Locally Accessible Cloud System (LACS) as a potable communication tool in disaster situations

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Abstract

With the worldwide popularization of the Internet, the Information and Communication Technology (ICT) has become indispensable not only in daily life but also in disasters like earthquakes or typhoons, to efficiently save people's lives and to mitigate and recover from the damage. On the other hand, once a large disaster occurs, the Internet and mobile communication services are often disrupted, which prevents the government and responders from starting mitigation initiatives.

To address this issue, the Advanced Telecommunications Research Institute (ATR) proposes a system called Locally Accessible Cloud System (LACS) to urgently meet the ICT demand in disaster-affected areas. LACS is designed to host multiple services for delivering, sharing, and exchanging information among local people and to fulfil the explosive demand for ICT even in the absence of mobile or broadband internet. LACS has a form of a portable case and is comprised of a small server, a Wi-Fi access point, a battery and peripheral devices. LACS conforms to ITU standard, which is the Movable and Deployable ICT Resource Unit or the MDRU.

To confirm the LACS's performance in a real disaster situation, we developed a LACS system and conducted its feasibility studies in Cebu, Philippines. LACS server was deployed at a local government facility and was connected to the Wi-Fi access point in a remote island from the facility, using fixed wireless access equipment to provide e-education and other services. We demonstrated and applied the system to the real issues in a disaster situation and during the COVID-19 pandemic, with the participation of the local government officials, teachers, students and residents. The results show that LACS is a very useful communication tool in disaster situations and also for providing various services such as e-education.

Introduction

The number of natural disasters like earthquake, typhoon, and flooding has increased in recent years. In the last couple of years, the unprecedented effect of the COVID-19 pandemic has flared worldwide and people are looking for ways to engage in social activities while avoiding the risk of the pandemic. In these disaster situations, Information and Communication Technology or ICT, including Internet-based services, play a critical role. Most people in disaster-affected areas use their mobile phones and any other communication medium to confirm the safety of their family, friends, and acquaintances. Disaster responders like local government officials, police officers, fire station workers, and medical staff use communication tools to collect and share the information necessary to do their job.

The local government regularly reports the damage and the number of victims in its area to the national government in order to get support. Besides, the local government has to deliver important information and instructions to residents to save their lives.

During many disasters, however, the telecom network and the Internet are not available or only have limited use due to the disruption of the communication infrastructure and/or the electric power outage. In the aftermath of natural disasters like earthquake, tsunami, typhoon, and flooding, network infrastructure including subscriber lines, mobile base stations, and other telecom facilities are damaged. Besides, the network sometimes stops to operate due to the electric power outage. For example, during the pandemic, people began using the Internet heavily and other network services to keep up with their life, especially in work and education. In effect, this led to congestion of traffic in the network, causing a degradation in the performance of services.

To meet the critical and explosive demand for ICT, we propose a system called Locally Accessible Cloud System (LACS), which can satisfy the ICT demand in the disaster-affected areas or any other similar situation, such as the pandemic. LACS is made up of a portable case and it comprised a small server, a Wi-Fi access point, a battery and peripheral devices. LACS is designed to host multiple services for delivering, sharing, and exchanging information among local people. The deployment of LACS in the disaster-affected areas immediately after the occurrence of a large-scale disaster fulfils the explosive demand for ICT, and bridges the communication gaps

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created by the absence of mobile and/or broadband internet connectivity.

To confirm the LACS's performance in disaster situations, we developed a LACS system and conducted a feasibility study on an island of Cebu, Philippines. In this study, the LACS was deployed at a local government facility and was connected to the Wi-Fi access point on a remote island, where access to the internet is limited, using fixed wireless access equipment. Furthermore, we tested the capacity of LACS to provide e-education and other services on the remote island. In addition, we demonstrated and applied the system to real issues during the COVID-19 pandemic, with the participation of the local government officials, teachers, students, and residents. Most participants agreed that the system was an extremely useful communication tool during disasters and for providing e-education as well.

Demand and supply gap in tele-communication sector

An enormous number of disasters has occurred worldwide in the past 40 years and their economic consequences cannot be underestimated (UNDRR, 2020). The number of disasters has increased in most disaster categories, if one compares the number of disasters in the recent 20 years (2000 through 2019) with that from 20 years ago ('80s through '90s). The impact of disasters has also worsened, which indicates that the scale of disasters has also increased in recent years.

In the telecommunication or the Information and Communication Technology (ICT) sector, disaster occurrence often affects the services seriously. Fig.1 shows a typical configuration of ICT infrastructure and its possible damage caused by disasters. Nowadays, people access the internet through mobile devices like smartphones and/or personal computers from home. These devices are connected through the access network that comprise the base station and/or optical fibers, which connect subscriber's devices and the telecom equipment in the nearest communication building. Communication buildings are mutually connected by optical fibers to form a transport network. Using this transport network, the Internet routers deployed worldwide in a distributed manner are interconnected to form the Internet. Data-centers or huge computer systems are connected to the Internet to deliver Internet-based services like social networking service, e-Commerce service, and Information retrieval service. During a disaster, the components of network access, including base stations and optical fibers, are damaged and/or stop operating due to a power outage in the disaster-affected area. Moreover, in a large-scale disaster, even communication buildings, transport networks and other building blocks sometimes get damaged. These damages disrupt the ICT services like telephone and other internet-based services.

During the massive East Japan earthquake in March 2011, 1.5 million subscriber lines of NTT East, the major telecom service operator in the disaster region, were disrupted due to the damages of access network and transport network. It took almost one and a half months to restore the damages (NTT-East., 2012). During the restoration of the ICT infrastructure post-disaster, sometimes the ability to supply ICT services degrades seriously. Once a disaster occurs, most people make telephone calls to their family, friends, and acquaintances to confirm their status and safety, which causes serious traffic congestion in the telephone network. Disaster responders like government officers, police officers, fire department workers, and medical staff, need to collect information on what occurs in the disaster area, and then closely communicate among themselves to efficiently proceed in their missions

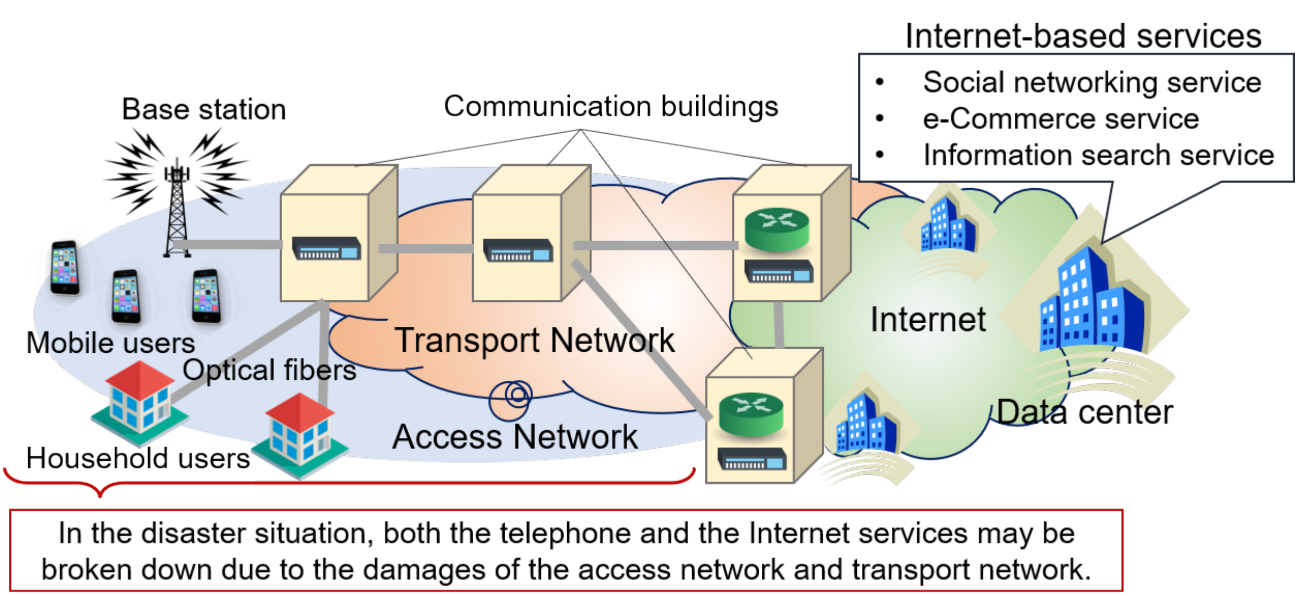

Figure 1. Possible damage in ICT infrastructure under disasters

under critical situations. Generally speaking, during the disaster, the demand for ICT services explosively increases. Filling this gap between supply and demand for ICT services during the disaster becomes one of the critical factors in saving lives and achieving early restoration from the damage.

Supply-Demand-Gap of ICT in COVID-19 pandemic

In 2019, the COVID-19 pandemic occurred worldwide, which accelerated the transition of the format of people's social activities from physical to cyber. Several countries had to enforce lockdowns and in schools and change the traditional structure of educational activities, which went from being 'in-person' to online. This called for the teachers and students to have access to the Internet. This transition caused serious issues worldwide due to the limited penetration of broadband connectivity.

According to a report of ITU, released in 2020, the year-by-year population coverage of the LTE/WiMAX mobile network, developed countries and/or urban areas worldwide was over 70%. On the other hand, developing countries and/or rural areas had low population coverage of below 70%. In the rural areas of the Least Developed Countries (LDCs), Land Locked Developing Countries (LLDCs), and Small Island Developing States (SIDS),particularly, the population coverages of a typical mobile broadband service were in the range of 20% to 40% in 2020, lagging far behind the other areas. A large demand-supply gap in ICT had appeared, especially in the education sector, in various areas of the world due to the COVID-19 pandemic.

Existing resilient ICT solutions

To countermeasure the ICT disruption in disaster situations, various solutions have been proposed and studied (Sakano et. al., 2013, Sakano et. al., 2016, ITU-T, 2016, Miranda et. al. 2016). NTT in Japan proposed a resilient ICT architecture called Movable and Deployable Resource Unit (MDRU) (Sakano et. al., 2013, Sakano et. al., 2016). MDRU is a unit that accommodates communication equipment along with a battery/generator. Once a network disruption occurs in a disaster-affected area, MDRU is carried to the area and it quickly creates an access network or local area network, delivering mainly telephone service to the local people. Users access MDRU from their daily use ICT device like a smartphone, and can make telephone calls to anyone in the local area by using their own telephone number. This MDRU architecture was standardized by International Telecommunication Union (ITU) as L.392 (ITU-T, 2016).

Similar ICT architectures to countermeasure the disasters are proposed and demonstrated (Miranda et. al., 2016, Panda et. al., 2019, Salamanca et. al., 2016, Kishorbhai et. al., 2017, Jahir et. al., 2019, and Pozza et. al., 2018). Many of them focus on restoring damaged network by temporarily replacing damaged network components. With the evolution of fifth-generation (5G) wireless network and the edge computing technology, a new concept called Network-In-a-Box (NIB) is proposed in (Pozza et. al., 2018). NIB is a concept that all the ICT components are packed in a box and the box is attached anywhere in the network to fulfil the demand for varied uses flexibly.

Locally Accessible Cloud System

To fill the ICT demand-supply gap, which became a critical issue in the disaster-affected areas, we proposed a system called Locally Accessible Cloud System (LACS) (Sakano et. al., 2019, and Teng et. al., 2020). LACS is a portable system that can temporarily form an Internet-like environment in its surrounding local area where ICT services are delivered locally. People near the LACS can access the LACS functions using their

Figure 2. Locally Accessible Cloud Sysstem (LACS)

smartphones to collect and share information, and communicate with their families and acquaintances. The basic idea in the proposal is that LACS brings the service functions of the data center to local area and then integrates them with newly deployed and/or surviving access network so that local people can access the functions directly, using popular ICT devices like smartphones.

Development of a LACS pilot product

Fig.2 gives an overview of the developed LACS pilot product, its architecture and components. LACS accommodates a small server, Wi-Fi access point, a battery, and other peripheral devices in a carry case. In the server, software for communication functions is installed. The Wi-Fi access point is to enable people in the vicinity to access LACS using Wi-Fi on their smartphone and other ICT devices. With the access point given in the pilot product, users in the area (within ten to a hundred meter line-of-sight radius) can be covered. The battery is an important building block to run the LACS for hours without electric power feed from outside. The pilot product is able to operate about 8 hours in normal use without power feed from outside.

Fig.3 shows an example of the LACS top page. LACS offers basic ICT functions. Users can access the functions by tapping the corresponding buttons on the top page. The login/user registration allows users to create an account to access the full functionality of services deployed on LACS. The LACS software is equipped with a messaging function similar to Chat and Video communication system in social networking services, which enables us to make bi-directional communication and information exchange. In addition, the Feed is the function for broadcasting type communication. Users can use this function to upload content including text, images, video files and so on. The user registration is necessary to use the chat function and also to upload information to LACS. Only the authorized persons can upload information for delivery and anyone who has access to the LACS can access the uploaded information. During a disaster, local government officials, for example, can announce evacuation information to the residents by uploading it to this Feed page. With these basic functions, people within the vicinity of LACS can collect, share, and communicate with other people, at least locally, even in the situation where no internet connection exists.

Table 1 shows the potential uses of LACS. The main purpose of LACS is to quickly create a local ICT environment during a disaster. Disaster response officials, from the local government, police, fire-station and hospitals, bring LACS to the site of activity and use it for communication among team members (Ojetunde et. al., 2021, and Ojetunde et. al., 2022). LACS can be deployed in an evacuation center for effective communication there. LACS can be used as a temporary local communication tool for events and training in normal situations. People in developing areas can use LACS in daily life as a tool for local communication under the restricted Internet access environment. LACS conforms to ITU standard L.392 (ITU-T, 2016) and can be classified as a kind of Network-In-a-Box solutions.

Figure 3. Basic functions provided by LACS

User	Disaster situation	Non-disaster situation
National/Local government, Fire station, Police, Hospitals	➢ Usage in disaster response headquarters ➢ Usage in other organizations that support the activities in disasters like hospitals	➢ Drills for disaster prevention ➢ Daily use in the government work
People in disaster areas / residential areas	➢ Offer a tool for information delivery and sharing in disaster affected area with no Internet.	➢ To offload the condensed traffic at events. ➢ Daily use in residential areas as a conventional information sharing tool.
People in developing areas	Use as an instant ICT installation tool in developing areas with not-rich network infrastructure.	

Table 1. Expected use cases of LACS

Collaboration of LACS and the Internet cloud

In the case of ICT's supply-demand gap, which appears especially in the rural areas in the developing countries, installing a standalone LACS is effective in alleviating the gap but seems to be insufficient, since the information upload/sharing/exchange are performed only locally, with most of the content being handled just within the area. As stated in ITU-D, 2020, broadband mobile internet environment in developing countries and/or rural areas tend to have low population coverage. This means that in such areas, most people have smartphones or mobile devices but the connectivity to the internet is not fully updated to 4G or the latest service. Besides, the connectivity to the internet is often disrupted, probably due to the traffic congestion and unstable power feed to the base station and other network components. This network environment prevents mobile users from fully relying on the Internet for their daily activities (which included education during the COVID-19 pandemic). Therefore, it is important to extend the function of LACS to bridge the gap in such situations.

Fig.4 shows the concept of a LACS-based system to suit the ICT demand during the pandemic and in the rural areas worldwide. In a disaster-affected or rural area with limited broadband, LACS is installed to accommodate local ICT demand. Here we call it the Local-LACS (L-LACS). In L-LACS, LACS's primary functions to deliver basic communication services are installed. Application-specific software like a learning management system (LMS) for e-education is also installed. Users in the L-LACS perimeter, just like the local government officials and residents, can now access L-LACS using the Wi-Fi on their smartphones and use it as a local social networking service. Teachers and students can also access L-LACS and the LMS in it to deliver/access educational content and exchange reports between teachers and students. In addition to the L-LACS, the software package of the L-LACS is deployed in the Internet Cloud. We call it Central-LACS (C-LACS). C-LACS is a copy of L-LACS. C-LACS and L-LACS are mutually connected through the Internet. C- and L-LACSs are controlled so that they are synchronized with each other. If information is uploaded to the C-LACS, then the uploaded information is automatically copied to L-LACS whenever a connection between L- and C-LACSs is available.

The system configuration shown in Fig.4 has several features in the LACS-based system, which are applicable in the context of the COVID-19 pandemic. During the COVID-19 pandemic, the Internet connectivity was disrupted and had suffered serious performance degradation due to the access concentration of users, since most people had increased the Internet access during the lockdown. Even in such a situation, local teachers and students can use LMS by accessing it in the L-LACS locally. Besides, a local teacher can access C-LACS directly over an internet access service and then acquire educational content from a content provider on the Internet. The acquired content can be stored in the LMS in C-LACS without any delay since the connection between the content provider and C-LACS can be assumed to be broadband, which is always stable. The educational content once stored in C-LACS is then automatically copied in L-LACS when the connection between C- and L-LACSs is available. The local teacher, thus, does not have to stress about waiting for a long time to download the content to a local device using an unstable narrowband. During disasters, the same configurations of C- and L-LACSs work effectively too.

Local government officials and residents in a disaster-affected area can upload the disaster-related information like pictures of the damage or messages from evacuation centers to L-LACS. The uploaded information is then automatically copied to C-LACS when the connection between L- and C-LACS is available. The C-LACS can be accessed by anyone who has the permission and the rights to access from anywhere over the Internet. Government

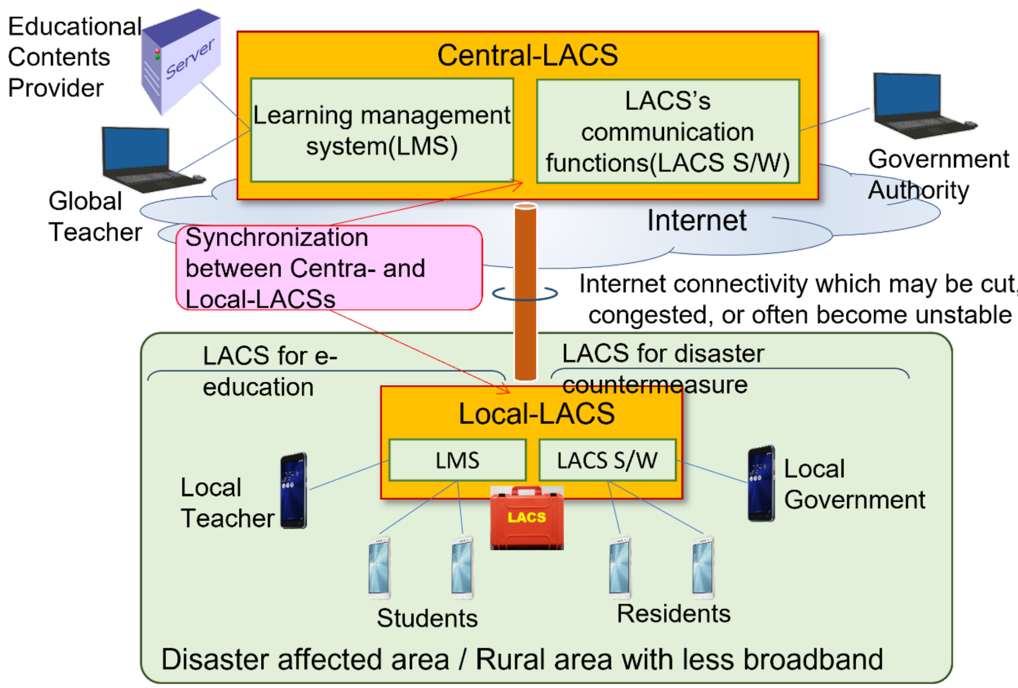

Figure 4. System concept for Central-/Local-LACSs collaboration

officials, for example, can get any information in or relate to the disaster-affected area simply by accessing C-LACS.

Feasibility studies

To confirm the feasibility of LACS, we have conducted a series of feasibility studies in Cebu, Philippines, since the completion of prototype development in 2019. Fig.5 shows the location of feasibility studies. The feasibility studies were conducted in the Municipality of Cordova near Cebu city in the Philippines. Cordova is located in the southern part of Mactan island and its population is about 60,000. It has thirteen barangays (a local administrative unit), one of which is the island barangay of Gilutongan, located on the opposite side of Hilutungan Channel.

Fig.6 explains the feasibility studies we have conducted. During its first study in 2019, the prototype LACS was demonstrated and evaluated as a stand-alone system in Cordova municipality hall. The Wi-Fi network of LACS was extended to Gilutongan Island by using Fixed Wireless Access system in 2020. In 2021, we installed C-LACS to the system with Internet connectivity and demonstrated several uses of LACS to evaluate the functionality of the system during the pandemic. In 2022, the feasibility study focused on e-education, and was conducted in Visayas State University (VSU) located at the island of Leyte. In 2023, the feasibility study was meant for evaluating the upgraded LACS software, which had a newly accommodated video conferencing function for use in the event of a disaster or under normal circumstances. Among the feasibility studies that have happened so far (as shown in Fig. 6), the details of the feasibility study of 2021 have been reported in this article.

To confirm the fitness of LACS and the architecture shown in Fig.4 for LACS functionality, we conducted a feasibility study in Cordova and Gilutongan island in February, 2021. At the time of the study, schools were closed nationwide due to COVID-19 and educational activities had become predominantly online. So, another objective of the study was to contribute to solving the real issue on the ICT's demand/supply gap, which people were facing with the LACS-based system during the pandemic. LACS- based system was developed and deployed in Cordova for the feasibility study.

Fig.7 shows the developed system. A LACS server was set up in Cordova municipal hall as L-LACS. The server was connected to a Wi-Fi access point to form a Wi-Fi area in and around the municipal hall. The Wi-Fi area was extended to the Gilutongan Island about 6.5km away from the hall, using fixed wireless access equipment and another Wi-Fi access point that was located on the island. The LACS server was also connected to the Internet using a fiber- to- the -home (FTTH) service provided by an internet service provider. We developed C-LACS as an Internet Cloud to be the counterpart of the L-LACS in Cordova. In both C- and L-LACSs, an opensource learning management system for e-education and LACS's communication functions for disaster countermeasure were respectively installed. Using the constructed system shown in Fig.7, the feasibility study was conducted as a two-day session and activity.

Table 2 summarizes the items conducted in the feasibility study. E-education, disaster response, and platform as a service were selected as the areas of usage for the LACS- based system. In the e-education category, general instruction for the

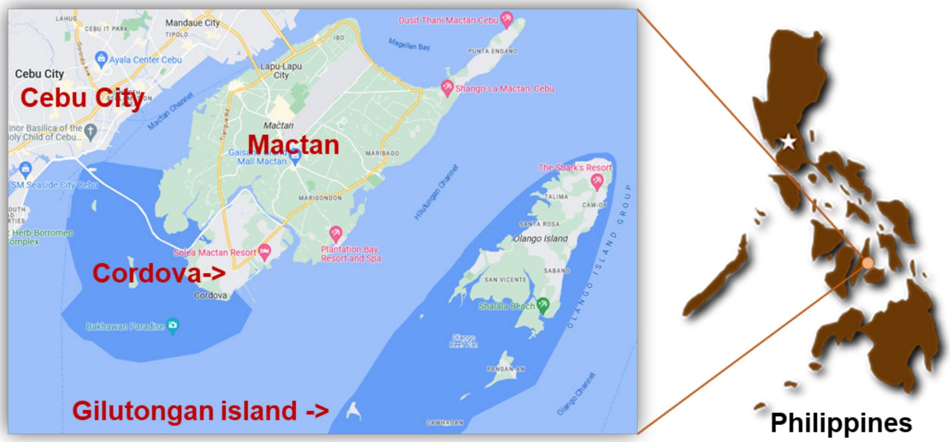

Figure 5. Map of Gilutongan Island, Cordova, Cebu, Philippines

2019	2020	2021	2022	2023
Start of LACS FS	**Propagation Testing**	**Pandemic**	**Expansion to VSU**	**Continuity**
Surveys	Technical training	Module integration	Multiple LACS test	New modules
Social preparation	Island connection	Learning Mgt System	Moodle LMS test	Call features
Testing of equipment	Distance testing	eHealth (CRIS)	Technical training	Non disaster usage
Technical training	Group usage	Distance learning	On-line collaboration	Commercialization

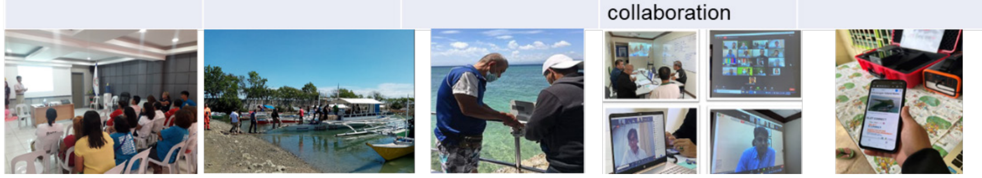

Figure 6. Timeline of feasibility study activities

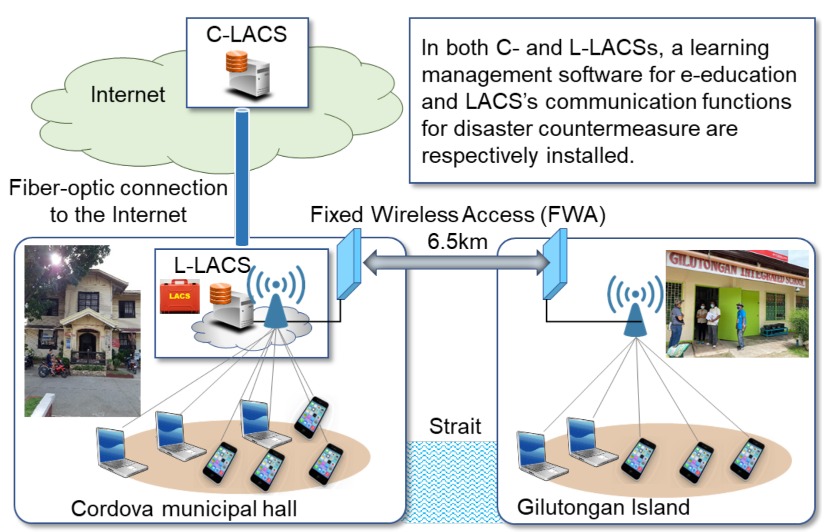

Figure 7. Developed system for the feasibility study in Cordova

Category	Study Item	Main participants
E-Education	LMS Training (General)	Local teacher/student, University professor
	LMS Training for teachers	Local teacher, University student
	LMS Training for students	Local student
	L-LACS by a local teacher	Local teacher and student
	Trial of downloading the contents to student's smartphone and work out with the contents and then upload the reports by local students.	Local student
	Trial of access to the student's report and make evaluation	Local teacher
Disaster response	Training for usage of LACS for communication	Municipal Official Stakeholders Community Residents
	Demonstration of LACS application in searching for a missing person	Municipal Official Stakeholders Community Residents
Platform as a service	Demonstration of a residents management system	Municipal Official Stakeholders Community Residents

Table 2. Feasibility study items

usage of the installed learning management system was conducted first, and then trainings for teachers and students were respectively performed. For disaster response, participants were instructed in the usage of LACS's communication functions, followed by a demonstration of the search for a missing person using LACS. In addition to the two items above, we also demonstrated an application of LACS-based system for a platform as a service. A resident management system was installed in L-LACS and was used by municipal officials for monitoring the COVID-19 status for demonstration.

Results of the feasibility study

Various potential users of LACS in disasters and pandemic, such as teachers and students of a local school, a university professor, local government officials, and community residents, participated in the feasibility study. Fig.8 shows a view of the introduction of the LACS and the feasibility study for participants.

Fig.9 shows overviews of demonstration for e-education. A student is shown accessing the LACS using her smartphone to download content from the LMS in L-LACS easily in Fig.9(a). She made a report on the content and then uploaded it to LMS over Wi-Fi. The teacher then accessed LMS in LACS and evaluated the report. Fig.9(b) shows a screen of the teacher's smartphone when she accessed LMS in LACS. The processes, which include the upload of educational content to LACS by a teacher, the acquisition of the content from LACS by a student, the submission of a report, and the access to the report for evaluation by the teacher, were successfully performed without any difficulty. The same level of performance can be achieved even with an unstable internet connection if all the processes are performed locally.

For the demonstration of LACS in the case of disaster response, participants tried to use LACS using their smartphones. They accessed LACS over Wi-Fi function of the smartphone and then used it as a trial for sharing images and exchanging messages among friends as shown in Fig.10 (a). The participants went outside of the municipal hall and took pictures of the neighboring area and uploaded the images to LACS for the demonstration of the search for a missing person using LACS. They also checked the uploaded images in the LACS from their smartphones to understand the status of the search, as shown in Fig.10(b).

Questionnaires were provided to participants for the evaluation of the LACS system for various usage. Table 3 summarizes the subjective evaluation of LACS and its

Figure 8. Introduction of the system and the feasibility study to the participants in the feasibility study.

(a) A student downloads content

(b) Teacher can access the submitted report locally anytime

Figure 9. Overview of e-education application of LACS

Application Category	Subjective evaluation of LACS by participants (N =10)				
	Very useful	Useful	Not useful	Quite useless	No answer
e-Education	70%	30%			
Disaster response	70%	10%			20%
Resident management	80%				20%
LACS usage in disaster (overall)	80%	20%			
LACS usage in non-disaster/daily use (overall)	50%	40%			10%

Table 3. Subjective evaluation of LACS in use cases

(a) Residents try to use LACS's communication functions

(b) Residents upload the image of surrounding area to LACS to search for a missing person

Figure 10. Overview of the demonstration for disaster countermeasure

various uses by participants. Most participants evaluated LACS to be very useful or useful in each case: e-education, disaster response, and resident management. As for the usage of LACS in a disaster situation and in non-disaster/daily use, only half of the participants evaluated LACS as very useful whereas 80% of them evaluated it as very useful for usage in disaster.

Future of LACS

Despite the widespread use of the Internet in everyday life in many high-income countries, the case is quite different when compared to the situations in low- and middle-income countries. According to the data provided in the source Thomas et. al., 2020, in 71 out of 183 countries, less than half the population has access to the internet. This fact suggests that if we succeed in proving the usability of LACS, there are plenty of areas globally where LACS can contribute to achieving Sustainable Development Goals (SDGs). As part of the future development and deployment of LACS, we will focus on the improvement of LACS to provide solutions that can bridge the wide gap in the internet penetration worldwide, especially in most developing countries where access to the internet is said to be less than 25% (Thomas et. al., 2020).

Summary

In this paper, Locally Accessible Cloud System or LACS was introduced as a new and promising solution to tackle the difficulty of using telephone and Internet services during disasters. We demonstrated that in the application of LACS to the areas with unstable or intermittent Internet connectivity, a system configuration with Local-LACS, Central-LACS on the Internet, and the synchronization between the two would be useful in filling the supply-demand gap in ICT, a critical issue that surfaced during the COVID-19 pandemic. A feasibility study for the LACS was conducted in Cordova, the Philippines for the spheres of e-education, disaster response, and platform as a service.

The results of a subjective evaluation by the participants supported the feasibility of the LACS system for the above cases. In this feasibility study, various people cooperated as participants despite the COVID-19 pandemic. According to the teachers of local schools, critical issues, such as delivering educational content to the students, collecting reports from the students, and facilitating communication between the teachers and the students, remain to be solved. We plan to keep the LACS study, especially for the area of e-education, as a long-term feasibility confirmation of the LACS system.

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References

- ✓ ITU-D. (2020). "Measuring digital development Facts and figures 2020", https://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx. 30 Nov.
- ✓ Karen Miranda, Antonella Molinaro, and Tahiry Razafindralambo. (2016). "A Survey on Rapidly Deployable Solutions for Post-Disaster Networks", *IEEE Communications Magazine*, Vol.54, No.4, pp.117-123.
- ✓ Kirtan Gopal Panda, Shrayan Das, Debarati Sen, and Wasim Arif. (2019). "Design and Deployment of UAV-Aided Post-Disaster Emergency Network", *IEEE Access*, Vol. 7, pp. 102985-102999.
- ✓ María del Pilar Salamanca and Jorge Camargo. (2016) "A Survey on IEEE 802.11-based MANETs and DTNs for Survivor Communication in Disaster Scenarios", 2016 IEEE Global Humanitarian Technology Conference (GHTC), pp. 197-204, Seattle, 13-16 Oct.
- ✓ Matteo Pozza, Ashwin Rao, Hannu Flinck and Sasu Tarkoma. (2018). "Network-In-a-Box: A Survey About On-Demand Flexible Networks", *IEEE Communications Surveys & Tutorials*, Vol.20, No.3, pp. 2407-2428, 3rd quarter.
- ✓ NTT-East. (2012). "Recovering from the Great East Japan Earthquake: NTT East's Endeavors", https://www.ntt-east.co.jp/info/detail/pdf/shinsai_fukkyu_e.pdf.
- ✓ Ojetunde, B.; Ano, S.; Sakano, T. (2022). "A Practical Approach to Deploying a Drone-Based Message Ferry in a Disaster Situation", *Appl. Sci*., 12, 6547. https://doi.org/10.3390/app12136547.
- ✓ Ojetunde, B.; Sakano, T.; Suzuki, Y. (2021). "Information Delivery and Collection System Based on Locally Accessible System", In Proceedings of the 2021 International Conference on Information and Communication Technologies for Disaster Management
- ✓ (ICT-DM), Hangzhou, China 3–5 December, pp. 142–149.
- ✓ Recommendation ITU-T L.392. (2016). "Disaster management for improving network resilience and recovery with movable and deployable information and communication technology (ICT) resource units".
- ✓ Rui Teng, Toshikazu Sakano and Yoshinori Suzuki. (2020). "Instantaneous Networking Service Availability for Disaster Recovery", *Appl. Sci.* 2020, 10(24), 9030; https://doi.org/10.3390/app10249030, 17 Dec.
- ✓ Sakano, T.; Kotabe, S.; Komura, T.; Kumagai, T.; Shimizu, Y.; Takahara, A.; Ngo, T.; Fadlullah, Z.M., Nishiyama, H.; Kato, N. (2016). "Bringing Movable and Deployable Networks to Disaster Areas: Development and Field Test of MDRU". *IEEE Network*, vol.30, no.1, pp. 86-91.
- ✓ Thomas Dreesen, Spogmai Akseer, Mathieu Brossard, Pragya Dewan, Juan-Pablo Giraldo, Akito Kamei, Suguru Mizunoya, and Javier Santiago Ortiz Correa. (2020). "Promising practices for equitable remote learning Emerging lessons from COVID-19 education responses in 127 countries", UNICEF
- ✓ Toshikazu Sakano, Rui Teng, Kazuto Yano, Satoru Shimizu, and Yoshinori Suzuki. (2019). "A Study on a system for alleviating communication difficulty based on promptly deployable local clouds in the disaster-affected areas", IEICE General Conference 2019, B-7-46, Mar. (in Japanese).
- ✓ Toshikazu Sakano, Zubair Md. Fadlullah, Thuan Ngo, Hiroki Nishiyama, Masataka Nakazawa, Fumiyuki Adachi, Nei Kato, Atsushi Takahara, Tomoaki Kumagai, Hiromichi Kasahara, and Shigeki Kurihara. (2013). "Disaster-Resilient Networking: A New Vision Based on Movable and Deployable Resource Units", *IEEE Network*, vol. 27, no. 4, pp. 40-46.
- ✓ UNDRR (2020). "Human cost of disasters. An overview of the last 20 years 2000-2019", https://www.undrr.org/news/drrday-un-report-charts-huge-rise-climate-disasters. 13 Oct.
- ✓ Vasani Yash Kishorbhai and Nagekar Nainesh Vasantbhai. (2017) "AON: A Survey on Emergency Communication Systems during a Catastrophic Disaster", *Procedia Computer Science*, Vol.115, pp. 838-845.
- ✓ Yasmin Jahir, Mohammed Atiquzzaman, Hazem Refai and AnirudhParanjothi. (2019). "Routing protocols and architecture for disaster area network: A survey", *Ad Hoc Networks*, Vol.82, pp. 1-14.