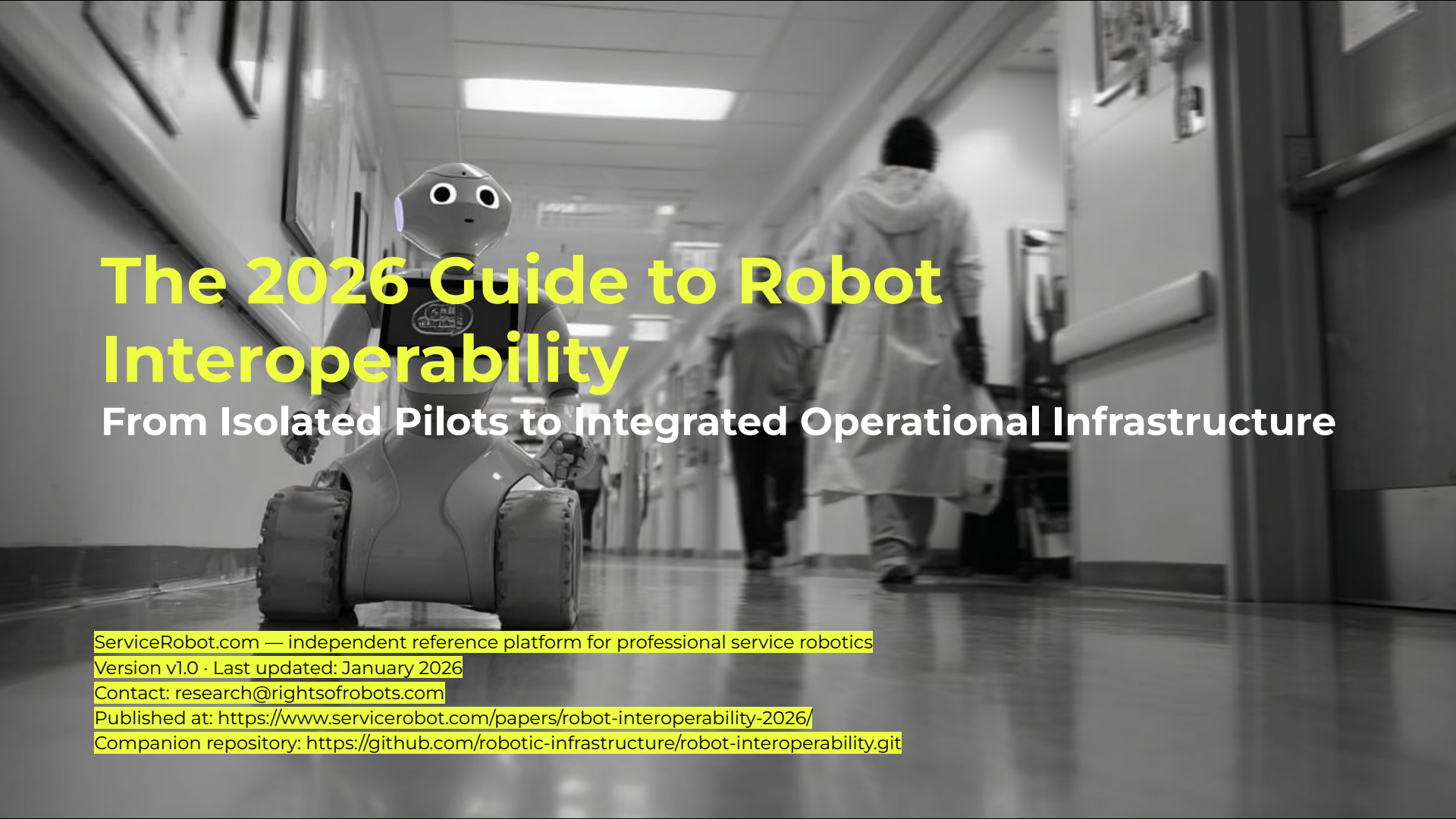


The 2026 Guide to Robot Interoperability

From Isolated Pilots to Integrated Operational Infrastructure

ServiceRobot.com — independent reference platform for professional service robotics
Version v1.0 · Last updated: January 2026
Contact: research@rightsofrobots.com
Published at: https://www.servicerobot.com/papers/robot-interoperability-2026/
Companion repository: https://github.com/robotic-infrastructure/robot-interoperability.git

02 | **Executive Summary**

In 2026, the decisive question in service robotics is no longer whether a robot can perform a task, but whether it can be integrated into an existing operational ecosystem. As multi-vendor fleets become common across logistics, healthcare and facility operations, interoperability has shifted from a technical preference to an operational prerequisite.

Interoperability is often reduced to protocol compatibility. Scaling fails for different reasons: fragmented semantics, inconsistent state models, missing coordination logic in shared spaces, insufficient infrastructure coupling, and weak identity and auditability practices. This guide provides a layered reference model to separate these concerns and evaluate interoperability beyond vendor claims and interface checklists.

The framework distinguishes three complementary layers: **syntactic** interoperability (reliable data exchange), **semantic** interoperability (shared meaning of state, intent and environment), and **operative** interoperability (coordinated behaviour in shared physical spaces). Building on this model, the guide maps the functional roles of widely used interoperability standards and clarifies why no single standard dominates the ecosystem.

The guide further explains middleware as an abstraction and integration layer, including simulation practices that reduce integration risk before deployment. Finally, it addresses brownfield realities and security as structural preconditions: interoperability increases connectivity, which expands the trust surface and requires explicit identity, scoped access and operational auditability.

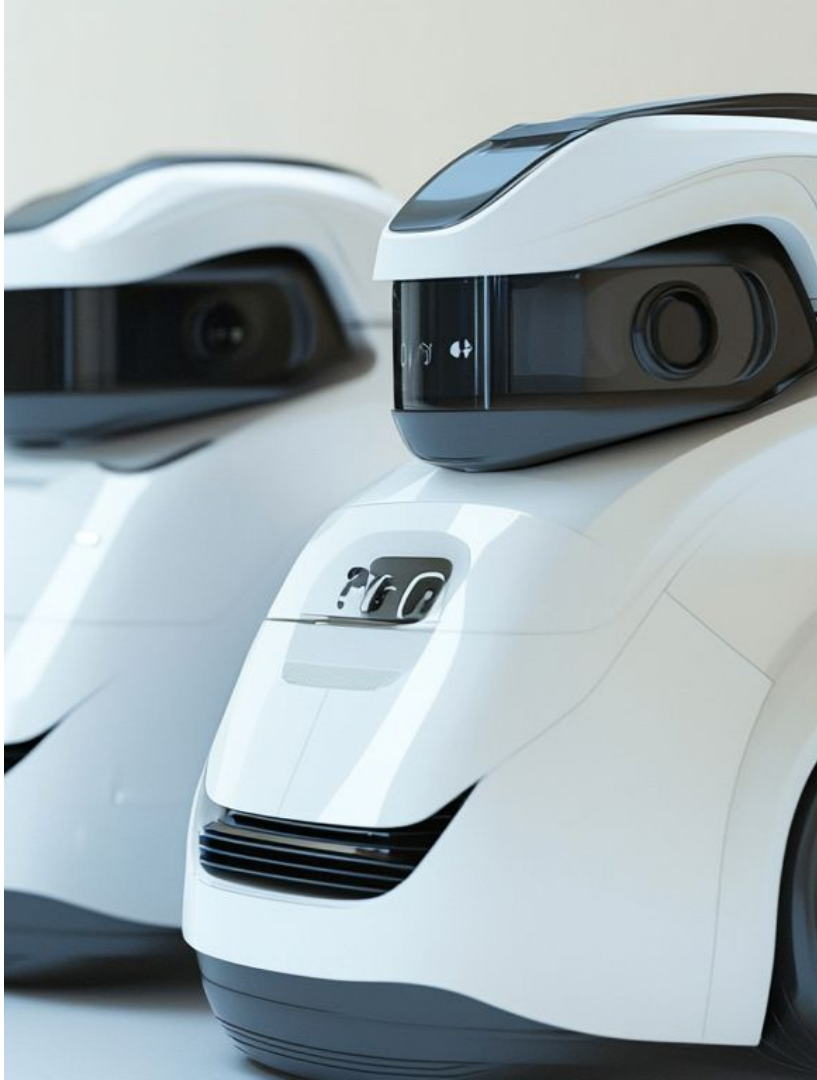
This publication provides contextual and architectural orientation only. It does not define standards, certify systems, recommend vendors, or provide compliance guidance.

03 | **From Pilots to Systemic Infrastructure**

Isolated pilots optimise for feasibility: one robot type, one workflow, limited environmental complexity. Operational infrastructure optimises for continuity: multiple robot types, shared spaces, mixed building systems and lifecycle control. The transition introduces integration constraints that cannot be solved at the robot level alone.

At scale, integration itself becomes critical infrastructure. Systemic integration determines whether autonomous systems remain isolated tools or evolve into operational foundations that organisations can rely on.

Key shift: integration is no longer a technical subtask — it is the scaling condition.



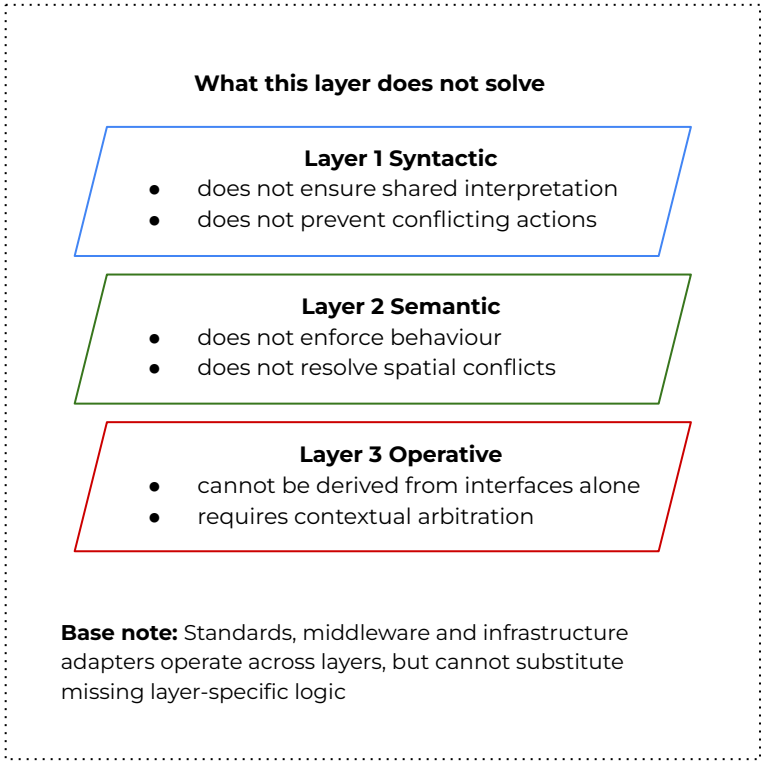
04 | **Why Interoperability Breaks When Layers Are Confused**

Interoperability in service robotics fails when distinct integration problems are treated as one. Progress on one layer does not compensate for gaps in the others.

Syntactic interoperability
Data exchange

Semantic interoperability
Shared state & intent meaning

Operative interoperability
Coordination in shared physical spaces



05 | **Layer 1: Syntactic Interoperability**

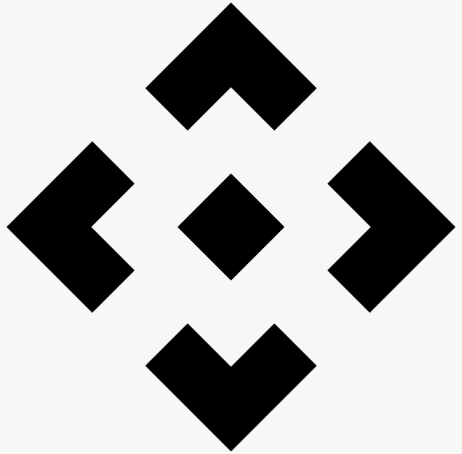
Definition: the ability to exchange data via standardised interfaces and protocols

Enables

- connectivity between robots, orchestrators and monitoring tools
- status transmission, telemetry, event reporting
- external access via documented APIs

Does not guarantee

- shared meaning of “state”, “error”, “intent”
- comparable metrics across vendors
- coordinated behaviour in shared environments

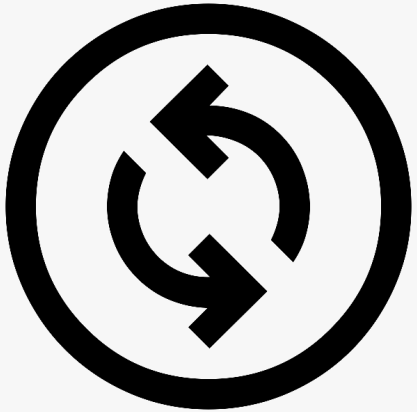


06 | **Layer 2: Semantic Interoperability**

Semantic interoperability determines whether different systems interpret exchanged data in the same operational way. It requires aligned state models and shared representations of intent and environment.

Operational distinction: “obstacle” may represent a static object, a human, a dynamic restriction zone or a transient sensor artefact. Without semantic alignment, identical terms produce incompatible behaviours.

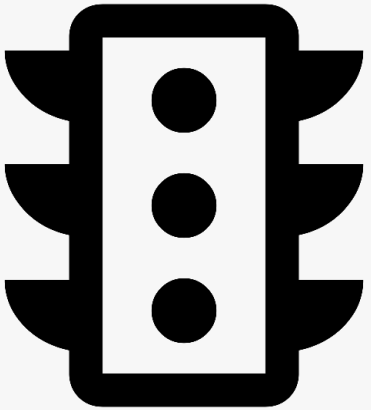
Core point: semantic alignment enables awareness and comparability, but it does not enforce coordination.



07 | **Layer 3: Operative Interoperability**

Operative interoperability concerns coordinated behaviour in shared spaces: bottlenecks, intersections, shared corridors, elevators, doors, safety zones. It is context-dependent because coordination must reflect physical layout, safety constraints, human presence and infrastructure logic.

Core point: operative interoperability cannot be solved by data exchange alone; it requires arbitration, scheduling and enforceable behavioural rules.



08 | **Standards Landscape 2026**

No single standard covers all interoperability layers. Instead, a complementary ecosystem has emerged, addressing different integration problems.

Non-exhaustive functional role map (2026)

- **VDA 5050** — interface between master control and vehicles for mission coordination; current release: **v2.1.0 (Jan 2025).** (VDA)
- **MassRobotics AMR Interoperability** — vendor-neutral status/awareness exchange; documented “Version 2.0”. (MassRobotics)
- **Open-RMF** — multi-fleet interoperability with building infrastructure such as doors and elevators. (Open-RMF)
- **OPC UA Robotics (Companion Specification)** — information models for manufacturer-independent access and diagnostics; Companion Spec structure is published by OPC Foundation/VDMA. (OPC Foundation)

Analyst note: control-oriented interfaces optimise execution, awareness-oriented interfaces optimise shared visibility. Scaling commonly relies on layered combinations rather than a single standard.

The term ‘Physical AI’ (often used interchangeably with ‘Embodied AI’) refers to systems that perceive, reason and act in the physical world through sensors, control and embodied systems such as robots and autonomous machines. In this context, interoperability and middleware become scaling conditions: they translate heterogeneous robots, infrastructure and operational constraints into integrated operational infrastructure.

09 | **Standards and Frameworks — Indicative Scope Across Interoperability Layers (2026)**

Standard / Framework	Syntactic	Semantic	Operative	Infrastructure coupling (non-robotic systems)
VDA 5050	■	◐	■	—
MassRobotics AMR Interoperability	■	■	—	—
Open-RMF	◐	◐	■	■
OPC UA Robotics	■	■	—	—

Legend
■ in scope ◐ partial — out of scope

Notes
Documented scope only. Infrastructure coupling denotes integration with non-robotic physical systems and does not constitute an additional interoperability layer.

10 | **Middleware, Brownfield, Security**

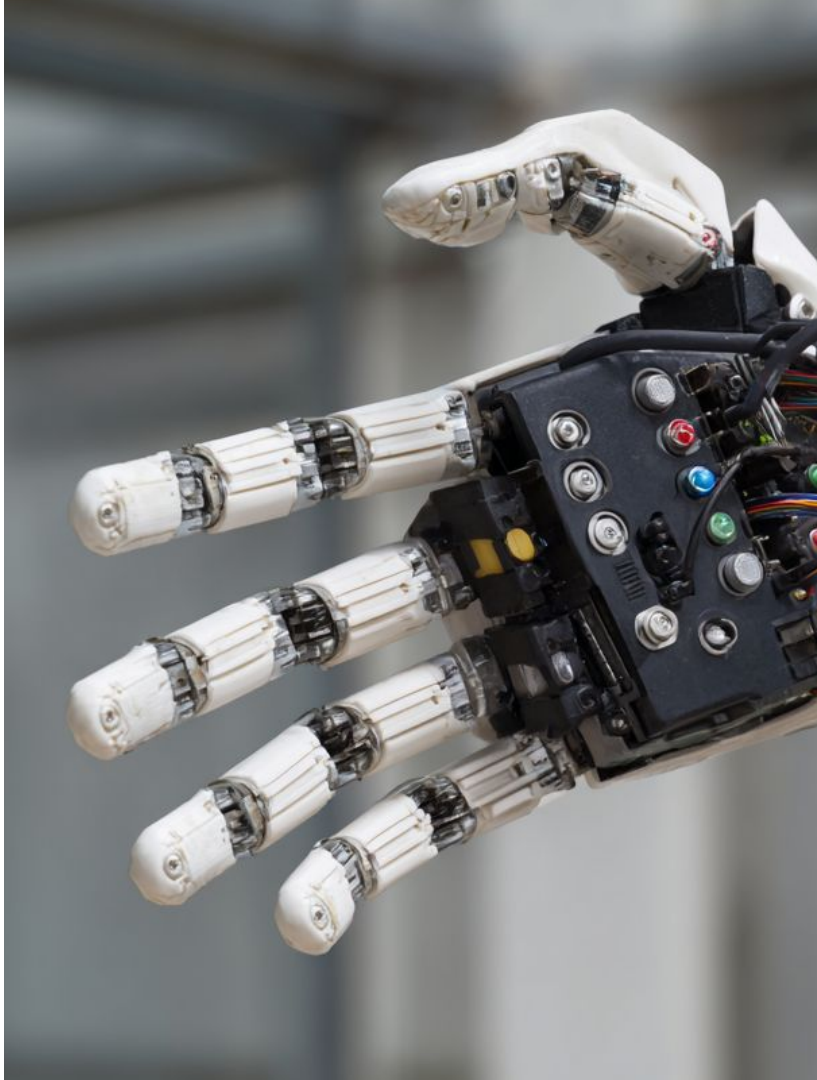
Middleware as abstraction: decouples fleet logic from robot-specific implementations, reduces point-to-point integration fragility and supports heterogeneous fleet evolution.

Simulation / digital twins: used to test compatibility, traffic logic and infrastructure coupling before deployment.

Brownfield reality: legacy robots often require wrappers/gateways/retrofits, creating operational debt and integration complexity.

Security interoperability: interoperability expands the trust surface; identity, scoped access and auditability become structural requirements, not add-ons.

Mini-line: interoperability without security is structurally unstable.



11 | **Decision Checklist + Publishing Note**

Decision checklist (2026)

- Does the robot provide an open, documented interface (e.g., REST, MQTT, equivalent)?
- Which interoperability layer is actually covered (syntactic / semantic / operative)?
- How is infrastructure coupling handled (doors, elevators, safety systems, access control)?
- Can the robot communicate intent to other systems (yielding, turning, waiting)?
- Are identity, access scopes and credentials lifecycle-managed?
- Are logs/audit trails available and semantically consistent across vendors?
- What is the brownfield plan for legacy robots and non-upgradable components?

Publishing note: Versioned reference (v1.0). Revisions reflect ecosystem evolution and clarification, not normative change.
Architectural scope note: This guide deliberately operates at an architectural level, abstracting from individual sectors or use cases in order to remain applicable across domains such as healthcare, logistics, facilities and industrial services.
Published at: https://www.servicerobot.com/papers/robot-interoperability-2026/
Companion repository: https://github.com/robotic-infrastructure/robot-interoperability.git
Disclaimer: Contextual orientation only. No legal, regulatory, security or compliance guidance.