Introduction to Spatial Web Protocol, Architecture & Governance
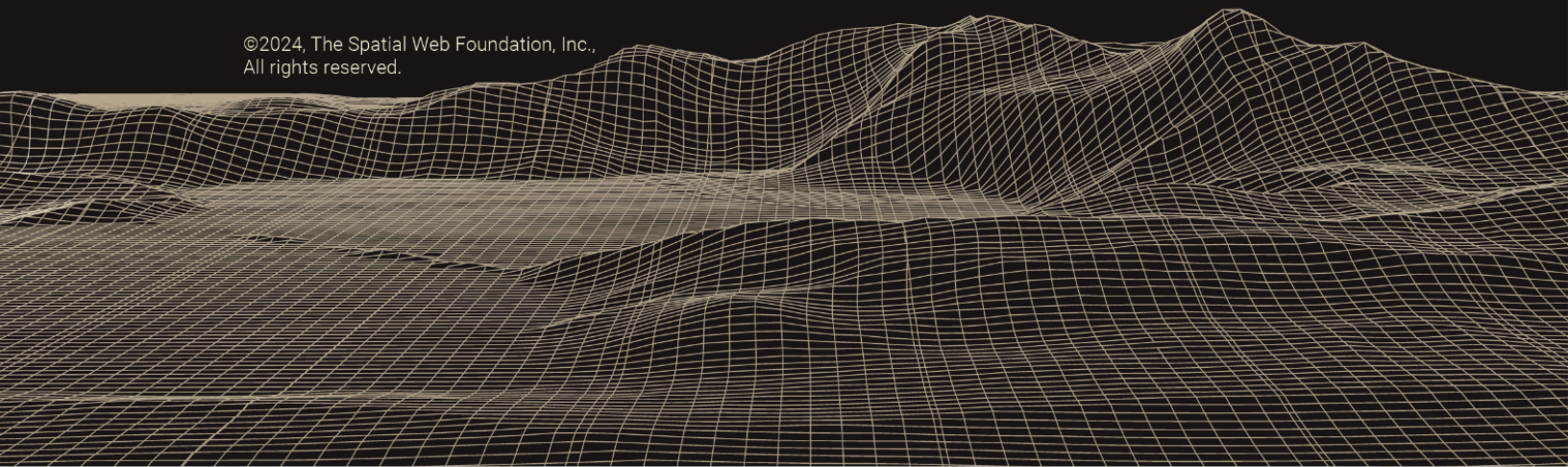
The Spatial Web Foundation

June 2024

The Spatial Web

The Spatial Web merges the physical and virtual worlds, transcending geographic and national boundaries to create a global commons for expression and imagination. This convergence, enabled by decentralizing technologies, artificial intelligence, autonomous vehicles, robots, and the Internet of Things, heralds a new era of interconnectedness. The Spatial Web is built on the foundations of the Internet. The Spatial Web, including the Hyperspatial Modeling Language (HSML) and the Hyperspatial Transaction Protocol (HSTP), creates a seamless digital-physical reality, leveraging augmented and virtual reality and integrating shared values such as privacy, data ownership, and autonomy by design. The Spatial Web is an ecosystem of interoperable, autonomous AI agents based on open standards including HSML and HSTP.

This document is an introduction to The Spatial Web Protocol, Architecture and Governance specification, version D3.1, which defines requirements for the interoperability and governance of cyber-physical systems at a global scale, including autonomous devices, applications, spatial content, and operations. The full specification is developed by the Spatial Web Foundation and the IEEE P2874 Spatial Web, Architecture and Governance Working Group.

In order to highlight foundational concepts of the Spatial Web — ENTITY, ACTIVITY, AGENT, CONTRACT, CHANNEL, CREDENTIAL, DOMAIN, HYPERSPACE, and TIME— are represented in this document using uppercase.

> ## The Spatial Web: agents in a cyber-physical ecosystem
>
> **Intelligent AGENTS with CREDENTIALS,**
>
> **performing ACTIVITIES discussed in CHANNELS,**
>
> **on and in DOMAINS represented in HYPERSPACES,**
>
> **fulfilling CONTRACTS with other AGENTS.**

Contents

1 Spatial Web concept

The Spatial Web Protocol, Architecture and Governance specification defines the Spatial Web system design by specifying requirements for interoperability and governance of cyber-physical systems at global scale, including autonomous devices, applications, spatial content and operations. Networked communications systems constructed to meet these requirements enable representation of all statements and interactions of the physically oriented, socially-constructed world to be universally represented in a way that makes them amenable to computational modeling and, where applicable, simulation and automation.

The system design includes:
● a shared and linkable knowledge domain architecture ("Architecture"),
● a common language with which to describe domain elements and their interrelationships,
● a method for querying and updating the states of those elements ("Protocol"), and
● the ability to allow access and control of that method ("Governance").

Collectively these elements are the Spatial Web Standards.

The present specification is comprehensive, encompassing an entire, emerging ecosystem and reflecting trends and needs that drive its development, including but not limited to:
● the increasingly graph-like nature of global data,
● the opportunity autonomic activities using context-aware, cognitive AI,
● the need for composable systems and applications including the governance of such systems,
● the intrinsic need for secure transactions,
● the rise of machine learning and neural network computation and edge computing,
● the need for explainable AI and robotic governance, and
● the rise of Digital Twins, IoT and sensor meshes.

For further background on these emerging ecosystems and trends, see The Spatial Web [B114].

The Spatial Web is a socio-technical system of systems. The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems [B118] identifies the need for early incorporation of socio-technical standards as crucial for aligning AIS with human values, intentions, and understanding, and for reducing the risk of behaviors understood by stakeholders to be undesirable. As a socio-technical standard, the provisions of the specification define a Spatial Web governance framework.

The Spatial Web specification provides a reference model composed of three viewpoints: 1) Value for stakeholders, 2) Knowledge model, and 3) Distributed computing. The viewpoints include requirements on components of the Spatial Web system. The concepts and requirements of the reference model guide subsequent development of Spatial Web Implementation standards and domain-specific Spatial Web architectures.

The Spatial Web specification applies an architectural design approach to the Spatial Web System (Figure 1). Requirements are identified by examining stakeholder perspectives and application scenarios. As a result of design synthesis, architecture components are identified as:

- Hyperspatial Modeling Language (HSML),
- Hyperspatial Transaction Protocol (HSTP),
- Universal Domain Graph (UDG),
- Spatial Web Governance,
- Domain-specific Architectures, and
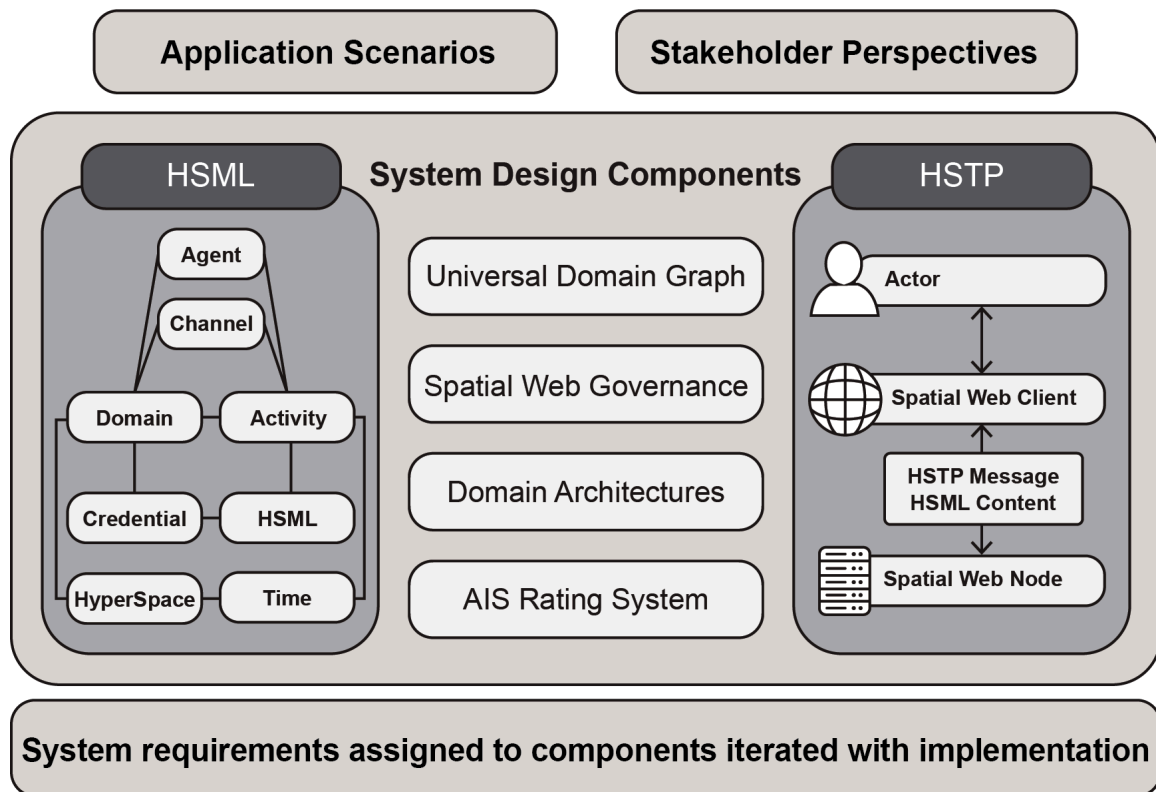- Autonomous Intelligent Systems (AIS) Rating System.

Figure 1 — System engineering of the Spatial Web

Requirements listed in various clauses of the Spatial Web Specification are assigned to the architectural components, e.g., HSML, HSTP, etc.. A summary of requirements for each component is provided in an Annex of the Standard.

2 Value for stakeholders

2.1 Guiding principles

The Spatial Web is guided by these principles:

Table 1 — Guiding Principles

Spatiality	Representing information as locations and relations in hyperspace with well-defined metrics enables cognitive computing to be performed based on context.
Ownership	Users can own their data and digital property and choose with whom they share this data. Moreover, they can retain control of it when they leave a given service provider.
Security	Secure data collection, transmission, and storage enables interactions and transactions with virtual and physical assets between any user within and across any space — physical or virtual.
Privacy	Individual control, trust, and security utilizing cryptographically secured and decentrally-stored digital identity enables "trustless" complete interactions and transactions with anonymity and auditability.
Trust	Trust is based on reliable real-time, permission-driven validation of all users, assets, and spaces and their interactions with certifiable and verifiable records that validate various proofs of ownership, activity, traceability, and rights.
Interoperability	Searchability, viewability, interaction, transaction, and transportation of asset or user within or across any spaces. Seamless user navigation and asset transfer within and between spaces across devices, operating systems, and locations.
Responsibility	Creating technology in a manner guided by upholding ethical principles of inclusivity, transparency, and cooperation to create a better world for all humanity.
Governance	Governance is facilitated by the nested structure of domains; Domain Authorities which define norms and laws for a domain; and clearly communicated contracts.

2.2 Stakeholder perspectives

Stakeholders are parties with direct or indirect interests in the Spatial Web. Stakeholder interests in the Spatial Web include matters of relevance or importance to stakeholders. Stakeholder interests include items of concern to the public at large as well as the interests of organization. Stakeholder perspectives identify requirements for the Spatial Web.

These stakeholder perspectives are addressed in the specification:
- Societal Scope
  - Enterprise, community, humanity
- Information Technology
  - Immersive shared experiences; Representation of physical entities
- Geography of Hyperspace
  - 1st law of geography: near things are more related than far things.
- Multi-scale cognitive computing
  - Ecosystems of intelligence
- Polycentric Governance
  - Self-sovereign humans; Multiple overlapping polycentric nodes

2.3 Application scenarios

Functional requirements for the Spatial Web are defined by the scenarios listed in Table 1. Scenarios provide the motivation for elements in other clauses of the standard, e.g., conceptual model elements. Table 2 is organized by spatial extent and societal extent. Each scenario is described in the standard as a set of steps and a diagram.

Table 2 — Summary listing of scenarios

	Enterprise	**Community**	**Humanity**
Indoor	Warehouse Robot Industrial XR		
Urban		Cultural location tourism Urban autonomous mobility	Urban digital twin/Smart City
Global		Global supply chain	Digital earth: Greenhouse Gasses Entertainment XR

Figure 2 shows an example scenario diagram for the Warehouse robot scenario. The scenario involves an employee and a robot working together to retrieve a book from an automated warehouse bin and packing it for shipping. The steps in the scenario include Spatial Web Entities in all caps. Each step in the scenario is implemented by a Distributed computing use case.
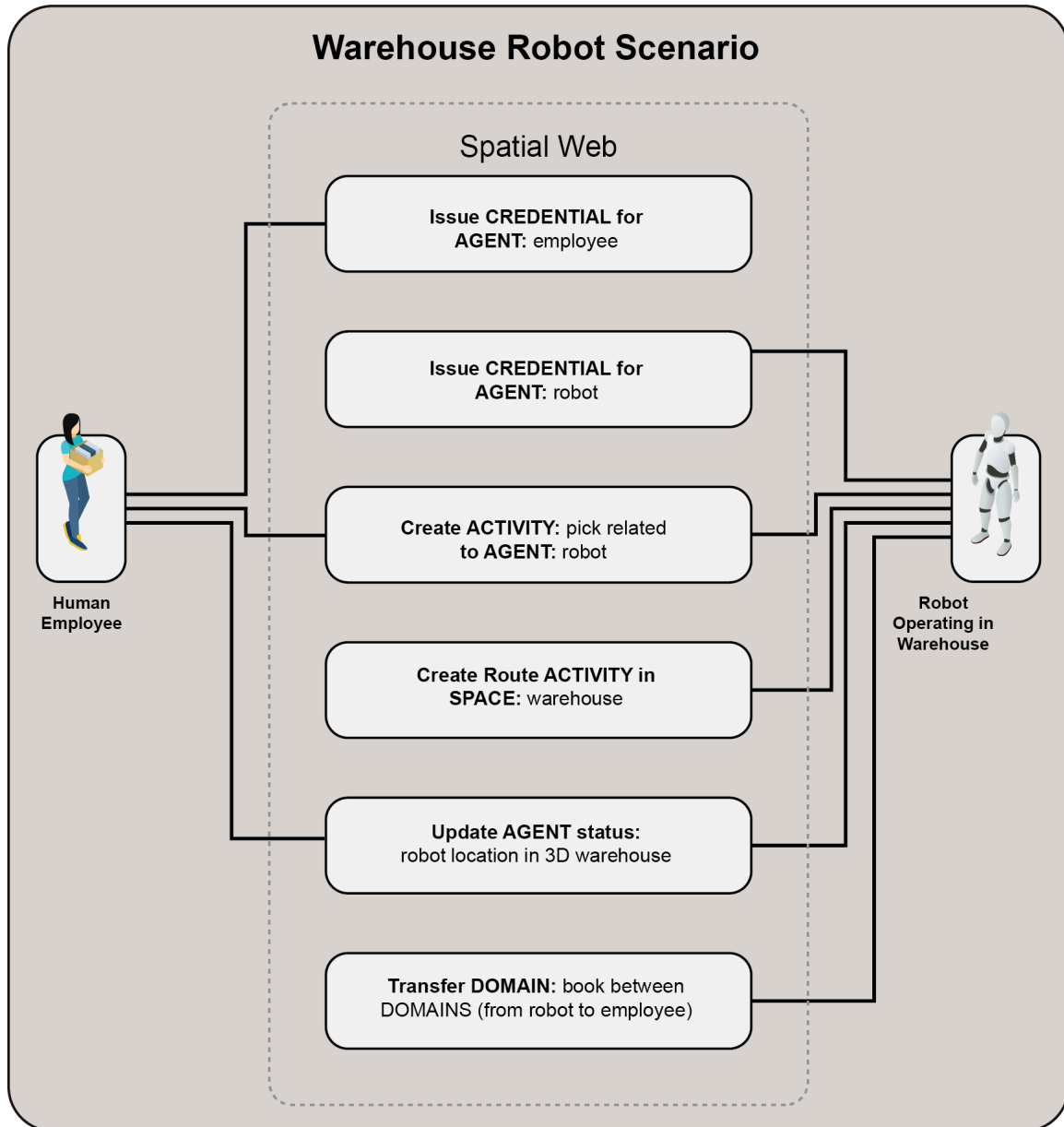

Figure 2 − Warehouse robot application scenario

Figure 3 shows the scenario of applying Urban Digital Twin (UDTs) to Smart Cities. This scenario shows how the Spatial Web provides interoperability of UDTs and AI agents to address urban sustainability with a focus on energy. Energy system modeling informs action plans developed in the Spatial Web multi-scale cognitive computing ecosystem to benefit next generation cities. The Digital Twin Domains in this scenario - both geographic and energy grid UDTs - are detailed in Domains and identities clause of the full specification. Each step in the scenario is implemented by a Distributed computing use case.
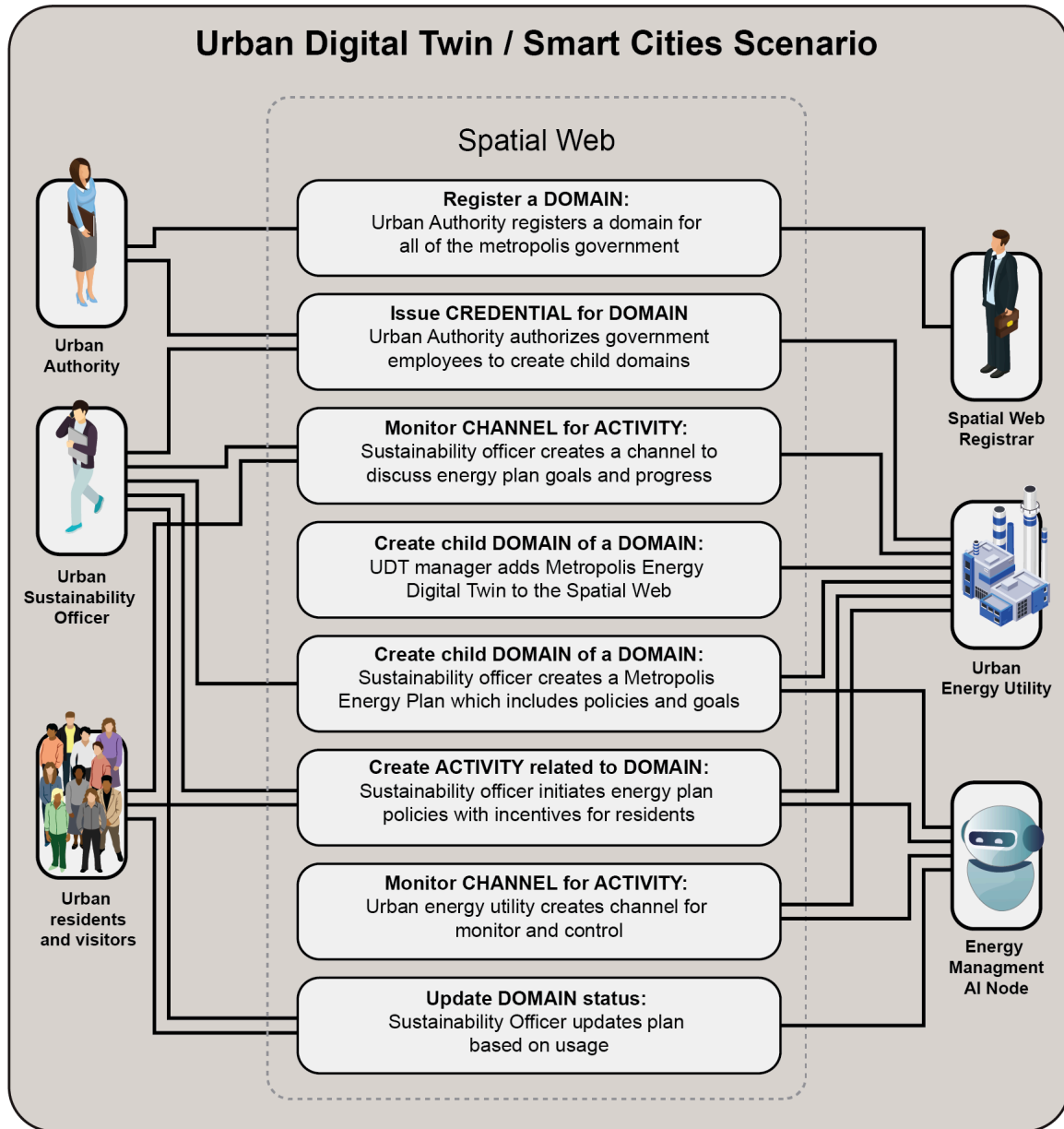

Figure 3 – Urban digital twin / Smart city scenario

3 Knowledge model

A knowledge model is an abstract description of a system using concepts and ideas. The model represents the conceptual entities that define the system and the relationships between the entities. Figure 4 provides an overview of the Knowledge Model as described in the following clauses.
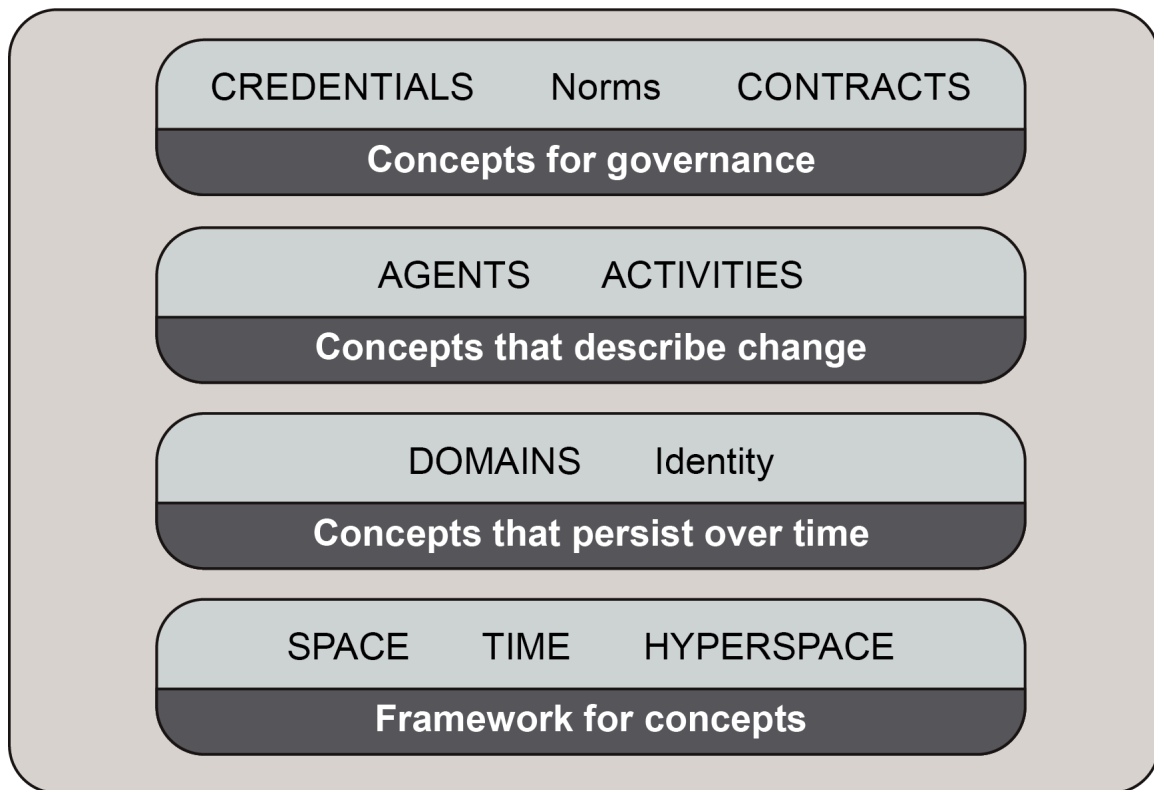

Figure 4—Knowledge model overview.

3.1 Space, time, and hyperspace

The term 'hyperspace' is used to capture a generalized concept of *space*, in an acknowledgment that not only do Euclidean and geographic spaces have spatial structure, but also many other, more abstract data types. These spaces and types can be combined to form complex spaces that can be navigated. The concept of hyperspace is derived from category theory, from which it inherits its compositionality, and is fundamental for the Spatial Web. Figure 5 provides a summary of the various classes of hyperspace.
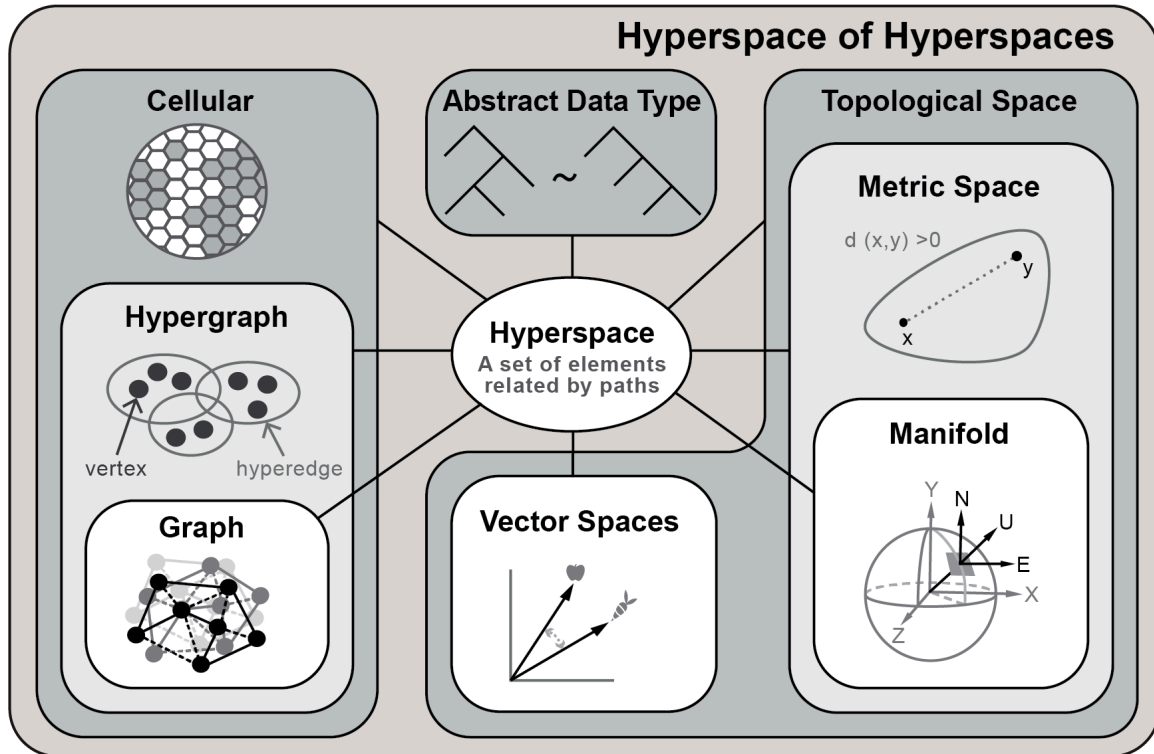
Figure 5 —Basic classes of hyperspace.

3.2 Domains and identities

Typical types of Spatial Web Domains are shown in Table 3. Domains may encompass more than one type. Domains may exist for variable lengths of time. In addition to permissions, Domains include information about each entity's temporality and roles, functions assumed, or parts played by the entity or thing in a particular place and time, and information regarding the provenance and material composition of the entity.

Table 3 — Domain types based on their defining characteristics.

Type of Domain	Description
Geographic	Implicitly or explicitly associated with a location
Concept	Intangible concepts and abstract ideas shared by a community of users
Organization	Pertaining to membership within an entity
Agent	Individual domains with active states and agency
Person	Special subtype of agent maintaining a self-sovereign identity
Thing	Bounded items without agency

Every Spatial Web entity, including Domains, shall include a Spatial Web Identifier (SWID) using W3C did-core. Spatial Web entities are registered and linked in the Universal Domain Graph (UDG). The Spatial Web provides a registration capability as a system of distributed, decentralized registries. The Spatial Web Foundation, on behalf of the public, shall be the Registration Authority governing general rules for changes to the UDG, such as Domain Authority, allowable Domain names, Domain claim dispute resolution, cost of registration, and restrictions on the addition or deletion of names.

There shall be a Domain Authority for every Spatial Web Domain. The Domain Authority shall be an entity that is credentialed to define within a Domain the norms and terms under which contracts are created for: agents, actions and credentials within that Domain.

Spatial Web Domains can be geopolitical (e.g., Earth, countries), authority-driven (e.g., BigCo, SpatialWebFoundation) or IP work-related (e.g., ArthurianWorld). A given Spatial Web Domain identifier can have multiple associated qualified names. Authoritative credentialed domains can be issued with unique relationships defined in SPACEs (.Earth).

The Spatial Web enables the capability for all human persons to receive without cost an irrevocable and non-transferable individual Spatial Web Domain, with respect to which that individual will, upon acceptance, be registered as a Domain Authority at no cost (where the exercise of such authority may be subject to limits imposed by relationships to other authorities, e.g. citizenship).

The Spatial Web shall be a Global Commons network of networks; a portion of spaces registered in the UDG shall be gateways to private networks managed by network administrators. The UDG shall be a publicly accessible knowledge graph that serves as a key infrastructure component of the Spatial Web. The UDG shall be similar to existing knowledge bases held within current web platforms but shall be a public utility compared to proprietary platform knowledge. The UDG is a hypergraph containing relationships between all known SWIDs in the Spatial Web. The UDG is composed of nodes and links where the nodes are ENTITIES, and the links are relations between the ENTITIES. Figure 6 shows a notional visualization of the UDG with varying cluster patterns of the nodes. Based on current large knowledge graphs and a DGGS of the Earth where every cell is a decimeter-scale node, the global UDG contains approximately 10^{14} nodes.
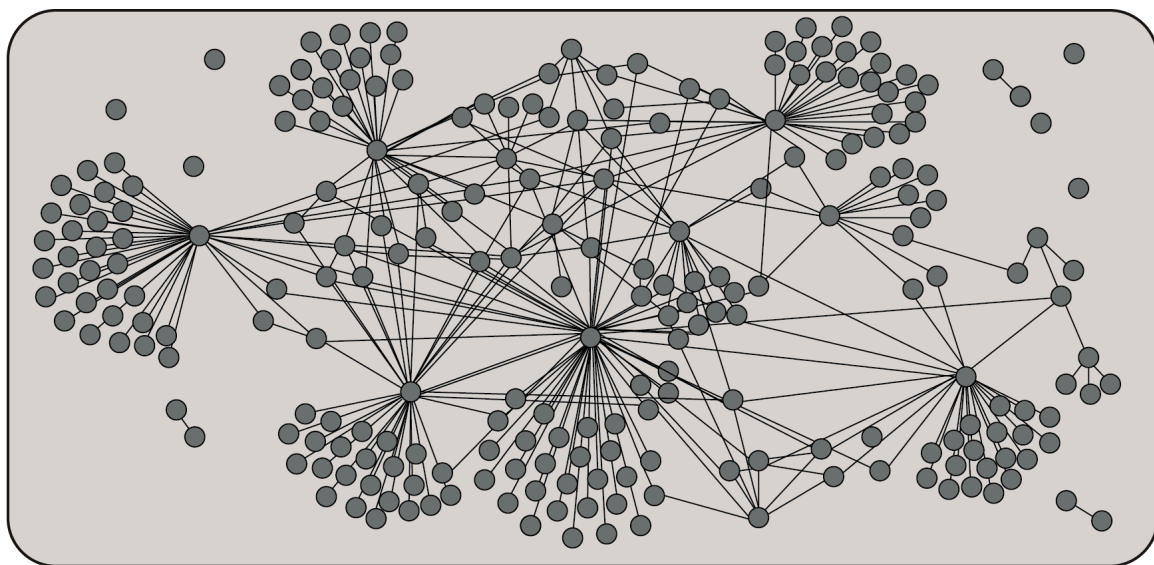

Figure 6 — Notional structure of the UDG.

3.3 Agents and activities

Spatial Web Agents

An Agent is a Domain that senses and responds to its environment, maintains a model of its environment, and takes actions to achieve its goals (Figure 7). An Agent type of Domain is characterized by its capacity for agency. It engages in Activities, which are actions aimed at effecting changes in its environment (from ISO/IEC 22989). An Agent may include natural intelligence or artificial intelligence.
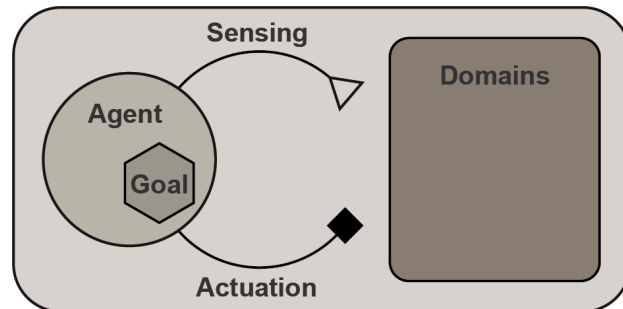

Figure 7 — Agent-based paradigm

Agents can be both digital, such as software applications or AI systems, and cyber-physical, like robots or autonomous vehicles. Their core functionalities include sensing and perceiving the environment, which are vital for gathering data, formulating plans, and making informed decisions to execute goal-directed actions. Physical or digital actuation capabilities enable Agents to implement changes within their environment and interact with other Entities, including other IoT devices, services, digital interfaces, and other Agents. Their functionality extends to simulating real-world scenarios, modeling spatial interactions, manipulating virtual or physical constructs, and facilitating user interactions by providing guidance, information, or immersive experiences.

Agents exhibit a spectrum of behaviors that reflect their varying levels of intelligence, from simple reactive response to complex, goal-oriented actions and sophisticated social interactions. The capacity for enacting autonomous, goal-oriented behavior underpins the functionality, interoperability, adaptability, and realization of shared intelligence within the Spatial Web (Friston, et.al. [B22]).   The Autonomous Intelligent Systems (AIS) Rating System provides a standardized mechanism for evaluating and identifying the various capabilities of autonomous intelligent Agents. This system establishes a flexible and structured framework, enabling developers, policymakers, and other agents to effectively identify, interact with, and manage agent activities, serving as a key component of the Spatial Web governance framework.

HSML Activities

HSML Activities refer to the actions or sets of actions performed by Agents. Activities can range from simple tasks like retrieving information or updating a status, to complex operations involving multiple steps, decisions, and interactions with other Agents. Activities are essential for representing and translating Agents' objectives into concrete actions, facilitating their interaction with the environment, and coordination with other Agents. The HSML framework supports this relationship by offering a unified language and protocols for defining, instantiating, executing, and monitoring Agent Activities. This standardization is crucial for ensuring interoperability among diverse systems and Agents, ensuring that Agents can interact with and understand each other, as well as with the digital and physical environments they operate in.

3.4 Credentials, norms, and contracts

A Credential is a set of one or more claims made by a Domain. A Norm is a standard or principle of right action serving to guide, control, or regulate proper and acceptable behavior, which can be specified in terms of the conditions under which it is binding on agents' actions and the conditions under which such actions conform or fail to conform to it. A Contract is a binding agreement between two parties, especially enforceable by law, or a similar internal agreement wholly within an organization.

HSML Activities, as described in the previous clause, represent possible actions on the part of Agents operating on the Spatial Web, and are defined in terms of the conditions they aim to bring about, specified in terms of HSML data structures. Activity conditions can, for example, be represented as a query run against the HSML representation of a Domain, which evaluates to a Boolean indicating whether or not the Activity's defining conditions have been satisfied in the Domain model.

The execution of Spatial Web Activities within Domain(s) may also be subject to conditions imposed unilaterally, mutually agreed upon or negotiated between parties to a transaction. Examples include provisions in a contract for work or transfer of ownership, as well as Domain rules that actors within a Domain explicitly or implicitly agree to abide by, including laws and regulations issued by various authorities. These conditions can similarly be represented as expressions evaluable against the state of HSML Domain models.

HSML Contracts and Activities encode expectations about how certain entities will behave, conditional on specific assumptions encoded as Activity conditions (predicates). Activities encoding a machine-readable description of normative constraints on Agent behavior in an Activity's initial conditions and the consequences of conforming to or violating the rule in its resulting conditions can represent rules or other normative structures. Agents operating in a governed Domain may then assent to this form of governance by explicitly signing a Contract to participate in the enforcement Activity, or Domain-specific sub-types of Activities may be created based on such normative constraints, as described above. Where these constraints are applied, governance of Activities within relevant Domains is accomplished by granting Credentials for only those Activity types found consistent with Domain Authority rules.

Activities occurring within a Domain are subject to rules (more broadly, norms) enforced by relevant Domain Authorities, but this entails nothing about the legitimacy, in absolute terms, of the rules specified by such Authorities, or their claimed right to impose or enforce them. In particular, the authority of a Domain Authority over any Domain is limited by factors such as the existence of higher-level Domain Authorities in a Domain hierarchy, and by the self-sovereignty of some Domains, such as those representing individual human beings.

The Spatial Web Foundation takes no position on which norms enforced by Domain Authorities are binding on any given individual, organization, nation, etc., but allows participants in the Spatial Web to *represent their normative claims* by way of rules associated with credentialed Domain Authorities, as well as via Contracts. Some Domain Authorities in the Spatial Web will mirror relevant authorities in the real world (e.g. sovereign nations, which, like sovereign human individuals, have the right to control over the Spatial Web Domains representing their territories). The infrastructure of the Spatial Web is not designed to settle conflicts among Domain Authorities, but to represent such conflicts accurately in the form of competing claims, each with its provenance. Participation in a Domain (via the execution of Activities by a Spatial Web agent) may involve explicit consent to the terms governing that Domain, via HSML Contract.

3.5 Spatial Web ontology

The Spatial Web ontology is composed of Entities that are the primary concepts used across the Spatial Web and in HSML. HSML implements the Spatial Web ontology as a set of schemas that enable increased coherence across diverse datasets without sacrificing flexibility.

The Spatial Web ontology Figure 8 defines several classes. All classes are types of the Entity base class. The Spatial Web ontology builds upon several existing ontologies, i.e., IEEE 7007-2021 [B40], ISO/IEC 21838-1:2021 [B55], Suggested Upper Merged Ontology (SUMO). Available at: [B117], and Pease [B113].
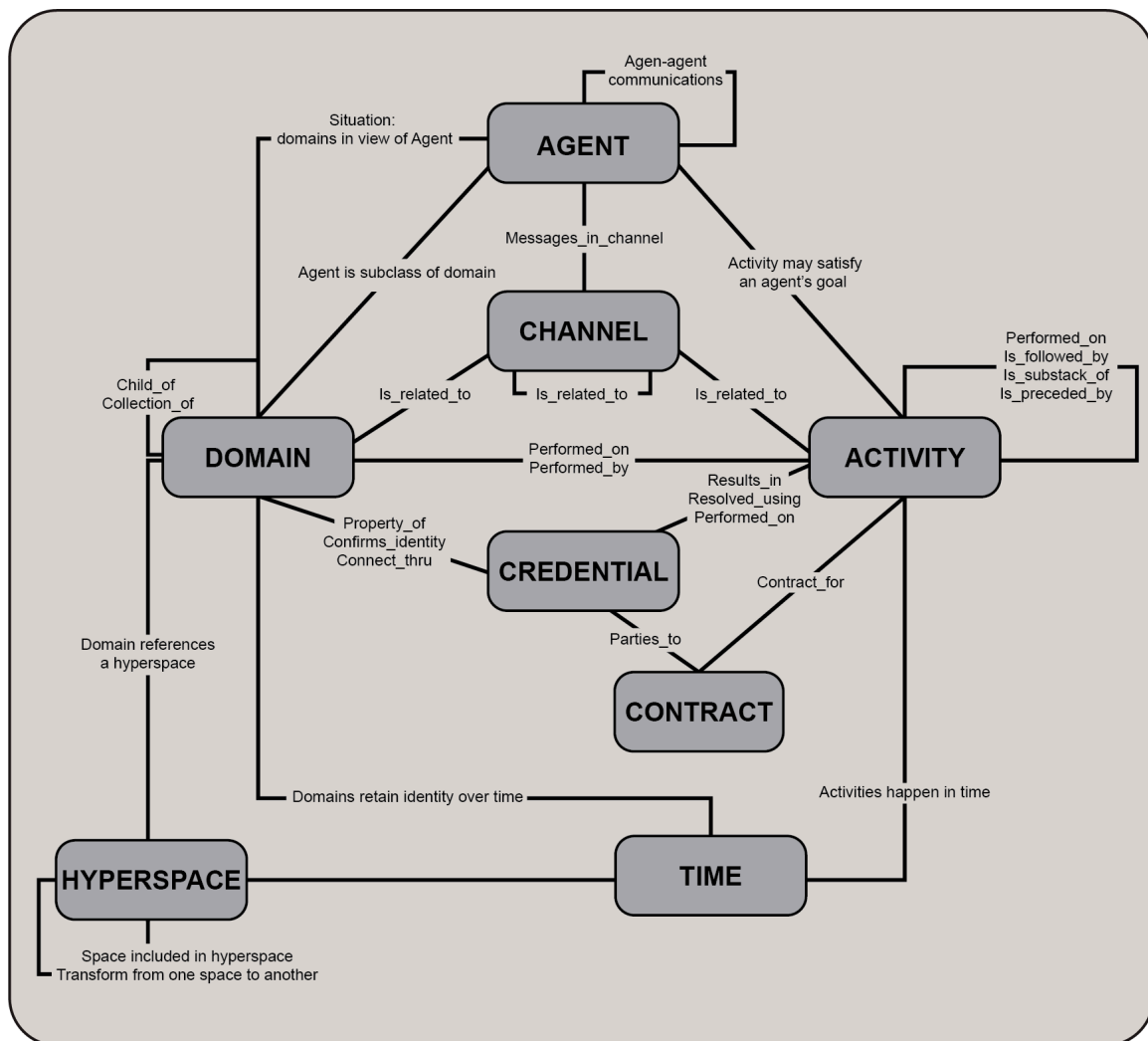

Figure 8 — Spatial Web entity relationship diagram.

Figure 9 depicts the core relationships that are obtained in the HSML ontology among (a) AGENTs, (b) ACTIVITY Schemas, (c) ACTIVITIES (aka ACTIVITY Instances), (d) CONTRACTS. A Requester is an AGENT requesting the performance of a task or other CONTRACT. The loop connection on ACTIVITY Schema represents the composition of Complex ACTIVITY Schemas.
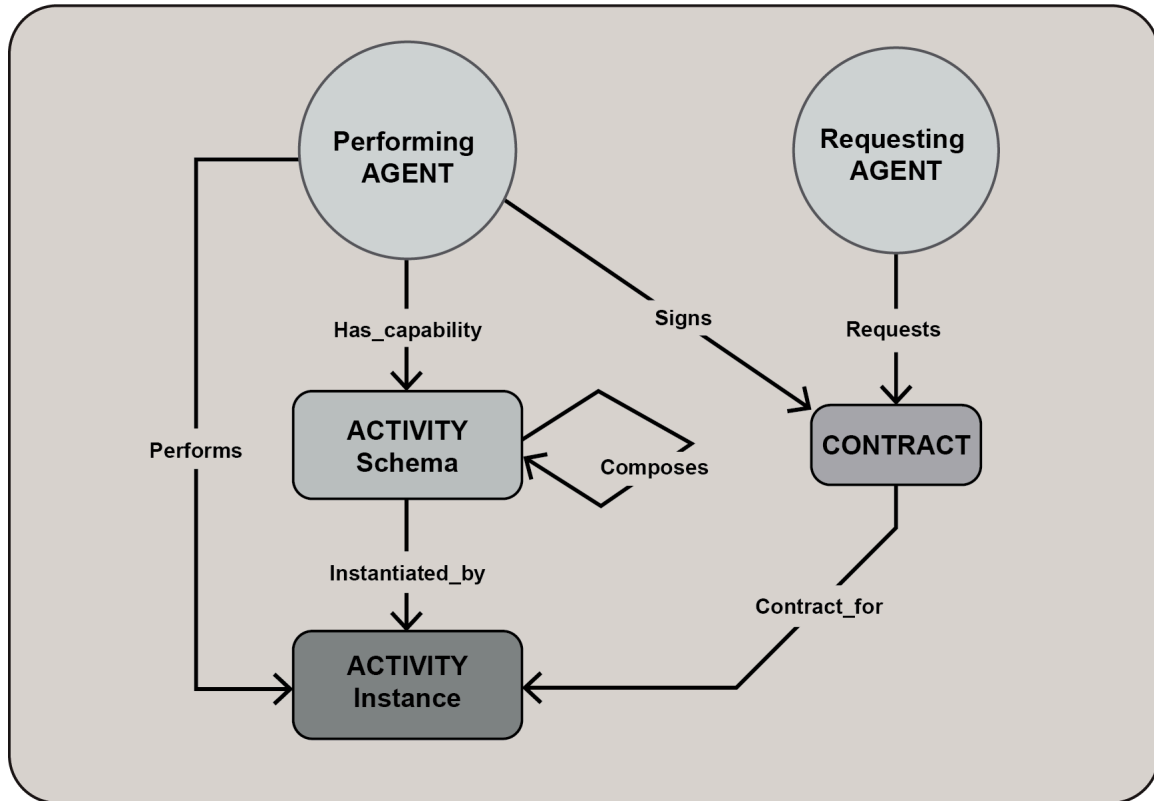

Figure 9 — Agent-Contract-Activity relationship diagram

3.6 Queries

Queries on the Spatial Web are expressed using HSML and are used to identify information about DOMAINS in the Universal Domain Graph. HSML enables a variety of query types, including but not limited to:

- Bootstrapping/Context queries
- Activity queries
- Hyperspace range queries
- Abstract data type query
- Graph queries
- Semantic queries
- Vector queries

4 Distributed computing

4.1 Distributed computing continuum

The Spatial Web is a distributed computing system with nodes connected by communications networks. Distributed computing is a model of computing in which a set of nodes coordinates its activities by means of digital messages passed between the nodes (Definition from ISO/IEC TR 23188:2020, 3.1.1 [B58]). The Spatial Web distributed computing model is organized as a set of tiers with each tier containing a set of nodes. Nodes within a tier are similar and may be close to each other in a network sense of close, e.g. enterprise nodes. The Spatial Web distributed computing model contains four tiers as shown in Figure 10.
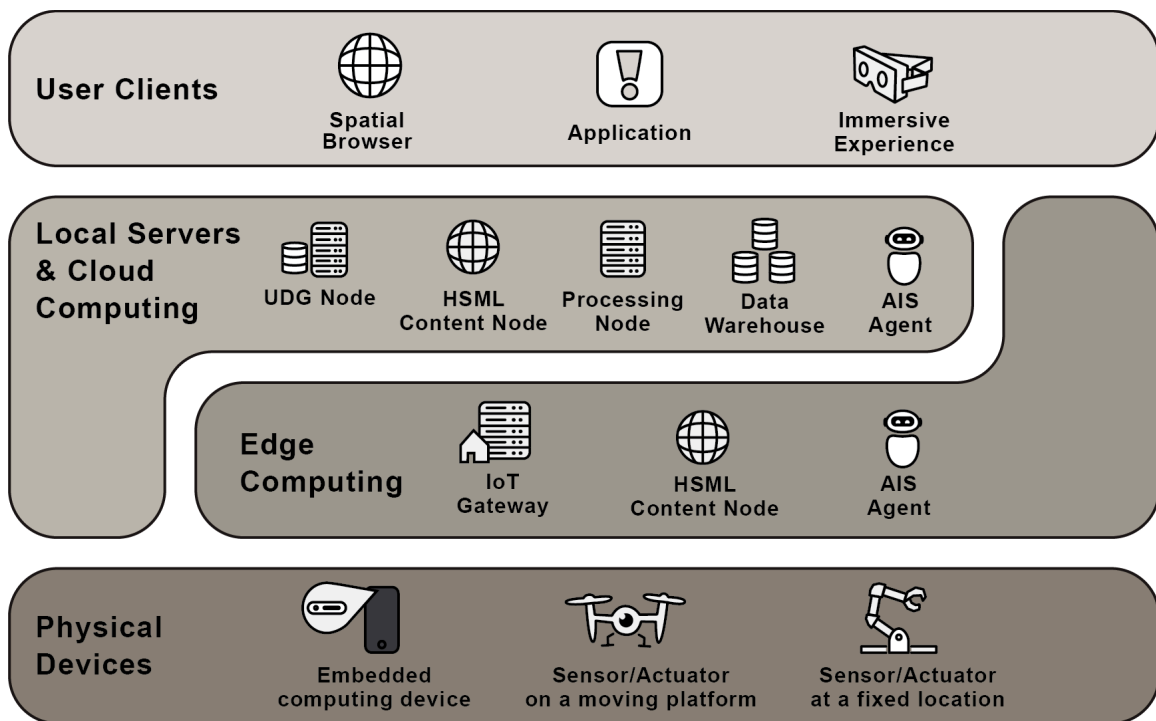

Figure 10 — Distributed computing continuum.

4.2 Distributed computing concerns

The Spatial Web distributed computing design complies with the concerns in Table 4.

Table 4 – Distributed computing concerns for the Spatial Web

Internet scale	The Spatial Web shall be inherently scalable from the simplest interoperation of two systems to the interoperability of a dynamic coalition of distributed, autonomous, and heterogeneous systems within a complex and global ecosystem containing millions of unique entities.
Interoperability and heterogeneity	The Spatial Web shall span over many existing heterogeneous systems with differing protocols, data types, and applications. The Spatial Web shall provide Interoperability which is the ability of two or more systems to exchange information and mutually use the information that has been exchanged.
Open standards	The Internet has succeeded because of its purposeful avoidance of any single controlling entity IETF RFC 9518 [B46]. Architectural design provided by open standards offers control over this sort of centralization, providing a balance of innovation and consolidation.
Deployment across continuum	Deployments of the Spatial Web shall take advantage of the features in the different layers of the continuum.
Mobility, automatic configuration	Nodes in the Spatial Web may be mobile and transiently connected to networks. The Spatial Web system supports discoverability and automatic configuration of Spatial Web nodes.
Real-time capability	The Spatial Web is designed to operate with communication network performance where bandwidth ranges from hundreds of gigabits per second to several terabits per second (i.e. having latency in the sub-millisecond range).
High latency / low connectivity network and device support	While the Spatial Web, and HSTP in particular, enables real-time capabilities, it also supports high latency / low connectivity networks. This support is implicit in the definitions of discovery and automatic configuration, but important to recognize in contrast to the real-time capabilities.
Location Awareness for nodes	For some Sensor Web nodes, application-level awareness of the node's physical location may be necessary. The Sensor Web enables application domains to enable location awareness.
Safety	Spatial Web implementations will need to consider reducing the risk of harm or damage to an acceptable level. When the Spatial Web is anticipated to operate in safety critical operations, additional analysis beyond that taken for the design of this Reference Model should be taken to ensure the risk is appropriate for the application.
Resilience	Resilience is the ability of a system to adapt and continue to perform their functions in the presence of faults and failures ISO/IEC 30141:2018 [B70]. The Spatial Web should be designed to be resilient to faults.
Zero-Trust Security	Spatial Web relies upon zero-trust security concepts. Zero Trust requires all users to be authenticated, authorized, and continuously validated for security configuration before being granted access to applications and data.

4.3 Spatial Web nodes

The Spatial Web is a set of distributed computing nodes with messages passing between the nodes. The specification defines these canonical nodes:

- Spatial Web client nodes
  - Spatial Web browser
  - Spatial Web application client
  - Immersive experience client
- Cloud nodes.
  - UDG node
  - HSML content node
  - Processing nodes
  - Data warehouse:large KBs, Digital Twins, Geo datastores
  - AI Agent
- Edge nodes.
  - IoT gateway
  - HSML content node
  - AI agent.
- Physical devices
  - Embedded node
  - Moving platform with sensors and actuator; Includes robots
  - Stationary platform with sensors and actuators;

4.4 HSTP operations

HSTP enables nodes to communicate to one another to execute functionality and share HSML data. HSTP is an application-layer protocol. A single request may generate multiple responses. A single specific response may require multiple collaborating requests. HSTP sends messages in the form of HSTP Operations, passed over a transport protocol. HSTP requests and responses are encoded using profile encoding formats defined by the HSML Implementation Specification. Figure 11 shows a simple exchange where one domain queries another regarding its capabilities.
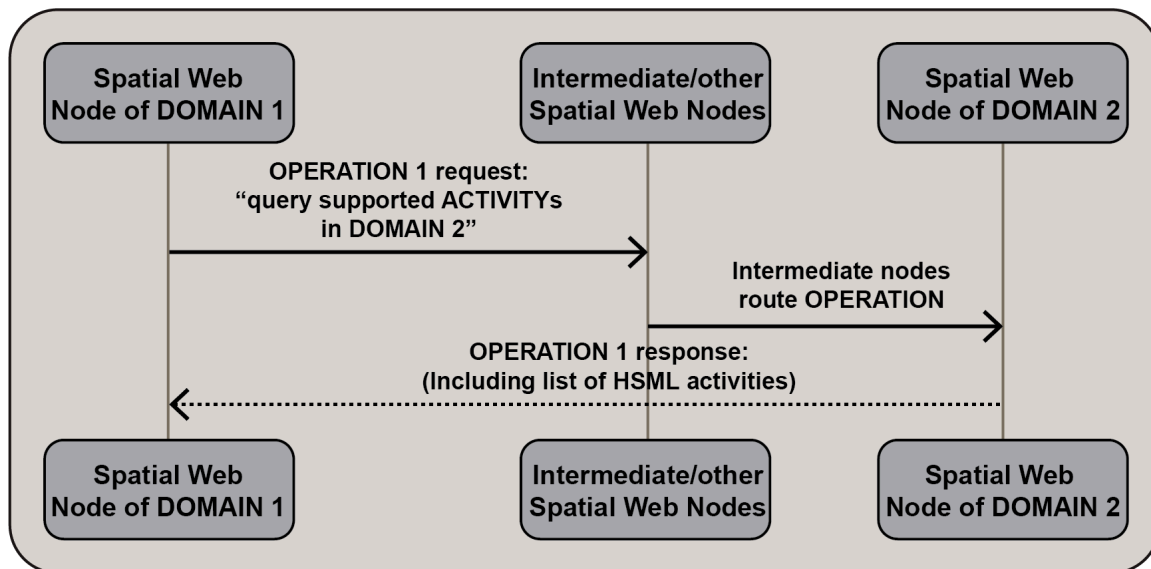

Figure 11 — HSTP operation example: simple lookup

4.5 HSTP protocol bindings

HSTP is a generic and generalizable protocol designed to enable the standardized communication between systems that are required to build a coherent, decentralized, secure, and privacy-respecting Spatial Web.

HSTP is designed to be consistent with multiple protocol bindings (Figure 12). These protocol bindings are used to facilitate communication and data transfer between systems in various contexts. HSTP provides a common semantic layer for each of these protocol bindings, enabling HSTP-compliant systems to communicate with one another regardless of the specific protocol binding being used. This allows HSTP to provide a consistent and standardized way of exchanging information and executing functionality across different types of systems and applications.
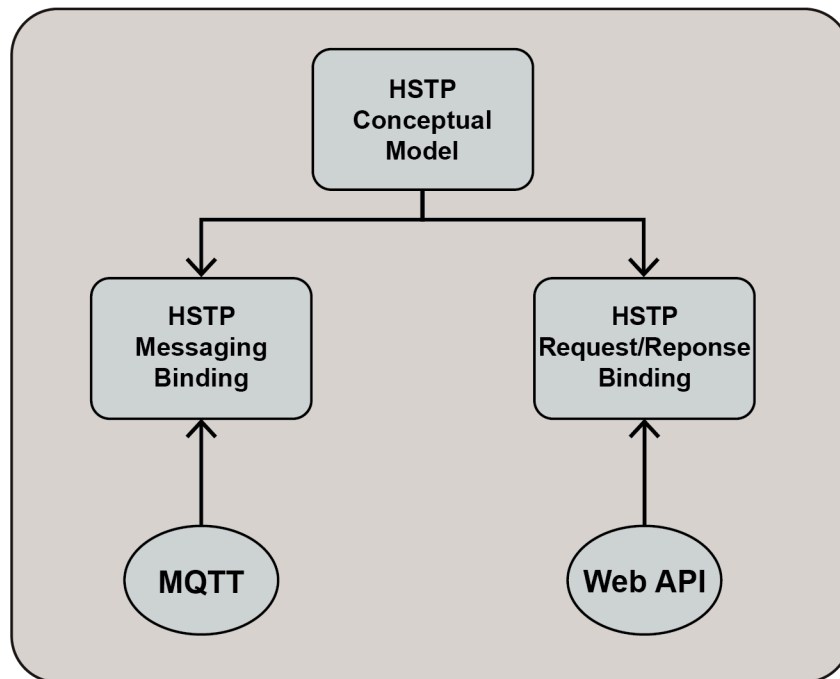

Figure 12 — HSTP bindings.

4.6 Distributed computing use cases

Use cases in this clause show exchanges of messages between the Spatial Web nodes listed in computing architectures and Spatial Web Nodes. The messages in the use cases make use of HSML and HSTP. Use cases are defined as generally as possible to allow a minimum number of use cases to achieve events in a diverse set of scenarios. Coherence of the Spatial Web architecture is demonstrated by the use cases satisfying the needs of the Application Scenarios. Each use case is defined using a sequence diagram. The sequence diagrams show dynamic behavior as interactions among distributed Spatial Web nodes via sequences of HSTP messages exchanged. A summary of the Spatial Web use cases is provided in Figure 13.
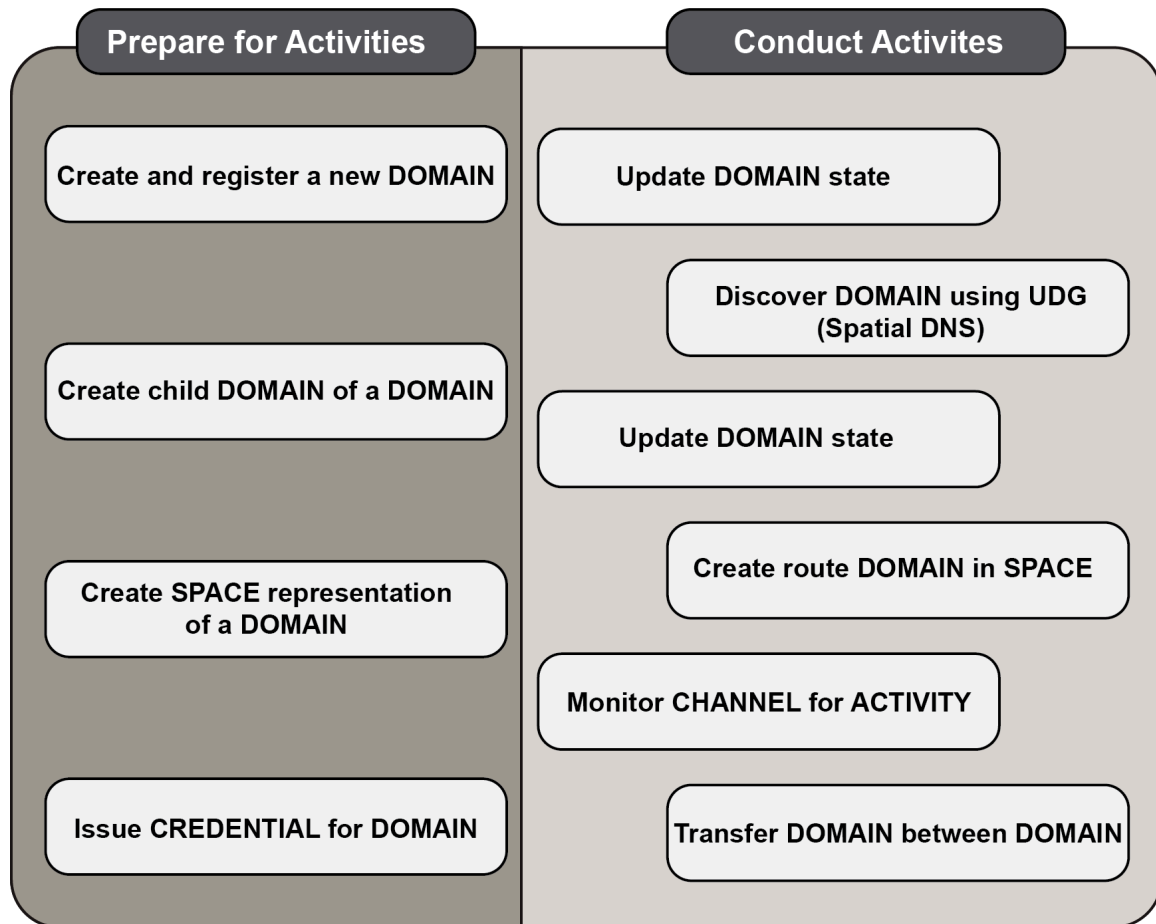

Figure 13 — Summary of distributed computing use cases

A use case diagram is provided in the specification for each use case. The use case diagrams show the sequence of messages exchanged between canonical nodes necessary to achieve the function identified for the use case.

5 Spatial Web development

The Spatial Web Protocol, Architecture and Governance specification defines a reference model for development of the Spatial Web. The specification was based in-part on early prototypes of HSML, HSTP and Spatial Web nodes. This iterative and coordinated development of specifications and implementations will continue for increasing maturity of the Spatial Web.

Development has begun of SWF Implementation Specifications for HSML, HSTP, UDG, and AIS Rating System. Development of Spatial Web Governance and Domain-specific Architectures will quickly follow. SWF Implementation Specifications provide sufficient detail to allow a developer to implement the specification and verify compliance to the specification. SWF Implementation Specifications fulfill requirements listed in the Spatial Web Protocol, Architecture and Governance specification. SWF Implementation Specifications will be developed in unison with implementation of Spatial Web nodes.

The Spatial Web Foundation fosters implementation to increase the functionality of the emerging Spatial Web. SWF interoperability sprints are key to synchronization of independent code developments with development of the implementation specifications. Running code is essential evidence that the specifications are ready for adoption as consensus standards. Sprints will initially focus on simple use cases. Subsequent sprints will implement and test incrementally more complex use cases. The early sprints provide the foundation for later sprints demonstrating the application scenarios listed in the Stakeholder viewpoint discussed above. As the capability and complexity continues to grow, Domain-specific architectures will emerge and will be managed by Spatial Web domain working groups.

Development of the Spatial Web based on the Spatial Web Protocol, Architecture and Governance specification will lead to the transformations identified by Rene and Mapes: The Spatial Web will connect humans, machines and AI to transform the World.

References

The Spatial Web Protocol, Architecture and Governance specification lists normative references that are indispensable in the understanding of the specification. Also in the specification is an extensive bibliography that provides additional and helpful material.

Listed below are documents referenced in this Introduction.

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Comments about the Spatial Web and this introduction
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