Matched-Pair Settlement: Bilateral Finality From Spatial-Temporal Proximity

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Settlement Imposes Latency Walls That Don't Match Physical Interaction

Tolling collects from millions of vehicles at highway speed using transponders, but the settlement happens hours or days later through a centralized authority. EV charging deducts payment after the session completes through a payment processor. Port custody transfer involves multi-day reconciliation between shippers, carriers, and customs.

These delays exist because the settlement architecture lives somewhere other than the physical interaction. The transponder reads the toll; the toll is forwarded to a clearinghouse; the clearinghouse settles against the account. Each hop adds latency, infrastructure cost, and a point at which the settlement can be disputed, lost, or reversed.

Blockchain-based settlement attempted to remove the intermediary but added consensus latency that is incompatible with physical-interaction speed. Lightning Network HTLCs, atomic swaps, and similar mechanisms still require pre-negotiated session state and presume a trusted custody layer underneath.

1. The Primitive: Two Observations, A Window, Finality

Matched-pair settlement defines settlement as a structural property: two governance-credentialed observations from distinct parties, falling within a defined spatial-temporal proximity window, constitute a finalized transaction. The settlement record is the matched pair itself; no intermediary processes it, and no consensus ratifies it.

Concretely: a vehicle and a tolling gantry produce credentialed observations at the moment of passage. The two observations carry compatible identifiers, the spatial-temporal window matches, and the governance authorities of both parties admit the pairing. The settlement is final at the moment of pairing.

Settlement records are non-repudiable: each party's signature on its own observation is unforgeable, and the lineage records both observations together. A dispute does not unwind the settlement; it produces a counter-claim observation that is itself evaluated through governance.

2. Spatial-Temporal Proximity Window as the Finality Trigger

The proximity window is defined in the joint spacetime frame established by the mesh coordinate and time primitives. The window has spatial bounds (the toll-zone geometry, the charging-pad footprint, the port-gate proximity envelope) and temporal bounds (the duration over which the pairing is admissible).

Window definition is governance-credentialed: the toll authority signs the window for its tolling gantries, the charging operator signs the window for its charging stations, the port authority signs the window for its custody-transfer points. A transaction outside the window does not pair, and a pairing claim outside the window is rejected.

The window is the structural answer to the question 'what makes this settlement finalized?' In trusted-intermediary architectures, finality is a clearinghouse decision. In blockchain architectures, finality is a probabilistic depth in the chain. In matched-pair settlement, finality is geometric: the two parties were here, at the same time, with credentials that admit the pairing.

3. Cross-Authority Taxonomy Translation

Real-world settlement crosses authority boundaries: a vehicle from one tolling-authority's domain crossing a gantry operated by another, a charging session with utility on one side and EV-operator on the other, a port handoff between a ship's flag-state authority and the receiving port's authority.

Cross-authority composition handles this through taxonomy translation: each authority's observation declares its credential class, and the matched-pair primitive translates between class-equivalent credentials when the authorities have signed cross-recognition policies.

The mechanism is the same one used for marker-track route composition (Article 3): authorities sign their own observations, mutual recognition is governed by credentialed cross-recognition policies, and operating units accept whichever authority composition matches their policy. Pre-negotiated authority interoperability is not required.

4. Integrated Counter-Offer and Escrow Mechanisms

Not every interaction is a simple two-observation pairing. Some transactions require negotiation: counter-offers, conditional acceptance, escrow until performance, dispute escalation. The matched-pair primitive composes with these mechanisms structurally.

A counter-offer is itself a credentialed observation: the responding party publishes a modification to the originator's offer, with the modification visible to both parties and to the authority. The original offer remains open until accepted, withdrawn, or expired; the counter-offer modifies the matched-pair window for that transaction.

Escrow is a deferred matched-pair: the initial pairing locks resources but does not finalize, with a release condition (delivery confirmation, performance attestation, third-party verification) gating the final settlement. Disputes produce counter-claim observations evaluated through the same governance framework that admitted the original pairing.

5. Tolling Embodiment

The tolling embodiment makes the architecture concrete. A roadway gantry installed under a transportation authority publishes a credentialed proximity-window observation each time a vehicle passes. The vehicle, operated under a governance-credentialed account, publishes its own credentialed pass-through observation. The matching pair finalizes the toll instantly.

The gantry has no need to forward the toll to a clearinghouse. The vehicle has no need to maintain a pre-funded account at the clearinghouse. The tolling authority simply collects the matched-pair records and aggregates them on whatever cadence its accounting requires.

Multi-jurisdictional tolling — a vehicle traveling across state lines, across national borders, between toll authorities — works through cross-authority taxonomy translation: the home authority and the visiting authority have signed cross-recognition policies, and the vehicle's credential is admitted under the visiting authority's gantries.

6. V2G Charging Embodiment

Vehicle-to-grid bidirectional charging is the canonical case where settlement at physical-interaction speed matters: the energy flow needs to settle continuously over the charging session, with the grid operator paying for energy returned and the vehicle paying for energy received, all under regulatory oversight.

Matched-pair settlement provides this. Each unit of energy transferred is recorded as a paired observation: the charger publishes a credentialed metering observation, the vehicle publishes its own metering observation, the proximity-window admits the pairing (the cable connection geometry plus the metering interval), and settlement accumulates.

Disputes about metering accuracy resolve through additional credentialed observations from utility-grade meters, regulator-credentialed reference meters, or post-session reconciliation. The dispute mechanism is the same as for tolling, configured for the energy-settlement context.

7. What This Is Not

This is not E-ZPass / FasTrak. Those systems pair vehicles with gantries but settle through a centralized clearinghouse with hours-to-days latency. The governed primitive's settlement is final at the moment of pairing.

This is not Lightning Network HTLCs or atomic swaps. Those mechanisms enable trustless settlement over an existing custody layer. The governed primitive's custody is the proximity-window admission itself; no underlying custody layer is required.

This is not EMV chip-and-PIN. EMV authenticates a card-present transaction; the governed primitive authenticates a co-located, co-temporal pairing where neither party is a card and the settlement is bilateral rather than card-issuer-mediated.

Conclusion

Matched-pair settlement provides bilateral finality from spatial-temporal proximity, eliminating both the trusted-intermediary and the consensus-based alternatives at the speed of physical interaction. The proximity window is the structural finality trigger. Cross-authority composition handles multi-jurisdictional cases. Counter-offer and escrow mechanisms handle negotiation and dispute. Tolling and V2G embodiments demonstrate concrete §101-defensible apparatus claims.

Disclosed under USPTO provisional 64/049,409, the primitive composes with mesh-derived coordinates and time (proximity window definition), marker-track transport (gantry-as-credentialed-marker), and the five-property governance chain umbrella. It generalizes to n-party coordination for multi-party ceremonies (Article 8).