Quantum Hyper-Aether: Semantic Geometry, Quantum-Like VM State Models, Layer-Wise Weight-State Evolution, Semantic Entropy, and Semantic Temperature

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Abstract

This paper proposes an extended semantic-native computational framework called *Quantum Hyper-Aether*. The framework unifies semantic-cognitive virtual machines, associative semantic distance, quantum-inspired semantic computation, dynamically evolving semantic graphs, neural semantic communication, distributed cognition, semantic entropy, semantic temperature, and a quantum-like virtual machine state model.

The main extension introduced in this paper is the inclusion of internal neural network weights as part of the virtual machine state itself. Instead of treating a virtual machine as a container that merely executes code over data, the proposed model represents each VM as a joint semantic state containing semantic state, layer-wise neural weight states, memory, context, purpose, policy, and quantum control state. Thus, learning is no longer interpreted only as external parameter optimization. It becomes the time evolution of internal weight states inside a self-adaptive semantic entity.

For an N-layer neural network embedded in a VM, each layer weight is represented as a state component. The complete VM state evolves through joint transformations that update both activations and weight-state components. In Quantum Hyper-Aether, this model is further extended by introducing superposition, interference, entanglement, and measurement-like selection. VM-to-VM communication becomes entangled semantic interaction, routing becomes quantum-like route selection, and VM generation or deletion can be interpreted as a semantic phase transition.

The resulting architecture models Quantum Hyper-Aether as an entangled distributed semantic state field composed of self-adaptive quantum-like VM states. This provides a theoretical basis for AI-native operating systems, semantic computing fabrics, adaptive routing, autonomous learning, distributed cognition, semantic thermodynamics, and self-organizing semantic infrastructure.

1 Introduction

Modern computing systems separate execution, communication, memory, reasoning, and semantic interpretation. Conventional operating systems mainly provide process scheduling, memory management, file systems, device control, and network communication. AI systems, on the other hand, are typically treated as external applications or services running on top of such systems.

Quantum Hyper-Aether proposes a different architecture. In this framework, computation itself becomes semantic evolution. Virtual machines are not passive containers but semantic-cognitive entities. Communication is not merely packet transfer but semantic resonance or semantic interaction. Memory is not merely storage but semantic topology. Routing is not merely address-based forwarding but semantic affinity propagation. Intelligence emerges from distributed semantic interaction.

This paper extends the previous Quantum Hyper-Aether model by introducing a *VM-state model* in which neural network weights, memory, context, and purpose are included directly in the state of each VM. This enables a unified interpretation of inference, learning, routing, memory update, autonomous adaptation, and VM lifecycle control.

The main contributions are as follows:

1. A VM-state formulation in which each VM is represented as a joint semantic state.
2. An N-layer neural-network interpretation in which all layer-wise weight states are included in the VM state.
3. A formulation of learning as weight-state evolution rather than only external parameter update.
4. A Hyper-Aether interpretation in which VM-to-VM communication, semantic routing, VM spawning, and VM deletion are unified as state-evolution processes.
5. A Quantum Hyper-Aether extension in which VM states may exhibit superposition, interference, entanglement, and measurement-like selection.
6. A connection to semantic entropy, semantic temperature, and semantic phase transitions.

2 Quantum Semantic Foundations

Semantic computational states are represented in a semantic Hilbert space:

$$|\Psi\rangle \in \mathcal{H}_{sem}. \tag{1}$$

A semantic state is not merely a symbolic label or a static embedding vector. It is a dynamic state in a structured semantic space. A virtual machine may exist in a semantic superposition:

$$|\Psi_{VM}\rangle = \sum_i c_i |VM_i\rangle, \tag{2}$$

where $|VM_i\rangle$ denotes a possible semantic VM state and c_i denotes a semantic amplitude.

In Quantum Hyper-Aether, the entire computational system evolves as a semantic graph field. A semantic graph may also exist in superposition:

$$|G\rangle = \sum_i \alpha_i |G_i\rangle, \tag{3}$$

where $|G_i\rangle$ represents a possible semantic graph configuration.

3 Conventional Semantic-Cognitive Virtual Machines

In the earlier Hyper-Aether formulation, each VM is modeled as an autonomous semantic-cognitive entity:

$$VM_i = (S_i, N_i, I_i, M_i, R_i, F_i), \tag{4}$$

where:

- S_i is the semantic state,
- N_i is the neural inference engine,
- I_i is the semantic communication interface,
- M_i is the semantic memory,
- R_i is the routing intelligence,
- F_i is the adaptive learning feedback system.

This formulation already makes the VM more than a conventional execution unit. However, it still separates the VM components as functional modules. The VM-state model introduced in this paper goes further by representing these components as parts of a single evolving state.

4 VM as a Joint Semantic State

In the proposed state-inclusive formulation, a VM is represented as:

$$|\Psi_{VM}\rangle = |\psi_{sem}\rangle \otimes |W_1\rangle \otimes \cdots \otimes |W_N\rangle \otimes |M\rangle \otimes |C\rangle \otimes |P\rangle. \tag{5}$$

Here:

- $|\psi_{sem}\rangle$ is the current semantic state,
- $|W_l\rangle$ is the weight state of the l-th neural layer,
- $|M\rangle$ is the memory state,
- $|C\rangle$ is the context state,
- $|P\rangle$ is the purpose or policy state.

This changes the interpretation of a VM from:

$$\text{VM} = \text{code} + \text{data} + \text{runtime} \tag{6}$$

to:

$$\text{VM} = \text{semantic state} + \text{neural weight states} + \text{memory} + \text{context} + \text{purpose}. \tag{7}$$

Thus, a VM becomes a self-adaptive semantic processing unit.

5 N-Layer Neural Network with Weights in the State

A conventional N-layer neural network is usually written as:

$$x^{(N)} = f_N \circ f_{N-1} \circ \cdots \circ f_1(x^{(0)}), \tag{8}$$

where:

$$f_l(x) = \sigma_l(W_l x + b_l). \tag{9}$$

In this view, W_l is an external parameter or operator acting on the activation state. In the quantum-style VM-state model, each weight matrix is represented as a state component:

$$|\Psi_0\rangle = |\psi_0\rangle \otimes |W_1\rangle \otimes |W_2\rangle \otimes \cdots \otimes |W_N\rangle. \tag{10}$$

A richer time-dependent state is:

$$|\Psi_t\rangle = |\psi_t\rangle \otimes |W_{1,t}\rangle \otimes |W_{2,t}\rangle \otimes \cdots \otimes |W_{N,t}\rangle \otimes |M_t\rangle \otimes |C_t\rangle \otimes |P_t\rangle. \tag{11}$$

Each layer is then described by a joint transformation:

$$|\Psi_l\rangle = A_l |\Psi_{l-1}\rangle, \qquad l = 1, \ldots, N. \tag{12}$$

The complete N-layer evolution becomes:

$$|\Psi_N\rangle = A_N A_{N-1} \cdots A_1 |\Psi_0\rangle. \tag{13}$$

The important difference is that A_l updates the total state, not only the activation state. Thus, activations, layer-wise weights, memory, context, and purpose may co-evolve.

6 Learning as Weight-State Evolution

In ordinary neural-network training, learning is expressed as:

$$W_l \leftarrow W_l - \eta \frac{\partial L}{\partial W_l}. \tag{14}$$

In the state-inclusive formulation, learning becomes the evolution of the weight state:

$$|W_{l,t+1}\rangle = G_l(|W_{l,t}\rangle, |\psi_{l-1,t}\rangle, \delta_l, L_t), \tag{15}$$

where δ_l denotes the error or feedback signal associated with layer l.

For a semantic VM, the learning update may depend on semantic state, memory, context, purpose, and loss:

$$|W_{l,t+1}\rangle = G_l(|W_{l,t}\rangle, |\psi_{sem,t}\rangle, |M_t\rangle, |C_t\rangle, |P_t\rangle, L_t). \tag{16}$$

The total VM update can be written as:

$$|\Psi_{VM}(t+1)\rangle = A_{VM}\left(|\Psi_{VM}(t)\rangle, |\Phi_{env}(t)\rangle\right), \tag{17}$$

where $|\Phi_{env}(t)\rangle$ denotes the environment, user input, other VMs, or semantic fabric.

Thus, inference, memory update, context update, and learning are unified as state evolution.

7 Autonomous Learning

Autonomous learning extends ordinary training by adding internal evaluation criteria. Instead of minimizing only an externally defined task loss, the VM minimizes or regulates a composite objective:

$$\mathcal{J} = L_{task} + \lambda_1 L_{self} + \lambda_2 L_{consistency} + \lambda_3 L_{novelty} + \lambda_4 L_{stability}. \tag{18}$$

Here:

- L_{task} is the external task loss,
- L_{self} is self-model or self-prediction loss,
- $L_{consistency}$ measures semantic or internal consistency,
- $L_{novelty}$ encourages curiosity, exploration, or novelty seeking,
- $L_{stability}$ penalizes collapse, instability, or incoherence.

The corresponding weight-state update becomes:

$$|W_{l,t+1}\rangle = G_l(|W_{l,t}\rangle, |\psi_{sem,t}\rangle, |M_t\rangle, |C_t\rangle, |P_t\rangle, \mathcal{J}_t). \tag{19}$$

Autonomous learning therefore changes not only the external behavior of a VM but the VM state itself.

8 VM-to-VM Semantic Interaction

In conventional communication, one VM sends a message to another VM. In Hyper-Aether, communication is modeled as interaction between semantic states.

Let $|\psi_{msg,1\to 2}\rangle$ be a semantic message from VM1 to VM2. Then VM2 evolves as:

$$|\Psi_{VM2}(t+1)\rangle = I_{12}\left(|\Psi_{VM2}(t)\rangle, |\psi_{msg,1\to 2}\rangle\right). \tag{20}$$

This communication may modify not only the immediate semantic state but also memory, context, purpose, and possibly weight-state components.

Thus, VM-to-VM communication is not merely packet transfer. It is semantic state interaction.

9 Semantic Routing and VM Lifecycle

Semantic routing selects a VM based on the compatibility between a task state and candidate VM states:

$$R(i,j) = \text{sim}\left(|\psi_{task}\rangle, |\Psi_{VM_j}\rangle\right). \tag{21}$$

The similarity may include:

- semantic similarity,
- learned competence,
- memory relevance,
- context compatibility,
- goal alignment,
- stability.

A new VM may be generated when no existing VM sufficiently matches the task:

$$\max_j R(task, VM_j) < \theta_{spawn}. \tag{22}$$

A VM may be deleted when its state value becomes too low:

$$V(|\Psi_{VM}\rangle) < \theta_{delete}. \tag{23}$$

The value function V may include semantic utility, routing relevance, memory value, stability, and computational cost.

10 Hyper-Aether as a Distributed Semantic State Field

The entire Hyper-Aether system can be represented as:

$$|\Omega_{HA}\rangle = |\Psi_{VM1}\rangle \otimes |\Psi_{VM2}\rangle \otimes \cdots \otimes |\Psi_{VMK}\rangle. \tag{24}$$

Here K is the number of currently existing VMs. In this interpretation, Hyper-Aether becomes a distributed field of interacting self-adaptive VM states. System-level behavior emerges from the evolution of many such VM states:

$$|\Omega_{HA}(t)\rangle \rightarrow |\Omega_{HA}(t+1)\rangle. \tag{25}$$

Communication, routing, learning, VM spawning, VM deletion, and semantic coordination are all interpreted as state-evolution processes.

11 Quantum Hyper-Aether VM State

Quantum Hyper-Aether extends the VM-state model by adding a quantum-control component:

$$|\Psi_{QVM}\rangle = |\psi_{sem}\rangle \otimes |W_1\rangle \otimes \cdots \otimes |W_N\rangle \otimes |M\rangle \otimes |C\rangle \otimes |P\rangle \otimes |Q\rangle. \tag{26}$$

The component $|Q\rangle$ represents quantum-like control properties such as:

- superposition,
- interference,
- entanglement,
- measurement-like selection.

Thus, a QVM is a quantum-like semantic processing unit with semantic, weight, memory, context, purpose, and quantum-control states.

12 Superposition of Meaning and Weight States

A QVM can hold multiple candidate meanings before selection:

$$|\psi_{sem}\rangle = \sum_i \alpha_i |s_i\rangle, \tag{27}$$

where $|s_i\rangle$ denotes a candidate semantic interpretation and α_i is its semantic amplitude.

Similarly, the layer-wise weight state may be represented as:

$$|W_l\rangle = \sum_k \beta_{l,k} |W_{l,k}\rangle, \tag{28}$$

where $|W_{l,k}\rangle$ denotes a possible transformation mode of layer l.

This means that a QVM can preserve both semantic ambiguity and transformation ambiguity. It can maintain several possible meanings and several possible weight modes before a measurement-like selection or collapse occurs.

13 Entangled VM-to-VM Semantic Interaction

In Quantum Hyper-Aether, VM-to-VM communication may produce entangled semantic states. For two QVMs:

$$|\Omega_{12}\rangle \neq |\Psi_{QVM1}\rangle \otimes |\Psi_{QVM2}\rangle. \tag{29}$$

A simple semantic entanglement form is:

$$|\Omega_{12}\rangle = \sum_{i,j} \gamma_{ij} |s_i\rangle_{QVM1} \otimes |s_j\rangle_{QVM2}. \tag{30}$$

This models semantic correlation between VMs. The interpretation of one VM may affect or constrain the interpretation of another VM. This provides a model for nonlocal semantic coordination, shared context, synchronized reasoning, and distributed cognition.

14 Quantum Semantic Routing

In ordinary semantic routing, a VM is selected by similarity. In Quantum Hyper-Aether, candidate routes may first exist in superposition:

$$|\rho_{route}\rangle = \sum_j r_j |\mathrm{route}_j\rangle. \tag{31}$$

Semantic similarity and learned competence modulate the route amplitudes:

$$r_j \leftarrow r_j \cdot \mathrm{sim}\left(|\psi_{task}\rangle, |\Psi_{QVM_j}\rangle\right). \tag{32}$$

Finally, a measurement-like operation selects one or more routes:

$$\mathrm{Measure}\left(|\rho_{route}\rangle\right) \to QVM_k. \tag{33}$$

Routing therefore becomes a quantum-like selection process in which candidate routes are weighted, interfered, and measured.

15 VM Spawn and Delete as Quantum-Like Phase Transitions

In Quantum Hyper-Aether, VM generation and deletion can be interpreted as semantic phase transitions.

A new QVM may be spawned when the semantic field cannot stably resolve a task:

$$\Delta E_{sem} > \theta_{spawn}, \tag{34}$$

or when route uncertainty is too high:

$$H(|\rho_{route}\rangle) > \theta_{uncertainty}. \tag{35}$$

A QVM may be deleted when its amplitude, value, or semantic contribution fades:

$$A_{QVM} \to 0. \tag{36}$$

Thus, lifecycle management can be interpreted as instability, transition, and decay in the semantic field.

16 Quantum Hyper-Aether as an Entangled Semantic State Field

The global state of Quantum Hyper-Aether is not merely a tensor product of independent VM states. It includes entanglement, semantic correlation, and interference:

$$|\Omega_{QHA}\rangle = \mathcal{E}\left(|\Psi_{QVM1}\rangle, |\Psi_{QVM2}\rangle, \ldots, |\Psi_{QVMK}\rangle\right), \tag{37}$$

where $\mathcal{E}$ denotes a coupling operation that includes semantic entanglement and correlation.

A more general expansion is:

$$|\Omega_{QHA}\rangle = \sum_{\boldsymbol{s},\boldsymbol{w},\boldsymbol{m},\boldsymbol{c},\boldsymbol{p}} A_{\boldsymbol{s},\boldsymbol{w},\boldsymbol{m},\boldsymbol{c},\boldsymbol{p}} |\boldsymbol{s}, \boldsymbol{w}, \boldsymbol{m}, \boldsymbol{c}, \boldsymbol{p}\rangle. \tag{38}$$

Quantum Hyper-Aether therefore becomes an entangled distributed semantic state field of interacting, self-adaptive QVM states.

17 Associative Semantic Fields

For a semantic entity S_i, define an associative semantic field:

$$A(S_i) = (k_n, w_n), \tag{39}$$

where k_n are associative semantic keywords and $w_n \geq 0$ are associative strengths.

Semantic similarity between two associative fields can be defined as:

$$Sim(i,j) = \frac{|A_i \cap A_j|}{|A_i \cup A_j|}. \tag{40}$$

Semantic distance is:

$$D(i,j) = 1 - Sim(i,j). \tag{41}$$

For weighted associative fields:

$$Sim_w(i,j) = \frac{\sum_{k \in A_i \cap A_j} \min(w_k^{(i)}, w_k^{(j)})}{\sum_{k \in A_i \cup A_j} \max(w_k^{(i)}, w_k^{(j)})}. \tag{42}$$

The weighted semantic distance is:

$$D_w(i,j) = 1 - Sim_w(i,j). \tag{43}$$

18 Quantum Associative Semantic Fields

A semantic associative wave function is:

$$\Phi(S) = \sum_n w_n e^{i\theta_n} |k_n\rangle, \tag{44}$$

where w_n is semantic amplitude, θ_n is semantic phase, and $|k_n\rangle$ is a keyword basis state.

Quantum semantic similarity is:

$$Sim_Q(i,j) = |\langle \Phi(S_i) | \Phi(S_j) \rangle|^2. \tag{45}$$

Quantum semantic distance is:

$$D_Q(i,j) = 1 - Sim_Q(i,j). \tag{46}$$

The complete semantic distance metric is:

$$D_H(i,j) = \alpha D_w(i,j) + \beta D_Q(i,j) + \gamma D_G(i,j), \qquad \alpha + \beta + \gamma = 1, \tag{47}$$

where D_G is semantic graph distance.

19 Semantic Entropy

If the semantic graph exists in superposition:

$$|G\rangle = \sum_i \alpha_i |G_i\rangle, \tag{48}$$

then the probability of observing graph state G_i is:

$$p_i = |\alpha_i|^2. \tag{49}$$

Semantic graph entropy is defined as:

$$H_G = -\sum_i p_i \log p_i = -\sum_i |\alpha_i|^2 \log |\alpha_i|^2. \tag{50}$$

For VM clusters:

$$H_{VM} = -\sum_k P(C_k) \log P(C_k), \tag{51}$$

where $P(C_k)$ is the probability that a VM belongs to semantic cluster C_k.

Using the composite semantic distance $D_H(i,j)$, distance-based semantic entropy is:

$$H_D = \sum_{i,j} p_i p_j D_H(i,j). \tag{52}$$

Moderate semantic entropy enables creativity, analogy, exploration, and new semantic cluster formation. Excessive entropy leads to semantic fragmentation, routing confusion, and collapse instability.

20 Semantic Temperature

In thermodynamics, temperature is related to entropy and energy by:

$$\frac{1}{T} = \frac{\partial S}{\partial E}. \tag{53}$$

In Quantum Hyper-Aether, semantic temperature is defined as:

$$\frac{1}{T_{sem}} = \frac{\partial H_{sem}}{\partial E_{sem}}, \tag{54}$$

or:

$$T_{sem} = \left(\frac{\partial H_{sem}}{\partial E_{sem}}\right)^{-1}. \tag{55}$$

Semantic energy may be formulated as:

$$E_{sem} = \sum_i p_i V(S_i) + \sum_{i,j} w_{ij} D_H(i,j) + \lambda C_{comp}. \tag{56}$$

For practical implementation, semantic temperature can be estimated by:

$$T_{sem} = a, Var(D_H) + b, Var(P_{ij}) + c, Var(S_i) + d, R_{collapse} + e, R_{birth/delete}. \tag{57}$$

Semantic temperature measures the intensity of semantic fluctuation, exploration, and instability.

21 Behavior by Semantic Temperature Region

Semantic temperature defines the operational regime of Quantum Hyper-Aether:

$$T_{sem} \approx 0 \Rightarrow \text{automation-dominant regime}, \; T_{sem} \approx T_{optimal} \;\; \Rightarrow \text{adaptive intelligence regime}, \; T_{sem} > T_{optimal} = \tag{58}$$

A semantic thermal controller may regulate the system:

$$u_T(t) = K_p(T_{target} - T_{sem}(t)) + K_i \int_0^t (T_{target} - T_{sem}(\tau))d\tau + K_d \frac{d}{dt}(T_{target} - T_{sem}(t)). \tag{59}$$

This controller can adjust:

- VM birth rate,
- VM deletion rate,
- routing randomness,
- semantic collapse threshold,
- exploration probability,
- semantic memory activation range,
- learning rate.

22 Semantic Free Energy

A semantic free energy may be defined as:

$$F_{sem} = E_{sem} - T_{sem} H_{sem}. \tag{60}$$

Minimizing semantic free energy does not necessarily mean minimizing entropy. Instead, it means maintaining a useful balance between semantic coherence and semantic diversity.

This is particularly important in Quantum Hyper-Aether. If entropy is too low, the system becomes rigid automation. If entropy is too high, the system becomes unstable semantic turbulence. Useful intelligence occurs between these extremes.

23 System Interpretation

The extended framework can be summarized as follows:

Aspect	Hyper-Aether	Quantum Hyper-Aether
VM	self-adaptive semantic state	quantum-like semantic state
Meaning	semantic state	semantic superposition
Weights	learned weight states	superposed weight modes
Communication	state interaction	entangled semantic interaction
Routing	semantic similarity	superposition, interference, measurement
Learning	weight-state evolution	probabilistic convergence of states
Lifecycle	spawn/delete by fit and value	phase transition and decay
System	distributed semantic field	entangled semantic state field

Table 1: Comparison between Hyper-Aether and Quantum Hyper-Aether under the VM-state model.

24 Advantages

The proposed framework provides the following advantages:

- semantic-native computation,
- distributed cognition,
- adaptive semantic routing,
- self-evolving VM topology,
- layer-wise weight-state learning,
- autonomous learning,
- emergent VM specialization,
- creativity through semantic interference,
- semantic memory organization,
- nonlocal semantic coordination,
- AI-native operating behavior,

- entropy-based stability evaluation,
- temperature-based control of exploration and creativity,
- unified treatment of inference, learning, routing, and VM lifecycle.

25 Challenges

Major challenges remain:

- defining measurable semantic states,
- verifying semantic coherence,
- measuring weight-state evolution,
- implementing autonomous learning safely,
- estimating semantic entropy,
- defining semantic energy,
- calibrating semantic temperature,
- controlling excessive semantic turbulence,
- avoiding unstable semantic collapse,
- scaling entangled VM interactions,
- implementing practical quantum-like routing,
- preventing uncontrolled VM birth and deletion,
- maintaining security and interpretability.

Especially important is the distinction between physical quantum mechanics and quantum-like semantic modeling. The proposed equations should be interpreted as an effective mathematical framework unless implemented on actual quantum hardware.

26 Conclusion

This paper introduced an extended formulation of Quantum Hyper-Aether based on a VM-state model. In this formulation, a VM is not merely a runtime container but a joint semantic state containing semantic state, layer-wise neural weight states, memory, context, purpose, and quantum-control state.

For an N-layer neural network embedded in a VM, all layer-wise weights are included as state components. Learning becomes the time evolution of these weight states. Autonomous learning further introduces internal objectives such as self-consistency, novelty, and stability. VM-to-VM communication becomes semantic state interaction, and in Quantum Hyper-Aether it becomes entangled semantic interaction.

At the system level, Hyper-Aether becomes a distributed semantic state field, while Quantum Hyper-Aether becomes an entangled distributed semantic field of self-adaptive quantum-like VM states. Semantic entropy and semantic temperature provide analytical and control parameters for stability, creativity, routing, learning, VM lifecycle, and semantic phase transitions.

The resulting framework provides a theoretical foundation for AI-native operating systems, semantic computing infrastructures, distributed AGI architectures, semantic thermodynamics, and future semantic-state computing fabrics.

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