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PERFORMANCE METRICS EVALUATION AND TECHNICAL COMPARATIVE ANALYSIS OF 5G AND FIBRE OPTICS NETWORKS TECHNOLOGY FOR REAL-TIME VIDEO STREAMING

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ABSTRACT

Driven by developments in high-speed networks such as Fibre and 5G technologies, live streaming technologies have fast changed over the past several years. Growing consumption of video content across several platforms—including social media, entertainment, education, and business sectors—is driving demand for premium, flawless streaming experiences. The preference for live streaming technologies is examined in this article, with an emphasis on the combination of 5G and fiber networks. The goal is to investigate the technical advantages, difficulties, and possible advancements of live streaming using both technologies. This study illustrates the enhancements in latency, bandwidth, and dependability provided by these technologies by contrasting traditional and contemporary networks. These improvements are crucial for maximizing live

Introduction

The need for quicker and more dependable internet connectivity is driving technological innovations to unprecedented levels in today's quickly changing digital landscape. Fiber and 5G technologies, which are revolutionizing the way we access and enjoy online information, are two of the most exciting developments in this field. Among the most prominent sectors reaping the benefits of these developments is live streaming, which has permeated every aspect of our lives, from education to entertainment and beyond. The combination of 5G and fiber

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streaming experiences. When comparing the suitability of 5G and fiber optic technologies for dependable, high-quality livestreaming, fiber optic technology is the better option. The demanding requirements of contemporary livestreaming applications are well-suited to its steady high bandwidth, low latency, and strong dependability. Because fiber optic networks guarantee seamless data transfer in both directions, they provide symmetrical upload and download speeds, which are essential for livestreaming. By reducing buffering and latency problems, this feature gives viewers a flawless viewing experience. Furthermore, fiber optics ensure a steady and continuous connection because they are less vulnerable to environmental interferences like weather or physical obstacles. Conversely, 5G technology is appropriate for situations where permanent infrastructure is impractical due to its mobility and ease of implementation. However, there are a number of variables that can affect 5G's performance, including coverage restrictions, network congestion, and signal interference. These factors have the potential to cause irregular bandwidth and elevated latency, which could lower livestreaming quality. Although 5G is continuously changing and has great potential for future uses, its present constraints make it less suitable for situations when dependable, high-quality livestreaming is absolutely necessary. Fiber optic technology is therefore advised as the optimum alternative for applications where performance consistency and reliability are essential.

Keyword: Fiber, technology, 5G, Livestreaming, Infrastructure, Network, Symmetrical

Networks has become a potent enabler of next-level live streaming as customers want more seamless, high-quality viewing experiences. This combination of extremely fast internet speeds and low-latency capabilities has the potential to completely change how consumers around the world are able to access live events, broadcasts, and interactive information. In this conversation, we examine how the future of digital media consumption is being shaped by the growing popularity of live streaming enabled by Fibre and 5G technologies. (Zhang. L. & Zhao. H. (2020)).

The two technologies are also thoroughly examined in this research, which explores their system topologies and assesses their performance using pertinent models. In order to determine which option is best for livestreaming, a detailed evaluation of each of their advantages and disadvantages will be provided. By examining the

potential and constraints of 5G and fiber optic technologies, this study seeks to offer insightful information to stakeholders looking to create top-notch livestreaming experiences. (Zhang. L. & Zhao. H. (2020))

SYSTEM OVERVIEW

Essentially, live streaming is the process of sending video content over the internet in real time. ADSL, 4G, and other wireless technologies have historically supported it; but, during periods of high usage, these networks frequently have congestion, latency, and capacity issues. Because of their high bandwidth, low latency, and potential for large-scale communication, 5G and fiber technologies are regarded as a game-changer. (Han. M. & Lee. D. (2021))

Fibre Technology: Data transmission has changed significantly as a result of optical fiber technology. Optical fibers employ light to transport data, as opposed to conventional copper-based systems that use electrical signals. This leads to far higher bandwidth, much lower latency, and better transmission speeds. Because of these characteristics, fiber networks are the go-to option in places where dependable and continuous internet connectivity is most desired. Fiber technology has several benefits, especially when it comes to applications like live streaming. An extensive engineering technique for fiber networks is presented in this document, with an emphasis on how well-suited they are for high-demand services like live streaming. (Han. M. & Lee. D. (2021))

Fibre Technology Architecture: Fiber-optic networks, which provide high bandwidth and low latency, use light to transfer data through glass or plastic fibers. Important elements consist of: The central office of the service provider is home to the Optical Line Terminal (OLT). The optical distribution network (ODN) is made up of passive splitters and fiber cables. An optical network terminal (ONT) is set up at the client's location. High-speed, reliable, fixed-location internet connectivity is best served by fiber networks. (Han. M. & Lee. D. (2021).

Figure 1: Conceptual Diagram of Fibre Network Architecture

Requirements Analysis and Assessing Network Demands

A thorough analysis of the target area's present and prospective internet usage trends must be carried out before starting any network design. This entails figuring

out the important latency requirements for the apps that will operate on the network, recognizing peak usage periods, and comprehending the particular bandwidth requirements of the community or organization. For instance, live streaming frequently has a large bandwidth demand since uninterrupted delivery of high-definition or even 4K video content is required. To make sure the network can support their needs, additional data-intensive activities like cloud computing, online gaming, or video conferencing should also be taken into account during this assessment. In order to guarantee that the network can be adjusted when demand increases or new technologies are developed, future scalability should be taken into consideration. (Kumar. S. & Gupta. V. (2020)).

Environmental Considerations

The geographic and environmental characteristics of the target area will also affect the design and deployment of the optical fiber network. Factors including terrain, temperature, and urban congestion need to be carefully taken into account. Even though fiber optic cables are immune to electromagnetic interference, which makes them ideal for areas with high electrical noise levels, environmental variables like inclement weather or difficult terrain can still affect them. Whether to use an aerial, underground, or in-building cable will depend on these factors. Additionally, environmental issues include things like local laws, authorization needs, and the best approach to minimize environmental impact during deployment. (Kumar. S. & Gupt. V. (2020)).

Stakeholder Engagement

The success of the fiber optic rollout depends on efficient cooperation with stakeholders, including end consumers, local governments, and internet service providers (ISPs). While local governments may have particular rules and policies pertaining to infrastructure development, ISPs can offer insights into the technological requirements and integration demands. Early end-user engagement helps to pinpoint their unique requirements and expectations, ensuring that the network can satisfy them while being in line with the project's overarching objectives. (Kumar. S. & Gupta. V. (2020)).

Design, Planning and Network Architecture

Designing the network architecture is the next stage. Performance requirements and economic factors will determine whether to use an Active Optical Network (AON) or

a Passive Optical Network (PON). For instance, a PON can be more economical for bigger installations since it distributes the signal to numerous customers using passive splitters rather than active network components. AONs, on the other hand, provide you more control over the network, but they could cost more to run. In order to guarantee effective data flow, minimize bottlenecks, and offer scalability, the network design should also take into account how the core, distribution, and access layers will cooperate. (Kumar. S. & Gupta. V. (2020)).

Case Study: Fibre for Live Streaming with its Challenges.

Live streaming puts a lot of strain on a network, particularly when it's done in high definition or 4K. Real-time video data transmission can need enormous amounts of bandwidth, particularly when there are several streams running at once or when the content is of high quality. Furthermore, even little delays can cause buffering or interfere with the user experience, making latency crucial in live streaming apps. In order to overcome these obstacles, the network needs to be dependable and quick, offering steady service even during periods of high traffic. (Singh. R. & Chawla. S. (2021)).

Fibre's Advantages

Networks of optical fiber are perfect for tackling these issues. Even during times of heavy demand, fiber can guarantee that video streams are delivered without buffering or disruptions thanks to its capacity to transfer massive volumes of data at incredibly fast speeds. Fiber-optic connections' low latency further reduces delays, guaranteeing a flawless live streaming experience. Additionally, fiber networks may grow to meet increased bandwidth requirements as the demand for video content rises, enabling future developments like 8K streaming and lifelike virtual reality experiences. (Singh. R. & Chawla. S. (2021)).

5G Technology Architecture

The fifth generation of wireless technology is known as 5G. It is intended to provide large device connectivity, low latency, high data speeds, cost and energy savings. Important elements consist of: Sensors, IoT devices, and cell phones are examples of user equipment (UE).

Base stations (gNodeBs) are part of the Radio Access Network (RAN), which links devices to the core. 5G Core (5GC): Oversees functions like network slicing, authentication, and data routing.

5G is perfect for applications requiring ultra-low latency, smart cities, and mobile broadband.

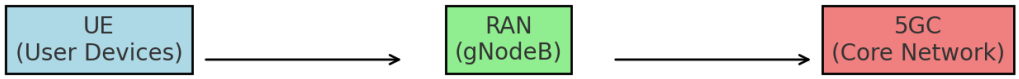

Figure 2: Conceptual Diagram of 5G Network Architecture. (Singh. R. & Chawla. S. (2021)).

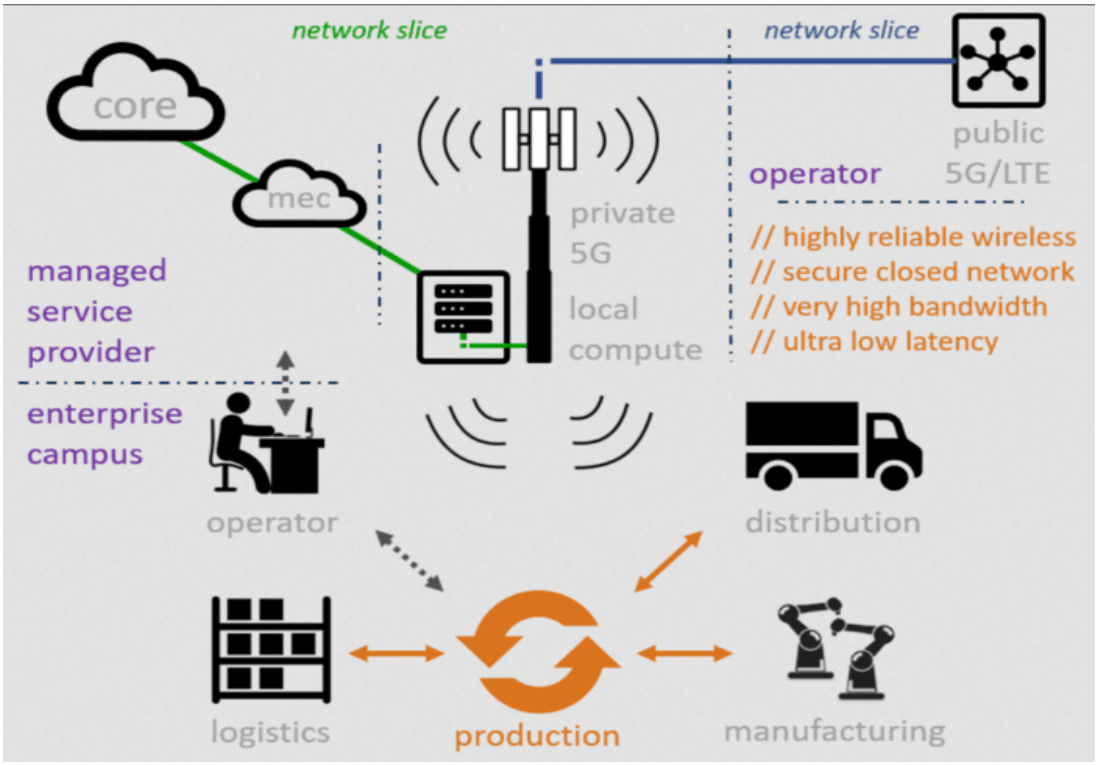

Figure 3: 5G network overview. (Singh, R., & Chawla, S. (2021)).

Compared to earlier networks, 5G wireless cellular technology offers faster upload and download rates, more reliable connections, and greater capacity. 5G has the potential to completely change how we use the internet to access information, social networks, and applications because it is far quicker and more dependable than the already widely used 4G networks. For instance, 5G connectivity is expected to significantly improve technologies that need extremely dependable, fast data connections, such as self-driving cars, sophisticated gaming apps, and live streaming media.

Key Features of 5G Live Streaming:

- **Ultra-Low Latency:**5G offers significantly reduced latency (as low as 1 millisecond in ideal conditions), enabling near-instantaneous delivery of live video, which is crucial for real-time interactions during live events, gaming streams, or sports broadcasts.
- **Mobility and Flexibility:** 5G's primary advantage over fiber is its ability to provide high-speed internet to mobile users, allowing content creators and consumers to stream live video from virtually any location without being tethered to fixed infrastructure. This mobility opens up new opportunities for on-the-go streaming, such as live coverage from remote areas, concerts, or urban events
- **High Bandwidth:** 5G's bandwidth capabilities can support 4K and even 8K streaming under the right circumstances, albeit they aren't necessarily as reliable as fiber. Actual performance, however, may differ based on variables like as signal intensity, network congestion, and the distance from 5G cell towers.
- **Network Congestion and Coverage:** Network infrastructure has a significant impact on 5G's performance. Although the technology is still in its infancy, it has the ability to provide extensive coverage, and in densely populated or underdeveloped areas, performance may vary. Furthermore, 5G's high-frequency millimeter waves are more easily blocked by structures or natural barriers and have a shorter range. (Bansal. S. & Verma, D. (2020).

METHODOLOGY

This study employs qualitative and quantitative research approaches to examine preferences for live streaming using Fibre and 5G technologies.

Data Collection:

- **Surveys**: Survey was administered to 300 users from diverse demographics to ascertain preferences, experiences, and issues associated with live streaming utilizing various technologies.
- **Interviews**: Comprehensive interviews with streaming service providers, network engineers, and telecommunications specialists were conducted to obtain insights on the technological advantages and obstacles associated with the adoption of Fibre and 5G for live streaming.

Experimental Setup:

- Fibre-optic internet and 5G networks were used for live streaming tests in order to evaluate user experience, latency, buffering time, and video quality.
- Traditional streaming over 4G and improved streaming with 5G and fiber were compared.

Data Generation

Real-world situations of live streaming performance were simulated using both 5G and Fibre across numerous key performance indicators (KPIs):

- **Download Speed (Mbps)**
- **Upload Speed (Mbps)**
- **Latency (ms)**
- **Buffering Time (seconds)**
- **Streaming Quality (scale 1-10)**

Assume that each technology is tested during five (5) distinct live streaming events, such as news, concerts, sports, gaming, and education. (Bansal. S. & Verma, D. (2020)).

Table 1: Sample Data Table

Event Type	Technology	Download Speed (Mbps)	Upload Speed (Mbps)	Latency (ms)	Buffering Time (s)	Streaming Quality (1–10)
Sports	5G	250	80	28	1.2	8.5
Sports	Fibre	450	150	12	0.3	9.8
Gaming	5G	210	75	32	1.5	8.2
Gaming	Fibre	400	130	14	0.5	9.5
Education	5G	190	70	35	1.1	8.3
Education	Fibre	380	120	15	0.4	9.2
Concert	5G	230	85	30	1.3	8.6
Concert	Fibre	430	140	13	0.4	9.6
News	5G	200	60	31	1.0	8.1
News	Fibre	410	110	14	0.3	9.3

Data Analysis

Key Observations:

1. **Speed**:
    - Compared to 5G, fiber offers consistently faster upload and download speeds.

- Fiber is crucial for streaming and particularly dominates upload performance.

2. **Latency**:
   - Fiber has reduced latency, which is essential for real-time communication (such as online courses or live gaming).
3. **Buffering Time**:
   - Due to wireless connectivity fluctuations, 5G has somewhat longer buffering periods; in contrast, fiber, which is more reliable, enables playing that is almost instantaneous.
4. **Streaming Quality**:
   - Higher quality video feeds are supported by fiber, especially for high-motion events like concerts and sporting events. (Bansal. S & Verma, D. (2020)).

SUMMARIZED AVERAGE PERFORMANCE DATA

The evaluation metrics include buffering time, latency, download/upload rates, and overall streaming quality.

Below is the summarized average data across various live streaming event types:

Table 2: Average Data Across Various Selected Live Stream Event Types.

Technology	Download Speed (Mbps)	Upload Speed (Mbps)	Latency (ms)	Buffering Time (s)	Streaming Quality
5G	216.0	74.0	31.2	1.22	8.34
Fibre	414.0	130.0	13.6	0.38	9.48

SIMULATION OUTPUT DISPLAY:5G VERSUS FIBRE FOR LIVE STREAMING

Figure 4: Latency vs Time (Fibre has lower and stable latency).

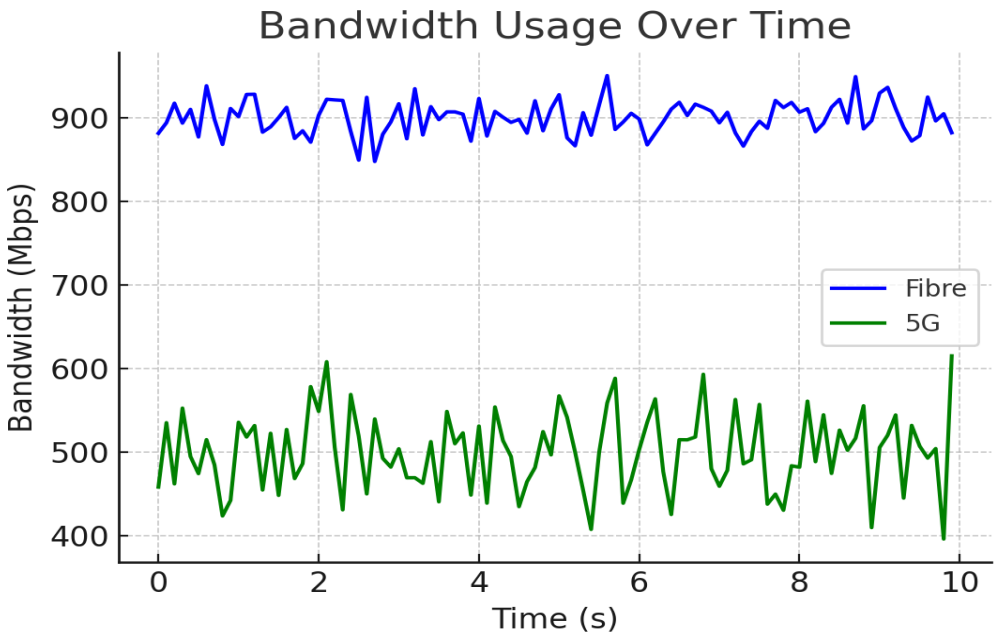

Figure 5: Bandwidth Usage Over Time (Fibre provides higher consistent throughput).

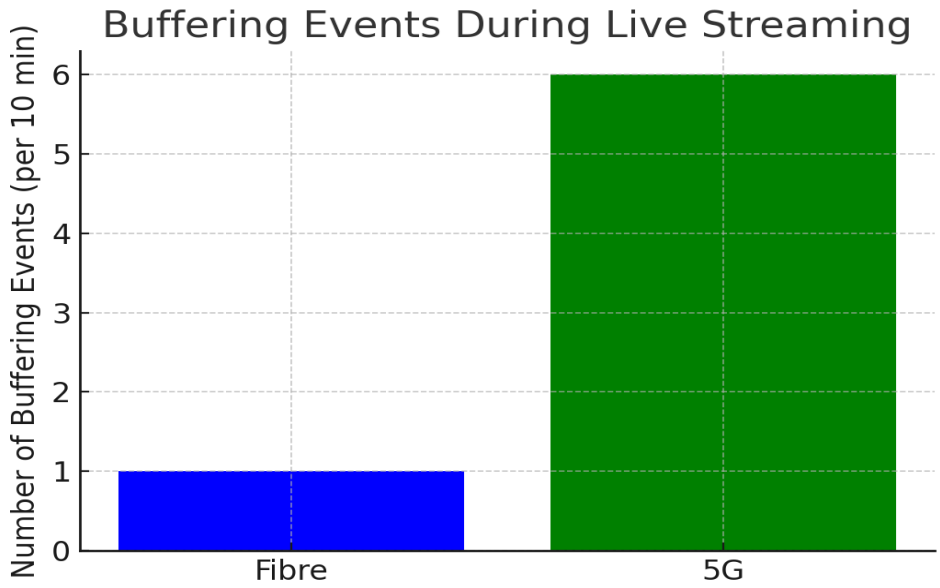

Figure 6: Buffering Events During Live Streaming (Fibre experiences fewer interruptions).

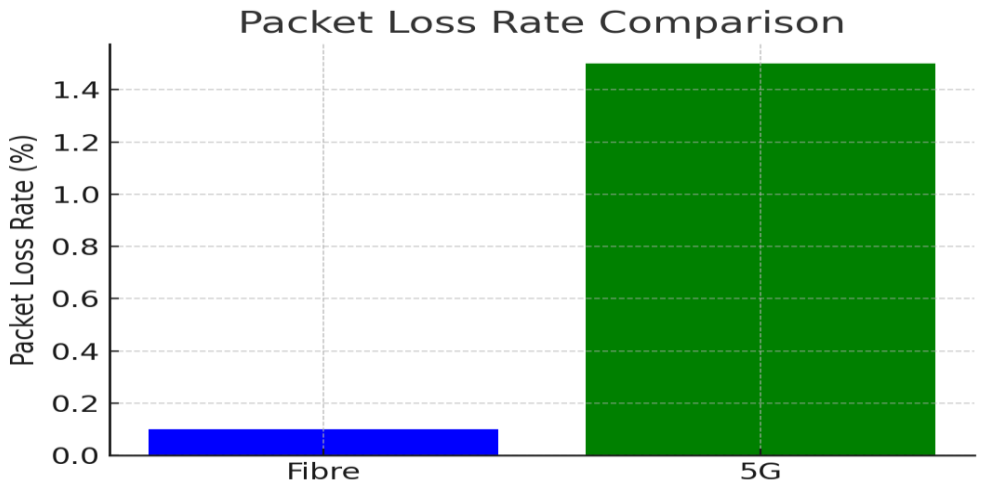

Figure 7: Packet Loss Rate Comparison (Fibre is more reliable).

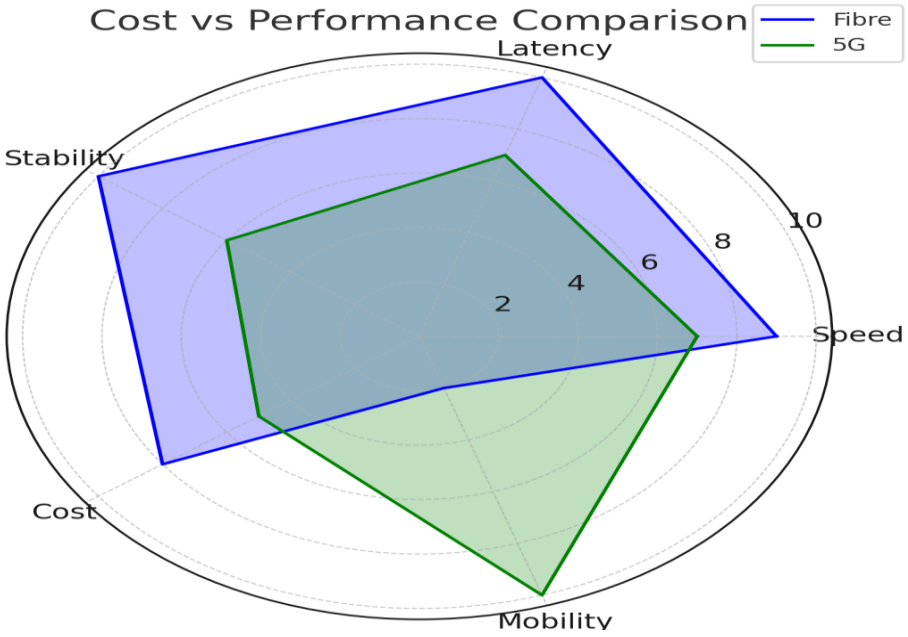

Figure 8: Cost vs Performance Comparison (5G is more mobile, Fibre is more stable and cost-effective).

RESULT AND DISCUSSION

Graphical Analysis:

The following charts provide a visual representation of the performance metrics:

1. Average Download and Upload Speeds

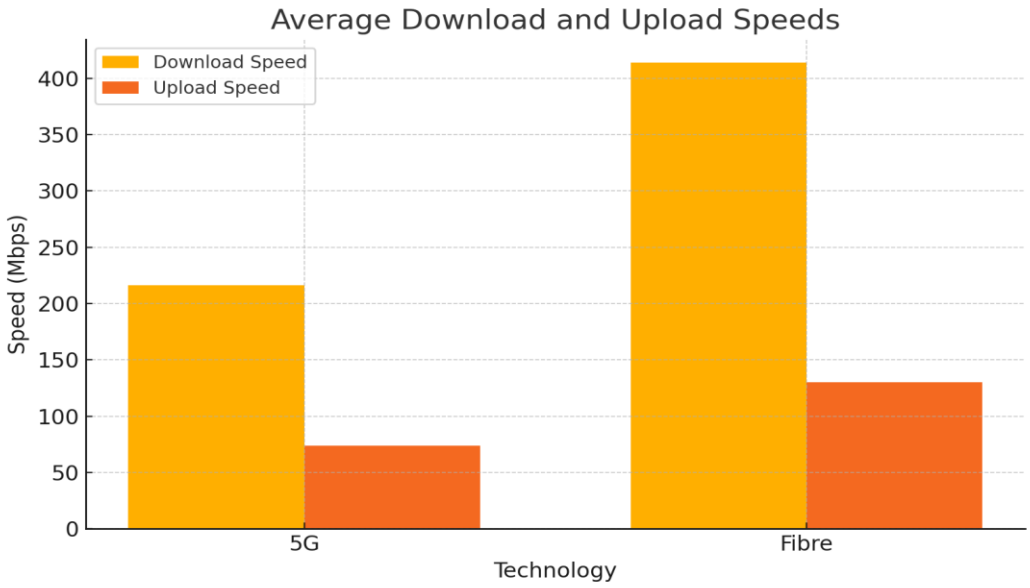

Figure 9: Average Download and Uploads Speeds

2. Latency Comparison Across Events

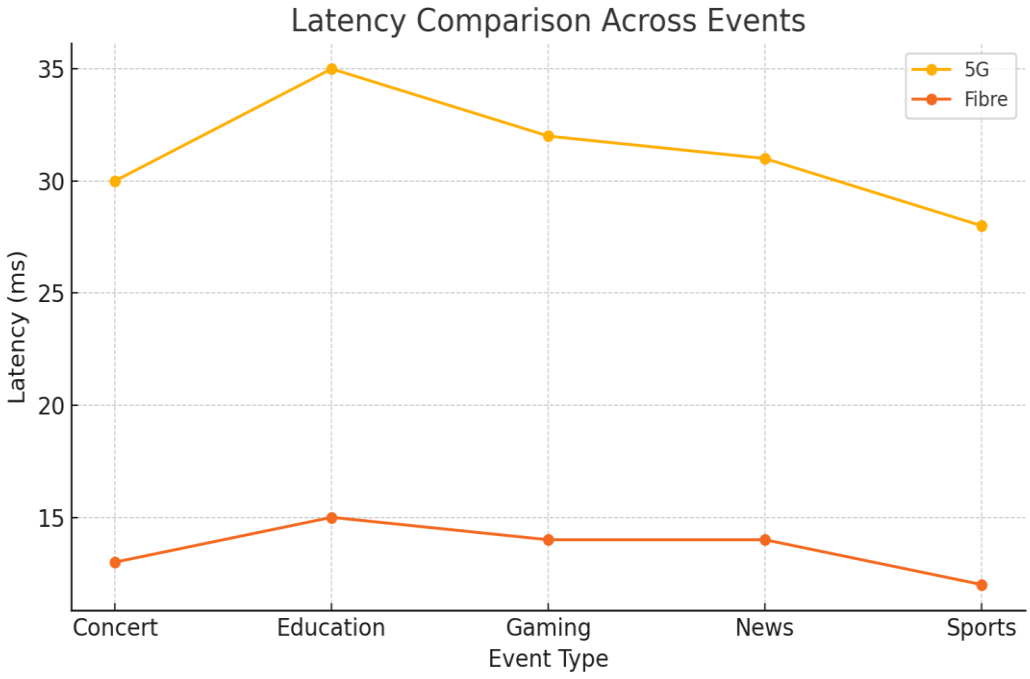

Figure 10: Latency Comparison Across Events

3. Average Streaming Quality Contribution

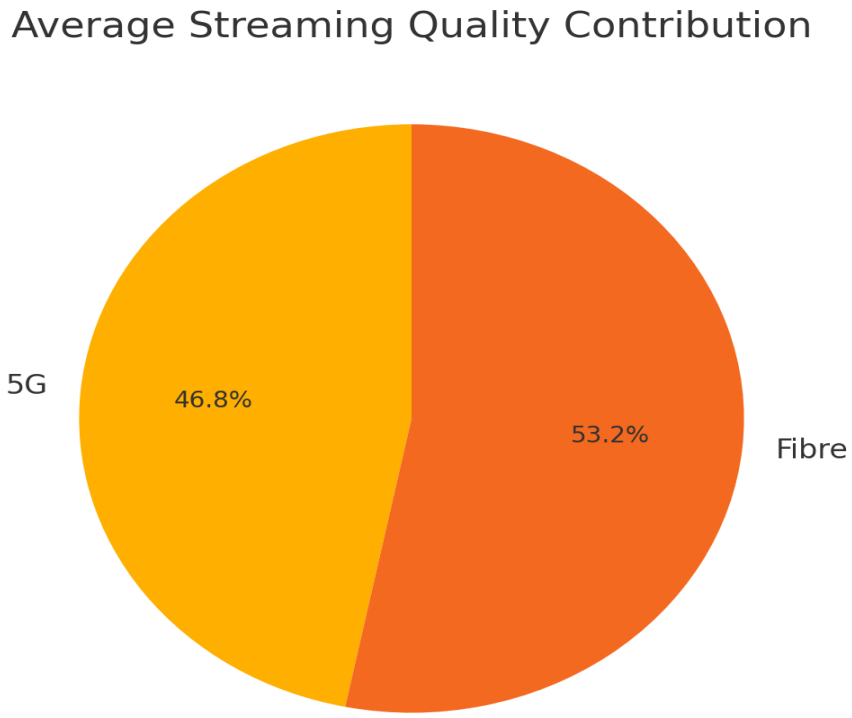

Figure 11: Average Streaming Quality Contribution

Fibre's greater bandwidth, reduced latency, and improved consistency make it superior to 5G in nearly every parameter. Nonetheless, 5G offers the benefits of portability and simplicity of deployment, which makes it a good substitute in some situations. Fibre continues to be the go-to option for live broadcasting that is professional and quality-sensitive. Therefore, it can be concluded from the analysis that 5G and fiber technologies greatly improve the live streaming experience. Several important conclusions include: (Bansal, S., & Verma, D. (2020)).

Bandwidth: Data transmission speeds supported by fiber optic cables are orders of magnitude faster than those of 4G networks or conventional copper lines. This makes it possible to transmit in HD and UHD with minimal to no buffering, particularly for bandwidth-intensive applications like 4K video streaming. (ITU-R. (2020))

Bandwidth and Quality of Experience

It has long been known that fiber-optic technology can provide extremely high bandwidth. Fiber-optic connections are the best option for uninterrupted streaming of HD, 4K, and even 8K material because of their speeds, which may reach up to 100

Gbps and beyond. Because of this, fiber is the preferred solution for fixed-location applications, broadcasting studios, and big venues where stream quality is crucial and bandwidth demands are high. Fiber offers unmatched stability and dependability for professional live streaming, such as sporting events, concerts, or news broadcasts, guaranteeing that the content is simultaneously presented to millions of people at the best possible quality. (ITU-R. (2020))

Even while 5G technology can achieve remarkable speeds—up to 10 Gbps under perfect circumstances—it is most useful in situations requiring mobility. For mobile streaming applications such as sports reporters on the go, mobile gaming, social media content providers, and live-event coverage from shifting or unpredictable locations, 5G is designed for low latency and real-time interaction. Another benefit of 5G is its low-latency performance (1 millisecond), which is crucial for applications like live sports commentary, interactive virtual events, and real-time collaboration that demand real-time interaction. (N. U. Hassan et al., 2020)

In summary, 5G is superior in delivery, but fiber is better suited for fixed, high-demand, high-quality applications.

Latency: Latency, or the interval between recording and showing content to viewers, is one of the most crucial aspects of live streaming. 5G networks are a major advance over 4G and other legacy systems because of their incredibly low latency (as low as 1 millisecond). This is especially helpful for interactive live streaming where real-time contact is essential, such live gaming or remote telemedicine.

- **Fiber**: Fiber typically offers **low latency**, which is important for real-time interactions during live streaming (especially for gaming, virtual events, or interactive broadcasts). Latency for fiber connections is usually in the range of **5-20ms**, making it ideal for high-quality streaming.
- **5G**: 5G has the potential for **very low latency**, sometimes as low as **1ms** in ideal conditions, but this is often not guaranteed in real-world situations. **Latency spikes** can occur due to network load or interference.

Mobility and Connectivity: With 5G, live broadcasting is possible from almost any place without compromising speed or performance since it can accommodate more devices per square kilometer. Due to the fact that users are not bound by fixed broadband connections, it is perfect for mobile streaming. ((Hassan, N. U, et al, 2020)).

Reliability and Coverage: Even in highly populated areas with high demand, consumers can anticipate reliable and high-quality service thanks to the combination

of 5G's mobile edge computing (MEC) with fiber technology in backhaul networks. In terms of stability and dependability, fiber-optic technology is frequently considered the gold standard. The types of interference that can impact wireless networks do not affect fiber-optic connections. This increases the reliability of fiber-optic links in high-density settings or in situations when network congestion is an issue. For instance, fiber guarantees that there won't be any signal deterioration or service disruptions during live-streaming events that need constant, uninterrupted data transfer, such major concerts or sporting events.

In contrast, network congestion and interference are potential problems with 5G, particularly in crowded regions or during periods of high demand. Despite its remarkable speeds, 5G may not be able to sustain high performance in scenarios with high demand, especially when many users are connecting to the network at once. For instance, the available 5G bandwidth may be saturated if a live-streaming event takes place in a packed metropolis or a sports stadium, resulting in decreased quality, buffering, or latency. (Lyu, X., Ni, W.,et al, 2021).

Additionally, the coverage of 5G is still growing. Although 5G coverage is generally good in urban areas, coverage gaps may occur in rural or underserved areas, making it less dependable in some settings. Fiber works well in this situation as the foundation for reliable, long-distance, high-quality streaming without the dangers of wireless interference.

However, some challenges still exist:

- **Cost of Deployment**: Installing and maintaining fiber infrastructure costs a lot of money, particularly in remote or underdeveloped locations.
- **Coverage Gaps**: Although 5G has promise, many places currently lack widespread coverage. Investing in the expansion of 5G infrastructure is essential for providers to ensure flawless live streaming experiences. (Lyu. X. et al, 2021).

CONCLUSION

The combination of 5G and fiber technologies is transforming live streaming by providing increased dependability, decreased latency, and faster speeds. This study's results validate that 5G's low latency and scalability, along with fiber's high bandwidth capabilities, are perfect for providing a seamless live streaming experience. It is anticipated that the integration of these two technologies will become commonplace as the need for high-quality, real-time video rises, elevating the caliber and accessibility of live content. Over time, the advantages surpass the

disadvantages, despite persistent obstacles including exorbitant deployment expenses and coverage restrictions. Furthermore, these problems should be lessened in the future as both fiber and 5G networks develop. (Choudhury, N., & Misra, S. (2021)).

RECOMMENDATION

To guarantee that everyone has access to high-quality live streaming services, governments and private businesses should keep funding the development of fiber optic networks and 5G infrastructure. Streaming platforms should also use these next-generation networks to maximize the services they provide. With the higher bandwidth and lower latency of Fibre and 5G, high-definition and interactive content—like virtual reality (VR) or augmented reality (AR)—can be served more successfully. Policymakers should also establish frameworks that support the quick rollout of 5G and fiber networks, such as incentives for businesses to invest in rural areas where high-speed internet is frequently scarce. In the meantime, consumers should be informed about the advantages of 5G and fiber streaming technologies so they may choose internet providers wisely for their live streaming requirements. (GSMA. (2021)).

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