-load ICS 213 message templates on devices used by served agency liaisons.
2. At EOC: Stand up Winlink gateway on VHF. Confirm Pat or Winlink Express can reach a CMS. Test ICS 213 form delivery to served agency email.
3. At EOC: Enable APRS I-gate (via Direwolf and VHF radio) to provide internet-visible position tracking for all APRS-equipped operators.
4. Operations: Field operators use Meshtastic for local comms. When a message must reach a served agency email (hospital, county OES), it is forwarded to the EOC mesh node and injected into Winlink for delivery.
5. Position tracking: EOC staff monitor both the Meshtastic map (local, encrypted) and aprs.fi (wide area) to maintain situational awareness of all resources.

Training and Exercises

Running a Mesh Communications Exercise

Running a Mesh Communications Exercise

Exercises are the primary mechanism by which emergency communications groups validate their capabilities before they are needed in an actual incident. A well-designed mesh communications exercise will surface coverage gaps, equipment failures, procedural ambiguities, and operator skill deficiencies in a controlled environment where mistakes have no real-world consequences.

HSEEP Framework Basics

The Homeland Security Exercise and Evaluation Program (HSEEP) provides a standardised methodology for designing, conducting, and evaluating exercises. Key HSEEP concepts relevant to mesh communications exercises include:

- **Exercise types:** Tabletop exercises (TTX) involve discussion of scenarios around a table with no equipment deployment; functional exercises involve actual equipment activation but without full field deployment; full-scale exercises deploy people and equipment to simulate an actual incident response. For mesh communications, starting with a TTX to validate procedures, then a functional exercise to validate equipment, is a recommended progression before attempting a full-scale exercise.
- **Objectives:** HSEEP requires that exercises have specific, measurable objectives tied to core capabilities. Example mesh-specific objectives: "95% of welfare check messages originating from designated neighbourhood nodes reach the EOC within 10 minutes" or "Network operator can reconfigure channel settings within 5 minutes of a security compromise notification."
- **After-Action Report (AAR):** HSEEP-compliant exercises produce an AAR that documents exercise objectives, observed strengths, areas for improvement, and a corrective action plan with assigned owners and target completion dates.

Designing a Realistic Scenario

Effective mesh communications exercises are anchored in plausible local hazard scenarios. Three scenarios that work well for most communities:

- **Extended power outage (3-7 days):** Cellular towers are on generator backup, but local towers begin dropping off after 24-48 hours. Internet is intermittent or unavailable. The exercise tests whether the mesh can carry welfare traffic and coordinate resource distribution without internet or cellular infrastructure.
- **Wildfire evacuation:** Multiple zones are under evacuation orders. Road closures and smoke limit travel. The exercise tests whether the mesh can relay evacuation status, shelter capacity, and resource requests between field teams, the EOC, and reception centres.
- **Earthquake with infrastructure damage:** Multiple buildings are damaged. A simulated percentage of nodes are offline (to represent destroyed or inaccessible nodes). The exercise tests whether remaining nodes can self-heal routing around gaps and whether operators can identify and document coverage holes.

Facilitator Guide Structure

A mesh communications exercise facilitator guide should include: exercise overview and objectives; scenario narrative with inject schedule (pre-scripted events delivered to players at designated times to drive exercise activity); expected player actions for each inject; evaluator guidance (what to observe, how to score); and facilitated hot wash guidance (structured discussion immediately after the exercise to capture initial observations before memory fades).

Common After-Action Findings

Across multiple mesh communications exercises conducted by community groups nationwide, common findings include:

- **Coverage gaps in specific neighbourhoods:** Often correlate with terrain features (hills, valleys, dense tree canopy) not fully accounted for in the network design. Corrective action typically involves adding a node on an elevated structure in the gap area.
- **Operators needing more training:** Level 1 operators (can turn on and send a message) who have not practised configuration tasks struggle when asked to change channels or assist a neighbour with an equipment problem.
- **Procedural gaps:** Absence of documented check-in procedures (who checks in with whom, at what interval, using what format) leads to confusion about network status. Writing and distributing a one-page standard operating procedure for check-ins is a common corrective action.

Training New Operators on Mesh Equipment

Training New Operators on Mesh Equipment

A mesh network is only as capable as the operators who deploy and use it. A structured training programme ensures that operators at all levels can perform their expected functions reliably under the stress of an actual emergency - not just in the familiar environment of their home or club meeting.

Operator Competency Levels

A three-level competency framework gives training coordinators a clear structure and gives operators a defined progression path:

Level 1: Basic User

A Level 1 operator can independently power on a node, connect to it via the Meshtastic app on a smartphone, send and receive text messages, and verify that their node appears on the network map. This level is appropriate for neighbourhood participants who will carry a node during an incident but are not responsible for network infrastructure. Expected training time: 60-90 minutes in a group setting, followed by self-directed practice at home.

Level 1 competency checklist:

- Powers on node and confirms LED status
- Connects smartphone to node via Bluetooth
- Sends a test message to the group channel
- Confirms message was received by at least one other node
- Locates their own node on the map view
- Can describe what to do if the node battery dies (recharge procedure)

Level 2: Configured Operator

A Level 2 operator can configure node settings (channel name, PSK, transmit power, GPS interval), change channels in response to a security compromise or coordination need, assist a Level 1 operator with connectivity problems, and interpret basic RSSI and SNR readings to assess link quality. This level is appropriate for neighbourhood zone leaders and ARES/RACES members who are part of the communications plan. Expected training time: 4-6 hours total, including hands-on configuration exercises.

Level 2 competency checklist (in addition to Level 1):

- Changes node name and role settings
- Configures a new channel with a specified PSK
- Adjusts transmit power and GPS reporting interval
- Reads and interprets RSSI/SNR values for two active links
- Assists a Level 1 operator who cannot connect via Bluetooth
- Documents node configuration in the deployment log

Level 3: Infrastructure Operator

A Level 3 operator can plan and deploy a mesh network for a defined area, select and mount infrastructure node hardware (antenna selection, weatherproofing, power supply), troubleshoot RF issues (interference, path loss, multipath), and train Level 1 and Level 2 operators. This level is appropriate for team leaders, club technical officers, and EMCOMM coordinators. Expected training time: 10-20 hours of structured training plus documented field deployment experience.

Running a Mesh Familiarisation Session in 90 Minutes

A 90-minute introductory session can bring a room of complete beginners to Level 1 competency. Suggested schedule:

1. **0-15 min:** Introduction to LoRa and mesh networking (what it is, why it matters for emergency communications, how it differs from cellular and WiFi).
2. **15-35 min:** Hardware overview: show and pass around nodes, explain the indicator LEDs, demonstrate pairing with a smartphone.
3. **35-65 min:** Hands-on practice: each participant pairs their smartphone to a node, sends a message, and locates their node on the map. Facilitator circulates to assist.
4. **65-80 min:** Scenario walk-through: facilitator narrates a simple scenario (power outage, neighbourhood check-in) and participants practice the check-in procedure.
5. **80-90 min:** Q&A, resource distribution (quick-reference card, link to Meshtastic documentation), and next steps (how to get a node, Level 2 training dates).

In-Person vs. Self-Paced Training

In-person training is strongly preferred for Levels 1 and 2, because the most common failure modes (Bluetooth pairing issues, incorrect channel configuration) are easiest to diagnose and correct when a knowledgeable facilitator is physically present. Self-paced video training works well as a supplement for operators who miss a session or need to review a specific procedure. Several ARRL and Meshtastic community members have published tutorial videos suitable for self-paced Level 1 and Level 2 training. Level 3 training requires field experience that cannot be replicated in a self-paced format.

Maintaining Operator Readiness

Skills degrade without practice. Scheduling quarterly mesh nets (structured on-air sessions where operators check in, pass practice traffic, and report node status) keeps all operator levels engaged and surfaces equipment problems before they matter in a real incident. Pairing quarterly nets with the exercises described in the companion page "Running a Mesh Communications Exercise" provides a complete readiness maintenance programme.