A Systematic Study and Comprehensive Comparison of Online Teaching and Learning (OTL) Apps for Measuring the Quality of User Experience

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Abstract: *Due to the rapidly evolving Covid-19 pandemic, the world around us has radically transformed our lives to stay, learn, and work from home. During this crisis, almost all Universities and academic Institutions have adopted for quick transition from the regular classroom to online teaching and learning (OTL) through many applications (apps). However, the real challenges arise due to the lack of user experience with fully OTL apps, even in the most technologically developing world. Little research has assessed the availability and effects of OTL apps, hence, so far found as indecisive, just as research on the Coronavirus. Therefore, in this paper, various OTL apps that are used in academic institutions for the purpose of teaching and learning online are studied and compared to measure the quality of user experience with respect to several technical parameters. Initially, 45 features and 40 parameters of an OTL app are listed and classified into six different categories. Thirty-two OTL apps are identified, were studied, and compared based on all the features and parameters. Then, the world's six popular apps are identified, a comparison and comprehensive study is done on them and systematic evaluation is accomplished to measure the quality of experience. Finally, a list of 41 Frequently Asked Questions (FAQs) and answers and several recommendations are provided. Based on such a comprehensive review, this paper provides the reader to understand the features, limitations, merits, demerits, technical aspects, security provisions, etc. while selecting the suitable OTL app as per the requirement and situation.*

Keywords: Adobe Connect; Cisco WebEx; Google Meet; Microsoft Teams; Online Teaching and Learning; Quality of Experience; Zoho; Zoom

1. Introduction

The term e-learning was first coined by Elliott Maisie in 1999 and was used professionally since then. The advancements and usage in the Internet, multimedia technology, digital devices [1], and Learning Management Systems (LMS) strengthened e-learning. Further, due to the rapid usage of e-learning materials and courses, and the benefits of synchronous teaching and learning through Internet, the field of Online Teaching and Learning emerged. Some of the application areas in which OTL is used include academics, industry, trade and commerce, administration, social meetings, etc. Different stakeholders of OTL include managers, employees, teachers, students, partners, family, friends, etc. However, there exist many OTL apps that create a classroom, discussion groups, and conference meetings virtually of sorts in the market. A growing number of participants are adopting various devices including desktops, laptops, workstations, tablets, pads, smartphones, etc. for using OTL apps for a purpose.

The worldwide e-learning market is projected to be worth $325 Billion in 2025. (Source: Forbes) In 2017, approximately 77% of US corporations used online learning, but 98% planned to incorporate it in their program by 2020. (Source: eLearning Industry, Small Business Trends)

In 2017, 67% of US companies offered learning opportunities via smartphones. (Source: eLogic Learning)

OTL increases retention rates by 25% to 60%. (Source: SH!FT)

A survey of 2,500 companies found that those with "comprehensive training programs" have 218% higher revenue per employee and 24% higher profit margins. (Source: darlo digital)

IBM saved approximately $200 million after switching to online learning. (Source: SH!FT)

1.1. Online Teaching and Learning Statistics

Some of the incredible statistics given below provides the importance of OTL.

1.2. Benefits of Online Teaching and Learning

Some of the primary benefits of OTL include:
1) Improves Performance and Productivity: OTL allows learners to train quicker and easier, increased depth of

understanding, retention of course content, feel more motivated and engaged, and more importantly self-disciplined.

2) Cost Effective: OTL removes the need for costly printed course materials and onsite trainers or instructors.

3) Saves Time: Participants can easily update course content and manage training delivery through the LMS, while learning doesn't have to rely on scheduled training.

4) Lower Environmental Impact: OTL provides alternative paper-based training and lowers the organization's environmental impact.

5) Convenience: OTL provides 24/7 access from any online computer, overcomes busy schedules, and no commuting. It also makes it possible to conduct classes even in situations unfavorable for all the participants to be physically present at one place

6) Interaction: OTL provides improved student-to-teacher and student-to-student interaction, student-centric learning environment and a great sense of correctness and synergy.

7) Improved Administration: The time required to examine student work can be done more thoroughly, the ability to document and record online interactions.

8) Maximize Resource Utilization: OTL could lessen the demand on limited campus infrastructure, decrease congestion on campus, and parking lots.

9) Outreach: This could give students options, reach new student markets, appeal to current students, thus increasing enrollments.

10) Repetition: Unlike regular classroom teaching, the participants can access the content an unlimited number of times from anywhere. This may be required at the time of revision when preparing for an exam.

11) Effective Teaching: Teaching can be more effective as the teacher can use resources from several different formats.

12) Scalable: It is scalable as it allows any number of students to participate in a class.

13) Focused Teaching: Teaching will be more focused as there will be less disturbance from the participants and hence more topics can be covered compared to classroom teaching.

14) Independent Learning: It promotes independent learning as nobody needs to depend on anybody to learn.

1.3. Disadvantages of Online Teaching and Learning

Some of the prime disadvantages of OTL include:

1) Hostile Ambience: Digital classroom cannot replace the conventional physical classroom using chalk and talk. Digital classroom is indeed far more unequal than the physical classes.

2) Social Isolation: It lacks face-to-face communication and causes social isolation.

3) Teaching Disparity: Teaching speeds up because of the usage of slides, presentations, graphics and videos making it difficult for the students to keep in sync with the teacher.

4) Inaccessibility: Poor Internet connectivity in rural areas makes it difficult for students from these regions to actively participate in online classes.

5) Power Issues Electricity outrages for many hours in cities and towns requires the participants to keep the laptops and smartphones sufficiently charged and also have a UPS backup for the Wi-Fi router to provide uninterrupted Internet connectivity during power cuts.

6) Expensive: Laptops, expensive tablets, desktops and smartphones may not be affordable to economically weaker section of students.

7) Disrupted Supervision: Audio and video may get switched off due to poor Internet connectivity making it unable to monitor students.

8) Ineffective Academics: Remote problem solving sessions, group discussions, online test (subjective and objective) remote proctoring and practical sessions are not effective and cannot replace traditional physical tutorials and examinations.

9) Toilsome Teaching: Teachers should put in more effort and take more time to teach effectively. 10. Obligatory Add-ons: A whiteboard needs a digital pad with a writing stylus.

10) Uncontrolled exams: Exams and home assignments do not eliminate the possibility of copying and plagiarism.

11) Need of Advanced Technology: Proctored online exams require Artificial Intelligent (AI) systems equipped with camera-based face and body tracking, device screen monitoring, facial expression, lip twitches, etc. Such artificial monitoring tools do not match the traditional examination tools.

12) Lack of Specialized Devices: Online classes require video recordings, artificially intelligent teaching bots, hosted on the Internet and a device to connect.

13) Desirable Characteristics for Selecting an OTL

The ten desirable characteristics for selecting an OTL app are as follows:
1) Context Relevance
2) Audio and Video Quality
3) Performance
4) Design and Usability
5) Infrastructure and Bandwidth Cost
6) Security
7) Enhanced Communication
8) Vendor Reputation
9) Data Ownership
10) Open Source and Update

However, there are many other characteristics apart from the listed above that the OTL app shall posses.

1.5. Motivation

Currently, finding a suitable app for OTL seems like a daunting task particularly when taking into account that there are hundreds of thousand apps. People spend more time than required researching, trying, and testing OTL apps available on the Internet for their purpose. Also, most of the apps are not formally regulated and users have limited guidance on how to select the best app for the purpose and there are often no formal guidelines to assist with evaluating apps. Hence, finding good quality and suitable OTL app that actually enhance teaching and learning can be tricky.

1.6. Contributions

The main contributions of this paper include the following:
1) Studying various online training and learning apps.
2) Providing a detailed comparison of various online training and learning apps with all possible features and parameters.
3) Identify world's popular and trusted OTL apps and provide a comprehensive comparison on them.
4) Evaluating the OTL apps systematically for measuring the Quality of Experience.

The rest of the paper is organized as follows. A brief description of 45 features of an OTL app that are classified into 6 categories is provided in Section 2. A list of 36 parameters of an OTL app that are classified into 6 categories is discussed in Section 3. In Section 4, a detailed comparison of the 32 apps based on features and parameters are presented. Six popular apps are identified and are summarized in Section 5. These six OTL apps are compared with 36 parameters in Section 6. In Section 7, several discussions and FAQs are provided. The concluding remarks are presented in Section 8.

2. Features of Online Teaching and Learning Apps

In this section, the features of OTL apps are listed and classified into six categories, namely, administration, control settings, screen sharing, communication, security, and other features.

2.1 Administration

This class of features are related to administration of the OTL app and are briefly explained in the following:
1) Schedule Meeting: This feature allows the host of the meeting to fix the time table or session of future meetings. The host can set various parameters related to screen sharing, chat, audio, and video of the users, admit policy, etc., while scheduling a meeting. The details of the meeting such as meeting-ID, password, and the meeting URL are shared with the intended participants in advance.
2) Cloud based Download: This feature allows the users to back up the online content to a private cloud space or in local memory and access whenever it is needed. An application may provide limited cloud space for free for a certain period of time. However, the user has the option of getting more cloud space at a subscription price.
3) Screen Recording: Screen recording allows a user to record video from his screen. It may allow us to capture any area of the screen with an option to add narration from microphone and video via camera.
4) Contact Availability Status: This feature allows us to know the current availability status of a user, thus enabling a real-time online conversation, if needed.
5) Invite Participants: This feature allows one to invite other participants to a scheduled or an ongoing meeting by sharing the meeting invite/meeting links through email or sharing the meeting credentials (Meeting ID, URL, and/or an optional password) through contacts.

6) Accounting and Auditing: Accounting involves maintaining information related to the meeting like meeting ID, meeting duration, number of participants, meeting host, location, bandwidth usage, memory consumption, CPU usage, etc. Auditing is the process of periodically analyzing the information gathered over a period of time to draw useful business and performance conclusions. Accounting and Auditing help the vendor to improve the quality of his product through continuous evaluation and provide better service.
7) Active/Passive Participant: Active participants show a keen interest and involve themselves in the meeting whereas passive participants just listen to the conversation without involving themselves in the meeting.

2.2. Control Settings

This class of features comprises of the control settings that the host or participant has control over using the app based on the authorization granted.
1) Plug-and-Play: This feature facilitates the discovery of a hardware component in a system without the need for physical device configuration or user intervention in resolving resource conflicts.
2) Type of Network needed: This determines whether the device on which the application is installed connects to the Internet using a wired or a wireless connection like Wi-Fi, Wi-Max, mobile hotspot, etc. The connection has to be reliable for the application to provide better service.
3) Video Hide: This feature allows a user to hide and unhide his own and other's videos. Usually, a participant other than the host can mute or unmute only themselves.
4) Audio Mute: This feature allows a user to mute and unmute himself and others in a meeting to avoid unnecessary disturbances. Usually, the host will have the flexibility to mute individual user or all the users in the group, if needed. Participants other than the host can mute or unmute only themselves.
5) Keyboard Shortcuts: Keyboard shortcuts are the alternatives to a mouse click which enable a user to invoke a preprogrammed action using a single key or a combination of keys when using an OTL app.
6) Virtual Background: This feature allows a user to display a virtual image or video as his background, replacing the actual background present.
7) Remote Controlling: This feature allows a user to take control of another user's screen. The control is transferred by mutual consent wherein a user can either send a request to control other persons' screen or the other person voluntarily gives the control.

2.3. Screen Sharing

This class of features is one of the important features of an OTL app that enables a user to share the contents of the screen with other participants. The user may share all the elements on a screen or simply share one window, thus allowing him to have complete control over the visibility of the contents being shared. Some of the screen sharing features includes the following:
1) White Board: The Whiteboard is an interactive display board that allows multiple users to interact, manipulate

the contents that are projected and displayed. It can be operated on a touchpad, stylus pen, or even finger in some apps.

2) Photo Sharing: This feature allows a user to share photos/images stored in his local device or from the Internet with all the other users of the group. The formats that an app support may include JPEG, TIFF, GIF, PNG, BMP, Raw etc.

3) Notes Sharing: This feature allows a user to share his notes with all the other users in the group. The notes may be either in plain text, PowerPoint or a PDF format. It may not be convenient for an application to support all these formats. Hence, most of the applications support the PDF format which is convenient to share and use on various platforms with ease.

4) Sharing from Cloud: It is convenient for a user to store data in cloud rather than on his local device so that the data can be accessed easily from any device with Internet access [3]. This feature allows a user to share the contents that the user has stored in his cloud space. The contents may be documents, photos or videos that he has stored in a cloud like iCloud, Google drive, Microsoft Onedrive, dropbox, Google photos, etc.

5) Drop Box: The Dropbox is a cloud space that allows a user to store his files, documents; photos etc. in the cloud and sync it on multiple devices. The Drobox gives a 2 GB of free cloud space upon signing up using a valid e-mail id. However, more cloud space can be availed upon subscription depending on the requirement.

6) Share using URL: Sometimes the user may feel it convenient to share documents or videos from the Internet to make the interaction more interesting. This feature allows the user to share such contents using the URL in a web browser.

7) Bookmark: A user may want to save the address of a web page during the course of interaction for future reference. This feature allows a user to bookmark/save the web address of his interest.

8) Screen Writing and Stylus: Apart from interacting with the group using notes and presentations, a user may want to share information by writing something on his screen and sharing the same with all the others in the group. This feature allows a user to write anything on his screen, using a stylus, and share the same easily.

9) Annotate Tools: To write the contents on a white board when the screen is shared, the following annotate features are used.

a) Pause Share: This feature allows a user to stop sharing his screen temporarily and continue later from the point where he paused.

b) Stop Share: This feature completely stops sharing his screen in the group. A user uses this feature if he has done with sharing whatever he wants to share or do not want to continue sharing anymore for whatsoever reason.

c) Mouse: This feature allows a user to switch to mouse pointer by deactivating annotate tools.

d) Text: This feature allows a user to type text on his screen using the keypad. A user may use this feature if he wants to type instead of writing on the whiteboard to make the contents more legible.

e) Draw: This feature allows a user to draw simple graphic objects like lines, circles, arrows, boxes, etc. on the screen.

f) Eraser: An eraser enables a user to delete selected objects on the screen. This feature can be used if the user does not want to clean the entire screen and use contents written in certain portions of the screen.

g) Format: This feature allows a user to use various formatting options while writing, like changing the type and size of font, color of writing, line thickness, etc.

h) Undo/Redo: This feature allows a user to undo/redo a sequence of actions performed earlier. An app will generally have a restriction on the number of such undo/redo actions.

i) Clear: This option is used to clear all the contents on the current screen. A user uses this feature if there is no more space on the screen to write or he has done with the current contents of the screen.

j) Save Screen: This feature allows a user to save the contents of the screen as an image on a local storage in a image format supported by the application. The app may alternatively allow a user to save the image onto the cloud space.

2.4. Communication

This class consists of different communication features used by an OTL app.

1) Audio Support: The audio support feature enables one to have audio conversations and to manipulate audio files in different formats such as WAV, AVI, FLAC, MP3, etc. This feature enables an application or a web browser to read, write, playback and record audio files.

2) Video Support: The video support feature supports different formats of video files enabling one to have a video conversation in a platform (application or web browser) and helps to manipulate these files. Some of the popular video formats are MP4, AVI, FLV, MOV, WebM, WebVTT, etc.

3) Chat and SMS: This feature enables real-time communication by allowing a user to send messages to other users in the group. Messages can be sent to individual users in a private mode or to the whole group. It also allows to save the chat for future reference.

4) Hand Raise: This feature allows a user to let know the host and others, that he has a query, without interrupting the conversation.

5) Polling: This feature allows the host to create poll questions and launch them during the meeting requiring the users to answer these questions amidst the meeting. This keeps the meeting interactive and engaged throughout.

6) Annotate: This feature allows a user to provide additional information about a concept which helps in better understanding of the concept. Optionally, it may allow other users also to contribute with their ideas.

7) Reminder: Reminder is a tool that maintains records of certain events along with their start-time and reminds the user about those events.

8) Quiz and Exams: Quiz and exams are events that can be conducted online between a student and a teacher within a digital platform.

9) Language support: This feature allows the user to select a language of his preference for use, from a list of languages that are supported by the app.
10) Voice over IP: Voice over IP is a communication technology that allows the transmission of voice and multimedia content over the Internet Protocol (IP).
11) Dial-In: This feature enables multiple participants to access a conference service seamlessly.

2.5. Security Features

This class consists of features that are related to security provided for an OTL app.

1) Admit Policy: Admit policies are set by the host to restrict users' entry into the meeting, while scheduling or during ongoing meetings, the host uses this feature to set policies to allow users to work securely. For instance, one can admit desired users into the meeting and deny or make others wait.
2) Security Access: Security Access is the process of providing access to certain resources and entry to certain places for authorized users and restricting unauthorized users. Security access may be provided to software resources like, files, user accounts, user data, applications, etc., and hardware resources like disk, memory, monitor, etc.
3) Encrypted Communication: It is a means by which the users of an app are provided secure communication via end-to-end encryption. Some of the standards widely used are SSL, 128-bit AES, 256-bit AES, etc.

2.6. Other Features

Some of the other features that are not presented above, are listed and grouped in this subsection and is briefly explained in the following.

1) Open Source: The term Open source is used to indicate that the source code, design documents and contents of a product can be accessed, modified and distributed free of charge.
2) Browser/App Based: An OTL app may be either browser or app-based or both. A app-based application provides service only through the app developed for that purpose, and a user needs to install the app. A browser-based app, on the other hand, needs just a browser to provide the service. Most of the apps provide service in both versions. If the service is provided in both the versions, it will be more flexible for the users to use the service, and it will be more reachable.
3) App Demo: It is a feature that demonstrates the app to its users.
4) 247 Support: It is the support service that is provided by the vendor 24 hours a day and 7 days a week to the end user seamlessly.
5) Lock Meeting: This option enables the host to restrict participants from entering the meeting after a certain period of time once the meeting has started. This helps the host impose discipline among the participants by disallowing participants who try to enter the meeting too late.
6) Enable Waiting Room: Waiting Room is an area in the app where the participants are made to wait when they login, until the host allows them to enter the meeting

area. This provides a level of security by allowing the host to verify whether a participant trying to enter the meeting is genuine or not and allow only intended participants to the meeting.
7) Allow Participants:
   a) Screen Sharing: Usually, only the host can share contents with the other members of the meeting. On certain occasions, other participants of the meeting may want to share their screen to share some information. This feature allows the host to extend the option of sharing their screen during the meeting.
   b) Chat: By default, the members of the group are allowed to chat only with the host and not among themselves during the meeting. If the meeting requires that the participants be allowed to exchange information among themselves, then the host can enable this option so
   c) That a participant is allowed to chat with anybody in the meeting.
   d) Rename Participants: A participant identifies himself by giving a name while entering the
   e) Meeting. If by mistake a participant has given a wrong name while entering the meeting or wants to change his name, this feature allows the user to rename himself.
8) Remove Participants: This feature allows the host to remove a participant if he is creating disturbance in the meeting.

3. Parameters for Evaluating the Online Teaching and Learning Apps

The parameters for evaluating the OTL apps are classified in to management, performance, security, quality, support and reputation. These parameters are briefly explained in the following.

3.1. Management Parameters

1) Capacity: It refers to the maximum number of users allowed to participate in the meeting at once. Apps support participants ranging from 100 to 10,000 in a meeting simultaneously.
2) Log: Log is a list that maintains information related to various aspects of an app such as a system's usage, performance, schedules, user activities, events, recovery, etc.
3) Cost: The total cost incurred for buying the services of the app depending on various parameters including usage, capacity, user interface, security, etc.
4) Meeting Configuration: Settings that define the type of meeting and allows to enable or disable the features of meeting. The various features that can be enabled and disabled include, the participants who can enter the meeting, recording the meeting, configurations related to video, audio, chat, etc.
5) Meeting Duration: It is the length of the time interval the meeting is conducted and is generally expressed in terms of minutes. A meeting can have a fixed duration or there may be no limit on the duration.
6) Number of Subscribers: It is the count of the number of users who are paying to use a particular service or application.

7) Focus Group: A focus group is a gathering of deliberately selected people who participate in a planned discussion [38].

3.2. Performance Parameters

1) Bandwidth: It is the amount of data that can be transferred on a communication channel in a fixed amount of time. It is typically measured in bits per second (bps). A communication channel must have large bandwidth for better performance [7].
2) CPU: The CPU is the core component of a computing device. It receives input from the user, processes the input and produces the output. It consists of a processor which has a certain level of processing capacity. The clock speed of a processor is measured in terms of Hertz per Second. Typical clock speeds are 3 – 4 GHz for desktops, 2 – 3.5 GHz for laptops, 1 – 2 GHz for mobile devices. Higher the clock speed, better the performance.
3) Memory: It refers to the storage device that is used to store the instructions that are executed by the processor and the data needed by these instructions. Typically, the capacity of memory in computing devices range between 2 GB to 64 GB. Since the data and the instructions executed by the processor are stored in memory, it is necessary to have larger memory for better performance.
4) Audio Frequency: It is the range of frequency that is audible, which ranges between 20 Hz and 20 KHz.
5) Audio Latency: Audio Latency is the time delay or lag for the audio in reaching the destination from the source. It is measured in milliseconds. The latency depends on various factors including the network hardware, network software and configuration, distance and congestion in the network [39].
6) Audio Jitter: It is the loss of a sample or block of samples in a digital audio bitstream. It depends on the strength of the network and network congestion [39].
7) Audio Packet Loss: It refers to the loss of audio packets during the transfer of audio packets from the source to the destination. It is measured as a percentage of packets lost with respect to packets sent. Packet loss is caused by errors in data transmission or network congestion. A packet loss of 0 – 2.5 % is considered acceptable.
8) Video Frequency: It refers to the frequency range within which videos can be viewed.
9) Video Latency: It refers to the time delay for the video to reach the destination from the source. Latency varies between ($< 10ms, > 1s$). A latency of $> 100ms$ can cause severe lags during video streaming [40].
10) Video Jitter: Video jitter refers to the amount of data lost during transmission between network devices.
11) Video Packet Loss: It refers to the loss of video packets during the transfer of video packets from the source to destination.
12) Frame per Second (FPS): It refers to number of frames that appear on a display device every second. The most popular frame rates for video is 24 FPS, 30 FPS and 60 FPS. 24 FPS is usually best for movies, 30 FPS for TV productions and 60 FPS for sports footage. The quality of a video improves as the number of frames per second increases. However, it requires more bandwidth and may affect the performance considerably [41].

13) Resolution: It refers to resolution of an image used for communication. It is represented in terms of number of pixels. The resolution is identified by the number of pixels arranged across the width and height of the image. For example, a 3 megapixel (2048 x 1536) image consists of 2048 pixels along the width and 1536 pixels along the height. Higher resolution increases the clarity of the image but consumes more space.
14) Data Consumption: It refers to the amount of data consumed during a meeting. It depends on various factors including the number of users, the audio and video quality, end-to-end encryption of the data, etc.
15) Upload Time: It is the time taken by an application to upload a file on the Internet. It depends on the size of file to be uploaded and network bandwidth.

3.3. Security Parameters

1) Security Access: Security Access is the process of providing access to certain resources and entry to certain places for authorized users and restricting unauthorized users. Security access may be provided to software resources like, files, user accounts, user data, applications, etc., and hardware resources like disk, memory, monitor, etc.
2) Encrypted Communication: It is a means by which the users in an application are provided secure communication via end-to-end encryption. Some of the standards widely used are SSL, 128-bit AES, 256-bit AES, etc.

3.4. Quality Parameters

1) Display Resolution: Display resolution is the number of distinct pixels in terms of width and height that can be displayed on a display device. A display resolution of 1024 768 means the pixels are arranged in a two-dimensional arrangement of 1024 rows each consisting of 768 columns. Most popular standard resolutions are 640360 and 640480 for video; 720480 and 720576 for DVD, 1280720 (720p) for HD video and 19201080 (1080p) for Full HD video [42].
2) Audio Quality: Audio quality is the assessment of the accuracy, fidelity or intelligibility of audio output from an electronic device. Quality can be measured objectively using tools to gauge the accuracy with which the device reproduces an original sound or subjectively when human listeners respond to the sound or gauge its perceived similarity to another sound. The sound quality of a recording depends on a number of factors, including the equipment used to make it, processing and mastering done to the recording and the equipment used to reproduce it.
3) Video Quality: Video quality is the characteristic of a video passed through a video transmission/processing system.
4) Graphical User Interface: It is an interface provided by the app through which the user can interact with the app. An app which has a GUI consists of buttons, menus, images, etc., which makes it convenient for the user to navigate and to perform various operations in the app. If a GUI is absent, then the user has to use text based commands to use the application and it becomes

difficult for the user to use the app comfortably. All the applications today come with a easy-to-use GUI making the app more user-friendly.

3.5. Support Parameters

1) Supporting Platform: The environment consisting of the software and hardware that supports a particular application to run. Software includes the operating system, web browser, application programming interface etc [2,4].
2) Device Type: Device type is the type of the device used by the hosts and the participants to attend the meeting which includes mobile phones, laptops, desktops, tablets, pads, headsets, speakers, etc.
3) Minimum Hardware Requirements: The lowest level of capability of a hardware required for the app to run includes the disk space, processor speed, memory, display, etc [5].
4) Plugins: A plugin (Addin/Addon) is a software component that adds a specific feature to an existing program. When a program supports plugins, it enables customization.
5) Supporting Web Browser: Apps are developed to run on certain web browsers and they may not be compatible on others [6]. This parameter specifies the web browsers that are supported by the application.
6) User Support: User support is the range of services provided by the vendor to assist customers in making cost effective and correct use of a product. It includes assistance in planning, installation, training, troubleshooting, maintenance, upgrading and disposal of a product.
7) Ease of Installations: It refers to the difficulty level involved in installing all the minimum requirements for

running an application. The easier the level, the application is more user-friendly and more people prefer to use the application.

8) Documentation and Help: An app must be supported with a detailed document explaining the various options it is providing and also give description about how to use the application. This assists the user in understanding the app better. Documentation and Help is very essential from the end-user's perspective.

3.6 Reputation Parameters

1) Vendor Stability: Vendor stability is the probability that a particular vendor will not change in the future for an unidentified duration. A vendor who is more stable is more reliable.
2) Year of Establishment of the Company: This refers to the year in which the company/vendor came into existence. It is important to know how long the company has been in this business line as it gives a measure of vendor stability.
3) Year of Launch of OTL App: It refers to the year in which the app was launched for public use. It gives the information about how long the app has been in use.
4) User Ratings: Rating is an evaluation or assessment in terms of quality, quantity, or combination of both. Generally, the rating value ranges from 1 to 5 stars, 5 being the best rating.

4. Comparison of Various Online Teaching and Learning Apps

In this section, 32 OTL apps are identified and are compared with 46 features and 40 parameters.

Table 1: Comparison of OTL Apps based on Administration and Control Settings Features

SN	Apps	Administration						Control Settings					
		Cloud Download	Screen Recording	Availability Status	Invite Participants	Account & Auditing	A/P Participant	Ethernet/Wi-Fi	Video Hide	Audio Mute	Keyboard Shortcuts	Virtual Background	Remote Controlling
1	Adobe Connect	X	X	X	X	X	X	X	X	X	X	X	X
2	AirMeet	X	7	7	X	7	X	X	X	X	7	X	X
3	Amazon Chime	X	X	X	X	X	X	X	X	X	X	X	X
4	AnyMeeting	X	X	X	X	X	7	X	X	X	7	X	X
5	AT & T Connect	X	X	X	X	X	X	X	X	X	X	7	X
6	BigBlueButton	7	X	X	X	X	X	X	X	X	X	X	X
7	Cisco Jabber	X	7	7	X	7	X	X	X	X	X	7	X
8	Cisco WebEx	X	X	X	X	X	X	X	X	X	X	X	X
9	Click Meeting	X	X	7	X	X	X	X	X	X	7	X	X
10	CyberLink U	7	X	7	X	7	X	X	X	X	X	X	7
11	Freeconference	7	X	7	X	7	X	X	X	X	X	X	X
12	FreeConferenceCall	X	X	X	X	7	X	X	7	X	X	X	X
13	Fuze Meeting	X	X	X	X	7	X	X	X	X	X	7	X
14	Google Meet	X	X	7	X	X	X	X	X	X	X	X	X
15	GoToMeetings	X	X	7	X	7	X	X	X	X	X	X	X
16	Impartus	X	X	X	X	X	X	X	7	X	7	7	X
17	Jitsi Meet	X	X	7	X	X	X	X	7	X	X	X	X
18	Join me	X	X	7	X	7	X	X	X	X	X	X	X
19	Lifesize	X	X	X	X	X	X	X	X	X	7	X	X

20	LiveStrom	7	X	7	X	7	7	X	X	7	X	7	X
21	Microsoft Teams	X	X	X	X	X	X	X	X	X	X	X	X
22	Mikogo	X	X	X	X	7	X	X	X	X	X	7	X
23	Pexip	X	X	X	X	7	X	X	X	X	X	X	X
24	Saynamaste	X	X	7	X	7	7	X	7	X	7	7	7
25	Skype for Business	7	X	X	X	X	X	X	7	X	X	X	X
26	Slack	X	X	7	X	X	X	X	X	X	X	X	X
27	TCS iON	X	X	7	X	7	X	X	X	7	X	7	X
28	TrueConf	X	X	X	X	X	X	X	X	X	X	X	X
29	TurboMeeting	X	X	7	X	7	X	X	X	X	7	X	X
30	VidyoConnect	X	X	X	X	X	X	X	X	X	X	X	X
31	Zoho	X	X	X	X	X	X	X	X	X	7	X	X
32	Zoom	X	X	X	X	X	X	X	X	X	X	X	X

Table 1 provides comparison of 32 OTL apps based on administration (07) and control settings (07) features. The schedule meeting and invite participants are the essential features of any OTL app; hence, all the apps posses these features. It is observed that except a few OTL apps like BigBlueButton, CyberLink U Meeting, Freeconference, LiveStrom and Skype for Business, all other apps have the cloud downloading feature. The screen sharing is another important feature of an OTL app. It is found that only AirMeet and BigBlueButton do not posses this feature. It is observed that Adobe Connect, Amazon Chime, AnyMeeting, At & T, BigBlueButton, Cisco WebEx, Click Meeting, Google Meet, Impartus, Lifesize, Microsoft Teams, Saynamaste, Skype for Business, Slack, TruwConf, VidyoConnect, Zoho and Zoom apps posses the account and auditing feature. Apps like AnyMeeting, LiveStorm and Saynamaste do not posses the active/passive participant feature. The plug-and-play and Ethernet/Wi-Fi features are existing in all the OTL apps. Video hide feature is not included in few apps like Impartus, Jisti Meet, etc. and audio mute feature do not exist only in two apps namely, LiveStorm and TCSiON. Some of the features that are desirable for an OTLapp like keyboard shortcuts and virtual background are not present in few apps. It is observed that, only CyberLink U Meeting and Saynamaste do not possess the remote controlling feature.

Table 2 provides comparison of 32 OTL apps based on screen sharing features. The eight screen sharing features include white board, photosharing, notes sharing, sharecloud, share-URL, bookmarks, screen writing and annotate tools. The White board, notes sharing, screen writing and annotate tools are the important features for an OTL app. From the table, It is observed that out of 32 OTL apps, few apps like Adobe Connect, AT&T Connect, Bigblue button, Cisco Webex, Fuze Meeting, GoTo Meetings, Microsoft Teams, TrueConf and Zoom provides all the screen sharing features, whereas Zoho and Any Meeting apps posses all screen sharing features except the whiteboard. It is also observed that, few screen sharing feature information is not available indicate using NA for few apps.

Table 3 presents the comparison of communication, security and other features of 32 OTL apps. The audio and video support are the prerequisite features of all OTL apps. The language support is another vital feature for any OTL app. Apps like Livestorm, Slak, Lifesize, Saynamaste and TCS iON do not support the Voice Over IP feature, while all other apps supports this feature. The Dial in feature is supported by all 30 apps except Saynamaste and TCS iON apps. The chat and SMS feature is another important feature supported by all OTL apps. About 50% of apps of 32 OTL apps support quiz and exams features along with teaching and presentation. The most important security features are security access and encrypted communication which are provided by all 32 OTL apps. It is observed in the Table 3 that few apps like AirMeet, Amazon Chime, CyberLink U Meeting, Imapartus, Saynamaste, Slack, TCS iON, TurboMeeting and VidyoConnect do not support the admit policy and lock meeting features. The BigBlueButton and Jitsi Meet apps are the apps that are open source among the 32 OTL apps. All 32 OTL apps are browser/app based tools and app demo is available in their help centers.

In continuation, the 32 apps are compared based on the 26 parameters as described in Section 3. Table 4 provides comparison of 32 OTL apps based on management parameters. The capacity and the cost are the primary management parameters of an OTL app. It is observed that the OTL apps like Airmeet, Google Meet, Microsoft Teams, and Zoom supports the highest attendees in a meeting simultaneously. Airmeet claims to accommodate up to a million concurrent attendees, Google Meet support for up to 250 participants and 100,000 live stream viewers, Microsoft Teams is limited to 250 and is can be scaled up to 10,000, and the Live events support attendees up to 10,000 and Zoom licenses start at a capacity of 100 participants and scale up to 10,000 participants. All the 32 Apps maintains a log file to track the transactions and history information. OTL Apps such as Airmeet, AT&T Connect, Cisco Jabber, Fuze Meeting do not offer a free version or a free trial. The vendor does not provide the price of Airmeet and Cisco Jabber. Apps such as GoToMeeting, Impartus, Pexip, Saynamaste, TCS iON, and TurboMeeting do not have a free version but offers a free trial. In contrast, Cisco Jabber is available at zero cost for an end-user license to all Cisco employees. The administrator controls the meeting configuration of the apps such as AirMeet, Cisco Jabber, Cisco WebEx, Impartus, TCS iON, and TrueConf. Moderators and presenters manage BigBlueButton, Lifesize, GoogleMeet, and Zoho

Table 2: Comparison of OTL Apps based on Screen Sharing Features

SN	Apps	White Board	Photo Sharing	Notes Sharing	Share-Cloud	Share-URL	Bookmarks	Screen Writing	Annotate Tools
1	Adobe Connect	X	X	X	X	X	X	X	X
2	AirMeet	7	7	7	X	X	NA	NA	X
3	Amazon Chime	X	X	NA	X	7	X	X	7
4	AnyMeeting	7	X	X	X	X	X	X	X
5	AT & T Connect	X	X	X	X	X	X	X	X
6	BigBlueButton	X	X	X	X	X	X	X	X
7	Cisco Jabber	7	7	7	X	X	X	X	X
8	Cisco WebEx	X	X	X	X	X	X	X	X
9	Click Meeting	7	X	X	NA	X	X	X	NA
10	CyberLink U	7	X	7	X	7	NA	NA	X
11	Freeconference	7	X	7	X	X	7	7	NA
12	FreeConferenceCall	X	X	NA	NA	X	X	X	X
13	Fuze Meeting	X	X	X	X	X	X	X	X
14	Google Meet	7	X	X	X	NA	7	7	X
15	GoToMeetings	X	X	X	X	X	X	X	X
16	Impartus	X	X	X	NA	7	X	X	X
17	Jitsi Meet	7	X	X	7	X	NA	X	X
18	Join me	7	X	7	7	NA	NA	NA	NA
19	Lifesize	7	7	7	NA	7	X	X	NA
20	LiveStrom	7	X	X	X	X	NA	X	X
21	Microsoft Teams	X	X	X	X	X	X	X	X
22	Mikogo	X	X	NA	NA	X	X	X	X
23	Pexip	7	X	NA	X	X	NA	NA	X
24	Saynamaste	7	7	7	7	7	7	NA	7
25	Skype for Business	X	X	7	7	X	X	X	X
26	Slack	7	X	X	X	7	7	X	7
27	TCS iON	7	NA	7	X	X	NA	NA	7
28	TrueConf	X	X	X	X	X	X	X	X
29	TurboMeeting	7	X	X	NA	7	NA	NA	X
30	VidyoConnect	X	X	7	X	7	X	NA	X
31	Zoho	7	X	X	X	X	X	X	X
32	Zoom	X	X	X	X	X	X	X	X

NA: Not Available.

Table 3: Comparison of OTL Apps based on Communication and Security Features

SN	Apps	Communication										Security			
		Audio Support	Video Support	Language Support	Voice Over IP	Dial-In	Chat and SMS	Hand Raise	Polling	Reminder	Quiz and Exams	Admit Policy	Security Access	Encrypted Commn.	Lock Meeting
1	Adobe Connect	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	AirMeet	X	X	X	X	X	X	X	X	X	X	7	X	X	7
3	Amazon Chime	X	X	X	X	X	X	X	7	X	7	7	X	X	7
4	AnyMeeting	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	AT & T Connect	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6	BigBlueButton	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	Cisco Jabber	X	X	X	X	X	X	X	X	X	7	X	X	X	X
8	Cisco WebEx	X	X	X	X	X	X	X	X	X	7	X	X	X	X
9	Click Meeting	X	X	X	X	X	X	7	X	7	7	X	X	X	7
10	CyberLink U	X	X	X	X	X	X	7	X	7	7	7	X	X	7
11	Freeconference	X	X	X	X	X	X	X	SJX	X	X	X	X	X	X
12	FreeConferenceCall	X	X	X	X	X	X	X	X	X	X	X	X	X	X
13	Fuze Meeting	X	X	X	X	X	X	X	X	X	X	X	X	X	X
14	Google Meet	X	X	X	X	X	X	X	X	X	X	X	X	X	X
15	GoToMeetings	X	X	X	X	X	X	X	X	X	X	X	X	X	X

16	Impartus	X	X	X	X	X	X	X	X	X	7	7	X	X	7
17	Jitsi Meet	X	X	X	X	X	X	X	X	X	X	X	X	X	X
18	Join me	X	X	X	X	X	X	7	7	X	7	X	X	X	X
19	Lifesize	X	X	X	7	X	X	X	7	X	7	7	X	X	7
20	LiveStrom	X	X	X	7	X	X	X	X	X	X	X	X	X	X
21	Microsoft Teams	X	X	X	X	X	X	X	X	X	X	X	X	X	X
22	Mikogo	X	X	X	X	X	X	X	X	X	X	X	X	X	X
23	Pexip	X	X	X	X	X	X	X	X	X	X	X	X	X	X
24	Saynamaste	X	X	X	7	7	X	7	7	7	7	7	X	X	7
25	Skype for Business	X	X	X	X	X	X	X	X	7	X	X	X	X	X
26	Slack	X	X	X	7	X	X	X	X	X	7	7	X	X	7
27	TCS iON	X	X	X	7	7	X	7	X	X	X	7	X	X	7
28	TrueConf	X	X	X	X	X	X	X	X	X	X	X	X	X	X
29	TurboMeeting	X	X	X	X	X	X	7	X	X	7	7	X	X	X
30	VidyoConnect	X	X	X	X	X	X	X	X	X	7	7	X	X	7
31	Zoho	X	X	X	X	X	X	X	X	X	7	X	X	X	X
32	Zoom	X	X	X	X	X	X	X	X	X	7	X	X	X	X

Table 4: Comparison of OTL Apps based on Management Parameters

SN	Apps	Capacity	Cost	Meeting Config.	Meeting Duration	No. of Subr.	Focus Group
1	Adobe Connect	1-1500	Free Ver. and Trial, Paid-$17.48/u/m	H	UL	5M	AV
2	AirMeet	1 Million	Not Specified	A	60min	10K+	NA
3	Amazon Chime	1-1000+	Free Ver. and Trial Plus - $2.50/u/m Pro - $15/u/m	H	24hrs-Paid Ver.	40M	NA
4	AnyMeeting	1-1000+	Free Trail Small $150/u/m Medium $200/u/m Large $300/u/m	H	U	U	NA
5	AT & T Connect	1-1500	Starts at $17.48/u/m	H	UL	75M	AV
6	BigBlueButton	1-150	Free Ver.	M	60 min	7.6K	AV
7	Cisco Jabber	1-1000+	Not provided by vendor	A	U	U	AV
8	Cisco WebEx	Jan-00	Free Ver. and Trial $13.5-26.8/u/m	A	40min-Free 24hrs-Paid Ver.	130M	AV
9	Click Meeting	Jan-25	Free Trial $25.00/u/m	H	UL	8.5M	NA
10	CyberLink U	1-100	Free Ver. Pro 50 Plan $29.99/u/m Pro 100 plan $49.99/u/m Pro 500 plan $149.99/u/m	H	30min-Free 24hrs-Paid Ver.	U	AV
11	Freeconference	1-100	Free Ver. $9.99/u/m	H	12hrs-Free	10K+	NA
12	FreeConferenceCall	1-1000	Free Ver. $14.95/u/m	H	UL	1M	NA
13	Fuze Meeting	1-1000	Starts at $ 20.00/u/m	H	UL	2M	NA
14	Google Meet	250-100000	Free Ver. $6 for 25 participants $12 for 50 participants	P	UL	0.85M	AV
15	GoToMeetings	1-1000	14 days Free Trial $14-$19 /u/m	H	UL	5 M	AV
16	Impartus	1-1000	Free Trial $1000/m	A	U	0.2M	AV
17	Jitsi Meet	1-1000	Free	H	UL	5 M	NA
18	Join me	1-499	Free Ver. and Trial Basic $10.00/u/m Pro $20/u/m Pro Business $30/u/m	H	UL	5.24K	AV
19	Lifesize	1-300	Free Ver. and Trial $16.95/u/m	M	UL	2.28K	NA
20	LiveStrom	1-1000+	Free Ver. and Trial $39.00/u/m	H	20min-Free and UL-Paid Ver.	U	NA
21	Microsoft Teams	250-10000	Free Trial $5.00/u/m	H	U	44M	NA
22	Mikogo	1-1000+	Free Ver. and Trial Basic $14/u/m and $156 annual plan	H	UL	U	NA
23	Pexip	500-1000+	Free Trial for 15 days	H	UL	0.5M	NA
24	Saynamaste	1-100	Free Trial	H	UL	U	NA
25	Skype for Business	1-1000	Free Ver., Paid - $12.50/u/m	H	14 days	U	AV
26	Slack	Jan-15	Free Ver. and Trial $6.67/u/m	H	40min	12M	AV
27	TCS iON	Jan-50	Free Trial Rs 60 and Rs 100/student/m	A	30min-Free	0.1M	AV
28	TrueConf	1-1000+	Free Ver. and Trial $450.00/year	A	23min	U	AV
29	TurboMeeting	1-1000+	Free Trial $795.00/one-time	H	UL	4M	AV
30	VidyoConnect	1-499	Free Ver. Starts at $ 18.99/u/m	H	UL	U	AV
31	Zoho	1-1000+	Free Ver. and Trial Rupees 300/u/m	P	UL	20M	NA
32	Zoom	100-10000	Free Ver., Pro - $14.99 Business- $19.99	H	40min-Free 24hrs-Paid Ver.	300M	NA

AV: Available, NA: Not Available, UL: Unlimited, U: Unknown, A: Admin H: Host M: Moderator P: Presenter

Apps, and the host himself controls the other apps. All the 32 apps support a meeting duration of 24 hours or unlimited for the paid version. The Zoom app has a higher number of subscribers. The Focus Group is available for the apps like Adobe Connect, At & T Connect, BigBlueButton, Cisco Jabber, Cisco WebEx, CyberLink U Meeting, Google Meet, GoToMeeting, Impartus, Join me, Skype for Business,

Slack, TCS iON, TrueConf, TorboMeeting and VidyoConnect.

The comparison of 32 OTL apps based on all the 14 performance parameters considered in this paper are provided in Table 5 and 6. Performance parameters like bandwidth, CPU, memory and those related to audio are considered in Table 5 and parameters related to video, Frames Per Second (FPS), data consumption and upload time required are considered in Table 6. From the Table 5, it is observed that the bandwidth requirement of OTL apps range from 500Kbps to 2Mbps for High Quality (HQ) video. The minimum CPU clock speed of an OTL app is 300MHz, and the maximum CPU clock speed is 3.6MHz, and the memory range from 220MB to 8GB. OTL Apps such as Amazon chime, Cisco Jabber, Cisco WebEx, Slack, TCS iON, VidyoConnect, and Zoom apps have the maximum audio latency. The Audio Jitter is more in Cisco WebEx, LifeSize, Saynamaste, VidyoConnect, Zoom.

AnyMeeting and VidyoConnect have the highest video latency, and Fuzemeeting app has the Skype for Business has the highest video jitter. Audio and Video packet loss of all the 32 Apps are listed in the table. It is observed from the table that the apps such as Lifesize, Saynamaste, TrueConf, and Zoom has more number frames per second. The data consumption of apps ranges from 810MB for the standard quality video to 2.5GB for very high quality video The upload time of the OTL varies depending on the file size and available network bandwidth.

The student joins online class by entering the meeting code or right-click over meeting URL, or user-name and password. The teacher who has scheduled online classes is the administrator for the ongoing online class; therefore, the teacher can admit students using manual or automatic options available in the OTL app. All online teaching and learning apps adhere to security standards to keep online class safe. All data is encrypted in transit by default between the student and teacher. In Table 7, most of the OTL app use AES-256/128 bits as end-to-end encryption protocols, merely FreeConferenceCall, Fuze Meeting, Pexip OTL apps use Datagram Transport Layer Security (DTLS) and Secure Real-time Transport Protocol (SRTP) as end-to-end encryption protocols. Most of OTL app follows ISO/IEC 27001:2013 International standard to ensure Security, Availability, Integrity, Confidentiality, or Privacy of user data. Some of the OTL follow System and Organization Control (SOC2) standards to ensure security, availability, processing integrity, confidentiality, and user data privacy.

Table 8 provides comparison of 32 OTL apps based on Quality and Reputation parameters. Display Resolution, Audio Quality, and Video Quality are the significant Quality and Reputation parameters of an OTL App. It is observed that the Cisco Jabber and Google Meet Apps have better display resolution than other Apps. Audio Quality and video quality for all the Apps range from High Definition to Ultra High Definition. The Graphical User Interface of all the apps are Simple, Intuitive, Easy-to-Navigate, User Friendly, and Affordance in user interface design. The vendor stability is Excellent for the Apps such as Adobe Connect, AnyMeeting, Cisco Jabber, Cisco WebEx, CyberLink U meeting, FreeConference, FreeConferenceCall, Impartus, Lifesize, Pexip, and Zoom. The most experienced company that is still in the business line is Amazon that started the Amazon Chime app. FreeConference and FreeConferenceCall are the oldest Apps that are in the market for more than 19 years. The topmost user rating is bestowed to the Zoom App.

Table 5: Comparison of OTL Apps based on Performance Parameters

SN	Apps	Bandwidth	CPU (%)	Memory (GB)	Audio Freq. (KHz)	Audio Latency (ms)	Audio Jitter (ms)	Audio Packet Loss (%)
1	Adobe Connect	512Kbps: SD 1.5Mbps: HD 5Mbps: VHD	14-20	0.512	22	12-14	3-4	0.0
2	AirMeet	1 Mbps	30-50	2	24	12-16	1-3	0.0
3	Amazon Chime	Audio: 54-86Kbps Video: 650Kbps Share: 1.2Mbps (HD)	50-80	2	22	100	10-30	0.0
4	AnyMeeting	1 Mbps	30-50	4	22	50-100	10-30	0.0
5	AT & T Connect	3Mbps	20-30	4	26	50-80	5-10	0.0
6	BigBlueButton	0.5-1 Mbps	10-20	4	22	20-50	5-10	0.0
7	Cisco Jabber	0.5Mbps: SQV 1.0-1.5Mbps: HQV 2.5-3.0Mbps: HDV	25-50	1	24	150	20-50	0.1
8	Cisco WebEx	1Mbps: Host 320Kbps: Others	30-35	0.40	50-12	150	20-50	0.1
9	Click Meeting	Audio: 512 Kbps video SD:1Mbps video HD:2Mbps	30	2	22	80-100	20-30	0.1
10	CyberLink U	3 Mbps	20	1	24	50-80	20-30	0.1
11	Freeconference	HD:1 Mbps	50-80	2	22	40-60	10-30	0.1
12	FreeConference Call	Audio HD: 100Kbps Share: 400Kbps Video: 1.1Mbps	50-80	1	24	50-60	5-10	0.1
13	Fuze Meeting	Audio: 1Mbps Share: 100Kbps Video: 200-300Kbps	80	8	22	70-100	5-10	0.1
14	Google Meet	4Mbps: Host 1.1Mbps: Others	12-25	0.46	25	50-70	7-10	0.0
15	GoToMeetings	Audio: 40Kbps Share: 40K-8Mbps Video: 700K-2Mbps	30	0.45	28	30	20	0.0
16	Impartus	4- 5Mbps	7-20	0.24	20	08	16	0.5
17	Jitsi Meet	4-5Mbps	50-80	8	22	<2 sec	10-50	0.1

18	Join me	1Mbps	80	2	20	80-100	10-15	0.0
19	Lifesize	2Mbps	80-100	1	22	100-200	10-30	0.0
20	LiveStrom	5-15Mbps	5-10	16	24	100-120	10-20	0.1
21	Microsoft Teams	500Kbps: SD 1.5Mbps: HD 2Mbps: VHD	20-30	0.43	24	50-60	30-40	0.1
22	Mikogo	1-2Mbps	10-20	3	22	30-40	20-30	0.1
23	Pexip	HD: 1.6Mbps	10-20	4	26	<2 sec	50	<0.5
24	Saynamaste	1 Mbps	10-20	2	22	200-300	100-150	0.2
25	Skype for Business	Audio: 5Kbps Video: 15Kbps	25-35	2-3.3	24	<150	<35	0.1
26	Slack	2Mbps	25	1	24	100-120	30-40	>0.2
27	TCS iON	2Mbps	20-30	0.51	22	100-150	10-15	0.0
28	TrueConf	1.2 Mbps	30-40	4	24	<1 sec	3-4	0.0
29	TurboMeeting	1.5Mbps	20-30	1	24	50-60	<1 sec	0.1
30	VidyoConnect	6Mbps	30-40	4	22	100-250	10	0.1
31	Zoho	4Mbps: Host 2Mbps: Others	3-14	0.22	24	40-56	20-30	0.0
32	Zoom	600Kbps: SD 1.2Mbps: HD 2Mbps: VHD	7-18	0.24	16-24	100-150	10-40	0.2

Table 6: Comparison of OTL Apps based on Performance Parameters

SN	Apps	Video Freq. (MHz)	Video Latency (ms)	Video Jitter (ms)	Video Packet Loss (%)	Frames Per Second (fps)	Data Cons.	Upload Time (sec⁺)
1	Adobe Connect	55-65	120-150	10-12	0.0	10-20	810MB: SD 1.6GB: HD 2.5GB: VHD	10
2	AirMeet	50-60	10-11	1-5	0.0	26	2GB	10
3	Amazon Chime	30-50	100-150	10-30	0.1	15	500MB-1.2GB	20
4	AnyMeeting	30-50	200-250	30-50	0.1	24-30	1-2GB	20
5	AT & T Connect	30-60	30-80	5-15	0.0	30	1-2GB	20
6	BigBlueButton	20-60	50-80	10-15	0.0	5-15	1GB	15
7	Cisco Jabber	50-60	150-300	10-50	0.5	30	500MB-1.3GB	12
8	Cisco WebEx	50-60	150-300	10-50	0.5	30	700MB:SD 1.2GB:HD 2.3GB:VHD	12
9	Click Meeting	80-100	30-50	50	0.3	30	500MB-2GB	10
10	CyberLink U	60-80	15-30	30	0.1	30	2GB	20
11	Freeconference	50-60	10-15	20	0.2	30	1GB	20
12	FreeConferenceCall	50-60	5-10	20	0.2	30	500MB - 1.6GB	20
13	Fuze Meeting	50-10	30-150	50-80	0.0	30	2GB	20
14	Google Meet	55-60	70-80	10-13	0.0	15-26	810MB:SD 1.4GB:HD 2.4GB:VHD	12
15	GoToMeetings	60-80	20	10	0.1	30	SD:1.5GB	10
16	Impartus	174–216	150	30	0.1	30	1020MB	10
17	Jitsi Meet	100-150	100-150	10-30	0.1	15-30	1GB	15
18	Join me	55-60	80-120	10-15	0.1	30	2GB	25
19	Lifesize	50-60	100-120	10-20	0.2	60	2GB	20
20	LiveStrom	60-80	100-120	10-15	0.1	30	2GB	20
21	Microsoft Teams	50-60	80-100	15-20	0.1	15-30	500MB:SD 1GB:HD 2.1GB:VHD	20
22	Mikogo	50-60	100-150	10-20	0.1	30	500 MB	20
23	Pexip	150	150-160	30-40	0.4	30	600MB:SD 2GB:HD	20
24	Saynamaste	150-200	100-150	30	<0.4	30-60	2GB	40
25	Skype for Business	25-70	<300	<67	<0.2	30	2GB	10
26	Slack	30-50	7-9sec	20-30	0.7	30	600Mb-2GB	30
27	TCS iON	30-50	100-120	10-15	0.0	30	2GB	15
28	TrueConf	40-50	150-300	10-20	0.0	30-60	0.2MB:SD 2MB:HD 4MB:VHD	20
29	TurboMeeting	55-65	120-150	10-15	0.2	29	500MB	30
30	VidyoConnect	50-60	200	15	<0.5	30	500MB:SD 1GB:HD 2GB:VHD	20

| 31 | Zoho | 55-60 | 100-120 | 15-16 | 0.0 | 30 | 720MB:SD 1.2GB:HD 2.4GB:VHD | 20 |
| 32 | Zoom | 50-60 | 100-150 | 10-20 | 0.2 | 30-60 | 810MB:SD 1.35GB:HD 2.4GB:VHD | 20 |

+: Depends on file size and available network bandwidth

Table 7: Comparison of OTL Apps based on Security Parameters

SN	Apps	Authorization	Authentication	Admit Policy	Secure Access	Encryption-Decryption
1	Adobe Connect	Admin	Login Name, PW	A†	ISO27001, GLBA	AES 256bit
2	AirMeet	Host	Login ID	M*	No Information	No information
3	Amazon Chime	Organizer	Meeting ID	M	Amazon S3	AES 256bit
4	AnyMeeting	Organizer	Email, Meeting ID	M	SOC 2 Type II	TLS/DLS
5	AT & T Connect	Host	Email, Meeting ID	M	ISO27001	AES 128bit
6	BigBlueButton	Admin	Meeting URL	M	No Information	Encryption-Moodle
7	Cisco Jabber	Admin	Username, Email	M	SAE-16/ISO-27001	SSL/TLS
8	Cisco WebEx	Host	Name, Email PW	M	SOC3	AES 128bit SHA
9	Click Meeting	Admin	Meeting ID, Email	M	SOC 2	AES 256bit SSL
10	CyberLink U	Admin	Email	M	No information	AES 128bit
11	Freeconference	Organizer	Email, Meeting ID	M	No information	SSL/TLS
12	FreeConferenceCall	Host	Email, PW	A	SSAE-16	DTLS SRTP
13	Fuze Meeting	Host	Meeting ID/URL	M	ISO27001	SSL/DTLS
14	Google Meet	Organizer	Gmail ID	M	ISO 27001	AES 256bit
15	GoToMeetings	Host	Meeting ID	M	ISO27001	AES 128bit
16	Impartus	Host	Unique ID, PW	M	No Information	AES 128bit
17	Jitsi Meet	Admin	Login name, PW	M	No information	No information
18	Join me	Host	Email PW	M	No information	AES 128/256bit
19	Lifesize	Host	Email, PW	SSO+	AWS	AES 128bit
20	LiveStrom	Organizer	Name, Email ID	M	No information	TLS SSL
21	MS Teams	Owner	Username, PW	A	Azure Active Dir.	AES 256bit
22	M1Zikogo	Admin	Meeting ID, Name	M	ISO 27001	AES 256bit
23	Pexip	Admin	Single sign-on	M	SO/IEC 27001	DTLS SSL
24	Saynamaste	Admin	Name, ID, Code	M	No information	AES 256bit
25	Skype4B	Organizer	Email, PW	M	ISO 27001	AES 256bit
26	Slack	Admin	Email, PW	M	SO/IEC 27001	No e2e
27	TCS iON	Admin	ID number	A	Homo Encryption	AES 256bit
28	TrueConf	Host	Registration Key	M	SOC 2 ISO27001	AES 256bit
29	TurboMeeting	Host	Meeting URL	M	No information	No information
30	VidyoConnect	Host	Meeting link	M	No information	AES 128bit TLS
31	Zoho	Presenter	Client ID Code	M	SOC 2 Type II	AES 128bit
32	Zoom	Host	Meeting ID, PW	M	SSAE16 SOC2 T2	AES 256bit

Table 8: Comparison of OTL Apps based on Quality and Reputation Parameter

SN	Apps	Display Resolution	Audio Quality	Video Quality	GUI	Vendor Stability	Company Estd.	App Launch	User Rating
1	Adobe Connect	1024768	HD	HD, HQ	Intuitive	Excellent	2018	2018	2.9
2	AirMeet	19201020	HD	HD	Comfort	Good	2019	2019	3.7
3	Amazon Chime	1024768	HD	HD	Easy	Good	1994	2019	3.7
4	AnyMeeting	19201080	HD	HD, FHD	Simple	Excellent	2009	2009	3.9
5	AT&T Connect	1024768	HD	VGA, HD	Simple	Good	2016	2016	4.1
6	BigBlueButton	1366768	HQ	HD	Easy	Good	2006	2009	3.4
7	Cisco Jabber	38402160	HD	FHD, UHD	Navigate	Excellent	2008	2008	4.0
8	Cisco WebEx	19201080	HQ	HD, FHD	Navigate	Excellent	1995	2007	4.2
9	Click Meeting	19201080	HD	HD	Interactive	Good	2010	2012	3.1
10	CyberLink U	19201080	HD	FHD	Intuitive	Excellent	2017	2017	4.2
11	Freeconference	19201080	HD	FHD	Interface	Excellent	2001	2001	3.7
12	FreeConferenceCall	1024760	HD	VGA, HD	Navigate	Good	2001	2001	4.2
13	Fuze Meeting	19201080	HD	FHD	Simple	Good	2006	2006	3.6
14	Google Meet	25601440	HD	HD, FHD	Comfort	Good	1998	2010	3.7
15	GoToMeetings	19201080	HD	HD, FHD	Design	Good	2004	2004	4.2
16	Impartus	19201020	HD	HD, FHD	Navigate	Excellent	2013	2013	3.8
17	Jitsi Meet	1280720	HD	HD	Simple	Good	2003	2003	3.4
18	Join me	1280720	HQ	HD	Friendly	Good	2003	2003	4.3
19	Lifesize	19201020	HD	HD, FHD	Intuitive	Excellent	2003	2005	3.9
20	LiveStrom	1280960	HD	HD	Simple	Good	2016	2016	4.1
21	MS Teams	10801920	HD	HD	Navigate	Good	2017	2017	4.4

22	Mikogo	1280720	HD	HD	Easy	Good	2009	2009	2.9
23	Pexip	19201080	HQ	HD, FHD	Navigate	Excellent	2012	2012	4.3
24	Saynamaste	1280720	HD	HD, FHD	Simple	Good	2020	2020	3.6
25	Skype for Business	1280720	HD	HD, FHD	Easy	Good	2015	2017	4.4
26	Slack	12801024	HD	HD	Simple	Good	2014	2015	4.3
27	TCS iON	19201080	HD	HD	Friendly	Good	2018	2018	2.9
28	TrueConf	19201080	HD	HD	Simple	Good	2003	2003	4
29	TurboMeeting	1366768	HD	HD	Navigate	Good	2005	2005	3.2
30	VidyoConnect	1024768	HD	HD	Simple	Good	2005	2005	3.3
31	Zoho	1280720	HD	HD	Highly	Good	2006	2013	2.9
32	Zoom	1080480	HD	HD	Design	Excellent	2011	2013	4.5

Table 9: Comparison of OTL Apps based on Support Parameters

SN	Apps	Platform	Min. Hardware	Plugin	Web Browser	User Support
1	Adobe Connect	Windows 8.1, Mac OS, Android 4.4,iPad, iOS	1.4GHz, 1GB RAM	Moodle	IE 11, Chrome Edge, Firefox,	Connect Support
2	AirMeet	iOS, Android, Windows 8	1.2G Hz 2 GB RAM	No Specific Plugin	IE, Firefox Edge, Chrome,	Unknown
3	Amazon Chime	Windows 7 Mac OS 10.11, iOS 10.0	2 GHz, 3 GB RAM	Amazon Chime, Chrome	Edge, Chrome Safari Firefox	Amazon Chime Help Center
4	AnyMeeting	Windows 7 Mac OS 10.8 Linux/Ubuntu	300 MHz 4 GB RAM	VMWare Console Browser Plugin	IE, Safari, Edge, Firefox, Chrome	Intermedia AnyMeeting
5	AT & T Connect	Windows Mac OS and iOS	300 MHz 128 MB RAM	Adobe Flash player	IE, Chrome Edge, Firefox	At & T Connect Support
6	BigBlueButton	iOS 12.2+ and Android 6.0+ Ubuntu 16.04	2 GB RAM, 500 MHz	BBB Plugin	IE, Safari,Chrome Edge, Firefox	Community Support
7	Cisco Jabber	Windows 10 Mac OS 11/12 iOS 12 Ubuntu 14.04 32-bit	2.16 GHz, 2 GB RAM	SDK and Sennheiser Cisco Jabber	IE, Safari, Edge, Firefox, Chrome	Cisco Jabber - Webex Help Center
8	Cisco WebEx	Windows 7, Mac OS Android 4.4,iOS, iPad	2 GHz, 2 GB RAM	No Plugins	IE, Chrome, Edge, Firefox	WebEx Help
9	Click Meeting	Windows 8/10, Mac OS 10.13 or higher, Linux	2 GHz 2 GB RAM	Zaiper Dropbox	Chrome,Firefox, Safari, Edge, Opera	Knowledge Base
10	CyberLink U	Windows 1/8.1/10 Mac, iOS	4 GB RAM	No Plugin	IE, Chrome, Edge, Firefox	U Support Center
11	Freeconference	Windows Mac OSX 10.7 Ubuntu 12.04 and up	2 GHz Proc., 3 GB RAM	Outlook	IE, Safari,, Firefox, Chrome	Live-Support
12	FreeConference Call	Windows 7 and up Mac OSX 10.9 and up Ubuntu 14.04 and up	1 GHz Proc., 2 GB RAM	Microsoft Outlook	IE 10, Safari Firefox, Chrome 16	Support Center
13	Fuze Meeting	Windows 7/8/10 or later iOS 12/13 Android 10.0	300 MHz, 2 GB RAM	No specific Plugin	IE, Safari, Edge, Firefox, Chrome	Fuze Help Center
14	Google Meet	Windows/8, Mac OS 10.13, Ubuntu 16.x Android 4.4, iOS 8.1.2, iPad	2 GHz, 3 GB RAM	No specific Plugin	IE 11, Safari, Edge, Firefox, Chrome	Google Meet Help
15	GoToMeetings	Windows 7/10, Mac OS X 10.9 Linux/Ubuntu	1.5 GHz, 2 GB RAM	No specific plugin	Chrome and Edge	GoTo Support
16	Impartus	Windows/Mac/Ubuntu	1 GHz 2 GB RAM	No plugins	IE, Chrome, Edge, Firefox,	Impartus Support
17	Jitsi Meet	Windows 32bit and up MAC OS X 10.6/10.7 Ubuntu	2 GHz, 1GB RAM	Moodle	IE, Safari, Edge, Firefox, Chrome	Telephony Support on meet.jit.si
18	Join me	Windows 7/8/8.1/10 Mac OS X and up iOS 11/13	2 GB RAM	Microsoft Outlook	IE 11, Chrome Edge, Firefox,	Contact Support
19	Lifesize	Windows, Mac iOS, Android	1.3 Ghz 2 GB RAM	Microsoft Outlook	Safari, Chrome Edge, Firefox	Lifesize Customer Support
20	LiveStrom	Windows, Mac, iOS, Android	1.2 GHz., 2 GB RAM	No plugin	Safari, Chrome Opera, Firefox	LiveStrom Documentation
21	Microsoft Teams	Windows 7, Mac OS 10.xx, Ubuntu 16.x, Android 4.4, iOS 8.1.2, iPad	1.6 GHz Proc., 2 GB RAM	Microsoft Outlook	IE 11, Safari, Edge, Firefox, Chrome	Microsoft Support
22	Mikogo	Windows 7,iOS Mac OS, Android	2 GB RAM	No Plugins	IE, Chrome, Edge, Firefox,	Tech-Support
23	Pexip	Microsoft Windows 7 Mac OS X 10.7, Linux	2.7 GHz 2GB RAM	Pexip Client	Opera, Chrome Edge, Firefox	Pexip Service Help Center
24	Saynamaste	Mac, iOS, Android	1 GHz, 2 GB RAM	No Plugin	Firefox, and Chrome	Unknown
25	Skype for Business	Mac OS, Windows, Android, iOS, Linux	1 GHz, 2 GB RAM	Web App plug-in	IE, Chrome, Firefox	Skype for Business help

26	Slack	Mac OS, Windows 7 Linux, iOS, Android 5.0	586 MHz, 2 GB RAM	Jenkins Dropbox	Safari, Edge, Firefox, Chrome	Slack Help Center
27	TCS iON	Windows Android 2.3. 6 and above	2 GHz 2 GB RAM	No Plugin	Firefox, Chrome	iON Help Central
28	TrueConf	Mac OS 10.7.5+ iOS, Android 6+ Windows 7/8/8.1/10	3.6 GHz, 2 GB RAM	Web RTC	IE, Safari, Edge, Firefox, Opera, Chrome	TrueConf Support Center
29	TurboMeeting	Windows, Mac 10.7 iOS 7.0, Linux, Android	2 GB RAM	R-HUB Server	IE, Chrome, Edge, Firefox	RHUB Support
30	VidyoConnect	Mac OS, iOS Android: 5.0 Windows 7	2 GHz, 4 GB RAM	VidyoNeo Outlook	IE, Chrome, Edge, Firefox	VidyoCloud Support
31	Zoho	Windows 7, Mac OS 10.xx, Ubuntu 16.x, Android 5.x, iOS 8.1.2 iPad	1 GHz, 2 GB RAM	CRM-Plugin	IE, Safari Opera Firefox, Chrome	Zoho Help
32	Zoom	Windows 8, Mac OS 10.xx, Ubuntu 16.x, Android 4.4, iOS 8.1.2 iPad	2 GHz, 4 GB RAM	Microsoft Outlook	IE 10, Safari, Edge, Firefox, Chrome	Zoom Support

Table 9 gives overview of various supporting parameters. Understanding support parameters are essential to run any OTL apps either on desktop or on mobile devices. The minimum memory and CPU clock speed required to execute OTL is given in table. It is observed from table that, the minimum CPU clock speed can be 300MhZ and maximum CPU clock speed can be 3.6Mhz. All OTL apps can execute on all operating system. It is noticed from the table that CyberLinkU Meeting and AT & T connect OTL app do not support Android Operating system. The AT&T require 128MB and 300Mhz CPU clock speed to run app on desktop. The VMWare Console Browser Plugin is required for AnyMeeting app, AT&T Connect require Adobe Flash player to execute the app. Similarly, BBB Plugin required for BigBlueButton, SDK and Sennheiser plugins for Cisco Jabber. TCSiON supports only Firefox and Google Chrome web browser, but all other apps support all web browsers available. Each app provides its own user manual and help centre for user. It is noticed from the table that AirMeet installation procedure is unknown. It is observed that Google meet, Microsoft Team, Zoom and WebEx app minimum hardware requirements are almost same and support all operating systems. Finally, the installation procedure for many of the apps is found to be easy and quite a few is moderate. However, few apps like AnyMeeting and Zoho provides installation on desktop computers to be easy compared to on mobile devices. Installation guidelines are also provided to guide the user to install the app on desktop, pads and mobile devices.

5. World's Six Top Online Teaching Apps

In this section, out of the32appsidentifiedin Section2, world's six popular OTL apps are selected based on the features, parameters, usage and popularity. These includes1 Adobe Connect, Cisco WebEx, Google Meet, Microsoft Teams, Zoho and Zoom,. A summary of these six apps based on the comparison with respect to features and parameters in Sections 2 and 3 is presented in the following subsections.

5.1. Adobe Connect

Adobewasfoundedin1982byJohnWarnockandCharlesGeschke. Adobe Connect was launched in July 2003 as a web conferencing system that enables secure online meetings, training and webinars that anyone can access through any web browser. It allows the user to easily create online meetings and web communications that include voice, video, animations, and interactive multimedia that participants view using the Adobe Flash Player run-time in a browser or from mobile applications. Adobe Connect supports HD audio and video. It allows screen sharing on desktop, tablet and mobile devices running Adobe Connect and optimize the screen sharing quality. This app allow to share a whiteboard that host and other participants can annotate on. It offers multiple methods to schedule a meeting. A host has control over the options for their scheduled meetings except for settings that an administrator has locked for all users in the account or for all members of a specific group. In addition, Adobe Connect provides features like chat and SMS, cloud based download, screen recording, admit policy, video hide, audio mute, hand raise, polling, etc. However, the plug-and-play, quiz, exams, are some of the features that are not supported in this app. The capacity of the app is 1000 and has a good user interface.

Adobe Connect provides both encryption in-transit as well at-rest using 256-bit AES algorithm. The bandwidth used by Adobe Connect will be optimized for the best experience based on the participants' network. It will automatically adjust for 3G, Wi-Fi or Wired environments. The recommended bandwidth for meetings and webinars include:
1) 512Kbps (up/down) for high quality video
2) 1.5 Mbps (up/down) for 720p HD video
3) 5 Mbps (up/down) for 1080p HD video

The six apps are listed in alphabetical order with neither prioritizing nor persuading any app.
Adobe connect consumes data depending on the multiple features like video call, audio call, screen sharing, whiteboard etc. For example, if host make a 1080p HD video call, that lasted one hour, he would use 1.6GB of data downloading video, and another 1.6GB uploading video. That brings the total usage for the hour to just over 3GB. Adobe connect provides the following administrator features to enhance security:
1) Disable undesired functionality.
2) Disable screen Sharing.
3) Record and retain communications for auditing purposes.
4) Control access to meetings.

In addition, some of the security access features provided includes:
1) Role-based user security
2) Host and client authenticated security
3) Open or password protected meeting
4) Edit or delete meeting
5) Host controlled joint meeting 6. In-meeting security

Adobe Connect uses 1024x768 display resolution for screen sharing.

5.2. Cisco WebEx

Cisco WebEx is an American company that develops and sells web conferencing and video conferencing applications [54]. It was formed in 2007 when Cisco Systems acquired Webex. Webex was founded in 1995 by Subrah Iyar and Min Zhu [55].

WebEx meeting is a tool to conduct online meetings and video conferences, that allows to virtually meet with other people, without leaving your home or office. With this high-tech software, you can organize events, webinars and video conferences. Webex Meeting Center offers numerous services that make it easier for businesses to communicate. It is in business since 1995, so you can be assured that this online web conferencing tool will provide dependable and cost-effective service [56].WebEx supports HD audio and video. It allows screen sharing on desktop, tablet and mobile devices. This app allow to share a whiteboard that host and other participants can annotate on. It offers multiple methods to schedule a meeting. A host has control over the options for their scheduled meetings except for settings that an administrator has locked for all users in the account or for all members of a specific group. In addition, WebEx provides features like chat and SMS, cloud based download, screen recording, admit policy, video hide, audio mute, hand raise, polling, etc. However, quiz and exams features are not supported in this app. It is not an open source. The capacity of the app is 3000 and has a good user interface. It provides 33 keyboard shortcuts.

All communications between Cisco Webex applications and Cisco Webex Cloud occur over encrypted channels [57]. Cisco Webex uses TLS 1.2 protocol and uses high-strength ciphers (for example, AES 256). After a session is established over TLS, all media streams (audio VoIP, video, screen share, and document share) are encrypted. User Datagram Protocol (UDP) is the preferred protocol for transmitting media. In UDP, media packets are encrypted using 128-bit AES. The initial key exchange happens on a TLS-secured channel. Additionally, each datagram uses Hash - Based Message Authentication Code (HMAC) for authentication and integrity. It will automatically adjust for 3G, Wi-Fi or Wired environments.

The recommended network bandwidth for meetings and webinars is from 320Kbps per participant to 1Mbps per participant. In WebEx, data consumption is dependent on the multiple features like video call, audio call, screen sharing, whiteboard etc. It consumes 0.7GB for Standard Definition 360p video, 1GB per hour for Webinar and 300MB for WebEx call.

WebEx supports all platforms like Windows, Mac OS X, Linux and Solaris, iOS, Android. It is easy to install and support the integration of Microsoft Office, Google Calendar, Facebook Live and more.

Webex has High Resolution Display support; you may set your display settings to 1080p - 19201080. It Supports 16 languages such as Chinese, Danish, Dutch, English, French, German, Italian, Japanese, Korean, Portuguese (Brazil),cRussian, Spanish (European), Spanish (Latin America), Swedish and Turkish.

WebEx provides the administrator features to enhance security such as Disable Undesired functionality, Disable Screen Sharing, Record and retain communications for auditing purposes, Control access to meetings. In addition, some of the security access features provided includes Role-based user security, Host and client authenticated security, Open or password protected meeting, Edit or delete meeting, Host controlled joint meeting, In-meeting security etc.

5.3. Google Meet

Google meet app provides a platform for teacher to transfer his subject erudition to students/learners [43]. To achieve the objective of teaching-learning process, Google meet provides smooth navigation, screen sharing, record and broadcast meetings, use of caption, chat message, share attachment and live stream video meeting. The Internet connection may not be stable, therefore, Google Meet allows to upload contents of meetings, resources on cloud and such contents are available and accessible at any time. The Google Meet is not device specific, it is accessible on all devices and compatible with all operating systems. The Google Meet has end-to-end encryption to prevent accidental accessing data by an unauthorized user.

The Google Meet enable teacher or students either to start new video online or join video online. A teacher can start a new video online class from laptop or computer or mobile device with G suite account or gmail account. Teacher schedules online class with Google Calendar, Microsoft Outlook or another scheduling system and send scheduled events details to student through email or display URL of meeting. The student who has access to gmail can join the meeting by clicking Join Meeting in sidebar, and enter meeting code or nickname. The student can also join online class by selecting the online class/meeting from list of scheduled events. Other options for joining online class are by clicking the online class/meeting link sent in a chat message and dial-into meetings with a phone.

Once online class begins, Google Meet automatically display the active content and students. Teacher appear in large tile with all students on sidebar, a teacher can see 16 students in tiled windows. Teacher can pin a student, mute/un-mute student's microphone and remove students from online class. Google Meet provides a chat option to send messages to other from a computer or mobile device during ongoing online class. Teacher can share entire screen or a specific window in an ongoing class. While teaching, a teacher can share information such as documents, presentations, window desktop, command prompt, whiteboard and more. If a student wants to present, he/she

can present his/her screen and it is visible to others. The online class can be recorded for students to watch later. The online class recording can be saved on the drive and mail the recording link to the students. In the bottom-left corner, Google Meet display online class name, link, agenda, description, attachments and attendees.

The Google Meet supports upto 250 students/ participants and message/content is encrypted in transit by default. The bandwidth requirement depends on the number of participants as follows [44]:
1) 2.6 Mbps with 2 participants
2) 3.2 Mbps with 5 participants
3) 4.0 Mbps with 10 participants
4) Inbound signals from a participant in all situations must meet a 3.2Mbps band width requirement.

The Google Meet utilizes 5% to 7% CPU cycle and 466MB memory is required when Google Meet run on Google Chrome. Google Meet app has the following technical specifications.
1) Audio Frequency: 25KHz to 26KHz.
2) Audio Latency: Send-50ms and Receive-40ms.
3) Audio Jitter: Send-7ms and Receive 10ms for 30 minutes duration and 932 participants.
4) Audio Packet Loss: participants [45]. Send-0.0% and Receive-0.0% 10ms for 30minutes duration and 932
5) Video Frequency: 55MHz to 60MHz.
6) Video Latency: Send-80ms and Receive-70ms.
7) Video Jitter: Send-10ms and Receive-13ms.
8) Video Packet Loss: Sender 0
9) Frame Per Second: Send-15fps and Receive-26fps
10) Resolution: SD quality 1280720 pixels, HD quality 19201080 pixels.

The Google Meet supports different devices such as desktop/laptop with 2.2GHz, iPad and iPhone, Mobile with Android OS. The video quality supported by Google Meet are 360p for SD, 720p for HD.

5.4. Microsoft Teams

Microsoft has founded in 1975 by Bill Gates and Paul Allen. Microsoft Teams was launched in March 2017. Microsoft Teams is a Unified Communication and Collaboration Platform which enables

Secure Video Meetings, WorkplaceChat, Online Training and Application Integration. MicrosoftTeams service integrates with Office 365 subscription office productivity Suite, which allows to integrate with non Microsoft products also for extension of features.

The Microsoft Teams offers multiple methods to schedule a meeting. It allows groups, teams or communities to join meeting through a specific URL or invitation sent by an administrator or owner (host). Microsoft Teams for Education allows admins and teachers to setup a specific team for online classes or training. It supports online Quiz and Assignments for students through integration with office forms.

The Microsoft Teams supports Instant private or group messaging, HD quality audio and video. It allows Screen Sharing on desktop and tablet. It supports to record a meeting or a group call. It does not have white board feature but it allows to integrate with Microsoft white board app so that meeting participants can annotate on the digital canvas and share.

The Microsoft Teams provides a cloud storage capacity of 1TB to 25TB depending on the subscription. It provides features like chat and SMS, cloud based download, admit policy, video hide, audio mute, Polling etc. The capacity of the application is 10000 and has a good user interface.

The Microsoft Teams provides Transport Layer Security (TLS) and mutual TLS (MTLS) which encrypt instant message traffic and enable end-point authentication. Point-to-point audio, video, and application sharing streams are encrypted and integrity checked using Secure Real-Time Transport Protocol (SRTP) and other industry standard Encryption techniques, including 256-bit Advanced Encryption Standard (AES) Encryption, all Microsoft Teams data is protected on the network.

The Microsoft Teams is designed to give the best audio, video and content sharing experience regardless of user's network conditions. If bandwidth is insufficient, Microsoft Teams prioritizes audio quality over video quality. Microsoft Teams is always conservative on bandwidth utilization.

Recommended bandwidth for meetings and webinars:
1) 30Kbps : Peer-to-peer audio calling
2) 130Kbps: Peer-to-peer audio calling and screen sharing
3) 500Kbps: Peer-to-peer quality video calling 360p at 30fps
4) 1.2Mbps: Peer-to-peer HD quality video calling with resolution of HD 720p at 30fps
5) 1.5Mbps: Peer-to-peer HD quality video calling with resolution of HD 1080p at 30fps
6) 500Kbps/1Mbps: Group Video calling
7) 1Mbps/2Mbps: HD Group video calling (540p videos on 1080p screen)

Microsoft Teams provides the following security access features:
1) Role-based user security
2) Host and Client authenticated meeting
3) Edit or delete meeting
4) Host controlled joining meeting
5) InMeeting Security
6) Media Encryption

Microsoft Teams Provides better security by handling the following attacks.
1) Compromised-Key Attack
2) Network Denial-of-Service Attack
3) Eavesdropping
4) Identity Spoofing (IP Address Spoofing)
5) Man-in-the-Middle Attack
6) RTP Replay Attack
7) Spim
8) Viruses and Worms

Microsoft Teams supports 1024x768 display resolution.

5.5. Zoho

The Zoho Meeting app facilitates teacher to host web-based live interactive online class with students. The online class with audio and video, whiteboard and screen share option encourages teacher to deliver presentations or demonstrate concepts. It enables students to ask their doubts and get a relevant answer on the topic. The Zoho meeting enables the teacher to ask students to demonstrate what they learned; if the student fails to do so, the teacher can clarify topics where the student is unable to do so.

The Zoho Meeting app is compatible with all modern operating systems, browsers and mobile devices. The following are the minimum requirements to conduct or attend online-class using Zoho meeting app.
1) Laptop/Desktop with Windows 7/MacOS/Linux or Android 5.x or iOS 10 Mobile phone or iPad or iPhone with latest Operating system.
2) Built-in wireless speakers and microphone.
3) For audio-online class, required Internet speed is 2Mbps. For audio and video online class, required Internet speed is 5Mbps. For audio, video, and screen sharing online class, required Internet speed is 8Mbps.
4) Download Zoho Meeting desktop app for Laptop/Desktop or Zoho Meeting iOS or Android apps for mobile phones.

A Teacher can schedule online class using Zoho Meeting app, online class details and the email addresses of students are entered in the schedule meeting form. All the students of class will receive invitations through e-mail, using invitation, the student can join the scheduled online class. The Teacher also send online class invitation by embedding online class link in organization website. The student can join online class by entering their e-mail address. The scheduled online class details are added to Zoho and Google calendar to get remainders for students and teacher.

The Teacher can record online class with start record option available in Zoho meeting app. The recorded online class can be shared with students who could not attend class. Teacher starts explanation and demonstrates concepts on white board, Zoho meeting app provides a set of annotated tools that assist the teaching process. Teacher set the tone of interaction with students by encouraging students to ask their doubts and get relevant answer. In Zoho Meeting, the teacher Lock ongoing online class to reduce interruptions, mute students audio or video to minimize noise and encourage constructive discussion into online class. Teacher can see list of attendees on the left pane. The teacher can either give control to the students, or the students can request control during screen sharing. The remote access option in Zoho meeting enables students of an online class to interact with the teacher's screen, and collaborate on documents. The students can use Raise Hand option as a signal to get the attention of the teacher and ask questions or share thought to everyone. The Zoho meeting app allows teachers to conduct live polls to gather students' responses on a subject they learned.

The Zoho meeting uses SSL/128-bit AES encryption protocols for end-to-end encryption and decryption [13]. If teacher/students/customer faces any problems, teacher/students/customer can call support center and get response, it takes on average 456 seconds for any type of service[11] it supports different types of display resolution. For standard resolution, 720 MB data is consumed for one hour online class, for high resolution, 1.2GB data is consumed for one hour online class using Zoho meeting app, similarly for 1080p-2.4 GB per hour [12]. The zoho app uses 24KHz audio frequency to send/receive audio, use 55MHz-60MHz frequency to send/receive video and send/receive 30ftp in one hour class.

5.6. Zoom

The Zoom Video Communications, Inc. (Zoom) is an American communications Technology Company headquartered in San Jose, California. Eric Yuan, a former Cisco Webex engineer and executive, founded Zoom in 2011, and launched its software in 2013 [47]. It was founded by Eric Yuan, who was inspired to develop the software while, as a student in his native China in 1987, he took 10-hour train rides to visit his girlfriend and was looking for an easier way to "visit" her. After receiving a travel visa on his 9th attempt, Yuan immigrated to the United States in 1997 and joined Cisco Webex. He rose to Vice President, but after realizing that customers were not happy with the product, he left in 2011 to start Zoom app. With the help of 40 engineers, Zoom launched a beta version in September 2012 that could host conferences with up to 15 video participants [48]. In January 2013, the company raised a $6 million Series and by the end of its first month, Zoom had 400,000 users [49]. By May 2013, it had 1 million users [50].

The Zoom is a cloud-based video conferencing tool with a local, desktop client and a mobile app that allows users to meet online, with or without video and it is popular for its ease of use, high quality HD video and audio, and collaboration facilities such as text chat and screen sharing performance across Windows, Mac, Linux, iOS, Android, Blackberry, Zoom Rooms, and H.323/SIP room systems. It provides consistent and powerful services such as video webinar, Zoom Rooms, online meetings and group messaging. Zoom users can choose to record sessions, collaborate on projects, and annotate and co-annotate shared documents as well as gain control of the keyboard, mouse, and even the whiteboard on one another's screens all with one easy-to-use platform.

The Zoom supports features like dynamic voice detection and a choice of either full-screen, gallery view, or both using dual streaming for those with twice the amount of screens. The data Consumption in Zoom is for 360p High Quality Video requires 810MB per hour, for 720p HD Video consumes 1.35GB per hour, and for 1080p HD video consumes 2.4GB per hour [51].

The Zoom can encrypt all presentation content at the application layer using the 256-bit AES algorithm. The Zoom chat encryption allows for a secured communication where only the intended recipient can read the secured message [52].

In Zoom, we have the option of either starting an instant meeting or creating a scheduled meeting. When you schedule a meeting, a Personal Meeting ID will be assigned for you to share or distribute. As a host you have special privileges to record a meeting or mute participants. The Zoom allows you to create MP4 and M4A recordings throughout a meeting, and offers Google Chrome and Outlook plug-ins. During zoom meeting, participants can have the option of virtually raising their hand for permission to ask a question or speak to a group. And using the Zoom meeting format's breakout groups, hosts can designate times for small group collaboration without ending or restarting a meeting.

The Zoom helps universities and schools to improve student outcomes with secure video communication services for hybrid classrooms, office hours, administrative meetings, and more. The Zoom provides the powerful virtual classroom security settings for teachers and admins to ensure disruption-free virtual classes and increase student participation and learning retention with virtual and hybrid classrooms and micro-learning. It is an ideal tool for any business as it provides a great communication experience at an incredibly affordable cost and the basic version is also completely free of charge. This platform is uniquely designed and optimized to offer seamless services and maximum reliability, and it comes with a user-friendly interface [53].

6. Comparison of Six Popular OTL Apps with respect to Features and Parameters

In this section, the six popular OTL apps are compared with respect to features and parameters. Table 10 provides the comparison of six popular OTL apps namely Adode Connect, Cisco WebEx, Google Meet, Microsoft Teams, Zoho and Zoom with respect to 46 features. The seven administration features mentioned in table are supported by all six OTL apps except Google meet do not provide the Contact status feature. It is found that, all six OTL apps supports the seven control settings features except keyboard shorcuts does not exist in Zoho app. The Google Meet and Zoho do not provide white board, we have to integrate separately with this app and use for teaching. In Google Meet, URL sharing, bookmark and screen writing features do not exist. All communication features exist in six OTL apps, except quiz and exams feature is provided by Microsoft Teams Only. It is observed that all the six OTL apps are secured by providing the security features like security access, encrypted communication, admit policy, and Lock meeting. The features like browser/app based, app demo, and 247 features are furnished by all six OTL apps. Further, it is observed that, all these six OTL apps selected are not open source tools.

In Table 11, the comparison of six apps selected are compared with respect to management, performance, security and quality parameters. In Table 12, the comparisons of six apps selected are compared with support and reputation parameters.

From the Table 11, it is observed that the capacity of Microsoft teams and Zoom provide more number of participants at a time with a maximum of 10,000 participants, whereas the Google Meet allows to connect only 250 participants. The lag in Zoom app is less (35-40ms) comparatively with other apps since there is no call dropping and calls are not static. Zoom permits the host to schedule a meeting for 40 minutes free duration. The usage and subscription cost of the OTL app is free, per person, per host or per month basis. All the six OTL apps provide unlimited duration of the meeting in which the app is subscribed. However, Google Meet and Zoom provide 40 minutes free version of using the app. One of the important parameters in which an OTL app may be evaluated is based on the number of subscribers. It is found that, out of six OTL apps chosen, Zoom has the highest number of apps i.e. 300 Million subscribers. Further, the focus group is available in apps like Adobe Connect, Cisco and Google Meet, whereas the other three do not posses this feature. It is found that the bandwidth required by the Adobe Connect and Microsoft teams is minimum with 512Kbps and 500kbps for standard definition (SD) and the bandwidth required by the Microsoft teams and Zoom is minimum with 2Mbps and for Very High Definition (VHD). The CPU consumption of Zoho app is the minimum with 3 14% and Cisco WebEx with maximum 30 35%. The minimum average memory usage is with Zoho app and Adobe Connect consumes more memory relatively compared to other OTL apps.

Table 11 shows the data consumption for one hour video by different OTL apps. Google Meet consumes up to 1.4GB for HQ quality and up to 810MB for SD quality. Further, it is observed that, Zoho Meeting consumes less data comparatively with other apps since it use AES 128bit algorithm for end-to-end encryption and other optimization features. The audio and video frequency range used for conduction for online classes also shown in Table. The audio jitter is more in Ciscoweb Exapp. All OTL apps support 1280720, 640360 resolution for better video and audio quality. The Zoho meet app uses AES 128bit as an end-to-end encryption algorithm, but all other app uses AES 256bitalgorithm. The Zoom, Zoho and Cisco webEx OTL app follow System and Organization Control (SOC2) standard to ensure security, availability, integrity, confidentiality, or privacy of user data. Adobe connect and Google Meet follows ISO27001 GLBA ready, Azure Active Directory to ensure security, availability, integrity, confidentiality, or privacy of user data.

Table 10: Comparison of Six Popular OTL Apps with respect to Features

SN	Features	Adobe Connect	Cisco WebEx	Google Meet	Microsoft Teams	Zoho	Zoom
			Administration				
1	Schedule Meeting	X	X	X	X	X	X
2	Cloud Download	X	X	X	X	X	X
3	Screen recording	X	X	X	X	X	X
4	Contact Status	X	X	7	X	X	X
5	Invite Participants	X	X	X	X	X	X
6	Accounting & Auditing	X	X	X	X	X	X
7	Active / Passive	X	X	X	X	X	X
			Control Settings				
8	Plug-and Play	X	X	X	X	X	X
9	Network Model	X	X	X	X	X	X
10	Video Hide	X	X	X	X	X	X
11	Audio Mute	X	X	X	X	X	X
12	Keyboard Shortcuts	X	X	X	X	7	X
13	Virtual Background	X	X	X	X	X	X
14	Remote Controlling	X	X	X	X	X	X
			Screen Sharing				
15	White Board	X	X	7	X	7	X
16	Photo Sharing	X	X	X	X	X	X
17	Notes Sharing	X	X	X	X	X	X
18	Sharing via Cloud	X	X	X	X	X	X
19	Drop Box	X	X	X	X	X	X
20	URL Sharing	X	X	7	X	X	X
21	Bookmark	X	X	7	X	X	X
22	Screen Writing	X	X	7	X	X	X
23	Annotate Tools	X	X	X	X	X	X
			Communication				
24	Audio Support	X	X	X	X	X	X
25	Video Support	X	X	X	X	X	X
26	Chat & SMS	X	X	X	X	X	X
27	Hand Raise	X	X	X	X	X	X
28	Polling	X	X	X	X	X	X
29	Reminder	X	X	X	X	X	X
30	Quiz & Exams	7	7	7	X	7	7
31	Language Support	X	X	X	X	X	X
32	Voice Over IP	X	X	X	X	X	X
33	Dial-in	X	X	X	X	X	X
			Security				
34	Admit Policy	X	X	X	X	X	X
35	Security Access	X	X	X	X	X	X
36	e2e Encryption	X	X	X	X	X	X
37	Lock Meeting	X	X	X	X	X	X
			Other Features				
38	Open Source	7	7	7	7	7	7
39	Browser/App	X	X	X	X	X	X
40	App Demo	X	X	X	X	X	X
41	247 Support	X	X	X	X	X	X

Table 11: Comparison of Six Popular OTL Apps with respect to Parameters

SN	Parameters	Adobe Connect	Cisco WebEx	Google Meet	Microsoft Teams	Zoho	Zoom
				Management			
1	Capacity	1-1500	1-3000	1-250	250-10000	1-1000+	1-10000
2	Lag	80-100ms	100-120ms	150-250ms	60-80ms	100-150ms	35-40ms
3	Cost	$17.48PM	$13.5-26.8	$6/25 parx	$5.00PM	Rs.300/Host	Free/$14.99
4	Meeting Conf.	Host	Admin	Presenter	Host	Presenter	Host
5	Meeting Duration	Unlimited	Unlimited	40min/Un	Unlimited	Unlimited	40min/Un
6	# Subscribers	5Million+	130Million	85,0000	44Million	20Million	300Million
7	Focus Group	Available	Available	Available	NA[1]	NA[1]	NA[1]
				Performance			

8	Bandwidth	512Kbps:SD 1.5Mbps:HD 5Mbps:VHD	1Mbps:Host 320Kbps Participants	4Mbps:Host 1.1Mbps participants	500Kbps:SD 1.5Mbps:HD 2Mbps:VHD	4Mbps:Host 2Mbps Participant	600Kbps:SD 1.2Mbps:HD 2Mbps:VHD
9	CPU	14-20%	30-35%	12-25%	20-30%	3-14%	7-18%
10	Memory	512MB	409MB	466MB	430MB	220MB	240MB
11	Audio Freq.	22KHz	50-12KHz.	25KHz	24KHz	24KHz	16-24KHz
12	Audio Latency	12-14ms	150ms	50-70ms	50-60ms	40-56ms	100-150ms
13	Audio Jitter	3ms-4ms	20-50ms	7-10ms	30-40ms	20-30ms	10-40ms
14	Audio Packet Loss	0.0%	0.1%	0.0%	0.1%	0.0%	0.2%
15	Video Frequency	55-65MHz	50-60MHz	55-60MHz	50-60MHz	55-60MHz	50-60MHz
16	Video Latency	120-150ms	150-300ms	70-80ms	80-100ms	100-120ms	100-150ms
17	Video Jitter	10-12ms	10-50ms	10-13ms	15-20ms	15-16ms	10-20ms
18	Video Packet Loss	0.0%	0.5%	0.0%	0.1%	0.0%	0.2%
19	FPS	10-20fps	30fps	15-26fps	15-30fps	30fps	30-60fps
20	Resolution	1280 720 640 360	1280 720 640 360	1280 720 640 360	1280 720 640 360	1280 720 640 360	1280 720 640 360
21	Data Consumption	810MB:SD 1.6GB:HD 2.5GB:VHD	700MB:SD 1.2GB:HD 2.3GB:VHD	810MB:SD 1.4GB:HD 2.4GB:VHD	500MB:SD 1GB:HD 2.1GB:VHD	720MB:SD 1.2GB:HD 2.4GB:VHD	810MB:SD 1.35GB:HD 2.4GB:VHD
22	Upload Time	10sec†	15sec†	12sec†	20sec†	20sec†	20sec†
	Security						
23	Admit Policy	Automatic	Manual	Automatic	Manual	Manual	Manual
24	Security Access	ISO27001 GLBA-ready	SSAE16 ISAE 3402 SOC 2	Azure Active Directory	SSAE18 SOC2 type 2	SSAE16 SOC 2 Type 2	SSAE16 SOC2 Type 2
25	e2e Encryption	AES 256bit	AES 128bit	AES 256bit	AES 256bit	AES 128bit	AES 256bit

† Depends on file size and network bandwidth, Unlimited Meeting duration for subscribed user,1 Not Available

Table 12: Comparison of Six Popular OTL Apps with respect to Parameters

SN	Parameters	Adobe Connect	Cisco WebEx	Google Meet	Microsoft Teams	Zoho Meet	Zoom
				Quality			
26	Display Resolution	1024*768	1920*1080	2560*1440	1080*1920	1280*720	1080*480
27	Audio Quality	720p:HD	720p:HD	720p:HD	720p:HD	720p:HD	720p:HD
28	Video Quality	720p:HD 1080p:VGA	720p:HD 1080p:VHD	720p:HD 1080p:VHD	720p:HD	360p:SD 720p:HD	360p:SD 720p:HD
29	GUI	Visible, Easy to use	Easy-to navigate & Use	Comfortable to navigate	Visible, Navigate Easily	Clean, Highly Functional	Clearer Affordable Use
				Support			
30	Platform	Windows 8.1 Mac OS Ubuntu 14.x Android 4.4 iOS 8.1.2 iPad	Windows 7 Mac OS 10.13 Ubuntu 14.x Android 4.4 iOS 8.1.2 iPad	Windows 8 Mac OS 10.13 Ubuntu 16.x Android 4.4 iOS 8.1.2 iPad	Windows 7 Mac OS 10.xx Ubuntu 16.x Android 4.4 iOS 8.1.2 iPad	Windows 7 Mac OS 10.xx Ubuntu 16.x Android 5.x iOS 8.1.2 iPad	Windows 8 Mac OS 10.xx Ubuntu 16.x Android 4.4 iOS 8.1.2 iPad
31	Device Type	Desktop Mobile Tablet Laptop	Desktop Mobile Tablet Laptop	Desktop Mobile Tablet Laptop	Desktop Mobile Tablet Laptop	Desktop Mobile Tablet Laptop	Desktop Mobile Tablet Laptop
32	Minimum Hardware (CPU & RAM)	1.4GHz 1GB	2.0GHz 2GB	2.0 GHz 2.0GB	2.0GHz 2GB	1 GHz 2MB	2.5 GHz 4GB RAM
33	Plugins	Moodle Plugin	No Plugins	No Plugins	Microsoft Outlook	CRM-Plugin	Microsoft Outlook
34	Web Browser	IE FireFox Chrome Safari	IE FireFox Chrome Safari	IE FireFox Chrome Safari	IE FireFox Chrome Safari	IE FireFox Chrome Safari	IE FireFox Chrome Safari
35	User Support	Connect Support	WebEx Help	Meet Help	Microsoft Support	Zoho Help	Zoom Support

36	Ease of Installation	Moderate Desktop Mobile	Easy on Desktop Mobile	Moderate Desktop Mobile	Easy to Desktop Mobile	Easy on install on desktop	Easy on Desktop Mobile
37	Audio Input	Microphone Headphone	Microphone Headphone	Microphone Headphone	Microphone Headphone	Microphone Headphone	Microphone Headphone
38	Documentation & Help	User Guide	Help Document	Quick Guides	Microsoft Docs	User Guide	Quickstart Guides
	Reputation						
39	Vendor Stability	Excellent	Excellent	Good	Good	Good	Excellent
40	Establishment Year	2018	1995	1998	2017	2006	2011
41	App Launch Year	2018	2007	2004	2009	2013	2013
42	User Rating	2.9	4.2	3.7	4.4	2.9	4.5

Table 12 describes the quality, support and reputation of OTL apps. The Google meet has better display resolution comparatively with other apps. The audio and video quality is almost the same in all OTL apps. However, quality depends on available bandwidth. The Adobe Connect requires Moodle Plugin, Zoho meeting app requires CRM and Zoom requires outlook plugins to send the meeting invitation. Six apps chosen have easy to use GUI; however, Google Meet has comfortable navigation, Zoho has a highly functional user interface, and Zoom provides Clearer and affordable use.

The six apps are compatible with the mostly used platforms including Windows, Mac, Ubuntu, iOS, etc., and most commonly all the devices including desktop, laptop, pads, tablets and smart mobile phones allow installation of OTL apps. The six apps allow popular web browsers to be used. The user support and documentation is provided in all six OTL apps. As per the review and literature, the vendor stability of Adobe Connect, Cisco WebEx and Zoom are found to be excellent, whereas the user rating on a scale ranging from 1-5 is provided in the Table 12.

Table 13: Comparison of 6 OTL Apps based on Annotate Tools

SN	Annotate Tools	Adobe Connect	Cisco WebEx	Google Meet	Microsoft Teams	Zoho	Zoom
1	Pause Share	X	X	X	X	X	X
2	Stop Share	X	X	X	X	X	X
3	Mouse	X	X	X	X	X	X
4	Text	X	X	X	X	X	X
5	Draw	X	X	X	X	X	X
6	Eraser	X	X	X	X	X	X
7	Format	X	X	X	X	X	X
8	Undo/Redo	X	X	X	X	7	X
9	Clear	X	X	X	X	X	X
10	Save Screen	X	X	X	X	7	X

Note: Supports collaborative apps for annotate.

Finally, the 6 OTL apps are compared based on annotate tools (10) and is presented in Table 13. Annotate tools are the important features for conducting online class teaching/presentations. All the six apps provide annotate tools, whereas Google Meet and Microsoft Teams do not have built-in annotate tools but it supports integration with annotate tools apps. From the Table 13, it is also observed that, Zoho app does not have Undo/Redo and save screen options for annotation.

7. FAQs and Recommendations

In this section, analysis of the existing OTL apps, Frequently Asked Questions (FAQs) and recommendations for future use are proposed.

7.1. Frequently Asked Questions (FAQ)

1) Which are the essential features of an OTL app?
   Answer: The essential features of an OTL app include (but not limited to) audio and video support, whiteboard, screen sharing, scheduling and inviting participants, and security.

2) Which are the prominent parameters to assess an OTL app?
   Answer: The prominent parameters to assess an OTL app include (but not limited to) CPU, memory, bandwidth, performance, ease of installation, capacity and cost.

3) What are the minimum hardware requirements to install an OTL app?
   Answer: The minimum hardware required to install an OTL app differs from one app to another depending on the features provided by the app and its design. An OTL app may require a minimum memory of around 2GB, networking capability with minimum band width requirement ranging from 320Kbps to 4Mbps, display with a minimum resolution of 1080480 and CPU with a minimum clock speed of 1.4GHz.

4) What are the minimum software requirements to install an OTL app?
   Answer: An OTL app just needs a supporting platform on which it can run and a standard web browser, if the user wants to use the web version of the app. Minimum platform required differs from one app to the other ranging from Windows 7 and above, Mac OS 10 and

above, Ubuntu 14 and above, Android 4.4 and above, iOS 8.1.2 and above. Any standard web browser like an Internet Explorer, Firefox, Google Chrome, Safari, etc. would be sufficient.

5) What are the recommended hardware and software components requirements to use an OTL app comfortably?
Answer: The minimum hardware and software components required to use an OTL app comfortably include a minimum memory of around 2GB, networking capability with a minimum bandwidth requirement ranging from 320 Kbps to 4 Mbps, display with a minimum resolution of 1080 * 480, CPU with a minimum clock speed of 1.4 GHz, a standard operating system like Windows 7 and above, Mac OS 10 and above, Ubuntu 14 and above, Android 4.4 and above, iOS 8.1.2 and above; and any standard web browsers like an Internet Explorer, Firefox, Chrome, Safari, etc.

6) What is the minimum and desirable Internet connectivity to use an OTL app?
Answer: An Internet connectivity with a minimum bandwidth ranging from 320 Kbps to 2 Mbps for a participant and 1 Mbps to 4 Mbps for a presenter is necessary for the smooth functioning of an OTL app.

7) What are the pros and cons of using an OTL app in desktop, pad and mobile?
Answer: The pros of using an OTL app in a desktop are: it has a bigger screen and hence gives a better viewing experience, more participants can be seen in one screen, the documents shared are very clearly visible, Internet connectivity is stable as it is wired, easy to type using the keyboard and navigation would be convenient. However, some of the drawbacks of desktop are: it is not portable, screen may not be touch sensitive thus requiring a stylus for smooth communication, an external camera may be required if the desktop does not have an in-built camera and consumes more data. A mobile on the other hand makes it convenient to attend the meeting where ever you are, allows you to write on the screen and consumes less data compared to a desktop but may not give a pleasant experience because of the screen size and the Internet connectivity may be unstable because of wireless connectivity. A pad having a bigger screen compared to a mobile combines the advantages of both a desktop and a mobile and hence gives a better user experience altogether.

8) What effects the data usage/consumption?
Answer: It is known that for better video picture and/or audio, more bandwidth is required. Suppose you are using a mobile 4G data in MB that would be consumed by a typical app for one hour video conference and use 32-kbit mono with QVGA 5 fps, it will take less data than 160-Kbit stereo FHD 60 fps.

9) How much data will it consume if I attend a three-hour online class?
Answer: It would be common to stream SD video at a rate of 700MB/hour, with 1080 HD video at closer to 3000MB/hour, and 720p video about half of that, at say, 1500MB/hour. The nearest estimate for lack of additional information to the contrary would be 2GB of data for a 3-hour class at lowest quality MPEG-4 compression, although even that does seem quite high.

10) How much data (MB) does a one-hour online call use for each participant?
Answer: The data consumed during a call depends on whether it is an audio call or a video call and also the video format used in the call. A typical one-hour video call consumes 810 MB if the video format used is 360p, 1350 MB (1.35GB) using 720p, and 2400 MB (2.4GB) using 1080p, whereas an audio call consumes around 300 MB per hour.

11) How much time is required to upload a one-hour recorded meeting to the cloud and convert to the local drive?
Answer: Generally, when a meeting is recorded it is saved in the cloud space provided by the vendor. The recorded video will be available for download after a time period of about 30 minutes after the meeting ends. However, the time required to download depends on the Internet speed.

12) Does disabling the video option save the Internet bandwidth?
Answer: Yes, disabling the video option saves Internet bandwidth.

13) What is the effect of OTL app performance when the screen is shared?
Answer: The performance of the app may reduce marginally when the screen is shared as it has to transfer more data. However, this reduction in the performance may be unnoticed.

14) What does the term lag denote in an ongoing meeting of OTL app?
Answer: Lag is the delay encountered in transmitting a video from one user to another user. 15. How does an OTL app installed get updates for enhanced versions provided by the vendor?
Answer: Generally, every app has an auto update feature which is set by default. Whenever an enhanced version of the app is provided by the vendor, app gets automatically updated over Internet. Alternatively, the vendor sends notifications when an enhanced version is released. The user can download the updated version and install.

15) What is encryption?
Answer: Online communication always has a threat to the data being snooped by unknown users. Hence, to secure the data, applications provide secure communication via end-to-end encryption. Encryption is a mechanism by which the information that is shared can be viewed only by the intended user and not by anybody else. Encryption of the data is done with the help of a key. Encryption can be symmetric, where all the members use the same key for encrypting or decrypting, or asymmetric, where different keys are used for encryption and decryption.

16) What are the different types of end-to-end encryption techniques?
Answer: There a number of encryption techniques available for providing data security. Some of the popular ones are,Triple DES (Data Encryption Standard), Diffie-Hellman Key Exchange, RSA, ECC (Elliptic Curve Cryptography) AES (Advanced Encryption Standard) 128-bit, 192-bit and 256-bit, TLS (Transport Layer Security), Blowfish, SSL (Secure Sockets Layer), SHA (Secure Hash Algorithms), DTLS

(Datagram Transport Layer Security), SRTP (Secure Real-Time Transport Protocol), etc.

17) What is the difference between an 128-bit end-to-end encryption and 256-bit end-to-end encryption provided for an OTL app?

Answer: It is a security feature provided to secure the end-to-end transmission of the data. The 256-bit encryption technique provides more security than the 128-bit encryption standard, however, at the cost of more data consumption. Whereas the data secured using 128-bit encryption standard takes 1.02×10^{18} years to crack, the data secured using 256-bit takes 3.31×10^{56} years [46].

18) What is the difference between screen recording by the host and participant?

Answer: Ideally there is no difference between screen recording by the host and by the participant. However, apps generally provide the recording option only to the host and the host can enable this option to a participant, if he wishes.

19) Do plug-and-play options effect the performance of an OTL app?

Answer: No. Plug-and-play options don't affect the performance of an OTL app. Infact they enhance the convenience level to the user.

20) Is it possible for multiple hosts/participants write on the same shared screen at the same time?

Answer: Yes. However, the host may restrict this option to avoid unnecessary disturbances.

21) What is the effect of performance when the numbers of subscribers are scaled up and down?

Answer: The numbers of subscribers have a direct impact on the performance. As the number of subscribers increase the performance may drop significantly. The data consumption increases exponentially and it requires more bandwidth for a smooth experience.

22) Is the data secure when it is uploaded to cloud?

Answer: The data is secure provided the vendor encrypts the data before uploading to the cloud.

23) What are the different security threats while using an OTL app?

Answer: The various Security threats while using an OTL app include: unauthorized users entering the meeting, stealing of participants' personal data from their device, accessing sensitive data related to meetings and accessing the meeting data stored in the cloud.

24) What is the minimum and maximum time duration limits while using an OTL app?

Answer: The free version of the OTL app generally has a maximum time duration of up to 40 minutes for one session, but, the licensed versions have unlimited duration. However, there is no minimum time duration imposed on the duration by the apps.

25) Do you really require an valid e-mail address to install an OTL app?

Answer: Instead of creating a new user ID most of the apps insist on using their e-mail address as their user ID. Hence, a valid e-mail address is required to install an OTL app.

26) What is the energy consumed by a typical laptop and mobile phone of one-hour meeting?

Answer: A one-hour meeting on a laptop consumes around 20 to 50 watts of power for video and around 20 to 30 watts if only audio is used whereas a mobile consumes around 400mW of power. (http://ziyang.eecs.umich.edu/projects/powertutor/)

27) What is the importance of using touch screen devices while using an OTL app?

Answer: Touch screen devices make it more convenient to use the app.

28) What are the features and parameters that effect the audio quality?

Answer: Audio quality is affected by the audio frequency, audio latency, audio jitter, audio packet loss and bandwidth. The features that depend on audio quality are audio support, voice over IP, etc.

29) What are the features and parameters that effect the video quality?

30) Answer: Video quality is affected by video frequency, video latency, video jitter, video packet loss, bandwidth, image resolution and frames per second used in the video recordings. The video support feature mainly depends on video quality.

31) Does the OTL app vendor stores the meeting audio and/or video recordings?

Answer: TheOTLappvendorgenerallystoresthemeetingaudioand/orvideooffreesubscribers in the cloud space for a limited period of time and continues to retain for longer period only on subscription.

32) Does the OTL app vendor keeps track of the meeting schedules and log?

Answer: Yes, the OTL app vendor keeps track of the meeting schedules and log for accounting and auditing purposes.

33) Which are the best OTL apps suitable for conferences, teaching, learning, chatting and meeting?

Answer: Most of the apps are developed to serve a variety of purposes. However, some apps suit very well for certain applications like: Microsoft Teams and Google meet for Conferences; Zoom, Zoho, Impartus, BigBlueButton and Cisco Webex for Teaching and Learning; Skype for Business and Google Meet for Meetings; and all apps provide the basic capability of chatting.

34) What are the hardware equipment, software and technologies to design and build our own app?

Answer: Inordertodesignandbuildaownapptheinfrastructurerequiredincludesthefollowing: Hardware: 2.5 GHz i5 core and above processor, 4 GB RAM; Platform: Windows 8 and above / Android 5.5 and above, iOS 10.1 and above; Technologies: Corona 3D, PhoneGap, Snencha, JSON, XML_XCode, iPhoneSDK, Objective C, titanium etc.; and any standard web browser like Internet Explorer, Firefox, Chrome, Safari, etc.

35) How much 4G data is consumed in a mobile phone when used for one-hour meeting?

Answer: The data consumed depends on the quality of the video used for communication and it may range from around 400 MB to 1 GB per hour of meeting.

36) What are the differences between a non-subscribed and subscribed OTL app?

Answer: A non-subscribed user is one who does not pay any subscription fee for using the OTL app whereas a person who has subscribed for the OTL app pays subscription fee periodically for using the app. The features provided to non-subscribed and subscribed users vary accordingly depending on the subscription plan.

37) What is the effect of using annotate tools during an ongoing meeting?

Answer: Annotate tools draw the attention of users to the content the presenter wants to emphasize, allows the presenter to control the flow of presentation making the presentation more appealing and interesting.

38) Why do the mobile phones gets heated faster than laptop or pad?

Answer: The architecture of the processor used in a laptop, mobile and pad are different. The processor of a mobile is not designed to handle complex tasks as efficiently as a laptop or a pad. Hence, the mobile phone gets heated faster than a laptop or a pad even though they are performing similar kinds of tasks. The laptops are equipped with fans to cool them which is not present in a mobile.

39) What types of erasers are required on a white board?

Answer: A whiteboard is expected to be equipped with different types of erasers like an eraser to erase the selected portion of the whiteboard, erase all the contents of the whiteboard and selectively erase the contents written by other participants in the meeting.

40) What is the effect of using a finger or pencil while writing on a white board?

Answer: Even though a finger and a pencil can be used interchangeably to write on a whiteboard, a pencil is more preferable while writing on a whiteboard because, it is very easy and convenient to use, the contents written using a pencil are more legible, and the pencil provides lines of different thicknesses to be chosen while writing, making the contents more presentable.

41) What happens when the bandwidth gets reducing?

Answer: As the network bandwidth gets reducing, there may be a lag in the audio or / and video transmission, or even the audio or / and video may go off. As the bandwidth drops further, the user may even get disconnected from the meeting and may not be able to join back until the bandwidth is sufficient enough to support the connection.

7.2. Recommendations

In this section, some recommendations of OTL apps for future use are given below.

1) Admit participants

Currently, meeting ID and password are being used to login to a meeting and the same id and password can be used to login from multiple devices simultaneously. This can give way for the misuse of the login credentials. Hence, it would be more secure if a one-time digital key is generated which allows the participants to enter only once to the meeting from a single device.

2) Regulations to be made in the chat box

During the course of a meeting, some participants may engage in interesting conversations or discussions, give

useful suggestions, and ask thought-provoking questions through chat. Hence, it would be convenient if an option is provided to search and preferably save a particular chat of a participant in the chat box.

3) Create focus groups

The app can include features to create groups of interest called focus groups which enables the host to assign specific tasks to different groups and engage in discussions with a particular group of users in the meeting. This enables a group of people interested in a particular topic to involve in a discussion / activity without disturbing others in the group who are either not intended or interested.

4) Basic drawing tools

Including the option to draw various drawings like, lines, circles, squares, rectangles, ellipses, etc., gives the flexibility to the presenter to share his thoughts through drawings, rather than the usual text, making the presentation more interesting.

5) Mathematical symbols and notations

Some of the presentations may require mathematical symbols and notations like, square root, less than or equal to, greater than or equal to, summation, sigma, alpha, beta, gamma, theta, etc. Including options to use such commonly used mathematical symbols and a notation reduce the effort of the presenter in conveying this information and makes the presentation more concise.

6) Improvements in screen sharing experience

Screen sharing experience can be improved by including more options like providing an arrow pointer to point at a particular object, a highlighter to highlight specific portion of the screen, a pointer to point at a particular location on the screen etc.

7) Arrow or pointer to point a particular object on a screen

An arrow or a pointer helps the presenter to draw the attention of the participants to a particular object on the screen so that he can emphasize on that object and keep the participants focused on the object of interest at any point of time during the presentation.

8) Enable and disable participants

Enabling and disabling participants makes it convenient for the host to enable a interested participant to share his views and thoughts during a meeting and also to disable an unwanted participant who may be creating disturbances during the meeting.

9) Editing the unwanted recording video and audio program:

During the course of the meeting many unwanted events might have occurred and if the meeting is recorded all these events get recorded taking up more storage space. Hence, it would be desirable to have editing options so that the unwanted portions of the audio and video can be edited and only the essential portion of the meeting can be saved.

8. Conclusion

In this paper, a systematic and comprehensive comparison of online teaching and learning apps is studied and presented. A total of 32 OTL apps are compared with respect to 46 features and 40 parameters. The features and parameters are categorized into six classes each. Out of 32 OTL apps, six

popular apps are selected and their prominent features are highlighted. Several frequently asked questions and some recommendations for future use are presented in this paper. This paper provides the reader a complete knowledge of understanding to select an appropriate OTL app as per the requirements.

9. Disclaimer

All the OTL apps considered in this paper and that are listed in all the tables are placed in alphabetical order by neither prioritizing nor persuading any app. The data and information presented throughout the paper are purely based on the availability of data in the literature, extraction from their respective or other related websites and to the best of our knowledge.

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