Satellite Communication With Delay-Tolerant Governance

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Satellite networks operate under physical constraints that terrestrial networking ignores: propagation delays measured in hundreds of milliseconds, intermittent connectivity windows, and rapidly changing orbital topology. These constraints make real-time consultation with central routing authorities impractical. Memory-native protocols embed governance directly into the transport layer, enabling satellites to make authoritative routing and trust decisions locally with governance that tolerates the delays inherent in space communication.

The latency constraint in satellite governance

A LEO satellite constellation with inter-satellite links must make routing decisions in the time it takes a signal to traverse one orbital hop. Ground station connectivity is intermittent. A satellite in polar orbit may have ground contact for only a few minutes per pass. A satellite relaying data through a multihop inter-satellite link cannot pause at each hop to query a ground-based routing authority for the next routing decision.

Current satellite networks address this through pre-computed routing tables uploaded from ground control. The ground station calculates optimal routes based on orbital mechanics, uploads the tables during the contact window, and the satellite follows those tables until the next update. This works for predictable traffic patterns and stable orbital configurations. It fails when traffic patterns change between updates, when a satellite in the relay chain fails, or when priority traffic needs immediate rerouting that the pre-computed tables did not anticipate.

As constellations grow to thousands of satellites with dynamic inter-satellite links, the ground-based route computation becomes a bottleneck. The number of possible routing paths grows combinatorially with constellation size. The upload window constrains how often routes can be updated. The gap between the network's actual state and the ground station's model of that state grows with constellation complexity.

Why store-and-forward DTN is necessary but insufficient

Delay-Tolerant Networking (DTN) protocols handle the store-and-forward mechanics of intermittent connectivity. A DTN node can store a bundle until a suitable forwarding opportunity arises. But DTN bundle protocol addresses the transport problem without addressing the governance problem. A DTN node knows how to store and forward. It does not know whether it is authorized to handle a particular bundle, whether the bundle should be prioritized over other bundles, or whether the forwarding path crosses a trust boundary that should restrict propagation.

Military and intelligence satellite payloads carry data with classification and compartmentalization requirements that must be enforced at every routing hop. A DTN protocol that routes based on connectivity opportunity without evaluating governance constraints can inadvertently route classified data through unauthorized relay paths. The governance must travel with the data, not reside in a ground station that the satellite cannot reach when the routing decision must be made.

How memory-native protocols address this

A memory-native protocol embeds routing policy, trust scope, classification constraints, and propagation rules into the transport substrate. Each data object carried by the satellite network contains its own governance. When a satellite receives a data object, it evaluates the object's intrinsic governance against its own capabilities and trust relationships to make an immediate routing decision.

Trust-weighted routing enables satellites to select inter-satellite links based on accumulated trust with adjacent satellites rather than pre-computed tables from ground control. Dynamic routing adapts to link availability changes in real time. If an inter-satellite link degrades, the satellite routes around it immediately based on local observation, without waiting for ground control to compute and upload a new routing table.

Health monitoring agents assess the viability of each communication path continuously. When a satellite detects degradation in a relay path, it adjusts its local routing decisions and propagates health information to adjacent satellites through the same memory-native transport layer. The health information itself carries governance that determines how far it should propagate and which satellites should act on it.

What implementation looks like

A satellite constellation using memory-native protocols operates each satellite as a self-governing routing node. Ground stations provide policy updates and long-term orbital predictions during contact windows, but satellites make real-time routing decisions based on intrinsic data governance and local trust relationships.

For constellation operators, this reduces dependency on ground station availability for network operations. The constellation continues to route data with full governance integrity during ground station outages, solar interference events, or periods when ground infrastructure is under attack.

For government and defense payloads, memory-native governance ensures that classification and compartmentalization requirements are enforced at every orbital hop without requiring real-time ground station connectivity. Each data object carries its own classification authority. Each satellite evaluates that authority locally.

For commercial constellations providing global connectivity, memory-native protocols enable quality-of-service guarantees that do not depend on ground-based traffic management. Priority traffic carries its own priority governance, and each satellite in the relay chain respects that priority based on intrinsic properties rather than centrally managed traffic classes.

Memory-Native Protocol All 21 steps →

Authority intrinsic to the object. Routing by semantic properties.

Patent
US 19/366,760 · filed
Primary Technical Disclosure
○ Memory-Native Networking: A Cognition-Compatible Protocol Substrate
Secondary Technical
○ Protocol-Native Carriers: Agents as the Fundamental Unit of Transmission○ Dynamic Routing Protocol: Memory-Aware Path Selection for Semantic Agents○ Trust-Weighted Route Scoring: Dynamic Path Selection Through Policy-Defined Trust Thresholds○ Network Health Monitoring System: Signed Health Agents as Distributed Operational Telemetry○ Health Agents as Semantic Objects: Operational Metrics That Route Like Any Other Agent○ Dynamic Indexing Protocol: Entropy-Driven Restructuring of Semantic Flows○ Soft-Index Anchors: Ephemeral Index Points Inferred From Agent Lineage○ Adaptive Consensus Protocol: Memory-Native Quorum Without Fixed Validator Sets○ Trust-Weighted Voting in ACP: Domain-Scoped Votes Accumulated Against Agent Memory○ Dynamic Alias Resolution: Zone-Local Semantic Aliases Resolved Through Transport Headers○ Horizontally Composable Protocol Stack: Independent Layers Operating in Parallel○ Transport-Layer Agnosticism: One Protocol Stack Above Any Carrier○ Federated Semantic Zone Deployment: Heterogeneous Nodes Coordinating Across Trust Boundaries○ Health-Triggered Quorum Adjustment: Dynamic Thresholds From Network Stability Signals
Applications (General)

Legal

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