JURNAL UPI

Jurnal Pendidikan Multimedia (EDSENCE)

Jurnal Pendidikan Multimedia EDSENCE Education, Science, and Creative Technology

Journal homepage: https://ejournal.upi.edu/index.php/Edsence

Challenge In Future Ip-Based Voice Communication System for Air Traffic Control

Nurhidayatulloh[1], Hendrawan[2]

[1]Universitas Pendidikan Indonesia, Bandung, Indonesia
[2]Bandung Institute of Technology, Bandung, Indonesia
Correspondence: E-mail: nurhidayatulloh@upi.edu

ABSTRACT

The most important part of the modernization of Air Traffic Management (ATM) is the Voice Switching and Control System (VSCS) based on Circuit Switching (CS) technology. This technology has Quality of Service (QoS) on Bandwidth, Delay, and Jitter, but it is expensive to implement in small and medium airports. The development of Packet Switching (PS) technology with Internet Protocol (IP) is expected to become an alternative to modern and affordable systems such as the IP-based VSCS communication system. This research uses literature study and experimental methods to develop features and components of a portable IP-based VSCS communication system. The measurement results of this prototype have a delay of 100-150 ms, jitter below 50 ms, 0% packet loss, and varying throughput. Thus, the VSCS prototype built has performed according to the standards required by the International Civil Aviation Organization.

ARTICLE INFO

Article History:
Submitted/Received 01 Feb 2024
First Revised 20 Feb 2024
Accepted 10 May 2024
First Available online 10 Jun 2024
Publication Date 10 Jun 2024

Keyword:
Voice Switching and Control, System (VSCS),
Circuit Switching (CS),
Packet Switching (PS),
Internet Protocol (IP),
Air Traffic Control (ATC),
portable.

1. INTRODUCTION

Aviation is one of the most important aspects of our lives today, including Indonesia, a nation of more than 17,500 islands and 250 million people. Aviation is an efficient and effective way to connect Indonesians. Thanks to the growth of the middle-class population and the growth of flights by low-cost airlines over the past decade, the Indonesian aviation market has experienced very significant growth, both domestically and internationally. However, in 2019, the aviation world went downhill due to the Covid-19 pandemic requiring restrictions on flight operations systems. It will take 18-24 months to overcome pandemic conditions and continue to do prevention or mitigation work to reduce the spread of Covid-19 (Hussain and Varon, 2021).

The situation in Indonesia at this point is beginning to improve. It issaffected by Indonesia's population, which accounts for 41% of Southeast Asia's total population, and Indonesia's US $ 1.1 billion GDP, which accounts for 35% of Southeast Asia's economy. Indonesia's GDP is expected to grow by 24% in 2025, based on IHS Economics data. This year, industrial production is projected to increase by 15% and personal consumption is projected to increase by 25%, and in the end Indonesia in 2039 is projected to become the world's largest aviation market, -4 countries. To tackle the future of aviation, Boeing will update fleets, improve flight efficiency and sustainability, increase travel demand, market diversity, create new innovations, improve network flexibility and capabilities, and more. We anticipate various trends in the industry. Indonesia is projected to become one of the countries with the largest aviation market in the world - Bandung Institute of Technology (Permana, 2022). Apart from that, this is also supported by the findings in research (Nishkar Kumar and Patel, 2024) which discusses that the world of tourism also influences the real exchange rate of money and the arrival of tourists using flight routes.

To deal with these conditions, it is necessary to modernize air traffic management. Globally, air traffic modernization refers to ICAO's global air traffic management (ATM) concept (Sivaraman *et al.*, 2019). The ICAO Global ATM Operation Concept is a vision that defines how ATMs will operate in the future to achieve goals such as air traffic safety and efficiency. This air traffic management aims to provide air traffic services for aircraft flying within aviation airspace as well as transfer air traffic control authority between adjacent controllers (Özmen, Hamzaoui and Chen, 2024). Meanwhile, in Indonesia, the modernization of air traffic management is carried out by the Indonesian Air Navigation Services Modernization Program (IMANS), established by AirNav Indonesia, a state-owned company operating as an air navigation service provider (ANSP) (Nguyen *et al.*, 2019). IMANS is needed to effectively manage various aviation modernization activities that occur throughout Indonesia.

Significant air traffic growth has not only occurred in Indonesia but also in other countries. For example, air visitors extent in Japan is predicted to boom via way of means of 1. five instances from 2005 to 2027 (Shorten and Khoshgoftaar, 2019). Therefore, the need for air traffic modernization is not only limited to Indonesian flights, but also other countries such as Japan, Europe, and the United States. With this growth the need for ATM modernization is critical to address the issues that have arisen as a result of this significant growth, such as security and capacity. Therefore, to overcome security problems originating from risk factors during air traffic control operations in the last two decades, it is possible to carry out data-based risk management as a form of modernization (Liu *et al.*, 2023). One of the maximum

DOI: https://doi.org/10.17509/edsence.v6i1.72266
p-ISSN:2685-2489 | e-ISSN:2685-2535

vital components of modernizing air visitor control is the Voice Switching and Control System (VSCS). Conventional and dominant VSCS era in recent times is based totally mostly on Circuit Switching (CS) and Time Division Multiplexing (TDM) technologies. Although this era has QoS ensures in phrases of bandwidth, latency/latency and jitter, the era is complex and high priced to put into effect in small and medium sized airports in Indonesia (Dwivedi *et al.*, 2019). With the improvement of Packet Switching (PS) era with Transmission Control Protocol/Internet Protocol (TCP/IP), the complex and high priced VSCS gadget with CS era may be changed through a Voice over IP (VoIP) is extra current and cheaper. Another benefit of an IP-primarily based totally VSCS gadget is that it's miles less complicated to combine with Communications, Navigation, and Monitoring (CNS) additives over a TCP/IP packet network. In addition to having advantages in the field of aviation, the system is also expected to be a medium for learning and training as an example of the ATC communication system on aircraft that is portable and easy to carry.

2. METHODS

This research uses literature study and experimental methods. The initial steps taken are looking for references related to relevant research and making an initial design of an IP-based VSCS prototype. The next stage is to integrate the results of the prototype development in the form of hardware and software to obtain efficiency values which include delay, jitter, packet loss, and throughput.

Primary data collection was carried out through interviews with AirNav Husein Sastranegara Airport regarding equipment and communication processes on flights. Secondary data retrieval is carried out from literature studies with the aim of studying concepts and theories that can support the process of designing, implementing, and testing IP-based prototypes in portable form.

3. RESULTS AND DISCUSSION

3.1. Future Communication of ATC

In the destiny, the multiplied trade of records and the complexity of records among controllers and pilots needs using current communique technologies. This approach that similarly growth of using virtual facts hyperlink communications is expected. Voice isn't always sufficiently able to effectively conveying the records required for destiny operational procedures.

The European Organization for Aviation Safety (EUROCONTROL) and the Federal Aviation Administration (FAA) launched a joint study in 2004 to facilitate ICAO discussions (Mosavi *et al.*, 2019). This initiative is called Future Media Research (FCS) and started with a research agreement called Action Plan 17 (AP17). FCS has two main activities, identifying future communication needs based on the emerging global ATM concept of the future (Palanisamy and Thirunavukarasu, 2019) and evaluating technology to determine the most appropriate technology to meet the requirements. that communication (Sadowski, 2019). The Future Communications Infrastructure (FCI) was developed to meet these communication requirements.

DOI: https://doi.org/10.17509/edsence.v6i1.72266
p-ISSN:2685-2489 | e-ISSN:2685-2535

Future Communications Infrastructure (FCI) may be a key enabler for brand new ATM offerings and applications, in an effort to deliver operational blessings in phrases of capacity, performance and security.

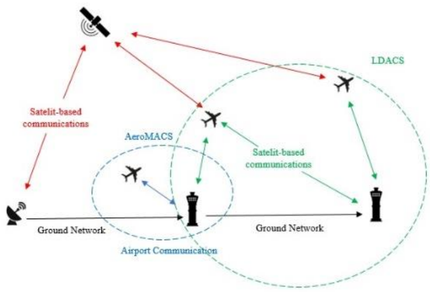

Figure 1. FCI consisting of AeroMACS, LDACS. satellite-based communications

3.2. Communication Process of ATC

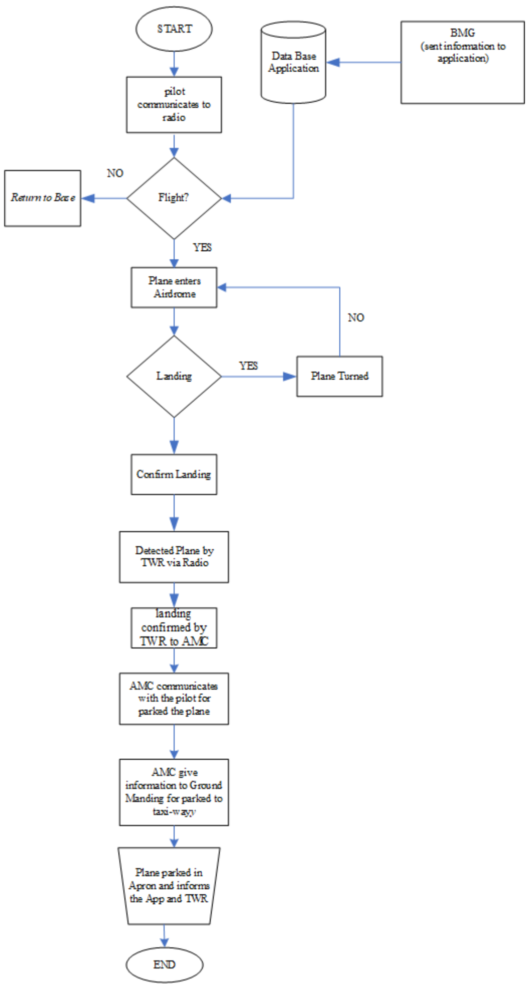

Figure 2. Flowchart Communication Process in ATC

DOI: https://doi.org/10.17509/edsence.v6i1.72266
p-ISSN:2685-2489 | e-ISSN:2685-2535

Above **Figure 2**, The communication session between the pilot and APP begins when the aircraft is at the check-point position. The APP starts when the aircraft is at the check-point position. This communication is carried out, among others, to find out information on weather conditions at the destination airport, when the aircraft enters the Aerodrome area, further communication is carried out by the TWR unit. This communication starts when the TWR unit gives confirmation to the APP unit.

In carrying out this communication, the TWR unit is supported by two radio devices, namely a main radio and a standby radio (backup). The frequency used in this communication uses VHF with a frequency range of 117,975–137 MHz. The use of this frequency is in accordance with ICAO provisions for radio communications for civil aviation. This frequency is used for voice and data communication purposes **(Yu *et al.*, 2019)**. For the European region, the spacing between channels is 8.33 kHz, and 25 kHz for other places **(Huang *et al.*, 2019)**.

The main radio is used in normal conditions without any interference, while the standby radio is only used if there is a failure or performance failure on the main radio. The area coverage of an ATC is calculated in units of Nautical Mile distance. Nautical Mile is a unit of distance used in air and sea navigation. The pilot's communication with ATC apart from the coverage of the area is also based on the aircraft's altitude in feet (feet).

The pilot made communication contact with APP at a range of 60 Nautical Miles from the destination airport at an altitude of 40 thousand feet. After the pilot receives a response from APP, APP will then coordinate with the TWR that an aircraft will enter the Aerodrome area to make a landing. The conversation between the pilot and the APP unit can also be heard by other aircraft, because all aircraft in the airspace of an airport must use the same frequency as the APP in that airspace. The TWR unit, which has received information about the arrival of the aircraft from APP, will then monitor whether the aircraft is visually visible. If the aircraft is seen, the TWR unit will instruct the APP unit to provide the radio frequency used by the TWR to the pilot, so that the pilot and TWR can coordinate directly related to landing navigation. The APP then assigns the main frequency and the backup frequency used by the TWR to the pilot. The pilot then changes the radio frequency to the frequency used by the TWR and communicates with the TWR for further instructions. After the plane effectively lands at the runway, the TWR unit then conducts radio communication with the Apron Movement Control (AMC) or the aircraft parking section. The AMC instructed the TWR unit to provide the radio frequency they use to the pilot. The TWR unit provides the radio frequency used by the AMC to the pilot so that the two of them communicate directly regarding aircraft parking arrangements. The aircraft that is taxiing on the runway then communicates and coordinates with the AMC regarding the aircraft parking lot or apron. The aircraft then goes to the AMC designated Apron via taxi-way.

3.3. Development of Voice Communication System

Communication between ground and air is usually done verbally via radio. When traffic volume increases, communication becomes congested and exceeds communication capacity, it increases the risk of human error such as misunderstanding in ATC communication.

One of the maximum critical additives of an Air Traffic Controller (ATC) is the Voice Switching Control System (VSCS). VSCS is a laptop managed switching device to offer air visitors controllers with all voice circuits (air-to-floor and floor-to-floor) required for ATC (Al-

Turjman, Zahmatkesh and Mostarda, 2019). VSCS gives voice verbal exchange facilities (radio, push-to-talk (PTT), telephone) further to recording to the Controller Working Position (CWP) to govern air traffic the least bit levels of the controller. VSCS have to be able to assist air-to-ground and ground-to-ground communications from VHF and UHF verbal exchange bands to even High band (HF) bands for communications withinside the sea location collectively with redundancy for pilot-control facts link communications.

Conventional voice communique structures for air site visitors manage depend on circuit-switched technology (Kumar and Singh, 2019). In this system, point to point communication is built with a dedicated wired circuit. The circuit-switched voice communication system has several advantages such as good voice quality, low latency, and low voice delay. However, the circuit-switched voice communication system has some limitations. Systems are constructed on proprietary software program and hardware whose hardware or software program is managed with the aid of using the owner. As a result, hardware will become very high-priced and it's far hard to attach structures from specific vendors. The gadget lacks records integration, that is required to engage with records offerings including climate facts structures. The system is also less flexible due to special wiring circuitry, ATC can communicate via radio or telephone but not both using a single controller workstation.

In recent years, the communications industry has moved from circuit-switched technology to packet-switched technology based on Internet Protocol (IP). This also applies to voice communications in ATC, where the importance of infrastructure for voice communications has shifted from circuit-switched to packet-switched (Ang *et al.*, 2018). Compared to the old technology of circuit-switched communication systems, the reliability and quality of Voice over Internet Protocol (VoIP) is comparable. Moreover, VoIP is more modern and not as complicated and expensive as its predecessor. With the development of packet switching technology with the TCP/IP protocol, it is hoped that a more reliable and better technology can be expected, so that expensive voice communication systems with circuit switching technology can be replaced.

Packet-switched voice communication systems have several advantages over circuit-switched systems. A significant advantage of using a packet-switched system is the increased interoperability. This means that more commercial off-the-shelf (COTS) components from different manufacturers can be interconnected using IP. Improved interoperability allows expensive hardware and software to be replaced with off-the-shelf software and standard Internet equipment such as routers and switches. It also allows integration with external data services such as weather information and wide area network (WAN) connectivity, so that the controller can perform its tasks remotely (Lau *et al.*, 2019). Another important advantage of a packet-switched system over a circuit-switched system is error recovery where alternative paths for packets are automatically calculated as a result of normal network activity in the field. in the event of a link or node failure (Wu *et al.*, 2019). Otherwise, failure of nodes or links in a circuit-switched network will lead to communication interruptions.

3.4. IP Based VCS Implementation for Air Traffic Control

ATM communication modernization encourages communication system technology companies to build IP-based voice communication systems that can meet the needs of ATM modernization. Although the internal architecture for each product is different but the main

DOI: https://doi.org/10.17509/edsence.v6i1.72266
p-ISSN:2685-2489 | e-ISSN:2685-2535

components under the Vienna Agreement and the performance requirements under the EUROCAE remain the same for all products. This section will discuss the general architecture of the IP-based voice communication system products used by all ATMs today.

The modern IP-based voice communication system architecture distributes core of the network to the peripherals. Because intelligence is distributed across many elements, failure in one part of the system does not affect the operation of other systems, and IP networks do not depend on a single interface connection. Using a redundant network protects against network outages, ensures continuous voice network operations, which ultimately leads to higher system reliability and availability. Although VoIP is used for voice communication, most IP-based voice communication systems allow coexistence between new IP-based systems and old conventional systems. This allows for a seamless transition to ATM modernization programs of any size and complexity, from small single tower installations to national and multinational voice systems. The system also functions as a fully networked business voice system, with enhanced capabilities for business continuity planning, asset sharing, and future installations.

The components of a typical IP based voice communication system are stated below as depicted in **Figure 3**.

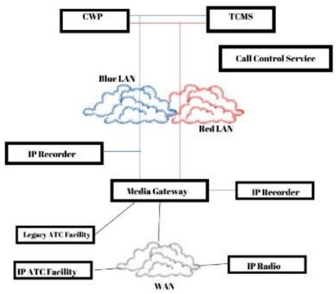

Figure 3. Typical IP-based voice communication system architecture

- Control workstation (CWP) for radio and telephony communications, the CWP can be expanded to hundreds of CWPs.
- Media Gateway for radio and telephone line interface functionality, allowing any combination of communication and legacy networks
- Dual base active LAN (red and blue IP networks) running on each component, with no switching times (compared to traditional TDM cores)
- Radio unit to emulate all legacy remote terminal functions while supporting A/G network functions on the ED137
- Call control server to manage endpoint connectivity and conferencing capabilities
- TMCS and for fault reporting, monitoring, control and system configuration.

3.5. Development of IP-Based VSCS Mock-up for Education Training

The air site visitor's controller (ATC) voice switching and manage gadget is crucial to the navigation of plane thru radio communications. Asterisk VoIP Server may be a technique to construct a reasonably-priced and effective VSCS gadget in Air Traffic Controller. The Asterisk VoIP server is on the coronary heart of this VSCS infrastructure. Purpose VSCS is used to attach ATC with voice conversation technology which include public telephony and radio networks

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(PSTN). First, to connect with a pay telecellsmartphone (PSTN), we want a PSTN port to transform analog telephones to IP telephones. The PSTN gateway has an FXO (the Forex market Office) port, which accepts analog traces over phones or fax machines. This establishes a connection to the analog line (FXS). FXS gadgets related to the telecellsmartphone gadget are known as terminals. The proposed gadget effectively connects radio conversation gadgets with softphones over IP network. Finally, in CWP, ATC can screen flight radar, take a look at name logs, and click-to-name via an internet interface with the telecellsmartphone gadget and radio communications running on the airport (Vinayakumar *et al.*, 2019).

This study creates a prototype IP-based VSCS communication system that meets ICAO-based VoIP communication standards by measuring several variables, including:

1. The radio signal power is 136MHz. Power was measured using the Aaronia Spectran Spectrum Analyzer [HF-6065V4].
2. One-way delay, jitter, packet loss, and throughput parameters using Wireshark software to measure VoIP communications from Push-to-Talk radio (PTT), softphones, and public exchange networks (PSTNs).

The layout of the prototype is accomplished in 2 stages, specifically Topology Design and Antenna Dimension Design.

3.5.1. Prototype Components

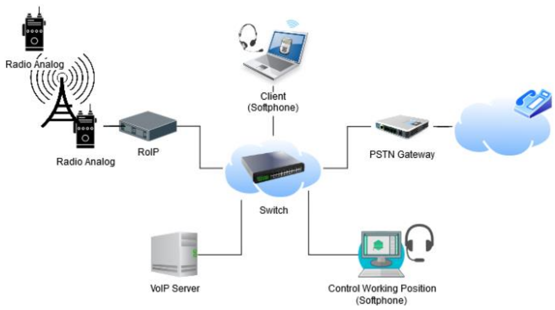

Figure 4. Topology Design on the VSCS Prototype
(Setiawan and Hendrawan, 2020)

The components that make up this prototype are:

a. Analog Radio (Rig VHF 136Mhz – 173Mhz 8900)
Is a device used for two-way radio communication Communication using this radio uses the VHF frequency of 136-174 MHz. UHF 400-480 MHz, Output Power: VHF 25Watt, UHF 20Watt.
b. RoIP Gateway 102
RoIP is a tool that converts analog indicators from radio communications to VoIP communications over IP networks with the subsequent specifications:
    - VoIP Protocols: SIP V2
    - Voice Code: G.711, G.729, G.723.1
    - PTT Ports:1
    - Links: 100 Mbit/s

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c. Switch
   Is an intermediary device that connects all elements of this VoIP communication
d. Laptop
   Laptop computers function as VoIP clients for VoIP communication. The softphone is installed on two laptops, which function as CWP and which function as Client. Softphone used is software based on Open Source Linphone.
e. PSTN Gateway
   PSTN Gateway is a device that converts analog telephone communications to data packets and forwards them to the IP network. Through the PSTN Gateway enables analog telephone interworking with VoIP communication.
f. VoIP
   Server A VoIP server is the main component that manages all SIP-based communication sessions in a VoIP network. The VoIP server used in this VSCS prototype uses the Asterisk Softswitch.

3.5.2. VSCS Features

Figure 5. User Interface VSCS Portable Box

In the interface design above there are three parts.

a. The left interface button (blue background color) is the control interface for telephony actions to the radio.
b. Interface button on the right (yellow background color) is a control interface for telephone to PSTN line, local extension, other IPPBX extension, SIP Trunk (Route Public Telephony), or direct access to Satellite. On the right interface button, contact data of the destination number can be stored directly, so that if you press the desired box, it will automatically call the destination number without entering the number manually.
c. On the bottom, namely Phone, Conf, Trans, Hold, Pickup, Combine, Split, Dialpad, Mon are a few buttons for operations on web-based telephony systems.

3.5.3 IP Based VSCS Mock-up Display

The portable box design was created using the AutoCAD 2017 application to provide an overview of the placement of IP-based VSCS components according to their size. The portable box design is shown in **Figure 6**.

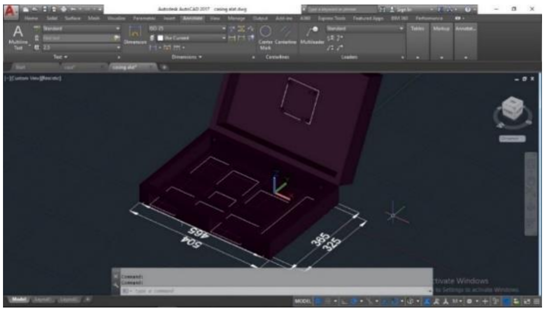

Figure 6. Box portable Design

The prototype of this communication tool is designed in the form of a portable box that makes it easy to carry anywhere. In designing this communication tool, of course, through the process of selecting the best components and tools and developing a computer program that has a similar level of function to the real thing in the field like the one at the Indonesian airport. VSCS is packaged in a hard case with the aim that the components contained in it are protected from water or impact. A closed view of the Portable Communication System is shown in **Figure 7a**.

Figure 7a. Close-Up Display of Portable Communication System

The back view of the VSCS box has a control system for air circulation generated by the VSCS communication system and its electricity as a form of prevention when the system generates hot temperatures. Rear view with air and electrical control system on VSCS Portable Communication system is shown in **Figure 7b**.

Figure 7b. Close-Up Display of Portable Communication System

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The VSCS device on the bottom box has been coated with a clear acrylic cover so that the components inside can be seen clearly. The VSCS communication device on the bottom box with an acrylic cover is shown in **Figure 7c.**

Figure 7c. VSCS communication device on bottom box with acrylic cover

The VSCS communication system as a whole consists of a monitor and components, the monitor is located on the top of the hardcase while the components are on the hardcase. The VSCS Portable Communication System is shown in **Figure 7d.**

Figure 7d. Portable VSCS communication system

The antenna used in the VSCS prototype is a 5⁄8λ ground antenna with a working frequency of 136 MHz. This type of antenna is commonly used in mobile and fixed stations. Design and size of 5/8 Vertical Antenna are shown in **Figure 8**.

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p-ISSN:2685-2489 | e-ISSN:2685-2535

Figure 8. Design and Dimensions of the 5/8 λ vertical antenna

4. CONCLUSION

Performance measurements of this prototype show delays below the maximum allowed Voice over Internet Protocol (VoIP) communication of 100-150 ms. The jitter value is less than 50 ms, which corresponds to the maximum margin of error for streaming communication. The packet loss for this prototype shows very good results, or 0%, but the throughput shows varying values. This is strongly influenced by the strength of the speech and the incoming noise during the measurement. Therefore, the VSCS prototype built has performance that meets the standards required by the International Civil Aviation Organization (ICAO). The advantage of IP-based VSCS systems is that they can be easily integrated with communication, navigation, and monitoring (CNS) components over TCP / IP network packets. This system is a portable ATC communication system.

ACKNOWLEDGMENT

The author would like to thanks reviewers for the suggestions that helped improve the quality of this paper. In addition, the authors are also very grateful to the School of Electrical Engineering and Informatics, Bandung Institute of Technology, West Java, Indonesia for providing resources

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