Analysis of 4G and 5G Networks for IPTV Transmission in Albania: Evaluating Key Factors

Fatmira Prodani, Frida Gjermeni and Eris Zeqo

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Fatmira Prodani[1][0009−0004−5373−8452], Frida Gjermeni[2,][0000−0002−9781−2704], and Eris Zeqo[3]

Aleksandër Moisiu University of Durrës Albania fatmiraprodani@uamd.edu.al
http://www.uamd.edu.al

Abstract. With the rapid advancements in wireless communication technologies, the deployment of high-speed networks has become crucial for the delivery of multimedia services, such as Internet Protocol Television. IPTV, which enables the streaming of television content over IP networks, has gained significant popularity in recent years. In the context of Albania, understanding the implications of transitioning from 4G to 5G networks for IPTV transmission is essential. 4G has been the dominant network for mobile broadband services in Albania for several years, with significant coverage across urban and some parts of rural areas.
The analysis of 4G and 5G networks for IPTV transmission in Albania must consider several key factors, including network performance, infrastructure requirements, and the potential impact on user experience. 4G has been the dominant network for mobile broadband services in Albania for several years, with significant coverage across urban and some parts of rural areas.
This research paper examines the potential impact of 5G technology on IPTV transmission in Albania, evaluating its superiority over 4G networks in key factors such as bandwidth, latency, and packet loss. The paper highlights the critical role of the Albanian telecommunications regulator, AKEP, in creating an enabling environment for 5G deployment and fostering public awareness to realize the full benefits of this transformative technology for IPTV services and beyond.

Keywords: IPTV · 4G/5G network · Albania telecommunications · bandwidth · latency · packet loss .

1 Introduction

The development of 5G Networks has, in one way or another, affected many sectors, including the telecommunication and entertainment industries, at a very high rate. Internet Protocol Television (IPTV) has been the most effective because users expect sharp, real-time video streaming. IPTV, which delivers television programs through internet protocol networks, is very flexible and allows users to request media content from anywhere at a certain time. However, many users and high-quality requirements for modern content, such as 4K and 8K videos, present a problem related to the network characteristics for performance, bandwidth, and response time. Additionally, 5G networks are designed to support a larger number of concurrent connections, which is particularly important for IPTV services that cater to multiple users within a household or a community.

In contrast, 4G networks may struggle to accommodate the growing demand for IPTV, as bandwidth and connection density may not be sufficient to provide a seamless viewing experience, especially in densely populated areas.

The deployment of 5G infrastructure in Albania, however, requires significant investment in upgrading the existing cellular network infrastructure. This includes the installation of new cell towers, the deployment of small cells, and the implementation of fiber-optic backhaul connectivity to support the high-bandwidth requirements of 5G. The transition to 5G may also require the acquisition of additional spectrum, which could pose regulatory and financial challenges for operators. Nonetheless, the investment in 5G infrastructure can be justified by the potential benefits it offers for IPTV transmission. As video streaming becomes the dominant form of entertainment, assessing the quality of service (QoS) and network performance is essential for ensuring smooth and uninterrupted IPTV experiences.

The main search of this paper is to analyze the performance of two major telecom operators in Albania—Vodafone and One—by evaluating key network parameters such as download speed, upload speed, latency, and jitter in the cities of Tirana and Durrës, where the largest number of the population is also concentrated. These cities represent urban and suburban environments where both 4G and partial 5G coverage are available. The goal is to determine how well these networks support IPTV streaming, particularly in high-definition (HD) and ultra-high-definition (4K/8K) formats. By comparing network performance at different times of the day, this study identifies potential bottlenecks, highlights performance gaps between operators, and provides recommendations for optimizing QoS in mobile networks for IPTV services. The findings offer valuable insights for telecom providers, policymakers, and IPTV service operators aiming to enhance Albania's digital streaming infrastructure.

2 Methodology

2.1 Data collection

This analysis was conducted to evaluate the performance of Vodafone and One two cellular operators in Tirana and Durrës, focusing on their suitability for IPTV streaming. The methodology follows a structured approach, ensuring accurate and comparable results. The first is data collection for Technical Specifications: Information used in this study was collected through speed test service that Electronic and Postal Communications Authority (AKEP) of Albania offers on its official website. This tool allows users to measure their internet connection's download and upload speeds, latency and jitter. Second is Geographic Data: Obtain geographic data of the coverage and performance of 4G and 5G networks in different regions.

2.2 Data collection Method

Speed tests were performed using real-world conditions on mobile devices in different locations within Tirana and Durrës. Network selection was automatic, ensuring tests were conducted under standard user conditions. Each test was repeated multiple times to ensure reliability. Tests were conducted on both 4G and 5G networks, depending on availability.

2.3 Performance evaluation

Define and measure key performance indicators for IPTV transmission, including bandwidth utilization, latency, packet loss, jitter, and video quality. These KPIs will be used to compare the performance of 4G and 5G networks. We will Identify the strengths and weaknesses of each technology in the context of the Albanian telecommunications landscape. Based on industry standards for IPTV performance, results were categorized as:

Table 1. Results for IPTV performance

Metric	**Excellent**	**Good**	**Moderate**	**Poor**
Download Speed (Mbps)	50+ Mbps	25-50 Mbps	10-25 Mbps	$<$10 Mbps
Upload Speed (Mbps)	10+ Mbps	5-10 Mbps	3-5 Mbps	$<$3 Mbps
Latency (ms)	0-50 ms	50-100 ms	100-150 ms	$>$150 ms
Jitter (ms)	0-5 ms	5-10 ms	10-15 ms	$>$15 ms

3 Literature rivew

3.1 An overview of IPTV network architecture

IPTV, Internet Protocol television, is a technology that brings or distributes television services through IP networks instead of satellite or cable. The IPTV industry relies on the technology of Internet Protocol Television (IPTV) to deliver television programs and other video content to users over the internet. A key aspect of this industry is the design and analysis of the underlying IPTV core network, which is essential in providing a high-quality and reliable service to customers. This includes effective management of bandwidth, addressing latency issues, ensuring proper security and confidentiality of the transmitted data, and much more." The IP core network is the backbone of an IPTV service and is responsible for transmitting video and other data to users' devices. To ensure smooth and efficient transmission, the IP core network must be designed with sufficient capacity and low latency. The capacity of an IP core network refers to the maximum amount of data that can be transmitted through the network at any given time. This capacity is typically measured in bits per second (bps) and can vary depending on factors such as the technology used for the network, the number of devices connected to the network, and the amount of congestion on the network. The IP core network must also be designed to handle the expected demand and traffic load, ensuring that users can access IPTV services without interruptions or degradation in quality. A network with sufficient capacity can handle the expected volume of traffic without becoming congested and causing delays. Depending on the network architecture of the service provider (fig 1), there are two main types of IPTV architecture that can be considered for IPTV deployment: centralized and distributed. In a centralized IPTV architecture, all the IPTV services are hosted and managed from a central location, typically a data center. This approach offers the advantage of easier management and control of the IPTV services, but it also means that the entire network is dependent on the central data center, which can be a single point of failure.

In contrast, a distributed IPTV architecture involves the deployment of multiple smaller data centers or edge nodes closer to the end-users. This approach can improve the overall reliability of the IPTV service by distributing the load across multiple locations, reducing the risk of a single point of failure. Additionally, a distributed architecture can also improve the quality of service for end-users by reducing the distance between the content source and the viewer, thereby reducing latency and improving the overall user experience.

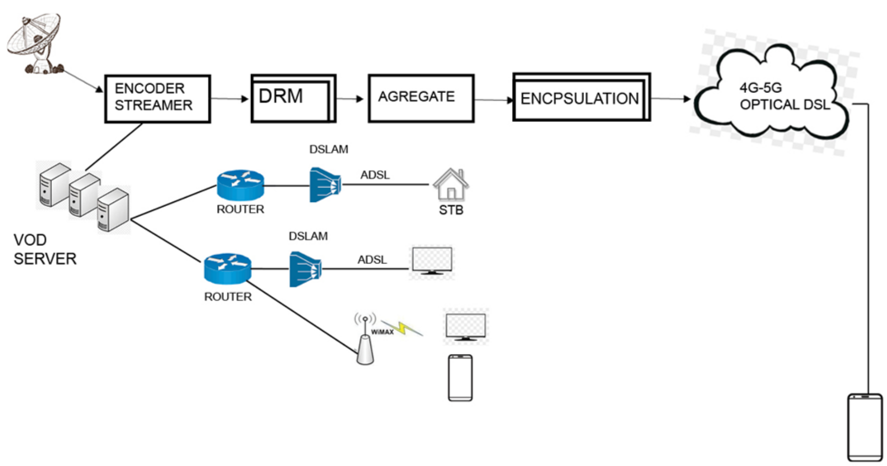

Fig. 1. IPTV architechture

For high-quality transmission without delays, the parameters the network must provide are as follows:

1. **Latency** is the time it takes for data to travel from a sender to a receiver and back (round-trip time) and it is measured in millisecond range (ms). For a IPTV suitability video streaming 4K (excellent) the latency range is 0-50 ms, for video streaming HD (good) the latency range is 50 - 100 ms, if latency exceeds

10-150 it may be acceptable for HD video streaming but there will be lag for 4k videos. If latency exceeds the values 150-250ms lag and buffering is expected, and as a result of this high value of latency can provide poor stream for live IPTV. If latency exceeds values 250 + ms, IPTV streaming is not recommended because the streaming will be unstable and there will be there will be frequent buffering.

2. **Jitter** represents fluctuations in packet delay. High jitter can cause IPTV buffering, stuttering, and poor video quality, especially for live stream transmission. Jitter is measured in milliseconds (ms). For a IPTV suitability video streaming the range from 0-50 ms is excellent, with smooth playback and no buffering, 50 - 100 ms is good, minor occasional buffering, 10 - 15 ms is acceptable but can cause possible video stuttering. If Jitter exceeds the values 150-250ms the stream is unstable, with buffering especially for 4K IPTV. If Jitter exceeds values 250 + ms, IPTV streaming is poor with frequent buffering and interruptions.

3.2 The key differences between 5G and 4G

All mobile networks, regardless of technology generation, are using the same basic principles for how they work. Mobile networks consist of three parts. First, the Radio Access Network, which is what your phone connects to. Its antennas can often be seen on city rooftops or on masts and towers in the countryside. Radio waves have been used for wireless communication for 120 years and we use them for radio and TV broadcasting, for communication in mobile networks and for WiFi. Radio waves are, just as light, a kind of electromagnetic waves but they have much lower frequencies than light, which means that they travel around corners and even reach into buildings - perfect for mobile communication. The Core Network – the central part of the mobile network – that for example connects your call to the right person or connects you to the internet service you want to use. The Transport Network that connects the Radio Access Network and the Core. When mobile networks are getting advanced day by day, 4G and 5G have become two important terminologies in the case of wireless communication. Even though both aim at connecting devices to the internet, there are certain unique differences in terms of speed, latency, capacity, and coverage among others. 4G is a mobile phone network technology that can be used for downloading data and accessing the internet. It provides broadband cellular network services with bandwidth higher than 100 Mbps. With this bandwidth, high-quality multimedia content can be streamed. Its development started in 2000 and was completed in 2010 with LTE and WiMax technology. Access System for the same is CDMA (Code Division Multiple Access) with a bandwidth of 2000 Mbps to 1 Gbps. The purpose of 4G is to provide high quality, high speed, and high capacity to users while improving security. It also lowers the cost of voice and data services, multimedia, and the internet over IP. Nowadays 4G LTE (Long Term Evolution) provides reliable connectivity for basic IoT applications, but it has limitations when handling advanced technologies like Artificial Intelligence (AI), Industrial

IoT (IIoT), Smart Cities, and Autonomous Vehicles ect. these technologies needs high performance.

The architecture of 4G consists of multiple interconnected components that manage data transmission, mobility, and quality of service (QoS) as shown in fig.2. ENode B is the 4G site that the User Equipment (UE) connects to. It provides the radio interface to the UE. MME refers to "Mobility Management Entity" and is resposable for authenticating the UE. In additional, it tracs the location of UE and selects the suitable SGW and PGW that shoud serve this UE. SGW refers to "Serving Gateway" , works as an anchor point while the UE moves between different eNodeBS. SGW forwards user data between the eNodeB and PGW. PGW refers to PDN Gateway is the node that connects between LTE network and PDN. HSS refers to "Home Subscriber Server" is the database that stores the subscription information of the users in Network. PDN refers to Public Data Network, and is the network that UE like to connect to.

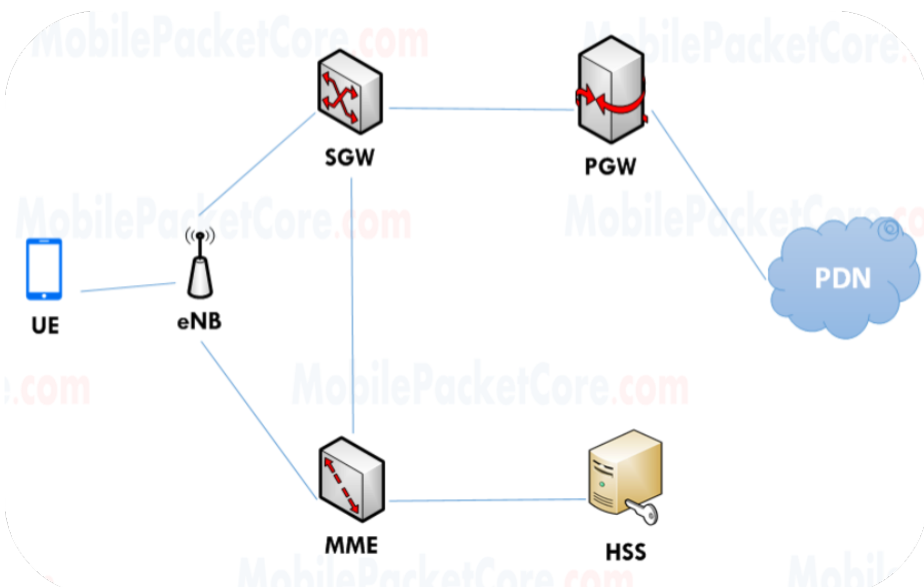

Fig. 2. 4G network architecture

5G is the fifth generation of wireless network technology is built on millimeter waves, a section of very high-frequency spectrum upwards of 20 GHz all the way up to 96 GHz.. 5G offer much faster speed than 4G networks, more reliability with much lower response times. It used OFDM (orthogonal frequency-division multiplexing) and millimeter wireless that enables data rate of 20Mbps and frequency band of 2-8 GHz. It can reach upto 1000 Mbps or even upto 2.1 Gbps, and can be used for streaming high-quality videos, more accurate location tracking, low-latency communication and better ability for real-time analytics. By carefully analizing Figure 2 and Figure 3, it becomes clear that 5G network presents a more complex architecture. 5G Architecture introduces a more decentralized and cloud-native approach, including Network Slicing, Edge Computing, and a Service-Based Architecture (SBA), enabling lower latency, higher efficiency, and better scalability.

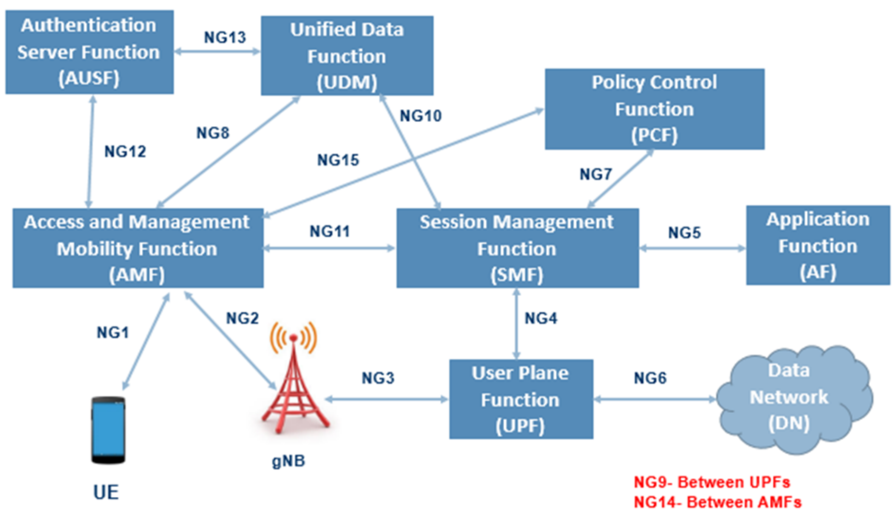

Fig. 3. 5G network architecture

Network nodes and their functions in 5G architecture:

1. **User Equipment (UE)**
2. **Next Gen Node Basestation (gNB)**
3. **Core Access and Mobility Management Function (AMF)** that is responsible for: · Termination of RAN Control Plane interface (NG2) · Termination of NAS (NG1), NAS ciphering and integrity protection · Mobility Management Lawful intercept (for AMF events and interface to Lawful Inetercept System) · Transparent proxy for routing access authentication and SM messages · Access Authentication · Access Authorization · Security Anchor Function (SEA): It interacts with the UDM and the UE, receives the intermediate key that was established as a result of the UE authentication process; in case of USIM based authentication, the AMF retrieves the security material from the UDM · Security Context Management (SCM): it receives a key from the SEA that it uses to derive access-network specific keys
4. **User plane Function (UPF)** – functions are: · QoS handling for User plane · Packet routing & forwarding · Packet inspection and Policy rule enforcement · Lawful intercept (User Plane) · Traffic accounting and reporting · Anchor point for Intra-/Inter-RAT mobility (when applicable) · Support for

interaction with external DN for transport of signaling for PDU session authorization/authentication by external DN

5. **Session Management Control Function (SMF)** – supports following: · Session Management · UE IP address allocation & management (including optional Authorization) · Selection and control of User Plane function · Termination of interfaces towards Policy control and Charging functions · Control part of policy enforcement and QoS · Lawful intercept (for Session Management events and interface to Lawful Intercept System) · Termination of Session Management parts of NAS messages · Downlink Data Notification · Initiator of Access Node specific Session Management information, sent via AMF over NG2 to Access Node · Roaming functionality · Handle local enforcement to apply QoS SLAs (VPLMN) · Charging data collection and charging interface (VPLMN) · Lawful intercept (in VPLMN for Session Management events and interface to Lawful Intercept System)

6. **Data Network (DN)**: Operator services, Internet access or other services

7. **Authentication Server Function (AUSF)** – Performs authentication processes with the UE

8. **Unified Data Management (UDM)** – Supports: · Authentication Credential Repository and Processing Function (ARPF); this function stores the long-term security credentials used in authentication for AKA · Storing of Subscription information

9. **Policy Control Function (PCF)** – Provides: · Support of unified policy framework to govern network behavior · Policy rules to control plane function(s) that enforce them

10. **Application Function (AF)** – Requests dynamic policies and/or charging control

3.3 Comparison between IPTV Transmission on 4G and 5G

The transition from 4G to 5G networks can have a significant impact on the quality and performance of IPTV transmission in Albania. 4G networks, while capable of providing high-speed internet access, may face challenges in delivering consistent and reliable IPTV services, especially in areas with high user density or complex terrain. According to, 4G networks are not optimized for the low-latency and high-bandwidth requirements of IPTV, which can result in buffering, pixelation, and other quality issues. In contrast, 5G networks are designed to address these limitations offering several key features that can enhance IPTV transmission. 5G network coincides with the maturation of technologies that promote open, agile, and flexible capabilities across the network. Specifically, disaggregated and distributed software-defined network solutions, virtualization, and cloud-native functions are at least as impactful as the new 5G radios. 5G networks are designed to be open and virtualized, allowing individual services with different performance requirements to share the same infrastructure. The virtualization of functions effectively separates software from hardware implementations. This allows each function to be scaled independently and distributed optimally, with respect to available bandwidth capacity and latency requirements. Distributed architectural design, enabled through control/user plane separation, allows operators to position functions and services where they can best service the end user. Previous cellular architecture placed radio network access equipment at every cell station, which was costly to install and maintain. With progress made in virtualized, cloud-native RAN solutions and automation, the hardware at cell sites can be minimized, reducing real-estate costs for the cell stations. This change provide better performance, better energy efficiency, easier management, and lower network costs. 5G Network uses three different bands, each using different parts of the radio spectrum. Low, medium and high bands offer performance with inversely varying speed and distance attributes. 5G's low band sits at under 1GHz, near the frequencies used by 4G (under 6 GHz). Medium band use frequencies 1-2.6 GHz and 3.5-6 GHz range and the high band uses frequencies 24-40GHz range. Increasing the number of antenna at cell base stations allow 5G to use its bandwidth to transmit over more antenna at once, performing multiple inputs and outputs simultaneously. 5G has the ability to operate on multiple bands at the same time. When using its high-frequency bandwidth 5G peak speeds cud be up to 10 times faster than 4G, allowing heavy-data applications such as 4K/8K playback to stream from the cloud faster. 5G latency can be four to five times less than 4G's, some of this reduction comes from improved technology in 5G radio. 5G can support up to 100 times as many devices and endpoints as 4G. This means 5G is ready to support the next generation of user growth and the millions of IoT(Internet of Things) devices expected to come online. 5G is more energy efficient than 4G, starting with cell base design. Mobile devices operating in 5G use less energy, providing extended battery performance 10% less than 4G requires. 5G;s data capacity can be up to 1000 times that of 4G. With the increased data capacity, the performance will remain robust for all users when they connect to public networks in locations like airports, public transport ect. Private 5G networks are designed to control and monitor factory and warehouse operations, as well as facilitate better communication with IoT devices, robotic equipment, and autonomous devices. AI applications that communicate continuously with the cloud will also benefit from 5G performance attributes especially its low latency. Virtual and Augmented Reality use large amounts of data, are latency sensitive and require continuous processing to be executed in the cloud. Development of Virtual and augmented reality has been held back by previous Wi-Fi and cellular networks. Now with 5G and WI-Fi 6 are being continued on help accelerate growth. 5G networks are designed to provide lower latency and higher reliability compared to 4G, which is crucial for delivering a seamless IPTV experience. The reduced latency can enhance the interactivity of IPTV services, enabling features such as real-time video conferencing, interactive gaming, and responsive user interfaces. Furthermore, the increased reliability and resilience of 5G networks can contribute to the overall quality of IPTV services, reducing the likelihood of service interruptions and providing a more consistent user experience. In conclusion, the analysis of 4G and 5G networks for IPTV transmission in Albania must consider the trade-offs between network performance, infrastructure requirements, and the potential impact on user experience. While the deployment of 5G networks presents significant challenges, the enhanced capabilities of 5G, such as higher bandwidth, lower latency, and increased connection density, can enable the delivery of high-quality IPTV services and support the growing demand for multimedia content in Albania. Telecomunications companies like Vodafone and One have started offering 5G services in some areas of Tirana, but this is still in the development phase. The part of Tirana that has access to 5G is limited and requires more time and investment to cover more areas.

4 Factors to consider for IPTV transmission in Albania

According to the data collected from the 2023 annual report of the Electronic and Postal Communications Authority (AKEP), Albania has a 3G network coverage of approximately 99% of the population. Regarding LTE (4G) network coverage of both territory and population, Vodafone Albania has the widest coverage with this technology, reaching 97% of the territory with a 4G network and 100% population coverage. One Albania sh.a. has 96% territory coverage with a 4G network and 99% population coverage.Additionally, Vodafone Albania has secured the new 5G spectrum in the 3400-3800 MHz frequency bands in the latest auction held by AKEP. This acquisition is expected to enhance the existing mobile network capacity and pave the way for innovative applications in the future. In November 2024, One Albania was awarded a 5G license for the 3.5 GHz . The company secured 120 MHz in the 3420-3540 MHz frequency range. Following the acquisition, One Albania partnered with Ericsson to build its 5G network, aiming to enhance network capacity and support innovative applications.

4.1 CASE STUDY/ Current situation of signal parameters in Albania

When analyzing 4G and 5G networks for IPTV (Internet Protocol Television) in Albania, several key factors must be considered. We have collected data for technical specifications that must be evaluate for this analyze. Information was collected through speed test service that Electronic and Postal Communications Authority (AKEP) of Albania offers on its official website. This tool allows users to measure their internet connection's download and upload speeds, latency and jitter.

Speed tests were performed using real-world conditions on mobile devices in different locations 3 times daily in Tirana and Durrës. The data collected in **Table 2** and **Table 3 Fig. 4 and Fig. 5** shows that 4G speeds in Albania can be quite variable, with download speeds ranging from around 6.7 Mbps to over 78.8 Mbps, and upload speeds varying from 1.8 Mbps to 27.5 Mbps. From these tests we note that in morning and afternoon Vodafone in Tirana performs, reaching 78.8 Mbps, which is great for 4K IPTV. One in Tirana is inconsistent; while the morning speed of 48 Mbps is good, evening speeds drop to 6.7 Mbps, which is too low for stable IPTV. There is a significant performance gap between

Table 2. Data collected in Durrës and Tirana of network performance Download and Upload speed

Date	City	Provider	Time	Download (Mbps)	Upload (Mbps)
1/25/2025	Tirana	Vodafone	Morning	30.2	20.5
1/25/2025	Tirana	Vodafone	Afternoon	39	27.1
1/25/2025	Tirana	Vodafone	Evening	78.8	51
1/25/2025	Tirana	One	Morning	48	11.4
1/25/2025	Tirana	One	Afternoon	11.9	21.3
1/25/2025	Tirana	One	Evening	6.7	3.24
1/26/2025	Durrës	Vodafone	Morning	89.9	11.4
1/26/2025	Durrës	Vodafone	Afternoon	49.9	2.19
1/26/2025	Durrës	Vodafone	Evening	38.6	1.97
1/26/2025	Durrës	One	Morning	94	5.25
1/26/2025	Durrës	One	Afternoon	41.7	6.61
1/26/2025	Durrës	One	Evening	10.7	1.8

Fig. 4. Collected Data on Download and Upload Speeds

Table 3. Data collected in Durrës and Tirana of network performance Latency and Jitter

Date	City	Provider	Time	Latency	Jitter (Mbps)
1/25/2025	Tirana	Vodafone	Morning	112	13.2
1/25/2025	Tirana	Vodafone	Afternoon	103	5.22
1/25/2025	Tirana	Vodafone	Evening	81.8	17.5
1/25/2025	Tirana	One	Morning	190	15.3
1/25/2025	Tirana	One	Afternoon	121	9.75
1/25/2025	Tirana	One	Evening	207	17.8
1/26/2025	Durrës	Vodafone	Morning	70.3	12.9
1/26/2025	Durrës	Vodafone	Afternoon	83.2	5.93
1/26/2025	Durrës	Vodafone	Evening	213	18.6
1/26/2025	Durrës	One	Morning	130	15.1
1/26/2025	Durrës	One	Afternoon	275	9.69
1/26/2025	Durrës	One	Evening	229	15.3

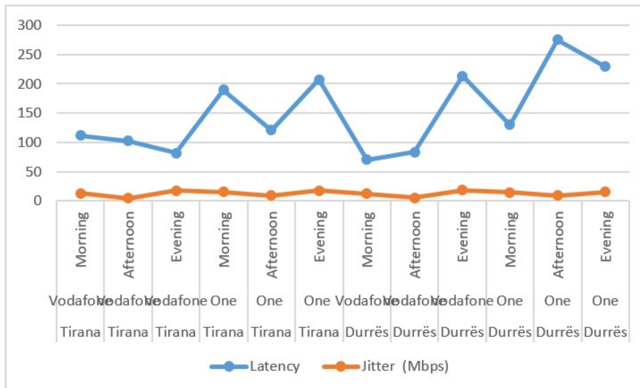

Fig. 5. Collected Data on Latency and Jitter

Vodafone and One, even though both provide 4G coverage across most part of Albania. This network congestion, make HD streaming difficult not only in the peek hours but during all the day. These findings indicate that while 4G networks in Tirana have the capability to support IPTV, real-world performance can be inconsistent and may not meet the bandwidth requirements, especially for HD and 4K streaming. Vodafone in Durrës performs better in the morning (89.9 Mbps), making it excellent for 4K IPTV, evening speed varios (38.6 Mbps) is still good for HD IPTV, but for 4K/8K can buffer.

Vodafone has the best latency (81.8 ms in the evening), which is acceptable for HD IPTV, and can work for 4K if speeds are sufficient.One has high latency (207 ms in the evening), which is not ideal for IPTV. Latency above 150 ms can cause buffering and delays. Vodafone in Durres performs well in the morning (70.3 ms) and afternoon (83.2 ms), but evening latency spikes to 213 ms, likely due to congestion. One's latency is unstable, reaching 275 ms in the afternoon, making it unsuitable for IPTV, especially for live content. Comparing this result with the throughput data, we can conclude that while 4G networks in Albania have the technical capabilities to support IPTV, the real-world performance can be inconsistent, especially during peak usage times.

4.2 Conclusions

The data shows that 4G speeds in Albania can be quite variable, with download speeds ranging from around 6.7 Mbps to over 78.8 Mbps, and upload speeds varying from 1.8 Mbps to 27.5 Mbps. From these tests we note that in morning and afternoon Vodafone in Tirana performs, reaching 78.8 Mbps, which is great for 4K IPTV. One in Tirana is inconsistent; while the morning speed of 48 Mbps is good, evening speeds drop to 6.7 Mbps, which is too low for stable IPTV. There is a significant performance gap between Vodafone and One, even though both provide 4G coverage across most of Albania. This network congestion, make HD streaming difficult not only in the peek hours but during all the day. These findings indicate that while 4G networks in Albania have the capability to support IPTV, real-world performance can be inconsistent and may not meet the bandwidth requirements, especially for HD and 4K streaming. Vodafone in Durrës performs better in the morning (89.9 Mbps), making it excellent for 4K IPTV, evening speed varios (38.6 Mbps) is still good for HD IPTV, but for 4K can buffer. One – Albania in Durrës shows great morning speeds (94 Mbps) but drops to 10.7 Mbps in the evening, making it unreliable for IPTV. We notice a higher performance of the One company in Durrës comparing with Tirana but both providers slow down significantly in the evening, indicating network congestion. For a deeper analyze of network performance we have collected latency (ms) data and jitter, packet loss. Vodafone has the best latency (81.8 ms in the evening), which is acceptable for HD IPTV, and can work for 4K if speeds are sufficient. One has high latency (207 ms in the evening), which is not ideal for IPTV. Latency above 150 ms can cause buffering and delays. Vodafone in Durrës performs well in the morning (70.3 ms) and afternoon (83.2 ms), but evening latency spikes to 213 ms, likely due to congestion. One's latency is unstable, reaching 275 ms in the afternoon, making it unsuitable for IPTV, especially for live content. Comparing this result with the throughput data, we can conclude that while 4G networks in Albania have the technical capabilities to support IPTV, the real-world performance can be inconsistent, especially during peak usage times. Jitter represents fluctuations in packet delay. High jitter can cause IPTV buffering, stuttering, and poor video quality, especially for live streaming. Jitter under 10 ms is ideal for smooth IPTV streaming. Analyzing Jitter we noticed that the result are consistent with the analysis of other factors. Vodafone demonstrates good jitter performance, even during peak times in Tirana, while One's jitter is significantly higher, especially in Durrës, indicating potential issues for IPTV. Packet loss is a critical factor for IPTV quality, as lost packets can lead to pixelation, freezing, and loss of synchronous. Packet loss under 1% is generally considered acceptable for IPTV. Vodafone maintained packet loss under 1% across all tests, while One experienced significantly higher packet loss, especially in Durrës in the afternoon and evening, reaching over 3%. This high packet loss would likely result in a very poor IPTV experience for customers. In summary, the analysis of 4G network performance in Albania shows that while the underlying technology has the capability to support IPTV, real-world performance can be inconsistent, especially during peak usage times. Vodafone appears to offer better and more stable performance compared to One, with lower latency, jitter, and packet loss. Vodafone likely has better backhaul capacity, more optimized towers, better Congestion Management and Coverage Quality.

4.3 Sugestions

The analysis of 4G and 5G network for IPTV transmission in Albania highlights the potential for 5G to revolutionize the delivery of high-quality multimedia content in the country. By addressing the key requirements of IPTV, such as high bandwidth, low latency, and high connection density, 5G can provide a superior user experience and enable the deployment of advanced IPTV services. To realize this potential, it is crucial for the Albanian government, through AKEP, to work closely with Telecom Operators to create an enabling environment for 5G deployment. This includes addressing the operators' concerns, providing necessary infrastructure support, and launching a comprehensive public awareness campaign to educate the population on the benefits of 5G for IPTV and other digital applications. The successful implementation of 5G for IPTV in Albania can have far-reaching implications, including:

1) Improved access to high-quality multimedia content for citizens across the country, including in rural and underserved areas.

2) Increased opportunities for IPTV service providers to develop innovative and interactive services, driving digital transformation.

3) Potential for new economic opportunities and job creation in the media and telecommunications sectors.

4) Optimizing Quality of Service (QoS) for IPTV over 4G/5G in Albania focusing on reducing latency, jitter, and packet loss while ensuring stable bandwidth. For best quality of service bandwidth that determines video quality the right parameters vary from 25+ Mbps (HD), 50+ Mbps (4K)(HD/4K). Latency that causes delay & buffering should have the lowest possible value <100 ms (ideal), <50 ms for live IPTV. High jitter causes stuttering and the preferred value is <10 ms. Packet Loss Causes video freezing and quality drops and ideal value is $<1\%$, $<0.5\%$ for smooth IPTV). To optimize network performance and provide reliable IPTV services, telecommunications providers in Albania should focus on enhancing their network planning and optimization efforts.

5) Implement Advanced QoS Mechanisms: Dynamic bandwidth allocation, Admission Control, traffic prioritization, congestion management to ensure stable performance.

6) Is necessary to invest in Network Infrastructure Improvements: Optimize 4G LTE Networks, upgrading backhaul capacity (fiber-optic links) to prevent network congestion, upgrading cell sites, using more efficient modulation schemes and increasing spectral bandwidth utilization.

7) Optimize IPTV Delivery Architecture: Utilize Content Delivery Networks, edge caching, and load balancing to reduce latency and packet loss.

8) Leverage 5G Technology: 5G offers significantly enhanced capabilities in throughput, latency, and reliability, making it well-suited for IPTV delivery. Telecom providers in Albania should develop a strategic migration plan to 5G to future-proof their IPTV services.

9) Enhance Network Monitoring and Analytics: Implement robust network monitoring and analytics tools to identify performance bottlenecks and proactively address issues.

10) Collaborate with IPTV Content Providers: Work closely with IPTV content providers to optimize video encoding, streaming protocols, and delivery mechanisms for the Albanian market. By adopting these strategies, telecommu-

nications providers in Albania can significantly improve the quality of IPTV services and deliver a seamless, high-quality experience to their subscribers.

Albania can bridge the digital divide and enhance the delivery of IPTV and other digital services, ultimately improving the quality of life for its citizens and supporting the country's overall development.

References

1. Ahmedin, A., Ghosh, A., & Ghosal, D. (2018). A Survey of Multimedia Streaming in LTE Cellular Networks. In arXiv (Cornell University). Cornell University. https://doi.org/10.48550/arxiv.1803.05080
2. Alper, C. E., & Miktus, M. (2019). Bridging the Mobile Digital Divide in Sub-Saharan Africa: Costing under Demographic Change and Urbanization. In SSRN Electronic Journal. RELX Group (Netherlands). https://doi.org/10.2139/ssrn.3523121
3. Architectures and Key Technical Challenges for 5G Systems Incorporating Satellites. (n.d.). https://doi.org/10.1109/tvt.2019.2895263
4. Chaoub, A., Giordani, M., Lall, B., Bhatia, V., Kliks, A., Mendes, L. L., Rabie, K. M., Saarnisaari, H., Singhal, A., Zhang, N., Dixit, S., & Zorzi, M. (2020). 6G for Bridging the Digital Divide: Wireless Connectivity to Remote Areas. In arXiv (Cornell University). Cornell University. https://doi.org/10.48550/arxiv.2009.04175
5. Elsayed, M., & Erol-Kantarci, M. (2019). AI-Enabled Future Wireless Networks: Challenges, Opportunities, and Open Issues. In IEEE Vehicular Technology Magazine (Vol. 14, Issue 3, p. 70). Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/mvt.2019.2919236
6. Lema, M. A., Laya, A., Mahmoodi, T., Cuevas, M. del P. D., Sachs, J., Markendahl, J., & Döhler, M. (2017). Business Case and Technology Analysis for 5G Low Latency Applications. In arXiv (Cornell University). Cornell University. https://doi.org/10.48550/arxiv.1703.09434
7. Sánchez, J. L., Yahia, I. G. B., Crespi, N., Rasheed, T., & Siracusa, D. (2015). Softwarized 5G Networks Resiliency with Selfhealing. In arXiv (Cornell University). Cornell University. https://doi.org/10.48550/arxiv.1507.02951
8. Yu, H., Lee, H., & Jeon, H. (2017). What is 5G? Emerging 5G Mobile Services and Network Requirements. In Sustainability (Vol. 9, Issue 10, p. 1848). Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/su9101848
9. Zhong, Z., Jipu, L., Hua, N., Figueiredo, G. B., Li, Y., Zheng, X., & Mukherjee, B. (2016). On QoS-Assured Degraded Provisioning in Service-Differentiated Multi-Layer Elastic Optical Networks. In 2015 IEEE Global Communications Conference (GLOBECOM) (p. 1). https://doi.org/10.1109/glocom.2016.7842043
10. https://akep.al/wp-content/uploads/2024/07/AKEP-RAPORTI-VJETOR-2023-FINAL.pdf
11. https://www.uniqcast.com/ott-iptv/iptv-core-network-tutorial
12. https://www.techplayon.com/5g-reference-network-architecture/
13. https://www.cisco.com/c/en/us/solutions/what-is-5g/5g-vs-4g.html
14. https://www.ericsson.com/en/5g/5g-vs-4g
15. https://mobilepacketcore.com/lte-4g-network-architecture/
16. https://www.vodafone.al/