



# Commercial Cloud Services for a Robust Mobile Application Backend Data Storage

Folasade M. Dahunsi<sup>1\*</sup>, John Idogun<sup>1</sup>, Abayomi Olawumi<sup>2</sup>

<sup>1</sup> Computer Engineering Department, Federal University of Technology Akure, P.M.B. 704, Akure, Nigeria

<sup>2</sup> Electrical and Electronics Engineering Department, Federal University of Technology Akure, P.M.B. 704, Akure, Nigeria

Correspondence: E-mail: [fmdahunsi@futa.edu.ng](mailto:fmdahunsi@futa.edu.ng)

## ABSTRACT

Rapid advancements in the infrastructure of Information and Communication Technology (ICT) have led to radically new but ubiquitous technology; cloud computing. Cloud computing has gracefully emerged offering services that possess on-demand scalability, huge computing power, and a utility-like availability, all at a relatively low cost. It has unsurprisingly become a paradigm shift in ICT, gaining adoptions in all forms of application i.e., personal, academic, business, or government. Not only for its cost-effectiveness but also for its inherent ability to meet business goals and provide strategic ICT resources. More recently there have been advances in cloud computing leading to the evolution of newer commercial cloud services, one of which is the Mobile backend as a Service (MBaaS). The MBaaS is important and required for a robust mobile application back-end data storage and management. Its wide adoption and importance stem from its ability to simplify application development and deployment. Also, MBaaS is robust, with the ability to cope with errors by providing nifty tools and other features. These enable rapid scaffolding of mobile applications. This paper reviews Mobile backend as a Service (MBaaS) and provides required background knowledge on some cloud services and their providers to enable stakeholders to make informed decisions and appropriate choices.

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## 1. INTRODUCTION

Cloud computing is utility-like computing proposed in 1961 by John McCarthy but became a marketing term in 2006 (Buyya et al., 2013; Erl et al., 2013). Following its wide-

spread adoption, utilization, and explosive usage of mobile devices, various Cloud Service Providers (CSPs) have ventured into Mobile backend as a Service (MBaaS). This is in a bid to provide developers with compelling, reliable, dependable, and economical services

for mobile application backend data storage and management. The number of CSPs has increased rapidly with small and large infrastructure. Therefore, determining the right vendor out-of-the-box for developers has become a herculean task.

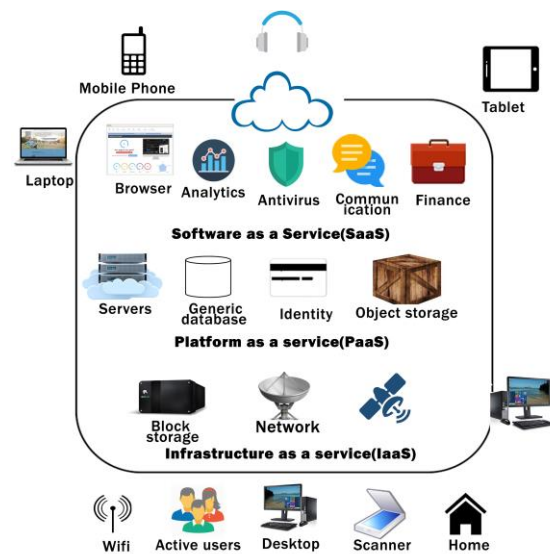
Some vendors pride themselves in offering highly scalable and economical but average storage platforms with minimal setup complexities. Whereas others have larger volumes of data storage while maintaining average performance metrics in terms of scalability, setup complexities, and economic return. However, the focal point(s) of CSPs is that services are designed to meet the basic features of contemporary cloud computing platforms as contained in the definition provided by (Mell and Grance, 2011) of the National Institute of Standards and Technology.

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services). The network access can be rapidly provisioned and released with minimal management effort or service provider interaction. Computing in the “cloud” is diagrammatically illustrated in **Figure 1**.

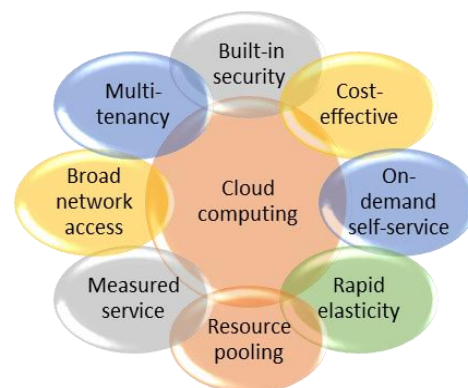
An inference made from the given cloud computing definition reveals that any system that is truly a cloud computing platform should (Almishal and Youssef, 2014; Hung et al., 2012; Mell and Grance, 2011):

- i. possess services that are available on-demand and can be utilized by users without the providers’ interference;
- ii. be accessible heterogeneously on a variety of platforms, for example, mobile device, laptop, desktop, or other standardized devices (s);
- iii. have a dynamic resource allocation capability to aid utilization by multiple users;

- iv. possess resources that are rapidly elastic depending on user’s demand;
- v. be able to automatically measure user’s consumption based on the platform’s payment strategy while maintaining significantly higher economical return when compared to traditional computing; and
- vi. boast of standard security measures to prevent user’s data from unwarranted and illegal exploitation by the platform providers and/or any third party.



**Figure 1. Computing in the “cloud”.**



**Figure 2. Key and distinguishing features of cloud computing.**

These must-have features are summarized and illustrated in **Figure 2**. Cloud computing comes in various models for deployment and services to suit individual preferences based on business requirements (Mell and

Grance, 2011). **Figure 3** illustrates the hierarchical general overview of these models and section 1.3 gives a detailed explanation of them.

From the foregoing, it is important to have a clear understanding of CSPs operations to decisively select preferred services, hence this paper.

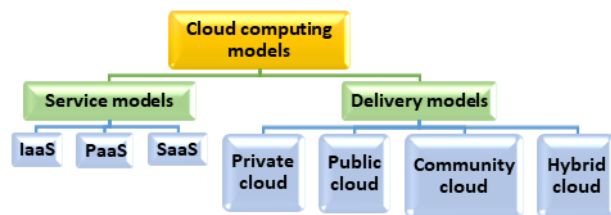


Figure 3. Cloud Computing models.

### 1.1. Related Works

A succinct review of relevant and related review articles on commercial cloud services for mobile application backend data storage is presented here.

A comparative analysis was presented by Daher and Hajjdiab (2018) which was restricted to Amazon simple storage and Microsoft Azure blob storage with a few but in-depth metrics whereas, Khawas and Shah (2018) introduced Google's Firebase as a case study glossing over other available options. Manujakshi and Ramesh (2018) gave a general overview of cloud computing storage as a service and in (Hung et al. 2012), a novel framework which hopes to solve some mobile storage as a service issue such as cloud providers eavesdropping was presented while discussing the pitfalls of other frameworks.

The focus was placed on big data as a service in Zheng, Zhu, and Lyu (2013), and Satri, Satri, and Reddy (2012) reviewed a similar area: Data as a Service. A myriad of issues that tend to pose some difficulty in optimizing mobile cloud computing to its full potential such as resource scarcity, frequent disconnections, and mobility among others was dis-

cussed and solutions provided in Fernando, Loke, and Rahayu (2013).

Papers surveyed did not focus on analyzing available commercial cloud services for mobile applications backend. This paper takes a comparatively in-depth analysis of the various state-of-the-art commercial cloud services available for mobile applications backend to present their inherent features and the capabilities offered by the cloud service providers to their customers. The paper further discusses some capabilities of MBaaS offered by CSPs. This is to provide stakeholders with the knowledge required to decisively select preferred services.

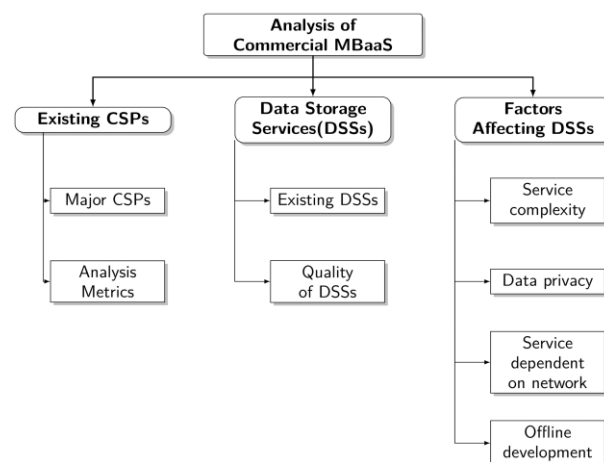


Figure 4. A detailed taxonomy of the analysis of commercial cloud services for mobile application backend data storage.

### 1.2. Taxonomy

A detailed taxonomy of the comparative analysis of commercial cloud services for mobile application backend data storage based on existing cloud service providers is illustrated in **Figure 4**. This analysis is based on data storage services provided by the CSPs, and issues affecting quality service provisioning. The focus of this paper is on CSPs with the largest market share for brevity. Section 2 and 3 discuss the mobile backend storage services provided. Analysis of some factors affecting the quality of their services is presented in section 4. Section 4 also discusses some limi-

tations or concerns of using these services. Section 5 concludes the paper.

### 1.3. Cloud Computing Models

According to (Mell and Grance, 2011), Cloud computing exists in two kinds of models as illustrated in Figure 3. The first being Service Models which represent the flavors in which cloud computing exists. Deployment Model, the second model, is defined by where the infrastructure of these services is located for accessibility, as some infrastructure can rely on customer's resources while others may rely on public infrastructure which can be accessed over the internet.

#### 1.3.1. Service Models

The fundamental feature of cloud computing is to remotely provision or provide scalable, secure, cost-effective, and rapidly elastic IT services to customers. Also, classification can be made on these features based on offered services (Murugesan and Bojanova, 2016). This classification is in three folds: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). Everything as a Service (XaaS) is a new cloud computing term to account for the emerging cloud services which are either subsets or super-sets of the aforementioned models (Castro-Leon and Harmon, 2016).

##### a. *Software as a Service (SaaS)*

This is a service offering in which various applications and services are made remotely available by CSPs and are mostly based on customer's demand over the internet (Murugesan and Bojanova, 2016). SaaS allows the software products to be accessible to users over the internet from their publishers. It is subscription-based and as a result, the customer only pays a relatively smaller and steady payment compared to the large sums required to purchase software discs or executable files for installation on the user's physical systems. Besides, the maintenance of the software product is automatic. This implies that security patches and updates are

automatically added as soon as the software publisher releases a new version or update.

However, a prominent downside to this offering and many cloud computing offerings is that user's data security is not guaranteed. Also, since the software is remotely provisioned, a good internet connection is a requirement for accessibility; thereby posing a challenge to users with a poor internet connection (Hung et al., 2012). Users also have little control over such a software product.

Google's G Suite, Atlassian's Jira, Slack Technologies' Slack, Microsoft 365, Azure IoT Central and Azure Sentinel, Microsoft's Power Platform, Dynamics 365, Salesforce.com, and Oracle's NetSuite are some of the Juggernauts of SaaS offerings.

##### b. *Platform as a Service (PaaS)*

In this service offering, rapidly elastic environments, in the form of hardware and software, that supports applications runtime and execution are remotely provisioned on demand by CSPs for application developers (Buyya et al., 2013; Murugesan and Bojanova, 2016). These environments are majorly used to build software products. Therefore, this offering mainly targets software developers. This offering usually possesses high scalability to meet the requirements of some customer's products. PaaS helps to effectively manage the overheads of user's products. It also ensures faster software programming as many PaaS providers make available boilerplate codes and directories from which development starts. However, integrating user's applications with PaaS platforms can be overwhelming, as difficulties and contradictions are very common. This weakness is an addendum to some other disadvantages of cloud computing. Examples of PaaS offerings are Amazon Web Services (AWS) Elastic Beanstalk, Oracle Cloud Platform (OCP), Google App Engine, Microsoft Azure, Heroku, and IBM Cloud Platform.

### c. Infrastructure as a Service (IaaS)

IaaS provides ICT infrastructure such as block storage, computer virtualization, and networking tools or equipment such as virtual private networks (VPNs), virtual machines (VMs), and containers on-demand (Mell and Grance, 2011). IaaS vendors manage user's servers off-premise. This service offering provides awesome scalability though its costs can be unpredictable. Microsoft Azure, Amazon Web Services, IBM Cloud, Google Cloud, Oracle Cloud, DigitalOcean, and Linode provide IaaS offerings.

### d. Everything as a Service (XaaS)

Following Nicolas Carr's 2003 remark, a cloud service model variance termed Everything as a Service (XaaS) has emerged in the cloud computing market space and has become very famous. This term encapsulates the ubiquitous nature of cloud computing while accounting for all the cloud supporting services that have become prevalent in contemporary times (Castro-Leon and Harmon, 2016).

**Table 1. Overview of the cloud service model variance**

Service models	Examples and/or Providers	Scholarly articles or Lectures
AI as a Service (AlaaS)	Amazon Machine Learning, Microsoft Cognitive Services, Google Cloud Machine Learning, IBM Watson Cloud	(Kidd, 2018)
API as a Service (APIaaS)	Stripe, Checkr, Plaid, PayPal(Braintree)	(Levine, 2019)
Analytics as a Service (AaaS)	CloudMoyo, Zoho Analytics	(Datafloq Sponsored, 2018)
Backend as a Service (BaaS)	Managed Database by DigitalOcean, Google Firebase, and Microsoft Azure	(Cloudflare, Inc., 2020)
Database as a Service (DBaaS)	IBM Db2, Amazon Relational Database Service (RDS), Amazon Aurora, Amazon DynamoDB, MongoDB Atlas, Ninox database, Google Cloud Firestore.	(Honig, 2019; IBM Cloud Education, 2019)
Knowledge as a Service (KaaS)	Got it	(Abdullah et al., 2011; Gomes Barreto et al., 2018; Murugesan and Bojanova, 2016; Xu and Zhang, 2005)
Network as a Service (NaaS)	ATandT, CenturyLink, China Telecom, Cogent, Deutsche Telekom, NTT, Orange, Sprint	(Musthaler, 2018)
Sensing and Actuation as a Service (SAaaS)	Xively.com, ThingsWorx, ThingsSpeak, Sensor-Cloud, Realtime.io	(Distefano et al., 2012; Satpathy et al., 2018)
Storage as a Service (STaaS)	Hitachi Vantara, IBM, DXC, Zadara and Pure.	(Kulkarni et al., 2012)
Video Surveillance as a Service (VSaaS)	Pacific Controls (PCS) VSaaS, 1000eyes, 3dEYE, Aegis AI, Angelcam, Arcules	(Dašić et al., 2016)
Virtualization as a Service (VaaS)	VMware Infrastructure	(Stefanski and Personett, 2009)

*Note:* This compilation is not exhaustive as there are more cloud support services models, more examples and providers as well as more scholarly articles and/or lectures about them. However, the review carried out much credence in the above resources.

Some of these cloud service model variants are presented in **Table 1**. **Table 1** contains the state-of-the-art compilation of emerging cloud support services, examples of their providers (if applicable), and a reference to various scholarly write-ups, lectures, and literature where in-depth information can be mined about them.

### 1.3.2. Deployment Models

Deployment models depend on where the ICT resources for the services rendered are domiciled or located. It is defined by where the infrastructure's data center is hosted and whose ICT team is responsible for its maintenance (Buyya et al., 2013). These, according to (Buyya et al., 2013; Mell and Grance, 2011; Murugesan and Bojanova, 2016), can be categorized into four, namely: private cloud, public cloud, hybrid cloud, and community cloud.

#### a. Private cloud

In this deployment model, IT resources or infrastructure is owned and hosted by the user whose IT team is responsible for its maintenance. When compared with the Public cloud, it promises to be more. However, the upfront investment is higher, and scalability is slower than or not as quick as a publicly deployed cloud platform where more capacity can be rapidly added on demand.

#### b. Public cloud

This model has its resources hosted and maintained by a vendor and made available over the internet on a pay-per-use subscription plan. It scales rapidly and easily; it is more widely used compared to the private cloud.

#### c. Hybrid cloud

In this deployment model, private and public cloud resources are combined to offer more seamless data transfer between both cloud models.

#### d. Community cloud

The community cloud deployment model combines the resources of many private cloud providers which have common concerns.

### 1.4. Significance of Cloud computing

Cloud computing is in widespread use in contemporary times largely due to its impacts, advantages, and benefits. These impacts, advantages, and benefits constitute the significance cloud computing has (Buyya et al., 2013; Murugesan and Bojanova, 2016; Velte et al., 2009) some of which are presented in this section.

- i. Unlike traditional computing, cloud computing offers a seamless and easy approach to infrastructure's scalability without the need to manually install and configure them.
- ii. This greatly improves performance and team collaboration.
- iii. Higher economical return is recorded with cloud computing when compared with traditional computing. This is largely due to lower operational and maintenance costs.
- iv. The agile design pattern of the systems and the fairly simple setup processes also make cloud computing stand out. This enhances the systems' flexibility and mobility.
- v. Potentially, cloud services are secure and disaster recovery is almost always possible. This is because cloud providers invest hugely to secure their systems. Notwithstanding unwarranted and uncensored exploitation of user data by vendors sometimes occur.

## 2. CLOUD SERVICE PROVIDERS (CSPS)

Cloud computing commands one of the biggest market spaces in the world of technology as many businesses (small, medium, and large) have unanimously adopted it. This is due to its inherent abilities to ameliorate

business process efficiency, and drastically reduce business' time to the market. As a result of this wide adoption, cloud computing has a myriad number of providers with a distinct menu of services to offer. However, Google Cloud, Amazon Web Services, IBM Cloud, Microsoft Azure, and Salesforce are arguably the biggest names in this market (Almishal and Youssef, 2014). Alibaba Cloud, Oracle Cloud Infrastructure, Slack, Cisco, Rackspace, FlexiScale are the other noteworthy providers.

## **2.1. Some Popular Cloud Services Providers (CSPS)**

This section discusses some of the popular cloud service providers in recent times and these are Amazon Web Services (AWS), Google Cloud, Microsoft Azure, IBM Cloud, and Salesforce.

### **2.1.1. Amazon Web Services (AWS)**

Amazon is one of the world's tech Juggernauts and they entered the lucrative market of cloud computing in 2006 by launching Amazon Elastic Compute Cloud. This famous PaaS offering, together with other offerings, has metamorphosed into the popular Amazon Web Services. According to (Almishal and Youssef, 2014), AWS has many products across various cloud offerings. Specifically, AWS Amplify and AWS Mobile Hub are Amazon's MBaaS offerings (Batschinski, 2020), the former being the most dominant.

### **2.1.2. Google Cloud**

Since its emergence in the cloud space in 2007, Google Cloud has been one of the major names in the market having offerings in all service models including Google Compute, Google Storage and Databases, Google Networking, and a host of others (Google Cloud, 2020). However, the popular service, Firebase, is its backend service for mobile and web applications (Khawas and Shah, 2018).

### **2.1.3. Microsoft Azure**

Microsoft Azure is the business name of all Microsoft's Cloud offerings which span all major service models (Microsoft Corporation, 2020). Among its numerous offerings, Azure Mobile Apps provides backend data storage facilities for software engineers.

### **2.1.4. IBM cloud**

IBM, one of the world's technologies juggernauts, provides its IaaS and PaaS as IBM Cloud, formerly IBM Bluemix and IBM SoftLayer.

### **2.1.5. Salesforce**

The Cloud behemoth, Salesforce.com, inc., has become the leading provider of Customer Relationship Management (CRM) cloud platform. It also has offerings in PaaS and IaaS having acquired Heroku.com in recent times. Some others offer are service cloud, marketing cloud, health cloud, app cloud, community cloud, analytics cloud, IoT cloud, Chatter cloud, and commerce cloud among others.

## **2.2. Comparative Analysis of Cloud Services Providers (CSPS)**

The popular cloud service providers discussed above are analyzed and compared based on their year of establishment, primary operating system (OS), supported service, deployment models, security compliance, cost, and availability as presented in **Table 2**. From **Table 2**, it can be inferred that most of the providers embrace security and the de facto pay-as-you-go payment model, though each has a slightly different flavor, which allows consumers to pay for only the consumed services. Though the level of system security varies, most CSPs maintain the average security required by most enterprise-grade applications. The public deployment model is also the most commonly chosen as it allows access to the entire public resource.

**Table 2: Comparative overview of existing and prominent cloud service providers**

Analysis Metrics	Amazon Web Services	Google Cloud	IBM cloud	Salesforce	Microsoft Azure
Year launched	2006	2008	2013	1999	2010
Server Operating System	Windows, Linux	Windows, Linux	Windows, Linux	Windows, Linux	Windows, Linux
Service Models	SaaS, PaaS, IaaS	SaaS, PaaS, IaaS	SaaS, PaaS, IaaS	SaaS, PaaS	SaaS, PaaS, IaaS
Tools or Services	Amazon Elastic Compute Cloud (EC2), Amazon Simple Storage Service (S3), etc.	Google Compute, Google Storage and Databases, Google Networking, etc.	Smart Cloud	Sales cloud, Service Cloud, Marketing Analytics, and so on	Azure, Microsoft 365, Dynamics 365
Deployment model	Public, hybrid	Public, Hybrid	Public, Hybrid	Public	Public, Hybrid
Security and Compliance	Highly secured and compliant	Highly secured and compliant	Highly secured and compliant	Secured and compliant	Secured and widely compliant
Pricing model	Free introductory tier, Per second billing	Free introductory tier, Per second billing	Free introductory tier, Pay-as-you-go or per-second billing, subscription	Free introductory tier, subscription, or monthly/ annual billing	Free introductory tier, Per second billing
Worldwide availability	About 25 GRs <sup>b</sup> , 78 AZs <sup>a</sup>	About 21 GRs, 61 AZs	About 6 GRs, 18 AZs		About 54 GRs, 140 AZs(countries)

Note: AWS and Google Cloud are yet to fully adopt the Hybrid cloud deployment model. <sup>a</sup>AZs represents Availability Zones. <sup>b</sup>GRs represent Geographical Regions.

### 3. ANALYSIS OF DATA STORAGE SERVICES TO MOBILE APPLICATIONS

As cloud computing evolves, various as-a-service emerge to suit the needs of consumers. One of such services is the Mobile backend as a Service (MBaaS), sometimes and broadly referred to as backend as a Service (BaaS). This service offering affords Software Engineers cum Developers the luxury of overlooking backend operations such as manual database management, tasking server administration, technical load balancing, and daunting product scaling (Carter, 2016).

David (2019) points out that it also provides authentication systems, push notification services, analytics, and ad management among others out-of-the-box for Engineers who then have ample time to concentrate on the logic of their applications as well as ensuring

a nice and friendly user interface and experience. One important thing to point out is that all these awesome services are provided affordably on-demand.

Many of these MBaaS providers utilize a pricing model, largely known as "freemium", which allows the usage of the services' basic features without any payment for some time under some usage limitations (Siripathi, 2017). Though many of these providers tend to focus more on some features, they all tend to provide the basic needs of software engineers which are user authentication and authorization with social integration, data security and synchronization, application's file handling, and push notification the de facto requirements of modern mobile applications. Some popular names in this market space are Firebase, Apple CloudKit, Azure Mobile Apps, AWS Mobile Hub, and Kinvey among others.

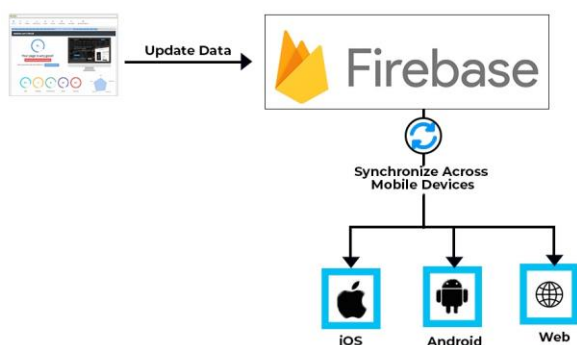


### 3.1. Mobile Backend as a Service (MBaaS) Providers

#### 3.1.1. Firebase

Firebase is a software development platform with a real-time NoSQL (non-relational database) database which allows the storage of data in a non-tabular format using JavaScript Object Notation (JSON). After its acquisition in October 2014 by Google, Firebase has risen to be at the forefront of BaaS. It has appealing features such as Analytics, Authentication, Real-time Database, Cloud Firestore, Cloud Storage, and Push Notifications (David, 2019; Khawas and Shah, 2018). The basic overview of Firebase services is illustrated in **Figure 5**.

Though built with Android in mind, it has a Software Development Kit (SDK) for iOS devices (Siripathi, 2017) and Web applications. Other features worth noting are Hosting and Content Delivery Network (CDN), Testing Lab, Crashlytics (Crash Reporting), Dynamic application links, Cloud messaging, remote configuration, and some other features which are still in Beta versions. It can also be integrated with other services such as Slack, Jira, BigQuery, Play Store, and Data studio among others. Despite Firebase's awesomeness, there are some downsides to use it.



**Figure 5.** Basic overview of Firebase services. Adapted from Google Cloud (2020).

Firebase only supports NoSQL database and RESTful APIs thereby striking out the possibilities of utilizing GraphQL APIs and SQL databases. Also, it has limited support for iOS development as it was initially built with An-

droid in mind and as a result, certain features of the platform are not available for iOS application development. Firebase's real-time database also has limitations such as a lack of support for complex querying and filtering.

#### 3.1.2. Apple Cloudkit

Apple Cloudkit is Apple's MBaaS offering released alongside iOS 8 updates in 2015 to provide easy integration with iOS applications (David, 2019; Shraer et al., 2018). However, with CloudKit JS, utilizing the platform for web applications is now relatively easier. It supports all the basic features of BaaS including secure authentication, various forms of the database, automatic data syncing, and an out-of-the-box cloud kit dashboard with up-to 1PB free storage for each application. A unique feature of this platform is its scheme management and evolution which enables the automatic database schema inference from the data being saved (Shraer et al., 2018).



**Figure 6.** Apple Cloudkit architecture showcasing the interfaces of the platform (Shraer et al., 2018).

From **Figure 6**, Cloudkit presents the Device API being utilized by mobile client applications, Web Service API for connecting to web applications, and a custom Remote Procedure Calls (gRPC) for communicating with third-party backend services (Shraer et al., 2018). One major drawback of this platform is that it only supports iOS and web application development.

### 3.1.3. Azure Mobile Apps

To extend its growing space, Microsoft's Azure Blob Storage introduced the Azure Mobile Apps to join the MBaaS race (Microsoft Corporation, 2020). This platform provides services such as push notifications, single sign-on, offline support and sync, auto-scaling, and social integration, to software developers building cross-platform applications for Android, iOS, and Windows. Custom backend codes are also supported but the choice of the technology stack is limited to C# and Node.js (Microsoft Corporation, 2020). It is also regarded as the most secure MBaaS offering due to inheritance considering that Microsoft Azure is a leader in cloud services security.

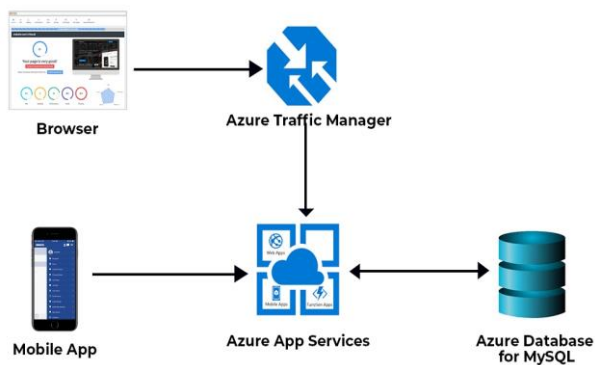


Figure 7. Microsoft Azure Mobile Apps scalable applications development architecture. Adapted from Microsoft Corporation (2020).

A major setback of Azure Mobile Apps is its unorganized documentation which propagates to a rather steep learning curve. Not only this, but the community support is also weak. **Figure 7** shows the Microsoft Azure Mobile Apps scalable applications development architecture.

### 3.1.4. AWS Amplify and AWS Mobile Hub

Being the leading cloud giant, Amazon Web Services (AWS) provides some robust platforms for building mobile applications, testing their functionalities, and a subsequent dashboard for monitoring the applications' usage. There is also an open-source JavaScript Framework called AWS Amplify which is used

to support mainly React and React Native extensions for building interactive applications (Batschinski, 2020).

However, most AWS Mobile Hub SDKs for Android and iOS are now part of AWS Amplify and as a result, the latter is an ultimate replacement of the former. This open-source MBaaS offering has the workflow shown in **Figure 8**. Features including but not limited to authentication, storage, content delivery, and analytics are provided out-of-the-box in AWS Mobile Hub. Since its parent company is AWS, there is seamless integration with other Amazon cloud services such as Amazon S3 for storage, and a host of others. However, this platform has a rather steep learning curve and some overwhelming complexities. Therefore, some level of experience is needed to fully utilize its potential.

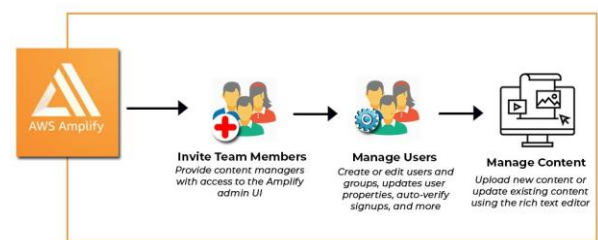


Figure 8. The workflow of application development with AWS Amplify. Adapted from Amazon Web Services (2021).

### 3.1.5. Kinvey

Kinvey affords application developers the luxury of building serverless, robust, and multi-channel applications (Kinvey, 2020). It has excellent features ranging from user management, serverless development, datastore, collaboration services, push notifications, location services, to web hosting (**Figure 9**).

Kinvey, alongside Parse (the pacesetter of MBaaS which is now open-sourced), has stood the test of time (Kinvey, 2020). Kinvey supports developing native applications for the web, iOS, Android, Progressive Web Applications (PWAs), and instant messaging. A distinguishing feature of this platform is its life-cycle management tool which allows ap-

plication versioning for easy collaboration. Its free plan has 2GB of data storage and 5 million notifications which can be tested for about 1000 users.

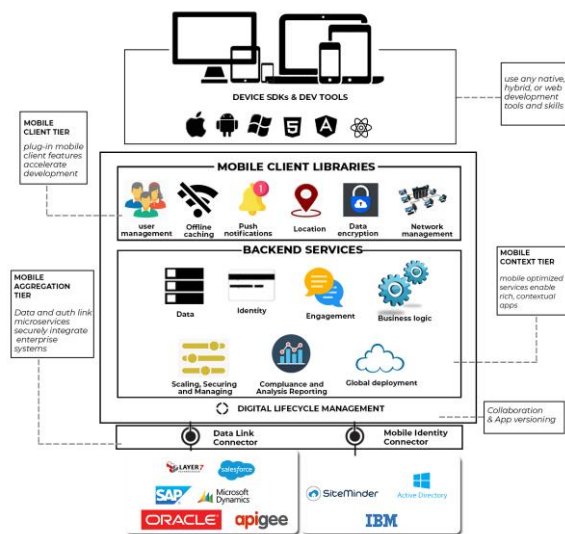


Figure 9. Kinvey's 4-tier architecture addressing all the client, delivery, and aggregation tiers requirements. Adapted from O'Connor (2017).

Other great platforms that do not have a backend are, Kumulos, Meteor, Back4App, and Kii.

### 3.2. Comparative Analysis of Mobile Backend as a Service (MBaaS) Providers

This section provides, in a tabular format shown in **Table 3**, an analytical comparison between the leading MBaaS providers with a focus on storage, economic return, security, support, and reliability.

The core features required by Software Engineers, such as authentication and analytics, are prevalent to all these providers though some have extended abilities. As for reliability and scalability, these providers are reliable and scalable while supporting the most popular platforms: Android, iOS, and web. Free tiers are also common for testing purposes and then pay-as-you-go payment plans with varying charges per second or hour. Security and availability are guaranteed aside from some salient issues, which shall be discussed in the next section.

Table 3: Comparative analysis of the major MBaaS providers

Analysis metrics	Firebase	AWS Amplify	Kinvey	CloudKit	Azure Mobile
Core features	Analytics, messaging, crash reporting, databases, Authentication	Analytics, APIs, storage, XR, Authentication	User management, Collaboration, Serverless development, Datastore	Authentication, Automatic syncing, analytics dashboard	Push notifications, Single sign-on, Offline support and sync, auto-scaling
Supported Platforms	Android, iOS, and Web	Android, iOS, and Web	Android, iOS, and Web (and PWAs)	iOS, and Web	Android, iOS, and Windows
Reliability	Very Reliable	Reliable	Reliable	Reliable	Reliable
Scalability	Scalable	Highly scalable	Scalable	Scalable	Scalable
Pricing	The free plan (excluding phone authentication) ; spark plan; and Blaze plan (pay-as-you-go)	Free tier; pay-as-you-go	Free trial available; Unpublished payment plan	Free tier (1PB for each app, 5GB free for private data) ; Pay-as-you-go after exceeding free limit	No upfront cost; Flexible Pay as you go payment plans
Security	Highly secure	Highly secure	Secure	Secure	Highly secure
Customer Support Services	Case submission support	Support Options include Developer, Business, Enterprise	Available	Available	Available at Azure

#### **4. FACTORS AFFECTING MOBILE BACKEND AS A SERVICE (MBaaS)**

As with every human invention, cloud service, and modern technological advancement, MBaaS has a couple of issues despite its appealing and impressive qualities of relieving software engineers the cumbersome tasks of managing every single aspect of the software product. There is also the acclaimed higher economical return when compared with traditional or custom solutions. These factors arise from MBaaS complexities, limited flexibility, data infringement, and lack of support for offline development (Hung et al., 2012).

##### **4.1. Service complexities**

One of the major plagues of MBaaS offerings is the complexities they pose to developers. Aside from learning the nitty-gritty of the technology stack to be used, developers are also saddled with the responsibility of dissecting how to incorporate them in their software products. Coupled with the fact that most MBaaS offerings have steep learning curves. These operations may not be an easy task for even experienced Engineers (Hung et al., 2012).

##### **4.2. Data privacy infringement**

Most cloud providers legally and illegally utilize customer's data for statistical, marketing, or other purposes. Since some data are meant to be private, it can result in data privacy infringement. Hung et al., (2012) argued that not only can the data be exploited by the MBaaS providers but also by malicious hackers lurking around to exploit the possibilities of data hijacking when they are being transferred over the internet. Data privacy infringement has been a perennial issue with cloud services and no viable solution yet. To minimize data eavesdropping, traditional solutions should be utilized.

##### **4.3. Limited flexibility**

Unlike custom solutions, MBaaS has a lot of limitations when it comes to customization. This is a result of their specialized focus when rolling out the services. If flexibility is one of the requirements of the user's product, a custom back-end should be built instead of using MBaaS.

##### **4.4. Lack of support for offline development**

Using MBaaS requires uninterrupted and constant internet connection even during development. This can impede development speed for users in areas where an erratic network is prevalent (Hung et al., 2012).

#### **5. CONCLUSION**

MBaaS or cloud service for mobile backend data storage provides web and mobile application developers not only with a platform to link their applications to backend cloud storage but also providing impressive features. Such features include user management, push notification and location services, analytics, artificial intelligence (AI) and extended reality (XR) tools for embedding machine learning and augmented reality, and other appealing functionalities. Thereby ameliorating developers' productivity at a relatively low amortized operation cost. They also tend to address automatic scalability issues.

This paper has analyzed prominent MBaaS offerings for robust mobile applications based on some salient metrics to present their features, reliability, and scalability status, as well as their economic returns. However, the decision to select the service of choice depends solely on organizations' requirements and use cases since MBaaS advantages are different based on the size of the organizations.

Similarly, some MBaaS solutions are platform-dependent such as Apple CloudKit, which only works for iOS and, recently, web applications, while others focus

mainly on enterprise applications. Therefore, before considering any provider, it is important to grasp the fundamental concepts of cloud services, platform coverage, and route of integrating them with the development plan. These determine the success of the timely and on-budget

implementation of the task largely and ultimately project.

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