The role of groups in a user migration across blockchain-based online social media

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***Abstract*—User migration is one of the main phenomena occurring on modern online social media. And, it is even involving the most recent alternative paradigms of online social media, such as blockchain online social media. In these platforms, user migration is strongly linked to the hard forks of the supporting blockchain, i.e. a split of the original blockchain and the creation of an alternative one.**

Our understanding of user migration is still limited, especially when we look at it from a network-based standpoint. What is the role played by densely connected groups of users during user migration and fork events? Are there differences in the network structure of groups of users who stay and those leaving for a new platform? Guided by these questions, here, we show, through a network-based analysis rooted in the identification of communities on multi-layer networks, that i) the “position” of a group within the network of social and economic interactions is connected to the likelihood of migrating, i.e. marginal groups are more likely to leave; ii) users in densely connected groups interacting through monetary transactions are more likely to stay, and iii) user migration differently impacts on the network built on social interactions and the network based on monetary transactions.

These findings highlight the importance of social and economic relationships among users along a user migration caused by fork events. In the general context of online social media, it motivates the need to investigate user migration through a network-inspired approach based on groups.

***Index Terms*—user migration, blockchain online social media, multi-layer network, community detection**

I. Introduction

Nowadays landscape of online social media (OSM) is still very dynamic: new players along with novel platforms and services are continuously coming into the scene to compete even with well-established worldwide platforms, such as Facebook, Instagram, Twitter, Weibo, for gaining ever-larger audiences. However, this competitive scenario is just a partial view of the OSM big picture. Misinformation, fake news spreading, privacy issues, data leakage and censorship are some of the issues which are afflicting these platforms and are undermining the user experience. Many users are reacting to this situation by leaving mainstream platforms in favor of novel platforms which better fit their idea of online media, or which promise to overcome or limit, at least, the aforementioned issues. This phenomenon is generally described as *user migration*, and it is becoming one of the main issues, modern centralized online social media are facing.

User migration is not limited to well-established and centralized social platforms, but it is a widespread phenomenon even involving the most recent alternative paradigms of online social media. Blockchain-based online social media - BOSM - are becoming the most promising solution among them. Essentially, BOSM leverage a blockchain to support all the functionalities which facilitate social interactions, along with some advantages and peculiar features, such as resistance to censorship, the guarantee of content authenticity and a reward system based on cryptocurrencies, which aims at promoting worthy behaviors as the production of high-quality contents or the reporting of misinformation and fake news. As for user migration, this kind of online social media stands out for three specific aspects: i) through the mechanism of the hard fork, blockchains make available a tool to manage the creation of new platforms originating from the original BOSM, and support the migration of their users; ii) a hard fork, and the resulting user migration, is feasible only if there is a large consensus among the witnesses, i.e. we may expect leader-follower mechanisms driving the migration along with a substantial volume of migrating users; and iii) the implementation of a hard fork, i.e. a bifurcation of the main branch of the original blockchain, allows a precise tracking of all the interactions before and after the event, and the identification of all the users who migrate towards the new blockchain or decide to stay in the native one.

For these reasons, in this paper, we deal with user migration as a result of a hard fork in blockchain-based social media. Specifically, we analyze user migration through the lens of network science from a mesoscale perspective [1]. In fact, our main goal is to highlight the role of groups, identified through community detection algorithms [2], during the user migration process. It is well-established that groups or densely connected regions of a social network may exert pressure through peer influence on the choice of their members. So, groups may play a fundamental role when users have to decide to migrate or not; especially in BOSM, where the event causing the migration is a direct consequence of voting. Lastly, in our analysis, we also take into account that interactions in BOSM are richer than in traditional OSM, since the usual social interactions are complemented with monetary interactions and transactions supported by the underlying blockchain. Indeed, in this context, groups may arise not only by social interactions but also form around economical interests.

In the BOSM landscape, we focus on the ecosystem of social platforms based on the Steem blockchain, whose main member is Steemit, and Hive, the blockchain originating from a hard fork of the Steem blockchain on March 20, 2020. We gathered data from both publicly available blockchains and represented the interactions among their accounts by a multi-layer temporal network, so as to distinguish between the networked structure determined by social interactions and the one resulting from monetary transactions. Then, we identified groups - communities - on both layers by applying one of the state-of-art community detection algorithms for multi-layer networks. By inspecting users' activity on both blockchains we also identified users who have migrated after the hard fork. Finally, by combining the information about groups and migrating users, we analyzed how groups are composed in terms of migrant and resident users, and which are the relationships among the groups. The above analysis, applied on both layers, has highlighted the following main findings:

- the longitudinal analysis on networks derived from social interactions and monetary transactions has pointed out a negative impact of the hard fork for both the original and the new blockchain, i.e. lots of users decided to stay away from both platforms and to be inactive. Meanwhile, as for the active part of the audience, user migration has more widely affected users interacting through monetary transactions, in fact, half of them have moved to a new blockchain to do transactions.
- how groups - communities - are embedded into the network of the communities is crucial in determining whether their members will migrate or not. Specifically, marginal groups, loosely connected to the core of the community network are more likely to contain members who will migrate to another platform.
- the density of a group, i.e. how it is tight-knit, has a stronger impact on the decision to migrate or stay in the monetary layer rather than in the social one. It may be the first evidence that peer influence exerts more efficiently through economic interactions.

The paper is organized as follows. Section II introduces the concepts that are most relevant to our paper, and the related works on user migration in online social networks. Section III describes how we model the social and monetary interactions stored in the blockchains and the methods to identify and characterize groups and users who migrate. In Section IV we briefly describe the dataset, while Section V presents our results concerning how the properties of groups and the structure of the network among groups affect user migration. Finally, Section VI concludes the paper, pointing out possible future works.

II. Background and related works

Blockchain online social media: The introduction of blockchain technology in the ever-changing landscape of online social media has led to blockchain online social media platforms, BOSM in short. In a BOSM, the underlying blockchain stores the data and it is used for validation. BOSM offer a solution to some of the issues that plague traditional OSM. For example, BOSM are more resistant to censorship. Moreover, while on traditional OSM, users do not receive any compensation from the data they provide, in BOSM users are rewarded through cryptocurrency for their participation. In particular, a portion of the token produced by the blockchain is reserved for rewarding users who generate interesting and/or high-quality content on different topics such as movies, news, arts, sport and so on. Among the various BOSM, one of the most widespread is Steemit. Steemit is a social media platform launched in 2016, which was one of the first to implement a reward system. The platform is hosted on a blockchain called Steem, geared towards social media content. Steemit has gathered the interest of researchers for its characteristics. For example, we had some studies on social network structure [3], [4] and communities [5], economical aspects [6]–[8], text mining and bot detection [9], [10], and dynamical aspects [11].

User migration and hard fork: Online social platforms have always offered services to attract and support large and very active communities, but for different reasons some of their members have opted to migrate towards alternative platforms. Such a phenomenon is denoted as *user migration*. User migration is a "universal" process spanning both centralized and decentralized online social media, but in the latter case, it has some peculiarities. In BOSM, as in all blockchain systems, the reliance on consensus protocol means that fork events may happen, i.e. scenarios where miners change the consensus protocol. In soft forks, miners introduce changes to the consensus protocol that are still retro compatible with the previous consensus protocol. Thus miners will add new blocks to the same chain. This kind of fork is used to introduce small modifications to the consensus protocol, freeze account funds or revert certain transactions. On the contrary, for hard forks, miners will not recognize as valid the blocks validated with the different protocol. If the choice between protocols is not made, it will cause the creation of two different branches. Indeed, Steemit experienced a hard fork event: after a dispute inside the network, some of its users created the Hive blockchain through a hard fork; thus, effectively creating a new social media platform, with his own interface - Hive Blog - and cryptocurrency system, and causing a user migration which is still acting.

Despite being a common phenomenon in traditional online social media but also in the landscape of blockchain social media, user migration is not fully understood yet, mainly due to a lack of precise and high-resolution data on the process. Indeed, we find a few works on cross-platform user migration such as [12], which has analyzed user migration patterns, by matching user accounts through external data, such as BlogCatalog. Cross-platform migration has been also studied in [13], where authors have conducted a macroscopic analysis of user activity that relies on user surveys to understand the motivations behind migration. Specifically, the focus is on the permanent migration of users from Reddit to some alternative websites, where users are matched through an algorithmic approach. Other works focus on a more specific type of user migration, i.e. users migrating across communities in the same platform. For example, [14] has shown the presence of non-random migration patterns through a graph-based modeling which treats Facebook groups as vertices, while weighted edges represent the amount of users migrating across them. A different approach is the one by [15], who identify and quantify migration in COVID-19-related subreddits both at the microscopic (attention migration, shift of activity from post to post) and macroscopic time scale (shift of activity of entire groups).

Even though it is still an open problem, works on user migration are limited, mainly because it is hard to get reliable longitudinal data. Another important issue is user account matching i.e. tracking users across different platforms, as usernames could be different. Moreover, none of the above works is focused on the study of the impact of network structure on the migration of users, i.e. the goal addressed in this work. Blockchain technology enables this type of analysis since the access to its data offers researchers a source of reliable longitudinal data. And, unlike other platforms, in BOSM account matching is a straightforward task, as user accounts are duplicated during a hard fork.

III. Methodology

In this section, we present the methodology. We first specify how to model the dataset for the task, extract the network structure and define user migration-related labels. Then, we present how we perform the analysis at the mesoscopic level, i.e. the identification of communities and the creation of community graphs.

A. Modeling BOSM and user migration

All the actions supported by BOSM - which are also tracked and stored in the blockchain - form a varied set, where the usual "social" interactions lie alongside economical or financial operations, related to the transfer of cryptocurrency tokens. Moreover, each action is stored with a timestamp. In modelling this scenario, each action is described by a tuple (u, v, t, r), where u, v are users who interact through an action of type r at time t. From the sequence of all the users' actions, we can construct a multi-layer network $G_{T_{fork}} = (V, E, R)$, where:

- V is the set of users u in at least one interaction action in the set $I = \{(u, v, t, r)\}$ which has occurred before or at the timestamp T_{fork};
- E is the set of triple (u, v, r) with $u, v \in V$ and $r \in R$, which represents a specific type of action taking value on the set R of actions offered by the blockchain.

The resulting multi-layer network captures the structure of the interactions among users before T_{fork}, i.e. the date of the hard fork; while the layers correspond to the different types of action supporting the above interactions. In particular, here, we have grouped social and economical/financial interactions into two separated groups, thus reducing the number of layers in $G_{T_{fork}}$ to two, the "social" and the "monetary" layers.

Given this setting, we face the modeling of a fork event, and the subsequent cross-platform migration, where users might migrate to another platform. Specifically, given two platforms, S and H, and a fork event at time T_{fork}, we consider *a)* **Migrant**: a user who performs at least one action on the new platform H after time T_{fork}; *b)* **Resident**: user staying on the original platform S, without performing any actions on the new platform H after time T_{fork}; and *c)* **Inactive**: users who are inactive or abandoned both platforms.

B. Community graphs

Our main goal is to highlight the role of groups during the user migration process. In order to identify groups in the network structure, we rely on community detection algorithms. Then, we construct community graphs to perform our analysis.

Community detection: Among the possible state-of-art solutions for the identification of communities in a multilayer network [2], we decided to use Infomap [16], a community detection algorithm based on the notion of random walks. We selected this algorithm mainly due to its scalability [2]. In Infomap, a prefix-free code as Huffman is used to assign a codeword to each node. A random walk on the network can be represented as a concatenation of codes. The key idea is that once a random walker enters into a denser region - a group or community -, it will probably stay there for a long time. This happens because each node is more connected with nodes in the same region w.r.t. external nodes. Assigning a different codebook to each region, called *module*, we can shorten the codewords that refer to nodes in the same region. So, communities in a network can be detected by finding the partition that minimizes the code length. As we are working on a multi-layer network, we rely on the multi-layer version of Infomap [17]. The multilayer Infomap works similarly to the single-layer version. In this case, the same user is present in both layers, and we connect the users with inter-layer edges. This way, the random walker can follow a path, using the inter-layer edges to reach the edges of another layer. It is worth noting that the same user may belong to different communities depending on the layer, but still considering information from both layers.

Therefore we can define *social communities* as the community assigned to each node in the social layer, and similarly *monetary communities* for the monetary layer.

Generating community graphs: To understand the role of groups in user migration, it is also important to highlight the relations among them. To this aim, we define the community graph $G^C = (V^C, E^C)$ as an attributed network, where the nodes are communities, and links represent connections between users in different communities, i.e. we have a link between communities c_1 and c_2 if there is a link between a user in c_1 and a user in c_2, weighted by the number of links connecting nodes in c_1 and nodes in c_2. This construction can be applied for both social and monetary communities, so we obtain a *social community graph* and a *monetary community graph*.

As attributes for a community c_i, we consider the number of inactive, resident and migrant members. Moreover, to characterize how a community is unbalanced towards a specific category of users (migrants or residents), we compute the community entropy $H(c_i)$, defined as:

$$H(c_i) = \sum_{q=1}^{m} p_q(c_i) \log_2 p_q(c_i)$$

where $p_q(c_i)$ denotes the fraction of users in community c_i with label $q \in \{resident, migrant\}$.

Finally, we also consider the subgraph induced by the nodes in a community c_i and compute its density $\frac{|E|}{|V|*(|V|-1)}$, where $|E|$ is the number of edges in the subgraph and $|N|$ the number of nodes.

C. Analysis of community graphs

Given the community graphs, we perform three types of analyses. First, we conduct an analysis of the community graphs by focusing on the connectivity among communities, as a function of the migration status of the community members. Then, we analyze the density and entropy of the communities as a function of the migration labels. Finally, we follow up with a quantitative analysis. For each community we consider the number of inactive, residents, migrants, its density and its entropy, and measure the correlation between the selected community features, focusing on density and entropy with respect to other features.

It is to note that some communities may have too few nodes, or even no links inside, since nodes can belong to the same community because of information coming from the other layer, without being directly connected - a side-effect of multilayer InfoMap. Finally, we may have communities made up of only inactive nodes, or with a majority of inactive nodes. We discard this kind of communities from our analysis.

IV. Dataset

We study the impact of the mesoscale properties of the network layers on user migration, using data from the blockchain Steem and its new derivative blockchain Hive. All actions are memorized as transactions in the supporting blockchain. All the interactions are saved as operations and a complete list is available for both platforms, Steem and Hive [18], [19]. In this work, we focus on actions that represent an interaction between users. More precisely, we study two main groups: *i)* financial and *ii)* social operations. Financial operations are those operations designated for rewards and token management, asset transfer and share transfer; whereas social operations are those that users usually do on traditional social media platforms, like posting, rating, voting, sharing and following.

All blocks and the corresponding operations can be gathered through official APIs. For the construction of the graph, we gathered operations from the very first block on Steem blockchain, produced on 24th March 2016, up to the fork event, i.e. to block $41,818,752$, with timestamp *2020-03-20T14:00:00*. While for migration status, we examine data after that timestamp, and up to January 2021. Overall, from Steem blockchain, we extract $993,641,075$ operations related to social interaction actions and $72,370,926$ operations related to financial actions; from Hive blockchain we get a total of $206,224,132$ social operations and $4,041,060$ financial actions.

TABLE I: Statistics for the multi-layer network $G_{T_{fork}}$, grouped by social and monetary layers.

	Social layer	**Monetary layer**
Nodes	1352114	1247587
Edges	217926899	5056317
Inactive	1287321	1218535
Resident	43339	12757
Migrant	21454	16295

V. Results

A. Multi-layer network and user migration

We apply the methodology presented in Section III, relying on the Steem/Hive dataset, to obtain a multi-layer network with two layers: *social* and *monetary*. Then, according to the definitions in Section III, we label each node based on its activity after the fork. A summary of network statistics and labels is shown in Table I.

The social layer has overall more active users and more links. It is in line with the type of operations considered, indeed, social operations are much more frequent than monetary transactions. But, although the monetary layer has fewer links, it still involves a comparable amount of users, i.e. the volume of nodes is more or less the same as in the social layer. Moreover, as for the migration-related labels, we observe that a lot of nodes became inactive in the following 9 months in both layers, pointing out a *general negative effect of the hard fork for both blockchains*. Finally, we also note that the social and monetary layers differ when we focus on the fraction of resident and migrant users. In fact, in the social layer, most of active users are resident, i.e. one-third of the active users has migrated to Hive; while *in the monetary layer* we observe an opposite trait where *user migration has had a stronger impact, i.e. the majority of users has decided to migrate to Hive to do their financial transactions*.

B. Community graphs

Applying the methodology in Section III, we generated the monetary community graph and social community graph. The community graph in the monetary layer is composed of 76 communities, 252 inter-community edges, and the community graph for the social layer is made up of 105 communities and 205 inter-community edges. We visualize the obtained community graphs in Fig. 1, where nodes - communities - are colored according to the fraction of migrants and residents among their members.

Connectivity: Considering only node coloring, we note that migrant communities tend to be marginal in the community graph, with few or no inter-community links. This trait can be observed in both layers, monetary and social. We can also observe that there is a more central part in the community graphs, composed of very connected communities whose majority of members are resident. Whereas, only a few communities with a majority of migrants are connected to the central core of the

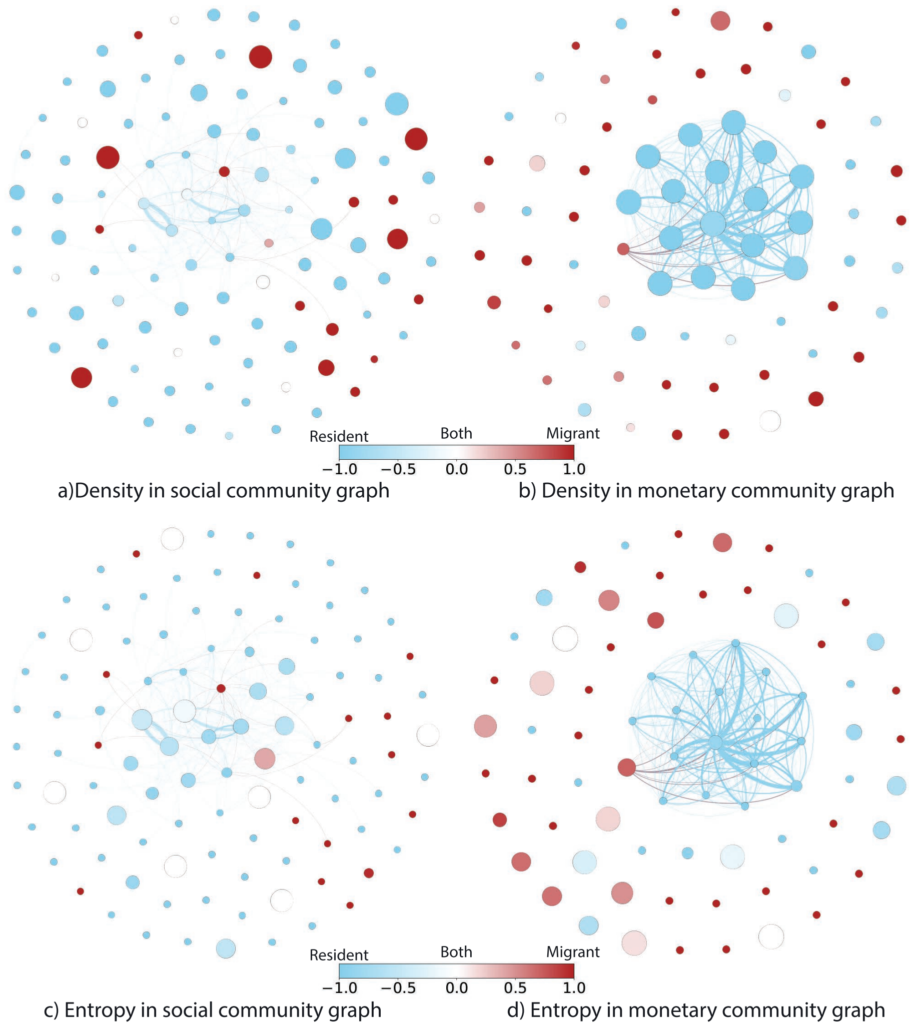

Fig. 1: Community graphs, for social layer - left - (105 communities, 205 inter-community edges) and monetary layer - right - (76 communities, 252 inter-community edges). In a) and b) community node size is proportional to its density. In c) and d) node size is proportional to its community entropy. We use colors to represent the majority between migrant and resident nodes: communities with more residents will go towards sky blue, while more migrants will lead to red nodes, white is for nodes with a balanced mix of both. Edge width is proportional to the weight of the inter-community edge.

community graphs. The isolation of migrant nodes and migrant communities is an important first evidence of the importance of network structure. *Being marginal for a community may be a trait that can lead to the migration of the majority of its members*.

Density and entropy: For the evaluation of the impact of community density on migration, we focus on the size of the community nodes, for the social community graph in Fig. 1a and for the monetary community graph in Fig. 1b. From a visual inspection of the network representation of the social community graph, we can observe that among the densest communities, we find both resident and migrant communities. A clear difference is missing. On the contrary, in the monetary layer, we can observe that the highest density values are mostly for resident communities; in particular, as for the communities in the more central part of the network.

Similarly, we consider the size of communities for the study of entropy values, looking at the social community graph in Fig. 1c and at the monetary community graph in Fig. 1d. We observe that entropy values are pretty similar in the social layer. Entropy values are high across all communities, and we cannot observe particular differences. On the monetary layer, we can observe a more diverse situation. First, the communities in the central part are characterized by low entropy values, so they tend to be connected with other residents. Then, we observe high entropy values in isolated communities, both resident and migrant communities. Overall, entropy does not help characterize the two groups.

Community features correlation: We then move on to the quantitative analysis of the relationship between the network structure (density and entropy) and the migration decision (inactive, resident, migrant). We computed correlation statis-

TABLE II: Correlations on community properties in the social layer. p-values are reported in parenthesis.

	density	entropy
inactive	-0.187 (0.057)	0.176 (0.073)
resident	-0.123 (0.211)	0.025 (0.797)
migrant	-0.075 (0.448)	0.357 (0.005)

TABLE III: Correlations on community properties in the monetary layer. p-values are reported in parenthesis.

	density	entropy
inactive	-0.296 (0.009)	0.164 (0.157)
resident	0.583 (0.0)	-0.209 (0.07)
migrant	-0.275 (0.016)	-0.060 (0.608)

tics between the above community features, considering the communities on the social and monetary layers. In Table II we report the obtained correlation measures for the social communities.

We can observe that for the social communities, density has a slightly negative correlation with the number of resident and inactive users, while there is no correlation with the number of migrant users. This is in line with the previous visual inspection based on network representation. Whereas, entropy shows a significant positive correlation (p-value ≤ 0.005) with the volume of migrants.

The same analysis has been conducted on the communities in the monetary layer. We report the correlation measures in Table III. Here, we can observe that density has a moderate positive correlation with the number of residents, with a negative correlation with the presence of migrant nodes. In line with the visual analysis, we have that density characterized monetary communities composed of residents, while migrants are more loosely connected. On the same note, entropy shows a slight negative correlation with the number of resident nodes.

So even at a quantitative level, we can confirm that group density can characterize users at a mesoscopic level. On the contrary, entropy did not provide helpful insights.

VI. Conclusions

Blockchain technology is supporting lots of services, among them online social media. Similarly to their centralized counterparts, BOSM can run into user migration events, a phenomenon becoming ever more common among social platforms, but not much explored yet, mainly because it is hard to get reliable longitudinal data, and it is difficult to perform account matching.

In this work, we addressed the open problem of user migration due to hard fork events occurring in BOSM. Specifically, we investigate the impact of network structure in the decision making: either to stay (resident) or leave (migrant). By focusing on groups and their relationships, we highlighted differences in the network structure between these two classes of users. Specifically, from the analysis of the density of groups, we can conclude that density is an important feature for groups made up of residents, primarily in the monetary layer. The impact of density is an important result in the field of user migration since this indicates that network structure should be considered for user migration-related tasks, such as migration prediction. These findings may extend to other blockchains, as they show the importance of designing proper consensus protocols to handle turning-point events.

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