

## BleedIO Tech — netMESH for Drone Swarm Operations

### netMESH for Drone Swarm Operations

How BleedIO's decentralized BLE Mesh platform enables resilient relative positioning and inter-drone communication for autonomous swarm coordination — without GPS or centralized infrastructure.

#### The problem

Conventional drone swarm coordination depends on GPS and centralized radio control. These systems are vulnerable in contested, indoor, subterranean, and RF-obstructed environments. When GPS is denied or infrastructure is unavailable, swarms lose coordination — and missions fail.

This is not theoretical. DARPA's OFFSET program (250+ UAVs for urban swarm tactics) documented "**intermittent and unreliable communications with swarm assets**" as a recurring challenge — congestion from launching hundreds of vehicles in dense RF environments overwhelmed traditional comms. The DARPA CODE program proved autonomous GPS-denied coordination is possible (6 live drones + 24 virtual at Yuma Proving Ground, 2019), but relied on expensive military-grade proprietary systems inaccessible to commercial operators.

The DoD's Drone Dominance program now targets **\$5,000 per drone** (dropping to \$2,300). At those price points, existing mesh radios — Persistent Systems MPU5 (~\$30K), Silvus StreamCaster (~\$5–15K) — **cost more than the drone itself**. The military needs sub-\$100 mesh networking for attritable swarm platforms.

#### How netMESH solves it

netMESH is BleedIO Tech's decentralized BLE Mesh networking platform. Each drone in the swarm operates as a mesh node, enabling two core capabilities without any external infrastructure:

##### Relative positioning via BLE beacons

- Each drone embeds a BLE beacon and continuously broadcasts its presence.
- RSSI measurements between drones feed trilateration and proximity clustering algorithms to compute relative positions within the swarm.
- Position accuracy can be enhanced through sensor fusion (RSSI + IMU data).
- Collaborative positioning — where drones share relative position data via mesh — is emerging as the most promising approach for small drone swarms in GPS-denied environments.

**Result:** Drones maintain spatial awareness of each other in GPS-denied environments — indoors, underground, in urban canyons, or in contested airspace — using low-cost, energy-efficient BLE modules rather than high-cost GPS or UWB hardware.

### Inter-drone data exchange

netMESH provides the mesh data fabric for real-time swarm communication:

- **Decentralized mesh routing** — no single point of failure; the swarm network self-heals in <3 seconds under node loss.
- **Low-latency communication** — ultra-low latency (~milliseconds) critical for real-time maneuver coordination.
- **AES-encrypted transport** — secure message exchange between drones with anti-replay protection.
- **Dynamic topology support** — the mesh adapts automatically as drones move, join, or are lost.
- **Frequency hopping** — BLE operates across 40 channels (2 MHz spacing), making detection and jamming significantly harder than single-frequency systems.

### Data types exchanged across the mesh:

- Altitude, velocity, and relative position
- Obstacle proximity (from onboard sensors)
- Command acknowledgments and broadcast instructions
- Health/status and environmental telemetry

### The cost and weight problem netMESH solves

Existing military mesh radios are designed for large platforms with large budgets. For attritable drone swarms at scale, they are physically and economically incompatible:

Factor	Military MANET radios	netMESH (BLE Mesh)
<b>Cost per node</b>	\$5,000 – \$30,000	Sub-\$100 target
<b>Weight</b>	300g – 1kg+	<50g
<b>Power draw</b>	5 – 25W	10 – 100 mW
<b>Swarm scale</b>	Dozens	Hundreds to thousands
<b>Attritable?</b>	No (too expensive to lose)	Yes
<b>ITAR restricted?</b>	Typically yes	No

BLE consumes **10–100x less power** than Wi-Fi, directly extending mission time or enabling smaller, lighter drones. For sub-250g platforms with 15–30 minute flight times, this is decisive.

### Implementation architecture

Component	Detail
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Component	Detail
<b>Per-drone hardware</b>	BLE 5.0+ transceiver, netMESH firmware stack, environmental + motion sensors (optional)
<b>Network topology</b>	Fully decentralized, peer-to-peer, self-routing mesh
<b>Central controller</b>	Optional — receives telemetry and issues mission-level instructions when available
<b>Mesh scale</b>	Up to 32,767 nodes per mesh (BLE Mesh standard)
<b>Reconvergence</b>	<3 seconds under 10% node loss
<b>Packet loss under stress</b>	<1%
<b>Network uptime</b>	>99.9% (self-healing architecture)

### netMESH vs. alternatives

Capability	Wi-Fi mesh	Military MANET	LoRa	netMESH (BLE Mesh)
GPS-free operation	No	Varies	No	Yes
Self-healing	Limited	Yes	No	Yes — <3 s
Mesh scalability	Poor	Dozens	Varies	32,767 nodes
Energy consumption	High (100–1000 mW)	High (5–25W)	Low	Very low (10–100 mW)
Cost per node	\$50–200	\$5,000–30,000	\$20–100	Sub-\$100
Weight	50–200g	300g–1kg+	20–50g	<50g
Attritable at scale	Yes	No	Yes	Yes
Jam resistance	Low (2.4/5 GHz)	High	Medium	Medium (40-ch hopping)
Single point of failure	Router	Varies	Gateway	None

### Why it matters

#### Defense and contested environments

The DoD is investing heavily in autonomous drone swarms:

- **Replicator Initiative / DAWG:** \$1B+ for thousands of autonomous uncrewed systems
- **Drone Dominance:** \$1B for 30,000 attack drones from 12 vendors at \$5K–\$2.3K per unit
- **Navy FY2026:** \$5.3B for unmanned systems (\$2.2B increase over FY2025)
- **Drone swarm market:** 55% CAGR through 2030

These programs explicitly require **low-cost, attributable platforms**. netMESH’s sub-\$100, sub-50g mesh node fills the gap between expensive military MANET radios and the \$5K attributable drone price target.

### Public safety

Search-and-rescue operations in collapsed structures, underground spaces, or wildfire zones require drone coordination where GPS signals are unavailable. netMESH enables swarms to navigate and relay sensor data through BLE mesh without external infrastructure — directly relevant to BleedIO’s active firefighting vertical (2 departments signed, 50 target by end of 2026).

### Industrial inspection

Indoor warehouse navigation, facility inspection, and infrastructure monitoring require coordinated drone operations in GPS-denied spaces. netMESH provides the positioning and communication backbone for autonomous inspection swarms in oil & gas (Chevron), manufacturing (Snap-on), and energy infrastructure.

### Market opportunity

Segment	2025	2030+	Source
Military drone market	\$15.8B	\$22.8B	MarketsandMarkets
Drone swarm market	—	55% CAGR	MarkNtel Advisors
Military IoT	\$487B	\$1.2T (2034)	Precedence Research
Counter-UAS spending	\$400M+ (Army alone)	Growing	FY2025 NDAA

### Intellectual property

BleedIO’s patent-pending “Network in Advance” pre-provisioning method (Provisional Patent #63/804,380, filed May 12, 2025) enables rapid deployment of mesh networks for swarm operations — drones arrive mission-ready with pre-provisioned mesh identities, eliminating field setup time.

### Relevant precedents

- **DARPA OFFSET** (2019–2023): 250+ UAV swarms for urban ops — documented communication congestion as a key challenge that decentralized mesh directly addresses.
- **DARPA CODE** (2019): Proved GPS-denied autonomous swarm coordination is viable — but used expensive proprietary comms.
- **DARPA Subterranean Challenge**: Underground/tunnel navigation without GPS — proved the need for infrastructure-free positioning.
- **Airbus/Quantum Systems** (Aug 2024): 7 mixed-type drones maintained formation despite simulated jamming and mid-flight drone removals — demonstrated mesh resilience in contested environments.

## Source references

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- IEEE: “Congestion Analysis for the DARPA OFFSET CCAST Swarm” (2023)
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- Replicator/DAWG: [diu.mil/replicator](https://diu.mil/replicator)
- Drone Dominance: [govconwire.com](https://govconwire.com)
- Military drone market: MarketsandMarkets, Grand View Research
- RAND Corporation: UAV Swarm Technology (RRA2380-1)
- Marketing/Using netMESH for Drone Swarm Operations.docx — original white paper
- `bleedio-product-plan` repo: `docs/product/product-vision-master.md`

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