جامعة الأمير سلطان
PRINCE SULTAN UNIVERSITY

EMERGING INTELLIGENT AUTONOMOUS SYSTEMS
EIAS
DATA SCIENCE & BLOCKCHAIN LAB

Agentic AI for Open RAN

Enabling Fully Autonomous and Intelligent Radio Access Networks

Assoc. Prof. Abdelhamied Ateya

aateya@psu.edu.sa

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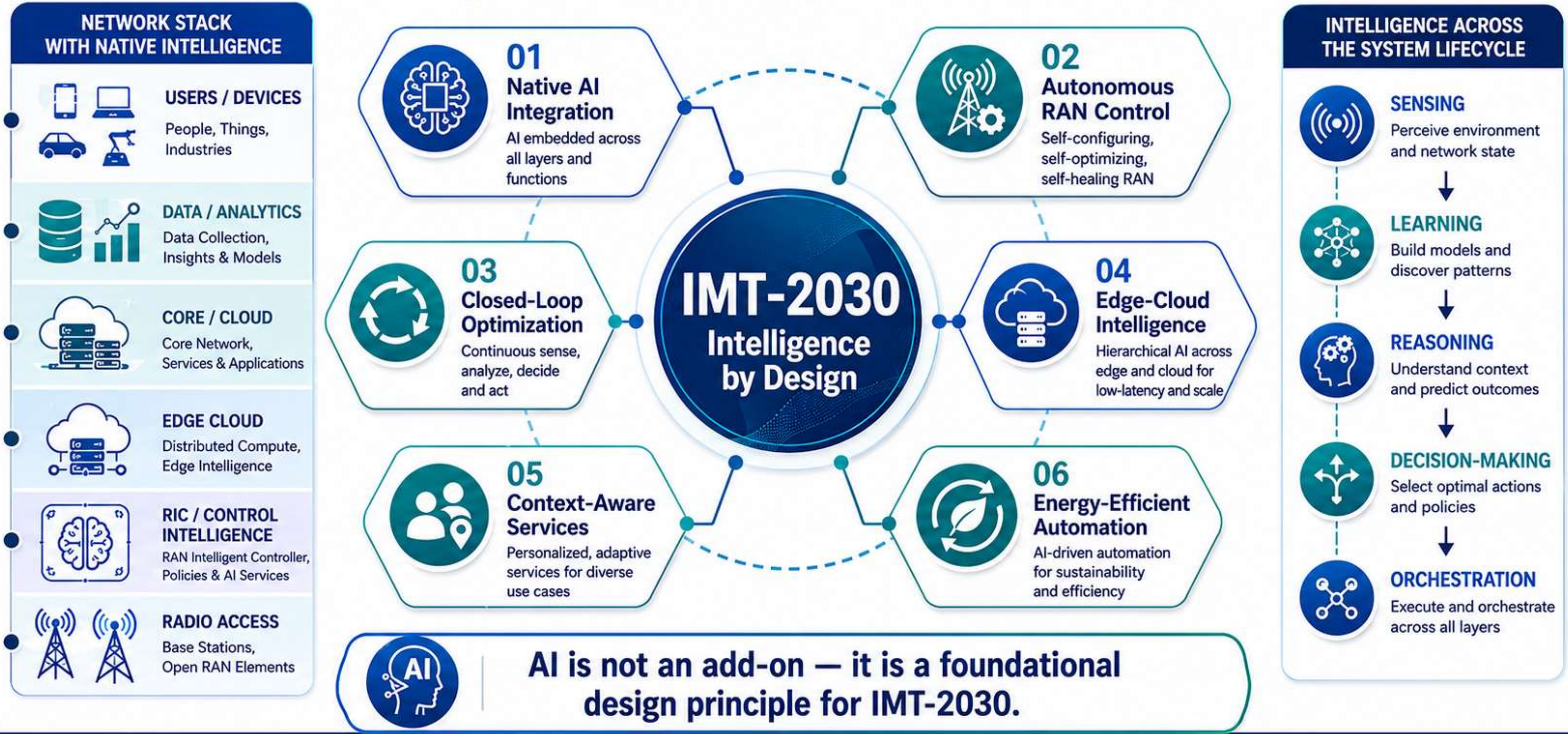
ITU Anchor: IMT-2030 Requires Intelligence by Design

Intelligence is embedded natively across the IMT-2030 / 6G system



Conceptual figure aligned with the ITU IMT-2030 vision.

OPEN RAN: PROGRAMMABLE FOUNDATION, HARDER OPERATIONS

Open RAN increases programmability and innovation, but also makes operations more complex.

1 1. Programmable Foundation

- SMO / Service Management & Orchestration
- Non-RT RIC + rApps
- Near-RT RIC + xApps
- O-Cloud
- O-CU
- O-DU
- O-RU / Radio Unit
- UEs / Devices

O1 / O2

A1

E2

Open Fronthaul

Disaggregation + open interfaces + virtualization enable programmability and vendor interoperability.

Open RAN Opportunity

- Vendor openness
- Cloud-native scaling
- Flexible deployment
- Faster innovation

Programmability unlocks innovation.

2 Harder Operations

Operational Complexity

Multi-vendor interoperability
interoperability across heterogeneous vendors

Security and trust management
broader attack surface and zero-trust requirements

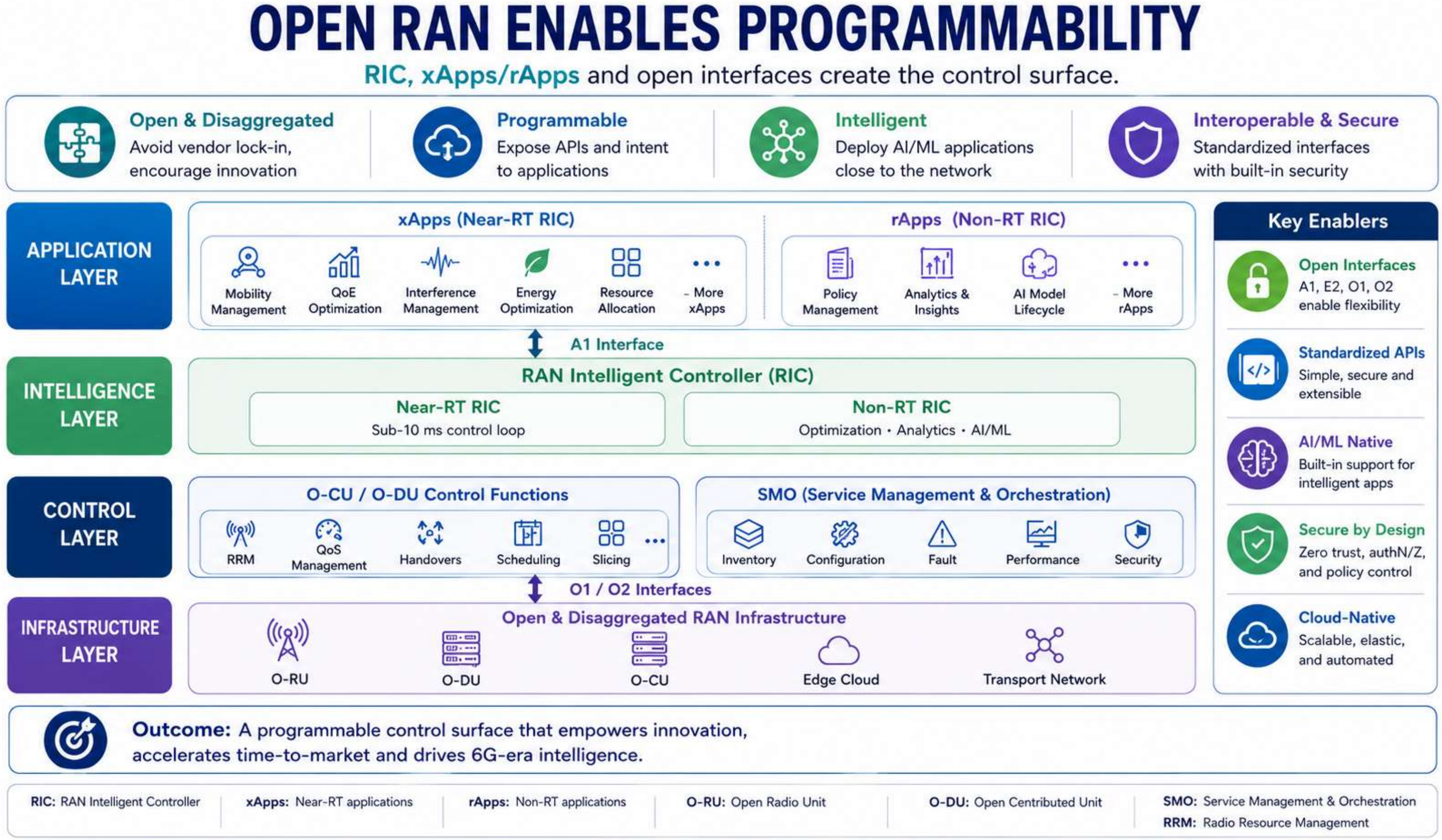
Real-time optimization
faster control loops and dynamic adaptation

Energy efficiency at scale
optimize power and sustainability

Fault & performance assurance
end-to-end visibility and root-cause analysis

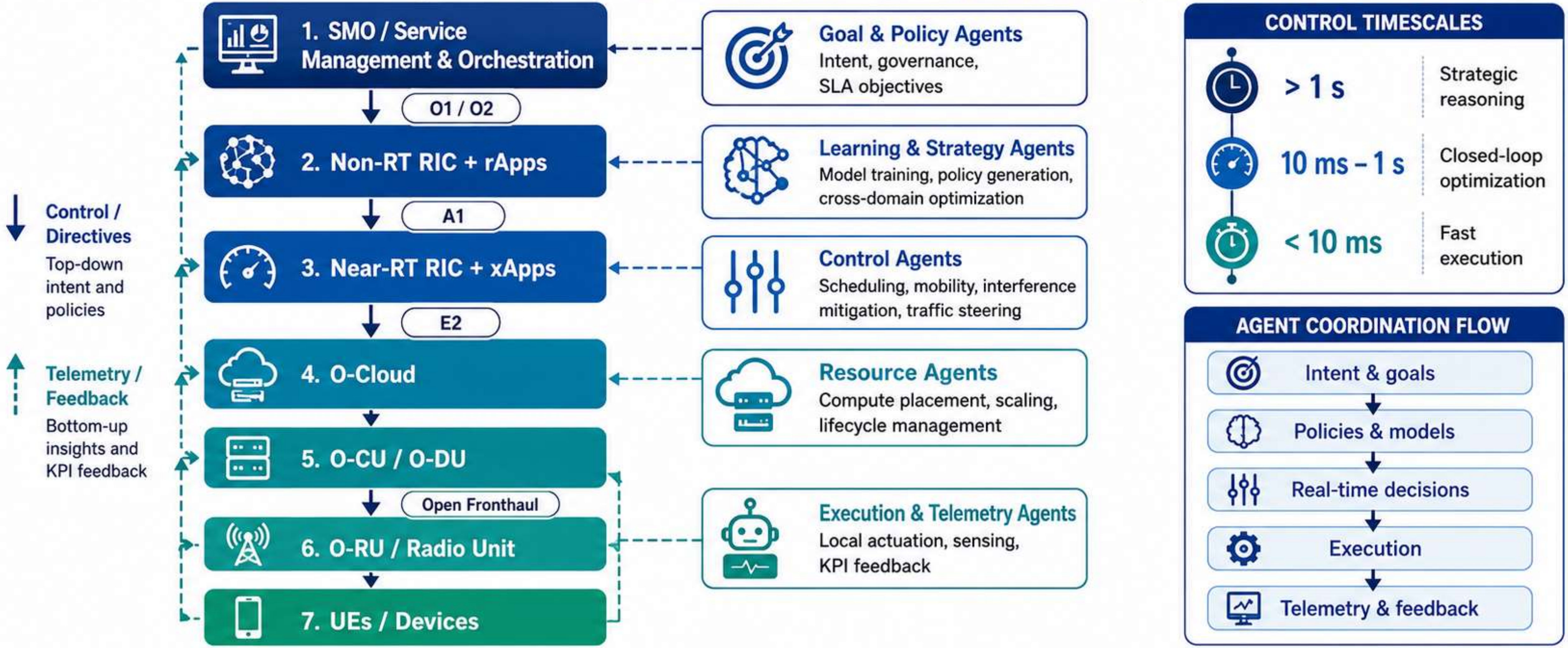
Closed-loop automation across layers
cross-domain coordination and automated actions

Key implication: Open RAN needs intelligent, automated, and coordinated control to manage complexity.


OPEN RAN ENABLES PROGRAMMABILITY
RIC, xApps/rApps and open interfaces create the control surface.
Open & Disaggregated
Avoid vendor lock-in, encourage innovation
Programmable
Expose APIs and intent to applications
Intelligent
Deploy AI/ML applications close to the network
Interoperable & Secure
Standardized interfaces with built-in security
APPLICATION LAYER
xApps (Near-RT RIC)
Mobility Management
QoE Optimization
Interference Management
Energy Optimization
Resource Allocation
More xApps
rApps (Non-RT RIC)
Policy Management
Analytics & Insights
AI Model Lifecycle
More rApps
A1 Interface
INTELLIGENCE LAYER
RAN Intelligent Controller (RIC)
Near-RT RIC
Sub-10 ms control loop
Non-RT RIC
Optimization • Analytics • AI/ML
CONTROL LAYER
O-CU / O-DU Control Functions
RRM
QoS Management
Handovers
Scheduling
Slicing
SMO (Service Management & Orchestration)
Inventory
Configuration
Fault
Performance
Security
O1 / O2 Interfaces
INFRASTRUCTURE LAYER
Open & Disaggregated RAN Infrastructure
O-RU
O-DU
O-CU
Edge Cloud
Transport Network
Key Enablers
Open Interfaces
A1, E2, O1, O2 enable flexibility
Standardized APIs
Simple, secure and extensible
AI/ML Native
Built-in support for intelligent apps
Secure by Design
Zero trust, authN/Z, and policy control
Cloud-Native
Scalable, elastic, and automated
Outcome: A programmable control surface that empowers innovation, accelerates time-to-market and drives 6G-era intelligence.
RIC: RAN Intelligent Controller
xApps: Near-RT applications
rApps: Non-RT applications
O-RU: Open Radio Unit
O-DU: Open Centributed Unit
SMO: Service Management & Orchestration
RRM: Radio Resource Management

WHERE AGENTS LIVE IN THE OPEN RAN CONTROL HIERARCHY

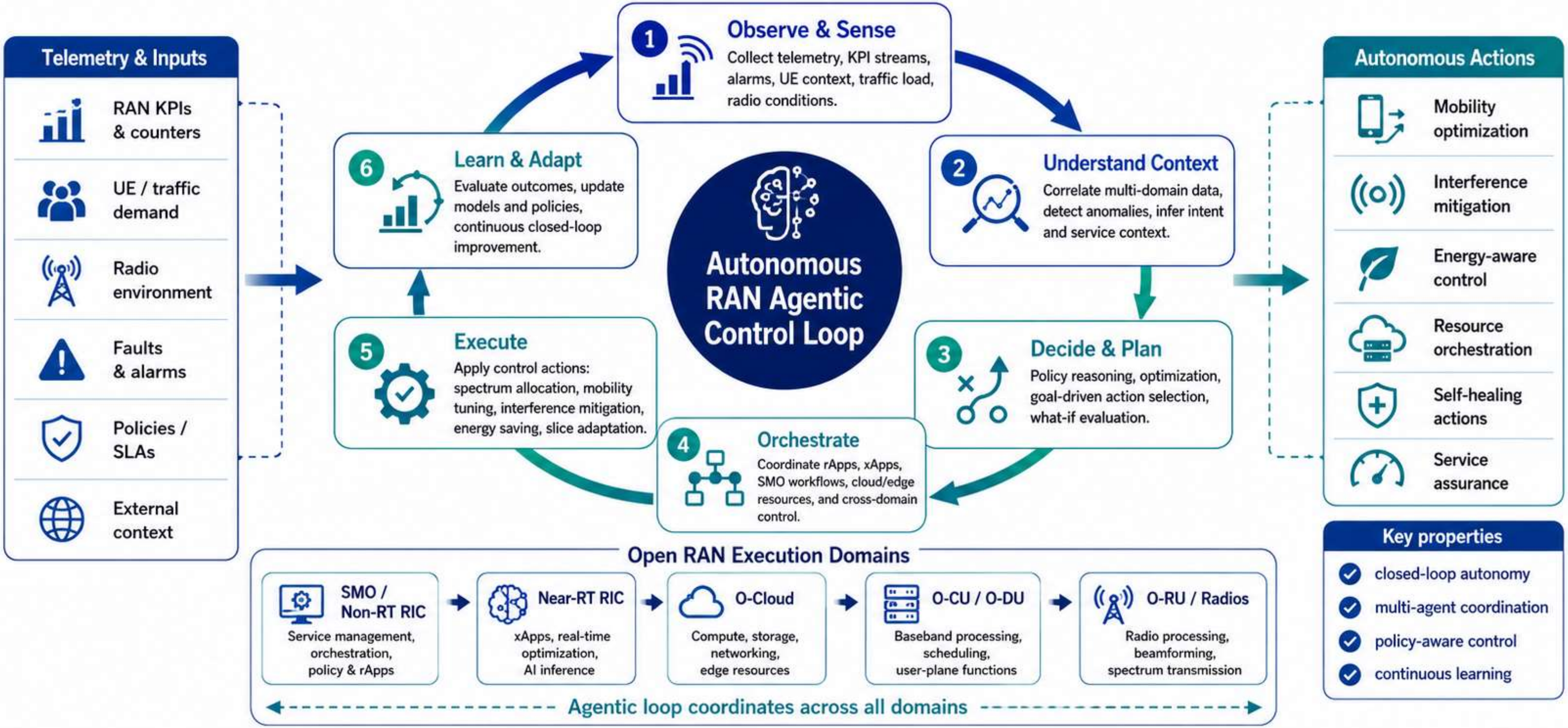
Agentic AI spans the SMO, RIC, cloud, and RAN execution layers.



Key idea: Agents do not replace Open RAN functions — they augment each control layer with intelligence and autonomy.

AGENTIC AI CONTROL LOOP FOR AUTONOMOUS RAN

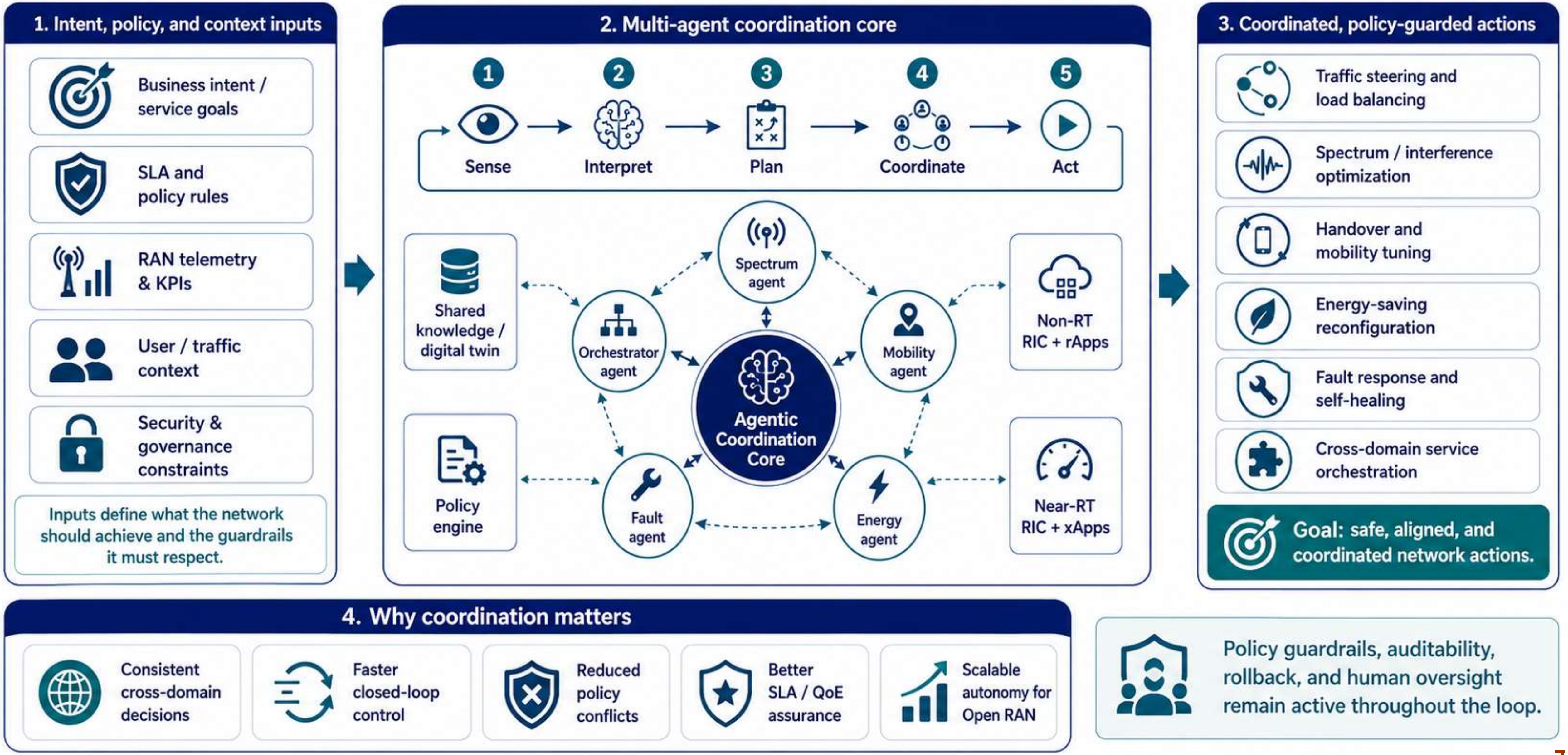
Intelligent, policy-aware, closed-loop control across the Open RAN ecosystem

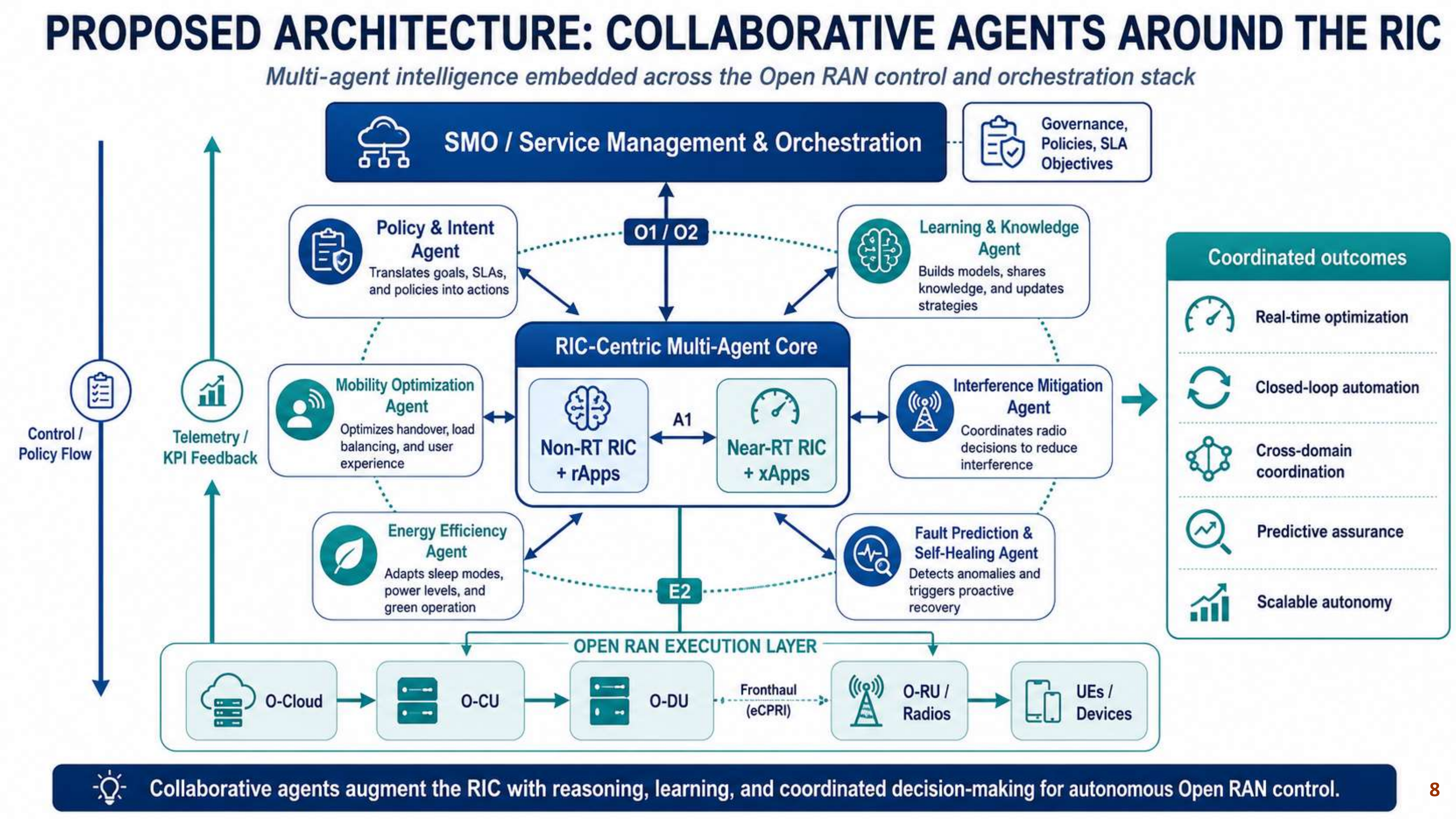


Agentic AI turns Open RAN from reactive optimization into proactive, coordinated, and self-improving autonomous control.

AGENTIC AI ENABLES COORDINATION

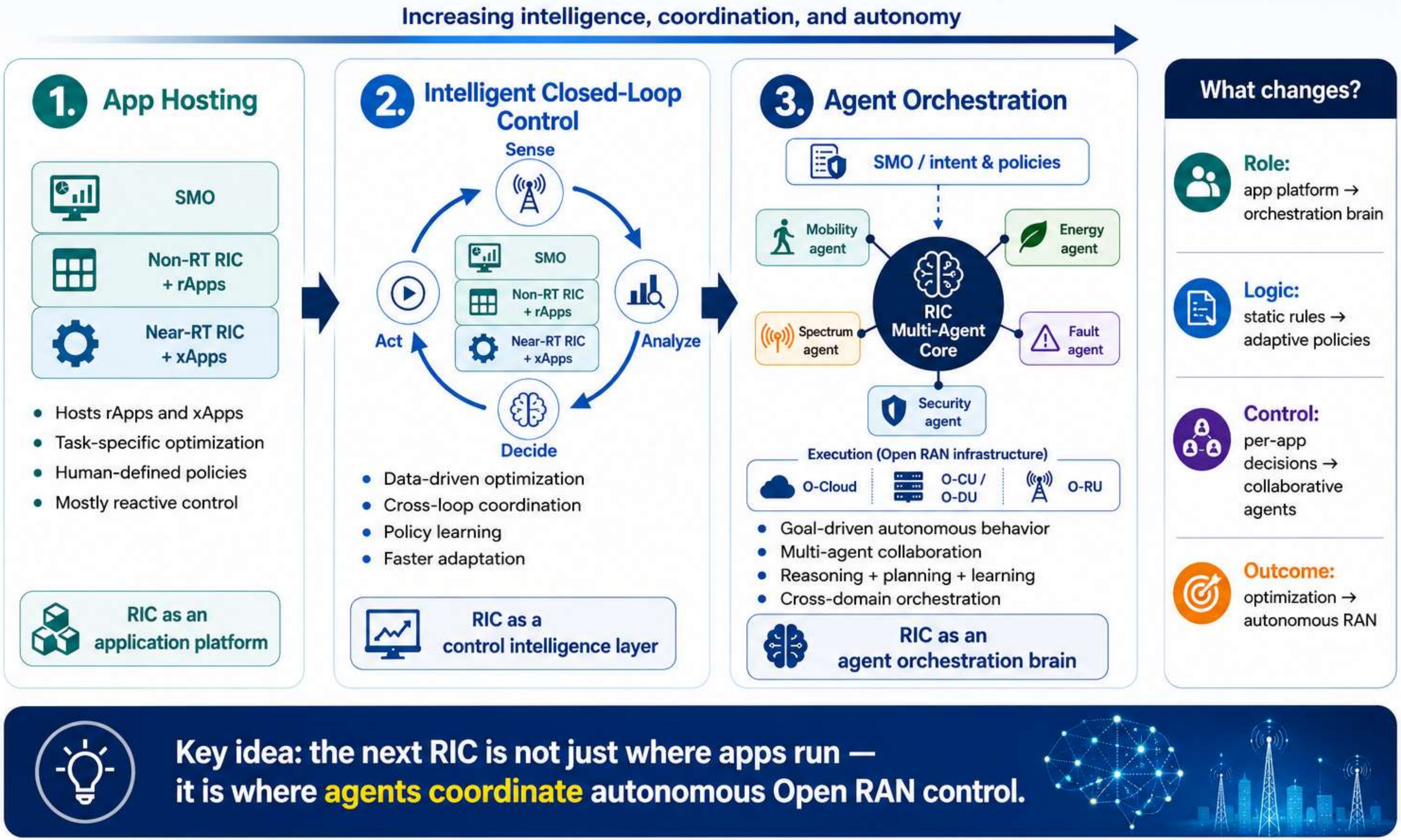
Agents translate intent into coordinated, policy-guarded actions.




PROPOSED ARCHITECTURE: COLLABORATIVE AGENTS AROUND THE RIC
Multi-agent intelligence embedded across the Open RAN control and orchestration stack
SMO / Service Management & Orchestration
Governance, Policies, SLA Objectives
O1 / O2
Policy & Intent Agent
Translates goals, SLAs, and policies into actions
Learning & Knowledge Agent
Builds models, shares knowledge, and updates strategies
RIC-Centric Multi-Agent Core
Non-RT RIC + rApps
A1
Near-RT RIC + xApps
Mobility Optimization Agent
Optimizes handover, load balancing, and user experience
Interference Mitigation Agent
Coordinates radio decisions to reduce interference
Energy Efficiency Agent
Adapts sleep modes, power levels, and green operation
Fault Prediction & Self-Healing Agent
Detects anomalies and triggers proactive recovery
E2
Control / Policy Flow
Telemetry / KPI Feedback
Coordinated outcomes
Real-time optimization
Closed-loop automation
Cross-domain coordination
Predictive assurance
Scalable autonomy
OPEN RAN EXECUTION LAYER
O-Cloud
O-CU
O-DU
Fronthaul (eCPRI)
O-RU / Radios
UEs / Devices
Collaborative agents augment the RIC with reasoning, learning, and coordinated decision-making for autonomous Open RAN control.

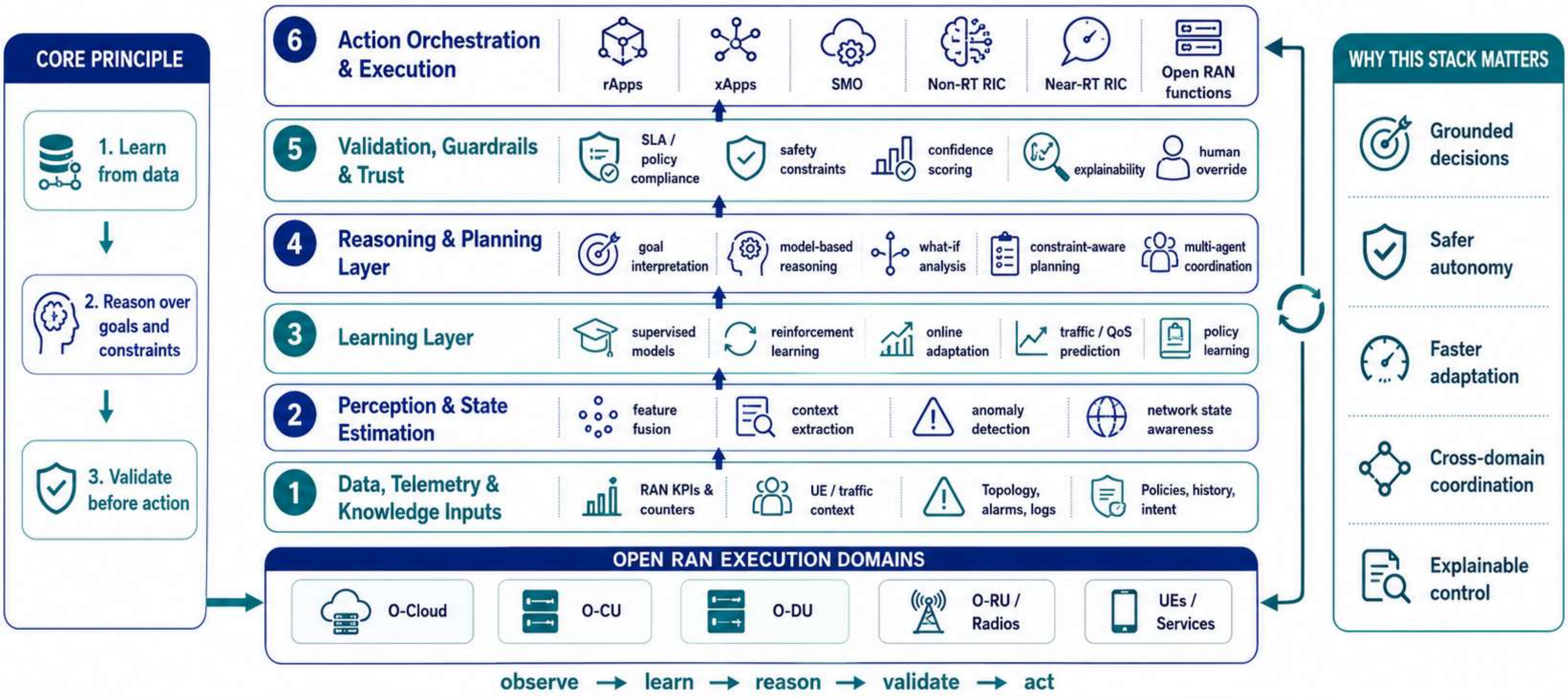
RIC EVOLUTION: FROM APP HOSTING TO AGENT ORCHESTRATION

The Open RAN RIC evolves from isolated app execution to coordinated, goal-driven autonomous control.



LEARNING + REASONING STACK

Agentic Open RAN combines model-based reasoning, learning, and validated action



Key idea: Agentic Open RAN is not just learning-driven — it combines learning, reasoning, and validated execution for trustworthy autonomy.

USE CASES

Leveraging AI-driven intelligence and automation to deliver **autonomous**, **efficient**, and **secure Open RAN networks.**

01 Intelligent Network Optimization

AI agents continuously optimize radio resources, reduce congestion, and improve spectrum utilization.

- Higher Throughput
- Better User Experience
- Resource Efficiency

02 Self-Healing Networks

Detect, localize, and resolve faults autonomously to minimize downtime and maintain service continuity.

- Faster Recovery
- Reduced MTTR
- High Availability

03 Autonomous Service Orchestration

Orchestrate network slices and services across RAN, edge, and cloud based on intent and policies.

- Agility
- Policy-driven Automation
- End-to-End Simplification

04 Security & Threat Mitigation

AI agents detect anomalies, predict threats, and respond in real-time to secure the network proactively.

- Threat Detection
- Proactive Response
- Zero Trust Security

05 Mobility Management & Handover

AI-driven mobility prediction and handover optimization ensure seamless connectivity for high-mobility users.

- Seamless Mobility
- Lower Drop Rate
- Improved QoE

06 Edge & Cloud Resource Management

Dynamically allocate and scale edge/ cloud resources to meet service demands with minimal latency.

- Lower Latency
- Optimal Utilization
- Cost Efficiency

07 Energy Efficiency & Sustainability

AI agents optimize energy consumption across RAN elements while reducing carbon footprint.

- Energy Savings
- Lower OPEX
- Sustainable Operations

08 Business Analytics & Assurance

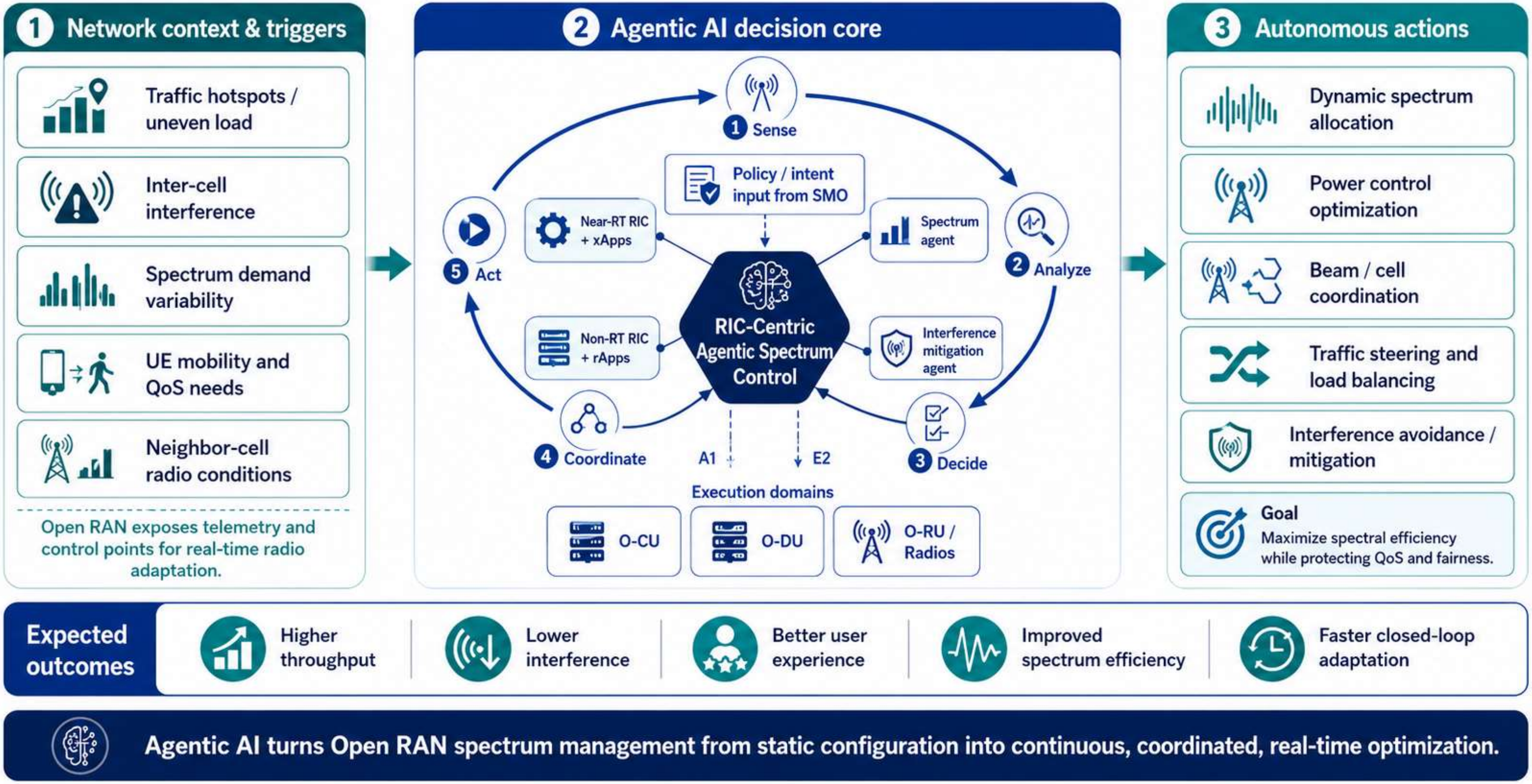
AI-powered analytics deliver real-time insights, SLA assurance, and business impact visibility.

- KPI Visibility
- SLA Assurance
- Data-driven Decisions

AI agents make Open RAN networks autonomous, intelligent, and future-ready.

USE CASE 1: DYNAMIC SPECTRUM AND INTERFERENCE MITIGATION

Agentic AI continuously senses, decides, and acts to optimize spectrum and minimize interference in real time.



Use case 2: Energy-efficient Open RAN without SLA damage

AI-driven decisions reduce energy consumption while preserving user experience and SLA commitments.

1 INPUTS

- Traffic demand & forecasts
- User KPIs & SLA targets
- Energy metrics (sites, CU/DU)
- Network state & alarms
- Context (time, location, weather)
- Cost & carbon intensity

2 AI AGENT CONTROL LOOP

1 OBSERVE
Collect telemetry, KPIs, energy and context

2 ANALYZE
Detect low-load periods and optimization opportunities

3 DECIDE
Choose actions that minimize energy while preserving SLAs

4 ACT
Execute policies via RIC xApps / rApps

3 OBJECTIVES & GUARANTEES

Minimize Energy Use
Reduce site and compute energy consumption

SLA Preservation
Maintain latency, throughput, and availability

Cost & Carbon Efficiency
Lower OPEX and carbon footprint

Fair & Reliable Service
No degradation for critical or high-priority users

4 EXECUTION IN OPEN RAN

Policy & Action Translation
Convert decisions to enforceable policies

→ **RIC xApps / rApps**
Implement energy-saving and performance policies

→ **Control & Orchestration**
E2 interface to Near-RT RIC
AI policy to Non-RT RIC

→ **RAN Infrastructure**
Apply actions on O-CU, O-DU and O-RU

5 OUTCOMES

- Lower energy consumption
- SLA targets maintained
- Lower OPEX and carbon
- Improved sustainability

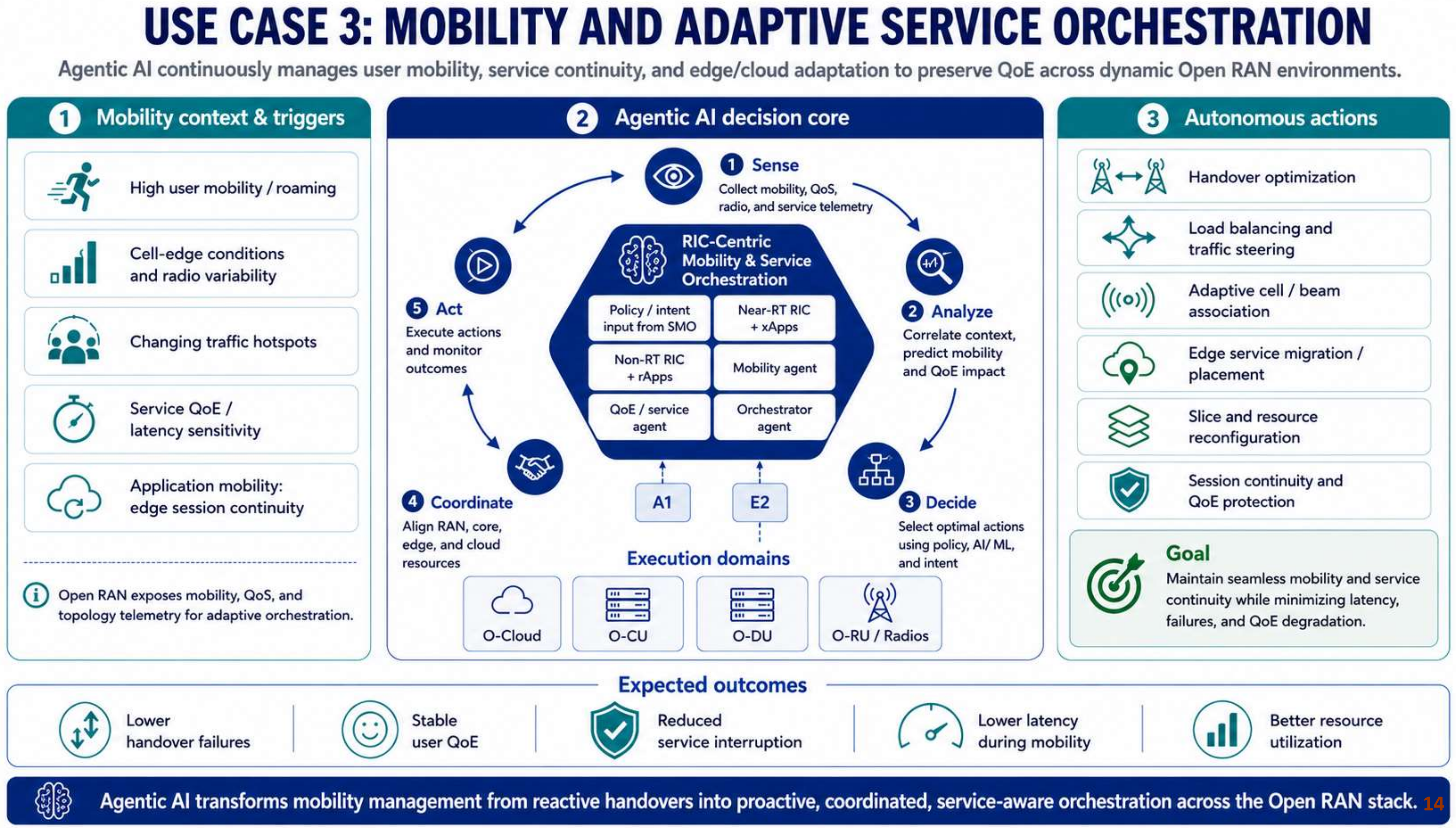
6 EXPECTED IMPACT

20–40%
Energy Savings

SLA TARGETS
Latency / Throughput / Availability

10–25%
OPEX Reduction

LOWER CO_2
Carbon Footprint


USE CASE 3: MOBILITY AND ADAPTIVE SERVICE ORCHESTRATION
Agentic AI continuously manages user mobility, service continuity, and edge/cloud adaptation to preserve QoE across dynamic Open RAN environments.
1 Mobility context & triggers
High user mobility / roaming
Cell-edge conditions and radio variability
Changing traffic hotspots
Service QoE / latency sensitivity
Application mobility: edge session continuity
Open RAN exposes mobility, QoS, and topology telemetry for adaptive orchestration.
2 Agentic AI decision core
1 Sense
Collect mobility, QoS, radio, and service telemetry
2 Analyze
Correlate context, predict mobility and QoE impact
3 Decide
Select optimal actions using policy, AI/ ML, and intent
4 Coordinate
Align RAN, core, edge, and cloud resources
5 Act
Execute actions and monitor outcomes
RIC-Centric Mobility & Service Orchestration
Policy / intent input from SMO
Near-RT RIC + xApps
Non-RT RIC + rApps
Mobility agent
QoE / service agent
Orchestrator agent
A1
E2
Execution domains
O-Cloud
O-CU
O-DU
O-RU / Radios
3 Autonomous actions
Handover optimization
Load balancing and traffic steering
Adaptive cell / beam association
Edge service migration / placement
Slice and resource reconfiguration
Session continuity and QoE protection
Goal
Maintain seamless mobility and service continuity while minimizing latency, failures, and QoE degradation.
Expected outcomes
Lower handover failures
Stable user QoE
Reduced service interruption
Lower latency during mobility
Better resource utilization
Agentic AI transforms mobility management from reactive handovers into proactive, coordinated, service-aware orchestration across the Open RAN stack.

Use case 4: Self-healing and predictive fault management

AI agents predict, detect, localize and heal faults automatically to maximize availability and reliability.

1 INPUTS

Telemetry & KPIs
Performance, alarms, logs

Events & Notifications
RAN, transport, core

Topology & Inventory
Sites, nodes, links, configs

Historical Fault Data
Incidents, RCA, resolutions

Context
Traffic load, weather, mobility

2 AI AGENT CONTROL LOOP

1 OBSERVE
Collect and correlate telemetry, alarms and events

2 ANALYZE
Detect anomalies, predict faults and estimate impact

3 DECIDE
Infer root cause and select optimal healing actions

4 ACT
Execute remediation via RIC xApps / rApps and automation

3 OBJECTIVES & GUARANTEES

Maximize Availability
Proactive detection and fast recovery

Minimize Downtime
Reduce MTTR and service disruption

Service Quality Assurance
Maintain SLAs and user experience

Automation & Efficiency
Closed-loop automation with human-in-the-loop

4 EXECUTION IN OPEN RAN

Fault Insight & RCA
AI models provide root cause and impact analysis

→ **Policy & Action Translation**
Convert decisions to enforceable policies

→ **RIC xApps / rApps**
Implement healing actions and configuration updates

→ **Control & Orchestration**
E2 interface to Near-RT RIC, A1 policy to Non-RT RIC

→ **RAN Infrastructure**
Apply changes on O-CU, O-DU and O-RU

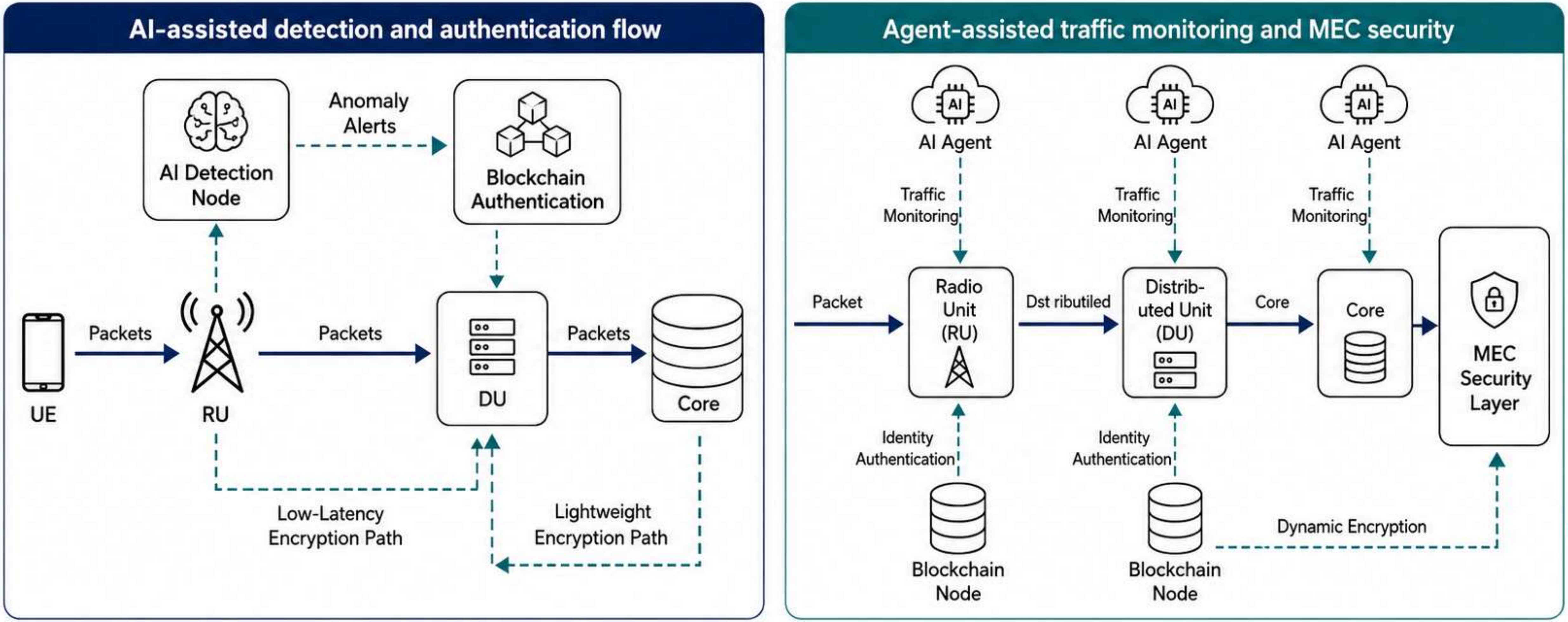
5 OUTCOMES

- Higher availability & reliability
- Faster fault detection & recovery
- Reduced MTTR and impact
- Lower OPEX and truck rolls
- Continuous learning & improvement

6 EXPECTED IMPACT

30–60% Faster Fault Detection	**40–70%** Reduction in MTTR	**99.99%+** Target Availability	**20–40%** Lower OPEX	**Lower CO_2** Reduced Operational Footprint

Flow of the Proposed ORAN-uRLLC Platform

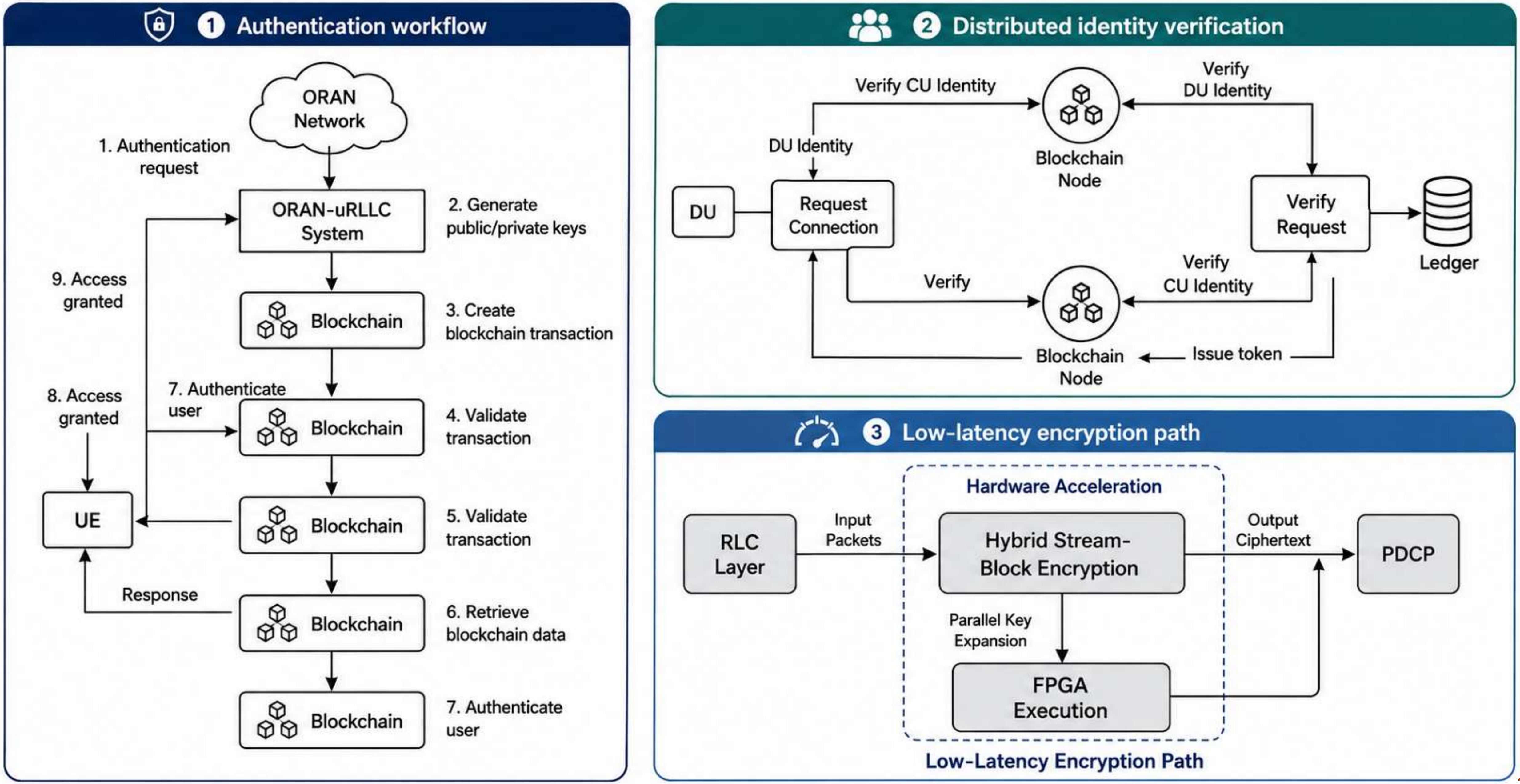


Main Traffic Flow
(Packets / Data Flow)

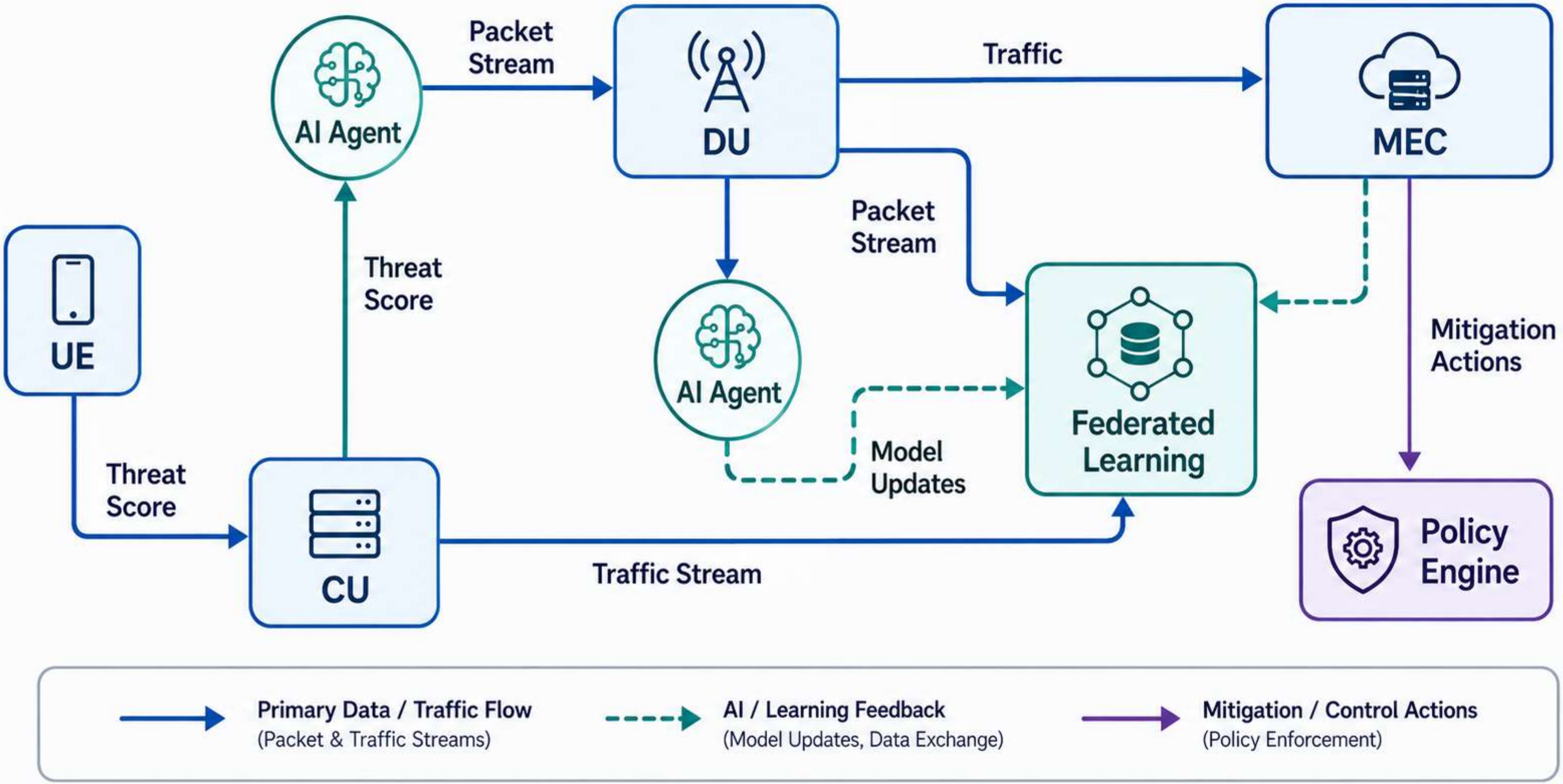
Monitoring / Authentication Paths
(Traffic Monitoring, Identity Authentication, Alerts)

Encryption Paths
(Low-Latency, Lightweight, Dynamic Encryption)

Blockchain Authentication Flow in the ORAN-uRLLC Platform



Proposed AI Threat Detection and Response Loop



HOW TO EVALUATE AGENTIC OPEN RAN

A multi-dimensional framework to assess performance, autonomy, trust, and operational impact

1 Evaluation pillars

- Network performance
- Autonomy & closed-loop behavior
- Intelligence quality
- Trustworthiness & safety
- Efficiency & sustainability
- Interoperability & scalability

Evaluation must go beyond throughput and latency.

2 What to measure

Agentic Open RAN Evaluation

A) Network performance
- throughput / spectral efficiency
- latency / jitter
- packet loss / reliability
- QoE / SLA attainment

B) Autonomy
- decision latency
- % automated actions
- closed-loop success rate
- human intervention rate

C) Intelligence quality
- prediction accuracy
- policy effectiveness
- adaptation speed
- reasoning quality / plan validity

D) Trust & safety
- policy compliance
- guardrail violations
- explainability / auditability
- rollback or safety-trigger rate

E) Efficiency
- energy savings
- OPEX reduction
- compute overhead
- carbon impact

F) Scale & openness
- multi-vendor interoperability
- xApp/rApp coordination quality
- scalability with users/cells
- portability across deployments

3 How to evaluate

Offline testing
(simulation, digital twin, replay)

↓

Sandboxed validation
(policy checks, what-if analysis)

↓

Live trial / A-B testing

↓

Continuous monitoring in operation

↓

Feedback for learning and improvement

Representative scenarios
- spectrum & interference control
- energy-aware operation
- mobility orchestration
- self-healing and fault management

Key outputs

- Technical KPI gains
- Safe autonomy score
- Trust / compliance score
- Cost & energy impact
- Deployment readiness

Key idea: Agentic Open RAN should be evaluated across performance, autonomy, intelligence, trustworthiness, and operational value — not by network KPIS alone.

How to evaluate agentic Open RAN

Move beyond single-model accuracy toward closed-loop network outcomes

Radio KPIs	SINR, throughput, latency, handover success, PRB utilization
Autonomy KPIs	goal completion, conflict rate, rollback rate, recovery time
Trust KPIs	explainability, policy violations, audit coverage, model drift
Efficiency KPIs	energy per bit, compute overhead, signaling overhead, cost
Resilience KPIs	fault recovery, adversarial robustness, service continuity

Suggested experimental loop

Scenario generation → digital twin validation → near-RT emulation → field canary → operational audit

Evaluation should cover radio performance, autonomy, trust, efficiency, and resilience.

Collaborating Organizations

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DEPLOYMENT ROADMAP

A pragmatic path from AI-assisted Open RAN to agentic autonomy

Standards-aligned view across ITU / ITU-T, 3GPP, ETSI, O-RAN, and our recommended framework

1 Phase 1: Foundation & observability — telemetry, KPIs, data quality, policy baseline

2 Phase 2: AI-assisted decisions — recommendations, analytics, what-if evaluation

3 Phase 3: Bounded closed loops — guardrailed automation for limited use cases

4 Phase 4: Collaborative agents — multi-agent coordination across RIC, cloud, and SMO

5 Phase 5: Trusted agentic autonomy — goal-driven orchestration with governance and assurance

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
ITU / ITU-T	IMT-2030 vision, intelligence by design	Autonomous-network architecture concepts	Y.3061-style closed-loop autonomy	FG-AINN / AI-native network evolution	AI-native, trustworthy autonomous networks
3GPP	5GS observability, NWDAF / MDA foundations	AI/ML management support	Rel-18 NG-RAN AI/ML for energy, mobility, load	Intent, lifecycle, and cross-domain AI/ML management	Scalable autonomous optimization in 5G-Advanced / beyond
ETSI	ZSM reference architecture	Policy-driven automation and service assurance	Intent-driven closed loops	Zero-touch multi-domain orchestration	Network digital twins + trusted zero-touch autonomy
O-RAN	SMO, O-Cloud, open interfaces	Non-RT RIC with rApps	Near-RT RIC with xApps, A1/E2 policy control	RIC-centric multi-agent coordination	Agent-augmented SMO + RIC ecosystem
Recommended for our framework	Build telemetry lake, KPI model, governance baseline	Deploy advisory agents and decision-support dashboards	Automate one use case first: energy or mobility	Add collaborative agents for spectrum, fault, mobility, orchestration	Enable trustworthy autonomy with guardrails, audit, HITL, rollback

Key principles

- Start with bounded autonomy
- Validate in a digital twin first
- Keep human-in-the-loop for high-risk actions
- Use policy guardrails and rollback
- Scale from single-use-case to multi-agent autonomy

Key message: a practical roadmap to agentic Open RAN is standards-aligned, incremental, validated, and trust-centered.

RESEARCH AND STANDARDIZATION AGENDA

What ITU-oriented work can contribute to agentic Open RAN

Aligning research priorities with ITU / ITU-T, 3GPP, ETSI, and O-RAN evolution

1 Priority research themes

Multi-agent RAN control
coordination among RIC, SMO, cloud, and radio functions.

Intent and knowledge plane
goals, policies, digital twins, knowledge sharing.

Trustworthy autonomy
safety, explainability, auditability, human oversight.

Learning + reasoning
combine ML, model-based reasoning, and planning.

Digital twins and validation
offline testing, what-if analysis, replay, sandboxing.

Sustainability and efficiency
energy-aware control, compute efficiency, carbon impact.

2 ITU-oriented standardization opportunities

ITU-oriented agenda for Agentic Open RAN

A. Terminology and reference models
common definitions for agentic AI, autonomy levels, and control roles.

B. Architecture framework
placement of agents across SMO, Non-RT RIC, Near-RT RIC, cloud, and RAN.

C. Interfaces and information models
intents, policies, context exchange, agent coordination, assurance signals.

D. Trust, governance, and assurance
policy guardrails, HITL, rollback, audit, safety constraints.

E. KPIs, benchmarks, and evaluation
autonomy metrics, trust metrics, resilience, efficiency, service impact.

F. Interoperability and conformance
profiles and guidance across ITU, 3GPP, ETSI, and O-RAN ecosystems.

3 Expected contributions and outputs

1. Technical reports and recommendations
2. Reference architecture and maturity model
3. Evaluation methodology and test scenarios
4. Governance and assurance guidelines
5. Interoperable path toward autonomous Open RAN

Beneficiaries
operators, vendors, academia, regulators, standards bodies

Suggested workstreams

1. Study items — explore needs, gaps, and opportunities. →
2. Requirements — capture functional, non-functional, and assurance needs. →
3. Architecture — define reference models, components, and deployment patterns. →
4. Evaluation framework — metrics, benchmarks, test scenarios, and validation methods. →
5. Implementation guidance — profiles, best practices, conformance, and deployment playbooks.

Key message: ITU-oriented work can provide the concepts, architecture, governance, and evaluation foundations needed to make agentic Open RAN interoperable, trustworthy, and deployment-ready.

ITU ALIGNMENT STRENGTHENS THE VISION

IMT-2030 emphasizes intelligence, sustainability, security, and resilience.

Why ITU alignment matters

- Common vision for IMT-2030
- Global interoperability
- Trusted autonomy principles
- Guidance for future Open RAN evolution

1 Intelligence

- AI-native operation
- Closed-loop optimization
- Context-aware automation
- Support for autonomous and adaptive networks

2 Sustainability

- Energy efficiency
- Resource optimization
- Lower carbon impact
- Responsible network growth

IMT-2030 Vision

ITU-aligned foundation for future Open RAN and 6G

3 Security

- Secure by design
- Policy enforcement
- Trustworthy control
- Protection of data, models, and interfaces

4 Resilience

- Fault tolerance
- Self-healing behavior
- Service continuity
- Rapid recovery from disruptions

Implication for Agentic Open RAN

Aligning agentic Open RAN with IMT-2030 helps ensure that autonomy is intelligent, sustainable, secure, and resilient by design.

From vision to architecture

- RIC intelligence
- Cross-domain orchestration
- Governance and assurance
- 6G-era service innovation

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Thank You

FOR YOUR ATTENTION

Together, we shape the future of **intelligent, autonomous** and sustainable **6G** networks.

INNOVATE with Purpose

COLLABORATE with Impact

AUTOMATE with Intelligence

SUSTAIN for Tomorrow

SELECTED SOURCES

- ITU, "IMT-2030: Technical requirements for the 6G future," 17 Mar 2026.
- ITU-R IMT-2030 Framework / Recommendation M.2160 and IMT-2030 website.
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- O-RAN Alliance Security Working Group, AI/ML security across SMO, RIC, rApps and xApps, 2024.
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