



**An-Najah National University Faculty of Engineering
Telecommunication Engineering Department**

GRADUATION PROJECT 2

Virtual Network Operations Center (VNOC)

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قال تعالى {يَرْفَعُ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ} (المجادلة: ١١)

إلى مَنْ ضَحَّوْا بِأَرْوَاحِهِمِ الطَّاهِرَةِ مِنْ أَجْلِ وَطَنِنَا الْغَالِي ، شُهَدَائِنَا الْأَبْرَارِ

إِلَى مَنْ صَبَرُوا فِي ظُلُمَاتِ السُّجُونِ مِنْ أَجْلِ حُرِّيَّتِنَا ، أَسْرَانَا الْأَبْطَالِ

إِلَى مَنْ قَدَّمُوا أَجْسَادَهُمْ فِدَاءً لِكِرَامَتِنَا ، جِرْحَانَا الشُّجْعَانَ

إِلَى وَالِدَيْنَا الَّذِينَ بَدَلُوا الْغَالِي وَالنَّفِيسَ لِأَجْلِنَا ، إِلَى مَنْ تَعَبُوا وَسَهَرُوا اللَّيَالِي الطَّوِيلَةَ مَعَنَا ، إِلَى مَنْ لَا يَقْبَلُونَ إِلَّا أَنْ نَكُونَ مُتَمَيِّزِينَ ، السَّنْدُ الْعَظِيمُ لَنَا فِي كُلِّ الْمَوَاقِفِ ، وَالِدَيْنَا ، أَدَامَهُمُ اللَّهُ لَنَا.

إِلَى إِخْوَتِنَا وَأَخَوَاتِنَا الَّذِينَ زَرَعُوا فِي أَنْفُسِنَا رُوحَ الْمُنَافَسَةِ

إِلَى دَكَاتِرَتِنَا الْأَفْضَالِ ، وَعَلَى رَأْسِهِمُ الْبُرُوفِيسُورِ عِلْمِ مُوسَى ، الْمَشْرِفِ عَلَى مَشْرُوعِ التَّخْرِجِ ، وَالْمُهَنْدِسِ أَحْمَدِ قَشُوعِ ، الَّذِينَ تَعَلَّمْنَا مِنْهُمْ الْكَثِيرَ ، وَكَانَا مَعَنَا لِحِظَةً بِلِحِظَةٍ.

إِلَى زُمَلَانِنَا الْأَعْزَاءِ الَّذِينَ شَارَكُونَا فِي تَحْقِيقِ هَذَا الْمَشْرُوعِ ، وَجَعَلُوا مِنْ هَذَا الْإِنْجَازِ حُلْمًا يَلَامِسُ الْوَاقِعَ.

إِلَى كُلِّ مَنْ سَاهَمَ فِي إِجْرَاحِ هَذَا الْعَمَلِ ، وَأَضْفَى عَلَيْهِ قِيَمَةً وَمَعْنَى.

إِلَيْكُمْ جَمِيعًا نُهْدِي هَذَا الْإِنْجَازَ بِكُلِّ فَخْرٍ وَامْتِنَانٍ.

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Contents

1	Abstract	8
2	Introduction	9
2.1	Overview.....	9
2.2	Problem Statement.....	9
2.3	Project Objectives.....	10
2.4	Project Significance.....	10
2.5	Project Organization	10
3	Network Operations Center in Mobile Networks	11
3.1	Mobile Network (MN)	11
3.1.1	Introduction.....	11
3.1.2	Base Station Controller (BSC):.....	11
3.1.3	Mobile Switching Center (MSC):.....	11
3.1.4	Base Transceiver Station (BTS):.....	11
3.2	Network Operations Center NOC	12
3.2.1	Introduction.....	12
3.2.2	What is NOC?.....	13
3.2.3	How NOC Collects Network Performance.....	13
3.2.4	How Does NOC Work?	14
3.2.5	Functionality of NOC.....	14
3.2.6	Interaction with Other Departments	15
3.2.7	Events, Incidents, and Alarms in NOC.....	16
3.2.8	NOC Backup and Redundancy	20
4	NOC Interaction with other Departments	22
4.1	Technical Operations and Maintenance Department.....	22
4.1.1	Importance of Technical Operations and Maintenance	22
4.1.2	Key Tasks	23
4.1.3	Collaboration With NOC	24
4.2	Radio Access Network (RAN)	25
4.2.1	A Radio Access Network Consists of three basic elements.....	26
4.2.2	How does a RAN work?.....	26
4.3	Network Performance Optimization (NPO) Department	26
4.3.1	What is network optimization?.....	26

4.3.2	NPO Department Inputs	27
4.3.3	Departments that provide information to the NPO department.....	27
4.4	Transmission Department in Telecommunications Companies.....	28
4.4.1	Definition of the Department	28
4.4.2	Main tasks of the Transport Department.....	28
4.4.3	The role of the correspondence department in providing communications services.....	29
5	Key Performance Indicator (KPIs) in NOC	29
5.1	Introduction	29
5.2	Drop Call	30
5.3	Call Setup	32
5.4	Handover	33
5.5	Availability	35
5.6	Traffic	36
5.6.1	Voice traffic.....	37
5.6.2	Data traffic	37
5.6.3	Erlang.....	38
5.7	Conclusion	38
6	Metaverse	38
6.1	Benefits of the Metaverse	39
6.2	Virtual Reality (VR).....	39
6.2.1	The functioning of VR technology.....	40
6.3	Designing a Network Operations Center (NOC) in the Metaverse	40
6.3.1	Unity & 3D Max.	41
6.4	Key Features of a NOC in the Metaverse	43
6.5	Benefits of a Metaverse-based NOC.....	43
7	Programing Languages	44
7.1	PyCharm	44
7.2	Why Did We Use PyCharm in the Project?	44
7.3	Comparison Between C# and Python	45
7.4	Using Python for Data Analysis in VNOC	45
7.5	Using C# for VNOC Programming	46
8	Integration of Unity, Python, and AI – Design and Results	46
8.1	Data Generation Using PyCharm	46

8.2	Linking Unity with PyCharm to Display and Analyze Network KPIs.....	47
8.3	Role of Artificial Intelligence (AI) in the VNOC System	49
8.4	Comparison Between Traditional NOC Engineer and AI-Based VNOC System.....	52
8.5	Project Deployment on Meta Quest 2 Headset.....	54
8.5.1	Deployment Methods for Unity Projects on Meta Quest 2	54
9	Economical Feasibility	55
9.1	Cost analysis	55
9.2	Effect on Society	56
9.3	Market Growth	57
9.4	Profitability Objectives	57
9.5	Cost Comparison between VNOC and Conventional NOC Systems.....	58
9.6	SWOT Analysis for the Virtual Network Operations Center (VNOC)	60
10	Discussion and Conclusion	62
10.1	Discussion	62
10.2	Conclusion	62
10.3	Future Work.....	62
	References	63
	Appendices	64

List of Figures

Figure 1	Basic Structure of the GSM Network	12
Figure 2	Block Diagram for The Network Department	12
Figure 3	Network Operations Center.....	13
Figure 4	Types of Network faults	14
Figure 5	Network Operations Center Activities	15
Figure 6	Events, Incidents, and Alarms in NOC.....	16
Figure 7	Type of Alarm classification	19
Figure 8	Backup.....	20
Figure 9	Maintenance and Technical Support	22
Figure 10	Cloud RAN (C-RAN).....	25
Figure 11	Network Performance.....	27
Figure 12	Telecommunication Network	29
Figure 13	Block Diagram for determining KPIs.	30
Figure 14	Drop Call Operation	30
Figure 15:	Cell Drop-Call plot over one week.	31
Figure 16	Call Setup	32
Figure 17	Call Setup Rate plot over a week.	33

Figure 18 Handover.....	33
Figure 19 Handover Rate plot over a week.	34
Figure 20 Network Availability.....	35
Figure 21 Availability Rate plot over a week.....	36
Figure 22 Traffic plot over a week.	37
Figure 23 Types of Traffic.....	38
Figure 24 Metaverse	39
Figure 25 Oculus Quest2	40
Figure 26 XR Rig(Origin)	42
Figure 27 Virtual NOC control room-Unity (Inside)	42
Figure 28 Virtual NOC-Unity (Outside).....	43
Figure 29Availability Trend for Cell T1B1 in February 2025	47
Figure 30 Traffic Performance for Cell T3D1 in December 2024.....	47
Figure 31Data Visualization on KPI Screens Inside the VNOC Environment.....	48
Figure 32 Alarm Visualization and AI Report Display in the VNOC Environment	50
Figure 33 AI-Generated Email Sent to Responsible Department for Alarm Resolution	50
Figure 34Department Assignment and NOC Action Plan in AI Email Report.....	51
Figure 35Automated AI Email Report Sent to the NOC Manager.....	52
Figure 36AI Report: Engineering Recommendations and Department Assignment	52

List of Tables

Table 1 Unity vs. Unreal Engine	41
Table 2 C# vs. Python	45
Table 3 Comparison Between Traditional NOC Engineer and AI	53
Table 4 Comparison of Deployment Methods for Unity Projects on Meta Quest 2	54
Table 5 Initial Cost Breakdown	56
Table 6 Comparison between VNOC and Conventional NOC Systems.....	59

List of Abbreviations

VNOC	Virtual Network Operation Centre.
NOC	Network Operation Centre.
MN	Mobile Network.
BSC	Base Station Controller.
MSC	Mobile Switching Centre.
BTS	Base Transceiver Station.
GSM	Global system Mobile.
CDMA	Code-Division Multiple Access.
KPIs	Key Performance Indicators.
UPS	Uninterrupted Power Supply.
TOM	Technical Operations and Maintenance.
CMMS	Computerized Maintenance Management System.
SOPs	Standard Operating Procedures.

RAN	Radio Access Network.
BBUs	Base Band Unit.
RRHs	Remote Radio Heads.
NPO	Network performance Optimization.
SLAs	Service Level Agreements.
QoS	Quality of Service.
VR	Virtual reality.
AR	Augmented Reality.
3D	3 Dimensional.
C#	Programming Language.
C++	Programming Language.

1 Abstract

This report explores the concept of a Virtual Network Operations Center (VNOC) within the metaverse, aiming to revolutionize network management and monitoring. Building traditional Network Operations Centers (NOCs), a VNOC leverages virtual environments to enhance real-time monitoring, incident management, and network optimization. The report discusses the integration of virtual reality technologies with existing NOC functionalities, such as 24/7 monitoring, security monitoring, and network performance analysis. It outlines how a VNOC can improve operational efficiency, enhance security, and provide immersive experiences for network professionals.

2 Introduction

2.1 Overview

The advent of the metaverse has opened new avenues for innovation in network management, particularly in the development of Virtual Network Operations Centers (VNOCs). A VNOC represents a significant evolution from traditional Network Operations Centers (NOCs), leveraging virtual reality technologies to enhance network monitoring, management, and optimization. This report explores the concept of building a VNOC, focusing on how it can integrate immersive virtual environments with existing NOC functionalities to improve operational efficiency, enhance security, and provide an immersive experience for network professionals.

In the context of mobile networks, traditional NOCs play a crucial role in ensuring network reliability and performance by monitoring various components, performing troubleshooting tasks, and responding to incidents. The integration of virtual reality into this framework offers potential benefits such as enhanced visualization of network data, improved collaboration among teams, and more effective incident management. This report aims to outline the feasibility and potential benefits of transitioning to a VNOC within the metaverse, highlighting its potential to revolutionize network operations and management.

2.2 Problem Statement

The increasing complexity and demand for mobile networks necessitate more efficient and innovative network management solutions. Traditional Network Operations Centers (NOCs) face challenges in providing real-time monitoring, incident management, and network optimization due to limitations in scalability, collaboration, and data visualization. The integration of virtual reality technologies in the metaverse offers a potential solution by enabling immersive environments for network monitoring and management. However, there is a lack of comprehensive frameworks for building Virtual Network Operations Centers (VNOCs) that can effectively leverage these technologies to enhance operational efficiency, security, and collaboration among network professionals.

2.3 Project Objectives

The project aims to address the challenges faced by traditional Network Operations Centers (NOCs) by developing a Virtual Network Operations Center (VNOC) within the metaverse. Traditional NOCs are crucial for ensuring network reliability and performance but face limitations in scalability, collaboration, and data visualization. By integrating virtual reality technologies, a VNOC can enhance operational efficiency, security, and collaboration among network professionals. The project seeks to design a comprehensive framework for a VNOC that leverages immersive environments for real-time monitoring, incident management, and network optimization. Key objectives include improving operational efficiency through advanced analytics, enhancing security measures, fostering collaboration, and ensuring scalability and cost-effectiveness. The VNOC will also focus on providing immersive training experiences and integrating emerging technologies into future-proof network operations.

2.4 Project Significance

This project on building a Virtual Network Operations Center (VNOC) in the metaverse holds significant value as it pioneers the integration of immersive technologies into network management. By leveraging virtual reality, the VNOC enhances operational efficiency, security, and collaboration among network professionals, offering a future-proof solution for managing complex network infrastructures. This innovation has the potential to revolutionize the telecommunications industry by providing more effective monitoring, incident management, and network optimization, improving network reliability and performance.

2.5 Project Organization

This report is organized as follows: The first chapter gives an introduction about the problem and the objectives of the project. Chapter two, talks about the Network Operations Center in Mobile Networks. In the third chapter, we present the Network Operations Center . In chapter four, talks about NOC Interaction with other Departments. Chapter fifth explained the Key Performance Indicator (KPIs) in NOC. In chapter six, discuss the We discuss the concept of the Metaverse. In the seventh chapter, we explained the programming languages that were used. The final chapter summarized the project in conclusion.

3 Network Operations Center in Mobile Networks

3.1 Mobile Network (MN)

3.1.1 Introduction

A mobile network (also wireless network) routes communications in the form of radio waves to and from users. It is composed of base stations that each cover a delimited area or "cell." When joined together these cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers (e.g., mobile phones, pagers, etc...) to communicate with each other and with fixed transceivers and telephones anywhere in the network, even if some of the transceivers are moving through more than one cell during transmission.

3.1.2 Base Station Controller (BSC):

The BSC is the communications network component responsible for controlling the operations of the base transceiver stations (BTS). It is a physical link between the BTS and the mobile switching center (MSC). It acts as a central hub for managing radio channels, receiving measurements from mobile devices, controlling BTS-to-BTS handovers, and supervising call setups.

3.1.3 Mobile Switching Center (MSC):

Mobile Switching Centers (MSCs) function as the backbone of GSM/CDMA network systems, orchestrating seamless connectivity and managing calls between subscribers. It acts as a central control center, facilitating the routing and switching of digital voice packets across the network.

3.1.4 Base Transceiver Station (BTS):

A base transceiver station (BTS) is a fixed radio transceiver in any mobile network. The BTS connects mobile devices to the network. It sends and receives radio signals to mobile devices and converts them to digital signals that pass on the network to route to other terminals in the network or to the Internet.

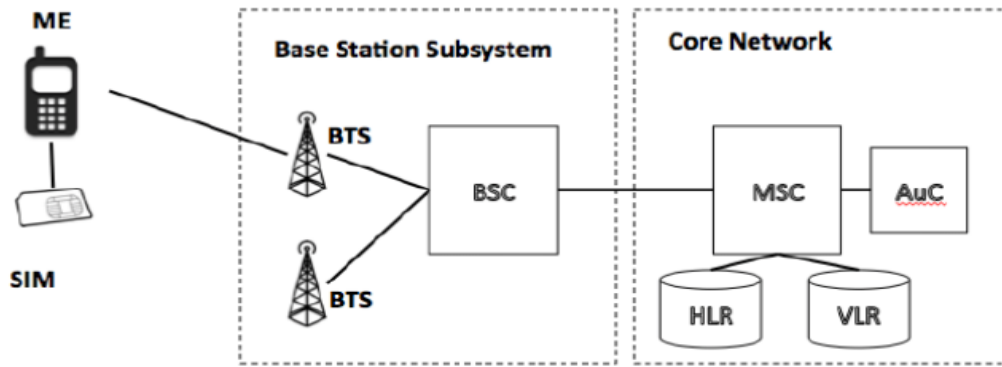


Figure 1 Basic Structure of the GSM Network

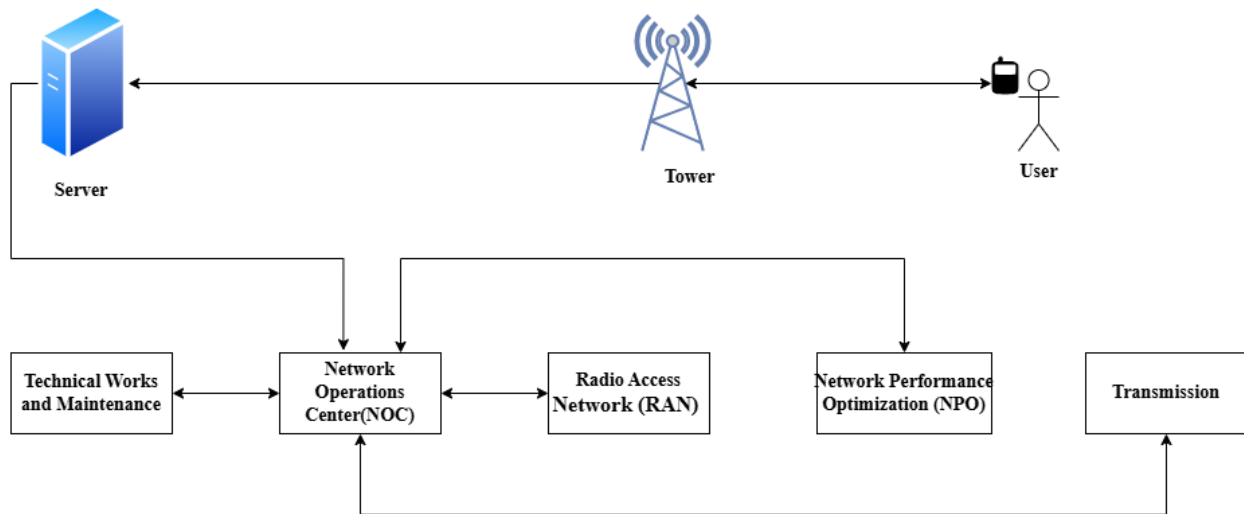


Figure 2 Block Diagram for The Network Department

3.2 Network Operations Center NOC

3.2.1 Introduction

Network Operation Center is one of the main components of the management and monitoring in Mobile communication networks, it serves as the backbone of the network reliability and performance and plays a crucial role in ensuring the service remains uninterrupted and efficient, in this part we will explore the functionality of NOC and its operation and mechanisms, and the relation with other departments in the mobile communication network organization.

3.2.2 What is NOC?

A NOC is a centralized facility where IT professionals monitor, manage, and maintain telecommunications infrastructure including hardware and software. The NOC is essential for ensuring the reliability and availability of network-based services that are critical for business operations.

The main responsibility of a NOC is to provide real-time monitoring and rapid response to issues as they occur within the network and communicate the solution to other departments to solve them on the spot. By utilizing advanced monitoring and management systems, this initiative-taking approach helps minimize downtime and maintain business continuity. Unlike a Help Desk, which typically addresses end-user issues related to devices, applications, and basic connectivity, the NOC focuses on the overarching health of the network infrastructure.

In summary, a NOC plays a vital role in managing an organization's network infrastructure by monitoring various components, performing troubleshooting tasks, ensuring quality control and assurance, and responding to incidents. This centralized hub not only enhances operational efficiency but also contributes significantly to the overall security and performance of the network.



Figure 3 Network Operations Center

3.2.3 How NOC Collects Network Performance

In mobile network operations, monitoring performance begins at the cell level, where each cell is equipped with performance counters that track metrics such as signal strength, call drop rates, and data throughput. This data is transmitted to the Base Station Controller (BSC), which aggregates and processes the information from multiple cells. The BSC plays a crucial role in managing radio resources and maintaining communication links between mobile devices and the core network.

Once the performance data reaches the Network Operations Center (NOC), it is analyzed using Key Performance Indicators (KPIs) like network availability, latency, packet loss rate, and throughput. NOCs employ specialized monitoring tools that visualize these KPIs in real-time dashboards, enabling quick identification of issues and facilitating efficient incident management. By leveraging this systematic flow of data from individual cells to the NOC, mobile operators can ensure high-quality service delivery and promptly address any performance-related challenges.

3.2.4 How Does NOC Work?

NOC teams work behind the scenes to ensure the service is up and systems and users have seamless continuous connected experience without issues or downtime. NOCs typically operate in a tiered fashion. Incidents are categorized into levels, with lowest level is the minor, and the highest level is the most severe incidents, such as a ransomware attack or network outage. If a NOC professional cannot resolve an issue in a timely manner, it moves up to more experienced team members. NOC professionals then troubleshoot problems that arise and look for ways to prevent future network downtime and connectivity issues.

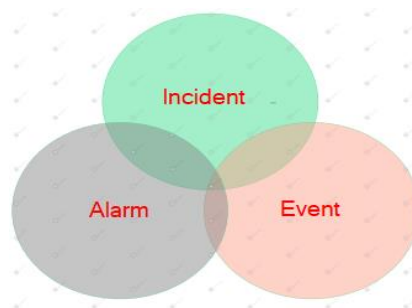


Figure 4 Types of Network faults

3.2.5 Functionality of NOC

The primary functions of a NOC include:

- **24/7 Monitoring:** NOC operate continuously to oversee network performance, detect anomalies, and respond to incidents. They monitor various network components such as servers, databases, firewalls, and communication lines to ensure optimal operation.

- **Incident Management:** NOC personnel are responsible for identifying and resolving issues that may disrupt service. This includes troubleshooting outages, managing power failures, and addressing communication line problems.
- **Network Optimization:** By analyzing network data and performance metrics, NOCs can optimize network efficiency and capacity to meet changing demands. This involves software updates and maintenance activities.
- **Security Monitoring:** The NOC acts as the first line of defense against cyber threats by monitoring unauthorized access and potential attacks. It ensures that security protocols are enforced across the network.
- **Reporting:** NOCs compile reports on network performance and incidents, which are essential for compliance with organizational policies and regulations.

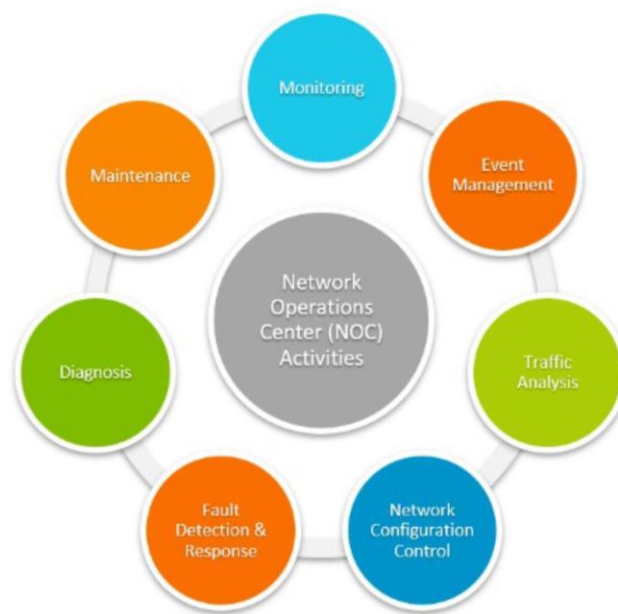


Figure 5 Network Operations Center Activities

3.2.6 Interaction with Other Departments

In mobile telecommunications, the Network Operations Center (NOC) plays a pivotal role in ensuring the smooth operation of the network. Its interaction with various departments is crucial for maintaining service quality and optimizing network performance. Here is an overview of how

the NOC collaborates with different technical and maintenance teams, Radio Access Network (RAN), network performance optimization, and transmission systems.

3.2.7 Events, Incidents, and Alarms in NOC

Network operations centers directly supervise complex network environments, including servers, databases, firewalls, devices, and related services. Network operations centers typically operate in a gradual manner. What happens on the network is classified into three sections:



Figure 6 Events, Incidents, and Alarms in NOC

3.2.7.1 Events

It is considered one of the most important basic elements that have an impact on network performance. It represents any event that occurs within the network, where the impact of these events is understood and analyzed to improve network performance and anticipate potential problems before they occur. The potential effects on the network include the following:

- 1- **Increased demand for data:** This means an increase in the number of users trying to use the same resources, and an increase in data traffic, which leads to an increase in demand on the network, which slows down the Internet speed.
- 2- **Pressure on servers:** As a result of the increasing requests, servers are exposed to excessive pressure, and if the servers are not designed to accommodate this pressure, the servers may collapse, and services may stop.
- 3- **Bandwidth consumption:** Network congestion occurs because of an increase in the consumption of available bandwidth, thus reducing the quality of services, such as call interruption.

An example of an event is the announcement of the results of the secondary school certificate, where excessive pressure is placed on the network due to this event.

3.2.7.2 Incidents

Modifications that occur on the network with the aim of improving performance or adding new features. They include changes that occur on network components such as devices and modifying the structure of the network itself. Possible Incidents in the Network:

1- Modifications to Data Transmission: This process occurs when any change occurs in the mechanism of data transfer between network components, such as changing communication protocols between base stations.

These modifications sometimes lead to a temporary stop in services during the modification process.

2- Determining the Slave & Master: The master and slave may be determined in the base stations or servers. This affects the way loads are distributed across the network.

3- Setting the Main & Backup: To ensure continuity of service in the event of a failure, the backup mechanism is applied. The main components (Main) and the backup (Backup) are determined by the system.

4- Adding New Features: The process of adding new features is considered one of the modifications that occur on the network to improve its performance and provide new services such as strengthening and accelerating the connection.

These modifications improve the service but may cause temporary risks to the system while the new feature is being integrated.

5- New maintenance: When maintaining network equipment and components, services are interrupted for a brief period.

6- Upgrade for Hardware or Software: Replacing old hardware with new hardware and updating software to provide new features with the aim of improving network performance.

3.2.7.3 Alarms

Alarms represent the backbone of network management by monitoring network components and devices and help predict problems before they occur to ensure the continuity of service quality. For this to happen, alerts must be managed effectively, and alerts in communications networks are divided into two main sections:

- **Alarm classification & Severity:** It is the process of dividing alerts based on the severity of their impact, where these alerts are divided based on a certain threshold as follows:

1- Critical alerts: They are the most dangerous types of alerts and indicate the presence of problems that directly affect services, leading to the interruption or cessation of services, and require an immediate response from the technical support and maintenance team.

An example of this type of alert is a power outage in the entire base station, where the node notifies the technical works department, specifically the department responsible for energy, of a power outage, and thus the technical works department takes the necessary intervention to restore service.

2- Major Alarms: These are major problems that lead to a deterioration in the quality of service without a complete interruption of service, and ignoring these alarms leads to them becoming critical alarms over time (i.e., they may lead to a complete interruption of service).

An example of this type of alarm is a malfunction in part of the network equipment, such as a malfunction in one of the units in the base station.

These alarms must be dealt with quickly to ensure that they do not develop into a critical situation.

3- Minor Alarms: These are minor problems that do not cause a noticeable interruption in service, and these problems do not require an immediate response, but it is necessary to monitor them to prevent them from worsening.

An example of this type of alarm is a rise in the temperature of a device, and this type of alarm should not be ignored and should be dealt with so that it does not turn into a major or critical situation.

4- Warning Alarms: They indicate the possibility of a problem occurring in the future if appropriate action is not taken, and they do not pose a direct threat to the network at the present time.

An example of this type of alert is a decrease in VSWR, where VSWR is:

The ratio of the maximum voltage to the minimum voltage amplitude in the transmission line by the voltage standing wave ratio (VSWR). In many practical conditions, this

parameter can be easily measured and then used as an indicator of the performance of the transmission line.

The voltage standing wave ratio can be linked to the reflection coefficient (magnitude). If we define the reflected wave amplitude as (V_r) and the incoming voltage as (V_i), the maximum voltage in the standing wave is:

$$V_{\max} = V_i + V_r$$

$$V_{\min} = V_i - V_r$$

$$\begin{aligned} \text{VSWR} &= \frac{V_{\max}}{V_{\min}} \\ &= \frac{V_i + V_r}{V_i - V_r} \end{aligned}$$

A decrease in it leads to a partial or complete reflection of the transmitted energy, which leads to a loss of energy and a decrease in the quality of the network, so preventive measures must be taken to avoid real problems.

5- Informing Alarms: These alerts do not indicate the presence of problems or faults in the network but rather provide information about the status of the network and are used to monitor and analyze network performance.

An example of this type of alert is receiving a notification that the door of the baseband unit cabinet is open, and this alert indicates that a theft of equipment on site may occur.

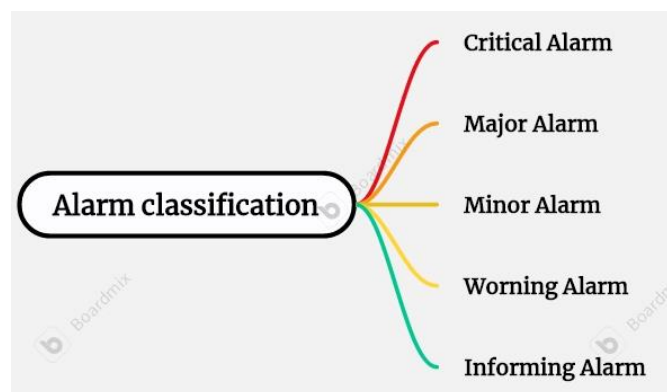


Figure 7 Type of Alarm classification

3.2.8 NOC Backup and Redundancy

In a Network Operations Center (NOC), backup and redundancy are critical components that ensure the reliability and continuity of network services. These elements play a vital role in mitigating risks associated with data loss, system failures, and unexpected outages.

3.2.8.1 Backup in NOC

Backup systems within a NOC are designed to protect vital data and ensure quick recovery in the event of data corruption, system failures, or cyberattacks. The significance of backup processes includes:

- **Data Protection:** NOCs implement regular data backup protocols that safeguard essential information from loss or damage. This includes automated backups that occur at scheduled intervals, ensuring that the most recent data is always available for restoration if needed.
- **Rapid Recovery:** In case of an incident that compromises data integrity, NOCs utilize backup solutions to quickly restore operations. This capability minimizes downtime and ensures that business processes can continue with minimal disruption.
- **Disaster Recovery Plans:** NOCs play a crucial role in an organization's disaster recovery strategy by managing data backups and ensuring that contingency plans are in place. This preparation allows for swift restoration of network operations following significant outages or disasters.
- **Remote Backup Solutions:** Many NOCs offer remote backup capabilities, which reduce the reliance on in-house systems. By backing up data to off-site locations, organizations can enhance their storage capacity and ensure that critical information is protected against local disasters.

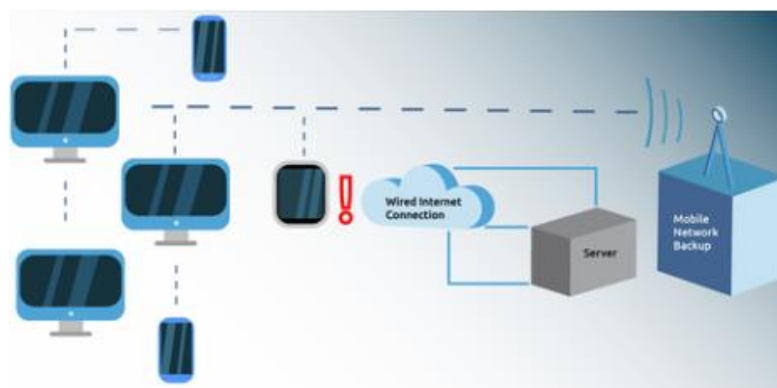


Figure 8 Backup

3.2.8.2 Redundancy in NOC

Redundancy refers to the implementation of additional systems and processes to ensure continuous operation even in the face of failures. Key aspects of redundancy in a NOC include:

- **Redundant Power Supplies:** To prevent outages caused by power disruptions, NOCs are equipped with redundant power supplies, including Uninterruptible Power Supply (UPS) systems and backup generators. This ensures that the NOC remains operational during power failures or other unforeseen events.
- **Network Redundancy:** A well-designed NOC incorporates redundant network connections to maintain high availability. This means having multiple pathways for data transmission, ensuring that if one connection fails, others can take over without impacting service quality.
- **Geo-Redundant Deployments:** Some organizations implement geo-redundant setups where backup systems are in different geographical areas. This strategy protects against localized disasters that could affect primary operations, ensuring continuous service availability.
- **High-Availability Software:** NOCs utilize high-availability designs for their software infrastructure to ensure recovery from hardware failures. This includes using virtual platforms that can seamlessly transition operations to backup systems when necessary⁵.

In conclusion the integration of robust backup and redundancy strategies within a Network Operations Center is essential for maintaining network reliability and performance. Backup systems protect vital data and facilitate rapid recovery from incidents, while redundancy measures ensure continuous operation during failures or disasters. Together, these elements enhance the resilience of network services, allowing organizations to operate smoothly and effectively even in challenging circumstances. By prioritizing backup and redundancy, NOCs play a pivotal role in safeguarding organizational assets and ensuring uninterrupted connectivity for users.

4 NOC Interaction with other Departments

4.1 Technical Operations and Maintenance Department

The Technical Operations and Maintenance (TOM) department plays a crucial role in ensuring the efficiency, reliability, and safety of an organization's physical assets. This department is responsible for a variety of tasks that are essential for the smooth operation of facilities, equipment, and systems. By implementing initiative-taking maintenance strategies, the TOM department minimizes unexpected equipment failures and reduces downtime, which can significantly impact productivity and operational costs.



Figure 9 Maintenance and Technical Support

4.1.1 Importance of Technical Operations and Maintenance

- **Equipment Reliability and Efficiency:** The primary objective of the TOM department is to ensure that all equipment operates at optimal levels. This involves conducting regular inspections, preventive maintenance, and timely repairs to prevent breakdowns. By maintaining equipment functionality, organizations can enhance operational efficiency and extend the lifespan of their assets.
- **Safety Compliance:** Safety is paramount in any operational environment. The TOM department implements safety protocols and conducts regular training to ensure compliance with safety standards. This initiative-taking approach not only protects employees but also minimizes the risk of costly accidents and legal issues.
- **Cost Management:** Effective maintenance management leads to significant cost savings. By forecasting maintenance expenditures and managing spare parts inventory efficiently,

the TOM department can reduce unnecessary expenses associated with emergency repairs and equipment replacements.

- **Data-Driven Decision Making:** Modern TOM departments utilize Computerized Maintenance Management Systems (CMMS) to track maintenance activities, analyze performance metrics, and facilitate predictive maintenance. This data-driven approach allows organizations to make informed decisions about asset management and operational improvements.

4.1.2 Key Tasks

The Technical Operations department in cellular telecommunications plays a crucial role in ensuring the efficient functioning of network infrastructure. This department is responsible for various tasks, including the installation and maintenance of sites, which are essential for delivering reliable cellular services. Here are the key responsibilities typically undertaken by this department:

4.1.2.1 Site Installation

Equipment Setup: The Technical Operations team installs and configures communication equipment at various sites, including antennas, base stations, and supporting infrastructure.

Site Surveys: Before installation, technicians conduct site surveys to assess environmental conditions and determine optimal locations for equipment placement to maximize coverage and performance.

4.1.2.2 Maintenance and Repairs

Routine Maintenance: Regular inspections and maintenance are performed to ensure that all equipment operates efficiently. This includes checking connections, updating software, and replacing worn-out components.

Troubleshooting: When issues arise, technicians diagnose problems and perform necessary repairs to minimize downtime and maintain service quality.

4.1.2.3 Network Optimization

Performance Testing: The team conducts tests to evaluate network performance, identifying areas for improvement. This may involve analyzing traffic patterns and adjusting configurations to enhance service delivery.

Upgrades: As technology evolves, the Technical Operations department is responsible for upgrading equipment and systems to keep pace with advancements in telecommunications technology.

4.1.2.4 Collaboration with Other Departments

Coordination with Engineers: The Technical Operations team works closely with network engineers to design and implement innovative solutions that improve network reliability and efficiency.

Support for NOC: They provide critical support to the Network Operations Center (NOC) by addressing issues that arise during monitoring and ensuring that all systems are functioning optimally.

4.1.2.5 Documentation and Reporting

Record Keeping: Maintaining accurate records of installations, maintenance activities, and repairs is essential for tracking performance and planning future upgrades.

Reporting: The department regularly reports on network performance metrics, site status, and any incidents that may impact service delivery.

4.1.3 Collaboration With NOC

The collaboration between the Technical Operations department and the Network Operations Center (NOC) is vital for enhancing network performance and ensuring seamless operations within an organization. This partnership leverages the strengths of both departments to address technical challenges proactively and efficiently.

4.1.3.1 Key Areas of Collaboration

- **Incident Management:** The Technical Operations department works closely with the NOC to manage incidents effectively. When a network issue arises, the NOC monitors and identifies the problem, while the Technical Operations team provides the necessary technical support to resolve it. This coordinated response minimizes downtime and enhances service reliability.
- **Proactive Monitoring:** Both departments engage in proactive monitoring of network performance. The NOC utilizes advanced tools to monitor network health continuously, while the Technical Operations team ensures that all hardware and software components are

functioning optimally. Together, they can detect potential issues before they escalate into significant problems.

- **Maintenance and Upgrades:** The Technical Operations department is responsible for maintaining physical assets, which includes regular updates and upgrades of network equipment. The NOC communicates any performance issues or requirements for upgrades, allowing the Technical Operations team to schedule maintenance activities that align with operational needs.
- **Data Analysis and Reporting:** Collaboration involves sharing data insights between the two departments. The NOC collects extensive data on network performance, which can be analyzed by the Technical Operations team to identify trends, optimize maintenance schedules, and improve overall system efficiency.
- **Standard Operating Procedures (SOPs):** The development of SOPs is a critical aspect of their cooperation. The NOC establishes clear procedures for incident response, while the Technical Operations department contributes technical expertise to ensure these procedures are practical and effective in real-world scenarios.

4.2 Radio Access Network (RAN)

Radio Access Network (RAN) is the part responsible for providing communication between mobile devices and the communications network. The cellular network consists of cells served by radio transmitters and receivers.

The components of a radio access network include base stations and antennas that cover a specific area, depending on their capacity.

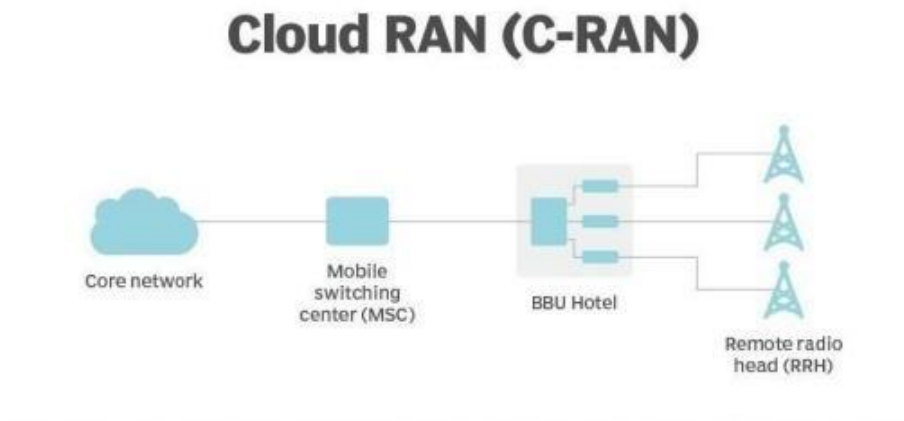


Figure 10 Cloud RAN (C-RAN)

4.2.1 A Radio Access Network Consists of three basic elements.

- **Antennas:** Convert electrical signals into radio waves.
- **Radios:** Convert digital information into signals that can be transmitted wirelessly and ensure that transmissions are in the correct frequency bands with the correct power levels.
- **Baseband units (BBUs):** Provide a set of signal processing functions that make wireless communication possible. BBU processing detects errors, secures the wireless signal, and ensures that wireless resources are used efficiently.

4.2.2 How does a RAN work?

A phone or other device is connected wirelessly to the core network, and the radio access network sends its signal to different wireless endpoints so that it can travel with traffic from other networks. One phone or device can be connected to multiple radio access networks at the same time.

4.2.2.1 Open RAN

It is a hot topic in the world of access networks. It involves the development of open, interoperable hardware, software, and interfaces for cellular wireless networks that use white-box servers and other standard equipment, rather than the custom-made hardware typically used in base stations.

4.2.2.2 C-RAN

Separate the radio elements at the base station into remote radio heads (RRHs). They can be used on top of cell towers for more efficient radio coverage. The RRHs must be connected to central baseband controllers via fiber or microwave radio links. Most baseband processing uses standard white-box servers.

4.3 Network Performance Optimization (NPO) Department

4.3.1 What is network optimization?

Network optimization refers to a set of strategies, tools, techniques, and best practices for monitoring, managing, and improving network performance and reliability. Network optimization is not a single strategy or plan, but rather an ongoing series of adjustments and changes that are continually updated and improved as an organization's understanding of its network and user requirements improves.

There are many ways to optimize a network, such as ensuring that hardware and software are up to date, and there are more technical ways, such as optimizing an organization's network settings,

or using network monitoring software to gain actionable insights, manage bandwidth, reduce latency, and improve traffic efficiency.

Improved Network Performance



Figure 11 Network Performance

4.3.2 NPO Department Inputs

The NPO department obtains information related to network performance from several sources, where all departments work in an integrated manner with each other to ensure improved network performance.

4.3.3 Departments that provide information to the NPO department

4.3.3.1 Network Operations Center (NOC)

This department is responsible for monitoring the network in real time and providing the NPO department with information about:

- Network faults.
- Weak coverage areas.
- Immediate performance data such as signal quality and data speed.

4.3.3.2 Network Planning Department

- Information provided by the NPO:
- Planning and distribution of towers and antenna locations.
- Details about the network frequencies used.
- Future network expansion strategies.

4.3.3.3 *Field Maintenance & Technical Support*

- Provides field reports on faults that have been repaired and problems that have been detected during maintenance.
- Contributes to identifying the physical or technical causes of any performance degradation.

4.4 Transmission Department in Telecommunications Companies

4.4.1 Definition of the Department

The Transmission Department is responsible for designing, building, operating, and maintaining the transmission systems that connect the various stations and centers within the communications network. This includes wired and wireless networks such as optical fibers, communication towers, microwave networks, and satellite systems.

4.4.2 Main tasks of the Transport Department

4.4.2.1 *Network Design and Planning*

This includes developing infrastructure plans to connect different sites within the network, while identifying the best available transmission technologies (such as fiber optics, microwaves, or satellite networks). also identifying efficient paths that ensure quality of service and reduce data loss and latency.

4.4.2.2 *Fiber Optic Network Management*

Designing the fiber optic network, which is one of the most efficient means of data transmission at present, is due to its ability to transmit enormous amounts of data at high speeds. Also managing alternative paths in the event of failures to ensure continuity of service.

4.4.2.3 *Wireless Network Management (Microwave)*

Operating microwave networks that provide data transmission via wireless signals between stations.

4.4.3 The role of the correspondence department in providing communications services

correspondence department represents the backbone of the communications network, ensuring that all data reaches the desired destinations accurately and quickly. The department is also responsible for providing the necessary infrastructure for various applications and services that relieve data transfer, such as the Internet, telephone, and television broadcasting.

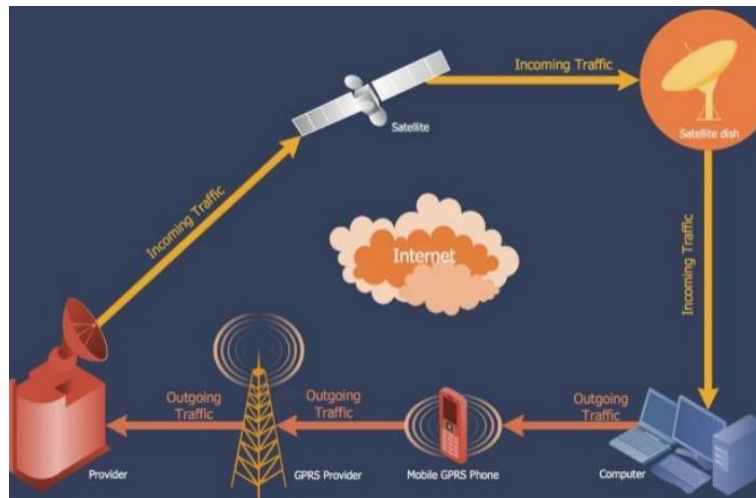


Figure 12 Telecommunication Network

5 Key Performance Indicator (KPIs) in NOC

5.1 Introduction

Network Operations Centers (NOCs) are crucial for maintaining the performance, reliability, and security of an organization's IT infrastructure. To effectively manage operations, NOCs rely on Key Performance Indicators (KPIs) that provide insights into various aspects of network performance. This paper examines several critical KPIs in NOC operations: drop call rate, call setup success rate, handover success rate, data volume, availability, and traffic. Each of these metrics plays a vital role in assessing the quality of service delivered to end-users and ensuring operational excellence.

The process of determining KPIs in the Network Operations Center depends on three essential elements: thresholds, formulas, and counters. They work together to ensure that performance is measured well and reliably.

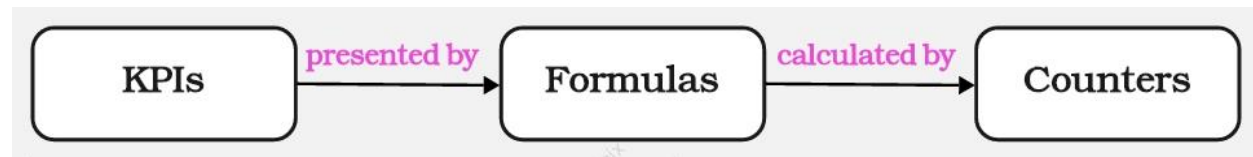


Figure 13 Block Diagram for determining KPIs.

- **Thresholds:** Are values that are referred to determine the levels of acceptance of network performance. This means that if the specified percentages are exceeded, this is considered an indication of the presence of a problem that requires rapid intervention.
- **Formulas:** Are mathematical equations that are used to calculate network performance indicators. They provide standardized methods for measuring network performance and facilitate the process of comparing results over different time periods.
- **Counters:** Are tools or units used to measure specific events and data in the network.

Network performance is communicated to each cell through counters in the base station controller and specialized tools. These counters collect key metrics such as call success rate, signal strength, and interference levels. Analytical tools process this data to evaluate performance and identify issues such as interference and signal weakness and generate detailed reports.

5.2 Drop Call

Definition: The drop call rate is the percentage of calls that are terminated unexpectedly before completion. It serves as a critical metric for assessing the quality of voice services within mobile networks.



Figure 14 Drop Call Operation

Importance: A high drop call rate can indicate issues such as network congestion, poor coverage, or technical failures, which can lead to customer dissatisfaction. Monitoring this KPI allows NOC teams to identify and address performance problems, enhancing user experience and service reliability.

Threshold: 0.1%

Formula: The drop call rate is calculated using the formula:

$$\text{Drop Call Rate} = \frac{\text{Number of Dropped Calls}}{\text{Total Number of Calls Attempted}} \times 100$$

This formula provides a clear percentage that reflects the proportion of calls that were dropped relative to total attempts.

In the “Cell Drop-Call plot over one week” figure we can see that when the rate is over 0.1% an alarm will be triggered (represented by the red point on the plot, otherwise the cell status would be normal).

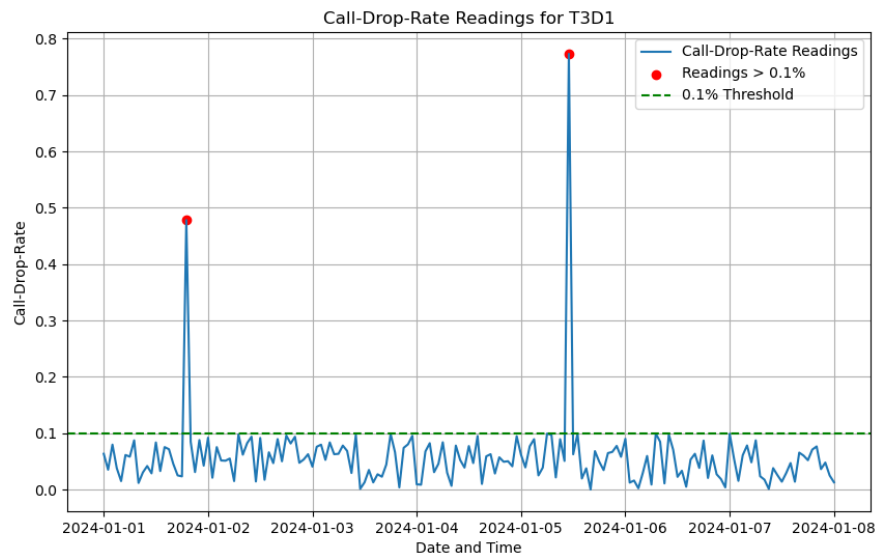


Figure 15: Cell Drop-Call plot over one week.

5.3 Call Setup

Definition: This KPI measures the percentage of calls that are successfully established compared to the total number of call attempts made by users.

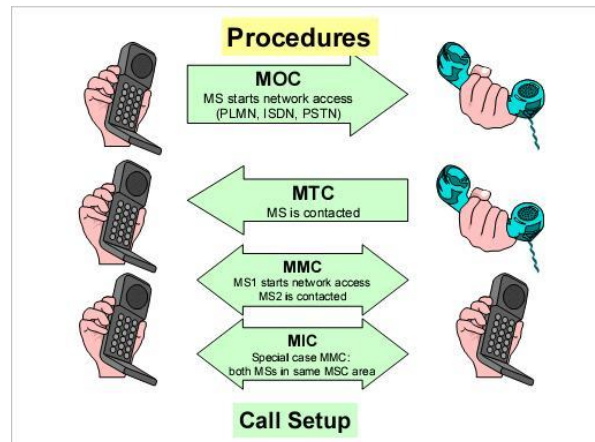


Figure 16 Call Setup

Importance: A low call setup success rate may indicate problems with network signaling or capacity issues. By analyzing this metric, NOC teams can optimize network resources to improve connectivity and overall service quality, thereby ensuring a more reliable communication experience for users.

Threshold: 100%

Formula: The call setup success rate is calculated as follows:

$$\text{Call Setup Success Rate} = \frac{\text{Successful Call Setups}}{\text{Total Call Attempts}} \times 100$$

This calculation provides insight into the effectiveness of the network in establishing connections.

In the “Call Setup Rate plot over a week” figure we can see that when the rate is less 100% an alarm will be triggered (represented by the red point on the plot, otherwise the cell status would be normal).

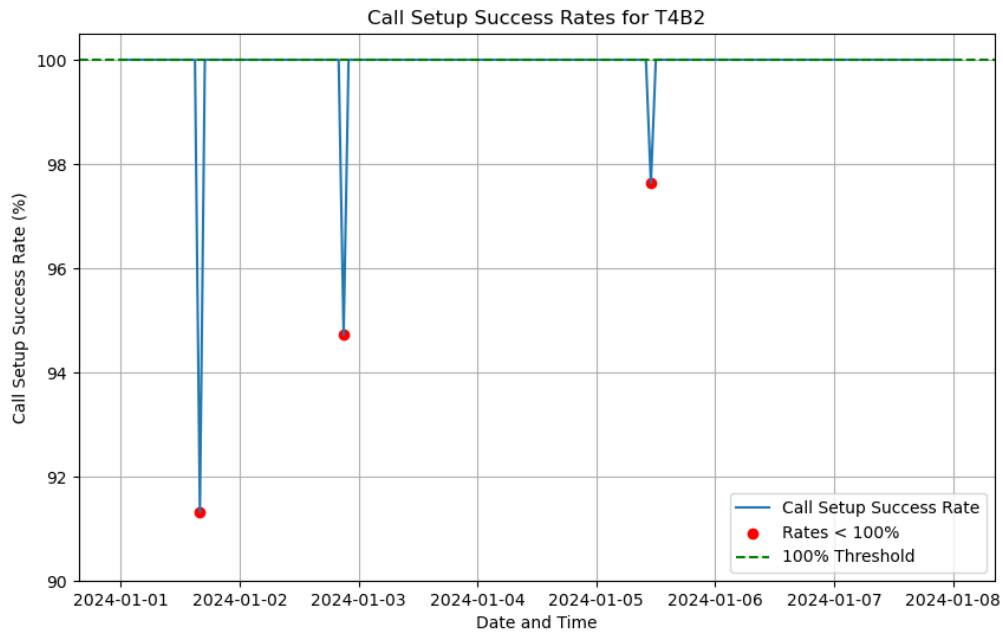


Figure 17 Call Setup Rate plot over a week.

5.4 Handover

Definition: The handover success rate measures the percentage of calls that successfully transition from one cell or base station to another without interruption during a call.

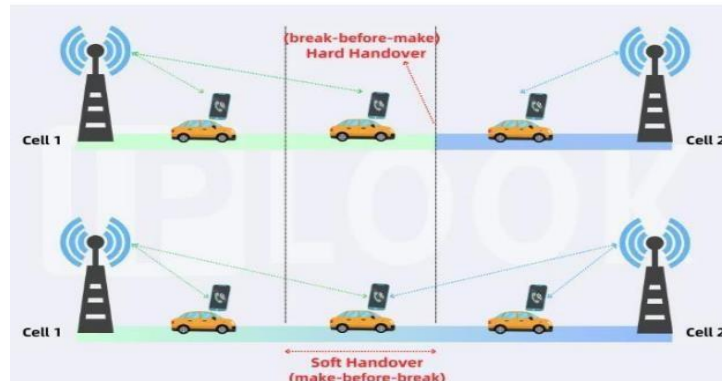


Figure 18 Handover

Importance: This KPI is crucial for maintaining seamless communication, particularly in mobile environments where users frequently move between coverage areas. A low handover success rate can lead to dropped calls and user frustration. Monitoring this metric enables NOC teams to identify potential issues related to interference or inadequate resource allocation.

Threshold: 98%

Formula: The handover success rate is calculated using the formula:

$$\text{Handover Success Rate} = \frac{\text{Successful Handovers}}{\text{Total Handovers Attempted}} \times 100$$

This formula provides a clear understanding of how well the network supports ongoing calls during transitions between cells.

In the “Handover Rate plot over a week” figure we can see that when the rate is less than 98% an alarm will be triggered (represented by the red point on the plot, otherwise the cell status would be normal).

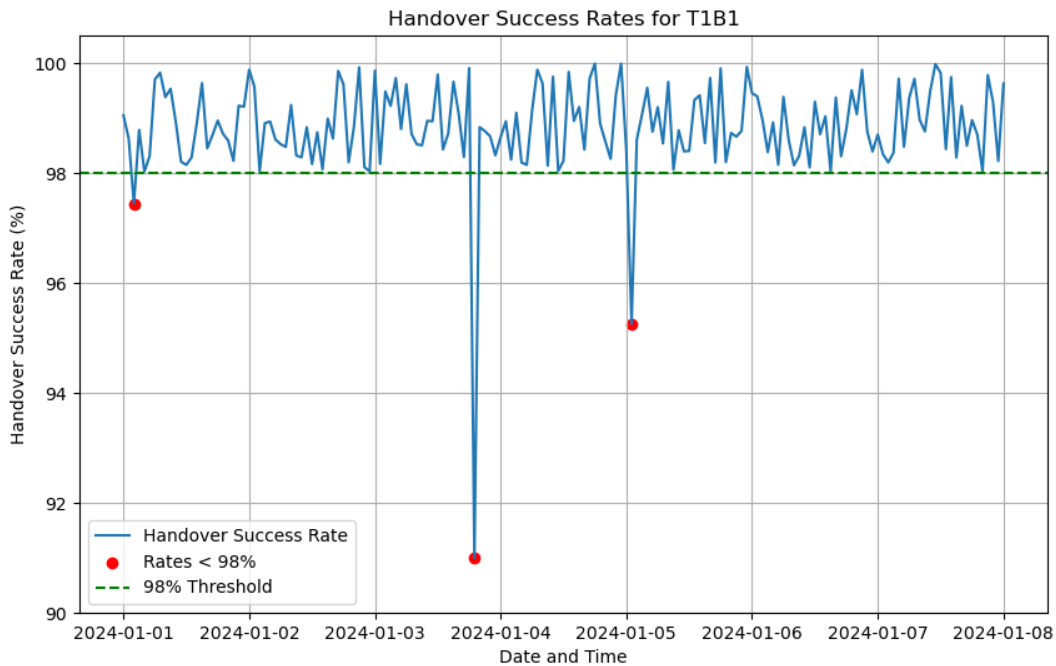


Figure 19 Handover Rate plot over a week.

5.5 Availability

Definition: Availability measures the proportion of time that a service or system is operational and accessible to users.

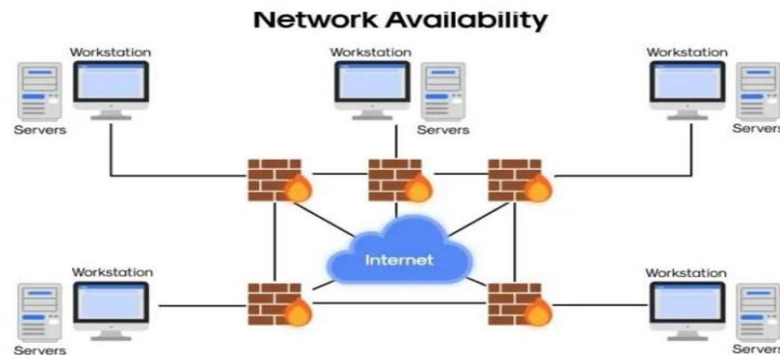


Figure 20 Network Availability

Importance: High availability is critical for customer satisfaction and operational efficiency. NOCs must monitor this KPI closely to minimize downtime and ensure services meet established Service Level Agreements (SLAs). Effective management of availability ensures that users have reliable access to services when needed.

Calculation: Availability can be calculated using the following formula:

$$\text{Availability} = \frac{\text{Total Uptime}}{(\text{Total Uptime} + \text{Total Downtime})} \times 100$$

This formula provides a percentage that reflects how often services are available versus unavailable due to downtime.

In the “Availability Rate plot over a week” figure we can see that when the rate is less 100% an alarm will be triggered (represented by the red point on the plot, otherwise the cell status would be normal).

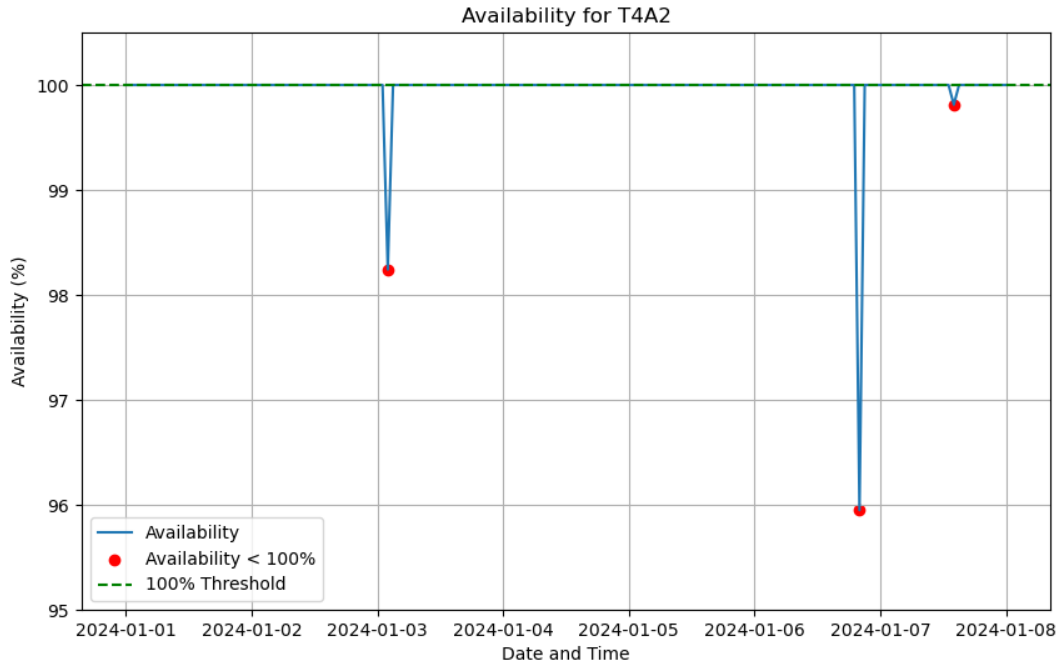


Figure 21 Availability Rate plot over a week.

5.6 Traffic

Definition: Traffic refers to the amount of data being transmitted across the network at any given time, typically measured in bits per second (bps).

Importance: Understanding traffic patterns allows NOC teams to optimize bandwidth allocation and manage congestion effectively. By analyzing traffic data, NOCs can make informed decisions about scaling infrastructure or implementing Quality of Service (QoS) measures to prioritize critical applications, ensuring efficient use of resources.

Formula: Traffic can be measured by monitoring data flow over time:

$$\text{Traffic} = \frac{\text{Total Data Transmitted}}{\text{Time Period}} \times 100$$

where total data transmitted is measured in bytes or bits over a specified period (e.g., DDDDDseconds). This calculation provides insights into current network load and usage trends.

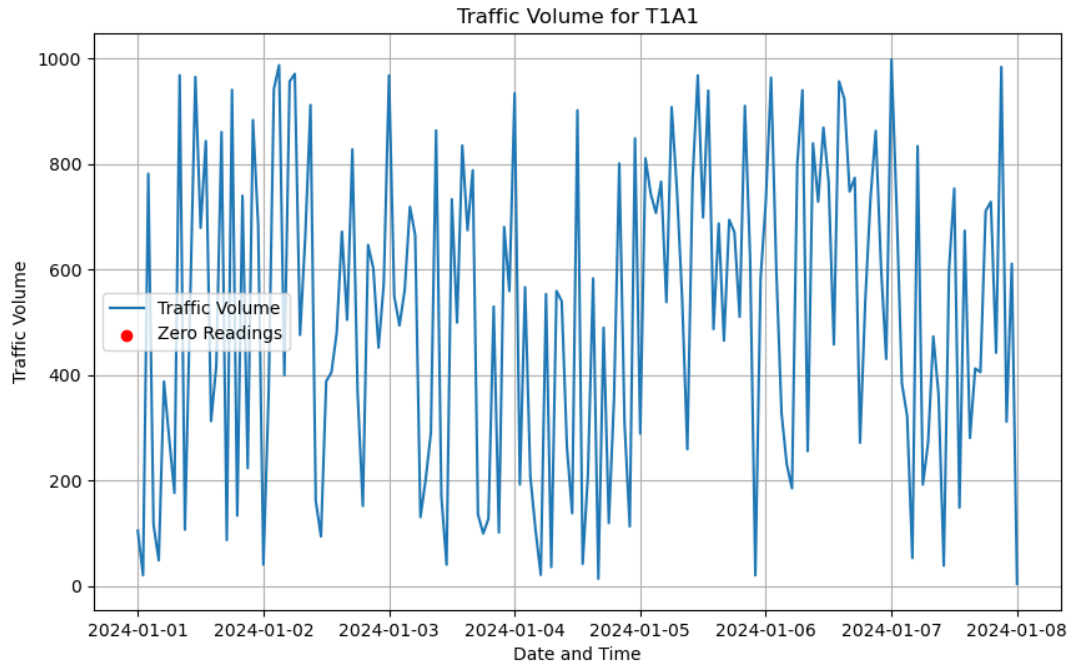


Figure 22 Traffic plot over a week.

5.6.1 Voice traffic

is a real time and sensitive traffic type. The voice packets must be delivered at the same time or with an extremely low delay. Because, if the voice packets arrive in several types to the destination, we cannot understand what they are saying. So, delay time is important for such traffic.

5.6.2 Data traffic

is the other important traffic type. This type of network traffic is insensitive traffic to packet loss if we compare it with voice traffic. It uses retransmission mechanism if any packet loss occurs.

Formula: Data volume can be calculated by summing up the total bytes transmitted over a specified period:

$$Data\ Volume = \sum_{i=1}^n Data\ Transmitted\ i$$

where n is the number of data packets transmitted during the time interval. This calculation provides a comprehensive view of network usage over time.

5.6.3 Erlang

An Erlang is a unit of telecommunications traffic measurement. One Erlang is the continuous use of one voice channel. In call minutes, one Erlang is 60 min/h, 1440 call min/24 h. In practice, when doing mobile capacity calculations, an Erlang is used to describe the total traffic volume of 1 h, for a specific cell.

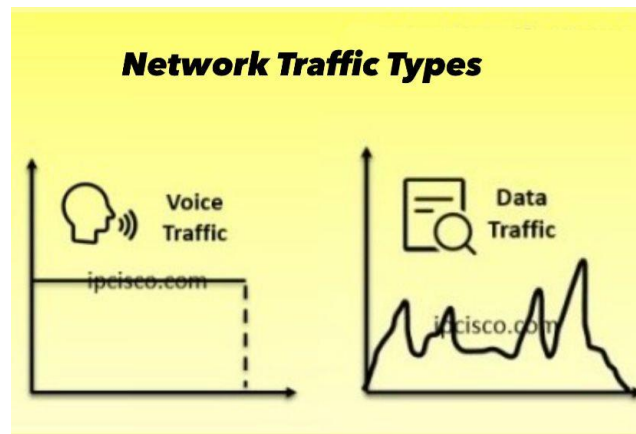


Figure 23 Types of Traffic

5.7 Conclusion

In conclusion, monitoring these KPIs Drop Call Rate, Call Setup Success Rate, Handover Success Rate, Data Volume, Availability, and Traffic is essential for effective NOC operations. By leveraging these metrics, NOC teams can enhance service delivery, ensure compliance with SLAs, and improve customer satisfaction. Continuous assessment and optimization based on these KPIs will enable organizations to maintain robust network performance in an increasingly complex digital landscape.

6 Metaverse

The metaverse is an expansive digital universe that merges virtual reality (VR), augmented reality (AR), and the internet, allowing users to interact with each other and the environment in real-time. It encompasses various virtual spaces where individuals can socialize, work, play, and conduct business. The metaverse aims to create immersive experiences that mimic or enhance real-world interactions, fostering a sense of presence and community.

6.1 Benefits of the Metaverse

- **Enhanced Collaboration:** The metaverse facilitates remote collaboration among teams across various locations, allowing for seamless communication and project management in a shared virtual space.
- **Innovative Training and Education:** Organizations can utilize immersive simulations for training purposes, providing realistic scenarios for employees to practice skills without real-world consequences.
- **New Business Opportunities:** The metaverse opens avenues for businesses to create virtual storefronts, host events, and engage with customers in novel ways.
- **Social Interaction:** Users can connect with others in a more engaging manner than traditional social media platforms, fostering community and shared experiences.
- **Education:** The Metaverse contributes to the development of the education process as it allows the possibility of conducting the teaching process virtually, which facilitates this process and contributes to breaking geographical barriers.
- **Healthcare:** The Metaverse world has facilitated the health care process by conducting remote surgeries, conducting virtual medical consultations, and medical training.



Figure 24 Metaverse

6.2 Virtual Reality (VR)

Virtual reality (VR) is a technology that allows users to immerse themselves in an artificial, computer-generated environment and interact with it in real-time.

6.2.1 The functioning of VR technology

The basis of VR technology is an end-to-end mechanism that replaces the natural environment with a deceptively real-looking simulation.

This simulation is strongly oriented towards the real world. To adapt the digital world to the real world as best as possible, modern AI algorithms are usually used. These have the task of projecting new and familiar elements onto a mathematically defined surface. The result is a virtual world that looks deceptively real to users.

The hardware typically includes a headset or display, motion controllers, and sensors that track the user's movements and gestures in real-time. The software involves creating a digital environment using computer-generated graphics, audio, and other sensory inputs to simulate a fully immersive experience.

Here are VR headsets:



Figure 25 Oculus Quest2

6.3 Designing a Network Operations Center (NOC) in the Metaverse

A Network Operations Center (NOC) is essential for monitoring and managing telecommunications infrastructure. In the context of the metaverse, designing a NOC can leverage its unique capabilities to enhance network performance and reliability.

6.3.1 Unity & 3D Max.

Comparison between Unity and Unreal :

- **Unity** is a video game engine that is also used in many other industries. It powers 84 percent of the top one hundred games and over 60 percent of the top-grossing VR Steam experiences .

What language does Unity use? Unity uses C#, an open-source, object-oriented, and cross-platform programming language. When we write code, Unity will default to the Visual Studio editor, but we can also select preferred editor from the External Tools panel.

- **Unreal Engine** is a comprehensive suite of tools designed for anyone working with real-time technology. From game developers to architects, it is used across various industries for creating interactive experiences.

Which Programming Languages Does Unreal Engine Use in Game Development? Unreal Engine uses C++ as the programming language for developing games within the tool. C++ offers overall stability and excellent memory allocation, which is why Unreal Engine developers use it.

Comparison table between Unity and Unreal:

<i>Feature</i>	<i>Unity</i>	<i>Unreal Engine</i>
<i>Learning Curve</i>	Easy to moderate	Steep
<i>Graphics Quality</i>	Good	Excellent
<i>Performance</i>	Mobile-friendly	High-end hardware needed
<i>Scripting</i>	C#	C++
<i>Cost</i>	Free tier, paid plans	Free, 5% royalties on revenue
<i>Best Use Cases</i>	Indie, mobile, AR/VR	cinematics, simulations

Table 1 Unity vs. Unreal Engine

Based on the previous comparison, we adopted the Unity program, as the environment was built on the **3D Max program**, which is a powerful 3D modeling, animation, and rendering software widely used in game development, film production, and architectural visualization. Then we uploaded the environment to the Unity program as shown in the following images:

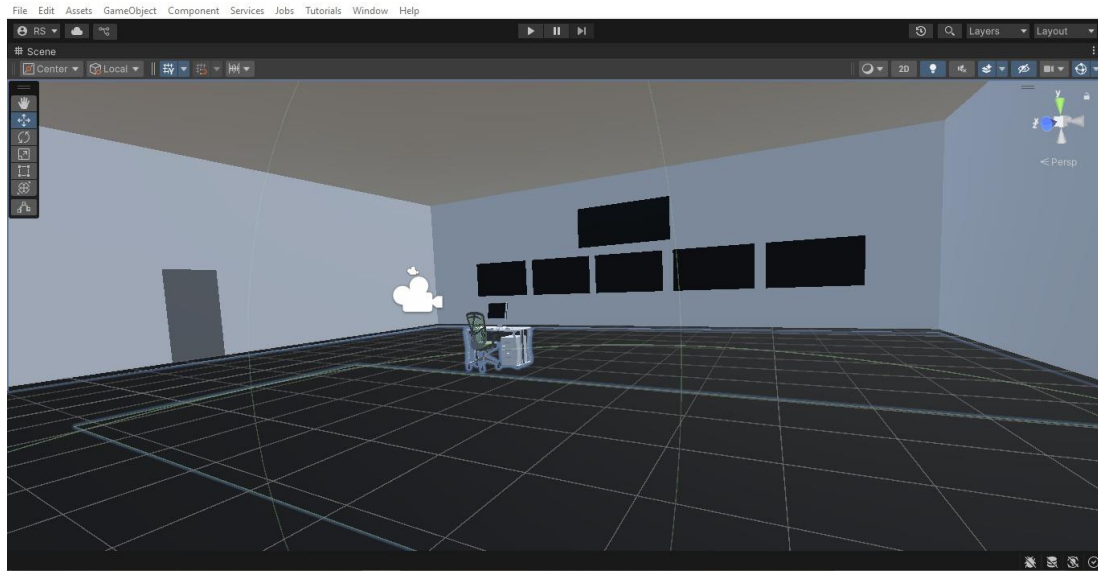


Figure 26 XR Rig(Origin)

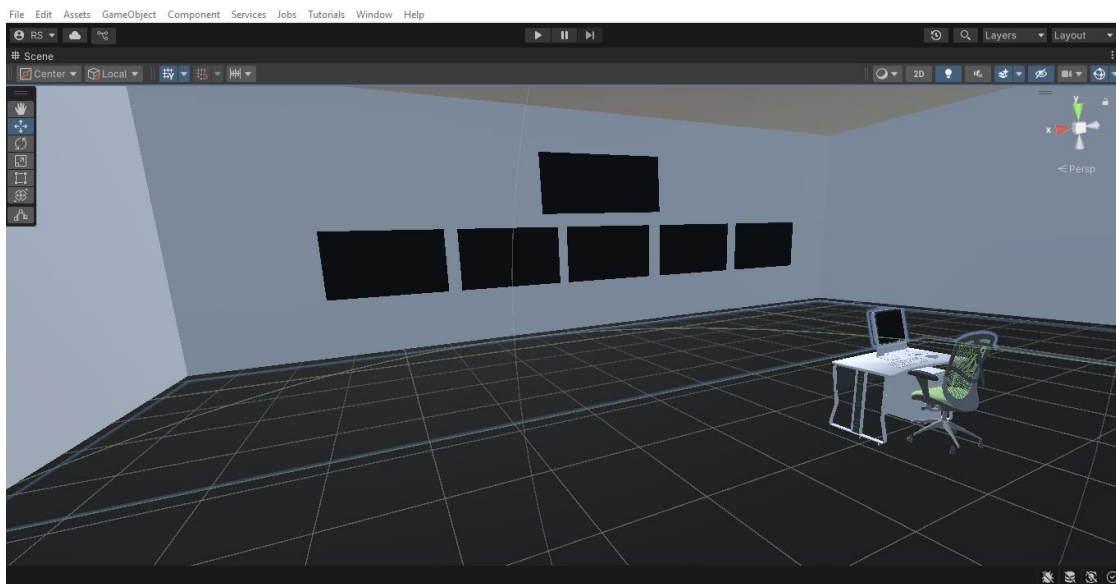


Figure 27 Virtual NOC control room-Unity (Inside)

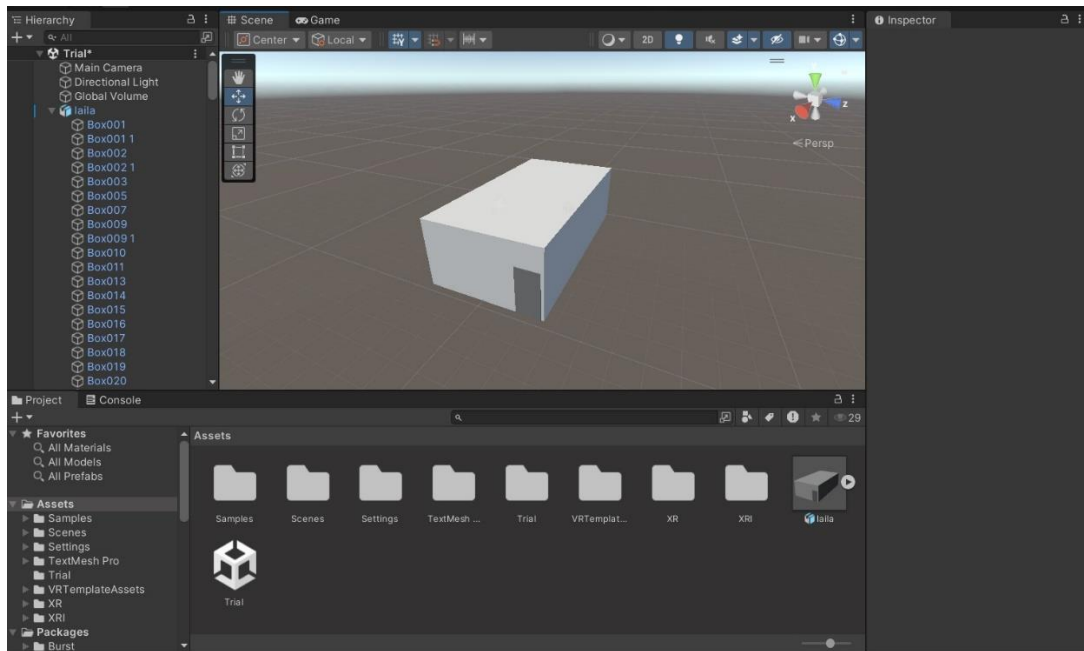


Figure 28 Virtual NOC-Unity (Outside)

6.4 Key Features of a NOC in the Metaverse

Virtual Monitoring Environment: Utilizing VR technology, NOC personnel can visualize network data in a 3D space, allowing for more intuitive monitoring of network performance metrics.

Real-time Collaboration: Teams can work together within the metaverse to troubleshoot issues, share insights, and manage incidents as they arise.

Enhanced Incident Response: Through immersive simulations, NOC teams can practice incident response strategies and refine their protocols in a risk-free environment.

Data Visualization Tools: Advanced analytics tools integrated into the NOC can present complex data sets visually, making it easier to identify trends and anomalies.

6.5 Benefits of a Metaverse-based NOC

- **Increased Efficiency:** By providing an immersive working environment, NOCs can improve focus and productivity among staff.
- **Cost Savings:** Virtual operations may reduce the need for physical infrastructure and associated costs while maintaining high service levels.
- **Scalability:** As organizations grow, a metaverse-based NOC can easily scale to accommodate increased demand without significant physical expansion.

In conclusion, integrating a Network Operations Center within the metaverse not only enhances operational capabilities but also aligns with the evolving landscape of digital communication and collaboration. By leveraging the unique features of the metaverse, organizations can significantly improve their network management processes while embracing innovative technologies that redefine how we interact with digital environments.

7 Programing Languages

7.1 PyCharm

We used PyCharm in our project as a powerful and specialized Integrated Development Environment (IDE) for Python. Our decision to use PyCharm was not random it was based on a set of features that significantly supported the development of the backend system, particularly for data analysis and generating intelligent reports using Artificial Intelligence (AI).

7.2 Why Did We Use PyCharm in the Project?

- **Professional Project Organization:** PyCharm enables the creation of a clear and organized file structure, which made it easier for us to separate the code responsible for data analysis and image generation.
- **Strong Support for Data Analysis Libraries:** It provides excellent support for libraries such as pandas, matplotlib, openpyxl, and flask, which were essential for generating Excel files, creating performance charts, and handling requests sent from Unity for AI-based analysis.
- **Easy Debugging:** PyCharm offers a visual and user-friendly debugging environment that allowed us to inspect values and efficiently identify and resolve issues in our network analysis scripts.

7.3 Comparison Between C# and Python

C# and Python are two distinct programming languages with different strengths and use cases. Here is a comparison of their key features:

<i>Feature</i>	<i>C#</i>	<i>Python</i>
<i>Syntax</i>	More complex, uses braces and brackets for code blocks	Simpler uses whitespace for code blocks ¹⁵ .
<i>Type System</i>	Statically typed, type determined at compile time ¹³ .	Dynamically typed, type determined at runtime ¹³ .
<i>Compilation</i>	Compiled language, converted to Intermediate Language (IL) before execution.	Interpreted language, executed line by line without compilation.
<i>Performance</i>	Faster due to compilation, suitable for resource-intensive tasks.	Slower than C# but can be optimized with libraries.
<i>Use Cases</i>	Primarily used for Windows desktop applications, game development, and enterprise software.	Commonly used for scientific computing, data analysis, web development, and AI/ML.
<i>Platform Independence</i>	Primarily Windows but it can run on other platforms with .NET Core.	Highly platform-independent ¹ .
<i>Learning Curve</i>	Steeper learning curve due to complex syntax.	Gentler learning curve, easier for beginners.

Table 2 C# vs. Python

7.4 Using Python for Data Analysis in VNOC

For the data analysis component of the Virtual Network Operations Center (VNOC), Python is an ideal choice. Here is why:

- **Extensive Libraries:** Python offers powerful libraries like **Pandas** for data manipulation, **NumPy** for numerical computing, and **TensorFlow** for machine learning tasks.
- **Ease of Development:** Python's dynamic typing and straightforward syntax make it easier to write and understand code, leading to faster development times.
- **Cross-Platform Compatibility:** Python can run on multiple operating systems, ensuring flexibility in deployment.

7.5 Using C# for VNOG Programming

For the core programming of the VNOG, C# is suitable due to its strengths in building robust applications:

- **Performance and Reliability:** C# provides better runtime performance and reliability, which is crucial for a VNOG that may manage large volumes of network data.
- **Integration with .NET Framework:** C# integrates well with the .NET framework, allowing for efficient development of Windows-based applications and enterprise software.
- **Security and Scalability:** C# is well-suited for building secure and scalable applications, which are essential for a VNOG managing sensitive network operations.

By leveraging Python for data analysis and C# for core VNOG programming, you can create a robust and efficient solution that combines the strengths of both languages.

8 Integration of Unity, Python, and AI – Design and Results

8.1 Data Generation Using PyCharm

In our project, we used **PyCharm** to develop Python scripts responsible for generating **live network performance data**. The data generation started from **December (month 12)** and continued through to **June (month 6)**, which represents the current month. At the end of each month, the system aggregates the **quarter-hour readings** to calculate **hourly averages**, which are then used to compute the **daily averages**, followed by the **monthly averages** based on the daily data.

All generated data is **automatically stored in Excel files** in real time, ensuring a complete and organized dataset for later analysis.

The structure of the simulated network is based on **An-Najah National University**, where we modeled **four telecom towers**, each consisting of **four cells**. Every cell is monitored using **five key performance indicators (KPIs)** to assess its network performance.

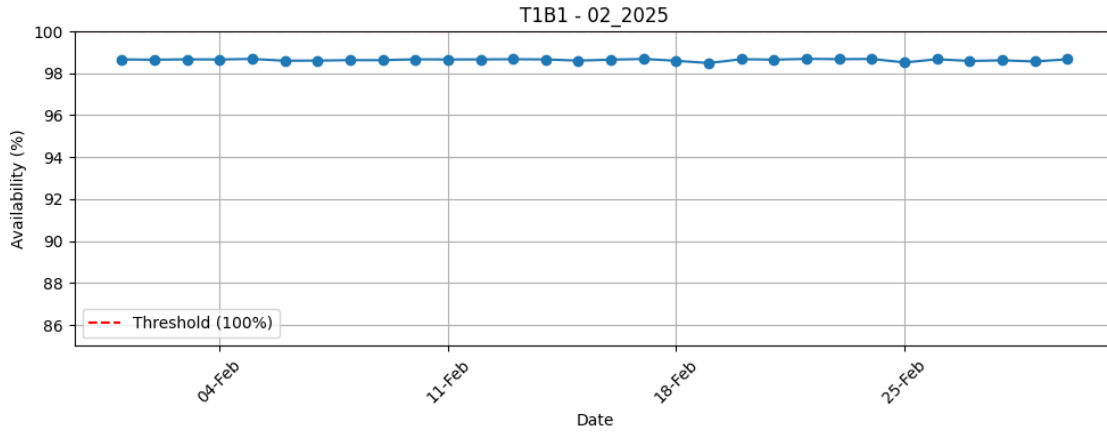


Figure 29 Availability Trend for Cell T1B1 in February 2025

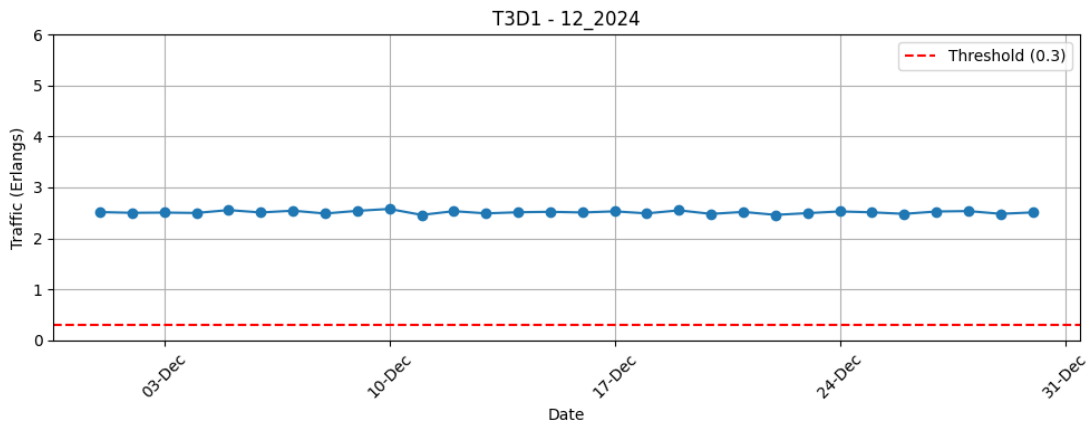


Figure 30 Traffic Performance for Cell T3D1 in December 2024

8.2 Linking Unity with PyCharm to Display and Analyze Network KPIs

After completing the design of the Network Operations Center (VNOC) environment using 3ds Max, we exported the 3D models in a suitable format (such as .FBX) and then imported them into the Unity game engine to build an interactive environment that simulates a real-world scenario. The models and interfaces were arranged inside Unity to resemble a realistic network control room, including five screens dedicated to displaying the main Key Performance Indicators (KPIs), in addition to a sixth screen dedicated to displaying smart reports on network performance.

Later, we integrated Unity with PyCharm, where PyCharm was responsible for generating the data using Python, while Unity handled the visualization and interaction within the 3D environment.

✓ **Integration Mechanism:**

The integration between Unity and PyCharm was achieved through a local Flask server developed using Python, which acts as an API bridge between the two systems. The integration workflow was as follows:

○ **PyCharm (Python):**

Continuously generates data and stores it in Excel files.

Hosts a Flask server that receives requests from Unity to analyze data or send reports.

○ **Unity (C#):**

Contains dedicated scripts for each KPI screen (such as AvailabilityImageSlider.cs and KPIReportSender.cs).

These scripts read images and data from continuously updated folders.

When an alarm is triggered, a request is sent to the PyCharm server to analyze the corresponding file using AI.

The analysis or report is then displayed on the sixth screen (PC_Screen), dedicated to performance reports, and is also automatically emailed to the responsible department.

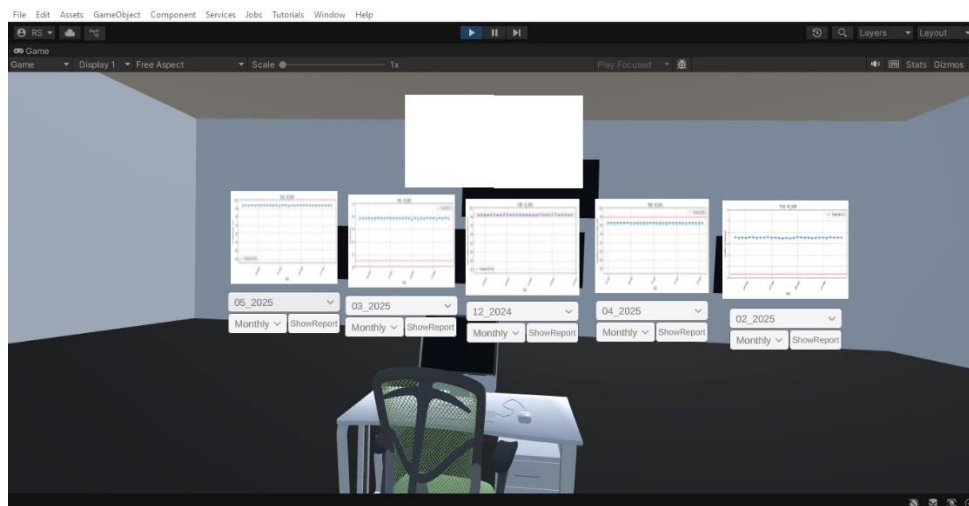


Figure 31 Data Visualization on KPI Screens Inside the VNOG Environment

8.3 Role of Artificial Intelligence (AI) in the VNOC System

We subscribed to **OpenAI services for a period of three months** and fully integrated it into our VNOC system to provide intelligent analysis of network performance and automated alarm handling. The AI functionality was applied in two main scenarios:

✓ **Real-Time Alarm Analysis**

When live data is being displayed and an alarm appears on any of the five KPI screens, the AI component is triggered to perform the following tasks automatically:

1. It extracts the cell name and KPI type from the image file name.
2. It sends a request to the GPT model along with the relevant performance data file (Excel).
3. The AI generates a detailed report that includes:
 - The name of the affected cell
 - The specific KPI that triggered the alarm
 - A technical analysis of the root cause
 - A recommended solution
 - The department responsible for handling the issue (e.g., Radio, Power, Transmission, Field)
4. The report is then **displayed on the sixth screen (PC_Screen)**.
5. It is also **automatically emailed to the responsible department**.

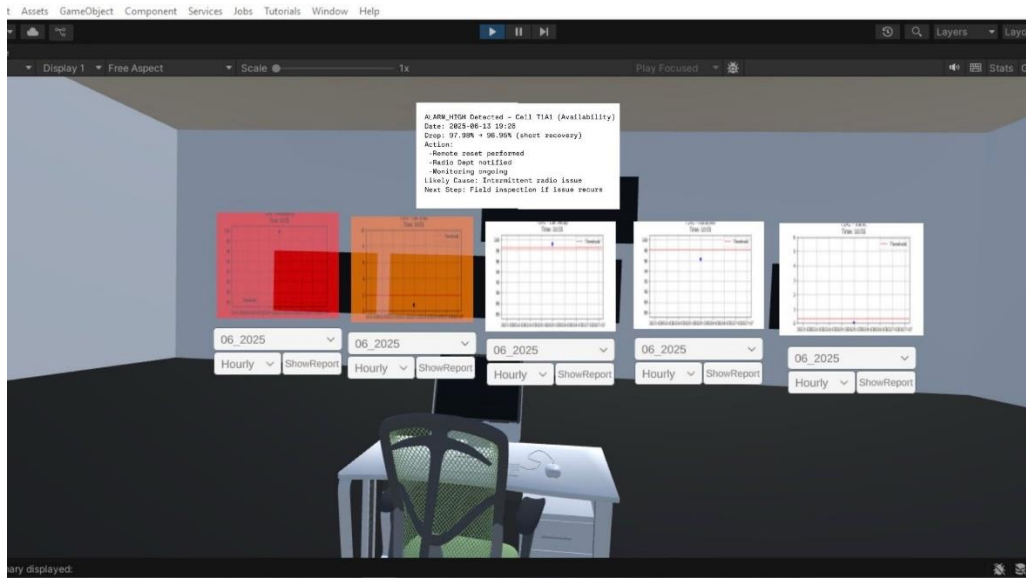


Figure 32 Alarm Visualization and AI Report Display in the VNOc Environment

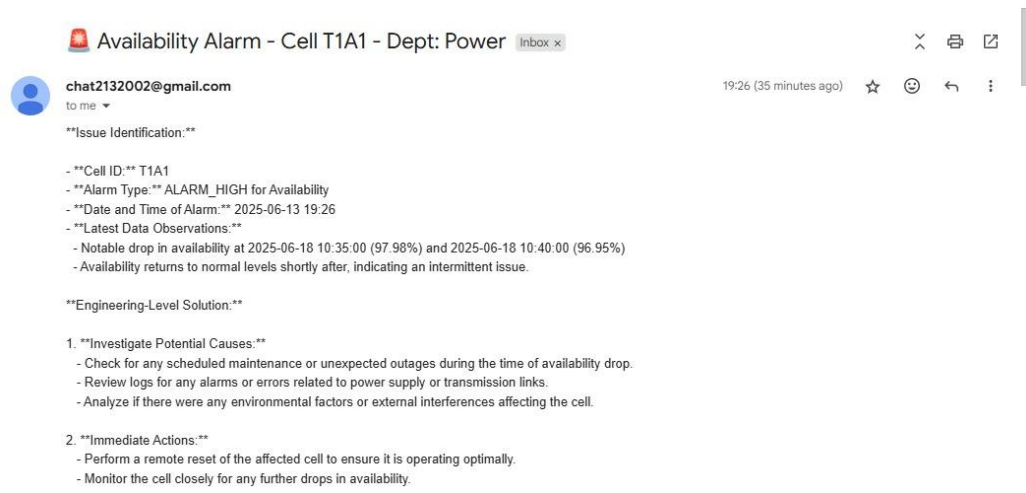


Figure 33 AI-Generated Email Sent to Responsible Department for Alarm Resolution

3. **Long-term Actions:**
 - Conduct a detailed audit of the cell's hardware and software configurations.
 - Schedule a site visit to physically inspect the equipment for any signs of wear or damage.
 - Ensure all firmware and software are up-to-date to prevent future issues.
- Responsible Department:**
- **Primary Responsibility:** Radio Department
 - The issue appears to be related to the radio equipment or configuration, given the specific drop in availability and quick recovery.
 - **Secondary Support:**
 - Field Department for on-site inspections if remote diagnostics do not resolve the issue.
 - Transmission Department to verify the integrity of the backhaul links if the issue persists after radio checks.
- NOC Action Plan:**
1. **Log the Issue:** Document the alarm and actions taken in the NOC system.
 2. **Notify Radio Department:** Escalate the issue to the Radio Department for immediate investigation.
 3. **Monitor the Cell:** Keep the cell under observation for any further anomalies.
 4. **Follow-up:** Schedule a follow-up review with the Radio and Field Departments to ensure resolution.

Figure 34 Department Assignment and NOC Action Plan in AI Email Report

✓ Historical Monthly Analysis

For past months (December through May), when historical data is displayed on the KPI screens, the user can click the "Show Report" button to trigger a different analysis flow:

1. The corresponding Excel file for the displayed month is sent to the GPT model.
2. The AI performs a comprehensive analysis of all cell performances during that month.
3. It generates a full report containing:
 - Individual cell performance evaluations
 - Identification of weak-performing cells
 - Trend analysis and performance decline
 - Engineering recommendations for improvement
4. The final report is **automatically emailed to the NOC manager** for further review.

This integration between AI and the VNOC system allows for highly accurate, fast, and automated network supervision, simulating the role of a professional NOC engineer—yet operating 24/7 without fatigue or delay.

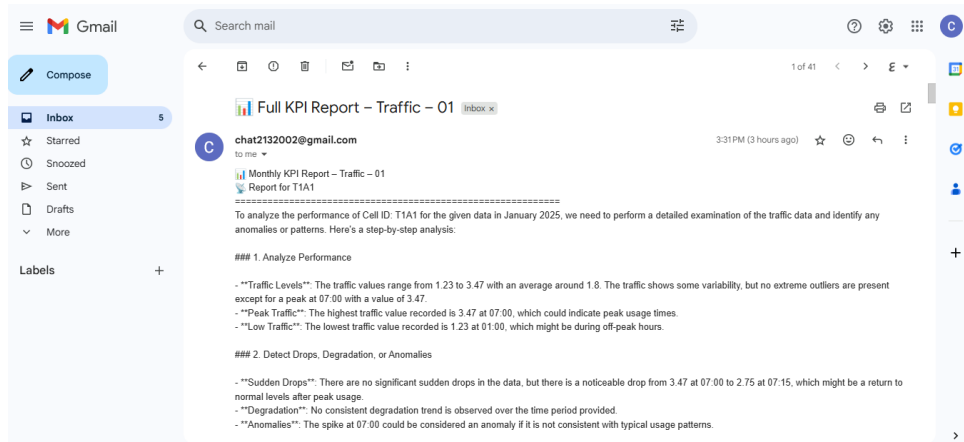


Figure 35 Automated AI Email Report Sent to the NOC Manager

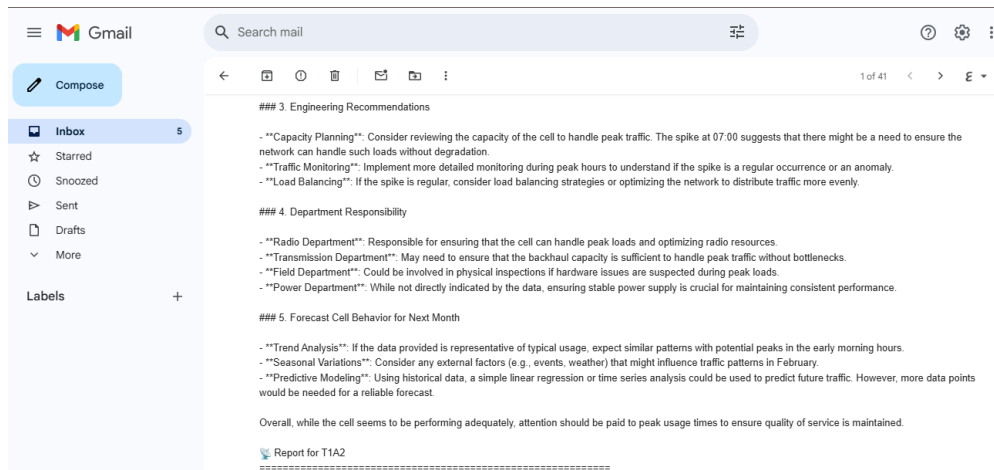


Figure 36 AI Report: Engineering Recommendations and Department Assignment

8.4 Comparison Between Traditional NOC Engineer and AI-Based VNOC System

In modern network environments, the AI-based VNOC system significantly outperforms traditional NOC engineers in terms of speed, awareness, and accuracy. The AI operates continuously 24/7 without being affected by fatigue or distraction, enabling it to detect performance degradation in real time and analyze KPI trends at fine-grained intervals (e.g., every 15 minutes). For instance, if performance drops in Cell A, the AI can instantly evaluate whether neighboring cells (B and C) are also affected, based on historical correlations and predictive analytics without the need to manually open and compare multiple reports.

However, human engineers still play a critical role in recommendations, tuning, and complex decision making especially in exceptional cases. While the AI may issue accurate alarms or suggest actions based on data, the engineer brings contextual understanding and situational judgment. For example, in emergency conditions like military incursions or hazardous zones, the AI might recommend dispatching a team to restore a site based on power outage detection. Yet, the engineer may decide not to act on that due to safety concerns, instead optimizing the power from nearby sites. This synergy between AI precision and human expertise ensures a smart and balanced network operations system.

<i>Aspect</i>	<i>Traditional NOC Engineer</i>	<i>VNOC AI System</i>
<i>Speed</i>	Slower due to manual verification and report navigation	Instant response through automated real-time analysis
<i>Awareness & Continuity</i>	Affected by fatigue, multitasking, and human limitations	Fully aware, operates continuously with no downtime
<i>Accuracy of Detection</i>	May overlook minor alarms or time-sensitive issues	Highly accurate, monitors KPIs every 15 minutes
<i>Comprehensiveness</i>	Needs to check multiple reports for cross-cell analysis	Instantly correlates data across cells based on learned patterns
<i>Exceptional Case Handling</i>	Excels in contextual decisions and adapting to real-world events	May misinterpret rare scenarios without human input
<i>Recommendations & Tuning</i>	Strong at proposing practical, field-aware solutions	Provides generic suggestions, needs validation
<i>Flexibility</i>	Can make non-standard decisions based on field experience	Limited to its training and predefined logic

Table 3 Comparison Between Traditional NOC Engineer and AI

8.5 Project Deployment on Meta Quest 2 Headset

After completing the system integration and successfully linking Unity with the Python backend and AI services, we proceeded to the **deployment phase**, during which the entire VNOC project was built and uploaded to the **Meta Quest 2** headset. This step marked the transition from development and testing to a fully immersive VR experience, allowing the system to operate directly on the headset without the need for a connected computer.

8.5.1 Deployment Methods for Unity Projects on Meta Quest 2

In developing VR applications for Meta Quest 2, there are two main methods for deploying Unity-based projects:

1. **Development Deployment (Wired):** The headset is connected via USB-C to a computer, and the app is pushed through Unity or ADB. This is mainly used during development and testing, and the project cannot be run independently later.
2. **Standalone Wireless Deployment:** The app is built as an APK and installed once on the headset. After installation, the project can be launched at any time independently, without needing a cable or a computer.

✓ **Adopted Method in VNOC Project:**

We adopted the Standalone Wireless Deployment method as our primary approach. This allows us to upload the app once to the Meta Quest 2, and then run it directly from the headset at any time, without needing to reconnect to a computer. This enables a realistic and independent VR experience.

<i>Aspect</i>	<i>Development Deployment (Wired)</i>	<i>Standalone Wireless Deployment</i>
<i>Execution Method</i>	Via USB from Unity	Direct from headset
<i>PC Required</i>	Yes, every time	No, after install
<i>Install Mechanism</i>	Build & Run each time	Install APK once
<i>After Installation</i>	Needs reconnect to PC	Can run anytime
<i>Best For</i>	Development/testing	Final use/demo

Table 4 Comparison of Deployment Methods for Unity Projects on Meta Quest 2

9 Economical Feasibility

Despite considerable initial investment in virtual reality equipment, development environments, and software integration, the Virtual Network Operations Center (VNOC) demonstrates promising economic viability for modern network management. While the immersive interface, real-time monitoring capabilities, and intelligent automation features present significant advantages over traditional NOC systems, operational costs such as continuous software updates, infrastructure hosting, and technical support may accumulate. Nevertheless, long-term cost savings driven by reduced need for physical infrastructure, remote scalability, and enhanced training efficiency make the VNOC model particularly attractive for telecom operators and innovative enterprises. As immersive and AI-driven technologies continue to evolve, the VNOC becomes an increasingly compelling solution for forward-thinking organizations seeking to modernize their network operations.

9.1 Cost analysis

The cost of implementing a Virtual Network Operations Center (VNOC) based on Metaverse and Virtual Reality technologies is generally higher compared to other traditional network management methods, such as conventional NOC systems, which hinders its widespread adoption.

However, the advantages it offers under evolving digital conditions include higher operational efficiency, enhanced real-time data interaction, and a significant reduction in physical infrastructure requirements. The initial investment in this technology is well justified by the potential gains in scalability, comprehensive training, and advanced monitoring capabilities especially in telecommunications operations, remote network management, and smart city infrastructure.

<i>Component</i>	<i>#OF</i>	<i>Price (ILS)</i>	<i>al (ILS)</i>
<i>Meta Quest 2 VR Headset</i>	1	1800	1800
<i>High-Performance Laptop</i>	1	5500	5500
<i>GPT-4 Subscription (3 months)</i>	1	240	240
<i>Total Cost</i>			7540 ILS

Table 5 Initial Cost Breakdown

9.2 Effect on Society

The implementation of a Virtual Network Operations Center (VNOC) powered by VR and AI technologies can drive a significant transformation across multiple sectors. The primary societal impact of adopting VNOC systems lies in enhancing the efficiency, reliability, and responsiveness of network operations in industries such as telecommunications, emergency response, education, and smart infrastructure.

By offering a more immersive, collaborative, and real-time monitoring environment, VNOC technology can lead to more secure and stable communication networks, especially in critical scenarios. It enables faster detection and resolution of faults, supports remote operations and training, and improves coordination between technical teams all of which are essential in large-scale communication infrastructures.

Its role in disaster response systems is also considerable. For instance, a metaverse-based VNOC could help telecom operators restore services rapidly in areas affected by natural disasters. Additionally, such platforms empower institutions to raise public awareness, promote digital sustainability, and enable inclusive remote education and professional development through immersive virtual training environments.

9.3 Market Growth

The Virtual Network Operations Center (VNOC) market is expected to witness significant growth, driven by the rising demand for advanced network monitoring, immersive training environments, and AI-powered automation in the telecommunications sector and beyond. Key industries and sectors likely to adopt this technology include:

- **Telecommunications** : VNOC platforms can revolutionize how network faults, KPIs, and service outages are detected and managed, enabling telecom operators to respond faster, reduce downtime, and optimize performance with real-time 3D visualizations.
- **Defense & Security** : Secure, immersive NOC environments offer military and government agencies a way to simulate and manage critical communication infrastructure, enhancing cyber defense, surveillance, and response coordination.
- **Education & Training** : Universities and telecom companies can use VNOC systems to provide hands-on, immersive training for engineers and technicians, improving skill development in a realistic, risk-free environment.
- **Smart Cities & Infrastructure** : As smart cities evolve, VNOC solutions can support centralized monitoring and incident handling for IoT networks, traffic systems, public safety, and energy grids.

With the increasing reliance on complex communication systems, and the global push toward digital transformation, the demand for intelligent, scalable, and immersive network operations platforms like VNOC is expected to grow rapidly opening up new opportunities in both public and private sectors.

9.4 Profitability Objectives

By targeting key strategic areas, the following profitability objectives of the VNOC project can be achieved:

1. **High-Tech System Design and Deployment:** Offering the design and development of fully integrated VNOC systems to telecom providers, training centers, and critical infrastructure operators.

2. **Platform-as-a-Service (PaaS):** Providing subscription-based access to VNOC environments for telecom companies, educational institutions, and government agencies that require immersive network monitoring and remote collaboration tools.
3. **Technology Licensing:** Licensing the VNOC software framework and AI-powered analysis modules to international partners seeking to modernize their network operations and virtual training infrastructures.
4. **Public-Private Partnerships:** Collaborating with governmental bodies and private companies to build and maintain virtual NOC facilities for smart cities, national telecom control centers, and emergency response networks—ensuring stable, recurring revenue streams.

By combining commercial licensing, subscription models, and institutional contracts, the VNOC project holds strong potential for sustainable profitability while also contributing to the evolution of future-ready communication management systems.

9.5 Cost Comparison between VNOC and Conventional NOC Systems

In general, the initial cost of implementing a Virtual Network Operations Center (VNOC) is higher than that of conventional physical NOC systems. This is primarily due to the integration of advanced virtual reality hardware, immersive 3D environments, and AI-powered data processing tools.

However, benefits such as real-time interactive visualization, enhanced remote collaboration, reduced physical infrastructure requirements, and improved training capabilities may justify the higher costs—particularly for organizations seeking scalable, future-ready, and more efficient network management solutions in sectors like telecommunications, defense, and smart infrastructure.

<i>Aspect</i>	Virtual Network Operations Center (VNOC)	Traditional Network Operations Center (NOC)
<i>Cost</i>	Higher initial cost (VR setup, development, AI integration)	Lower initial cost (physical setup, standard monitoring tools)
<i>Data Interaction</i>	Immersive, real-time 3D data visualization and interaction	2D dashboards, limited interaction
<i>Accessibility</i>	Remote access via VR, allows distributed teams	Typically centralized, physical location required
<i>Operational Flexibility</i>	High (supports simulation, training, AI automation)	Moderate (manual analysis, limited simulation capabilities)
<i>Technology</i>	Advanced (VR, AI, cloud-based analytics)	Conventional (SCADA systems, basic monitoring software)
<i>Innovation</i>	High (continuous development in immersive tech and AI integration)	Moderate to low (focused on reliability over innovation)

Table 6 Comparison between VNOC and Conventional NOC Systems

9.6 SWOT Analysis for the Virtual Network Operations Center (VNOC)

Strengths :

Immersive Data Interaction: Provides real-time 3D visualization and monitoring for network performance and alarms.

Remote Accessibility: Enables remote network operation, reducing reliance on physical location.

Advanced Training Capabilities: Offers simulation-based training environments for engineers and technicians.

Integration with AI: Allows automated data analysis, fault detection, and intelligent recommendations.

Scalability: Can be expanded easily without physical infrastructure constraints.

Weaknesses :

High Initial Cost: Requires investment in VR hardware, software development, and AI integration.

Technical Complexity: System setup, maintenance, and user training may require specialized skills.

Dependency on Stable Internet: Requires reliable network connection for cloud syncing and updates.

Hardware Compatibility: May face limitations in compatibility with legacy systems or outdated networks.

Limited Adoption: Still new in the telecom field; organizations may be hesitant to transition from traditional NOCs.

Opportunities :

Digital Transformation: Growing global demand for automation and smart monitoring tools in telecom and infrastructure.

Public & Private Sector Adoption: Potential for use in smart cities, emergency services, defense, and education.

Remote Work & Training: Supports the global trend toward decentralized operations and virtual upskilling.

Integration with IoT and 5G: Can evolve to monitor complex real-time systems across wide geographic areas.

Metaverse Growth: VNOC aligns with the expanding ecosystem of metaverse applications in various sectors.

Threats :

Resistance to Change: Organizations may resist moving from well-established traditional systems.

Cybersecurity Concerns: Being cloud-integrated and remote-accessible raises data security and privacy risks.

Technological Evolution: Rapid tech changes may require continuous updates to remain relevant.

Competition: Other network management platforms (non-immersive) may offer cheaper, simpler alternatives.

Regulatory and Data Compliance: May face regulatory hurdles regarding cloud data use and privacy in sensitive sectors.

10 Discussion and Conclusion

10.1 Discussion

The concept of a Virtual Network Operations Center (VNOC) in the metaverse offers a transformative approach to network management by integrating immersive technologies with traditional NOC functionalities. This integration enhances operational efficiency, security, and collaboration among network professionals. The VNOC's immersive environment allows for more effective real-time monitoring, incident management, and network optimization. By leveraging virtual reality, network professionals can visualize complex network data more intuitively, leading to quicker identification and resolution of issues. Furthermore, the VNOC's potential for remote collaboration and training can significantly improve skill development and knowledge sharing within teams.

10.2 Conclusion

In conclusion, the development of a VNOC within the metaverse presents a promising future for network operations. By harnessing the power of virtual reality, organizations can create more efficient, secure, and collaborative network management systems. The VNOC's ability to enhance real-time monitoring, incident management, and network optimization positions it as a critical tool for ensuring network reliability and performance. As technology continues to evolve, the VNOC model offers a scalable and adaptable solution that can integrate emerging technologies such as AI and IoT, making it an essential component for future-proofing network operations. Overall, the VNOC represents a significant step forward in the evolution of network management, offering potential benefits that can revolutionize the telecommunications industry.

10.3 Future Work

In the upcoming phase of the project, we plan to significantly expand the VNOC environment to support a wider range of mobile network technologies, including 2G, 3G, and 4G. Each technology will be handled with its specific KPIs and corresponding analytical models to ensure accurate performance monitoring. Our future development will also focus on generalizing the system to automatically process and analyze all types of KPI logs, enabling real-time visualization, alarm detection, and performance reporting for the entire network infrastructure. This scalable approach aims to make the VNOC system adaptable for various network configurations, ultimately

supporting more comprehensive and intelligent network operations within the metaverse-based environment.

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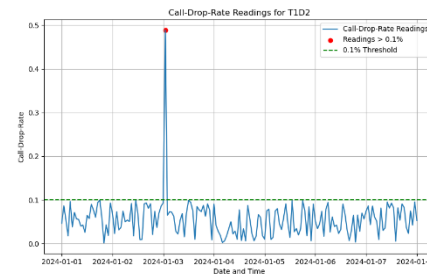
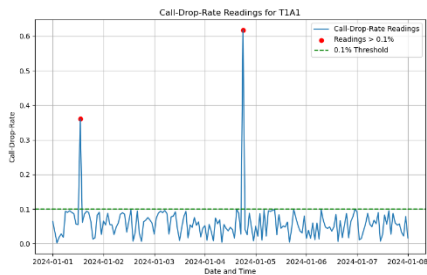
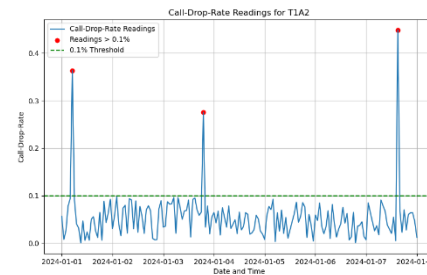
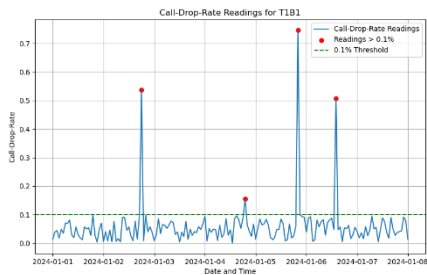
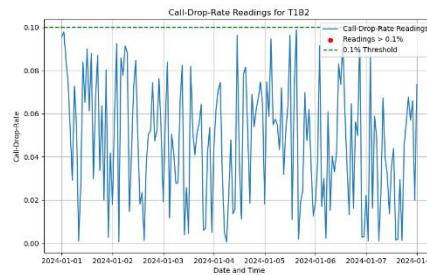
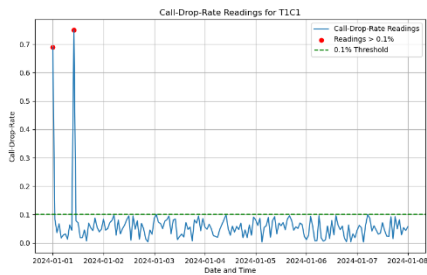
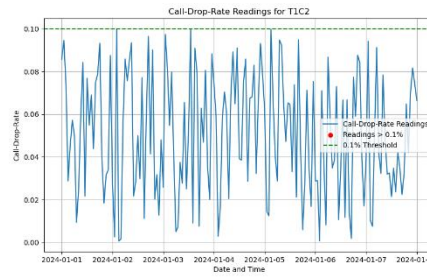
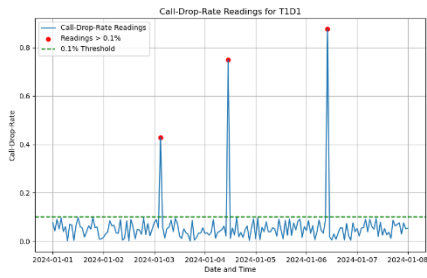
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Appendices

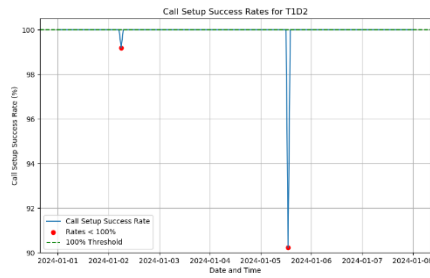
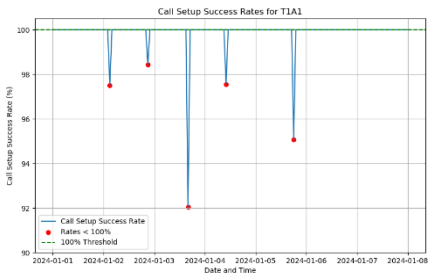
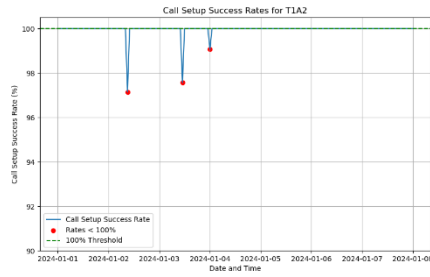
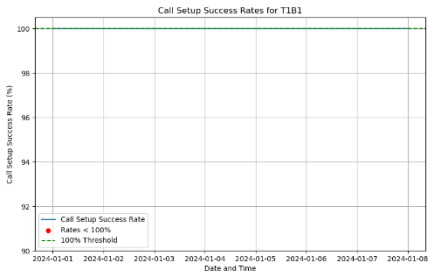
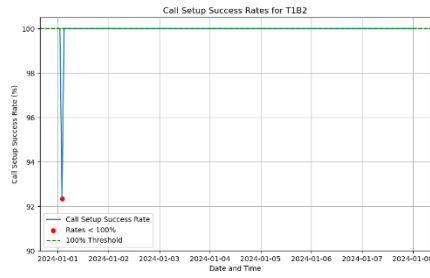
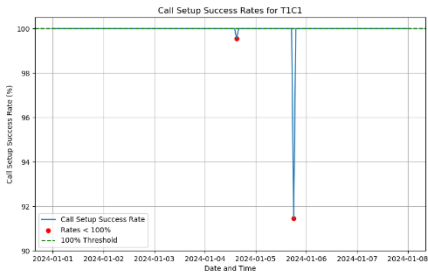
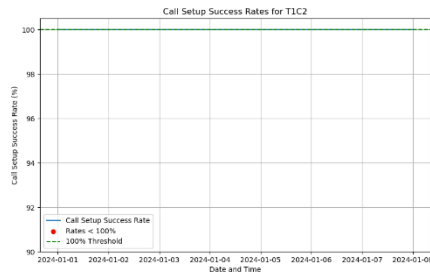
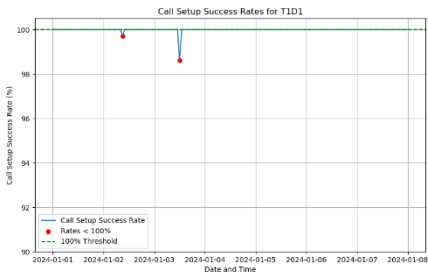
Appendix A: KPIs Performance for Telecom Tower located at Najah University¹

1. Call Drop:

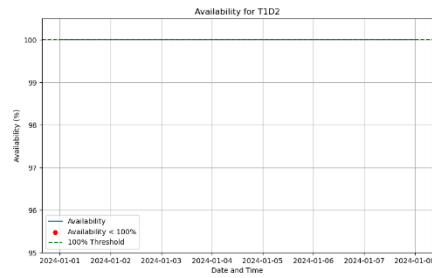
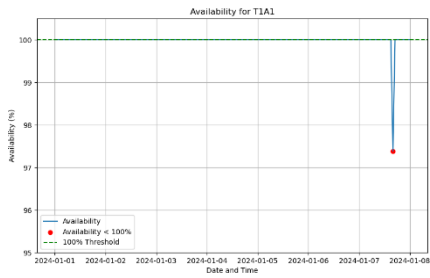
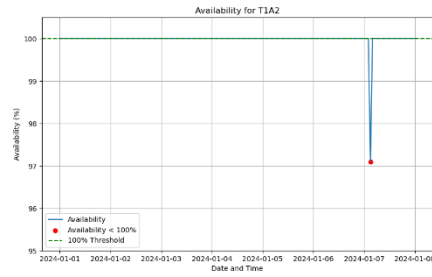
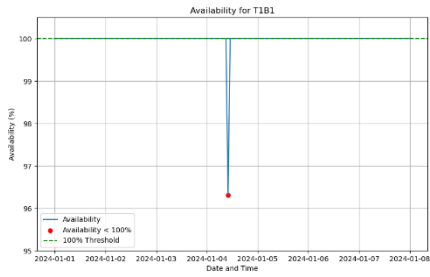
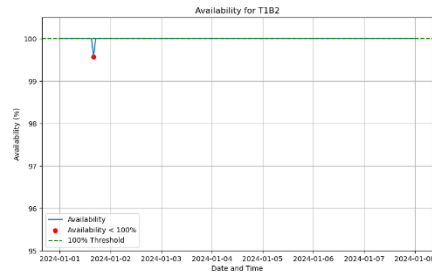
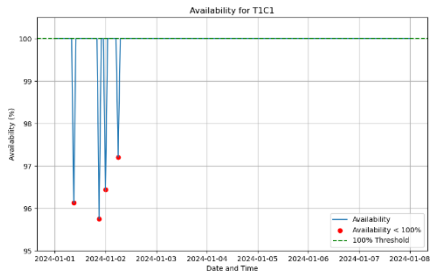
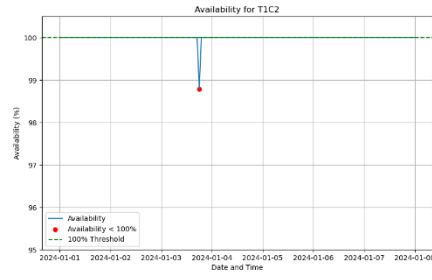
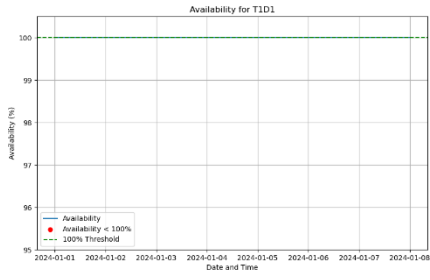


¹ This Data is generated as no actual data allowed to be exported outside Patel company

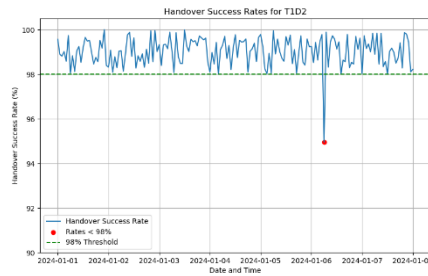
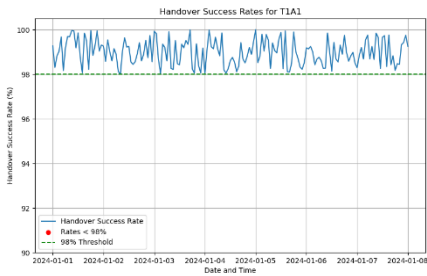
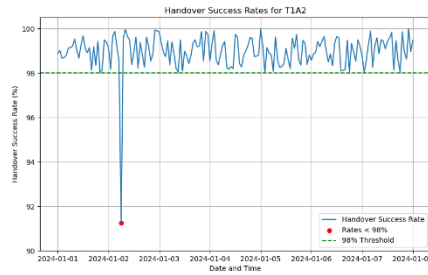
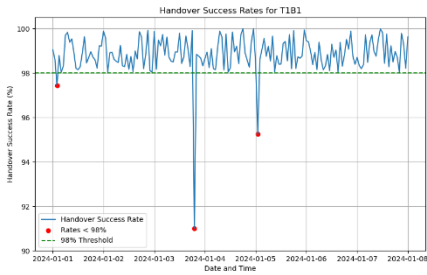
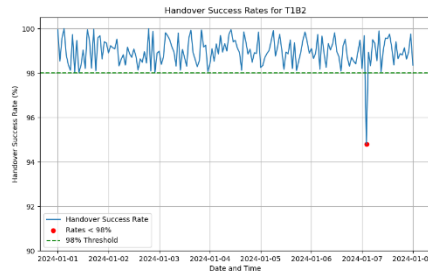
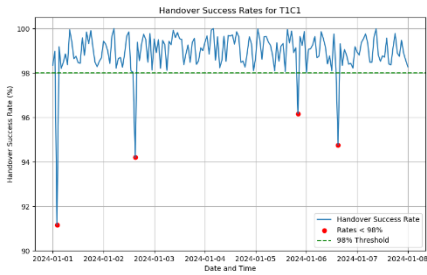
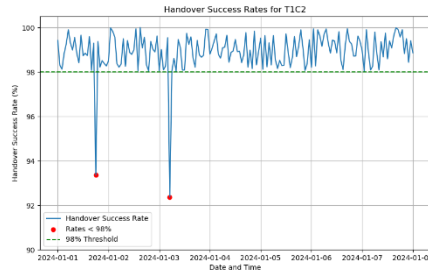
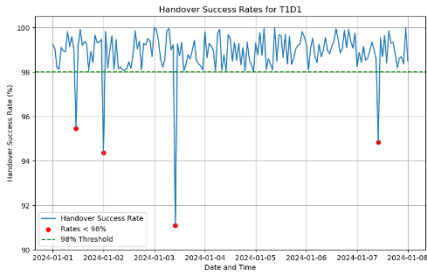
2. Call Setup:



3. Availability:



4. Handover:



Appendix B: Python Scripts Used for Data Generation and AI Integration

Appendix B.1 – generate_data.py:

```

import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import os
from datetime import datetime, timedelta
import matplotlib.dates as mdates

# إعدادات عامة
towers = ['T1', 'T2', 'T3', 'T4']
antennas = ['A', 'B', 'C', 'D']
cells = ['1', '2']
months = [(2024, 12)] + [(2025, m) for m in range(1, 6)]
base_path = r"C:\Users\actc\Desktop\مشروع تخرج\Images\Availability"
threshold = 100.0
os.makedirs(base_path, exist_ok=True)

# أداء أساسي لكل خلية، عالي جدًا + تريند شهري بسيط
base_performance_map = {}
for tower in towers:
    for antenna in antennas:
        for cell in cells:
            cell_id = f"{tower}{antenna}{cell}"
            base_performance_map[cell_id] = np.random.uniform(98.8, 99.9)

# توليد البيانات لكل شهر
for month_index, (year, month) in enumerate(months):
    month_str = f"{month:02d}_{year}"
    print(f"📁 Generating Availability data for {month_str}")

    month_folder = os.path.join(base_path, month_str)
    monthly_img_path = os.path.join(month_folder, "Monthly_Images")
    os.makedirs(month_folder, exist_ok=True)
    os.makedirs(monthly_img_path, exist_ok=True)

```

```

all_records = []

for cell_id, base_rate in base_performance_map.items():
    tower, antenna, cell = cell_id[:2], cell_id[2], cell_id[3]
    month_base = base_rate * (1 - 0.002 * month_index)
    cell_records = []

    for dt in generate_quarter_dates(year, month):
        hour = dt.hour
        if 9 <= hour <= 14 and np.random.rand() < 0.03:
            availability = np.random.uniform(90, 99.5)
        else:
            availability = np.random.normal(loc=month_base, scale=0.1)
        availability = max(85, min(availability, 100))
        cell_records.append({
            'DateTime': dt,
            'Tower': tower,
            'Antenna': antenna,
            'Cell': cell,
            'Cell ID': cell_id,
            'Availability': round(availability, 2)
        })
    all_records.extend(cell_records)

# رسم صورة الأداء الشهري للخلية
df_cell = pd.DataFrame(cell_records)
df_cell['Date'] = df_cell['DateTime'].dt.date
daily_avg = df_cell.groupby('Date')['Availability'].mean().reset_index()

plt.figure(figsize=(10, 4))
plt.plot(pd.to_datetime(daily_avg['Date']), daily_avg['Availability'], marker='o')
plt.axhline(y=threshold, color='red', linestyle='--', label='Threshold (100%)')

```

```

plt.title(f"{cell_id} - {month_str}", fontsize=12)
plt.xlabel("Date")
plt.ylabel("Availability (%)")
plt.ylim(85, 100)
plt.grid(True)
plt.legend()
plt.gca().xaxis.set_major_locator(mdates.WeekdayLocator(interval=1))
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%d-%b'))
plt.xticks(rotation=45)
plt.tight_layout()
plt.savefig(os.path.join(monthly_img_path, f"{cell_id}_{month_str}.png"))
plt.close()

# لكل شهر بطريقة مرتبة (كل خلية كاملة لحالها) Excel حفظ ملف
df = pd.DataFrame(all_records)
df.sort_values(by=['Cell ID', 'DateTime'], inplace=True)
excel_path = os.path.join(month_folder, f"Availability_{month_str}.xlsx")
df.to_excel(excel_path, index=False)

print("✓. وصور الأداء الشهري لكل خلية من ٢٠٢٤_١٢ إلى ٢٠٢٥_٠٥ بنجاح Availability تم توليد بيانات")

```

Appendix B.2 – report_server.py:

```

from flask import Flask, request, jsonify
import os
import pandas as pd
import openai
import smtplib
from email.mime.multipart import MIMEMultipart
from email.mime.text import MIMEText
from email.mime.application import MIMEApplication
import traceback

```

```

# 🗝️ GPT API Key
openai.api_key = "sk-proj-ZwFn0CT7GEw8EADI-VhoTEo2Cf9-
CrNahTdHNR1VJsJAodFtuvghRoFINXRv88pS1_qqLfIPfIT3B1bkFJv9U-PEC92-
9scxLz8_8Yh3Cn_Ikrv12XCnGyaSfRTj5DC4PpgUSFicTnfJiQexSvr2vx-zh9MA"

app = Flask(__name__)

# 📧 إرسال إيميل

def send_email_with_attachment(receiver_email, subject, body, attachment_path=None):
    sender_email = "chat2132002@gmail.com"
    app_password = "sodyjyetsetviaqg"

    msg = MIMEMultipart()
    msg['From'] = sender_email
    msg['To'] = receiver_email
    msg['Subject'] = subject
    msg.attach(MIMEText(body, 'plain'))

    if attachment_path:
        with open(attachment_path, "rb") as f:
            part = MIMEApplication(f.read(), Name=os.path.basename(attachment_path))
            part['Content-Disposition'] = f'attachment; filename="{os.path.basename(attachment_path)}"'
            msg.attach(part)

    try:
        server = smtplib.SMTP("smtp.gmail.com", 587)
        server.starttls()
        server.login(sender_email, app_password)
        server.send_message(msg)
        server.quit()

        print("✅ Email sent successfully.")
    except Exception as e:
        print(f"❌ Error sending email: {e}")

```

```

# 📄 تحليل كل خلية على حدة Excel تحليل ملف
@app.route('/analyze', methods=['POST'])
def analyze_excel():
    file = request.files.get('file')
    if not file:
        return jsonify({'error': 'No file uploaded'}), 400
    filename = file.filename
    kpi_name = filename.split("_")[0]
    month = filename.split("_")[1].replace(".xlsx", "").replace(".csv", "")
    save_folder = "uploaded_excels"
    os.makedirs(save_folder, exist_ok=True)
    file_path = os.path.join(save_folder, filename)
    file.save(file_path)
    try:
        if filename.endswith(".csv"):
            df = pd.read_csv(file_path)
        elif filename.endswith(".xlsx"):
            df = pd.read_excel(file_path, sheet_name="Sheet1")
        else:
            return jsonify({'error': 'Unsupported file format'}), 400
        if 'Cell ID' not in df.columns:
            return jsonify({'error': 'Missing "Cell ID" column in the data'}), 400
        all_reports = []
        cell_ids = df['Cell ID'].unique()
        for cell in cell_ids:
            cell_df = df[df['Cell ID'] == cell]
            sample_text = cell_df.head(30).to_string(index=False)

            prompt = f"""
You are a senior telecom NOC engineer.
You are given KPI data for *Cell ID: {cell}* related to *{kpi_name}* in month *{month}*.
Note: "Full script available upon request or in the project repository."

```