# 5G ENABLES HIGH BITRATE, LOW LATENCY AND MOBILITY ON THE LIVE PRODUCTION OF THE BIGGEST LATIN AMERICA REALITY SHOW

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## ABSTRACT

Reality show productions require many wired cameras to cover all the house and camera operators usually work on dark rooms, capturing the images through mirrors. In order to improve reliability and security, this project counted on a 5G Standalone Non-Public Network(S-NPN) dedicated to the reality show. The use of 5G made it feasible to reduce video cables and control the cameras remotely. The 5G solution empowered 2 cameras with SRT protocol and HEVC codec resulting on 80 Mbps of upload and 6 frames glass-to-glass delay. The high video quality and low delay solution allowed the coexistence of 5G connected cameras with wired cameras. The future vision is to scale the solution for more cameras, seek to downsize the solution, for a lighter weight, low energy consumption and use of 5G as connectivity for new applications.

## INTRODUCTION

Big Brother Brasil is the biggest reality show in Latin America, with 23 years on air in Globo TV. The reality uses more than 50 cameras in the studio with a complex infrastructure of cabling and demands expensive operation. In order to be more efficient, mobile interfaces can bring mobility, reduce physical installations and allow remote production.

Previous generations of mobile networks didn't allow high bitrate transmissions, due to low bandwidth on the upload. The new 5G networks open a new scenario where high bitrate and low latency can be achieved, changing the way live productions are made.

This paper will present the solution used in Big Brother reality show, 24 hours a day on air, during 100 days of program. 2 cameras transmitted 40Mbps each, using HEVC video coding and only 6 frames delay, operated remotely and delivering high-quality and low latency that enables the use of 5G cameras.

5G networks also applied network slicing dedicated to the reality show studio, ensuring reliability and quality of service by reserving network resources and guaranteeing a secured data transmission.

In the future, the 5G connectivity in the studios can be extended to new applications, such as IoT, studio automation and new live production models.

## APPLICATION TIERS: NEWS WEBLINK BACKPACK AND CONNECTED STUDIO

The arrival of 5G brings two interesting features for improving the video streaming experience using mobile network connectivity. The higher uplink rate capacity brings benefits in video quality, which can be transmitted at higher bitrates. Another aspect concerns network latency, which brings an experience of content with less delay, allowing the study of architectures that use 5G-connected cameras in conjunction with wired cameras.

Based on the experiments we have conducted, we can say that we can divide the use of 5G into two different types of applications, with different video rates and delay requirements, characterizing two different Tiers: News Backpack and Connected Studio.

### News 5G Backpack

The use of mobile connectivity for video transmission is a reality for broadcasters for some time, with the use of journalism weblinks backpacks, with several SIM Cards from different operators aggregating bandwidth for video transmission.

5G brings an improvement in this application, with greater possibilities to increase the transmission rate due to the upload link of 5G with greater traffic capacity. The impact of the new technology will be in improving video quality in live broadcasts.

This tier admits higher compression and higher video buffering in order to guarantee video transmission even in more remote usage scenarios. The bonding technology that is used for multiple cellular connections needs a buffer in an order of around one second for more secure transmission, resulting in a glass-to-glass delay of around 30 frames, not taking advantage of the low mobile network delay (~20ms, less than a frame). Also, the video rates (8-10Mbps) used in this model only takes up less than 10% of the available 5G upload capacity.

### Connected Studio

Compared to the 5G backpack scenario, this is a new possibility that 5G brings as an innovative possibility. This tier brings more demanding requirements regarding high video quality and low delay, with no admission of apparent deterioration, video artifacts and blocks. Those demands are only possible to be attended in mobile networks with 5G technology, using the network advantage of high throughput and low latency, in conjunction with low delay and highly efficient CODECs.

Since in the studio we need the coexistence of 5G connected cameras with wired cameras, the difference in quality between raw and compressed video should be less as possible. Therefore, the importance of working with more efficient CODECs and high rates, for example, our application was deployed with HD video with HEVC encoding at a rate of 40Mbps.

For the same reason of coexistence, the delay of the solution needs to be in the order of a few frames (4~6 frames) to avoid the apparent perception of lip sync. The 5G delay brings less than a frame of delay (20~25ms) and it is important that CODEC provide the shortest possible delay so that the glass-to-glass delay is not punished.

## PRIVATE 5G CONNECTIVITY ARCHITECTURE

The architecture developed in this application focused on reliability, security, high upload throughput and low glass-to-glass delay. For this scenario, a Private 5G Network was implemented with a specific configuration to fulfill those requirements. These details are exposed in the sequence.

## Overview Diagram

To provide camera connectivity with 5G, it was necessary to implement an infrastructure to connect Globo's internal network with the 5G network of a Telecom partner. For this purpose, a 10Gbps ring was created to attend to the demand of the reality show and so, promoting more security for the data transmitted over the network and quality of service. After creating the connectivity with the 5G network, it was necessary to internally provide a connecting link between the gateway of the 5G network inside Globo and the technical center facilities that serves the reality show. In the technical center, the IRU (indoor radio unit) was installed, whose function is to aggregate the signals and supply energy to the 5G small cell, and a Switch for integration of the decoder and the remote controls of the camera in the 5G network. As seen in figure 1.

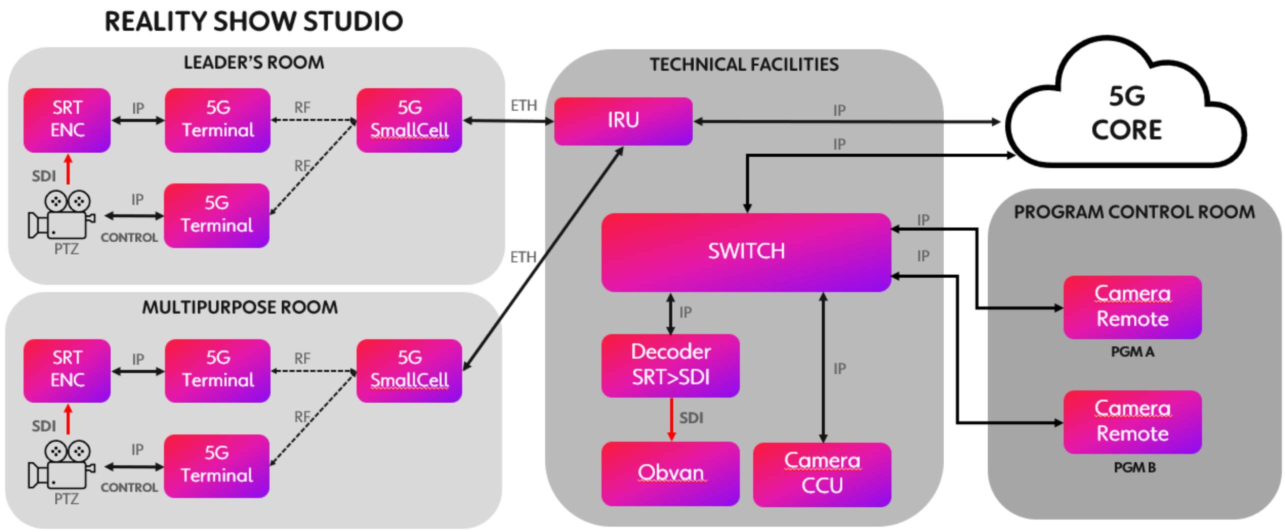


Figure 1 – Overview diagram

## Security Network Architecture

Because of the content confidentiality captured by the camera, which will be selected by the program's director for the exhibition, the program brought important security requirements to avoid content leaks.

Based on this concern, a Private 5G network was used in the program, with the concept of LAN architecture, with the same IP range and broadcast domain between the 5G terminals and the equipment connected in a switch inside this network. It was created an exclusive APN for the mobile network for traffic restrictions and security. The network inside the telecom partner has a MPLS tunneling without connection with other networks and no exposal for the Internet.

The SIM Cards used in the application only could anchor in the Base Units installed in reality show because of the TAC (Tracking Area Code) configuration. No other SIM Cards could connect to the installed 5G network other than the SIM Cards used in the application due to the restrictions applied on 5G core by using a permission list. Any other SIM Card that tries to connect to this Private Network was blocked.

## Private 5G Network Features

The 5G S-NPN was delivered by a telecom partner transmitting on 3,5GHz (n78 band), with 100 MHz bandwidth, SISO (Single input Single output) antenna terminal, TDD (Time Division Duplex), 64QAM modulation. Based on this configuration, it was possible to experience 20~25ms of RTT and 80Mbps of guaranteed upload throughput for each IRU. Considering this restriction of total upload throughput, due to the characteristics of the 5G system, and the necessity of 2 cameras transmitting simultaneously, it was configurated 40Mbps of the total video stream for each camera.

As we used the shared 5G core topology, the data stream and control traffic had to be routed to the telecom partner site, outside Globo Studios, to flow through the 5G core with UPF (User Plane Function) and CP (Control Plane). This connection was a 10Gbps fiber optics in ring topology between Globo Studios and Rio de Janeiro downtown.

The figure 2 shows the flow of video and control data inside 5G studio site (black line) and video data (green line) and camera control data (red line) that needs to be routed to the telecom 5G Core.

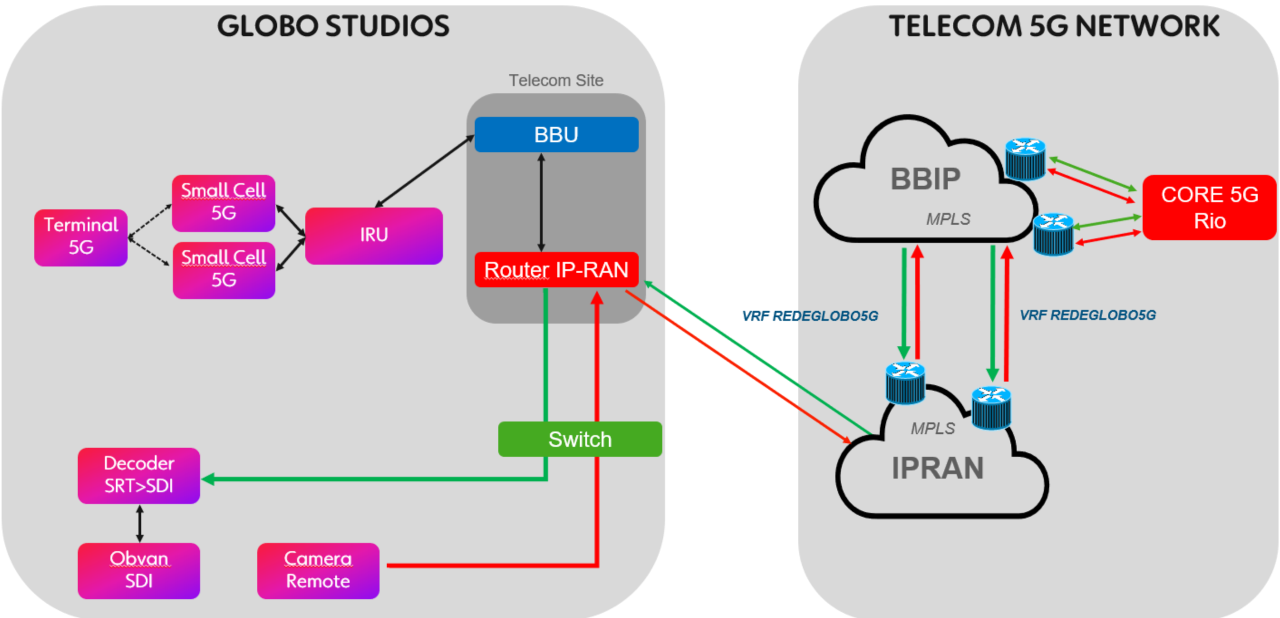


Figure 2 – Shared 5G Core topology

## Camera Connectivity Setup

In the reality show, a 5G small cell was installed to provide connectivity to the setup inside the house. In this location, two CPEs (Customer Premises Equipment) terminals were used, both with the 5G network connection. One CPE was connected via ethernet to the video encoder and the other CPE was connected via ethernet to the camera remote control ethernet port. This setup is represented in figure 3.

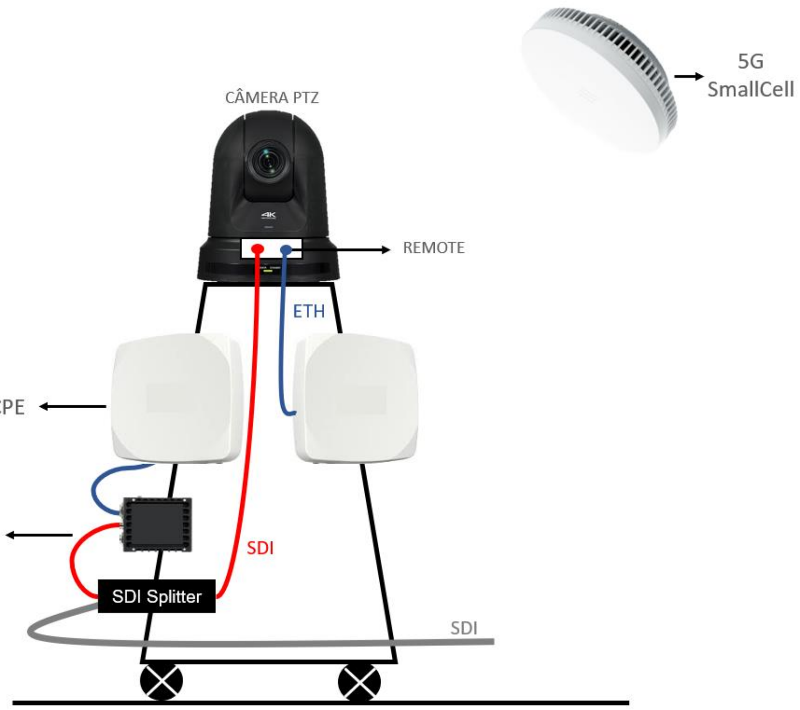


Figure 3 – Camera Setup

Regarding the CPE terminals, it was essential for the application to configure the CPE to work in Pure Bridge mode. This configuration allows that the IP address from the 5G network received by the SIM Card to be passed to the equipment connected to the terminal's ethernet port. This configuration will allow the elements connected to all 5G terminals and to the switch to be in the same broadcast domain enabling communication with each other like a LAN.

## VIDEO CODING SOLUTION

Due to the Tier requirements of the connected studio, it was necessary to look for video solutions that would address low delay, with a glass-to-glass solution of around 5~6 frames and an efficient compression that would allow the greater use of the 5G system's upload rate potential (in the order of 30~40Mbps for each SIM Card).

## NDI

The NDI (Network Device Interface) protocol is a video streaming that enables high-quality, low-latency video transmission over a computer network. NDI is based on Internet Protocol (IP) and uses a video distribution network architecture to transmit real-time video signals between devices connected to the same network.

NDI was designed to provide a flexible solution for network video production. It allows users to capture, transmit and receive bandwidth video streams, along with audio and metadata across IP networks for broadcast contribution and production.

The NDI protocol is highly scalable, allowing multiple video devices to be added to the network without compromising video quality. It also offers advanced network management features such as video routing, device auto-discovery and traffic prioritization to ensure the video stream is transmitted efficiently and reliably.

One of the main advantages of NDI is its ability to deliver high-quality video streams with low latency. This is especially important for applications that require real-time interaction, such as live video production, gaming, and virtual reality applications.

The use of NDI as a video transmission protocol was studied as the first solution. It was possible to see, with a notebook, the transmission of the NDI signal through the 5G network. However, for some unidentified reason, the signal was not recognized by the decoder. There is interest in identifying the problem so that NDI can also be used in future productions, given that the protocol meets the program's requirements, such as low latency and high video quality.

Because of this result, a new transport protocol needed to be used, and the SRT was chosen as a solution to carry the video stream.

**SRT**

The SRT (Secure Reliable Transport) protocol is a video streaming technology that aims to offer high quality, low latency and reliability over public internet networks and is an open-source protocol. It is considered a good example in the market that uses ARQ (Automatic Repeat Request), an error-control strategy that improves audio/video stream transmissions.

SRT is based on User Datagram Protocol (UDP) and uses encryption to protect video content during transmission. It is designed to enable high-quality video streaming under challenging network conditions such as unstable internet connections or public networks with traffic congestion.

The SRT protocol uses error correction techniques to ensure that data packets reach their destination without errors or data loss. This is important to ensure video quality and minimize the impact of unfavorable network conditions. SRT also includes bandwidth scaling capabilities, which allow video quality to be automatically adjusted based on network conditions.

Another important feature of SRT is its low latency glass-to-glass. SRT is designed to minimize latency and deliver a real-time video stream with minimal delay.

In the first moment, the installation of the codec set from vendor A was done. The choice of this equipment was due to the need for the installation location, which is an environment where noise is not tolerated, in addition to being a place with reduced space. The choice was also motivated by the need to obtain the lowest glass-to-glass delay, due to the importance of the application. With success, camera operation over 5G was successfully installed and validated and operated throughout the program, with extremely low delay. Another important point was the setup for video transmission over 5G. The RTT (round trip time), which is the time that the data packet takes to go and return to the destination, is an important metric for determining the health of a connection on a network and is commonly used to diagnose the speed and reliability of network connections.

In SRT stream protocol, it is possible to set the latency from 80ms to 8000ms. Increasing latency gives more time to buffer packets and resend any of them when any of them got lost in transit to the Destination. If this value is too low and there is packet loss over the network, retransmission of lost packets will not be possible and the video quality will suffer.

According to ‘SRT Alliance (1)’ to calculate the optimal SRT latency, the formula is:

$SRT\ Latency = RTT\ Multiplier \times RTT$, where the recommended range of the RTT Multiplier is a value from 3 to 20.

Table 1, from 'SRT Alliance (1)', provides guidelines recommended for what values to use when calculating latency. An RTT multiplier value less than 3 is too small for SRT to be effective and a value above 20 indicates a network with 100% packet loss.

| Worst Case Loss Rate% | RTT multiplier | Bandwidth overhead (%) |
|---|---|---|
| % is ≤ 1 | 3 | 33 |
| % is ≤ 3 | 4 | 25 |
| % is ≤ 7 | 5 | 20 |
| % is ≤ 10 | 6 | 17 |

Table 1 – SRT Latency calculation according to network RTT values

As shown on Figure 4, the measured average RTT was around 22ms and the network had no loss rate, the SRT latency was set to 100ms, following a 4xRTT multiplier to give more robustness to the system. With vendor A, the video delay was around 6 frames, using HEVC, with GOP Lenght = 120 and GOP Structure IP, which satisfied the application's needs.

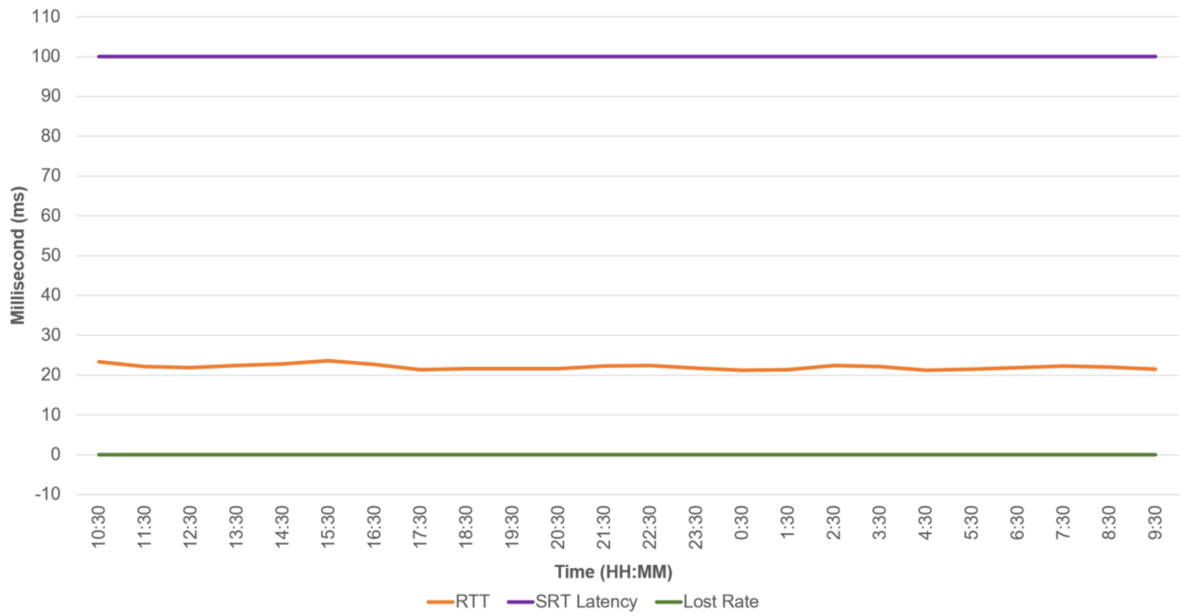


Figure 4 – Network RTT, SRT Latency and Lost Rate in 24h window

Looking for improvements in the system, vendor B was used to try finding a smaller glass-to-glass delay. The equipment from this vendor is much larger than that of vendor A, in addition to emitting more noise, but within the limits tolerated in the application. During these tests, the video quality was similar to vendor A, but it was more stable. On the other hand, with the same settings as the equipment from vendor A, equipment from vendor B presented an extremely high glass-to-glass delay for the intended application, whose measured value was 34 frames. Thus, realizing that vendor B could not guarantee a delay of around 200ms (max 6 frames), its use was discontinued.

In order to validate the video quality and minimize latency, several tests were performed. As a result, it was validated using 40Mbps of video bitrate coded in HEVC that outcome in a 6 frames glass-to-glass delay.

## FUTURE VISION

This opportunity proved to be perfectly feasible to use 5G networks on a TV Production environment to connect wireless cameras and achieve high bitrates and low latency in a way that the whole system could be integrated and synchronized in the same switcher.

Improvements to the current setup may include batteries to replace wired power. The video encoder used on these tests requires less than 6W and the 5G modems don't need more than 8W to transmit the video stream and exchange data to control the camera. This power consumption can be easily supplied by a traditional camera battery to support its consumption for hours and hours of operation.

As soon as 5G modems become smaller, on a very short time, next-generation cameras will be produced with 5G integrated to its hardware and all data traffic will be managed directly by the camera software as easy as if it was done by cables.

The achieved 80Mbps of video bit rate enabled us to use 5G networks in 4K UHD productions, combined with HEVC video coding, instead of having 12Gbps (single link) or 3Gbps (quad-link or 2SI) massive number of cables.

It opens a door to transform content production on more automated studios and more agile content creation processes.

Applications like these, connecting dozens of cameras on a studio, rather than connecting millions of devices, doesn`t need to exchange data with a centralized mobile operator`s core. It seems to be simpler and more cost efficient having a smaller and dedicated core to the broadcast operation. In this case, the total RTT (round trip time) tends to be even lower, improving the user experience and reducing frames difference between cameras and switchers.

## CONCLUSION

The arrival of 5G technology in mobile networks brings the possibility of developing new applications that demand high transmission rates and low delay.

The innovative application presented in this article is different from the traditional news weblink backpack applications, where the time between camera and studio represents seconds of delay. The new model of video transmission presented, also uses mobile 5G networks, but brings so high bitrates and so little delay to content production that it can be used on a studio environment together with wired cameras.

The solution used lightweight encoders consuming less than 6W and transmitting HD images at 40 Mbps in each device. A very low delay HEVC compression system together with the powerful SRT transport protocol resulted on a total latency between wired and wireless cameras of less than 6 frames. This system proved the concept of a new model of video transmission, applied in the biggest reality show in Latin America, Big Brother Brasil, opening the door for the concept of a full connected studios with wired and wireless cameras operating altogether.

In the future, this new video mobile transmission solution and the technology improvements, the model presented could bring a smaller and lighter solution, for more mobility, efficiency and further applications such as IoT.

## REFERENCES

1. SRT Alliance. Secure Reliable Transport Protocol Deployment Guide Version 1.1 | Issue 01. pp 26.

## ACKNOWLEDGEMENTS

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