Enhancing video projector connectivity and management with a low-cost solution

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***Abstract*—The video projector serves as an essential device for various purposes, such as education, corporate functions, and conferences. This article presents an affordable setup aimed at upgrading video projection equipment, including older models, with enhanced management and sharing features. The proposed solution tackles frequent connectivity challenges arising from differences in connectors, transmission methods, and mismatches in configurations (like frequency and resolution) between computers and projectors. Such incompatibilities often result in delays and hinder the effective use of video projectors. By incorporating a Raspberry Pi and three dedicated applications, this system introduces an intuitive solution that supports innovative teaching and work methods.**

***Index Terms*—video-projector, streaming, video-sharing, smart-projectors**

I. Introduction

There are more and more existing video interfaces (VGA, HDMI, Display Port, USB Type-C, etc.). With the increase in diversity, connectivity problems arise between the computer and the video projector. Computers tend to evolve and be replaced more frequently, which is not always accompanied by the connectivity solutions provided by video projectors.

The use of adapters is common, but these often end up being part of the problem, and not from the solution, not just the physical incompatibility between connectors, but problems related to drivers or even configurations (video definition and/or operating frequency) are common problems. In addition video projectors, especially fixed ones, are not always close to the computer - it is common for the connection cable to be more than a dozen meters long, which greatly contributes to the instability of the connection. It is not uncommon for significant time to be lost in establishing the connection or simply in maintaining it, under the minimum conditions of use. And also not to be possible to establish a connection at all - which could jeopardize a class, a work presentation, a master's or doctorate defense, or even the business of a lifetime. The probability of this happening and when access is requested by several users (involving several computers) is even bigger.

Furthermore, the way in which video projection resources are currently used is, in the authors' opinion, quite conditioned and limiting what can be done to promote more effective and creative forms of interaction and sharing of information and knowledge.

In the conventional solution, there is a pivot that takes control over the video projection resource and transmits the content, whether yours or third parties. Alternatively, each presenter takes turns taking on the role of pivot. None of the solutions are optimal and fall far short of what is possible with existing technology [1]. Interaction is compromised from the outset, due to the difficulty of easily changing content from different devices or that requires the involvement of several interlocutors. Changing the transmission equipment (computer), even when the aforementioned connectivity problems do not occur, is far from practical and sometimes it is even impossible as the transmission equipment (computers) are fixed and not within reach of the video projector. Also when more equipment is involved, more time is lost in disconnecting and connecting procedures, and the greater the likelihood of connectivity problems occurring.

The situation after we have experienced SARS COV 2 has forced us to change our habits, but also to be more creative, it has shown that much more can be done. The adoption of tools such as *Teams* or *Zoom* initially served as an alternative solution to secure meetings, classes or even conferences. But it quickly went beyond that, being adopted in the context of face-to-face classes, as a much more agile and effective way of sharing content, not only presentations and videos, but also demonstrations in real time [2] [3].

It is undeniable that this new form of sharing, which allows things like seeing what to do, quickly changing presenter, maintaining parallel channels of communication, among other things, will certainly have an impact on the learning and productivity of our organizations and companies.

This article is organized into four sections: the "Introduction" where the issues are explained; the Materials and Methods that includes: "State of the art", where technological alternatives are presented, and the "Architecture" where the idealized solution is described; the Results section includes the "Contexts of use" where ways of using the solution are explained, with the respective advantages and disadvantages compared to other solutions; and the "Conclusion" where the achieved results are summarized and future work is presented.

II. Materials and methods

A. State of the Art

Cast technologies and devices, such as PodCast, Miracast and Chromecast, are solutions that are gaining ground as a means of facilitating access to wireless video projection resources (video projector, LCD or even a laptop monitor).

They appear in the form of small physical equipment that connects to the video projection resource, usually through an HDMI connector, and powered by a USB port - possibly from the video projection resource itself. Within these conditions, we can consider that they are comprehensive and allow less recent equipment to be equipped with new features.

Once the installation and configuration has been resolved, which is normally not very complex to carry out, it avoids most of the connectivity problems that can occur with a cable connection.

Its operation is similar to a specialized hotspot, in which the casting device is connected to the existing Wi-Fi network (after configuration) and accepts a connection, also via Wi-Fi, from a smartphone, tablet or laptop. It is thus possible to retransmit from these to the casting device; or, using specific applications, instruct cast devices to download and view content directly from the web [4].

The same type of technology can be part of the operating system or added to laptops and computers that have the necessary hardware requirements. In this way, the computer/laptop itself starts to function as a video projection resource, which can in turn be connected to a video projector or LCD.

Despite the potential of these technologies and the many experiments carried out for educational purposes [5] [6] [7] [8] [9], its use is mainly for recreational purposes, such as viewing videos or photos. Perhaps for this reason, they are based on the paradigm of only allowing one user at a time to have access to the video projection resource, that is, the user who has access has to release the resource so that another user can use it. The process of switching between equipment is much faster and less subject to connectivity problems with physical connections – but compatibility problems between applications with CAST devices are well known. Retransmitting the desktop environment is also not simple, which substantially limits the usefulness of these solutions for more professional uses.

We also lose the advantages that result, and which are sometimes fundamental, from having a pivot that centralizes and controls access to the video projection resource. It is particularly relevant in classroom spaces or meetings, where the teacher/moderator/coordinator must be able to maintain access control to the video projection resource. This characteristic is essential for conferences and workshops [10].

The more professional alternative is to use video projectors with wireless connectivity, in which the video projector is available as a monitor that can be used to clone the computer monitor or extend the work area. Once the equipment that will access the video projector has been configured, connectivity is simple and without the problems previously described. Compared to cast devices, they allow you to easily retransmit the working environment, ideal for demonstrations. It also has the advantage of allowing one of the users to be the pivot that controls access to the video projection resource.

But wireless video projectors are not always the solution. Firstly, because the connectivity protocols that these video projectors provide do not always allow direct use on Wifi networks of a more institutional nature, such as Eduroam.

Furthermore, access to the video projector, whether through the pivot or by other users, requires its own software – software that normally depends on the brand of the video projector. In school spaces, it is normal for the video projector fleet to consist of equipment from different brands. This certainly complicates access to video projectors when this implies the mobility of users between spaces equipped with equipment from different brands.

But the most pertinent issue is that there is a substantial number of video projectors that do not have this type of technology, but which represent a significant part of the reality of our schools, including higher education institutions, but also of the reality of our companies. Replacing it necessarily involves costs, which may not offset the advantages stated. With the aggravating factor of prematurely ending the useful life of equipment that, in its basic function, may be in perfect condition, which certainly goes against current social values regarding impact and environmental footprint.

There are also solutions that emerged during the pandemic, such as Zoom and Teams. Its use was not designed for the classroom, but for online meetings. It turns out, however, that the ease of sharing is substantially better than other solutions, with the advantage of easily allowing you to view the work environment of any element that is connected, which is certainly an added value for demonstrations and a solution much more versatile, regardless of the type of content. This characteristic has led to these tools being used in the context of a face-to-face class/meeting, in which the meeting leader connects his computer to the video projection resource and uses one of these tools to provide participants with access to the video projection resource. With some additional advantages, namely: it allows maintaining the centrality of the pivot that controls access to the video projection resource and allows mixed use, that is, with elements present physically and online.

Compared to the use of wireless video projectors, the fact that it is based on a single software application avoids the problems that result from using video projection equipment from different manufacturers. Furthermore, there is software of this type that can be used free of charge, at least under certain conditions, thus not requiring any type of investment - which is always relevant. On the other hand, they do not require replacing the current fleet of video projectors.

However, the basic problem remains, that is, one of the devices must be physically connected to the video projection resource, with all the problems that may result. If, on the one hand, we have almost everything that may be necessary to streamline the way we teach or carry out presentations/demonstrations of work, on the other, we maintain the basic problem – only less evident because only one device requires to be connected to the video projection

B. Proposed solution

The authors began working on the solution presented below even before the SARS COV 2 pandemic. The use of tools such as Teams or Zoom was little or not common, much less in a classroom environment. Some applications of the same type would already be common in a business environment, but whose access was quite restricted as a result of the high cost of licensing this type of software.

Despite the undeniable democratization of these tools and the technological evolution that has occurred very quickly in recent months, the solution designed by the authors maintains some advantages and has the potential to further democratize the use of video projection resources and, together with other solutions, promote new forms of collaborative work or teaching.

The basic idea is to associate a small microcomputer, like Raspberry Pi, with the video projector. It is important that this microcontroller can be connected to the video projection resource, for example, via an HDMI connection. It should be noted that the connection will only have to be resolved once and that the microcomputer can be installed next to the video projection resource, not requiring long cables for connection.

It is also necessary for the microcomputer to have wireless connectivity to connect to the local network. Ideally it should also have good video processing capacity, hence the Raspberry Pi is the recommended choice. Furthermore, it is a low-cost device and does not require additional usage licenses.

C. The Architecture

A service runs on the microcomputer that is available on the local network and serves as a video stream receiver. The objective is that any equipment on the same network can connect to the server to transmit the video signal. The microcomputer receives this signal and redirects it to the video projection resource through the HDMI output.

Participants can have one of two roles: Issuer or Coordinator. Normally, there is a Coordinator and several Issuers, but it may happen that there is only one Issuer or one Coordinator.

The Coordinator is the one who takes control of the video projection resource and controls who has access to it. Issuers are participants who want or can be called upon to transmit to the video projection resource. The Coordinator himself can choose to access the video projection resource. At any given time, only one Coordinator/Issuer can be using the server's stream service.

In addition to the stream service, implemented with sockets, the server allows channels used to pass instructions and provide information between Issuer/Coordinator and server. These channels are implemented as HTTPS services and with WebSockets. There is never a direct connection between Issuer's and Coordinator, all communications are made via server.

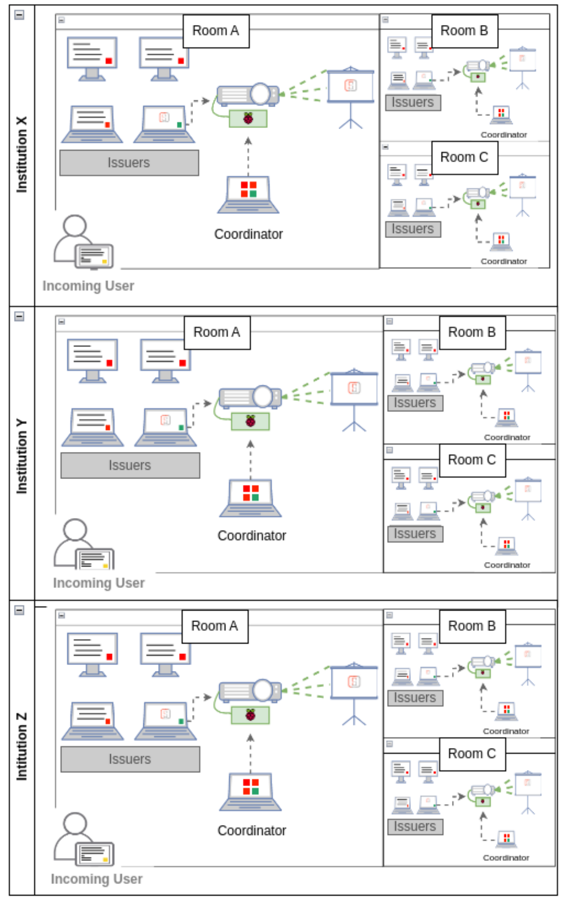


Fig. 1: Proposed architecture.

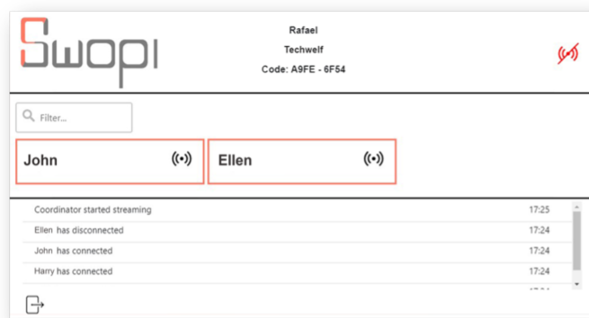


Fig. 2: Coordinator application.

To access the services available on the server, and generally benefit from the solution, the Issuer's and Coordinator's equipment must install the applications developed for this purpose.

In the case of Coordinator, it is an application with a user interface that allows: entering a server identification code, the purpose of which is explained below; have access to a chat for two-way communication between Issuer's and Coordinator (via server); and have access to the list of Issuers registered on the server, which allows the Coordinator to choose who should access the video projection resource. It also includes the option to disconnect, as can be seen at Figure 2.

The Issuer's application runs in the toolbar and is normally hidden. It provides a small settings menu, where you can define the server identifier and other usage parameters, namely whether transmission as a desktop video signal can be started automatically or whether it requires approval from the Issuer. This application has a small interface that appears automatically whenever there are chat messages and can be accessed to send messages.

Both applications run WebSockets clients, the client for accessing HTTPS services and the video stream client, which is responsible for collecting images from the desktop, from them producing the video stream and sending it to the server, if this has been requested.

1) Server identification: One of the guidelines behind this project is to consider that there may be different video projection equipment and that there is a surrounding community that can benefit from them, whether for work or recreational purposes.

In this context, and given that there is a server for each resource, the problem of identifying which server should be accessed arises. It should be noted that although it is normal for there to be one video projection resource per space, the respective servers are normally installed and available on the same data network. The ideal solution involves the server providing an access code directly to the video projection resource to which it is associated.

Clearly visible to everyone, simply being inserted at the start of the Coordinator application or in the configuration parameters of the Issuer application. This code is nothing more than the hexadecimal version of the server's IP address – the use of the hexadecimal representation was simply to reduce the code size and simplify the procedure.

This code is added to the stream signal and is available in a corner of the screen. Just highlight that the proposed solution has no function to turn on/off video projection resources. Therefore, when these are turned off, there is no way to view the aforementioned code.

2) Video projection resource access protocol: A second guideline that underlies this project is to create an open system of access to video projection resources, that is, to promote the simple, quick and degradation-free use of these equipment by the entire surrounding community.

In this context, anyone who has the applications installed can access the existing video projection resources. This creates priority problems in access management, the complete solution of which is part of the future work of this project. But for now, there is a protocol that establishes some rules of use, namely:

- If the connection is made by an Issuer and the resource is free, the Issuer assumes control and access;
- If the connection is made by an Issuer and the resource is occupied by another Issuer, both are in control;
- If the connection is made by an Issuer and the resource is occupied by a Coordinator, the Issuer is registered and added to the Coordinator's list of participants;
- If the connection is made by a Coordinator and the resource is free, then the Coordinator takes control (and eventually access);
- If the connection is made by a Coordinator and the resource is occupied by an Issuer, the latter is notified by the server that it will be disconnected and after a previously defined time, the Issuer is disconnected and the Coordinator takes control;
- If the call is made by a Coordinator and the resource is occupied by another Coordinator, the first is notified of this situation with the second Coordinator identification.

When a Coordinator disconnects, all remaining participants (Issuers) will remain present in the session, all of them having the right to transmit video, until another Coordinator is present.

3) Operation: Once the Issuer's and the Coordinator are registered on the server, communication channels are immediately established between each Issuer and server, and between the server and the Coordinator. These channels are implemented using WebSockets, thus allowing bidirectional communication, wilth all the communication being encrypted.

Simply put, when the Coordinator selects an Issuer to transmit, this intention is communicated to the server. If there is an active video stream connection, it is disconnected by the server, which then forwards the Coordinator's request to the targeted Issuer. If it is configured to automatically start streaming, the local video stream client requests a connection to the server and starts streaming.

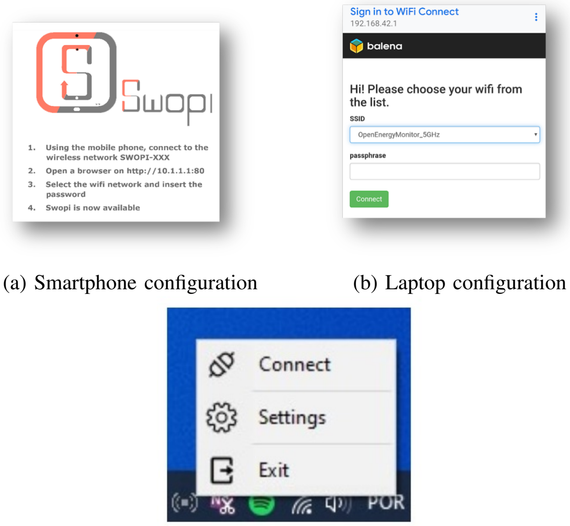
If it is configured to transmit only after authorization from the Issuer, a message requesting this authorization is displayed. The message remains visible for a few seconds. If the answer is affirmative, the request to connect to the server and start transmission is made. If there is no response or it is negative, the local application sends a response indicating unavailability to the server and this forwards it to the Coordinator.

At any time, whoever is transmitting can stop doing so. It is important to note the situation in which the Coordinator himself accesses the video projection resource. In this case, the connection request to the server is immediate, if there is any video stream connection it is deactivated and the transmission of the Coordinator's desktop begins as soon the connection is established.

4) Mobile App for Coordinator: The ideal solution includes a third application for mobile platforms (developed in Xamarin) aimed at Coordinators. The potential of what can be achieved in this way and the versatility that adds to the solution are substantial.

For now, it only allows choosing the Issuer that should access the resource, that is, by defining the server identification code, the list of associated Issuers becomes available and from here the user (Coordinator) can choose who should access the resource video projection.

5) Server configuration: Another problem that needs to be resolved is that the microcomputer associated with the video projection resource needs to be configured, namely to select and give access to the wireless network. This can be done by connecting a keyboard, creating an access account and



(a) Smartphone configuration (b) Laptop configuration

(c) App menu

Fig. 3: Server network configuration.

hoping that there is someone to resolve this. As the need to modify settings is not very frequent, this can even be done when installing the microcomputer.

However, the authors propose a more flexible solution that does not require specialized technical knowledge. When the service starts, the microcontroller does not connect to the wireless network. Create a local network and place instructions on the video projection resource to configure network access from the server, as can be seen at Figure 3.

This configuration simply means indicating that whoever wants to configure access must connect to the local network. When you do so, you are immediately taken to a page on an HTTP server that runs on the microcontroller, where you are asked to identify the network (among those available) and, if necessary, the access credentials. Once these parameters are defined, the server deactivates the local network and connects to the network for which it was configured. If by chance the process fails, it returns to the initial situation.

6) Graphics settings: When installing the microcomputer, some parameters related to the technical characteristics of the video projection resource and the bandwidth supported by the data network must be defined, namely matrix definition, sampling frequency and video quality (compression).

Whenever an Issuer/Coordinator connects, it obtains these parameters from the server. It is then the local client that collects the images and builds the video stream that ensures compatibility with these parameters. This ensures that regardless of the technical characteristics of the transmitting device, the video signal arrives in uniform conditions and appropriate to the technical characteristics of the resources involved.

III. Results

A. Usage scenarios

As previously mentioned, there is the possibility of there being a single Issuer or a single Coordinator connected to the server, whether or not they make use of the video projection resource. That is, you may be connected to the server but not want to transmit. Or it can be turned on and make full use of the feature. The advantages of this model, compared to the current solution (wired connection), is the simplicity of access. The user opens the application, enters the code that is visible on the resource and then simply connects (transmits) or stops transmission.

The most advantageous situation is when we have several Issuers and a Coordinator. The possibilities are countless, and it is an ideal environment for presentations with several participants. The ease with which you can switch contexts is addictive and really effective. It allows demonstrations in which there are several parts of a system running on different equipment and the aim is to show the integrated logic, jumping from context to context with a simple click. It should be noted that this equipment doesn't need to have people, it can be computers that have applications running – simply connect the application to the server and configure the automatic transmission option and, from there, at a central point you have access to all this equipment, without leaving your place.

If the Coordinator makes use of the mobile application, he will lose the possibility of transmitting his own content for now, but will gain mobility. This is particularly useful for classroom situations, particularly IT, where the teacher walks around the room looking at students' work and at any time, with the simplicity of a click on their smartphone, they can share a student's content. using the video projection resource to show/discuss with the other students. This is as if it were a simple television control.

The same model, with the requirement of the automatic transmission is active, allows you to have a tool that in certain situations can be very effective for monitoring, for example, tests/work being carried out on a computer. The teacher, at random, can change Issuer, and monitoring what each student is doing

In general, the authors hope that this solution will allow the creation of new dynamics and ways of holding meetings, providing training/classes, or even holding conferences and workshops, but this is part of future work and will consist of quantifying the real impact of this solution, advantages and disadvantages; as well validating its use in new dynamics of in-person collaborative work. The application is already deployed, and in at test phase for the students and teachers at the Polytechnic Institute of Bragança (IPB) on the following link: (https://swopi.ipb.pt/).

IV. Conclusions

The current state of the solution already involves many technologies and has already implemented and tested many functions in functional terms, as can be seen at Figure 4. But

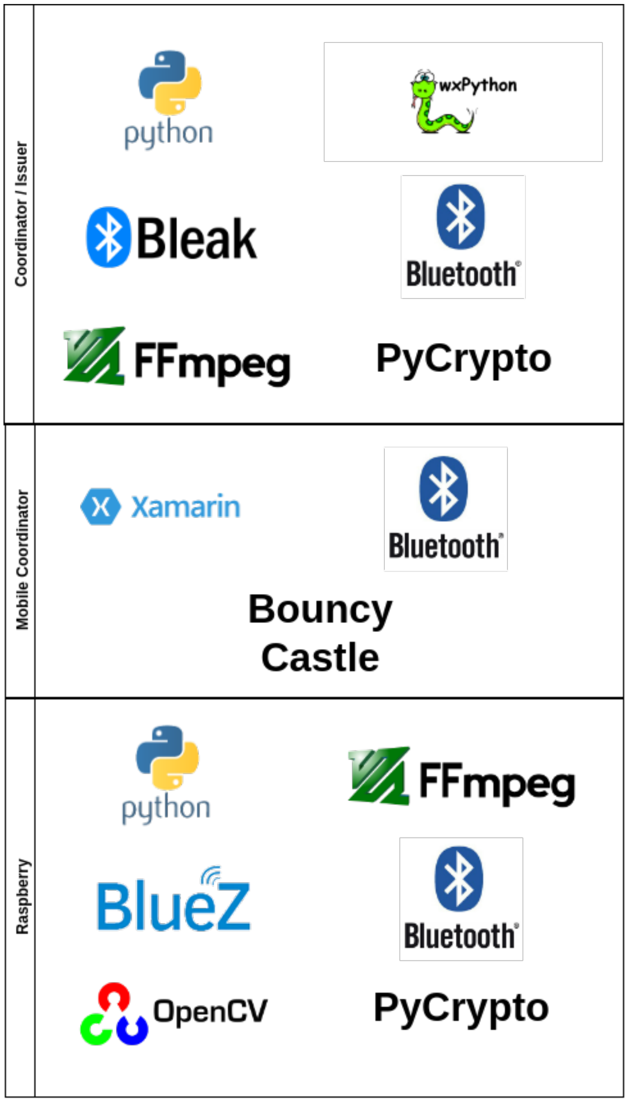


Fig. 4: Technologies used at each application.

the opportunities for improvement already identified are many. And the more the work progresses, the more opportunities arise, not only for improvement, but also for new ways of using it [11].

The solution presented does not in any way replace solutions such as *Zoom*/*Teams* or even the inevitable replacement of current video projection equipment with more modern and functional equipment. But with a very small investment, it allows the useful life of the current equipment to be extended, providing functions and advantages that go beyond those provided individually by each of the current alternatives.

We also reinforce that the basis of this solution has a much greater potential than current physical solutions (cast devices and wireless video projectors), for all intents and purposes we have a microcomputer where creativity is the limit of what can be done [12].

In terms of future work, it is urgent to allow content to be transmitted from mobile devices (Android and iOS platforms), bringing the solution to the level of what cast devices offer; include the audio aspect, essential to bring this solution closer to what is provided by *Zoom*, *Teams* and equivalent platforms; allow defining the monitor to be shared in cases where the user (Issuer/Coordinator) uses more than one; and continue to develop the solution, making it the equivalent of Eduroam wifi network, in video projection resources. Its use must also be validated in the contexts already presented, namely in meeting spaces and classrooms.

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