DEVELOPMENT ANALYSIS OF MULTIPOINT VIDEO CONFERENCING IN EDUCATION

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ABSTRACT

In this modern era, people can do meetings by doing video conferencing. By doing video conferencing we can reach our colleagues who are geographically far from us in real time, as if we are close to them through video and audio visual. it's just that sometimes the capacity of video conferencing tools becomes an obstacle in doing conference simultaneously for multiple locations. Video conferencing between three or more locations is possible through the Multipoint Control Unit (MCU) system. This research was conducted at one of the educational institutions which had several branches spread in various locations and each location had a video conference tool. MCU system that was used previously is the sx20 telepresence which can only accommodate 3 video conference locations simultaneously. from this problem this educational institution developed a new MCU system using Acano. By using this Acano system can support HD quality video so that video and audio can be clearly displayed.

ABSTRAK

Di era modern ini, orang dapat melakukan pertemuan dengan melakukan konferensi video. Dengan melakukan konferensi video, kita dapat menjangkau kolega kita yang secara geografis jauh dari kita secara real time, seolah-olah kita dekat dengan mereka melalui video dan audio visual. hanya saja terkadang kapasitas alat konferensi video menjadi kendala dalam melakukan konferensi secara bersamaan untuk beberapa lokasi. Konferensi video antara tiga

lokasi atau lebih dimungkinkan melalui sistem Multipoint Control Unit (MCU). Penelitian ini dilakukan di salah satu lembaga pendidikan yang memiliki beberapa cabang yang tersebar di berbagai lokasi dan setiap lokasi memiliki alat konferensi video. Sistem MCU yang digunakan sebelumnya adalah telepresence sx20 yang hanya dapat menampung 3 lokasi konferensi video secara bersamaan. dari masalah ini lembaga pendidikan ini mengembangkan sistem MCU baru menggunakan Acano. Dengan menggunakan sistem Acano ini dapat mendukung video berkualitas HD sehingga video dan audio dapat ditampilkan dengan jelas.

Kata Kunci : Konferensi Video, MCU, Telepresence

INTRODUCTION

With intensive competition and a rapidly changing business environment, effective communication is an increasingly important factor for the success of business agendas and tasks. With audio visual facilities in real time makes communication feel real, so we seem to be dealing directly with people / users even though they are in another city, this is what makes many companies invest to reduce official travel costs to other cities or regions and also can saving time.

Currently, there are many technologies that facilitate communication for example telecommunication media and internet media. where now the media exchange of information not only limited to text and voice only. But it can also send data in the form of video by using webcam. Video technology that can exchange data in the form of sound and picture is called video conference. This technology allows users to communicate instantly virtually without distance restrictions.

Video conferencing is a part of online distance education system; it is a communications medium variously used for lectures, tutorials, students, project reviews, remote visits, etc. A videoconference can be either point-to-point or multipoint, linking three or more sites with sound and video in real time. Multipoint conferences are technically more difficult. Videoconference can also include data sharing such as an electronic whiteboard that all participants can draw on, or text based real time (like e-mail but it appears instantly on recipients' screens), so that all participants can work on the same file (Alhlak, Ramakrisnan, Hameed, & Mohseni, 2012).

At present Video Conference has become an important part in supporting businesses considering that there are many branches owned by these Educational Institutions and are spread in various regions both in cities and outside the city.

The problem experienced at this time is the increasing number of needs that exist in this Educational Institution to conduct video conferencing with several locations (more than 3 locations) but due to the limitations of the existing system it cannot be fulfilled.

MCU server is the best solution that can accommodate those needs, with the MCU Server in this Education Institute can connect all branches that want to do Video Conference.

MCU is a bridge that interconnects call from several sources. All parties call an MCU, or the MCU can also call the parties that are going to participate in the conference (Figure 1) (E. Yang, Zhang, Yao, & Yang, 2016).

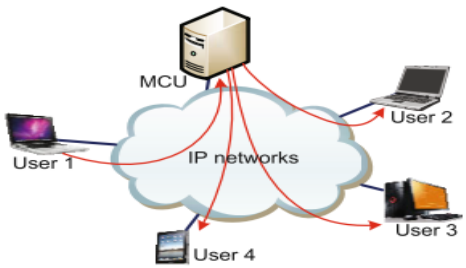

Figure 1. MCU-based solution

However, because all terminals send control messages and videos to the MCU, and MCU sends videos back to all terminals, the MCU solution needs high network bandwidth and may cause large delays. The MCU may become the bottleneck with a heavy handling burden. It is hard to ensure high-quality delivery, since its single function limits the scalability and reduces reliability (E. Yang et al., 2016).

METHODS

In conducting this study, researchers did the study design as follows figure 2.

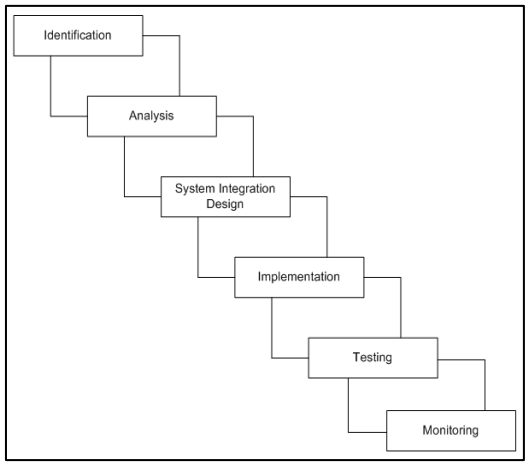

Figure 2. Research Methods

The researcher collected data, at this time the Educational Institution had tools for video conferencing spread across various locations.

ANALYSIS AND DISCUSSION

Based on the information provided (table 1), for the video conference tool that can be the MCU server is Telepresence SX20. however, the tool has limited connections, namely only being able to do video conferencing in only 3 places simultaneously.

Table 1. Teleconference Devices

No.	Video Conference Device	Location	Amount
1.	Telepresence - SX20	Syahdan Campus	1
2.	Telepresence - SX10	Syahdan Campus	2
3.	Telepresence - SX10	Anggrek Campus	1
4.	Telepresence - SX10	Alam Sutra Campus	1
5.	Telepresence - SX10	Bekasi Campus	1
6.	Telepresence - SX10	Semarang	1
7.	Telepresence - SX10	Palembang	1
8.	Telepresence - SX10	Malang	1

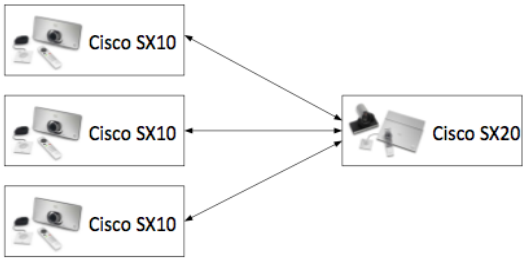

Figure 3. Visualization of SX20 Connectivity as MCU Server

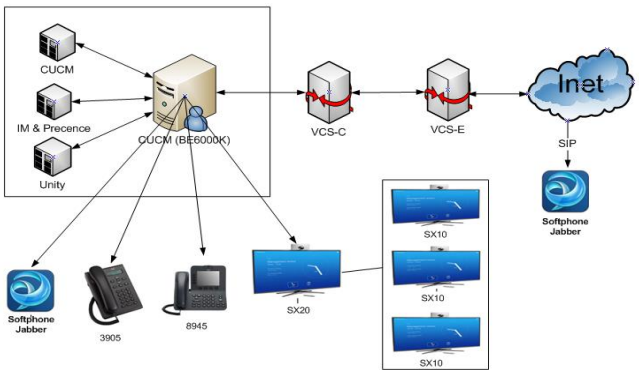

Figure 4. Connectivity of SX20 as an MCU Server in an Existing Network

The following data is obtained during 2017 and 2018 for the use of Video Conference.

Table 2. Year 2017

No.	Quartal	Video Conference Request
1.	Q1	4
2.	Q2	3
3.	Q3	11
4.	Q4	4

Table 3. Year 2018

No.	Month	Video Conference Request
1.	Q1	4
2.	Q2	12
3.	Q3	10

Table 4. Use of the SX20 as MCU Server

No.	Year	Request	Activities / Event
1.	2017	8	Meeting, student's inauguration, Briefing, Interview, Event Programs and Marketing Info Session
2.	2018	12	Meeting, student's inauguration, Briefing, Interview, Event Programs and Marketing Info Session

The number of locations of Educational Institutions that spread to several cities and regions so to doing video conference activities if more than 3 sites could not be carried out simultaneously, So that a solution what can be done is do a video conference by alternativel.

Table 5. Total Capacity Bandwidth Every Location

No.	Location	Bandwidth
1.	Syahdan	1 Gb
2.	Anggrek	200 Mbps
3.	Alam Sutra	100 Mbps
4.	Bekasi	10 Mbps
5.	Semarang	10 Mbps
6.	Palembang	10 Mbps
7.	Malang	10 Mbps

This video conference system owned by educational institutions only has 1 MCU machine in the SX20 telepresence device. This is a problem because there are more activities/ events that require video conference facilities. Therefore, Acano MCU was developed which has a maximum license capacity of conference reaching 25 participants and can use WebRTC as a softphone mediator in the form of web and not only that with this system does not change the user procedure in using telecommunications as usual (dial extension as usual example of pressing extension 12xx).

WebRTC enables web browsers with real-time communications capabilities via JavaScript APIs and can join a conference can be connected in a variety of ways like computer, laptop, and mobile device (Fai Ng et al., 2014).

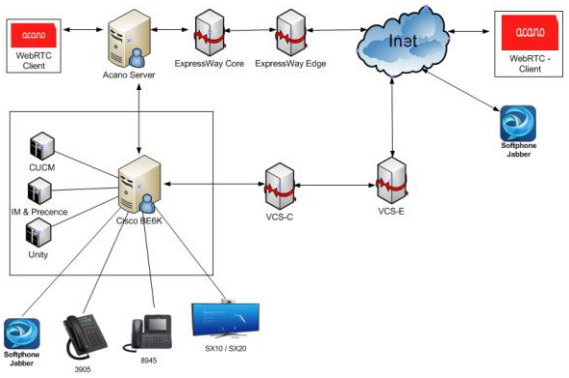

Figure 5. Designing the Acano MCU System Integration with the Existing System

The integration of the Acano MCU system with the CUCM system (Cisco Unified Communication Manager) will be as follows.

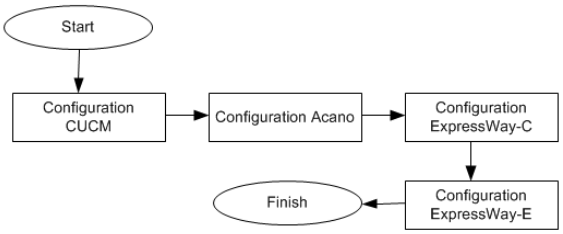

Figure 6 Configuration the Acano MCU

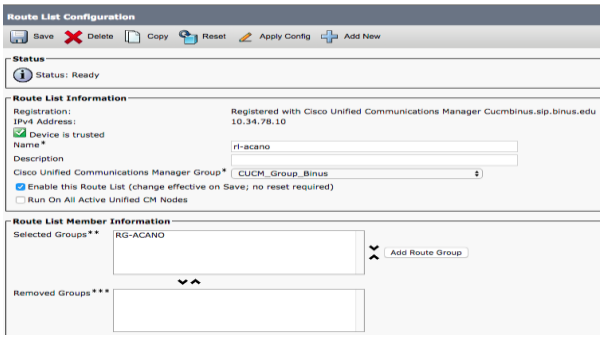

Figure 7 Configuration Route List to Acano System

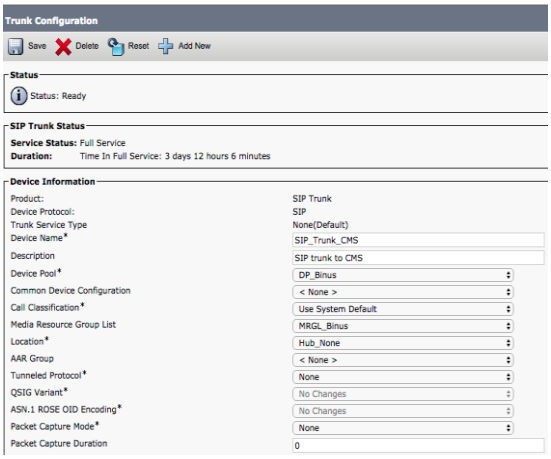

Figure 8. Create Connection to Acano System

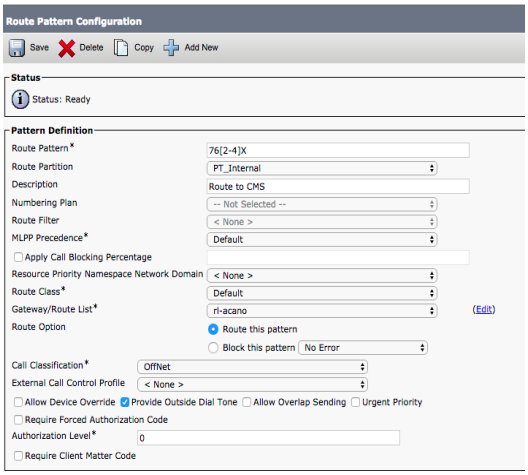

Figure 9 Configuration Route Pattern

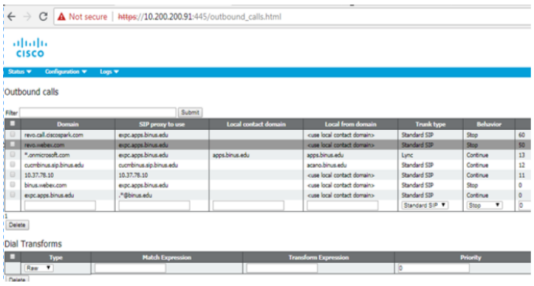

Figure 10. Configuration Outbound Call

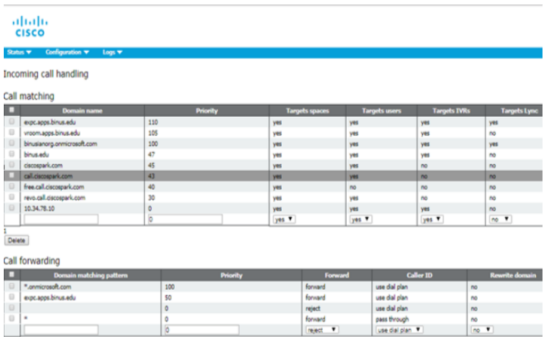

Figure 11. Configuration Inbound Call

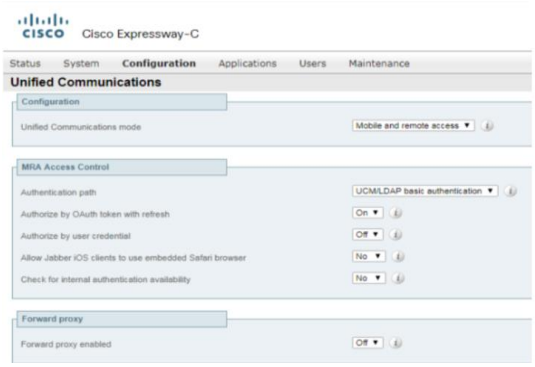

Figure 12. Configuration Expressway C

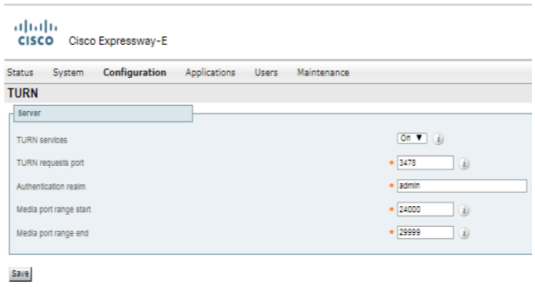

Figure 13. Configuration Expressway E

Referring to the trial schema previously mentioned in conducting video conferencing using the Acano MCU. Where Hardware (SX and IPPhone) and Software (WebRTC) are communicated with each other in the Acano Room. The tests were carried out through 2 connection scenarios and not only for video conferencing but also test share presentations and each location can see the presentation displayed.

Figure 14. Example Join Acano Room

The ability of a network to provide good services by providing bandwidth, overcoming jitter and delay. QoS parameters are latency / Delay, jitter, packet loss, throughput. QoS is largely determined by the quality of the network used (Lazzez & Slimani, 2013).

The European Telecommunications Standards Institute (ETSI) create a standard called *Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON)* in which there are several QoS quality groups which are divided into four categories based on the values of QoS parameters (table 6).

QoS testing flow through several Scenarios: first, 3 Telepresence connecting to Telepresence SX20 after that Telepresence SX20 Connecting to Acano and then the other device connecting direct to Acano. Second, All Device and Telepresence Device connecting direct through to Acano.

Table 6. Standardization QoS Quality

Value	Percentage (%)	Good
3,8 - 4	95 – 100	Very good
3 – 3,79	75 – 94,75	Good
2 – 2,99	50 – 74,75	Poor
1 – 1,99	25 – 49,75	Very Poor

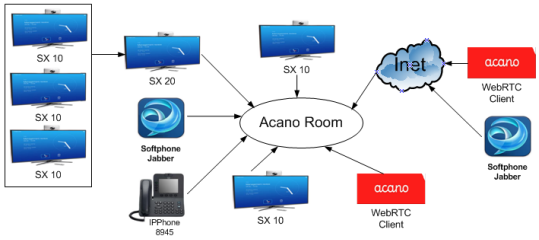

Figure 15. Scenarios Number 1 on Testing

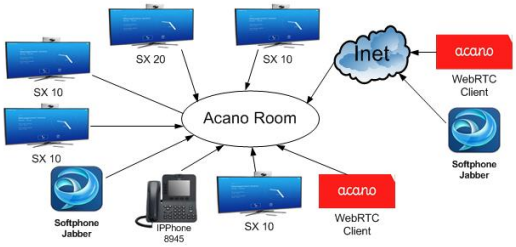

Figure 16. Scenarios Number 2 on Testing

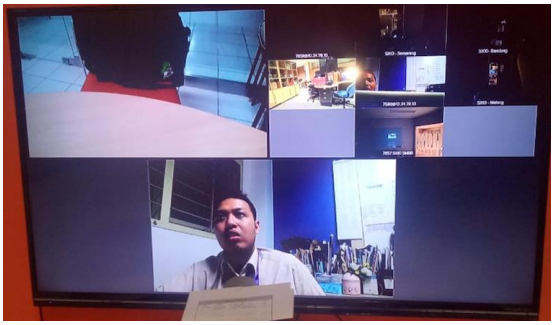

Figure 17. Result Scenarios Number 1 on Testing

Figure 18. Result Scenarios Number 2 on Testing

Table 7. Standardization of Throughput Value

Category	Throughput	Index
Very Good	100 %	4
Good	75 %	3
Medium	50 %	2
Poor	< 25 %	1

Source: Tiphon

Table 8. Throughput Scenario Number 1

No.	Video Conference Device	Intermediary	Throughput
1.	SX10 - Syahdan 1		
2.	SX10 - Syahdan 2	SX20 - Syahdan	100 %
3.	SX10 - Anggrek		
4.	SX10 - Alam Sutra	-	100 %
5.	SX10 - Bekasi	-	100 %
6.	SX10 - Semarang	-	100 %
7.	SX10 - Palembang	-	100 %
8.	SX10 - Malang	-	100 %
9.	WebRTC	-	100 %

Table 9. Throughput Scenario Number 2

No.	Video Conference device	Intermediary	Throughput
1.	SX20 - Syahdan	-	100 %
2.	SX10 - Syahdan 1	-	100 %
3.	SX10 - Syahdan 2	-	100 %

4.	SX10 - Anggrek	-	100 %
5.	SX10 - Alam Sutra	-	100 %
6.	SX10 - Bekasi	-	100 %
7.	SX10 - Semarang	-	100 %
8.	SX10 - Palembang	-	100 %
9.	SX10 - Malang	-	100 %
10.	WebRTC	-	100 %

Throughput is a measure of the number of packages successfully delivered in a network. This is measured in terms of packages/ seconds (Mehta & Gupta, 2012).

Acano usage throughput from scenario number 1 and scenario number 2 has good quality so that HD video quality is well maintained. Jitter can be called delay variation or packet delay variation. The jitter value is calculated from the end to end delay. Measuring jitter is an important element for determining network performance and the QoS that the network offers (Mehta & Gupta, 2012).

Table 10. Standardization of Jitter Value

Category	Jitter	Index
Very Good	0 ms	4
Good	0 s/d 75 ms	3
Medium	75 s/d 125 ms	2
Poor	125 s/d 225 ms	1

Source: Tiphon

Table 11. Jitter Scenario Number 1

No.	Video Conference Device	Intermediary	Jitter
1.	SX10 - Syahdan 1		
2.	SX10 - Syahdan 2	SX20 - Syahdan	0,2
3.	SX10 - Anggrek		
4.	SX10 - Alam Sutra	-	2,3
5.	SX10 - Bekasi	-	5,5
6.	SX10 - Semarang	-	8,6
7.	SX10 - Palembang	-	15,5
8.	SX10 - Malang	-	20,3
9.	WebRTC	-	0,2

Table 12. Jitter Scenario Number 2

No.	Video Conference Device	Intermediary	Jitter
1.	SX20 - Syahdan	-	0,2
2.	SX10 - Syahdan 1	-	0,1
3.	SX10 - Syahdan 2	-	0,2
4.	SX10 - Anggrek	-	0,4
5.	SX10 - Alam Sutra	-	2,3
6.	SX10 - Bekasi	-	5,4
7.	SX10 - Semarang	-	8,6
8.	SX10 - Palembang	-	15,5
9.	SX10 - Malang	-	20,5
10.	WebRTC	-	0,2

Based on the table above, the lowest jitter is in the location Syahdan (0.1) and the highest quality of jitter in Malang (20.5). Some packages are lost due to network problems or due to noise. Packet loss ratio must be minimum, thus maintaining successful QoS shipments (Mehta & Gupta, 2012).

Table 13. Standardization of Packet Loss Value

Category	Packet Loss	Index
Very Good	0 %	4
Good	3 %	3
Medium	15 %	2
Poor	25 %	1

Source: Tiphon

Table 14. Packet Loss Scenario Number 1

No.	Video Conference Device	Intermediary	Packet Loss (%)
1.	SX10 - Syahdan 1		
2.	SX10 - Syahdan 2	SX20 - Syahdan	0
3.	SX10 - Anggrek		
4.	SX10 - Alam Sutra	-	0
5.	SX10 - Bekasi	-	0
6.	SX10 - Semarang	-	0
7.	SX10 - Palembang	-	0
8.	SX10 - Malang	-	0
9.	WebRTC	-	0

Table 15. Packet Loss Scenario Number 2

No.	Video Conference Device	Intermediary	Packet Loss (%)
1.	SX20 - Syahdan	-	0
2.	SX10 - Syahdan 1	-	0
3.	SX10 - Syahdan 2	-	0
4.	SX10 - Anggrek	-	0
5.	SX10 - Alam Sutra	-	0
6.	SX10 – Bekasi	-	0
7.	SX10 - Semarang	-	0
8.	SX10 - Palembang	-	0
9.	SX10 – Malang	-	0
10.	WebRTC	-	0

Network Delay (latency), is the amount of time needed for a packet to travel from source to destination via a network (Lazzez & Slimani, 2013).

Table 16. Standardization of Delay Value

Category	Delay	Index
Very Good	< 150 ms	4
Good	150 s/d 300 ms	3
Medium	300 s/d 450 ms	2
Poor	> 450	1

Source: Tiphon

Table 17. Latency Scenario Number 1

No.	Video Conference Device	Intermediary	Latency (ms)
1.	SX10 - Syahdan 1		
2.	SX10 - Syahdan 2	SX20 - Syahdan	200
3.	SX10 - Anggrek		
4.	SX10 - Alam Sutra	-	228

5.	SX10 - Bekasi	-	91
6.	SX10 - Semarang	-	73
7.	SX10 - Palembang	-	70
8.	SX10 - Malang	-	146
9.	WebRTC	-	83

Table 18. Latency Scenario Number 2

No.	Video Conference device	Intermediary	Latency (ms)
1.	SX20 - Syahdan	-	54
2.	SX10 - Syahdan 1	-	66
3.	SX10 - Syahdan 2	-	42
4.	SX10 - Anggrek	-	128
5.	SX10 - Alam Sutra	-	225
6.	SX10 - Bekasi	-	91
7.	SX10 - Semarang	-	73
8.	SX10 - Palembang	-	70
9.	SX10 - Malang	-	140
10.	WebRTC	-	83

In this trial, not only testing video conferencing but also sharing presentations via video conference. The results of the trial are as follows:

Table 19. Bandwidth Usage Scenario Number 1

No.	Video Conference Device	Intermediary	Video	Presentation
1.	SX10 - Syahdan 1			
2.	SX10 - Syahdan 2	SX20 - Syahdan	5,3 Mbps	6,2 Mbps
3.	SX10 - Anggrek			
4.	SX10 - Alam Sutra	-	2,7 Mbps	3,9 Mbps
5.	SX10 - Bekasi	-	3,4 Mbps	4,2 Mbps
6.	SX10 - Semarang	-	3,2 Mbps	4.0 Mbps
7.	SX10 - Palembang	-	3,2 Mbps	3,9 Mbps
8.	SX10 - Malang	-	4,1 Mbps	5,1 Mbps
9.	WebRTC	-	3,2 Mbps	4,0 Mbps

Table 20. Bandwidth Usage Scenario Number 2

No.	Video Conference device	Intermediary	Video	Presentation
1.	SX20 - Syahdan	-	2,8 Mbps	3,4 Mbps
2.	SX10 - Syahdan 1	-	3,2 Mbps	4,1 Mbps
3.	SX10 - Syahdan 2	-	2,7 Mbps	3,8 Mbps
4.	SX10 - Anggrek	-	2,8 Mbps	3,4 Mbps
5.	SX10 - Alam Sutra	-	2,8 Mbps	3,2 Mbps
6.	SX10 - Bekasi	-	3,4 Mbps	4,2 Mbps
7.	SX10 - Semarang	-	3,1 Mbps	4.2 Mbps
8.	SX10 - Palembang	-	3,2 Mbps	3,9 Mbps
9.	SX10 - Malang	-	4,1 Mbps	5,4 Mbps
10.	WebRTC	-	3,4 Mbps	4,5 Mbps

Result for sharing presentations: first, using Telepresence SX10: FPS is used to have a maximum of 15 FPS so that when sharing video, the viewer will not see the lag of the shared content. Second, using Telepresence SX20 maximum FPS capability, 30-60 FPS so

that if sharing video, the viewer can see the content without lag. Third, using WebRTC maximum FPS capabilities up to 10-25 FPS so that if sharing video, the viewer will see the lag of the shared content. Four, IPPhone 8945 cannot share presentation but can view the presentation.

CONCLUSIONS

The implementation of Acano MCU server in educational institutions is very useful to deal with the problems that existed before, namely that it can only connect simultaneously as many as 3 locations using telepresence SX20 as the MCU server. When you want to do a video conference it is better to have the location connected directly to the Acano MCU system not through the Telepresence SX20 as an intermediary so that the video quality is better and the audience's appearance on the layer becomes bigger. The use of video conferencing is not only for audio and video, but also uses share presentations. We must also consider this as a reference if we want to allocate bandwidth. The minimum requirement for bandwidth allocation used when using the Acano MCU for video is 2.7 Mbps while if added with a presentation it is 3.2 Mbps and it is expected that video conferencing services use special bandwidth without sharing with other users to maintain good quality for video HD. Suggestion for future research it is expected to conduct further research on the FPS components (*Frame Per Second*) in the Quality of Service parameter.

REFERENCES

Akkuş, I. E., Civanlar, M. R., & Özkasap, Ö. (2006). Peer-to-peer multipoint video conferencing using layered video. In *Proceedings - International Conference on Image Processing, ICIP* (Vol. 34, pp. 3053–3056). https://doi.org/10.1109/ICIP.2006.313084

Alhlak, B. A., Ramakrisnan, P., Hameed, Z. S., & Mohseni, H. R. (2012). Video Conference: Integrated Tool for Identifying CSF in Education Development in UiTM. *Procedia - Social and Behavioral Sciences*, *67*(November 2011), 102–113. https://doi.org/10.1016/j.sbspro.2012.11.311

Bommes, M., Fazekas, A., Volkenhoff, T., & Oeser, M. (2016). Video Based Intelligent Transportation Systems - State of the Art and Future Development. In *Transportation Research Procedia* (Vol. 14, pp. 4495–4504). Elsevier B.V. https://doi.org/10.1016/j.trpro.2016.05.372

Cisco. (2013). Cisco WebEx Network Bandwidth, 1–24. Retrieved from http://www.wbximg.com/includes/documents/data-sheets/Webex-Network-Bandwidth.pdf

Fai Ng, K., Yan Ching, M., Liu, Y., Cai, T., Li, L., & Chou, W. (2014). A P2P-MCU Approach to Multi-Party Video Conference with WebRTC. *International Journal of Future Computer and Communication*, *3*(5), 319–324. https://doi.org/10.7763/IJFCC.2014.V3.319

Fan, Q., Yin, H., Min, G., Yang, P., Luo, Y., Lyu, Y., … Jiao, L. (2017). Video delivery networks: Challenges, solutions and future directions. *Computers & Electrical Engineering*, *0*, 1–10. https://doi.org/10.1016/j.compeleceng.2017.04.011

For, P., & By, P. (2018). Expressway, (39), 1–28.

Hu, H. (2012). Design and Application for Long-Distance TV Conference System. *Physics Procedia*, *25*, 382–387. https://doi.org/10.1016/j.phpro.2012.03.100

Kim, H. K., & Hwang, J.-N. (2006). Design and Implementation of Desktop Video Conference System Based on Client-Server and P2P. In *Communications in Computing*

(pp. 158–161).

Kydd, C. T., & Ferry, D. L. (1994). Managerial use of video conferencing. *Information & Management*, *27*(6), 369–375. https://doi.org/10.1016/0378-7206(94)90017-5

Lazzez, A., & Slimani, T. (2013). Deployment of VoIP Technology : QoS Concerns. *International Journal of Advanced Research in Computer and Communication Engineering*, *2*(9), 3514–3521. Retrieved from http://arxiv.org/abs/1312.2581%0Ahttp://www.arxiv.org/pdf/1312.2581.pdf%0Ahttps://arxiv.org/abs/1312.2581

Markopoulou, a. P., Tobagi, F. a., & Karam, M. J. (2002). Assessment of VoIP quality over Internet backbones. *Proceedings.Twenty-First Annual Joint Conference of the IEEE Computer and Communications Societies*, *1*(c), 150–159. https://doi.org/10.1109/INFCOM.2002.1019256

Mehta, V., & Gupta, N. (2012). Performance Analysis of QoS Parameters for Wimax Networks. *International Journal of Engineering and Innovative Technology (IJEIT)*, *1*(5), 105–110.

Ojo, O. E., Oluwatope, A. O., & Ajadi, S. O. (2017). Dynamical Analysis of an Internet-Based Video System. *IFAC-PapersOnLine*, *50*(2), 221–226. https://doi.org/10.1016/j.ifacol.2017.12.040

Paderanga, L. D. (2014). Classroom Video Conferencing: Its Contribution to Peace Education. *Procedia - Social and Behavioral Sciences*, *123*, 113–121. https://doi.org/10.1016/j.sbspro.2014.01.1404

Protocol, I. (2002). Etsi tr 101 329-7, *1*, 1–72.

Rodr, P., & Cervi, J. (2013). Deploying a Multipoint Control Unit in the Cloud : Opportunities and Challenges. *The Fourth International Conference on Cloud Computing, GRIDs, and Virtualization Deploying*, (c), 173–178.

Roesler, V., Longoni, G., Daronco, L. C., & Marins, A. (2016). Videoconference in education: “Mconf” and “Multipresence” Systems. In *IFAC-PapersOnLine* (Vol. 49, pp. 92–97). Elsevier B.V. https://doi.org/10.1016/j.ifacol.2016.11.134

Series, C. (n.d.). Journal of Physics : Conference Series multimedia guidelines.

Surahman, A., Imansyah, F., & W, F. T. P. (n.d.). ANALISIS QUALITY OF SERVICE (QOS) VIDEO CONFERENCE PADA JARINGAN INTERNET DENGAN MENGGUNAKAN AKSES WIMAX (WORLD WIDE INTEROPERABILITY FOR MICROWAVE ACCESS) Tabel 2 . Standarisasi Kinerja Jaringan Berdasarkan Nilai Throughput Sumber : TIPHON.

Venkat Rangan, P. (1993). Video conferencing, file storage, and management in multimedia computer systems. *Computer Networks and ISDN Systems*, *25*(8), 901–919. https://doi.org/10.1016/0169-7552(93)90098-O

Willebeek-LeMair, M. H., & Shae, Z. (1997). Distributed video conferencing systems. *Computer Communications*, *20*(3), 157–168. https://doi.org/10.1016/S0140-3664(97)00003-0

Yang, E., Zhang, L., Yao, Z., & Yang, J. (2016). A video conferencing system based on SDN-enabled SVC multicast. *Frontiers of Information Technology & Electronic Engineering*, *17*(7), 672–681. https://doi.org/10.1631/FITEE.1601087

Yang, S., & Ma, B. (2006). Study on the extensibility of video conferencing with speech mixing. *Computer Communications*, *29*(11), 2026–2033. https://doi.org/10.1016/j.comcom.2005.12.012