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A COMPREHENSIVE ANALYSIS OF WHATSAPP'S TECH STACK AND FUNCTIONALITIES

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ABSTRACT: Social media has evolved over time and gained widespread significance in how individuals and organizations interact, share information, and build communities. Defined in various ways depending on context, it is generally recognized as a group of internet-based applications built on the principles of Web 2.0, enabling the creation and exchange of user-generated content. Kaplan and Heanlein (2010) emphasize social media as a platform for participatory content creation, while Manning (2014) highlights its interactive nature, contrasting it with traditional broadcast media. Unlike one-way communication channels like radio, social media allows for real-time engagement and feedback, empowering individuals to connect, share, and communicate with many simultaneously. Igbafe and Anyanwu (2018) further define social media as modern interactive platforms through which users exchange ideas, experiences, and information. From Facebook and Instagram to Twitter and YouTube, social media encompasses a wide range of platforms that foster interactivity and community building. As social media continues to shape communication dynamics across the globe, its influence remains a key factor in the evolution of how we connect and share in the digital age.

Keywords: Social Media, Interactive Media, Web 2.0, User-Generated Content, Online Communities

Introduction

The term "social media" has enjoyed various and varying definitions depending on time and context. Kaplan & Heanlein (2010) defines "social media" as a group of internet-based applications that build on the ideological and technological foundations of web 2.0 and that allows creation and exchange of user generated contents. Manning, (2014) defines "social media" as the term often used to refer to new forms of media that involves interactive participation. He distinguished between two types of media: the broadcast and the interactive. While broadcast media such as radio utilizes one-way transmission and indirect feedback mechanism, the interactive media places interactivity at the center of new media functions. In the interactive media age, one individual could now speak too many and instant feedbacks are possible. Igbafe and Anyanwu (2018) defined social media as modern interactive channels through which people connect to one another, share ideas, experiences, pictures, messages and information of interest. From Facebook and Instagram, to twitter and Youtube, social media covers a broad range of apps and platforms that allow users to share contents, interact online and build communities. Today, almost everything is about social media. Some gurus claim that if you do not participate in Facebook, Youtube and other popular social media platforms, you are not part of the cyberspace (Kaplan &

Heanlein, 2010). As far back as 2008, internet surfers used "social media" by joining social media networks, reading blogs and contributing reviews to shopping sites.

Digital Global Overview Report on https://www.datareportal.com states that, in 2022, the number of social media users worldwide grew by 137 million or about 3%. The 2023 report has it that more than 4.7 billion people use social media equal to roughly 60% of the world's population. Approximately 61% of the world's population has a social media account, in 2022, the number of accounts surpassed 5 billion (Curry, 2023). The largest social media platforms are Facebook, Youtube, Whatsapp, Instagram and Wechat. Social media typically features user generated content and personalized profiles that lend themselves to engagement via likes, shares, comments and discussions. Therefore, it is reasonable to say that social media represents a revolutionary trend that should be of interest to companies and individuals operating in online space or any space for that matter. The vast majority of social media definitions draw on key elements which include; participation, openness, conversation, community and connectedness. Authors agree on the various forms of social media which includes; e-mail, blogs, content-communities, collaborative projects, social networking sites, virtual game worlds and virtual social worlds. Whatsapp qualifies as a social networking platform built for communication with people all over the world. Boyd and Ellison (2008) define social networks as web-based services that allow individuals to construct a public or semipublic profile, and within a bounded system, articulate a list of other users with whom they share connection and view and traverse their list of connections made by others. Whatsapp is a cross-platform instant messaging service for smart phones that relies on internet connectivity for the transmission of messages (Quist, 2018). Whatsapp can be used for texting and sending voice notes and is compatible with a multitude of file types that can be sent with a reasonable size limit. The Whatsapp application also comes with a phone call function that serves as a replacement for typical phone plan. Like many other innovations in media-tech and communications, the Whatsapp platform has enormous impacts on the social sphere. There are literatures that address issues arising from the use of social media, with only a few focusing on the Whatsapp application. These publications often concentrate on the use and impact of Whatsapp in the social sphere and not much has been done to explore the current state of both the frontend and backend of the Whatsapp development stack. This paper specifically attempts to appeal to tech-enthusiasts who would be more interested in exploring the backend tech stack in terms of understanding the architecture and system design, programming languages and protocols, database specifications and other tech related concepts associated with Whatsapp, as well as those in the social and non-tech world whose primary interest is to uncover the capabilities, opportunities and challenges associated with media technologies.

Origin of Whatsapp and Usage Statistics

The Whatsapp application is a social networking media that can connect many people in an audiovisual communication and is also supported by chat capabilities that are relatively fast compared to other applications, for example BBM, FB messenger or Yahoo messenger (Silfa, 2021). Recent technological advances in the world led to the development and launching of Whatsapp to facilitate good connection,

communication and interaction within educational (teaching and learning) and non-educational (family and friends) context (Igbafe and Anyanwu, 2018). According to Barhourmi (2015), Whatsapp was founded in 2009 by Brian Acton and Jan Koum. While Koum was an immigrant from Ukraine attending classes at San Jose University, Acton was a programmer working for Yahoo. It was Koum who saw the potential of operating through Apple's app store after purchasing an iPhone in early 2009 (Iqbal, 2023). The story of Whatsapp is an archetypical success story; both Acton and Koum were former employees of Yahoo (Barhourmi, 2015). Koum created the Whatsapp for Apple iPhone with support from Acton. While initially intended to track user's work statuses, notifying their contacts of their availability, it quickly transformed into a messaging platform, as its early user base took to the app's ability to send notification to other users. Whatsapp became a paid service, blackberry and Android compatible versions were created, it rose through the Apple app store charts and in 2011, attracted investors. Facebook acquired Whatsapp in 2014 for $19 billion. As of 2021, Whatsapp boast more than 2.2 billion users worldwide. It is most popular in India, with 487 million users, followed by Brazil with 118.5 million users and Indonesia with 84.8 million users (Iqbal, 2023). Whatsapp's widespread usage makes it the most popular messaging apps in the world, with nearly 800 million more users than the next most popular competitor, Wechat. According to the app's official website; https://www.whatsapp.com, the name Whatsapp is a pun on the phrase "what's up". Whatsapp started as an alternative to SMS. The app supports sending and receiving of a variety of media; text, photos, videos, documents and locations as well as voice call.

Table 1: Whatsapp overview

Launch Date	24 February 2009
Head Quarters	Menlo park, California
People	Will Cathcart (head of Whatsapp), Brian Acton (co-founder), Jan Koum (cofounder)
Business Type	Subsidiary
Owner	Facebook

Source: Iqbal, (2023)

According to Iqbal, (2023), Whatsapp is one of the few apps to be downloaded over 5 billion times on Android and iOS. It is the most popular messaging app in over 100 countries and in 2022, generated $906 million, almost all from the Whatsapp for Business App. Whatsapp has users in every region and was not as popular in the US and UK but that has started to change in recent times. In 2017 and 2019, whatsapp was the highest most downloaded app globally with 924 and 850 million downloads respectivelly. Excluding China, 69% of internet users use whatsapp while over 100 billion whatsapp messages are sent and over 2 billion minutes are spent on whatsapp voice and video calls per day. Whatsapp is available in 180 countries and in 60 languages (Iqbal, 2023).

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Table 2: Whatsapp users 2012-2022 (mm)

Date	Users (mm)
2012	103
2013	213
2014	409
2015	719
2016	1076
2017	1323
2018	1560
2019	1813
2020	2102
2021	2289
2022	2413

Source: Iqbal, (2023)

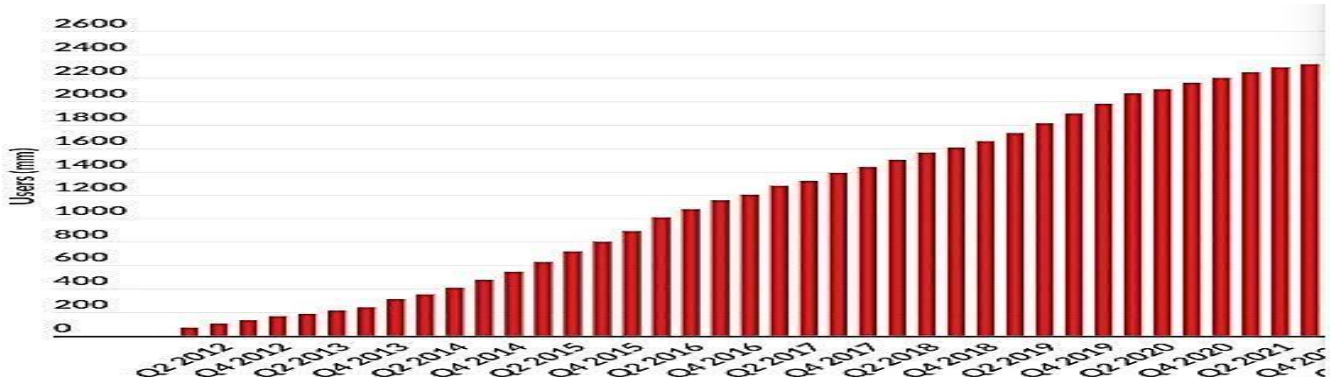

Figure 1: Whatsapp users 2012-2022. Source: Iqbal, (2023)

Table 3: Whatsapp users by country 2022 (mm)

Country	Users (mm)
India	390
Brazil	148
Indonesia	112
Untied State	98
Philippines	88
Mexico	77
Turkey	56

Egypt	55
Germany	44
Nigeria	40
Italy	35

Source: Iqbal, (2023)

Table 4: Whatsapp accumulative downloads 2013-2021 (mm)

Date	**Downloads (bn)**
2013	0.5
2014	0.8
2015	1.2
2016	2
2017	2.9
2018	3.4
2019	4.3
2020	4.9
2021	5.3

Source: Iqbal, (2023)

According to Dixon (2023), Facebook was the first social network to surpass one billion registered accounts and currently sits at more than 2.9 billion monthly active users. Meta platforms owns four of the biggest social media platforms, all with over one billion monthly active users each; Facebook, (core platform), Whatsapp, Facebook messenger and instagram.

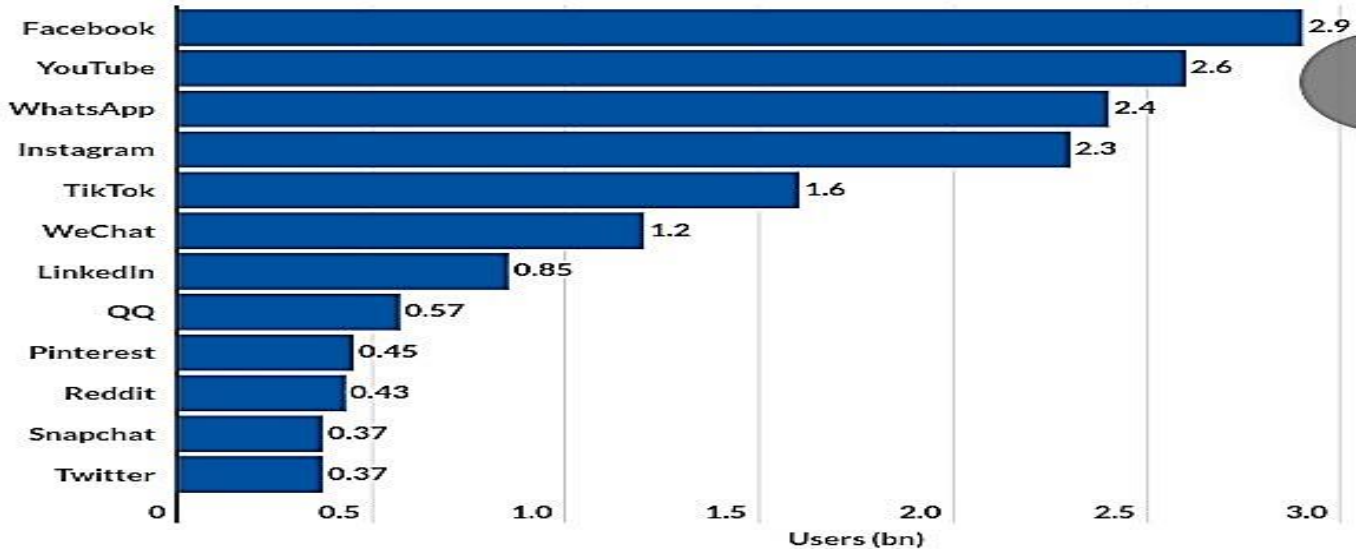

Figure 2: Whatsapp and Competitors; Users Source; Dixon (2023)

Factors Motivating the Adoption of Whatsapp

Social media has become very popular in the 21st century (Mohd Noorhadi & Zurinah Tahir 2017; Balasundran et al. 2021). Whatsapp has become the world's largest and most popular mobile text messaging service in India (Sathish Kumar et al, 2021), South Africa, Argentina, Singapore, Hong Kong, Spain including Malaysia (Normaziani et al, 2018). From all social media, Whatsapp has become a popular app in the world (Balasundran et al, 2021).Several literatures have been offered showing various factors that motivates the adoption of Whatsapp as choice mobile app in smartphones and desktop computers for communication. In a study carried out by Subramanian, (2017), Whatsapp application was discovered to be the first choice among adolescents which is 80% to 90% of them using the app because they believed that it can speed up the communication relationship. Another study (Normazani et al., 2018; Balasundran et al., 2021) attributed the use of Whatsapp by lecturers to its effectiveness in education management. Lecturers use Whatsapp to convey information and instructions even after working hours and these are focused on immediate tasks or requiring immediate feedback. Thota & Divatia (2015) posited that the factors motivating the use of Whatsapp by doctors is that Whatsapp serves as a medium to rescue ailing people during time of emergency. Whatsapp ensures availability of a medium for transfer of images and videos during the transportation of patients, plays a crucial role in avoiding mishaps, provided there is an active network of the mobile device operator. The study carried out by Shambare (2014) identified certain factors as motivators for the adoption of Whatsapp application as choice mobile communication app amongst South African youths. These factors include cost efficiency, simplicity, user-friendly features and the ability to run on multiple platforms.

Whatsapp System Design and Architecture

Software architecture is a representation of components and connectivity between these components (Cyrilrag, 2019). Quality software is developed by developing quality software architecture. The Whatsapp system design proves a quality one evident in its capacity to meet the communication needs of it numerous users, which has developed into trust for the app and has overwhelmingly increased its popularity. The Whatsapp system design is client-server architecture. The architecture consists of multiple layers including the client-layer, business logic layer and database layer (Wallis, 2023). The clientlayer is responsible for handling user interactions, while the business layer handles the processing of messages and communications between users. The database layer stores user information, message data and meta-data for user accounts. Broadly, Whatsapp architecture can be divided into the server and the client architecture (Cressler, 2021).

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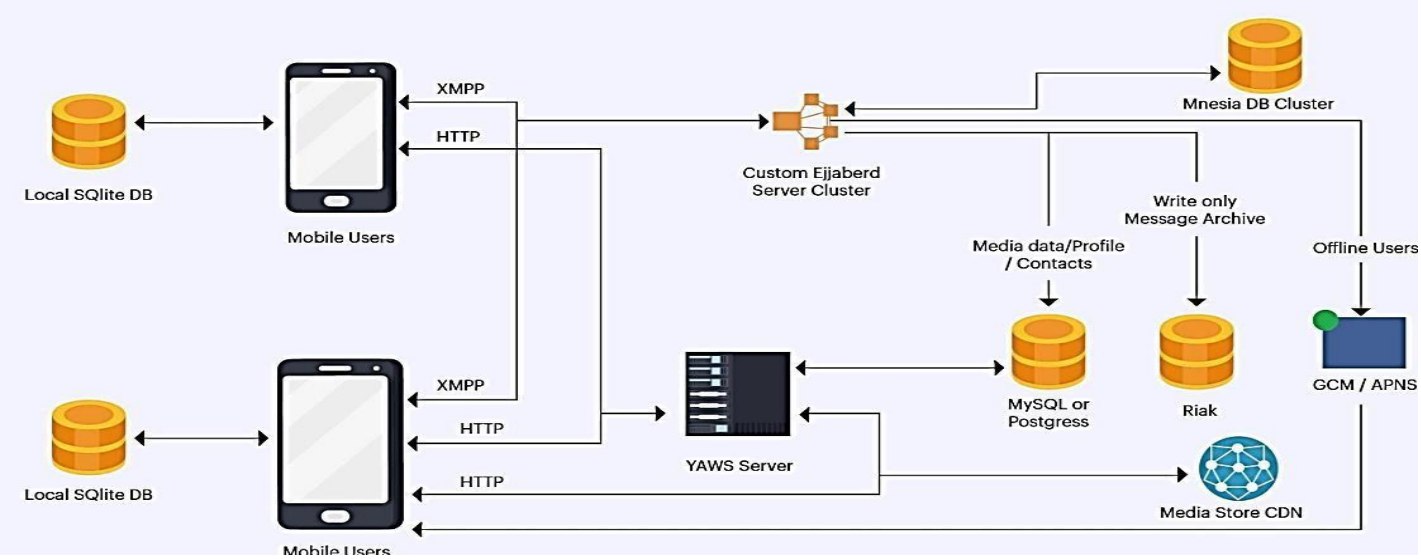

Figure 3: Whatsapp Architecture Source: Cressler, (2021)

UML Representations of Whatsapp Architecture

UML is Unified Modelling Language and is a general purpose modelling language that is intended to provide a standard way to visualize the design of a system. It offers a way to visualize a system's architectural blueprints in a diagram, including elements such as any activities, individual components of the system, how the system will run, how entities interact with others as well as external user interface. (Booch et al., 2005).

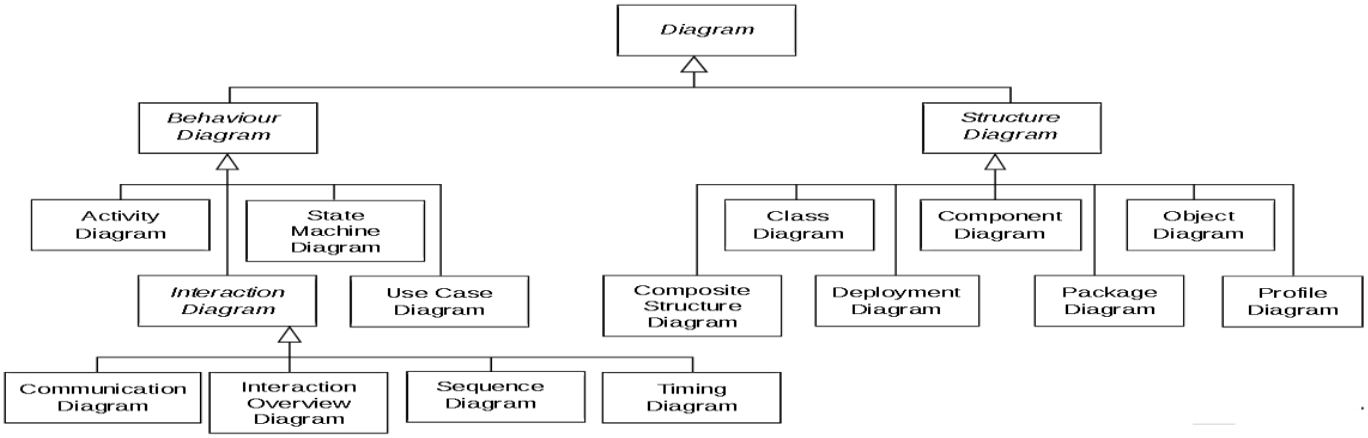

Figure 4; UML Notations Source: Booch et al., (2005).

Components of the Whatsapp architecture and communications between them can be represented using UML diagrams (Begum and Cyrilraj 2015). In this paper we shall represent Whatsapp architecture using use case diagrams, sequence diagram, activity diagram, class diagram and component diagram.

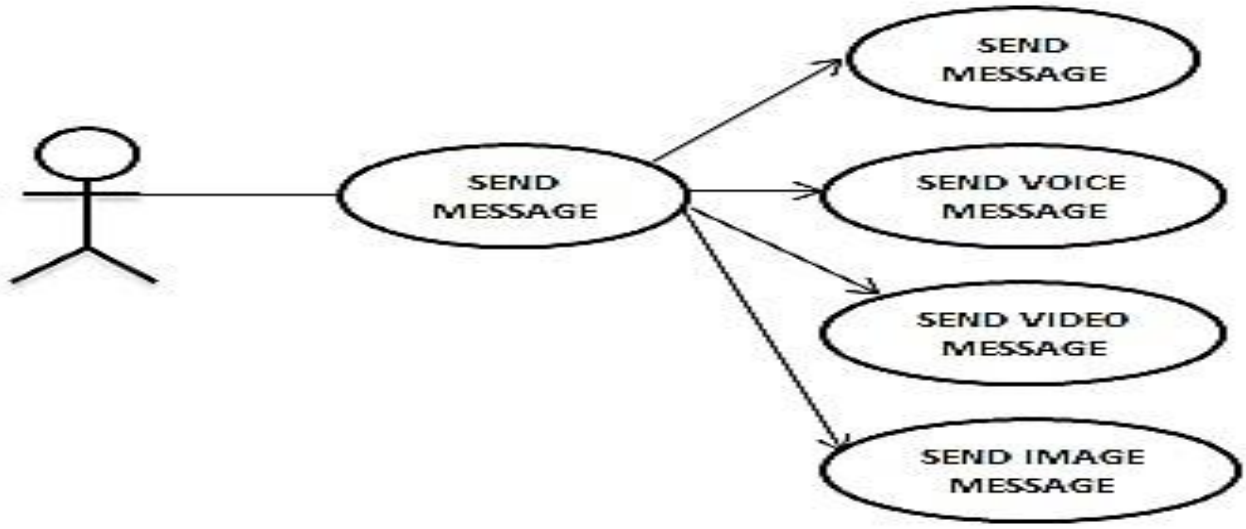

Figure 5: Use case diagram for Whatsapp messaging

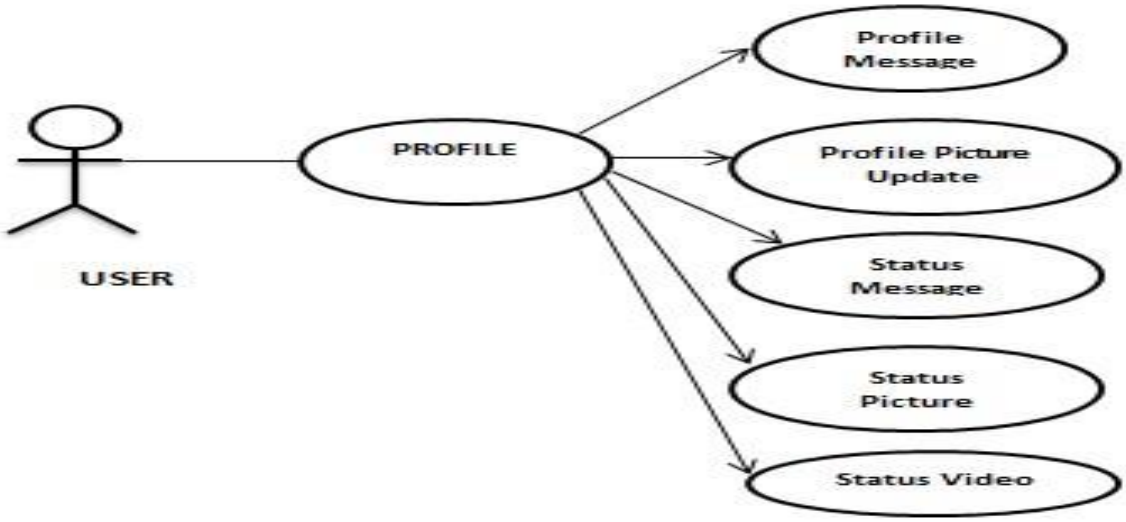

Figure 6: Use case diagram for Whatsapp profile/status

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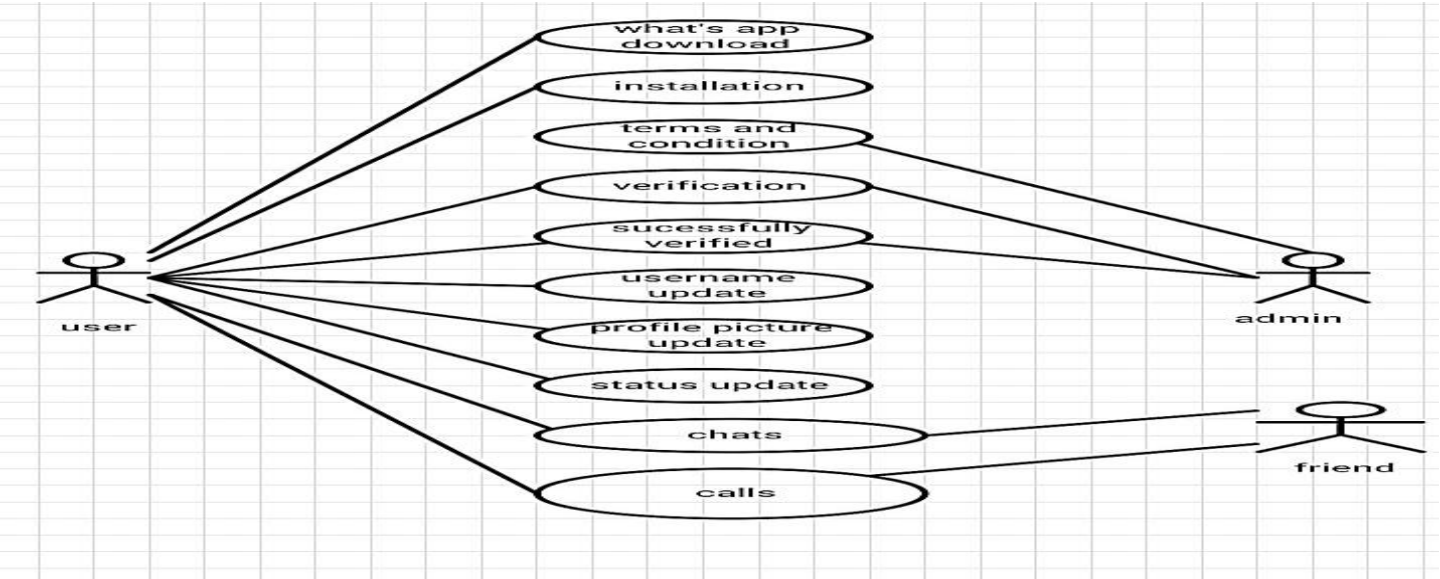

Figure 7: Use case diagram showing user and admin privileges

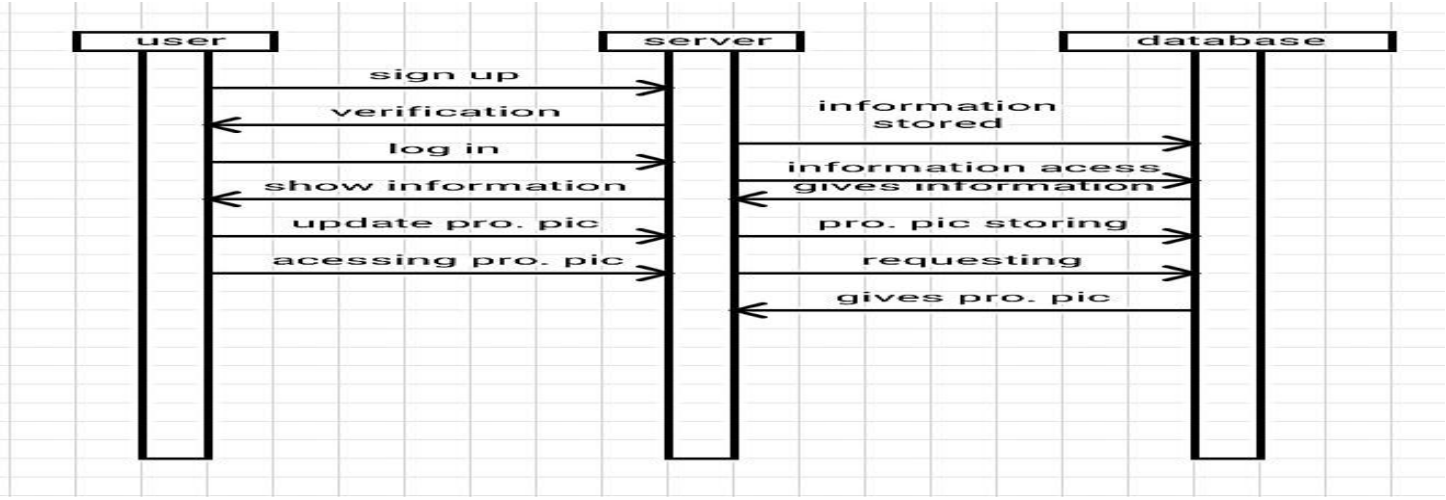

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Figure 8: sequence diagram

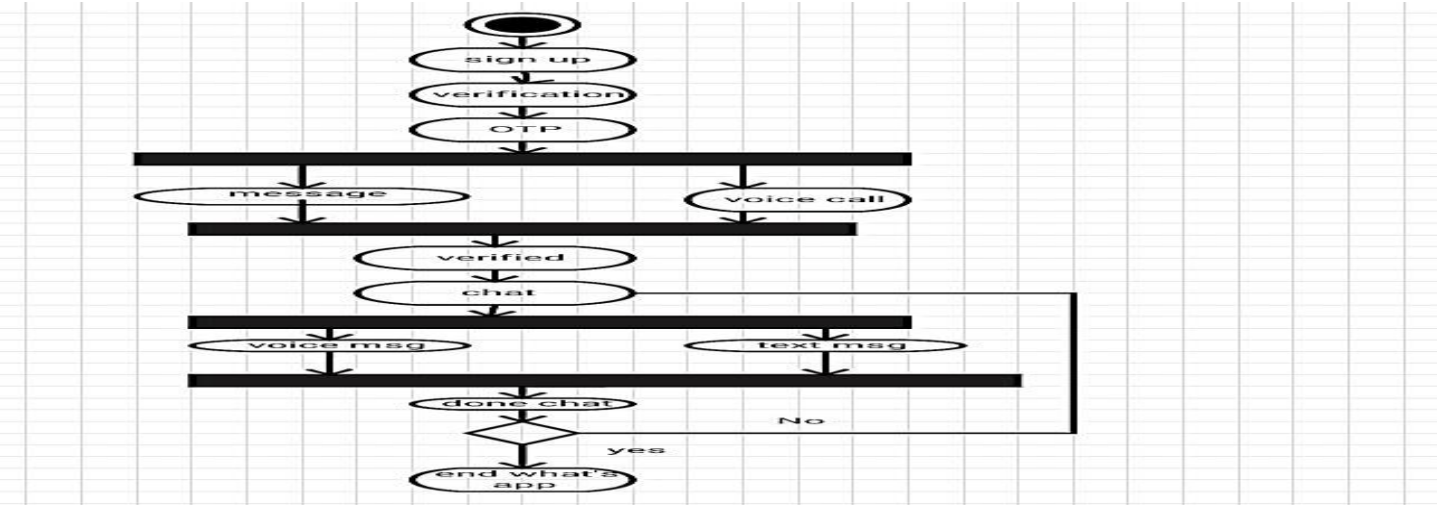

Figure 9: Activity diagram

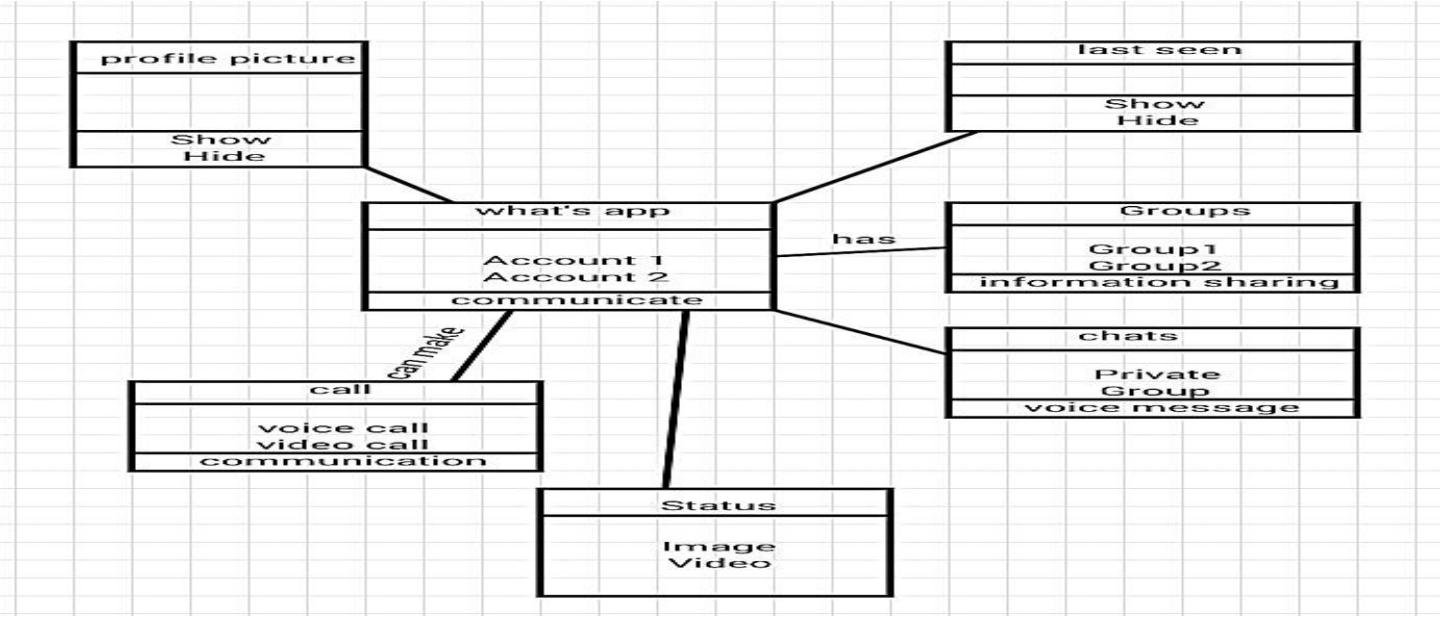

Figure 10: Class diagram

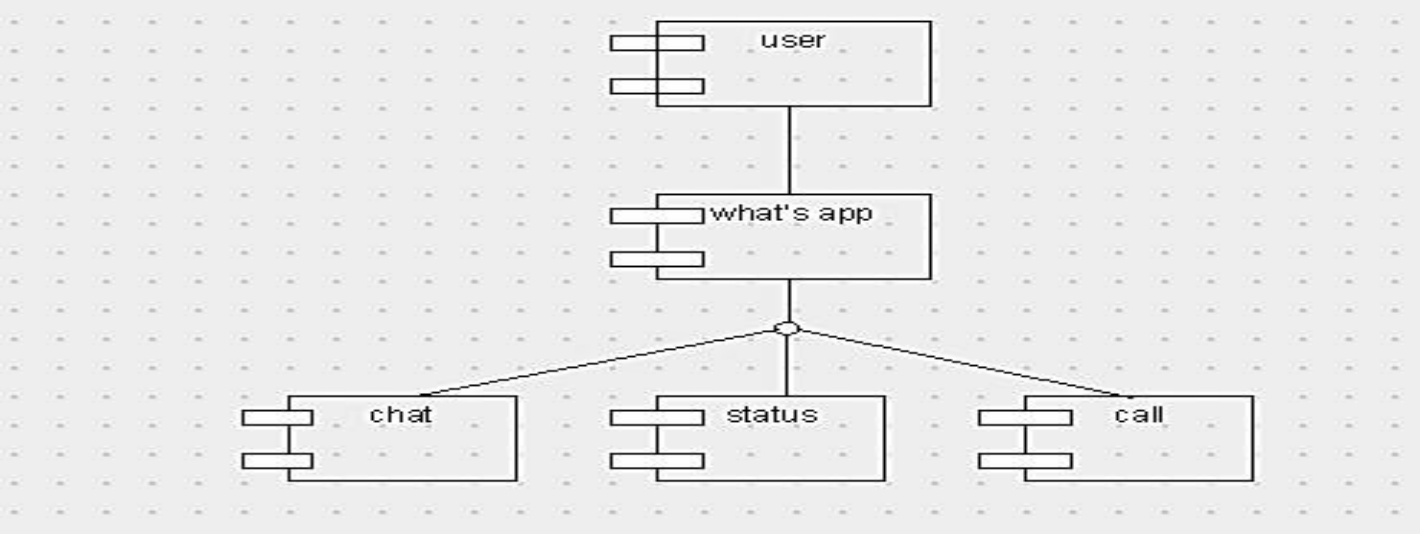

Figure 11: Component diagram

Whatsapp Frontend Stack

The Whatsapp client architecture is designed to provide a smooth and user friendly experience while ensuring security and privacy of messages. The client architecture is divided into several components namely; user interface, network layer, encryption layer and message delivery layer (Cressler, 2021). The user interface is responsible for displaying the apps features and providing users with an intuitive interface to interact with the app. Whatsapp supports almost all platforms. It has an iOS app, android app, desktop app, web app and windows phone app. The apps are built as native apps for each platform. Up until 2017, one could Whatsapp on blackberry (Cressler, 2021). Encryption is the process of converting plain text data into a secret code to prevent unauthorized access or viewing. It is the method of converting data into coded form with the help of key (Kumari, 2017). The Whatsapp encryption layer encodes messages so the intended recipient can only read them (Wallis, 2023). In using Whatsapp, when you send a message, it gets encrypted using a special protocol known as signal encryption protocol which was developed by open systems whispers to be a modern, open source, strong encryption protocol for asynchronous message systems (Cressler, 2021). Whatsapp then stores the message on the servers until it is delivered to the recipient. Upon delivery, the recipient's device decrypts the message using a cryptographic key. Across the entire process, Whatsapp never knows the content of the message. The message delivery layer ensures that messages are delivered to the recipient's device as quickly as possible. This layer uses various techniques such as push notifications, message queuing and message synchronization to ensure that messages are delivered even if the recipient is offline (Wallis, 2023). Whatsapp uses a highly modified version of XMPP on the server to communicate with clients. The XMPP stands for Extensible Messaging and Presence protocol. It is an open standard communication protocol based on XML (Extensible Markup Language). At its root XMPP is a chat protocol that allows

for the transmission of XML fragments. Unlike other chat protocols, the XMPP is designed for small chunks of XML data rather than large blobs or streams of binary data. XMPP works on the client-server architecture; this means that when you send a message via XMPP, it first sends to the server which then routes it to the correct client (user).

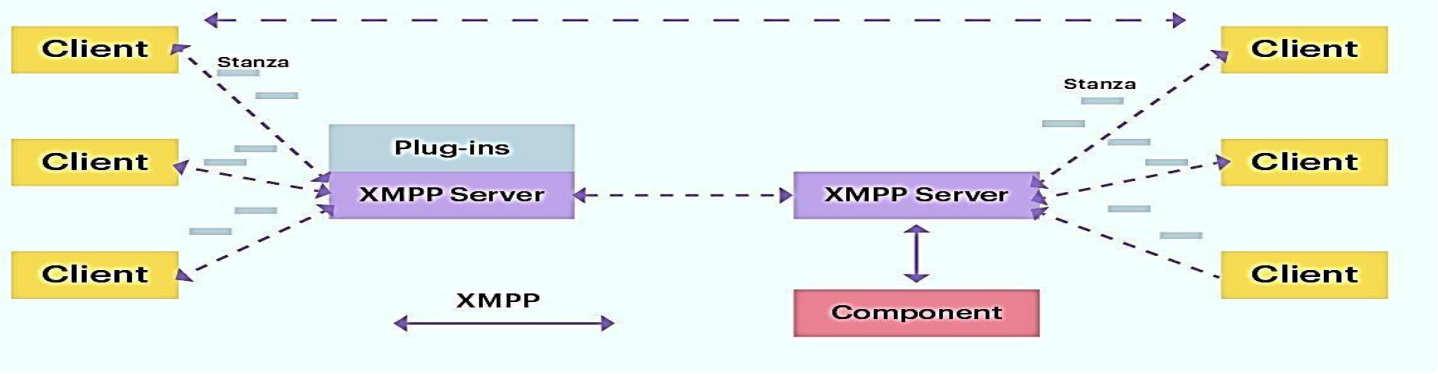

Figure 4: **XMPP Architecture** **Source**: Cressler, (2021)

Whatsapp makes use of both HTTP and XMPP for the communication. XMPP used during asynchronous federated limited purpose communication whereas HTTP used synchronous unfederated general purpose communication (Cyrilraj, 2019).

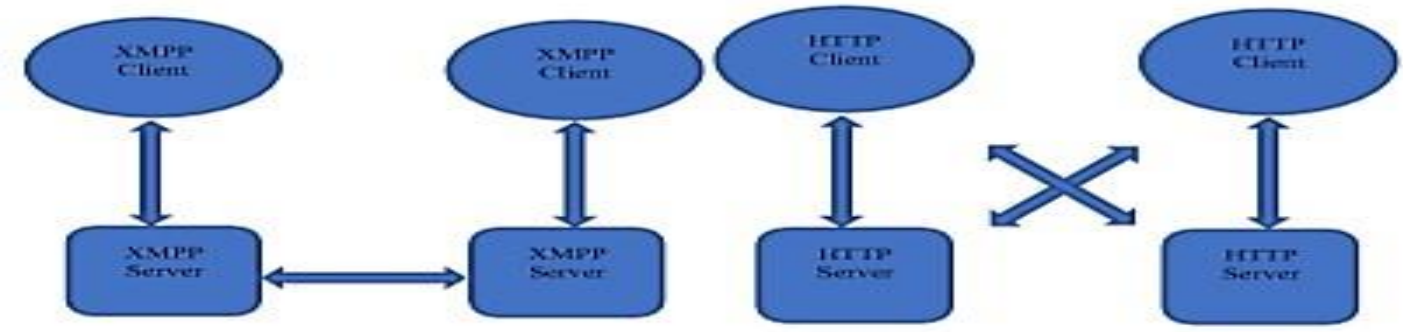

Figure 5: Comparison between XMPP vs HTTP Source: Cyrilraj, (2019)

As shown in the figure 3, to store chats locally, at the client-side, Whatsapp uses an SQlite database. SQlite is a standalone, self-contained, relational database that is meant to be embedded into application which lives on the client's device. In Whatsapp messaging, the XMPP on a client opens a socket to the Whatsapp servers. All the sent messages are queued on the servers until the client opens or reconnects to this socket to retrieve the message (Cressler, 2021). Once a message is successfully retrieved by a client, a success status is sent back to the Whatsapp server. The server then forwards this status to the original sender, letting them know that the message was received by adding the check mark icon next to the successfully sent message.

Whatsapp Backend Stack

The Whatsapp backend stack features the following: the main programming language which is Erlang, FreeBSD which is the operating system, Ejaberd which is the application server for XMPP, BEAM which is the Erlang-based virtual machine, Mnesia is the Erlang-based database and YAWS, the multimedia webserver (Cressler , 2021). Erlang is a functional programming language that is oriented towards building concurrent, scalable and reliable systems. It uses a process-based model called the "actor-model" in which small, isolated processes communicate with each other through messages. The processes can create new processes; send messages and modify their state in response to receiving messages. According to Cressler (2021), Brian Acton is said to have opened up in an interview about the decision to adopt FreeBSD as operating system for Whatsapp backend tech stack. FreeBSD has the advantage of been a single distribution with an extraordinary good ports collection while Linux operating system is complex. In terms of raw performance, especially in regards to system load per packet, FreeBSD beats others. Ejaberd is an open source XMPP server written in Erlang. The Ejaberd server is heavily customized to optimize for server performance. Features of Ejaberd include; one-on-one messaging, group chat, storing and forwarding offline messages and contact list and presence (Cressler, 2021). Yet Another Webserver abbreviated as YAWS is an open-source webserver that Whatsapp uses to handle HTTP requests. YAWS is known for its scalability and performance as is a popular choice for building high traffic web applications (Wallis, 2023).Whatsapp uses YAWS for storing multimedia data (Cressler, 2021). Wallis, (2023) posits that Whatsapp also utilizes a distributed streaming platform named Kafka to handle real-time data streams. Kafka provides high scalability and fault tolerance and is famous for building real-time applications. To store data and temporary messages, Whatsapp uses an Erlang-based distributed DBMS called Mnesia. The DBMS has no data structure difference with Erlang which makes coding quicker and more explicit. The Mnesia DBMS provides benefits such as real-time key/value look-up, high fault tolerance, dynamic reconfiguration and complex objects (Cressler, 2021). BEAM means Bogdan's Erlang Abstract Machine and is the virtual machine that compiles and executes Erlang source code. The BEAM is designed specifically for highly concurrent applications ideal for Whatsapp use case. BEAM uses light-weight processes that don't share memory and are managed by schedulers. The schedulers can manage millions of processes across multiple cores. BEAM is so crucial to the Whatsapp system design that the Whatsapp team has published many patches and fixes to the core source code (Cressler, 2021).

Whatsapp Functionalities

Currently Whatsapp is used by over 2 billion people in more than 180 countries and whoever you need to reach, they are probably on Whatsapp. Generally Whatsapp provides users with various functionalities; text messages, voice call and video call. Users can also send files, images and links to other users. In 2022, Whatsapp introduced several updates and features including avatars, messaging yourself, communities, in-chat polls, 32-person video call and larger groups and many more (Agrawal and Gupta, 2023). According to Singh, (2023), Whatsapp is set to launch a handful of new features in

the year 2023 and the company has already been testing some of the features. The Whatsapp features are likely to include a screenshot for desktop app, short video messages, screen sharing, a new interface for android and more. Times, (2023) posited that there are 8 new whatsapp features that will change the way the app is used. From improved functionality to boosting privacy, the new features provide users with new and improved ways to connect and communicate with others. The features include; use one whatsapp account on up to 4 phones, password protected chats, true caller on whatsapp. Animated emojis, saving disappearing messages, exit group chats without notifying anyone, control who can see you when you are online and prevent screenshot on view-once messages. Priya, (2023) also highlights 5 whatsapp features that can enhance productivity. They are elevated collaboration; screen sharing on video calls, visual excellence; high quality photo sharing, seamless group conversation; voice chats, correcting media caption; edit sent media captions, effortless group creation; no name group.

Conclusion

In this paper, we have explored the system design and architecture of the whatsapp application as well as expose the capabilities of whatsapp which may not be known to many of its users. The future is bright for whatsapp as many of its users are expectant of even more and more features and updates that could enhance business productivity and communications. Whatsapp currently stands as the most popular instant messaging app in the world and a situation in which its popularity could be overturned by another instant messaging app seems bleak.

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