

How to Get Accurate Positioning Without GPS: A Mesh-Derived Coordinate Architecture

If you build robots, vehicles, or infrastructure that has to know where it is indoors, underground, underwater, or anywhere a satellite fix drops out, GPS alone will fail you. This guide walks through an architectural approach that resolves position from a governed mesh of credentialed neighbors and mesh geometry instead of a satellite constellation. It describes an architecture disclosed in U.S. Provisional Application No. 64/049,409, the Mesh-Derived Coordinates inventive step, not a shipping library you can install.

What You Are Building

You need a device to know where it is when there is no satellite fix. Warehouse robots lose GPS the moment they roll through the dock door. Mining and tunnel equipment never had it. Autonomous vehicles in urban canyons get multipath garbage. Drones indoors, divers on a wreck site, forklifts in a steel-framed building: all of them face the same structural problem. The satellite signal is either absent, attenuated, or spoofable, and the moment it is denied, positioning stops.

This guide describes how to approach a positioning system whose coordinate frame comes from the environment itself rather than from orbit. Instead of every unit independently acquiring a broadcast fix, participating agents range against each other

and against known reference points, and the mesh of those observations becomes the coordinate reference frame. You are building a self-referencing spatial coordinate system that keeps working when GPS does not.

This is an architecture, not a package. It is disclosed in a patent filing, and what follows teaches you how the approach is put together and how you would build it yourself.

Why the Obvious Approaches Fall Short

The obvious answers all have real, structural limits worth stating accurately.

Global satellite navigation (GPS, and the broader GNSS family). These operate on broadcast signals from centrally operated constellations. Acquisition of that signal is a precondition for positioning, so denial of the signal precludes positioning. This is not a bug; it is the shape of the system. Indoors, underground, and underwater the signal simply is not usable, and outdoors it can be jammed or spoofed because a receiver trusts a pseudo-random-noise code it cannot independently authenticate.

Differential and assisted positioning (RTK, DGPS, A-GPS). These improve accuracy by layering reference-station networks maintained by a positioning-service operator on top of the satellite fix. They are genuinely accurate where they work, but they inherit the satellite dependency and add a dependency on an external service operator and its reference-station infrastructure. Lose the sky or lose the operator network, and you are back to nothing.

Fixed-identifier beacons (Bluetooth beacons, WiFi access points, RFID gates). These work indoors, which is their appeal. But most designs broadcast a static identifier that a receiver looks up in a map. A static identifier is spoofable, and the position it yields is only as trustworthy as the assumption that the identifier is genuine. There is usually no authentication of the individual range measurement itself, and each is typically tied to a single ranging modality and a single vendor's stack.

The common gap: every one of these treats positioning as *acquisition of an external truth* (a constellation, an operator's network, a beacon's advertised identity). None of them lets the environment cooperatively *produce* a coordinate frame that is authenticated observation by observation. That is the gap the architecture below closes.

The Architecture

The core idea disclosed in the filing is a **mesh-derived coordinate system** treated as a first-class architectural primitive: a shared coordinate reference frame produced cooperatively by participating mesh agents through inter-agent ranging, anchor-observation admission, and governance-credentialed frame definition, without dependence on any specific external positioning infrastructure. The mesh itself constitutes the coordinate reference frame.

It is built from a set of composable mechanisms. Each is described in the disclosure as a component of the primitive:

- **Governance-credentialed inter-agent ranging.** Agents produce range observations between each other using at least one of many ranging modalities (the disclosure describes admitting fifteen-plus modalities into a single coordinate graph, rather than being locked to one). Critically, every range observation is credentialed, not anonymous.
- **Anchor observation admission.** Some points have known positions. The interface admits governance-credentialed anchor position contributions. In this disclosure, the passive markers of the broader system can serve as anchor nodes, carrying a spatial reference in a chosen coordinate frame. Anchors ground the frame to real-world coordinates when they are present.
- **Cooperative localization engine.** This determines agent positions through multilateration from the admitted range observations and anchor positions. Given enough ranges to enough known points, position is solved geometrically.

- **Transitive localization extender.** When an agent cannot range directly to enough anchors, it is positioned through its neighbors: an agent localized against anchors becomes a reference for the agent beyond it. Position propagates outward through the mesh graph.
- **Precision-and-uncertainty propagator.** Ranging precision and ranging covariance are carried through the localization chain to produce per-position uncertainty estimates. You do not just get a point; you get a point with a stated uncertainty, and that uncertainty grows honestly as you hop transitively away from anchors.
- **Ambiguity-resolution mechanism.** Multilateration can admit more than one geometric solution. This selects among them.
- **Adversarial-range rejection.** Spoofed, injected, or otherwise inadmissible range observations are rejected. Because each range is authenticated through the system's governance-chain continuity identity and evaluated for admissibility, a fabricated measurement does not silently corrupt the frame.
- **Anchor-less bootstrap.** When no anchor observations are available at all, the mechanism still produces a relative-only coordinate frame from zero-anchor conditions. You get a self-consistent internal frame (agents know where they are relative to each other) even before any absolute reference exists.
- **Coordinate-frame federation.** Two or more independently maintained mesh-derived coordinate systems can be aligned into a shared frame, with governance chain preserved across the join.
- **Self-healing topology maintainer.** The coordinate graph is updated under agent failure, removal, or addition, so the frame survives churn in the population of participants.
- **Evidential fusion.** Mesh-derived positions can be combined with externally sourced positions (satellite navigation, inertial dead-reckoning, visual-inertial odometry, any external source) through the system's composite admissibility

evaluator. GPS is not the enemy; when it is available it becomes one more admissible input, not the sole point of failure.

- **Coordinate-lineage recorder.** Every range observation, localization event, frame definition, uncertainty update, ambiguity resolution, rejection, federation, and consumption is recorded in a governance-chain lineage. Any position can be reconstructed back through its full derivation chain.

Two properties fall out of this design that are worth internalizing. First, **positioning is produced, not acquired**: the frame is an emergent product of credentialed neighbors and mesh geometry. Second, **trust is per-observation**: authentication and admissibility live at the level of each range, so the coordinate frame degrades gracefully and rejects injected error rather than trusting a broadcast wholesale.

One honest bound, stated in the disclosure itself: the precision of mesh-derived coordinates is bounded by the ranging-modality accuracy and by reference-node density within ranging distance of the consuming agent. Sparse references or a low-accuracy modality mean a looser fix. The disclosure addresses this with a densification mechanism (detecting regions where precision falls below a policy threshold and deploying additional reference nodes to raise it), but the underlying tradeoff is real and you should design around it.

How to Approach the Build

You are implementing this yourself. A reasonable ordering:

- 1. Choose your ranging modality (or modalities).** This is the physics layer and it sets your accuracy floor. The architecture is deliberately modality-agnostic and lets you fuse several, but you have to pick real ones for your environment: time-of-flight radio, ultra-wideband, acoustic ranging underwater, and so on. Whatever you pick, your measurement is a distance between two agents with an uncertainty.

2. Give every agent a credentialed identity and sign every range. This is the load-bearing decision that separates the approach from a beacon network. A range observation should carry the credentialed identity of its producer so a downstream localizer can authenticate it and reject injected measurements. Sketch the observation as something like this (illustrative, and faithful to the disclosed component set, not a shipping interface):

```
RangeObservation {  
  from_agent:  credentialed identity  
  to_agent:    credentialed identity  
  distance:    measured range  
  covariance:  ranging uncertainty  
  modality:   which ranging method  
  attestation: signature binding this range to its producer  
}
```

3. Admit anchors. Wherever you have points of known position (surveyed markers, fixed infrastructure, pre-placed reference nodes), express them as credentialed anchor observations carrying a spatial reference. These are what tie your frame to absolute coordinates. Decide early whether your deployment even needs absolute coordinates or whether a relative frame suffices.

4. Build the cooperative localization solver. Take admitted ranges plus anchor positions and solve agent positions by multilateration. Include ambiguity resolution for the multi-solution case, and propagate covariance through the solve so each output position carries an uncertainty, not just a coordinate.

5. Add transitive extension. Most agents will not see enough anchors directly. Let an agent that has been localized serve as a reference for agents further out, and make sure your uncertainty propagation reflects the extra hops so a deeply transitive position honestly reports as less certain.

6. Implement anchor-less bootstrap as the fallback path. Before any anchor is admitted, still produce a relative-only frame so the mesh is internally consistent from the first exchange. Absolute grounding can arrive later and align the relative frame to it.

7. Handle adversarial input and churn. Wire range admission through an admissibility check that rejects spoofed or inconsistent measurements, and implement a self-healing update of the coordinate graph as agents join, leave, or fail. A positioning frame that cannot survive a hostile or changing population is not deployable.

8. Record lineage, and only then fuse external sources. Log each ranging, localization, rejection, and frame-definition event so any position is reconstructable. Once the mesh frame stands on its own, fold in GPS, inertial, or visual-inertial estimates as additional admissible inputs through your fusion path rather than as a foundation you depend on.

Build and validate 1 through 6 before reaching for external fusion in step 8. The whole point is a frame that is correct without the satellite.

What This Does Not Give You

Be clear-eyed about the boundaries.

This is an **architecture, not a drop-in library**. There is no package to install and no SDK behind this guide. Every mechanism above (the solver, the ranging layer, the credential and admissibility checks, the lineage store) is something you design and implement. Nothing here "just works" out of the box.

It is **disclosed, not benchmarked**. The approach is described in a patent filing. This guide does not report accuracy numbers, latency, or production results, because the filing describes the architecture rather than a productized, benchmarked system. Do not cite a precision figure from here, because there is not one to cite.

Its **accuracy is bounded by physics and density**. Precision is limited by your ranging modality's accuracy and by how many reference nodes sit within ranging distance of the agent that needs a fix. A sparse mesh in an open area gives you a loose fix; densification helps but costs deployment effort. If you need centimeter accuracy across a barren field with two anchors, this architecture will not conjure it.

It **does not remove the need for anchors if you want absolute coordinates**. Anchor-less bootstrap gives you a self-consistent relative frame, which is enough for many coordination tasks, but tying that frame to real-world coordinates still requires admitting anchors with known positions.

And it presumes a **population of participating, credentialed agents**. A single isolated device with no neighbors and no anchors has nothing to range against. The approach earns its keep exactly where GPS struggles and where multiple cooperating units or reference points exist.

Disclosure Scope

The mesh-derived coordinate approach described in this guide, the Mesh-Derived Coordinates inventive step, is disclosed in U.S. Provisional Application No. 64/049,409. Every mechanism attributed here to the approach (cooperative multilateration, anchor admission, transitive extension, uncertainty propagation, adversarial-range rejection, anchor-less bootstrap, coordinate-frame federation, self-healing topology maintenance, evidential fusion, and coordinate lineage) traces to that filing. This guide is educational: it explains an architecture so that a skilled developer can understand and build it. It is not a warranty, not a specification of a shipping product, and not an offer of software.

Mesh-Derived Coordinates (</mesh-coordinates>) [All 40 steps → \(/inventive-steps\)](#)

es)

Cooperative localization with credentialed ranges. Densification on demand.

Provisional application

PRIMARY TECHNICAL DISCLOSURE

- [Mesh-Derived Coordinates: Cooperative Localization With On-Demand Densification \(/articles/mesh-derived-coordinates-cooperative-localization-with-on-demand-densification\)](/articles/mesh-derived-coordinates-cooperative-localization-with-on-demand-densification)

SECONDARY TECHNICAL

- [Multi-Modality Cooperative Ranging \(/articles/mesh-coordinates/multi-modality-ranging\)](/articles/mesh-coordinates/multi-modality-ranging)
- [Cooperative Localization Across Mesh Units \(/articles/mesh-coordinates/cooperative-localization\)](/articles/mesh-coordinates/cooperative-localization)
- [Relative Frame Bootstrap Without Absolute Reference \(/articles/mesh-coordinates/relative-frame-bootstrap\)](/articles/mesh-coordinates/relative-frame-bootstrap)
- [Credentialed Range Observations With Lineage \(/articles/mesh-coordinates/credentialed-range-observations\)](/articles/mesh-coordinates/credentialed-range-observations)
- [Lineage-Bound Multilateration \(/articles/mesh-coordinates/lineage-bound-multilateration\)](/articles/mesh-coordinates/lineage-bound-multilateration)
- [Anti-Spoofed Observation Rejection \(/articles/mesh-coordinates/anti-spoofed-rejection\)](/articles/mesh-coordinates/anti-spoofed-rejection)
- [Reference Node Densification \(/articles/mesh-coordinates/reference-node-densification\)](/articles/mesh-coordinates/reference-node-densification)
- [Airdroppable and Rapidly-Deployable Reference Nodes \(/articles/mesh-coordinates/airdroppable-deployable-nodes\)](/articles/mesh-coordinates/airdroppable-deployable-nodes)
- [Coordinate Frame Federation Across Mesh Regions \(/articles/mesh-coordinates/coordinate-frame-federation\)](/articles/mesh-coordinates/coordinate-frame-federation)
- [Cross-Jurisdictional Coordinate Alignment \(/articles/mesh-coordinates/cross-jurisdictional-alignment\)](/articles/mesh-coordinates/cross-jurisdictional-alignment)

APPLICATIONS · GENERAL

- [How to Position Forces When GPS Is Jammed: GNSS-Denied Defense PNT \(/articles/mesh-coordinates/gnss-denied-defense-positioning\)](/articles/mesh-coordinates/gnss-denied-defense-positioning)
- [GNSS-Denied Positioning for Underground Mining, Tunneling, and Subterranean Operations \(/articles/mesh-coordinates/subterranean-operations-positioning\)](/articles/mesh-coordinates/subterranean-operations-positioning)
- [Urban Canyon Positioning Without GNSS Lock: Cooperative Ranging for City Streets \(/articles/mesh-coordinates/urban-canyon-civilian-positioning\)](/articles/mesh-coordinates/urban-canyon-civilian-positioning)

- [GNSS-Independent Positioning for Autonomous Ships at Sea \(/articles/mesh-coordinates/autonomous-shipping-ocean-positioning\)](/articles/mesh-coordinates/autonomous-shipping-ocean-positioning).
- [DDoS-Resilient Positioning: Jamming and Spoofing Defense Through Mesh Cooperation \(/articles/mesh-coordinates/ddos-resilient-positioning\)](/articles/mesh-coordinates/ddos-resilient-positioning).
- [Drone Airspace Integration: GNSS-Independent BVLOS Positioning with Credentialed Lineage \(/articles/mesh-coordinates/drone-airspace-integration\)](/articles/mesh-coordinates/drone-airspace-integration).
- [Indoor Medical Positioning for HIPAA-Compliant Hospital RTLS \(/articles/mesh-coordinates/indoor-medical-positioning\)](/articles/mesh-coordinates/indoor-medical-positioning).
- [High-Accuracy Positioning for Mass-Market Mobile Without Reliable GNSS \(/articles/mesh-coordinates/sub-meter-mass-market\)](/articles/mesh-coordinates/sub-meter-mass-market).

APPLICATIONS · SPECIFIC

- [Hexagon SmartNet Alternative: Governed Cooperative Positioning \(/articles/mesh-coordinates/hexagon-smartnet\)](/articles/mesh-coordinates/hexagon-smartnet).
- [Locata Alternative: Cooperative Mesh Coordinates Beyond Site-Specific Pseudolites \(/articles/mesh-coordinates/locata-positioning\)](/articles/mesh-coordinates/locata-positioning).
- [NextNav Pinnacle vs Cooperative Multi-Modality Positioning \(/articles/mesh-coordinates/nextnav-pinnacle\)](/articles/mesh-coordinates/nextnav-pinnacle).
- [Apple UWB vs Governed Mesh Coordinates: The Cooperative Positioning Layer Above U1 \(/articles/mesh-coordinates/apple-ubw\)](/articles/mesh-coordinates/apple-ubw).
- [Decawave/Qorvo UWB Alternative: Governed Cooperative-Ranging Substrate \(/articles/mesh-coordinates/decawave-ubw\)](/articles/mesh-coordinates/decawave-ubw).
- [Septentrio GNSS vs Governed Cooperative Positioning \(/articles/mesh-coordinates/septentrio-gnss\)](/articles/mesh-coordinates/septentrio-gnss).
- [Topcon Positioning Alternative: GNSS-Independent Mesh Coordinates \(/articles/mesh-coordinates/topcon-positioning\)](/articles/mesh-coordinates/topcon-positioning).
- [u-blox GNSS Alternative: Cooperative, GNSS-Independent Positioning \(/articles/mesh-coordinates/u-blox-gnss\)](/articles/mesh-coordinates/u-blox-gnss).

[Mesh-Derived Coordinates overview → \(/mesh-coordinates\)](/mesh-coordinates)