

N-Party Coordination: Physical-Proximity-Grounded Multi-Party Settlement

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Multi-Party Coordination Across Authority Boundaries Is Not Solved

Industrial multi-party transactions — intermodal freight transfer (sea-rail-truck), airspace handoff (departure-control to en-route, civil-to-military), medical patient transfer (EMS to ED to OR to ICU to discharge) — fail in a structurally consistent way: lineage discontinues at every authority boundary.

Each authority maintains its own records, its own taxonomies, its own settlement timing. When custody transfers, the receiving authority captures partial information, restates it in its own taxonomy, and operates on that restatement. The original lineage is lost; disputes require manual reconstruction; audit gaps drive liability and regulatory burden.

Existing solutions — EDI, GS1 EPCIS, HL7 FHIR — provide data-format interoperability but not lineage continuity. Each handoff still translates between systems with structural information loss.

1. The Primitive: Matched-Pair Generalized to N Parties

N-party coordination extends matched-pair settlement (Article 7) from bilateral to multi-party finality. N participating authorities each contribute a credentialed observation; the coordination is finalized when the configured outcome function over the contributions returns success within a defined spatial-temporal proximity window.

Role-differentiated attestation is structural: each participant occupies a defined role in the ceremony, with the role specifying what observations the party must contribute, what other observations the party admits as evidence, and what outcome the party's contribution affects. The custody-chain pattern, for example, has a relinquishing role and a receiving role; the multi-authority-approval pattern has a primary role and approving roles; the quorum pattern has voting roles.

Coordination ceremonies are first-class governed observations. The ceremony itself is published, the participants are credentialed, the outcome function is signed, and the lineage records every contribution and the final outcome.

2. Pattern-Agnostic Outcome Functions Across 13+ Patterns

The primitive supports a parameterized outcome function that handles a documented family of coordination patterns: consensus, quorum, auction, lead-follower, custody-chain, federated approval, multi-authority approval, voting (simple majority, supermajority, ranked, weighted), threshold signature, m-of-n approval, and others. Adding a new pattern requires defining the outcome function, not modifying the primitive.

Each pattern's outcome function consumes the role-differentiated contributions and produces a Boolean (or graded) finality determination. A custody-chain pattern returns success when the relinquishing observation and the receiving observation are both present and the outcome function admits the pairing. A quorum pattern returns

success when contributions from a defined fraction of admitted participants exceed threshold.

Pattern-agnosticism is the load-bearing element. The same primitive serves auctions and custody-chains and threshold signatures; deployment configures rather than reimplementing.

3. Byzantine Robustness and Partial-Quorum Handling

Real coordination tolerates partial participation. A flight handoff between FIRs may proceed if N-1 controllers concur but one is unreachable; a port custody transfer may proceed under partial customs participation if the missing party's policy admits it. The primitive's outcome functions admit this structurally.

Byzantine-robust outcome functions tolerate a bounded fraction of contributing parties acting maliciously or adversarially: the function detects inconsistency, identifies the dissenting participants, and returns either a constrained success (the consistent parties' agreement) or a structured failure (the dissent recorded with lineage).

Partial-quorum handling produces graduated finality: full quorum gives full finality, partial quorum gives constrained finality with the missing parties' contributions recorded as outstanding. Outstanding contributions can be resolved later through governance-credentialed update without unwinding the partial settlement.

4. Dynamic Membership Across the Ceremony

Coordination ceremonies are not static. Participants may join (a new authority enters the airspace transition), leave (a vessel exits the port custody-transfer ceremony), or

be replaced (a relief crew takes over from an outgoing crew). The primitive admits dynamic membership through credentialed admission and departure observations.

Each membership change is itself a credentialed observation that the ceremony's outcome function consumes. The function may admit the change (new participant joins with full role authority), constrain it (new participant joins in observer-only role), or reject it (membership change exceeds policy bounds and the ceremony aborts).

Dynamic membership is required for long-running ceremonies (multi-hour port custody transfers, multi-day medical-care episodes) where the participant set evolves under operational realities.

5. Cross-Pattern Composition

Real ceremonies often combine patterns. A port custody transfer may use custody-chain (relinquishing-receiving) at the gate plus multi-authority approval (port + customs + carrier) for the documentation plus quorum (subset of ship's crew sign release) for the master's authority.

Cross-pattern composition is structural: the composite ceremony is a credentialed observation referencing the sub-ceremonies, with the outer outcome function consuming the inner outcome functions' results. Lineage links every contribution to its place in the composition.

Composition enables real-world coordination patterns to be expressed faithfully rather than approximated through pattern-mapping workarounds.

6. Cross-Domain Authority Handoff

The most commercially distinctive case is cross-domain authority handoff: intermodal freight (sea-rail-truck), airspace transitions (FAA-to-FAA region, civil-to-

military, civilian to UAM), medical patient transfer (EMS-ED-OR-ICU-discharge), border-crossing custody.

Each cross-domain handoff is a custody-chain ceremony with explicit taxonomy translation: the relinquishing authority's observation is in its taxonomy, the receiving authority's observation is in its taxonomy, and a credentialed translator (a coordination authority that signs both taxonomies) admits the equivalence. The handoff is final when both observations and the translation are admitted.

Lineage continuity across the handoff is structural rather than reconstruction-based. A patient's medical lineage at discharge references the EMS observation, the ED observation, the OR observation, the ICU observation, and the discharge observation, with explicit translation observations bridging any taxonomy boundaries (EMS pre-hospital codes to ED clinical codes, surgical taxonomies to ICU monitoring taxonomies).

7. What This Is Not

This is not PBFT, HotStuff, Raft, or other distributed-consensus protocols. Those produce abstract state-machine agreement; the governed primitive produces physical-coordination finality grounded in spatial-temporal proximity.

This is not threshold cryptography or multi-party computation. Those provide cryptographic primitives that the governed primitive can use as one of its outcome functions; the architecture is broader than any specific cryptographic mechanism.

This is not GS1 EPCIS, HL7 FHIR, or other industry-specific data formats. Those provide interoperable data exchange; the governed primitive provides lineage-continuous custody with structural cross-authority taxonomy translation.

Conclusion

N-party coordination generalizes matched-pair settlement to multi-party ceremonies grounded in physical proximity, with role-differentiated attestation, pattern-agnostic outcome functions, Byzantine robustness, dynamic membership, cross-pattern composition, and cross-domain authority handoff with taxonomy translation.

Disclosed under USPTO provisional 64/049,409, the primitive serves intermodal freight, airspace handoff, medical patient transfer, border custody, and other multi-authority coordination cases where current architectures lose lineage at every boundary.