Introducing a Framework for a Vendor-Agnostic 5G Network Data Space

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***Abstract*—This paper proposes a 5G network data space targeting the collection, storing, and sharing of metrics generated by 5G infrastructure, such as latency, throughput, and network slice performance, for universal access by applications. The primary challenge is standardizing these metrics across commercial vendors (e.g., Nokia, Ericsson, Huawei, Samsung) and open-source implementations to ensure interoperability in a decentralized ecosystem. Current approaches, such as NWDAF, O-RAN, and Gaia-X, face this interoperability challenge but remain limited in scope. We present a vendor-agnostic framework that supports multiple metric-gathering methods, including standardized mechanisms, and proprietary telemetry protocols, to enable cooperative data collection The paper includes a detailed architecture which is organized into four layers—Data Collection, Standardization, Data Management, and Application Interface, providing solutions to vendor heterogeneity, fostering scalable, secure, and interoperable data sharing for advanced applications and services. This work is a conceptual and architectural foundation, that outlines the main directions for such a future 5G Dataspace, with validation and prototyping left to subsequent research.**

***Index Terms*—5G,6G, dataspace, monitoring,**

I. Introduction

The introduction of fifth-generation (5G) wireless networks represents a huge leap in telecommunications, delivering ultra-low latency, high bandwidth, and massive device connectivity that redefine industrial and societal applications. Unlike 4G, which primarily enhanced mobile broadband, 5G Standalone (SA) deployments, powered by a cloud-native 5G Core, allow for even more capabilities. These include mission-critical communication and automation (MCC) augmented/virtual/extended reality (AR/VR/XR), industrial Internet of Things (IoT), and artificial intelligence (AI)-enhanced applications, allowing for innovative applications such as smart factories, autonomous vehicles, and immersive digital experiences all of these further enhanced by slicing which allows further refinement in the handling of such use case (1) (2).

These 5G networks however are being deployed by multiple vendors and operators, with each one diverging from the standard architecture and creating custom methodology and tools that can be used to harness and manage them. (1).

As a result, the generated telemetry data may be inconsistent both in data modelling, variety and quality which brings a disadvantage to monitoring such networks or using such generated data for applications like Artificial Intelligence (AI) -driven optimization strategies. Furthermore the non standard metric representation, makes cross-vendor operability even more challenging and the ability to aggregate data for predictive maintenance or real-time decision-making.

The many facets of data representation and data access methods for 5G performance metrics instead of a more unified way to either data models or even common way to access these metrics pose a critical barrier to realizing the full potential of 5G ecosystems. It is difficult to compare network performance across different vendors deployments because of such different telemetry procedures which also hinders AI driven anomaly detection across such networks or even integrating these different systems in a single framework.

The heterogeneity in vendor approaches impacts advanced 5G applications, like Advanced Monitoring, AI/ML enabled applications Digital Twins (DT) and Security in 5G networks.

The above show the need for creating a 5G network data space, an organized environment where 5G data exists and can be accessed and processed. aiming to harness these metrics. Unlike data spaces that use 5G as a transport layer, this framework focuses on data produced by the network infrastructure itself, such as base stations (gNodeBs), core networks, and edge nodes aiming to enhance the functionality of the 5G network itself.

The motivation for such a data space lies in its potential to unlock significant value for the above mentioned advanced use case. However, a critical barrier to realizing this vision is the lack of standardization across the various solutions either open source or commercial which complicates the development of a cohesive data space, as applications must navigate vendor-specific systems to access and interpret metrics. By establishing common formats and protocols, a 5G network data space can support such advanced cases, s while ensuring compliance with regulations like GDPR (3). This paper explores the design of such a framework.

Our goal in this paper is to outline the vision and framework of a 5G Network Dataspace, identifying the key layers and processes required to enable standardization, sovereignty, and interoperability. Practical validation and prototyping are reserved for future work.

The rest of this paper is structured as follows: Section II reviews related work on data spaces, 3GPP standards, and existing 5G monitoring solutions. Section III focuses on 5G architecture, service-based architectures, advanced 5G services, and current open-source and commercial 5G implementations. Section IV presents the proposed 5G dataspace architecture, detailing a four-layer framework. Section V concludes with a summary of the proposed approach and its potential impact on 5G networks, either commercial, private or research oriented in the context of efficient data sharing.

II. Literature Review

Data spaces are digital ecosystems where organizations can work together in the context of sharing data without giving up ownership. Each participant retains control and sets policies about who can access their data and how it can be used. A vital element in such architectures is the concept of "connectors" that allow enforce access control, contract rules, and data transfers. Data spaces are already helping sectors like healthcare, manufacturing, mobility, and smart cities share insights while keeping data private and governance intact.

The idea of data spaces has been getting a lot of attention lately, especially in Europe, where various projects are setting the foundations for such data sharing among different organizations. Gaia-X (4) focuses on making sure organizations keep control over their own data (data sovereignty) and that everything is interoperable. Its reference architecture could be really useful when dealing with 5G network data. Another one, IDSA (5) offers a reference architecture incorporating ideas like the Data Connector and governance models to facilitate multiple vendor systems are involved.

There is also work being done in this direction by FIWARE (6) who focuses on building smart solutions that gather data from many different sources, like IoT devices for services like weather forecast for example, and aim to develop a framework for this kind of data sharing.

The authors in (7) work on data sovereignty and among others also analyze those approaches.

The 3rd Generation Partnership Project (3GPP) (8) is the primary standards body defining 5G specifications, providing frameworks for performance measurements (TS 28.552) (9) specifying metrics like end-to-end latency and throughput, as well as configuration parameters. However, while 3GPP provides a common baseline, vendors implement these standards with proprietary and different approaches.

The Network Data Analytics Function (NWDAF) (10), introduced in 3GPP Release 15 and enhanced in Releases 16 and 17, is 5G core component which collects, analyzes, and exposes network data possible making it a useful tool for a 5G network data space. NWDAF uses standardized interfaces (e.g., Nnwdaf, Ndccf) to gather metrics like latency, throughput, and network slice performance from the various part that constitute a 5G network and with the Network Exposure Function (NEF) enables third-party access via APIs.

Open Radio Access Network (Open RAN), is led by the the O-RAN Alliance initiative, and aims to disaggregate RAN components promoting interoperability and vendor neutrality (11). This is achieved by the introduction of standardized interfaces, such as the RAN Intelligent Controller (RIC) and E2 interface which enable real-time control and monitoring across multi-vendor equipment. However, while Open RAN adoption is advancing, not all vendors are supporting or prioritizing it.

The CAMARA Project, a Linux Foundation initiative in collaboration with GSMA, focuses on standardizing APIs for Mobile Network Operators (MNOs) which would enhance interoperability across them (12). CAMARA provides a framework for vendor-agnostic APIs to be used be external parties and mainly focuses on application-layer APIs.

III. 5G and 5G services

A. 5G architecture

The 5G network mainly consists of two parts: the Radio Access Network (RAN) and the core network (5GCore) (13). The gNodeB (gNB) is the base station which handles radio communications, while the 5GC manages control, session, and user plane functions. These 5G services communicate with each other to deliver to the end user all the performance advantages promised by 5G. Integrating 5G components from different vendors has been a major focus point in telecommunications both research and production-wise, because of 5G's Service-Based Architecture (SBA) and the need for interoperable systems among different vendors. The 3GPP defines the 5GC's SBA, where Network Functions (NFs) communicate via HTTP based Service Based Interfaces (SBIs), allowing services synchronization. (13).

- **gNB**: Handles Radio Access Network (RAN) via RRC Radio Resource Control (RRC) and NG Application Protocol (NGAP) , managing User Equipment (UE) connections and radio resources.
- **Core**: 5G networks introduced Control and User Plane Separation (CUPS) as a key architectural concept in by separating Control Plane (CP) functionality like registration, session management, billing etc) and User plane functionality like user data traffic. This is implemented in the 5G Core.

A high level description of 5G architecture can be seen in Fig:1 (14)

1) Service-Based Architecture (SBA) in 5G Networks: As mentioned above, the in 5G a new architecture model was introduced, SBA which replaces the traditional monolithic single application implementations with a microservices cloud-native, API-driven approach. Unlike legacy networks which relied on various and many times proprietary interfaces, the 5G Core network functions interact via well defined, standard RESTful APIs, enhancing flexibility, automation, and scalability (15) (16).

2) Key Concepts of SBA:

- **Network Functions (NFs):** Each task of the network is handled by a specific function implementation developed

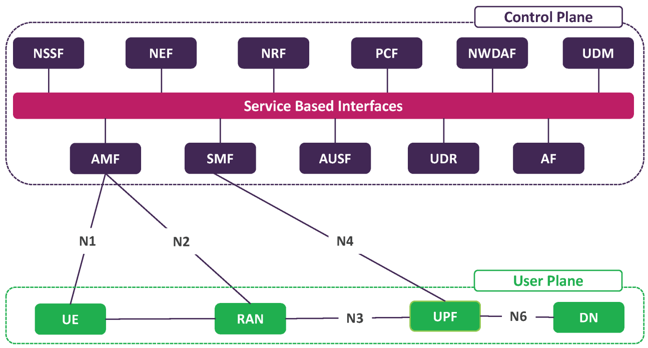

Fig. 1. 5G SBA architecture

for this purpose. This includes for example the Authentication Management Function (AMF) for authenticating users or Session Management Function (SMF) for handling the user sessions. Each NF is implemented as a different service.

- **Service Interfaces:** These NFs need to exchange data between them and possibly with external actors as well. This communication is achieved via defined REST-APIS.
- **Service Discovery and Registration:** In 5G networks it is possible for such NFs to be deployed or modified during run time for better service delivery. To achieve this, SBA architecture allows for dynamically discovery and registering of such services, which might be located in another physical area and connected to the main core.
- **Centralized Control and Management:** According to cloud native philosophy all the NFs that constitute a 5G network need to be managed by a central component for lifecycle, like deployment, scaling, and monitoring.

3) Advantages of SBA: With SBA the performance of modern telecommunications networks is improved since the deployment of new advanced network functions is done through REST APIs allowing faster integration of such new services to existing systems. SBA also allows for dynamically adding, modifying, or scaling existing or new functions to mirror changes in operational requirements. SBA with the cloud native architecture makes the automation of such networks easier and faster while the allocated resources can be modified on demand allowing for better and more efficient resource allocation. Third party applications can also be integrated in such networks with this approach for faster development and evaluation of solutions and . The CUPS approach on the other hand provides a clear separation between control and data planes allowing for better network management and simplifying operations on a system level.

B. 5G advanced services

The idea of data spaces and sharing 5G data among interested parties can be an efficiency multiplier for various services deployed for 5G networks:

- **Real Time Monitoring**: Real-time monitoring requires consistent Key Performance Indicators (KPIs) across vendors to track QoS and detect anomalies. The authors in (17) comment on the various KPIs that can be gathered in a 5G system.
- **AI/ML**: Machine learning models for traffic prediction or resource optimization rely on standardized, high-granularity data. Semantic differences in KPIs (e.g., “latency” definitions) reduce model accuracy or even applicability. The authors in (18) use the Network Data Analytics Function (NWDAF), a vital element of 5G core architecture to overcome this.
- **Digital Twins**: Digital twins simulate network behavior for planning and optimization, requiring synchronized metrics and configurations. The authors in (19) note the different models needed for such solutions.
- **Security**: Security analytics, such as intrusion detection, depend on unified metrics to identify threats especially when the underlying network is not uniform in the deployed components.

C. Existing implementations

Many implementations of gNb and 5G cores are currently available. Some of them are open source more suited for research and development environments where other are commercial solutions aiming production grade services. The following is a non-exhaustive list of the main solution at the moment, while at (20) a more detailed comparison of commercial 5G solutions is presented.

1) Open Source Implementations:

OpenAirInterface (OAI):

5G NR gNB (21) and core network stack (22). The main target of this implementation is for research and prototyping. SDRs are supported for the physical layer and RAN protocols with software-defined radio frontends. OAI uses logging and system tools for performance metrics and network information.

srsRAN: srsRAN (23) offers a 5G NR gNB implementation. This software stack also operating on SDRs uses logging and json formats for radio metrics. These metrics include basic performance values and link statistics.

Free5GC: Free5GC (24) is a 5G core implementation.5G network functions are implemented including AMF, SMF, UPF while a NWDAF implementation is also present. Metrics from both control and user plane are gathered through REST APIs and Prometheus exporters, providing detailed telemetry about session states and network resource usage. The NWDAF module is specifically designed to gather data relevant for AI-driven analytics, serving as a foundational step toward intelligent network operations.

Open5GS: Open5GS(25) offers a modular 5G core implementation. It supports data collection through standardized APIs through the built in Prometheus support enabling basic monitoring of network functions and subscriber sessions.

2) Commercial Implementations:

Ericsson: Ericsson (26) offers both gNB (27) and core network solutions. These implementations offer telemetry that supports both 3GPP standards and ORAN specifications. The data collection mechanism offered gives access to performance counters, events and various systems logs via proprietary APIs, with results being offered in XML format. **Nokia:** Nokia: Nokia (28) also deploys a cloud-native 5G core and gNB implementations that collect network metrics. Nokias' monitoring system is based on gNMI(29) and REST APIs for external access (30) and allows for metric and event gathering leading to better understanding of network status and performance.

Huawei: Huawei (31) also offer gnb and 5G core solutions with integrated data collection mechanisms for its 5G products, including performance monitoring and fault diagnostics.

Cisco: Cisco's 5G (32) core network solutions use open, standardized APIs for data collection enabling network monitoring and automation tools, for efficient network control.

Amarisoft: Amarisoft offers a software-based gNB(33) on commodity hardware with Software Defined Radios (SDRs) (e.g.,USRP N310) and supports 3GPP Release 18 and a 5G Core implementation (34). This setup is used among research entities around the world (35; 36), as it simplifies 5G testing and private network deployment.

IV. 5G Dataspace Architecture

The architecture for our 5G network data space, is illustrated in Figure 2 and show a high level representation of our framework, which aims to enable secure, standardized sharing of network intelligence across multiple stakeholders in the telecommunication This architecture transforms raw network data from heterogeneous 5G infrastructure into actionable insights through a layered approach that ensures data governance, interoperability, and compliance.

A. 5G Network Infrastructure (Data Source)

The basis of the dataspace architecture lies in the presence of multiple of vendors providing 5G equipment around the various infrastructures which serve as the primary source of raw data to be used for network intelligence. This layer includes all the hardware and software elements of such networks either commercial or open source that may generate such metrics.

The infrastructure includes:

- **gNodeB (Base Stations)**: 5G radio access points that connect user equipment to the network and generate radio frequency performance data
- **5G Core Network Functions**: Service-based architecture components (AMF, SMF, UPF, etc.) that provide network control and user plane functionality
- **MEC Nodes**: Multi-access Edge Computing infrastructure for low-latency processing and edge analytics
- **Vendor Diversity**: Equipment from multiple manufacturers (Ericsson, Nokia, Huawei, Samsung, etc.) each with proprietary data formats and interfaces

B. 5G Dataspace Platform

The high level architecture of the 5G data space consists of four stacked layers. Raw network metrics go through each layer to be transformed into consumable meaningful metrics to be used be external parties or applications.

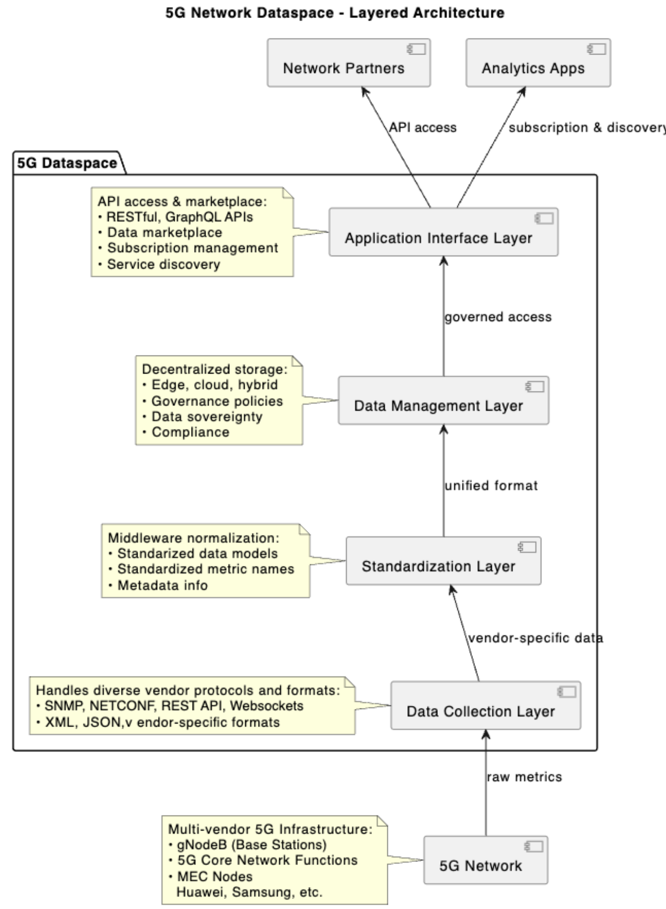

Fig. 2. 5G dataspace framework

1) Data Collection Layer: The Data Collection Layer (DCL) is the initial interface. It connects to the various components of the 5G infrastructure from where metrics are to be gathered. This layer includes collectors for the various types of equipment each satisfying the various protocols, APIs and data formats supported by each implementation.

Key capabilities include:

- **Gathering metrics and data from standardized or proprietary APIs**: If NWDAF or O-RAN interfaces are available they can be used to retrieve metrics.
- **Handles diverse vendor protocols**: SNMP, NETCONF, REST API, WebSockets and other vendor-specific interfaces.
- **Implement, handle and use the various diverse protocols used by the vendors**: SNMP, NETCONF,REST API, WebSockets and other vendor-specific interfaces.
- **Collects raw metrics**:Metrics like performance data, telemetry, operational statistics and even configuration parameters are collected from all 5G infrastructure components
- **Manages multiple data formats**: XML, JSON, and vendor-specific proprietary formats
- **Acts as abstraction layer**: Hides the various vendors-

specific implementations from the upper layers.

2) Standardization Layer: This layer implements the middleware component which has a critical functionality: Here the normalization of the various data formats gathered from the previous layer are transformed and all the gathered data are presented in a single data model that will be understood by the upper layers and eventually by the interesting external actors that want to consume these data.

The standardization process involves:

- **Use standardized data models**: Converts the data collected in vendor-specific schemas and format into a common data model defined by the framework.
- **Standardizes metric names**: A major issue is the different naming across vendors. The data model to be defined will have single entities that represent a specific metric.
- **Provides metadata information**: Can important part for the data creation is the inclusion of metadata, which describe where, how and under what context were these data generated..
- **Enables interoperability**: Uses standards like 3GPP specifications, OpenConfig models, and RDF ontologies.

For basic example, instance, Ericsson exposes metrics via XML, Nokia via while Free5GC through Prometheus exporters, with different names many times. Those two layers would allow harmonization into a common model, ensuring that higher layers and applications consume data in a vendor agnostic standard format.

3) Data Management Layer: The Data Management Layer implements the governance and storage infrastructure as set for dataspaces regarding the sharing of such data, This layer ensures that all gathered data are accessible by the rules set but their owner, following any Role Based Access Control (RBAC) already set and also comply with any regulatory requirements like security. The basis for trust in such a dataspace in defined and provided by this layer. Core functionalities for this layer include:

- **Storage**: Defines if, where and how the gathered data are stored.
- **Enforces governance policies**: Controls data access, usage, and sharing rules based on agreements between data producer, data owner and data consumer while satisfying and regulatory requirements
- **Ensures data sovereignty**: Making sure that the data are owned and managed by their respective owner who provides access to them for the consumers.
- **Manages compliance**: Uses and satisfies industry standards, privacy regulations, and other security frameworks.

4) Application Interface Layer: The Application Interface Layer is the North-Bound Interface (NBI) that allows external interested parties to discover, access, and consume network intelligence data through standardized interfaces. This layer provides the dataspace with external access capabilities transforming it from an internal platform into an system that supports advanced 5G use cases.

The interface layer offers:

- **Provides API access**: Various methods can be used to access the underlying data, RESTful and GraphQL interfaces for programmatic data access would be the major entry points depending on the use case needs.
- **Manages RBAC**: Handles user registration, authentication.
- **Enables service discovery**: External users need to be able to discover the available data sources and subscribe to them. This allows applications to find and connect to relevant data sources through catalog services.

C. External Consumers

The dataspace architecture serves two primary categories of external consumers, each with distinct requirements and use cases.

1) Network Partners: Other mobile network operators seeking to optimize network performance through sharing information and using this shared information for higher efficiency.

Partner categories include:

- Other mobile network operators seeking to optimize network performance through sharing information and using this shared information for higher efficiency.
- Infrastructure (either radio and/or compute) owners who want to monitor and coordinate resource utilization and maintenance activities
- Regulatory bodies requiring network performance data overall monitoring, security and policy development.
- Research institutions conducting studies on networks

2) Analytics Applications: Analytics Applications are data consumers that aim to transform collected network data into results and automated network operations. These applications leverage artificial intelligence, machine learning, and advanced analytics to extract value from the vast amounts of network data available through the dataspace as described above in the advanced use cases for 5G.

Application categories include:

- Advanced monitoring, where network optimization and performance tuning systems can automatically adjust network parameters under certain parameters,
- Predictive maintenance and fault detection applications which use the gathered data to trigger maintenance before a possible failure thus preventing service disruptions
- Capacity planning and resource allocation tools that optimize infrastructure investments
- Quality assurance and SLA monitoring systems that ensure service level compliance

V. Conclusions

The proposed 5G Dataspace architecture will be a multiplier by creating valuable insight through a continuous data flow that transforms raw network telemetry into meaningful data formats. The raw metrics coming from a multi vendor 5G Network infrastructure will flow through the Data Collection Layer, gathered and collected through diverse sources and protocols. At the Standardization Layer these data are normalised into data models that allow analysis and comparison without need of vendor format and access method. At the Data Management Layer all required polices regarding storage, security, access and data sovereignty are applied. Finally the Application Interface Layer provides standardized APIs for NB connectivity allowing external parties to access these data through catalog services. This end- to-end data flow allows data from 5G networks to be shared among multiple actors in a secure, standardized way which can be beneficial to all those participating in such an ecosystem. The architecture ultimately enables new business models, improved operational efficiency, and enhanced service quality through collaborative data sharing and analytics in the 5G ecosystem.

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