ITU-T STUDY GROUP 13

Velsanet: A Topology-First, Optical-Native Architecture for AI-Native Next-Generation Networks

Proposal for New Work Item under IMT-2030 / 6G Framework

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Abstract

This contribution proposes a fundamentally new network architecture for IMT-2030 (6G) and beyond, designated Velsanet. Unlike incremental extensions of existing Internet infrastructure, Velsanet introduces a topology-first, packet-free, optically-native design in which network space is defined prior to addressing, and end-to-end (E2E) connectivity is established through physically isolated parallel optical cores.

The Velsanet architecture is grounded in five polyhedral structural primitives (T_4, C_6, O_8, D_{12}, I_{20}) that define a closed and complete grammar for network space generation. Artificial intelligence is embedded natively across three structural layers (PAI, AAI, AsAI), replacing the conventional model of AI as an external overlay. Global governance is achieved through a projection-based hierarchical model (Q2–Q7) that preserves national sovereignty without centralized control.

This contribution requests the ITU-T Study Group 13 to consider Velsanet as a new architectural framework for study under the IMT-2030 standardization work programme, and invites collaboration from member states and sector members.

1. Motivation and Problem Statement

1.1 Structural Limitations of Conventional Networks

Current Internet architecture is built on packet switching, hop-by-hop routing, and address-centric communication. While this model has enabled remarkable growth, it embeds structural limitations that cannot be resolved through optimization or incremental enhancement:

- Traffic congestion and latency are architectural, not algorithmic — packet queuing introduces non-determinism that no software can eliminate.
- Security is procedural rather than structural — authentication occurs at upper layers, leaving the physical path unverified and vulnerable.
- Intelligence is external — AI is layered on top of the network, not integrated within its structure, limiting real-time cognitive capability.
- Complexity compounds over time — every attempt to extend the Internet adds a new protocol layer, increasing fragility and reducing manageability.

These limitations are not implementation failures. They are consequences of the graph-theoretic structure of conventional networks, where global node sets, shared links, and hop-by-hop routing create inherent bottlenecks, failure propagation, and logical-only parallelism.

1.2 Insufficiency of Incremental 6G Approaches

Current IMT-2030 research programmes, including large-scale European and Asian 6G consortia, address next-generation networking by enhancing existing Internet protocols with AI overlays, network slicing, and software-defined networking. While valuable, these approaches share a fundamental constraint: they retain the packet-switching substrate and address-centric topology that define conventional networks.

Velsanet contends that the structural requirements of AI-native, 6G-scale, sovereign-aware networks cannot be satisfied within this paradigm. A new architectural foundation is required.

2. Velsanet Architecture Overview

2.1 Core Architectural Principle: Topology First

The foundational principle of Velsanet is that network space is defined prior to the assignment of coordinates or addresses. In conventional architectures, topology is derived from addressing. In Velsanet, addressing is derived from topology.

This inversion enables:

- Structural fault containment — failures are bounded by topological locality, not propagated globally.
- Deterministic parallelism — parallel E2E connections are physically isolated at the optical core level.
- AI-native operation — intelligence agents operate as native participants within the topological space, not as external controllers.
- Verifiable sovereignty — governance boundaries are encoded into the structural hierarchy, not enforced through policy layers.

2.2 Polyhedral Structural Primitives

Velsanet defines network space through five polyhedral roles that function as structural primitives. These roles define the minimal topological conditions for space formation, expansion, and mediation:

Polyhedron	Role	Structural Responsibility
T_4 (Tetrahedron)	Access Node	Access emergence and initiation — entry point for devices into the optical domain
C_6 (Hexahedron)	Channel Node	Channel alignment and aggregation — coordination of parallel optical pathways
O_8 (Octahedron)	Local E2E Domain	Local parallel E2E domain — physically isolated multi-core connections for devices
D_{12} (Dodecahedron)	Mediation Node	Mediation and expansion control — inter-domain coordination and topology growth
I_{20} (Icosahedron)	Governance Node	Global balance and structural governance — planetary-scale coherence without central control

Network space in Velsanet is generated exclusively through valid compositions of these five primitives. No structural entity may exist outside this role set, ensuring that network growth remains bounded, composable, and formally verifiable.

2.3 Multi-Optical-Core Transceiver (MOCT)

Velsanet replaces packet switching and electrical routing with a fixed, non-pluggable Multi-Optical-Core Transceiver (MOCT) — a physically integrated photonic substrate that enables deterministic, parallel E2E connectivity at the hardware level.

Key properties of the MOCT:

- Supports tens to hundreds of simultaneously active parallel optical cores per node.
- Each E2E connection occupies a physically isolated, dedicated optical core — no multiplexing, no shared medium.

- 8 internal channels per core: Channel 1 is reserved for sensing, control, and physical-layer authentication; Channels 2–8 carry data.
- Pre-attached optical fibers (5m+) are fused at manufacture — eliminating connector-based reliability failure modes.
- MEMS-based alignment fixtures provide micron-level precision without active switching or beam steering.

The result is a passive, deterministic optical substrate in which security, parallelism, and reliability are structural properties — not software additions.

2.4 Three-Layer AI Architecture (PAI / AAI / AsAI)

Intelligence in Velsanet is not an external overlay. It is embedded structurally across three layers, each corresponding to a polyhedral node type:

- Personal AI (PAI) — Resident in O_8 nodes. Represents the individual user's context, intent, and environment. Manages local decisions and multimodal interaction.
- Agent AI (AAI) — Resident in D_{12} nodes. Coordinates PAI clusters within a region. Performs real-time orchestration and intelligent resource distribution.
- Assistant AI (AsAI) — Resident in I_{20} nodes. Oversees AAI cooperation across domains. Integrates policy, prediction, and multi-domain coordination at national and global scale.

This three-layer model replaces centralized AI controllers with distributed cognitive agents that are native to the network topology. Each AI layer operates within its structurally defined domain and cannot exceed its topological authority.

2.5 Projection-Based Global Governance

Velsanet addresses global coordination without centralized control through a layered governance model based on structural projection rather than command propagation:

- Q7 — Execution Layer: physical and logical devices, links, and real-time operations.
- Q6 — Regional Coordination: city-scale or regional adjustment.
- Q4 — National Sovereign Layer: the minimal sovereign unit where national laws, policies, and security constraints are structurally encoded.
- Q3 — Continental Network AI: a continental-scale Network AI formed by the federation of national Q4 structures.
- Q2 — Global Network AI (VELSA): the global projection layer that aligns multiple continental Q3 structures into a coherent planetary network space.

Higher layers project structural states — they do not issue commands. Lower layers execute, adapt, and respond locally. Sovereignty and local autonomy are preserved structurally at every tier.

3. Comparison with Conventional Network Architecture

Architectural Feature	Conventional / 5G / SDN	Velsanet
Network Topology Model	Address-centric (IP-based)	Topology-first (pre-coordinate)
Data Transport	Packet switching + routing	Physical parallel optical cores
End-to-End Path	Logical, shared, routed	Physical, isolated, deterministic
AI Integration	External overlay / service	Native to structural layer
Security Model	Upper-layer cryptography	Physical-layer structural trust
Scalability	Logical, additive complexity	Structural, bounded expansion
Governance	Centralized / federated policy	Projection-based sovereign hierarchy
Parallelism	Logical multiplexing	Physical multi-core isolation
Failure Containment	Global propagation risk	Structural locality constraint

4. Mathematical Structural Foundation

The Velsanet architecture is formally defined using multi-layer graph theory. Unlike conventional networks modeled as a single graph G = (V, E), Velsanet defines a structural layer set:

$$\mathbf{L} = \{L_4, L_6, L_8, L_{12}, L_{20}\}$$

Each layer L_n corresponds to a polyhedral role layer. Intra-layer connectivity and inter-layer relations are defined independently, forming a super-adjacency matrix that enforces structural decomposition at design time.

Operational and physical domains are mapped onto a Q7 hypercube:

$$Q^7 = (\{0,1\}^7, E), \text{ where } (u,v) \in E \leftrightarrow |u \oplus v| = 1$$

This structure guarantees structural locality, isolation, and scalable expansion. The bisection bandwidth of Q7 is $2^6 = 64$, ensuring high parallelism at regional scale.

Parallel E2E connectivity is formally guaranteed through a non-collision constraint:

$$\forall\ i \neq j: \mathrm{Core}(r_i) \cap \mathrm{Core}(r_j) = \emptyset$$

This guarantees physical parallelism — unlike packet-based sharing models where logical parallelism coexists with physical contention.

5. Differentiation from Existing IMT-2030 Proposals

Velsanet is distinct from existing 6G architectural proposals in the following respects:

- Packet switching is not retained — Velsanet does not extend or optimize packet-based transport. It replaces it with physically isolated optical cores.
- AI is not a service layer — intelligence is embedded structurally at each polyhedral node tier, operating within topologically defined authority boundaries.
- Topology precedes addressing — unlike all IP-based architectures, Velsanet defines spatial structure before introducing coordinate systems.
- Security is physical — trust is established through structural conformance at the spatial genesis phase, not through cryptographic protocols at upper layers.
- Governance is structural — national sovereignty is encoded into the Q4 layer architecture, not enforced through policy agreements.

These properties are not improvements upon existing approaches. They represent a different class of network architecture, one in which correctness, security, and intelligence are structural invariants rather than emergent properties.

6. Proposed Work Items for SG13 Consideration

This contribution requests Study Group 13 to initiate study of the following items under the IMT-2030 work programme:

- Work Item A — Topology-First Network Architecture: Formal definition of pre-coordinate topological space as an architectural foundation for future networks. Study of polyhedral structural primitives as a grammar for network space generation.

- Work Item B — Optical-Native E2E Connectivity: Study of physically isolated, multi-core optical path architecture as an alternative to packet-switched transport. Evaluation of MOCT-class hardware for deterministic parallel connectivity.
- Work Item C — Structurally Embedded AI: Study of three-layer distributed AI architecture (PAI/AAI/AsAI) native to network topology. Comparison with external AI overlay models.
- Work Item D — Projection-Based Sovereign Governance: Study of hierarchical projection model (Q2–Q7) for global network coordination without centralized control. Evaluation of structural sovereignty encoding at national layer (Q4).
- Work Item E — Mathematical Framework: Formal study of multi-layer graph model, Q7 hypercube mapping, and non-collision constraint as foundations for next-generation network design.

7. Conclusion

This contribution presents Velsanet as a new class of network architecture for IMT-2030 and beyond. By defining network space topologically prior to addressing, eliminating packet switching in favour of physically isolated parallel optical cores, embedding intelligence structurally across three AI layers, and realizing global governance through structural projection, Velsanet addresses the fundamental limitations of conventional Internet architecture at the design level.

The architecture is formally grounded in multi-layer graph theory, with 18 technical white papers covering network structure, optical hardware, AI architecture, mathematical foundations, identity, path lifecycle, governance, and city-scale management.

We respectfully request Study Group 13 to consider Velsanet for inclusion in the IMT-2030 study programme and invite member states, sector members, and associate members to engage in collaborative research and standardization activities.

References

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