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Empirical Quality and Usability Assessments of Five Common Online Real-Time E-Meeting Platforms

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Abstract

The COVID-19 pandemic has given a very significant impact on the lives of the world community, especially in video conferencing applications. E-learning is an alternative for the academic community to reduce the impact of outbreaks. This alternative changes the direction of physical learning into online and virtual learning. The use of online real time E-Meeting platforms is an option that provides many conveniences for employee, employers, students, and teachers to achieve learning or work goals without being in class or the office environment. Various types of conferencing applications can be used by people based on their needs and preferences. This study is carried out to examine five common online video conferencing applications especially during the outbreak. This study was conducted using qualitative methods through descriptive analysis of the results of observations and documentation. An experimental analysis was also carried out on the bandwidth and CPU load of the five different platforms, the features of each platform and their similarities. Overall analysis shows that Zoom was the most preferred application given bandwidth, ease of use and other features.

Keywords: *Virtual meeting, Covid-19 pandemic, Online teaching and learning, video conferencing*

1. Introduction

The global outbreak of the COVID-19 pandemic has spread worldwide, affecting almost all countries and territories. The outbreak was first identified in December 2019 in Wuhan, China. The countries around the world cautioned the public to take responsive care. The public care strategies have included handwashing, wearing face masks, physical distancing, and avoiding mass gathering and assemblies. Lockdown and staying home strategies have been put in place as the needed action to flatten the curve and control the transmission of the disease [15].

The COVID-19 pandemic has created the largest disruption of education systems in human history, affecting nearly 1.6 billion learners in more than 200 countries. Closures of schools, institutions and other learning spaces have impacted more than 94% of the world's student population. This has brought far-reaching changes in all aspects of our lives. Social distancing and restrictive movement policies have significantly disturbed traditional educational practices. Reopening of schools after relaxation of restriction is another challenge with many new standard operating procedures put in place. Within a short span of the COVID-19 pandemic, many researchers have shared their works on teaching and learning in different ways. Several schools, colleges and universities have discontinued face-to-face teachings. There is a fear of losing 2020 academic year or even more in the coming future. The need of the hour is to innovate and implement alternative educational system and assessment strategies. The COVID-19 pandemic has provided us with an opportunity to pave the way for introducing digital learning. Online meeting or video conference applications have been made vital because almost all of the world population uses them.

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This present paper reports a study of the comparison of Web conferencing environments. Comparisons in terms of ease of use and moderation, as well as other several technical criteria were made between five types of video conferencing applications viz a viz:

- Google Meet – a video conferencing application from Google.
- Zoom – a widely used videoconferencing system, both for personal and business use.
- Skype – a well-known program for communication and calls.
- Webex Meetings – system for videoconferencing in the corporate sector.
- Microsoft Teams – system for group work from Microsoft as a part of Office 365.

2. Review of Related Works

The introduction of web-based student learning systems has been adopted by universities as one means to overcome many of the limitations of face-to-face and distance learners and to provide learning environments that improve contact and increase student interaction. Research into the use of online learning systems have reported mixed results, for example, Hills [5] reported online sessions may not be beneficial to all students. "Some people find the virtual interaction better than face-to-face and others find it more sterile and less helpful" [5]. In a study of an e-learning environment, Wei [16] concluded that there was less interaction and it was less immediate than traditional face-to-face environments, leading possibly to a sense of isolation. As a result, Wei [16], recommended that Internet tools supplement, not replace, traditional teaching methods.

Developments in e-learning technologies such as Web conferencing environments have progressed a step closer to Morgan's [11] "Third generation learning systems" where high bandwidth supports virtual classrooms and collaborative as well as complex simulations. Morgan [11] suggested three stages of e-learning applications which includes: stage one, where technology was used as a delivery mechanism and stage two, where learning needs of students drive the design of the environment. The third stage builds on the second's philosophy of adapting to the learner's needs but with high bandwidth. He asserted that "The educational system adapts to the learning, not the other way around – as in the 'text or course online' models" [11].

A lack of feedback and contact with other students and lecturers has been found to lead students to losing motivation [4]. This lack of contact can partially be overcome by phone contact, email and asynchronous discussion boards; but these do not allow real-time discussion and interaction with other students. Second generation audiographics software, now commonly described as "Web conferencing", "virtual meetings" or "collaborative" software are available that create environments where integrated instructional tools (VoIP, shared whiteboards, shared applications, video windows and archival recording) are available. Examples include Centra 7, Webex, Breeze 5, Zoom, Google Meet, Citrix MeetingToGo, ASAP pro and Microsoft Teams, Skype [13].

Online learning opens up new solutions in the education world through the innovation of technology. However, online learning must be supported by supporting devices such as software and hardware. Oranburg, [12] classifies two tools that allow teachers and students to be connected in the implementation of online learning. The hardware equipment includes computers in CPUs, laptops, webcams, microphones, and internet networks. From the software, the teachers and students also need to have special knowledge to use online learning support applications such as the use of teleconferences or video call applications such as Google Meet, Zoom, Microsoft Teams and others. Video conference is a technology that allows users in different locations to hold prominent meetings without having to move or meet at the same location. This technology is felt comfortable and practical when learning is done directly (live). It certainly can save time without having difficulties related to travel so that it can complete the work but still be safe in their homes, even though there is a plague.

Rapid developments in technology have made distance education easy [10]. Most of the terms: online learning, open learning, web-based learning, computer-mediated learning, blended learning, m-learning have in common, the ability to use a computer connected to a network, that offers the possibility to learn from anywhere, anytime, in any rhythm, with any means [3].

Online learning can be termed as a tool that can make the teaching–learning process more student-centered, more innovative, and even more flexible. Online learning is defined as learning experiences in synchronous or asynchronous environments using different devices (e.g., mobile phones, laptops, etc.) with internet access. In these environments, students can be anywhere (independent) to learn and interact with instructors and other students [14].

The synchronous learning environment is structured in the sense that students attend live lectures, there are real-time interactions between educators and learners, and there is a possibility of instant feedback, whereas asynchronous learning environments are not properly structured. In such a learning environment, learning content is not available in the form of live lectures or classes; it is available at different learning systems and forums. Instant feedback and immediate response are not possible under such an environment [9]. Synchronous learning can provide a lot of opportunities for social interaction [10]. Amidst the deadly virus spread such online platforms are needed where:

a) Video conferencing with at least 40 to 50 students is possible.
b) Discussions with students can be done to keep classes organic.
c) Internet connections are good.
d) Lectures are accessible in mobile phones also and not just laptops.
e) Possibility of watching already recorded lectures.
f) Instant feedback from students can be achieved and assignments can be taken [1].

In this paper, we sought to conduct a study that will find out the Strengths, Weaknesses, Opportunities and Challenges of five different common online learning platforms during the Corona Virus pandemic in year 2020 to early 2021. The analysis was carried out in terms of ease of use and moderation, as well as several technical criteria. The study enables us to give some suggestions and recommendations for the success of online mode of learning during a crisis-like situation.

3. Research Methodology

The study is descriptive and tries to understand the importance of online learning in the period of a crisis and pandemics such as the Covid-19. The problems associated with online learning and possible solutions were also identified based on previous studies. The analysis was based on strength, weakness, opportunities, and challenges associated with online mode of learning during the pandemic in the year 2020 up to April 2021.

The research tool used for analyzing the data collected from different sources for this study is content analysis and the method adopted was descriptive research. We have taken into consideration the qualitative aspects of the research study. This study is based on the secondary data with a simple experiment. A systematic review was done in detail for the collected literature. Secondary sources of data used are (a) journals, (b) reports, (c) search engines, (d) company websites and scholarly articles, (e) research papers, and other academic publications. However, some other features, such as load time and CPU Load, which were not obtainable from the literature were empirically determined via experimental set-ups.

For the experiments, a free version of Windows PC was used to evaluate the load of communication channels. A 3 GHz Intel Core i5 8th Gen, 16GB RAM computer was used to estimate the load on the client equipment. The service, https://www.fast.com was used to estimate the bandwidth of the channel.

The testing took place with the participation of 3 people who used both computers and mobile devices with a connection to WIFI and 4G MTN Hynet network and the process was repeated 4 times in the same environment.

4.0 Results of the Analyses

4.1 Background Information on the Videoconferencing Systems Analyzed

1. Google Meet

Google Meet (formerly known as Hangouts Meet) is a video-communication service developed by Google. It is one of two apps that constitute the replacement for Google Hangouts, the other being Google Chat. After being invite-only and quietly releasing an iOS

app in February 2017, Google formally launched Meet in March 2017.The service was unveiled as a video conferencing app for up to 30 participants, described as an enterprise-friendly version of Hangouts. It has launched with a web app, an Android app, and an iOS app. While Google Meet introduced the above features to upgrade the original Hangouts application, some standard Hangouts features were deprecated, including viewing attendees and chat simultaneously. The number of video feeds allowed at one time was also reduced to 8 (while up to 4 feeds can be shown in the "tiles" layout), prioritizing those attendees who most recently used their microphone. Additionally, features such as the chat box were changed to overlay the video feeds, rather than resizing the latter to fit Hangouts is scheduled to cease operation in the first half of 2021.

During the 2020 COVID-19 pandemic, the use of Meet grew by a factor of 30 between January and April 2020, with 100 million users a day accessing Meet, compared to 200 million daily uses for Zoom as of the last week of April 2020. Google suspended its usual 60-minute limit for unpaid accounts[2][7][8].

2. Zoom

Zoom was founded in 2011 by an Engineer of Cisco Systems, a division of WebEx, formerly Vice President for collaboration software development at Cisco. The company is headquartered in San Jose, California. Anyone who has an account can organise a meeting. A free account allows for 40 minutes of videoconferencing, but for the period of the coronavirus pandemic, the service has removed this restriction. One can use his current Facebook account to log in to Zoom. He can also link using Google Account to the Zoom platform. Anyone with a link or videoconferencing ID can join the videoconference. One can plan an event in advance, as well as generate a recurring link. The platform is available for Windows, MacOS, Android, and iOS; it has a plugin that allows using Zoom in Google Chrome and Mozilla Firefox. Following the theft of Zoom user data, the UK intelligence services advised the Government and Parliament not to use the Zoom videoconferencing service for confidential conversations due to fears that it might be vulnerable to surveillance. The British National Cyber Security Centre (NCSC) has warned Parliament that Zoom can only be used for public activities. SpaceX, NASA, and Google have banned their employees from using the programme for videoconferencing. Other large companies, including Daimler, Ericsson, NXP Semiconductors, and Bank of America, have also banned their employees from using Zoom [6].

2. Skype

Skype is a proprietary software for VoIP Internet telephony created by two entrepreneurs Niklas Zennström and Janus Friis, in collaboration with Estonians who developed a backend that was also used in the Kazaa file-sharing application. Since 2011, Skype has been owned by Microsoft. The headquarters is located in the United States, Redmond, Washington. Skype users make phone and video calls through their computers using Skype software and the Internet. The system is based on free-of-charge communication among Skype software users. The product also allows Skype users to connect with regular landline or mobile phone subscribers. This software is now available for free and can be downloaded from the company's website. Skype raises a lot of security-relating issues. In particular, there is information on the Internet that Microsoft contractors can wiretape Skype conversations of users which get translated through the built-in interpreter. Also, Skype users have repeatedly complained about failures in the application operation, namely failure to log in, failure to receive messages and voice calls [6].

3. Webex Meeting

Webex was founded in 1995 by Subrah Iyar and Min Zhu. In 2007, Webex was acquired by Cisco Systems. Today, the headquarters is located in Milpitas, California. With Webex Meetings, one can conduct interactive and large-scale online conferences: from meetings and presentations up to trainings. Video conferences can be recorded and subsequently saved on one's own servers.

To use Webex Meetings, one should simply connect to the system from a PC, tablet, or smartphone. It supports audio conferencing via both VoIP and regular phone. It is integrated with MS Office and some messengers. The program has functions for noise reduction and automatic focusing of camera on the speaker. Participants who do not have Webex Meetings

installed can still join the conversation. To do this, one just needs to share a link to one's personal online chat room on the Webex site with such a person. The person will just need to enter the password specified in the mail. The platform easily integrates with mail, Google Calendar, Skype, Slack, and other applications. The use of the Webex Meeting videoconferencing platform has recently quadrupled in Europe and increased by 3.5 times in the Asia-Pacific region. Over the past two weeks, the platform has been hosting more than 22 million video conferences a week [6].

4. Microsoft Teams

Microsoft Teams is a team center for Microsoft Office 365 that integrates the users, contents and tools the team needs to work more efficiently. Microsoft Teams was introduced to the market in early 2017. The application combines everything in a common desktop environment, which includes chat for meetings, file sharing and corporate applications. Designed for smartphones running Android, iOS, Windows Phone and computers running Windows 10 S, Windows 7+ or Mac OS X 10.10+.

Key features in Microsoft Teams:

(a) Collaborative work with files and online discussions, support for remote access to shared documents within the channel.
(b) Individual and collective chats with the mode of text formatting: putting a sign "Importance", highlighting and other options.
(c) Transition between workspaces.
(d) Connection of reports from Power BI.
(e) Organisation of web conferences with the possibility of screen sharing.
(f) Viewing the history of communication.
(g) Quick search in personal and group chats, search by name or e-mail address.
(h) Archiving conversations.
(i) Notification of receiving a message or a mention in the chat.
(j) Connection of additional functions and services.
(k) Record webcasts. [6]

In 2020, Microsoft CEO Satya Nadella presented the corporation's quarterly report, which states that in April, more than 200 million people participated in online meetings in Microsoft Teams every day. They spent more than 4.1 billion minutes in negotiations. Microsoft Teams has more than 75 million active users each day, and two-thirds of them share files or collaborate on them in Microsoft Teams. More than 183,000 educational institutions around the world use Microsoft Teams. In business, 20 organizations with more than 100,000 employees use Microsoft Teams, including Continental, Ernst and Young, Pfizer and SAP. In May 2020, Abnormal Security reported that between 15,000 and 50,000 users received emails as part of a phishing attack. The company stressed that because Microsoft Teams is directly linked to Office 365, the successful theft of data to log in to the Microsoft Teams account allows full access to Office 365. Microsoft reports that the vulnerability identified by experts has already been fixed [6].

4.2 Qualitative Comparative Analysis Results

Table 1 shows the criteria studied and answer if the analyzed videoconferencing application meets the criteria.

Table 1: Qualitative criteria studied

Criteria	**Google Meet**	**Zoom**	**Skype**	**Webex Meetings**	**Microsoft Teams**
Videoconference Support	Yes	Yes	Yes	Yes	Yes
Identification of Participants	Yes	Yes (Although identification name can be changed)	Yes	Yes	Yes
Documents Sharing Support	No	Yes	Yes	Yes	Yes
Chat Support	Yes	Yes	Yes	Yes	Yes
Screen Sharing	Yes	Yes	Yes	Yes	Yes
Recording Option	No (Only for Premium Features)	Yes (Limited to 40 minutes for free plan)	No	No (Only for Premium Features)	Yes
Breakout Rooms	No	Yes	No	No	No
WhiteBoard	Yes	Yes	No	Yes	Yes
Cloud Based	Yes	Yes	No	Yes	Yes
Audio Support	Yes	Yes	Yes	Yes	Yes
Video Support	Yes	Yes	Yes	Yes	Yes
Video Quality	HD	HD	VGA, HQ, HD	VGA, HQ, HD	VGA, HQ, HD
Attendance Taking Support	No	Yes	No	Yes	Yes
Mobile Device Support	Yes	Yes	Yes	Yes	Yes
Capacity	1-250 (>250 for Premium plan)	1-500	1-50	1-3000	1-250 (>250 for Premium plan)
Premium Plan	Yes	Yes	No	Yes	Yes
Moderation of Videoconference	Yes	Yes	No	Yes	Yes
Usability of interface	Yes	Yes	No	No	No
Customer Support	Yes	Yes	No	Yes	Yes
License	Proprietary	Proprietary	Proprietary	Proprietary	Proprietary

(Adapted from: *https://en.wikipedia.org/wiki/Comparison_of_web_conferencing_software*)

From Table 1, the following are inferred:

1. Video Conference Support

All systems have Video Conference Support. However, Skype and Webex Meeting have the lowest support for video conferencing because they do not allow one to schedule a videoconference; just immediate scheduling. Zoom, Google Meet and Webex Meetings also have the function of setting a password for access to a videoconference and allow administering participants during the connection. In Microsoft Teams each participant must be invited personally, in Skype there is no possibility to set a password for guest access.

2. Identification of Participants

Google Meet allows a compulsory identification of participants since participants will be joining with their respective email. Zoom and Webex Meeting also allows participant identification but a participants can also change their names. Since Skype and Microsoft Team are based on invite, the name the participant choose is displayed as a form of identification.

3. Document Sharing Support

All systems have a functionality to exchange documents during videoconferencing.

4. Chat Support

All systems provide the possibility of text communication during the videoconference.

5. Screen Sharing Support

All systems provide the capability to screen share.

6. Quality of audio and video

All systems coped with the task, except for Skype when tested with participants. Zoom and Google Meet turned out to be the best and smoothest.

4.3 Other Supported Features and Plans

1. Google Meet

From Google Meet webpage anyone with a Google Account can create a video meeting, invite up to 100 participants, and meet for up to 60 minutes per meeting for free. Table 2 shows the different plans and other features supported by Google Meet.

Table 2: Google Meet Specific Features

Meeting Features	**Free Version**	**Workspace Essential**	**Workspace Enterprise**
Price	Free	*$8 per active user/month	Sales contact for Price
Maximum Meeting Length (1-1)	24 hours	24 hours	24 hours
Maximum group meeting length (3+)	1 hour	24 hours	24 hours
Maximum meeting participants	100	150	250
Number of meetings	Unlimited	Unlimited	Unlimited
Browser support	Yes	Yes	Yes
Inviting external participants	Yes	Yes	Yes
Mobile support	Yes	Yes	Yes
Live captions (Subtitles)	Yes	Yes	Yes
Screen Share and Presentation	Yes	Yes	Yes
Adjustable background	Yes	Yes	Yes

Dial-in numbers	No	Yes	Yes
Meeting recording saved to Google Drive	No	Yes	Yes
Hand Raise	No	Yes	Yes
Polls and Q&A	No	Yes	Yes
Breakout rooms	No	Yes	Yes
Attendance report	No	Yes	Yes
AI noise cancellation	No	Yes	Yes
Live-streaming	No	No	100,000 Viewers
Anti-Abuse features	Yes	Yes	Yes
Data Encryption in transit and rest	Yes	Yes	Yes
2-step verification	Yes	Yes	Yes
Data Loss Prevention for Drive	No	No	Yes
Google Drive Storage	15 GB per user	100 GB per user	Unlimited

Source: https://apps.google.com/intl/en/meet/pricing/

Video and Audio Quality

- **Send and Receive resolutions**

The send resolution is the image quality from a device that others see while the receive resolution is the image quality that one sees from other participants. At maximum, the send resolution can go as high as 720p (HD), which is available on computers with a quad-core CPU or higher and it uses more data, but the camera sends a better picture quality. At minimum, the video quality is 360p (SD) which uses less data and the camera send a lower quality picture.

For receive resolution, at maximum it can go as high as 720p (HD), which is available on computers with a quad- core CPU or higher and it uses more data, but the camera sends a higher quality picture. At minimum, the video quality is 360p (SD) which uses less data and a lower quality picture. It also supports single feed where the other participants' thumbnails is turned off and you can also use Audio only.

2. Zoom

Table 3 shows the different plans and other features supported by Zoom.

Table 3: Plans and features supported by Zoom.

Meeting Features	**Basic**	**Pro**	**Business**	**Enterprise**
Price	Free	*$149.90/year/lice-nse	*$199.90/year/licen-se	*$240/year/licen-se
Unlimited one-to-one meetings	Yes	Yes	Yes	Yes
Unlimited group meetings	Yes	Yes	Yes	Yes

Maximum Group Meeting Duration	40 Minutes	30 Hours	30 hours	30 hours
Recording	Local Storage	Local Storage & Cloud	Local Storage & Cloud	Local Storage &
Maximum meeting participants	100	100 (Can be increased to 1000 with additional payment)	300 (Can be increased to 1000 with additional payment)	500 (1,000 Enterprise +)
License count	1	1-9	10-99	50+
Number of meetings	Unlimited	Unlimited	Unlimited	Unlimited
Live Streaming	No	Yes	Yes	Yes
Personal Meeting ID	Yes	Yes	Yes	Yes
Private and Group Chat	Yes	Yes	Yes	Yes
Host Controls	Yes	Yes	Yes	Yes
Co- Annotation on Screen Share	Yes	Yes	Yes	Yes
Remote Keyboard and	Yes	Yes	Yes	Yes
Mouse Control				
Whiteboarding	Yes	Yes	Yes	Yes
Multishare	Yes	Yes	Yes	Yes
File attachments in chat (Size)	512MB	512MB	512MB	512MB
Browser support	Yes	Yes	Yes	Yes
Mobile support	Yes	Yes	Yes	Yes
Live transcription (Subtitles)	No	Yes	Yes	Yes
Recording transcripts	No	No	Yes	Yes
Language interpretations	No	No	Yes	Yes
Screen Share and Present	Yes	Yes	Yes	Yes
Virtual background	Yes	Yes	Yes	Yes

Scheduled Meetings	No	Yes	Yes	Yes
Telephone Dial-in	No	Yes (Toll-based)	Yes (Toll-based)	Yes (Toll-based)
Meeting recording	Yes	Yes	Yes	Yes
Hand Raise	No	Yes	Yes	Yes
Polling	No	Yes	Yes	
Waiting Room	Yes	Yes	Yes	Yes
Breakout rooms	Yes	Yes	Yes	Yes
Co-host & alternate host	No	Yes	Yes	Yes
Live-streaming	No	Yes	Yes	Yes
AES-256 Encryption for real-time content	Yes	Yes	Yes	Yes
Cloud Storage	No	1 GB Cloud recording (Per license) and can be increased with additional cost	1 GB Cloud recording (Per license) and can be increased with additional cost	Unlimited

Source: https://zoom.us/pricing

Video and Audio Quality:

While Zoom boasts of HD resolution video, it recommends a 3Mbps connection and by default it uses 720p. Users can manually change the video quality in the settings tab. It also supports single feed where the other participants' thumbnails are turned off and one can also use Audio only.

3. Skype

Skype works by the purchase of credits and the prices varies for respective countries. Skype is also used for making international call around the world. Although it cannot be used for emergency calling. Prices ranges from $2.99 per month upward. Table 4 shows the different plans and other features supported by Skype.

Table 4: Plans and features supported by Skype.

Meeting Features	**Skype**
Price	Varies for different country
Audio and HD Calling	Yes
Call recording and Live subtitles	Yes
Chat	Yes
Screen sharing	Yes
File attachments in chat (Size)	300MB
Browser support	Yes
Mobile support	Yes

Location sharing	Yes
Background Effects	Yes
Skype Translator	Yes
Raise hand	Yes

Source: https://www.skype.com/en/features/

Video and Audio Quality:

For video calling, Skype recommends upload and download speeds of 300 kilobytes per-second or 500Kbps for high-quality video. For even crisper high-definition video, Skype recommends upload and download speeds of 1.5 megabytes per-second. One will need high-speed connections - 512Kbps upload speeds and 2 to 8Mbps download speeds, the latter depending on how many people participate in the call - if one wants to make group calls with high-quality video.

4. Webex Meeting

Table 5 shows the different plans and other features supported by Webex Meeting.

Table 5: Plans and features supported by Webex.

Meeting Features	**Free version**	**Starter**	**Plus**	**Business**
Price	Free	*$14.95 per active host/month	*$19.95 per active host/month	*$29.95 per active host/month
Maximum Meeting Duration	40 mins	Unlimited	Unlimited	Unlimited
Maximum meeting participants	100	50	100	200
Meeting Recording		Yes	Yes	Yes
Drawing/Annotation tools		Yes	Yes	Yes
Screen sharing	Yes	Yes	Yes	Yes
Mobile Support	Yes	Yes	Yes	Yes
Browser support	No	No	No	No
Desktop Support	Yes	Yes	Yes	Yes
Polling				
File sharing				
Document Sharing				
White board				

Source: https://www.webex.com/pricing/index.html

Video and Audio Quality

Assuming all Webex Meetings applications have at least 2Mbps bandwidth, users in the meeting can enjoy 720p content sharing at up to 5 FPS. If Webex Meetings applications have at least 3- Mbps bandwidth, the content share quality is 1080p at 3 FPS. Webex also supports single feed where the other participants' thumbnails is turned off and one can also use Audio only.

5. Microsoft Teams

Table 5 shows the different plans and other features supported by Microsoft Teams.

Table 5: Plans and features supported by Microsoft Team.

Meeting Features	**Microsoft Teams Free**	**Microsoft 365 Business Basic**	**Microsoft 365 Business Standard**
Price	Free	*$5 per active user/month	*$12 per active
Maximum Meeting Duration	1 hour	24 hours	24 hours
Maximum meeting participants	100	300	300
Number of meetings	Unlimited	Unlimited	Unlimited
Maximum number of users (Chat)	500K	300K	300K
File attachments in chat (Size)	2 GB per user	1 TB per user	1 TB per user
Browser support	Yes	Yes	Yes
Inviting external participants	Yes	Yes	Yes
Mobile support	Yes	Yes	Yes
Real-time captions (Subtitles)	Yes	Yes	Yes
Screen Share and Present	Yes	Yes	Yes
Customized background	Yes	Yes	Yes
Scheduled Meetings	Yes	Yes	Yes
Host Webinars that include attendee registration pages, email confirmations, and reporting	No	No	Yes
Dial-in numbers	No	Yes	Yes
Meeting recording	No	Yes	Yes
Hand Raise	Yes	Yes	Yes
Polls and Q&A	Yes	Yes	Yes
Breakout rooms	Yes	Yes	Yes
Live-streaming	10,000 attendees	10,000 attendees	10,000 attendees
Data Encryption in transit and rest	Yes	Yes	Yes
Enforced MFA	No	Yes	Yes

Real Time collaboration in office apps (Word, Excel, PowerPoint)	Yes	Yes	Yes
Personal file storage and sharing with OneDrive	No	1 TB per user	1 TB per user
Storage	10 GB across all teams	1 TB per organization plus 10 GB per License	1 TB per organization plus 10 GB per

Source: *https://www.microsoft.com/en-ww/microsoft-teams/compare-microsoft-teams-options*

Table 6: Channel load, 1:1 Calling.

System	**1:1 Calling – low resolution**	**1:1 calling – High resolution (720p)**
Meet	0.4 Mbps up/ 0.4 Mbps down	3.5 Mbps up/ 2.8 Mbps down
Zoom	1 Mbps up/ 0.8 Mbps down	1.5 Mbps up/ 1.3 Mbps down
Skype	0.7 Mbps up/ 0.5 Mbps down	1.7 Mbps up/ 1.5 Mbps down
Webex Meeting	1.2 Mbps up/ 0.9 Mbps down	3 Mbps up/ 2.5 Mbps down
Microsoft Teams	0.5 Mbps up/ 0.5 Mbps down	1.2 Mbps up/ 1.2 Mbps down

Video and Audio Quality:

This connotes the image quality from a device that others see. By default, the resolution is at 1080p (HD) at 30fps (Frame per Second) with a minimum connection of 2Mbps or higher and it uses more data, but the camera sends a better picture quality. At minimum, the video quality is 360p (SD) which uses less data and the camera send a lower quality picture. It also supports single feed where the other participants' thumbnails are turned off and one can also use Audio only.

4.4 Measurements

Communication channel load, 1:1 Calling. Results obtained from this measurement are depicted in Table 6 for low and high resolutions.

Given the result generated with the table above, with low resolution, Google Meet has low bandwidth requirements but also has a high bandwidth when resolution is been changed to 720p. Zoom maintained a balance between its low resolution and high resolution. When hitting poor quality connection across all platforms, switching to a mobile device saved a lot of bandwidth compared to using PC.

Results obtained from group calling measurement are depicted in Table 7 for low and high resolutions.

The higher the bandwidth the higher the speeds you can download and upload files, and thus the higher the video quality you can stream a conference call. The more people who are on the call, the higher that bandwidth requirement gets. The same goes for the amount of devices you have on your Wi-Fi at the same time. According to the bandwidth below, Zoom should be able to deliver HD video quality in 3.5Mbps.

Table 7: Channel load, Group

System	Group Calling – low resolution	Group Calling – High resolution (720p)	Group Calling – High resolution (1080p) HD
Meet	2.8 Mbps up/ 2.6 Mbps down	3.2 Mbps up/ 3 Mbps down	4 Mbps up/ 3.5 Mbps down
Zoom	0.8 Mbps up/ 1 Mbps down	1.5 Mbps up/ 1.5 Mbps down	3.5 Mbps up/ 2.8 Mbps down
Skype	0.5 Mbps up/ 0.128 Mbps down	2 Mbps up/ 0.5 Mbps down	4 Mbps up/ 0.5 Mbps down
Webex Meeting	1.5 Mbps up/ 1 Mbps Down	2.8 Mbps up/ 2.5 Mbps Down	4.6 Mbps up/ 3.8 Mbps down
Microsoft Teams	0.5 Mbps up/ 1 Mbps down	3 Mbps up/ 2.7 Mbps down	4.8 Mbps up/ 4.0 Mbps down

Table 8: CPU load

System	Load (CPU)
Meet	40
Zoom	50
Skype	60
Webex Meeting	80
Microsoft Teams	130

The *average value* of the channel load means the default value, which remained unchanged most of the time. The *peak value* of the channel load means the maximum value obtained, which was repeated at least several times during the videoconference. The results obtained for Application Load on CPU is depicted in Table 8.

4.5 Discussion of Results

The study carried out showed that Zoom offers more functionalities than other video conferencing applications, although when price and time limits are put into consideration, Google Meet seems to be of higher advantage than others. When it comes to user experience and bandwidth, Zoom seems to do well above others. Although Zoom now supports web version, prior to when this paper is being published one had to always install the application either via desktop application or mobile, but with the new update one can easily use Zoom on the web, on the fly, Zoom offers breakout sessions and recordings which for others, these are paid features. There are so many more advantage that Zoom has over other video conferencing applications, but these have been well described in the feature Tables 1-8 above.

5. Conclusion

From the study above it has been established that Zoom is the best option so far based on the criteria used for comparison among all the video conferencing tools. In addition, it has been widely accepted not only in the academic world for delivering lectures, organizing meetings but also in the corporate world due to the obvious advantages of: breakout sessions, number of participants, functionalities and customer acceptance among others

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