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Research article

APRS and SSTV Technology for Audiovisual Data Transmission in Internet Blank Spot Areas to Increase the Effectiveness of SAR Activities

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ABSTRACT

Volcanic eruptions can be detected through several warning signs. The Indonesian National Disaster Management Agency (BNPB) reported that between 2010 and 2021, Indonesia experienced 156 volcanic eruptions. The most recent occurred in 2021 when Mount Semeru erupted, forcing 10,395 people to evacuate, injuring 104, and causing 51 fatalities. The BNPB often experiences problems in carrying out mitigation, evacuation, rehabilitation, and reconstruction in disaster areas. On average, the search and evacuation process for victims takes about 3-7 days, so the probability of finding disaster victims is only about 50%. The proposed solution is a combination of radio transmission with Auto Packet Reporting System (APRS) technology as a medium for determining evacuation locations and Slow-Scan Television (SSTV) as a medium for transmitting audio and images of disaster sites, called Radio All-in-One (RAIONE). Using the Prototype method, this research has been tested for about 7 months with continuous improvements. The results show that the maximum distance covered is approximately 20 km with a minimum central antenna height of 7-10 meters, which increases the time effectiveness of SAR operations. The probability of finding survivors in a disaster increases to 75%, and SAR operations speed up to 1-2 days because of acceleration in the determination of search and evacuation locations in the Blank Spot Areas, reaching 91.30%.

1. Introduction

Volcanic eruptions occur when magma beneath the earth's surface is released due to high-pressure gas. Magma is an incandescent liquid found in the earth's layers with an extremely high temperature, estimated to exceed 1,000 °C. Volcanoes that erupt frequently are called active volcanoes. The signs of an impending eruption can be observed through several signs, including the rising temperature around the mountain, often making roars and vibrations, wilting plants, and animals moving away from the area [1].

Efforts to mitigate the impacts of volcanic eruptions primarily involve continuous monitoring of volcanic activity using seismographs, which are instruments designed to record seismic activity. Another crucial measure is the mapping of volcanic disaster-prone areas. These maps provide detailed information on the types and characteristics of volcanic hazards, the extent of high-risk zones,

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guidelines for self-rescue, designated evacuation sites, and the location of disaster management posts [2].

According to a report by the National Disaster Management Agency (BNPB), Indonesia experienced 156 volcanic eruptions between 2010 and 2020. In 2020 alone, 14 volcanic eruptions occurred, including those of Mount Semeru, Mount Merapi, Mount Sinabung, Mount Anak Krakatau, and Mount Ile Lewotok. Figure 1 presents data on volcanic eruptions in Indonesia during the period from 2010 to 2020.

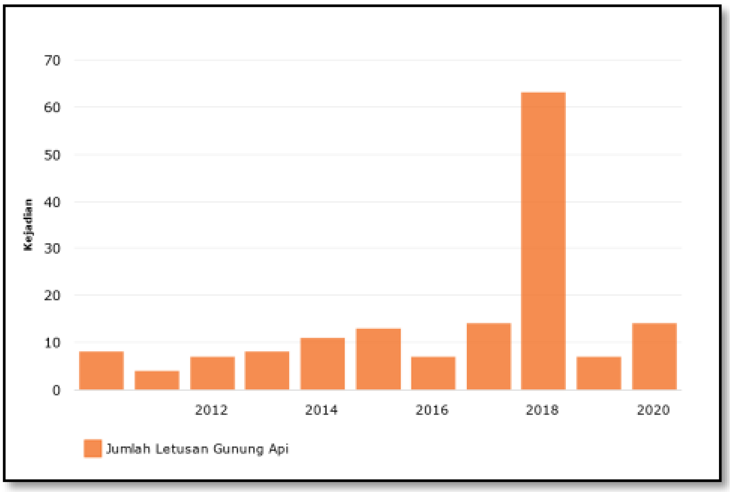

Fig. 1. Volcanic Eruption Data in Indonesia Throughout 2010-2020 [3]

Volcanic eruptions inevitably force residents living in the vicinity of the affected mountains to evacuate to safer locations. It is undeniable that such eruptions can sometimes lead to injuries and fatalities. Table 1 below presents data on the impact of volcanic eruptions from 2018 to 2021.

Table 1. Volcanic Eruption Impact Data 2018-2021 [4]

Num	Volcanoes	Year of Eruption	Victims Refuge	Injured Victim	Victim Died
1	Mount Semeru	2021	10.395 Peoples	104	51
2	Mount Merapi	2018	1.900 Peoples	-	-

Reflecting on the volcanic eruptions presented in Table 1, the subsidiary of BNPB, namely the Regional Disaster Management Agency (BPBD), through the Search and Rescue Team (SARDA Central Java), frequently encounters challenges in implementing mitigation, evacuation, rehabilitation, and reconstruction efforts during SAR operations in disaster-affected areas. Some of the data on these challenges were obtained through direct interviews with the Central Java SARDA. Table 2 below presents data on the constraints faced between 2018 and 2021.

Table 2. Data on Obstacles to SAR Operations in Central Java 2018-2021

Num	Obstacles	Location	Incident
1	*Blank Spot Area*	Mount Merapi slope	Merapi eruption 2018
2	Lack of Detectors	Dieng, Wonosobo	Extreme weather 2019
3	*Blank Spot Area*	Some Coordinates on Mount Ungaran	Expedition 2020 and OPSAR Missing Persons 2021
4	Detector Device Not Working	Sumberwuluh, Pronojiwo, Candipuro	Semeru eruption December 4, 2021
5	Lack of Detectors	Penanggal Village, Candipuro	Semeru Eruption December 16, 2021
6	*Blank Spot Area*, Late Reporting, Location Undetected	Gemukmas, Supiturang Village, Pronojiwo	Semeru Eruption December 16, 2021

Based on the aforementioned challenges, the primary issues encountered in SAR operations are the presence of blank spot areas and the lack of detection tools in disaster mitigation efforts. A blank spot

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area refers to a location where neither internet nor radio signals are accessible. This lack of connectivity results in delays in transmitting reports of findings and disaster conditions, consequently prolonging SAR operations. On average, the process of locating and evacuating victims in mountainous and forested takes approximately 3 to 7 days, leading to a survival rate of only around 50%.

The research team proposes a solution to this problem by integrating Radio Transmitting (RPU) technology with the Automatic Packet Reporting System (APRS) as a medium for determining search and evacuation locations. This is achieved through the transmission of data with text extensions that can be displayed on the APRS.FI Map web server. Additionally, Slow-Scan Television (SSTV) is utilized as a medium for transmitting data in the form of audio and images of locations affected by disaster based on coordinates generated by APRS [5] [6] [7]. SSTV enables the transmission of data through a decoding process that converts audio signals into images or vice versa. These two technologies are collectively referred to as Radio All in One (RAIONE), which remains operational in blank spot areas, even in the absence of signal propagation and without reliance on electricity from the State Electricity Company (PLN). Studies relevant to the application of these technologies include the use of Position Tracking for monitoring, coordination, analysis, and tactical planning to enhance the safety of Rescuers in Norway [6], as well as the implementation of SSTV for transmission and reception under various conditions, modes, and frequencies, while considering the security aspects of image transmission based on tests conducted on 10 radios and their potential interference [8] [9].

Radio All in One (RAIONE) introduces a new method for receiving and transmitting images via audio media using SSTV technology. This approach relies solely on radio communication through repeaters, enabling the implementation of the technology without requiring internet or satellite connections. Traditionally, SSTV technology has only been utilized when the ISS space satellite station orbits over Indonesia between December and January. Furthermore, this research incorporates a method for transmitting data with the extensions field reporting using APRS. By integrating radio devices with a Terminal Node Controller (TNC), sensors, and mini computers, the research team aims to operate APRS similarly to Global Positioning System (GPS) technology, enabling real-time tracking and monitoring until the device is deactivated. The findings of this study serve as a recommendation for enhancing SAR operations in Indonesia. It is anticipated that these findings will improve the efficiency of SAR operations and, ultimately, the percentage of survivors located during disaster evacuation efforts to approximately 75%.

2. Materials and Methods

The stages of research that will be carried out using the Prototype method contained in Fig. 2 below.

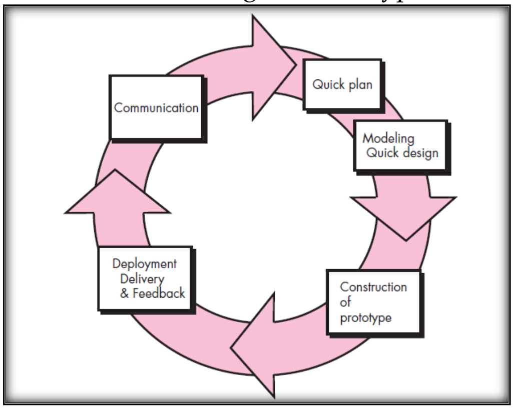

Fig. 2. Prototype Paradigm [10]

The stages of the Prototype method, as illustrated in Fig. 2, begin with the Communication stage, which involves an analysis of user requirements. At this stage, the research team conducted direct observations of the ongoing SAR operations at Central Java SARDA. These observations revealed several challenges encountered during SAR missions. Firstly, SAR teams frequently experience blank spot areas at certain altitudes. Additionally, the accuracy of location coordinates is often compromised, even when determined and read using a land navigation compass map. Furthermore, delays in reporting frequently occur due to excessive noise in radio communications. This interference arises from prolonged transmission times when using HT radio communications.

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Next is the Quick Plan, which involves developing a general design for further implementation. The proposed solution is the integration of APRS and SSTV technology, collectively referred Radio All in One (RAIONE). This system enables the transmission of data with text extensions and audiovisual content without relying on internet connectivity. Table 3 presents a comparison plan between conventional SAR and RAIONE activities.

Table 3. Comparison Between Conventional SAR Activities and RAIONE

Num	Comparison		Feature
	Conventional SAR Activities	RAIONE	
1	Unable to send an overview of the current conditions at the location	Able to send the latest pictures on location	SSTV
2	Unable to communicate with audio text because of a blank spot	Able to communicate using audio text	Repeater
3	The SAR team's whereabouts unknown	The SAR team's location can be identified	APRS Tracking
4	The SAR team's movement not observable	The SAR team's movement can be monitored	APRS Tracking
5	The tracking location at the time of sweeping often skipped over and over	The path that has been passed can be marked	APRS Tracking

Furthermore, in this stage, the necessary equipment for developing RAIONE is also designed. This includes RIG Motorola GM 3188 UHV, antenna, battery, repeater, COR cable, interface cable, Baofeng UV5R HT, smartphone, aprs.fi user, APRSDROID apps, and Direwolf apps.

The Modeling and Quick Design stage involves developing a prototype device plan, including testing and refinement. The proposed model plan consists of a prototype Radio All in One (RAIONE) topology, incorporating various supporting technologies, communication models, and block diagrams. This is illustrated in Fig. 3 below.

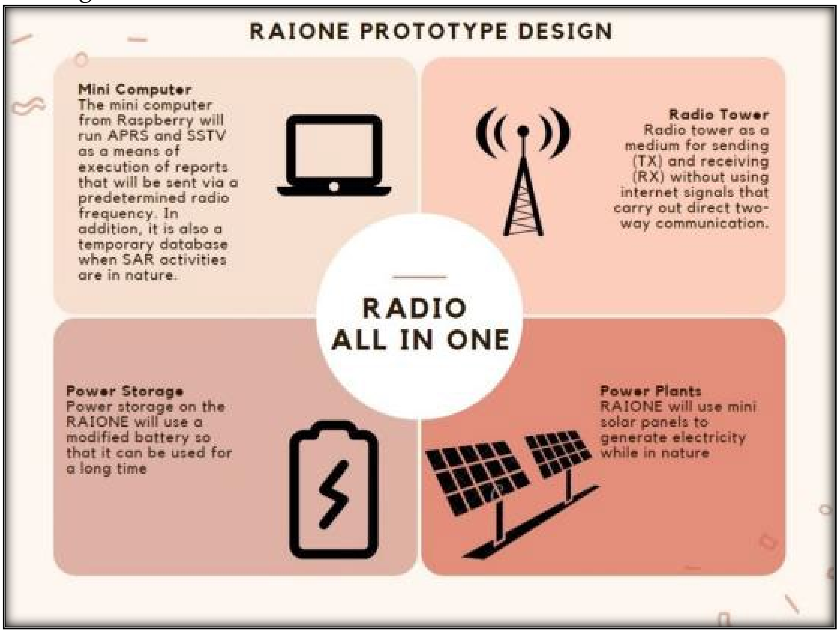

Fig. 3. RAIONE Prototype Design

The components to be include a radio tower as a medium for transmitting information without an internet connection, a mini computer to operate APRS and SSTV, power storage, and a power plant utilizing solar panels. Additionally, the communication model from RAIONE has been designed, as illustrated in Fig. 4 below.

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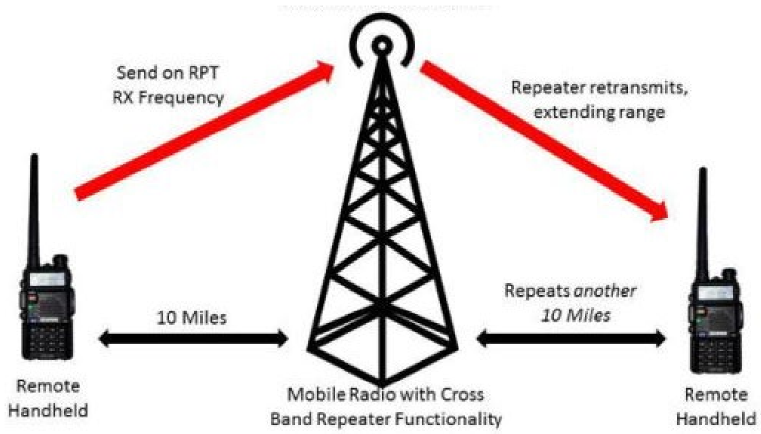

Fig. 4. RAIONE Communication Model

The communication model utilizes two Baofeng UV5R HT as a medium for transmitting location data, text, voice, and images between the SAR team members, integrated with APRS and SSTV technology. The block diagram detailing the electronic components of RAIONE is presented in Fig. 5 below.

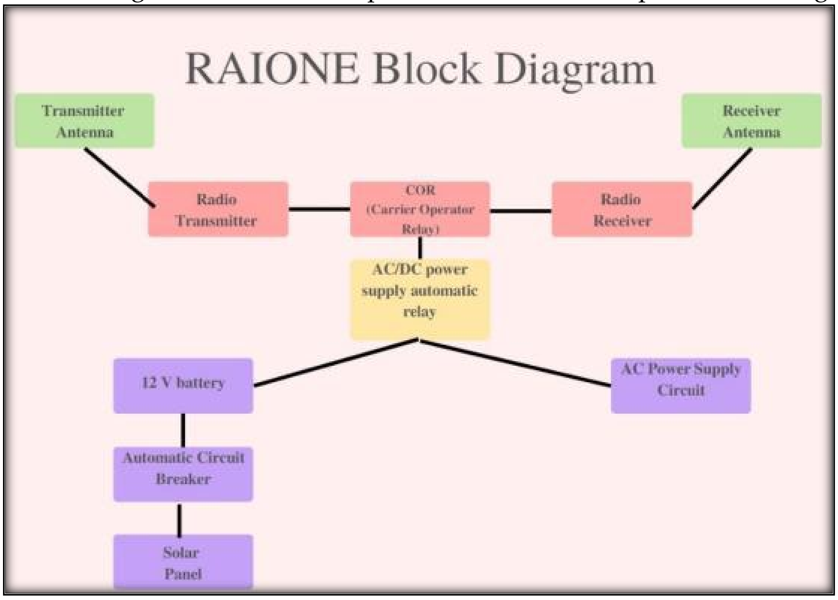

Fig. 5. RAIONE Block Diagram

The Construction of the Prototype stage involves the implementation of the RAIONE prototype design and its subsequent testing. The testing is planned to be conducted on Mount Ungaran to evaluate the effectiveness of the developed prototype.

The Development, Delivery, and Feedback stages involve the submission of the prototypes to SARDA Central Java, followed by an analysis of their effectiveness through user satisfaction surveys. Additionally, follow-up interviews will be conducted to gather insights for further development of All in One Radio technology (RAIONE).

2.1. Automatic Packet Reporting System (APRS)

The Automatic Packet Reporting System (APRS) is a radio-based system designed for real-time digital communication without the need for an internet connection. The transmitted data can include Global Positioning System (GPS) coordinates, weather station telemetry, various other telemetry, text messages, announcements, and questions [11] [12].

Globally, APRS has primarily been utilized for monitoring digital radio signals. Additionally, both homes and vehicles can employ APRS to perform GPS reporting in real-time without requiring an internet connection, simply by linking to digital repeaters available in various locations. The following in Fig. 6 is a schematic of the implementation of APRS.

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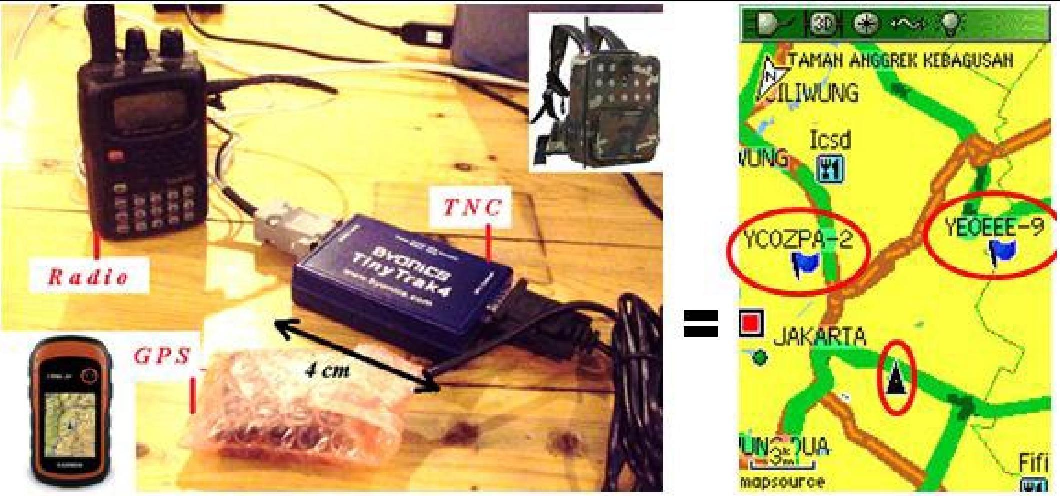
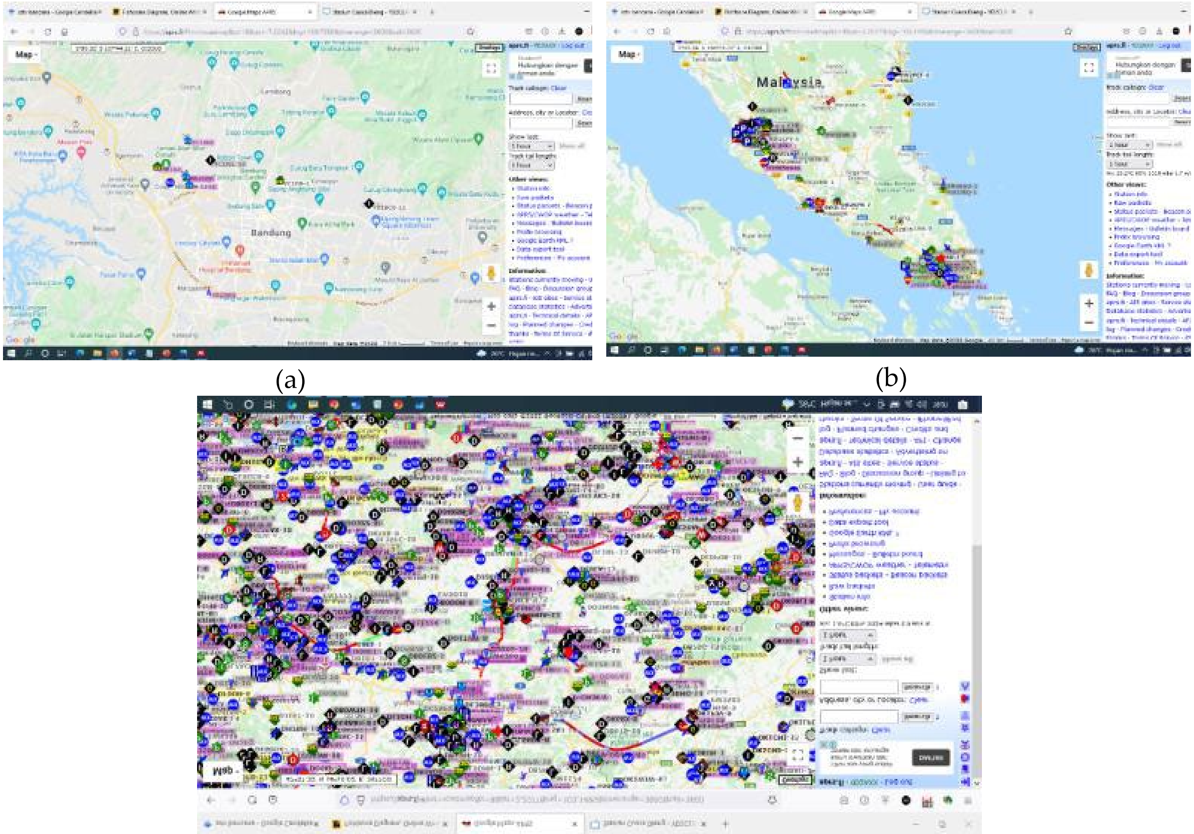


Fig. 6. APRS Schematic With Display [13]

The following in Fig. 7 are comparisons of several regions in Indonesia and abroad regarding the use of APRS traffic.



(a) (b)

(c)

Fig. 7. APRS Beams: (a) in Bandung; (b) in Malaysia and Singapore and (c) in Europe [14]

Fig. 7 presents a map illustrating the use of APRS technology in Indonesia in comparison with its usage in Malaysia, Singapore, and European countries. The highest concentration of APRS users is in Bandung, whereas its adoption in other cities remains unevenly distributed. Consequently, significant research opportunities remain in this field to further develop APRS in Indonesia.

2.2. Slow-Scan Television (SSTV)

Slow-scan Television is an image transmission method primarily by amateur radio operators to send and receive static images over radio frequencies in either monochrome or color [15] [16] [17]. The term SSTV literally refers to narrowband television, describing the process of transmitting and receiving static images via radio technology [18] [17]. The following in Fig. 8 are examples of images transmitted via SSTV technology from space using the ISS satellite and received using the RX-SSTV software.

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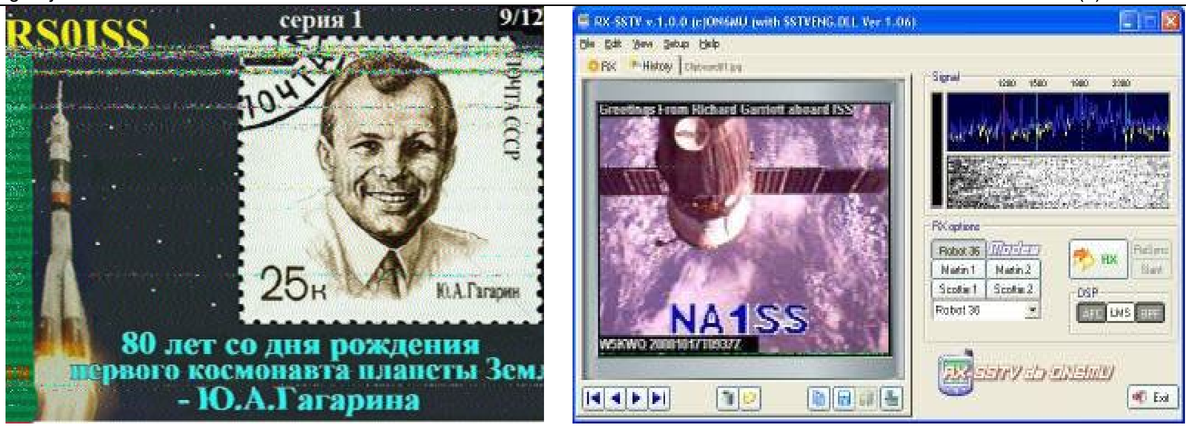


(a) (b)

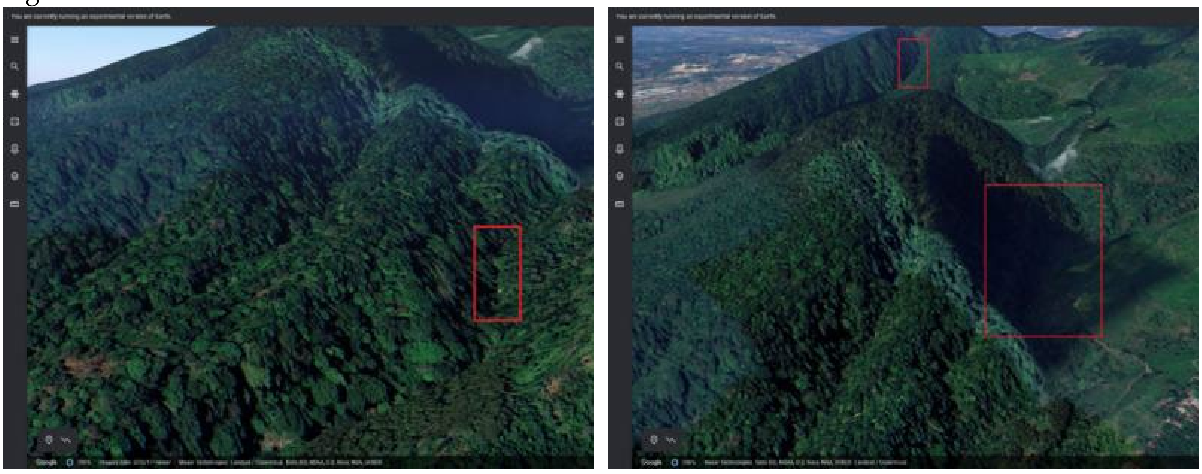
Fig. 8. SSTV Technology: (a) Image Sending Results Using SSTV [19] and (b) RX-SSTV Display [20]

In Indonesia, SSTV activities are organized by ORARI (Indonesian Amateur Radio Organization) during specific events via the IO-86 Satellite. The transmitted data often includes images commemorating national occasions, such as the independence anniversary and JOTA-JOTI [18]. Additionally, SSTV transmissions become the focus of a competitive event when the ISS Satellite passes over Indonesia between December and January. During this period, amateur radio operators compete to receive rare images transmitted by cosmonauts, which are very rarely made publicly available.

2.3. Blank Spot Area

A Blank Spot Area refers to a location that lacks coverage by communication signals, whether for analogue communication, such as telephone networks, or digital communication, such as internet networks. In the presence of a blank spot area, two-way communication becomes challenging or even impossible. The existence of a blank spot area will certainly be very detrimental to various parties, leading not only to material losses but also to the loss of critical data [21][22].

The existence of communication signals is crucial, especially for companies that require high mobility, such as for business communication. Blank spot areas are not only found in remote areas but can also occur in major cities, where they may disrupt the communication process. Typically, blank spot areas arise due to challenging geographical conditions, such as valleys, mountains, and forests. Additionally, weather factors also affect the occurrence of blank spot areas, such as bad weather, heavy rain, strong winds, storms, and so on [23]. The following in Fig. 9 are the blank spot areas on Mount Ungaran.



(a) (b)

Fig. 9. Blank Spot Areas on Mount Ungaran [24]

3. Results and Discussion

The result of this study is the development of a tool called RAIONE, which integrates APRS and SSTV technology with the aim of assisting SAR activities in Indonesia. An overview of the RAIONE prototype is presented in Fig. 10.

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Fig. 10. RAIONE Prototype Implementation

This prototype has undergone five testing phases in various places, evaluating the accuracy of location points generated by APRS and the transmission quality of images sent via SSTV over radio signals. The test results are quite good and will be improved in subsequent tests. The results of the RAIONE Prototype test are listed in Table 4 below.

Table 4. RAIONE Prototype Test Results

Num	Test Date	Session	Time	Latitude & Longitude	Via	APRS	SSTV
1	June 29, 2022	1	07.52 AM	6°59'10.9"S 110°29'58.4"E	APRSdroid	not detected	image sent
2	June 30, 2022	1	07:19 PM	6°59'22.6"S 110°30'06.6"E	APRSdroid	detected	image sent
3	July 2, 2022	1	07:41 AM	6°56'08.0"S 110°27'25.5"E	APRSdroid	detected	image sent
4	July 5, 2022	2	09:38 AM	6°59'10.9"S 110°29'58.4"E	Direwolf	not detected	image sent
5	December 14, 2022	2	09:01 AM	6°59'10.9"S 110°29'58.4"E	APRSdroid	detected	image sent

Meanwhile, the APRS and SSTV output display tests is shown in Fig. 11(a), Fig. 11(b), and Table 5.

Fig. 11(a). APRS Test Results: APRS's Log of Forming a Square Pattern on a Map aprs.fi

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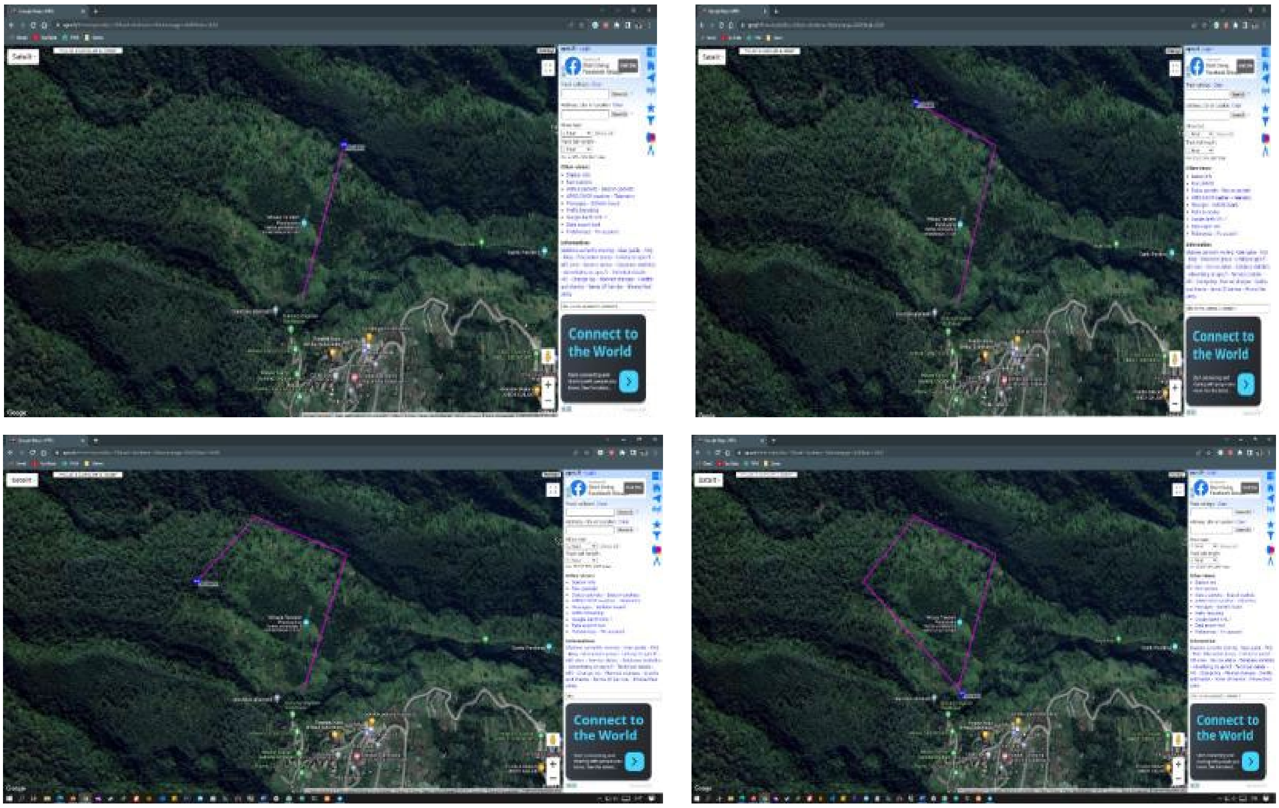

(b)

Fig. 11(b). APRS Test Results: The Process of Forming a Square Pattern on a Map aprs.fi

The process of creating an evacuation route map on the aprs.fi map is carried out by volunteers. This mapping facilitates the evacuation process in the event of an incident on the mountain that results in casualties. The affected area is marked with a square shape, so that the process of finding and evacuating victims will be quicker and easier.

Then, a test was conducted to evaluate the transmission of images from the incident location using SSTV technology. This aims to assist the SAR team in determining the appropriate equipment to be carried during the evacuation process on the mountain. The following in Table 5 are the results of testing image transmission using SSTV technology.

The clarity of the images transmitted via SSTV is influenced by several factors, including the height of the antenna located at the base camp, the distance the images are sent, and the level of the obscurity of the obstacles being traversed, such as trees and steep hills. The higher the antenna is positioned, the greater the clarity of the image sent by SSTV, even though the distance of the volunteer sending the image is far away. This also depends on the obstacle passed. The denser and denser the obstacles, the lower the quality of the images sent. Table 6 presents a matrix illustrating the relationship between antenna height and the maximum transmission distance for SSTV image transmission.

Table 6. Matrix of the Height of Antenna Installation and the Distance that can be Covered

Antenna Height	Reachable Distance
1 - 3 m	400 m - 500 m
3 - 5 m	500 m – 2 Km
5 - 7 m	2 – 10 Km
7 - 10 m	10 – 20 Km

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Table 5. SSTV Test Results

Num	Mode	Time	Original Image	Result Image
1	Robot36	36 seconds		
2	Martin 1	62 seconds		
3	Robot36	41 seconds		

Evaluation is conducted to determine the progress of the research. The way to do this is to fill in the checklist table as follows in Table 7.

Table 7. Evaluation Table Results

Tools	Num	Target	Check
Repeater	1	Can do reception well	**V**
	2	Can transmit well	**V**
	3	COR works	**V**
	4	Coverage area of more than 1 Km	**V**
	5	Coverage area of more than 3 Km	**V**
	6	Coverage area of more than 5 Km	**V**
	7	Coverage area of more than 10 Km	**V**
	8	Can radiate using electricity	**V**
	9	Can transmit using battery	**V**
	10	Can be filled with solar panels	**X**
SSTV	11	Can be used without internet on site	**V**
	12	No interface	**V**
	13	Using interface	**V**
	14	Interface works	**V**
	15	Interface can be RX	**V**
	16	Interface can be TX	**V**
	17	Can receive pictures	**V**
	18	Can send pictures	**V**
	19	Images can be converted to JPG/JPEG	**V**
APRS	20	Can be used without internet on site	**V**
	21	Able to do tracking	**V**
	22	Able to save tracking history	**V**
	23	Tracking is updated every time	**X**

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The progress of this research is measured using a structured checklist comprising 23 evaluations to assess the success of the study. From 23 evaluation points, 21 clear checklists were obtained so that the percentage of research progress to date is 21/23*100 = 91.30 %.

4. Conclusion

The progress of this research has reached 91.30 % and continues to be refined to further enhance the RAIONE. The determination of location points and the transmission of location images using RAIONE have already been successfully implemented, making the system a valuable tool for supporting the SAR Team. With RAIONE, the possibility of locating survivors during a disaster is expected to increase by approximately 75% and speed up the SAR process to 1-2 days. This is because the tool can determine location points quickly from the previous and send location images so that aid can be sent effectively in blank spot areas. This research was conducted to expand the range of methods in SAR operations, and it needs to be developed and tested continuously in disaster areas to ensure that RAIONE becomes a perfect product to assist SAR operations.

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Author Contributions

F. W. Christanto: Conceptualization, data curation, formal analysis, funding acquisition, methodology, project administration, software, writing – original draft, and writing - review and editing. S. Handayani: Validation, visualization, writing – original draft, and writing - review and editing. T. Handayani: Validation, and writing – review and editing. C. Dewi: Resources, investigation, supervision, writing – original draft validation, and writing – review & editing.

Declaration of Competing Interest

We declare that we have no conflict of interest.

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