Service Orchestration for Film Preservation Over 5G

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Abstract

In an era of digital imagery, the analog film archives around the world continue to age and perish. With a decaying film stock and conditions such as inadequate storing and limited reliable backup methods, an irreversible and progressively more rapid loss of recorded material is observed. Since the 1930's the FIAF (International Federation of Film Archives) has been contributing to significant efforts in order to avoid the permanent loss of these materials. UNESCO (The United Nations Educational, Scientific and Cultural Organisation), understanding the certainty of such a future gave the official status of World Heritage to international film archives in the 1980s in an effort to promote the works for its preservation. Despite these efforts though, constraints in fostering these works still exist. The 5G Networks that are being architected to pave the way for new technological services by 2020, will help to overcome some of those difficulties. This paper will address the service orchestration to protect the film archives around the world under the new 5G era.

Keywords: 5G, IMT-2020, 4K, 8K, Film Archives, Film Preservation, QoE, Media and Broadcasting, Cloud Services, OTT, CODECs, Next-Gen Optical Disk.

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1 Introduction

By studying history and anthropology throughout human evolution, one can trace how today's technologies of recording, storing and sharing data and information emerged and developed; evidently, it's been more than 10,000 years, since the Stone Age at the beginning of human history, that humans created artifacts to record and communicate themes or scenes of daily life. Cave and rock drawings along with pottery, sculptures, jewelry and other artifacts traveled to other regions conquest and migration; these are some of the recordings that it is used nowadays to read information about the past.

With the papyrus manufacturing around 2500 BC in South Sudan, recording became an even more specific practice; and transmitting and storing data and information was more accessible and easy. In modern history, in the 19th and 20th century, during the pre and post-industrial era, the inventions of the telegraph and the telephone allowed the recording and transmission of information over even longer distances. Notably, for the first time in human history, data could be communicated over a long distance and at a much faster rate.

The invention of film and the moving image, and later, audio and video recording in the 20th century, led to an altogether new exploration of delivering data. Spanning from CGI (Computer Generated Imagery), to news, to personal thoughts and private journals, film and the moving image, with their inherent attraction, became successful tools for recording, storing and communicating not only collective but also individual and personalized messages. The invention of the World Wide Web with its new metadata structures, alongside myriad other technological services, made those video files accessible, discoverable and transmittable to a broader range of transceivers at different geographical locations at the same time.

Today, in the 21st century, film and video online streaming are even more accessible to a variety of audiences with the aid of Mobile and Fixed Broadband, Cloud Storage Services and the support of OTT (Over The Top) media platforms. The strong presence of moving images is easily observed as while these are being projected on an increasing number of private and public screens in our everyday lives. This frequency of usage generates a high degree of familiarisation with the medium makes people in today's society nowadays consider film and video to be a private tool for recording, storing and communicating personal information, not just entertainment. More and more people dedicate their time to consuming these materials in their various forms and demand "online" space in order to produce and distribute them.

According to the Nokia Bell Labs Mobility Traffic Report [1], by 2020 video applications and streaming services will grow by 46 times. Thus, 56% of the total traffic on the Internet will be generated by video, and a great part of this video traffic will be handled on the consumer's side.

In 2017, the ITU (International Telecommunication Union) published the *Measuring Information Society Report Vol 1* [2], which brings a global view of the current *status quo* of the telecommunication services in developed and developing countries. The report, focusing on the last 10 years, shows a great increase in the number of people with Internet Access. It highlights the growth of 183% on fixed broadband subscriptions, a rapid increase in mobile network coverage and usage of mobile broadband. It also shows an increase in computer efficiency and Cloud Computing usage, pushed by a decline in the cost of storage and Cloud services. Such an affirmation only presents companies with an urgent demand for even more ways in which 'online' space can be expanded in order to cater to their customers' growing needs.

According to Orbis Research and their "Global Cloud Storage Market Analysis 2025" [3], a 70% growth of the market will take place by the end of 2025. Of course such a growth, despite being desirable, posed the technical questions regarding the exponential growth of Big Data. In accordance to technologist Edd Dumbill, Big Data is the "*data that exceeds the processing capacity of conventional database systems. The data is too big, moves fast, or doesn't fit the structures of conventional database architectures*". Moreover, with such growth, further challenges like reliability on source information, data protection, storing, curating with assertiveness, speed and content delivery needed to be improved. Additionally, it is important to secure QoS (Quality of Service) and QoE (Quality of Experience) for the users. To give continuity to this analysis, it is important to shed some light on the meaning of information and data, as this is a subject of a lot of confusion amongst people. Data requires analysis and without context it cannot be translated into something meaningful, for example a number, a bit, a pixel, and so on. If information were to be represented in a formula, it could be written as: "information" is equal to "data" plus "context". In order words, "information" is data combined with a particular structure to give a meaning to those who will interpret it. For example, a home address, this is considered information.

How to overcome the foreseen challenges posed by Big Data and its exponential growth? The answer is an economic and social investment on network infrastructure that has taken place to develop a novel network technology, which is being developed, and it is named 5G Networks, also known as

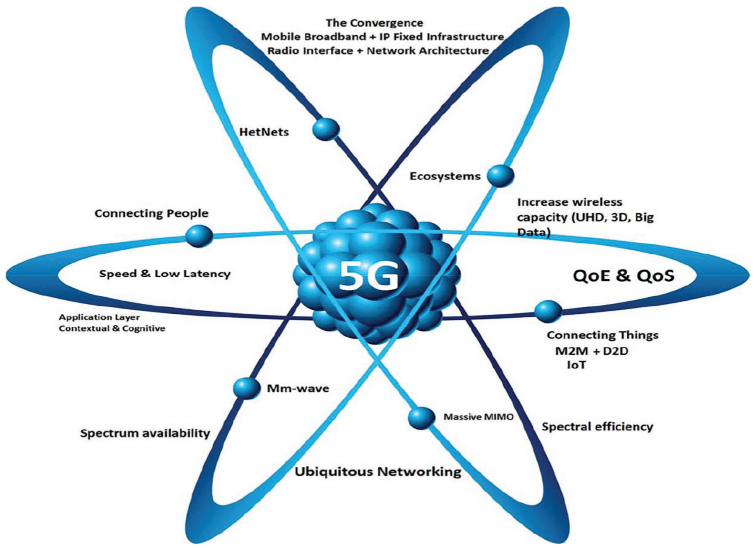

Figure 1 5G Atom.

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IMT-2020 (International Mobile Telecommunication System for 2020), with an official release date in 2020. 5G Network will be able to massively record, store and distribute information and data through larger audiences worldwide, on heterogeneous media formats, unifying mobile and fixed networks under a single entity. This will be possible by using a new RF spectrum on new network infrastructure that is designed to distribute data in dense wireless cells under a C-RAN (Cloud-Radio Access Network). 5G Networks, has as one of its objectives, to sustain the growth of different interconnected services, including video, and it must also sustain the growth of a multitude of other services such as AI (Artificial Intelligence), 4K, UHD TV (Ultra High Definition Television), IoT (Internet of Things), M2M (Machine-to-Machine), self-driving cars, flying cars, etc. As will be observed through its application, 5G is more than a new generation of the fixed or mobile communications system, it will be clever, cognitive, faster, ubiquitous and green.

With 5G Networks paving the way for the new generation of digital services, now is an important moment to reflect on how to protect the "future of the past" or in other words the future of film archives. It is relevant to consider that worldwide there are many new initiatives to protect film archives, which are part of the human heritage, as described by UNESCO. Film content in the analog format is under risk of being lost due to inadequate preservation techniques, lack of investment and planning or due to its "natural" end of life-cycle. This paper will put together a framework detailing the methodology that will be used to preserve analog films in the 5G era.

2 Film Quality and Preservation Process

2.1 Introduction

To prevent the irreversible loss of film content organizations are mobilizing media & broadcasting companies to protect their media archives. The majority of these film archives are important to our social, cultural and scientific history and UNESCO has emphasized the idea of preserving them. On the 23rd of September 1980, during the 21st Session of its general conference, UNESCO published the document called "*Recommendation for the Safeguarding and the Preservation of Moving Images*". [4]

This document emphasized the following areas:

- *Moving images are an expression of the cultural identity of peoples, and because of their educational, cultural, artistic, scientific and historical value, form an integral part of a nation's cultural heritage*;
- *Moving images constitute new forms of expression, particularly characteristic of present-day society, whereby an important and ever-increasing part of the contemporary culture is manifested*;
- *Moving images also provide a fundamental means of recording the unfolding of events and, as such, constitute important and often unique testimonies, of a new dimension, to the history, way of life and culture of peoples and to the evolution of the universe*;

Additionally it adds:

- *Due to the nature of their material embodiment and the various methods of their fixation, moving images are extremely vulnerable and should be maintained under specific technical conditions;*
- *Furthermore, that many elements of the moving image heritage have disappeared due to deterioration, accident or unwarranted disposal, which constitutes an irreversible impoverishment of that heritage;*

In 2005, based on the above recommendation UNESCO drafted the resolution **33C/Resolution 53** [5]. This document declared the 27th of October as a World Day for Audiovisual Heritage, in an effort to promote awareness for the protection of audio-visual archives. However, to understand the loss of archives one does not need to look far. For instance, we all have some experience of trying to recover an old K-7 audio tape with music or our own voice recorded in childhood, some VCR (Videocassette Recorder) or 8 mm footage, or even photographs stored in old IDE (Integrated Drive Electronics) Hard Drives. Thus film or audio material can deteriorate, the equipment originally used to play it back is no longer in the market, or when finding transfer equipment is possible, the actual process of recovering the material can be very costly. Film archives around the world suffer equally, not only from deterioration, lack of equipment, and costly transfers, but also from lack of further protective policies to prolong film life. In order to compensate, data scientists and librarians have begun considering ways to tackle a number of issues regarding the longevity of film life, including methods to transfer analog content into digital, and ways to safeguard and secure that film's content so that once preserved, it can be watched by the future generations.

The North American author Isaac Asimov was one of the pioneers to express the concern for preserving human archives, as addressed in his bestseller "The Foundation" [6], published in 1951. In his book, set in a distant future in 11.988 AD humans populate the entirety of our galaxy. The mathematician Heri Seldon predicts the collapse of human society and creates a galactic encyclopedia with records of all existing knowledge so far, in order to protect humanity from a return to the dark ages of ignorance. According to CSC Technology reports, "Big Data Universe Beginning to Explode" [7] in 2014, to store the total content of all human knowledge would require a storage capacity of 295 exabytes. Since 2007, an incredible data amount of 2.5 exabytes is generated daily, and this number grows every 40 months.

1 exabyte = 1 billion gigabytes

This data comprises content such as photos, videos, audio, and social media, which are unstructured data. Unstructured data are on the rise and are a new concept of a non-relational database. In order to be easily discoverable, film archives will have to compete with this new database unstructured and offer richer and better-structured metadata to allow discoverability inside its database. For this particular subject of curating unstructured data a scientific paper published on the 6th of December 2012, under the title, '*Addressing Big Data challenges for Scientific Data Infrastructure*' has elucidated many questions in how to orchestrate data management in modern e-Science [8].

2.2 Film Restoration – Technical Concepts

To safeguard film, there is a need to understand its nature and the main causes of film deterioration. Below there is an overview of the different types of film formats stockpiled on the film archives worldwide:

Table 1 Film Formats

Film Formats	
35 mm – A film format created by George Eastman in 1889, primarily for the medium of photography. It was later used in the first cinematic attempts. This film format was costly and due to its chemical components highly inflammable. Features:	• Film Width: 35 mm • Frame dimensions 22.05 × 16.03 mm • Frame Ratio 1.37 • Frame Diagonal: 27.26 mm • The distance between frames: 19.00 mm • Perforations per frame: 4 + 4 (4 on each side) • Drilling dimensions: 2.79 × 1.98 mm • Space reserved for sound: 2.13 mm • Projection rate: 24 fps or 45.60 cm/s • Frames in the 1m film: 53 • Projection time of 100 m of the film: 3 min 40 s
16 mm – A film format created by Kodak in 1923. This film format was widely utilized for documentaries and cinema.	• Film Width: 16 mm • Frame dimensions: 10,26 × 7,49 mm • Frame Ratio: 1.37 • Frame Diagonal: 12.70 mm • The distance between frames: 7.62 mm • Perforations per frame: 1 (positive) or 1 + 1 (negative) • Drilling dimensions: 1.83 × 1.27 mm • Space reserved for sound: 1.80 mm • Projection rate: 24 fps or 18.29 cm/s • Frames in 1 m of the film: 131 • Projection time of 100 m: 9 min 6 s
Super 8 mm – This film format was very popular amongst professional and beginning filmmakers in the 1970's. It offered enhanced film quality and was of low cost. It later was replaced by the video format during the '90s.	• Film Width: 8 mm • The magnetic track allows synchronized recording of the sound. • Projection rate: 24 fps • Projection time: 20 m 0 s
65 mm (70 mm) – This film format date from 1896 and it is still in use by the film industry and 70 mm is a version that allows storing magnetic soundtracks. However, this film format is very expensive.	• Film Width: 65 mm or 70 m • 70 mm version stores magnetic soundtracks • Aspect ratio: 2.2:1 • Projection rate: 24 fps to 30 fps • Camera aperture size: 22.04 × 48.59 mm

The main causes that define a film lifespan are the chemical deteriorations of the film rolls. Most film rolls around the world had *cellulose triacetate* as their film base, a chemical component that was very sensitive to heat and humidity. *Nitrocellulose* was another component used in film manufacturing. It was equally sensitive to heat and humidity and highly flammable under inadequate storing. When film stock is exposed to these threats, they trigger a proliferation of fungi that will destroy the fabric of the film. As a result of this investigation and according to FIAF (International Federation of Film Archives) [9], in an ideal storage environment that is dry, with an average temperature of 5 Celcius and 35% of relative humidity, the life expectancy of a film can reach up to 500 years.

In order to better evaluate the life expectancy of a film in storage, the IPI (Image Permanence Institute) has developed two KPIs (Key Performance Indicator), the PI (Preservation Index) and TWPI (Time Weighted Preservation Index) [10]. The PI represents the quantitative evaluation of the environmental conditions of storage, such as humidity and temperature, in order to calculate the life expectancy of film material. On the other hand, TWPI (Time Weighted Preservation Index) is an index that shows the film material's life expectancy according to temperature and RH (Relative Humidity), which are variables that combined will predict the film's materials lifetime, or its decaying rate while stored in specific conditions. Therefore a film's life expectancy can be evaluated using these two KPIs:

$$\boldsymbol{TWPIn} = \frac{n\boldsymbol{TWPI}\,(n-1)\,\boldsymbol{PI}\,n}{\boldsymbol{PI}\,n\,(n-1) + \boldsymbol{TWPI}\,(n-1)}$$

Table 2 TWPI Formula & Index

TWPI Value	Interpretation
1-45	Poor environment, faster change
45-75	OK environment
75-100	Good environment
>100	Excellent environment

To summarize this example, a new film stored under a temperature of 40 F/4°C, has a life expectancy determined by the next table.

It is important to notice that the table above shows an ideal situation that is difficult to maintain constantly over many years. Aside from the chart above, more challenges exist in sustaining an archive in an optimal situation of RH and temperature. Some of these challenges can be the cost and instability of power consumption, fire, floods, natural disasters, theft or

Table 3 Life Expectancy for a New Film at 40F/4°C

40F/4ºC	
RH (Relativity Humidity)	
20%	800 Yrs.
30%	600 Yrs.
40%	450 Yrs.
50%	350 Yrs.
60%	250 Yrs.
70%	175 Yrs.
80%	150 Yrs.

tertiary issues created by man. Another challenge can be the cost of maintaining the archive. This includes storage and organizing, creating, maintaining, restoring a film catalog when needed. These factors require as a solution, the digitizing of the film in formats, which are readable in any CODEC (Compression/Decompression Module). Another key aspect to remember is the indexing process in order to offer discoverability within the film catalog, as well as generating digital backups and preparing a disaster recovery plan using Cloud services.

3 Film Preservation Workflow Over 5G

3.1 The Current Status of Film Preservation

Some of the largest holders of film archives today are media & broadcasting companies that were established in the 20th Century. These are primarily TV or Film Companies, or legal repositories for media content regarding TV, and Radio, as noted by Marcos Ribeiro de Mendonça in the book *"O Futuro da Televisão Brasileira."* This model was mainly different in the US, as the local TVs were not film producers, in which they were relying on Hollywood as the sole film producer big budget movies [11]. However, this scenario has started to change due to a fierce competition faced by the Media & Broadcasting companies to win audiences over the models offered by the OTT providers. Some of these companies that have a well-kept film archive have not only been able to preserve their catalogs, but also generate financial gains from it. By making some of their film archives available to buy such as; documentaries, films, news or interviews now come with fixed prices for those who are interested in any footage, which the film archives have the content rights. An example of the type of business that allows individuals or companies to buy footage of a film archive is the INA (Institut National de

L'Audivisual). INA provides a web search portal for a variety of media content that can be purchased from its archives.

In order to apply the concept of film preservation over 5G networks, let's look into the current framework used by TV companies and some of their policies to restore, preserve and digitalize its film archive. Within these types of film archives one can find millions of photos as well as, thousands of CD (Compact Disc), Vinyl, videotapes, and films in different formats. Film Archives aim to:

- Provide the media content to meet the demand of productions
- Catalog and index electronically their videotape and film archives
- Perform the selection, decoupage and archive of images of their TV material
- Provide automated image and film search systems accessible to the company and general public
- Clean and restore films
- Digitalize its film archive

Today some film archives carry out the digitalization of their stored film collection by using on On-premises storage solutions, with digital storage that offers hundreds of TB (terabytes) of capacity, with fault tolerance, scalability and set up as a backup-as-a-service mode at a high cost. This current practice will serve as a base for the creation of a new workflow under the 5G stack.

3.2 Cloud Services, Medium and Media Files for Digitizing the Film Archive

In regards to the proposed service orchestration for delivering a film preservation workflow over 5G, every step in the process will be considered. Firstly, there is a need to analyze the lifespan of digital databases with the current storage technologies in place. That is due to the fact that many CTOs (Chief Technology Officer) or Film Archive Coordinators are not completely confident that the new media and backup methodology using cloud services are time resistant, therefore relying on digital technology to protect media archives in a long period of time becomes somewhat uncertain. According to the article *Data storage lifespan: how long will media really last*? published by CIO IDG magazine, the concern is as stated: "*The only true way to protect data is to have multiple copies of everything, and the best way to do that is to invest in a good backup and recovery solution*" [12]. Therefore, planning backup methods and processes are fundamental to succeed in developing this workflow, especially after the deployment of 5G.

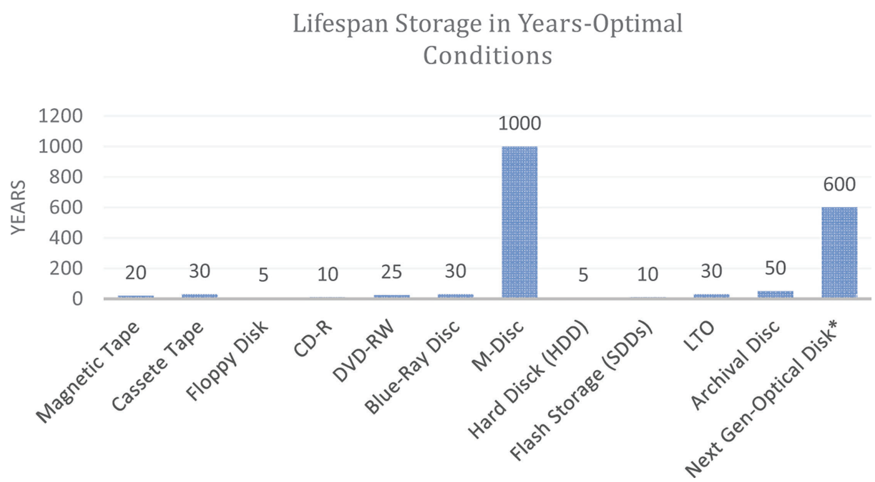

Figure 2 Lifespan of Storage in Years.

The table below describes the lifespan of each medium in an optimal condition.

The Next Generation of Optical Disk was created by scientists of RMIT (Royal Melbourne Institute of Technology) in Australia and Wuhan Institute of Technology in China [13]. This new optical disk has a lifespan of 600 years and it can store up to 10TB but has not been commercialized yet. Some people argue that the short lifespan of current disks is not really an issue as long as these are replaced before their EoL (End of Life). Despite this being true, the film archive coordinators do not trust what they see a short lifespan neither on this method of replacing hard-disks on the cloud service providers nor on the local storages. Therefore, this issue causes resistance on administrator's side, as they do not rely on the current technology as a sole method of film preservation. The reason for this statement is the high cost spent to generate the "backup" of the "backup" in a different type of medium that system solutions architects propose. As a result, it impacts the CAPEX/OPEX (Capital Expenditure/Operational Expenditure) of the planning of a film archive. Admittedly, until the Next Generation of Optical Disk starts being commercialized, Archival Disks are considered the best option for the 5G film preservation orchestration.

A second important decision is the type of Cloud Service Solution that will be capable of creating full resilience, backup and a disaster recovery plan. There are many Cloud deployment models following the CSA (Cloud Security Alliance) [12] current technical guidance.

A summary of these models is:

- Public Availability – anyone associated with a Cloud Provider
- Private – only available for a Single Organization – Internal use only
- Community – cloud service shared with multiple organizations for a common goal
- Hybrid – a combination of any one of the options above

Looking at the above information, the recommended solution would be the use of a Hybrid model. In terms of Service Layer there is a variable of Cloud Service architecture. These types of architectures are On-premises, IaaS (Infrastructure as a Service), CaaS (Container as a Service), PaaS (Platform as a Service), SaaS (Software as a Service), and the film archiving service orchestration will suggest which type is relevant. The inclusion of additional cloud datacenters geographically far from the main datacenter and in synchronization with the primary database, is one of the requirements of the disaster recovery plan. Furthermore, in order to protect the film database from cyber attacks, EBU (European Broadcast Union) published the "*Cloud Security For Media Companies – EBU R146*" [14], in 2017, giving relevant recommendations on media Cloud Services safeguarding. The EBU document recommends steps to consider before the decision regarding the CSP (Cloud Service Provider) is made.

Some of these best practices are summarized below:

- The business owner needs to carry out data classification
- The business owner should maintain a whitelist of acceptable cloud services providers
- The business owner shares with the Cloud Services Provider its data classification and its requirement of Cloud Service Model for confirmation and evaluation
- If the CSP approve the protection level of data, the business owner will grant the access to its database
- The business owner needs to demand the requirements, SLAs (Service Level Agreement), for functionality and security. If all is approved by the CSP the business owner can transfer the contract to be approved by the IT (Information Technology) and Legal Team
- The IT department performs the risk assessments on the chosen CSP (Cloud Service Provider)

Finally, another important consideration to evaluate is which CODEC will be used by the film archives to convert its analog film catalog to digital. It is important to use a CODEC that allows the new digital media file to be readable by different media formats at any time. In other words it will allow the archiver to secure the future of the film content. With this in mind, SMPTE (Society of Motion Picture and Television Engineers) has developed the media file MXF (Material eXchange Format) [13]. This file is a container format that encapsulates audio and video aiming to offer interoperability between different media formats. The MXF media file has a file extension the designation .mxf and this file can be converted to any other video format. MXF file main features are described below:

Table 4 SMPE MXF File Main Features

MXF File Features	
Support	Audio+Video+additional metadata
Support	2 channels of 48K audio
Support	File Size greater than 2Gb
Support	12 hours ofthe media file

The FDGI (Federal Agencies Digitization Guidelines Initiative) and AMWA (Advanced Media Workflow Association) have published the AS-07 specification document to provide higher QoE/QoS for audio and video, while using MXF file format to create *archive master files* (preservation master file) for film archives [15]. This document provides additional guidance on MXF file with an extra view on the side of metadata. This specification is truly an important document while designing the process of digitizing a film catalog.

3.3 Film Preservation Workflow Over 5G

Restoration and preservation are two interrelated actions that ensure that artistic works created in the field of a film are not lost or prevented from passing to the next generations. As noted at the beginning of this chapter, in order to create an optimal workflow to handle the film preservation over 5G Networks, the main services to consider are:

- Medium – Archival Disk (Sony)/Nex Gen of Optical Disks
- The type of Cloud Services Orchestration – Hybrid (Community + Private)
- DRP (Disaster Recovery Plan)
- BCP (Backup Plan)
- MXF file

The next picture proposes the service orchestration for film preservation over 5G Networks and shows its entire lifecycle:

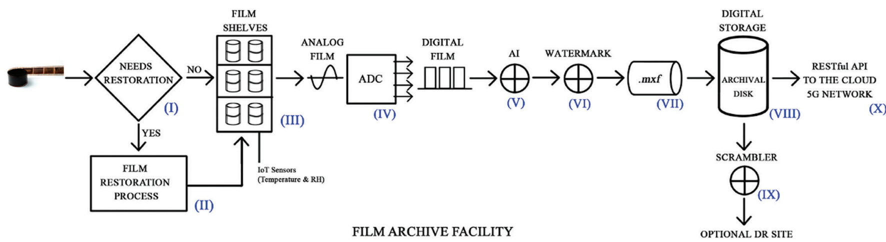

Figure 3 Film Preservation Workflow Over 5G End-2-End.

(I) The first step of the film preservation process is a technical diagnosis of the visual material to assess its condition. A specialized team analyzes the film stock taking into consideration its current physical state, the type of stock and the level of deterioration and decides whether the film requires restoring or not. In the case that it does not, it proceeds directly to the third stage of film shelve (III). In the case that it does, it proceeds first to the restoration stage (II). The restoration of a film relies on complex manual techniques, requires special tools and chemical processes and can vary in length in accordance with the needs and complexities of the material to be restored. Once the material completes the restoration process, it also moves to the shelve (III) where a set of IoT sensors will monitor optimum Temperature and RH. The film after storage is ready for immediate conversion into digital format (IV) a process called telecine. With the new technology of today, in many occasions, it is possible to restore a film and convert into a 4K format, which opens up a new perspective for the recovery of collections in even more enhanced quality.

(V) During the fifth step of the process, the digitized film copy will be indexed, this time using video AI, or other personalized recommendation algorithm solutions such as semantic algorithms [16], which are commercially available on the market. Both solutions will aim to carry out analysis on the digital film content to provide film identification and enhance its discoverability in the digital film catalog. Following, the digital film will receive a digital watermark (VI) to add data integrity and authenticity, and will then be encoded into an MXF file (VII). The MXF file will be stored in a Digital Storage (VIII) using Archival Disks or Next Generation of Optical Disks, which are due to be available in the market by 2020. At this stage, a disaster recovery plan will be created depending on the analysis of the CAPEX/OPEX by the film archiver strategist to offer a layer of security. Furthermore, the encoded film will be ready to be transmitted to the DR site using a scrambler (IX) to exchange files between sites. In case of non deploying a DR site a copy of the digital film will be sent to the CSP using RESTful API over 5G (X). The following picture provides a zoom in the stage (VIII) to (X) presented on the previous picture to highlight what happens when the digitized film is transferred over 5G Network to a Cloud Service Provider.

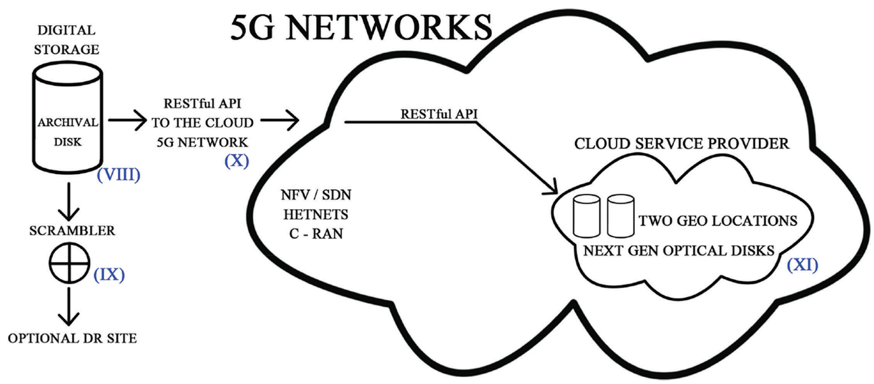

Figure 4 Zoomed View From the Digital Storage to CSP.

As can be seen from the picture above, the RESTful API (X) establishes a secure channel between the Film Archive and the Cloud Service Provider. This process creates a faster and more reliable exchange of the MXF file under the 5G Network infrastructure reducing latency in both directions (upload/download).

The three options of the disaster recovery plan are explained below:

1. The first solution will create a second backup using Cloud Services and deploy the database in a different geographic location on the CSP (Cloud Service Provider). This will work in full sync with the local digital storage located at the film archive facilities. Using the 5G infrastructure, compressing an MXF file that will potentially be greater than 2GB, will not be necessary. Notably, the exchange of MXF files between the film archive and the CSPs will be done using RESTful APIs [17] connected to the 5G core network.
2. The second solution will create digital backup storage with Archival Disks with the use of a DR (Disaster Recovery) site. This implementation though will be costly due to the use of second digital storage and the addition of new scramblers in both locations. Figure (4) demonstrates

where these are needed to implement data protection during the exchange of MXF files.
3. The third solution will be a combination of the first and second solutions as described in Figure (4).

4 Conclusion

In this paper we looked into film, its characteristics and shelve life, its current back up methods and the complicated storage conditions that need to be met in order to successfully extend the longevity of such material. Recognising the complexity of these parameters we have established that film preservation is a sensitive and obvious field of concern in modern days as a considerable amount of the visual world heritage is continuing to perish with each new day. The significance of such a realisation is underlined by the general efforts from official film bodies and international heritage institutions that have outlined guidelines and policies to support and prop up the film archives around the world.

Currently film archive managers, being faced with very serious limitations on backing up services, are unarguably sceptical about backing up analog films into physical hard drives when the life span of such devices is not guaranteed. Their alternative in the digital cloud storage, with an average life expectancy of a (present-day) cloud hard disk estimated at 2 years, leaves them with little choice for a secure and long-term solution. As an answer archives generate further analog copies of their film content, but this solution is adding to the precariousness of the situation, as it perpetuates an interim or temporary solution. It moreover and above all demands inflated costs related to increasing needs for film archive space facilities, and high maintenance costs for the storing environment.

Adopting a strategic approach of investigating the capacities of the future digital technologies will be key in tackling such issues, as they will offer financially viable and structurally greater prospects both in digital storage and longevity of archived materials. Such technologies are the Next-Gen of Optical Disks, which will offer a storage capacity per disk of 10TB and allow storing digital content for at least 600 years. With such characteristics these optical disks are proposing to offer a permanent new medium alternative to digitally storing MXF files.

An MXF file is a digital container of any analog master film format, such as 8 mm, 16 mm, 35 mm, 65 mm and videotapes. Due to this characteristic it will standardize all backup methods of film archives, and guarantee a safe future retrieval process, as these files will be decoded in a broader range of digital video file formats. Moreover, MXF file will be able to containerize digital content greater than 2GB that translates into a film and its metadata into one compact single file. This will grant a faster transferring of film content (in MXF format) between the film archives and the Cloud Service Providers, as a backup plan for a Disaster Recovery Site.

5G Networks will play a key and strategic role in the implementation and maintenance of all the above services. 5G will enable film archives to upload and circulate backup files and offload the film content to the film archives during the circumstance of data retrieving process, followed by triggering of a DR (Disaster Recovery) plan after a damaged site.

As the pace of technological evolution is growing exponentially as described by the Law of Accelerating Returns [18], humanity will foster further scientific merit and generate increasingly more advanced cutting-edge technologies. To make possible advancements in the film archives too, it is imperative to continually embrace such developments. Together with good preservation practises, advancing technology will always have a way to contribute to the further protection and restoration of film archives. A fine example of this possibility is the WW1 (World War I) documentary "They Shall Not Grow Old" [19]. The filmmaker Peter Jackson by embracing current latest technologies, such as in CGI and 3D Digital Format, he brought to life the BBC's 100 years old film archives and demonstrated the reality faced by the soldiers during this war.

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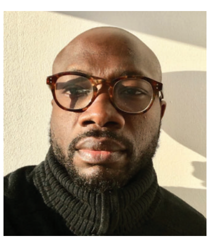
Biographies



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José Maria Pereira Lopes has almost 50 years of experience in TV and Film, and is the Director of TV and Film Restoration at TV Cultura in Brazil. He is a specialist in conservation and restoration of audio-visual works and a journalist, and his trajectory helped to build Brazilian television, having worked at TV Tupi, Excelsior TV and SBT TV. He currently is responsible for the Film Collection and Film Restoration at TV Cultura, alongside managing the film archive of the Museum of Image and Sound of Sao Paulo. José Maria has written a book called *"The manual of Film Conservation and Restoration"* which was launched during the 24° International Short Film Festival in Sao Paulo in 2003. His passion for quality of image and sound led him to be one of the pioneers in film restoration in Brazil and an international reference in this topic. He has delivered lectures, seminars, and workshops regarding film restoration such as the Conference of Audio-visual Heritage organized by UNESCO in Rio de Janeiro in 2010.