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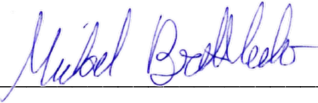
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Critical Evaluation and Comparison of BigBlueButton, Jitsi, MS Teams and Zoom for conferencing.

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Abstract

This paper examines the video conferencing tools BigBlueButton, Microsoft Teams, Jitsi and Zoom. These applications are examined in terms of user interface, user experience, privacy and security. All of these mentioned tools were installed and used by the author and all features were tested. Additionally, the companies' claims regarding privacy and security were analyzed and critically examined. Finally, these four applications are compared and the future of video conferencing is discussed.

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1. Introduction

Video conferencing tools have been around since 1930 and have been developed in parallel with telephony. However, video conferencing never got broadly accepted with the general public, even though they and experts were convinced that video conferencing was the future. The beginnings of video conferencing were also more of an experiment than a product for the masses. After all, it required a device that took up half of a room. It was not until 1956, thanks to the invention of transistors, that the technology was developed enough to fit into a desktop videophone and thus find a place in normal households. However, these devices delivered only two frames per second and were extraordinarily expensive, so even the mass-market product could not prevail. [29]

It was only when bandwidth, technology could be improved and costs could be reduced that video telephony caught attention and was used by private households. Even companies, long convinced that ICT (information and communications technology) cannot replace face-to-face meetings, are gradually switching to video conferencing, as the advantages of video conferencing increasingly outweigh the disadvantages.[29] However, video conferencing is playing an increasingly important role not only in the private sector, but also in healthcare and for educational purposes. While companies use this technology to hold meetings with stakeholders, in healthcare video conferencing is used by doctors to consult with colleagues when complex medical conditions are present and can attend lectures and conference in a more time efficient way. [28] Universities and schools use video conferencing in the field of education. Lectures and presentations are held via these applications and interactive learning without presence is made possible and is rated positively by students.[21] These are just a few examples of applications of video conferencing, others would be socializing, sports, culture. Obviously these tools are becoming more and more widespread and popular.

However, the future of the market is not in private use, but in the economy. According to a study published by Logitech [17], the use of video conferencing tools increased by 800% in the last 4 years alone. There are several reasons for this. For one, work is shifting to the home office or remotely, and video conferencing also allows companies to respond dynamically to situations and quickly call and hold meetings. Another important point is the cost savings through travel. Meetings that do not necessarily require the physical presence of the parties can be held digitally, saving time and money. Productivity can also be increased as employees can still hold meetings when they are traveling and downtime is reduced.

Video conferencing is not a panacea and only brings benefits. Meetings often involve the exchange of sensitive information that should not be accessible to all. Since no system is fully secure, there are security concerns with video conferencing as well. Unauthorized people listening in can intercept information and enable industrial espionage. For companies, the video conferencing tool must

offer the technical prerequisite that only desired persons can participate in the meeting and that the data transmission is secure and encrypted.[10] But here, too, a second perspective must be taken, namely the privacy of the employees. Many conferencing applications offer the possibility to check the attention of the participants, for example whether the participants have the conference actively open or whether they are surfing on the side. For companies, it is important to assess within the legal framework to what extent they may use such tracking tools on their employees and whether the program used also complies with the GDPR.[6]

In addition to the data processing of the applications, security also plays a major role so that data leaks and industrial espionage or the takeover of systems by third parties can be prevented. Since video conferencing tools are growing rapidly and many tools are being introduced to the market at the same time, there are always security vulnerabilities that can be extremely costly to users. [22] This seminar paper will deal with the video conferencing tools BigBlue-Button, Zoom, Microsoft Teams and Jitsi and critically examine them. It will look at which functions each of these programs provides, how data and privacy are handled, and which security measures can be taken. In addition, we will evaluate which tools users feel most comfortable with and which are easy to use and administrators have access to settings that can ensure a certain level of privacy and security.

2. Background

In order to start a video conference, there are only a few essential preparations to be made by the participants. Firstly, they must be on a terminal that has Internet access. Since video conferences with several participants and several video transmissions can consume a lot of data, a certain bandwidth must be available. Due to the high quality of the webcams and the fact that most video conferencing tools support HD transmission, you should have a correspondingly high bandwidth, but acceptable quality is achieved from 2048 kbps. [3]

In addition to the bandwidth, the hardware also plays a role, of course, but since the technology is so mature nowadays, almost every notebook, tablet and PC is capable of processing a video conference with several participants. Zoom recommends at least a single core 1 gigahertz processor and a RAM of 4 GB. In addition to the installed hardware, it is also necessary to have a webcam for video transmission and a headset or speakers and microphone for audio transmission if you want to actively participate in the video conference. It is also necessary to find out in advance which browsers are supported if you choose a video conferencing solution based on WebRTC (Web Real Time Communication).[38]

WebRTC was published as open source by Google in 2011 and is regarded

as a collection of protocols and APIs for creating Real Time Communication between end devices of different people. WebRTC is supported by all popular browsers. The various APIs allow the use of audio and video input from the user, the exchange of files as well as text messages. WebRTC is considered to be particularly user-friendly and WebRTC and the APIs are easy for developers to integrate into web applications. The inclusion of the MediaStream API gives the ability to use user audio and video input. The equally important RTCPeer-Connection takes care of the communication stream between the participants who want to exchange information with each other. This includes audio correction for echo, cover-up for packet loss, and other issues to increase the quality of communication. Since WebRTC also supports other real-time information flow and, among other things, remote access in addition to audio and video transmission, this use also requires its own API, namely RTCDataChannel. The communication takes place directly between the browsers and thus enables a fast exchange. WebRTC not only takes care of the communication but also how it is protected. WebRTC uses the DTLS encryption protocol and SRTP.[7]

The DTLS protocol was specifically designed to ensure secure transmission over UDP, the transport protocol also used for video and audio transmission. DTLS is located in the OSI layer model between the transport and application layers, namely on the session layer. After the handshake, a secure connection is established and the data exchange can be performed. [2] While DTLS is mainly responsible for the data stream, SRTP (Secure Real Time Protocol) takes care of the media stream.

The key exchange for SRTP is done via the DTLS-SRTP method, so that no man in the middle attack is able to detect the encryption. SRTP brings additional security aspects besides encryption. An algorithm is used to add authentication to the sent packets, which ensures integrity. Authentication also prevents replay attacks. SRTP and DTLS are among the basic requirements for WebRTC security and must be integrated on a mandatory basis.[27]

3. Big Blue Button

3.1. History

BigBlueButton is a web video conference tool which started as an open source project in 2007 at Carleton University in Ontario, Canada. Richard Alam is credited as the developer who wrote the first version of BigBlueButton, then known as the Blindside Project.

The goal of the project is to provide remote students with the best possible learning experience even if they cannot be physically present. The focus of the project was primarily to support students and create social value, but the entrepreneurial perspective was also important to the project owners. Therefore, the founders created a project that is completely free to use and should be a high quality alternative to the paid web video conferencing tools. For these reasons,

the project was not profit oriented but placed itself as an open source project. The decision to create BBB as an open source project enabled the creation of a worldwide community whose goal is to further develop BBB and create the best possible open source web video conference software. BigBlueButton is very popular among developers and already has over 2000 members who are involved in its development.

BigBlueButton is licensed as GNU Lesser General Public Licence and can therefore be used by other companies for free. It is also possible for companies to create and distribute applications that include source code of BigBlueButton, only changes and enhancements of the BigBlueButton source code have to be published under the same LGPL.

In 2009 the source code of BigBlueButton was uploaded to Google Code. Google Code was a platform for running open source projects, but not quite as popular among developers and project owners as its competitors. Therefore, BigBlueButton moved from Google Code to GitHub in 2010. [15]

3.2. UX / UI

After successful registration with e-mail and name, the host is redirected to his personal start page. This start page allows the host to make organizational and security settings. In addition to the preconfigured start room, the host can create other rooms and configure them individually. This allows a clear structure according to different categories/projects/classes. Since BigBlueButton supports conference recording, the recording for each room is stored separately in the overview and allows to keep track at any time. In addition, rooms can be preset separately, for the meetings that will be held in this room. So a room created for meetings of the board of directors of a company can give the participants different rights and provide the room with special security settings than a room created for a project manager with his project staff. Among the settings that can be made for each room is the creation of a separate room password, i.e. you need a link and password to join the room, the setting that participants can join the meeting with the microphone deactivated, as well as an access control when the participants can join and whether they are provided with moderator rights.

Furthermore, settings for the visibility of the recordings can be made in the start menu. You can make the recordings visible to everyone who has access to the room, or you can restrict the visibility of the recording and activate the corresponding setting so that only you have access to the recording. Furthermore, the recording can be played in two formats, by clicking on "Podcast" the recording is played without picture and only with audio, by clicking on "Presentation" the recording is played with picture and audio. In addition, each recording can be configured and deleted separately. Sending a recording via an e-mail link is also supported. Of course, the profile can also be set, whereby the account information such as name, e-mail address and password can be changed

in these settings, but also the possibility of deleting the entire profile.

If you are satisfied with the settings of the room, you can start the meeting by clicking on the start button and you will be forwarded to the conference. After choosing how you want to join the meeting, either with audio only or with audio and microphone, you can do a microphone check. In addition to the core settings of any video conferencing solution, namely audio, video and screen sharing, there are other exclusive participant settings available to the host. The host can decide which functions of BigBlueButton are available to the participants, such as sharing the microphone, using the chat, editing the notes. Within the meeting, the host can create breakout rooms and assign participants to them, these breakout rooms are like sub-video conferences where the participants assigned to the room can talk, brainstorm, solve a task or however you want to use these breakout rooms. This gives a wide range of possibilities and is definitely a standout feature of BigBlueButton.

Likewise, the host can either hold the whole meeting himself or appoint participants as presenters, which gives the participant the same rights as the host, if the source code has not been changed in an implementation of BBB on its own server. The presenter gets the right to use the whiteboard which is located centrally in the window. On this whiteboard text can be inserted and sketches can be drawn. Also the presenter can share his screen, start polls, play videos, upload presentations and make all other settings which can also be made by the host. The presenter has these rights as long as the host allows it, only someone of this can withdraw the presenter rights again.

BigBlueButton can definitely convince from the host's perspective. The possibility of clear design and use of rooms makes it possible to keep track even when managing multiple projects that require a video conferencing solution. The design is simple and lets you understand each feature when it makes sense to use it. Equally advantageous is the individual setting of the rooms, which allows you to respond individually to the needs of the participants in these rooms. As a host, you always have the feeling of control and overview and the corresponding functions to be able to react dynamically to any situation. The extensive recording functions, such as the different formats and the sending, give you a long-term benefit of the meetings held and you can offer your participants a backup in case not all participants can attend the meeting but need the information. The Greenlight web application is convincing on the whole line and gives BigBlueButton an added value through the intuitive handling of the interface.

Unlike the creator of rooms and meetings, participants of video conferences do not need to register and can join the web video conference immediately after they have chosen a name with which they can be identified and addressed in the meeting. After the participant has also decided if they want to join the conference with audio microphone or with audio only and has passed the microphone

check, the user will be forwarded to the meeting. In the center of the meeting there is a large area that can be used by the host or presenter. In addition to the buttons for audio and video sharing which can be found at the bottom, the user also has the option to use several functions of BigBlueButton which support the participants in the meeting. Besides a public chat, messages can also be sent privately to individual participants. Additionally, there are shared notes which allows everyone in the meeting to make notes, which are visible to everyone. These shared notes as well as the chat history can be saved by the participant to get offline information from them at a later time. Likewise, each participant can make individual settings that only affect him. This includes, for example, whether and how to receive a notification when participants join the meeting or start a conversation in the chat. BigBlueButton also takes into account participants with low bandwidth and allows them to disable webcams and screen sharing.

In times where data is as valuable as crude oil and you as a user want to reveal as little of yourself as possible on the internet, as well as not interested in the corporations monitor you to get to the data and with various tricks, such as an extensive registration. BigBlueButton is from the user's point of view a welcome alternative. Precisely because you do not have to register and can start the meeting immediately after choosing a name, you get a safe feeling as a user. Equally positive is the simple handling and design of the user interface of the web video conferencing solution. The simple design allows you to get an immediate overview of the functions, which are clearly marked with symbols and labels. The participant is not inundated with a large number of functions, but only a few but very important tools are available that definitely bring added value to the participants. The settings also allow the user to tailor the meeting to their needs. In general, BigBlueButton is also very intuitive for the user and does not require a lot of preparation time to find its way around.

3.3. Privacy

BigBlueButton allows the use of the software via the website, but the provided version of BBB is only a demo version and should only be used to try out if this software fits your needs. When using this version, not only are not all functions available, but also the control over your own data is lost. BigBlueButton explains in its privacy policy that when using the demo version several different data are collected automatically. This includes data about the Internet connection and which browser is being used, but also includes more sensitive data such as meeting records, duration, chat logs, names, email addresses, and any other information exchanged during a meeting. BigBlueButton uses this data to provide various functions, to identify the user, but also for analytical purposes to improve the software and to prevent illegal activities through BBB. The company emphasizes in its policy not to sell or share personal data with third parties unless you have explicitly agreed to it.

However, BigBlueButton can be used in other ways, namely by installing the

software on one's own server. If you rent a server instead of buying the hardware, you have to make sure that you choose a trustworthy server provider, because your personal information will pass through this server. If you decide to install BBB on your own server, you have full control over the data exchanged, as you also have full control over the source code. Accordingly, if privacy is important to you, it is recommended that you host your own instance of BigBlueButton so that you can be sure that no one but you has access to this information. Therefore, the open source software is also very popular among data protectionists and is increasingly used as a recommendable alternative to proprietary software.

3.4. Security

Since BigBlueButton is intended to be used for this purpose, the security of the software is to a large extent related to the technical knowledge and knowledge of security measures of the person who implements the software. Firstly, the server on which BBB is installed must be secured with a TLS certificate so that a secure connection is established between the server and the client using HTTP and the information flow is encrypted. Since BBB allows API calls to be processed, it must be ensured that these only come from authorized instances. For this purpose the BBB server uses a shared secret. The API calls are provided with a checksum generated by the shared secret and the server compares its checksum with the received one, if there is a discrepancy the api call is discarded.

Since the audio and video communication is done using the WebRTC standard, which sends the packets over a UDP connection, which is considered insecure, the Datagram Transport Layer Security protocol is used. This protocol enables encrypted transmission of the audio and video signals of the conference. To provide an additional level of security, the packets are encrypted using the Secure Real Time Protocol. BBB uses multiple protocols and methods to ensure a secure connection and transmission.

[30]

However, the administrator must take additional steps to protect against attacks. This includes, for example, closing all ports that are not required by BBB. In addition, a password can be required for all rooms as an additional safeguard and a precise role assignment that clarifies the rights. Although BBB uses many measures to encrypt the transfer and ensure a high security level, there are some security gaps. For one, an old Ubuntu version is used with NodeJS versions that are no longer developed and supported and can thus become a security risk, leaving BBB in the default configuration raises security concerns. In addition, communication with developers when a vulnerability is found is a bit bumpy and it often takes a long time for critical vulnerabilities to be closed. There are always new security updates from the developers, but often there is not enough documentation about which gaps have been closed.

[4]

4. Microsoft Teams

4.1. History

In the battle for the dominance of web video conferences, which experienced a boom due to the COVID-19 pandemic, Microsoft is sending its Microsoft Teams software, which was created in 2016, into the race. Microsoft Teams was originally planned as a competitor product for Slack. Slack is a groupware that was considered a popular means of communication in companies because it enabled a clear organization and structure of work groups. Microsoft Teams was included in the Office 365 package, so there were no additional costs for subscribers to this package. A year later, Microsoft Teams replaced Skype for Business and the software established itself in companies.

Microsoft quickly recognized the potential and possibilities of their own software and decided to expand their target audience to include professors and students who used Microsoft Classroom in Office 365 Education. Consequently, key features of Office 365 Education were incorporated into Microsoft Teams and Microsoft Classroom was dissolved. To further capture market share, Microsoft has made a free version of Microsoft Teams available since 2018, which includes all the core features of the full-price version but with markdowns on the number of users in a meeting as well as the available file storage.[16] Microsoft's strategy paid off, while in 2017 it could only count 2 million users, the user rate grew to 115 million by 2020, making it the fastest growing software Microsoft has ever produced.[35]

4.2. UX / UI

Microsoft Teams tries to create an overview by grouping teams and then sub grouping them into channels. These teams should reflect the departments, project groups, classrooms, courses and be named accordingly by the team creator. The created teams can be public and accessible to everyone in the organization, or closed and only available to one by invitation of the team leader. The host of the team can add the people either by name input, if this person is a part of the organization, but also by link and by e-mail. If one is not part of the organization, guests can still be added, they will be invited via email. Once you have passed this hurdle and you are part of a team, you will be presented with a very comprehensive software. On the left side you will find some apps that should provide a better overview and quick navigation. The most important apps besides holding the video conference are the feed, chat, teams, calendar, calls and files.

The most important feature in Microsoft Teams is holding video conferences, all other functions seem to be built around this feature and serve to immediately implement and edit what was discussed in the meeting in the application. A video conference can be called by the host, team member or guest of the team and will then be visible in the channel where the meeting is taking place for all people to join. When joining, participants can decide whether to join with

audio only or with video as well, setting a virtual background. The majority of the screen is taken up by the webcams of the participants. At the right edge the called function is indicated. If you want to see the chat, it pops up by clicking on the right edge and messages can be exchanged. You can also see which people are participating. By raising your hand you can visually tell the presenter that you want to contribute something to the meeting without having to interrupt him immediately. Like BigBlueButton, Microsoft Teams supports the creation of group rooms, to which participants are assigned by the host and again serve as a meeting room within a conference. In addition to the core features of video, audio and screen sharing, Microsoft Teams also supports the automatic generation of subtitles that translate what is being said in real time. In addition to the ability to record, Microsoft Teams also offers other fun features such as Together mode. This mode puts all people together in a virtual background and is supposed to support the immersion. When the meeting ends, the chat history is not lost but is displayed in the channel and is visible to everyone, even to people who did not participate in the meeting.

The information about the video conference is processed immediately and is visible in the feed. The feed serves as a notification window, where you can see activities that affect you, such as being mentioned in a team chat, receiving answers to a question or being assigned a task.

The chat is a private chat between one or more people, where you can communicate directly with colleagues, with whom you do not have to be in a common team. Messages and files can be sent via this chat, and direct audio and video calls are also possible.

The next app is the Teams app, where you can find a list of all the teams you are a member of. Each team is subdivided into channels, which are communication channels. Channels are again divided into tabs, each channel can have a different number of tabs. The basic tabs include the channel chat and the files sent through the channel. The channel chat has the same functions as the private chat but the sent messages are visible for everyone. In this chat you will also find the notification when a new meeting is scheduled or functions are added or deleted to the channel. In the Files tab, one can find an overview of all the files that have been sent in this channel, in addition, one can also directly upload, download or open files in SharePoint in this tab. There are a variety of tabs that can be added by someone authorized. These tabs can be classic Office applications such as PowerPoint, Word and Excel, but it is also possible to link web pages and access them in the Microsoft Teams application as if you were using a browser. The tabs can be selected according to the task to be done in this channel and offer the possibility to customize the channel according to the user's needs in order to work efficiently.

The next app, the calendar, is also used for organizational support and enables the creation of meetings. Meetings can be created by the user for entire

channels or only for other individual persons. The meeting can be given a title and a description that explains the necessity of the meeting. The meeting can also be configured as recurring, so that the meeting does not have to be created each time.

The Calls app allows users to quickly navigate through their contacts and make calls. Besides the possibility of group calls and speed dialing, the user is also allowed to save contacts and view the history of his calls. There is also a voicemail function that should be familiar to everyone, but also writes transcripts of voicemails as an extra feature.

In the Files application, you can find all recently used documents, including those that you have opened and edited outside of Microsoft Teams. These files can be opened either directly in Teams, on the desktop or in the browser. To search more specifically, you can also view only files that have been sent via Microsoft Teams or are in the cloud storage. If these apps and the registration cards in the individual channels are not enough, the user is free to add more apps to his bar or to search and use them. Almost all Microsoft products are available.

Microsoft Teams is aware of its complexity and, in addition to organizing apps, teams and registration cards, also tries to remedy this with a search bar. Teams, channels, files, messages, but also commands can be entered in this search bar. The commands can be used to call people, change the availability status or navigate to the integrated help, which is probably needed by many users.

While the design of the meeting is kept simple and clear and does not differ greatly from other applications, the functions and applications that are built around the possibility of video conferencing are difficult to grasp at first.

This is mainly due to the fact that Microsoft Teams seems incredibly large and complex, the application is hard to learn and hard to master. Although various tools are used to try and give the user an overview, some functions do more harm than others. Everything is nicely described and equipped with comprehensible icons, but if you start searching for a certain piece of information, it can still be a tedious process. If you are looking for a chat message and you don't know where it is stored, you not only have all the chats with your colleagues to search through, but also all the chats from the channels that are embedded in the different teams. While the chats, calls and file apps are still quite clear and empty at the beginning, this changes abruptly after a few hours of use. However, these hours are only enough to fill all possible communication channels with information, but not to really get to grips with Microsoft Teams and find your way around.

However, if you overcome this hurdle and show patience, Microsoft Teams rewards you. Once you find your way around the application, its full potential opens up and it has never been easier to communicate with your team and

colleagues and work on tasks without seeing each other face to face. Microsoft Teams as a video conferencing solution allows you to work efficiently and serves as an interface to all the other features you need when working with Office applications on a daily basis. Microsoft Teams is more than just a video conferencing solution, it allows you to realize the full potential of video conferencing and maintain the efficiency of your employees without seeing each other and having real meetings.

Once you have created your team as a host and selected the desired options, whether it should be a public or private team, you can already add your desired members. If you only want to use the video conference function, you can schedule a meeting with a few clicks and inform the members about it or call a meeting immediately. If you have not set it differently, all team members and guests have the same rights within the meeting. Therefore it makes sense to deal with the meeting options and to configure them according to your own wishes. In the options you can configure the permissions. You can take away the right to mute the participants or the right to present. Furthermore the host can configure if there is a waiting room and who is allowed to bypass it. Guests and participants can be muted separately by the host or brought into the spotlight, in which case these participants and their video transmission are highlighted. Likewise, people can be removed from the meeting individually or the host can also dissolve the entire meeting. It is important to note that the host is always the person who calls the meeting, the creator of the team is therefore not automatically the host of the meeting and he does not have the rights of the host in the meeting, if he has not started it himself.

However, the team owner has a much more important task, namely the administration of the team and its channels as well as the settings of the authorization. The team owner is significantly involved in the success of the use of Microsoft Teams due to his extensive possibilities to configure the team accordingly. Of course, all the functions already described are available to him and beyond. The person is responsible for the fact that each channel receives the appropriate registration cards and the team members with the functions the tasks of the channel can master. The team owner will find special settings that will not only show him the analysis of the team usage but also manage individual persons.

As a team owner you are especially challenged and have to deal with Microsoft Teams even more intensively than the user. Due to the large number of configuration options, it is up to the team owner to ensure order and to provide the user with an appropriate experience. Above all, the feeling of always being in direct contact with his team members and the possibility of viewing all the information that flows in the team give a team owner the chance to keep track of things and to be able to intervene if control is lost. The extensive settings increase the complexity of use for the team owner, but the team owner also has the analysis tools integrated in Microsoft Teams and can take appropriate

action. As a team owner, one has a special responsibility and technical know-how is definitely an advantage. Although there are a number of settings and access controls, all the options seem useful and not superfluous. From the video conferencing solution and all the features built around it, it's easy to see why.

4.3. Privacy

Since Microsoft is a profit-oriented company and does not offer an open source solution like BigBlueButton or Jitsi, a lot of data is collected about the users of Microsoft Teams. In addition to the data that you receive through your Microsoft account, i.e. name, email address, phone number, age, gender and other details, Microsoft automatically collects various information when you use Microsoft Teams. The information that Microsoft automatically uses includes chat conversations with other people, video conference recordings, voicemails and voicemails, files that are sent and transcripts of meetings. In addition, the company analyzes the network environment in which the participants are located and can thus collect not only the IP address, but also the location, type and version of the browser and the more detailed information about the meetings.

In the Microsoft Teams privacy policy, the company states that it will not share data with third parties unless the customer consents to it, subcontractors providing the services need it, and government agencies may have access to this personal data.

Microsoft owns data centers in the European Economic Area that are used to store customer data, but the company also forwards the data to data centers in the United States to process it. The transfer and storage of data in third countries is allowed under the GDPR, but it further limits the power over one's own data and the authorities of the United States, for example, can get access to it.

In this case, the collected data is not only stored for processing in the short term, but the company states that it will keep the collected information indefinitely. As a user of Microsoft Teams, you can contact the company and request to delete the collected data. This is supposed to be done within 30 days. If you terminate the contract and stop using Microsoft Teams and its services, the data will be deleted within 90-180 days. However, this does not apply to all data, phone records can be stored permanently.

[34] [37] [36]

Due to this data collection, storage, transfer and processing in the USA, Microsoft Teams is questionable from a data protection perspective. Although the Privacy Shield agreement has been overturned, MS Teams continues to find a way to transfer and process data in the US. Even though Microsoft Teams claims that they do everything to ensure security and are ready to defend themselves against US authorities if they want to have data from EU citizens, there is still doubt whether Microsoft can actually defend itself against such instances and protect the data of EU EEA citizens.

4.4. Security

Microsoft Teams uses various measures to ensure a high level of security. The user is also responsible for taking note of these security settings and configuring them accordingly. On the one hand, this includes logging into Microsoft Teams. This is done via the Microsoft 365 account, which supports two-factor authentication and should also be used by users. Furthermore, for proper security, the team creator must specify in the settings whether the team is publicly accessible or whether it is a private team that can only be joined with a code or link. In order to keep control over the team, the organizer of the team must manage the permissions for members and guests, so that no unauthorized channels can be created or deleted and the data cannot be lost. Likewise, the desired settings must be made for the respective meetings, so that a structured meeting can be held and only those people have rights, such as muting all participants, removing participants, adding participants and sharing content, who also need them. To make this possible, MS Teams supports assigning participant roles.

There are 3 roles, the organizer of the meeting, administrators and participants. While the organizer enjoys all rights, the role of the administrator is to share content and present information. The participants of a meeting can listen and see the presentations but cannot share their own information. In addition to the settings that can be made by the administrator and the organizer of a team, Microsoft promises high security through the use of end-to-end encryption. Like BigBlueButton, Microsoft Teams uses the Secure Real-Time Transport Protocol to encrypt audio and video communications and ensure the integrity of transmitted information. While server to client is encrypted using Transport Layer Security, server to server communication uses Mutual TLS encryption.

Microsoft uses its own Azure Active Directory to identify and store user profile information. Azure AD guarantees secure user identification and multi-level authentication. Through Azure AD, access privileges can also be controlled to guarantee high security. Single Sign On is also supported in order to maintain a high level of user experience despite a high security level. [31] [32]

5. Jitsi

5.1. History

Emil Ivov, a student at the University of Strasbourg, created the project "SIP Communicator" in 2003, the project was a messaging service that made use of the Session Initiation Protocol and contributed to the name. Over the years the project evolved and got more features and supported different protocols. Since the project was designed as an open source project, more and more developers joined and further developed the idea until little remained of the original SIP communication and thus the project was renamed to "Jitsi" in 2011.

After the introduction of video and audio support, the developers increasingly focused on the application possibilities. Therefore, the video conferencing system, i.e. audio/video telephoning with several people at the same time, was introduced and the project was made fit for WebRTC, which makes it possible to hold video conferences via the browser. The community around Jitsi recognized the potential and introduced Jitsi Meets, a browser-based video conferencing application. In the foreground was always that Jitsi remains an open source project and is characterized by a particularly simple application because neither a registration and deposit of personal data such as name, e-mail or phone number is necessary nor must an external program be downloaded and set up. These features helped the project to attract new users at a time when web video conferencing tools were booming.

In contrast to BigBlueButton, the open source software Jitsi is not subject to the Lesser Gnu Public License but to the Apache 2.0 License. This should simplify the use of the open source software for commercial use, because changes to the source code do not have to be published. This should enable a faster growth of Jitsi. Basically Jitsi can be used in 2 variants. One can call a meeting immediately over the Web browser and the use of public servers. This is especially user friendly as no technical knowledge is required and you can start with just a few clicks. The only requirement for a web video conference here is a web browser with the latest updates as well as an appropriate bandwidth for uploading and downloading the video recordings. The second variant allows installing Jitsi on your own servers, similar to BigBlueButton. However, this requires technical knowledge, as well as renting servers and buying your own hardware. It has to be considered that the limits of usability and number of participants are only set by the own hardware, the better and stronger the own servers are on which Jitsi runs, the better the quality and the more participants can be in the meeting at the same time.[12] [1]

5.2. UX / UI

Jitsi keeps the user interface simple, while other video conferencing applications makes one quickly lose track of all the options and features, Jitsi is neat and organized by icons comprehensible. Jitsi supports chatting during the video conference and gives you the possibility to chat with all participants of the conference, but also lets you send private messages to certain participants. All messages are provided with the name of the sender and a timestamp. If you want to add symbols to your messages, you can also choose from a dozen emojis. While chat is one of the core functions of any conferencing tool, simultaneous sharing of the screen of several conference topics is something that is rarely seen.

Jitsi allows the simultaneous transmission of the webcam and the screen for as many people as are in the meeting. The only limitation is the bandwidth and processing power of the hardware. Another feature of Jitsi is the "Raise Hand" button, which displays a hand symbol visible to all participants when a participant raises his or her hand to say or contribute something. This feature

is especially useful if you have an input but do not want to disturb the flow of speech or the presentation of the speaking participant.

The developers have also given participants with limited bandwidth the ability to adjust the video quality. The participant can decide whether he wants to have the video quality in low quality, standard quality or high quality. In addition, there is also the "low bandwidth" setting, but then it is no longer possible to share the screen and the camera or to receive the webcam and screens of other users. Likewise, participants are offered the option to stream the meeting via YouTube Live and record the meeting, but this requires a Dropbox account with sufficient storage space. When a user uses a feature, such as recording the session or removing users, all participants are notified via notification popups. In addition to these features, there is of course the option to mute yourself, share the webcam or end the sharing and leave the meeting.

Jitsi can convince with an extremely simple handling in the free web browser version. It can be used without registration and only requires a name or nickname for mutual identification of the participants in the meeting. Even for non-technical people, Jitsi does not pose any hurdles that speak against its use. Furthermore, the interface in the meeting is simple and clearly arranged. After a short time you already have a good overview of the available features, which is also due to the fact that there are only a few. Although there are only a handful of features, some are still superfluous, such as the ability to stream the meeting on YouTube Live. Also, the flat hierarchy of participants does more harm than good. It limits the possibilities and scenarios when it makes sense to use the platform for a meeting. For educational and business purposes, it can be problematic if all members have full access to invite and remove participants. If you want to hold a conference, you have to trust each participant not to take advantage of the equality and intentionally disrupt the meeting.

Jitsi does offer a handbook where you can look up features if you are not familiar with them or need help using the platform, but the handbook has been under development since 12/4/2020 and is not yet filled with content. [18] So you are on your own and have to go by trial and error. For meetings with friends and family, the free web version is suitable. On the positive side, there is no time limit or participant limit per meeting, so you don't have to keep an eye on the remaining time.

Jitsi also gives users the option to install the open source platform on their own server. This allows a completely new use of the features and also differs in other aspects from the web version, which runs on other servers. To install Jitsi on your own server you have to buy the hardware or sign a contract with a trusted server provider, ideally a server with Linux installed.

It is important to analyze in advance in which environment the server will be implemented and to consider the requirements. The installation of the server fol-

lows the same principle as the installation of BBB on an own server, here again it is extremely advantageous if you have the technical know-how to quickly set up the Jitsi-server. If you install the instance correctly with all security certificates and aspects, your own Jitsi-version allows a new, better access to the video conferencing tool and the user experience improves for the host and participants. By implementing and changing the settings, the flat hierarchy of Jitsi can be restructured. It is possible to appoint single persons as administrators and give them exclusive rights to add, mute, remove participants. Thus, all settings can be adapted to the environment in which Jitsi is used and accordingly more benefits can be drawn from the open source solution and adapted to individual scenarios. This allows for a smoother experience and makes the case for installing Jitsi on your own servers instead of using the online solution with third party servers.

5.3. Privacy

Open source software is known for its privacy friendly approach and Jitsi is no exception. As a user, you notice this immediately when you create the meeting. With no registration, no requirement to use a username and no application download, Jitsi doesn't seem like a data leech and lulls the platform user into a sense of data security. A first look at the privacy documentation and terms of service immediately show that there is not much to discover here. While with other companies and software providers these documents are page-long texts which are deciphered by legal wording, Jitsi clearly presents what data is used and for which purpose. [24]

Jitsi only uses information that is necessary to create a meeting and to use features that the participants can use. Therefore Jitsi needs the IP address of the participants to connect them and the name of the meeting to share the URL. Information such as the content of messages sent via general and private chat is only stored for the duration of the session and then discarded. This also means that you have to save the information sent in the chat to another location, because when the meeting is closed, the history is lost.

If you use the recording function of the meeting, the recording will be saved for up to 24 hours, depending on how fast Jitsi can upload the recording to the linked Dropbox. After uploading to Dropbox or after 24 hours at the latest, the recording will be irrevocably deleted from the Jitsi servers. Even if you provide personal information such as a profile picture and your own name or email address, this information is only stored for the duration of the meeting. Furthermore, the company guarantees not to sell any personal information to third parties and uses this information exclusively to guarantee the functions and to improve the platform. [24]

If you want to be on the safe side and keep full control over your own data, you should also consider installing Jitsi on your own server for the sake of data security. However, it is necessary to configure Jitsi in a privacy compliant

manner and takes time. This prevents third parties from analyzing and using the data of the participants, but it should be noted that security measures must be taken so that no attacks can have access to stored data. [24] [25]

5.4. Security

Like other platforms, Jitsi relies to some extent on the personal responsibility of the participants to make the meeting as secure as possible. Since you can join a meeting by clicking on a link that contains the name of the meeting, it is necessary that the host of the meeting chooses a name that cannot be guessed by unwanted guests. Jitsi helps the users and provides a name generator that strings together several independent words and thus tries to prevent link-guessing. Furthermore, you can create a password for the meeting, but you have to forward it to every invited participant so that desired and invited guests can participate. Another measure to increase security that can be used by users is to activate the lobby. In this case, new guests who have received or guessed the link are not immediately added to the meeting, but first enter a lobby where they have to wait until a moderator of the meeting accepts or rejects their request to join. Furthermore, Jitsi emphasizes that the meeting can only be held undisturbed if these measures are taken and the participants do not publish the link and the security settings such as the password on social media or through unintentional user errors.

However, Jitsi does not leave the security of the communication solely dependent on the users but also takes its own measures. Especially for one to one communication, i.e. when only 2 participants hold a meeting, Jitsi promises end to end encryption. In this peer to peer mode, all communication is encrypted from the sender to the receiver of the packets and is not decrypted at any point along the way. This is done using the Datagram Transport Layer Security and Secure Real Time Transport Protocol protocols, which are also used by all other video web conferencing platforms.

[19]

However, if there are multiple participants in the meeting, Jitsi switches from peer to peer mode to the Jitsi video bridge. The video bridge serves as a video router and ensures that the information, for example audio and video, of the sender reaches all other participants. The channels to the video bridge as well as from the video bridge to the users are encrypted and the packets cannot be read by third parties. However, in order for the video bridge to get the information necessary to forward the packets, it must unpack them and thus remove the encryption before decrypting it again after it got the information needed. This means that the provider of the Jitsi Videobridge has the possibility to view information from the decrypted packets that pass through the JVB (Jitsi Videobridge) and to access sensitive information.[8]

The developers of Jitsi are aware of the situation and have also taken measures to ensure encrypted communication even when using the JVB. They implemented the possibility to encrypt the conference end to end. However, certain

requirements have to be met and the functionality of features will be limited. In order for a meeting with several participants to be encrypted end to end via the JVB, this must be activated in the settings while the meeting is taking place. However, this security setting is only possible with Chromium based web browsers and these must also be Up to date. In addition, an encryption password must be entered by all participants for activation, if a participant does not enter the password and enters an incorrect password, he will receive the encrypted packets and thus have unusable information since neither video information nor audio information can be processed. Furthermore, participation in such encrypted meetings is only possible via the web browser and no longer via phone dial-in or app. In addition, by activating the encryption, the recording option of the meeting and the live streaming of the meeting is deactivated and is no longer possible. Nevertheless, it is recommended to make these extra settings and do without the features to guarantee a high level of security. If you decide to install Jitsi on your own server, you have to take into account that you have to take care of the encryption on your own. Since Jitsi is based on Web-RTC, it is necessary to apply for an SSL certificate to ensure secure transmission. [19]

6. Zoom

6.1. History

Zoom Video Communications was founded in 2011 by Eric Yuan and two years later the Zoom video conferencing solution was released and the first users were able to install Zoom. The application has been steadily developed over the years and grew in size. Over the years, important partnerships were also formed with large companies such as Sales Force and Slack. Due to the company's successes and steady growth, Zoom Video Communications went public in 2019 and raised over 360 million in its IPO. The Covid-19 pandemic saw user numbers increase twenty-fold and the company's value grow from 18 billion at the end of October 2019 to over 100 billion dollar.[41] [23]

Zoom was able to convince users across all industries at the beginning, but quickly experienced a damper when users took a closer look at the privacy precautions and security policies. Especially at the beginning of 2020, criticism of Zoom became very loud, stating that the company accesses personal data such as video, messages and documents and sells them to third parties.[20] In addition to the less than satisfactory privacy policies, Zoom also had several security breaches in the past. These security holes were also often not closed sufficiently and only stopgap solutions were found. Because of this, there has been a Zoom exodus by governments and corporations to ensure that no government secrets as well as corporate secrets are compromised either by security vulnerabilities or by the low level of data protection. Furthermore, the Federal Trade Commission stepped in and announced that Zoom had been luring customers with false security promises since 2016. As a result, the Federal Trace Commission has ruled that Zoom must provide a detailed report at least once a year and must significantly improve its security measures. [11]

6.2. UX / UI

Since Zoom is not a web-based video conferencing solution, it is necessary to download and install the application. After successful registration with email and name you can start the application and get to the start page. This allows one to immediately open a meeting, join an existing meeting or share the screen for a meeting, for both functions the meeting ID is necessary, as well as a meeting can be scheduled via calendar and for the scheduled meeting participants can already be notified by mail or via the Zoom app. Outlook, Google Calendar or other calendars are required for the last mentioned feature. Furthermore, the start page gives an overview of upcoming meetings.

When you start a meeting, you have several options to add participants. Zoom supports inviting by mail, by link, via the saved contacts in Zoom or by entering the meeting ID and additionally the meeting identification code. Security settings for the meeting can be set in the meeting. The settings are mainly related to the rights of the participants, so the participants can be deprived of the right to use the chat, screen sharing, audio sharing and video sharing, in addition, the host can remove individual participants. There is also a kind of emergency stop button that locks the meeting and takes away all rights from all participants. Besides the feature of security, Zoom has also implemented a chat in the conferences. Here the host can decide if this feature can be used by the participants or if the chat is exclusively available to him. Other exclusive rights of the host include the arrangement of the webcams, which is then changed for all participants, the request for muting and the setting of how many people are allowed to share their screen at the same time.

The host has a lot of rights in Zoom, and the host is also given a lot of options to shape the meeting according to his needs. This leaves you with the feeling that you have full control over the meeting at all times and can react adequately in any situation. However, it is necessary to study these control settings intensively, as they are not intuitive, and possibly resort to the help offered by Zoom to understand what effects these settings have. If you change too many parameters aimlessly and haphazardly, the meeting can turn into a negative experience for the participants and miss the goal of the video conferencing solution.

If you are invited as a participant to a meeting in Zoom it is not necessary to register and you can join the meeting via the browser. However, there are only a limited number of functions in the browser and not all web browsers are supported, so it makes sense to download and install the application. Joining can then be done as already described by check numbers or links. Depending on the settings of the host you will either enter the meeting directly or you will have to wait in a waiting lobby for a moderator to add you to the meeting.

Arrived in the meeting, a tiled display of the profile pictures, or if activated, the webcam pictures of the users and a bar at the bottom with all the functions awaits you. In the meeting, the use of the features depends on whether the host

allows the participants, which is assumed in the following. In addition to the core functions of any video conferencing application, namely the activation and deactivation of its own audio and video transmission, Zoom allows communicating with all participants, but also only with individuals, via the chat window. In addition to the separation between general chat and private chat, it is possible to save the entire chat history as a txt-file. Zoom also allows you to send files from your own computer or files stored in Dropbox, OneDrive cloud, Microsoft Sharepoint and other applications via the chat. Screen sharing, by one or more people, is also supported so that presentations can be held. The meeting can also be recorded and saved to a desired location as an MP4 file. In addition, participants can still react to situations in the meeting with smiley.

Zoom's functions for participants are designed to be clear and understandable through icons and text. Almost all functions have a right to exist and contribute positively to the meeting experience and do not have to be searched for first, but can be used with one click. Equally advantageous is that no registration is necessary for participants, so everyone can be invited without having to navigate through the registration process. Zoom also provides good audio and video quality, but this depends on the bandwidth and the number of participants. Furthermore, the user experience of the participants is only as good as the settings of the host, if the host of the meeting takes away all rights, the features become useless and an added value is lost. Likewise, the participant windows can be placed individually and windows of participants who do not share the webcam can be disabled.

6.3. Privacy

Since you have to register as a host with Zoom, you must be aware that Zoom stores and processes the data you provide to them during the registration process. However, Zoom also supplements this registration data with data that is generated by analyzing the interaction with the application. Thus, data is also collected from people who do not register and use Zoom only as a participant but never as a host. Non-registration data includes data from the operating system environment, data about meeting properties, meeting duration, number of participants, available bandwidth. Also, the location of the participants is automatically sent to Zoom, as well as the IP address, information about the Internet provider, information sent through the chat and information about the recordings. These are just a few examples, Zoom collects data on a large scale and stores it for analysis, further processing, transmission, disclosure and combination to obtain accurate user profiles. The company uses this data on the one hand to enable the use of the functions but also for business purposes. In doing so, Zoom makes the collected personal data available to business partners, suppliers and service providers, but also to government agencies. Zoom therefore transfers the data, also for EU citizens, to the United States and stores it there in data centers. Zoom also points out that this data has no expiration date and is stored as long as the company can derive added value from the data.[40] Although the company promises in various press releases to improve and create

clarity in terms of data protection, one must consider that this company is focused on profit and therefore has a great interest in the data of their users.

6.4. Security

When using Zoom, different data streams are encrypted in different ways. On the one hand, the data that Zoom collects and is uploaded to the Zoom Cloud by the subscriber is communicated via HTTPS and thus encrypted with the TLS protocol that has already been mentioned several times. For encrypted audio and video transmission via UDP, the company uses the Advanced Encryption Standard in 256-bit GCM mode. AES (Advanced Encryption Standard) is a symmetric key procedure, so the key for encryption and decryption is the same. 256 is the length of the key, AES supports 128 bit, 192 bit and 256 bit, the more bits the longer the key the higher the security. With the state of the art, it is not realistic to guess the key using brute force, because even with a 128 bit key, it would take longer than the universe exists. Zoom also uses GCM (Galois Counter Mode) which allows authentication and real-time encryption and is therefore a good and secure solution for real-time transmission as is the case with video conferencing.[26] [33]

After a large number of security scandals around Zoom and the company's misrepresentations regarding end-to-end encryption, the company has been forced to implement end-to-end encryption after a long time. However, this is not activated automatically but has to be activated in the profile settings on the Zoom page. [11] To enable it, you have to identify yourself with your phone number, which is then automatically loaded into the profile and is visible to all contacts and Zoom can process.

As a reason for the authentication via code received by telephone message, Zoom states that no unauthorized person can activate this end-to-end encryption in the profile settings, but since you are not required to enter your phone number when registering, the unauthorized person who absolutely wants E2E encryption could enter any phone number and then also receive this code. So the reasoning is not quite conclusive and after a short questioning one can come to the conclusion that the alleged authentication is just an empty justification of Zoom to get more data. In addition, Zoom's E2E solution is still in the beta phase and participation in the end-to-end encrypted meeting is only possible if all participants have also activated this setting.

In order to safeguard against Zoom-bombing and other disruptions, the moderator must take responsibility and make all security settings to prevent such unwanted participants from entering the meeting. This includes, for example, setting up a waiting room so that participants have to wait until a moderator adds them to the meeting. You can also lock the meeting so that no one can join the meeting. This is especially useful when all the desired participants have joined and no one is expected to join the meeting. In order to maintain the security among each other and to prevent the sending of harmful files, the

host can disable the general sending of files. Zoom does not have any security measures that check sent files for malicious code. [26]

7. Comparison

The open source solutions like BigBlueButton and Jitsi are very privacy friendly and have a clear interface. In addition, some features are implemented that provide added value to the users, but these features are not very extensive or spectacular. Additionally, this software is meant to be implemented on your own server, which requires additional effort and technical knowledge. Jitsi is also available online and can be used by users who don't have a server and don't know how to set it up, but if you want the full potential and value of your data, installing it on your own server is recommended. Since both video conferencing tools are open source, access to the source code allows you to customize the software to your own requirements and to correct any weaknesses on your own. In addition, the open source solutions are completely free of charge and the costs that arise are for maintenance, administration and the purchase or rental of a server. There are providers that offer complete solutions for BigBlueButton, where you don't have to take care of anything yourself and 100 participants are supported simultaneously for 80€ per month.[13] For Jitsi you can find providers that offer solutions for 300 participants for 99€ per month.[14]

The video conferencing solution, Microsoft Teams, on the other hand, is not open source and the source code cannot be changed at will. You also have no control over your own data, but must agree to Microsoft's privacy policy. However, Microsoft has developed a complex system with Microsoft Teams, which offers a variety of functions and uses. This video conferencing solution is clearly focused on the workplace and on efficiency and productivity. Microsoft Teams is more than just a video conferencing application, it is an entire hub with which many different Microsoft and other applications can be controlled. Microsoft Teams allows to hop in a video conference with colleagues, participate in the meeting and afterwards continue to work on the tasks that need to be done without having to leave the software. There is a free version of Microsoft Teams, but many functions are not included and you can only use a fraction of the potential of the tool. If you decide to use Microsoft Teams, you have to pay at least 4,20€ per user per month for the cheapest package according to their website [9], which is much more expensive than the presented open source solutions.

Zoom is neither an open source software nor complex like Microsoft Teams. However, this video conferencing solution is easy to install without much technical knowledge. The design as well as the functions are self-explanatory and simple but can also be completely sufficient. Its designed for users which do not need the large scope of a tool like Microsoft Teams but for users which need a simple video conference tool, which is easy to set up and easy to use. In addition to the simple handling, the audio and video quality can also convince. However, Zoom is also overshadowed by its, partly justified, bad reputation. Also that

the US authorities have cast an eye on the company, because the company lured customers with false promises, does not make a confidence-inspiring impression. According to their website, licenses of Zoom are to be acquired starting from 139,90€ per year[5].

In the following tables you can again see the features of user and host of the video conferencing solutions for a better comparison.

Table 1: Features

Features	BigBlueButton	Microsoft Teams	Jitsi	Zoom
Chat	x	x	x	x
Public Messaging	x	x	x	x
Private Messaging	x	x	x	x
Chat Features (Emojis,Gifs etc)	x	x	x	
Screen sharing	x	x	x	x
Multiple screen sharing			x	x
Raise Hand	x	x	x	

Features	BigBlueButton	Microsoft Teams	Jitsi	Zoom
Record session	x	x	x	x
Insert Video	x		x	
Live stream the meeting			x	
Push to talk			x	x
Audio only option	x	x	x	x
Whiteboard	x	x		x
Upload presentation	x	x		x
Edit together slides/whiteboard	x			
Polling	x	x		
save recordings as podcast	x			
Website integration	x		x	
File transfer		x		x
Scheduling		x	x	x

Features	BigBlueButton	Microsoft Teams	Jitsi	Zoom
Virtual background		x		x
Shared notes	x	x		
Save chat x	x	x		
Save notes	x			
End To end		x	x	x
Adjust streaming quality	x		x	

Host Exclusive Features	BigBlueButton	Microsoft Teams	Jitsi	Zoom
Enable E2E encryption			x	x
Mute participants	x		x	x
Disable video of participants	x	x	x	x
Remove participants	x		x	x
Give participants special roles x	x	x	x	
Activate breakout rooms	x	x		x
Require password	x		x	x
Activate waiting room	x	x	x	x

Table 2: Host Exclusive Features

8. Conclusion

After presenting the different video conferencing solutions and reviewing their interface, user experience, privacy and security, one might think that one particular application is the best. However, this assumption would be too simplistic and would not cover the full spectrum and scenarios in which these applications are used. In the end, it depends on the situation in which the video conference is used and what is expected from it.

It is important to consider that although video conferencing applications have been around for quite some time, it is only now that they are really catching on and although many video conferencing tools are already very good, they can only get better with the new budget available and thus the possible further development. In addition, for the first time the masses are using video conferencing solutions and the manufacturers can analyze where which functions are missing or what needs to be improved. Surprisingly, the open source solutions BigBlueButton and Jitsi do not have to hide from the big competitors like Microsoft and Zoom, but are much better in some aspects, such as data protection.

Each software presented has its own strengths and weaknesses and it is up to you to decide which video conferencing solution is best for your situation. In general, however, it can be said that the COVID-19 pandemic has greatly accelerated the development of video conferencing solutions and that these will continue to play a major role even after the pandemic is over. Especially in the business sector, many companies will continue to maintain the implemented video conferencing solutions, as even after the pandemic, more than 60% of the companies do not want to make changes in remote working according to [39]. At the same time, this means that this market has further potential and will not collapse, so that video conferencing applications will continue to be developed. Especially in security and data protection there is room for improvement and companies are willing to invest in these areas. Since the implementation has already been completed at the companies and the costs have already been incurred, it also makes further sense to refrain from unnecessary business trips or not to expand the office space further but instead to use the new solutions with home office.[39]

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