### **FIJISHI**

# Unlocking Intelligent Surface Control Through Advanced Data Architecture.

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## 1. Introduction: Reconfigurable Intelligent Surfaces - The Physical Layer Game Changer

Reconfigurable Intelligent Surfaces (RIS) represent a fundamental shift in how we design and control wireless environments. Moving beyond traditional network architectures that passively react to the channel, RIS panels, composed of numerous low-cost, programmable elements, offer the ability to actively and intelligently manipulate radio waves. By precisely controlling how signals are reflected, refracted, or absorbed, RIS can optimize signal propagation, extend coverage, boost capacity, reduce interference, and improve energy efficiency in ways previously unimaginable.

Poised to be a cornerstone technology for 6G and beyond, RIS can transform passive, uncontrollable wireless channels into a programmable platform. Potential applications span enhanced mobile broadband, precise localization and tracking for industrial automation and autonomous systems, and creating "smart" radio environments that adapt dynamically to user needs and environmental changes.

The physical realization of RIS panels, with their thousands or even millions of reflecting elements, is rapidly advancing. However, the true intelligence and transformative potential of RIS are bottlenecked not just by hardware capabilities, but critically, by the ability to effectively manage and utilize the complex data required for their real-time, optimal control.

#### 2. The Hidden Bottleneck: Data Fragmentation in RIS Networks

Optimal RIS performance is intrinsically linked to accurate, real-time information about the wireless environment and the network state. Each decision to configure an RIS element relies on data. The challenge lies in the sheer volume, velocity, and heterogeneity of this necessary data:

- Channel State Information (CSI): Precisely knowing the channel conditions between transmitting sources, the RIS panel, and receiving destinations is paramount but difficult to acquire, especially for passive RIS elements.
- **RIS Configuration State:** The current state and capabilities of potentially thousands or millions of individual reflecting elements on a surface.
- **Network Context:** Data on user locations, mobility patterns, traffic demands, interference sources, and the state of nearby base stations and other RIS.
- Environmental Data: Information that might affect propagation (e.g., weather, physical obstructions, temporal changes).
- **Control Feedback:** Performance metrics used to refine RIS optimization algorithms.

This data originates from disparate sources: base stations, user devices, dedicated channel sounders, other RIS panels, network controllers, and external databases. Like many rapidly evolving technical domains, the RIS ecosystem is plagued by fragmentation:

• **Diverse RIS Implementations:** Different vendors use varying hardware designs, control interfaces, and data formats for reporting RIS states and accepting commands.

- **Siloed Network Data:** CSI, user data, and network state information reside in separate systems, often without seamless integration with RIS controllers.
- Lack of Standardized RIS Data Models: There is a nascent but not universally adopted framework for describing RIS capabilities, configurations, and the associated channel data in a unified way.
- **Dynamic Nature:** The data required for RIS optimization changes rapidly due to user mobility and environmental fluctuations, demanding real-time data pipelines and processing, which monolithic or disconnected systems struggle to provide.

This data fragmentation creates a significant bottleneck for intelligent RIS control. Without a unified, accessible view of the necessary data, real-time optimization becomes incredibly complex or impossible. Training effective AI/ML models for predictive RIS control is hampered by disparate datasets. Coordinating multiple RIS panels or integrating RIS control with broader network management becomes a daunting task. The inherent value of RIS is diminished when its control is blind or delayed due because its supporting data is scattered and incompatible.

#### 3. Fijishi Aeterna: Proven Architecture for Complex, Dynamic Data

Solving the RIS data fragmentation challenge requires a robust, flexible, and intelligent data architecture capable of handling massive volumes of diverse, dynamic information from disparate sources. While initially developed to master the extreme complexity and fragmentation of biological data – integrating everything from genomic sequences and protein structures to experimental results and clinical trial outcomes – Fijishi Aeterna's core architectural principles are remarkably well-suited to the challenges presented by RIS data.

Aeterna is designed as a central nervous system for data, built on foundations that prioritize connectivity, standardization, and accessibility:

- **High-Throughput Data Ingestion:** Capable of integrating diverse data streams, regardless of their original format or source.
- Semantic Metadata and Ontology: Providing a universal language and structure to data, enabling disparate datasets to be understood, linked, and queried based on their meaning.
- **Open Standards and Interoperability:** Designed from the ground up to avoid vendor lock-in, facilitating data exchange and integration across different systems and tools.
- Adherence to FAIR Principles: Making data Findable, Accessible, Interoperable, and Reusable – essential for both real-time control and longterm AI training.
- Scalable and Flexible Architecture: Built to handle the growth in data volume and variety as RIS networks scale.

This proven capability in bringing order and intelligence to chaotic biological datasets positions Aeterna as a powerful solution for managing the equally, if not more, challenging data environment of RIS.

#### 4. Aeterna for RIS: Enabling Data Fluency for Intelligent Control

Applying the Aeterna architecture to the RIS data challenge provides the necessary foundation for overcoming fragmentation and enabling truly intelligent RIS control:

- Unified Data Fabric: Aeterna ingests and integrates all relevant RIS data CSI reports from base stations/UEs, RIS panel states, network context, etc. into a single, interconnected fabric.
- **Contextualized Data:** Using its metadata and ontology services, Aeterna links data points meaningfully. A CSI measurement is linked to the specific RIS panel, user, and time it corresponds to. An RIS configuration state is linked to the optimization objective it aimed to achieve. This creates a 'digital twin' of the RIS network's state and environment.
- Enabling Data Fluency for Control Loops: RIS optimization algorithms and AI-driven controllers require immediate, standardized access to correlated CSI, network state, and performance data. Aeterna provides this "data fluency," eliminating delays and errors caused by data silos and format incompatibilities, enabling real-time, adaptive RIS configuration.
- Accelerating AI for RIS Optimization: Training sophisticated AI models to predict optimal RIS configurations based on limited CSI or changing conditions demands vast amounts of high-quality, integrated data. Aeterna provides the ideal platform to prepare and serve these datasets, significantly accelerating the development and deployment of autonomous RIS control.
- **Promoting Interoperability:** By standardizing RIS data access and representation based on open principles, Aeterna enables different RIS control plane software, analytics tools, and panels from various vendors to interact seamlessly through a common data layer.

#### 5. Accelerating the RIS Revolution: A Data-Driven Future

Adopting a robust data architecture like Fijishi Aeterna is a strategic imperative for realizing the full potential of RIS. By transforming scattered, incompatible RIS data into a connected, fluent, and intelligent resource, Aeterna empowers:

- **Optimal RIS Performance:** Real-time, data-driven control maximizes the signal manipulation capabilities of RIS.
- **Rapid Innovation:** Researchers and engineers can develop and test advanced RIS algorithms faster with readily available, integrated data.
- Scalable Deployment: A standardized data layer simplifies the integration of new RIS panels and scaling of RIS networks.
- **Vendor Independence:** Reduces reliance on proprietary data formats and control interfaces.
- **New Capabilities:** Enables sophisticated, context-aware applications leveraging intelligent RIS control.

#### 6. Conclusion

Reconfigurable Intelligent Surfaces hold the potential to revolutionize wireless communications. However, the path to unlocking this potential is currently hindered by the critical challenge of managing the complex, fragmented data landscape associated with their control and operation. Fijishi Aeterna, with its proven architecture for handling diverse, dynamic, and siloed data ecosystems, offers a compelling solution. By establishing data fluency, standardization, and connectivity for RIS data, Aeterna provides the essential foundation for intelligent, real-time RIS control, accelerating their deployment and paving the way for a truly programmable wireless future.

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