British Journal of Applied Science & Technology
13(2): 1-13, 2016, Article no.BJAST.19896
ISSN: 2231-0843, NLM ID: 101664541

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Cloud Based Architecture Solution for Aircraft Flight Data Recorder

Bakare K. Ayeni[1*] and S. O. Yisah[2]

[1]Nigerian College of Aviation Technology, Zaria, Aeronautical Telecommunication Engineering School, P.M.B. 1031, Zaria, Kaduna State, Nigeria.
[2]Department of Mathematics, Ahmadu Bello University, Zaria, Kaduna State, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author BKA designed the system, performed the simulation of cloud based aircraft FDR, wrote the first draft of the manuscript and managed literature searches. Author SOY managed the analyses of the simulation and literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2016/19896
Editor(s):
(1) Samir Kumar Bandyopadhyay, Department of Computer Science and Engineering, University of Calcutta, India.
(2) Selvakumar Subbian, Laboratory of Mycobacterial Pathogenesis and Immunity, Public Health Research Institute (PHRI) at Rutgers Biomedical and Health Sciences, Newark, USA.
Reviewers:
(1) M. Bhanu Sridhar, GVP College of Engineering for Women, Vizag, AP, India.
(2) Higinio Mora-Mora, University of Alicante, Spain.
(3) Anonymous, University of Karachi, Pakistan.
(4) Anonymous, Penn State University, USA.
(5) Anonymous, Royal Military College of Canada, Canada.
Complete Peer review History: http://sciencedomain.org/review-history/12317

Original Research Article

Received 2nd July 2015
Accepted 17th October 2015
Published 16th November 2015

ABSTRACT

Flight Data Recorder (FDR) is an on board equipment in the aircraft, it records many different operating conditions of the flight, computer animated video reconstruction of the flight can be generated from data retrieved from FDR, the aircraft accident investigators can then visualize the last moments of flight before the accident. There may be instances when it was difficult to retrieve FDR from the scene of an accident, or even, if retrieved, the data could not be retrieved because FDR might have been burnt beyond allowable temperature. As a result of this, there is a need for alternative source of data. The cloud computing concept could be extended to the aircraft system data network environment with every aircraft subscribing to the cloud resources to run their mission-critical applications. This paper models cloud based architecture solution for aircraft FDR by implementing private cloud computing. Unlike the existing Cloud Computing Platform of Aviation

**Corresponding author: E-mail: bakarre@yahoo.com;*

Industry (CCPAI) framework which provides a mechanism to monitoring aircraft management only, the proposed model in this paper will provide alternative data for aircraft accident investigators to work with in case of any aircraft mishap. Reliability of internet connection and availability of large bandwidth to support real time flight data transmission are envisaged as potential limitation of the proposed model.

Keywords: Flight Data Recorder (FDR); cloud computing; mission-critical; CCPAI.

1. INTRODUCTION

The purpose of carrying out investigation on accidents or incidents is not to apportion blame or liability but to give safety recommendations or airworthiness directives in order to improve safety in aviation and prevent future reoccurrence [1]. Capturing evidence at an accident site is an important task for the aircraft accident investigators in order to answer the major pertinent questions like what happened and why this accident happened. One of the major evidence that accident investigators always try to retrieve from the scene of any accident is Flight Data Recorder (FDR). FDR on board aircraft records many different operating conditions of the flight. Standards and Recommended Practices for aircraft accident inquiries are available in ICAO Annex 13 [2].

Flight Data Recorder (FDR), (popularly called black box, but not black in actual sense, it is orange in colour) on board aircraft records more than 1,000 in-flight characteristics that can aid in the accident investigation. After the retrieval of FDR, it is taken to decoding laboratory for decoding and analyses. With the data retrieved from FDR, a computer animated video reconstruction of the flight can be generated. The investigators can then visualize the last moments of flight before the accident [3]. But there are challenges facing the existing FDR. There are instances where it is difficult to retrieve FDR from the scene of an accident, or if retrieved, data could not be retrieved because FDR has burnt beyond allowable temperature.

For example, Malaysia Airlines Flight 370 (MH370/MAS370) disappeared on 8 March 2014 [4], there has been no confirmation of any flight debris [5] and no crash site has been found in order to retrieve the FDR [6]. Even if the result of FDR analysis is tampered with, there is no alternative data to prove otherwise.

This paper presents cloud based architecture solution model for aircraft FDR using private cloud computing to serve as backup in order to provide alternative data for aircraft accident investigators. Reliability of internet connection and availability of large bandwidth to support real time flight data transmission are envisaged as potential limitation of the proposed model.

The rest of the paper is organized as follows; section 2 focuses on Flight Data Recorder, section 2.1 is on the challenges facing Flight Data Recorder, sections 2.2, 2.3, 2.4 and 2.5 focus on cloud computing, deployment of clouds, strengths of cloud computing and Cloud enterprise frameworks respectively. Section 3 focuses on the System Design; section 4 is on Simulation of Cloud Based Aircraft FDR while section 4.1 is on Result of Simulation. Related work and Future work are in sections 5 and 6 respectively. Section 7 concludes the work.

2. FLIGHT DATA RECORDER

The aircraft accident investigators retrieve FDR from the scene of the accident wreckage; it is then taken to decoding laboratory for decoding, animation video reconstruction and analyses. Based on the data retrieved from FDR, a computer animated video reconstruction of the flight can be generated using several techniques. The first technique used when the first generation of FDR was introduced in 1958 was data listings and plots which was used to examining the data particularly with a plot, then, mutual compatibility between parameters can be checked, for example, if the value of magnetic heading increases then the roll attitude parameter should show a bank to the right. The major limitation of this tool was that only a small number of parameters were being recorded, for instance, rate of climb and descent could not be obtained. Another technique used was total energy graph [7]. This was capable of producing a graph of total energy, that is, potential energy and kinetic energy versus time, which made it possible to estimate changes in aircraft configuration or engine thrust. Limitation with this model was in the plots, only a small number of parameters were being recorded. Mini Computer Graphic Flight Recorder Analysis was another technique. The first flight recorder readout system for commercial aircraft in Australia was acquired in 1972 by the Air Safety Investigation Branch. It was called FRAN (Flight Recorder Analysis) system and consisted of a DEC PDP 11/0529 mini-computer. It was upgraded to use two graphics minicomputers; PDP 11/45 and PDP 11/73. To obtain the necessary performance, Hewlett-Packard Unix workstations were used. In 1992, the software called 'Insight' Computer Graphic was developed by Flightscape Inc. and was converted to be used on PC. In 2005, Insight was adopted and flight recorder specialists operated the complete system on their laptops effectively giving them a portable flight recorder laboratory. Flight data decoding system OAZ is one of the decoding software, it operates in the WINDOWS environment on computer [8]. Nowadays, laptops run Insight animation and simulation for visualization purpose.

With animation, it is possible to place sequence of events into time perspective, link recorded data with ground features and correlate FDR data with other sources of data like radar data or eyewitnesses.

In practice, only the aircraft manufacturer will have access to the mathematical models required for simulations and accident investigation authorities would work cooperatively with the manufacturer to obtain the simulation. The major limitation for this latest tool is the conversion equations of thousands of parameters to visualization of the actual output in 3D, development and validation of results.

2.1 Challenges Facing Flight Data Recorder

In case any aircraft accident occurred, the aircraft accident investigators rely heavily on the data retrieved from the FDR to generate computer animated video reconstruction of the flight. But there are challenges facing the FDR that need to be managed in order to improve its efficiency in the context of flight safety. One of the challenges is that it might be difficult to retrieve FDR; this is possible because the wreckage of the aircraft may not be seen or the aircraft is burnt completely without any wreckage left. Even if FDR is retrieved, it might have been damaged or burnt beyond allowable temperature, so retrieving valid data from it becomes impossible. Another likely challenge is that if the result of the FDR analysis is tampered with, there is no alternative data to prove otherwise.

These challenges can be managed by combination of new technologies with existing ones and implementation of cloud based architecture solution for FDR.

2.2 Cloud Computing

The term 'cloud' has its origins in network diagrams that represent internet or various parts of it, as schematic clouds. Cloud computing was coined for what happens when applications and services are moved into the internet 'cloud'. It refers to the many different types of services and applications being delivered in the internet cloud. Gartner in [9] defines cloud computing as a style of computing where massively scalable IT-enabled capabilities are delivered 'as a service' to external customers using internet technologies. According to National Institute of Standards and Technology (NIST), cloud computing is on-demand access to a shared pool of computing resources [10]. It is an all-inclusive solution in which all computing resources (hardware, software, networking, storage, and so on) are provided rapidly to users as demand dictates [11].

The major characteristics of cloud computing includes:

2.2.1 Shared infrastructure

It uses a virtualized software model, enabling the sharing of physical services, storage, and networking capabilities.

2.2.2 Dynamic provisioning

It allows for the provision of services based on current demand requirements. This is done automatically using software automation, enabling the expansion and contraction of service capability as needed.

2.2.3 Network access

It can be accessed across the internet from a broad range of devices such as PCs, laptops, and mobile devices, using standard-based application programming interfaces (APIs).

2.2.4 Managed metering

It uses metering for managing and optimizing the services and to provide reporting and billing information.

2.3 Deployment of Clouds

The deployment of clouds can be divided into three core components [12]. These refer to three types of services as follows:

2.3.1 Private cloud

As the name implies, a cloud used by a single company. This cloud is either entirely hosted or operated by the company itself or can be located at a co-hosting facility. Reasons for considering and choosing this approach for a cloud is the control and security of the platform itself (as viewed by the company or a hired operator).

2.3.2 Public cloud

Public cloud is deployed on a shared infrastructure. The cloud thus shares resources and hardware with different customers. These resources may be located in the same data center and may be operated by a third party. Here the security aspects of using a cloud become more apparent as multiple entities are sharing a common infrastructure. Securing the services provided in such a way as to limit the threat of information leakage should be considered as a priority.

2.3.3 Hybrid cloud

This is a mix of both a private and public cloud. A company can run its own cloud on its own hardware in-house, while utilizing as necessary resources such as computing power and storage resources in a public cloud operated by a third party [13].

Cloud computing incorporates infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS). Although, these are generally accepted groups of generic services, a number of other specialized services have also been suggested, some of which are implemented in this paper, these include; Storage as a Service, Database as a Service, Security as a Service, Communication as a Service, Management as a Service, Integration as a Service, Testing as a Service, Business Process as a Service [14].

2.4 Strengths of Cloud Computing

Many companies are now delivering services from the cloud. Some notable examples are Google, Yahoo, Facebook, Hotmail, Microsoft etc. Cloud-based computing allows Internet-based resources, software, data and services to be provisioned on demand using a utility pricing model. The solutions provided are architected for scalability, because a cloud-based architecture can provide the ability to trade computation time against costs. Cloud is readily applicable to applications that require frequent bursts of computational activity. Nowadays many individuals and businesses use cloud-based services for email, web searching, photo sharing and social networking. Scientists and engineers use a similar paradigm to make use of massive amounts of computer and data handling resources provided by companies such as Amazon, Microsoft and Google [15].

2.5 Cloud Enterprise Frameworks

There are many enterprise frameworks, which share the same objectives but vary in focus, scope and intent. Each business sector (e.g. manufacturing, service and financial) operates differently and has its own objectives and goals. These frameworks or *architecture models* include:

i. Zachman 's Framework [16] - This is a widely used approach for developing enterprise-wise IS architectures and is considered as a reference model against which other frameworks can map themselves [17].
ii. RM-ODP - This uses a well-understood object-modelling technique (OMT) and is developed by highly reputable agencies such as ISO and International Telecommunications Union [18].
iii. TOGAF - This is an industry standard generic framework and is freely available [19].
iv. C4ISR / DODAF - These are frameworks developed mainly for the use of US Department of Defense [20,21].

The comparison and review of the best and efficient model are available in [22-25].

3. SYSTEMS DESIGN

The cloud computing concept could be extended to the aircraft system data network environment with every aircraft subscribing to the cloud resources to run their mission critical or non-mission-critical applications. The proposed Cloud based architecture solution for Flight Data Recorder model answered the following strategic questions adapted from [26] that are required to be addressed before any airline embarks on integration of FDR with the cloud computing. The questions are as follow:

i. Can the vendor facilities support aircraft FDR system specifications?
ii. Which Database Management Systems (DBMS) are required? Is there a vendor-maintained "image" that supports the DBMS?
iii. How much memory and processing power is required?
iv. Does the vendor provide sufficiently powerful machines, and is there room to grow?
v. What is the choice of the service, private, public, or hybrid cloud? What impels the decision?
vi. Do the aircraft management tools available support management in the cloud? Are there upgrades available?
vii. Do management satisfied with the vendor's documentation of its compliance with SAS 70 and ISO 27001?
viii. Does ICAO (International Civil Aviation Organisation) certify the vendor specifications?

In other to address the challenges facing the existing FDR mentioned in section 2.2, such as inability to retrieve the black box from the wreckage of the accident or difficulty to retrieve the data from FDR, maybe because it has burnt beyond allowable temperature, this paper presents cloud based architecture model for FDR to serve as a reference or backup to FDR to improve efficiency of the FDR analysis. This will enable the accident investigators to compare the result of decoded and analyzed data from the FDR, if retrieved with the one from cloud database, for video reconstruction of the aircraft before the accident.

In this paper, private cloud computing adapted from [27,28] is modified and implemented (Fig. 1) using private Google cloud storage architecture.

Every new modern airplane is expected to have IP address for communication over the internet via the Communication as a Service at the cloud end. Management as a Service monitors the data storage in the database and ensures integrity, availability and adequate retrieval whenever need arises. The management as a Service includes extraction of enforceable rules, use of strict policies, automated policy enforcement and active monitoring of data as employed in [29]. Because of the sensitivity nature of the flight data, Security as a Service ensures adequate security for the data; it ensures the protection of the data and allows only authorised users with right privilege to access the database.

In this model, the model FDR includes interface with vendor/provider (Google Cloud) automating service providers' who is in compliance with data protection laws and regulations and technical requirements in cloud computing. A unified directory and other components of security architecture such as automated provisioning, incident detection and response are employed for security purposes.

3.1 Aircraft Transmission

In the model, aircraft transmits different operating conditions of the flight to FDR on board the aircraft and dedicated private Google cloud architecture via satellite communications because VHF has a limited line of sight range and is not really suitable for direct communications over very long distances especially over the Atlantic ocean. The concept of NextGen, is employed where ADS-B equipped aircraft integrated with satellite sends their identification along with speed and precise vertical and horizontal positions [30]. A Geo-stationary Immarsat Global Navigation Satellite System (GNSS) already been used by airlines for data link is employed.

Because the data transmission is real time, a network of timed automata adapted from [31] is employed to enable many aircraft that belong to the same airline transmit to the cloud concurrently from any location.

Let A_i **=** $(L_i, l_i^0, C, A, E_i, I_i)$ *be a network of n aircraft . Let* $\bar{l}_0 = (l_1^0,...., l_n^0)$ *be the initial location vector. The semantics is defined as a transition system* $(S, s_0, \rightarrow)$,

where $S = (L_1 \times ..... \times L_n) \times R^C$ *is the set of states,* $s_0 = (\bar{l}_0, u_0)$ *is the initial state, and* $\rightarrow \sqsubseteq S \times S$ *is the transition relation defined by:*

- $(\bar{l}, u) \to (\bar{l}, u + d)$ *if* $\forall\ d' : 0 \le d' \le d \implies u + d' \in \mathrm{I}(\bar{l})$.

$(\bar{l}, u) \to (\bar{l}\,[l'_i / l_i], u')$ *if there exists* $l_i \xrightarrow{\tau g r} l'_i$ *s.t.* $u \in g$,

$u' = [r \mapsto 0]u$ *and* $u' \in 1(\bar{l})$.

- $(\bar{l}, u) \to (\bar{l}\,[l'_j / l_j l'_i / l_i], u')$ *if there exist* $l_i \xrightarrow{c!g_jr_j} l'_i$ *and*

$l_j \xrightarrow{c?g_ir_i} l_j$ *s.t.* $u \in (g_i \wedge g_j)$, $u' = [r_i \cup r_j \mapsto 0]u$ *and* $u' \in 1(\bar{l})$.

3.2 Latency and Bandwidth

This is a major concern in flight data transmission to cloud computing.

Given the length of the transfer n which is dynamic relative to location, the width of the channel c, the channel frequency vc, and the processor frequency v. The time t across a memory bus, then, the relationship is defined as follows,

$$t = t(v,vc,n,c),$$

which can be adapted for latency in transmission to the cloud.

In flight data transmission, to find the fixed frequency ratio of transmission a scale factor may be picked, for example if $\alpha_L c = 1$ and $\alpha^{-1}{}_T\ vc = 1$, to obtain the relationship, $v_c t = t(v/v_c,1,n/c,1)$ [32].

For a fixed frequency ratio $\varphi = v/vc$, define the variable $nc = n/c$ and the dimensionless number of channel cycles, $kc = vct$ and let $\tau(\varphi,nc)=t(\varphi,1,nc,1)$ with this relationship, for the latency becomes:

$$k_c = \tau(\varphi,n_c).$$

3.3 Security

Mathematical model adapted from [33] for the Cloud Based data Recorder is given below:

$$D_k = C(\text{node}) \tag{1}$$

$$K_k = f \times D_f \tag{2}$$

where C( ) represents node's visit. The first equation represents system application servers. D_f denotes chunk file matrix, K_f represents chunk file matrix for data center of system while f represents file. Because transmission is continuous, f could be: f = F(1),F(2),...,F(n) which means file f has n chunks, $F(i) \cap F(j) = \varnothing$, $i \neq j, i, j \in 1,2,3,...,n$.

In order to ensure safety and security of flight data transmitted to the cloud an Enhance Cloud Computing Data Security Model ECCDSM adapted from [33] is provided:

$$D'_{f(n)} = C_A(\text{node}) \tag{3}$$

$$D_{f(n)} = M \times D'_f \tag{4}$$

$$K_k = E(f) \times D_{f(n)} \tag{5}$$

where $C_A(\ )$ represents authentic visit to nodes; D'_f is for private protect model of file distributed matrix; M: To resolve private matrix; and E(f): is for encrypted file f block by block to get the encrypted file vector.

3.4 Client Device

Authorized clients are granted permission to access the system whenever there is a need to retrieve stored data about a particular aircraft using Flight Data Retrieval services.

3.5 Functional Services

In this unit, major services of our proposed Cloud based architecture solution for FDR are carried out. It includes Flight Data Ingest Services, where data are collected and stored on Data Repository, processed and analyzed. It includes specific Flight Data Retrieval services use by clients. As mentioned in section 2.2, one of the challenges is that it might be difficult to retrieve FDR, because the wreckage of the aircraft may not be seen or the aircraft is burnt completely. In the case of Malaysia Airlines Flight 370 which disappeared as mentioned in section 1, Inmarsat used SATCOM to analyze the time difference between the transmission of the ping and the

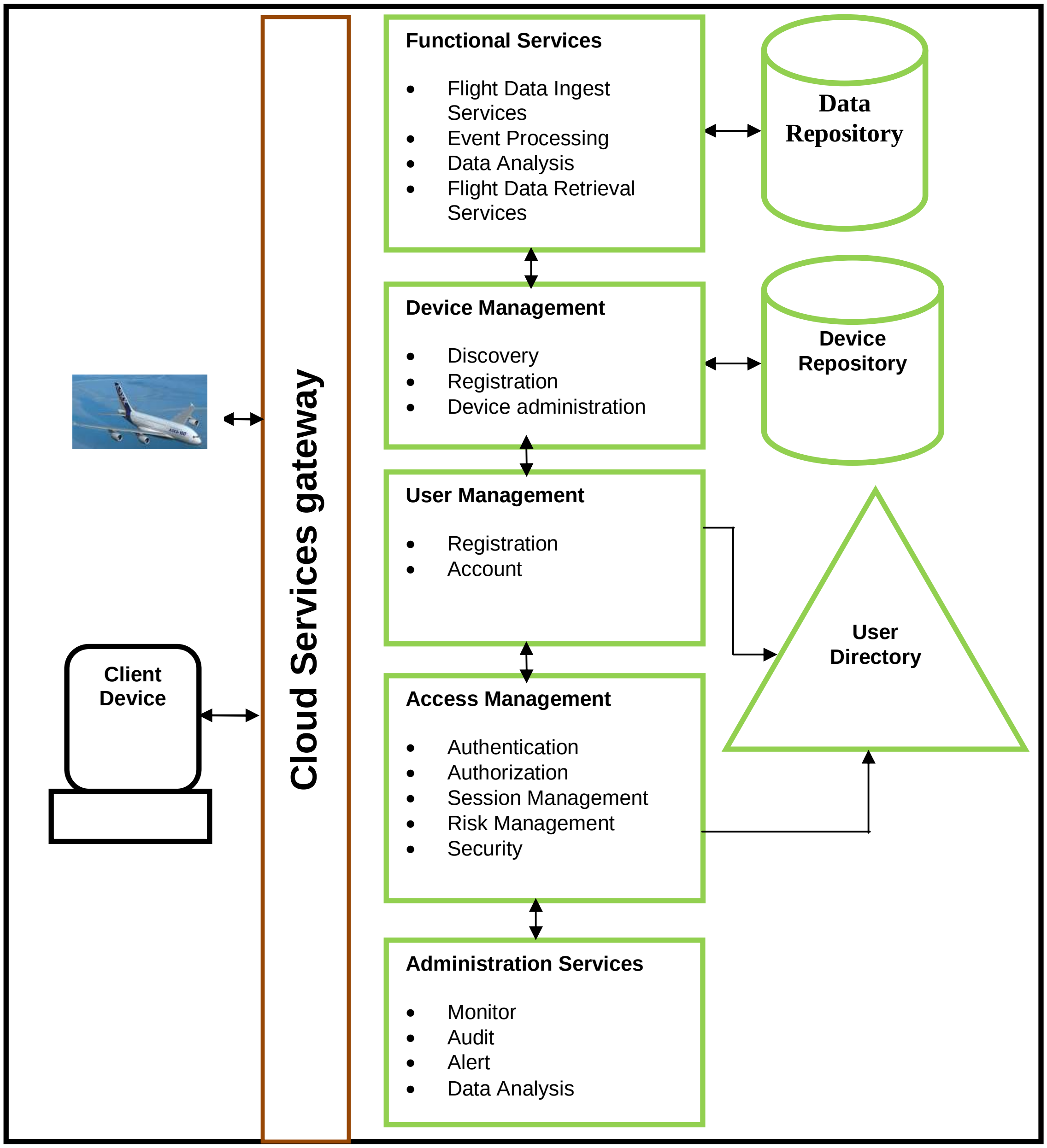

Fig. 1. Cloud based architecture solution model for aircraft flight data recorder

aircraft's response in order to determine the aircraft's distance from the satellite. This resulted in the plotting of two arcs referred to as the "northern corridor" and "southern corridor" where the aircraft might have been located at the time of its last complete handshake at 00:11 UTC [34]. This information was not enough to locate the crash site. With our proposed model, even if the FDR could not be retrieved, exact content of FDR can be retrieved from the cloud. With the data retrieved from the cloud, a computer animated video reconstruction of the last flight can be generated, the aircraft accident investigators can then visualize the last moments of flight before the accident.

3.6 Device Management

Authorization to connect to the cloud, secure access rules enforcement, registration and management of changes to the network are maintained in device management. All these are stored on Device Repository and managed from the project dashboard (Fig. 2).

3.7 User Management

Account administration which includes granting of appropriate permission rights and registration using user directory are handed in this unit.

3.8 Access Management

Flight data record is very vital; access management enforces security policy for application access by authorized users and the APIs that can be used on the architecture to accessing the functionality of the system.

3.9 Administration Services

The services render here have to do with monitoring the health status of the system components, provision of auditing and reporting of functions.

Cloud offerings are inherently global, highly available and large bandwidth capabilities are ensured for data aggregation and dissemination and dataset resides in a globally accessible cloud resources, these make it a valuable resources for aircraft manufacturer and airlines.

There is tendency that many aircraft may fly at the same time; infrastructure of the cloud should cope with predictable demand and unpredictable demand.

3.10 Cloud Downtime Management

The proposed Cloud Based Aircraft Flight Data Recorder is a critical mission, to ensure persistent data storage, airlines can subscribe to at least two cloud providers to prevent loss of data during cloud downtime. In aviation industry most of the equipment is always duplicate, while one is working, the other one may be on standby to take over operations in case of failure.

4. SIMULATION OF CLOUD BASED AIRCRAFT FDR

Cloud Based Aircraft Flight Data Recorder is simulated using MATLAB, a high-performance language for technical computing which is capable of integrating computation, visualization, and the programming environment (Fig. 3).

It is assumed that enough bandwidth is available for transmission of data to the cloud and that data integrity and security is maintained.

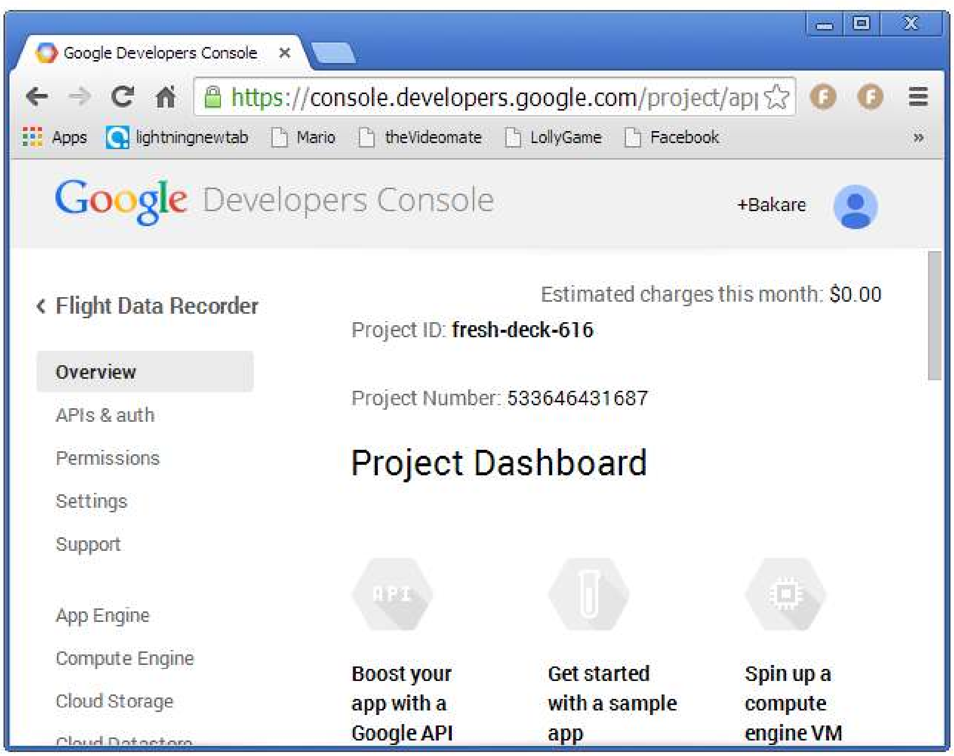

Fig. 2. Private Google cloud FDR DASHBOARD

The simulation used minimum amount of data required for flight: Timestamp, latitude, longitude and altitude; regarded as mandatory. Other non-mandatory data include pitch, bank, aileronPct, rudderPct and many more.

Immediately aircraft takes off from Kaduna (Lat, Long (10.550000, 7.43) en route Zaria (Fig 4), the flight parameters; latitude, longitude and altitude as well as time are transmitted to FDR on board the aircraft and concomitantly to cloud database on real time basis (Table 1). In this simulation distance apart from the destination is included; this will aid investigators in case of any accident.

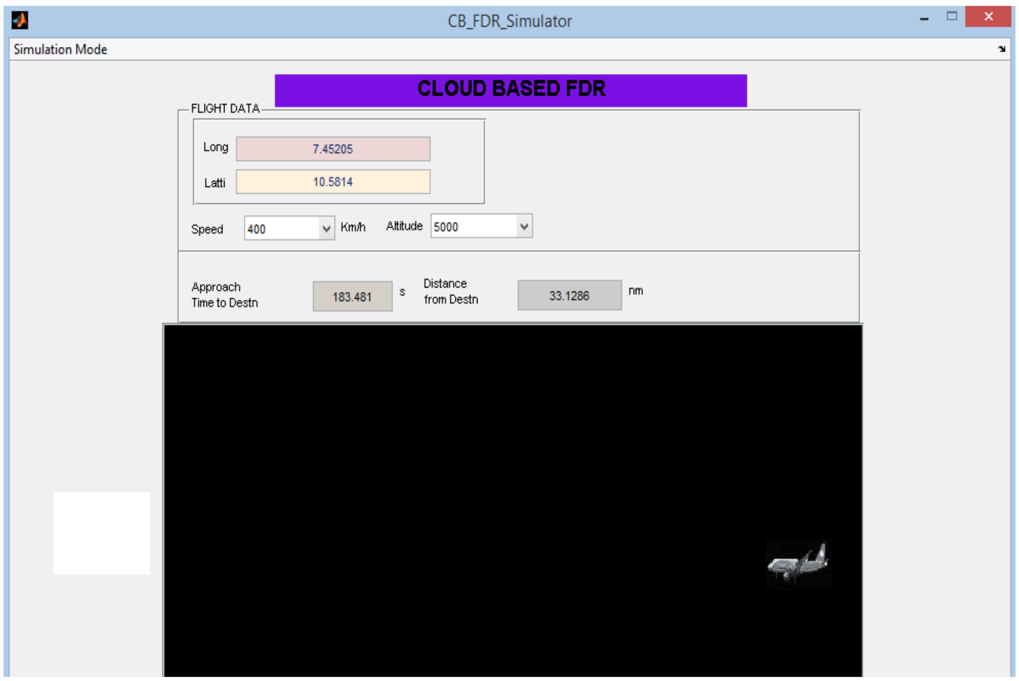

Fig. 3. Simulation of cloud based FDR

Fig. 4. Flight route from Lat, Long (10.550000, 7.43)

Table 1. Flight data from cloud based FDR simulation

Long	Lat	Altitude	Dist_To_Destn	Time_To_Destn	Timestamps
7.43	10.55	18,000 ft	37.86	247.81	2015-05-09 T 11:20 UTC
7.44	10.55	18,000 ft	37.65	246.46	2015-05-09 T 11:21:35 UTC
7.44	10.55	18,000 ft	37.45	245.12	2015-05-09 T 11:23:09 UTC
7.44	10.55	18,000 ft	37.24	243.77	2015-05-09 T 11:24:44 UTC
7.44	10.55	18,000 ft	37.04	242.42	2015-05-09 T 11:26:19 UTC
7.44	10.55	18,000 ft	36.83	241.08	2015-05-09 T 11:27:53 UTC
7.44	10.56	18,000 ft	36.63	239.73	2015-05-09 T 11:29:28 UTC
7.44	10.56	18,000 ft	36.21	237.04	2015-05-09 T 11:32:37 UTC
7.44	10.56	18,000 ft	36.01	235.69	2015-05-09 T 11:34:12 UTC
7.44	10.56	18,000 ft	35.8	234.34	2015-05-09 T 11:35:47 UTC
7.44	10.56	18,000 ft	35.6	233	2015-05-09 T 11:37:21 UTC
7.44	10.56	18,000 ft	35.39	231.65	2015-05-09 T 11:38:56 UTC
7.44	10.57	18,000 ft	35.19	230.31	2015-05-09 T 11:40:30 UTC
7.45	10.57	18,000 ft	34.98	228.96	2015-05-09 T 11:42:05 UTC
7.45	10.57	18,000 ft	34.77	227.61	2015-05-09 T 11:43:40 UTC
7.45	10.57	18,000 ft	34.57	226.27	2015-05-09 T 11:45:14 UTC
7.45	10.57	18,000 ft	34.36	224.92	2015-05-09 T 11:46:49 UTC
7.45	10.57	18,000 ft	34.16	223.57	2015-05-09 T 11:48:24 UTC
7.45	10.58	18,000 ft	33.95	222.23	2015-05-09 T 11:49:58 UTC
7.45	10.58	18,000 ft	33.75	220.88	2015-05-09 T 12:00:33 UTC

5. RESULTS OF SIMULATION

Calculated estimated time of arrival to the destination and distance from the destination and other trajectory data displayed continuously in Table 1 are stored on the private Google cloud storage architecture in real time using Flight Data Ingest Services, where data are collected and stored on Data Repository, processed and analyzed. Unlike traditional way of keeping flight data only on board FDR, validity, retrieval, security and availability of flight data stored on the cloud can be guaranteed.

This model will eradicate interference with flight data; because many countries don't have laboratory to analyse retrieved data from FDR, they have to take the retrieved FDR to overseas countries for analysis. Along the line, the result may be tampered with to serve some people interest. But using a cloud-based architecture solution, sharing of data can be as simple as changing access within the parties that have access to the data to ensure data integrity. Specific Flight Data Retrieval services on the Google cloud is used by clients to retrieve data from cloud based FDR.

The model can support more than one aircraft flight data at the same time because cloud computing offers near-instant scalability which is quicker and reliable When the crowded sky or workload declines, cloud computing permits the scaling back of resources.

With this model, aircraft manufacturers or airline may not necessary wait for disaster to occur or disaster recovery plans, because for every flight, they have flight data performance of the aircraft independent of on board FDR equipment.

6. RELATED WORK

Notable IT firms like IBM and Google have created the new computing paradigm, cloud computing that will allow big companies to open doors to Web 3.0 which refers an important and long term trend-computing over the internet. The integration of cloud computing into aircraft design was modeled in [35]. Their framework, Cloud Computing Platform of Aviation Industry (CCPAI) efficiently provides a mechanism of monitoring management and security unlike the proposed model which will serve as an alternative to on board FDR. Jasti et al. [36] explored the possibility of using cloud services for aircraft data networks. The authors evaluated the performance issues involved with the aircraft mobility and dynamic resource transfer between servers when the aircraft's point-of-attachment changes. The authors predicted that using cloud computing concepts would encourage many carriers to offer new services within the aircraft.

T-systems provides flexible and variable provisioning of IT resources through the cloud computing solution "Dynamic Services for SAP (Systems, Applications and Products) Solutions" for Jet Aviation. Some of the SAP applications include; SAP FI (Financial Accounting), SAP PM (Plant Maintenance), SAP SD (Sales and Distribution), SAP PP (Production Planning), SAP HR (Human Resources) and the industry-specific SAP iMRO solution for inspection, maintenance and repair. The cloud data center at the Langenthal location utilizes virtualization-based pooling effects and is connected to all of Jet Aviation's international locations [37]. Allegiant Travel Company has licensed the AirVault Mx Records Management Solution on January 21, 2014 to provide it with a new web-based aircraft mission critical maintenance record system [38].

The existing cloud computing in aviation industry only provides a mechanism for monitoring aircraft management while the proposed model in this paper provides cloud based FDR as an alternative source of data for aircraft accident investigators to work with in case of any aircraft mishap.

7. FUTURE WORK

Possible future work includes introduction of intelligent real time cloud based FDR system where artificial intelligence, learning and network technologies are incorporated to improve recording and logging of the execution for post-mortem analysis.

8. CONCLUSION

In this paper, cloud based aircraft Flight Data Recorder was modeled, simulated using MATLAB and implemented using Google private cloud computing. Result shows that, saving, retrieval, safety and security of flight data can be guaranteed. The data can serve as backup or alternative data when FDR on board the aircraft could not be retrieved; retrieved but damaged or burnt beyond allowable temperature. Cloud-based FDR model encourages modular design which allows output data to be easily compared. With this model, aircraft manufacturers or airlines may not necessary wait for disaster to occur or disaster recovery plans, because for every flight, it is possible to retrieve flight data performance of the aircraft from cloud database independent of an on board FDR equipment, this will enable them to take preventive or proactive action to resolve problems in order to avert disaster.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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