A Broad Perspective on Cloud Integrated Flight Data Recorder

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ISSN : 2382-5359(Online), 1994-1412(Print)

DOI:

https://doi.org/10.3126/njst.v21i1.49920

Date of Submission: 13/05/2021

Date of Acceptance: 27/10/2022

ABSTRACT

The history of air traffic, whether it's 'about the safety or the qualitative inspection of the several sensors and interconnected mechanical parts, is well known. Hence, the efforts applied through the research and analysis of several engineers profoundly made the air traffic investigation safer and more comfortable. As a result,the flight investigation of whether the lost aircraft or the ' 'airplane's found wreckage has become more secure and convenient than in the Past. The use of light and advanced materials, the development of excellent communication equipment, and the rapid development of the aviation sector have played a crucial role in increasing its safety and reach to the general public, and so do the several challenges associated with the aviation sector. As a result, there has been much research regarding the air traffic investigation with the help of advanced sensor and better software that can simulate and even predict the dangers provided by several parameters helping in the investigation and exploring better sides of safety. The accident can be prevented with the help of improvements provided based on accurate analysis of previous air accidents. In modern aircraft, there is a device called the Black Box which helps analyze and investigate. For example, after Malaysian flight MH370's disappearance, the airline again felt to upgrade the black box to a new working standard of the cloud-based technology. Currently, there are many cloud storage services worldwide such as GOOGLE, APPLE, AMAZON, MICROSOFT etc. After this accident and similar previous aircraft disappearances from different parts of the world, researchers finally decided to test steaming to nearby air traffic services and storing flight data in remote cloud storage. This study attempts to compile the worldwide efforts in the cloud-integrated flight data recorder (CIFDR) field. This research primarily focuses on different ways of storing data on cloud-based technology. The different trend worldwide approaches and different means applied to test this system without hindering the associated safety of the data going through encryption and decryption. Recently there has been a proliferation of internet facilities in flight. Although it is still in its infancy phase, the flight data can be sent to remote servers by improving this technique. Many challenges in transmitting flight data in real-time need to be overcome before commercializing this technique.

Keywords: Cloud computing, Blackbox, CIFDR, Aviation

1. INTRODUCTION

The aircraft industry is going through a revolution because of several new technologies, whether its materials or the current trend of hybrid technology. Thus airline Industry is commencing several battery-powered light aircraft. The airline industry has already considered a new kind of airplane called Blended wing body aircraft (Chaudhary & Sharma 2021). Demand for fuel economy, low noise, low carbon emission, greater lift gave the researchers and the technical aerospace engineers to build a unique aircraft of its kind known as Blended Wing Body Aircraft which is a cross between a conventional plane and a flying wing design whose airframe merges efficient high-lift wings with a wide airfoil-shaped body, allowing the entire aircraft to generate lift and minimize drag thus helps to increase fuel economy and creates larger payload. Thus this unique aircraft whose characteristics fascinated the great aerospace giants such as Boeing, Airbus, etc. marked its entry in the aviation world as a futuristic aircraft comprising the necessary characteristics needed in the aerospace industry. The BWB potential design is as a multi-role, long-range, high-capacity military and civilian aircraft.

In the Past, the flying wing design has proven itself potentially the most efficient aircraft from aerodynamics, structural weight, and better configuration (Chaudhary & Sharma 2021). Hence testing such kind of new aircraft, the use of a flight data recorder is essential to record pilots' commands, electronic equipment inputs, sensors' position, and behavior, etc. Thus in any emergency, the information or data stored and processed to analyze the situation or to simulate what happened, thus helping in preparing additional airplanes for that kind of situation, i.e., known as Blackbox (Li *et al.* 2014)

As of the 21st century, the technology of semiconductor chip or flash drives have seamlessly increased the storing as well as transferring of data smoothly over a capable system, hence increasing storing size unexpectedly without altering its size. Solid State Flight Data Recorder (SSFDR) is a similar type of flight data recorder which has a quite larger memBarkai 2013). Thus helping to record hundreds of flight hours in FDRs based on thousands of paramory size. As a result, almost all aircraft are currently equipped with SSFDR (Wiseman & eters. Apart from that, the latest data compression techniques are also needed to store the data in lesser memory space. Although flash memory drives have a lot of storage capacity, the use of data compression techniques has its importance. This process is an integral part of the memory management and is extremely helpful when FDRs run out of memory space (Wu *et al.* 2005; Weisberg &Wiseman 2013).

So, for example, if an investigation has to be set on any airplane on the ground or the crashed airplane, a Blackbox is searched, and data is analyzed. Hence by processing the information inside the Blackbox, a team of researchers simulated the conditions to find out the causes and factors of the plane crash. Therefore, the Blackbox is designed in such a way that it could able to survive in adverse situations or able to withstand extreme temperature, pressure, and mechanical forces. The exact cause of the accident can be determined by analyzing the data recovered from the Blackbox. As a standard procedure, appropriate parameters can be set to avoid similar kinds of failures in the future, which can make the flight safer. Recovering aircraft Blackbox from a crash site is tedious and often takes much time. This hinders the investigation process and takes time to reach the true cause of the accident. If the cause of the accident is manufacturing-related, then other aircraft of the same company are also susceptible to such types of failures (SOULEY & NKEMDILIM n.d.; Zubairi, 2019).

Therefore, delays in the investigation may exacerbate such dangers. In some cases, finding a Blackbox becomes a challenge in itself. For example, finding a Blackbox under the sea bed is a very strenuous task. Although the Blackbox has a battery-operated electronic signal sending system, the battery installed in it is not able to survive more than 30 days. Under these circumstances, it is mandatory to find the Blackbox within 30 days; otherwise, the Blackbox is lost for forever. After Malaysia Airlines flight MH370 disappeared mysteriously, it is felt that the technique used in Blackbox need to revamp. Live streaming of aircraft data to a remotely located server is a possible alternative of an onboard Blackbox and it may be a mode of aviation communications in the near future (Yu *et al.* 2017). An aircraft is equipped with thousands of sensors that produce both digital as well as analog data. Considering millions of aircraft around the globe, full-scale satellite tracking of every aircraft could be expensive but feasible. Efforts are being made globally to make this technology affordable and reliable (Yu 2015: 370). Appropriate technology is being developed to provide Internet in flight. The in-flight broadband Internet service has been discussed here in detail. The in-flight broadband Internet service has come into existence since the year 2004 (Wiseman 2016a). This service was first introduced by Lufthansa on a flight from Munich to Los Angeles.

Many other airlines are also expanding this service on their flights. Geostationary satellite systems and the use of 12-18 GHz frequency bands (Ku bands) for communications are primarily used to provide Internet service in aircraft (Holzbock & Senninger 1999; Karlin 2001). Establishing ad hoc network between aircraft to aircraft and direct link with ground stations or towers are some other approaches to provide in-flight broadband Internet service (Sakhaee & Jamalipour 2006). Sakhaee and Jamalipour (Sakhaee & Jamalipour 2005) proposed a unique algorithm for routing scenario between the aircraft, satellites and on-ground gateways and simulated it using Aerouter System. In this algorithm, aircraft are allowed to communicate either directly to on-ground gateways, or via satellite to the on-ground gateway. This algorithm was able to choose the best possible routing node automatically. In that way, it is possible to minimize the challenges like frequent transmission lags, atmospheric disturbances, handoffs, and changing network topologies which are usually faced during the data transmissions in such situations. To minimize the handoffs events, the Doppler Effect was also introduced by them. All the necessary flight data can also be streamed from aircraft to remote servers by making necessary modifications in this technique.

With the help of advanced computing techniques such as cloud computing etc., the attempts are being made to store the data of cloud Blackbox on remote servers. In this article, a comprehensive review of all such attempts is provided. All aspects related to it, such as technical, economic, legal etc., have been thoroughly discussed.

1.1 Brief History of Flight Data Recorder

David Warren was the first person officially to invent flight data recorder in 1956. Previously the device capability was limited to store the data of almost four hours of audio recordings and instrument readings (Witham 2005). In order to locate FDR at the crash site easily, it was painted with bright orange or bright yellow color in order to be recognizable and these colors are known to be more eye catchy than ordinary colors. We all know in event of crash the tail or the empennage is the region of the aircraft that hits the ground at lastly thus this region is associated to low damage than compared to other regions, so FDR housed in a strong box and installed at the rare end of the aircraft. These were digital FDRs. In these FDRs, magnetic tapes were used as a recording medium. At the same time, flight data acquisition unit were also introduced to process larger amounts of incoming sensor data. The most significant improvement in FDRs was marked in the 1980s when solid-state flight data recorders were introduced.

The recording capability, crash/fire survivability, and recorder reliability of FDRs were magnificently improved with it. Since then a cloud based platform has been in continuous development in Europe and The USA. Airbus has been testing since 2007. This safety issue give rise to a Cloud Integrated Flight Data Recorder. Finally the issue was raised globally by former chairman of US National Transportation Safety Board Mr. Mark Rosenker stating to reform the aviation sector Blackbox to be even more safety worthy in case of worst incident (Shalal n.d.; Wiseman, 2016a). He also reminded the 2009 incident of Air France investigation process to be outdated and more precise mechanism to be introduced in the aviation sector pointing towards the cloud based platform. Mr. Rosenker showed the aviation towards a new future technology in the process of quick and productive investigation thus helping authorities launch accident investigations sooner and locate a plane if it got into trouble while out of reach of ground-based radars (Shalal n.d.; Wiseman, 2016a).

2. MATERIALS AND METHODS

2.1 Cloud Integrated Flight Data Recorder

The main parts of a commonly used black box are cockpit voice recorder (CVR) and flight data recorder (FDR). As discussed earlier, CVR records cockpit voice activities and FDR records flight related data such as flight speed, altitude, temperatures, pilot inputs etc. Currently, in plane high capacity storage devices are used to store above mentioned activities. Now these activities will be stored to the secure cloud based computing mechanism having functionalities of encryption and decryption. It is a great idea to store all the flight related data in remotely located servers in real time (Ayeni & Yisah 2016; Wiseman 2016a; Zubairi 2019). In that way ground stations can monitor flight status or health in real time and react speedily in disastrous situations. Advanced video compression techniques allow sending video signals in real time. Using it, ground stations can take quick decisions in the event of an emergency and can ensure quick rescue measures. Flight can also be remotely controlled in case the crew is unable to handle it. The possibility of losing and destroying important flight data during any mishappening is also negligible when the data is stored in the cloud. This system can help a lot in taking effective steps during anti-hijacking operations and medical emergencies (Volner & Boreš 2005). Considering the immense potential of this system, strengthening of its security system is essential. The basic security requirements associated with this system are data confidentiality, data authentication and data encryption. In that way, the privacy of end-users can be maintained, data cannot be modified or deleted by malicious software and data can only be reached to authorized agencies, servers or personals. In addition to the above requirements, an inflight system will require additional protection when communicating between different network segments. During this period special arrangements will need to be made to protect the control unit from unauthorized access. In CIFDR, data transfer can take place either via satellite or wirelessly to the ground station (Fig. 1), depending on the location of the plane. Both the means have their own security related challenges (Thanthry & Pendse 2005; Volner & Boreš 2005).

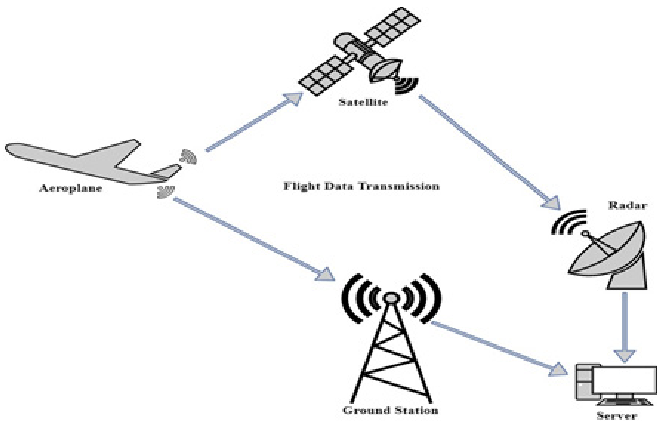

Fig. 1: Schematic diagram of cloud integrated flight data recorder

An efficient data compression system is needed to transfer sufficient amount of data from a flight data recorder to cloud. Thus, the data can be transmitted according to the desired transmission rate and as per network bandwidth capability. Wiseman (Wiseman 2016; Wiseman) suggested a compression algorithm for flight data transmission to cloud. He found that his compression algorithm was able to determine whether to compress data or not in real time based on the CPU cycle and the load on the network line. Yu *et al.* (2017) proposed a live Blackbox for tracking and verifying the locations of aircraft in motion. They found a simple locality-sensitive hashing technique is effective in compressing the communicated data stream. Yu *et al.* (2019) also proposed self-adaptive software architecture (LiveBox) for drones. This LiveBox can work as an alternative of Blackbox for drones. They found that using Block Chain technology for flight data recording purpose can able to provide tamperproof data. Therefore, anonymous and temper proof events logging can be ensured by using blockchain technology in distributed ledgers. Additionally, the security and accountability of transmitted flight data can be ensured (‘D’Angelo *et al.* 2018).

Yu (2015) stated that currently most critical data of the flight can be streamed online due to current bandwidth limitations. However, with the advancement of cloud computing and IoT, a full picture of the flight situation can be streamed in real-time in the near future. Here, all the flying airplanes can be treated as part of the internet of flying things. Shaji and Subbulakshmi (2013) investigated the feasibility of transferring data to ground stations in real time. They developed a set of algorithms for packetization and transmission of flight data to remote servers. The transmitted data was later integrated and flight information was retrieved. They stated that their system was distributed, scalable, reliable and realistic considering current bandwidth. Souley and Nkemdilim (2018) developed a model to collect the flight data to a cloud repository. Based on the collected data flight condition was monitored. The collected flight data were matched with the set of rules for a normal flight condition. In that way, necessary assistance can be provided to air bound flight in case of any abnormality observed. Their study shows that real-time support can be provided to the flight through stored data in the cloud repository apart from the accident investigation. Ayeni and Yisah (2016) modeled a cloud-based aircraft flight data recorder. This model was simulated in MATLAB and implemented using Google private cloud computing. Their model worked well in terms of saving, retrieval, safety and security of the data. This model can be more useful on better internet connection and large bandwidth availability.

Haider and Khateeb (2018) conducted a survey on cloud computing adoption in the aerospace industry for flight safety. They concluded that integration of this technique is barely possible at present owing to the shortage of a comprehensive cloud computing platform for aviation and security-related concerns. However, with the development of cloud computing technology, it is likely to be used efficiently in the future. Losavio *et al.* (2015) studied the legal and ethical perspective of the cyber black box. They found that by implementing the cryptographic technologies and IoT, the privacy and confidentiality of the collected data can be preserved. Now as we are advancing towards newer operating system and availability of several high speed storage devices such as SSDs as well as the availability of cloud computing facilities of GOOGLE, Apple, Microsoft as well as Amazon its eve more easier to store the data more efficiently and unlimited loads of data on the server (Wiseman 2016c). This implies that we never ran out of the memory for storing the data either practically or virtually which is good sign for the critical data that is stored on the airplanes flight computing systems (Wiseman 2016c).

So generally an embedded hybrid system can be used for the testing purposes in an aircraft such that the FDR and CVR data are transferred wirelessly to a ground station and the cloud facility available in the nearby place as well as can be transferred to International Space Station reserved for the testing purpose just like we used to send and receive radio signal at 145.80MHz (Drobczyk *et al.*, 2017). Hence the data is store in either of the platform fully encrypted now a code is previously generated to decrypt the data that is send through the aircraft and the investigation is completed. Now another problem is about the backup system in case of system failure. So while testing purpose as early discussed two blackbox must be used and tested time to time on different regions and different climates and analysis should be done based on the environment change.

2.1 Other Ways to Record the Flight Data

Installation of two Blackboxes in the aircraft was suggested to increase the probability of a Blackbox being discovered after the accident (Ahn & Han 2016). It was suggested to install two Blackboxes with protected memory to record flight data. These recorders would be installed near the nose and the tail of the aircraft simultaneously and both the recorders will record the same voice and data information. Thus at least one Blackbox is likely to be found after the accident. Another option was to deploy two different types of Blackboxes in the aircraft. One of them would be a protected memory type and the other one would be anejectable/deployable type recorder. Airbus is considering to deploy these options in A350 aircraft in 2019 (Dub & Parizek 2018).

Mekki *et al.* (2017) proposed the integration of hundreds of tiny sensors nodes on aircraft structure. A wireless sensor network is constructed by these nodes inside the aircraft. By storage protocol for WSN, latest flight data can be stored in each node using probabilistic based flooding schemes. In that way, information can be gathered from any piece of wreckage found.

3. CHALLENGES

CIFDR is in its developmental phase and requires lot more experimental and researches to come across a final evaluation, for this there are several hurdles such as selection of new design, selection of materials needed to make the new CIFDR, security parameters, effective and secure line data transfer etc. after all these consideration this thing can be brought to operational. Here are the few things discu`ed as the challenge in this grand research topic which must be resolved to make this CIFDR operational successfully.

a) Design and Selection of Material

One of the challenges on the CIFDR is the new effective and proven design which can bear all the stress, strains, extreme temperature and pressure while in operation or in case of crash. The new design must ensure that the CIFDR can bear the hydrostatic pressures in case of airplane engulfed in sea or water body or in other words it must be water resistant. The new design must incorporate effective ways to counteract several condition in real time operation.

The CIFDR should possess all physical strength to counteract several temperature and pressure in case of incident. While choosing such material can be a matter of hard choice because so many material I the material which can stand toe to toe in this material selection.

The material should possess all necessary strength and physical properties in order to bear the formidable physical damage.

b) Selection of Storage drive

As we already know that the CIFDR will incorporate real time data sharing as well as storing that data inside its internal storage system. Here comes another challenge to select the storage drives which can be easily written, forwarded, and very effective in operation as well as go long time in using. The storage device is also one of critical challenge involved in this topic. The storage system also should be of more capacity to store large amount of data, in the same way to transfer to system real time data sharing unit without any obstruction. The storage unit such should be selected whose writing and decoding speed should be higher in order to be more operation effective and the same way the storage system must be not over heated in such operations.

c) Selection of CIFDR Internal Operating System

The CIFDR must be incorporated with high value processors to process such large amount of data. The new OS must be capable of handling such large amount of operational data and identify the problems associated to them. The OS must be smart and efficient enough to be operation throughout the journey with constant link with real time data sharing unit. A group of electronic as well as IT based professionals required in this expert OS choosing.

Real-time embedded systems (RTES) represent a major proportion of the software being developed (Arcuri *et al.* 2010). The verification of their correctness is of paramount importance, particularly when these RTES are used for business or safety critical applications (e.g., controllers of nuclear reactors and flying systems). Testing RTES is particularly challenging since they operate in a physical environment composed of possibly large numbers of sensors and actuators. The interactions with the environment can be bound by time constraints. For example, if the RTES of a gate is informed by a sensor that a train is approaching, then the RTES should command the gate to close down before the train reaches the gate. Missing such time deadlines can have disastrous consequences in the environment in which the RTES works. Hence OS should incorporate all necessary intelligence system to solve this kind of problem (Arcuri *et al.* 2010).

d) Methods to Share the Data in Real Time

As this CIFDR is cloud based hence ' 'it's equally important to choose the mediums in order to transfer the data to nearby cloud or in some other case to the Space Stations using low frequency. A study should be brought in choosing the antenna type or the SATCOM link systems. The system be not be disrupted easily by small disturbance or turbulence.

This thing is itself a challenge to design this kind of parameter. A research must be done to choose such data transferring units. This system should be in continuous link with the cloud system we are using or storing unit in different system. The system must be effective enough to transfer large amount of data without any glitches or failure. It is very prominent to study this challenge and then focus on other test of subject

e) Selection of Primary and Secondary Power Units

CIFDR is itself a very challenge to brought to operational hence requires a rating of power and a better power source which can supply adequate power while in operation.

The power unit must be made keeping in made to survive extreme damages and continuous power to keep it operational. Since onboard computer and storage system require a better power rating to run smoothly. Finally the secondary power units must be made to keep the CIFDR operational in case of primary power cuts down due to error or in crash and keep systems running inside intact for prolonged period of time. Such secondary unit battery system should of heavy durable and better battery life to counteract the problem.

The secondary unit battery must be made keeping in mind to supply continuously but also to survive the damages too.

f) Design and Development of Underwater Beacons

When we look back the history there had been so much incident when the remnants or wreckage of aircraft found in the sea bed in such case to locate the aircraft or the CIFDR is of prime importance. This CIFDR should have real time data sharing but also should be capable of locating the aircraft position because the ' 'passenger's bodies are to be located and given to their families too or the cargo of high value should be taken out of that wreckage aircraft. Such beacons should incorporate low and high frequency bands to make a communication channel possible. The bands should be selected area wise whether to use high frequency or the low frequency. Here OS play a vital role.

3.1 Possible Ways to Overcome the Challenge

The system presented in this paper enables the FDR to configure compression technique to fit the current requirements automatically. When enough network bandwidth is available, for instance, no compression will be applied; thereby, the computational loads will be reduced; however, when network bandwidth is not enough for the transmitted data, the transmitted data will be compressed. The particular compression technique will be automatically selected, using dynamic data sampling techniques to assess compression's effectiveness and current rapidity (Wiseman 2016b).

There will be no considerable changeto the previous black box, but a slight change will be made instead of flat ends; the newly designed

CIFDR will incorporate hemispherical at both the ends. Doing so, it will increase its stress and strain withstanding capacity.

The second problem may be on the concept of cyber security i.e., the data can be hacked if it transmits in real time. For that setup, we have used advanced encryption standards. AES is the most secure encryption algorithm and is mathematically secure, tested with a combination of the most powerful computers in conjunction with the smartest minds in the world(Mahajan & Sachdeva 2013; Osvik *et al.* 2010).

After the encryption process, the data will be processed by a signal generator, producing a signal whose frequency bandwidth is suitable for transfer. Previously, flight data recorders could save data up to 25 hours and 2 hours of cockpit voice recording, which is recorded over itself in a loop (Tilley 2014). The CVR can track the inside crew interaction and, of course, the air traffic control. This CIFDR using solid state drive can increase the data saving to unlimited storage because of real timing streaming and continuous storing in the cloud.

In this CIFDR, we will use the Solid State Drive technology because the writing and the transferring, as well as operating speed, are much higher than the vintage system

Signal will be generated by a function generator that produces simple repetitive waveforms. Such devices contain an electronic oscillator, a circuit capable of creating a repetitive waveform. Before the signal is finally processed through the antenna, it will be encrypted via a secure algorithm and a key.

Hence using asymmetric key schemes in which the encryption and decryption keys are different and will be given to authorized parties only. In our case, authorized parties will be aircraft systems and receivers only. A private key will be given to both parties, which is the only way to decrypt the signal to readable form.

The encryption is Advanced Encryption Standard (AES), commonly called '"Rijndael's cipher algorithm with a private symmetric key which will be different for all aircraft to encrypt Black Box data (Daemen & Rijmen 2013).

AES is the most secure encryption algorithm and is mathematically secure, tested with a combination of the most powerful computers in conjunction with the smartest minds in the world (Daemen & Rijmen 2013).

After the encryption process, the data will be processed by a signal generator, producing a signal whose frequency bandwidth is suitable for transfer. The aircraft is already equipped with a range of HF and VHF systems, which are sufficient for our data sharing (Barès *et al.* 2005; Maslin 1987).

If an aircraft is within the range of an ATC, frequencies will be in the VHF (Very High Frequency) frequency range of 108 to 136 Megahertz (MHz), which is suitable for air-to-ground communication. If the aircraft is out-of-range, then the signal can be transferred via an avionics device installed in an aircraft called Satellite Data Unit (SDU). In this, the computer installed in it will transfer the data to the satellite via VHF antenna, and in case of failure, the same data can be sent through HF (Note ARISS Amateur Radio On the International Space Station works on HF frequency in the range of 144-146band) antenna which will allow air-to-ground communication via a satellite network.

After performing such operations, we can greatly enhance the effectiveness and time-efficient investigation process of any aircraft leading to fruitful results.

4. DISCUSSION

The review paper emphasizes using cloud computing technology in an onboard airplane for safe data transmission through encryption followed by decryption. Hence, security will not be compromised. The small test involved in the lab successfully encrypts a piece of data to the small host server. Therefore, this technology will be a better way to protect our data in the worst cases of accidents for better investigation. The experiment is costly and we will ensure we get more correct values and figures in the future. The Cloud Integrated Flight Data Recorder (CIFDR) is itself new emerging technology in the context of Black Box of mostly all types of airplanes. This technology incorporates numerous advantages over previous flight data recorders. Normally, flight recorders are of two types, i.e., cockpit voice recorder (CVR) and flight data recorder (FDR). However, this CIFDR not only records CVR and FDR but also collects the visual recording of both fronts, rear undercarriage, starboard, and port board wing along with the cockpit. In the cockpit, the visual recording is carried out as per the pilot's wish. CIFDR also transmits all of its data through cloud computing to nearby ATC and the linked satellite in coded form in case of severe worst-case misadventure. The advantage is that we 'don't need to waste time locating the Black box in terms of disappearance from the site or if it is severely damaged, making it hard to retrieve the data from a fatal crash. We will design a new platform incorporating the inboard computer and the new CIFDR that will transmit all its information to satellite or the nearby ATC. Thus helping in an efficient investigation process leading to accurate results. There has been several finding and experimental works around the world for the 4-wheel vehicles for proper investigation using a system capable of recording the condition of four-wheeled vehicles and notifying if there has been an accident. Vehicle condition recording utilizes Onboard Diagnostic-II (OBD-II) feature with parameter recording: gas pedal position, engine speed, vehicle speed, and engine temperature (Nugroho *et al.* 2018). Similarly, security and performance have been a top priority, and a researcher has mentioned those advantages by a system that allows users to run automated, on-demand, real-time and customized benchmark tests on cloud infrastructure, thus performance monitoring tool that provides multi-layer performance, greater visibility, insight etc. monitoring capabilities to Smart Cloud Systems utilizing corresponding resource consumption (Chhetri *et al.* 2014).

Another finding suggests using of smartphone sensors joint fusion network by implementing and evaluating end-to-end systems of android smartphones with cloud servers (Ahn & Han 2016). Mentioning this find suggests using hybrid architectural design of unused smartphone sensors to achieve high accuracy, customization and convenience (Ahn & Han 2016).

Similarly, other findings suggest that there might be difficulties in some cases where it is hard to rescue FDR from the accident scene, or if found, data cannot be retrieved due to exposure to extreme heat. Hence, a better system can be employed because our flight data is crucial because of enhanced metallurgy and carbon fiber composites that can survive high temperatures and pressure. Here strikes the use of cloud-based platforms to maintain an uninterrupted and continuous flow of data for flight improvement and investigation (Haider & Khateeb 2018).

This finding indicates how precisely and efficiently the global aviation investigation can be carried out by linking and saving the aircraft's data communications to cloud computing on the ground to facilitate the tracking and monitoring of aircraft in real time in case the aircraft crashes and loses or suffers damages on its black (Haider & Khateeb 2018).

Moving to the next journal, his new finding suggests using wireless sensor networks for fast flight data recovery stem using a paradigm called "communicating materials." Now the communicating material is developed by uniformly integrating hundreds of tiny sensor nodes in the aircraft structure (Mekki *et al.* 2017). The nodes could then construct a Wireless Sensor Network (WSN) inside the aircraft. Thus, the latest FDR data could be stored in the nodes using the data storage protocol for WSN. The proposed storage protocol uses the probabilistic-based flooding scheme to forward data to all nodes inside the aircraft structure within the lowest delay (Mekki *et al.* 2017).

Whilst another finding suggests using a system that collects onboard flight data to a cloud

cloud-based platform and cross-checking the condition of the flight to provide aid assistance (SOULEY & NKEMDILIM, n.d.). Thus, collecting the received flight data and comparing it with the active database provides some logic on what action should be taken. Hence, all flights with abnormal conditions are marked red, thus helping the flight control tower to alert the aircraft concerned and the emergency response team (SOULEY & NKEMDILIM, n.d.).

5. CONCLUSION

Following the mysterious disappearance of Malaysian flight MH370, new questions arose about the safety of the flight. Since it is impossible to find an airplane Blackbox in this incident, it is almost impossible to accurately analyze the cause of the accident or disappearance. If the flight data could be retrieved somehow, then the investigation of this incident would have been done smoothly. A new concept emerged in this context in which flight data was suggested to be stored in cloud storage. In that way, the fear of losing flight data will be eliminated in such incidents. Efforts are being made to develop this technology across the world. Recently there has been a proliferation of internet facilities in flight (Manimaraboopathy *et al.* 2017; Mekki *et al.* 2017). Although it is still in its infancy phase, the flight data can be sent to remote servers by improving this technique. Many real-time challenges in transmitting flight data need to be overcome before commercializing this technique. The development of equipment and facilities related to this technology, authentication of data compression technology, authentication of media transmission techniques, flight data security, formulation of technology-related policies etc., are some challenges that need to address. In a survey, it was found that due to the unavailability of a comprehensive cloud computing platform for aviation and security-related concerns, the possibility of commercialization of this technology is currently low.

However, with the development of cloud computing technology, there is a strong possibility of it coming into existence soon. Privacy-related concerns and data confidentiality can also be ensured using advanced IoT, blockchain, cryptographic technologies etc. Apart from this, research is also being done on other options like installing two Black boxes, installing a wireless sensor network etc. Thus, a better platform for the investigation must be carried out for a quick and fruitful investigation. There were many incidents in the past where we even ‘did not find the wreckage of the airplane and the black box. Thus, Cloud Integrated Flight Data recorder, which incorporates 21st-century technological advancement of storing and transferring real-time data to any cloud platform or satellite-based, can help retrieve essential information regarding the possible future misadventure (Mekki *et al.* 2017; SOULEY & NKEMDILIM n.d.; Zubairi 2019). If this technology flourishes and is under its way to be introduced in coming years, we can at least investigate the root cause of the problem regarding loss of communication over certain areas of the globe and improve the system of the airplane so that these accidents would be stopped to a greater extent (Ahmed & Kurtulus, 2019; SOULEY & NKEMDILIM, n.d.; Wiseman, 2016a). Thus, a new future awaits us to be developed and fitted in every aircraft for potential advantages in data storing and real-time data sharing over a secured network followed by encryption and decryption.

Suppose we look at the data provided by the World Health Organization. In that case, many people die in the transportation incident, and this continues because of a lack of proper incident or ineffective investigation, now here CIFDR comes to play the system can provide real and accurate even if the transportation, either airplane or ground vehicles, are lost (Haider & Khateeb 2018; SOULEY & NKEMDILIM n.d.; Wiseman 2016b). Thus we have possible ways to stop those kinds of incidents if we somehow make this system practical. As I have already stated, the CIFDR is in its high stage of development and going several associated challenges are being solved with the help of researchers currently working in this field through different means and medium of integrated sensors (Ahn & Han 2016). This system will provide us the real data, and our future vehicles, either aerial or terrestrial vehicles will be more safety-bearing standards than the current basis. Thus, the vehicles will be safer and more advanced if we investigate a similar problem in another vehicle leading to the incident. This facilitates the investigation team and the insurance team to investigate more precisely and make policies even better for the people (Nugroho *et al.* 2018). With this kind of robust data and analyzing capacity, we can presume that the accident rate can be down. Thus, making CIFDR a better scope for future vehicles.

The only problem is that the cost to equip every airplane in the world with the CIFDR will incur billions of dollars until Cloud computing and related sensor technology costs can be minimized (Galaguz *et al.* 2017). The research is going effectively in France, the European nations, and the USA to minimize costs. If we could minimize the cost and improve our real-time data-sharing capabilities in the current scenario, it would be better to equip every plane with the CIFDR technology leading the vehicles to the future timeline of the investigation (Ahn & Han 2016; Haider & Khateeb 2018; Zubairi 2019).

ACKNOWLEDGMENT

I want to express immense pleasure in completing this review paper on CIFDR. I am extremely happy and express my gratitude and appreciation to all of the great personalities who helped me complete this paper on CL Educate to Dr. Anil Bankoti and the Head of Department, Air Commodore Devender Sharma (Retd.).

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