A Comparative Tale of Peer-to-Peer, Client-to-Server and Hybrid Networks in Federated Social Networking Sites in Educational Institutions

B Mugoniwa[*1], E K Ngassam[2], S Singh[3]

[1-3]Directorate of Research and Graduate Studies, University of South Africa

E-mail: mugoniwabm@gmail.com*[1], eketcha@gmail.com[2], singhs@unisa.ac.za[3]

Abstract. Due to the increase in the usage of social networking sites (SNSs) in communities, it has become common for academic institutions to adopt SNSs for education. Federated social networking sites (FSNSs) are powerful decentralized platforms for educational activities. Qualitative scientific thorough review of relevant literature was done from multiple databases in order to make an informed decision among peer-to-peer, client-to-server and hybrid networks. Peer-to-peer, client-to-server and hybrid networks present an excellent way of decentralising SNSs, however institutions may need to scrutinise underlying functional and non-functional capabilities of each network architecture in order to adopt the best platform for their institutions. Contemporary education requires eLearning models that addresses critical needs for more effective and scalable educational solutions that can leverage benefits of SNSs while overcoming their limitations. Stakeholders should be able to make an informed decision as to which network to employ in their FSNSs, so that they can benefit from platforms' specific educational opportunities.

Keywords: federated social networking sites, peer-to-peer, client-to-server, hybrid networks, eLearning.

1. Introduction

The significant growth on the strategic importance of eLearning platform in the education sector, learning institutions has led to the adoption of SNSs as educational tool kits. While some are using SNSs as eLearning tools, others are still considering to approve their adoption while using them as communication channels [1]–[5]. The study carried out in five universities in Zimbabwe, proved to be ready for the adoption of FSNSs [6]. It is at this point that all educational facilities need to consider the use of FSNS to facilitate their educational activities such as communicating, video conferencing, resource sharing and collaboration.

In the paper we discuss three different types of architectures that educational facilities need to consider when adopting FSNSs. The decision may be informed by size of the institution, type of the institution and also level of students in the institution. These factors in turn, determine the amount of investment the institution can afford, the amount of data the institution would generate, the usage frequency of the system by stakeholders, which then will affect the way privacy systems should be deployed. The main contribution of this paper is to inform the decision makers in educational institutions on the trade-offs in different types of architectures to be considered when planning for federated social networking sites for eLearning (FSNS4eL) adoption.

The remaining part of this paper is organised as follows; section two, we state the objectives of this study; section three, we discuss the methodology of the study; section four, we discuss the FSNSs network architectures; section five, we compare the three networks as per the results; section six, we discuss and recommend; section seven, the paper summarises main points of the study and section eight presents the future study.

This study aims to provide an in-depth analysis of peer-to-peer, client-to-server and hybrid network architectures that can be considered in the adoption of FSNS4eL. The objectives of this study are outlined below:

- To comprehensively analyse the FSNSs network architectures
- Present the three different FSNSs, which are peer-to-peer, client-to-server and Hybrid FSNS network.
- Compare the peer-to-peer, client-to-server and Hybrid FSNS Network architectures using non-functional attributes.
- Suggest recommendations that are deemed as important factors guiding the adoption of each network architecture.

2. Research Method

The research adopts a qualitative research methodology, where a systematic thorough review of relevant literature including, journal articles, conference papers, scholarly papers and thesis research findings was done. This review was done as a way of architecture comparison in peer-to-peer, client-to- server and hybrid networks. Multiple academic databases were searched to gather information needed on peer-to-peer, client-to-server and hybrid networks, together with FSNSs and case studies applicable to them were studied. Data gathered was grouped according to different themes such as the architecture and case example as the main themes; protocols involved, privacy policies and data management were also in the discussion. In addition, a comparative analysis involving the strengths weaknesses, identifying non-functional requirements of each network was done. The focus was on the technical architecture, data management, security protocols and user engagement. Studies found to be more relevant were critically reviewed to expedite research by synthesising key considerations and common themes in the findings. The study was then concretised in design science (DS) research approach which supported the design of the hybrid FSNS architecture. Design Science Methodology (DSM), guided the development of the architecture. The main components that constitute the DSM were followed in the architecture construction and these are environment, Design Science Research (DSR) and knowledge base. The environment is regarded as the problem area and in our case educational institutions, people involved and technology was taken into consideration both in the development of the architecture and in the discussion of the differences between the FSNS that can be considered by different institutions. DSR enabled the study to regard theories such as Dubin's theory-building method, study the eLearning frameworks to determine constructs to be used and finally to select a precise validation criteria as part of knowledgebase that underpin the architecture development [7]–[12]. In addition on knowledgebase, the study relied on the developed models, use cases, reviews of some theories that guided the development of the architecture and a survey was carried out in a bid to validate and improve the proposed hybrid FSNSs recommended to be considered by educational institutions [9], [10], [13], [14].

2.1. Ethical Considerations

Approval was sort and granted from the Registrar of Midlands State University in Zimbabwe and the ethical clearance from University of South Africa Ethics Review Committee (ERC). The ethical approval is dated 14/05/2021 with the approval code: 2020/CSET/SOC/018. The following were taken into consideration:

- Informed consent: A written consent was sent to respondents prior to survey forms. The contents indicated purpose of the study, way of data gathering and its presentation. Participants were

allowed to withdraw from the research participation at any time they felt uncomfortable with the process [15].

- Confidentiality, Privacy and Anonymity: We ensured that all names were protected in gathering data, in line with privacy, social security and confidentiality principles. Thus, an anonymous questionnaire was designed without disclosing the people's and organisations' names[16], [17].

3. Result

The main users of the system are expected to be students, facilitators and administrators. These are the center of requirement analysis in any system to be developed or recommended. The study compares the three federated networks guided by the seven non-functional attributes given in Table 2.

Table 2. Comparison of peer-to-peer, client-to-server and hybrid FSNSs

Non-functional attributes	Peer-to-peer	Client-to-server	Hybrid
Availability	Highly available, same data is stored in different peers.	Server failure often cause service disruption.	Available since it switches between peer- to-peer and client-to-server whenever there is need.
Capacity and scalability	Scale well if the bandwidth and resources are available.	Difficulty to expand the network	Scalable since it inherits from both networks
System performance	High	Depends on bandwidth and latency	Distributed peers and centralised servers can achieve a balanced performance
Security	Poor security unless, end to end encryption is effected	Better security	Secure if end to end encryption is effected in p2p network
Technical	More technical knowhow is required from peers	Less technical knowhow required from clients	More technical knowhow required
Fault tolerance/ recovery	Easier	Difficulty if failure on the server occur	Combine fault tolerance techniques from the two networks.
Data management	Challenging due to decentralisation, data integrity, consistency and efficiency can be a problem	Centralised data management maintaining consistency.	Easier when leveraging the benefits of both peer-to-peer and client-to-server
Maintainability	Challenging due to decentralisation	Easier since most of the maintenance are done in central servers	Inherits the way client-to-server works to simplify the challenges in peer-to-peer

3.1. Federated network architectures

Federated social networks are social networking sites aiming to integrate users through a decentralised structure, "enabling interoperability among multiple social networks in a transparent way" [18]. When employing FSNSs, educational institutions need to factor in these two considerations that should be addressed in order for the FSNs application to deliver a seamless experience to users with diverse SNSs.

3.2. Heterogeneity considerations

Heterogeneity is the state of a network where there are varied types of nodes and communication protocols that encourages user choice, customisation at the same time may pose challenges in node compatibility issues. It is the "diversity, systems that use more than one kind of processors or cores (this is known as Heterogeneous Computing) to achieve optimal performance and energy efficiency" [19] The issues of compatibility may negatively affect the performance of data transmission. In heterogeneous networks, routers may be equipped with multiple, redundant paths to curb the network from security attacks:

- Device Heterogeneity. Since most clients/servers in the federated network sites may have different device configurations. This may hinder the performance of the whole network because different computer devices, software and network configurations affect the processing time of each task.
- Network Heterogeneity. Different administrators may have different configurations due to different infrastructure, resources, geographical areas, transmission rates, user needs and experiences. These uneven network resources and network protocols can reduce the network performance, due to network fluctuations in different nodes.
- Data Heterogeneity. Ubiquitous of data may not be necessarily achieved due to diverse information streams, multiplicity of devices, structure and unstructured data caused by various SNS participating in the federation that may have different data structure [19], [20][19]–[21].

3.3. Autonomy

Autonomy networks "possess the ability to monitor, operate, recover, heal, protect, optimize, and reconfigure themselves; these are commonly known as the self-properties" [22]. SNSs in FSNS should be under separate and independent control, where the systems in different SNSs can be used to design, associate, communicate and execute their own data. The SNSs under a certain FSNS should be willing to share their data and be free to associate with activities in the FSNSs. Autonomy also stresses that design of data is entirely the source SNSs' choice, how it should be managed and represented [19]. Although it is important for the SNSs to be autonomous, there is need for these to work together in the FSNS meaning protocols of SNSs need to be standardised to enable interoperability. An educational FSNS should be guided within a central objective, that informs all the activities that are transpiring on the platform, be it collaborations, streams of communication and resource sharing.

3.4. Architectural approaches and their comparative characteristics, strengths and weaknesses

In this section we discuss three architectural approaches that can be adopted to implement FSNS in educational institutions. Each network architecture will be defined, diagrammatically presented and one example of a FSNS that implemented a particular network is presented (case study). This forms the basis of network comparison, where the characteristics, strength and weaknesses are discussed.

3.5. Peer-to-Peer federated social network

Peer-to-peer architecture is a distributed network system that allows for the participating nodes are able to share their resources, network protocols and mere communication without passing through the main/central server. The control and management of activities is done within the node itself (figure 1). A summarising term called "servent" was coined to describe activities of peers in a network, where each peer act as a server and a client at the same time. The term was derived as "Serv..." from the term server and "…ent" from the term client [23].

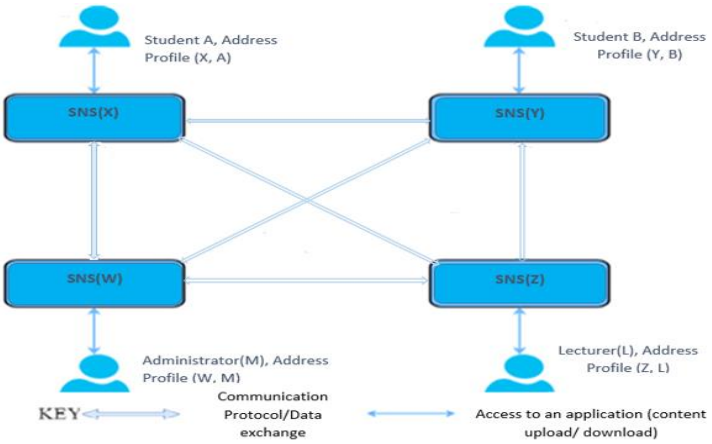

Figure 1. Peer-to-Peer FSNS modified from [6, p. 5]

In peer-to-peer architecture, centers have a direct link where they can communicate directly to each other without the use of the central server. With a peer-to-peer federation architecture, each SNS must have a mutual protocol or standardised protocol enabling them to perform mutual communication, although each SNS maintains its integrity but can pass messages to other SNSs. In this case **M** is the administrator registered to SNSs **W** and the student **B** is in the SNSs **Y** environment. According to the High level architecture in figure 4 generalised to help with the description of the three architectures. The dispatcher in the Peer-to-Peer receives and interprets requests from **M**, realising that **B** is in SNS **Y** environment, it probes Back-end(BE) Orchestrator to transparently invoke **Y**, opening conversation between **M** and **B** using the standard protocols available. The process above is guided by the notion that peer-to-peer system discourages broadcasting so as to avoid network flooding which can slow down the network system. The two communication systems encouraged are unicast and multicast, that involves direct chatting and sending of packets (such as streaming) to subscribed group of users scattered throughout the network, where users can choose to participate or not [24], [25].

Peer-to-peer network allows for efficient resource sharing, greater system performance, lower costs and decentralisation of authority, among other advantages. However, in this architecture, standardisation is not always achievable and might not be achieved in the near future. Moreover, there is a problem of complexity if an SNS would like to broadcast a message to many SNSs at a time and is more commonly implemented where less than ten computers are involved and strict security is not necessary[26].

3.6. Scuttlebutt a FSNS that employed peer-to-peer network

The Scuttlebutt protocol was established in the year 2014 in New Zealand. The developer, Dominic Tarr lived on a sail boat and thought of developing an open source application that can be used in an offline environment, although it maintains the attributes of being a friendly social networking application. The protocol allows users to download the application in order for them to set up a profile, data is stored locally on the individual's device with backup on friends' devices they connect with through the protocol. The process is enabled by periodical syncing of data by friends where data are then replicated across unique networks of different friends for communication and storage purposes. Participating in the app, entails the user to express interest in a particular stream, all new posts are automatically directed without further requests by individuals. The decentralisation part comes in the sense that since devices are only connected to part of the network it becomes very difficult to monitor all the activities on the platform.

a. Challenges of Scuttlebutt

- Privacy- Data that is stored in friend of friend's devices might lead to victimisation, discrimination and harassment.

- On boarding: The participation is not by default, this may discourage users who need automatic entry, since all processes including the one of sending codes to the pub that is designed to automatically follow new users, do not provide an automatic entry.
- Coordination: The absence of central coordination of messages may lead to multiple applications using the same type of field in incompatible ways.

b. Benefits of Scuttlebutt

- Resilience: Users' data are kept in isolated networks users' devices, a specific local area network where applications interact with the local replicas of logs in an offline network partition.
- Efficiency: The Scuttlebutt protocol has a subjective reader approach where all relays and application in programs can operate concurrently.
- Plurality and Disintermediation: Applications have the freedom to interpret their data encouraging end users and open source application writers to decide how they can leverage data they produce.

The Scuttlebutt protocol enables individual users to be publishers rather than larger organisations, where distribution is entirely around the content. Broadcasting of content is by a push model which allows for every client to produce log entries since there is no consumer or producer in the system. Every member is capable of being a server, at the same time can take up the roles of client [27], [28].

3.7. Client-to-server FSNS.

A client-to-server network is a distributed network that is made up of one high performance central coordinator hub called the server and lower performance nodes called clients. The Hub is the main provider of contents and services whereas the clients are the benefactors of the services and responses from requests. In client-to-server network (figure 2), clients are connected to the server for all communications, each client requests permission to either send or is granted permission to receive data by the controlling server. The client may as well send requests which are actioned by the server before sending back results to the client [29].

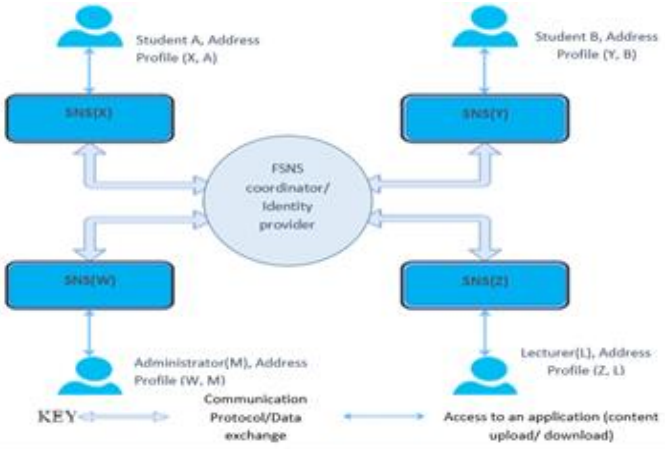

Figure 2. Client-to-server network FSNS modified from[6, p. 5]

In this architecture, all requests and transmissions pass through a coordinating model that handles all routings from one participating node to another and even within. The client-to-server network coordinator is the one with mandate to plug into connected node and vice versa. Registration of a new user to any SNS can be done from the central coordination for onwards transmission of messages. Client to server networks are easy to implement in larger networks, meaning they are more applicable in large institutions with large amounts of data. In addition, information in client to server network can be centralised and managed by a server which makes it easy to manage security control. Whereas drawbacks

are that when the server fails, it becomes very difficult to track the root of the problem and also data lost is difficult to recover it [26], [30].

3.7.1. Mastodon a FSNS that employed a client-to-server network.

Mastodon is a decentralised online social network (DOSN) with microblogging features where servers are responsible for running open source software. The platform, a subset of ActivityPub protocol, was developed in 2016 with the aim of restoring control of the content of distribution channels to people rather than sponsored feeds. It is a free and open source software application that hosts liberal internet based communities called instances on their computers. Mastodon has two layers: (i) that allows to manage communications among servers and a client-to-server interface which facilitates interactions among account holders; and (ii) the server-to-server layer where each server is responsible for managing its own rules, account privileges and how to share messages in their instances.

a. *Strengths of Mastodon*

- Privacy: Mastodon application allows easy switching of instances, in case one instance has compromise the users' privacy.
- Diversity: Users are in different platforms because of its decentralised model. Users can join and /or switch instances depending on the code of conduct given in each instance.
- Public Space: An open protocol that enables easy access to information, which helps tracking of the evolution of social networks for other research purposes.
- Decentralisation: Multiple independent servers(instances) can be created managed by anyone giving room for diversity and autonomy in the social networking community.
- Information on status of instances is readily available making it easier for the new user to register and form or join groups and communities with the instances of choice.

b. Weaknesses of Mastodon

- User abandonment and the social group: Not all users are connected to each other meaning a post can go as far as it could reach the connected users. This can create isolated instances, where if there are no more connections to the remaining part, the users may be left with their island with limited exposure since they will be interacting with like-minded individuals only, from their groups and communities.
- Social graph failure: Lack of centralised user base can make it more difficult for followers to reach each and every connection they may need to be linked.
- Lack of knowledge: Most users want to join the main server, the mastodon.social not knowing that it is just an option among more servers that are still there and this can affect the notion of decentralisation, and a threat to diversity of the network.

The Mastodon platform has no central server which oversees every message send in this FSNSs, meaning there is no contextual view of the activities. Each user can only see what can be seen by their instances, that they have subscribed for, to be precise. Although the instances are independent, they are connected by a federated protocol which allows the users from different instances to interact while data is stored and managed by the respective instances. Some instances host bots responsible for following many users and gathering as much updates as possible in order for them to post it on the federated timeline [31]–[34]**.**

3.8. Hybrid FSNS.

A hybrid network combines features of peer-to-peer network and Client-to-server network. In hybrid social network users can communicate and distribute their contents either via a decentralised system of client-to-server or peer-to-peer network. The hybrid network presented in figure 3 was proposed as the architecture for the implementation of FSNS in educational institutions. The architecture was developed with the DSM guide, taking the constructs (environment, Design Science Research (DSR) and knowledge base) as the main pillars of development *see a detailed explanation in (*unpublished no date) thesis. The

environment is comprised mainly of three; groups, students, administrators and lecturers. Design Science Research guided the initial development of the architecture through the use of knowledge base constructs as theories, frameworks and models before its validation.

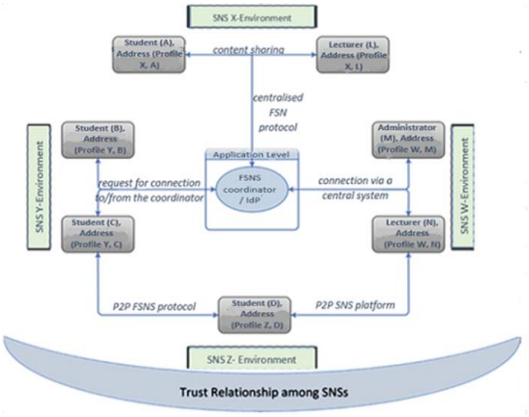

Figure 3. Proposed Hybrid FSNS (unpublished no date)

In this architecture, some requests and transmissions are directed through an FSN coordination model that handles requests from one SNS to another and even within. The FSNS coordinator is the one with mandate to plug into connected node and vice versa. Registration of a new user to any SNS can be done from the central coordination for onwards transmission of messages. Each SNS maintains mutual protocol or standardised protocol enabling them to perform mutual communication, although each SNS maintains its integrity but can pass messages to other SNSs The architecture is a hybrid combination of a client-to-server and peer-to-peer architectures. The communication in hybrid can take the client-to-server way or depending on the FSNS settings or network traffic **B, C** and **D** can have a communication connection using the principle in the peer-to-peer with no central coordination control.

3.8.1 Hybrid FSNS validation

As part of knowledge base mentioned in section 3, the proposed hybrid architecture was improved and validated by findings from the study carried out from surveys and expert reviews. Nine experts with not less than five years' experience working as IT specialists whether in the academia or in the industry were purposively selected. They reviewed the architecture and gave their input in order to improve/ validate the Hybrid Federated Social Networking Sites for eLearning(HFSNS4eL) developed. The validation process was guided by parameters such as relevance, usefulness, rigour and exactness, parsimony, completeness, logical flow/ consistency.

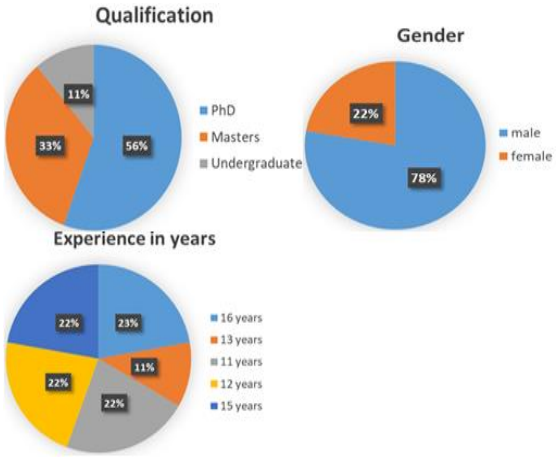

Figure 4. Demographic information of reviewers (unpublished no date)

Experts' demographic data. Figure 4 presents demographics of experts, two of nine reviewers were women, and the remaining seven participants indicated their gender as male, and six of these participants were from Zimbabwean universities. Five of nine participants had a highest qualification of a doctoral degree, while three of nine held a Master's degree, and only one expert had a BSc degree. Their designations are as follows; five participants were Lecturers, two ICT directors, a lecturer also a head of the department, and a senior lecturer as well as an ICT Director. The duties were divided into two main sections where those in teaching related field indicated their duties as teaching, supervising post and undergraduate students, researching, curriculum review, coordinating research and innovation, while ICT directors lead, plan and manage ICT strategies, operations and infrastructure.

3.8.2. Improved architecture

The architecture (figure 5) was redesigned to incorporate additional input from reviewers where the FSNS coordinators were increased to four for the purposes of sharing the load, in conjunction with the architectures of different SNSs with 3-tier servers to share the load. 3-tier servers reduce response time as well as improving performance, scalability and availability [35].

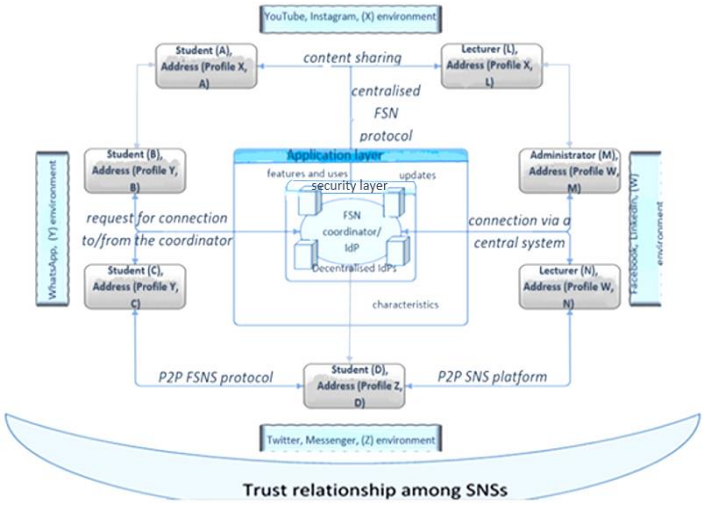

Figure 5: Improved HFSNS (unpublished no date)

A security layer was also added between the application layer and the coordinators; this can include firewalls and employing GPG(GNU Privacy Guard) encryption on messages [36].

The architecture also enabled peer-to-peer and client-to-server transmission on all nodes in the network, allowing communication through either peer-to-peer or client-to-server network, depending on the settings or on which way is free to accept the request.

3.8.3. Diaspora, a FSNS that employed a hybrid network.

Launched in 2010, Diaspora was built with the notion of user control and decentralisation as well as the principles of privacy and security, whereby users are encouraged to create and manage their own 'pods' connected to a large network of Diaspora with the facility of a protocol called The Diaspora Protocol. Diaspora was proposed to curb problems of privacy and freedom raised by users, who then obtained the mandate to maintain it after a crowdfunding campaign for its development. Diaspora's main aim is to avoid content centralisation, characterised by a shortage of central control over user data, by initiating a technology called pods, a network of personal servers. An individual pod stores user data, only allowing them to communicate with users on different servers.

a. Strengths of Diaspora:

- Scalability: Diaspora can handle large number of users and data by distributing load across the systems and servers.
- Data Privacy: Hybrid allows distribution of servers and the storage of data in friend's friend backup facility. Diaspora allows users to choose the server they would want to host their profile with an option of administering their profile as well.
- Fault-tolerant: Does not keep user data and accounts in one pod, so if one pod develops a problem, users can switch to other available pods without losing their data. It ensures continuation of social interaction even if there are pods with problems, because it managed to successfully employ an efficient data replication with concurrency control process.
- Flexibility: There are a lot of pods one can choose and customise to suit user requirements. Pods have a vast options of features, colours, themes and even codes of conduct are not fixed and rigid, because they are written according to each pod and users can choose whatever is best for them.

b. Weaknesses of Diaspora:

- Trust issues: No central server is monitored/ dedicated to backup all users' data, data is either stored in decentralised servers, or saved in friends' server.
- Security issues: Not all communications between servers are encrypted posing risks of eavesdropping, hacking and data diddling along the way to Diaspora servers and / networks.
- Lack of standardisation: Each pod has its own code of conduct, moderation rules and user base, meaning they can work on their own as isolated communities leading to limited interaction between servers.

In Diaspora network, there is need for users to be online at the same time so as to curb data loss in the networks, this is because the focus is on synchronisation of data with friends and decentralised servers managed by users, sometimes. Even if data is stored successfully in the networks or server, because of its decentralisation nature, it is difficult to access data feeds because there is no central algorithm feed, so data is manually searched or accessed via certain direct connection [37], [38].

3.9. High level architecture of FSNSs

Table 1. Key to the diagram (figure 6)

Back-End(BE)/Front-end(FE) orchestrator	Responsible for routing {messages/ commands/information/data} from the source SNS/FSN application to the Collector/Dispatcher. And Responsible for routing {messages/ commands/information/data} coming from the Dispatcher/Collector to the destination SNS/FSN application respectively.
Collector/Dispatcher	An orchestration module responsible for interpreting the packet received from the BE/FE orchestrator, appends the appropriate destination FSNS application/SNS then send it to the FE/BE orchestrator for routing respectively.

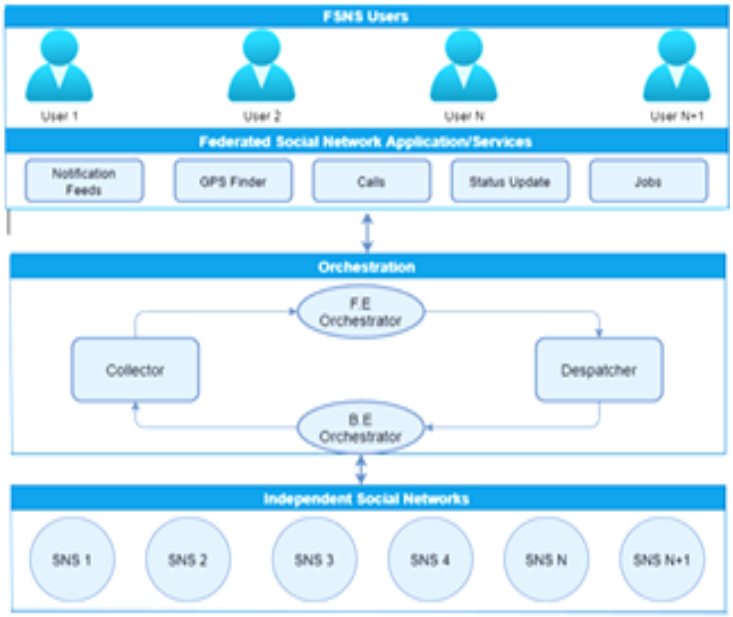

Figure 6: High-level architecture of the federation of social networking sites (unpublished no date)

The design of FSNSs above(figure 5) was partly informed by the high level architecture in figure 6. The architecture explains clearly the way data is expected to be transmitted in the FSNSs. The high-level architecture specifies the units needed for the FSNSs to be developed into a working architecture. The main units involved are the users, the applications, the orchestration and the source social networking sites. These units are logically arranged according to their purpose in the architecture. The key components of the architecture are first explained in Table 1.

4. Discussion

To facilitate federated social networking learning environment, educational institutions need to be equipped with specific user requirements at hand. The authorities, need to do their requirement gathering so that they make right decisions when it comes to the right choice of the network to be employed [39]. The decision is based on many factors such as type of educational facility, the size in terms of the capacity of the educational institution, the level of the learners at the institution and the purpose of the network [40]. On the purpose we will be looking on how the network is going to be utilised, is it for communication purposes, notices and announcement or teaching and learning interactive platform [6], [41]. The preceding section discussed the comparisons of three federated networks under given criteria. Results show that each federated network has its strengths and weaknesses, even the Hybrid which is complimenting the peer-to-peer and client-to-server networks has its own weaknesses and strengths as well, although most of the weakness inherited from parent network can be complemented/ leveraged by the strengths of the other network. The comparative analyses in the results section above was grounded on the nonfunctional attributes of the three FSNS architectures. Peer-to-peer proved to have strengths in attributes like availability, fault recovery, and system performance. Client-to-server strengths are in maintainability, data management, better security and needs less technical knowhow from clients. Whereas hybrid inherits strengths from both peer-to-peer and client-to-server. The comparative analysis is further elaborated in the recommendations below, where each recommendation will be justified by the characteristic of the network proposed.

Taking basic educational levels in Zimbabwe and most African countries we recommend the following:

1. *Primary level.* Here client-to-server network where most teachers would be acting as the servers and students would be the clients in their different grades. The decentralisation of servers would be according to where teachers are responsible for creating the code of conduct in their classes (instances) and the instances would be customised according to the class's specifications. Other interaction servers would be managed by administrators customising servers according to how they should work. Pupils would then be requested to join the network for learning, communication and other interaction purposes.
2. *Secondary level*. This level has teenagers who are more into technology than the primary group, so peer-to-peer network would be ideal for them. They have the technical know-how of creating and managing their own network system, they can customise their data sets according to the classes they attend. In secondary level students major in different subjects, so they need to download applications related to their subjects in order for them to set up profiles, data can be stored on individual's device with backup on friends' networks. They then express interest in streams from their teachers so that posts are automatically directed to their network. Peer-to-peer networks are generally faster as opposed to client-to-server, meaning it comes as advantage in the processing of their requests which in turn improves its performance, since communication will only be between the clients without an intermediary server. The peer-to-peer model is more fault tolerant than the client to server, data in peer-to-peer network is distributed to all clients, meaning if one client faces some technical fault which result in either loss of data or any damage. the other peer would be holding the same data, which can be used in the system [42].
3. *Tertiary level*. Most tertiary institutions are very large in terms of student capacity, they are also characterised with multi-campus settings, many programs, many departments and faculties that needs administration. Data to be handled in institutions like these is vast, although speed and system performance should be maintained. The recommended federated network in this case is hybrid model, to deal with scalability and reliability issues. Scalability in network means that when the network is expanding, by adding other users, that is more peers, clients and servers, the overall performance of the system does not degrade and the system is reliable enough to remain consistent in its functionality. "Scalable social network should not compromise on performance and maintain the same level of latency and response time even if more contents are added and more users connect to the social network simultaneously"[37, p. 8]. Hybrid network model, is secure enough considering that different people with different level of positions in life attend courses in tertiary institutions, their personal, school and other sensitive information's safety will be their concern so there is need for a more secure model. Most tertiary institutions are the hub of all the information, everything is handled in the same institution, from registration, teaching, learning, examination preparations and processing then graduations, so their system need to be fault tolerant no data should be lost otherwise many lives will be at stake.

Contemporary education need SNSs eLearning models that addresses critical needs for more effective and scalable educational solutions that can leverage the benefits of SNSs while overcoming their limitations. Recommendations given were compelled by the discussions above and it is the duty of the specific educational institution to thoroughly do the requirements gathering in their institution and take the right decision [39].

5. Conclusion

The study contributed to FSNSs literature, by comparing the three networks involved in federated networks. Each network was discussed and illustrated, strengths and weaknesses were identified. In peer-to-peer network there is scalability and fault tolerance, in client-to-server there is better maintenance and better security, while hybrid network compromises on the two by leveraging on their strengths.

The stakeholders, administrators, lecturers and students are informed on the design of each and every FSNSs network so that the issue of user acceptance during the deployment of any of the discussed network will not need much attention. Case studies that use each of the three FSNSs are discussed giving

the educational facilities a way to go when deciding, however the decision is also affected by the resources in the institution, the capacity of the institution, the priorities and the specific requirements of the system they are expecting.

6. Future research

Standardisation. research on how to develop protocols, standards and strategies that enable seamless communication across all social networking sites through the federation facilities.

Security. no matter how hard the developers try to address the issues of privacy and security in communication networks, there is always an outcry on the security issues. There is need for a continual progress in investigating the mechanisms to upgrade the security systems to ensure data privacy, increase user control and increased communication security across multiple platforms.

Scalability. research on the mechanisms to improve scalability of FSNSs4eL, this include exploration of resource allocation strategies especially in peer-to-peer and load balancing mechanism in client-to-server so that clients would not overload one server whilst others remain unutilised, or underutilised.

References

[1] M. Alghizzawi, M. Habes, S. A. Salloum, M. A. Ghani, C. Mhamdi, and K. Shaalan, "The effect of social media usage on students' e-learning acceptance in higher education: A case study from the United Arab Emirates," *Int. J. Inf. Technol. Lang. Stud.*, vol. 3, no. 3, pp. 13–26, 2019, [Online]. Available: http://journals.sfu.ca/ijitls.

[2] K. Laeeq, Z. A. Memon, and J. Memon, "The educational use of social networking sites among medical and health sciences students: a cross campus interventional study," *BMC Med. Educ.*, vol. 3, no. 1, pp. 1–11, 2020, doi: 10.1186/s12909-022-03569-3.

[3] N. R. Dash *et al.*, "The educational use of social networking sites among medical and health sciences students: a cross campus interventional study," *BMC Med. Educ.*, vol. 22, no. 1, pp. 1–11, 2022, doi: 10.1186/s12909-022-03569-3.

[4] V. H. Le, A. McConney, and D. Maor, "Social networking sites as affordable tools for high-potential personal learning networks: the case of teachers as learners in Vietnam," *Educ. Res. Policy Pract.*, vol. 23, no. 2, pp. 313–335, 2024, doi: 10.1007/s10671-024-09369-4.

[5] N. Cavus, A. S. Sani, Y. Haruna, and A. A. Lawan, "Efficacy of Social Networking Sites for Sustainable Education in the Era of COVID-19 : A Systematic Review," pp. 1–18, 2021.

[6] B. Mugoniwa and E. K. Ngassam, "The Readiness for Adoption of Federated Social Networking Sites to Enhance Contemporary Educational Engagement. The Case of Zimbabwean Universities," in *2021 IST-Africa Conference (IST-Africa)*, 2021, pp. 1–7.

[7] S. A. Lynham, "Quantitative Research and Theory Building: Dubin's Method," *Adv. Dev. Hum. Resour.*, vol. 4, no. 3, pp. 242–276, 2002, doi: 10.1177/15222302004003003.

[8] T. Wawire, G. Okeyo, and M. Kimwele, "A Social Network-based Framework for Interactive and Personalized Web-based Learning," *Int. J. Sci. Res. Publ.*, vol. 8, no. 3, 2018, doi: 10.29322/ijsrp.8.3.2018.p7535.

[9] M. Alasmri, W. C. Onn, and H. S. Hin, "S OCIAL N ETWORKING F RAMEWORK FOR L EARNING," *J. SOUTHWEST JIAOTONG Univ.*, vol. 54, no. 6, 2019.

[10] Gulara A. Mammadova, Firudin T. Aghayev and Lala A. Zeynalova, "Application of the method of clustering educational content in a social network," *Int. Sci. J. "SCIENCE. BUSINESS. Soc.*, vol. v, no. 1, pp. 31–34, 2020.

[11] S. Ebneyamini, "Towards Developing a Framework for Conducting Management Studies Using Design Research Methodology," *Int. J. Qual. Methods*, vol. 21, pp. 1–7, 2022, doi: 10.1177/16094069221112245.

[12] N. Alalwan, "Actual use of social media for engagement to enhance students' learning," *Educ. Inf. Technol.*, vol. 27, no. 7, pp. 9767–9789, 2022, doi: 10.1007/s10639-022-11014-7.

[13] M. Aparicio, F. Bacao, and T. Oliveira, "An e-Learning Theoretical Framework," *Educ. Technol.*

Soc., vol. 19, pp. 292–307, 2016.
[14] E. Mnkandla and A. Minnaar, "The use of social media in E-Learning: A metasynthesis," *Int. Rev. Res. Open Distance Learn.*, vol. 18, no. 5, pp. 227–248, 2017, doi: 10.19173/irrodl.v18i5.3014.
[15] T. Henderson, L. Hutton, and S. Mcneilly, "Ethics and online social network research – developing best practices," *Br. Comput. Soc. Work.*, no. Zimmer 2010, pp. 1–4, 2012.
[16] K. Eungoo and H.-J. Hwang, "The Importance of Anonymity and Confidentiality for Conducting Survey Research," *J. Res. Publ. Ethics*, vol. 4, no. 1, p. 4, 2023, doi: 10.15722/jrpe.4.1.202303.1.
[17] M. Saunders, P. Lewis, and A. Thornhill, *Research Methods for Business Students*. 2016.
[18] G. Silva, L. Reis, A. Terceiro, P. Meirelles, and F. Kon, "Implementing federated social networking: Report from the trenches," *Proc. 13th Int. Symp. Open Collab. OpenSym 2017*, no. April 2018, 2017, doi: 10.1145/3125433.3125455.
[19] M. Aledhari, R. Razzak, R. M. Parizi, and F. Saeed, "Federated Learning: A Survey on Enabling Technologies, Protocols, and Applications," *IEEE Access*, vol. 8, pp. 140699–140725, 2020, doi: 10.1109/ACCESS.2020.3013541.
[20] Y. Huang, Y. Xu, L. Kong, Q. Li, and L. Cui, *Towards Heterogeneous Federated Learning*, vol. 1681 CCIS, no. July. Springer Nature Singapore, 2023.
[21] Z. Guo, L. You, S. Liu, J. He, and B. Zuo, "ICMFed: An Incremental and Cost-Efficient Mechanism of Federated Meta-Learning for Driver Distraction Detection," *Mathematics*, vol. 11, no. 8, pp. 1–22, 2023, doi: 10.3390/math11081867.
[22] A. Cabellos-aparicio, A. López-brescó, and B. Qian, "ITU-T Technical Specification TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU Technical Specification Use cases for Autonomous Networks," no. October, 2021.
[23] R. Schollmeier, "A definition of peer-to-peer networking for the classification of peer-to-peer architectures and applications," *Proc. - 1st Int. Conf. Peer-to-Peer Comput. P2P 2001*, no. September, pp. 101–102, 2001, doi: 10.1109/P2P.2001.990434.
[24] N. Masinde and K. Graffi, *Peer-to-Peer-Based Social Networks: A Comprehensive Survey*, vol. 1, no. 5. Springer Singapore, 2020.
[25] K. Graffi and N. Masinde, "LibreSocial: A peer-to-peer framework for online social networks," *Concurr. Comput. Pract. Exp.*, vol. 33, no. 8, Apr. 2021, doi: 10.1002/CPE.6150.
[26] M. B. D. Kumar and B. Deepa, "Computer Networking : A Survey," *Int. J. Trend Res. Dev.*, vol. 2, no. 5, pp. 126–130, 2017, [Online]. Available: https://www.researchgate.net/publication/317101504_Computer_Networking_A_Survey/link/5926672ea6fdcc4443421892/download.
[27] K. Mannell and E. T. Smith, "Alternative Social Media and the Complexities of a More Participatory Culture: A View From Scuttlebutt," *Soc. Media Soc.*, vol. 8, no. 3, 2022, doi: 10.1177/20563051221122448.
[28] D. Tarr, E. Lavoie, A. Meyer, and C. Tschudin, "Secure ScuttleButt: An identity-centric protocol for subjective and decentralized applications," *ICN 2019 - Proc. 2019 Conf. Information-Centric Netw.*, pp. 1–11, 2019, doi: 10.1145/3357150.3357396.
[29] G. M. Nyabuto, V. Mony, and S. Mbugua, "Architectural Review of Client-Server Models," *Int. J. Sci. Res. Eng. Trends*, vol. 10, no. 1, pp. 139–143, 2024, doi: 10.61137/ijsret.vol.10.issue1.126.
[30] H.-C. Fu, Y.-Y. Xu, H.-T. Pao, and J. Wang, "An iaas based interactive video platform for E-learning and remote services," *J. Comput.*, vol. 24, no. 2, pp. 20–32, 2013.
[31] M. Zignani, C. Quadri, S. Gaito, H. Cherifi, and G. P. Rossi, "The Footprints of a 'Mastodon': How a Decentralized Architecture Influences Online Social Relationships," *INFOCOM 2019 - IEEE Conf. Comput. Commun. Work. INFOCOM WKSHPS 2019*, pp. 472–477, 2019, doi: 10.1109/INFCOMW.2019.8845221.
[32] R. W. Gehl and D. Zulli, "The digital covenant: non-centralized platform governance on the mastodon social network," *Inf. Commun. Soc.*, vol. 0, no. 0, pp. 1–17, 2022, doi: 10.1080/1369118X.2022.2147400.

[33] C. R. Shaw, "Decentralized Social Networks: Pros and Cons of the Mastodon Platform," 2022.
[34] N. Obreykov and N. Obreykov, "Evaluating network generation algorithms for decentralized social media platforms Evaluating network generation algorithms for decentralized social media platforms," 2021.
[35] V. Rohani and O. Hock, "On Social Network Web Sites: Definition, Features, Architectures and Analysis Tools," *J. Adv. Comput. Res.*, vol. 1, pp. 3–11, 2010, [Online]. Available: http://www.sid.ir/en/ViewPaper.asp?ID=241912&varStr=3.14159265358979;ROHANI VALA ALI,HOCK OW SIEW;JOURNAL OF ADVANCES IN COMPUTER RESEARCH;FALL 2010;1;2;41;53.
[36] F. Cabello, M. G. Franco, and H. Alexandra, "Social Networks Lorea Free Software Inhabitants Development Web Tools People Project," *Soc. Media Monop. Their Altern.*, vol. 8, 2013.
[37] T. Maqsood, O. Khalid, R. Irfan, S. A. Madani, and S. U. Khan, "Scalability issues in online social networks," *ACM Comput. Surv.*, vol. 49, no. 2, 2016, doi: 10.1145/2968216.
[38] M. Conrad, A. Hassan, L. Koshy, A. Kanamgotov, and A. Christopoulos, "Strategies and challenges to facilitate situated learning in virtual worlds post-second life," *Comput. Entertain.*, vol. 15, no. 1, pp. 1–9, 2017, doi: 10.1145/3010078.
[39] B. Mugoniwa, E. K. Ngassam, and S. Singh, "Towards a Hybrid Federated Social Networking Architecture. A Case of Zimbabwe's Higher Education," *2023 IST-Africa Conf. IST-Africa 2023*, pp. 1–9, 2023, doi: 10.23919/IST-Africa60249.2023.10187749.
[40] F. S. Hussenoeder, "Social network sites as learning environments and their implications for mental health," *Front. Digit. Heal.*, vol. 4, no. October, pp. 1–8, 2022, doi: 10.3389/fdgth.2022.939740.
[41] M. J. Ponera and P. Ngulube, "Implications of policies on the use of social networking sites for knowledge sharing: Experiences from postgraduate students in higher education institutions in Tanzania," *Soc. Sci. Humanit. Open*, vol. 8, no. 1, p. 100585, 2023, doi: https://doi.org/10.1016/j.ssaho.2023.100585.
[42] M. Chetoui and M. A. Akhloufi, "Peer-to-Peer Federated Learning for COVID-19 Detection Using Transformers," *Computers*, vol. 12, no. 5, 2023, doi: 10.3390/computers12050106.