

5G Network Management Framework for Improved Customer Experience using Artificial Intelligence and Big data

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Abstract—In the dynamic landscape of wireless communication, 5G technology has revolutionized connectivity, demanding unprecedented efficiency and reliability. To address these demands, artificial intelligence (AI) is leveraged as an active agent in network optimization. AI-driven algorithms, including machine learning and neural networks, are employed, to optimize resource allocation, predict maintenance needs, and enhance network efficiency. The methodology analyses extensive real-world testing and evaluation, demonstrating significant improvements in key performance metrics such as latency, throughput, and spectral efficiency. The research not only exemplifies the efficacy of AI-driven techniques but underscores the pivotal role of responsible AI implementation. Ethical considerations, including data privacy and security, were addressed, to ensure the seamless integration of AI into 5G networks. This paper provides a comprehensive overview of how AI-driven techniques can revolutionize 5G networks, unlocking their full potential for diverse applications while upholding ethical standards. It offers valuable insights for network operators and researchers striving to optimize 5G network performance in the AI era.

Index Terms—5G Networks, AI-Driven Techniques, Network Optimization Machine Learning, and Performance Enhancement.

I. INTRODUCTION

As per several statistics [1, 2], [3], it is projected that by 2050, between 66 and 70 percent of the world's population would reside in urban regions. There is little doubt that the massive increase in urbanization that is now occurring will have a substantial influence on the environment, security, and administration of big cities. In order to develop a practical means of ensuring that the services remain dependable and energy-efficient without compromising people's comfort and happiness, numerous researchers have examined the effects that such urbanization will have on cities, communities, infrastructures, and the environment [4, 5], [6]. Even after being examined from other perspectives by various scholars [7, 8], this research question is still highly debated. Since the implementation strategy is still being developed, a wide range of technologies and skills from several sectors are required at this moment.

The development of smart cities, communities, and buildings has often been seen as an isolated occurrence in the field of technology. This is partially because there are certain limitations with the internet technologies that are

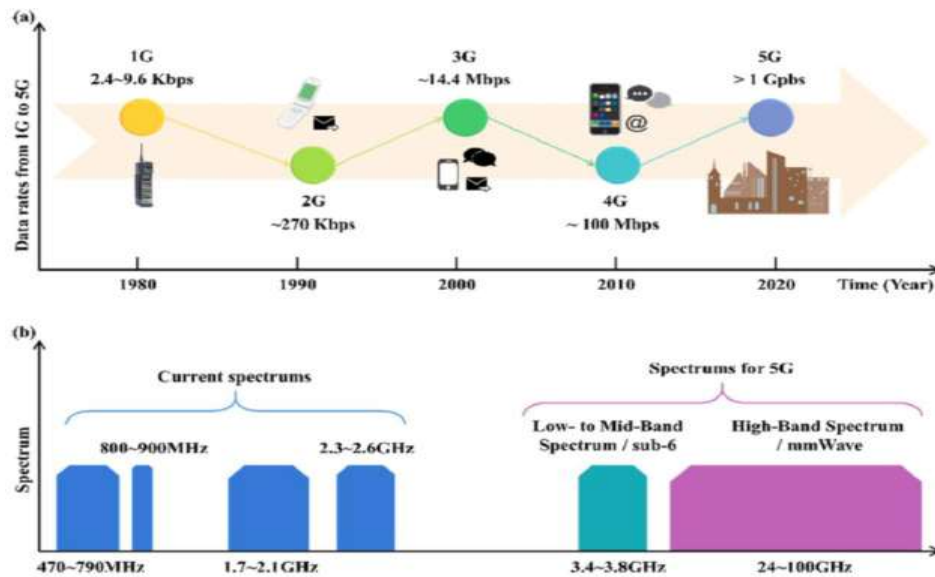


Fig. 1. Development 1G–5G data rates (b) spectrum [9]

now in use, and there are gaps in the seamless connectivity of the sensor networks that have been installed in infrastructures, buildings, and cities [9]. The goal of the 5G technologies is to provide support for a wide variety of vertical applications by linking heterogeneous devices and machines. Significant improvements in high quality of service, increased network capacity, and increased system throughput are the goals of these technologies [10]. The plethora of advantages that come with 5G technology (Figure 1) has cleared up many obstacles that were impeding the development of smart cities, infrastructures, and buildings.

There is ongoing study being conducted by both academics and industry professionals about the advantages of 5G technology. One example is the fact that several firms, like IBM and Intel, have already developed and introduced smart buildings [4]. This exemplifies the competitive advantage that 5G has as well as the bright future that it holds. Considering this, it is critical to comprehend how 5G technology may be effectively used to the creation of smart buildings. This is the case even if a few minor surveys have been conducted (refer to Fig. 2) [11]. This will expedite the process of developing smart buildings and help the development of 5G technologies.

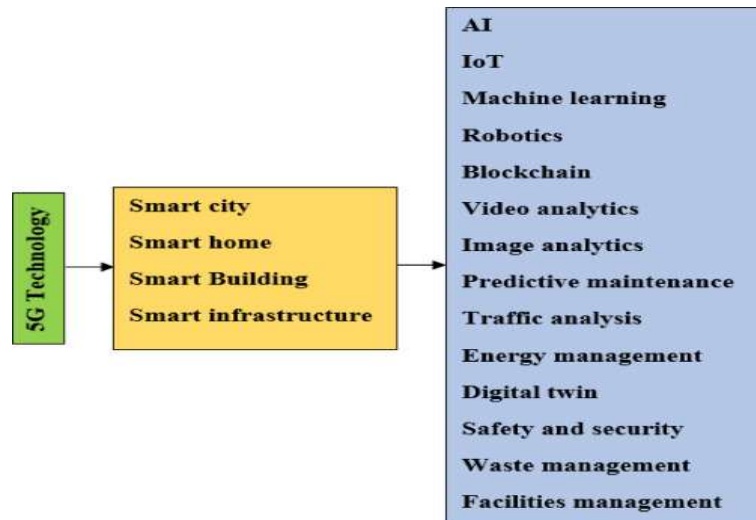


Fig. 2. 5G smart building applications

In addition to this, it may make it possible for various gadgets to collaborate without any problems. Because they generate a significant amount of data, Internet of Things apps are the most crucial part of smart city applications

[12,13]. Selecting the most suitable and successful course of action may be challenging given the vast quantity of available data and the complexity of the information. It is probable that this will assist businesses in making the most optimal choices [14] that are in accordance with their long-term goals [15]. It is possible that this will strengthen their learning capacity and enhance the results of their decision-making.

II. ARTIFICIAL INTELLIGENCE AND SON (AI-SON)

The incorporation of artificial intelligence into the automation of network management processes is required in order to accommodate the dynamic allocation of resources that is characteristic of 5G networks. Taking this into consideration, Self-Organizing Networks (SON) have developed from the conventional manual management procedures in order to fill the void left by automation [16]. Mobile network operators (MNOs) will have to set up wireless communication systems that can handle more use cases, a thousand times as much data, and a trillion linked devices. They will also have to meet tighter performance standards.

Within the body of research that was examined for this part, there are SON models that have been developed with the purpose of effectively integrating AI for big data analytics. These models are designed to handle the increasing traffic that is expected to arise from the MNO's deployment of 5G-RAN.

A. AI-based framework for planning and running a 5G network

Pérez-Romero et al. [17] built a 5G network design and operation infrastructure based on artificial intelligence to support the idea of Self-Organised Networks (SONs) and find and evaluate the 5G ecosystem in a smart way. Building this technology was done to help with the planning and running of the 5G network. In Figure 3, you can see how the framework gets data from its surroundings, processes it, and then sends the right network actions. These steps are meant to help the MNO make choices that are backed up by tools that help with decisions.

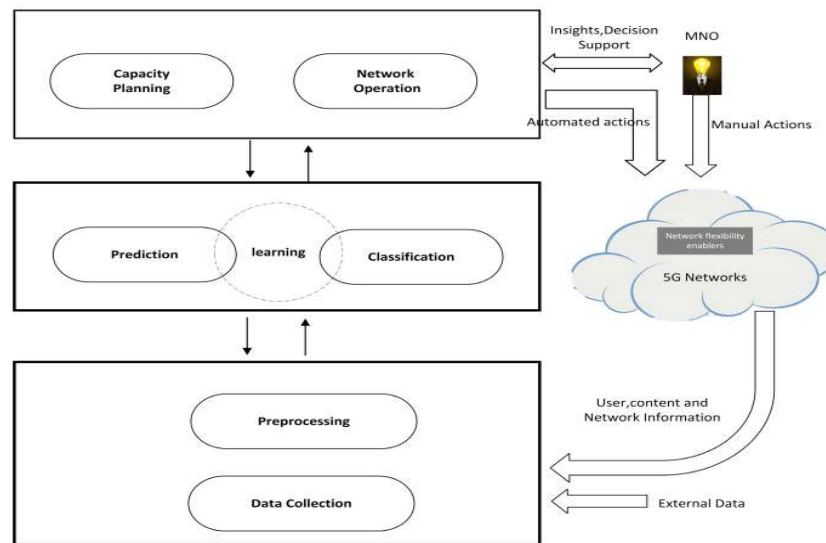


Figure 3. AI-driven planning and running of 5G networks

Mobile network operators (MNOs) use data from a number of different management systems to keep track of their customers, networks, bills, supplies, servers, deep packet inspection devices, and application-specific databases.

To sort the collected data into groups, the behavior of a network is described by its data. This includes radio-related measurements that are recorded by base stations and terminals, statistics on how much data is used at network setups, network routes and nodes, network performance indicators, and quality of service measures. Base stations and terminals are responsible for recording measures that are linked to radio.

- User data consists of subscriber profiles that access the network, demographic information, information on pricing and strategy, devices, subscription capacity, and applications that are used.
- Information pertaining to the apps that are connected to the network, including content data.
- External data consists of information obtained from sources that are not MNOs.

These steps include the integration of data, the selection of data, and the modification of data for specialized mining. The second step of the paradigm involves the use of knowledge discovery in order to draw inferences from the data that has been pre-processed and to develop models that are reflective of the relevant information in order to direct choices about operational and planning matters. [19] The use of acquired knowledge constitutes the third step. The only procedures that are permitted under the framework are those for capacity planning and network operation. The devices that provide network flexibility are engaged in the last stage.. Technologies such as software-defined networking (SDN) and network functions virtualization (NFV) make the AI-based architecture possible. In order to facilitate the implementation of insight choices for the MNOs, the SDN controller will provide assistance in enforcing either automated or manual actions. Multiple tenants are able to share network infrastructure via the use of network function virtualization (NFV), which enables flexibility in the design and architecture of the network.

B. A framework for personalized quality of life based on data

A two-step quality of experience modeling method was used to create a data-dependent approach for better customized quality of experience for 5G networks. [20] Proposed architectural design:

- A monitor that can capture data on user programs and the state of the quality of service in real time is included.
- Features a data mining engine that can predict users' expectations in relation to the application that is being used.
- Maintains an appropriate quality of experience by managing the transmission resources in accordance with the current quality of service condition and the anticipated demand.

A per-user, per-service paradigm is being used. [21] With regard to this paradigm, the Subjective Data Collector (SDC) is one of its components. The mobile agent that is placed on end-user devices for the purpose of monitoring quality of service (QoS), contextual monitoring, and experience monitoring is the most critical component of the data collecting component, as illustrated in Figure 4. This component is put on the devices in order to gather data.

- The QoS monitoring unit gathers information on a range of technical specifications.
- The person in charge of contextual tracking is in charge of getting the application's context information, which includes the device's location, movement, and sensing data.

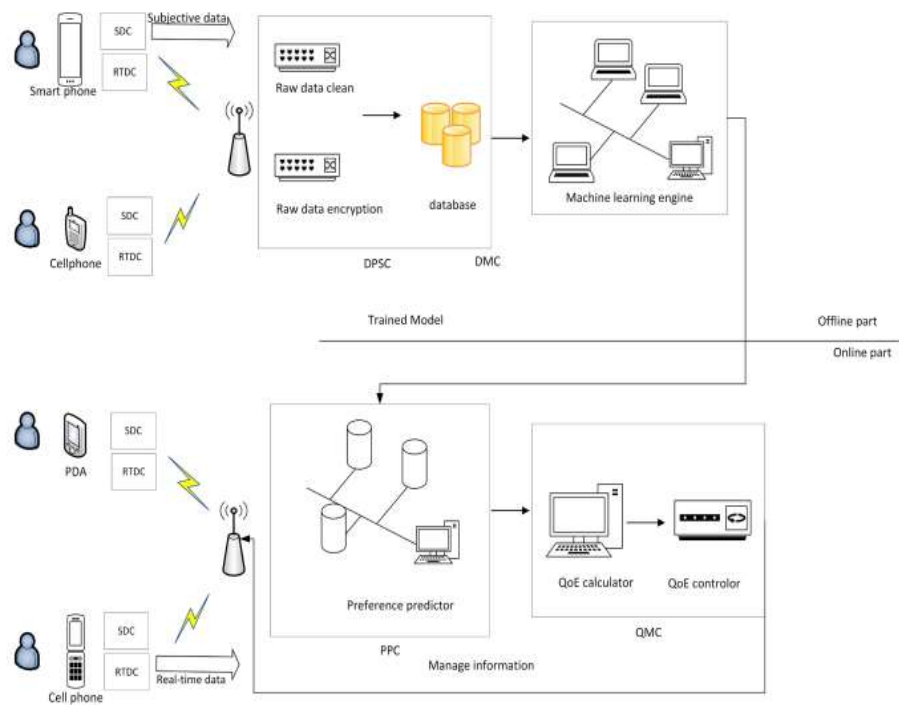


Figure 4. Data-driven personal QoE architecture

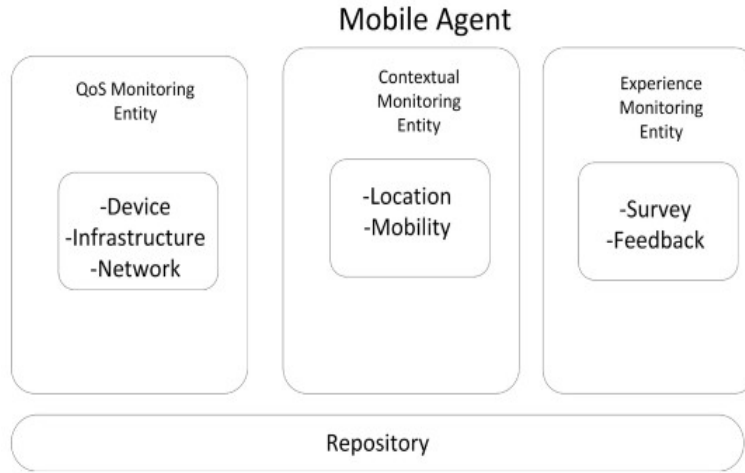


Figure 5. Mobile agent structure

- As a means of communication with users, the organization responsible for monitoring the experience collects explicit input via the use of questionnaires. Preparing data for mining purposes before saving it in databases is the primary duty of the DPSC. The Data Mining Component (DMC) is used to train the model so that it can comprehend user preferences. The DPSC data is used to build and train at least one data mining model. In the end, the learned models will be used in the online part. Predictions are made in offline environments by trained data mining algorithms. Three different aspects make up the online portion:
- The acronym "RTDC" represents "real-time data collector." RTDC (Real-Time info Capture) is used to get this info along with the user's services and network tools.
- Processing data from pay-per-click advertising (PPC) using the proper data mining model that has been developed offline in order to anticipate a particular user preference is the task of the predictor.
- The PPC sends user choices to the QoE Management Component, which is also called the QMC. The QMC comes with both a QoE controller and a computer. The manager not only knows what's going on with the goal network, but it also knows what various system users want. It is also possible to improve the level of experience for some people at QMC using this method.

III. MATERIALS AND METHODS

This part of the document contains the presentation of the research region of the dataset. A 5G network that is both multi-tenant and intent-based is being referred to here. In order to properly contextualize the issue that needs to be solved, Section 3.1 provides a concise overview of the primary components that make up a typical 5G network. The reader will have a better knowledge of the underlying causes of the numerous network aspects that will be covered in the subsequent subsections as a result of this explanation. Last but not least, the sources of data gathering for the 5G-IB network are discussed in Section 3.3.

A. 5G Infrastructure Architecture as a Reference

Figure 6 shows an example of a multi-tenant network design for 5G networks. This infrastructure allows network services to be softwarized and virtualized on the same physical infrastructure. In the picture, just the components that are part of the data plane have been shown.

In conclusion, Figure 7 illustrates the many stakeholders that comprise the 5G system. These groups are named by the 5G Public Private Partnership, or 5G PPP. The shown architecture facilitates the pursuit of network automation, which is accomplished via the use of cognitive loops. When a network has the qualities necessary for autonomous operation, it may self-manage and self-optimize its activities. The deployment of several network tiers, including the computing, service, and administration layers, enables this kind of automation. The blue boxes in Figure 7 are supposed to depict these different network layers. The development, implementation, and administration of services offered across the architecture of the 5G network are all included in the service layer. This layer offers effective service provisioning, scalability, and customization via the use of automation,

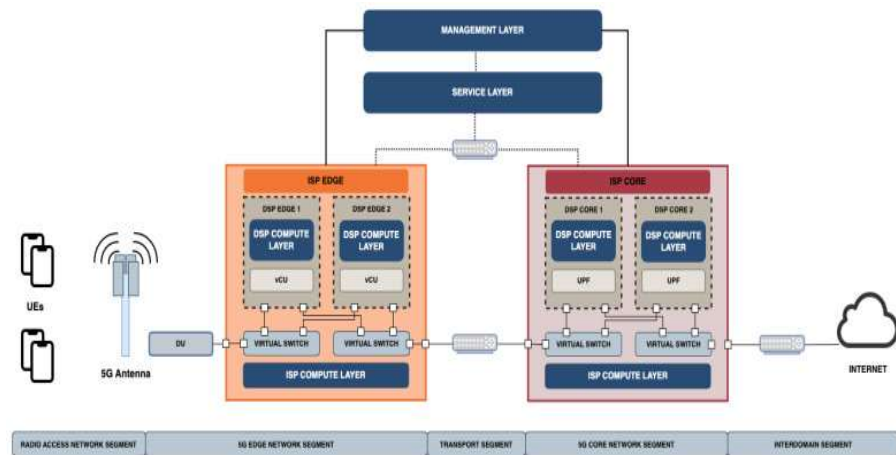


Figure 6 Data plane of 5G multi-tenant infrastructure

virtualization, and orchestration approaches. In addition, the management layer is in charge of monitoring and managing the use of the network's resources. Numerous network aspects, including as resource allocation, security, and performance, are monitored, analyzed, and optimized by sophisticated analytics and artificial intelligence algorithms. This layer makes intelligent judgments and automates network management operations by using the information and data provided by the compute and service levels.

B. An explanation of the 5G Intent-Based Architecture

In particular, the elements that comprise the suggested architecture are the levels of compute, services, and administration. These levels were previously discussed in more detail. A variety of network elements, such as sensors and actuators, that are dispersed at different levels work together to accomplish such autonomous qualities.

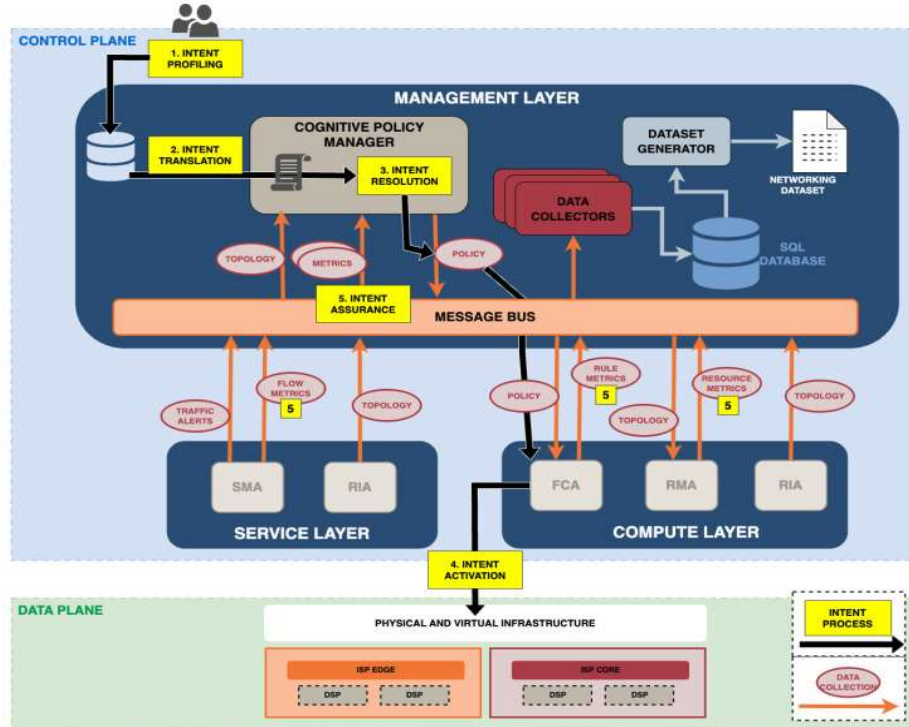


Figure 7 Presenting IW-IB-5GNET dataset data sources and IBN design

The deployment of our suggested IBN system creates a closed-loop platform that enables the network's high-level service demands to be autonomously orchestrated and executed. The whole process consists of five separate stages, starting from the point at which the intent is brought into the network and concluding when it is removed from it. Figure 7 has yellow boxes and black arrows, each of which represents one of these entities. The procedure is described in the following manner:

It is the first stage of the IBN, during which the user engages in interaction with the system in order to indicate the intended intent. Definition of the intent. The statement of purpose is then converted into a network policy, which will be comprised of a number of rules and settings for the network. Resolution of the intent. Taking into consideration the fact that the network may be experiencing numerous intents at the same time is something that must be done. Guarantee of one's actions. Once the intended goal has been accomplished, the last stage comprises making certain that the network in question does, in fact, comply with the established intention.

C. Planned Structure for Collecting Data

Part provides a description of the many software components that are required not only for the accomplishment of the intended goal, but also for the process of creating the dataset itself. Arrows in orange and circles in red provide a visual representation of the data extraction process. The integration of all the parts, each of which is in charge of a certain system function, results in the exact execution of network control rules. These forms of control regulations are a translation of earlier intentions. The program known as message bus, shown in orange in Figure 2, is in charge of enabling data interchange and communication amongst components. A publishing and subscription architecture is used to achieve this. The red circles in each case represent the kind of data being transmitted between the two parties, while the orange arrows show whether the data exchange in issue is a publication or a subscription. Below is a description of the software's constituent parts.

Resource Inventory Agent is abbreviated as (RIA). It is the segment of the network that is always in charge of spreading information about the topological network. This kind of data pertains to ports that are open for use, actual and virtual devices, and the connections that exist between them on a given system. The RIA finds the 5G network's topology, creates it, and broadcasts it for use by the other network elements.

First, it is responsible for increasing and expanding the capabilities that are offered by a conventional intrusion detection system (IDS). As such, the SMA works in tandem with Snort to enhance the data provided by this traditional network intrusion detection system (NIDS). Second, it offers data on network flows, such as traffic alerts and a catalog of all flows that pass via every network interface. (The acronym RMA implies "Resource Monitoring Agent." It makes it possible to keep an eye on a range of resources inside their own networks. In order to set the monitored metrics, a configuration file is used, and this configuration file may be readily expanded by the modification of the configuration file.

(CPM) stands for cognitive policy manager. In order to successfully develop network policies, this component is responsible for carrying out four distinct actions. To begin, it interprets the declarations of user intent that are included inside network regulations. Because of this, it is possible to provide a comprehensive study of the present state of the network. The network policy is taken into consideration, and a choice is generated via the use of such analysis. The policies that are enacted as a result might vary widely depending on the character of the purpose. The following are some instances of network policies: conducting a drop, mirroring traffic, diverting specific traffic, prioritizing a defined flow, and so on. After the decision has been made about the action that will be carried out, the calculation that is required to finish the policy information is carried out. This includes the following: what action is to be enforced, in which interface of the network is it to be enforced, how it will be enforced, and for how long will the policy be in effect? Following the completion of all of this information, it will then orchestrate the policy and publish it in the message.

FCA stands for flow control agent. The management plane is given access to the capabilities used for controlling network traffic. In addition, the FCA will occasionally report metrics that are linked with a rule that has been enforced in the network after it has been implemented. It is possible to get a comprehensive description of this agent and the performance it has.

those who gather data. Every piece of information that is exchanged over the message bus on a network must be gathered by the data collectors. There is a collector made especially for each kind of data, as shown in Figure 2. The collectors are in charge of gathering the data that the network agents release, altering it, and putting it into a SQL database. This means that all of the network's real-time information is kept up to current in a database that is maintained by the management layer.

The data that is held in the SQL Database is extracted, shaped, sorted, and adapted to CSVs (comma-separated values) by being a software component that is responsible for these tasks. The various characteristics of the dataset, which will be discussed in Section 5, are comprised of the data that was extracted.

IV. SIMULATING SCENARIOS AND MAKING DATASETS SIMU

This part talks about the testbed design and the data collection method that was used to make the IW-IB-5GNET dataset. This is done so that the situation can be simulated.

A. Details on how to implement

Within the most realistic 5G mobile edge computing architecture, every software component listed in Section 3.3 has been created, implemented, and tested. Most of them (the RIA, SMA, RMA, CPM, and Collectors) are implemented in Java 17, with the exception of the FCA and the Dataset Generator, which are both written in Python 3.8.

A network and a device operate in distinct network and process contexts, even if they both use the same kernel and file system. Furthermore, any kind of network, including wireless mobile networks, may be simulated thanks to the Linux environment's Ethernet bridging capabilities. This makes it possible to portray the vast structures this research presents in a more realistic manner. With cooperation from CORE, a system that makes it easier to build, configure, provision, emulate, and deploy several experimental scenarios in 5G multi-tenant networks was built. Additional information on the system in use may be seen above in [20].

In the context of our 5G simulation, stressing the generated network traffic's realistic quality is crucial. This assertion is important because it highlights that, apart from the link between the radio access network (RAN) component and user equipment (UE), the whole network is simulated. Although this simulation component is rather little, it makes no difference to the legitimacy of the network traffic. To maintain this realism, network components, protocols, and behaviors are painstakingly modeled. It is essential that the traffic patterns in the simulation closely resemble actual occurrences in order to preserve this authenticity. For instance, in addition to OpenAirInterface [29], we also employ authentic core network components from Osmocom (SGSNEmu [27] and GGSN [28]). Furthermore, we use a custom software-defined networking (SDN) controller inspired by Openstack Neutron to emulate multi-tenancy architecture.

B. Experiment Design

The most common kind of distributed denial of service attack is UDP, accounting for 54.4% of all assaults. We considered this aspect before deciding to open our network to UDP DDoS assaults. This was done to make sure that the generated dataset appropriately depicts the network's state at the time the intent was being carried out. As a result, the information that was obtained might be used to build artificial intelligence modules that could make the best decisions feasible at every stage of the intent process. These options will eventually be the best ones available since the precise network policy may be developed based on the network's state at any given time rather than being generated by default.

During the course of this endeavor, we have been concentrating on the behavior of the network while simultaneously removing any traffic flow that demonstrates malicious behavior or tries to get access without enough authorization. The amount of data files in each execution will vary based on the number of network rules that are currently in effect. It is important to remember that this will change depending on how many user equipments (UEs) are connected to the network. This suggests that more network rules are executed with the intention of removing malicious traffic from the network the more user equipment (UEs) that are attacking the system.

C. Experiment Execution

Within this part, the process of generating and collecting the data in order to produce the dataset is broken down and explained. The autonomous system will carry out the following actions to create the dataset as soon as the experiment is completed and all of the parameters listed in the preceding section have been determined:

A drop operation may be carried out over three different network interfaces, as Figure 3 illustrates. The eth0, eth6, and eth7 ports may be used to access technologies based on data planes OVS and TC, respectively. However, using the eth0 interface will be the sole way to access iptables. Consequently, the drop will occur at either eth6 or eth7, contingent upon the use of TC or OVS technologies. On the other hand, the drop procedure will occur at eth0 if iptables is applied. The network's incapacity to successfully enforce previous acts is the cause of this. The third step, called "Intent Resolution," is carried out after the completion of all of these assessments and the creation of the policy.

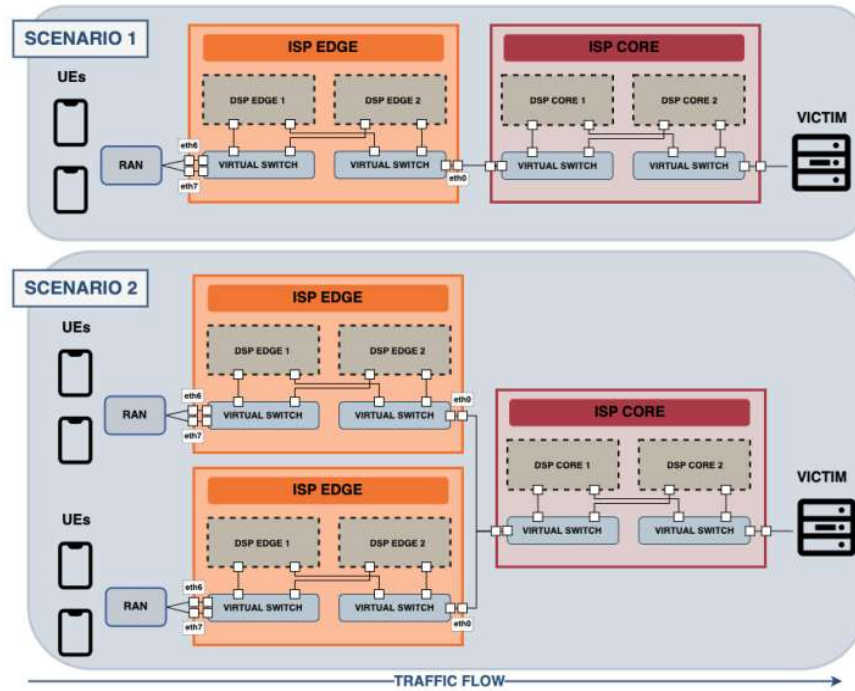


Figure 8 Architecture of Scenarios 1 and 2

V. CONCLUSIONS

Our results showed that a new dataset is needed to fully show how complicated B5G networks are. Two examples of this level of complexity are the fact that network control rules change all the time and that network layouts have many layers. IW-IB-5GNET is a unique and large networking dataset that was made available for this study. This infrastructure-wide dataset based on purpose was made because B5G networks need more reliable, adaptable, and data-driven ways to run and improve their networks right away. Our information has a lot of important benefits for managing and improving networks. First, it gives a full picture of how the network is changing and what its state is like because it can see the whole network environment because it covers a lot of infrastructure. As networks get more complicated and depend on each other, this addition is very important. Second, the dataset is intent-based, which means that it not only records the technical aspects of the network but also looks at the control activities and intentions that set the network's rules and settings. To show how special this dataset is, which was gathered from a closed loop on a B5G network, it is important to draw attention to its features. The results could be very helpful for making artificial intelligence (AI) models that improve quality of service and network policy improvement. The data could be used to create a classification model that, by making the most of the rules that are already in place in the network, can guess which technology will work best with a certain network policy.

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