CATHOLIC UNIVERSITY OF LOUVAIN-LA-NEUVE

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# A decentralized social network based on event-sourcing principles

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# 1 Introduction on social networks

## 1.1 Open social network

A social network is a website that allows you to connect with different people all over the internet and share data such as photos, videos, music and other information. They can be used for entertainment purposes like Facebook, Twitter, etc... but also for enterprise social networking like LinkedIn, SocialCast and Yammer. The quick rise of all those social-networks led to a lot of problems that we are currently facing, the main one being the malicious usage of user data. As we've recently seen with the introduction of the GDPR, the way all the users' information were handled led to a lot practices flirting very closely with the edge of the law and sometimes even breaking it. This led to a new era of social networking where data protection and transparency must be explicit as to enforce the many new digital rights an individual has, such as the right to be informed and to erasure.

Since then, a lot of new data exchange platforms have been created but with the twist that they are open social networks. Open-sourcing is nothing new in the domain of computer science, it is a decentralized software development model that encourages open collaboration. A main principle of open-source software development is peer production, with products such as source code, blueprints, and documentation freely available to the public. By being completely open to the public, these new open-source social-networks (OSN) solve, for the most part, the data transparency issue. In addition to all the perks provided with open-sourcing such as customization, collaboration, etc..., all the users can directly see how their information is handled and propose their own modifications to the code base of the network.

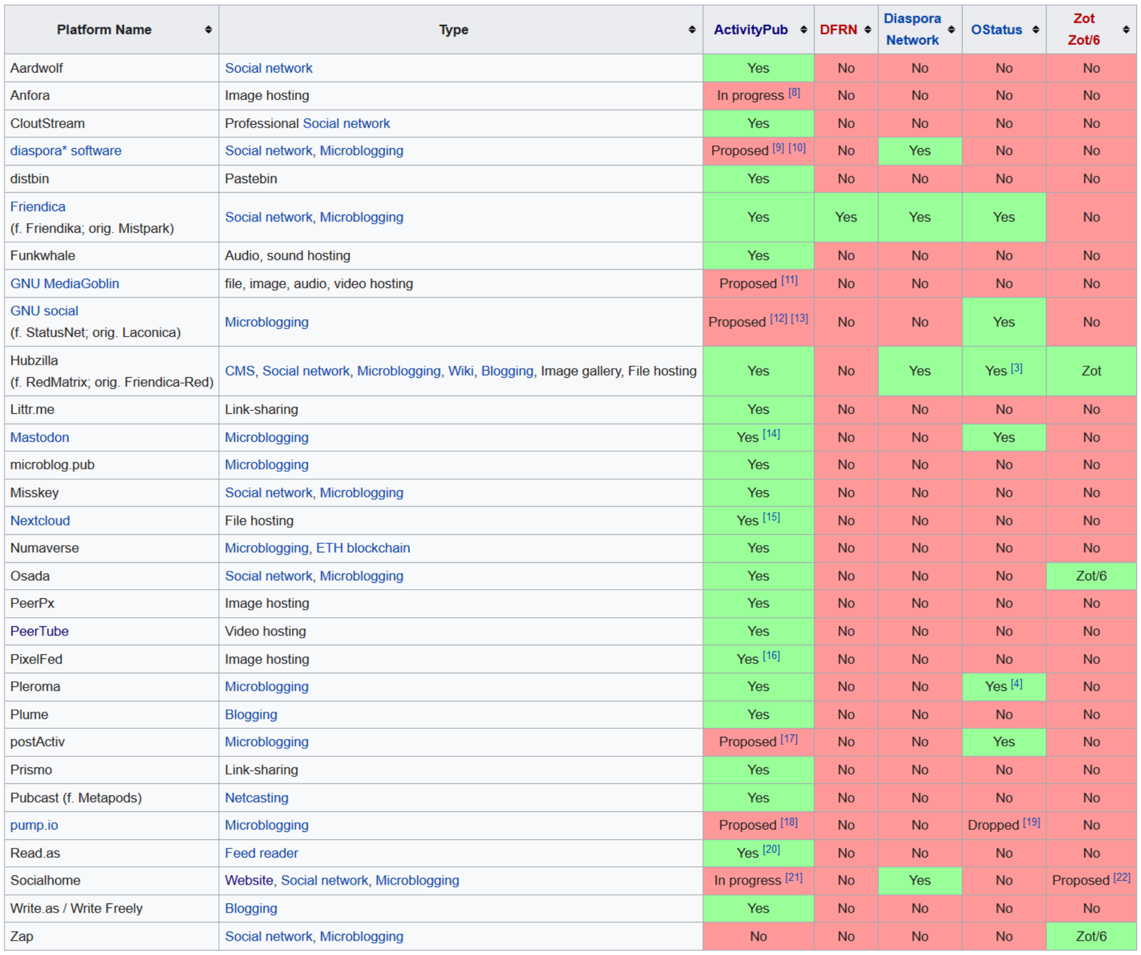
The major issue with social networks like Twitter and Facebook is that they are monopolistic, the power of these networks allows them to dictate their own rules. With the lack of concurrency, we see a trend where the goal of the company shift much more to how to raise the profitability instead of improving the quality. This is the case here because the users have already invested themselves in the website for a long time and there are no real alternatives, so instead of trying to find the best products between all the possibilities, every individual flocks to the website with the monopoly.

To fight this tendency and have a much more healthy market, OSN have started working together to become decentralized networks. Instead of collecting and storing social users data (friends, posts, comments, likes, etc...) on a single website, these social networks operate as a federation of independent networks called the Fediverse. It is the ensemble of federated servers that are used for web publishing (social networking) and file hosting. On different servers, users can create so called identities. These identities are able to communicate over the boundaries of the servers because the softwares running on them support one or more communication protocols which follow the open standard. As an identity on the Fediverse, you are able to post text and other media, or to follow posts by other identities. In some cases, you can even show or share data (video, audio, text and other files) publicly or to a selected group of identities and allow other identities to edit your data (calendar, address book, etc...). The softwares spanning the Fediverse cover a wide range of features like video hosting (PeerTube), microblogging (Mastodon) or even sound hosting (Funkwhale) [1].

This practice is completely adapted to the idea of a market where every individual is free to chose the solution he prefers without losing the time invested previously. With the Fediverse, we now have completely independent websites that are completely different from each other and yet are able to communicate between each others. This is a complete shift in the evolution of the social networks which was dictated for a long time by the aphorism *the rich get richer*, where individuals, almost exclusively, flocked to the biggest websites because that's where their relatives were. While that is part of the human nature and will still be relevant in the future, the Fediverse goal is to lead the market to be dominated by the quality of the product instead of the user base size. A good product arriving on the market will have a much higher chance of getting new users leading all the already established websites to seek to continually improve as to not get outperformed.

It is important to note that everything is not perfect, one of the main concern is that there is no real solutions in place to easily move the profile of an user between different networks. Instead, an individual as to manually recreate a new account each time he changes websites. This can easily be bothersome if there is a process in place such as Facebook's friend requests to connect with other people. There is also the issue of malicious websites being part the Fediverse and able to steal all the data that transit in the federation. There are currently different solutions being worked on such as having the profile being transferable through the block-chain to guarantee the protection of data. This also creates new problems relative to the GDPR where some rights might hard to preserve (i.e. right to erasure) because of the decentralization of information. The following list is not exhaustive but summarize the disadvantages of decentralized networks :

- Latency issues
- Duplication of storage
- Deletion of content
- No central authority to handle malwares, spams, ...
- Distributed authentication and authorization



| Platform Name | Type | ActivityPub | DFRN | Diaspora Network | OStatus | Zot Zot/6 |
|---|---|---|---|---|---|---|
| Aardwolf | Social network | Yes | No | No | No | No |
| Anfora | Image hosting | In progress [8] | No | No | No | No |
| CloutStream | Professional Social network | Yes | No | No | No | No |
| diaspora* software | Social network, Microblogging | Proposed [9] [10] | No | Yes | No | No |
| distbin | Pastebin | Yes | No | No | No | No |
| Friendica (f. Friendika; orig. Mistpark) | Social network, Microblogging | Yes | Yes | Yes | Yes | No |
| Funkwhale | Audio, sound hosting | Yes | No | No | No | No |
| GNU MediaGoblin | file, image, audio, video hosting | Proposed [11] | No | No | No | No |
| GNU social (f. StatusNet; orig. Laconica) | Microblogging | Proposed [12] [13] | No | No | Yes | No |
| Hubzilla (f. RedMatrix; orig. Friendica-Red) | CMS, Social network, Microblogging, Wiki, Blogging, Image gallery, File hosting | Yes | No | Yes | Yes [3] | Zot |
| Littr.me | Link-sharing | Yes | No | No | No | No |
| Mastodon | Microblogging | Yes [14] | No | No | Yes | No |
| microblog.pub | Microblogging | Yes | No | No | No | No |
| Misskey | Social network, Microblogging | Yes | No | No | No | No |
| Nextcloud | File hosting | Yes [15] | No | No | No | No |
| Numaverse | Microblogging, ETH blockchain | Yes | No | No | No | No |
| Osada | Social network, Microblogging | Yes | No | No | No | Zot/6 |
| PeerPx | Image hosting | Yes | No | No | No | No |
| PeerTube | Video hosting | Yes | No | No | No | No |
| PixelFed | Image hosting | Yes [16] | No | No | No | No |
| Pleroma | Microblogging | Yes | No | No | Yes [4] | No |
| Plume | Blogging | Yes | No | No | No | No |
| postActiv | Microblogging | Proposed [17] | No | No | Yes | No |
| Prismo | Link-sharing | Yes | No | No | No | No |
| Pubcast (f. Metapods) | Netcasting | Yes | No | No | No | No |
| pump.io | Microblogging | Proposed [18] | No | No | Dropped [19] | No |
| Read.as | Feed reader | Yes [20] | No | No | No | No |
| Socialhome | Website, Social network, Microblogging | In progress [21] | No | Yes | No | Proposed [22] |
| Write.as / Write Freely | Blogging | Yes | No | No | No | No |
| Zap | Social network, Microblogging | No | No | No | No | Zot/6 |

Figure 1: Fediverse software platforms

***https://en.wikipedia.org/wiki/Fediverse***

## 1.2 Platforms specialization and customization

When we look at the figure 1, we can see that many platforms have different types of content and as such, have completely different workings internally. It is important to notice that the Fediverse protocols must be as agnostic as possible of each OSN architecture to not require a complete shift of the code base to be able to use the protocol. Each of the platforms is specialized and most certainly use adapted techniques to reach the best performance for its type of content. One of the goal of the communication protocols must be to make the interoperability between two completely different platforms as easy as possible and as such only provide a core of features that do not depend on the features of the website and the type of content exchanged.

Most of the subjects approached previously were centered around the user experience as the main focus but is not all. Decentralized and open social networks are also a great boon for the designers and developers of all websites. The open-source component means, for the most part, that they have a much higher degree of freedom when implementing features. A few years ago, if a website wanted to add a comments features where user could write their opinion or share knowledge, they had to either do it themselves or use one of the market leaders solutions (facebook/google+ plugins) if they wanted more rich features. The issue stem, as always, from the dependency on another company if we want to implement already existing solutions. By being dependent, we lack the ability to modify the feature or control how the data is handled.

Recently, there has been a new trend in social media called vertical social network. These platforms contains a highly segmented user base heavily specialized on specific topics and are generally more private/gated (medicine, education, golf, etc...). This specialization means that features must be adapted to the needs of that specific community. The current and most popular solutions offered by the big companies are ill suited for these platforms because the need for secrecy is not respected and modifications cannot be made as the code-base is private. Up to today, their only choices was to reinvent the wheel each time and build PHP monoliths for the most part.

Open-source social networks aims to fix this problem by providing completely independent and customizable components. No longer will these websites require to associate with Facebook to have a comments module, instead they will be able to pick the one that suits them the most among all the open-source solutions. They will also be able to pick a component and make the change that fit their requirements, be it modifying, deleting or adding features. For example, the European history museum is planning on giving visitors a tablet each to guide them through the place. They want the possibility for the user to leave comments and communicate between each other without having to authenticate through Facebook. Instead of starting from zero and creating a brand new module, they will be able to simply use the open-source comment component that fits them the most.

## 1.3 Fediverse protocols

The capabilities of the Fediverse protocols all have some features in common that can be categorized as follows :

- A communications protocol and endpoint for introductions (e.g. the “friend request” of traditional social networks)
- A communications protocol and endpoint for responding to these requests and establishing permission to communicate
- A communications protocol and endpoint for notification of new or modified content with mutually authenticated source and destination
- A communications endpoint and protocol for polling available content with mutually authenticated source and destination
- A means to invisibly cross-authenticate within cooperating cells, so that communication is not impeded by requiring “in your face” authentication/authorization exchanges when crossing site boundaries

### 1.3.1 DFRN

The DFRN framework provides the communication basis for a decentralized social network where cooperating servers share information on your behalf while operating in a web of trust relationships you control. It can provide a “Facebook-like” experience without requiring a central company or server. The goal of DFRN is to provide an open and distributed social communication platform with server requirements comparable to that of a typical hosted blog. Instead of a central server, a collection of distributed ’cells’ or ’nodes’ are able to communicate with each other on your behalf. This goal of this protocol is to correct the common issues found in other distributed social technologies such as the weakness in the privacy model, the lack of specification of content deletion and re-distribution policies and poor ease of use.

### 1.3.2 Diaspora network

The Diaspora social network is constructed of a network of nodes hosted by many different individuals and institutions. Each node operates a copy of the Diaspora software acting as a personal web server. Users of the network can host a pod on their own server or create an account on any existing pod of their choice, and from that pod can interact with other users on all other pods. Diaspora users retain ownership of their data and do not assign ownership rights. The software is specifically designed to allow users to download all their images and text that have been uploaded at any time. It allows user posts to be designated as either "public" or "limited". In the latter case, posts may only be read by people assigned to one of the groups, termed aspects, which the user has approved to view the post. Each new account is assigned several default aspects (friends, family, work and acquaintances) and the user can add as many custom aspects as they like. It is possible to follow another user's public posts without the mutual friending required by other social networks.

#### 1.3.3 OStatus

OStatus is an open standard for federated microblogging (Twitter style), allowing users on one website to send and receive status updates with users on another website. The standard describes how a suite of open protocols, including Atom, Activity Streams, WebSub, Salmon, and WebFinger, can be used together, which enables different microblogging server implementations to route status updates between their users back-and-forth, in near real-time.

#### 1.3.4 Zot

Zot is a JSON-based web framework for implementing secure decentralised communications and services. In order to provide this functionality, Zot creates a decentralised globally unique identifier for each hub on the network. This global identifier is not linked inextricably to DNS, providing the requisite mobility. Many existing decentralised communications frameworks provide the communication aspect, but do not provide remote access control and authentication. Additionally most of these are based on 'webfinger', which still binds identity to domain names and cannot support nomadic identity. The primary issues Zot faces are :

- Decentralized communications
- Independence from DNS-based identity
- Node mobility
- Seamless remote authentication

#### 1.3.5 ActivityPub

Activity Pub is an open, decentralized social networking protocol providing a client/server API for creating, updating and deleting content, as well as a federated server-to-server API for delivering notifications and content. It has been defined by the W3C (in charge of standard of the web) and it provides two layers:

- A server to server federation protocol (so decentralized websites can share information).
- A client to server protocol (so users, including real-world users, bots, and other automated processes, can communicate with ActivityPub using their accounts on servers, from a phone or desktop or web application or whatever).

In ActivityPub, a user is represented by "actors" via the user's accounts on servers. User's accounts on different servers correspond to different actors. Every actor has an inbox to receive messages and an outbox to send messages to others.

### 1.4 The rigidity of monoliths

All OSNs participating to the Fediverse are built as rigid monolithic applications often using a single relational database. This design leads to poor flexibility of purpose: it is difficult to adapt these OSNs, for instance to support new forms of social interactions. It is also difficult to isolate in these platforms the components that are critical for security, and in particular the ones that manipulate sensitive user data. A bug or exploit in any part of the monolith can allow a malicious attacker to read the entire database, and bugs are difficult to detect due to the size of the software. These monoliths illustrate three common issues that computer scientist have been plagued with since the beginning of the field :

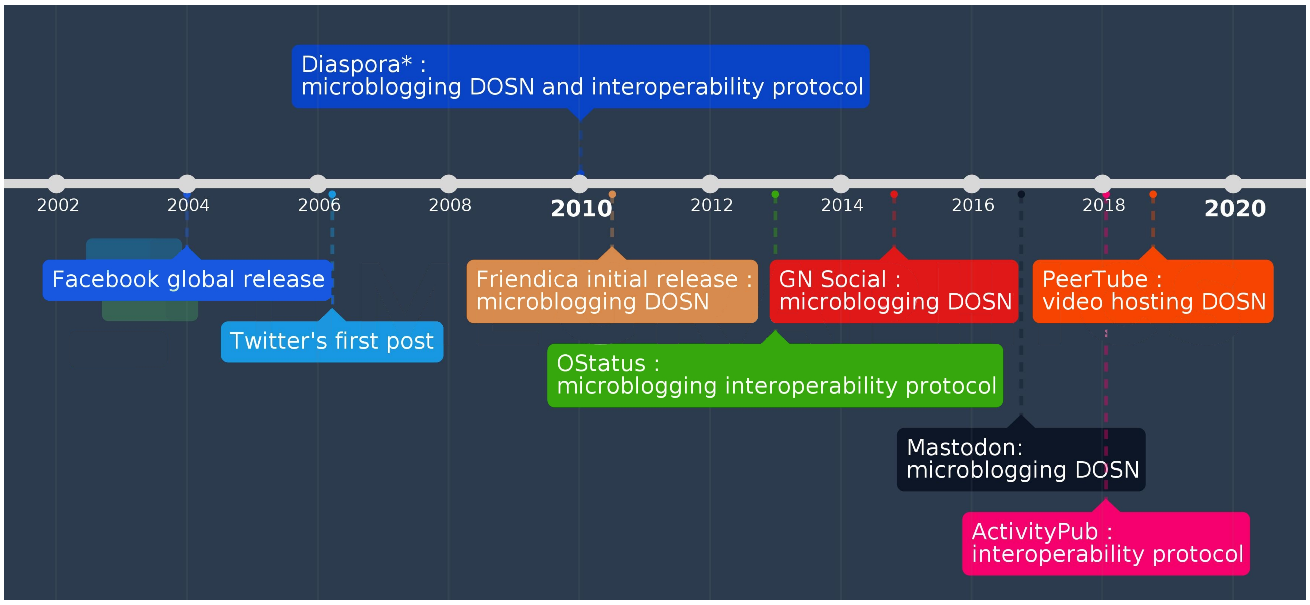


Figure 2: Social networks timeline

- Maintainability : solutions to have systems modifiable and improvable as easily as possible have been the subject of many books and projects. Most software systems are modified all the time after they have been delivered either to add new features or fix bugs. As time is money, the efficiency and effectiveness with which issues can be resolved and enhancements can be realized is therefore important, if an application is too large and complex to understand entirely, it is challenging to make changes fast and correctly. Social networks are heavily impacted by their maintainability or lack there of, as they last a long time and are in constant evolution. In a monolithic architecture, all the components are grouped together leading to an exponential increase in required time to perform maintenance (single-tiered software application). This also means that switching technologies during the development is an arduous task, costly both in time and efforts.

- Cascading failure : Cascading failures may occur when one part of the system fails. When this happens, other parts must then compensate for the failed component. This in turn overloads these nodes, causing them to fail as well, prompting additional nodes to fail one after another. A bug in any module (e.g. memory leak) can potentially bring down the entire process. Moreover, since all instances of the application are identical, that bug impact the availability of the entire application. One of the frequent source of crashes in social networks is simply the platform not having enough resources to handle all the requests when there is a huge number of users trying to access the application. While there is a lot of effort done to prevent these problems from happening, the monolithic architecture doesn't natively provide a solution.

- Scalability : it is the ability of a software to grow and manage increased demand. For a system to be highly scalable, it must allow for quick and efficient allocation/removal of resources according to the current requirements of the application. In a social network we can distinguish different components (authentication, notification, presentation, etc...), that are constantly being used but not at the same time. This means that since the components are all merged into one in a monolith architecture, the resources allocated to the platform must account for all of them at the same time. For example, if we have a sudden spike in connection request, the resources for the whole software must be increased and then decreased when no longer needed. The most common solution used in monolith is to have a very high static number of resources allocated at all time such no matter the number of requests, the website is able to handle them. This means that a large portion of the time, many resources are left unused, leading to a waste of money.

The design of monoliths itself goes against the principle of decentralization and customization. By being a single entity, the scalability/flexibility efficiency is largely diminished, we can only stockpile a large number of resources to prevent failures at the cost of having useless workers the majority of the time. The customization is also severely impacted because it is hard to isolate components, as they are not independent, and even in the best case, each modifications makes the maintainability much harder to perform. Moderate changes in a monolith always require for the engineer to be, at least, familiar with the whole code-base as to anticipate the consequences of his actions.

### 1.5 Collaboration at the forefront

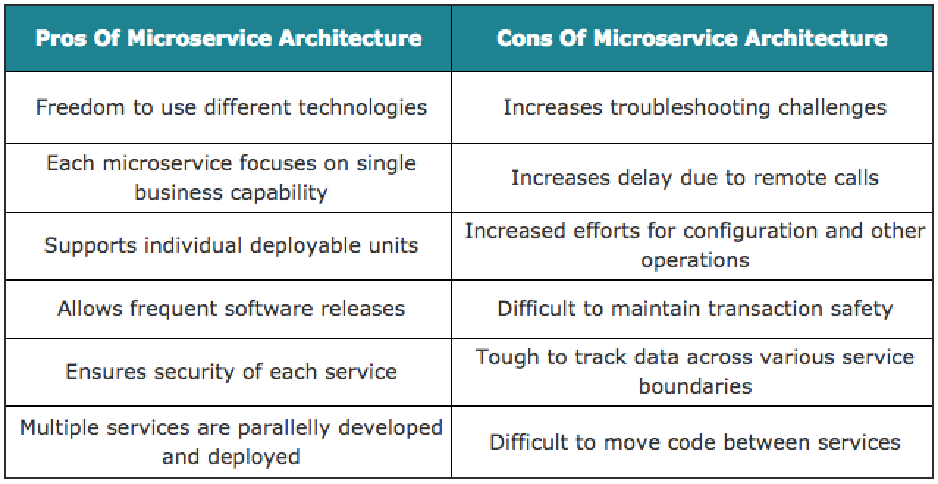
The collaboration between individual is what lead to the open-source paradigm shift and, by extension, the apparition of open-source social networks. Interoperability between the different platforms of the Fediverse was birthed by this will to work together to provide the best solutions. The ActivityPub protocol, and all of its predecessors, aim to push forward the universal side of social network, not as a way to reach the largest number of users but as to find customized solutions to each individuals needs. This protocol was designed to be scalable to every size and type of content in as many situation as possible. Social networks being very different from each other, ActivityPub tries to provide a common ground they can all work with instead of trying to unify them all. As stated previously, customization plays a very important part in DOSN but the monolith architecture is an obstacle that the interoperability protocol can't cross by itself. This lead to creation of a new type of architecture, called micro-services, which aims to support the interoperability protocol in providing truly decentralized and collaborative platforms. The requirements at the origin of this new architecture can be summarized as such :

- Need for independent components
- Need for efficient maintainability
- Need for efficient scalability

## 2 Technical introduction on the tools used

### 2.1 The role of micro-services

A micro-services architecture consists of a collection of small and autonomous services. Each service is self-contained and should implement a single business capability. They all have their separate code-base that can be deployed independently at any time. As such, they are responsible for persisting their own data and/or external state. To communicate with them, services publish their self-defined API that can be accessed by clients or any other services. This kind of architecture is well suited for large and/or complex applications requiring high scalability and efficient maintainability such as social networks. See fig 3 for more details on the advantages and inconvenient of micro-services architecture.



| Pros Of Microservice Architecture | Cons Of Microservice Architecture |
|---|---|
| Freedom to use different technologies | Increases troubleshooting challenges |
| Each microservice focuses on single business capability | Increases delay due to remote calls |
| Supports individual deployable units | Increased efforts for configuration and other operations |
| Allows frequent software releases | Difficult to maintain transaction safety |
| Ensures security of each service | Tough to track data across various service boundaries |
| Multiple services are parallelly developed and deployed | Difficult to move code between services |

Figure 3: Pros and cons of microservices architecture

***https://dzone.com/articles/microservice-architecture-learn-build-and-deploy-a***

#### 2.1.1 Separation of concerns

To avoid cascading failure and making the maintenance easier to perform, services are independent to each others. This way, if the authentication service is no longer available due to some failure, the rest of the application is not in jeopardy because the service is self-contained. This also means that we can set fail-safe mechanism to quickly restart crashed services. This separation of concern also improve the maintainability simply by allowing us to implement new features or modify existing ones without touching the rest. This way, small teams of developers can each work in parallel on their own business case without interfering with the work of other teams. Services not being reliant on each other also means that they can easily replaced or used elsewhere as independent components. As only the service's API is exposed to outside world, they behave like black box (language agnostic) that can be easily plugged in other applications to allow for easy and efficient customization.

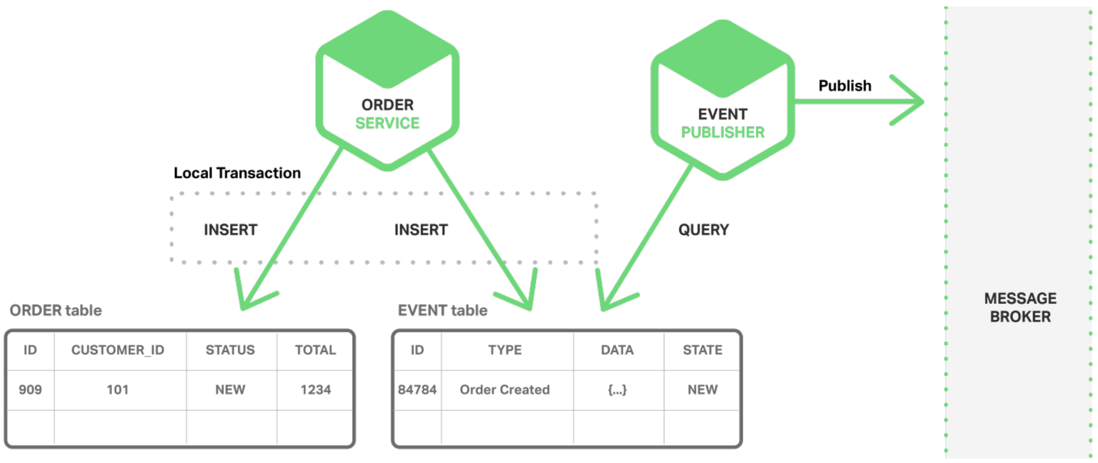
### 2.1.2 Scalability

The numbers of visits on a website is rarely linear, we may have more visitors in the evening than in the morning, leading to an increase in the required resources (RAM, storage, servers, etc...). On a monolithic application, this is often done by setting a static amount of resources, meaning that whenever the application is not at full capacity, we waste money. With micro-services, resources usage can be tailored to the actual need of the application. For example, if there is spike in connection requests, we can simply allocate more resources to the authentication service instead of upgrading the whole application and unrelated services.

## 2.2 Event-sourcing

Event-sourcing is an architectural pattern where a business object is persisted by storing a sequence of state changing events. Whenever an object's state changes, a new event is appended to the sequence. An entity's current state is reconstructed by replaying its events persisted in the event store, acting as a database of events and message broker at the same time. Services can either publish events or subscribe to them to be notified of the new ones. A parallel can be draw between this pattern and the behaviour of user on social network, where services publish and subscribe to events, individuals can post on the website and be notified of messages posted by the person they follow. This pattern also provide multiple additional benefits for the whole application :

- Complete rebuild : we can discard the application state completely and rebuild it by re-running the events from the event log on an empty application. We can determine the application state at any point in time by rerunning the events up to a particular time or event.
- History : as we do not store the current object state but each events starting at the creation of the objects, we have a complete trace of the previous events meaning that users' data is never lost and can be accessed at any time.
- Event replay : If we find a past event was incorrect, we can compute the consequences by reversing it and later events and then replaying the new event and later events. The same technique can handle events received in the wrong sequence, a common problem with systems that communicate with asynchronous messaging.
- Data protection : The micro-services architecture coupled with the event-sourcing patterns allows for data transparency, making it easier to comply with the law (GDPR, audit, etc...).



ORDER table

| ID | CUSTOMER_ID | STATUS | TOTAL |
|---|---|---|---|
| 909 | 101 | NEW | 1234 |
| | | | |

EVENT table

| ID | TYPE | DATA | STATE |
|---|---|---|---|
| 84784 | Order Created | {...} | NEW |
| | | | |

Figure 4: Creation of new order and publishing of the event to the event store

To illustrate better, let's take a command shipping application with an order service handling the operations on orders and a customer service that wants to be notified on all the events relative to its orders. When an order is created, approved or shipped, a new event will be published to the event store containing all the required information. As the customer is subscribed to all the events pertaining to his orders, he will be directly notified every time there is a new event persisted in the store and his view will be updated. Once he has received the new event, he will then be able to proceed and maybe even make a modification that will lead to the publishing of its own event. Figure 4 illustrate the create of a new order and it's publishing in the event store.

## 2.3 Command Query Responsibility segregation

CQRS is an architectural pattern that separates the data reading part (query) from the writing part (command), improving even further the separation of concerns. It makes it easier to scale read/write operations and to control security but introduce additional complexity to the system. This is represented by separating common services into a command service handling CRUD requests (PUT, POST, ...) and a query service handling the GET requests for the business, while still being connected to the same data storage. For example, in an authentication service, creating an account calls the command service and retrieving an user's information calls the query service.

The number of reads being far higher than the number of modifications inside an application, applying the CQRS pattern allows to focus independently on both concerns. One main advantage of this separation is the scalability. We can scale our reading part differently from our writing part (allocate more resources, different types of database). This pattern also improve the flexibility because it's easy to update or add on the reading side, without changing anything on the writing side. Data consistency is therefore not altered. Both of these benefits fully leverage the possibilities brought by the micro services architecture.

One of the ideas behind CQRS is that a database is hardly as efficient to manage reads and writes. It can depend on the choices made by the software vendor, the database tuning applied etc. Furthermore, we may also decide to handle distinct data models such as managing one model used in the context of a reporting view or another denormalized model efficient during the persistence on the write part etc. Concerning the views, we may decide to implement some consumer-agnostic ones (for example to expose a specific business object) or some that would be specific to consumers. For must use cases, CQRS is required when we implement Event Sourcing because we may want to retrieve a state in O(1) without having to compute n different events. Applying event sourcing on top of CQRS means persisting each event on the write part of our application. Then the read part is derived from the sequence of events (see figure **??**). One exception is the use case of a simple audit log where we don't need to manage views as we are only interested in retrieving a sequence of logs.

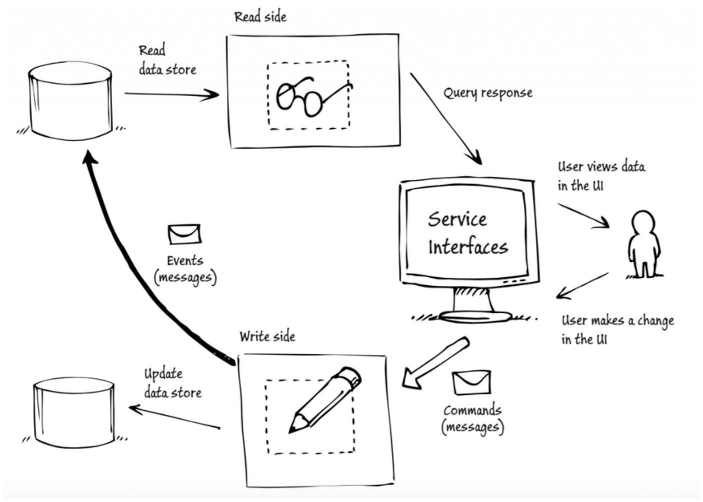


Figure 5: Schema of how the data is handled when using CQRS and event sourcing

***https://medium.com/eleven-labs/cqrs-pattern-c1d6f8517314***

## 2.4 Cloud computing

Cloud computing makes computer system resources, especially storage and computing power, available on demand without direct active management by the user. The term is generally used to describe data centers available to many users over the Internet. Large clouds, predominant today, often have functions distributed over multiple locations from central servers. If the connection to the user is relatively close, it may be designated an Edge server. Clouds can be limited to a single organization, be available to many organizations or a combination of both. Cloud computing relies on sharing of resources to achieve coherence and economies of scale. It allows companies to avoid or minimize up-front IT infrastructure costs and allows enterprises to get their applications up and running faster, with improved manageability and less maintenance. It also enables IT teams to more rapidly adjust resources to meet fluctuating and unpredictable demand. Among the most popular cloud platform provider are famous companies such as Amazon (AWS) and Microsoft (Azure).

## 2.5 Gateway

An API gateway is a door that sits in front of an application programming interface (API) and acts as a single point of entry for a defined group of micro-services. Because a gateway handles protocol translations, this type of front-end programming is especially useful when clients built with micro-services make use of multiple, disparate APIs. A major benefit of using API gateways is that they allow developers to encapsulate the internal structure of an application in multiple ways, depending upon use case. This is because, in addition to accommodating direct requests, gateways can be used to invoke multiple back-end services and aggregate the results. Because developers must update the API gateway each time a new micro-service is added or removed, it is important that the process for updating the gateway be as lightweight as possible. In addition to exposing micro-services, popular API gateway features include functions such as authentication, security policy enforcement, load balancing and cache management. Therefore, having an intermediate level or tier of indirection (Gateway) can be very convenient for microservice-based applications. Without it, we expose our application to different problems :

- Coupling: Without the API Gateway pattern, the client apps are coupled to the internal microservices. The client apps need to know how the multiple areas of the application are decomposed in microservices. When evolving and refactoring the internal microservices, those actions impact maintenance pretty badly because they cause breaking changes to the client apps due to the direct reference to the internal microservices from the client apps. Client apps need to be updated frequently, making the solution harder to evolve.
- Too many round trips: A single page/screen in the client app might require several calls to multiple services. That can result in multiple network round trips between the client and the server, adding significant latency. Aggregation handled in an intermediate level could improve the performance and user experience for the client app.
- Security issues: Without a gateway, all the microservices must be exposed to the "external world", making the attack surface larger than if you hide internal microservices that aren't directly used by the client apps. The smaller the attack surface is, the more secure your application can be.
- Cross-cutting concerns: Each publicly published microservice must handle concerns such as authorization, SSL, etc. In many situations, those concerns could be handled in a single tier so the internal microservices are simplified.

## 2.6 Tools justification

### 2.6.1 Wolkenkit

The event-sourcing pattern is implemented through the Wolkenkit framework. It is a CQRS and event-sourcing framework for JavaScript and Node.js adapted to domain-driven design (DDD). It provides an event-store and a scalable real-time API. It is implemented as an additional service, handling activities events. According to the CQRS pattern, the query services subscribe each to the activities they are in charge of (posted, liked, etc...) and the command services all publish their related events (post, like, ...). Subscribed services will be directly notified of what is happening once an event they are looking for is published and they can then take the appropriate measures such as sending them to the front-end or modifying the targeted object. The framework is also in charge of persisting activities in the event-store and allow services to retrieve them through a customizable filter.

### 2.6.2 Docker

Docker is a tool designed to make it easier to create, deploy, and run applications by using containers. Containers allow a developer to package up an application with all of the parts it needs, such as libraries and other dependencies, and ship it all out as one package. By doing so, thanks to the container, the developer can rest assured that the application will run on any platform. To handle the separations of concerns between services properly, Docker is used to isolate each of them into their own container making them only reachable through their exposed API. Docker-compose is used here to group all the services, starting them all in only one command.

### 2.6.3 Express

Express is a web application framework for Node.js, released as free and open-source software under the MIT License. It is designed for building web applications and APIs. The Express Router matches URLs and routes them to modules known as "middleware". Each middleware acts on a request coming into Express through the router and passes it onto the next piece of middleware as a chain. This request, response and "next" flow is the foundation of how Express works.

### 2.6.4 Express Gateway

Express Gateway is a microservices API Gateway built on Express.js, that centralizes all of the application configuration for the API use case into one YAML(or JSON) file. Within this file is an easy to understand description of how and what is configured. Express Gateway utilizes this configuration to run Express as an API Gateway dynamically. It comes with a component that registers consumers (users and apps) of APIs hosted. This component is a highly extensible identity and authorization system out of the box for APIs. The gateway stores application data centrally in a traditional or distributed data store. This component allows the data to be accessed globally and, in turn, developers can build to scale with multiple instances of Express Gateway. The data store can also be used to centralize application configuration across a cluster of Express Gateways.

## 2.7 Formal issue and its solution

All OSNs participating to the Fediverse are built as rigid monolithic applications, typically using Ruby on Rails or PHP and using a single relational database. This design leads to poor flexibility of purpose: it is difficult to adapt these OSNs, for instance to support new forms of social interactions. It is also difficult to isolate in these platforms the components that are critical for security, and in particular the ones that manipulate sensitive user data. A bug or exploit in any part of the monolith can allow a malicious attacker to read the entire database, and bugs are difficult to detect due to the size of the software.

With the architecture shift from monolithic to micro-services, we have a strong way to ensure that OSN will be able to efficiently scale their resources according to load of the network as each services is independent. This absence of dependence upon other services also means the components critical for security can be safely isolated to better handle sensitive information. Improving upon previous features and supporting new social interactions is also done easily thanks to the services segregation and ability of teams to work in a parallel fashion. Both the independence and the much more efficient maintainability allows for a wide range of customization possibilities on the components of each platforms. Event-sourcing and CQRS only improve the overall solution by fully taking advantage of the new architecture and providing new interactions completely in sync with the behaviour of users on social networks (publish and subscribe).

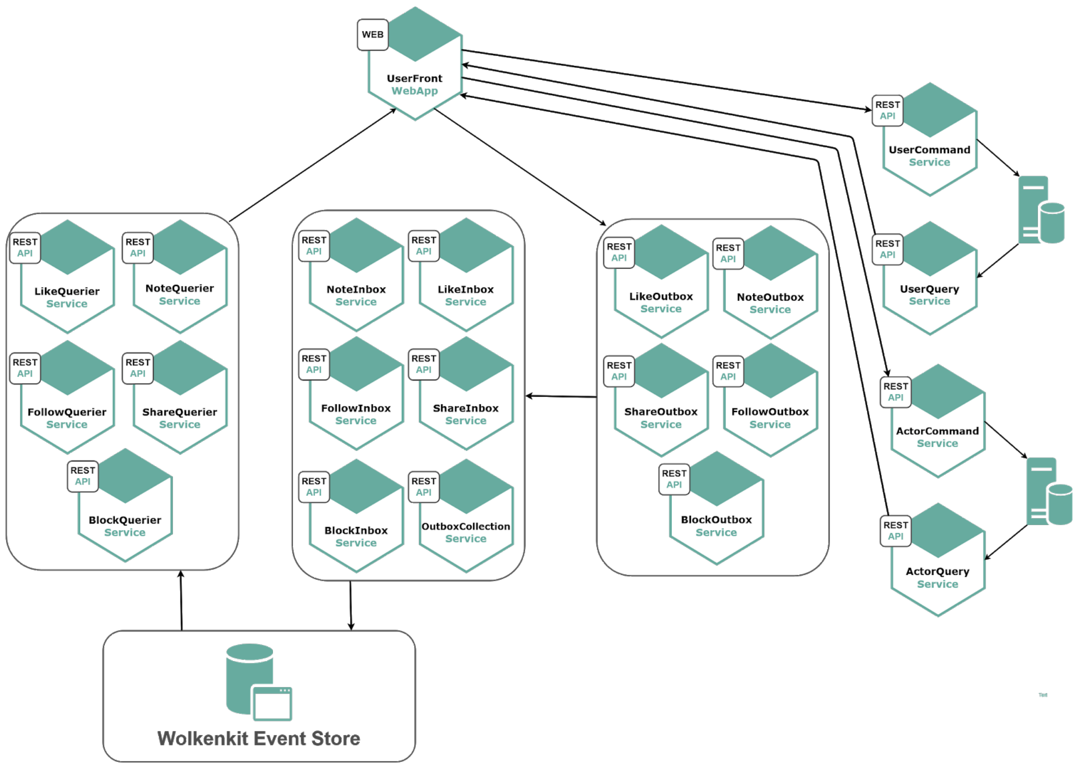


Figure 6: ActivityPub micro-services architecture

## 3 Architecture design

### 3.1 ActivityPub

## 4 Implementation

### 4.1 ActivityStreams

### 4.2 Authentication

At the first, the authentication was supposed to be done using either the OpenID Connect or Passport.js framework. The issue was that the first one was clearly too much complex to implement for a simple authentication mechanism and the second was not really adapted to this micro-services application. As such, I implemented the authentication process using the JsonWebToken library as to have a strong token based authentication. Each user once connected or after creating an account, receive its unique token identifying the current user's session and store it in the cookies.

### 4.3 Testing

#### 4.3.1 Unit testing

#### 4.3.2 Integration testing

#### 4.3.3 Load balance testing

## 5 Conclusion