Motivating the non-technical participation in technical communities

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***Abstract*—Technical communities are social structures that emerge around the interest of individuals to build and deploy their own technology or communication infrastructure, such as wireless community networks. In these communities, the access to shared resources is regulated by incentive mechanisms, which are usually based on the members' contributions. Typically, technical contributions are computed by these mechanisms, ignoring the non-technical activities that members voluntarily perform to keep the community alive, e.g., administration and coordination of the tasks performed by the sub-communities. This article presents a regulation mechanism that rewards not only the contribution of shared resources to the community, but also the participation of the community members in non-technical activities. This proposal was evaluated using simulations, and the obtained results allow researchers and managers of technical communities to build appropriate incentive mechanisms that rewards both, technical and non-technical contributions of their members.**

***Keywords*— Incentive mechanism, regulation mechanism, technical communities, non-technical activities, cooperation effort.**

I. Introduction

During the last years, the Wireless Community Networks (WCN) have showed up as a cutting-edge model of open communication infrastructure, as they offer low-cost but participatory connectivity to citizens. These novel infrastructures are built, operated, maintained and owned by the citizens themselves in a voluntary fashion. Many WCN succeeded in the recent years as non-profit actions, thanks to the progress of ad-hoc wireless technologies. Guifi.net [1], Athens Wireless Metropolitan Network [2], FunkFeuer [3], Seattle Wireless [4] and Consume [5] are some of the most fruitful exponents of WCN.

Beyond Internet access provision, the WCN can also provide several services to their members (e.g., distributed storage, peer-to-peer streaming or monitoring applications). These services are typically provided in an open-access fashion, without any regulation to use them. As a natural evolution, some community networks are looking for ways to implement high-level applications [6] that need to regulate the way in which the community members interact with the computational resources [7]. The feasibility of implementing these systems is highly dependent on the ability of the community to incentivize, rank and evaluate their members' participation.

In this paper we propose a regulation mechanism, able to reward users, not only for their effort in contributing with physical resources to the community, but also for their work on non-technical activities that benefits to the community (e.g., managing the community mailing list or coordinating the supporting activities performed by some community members). Using this regulation mechanism, participants in technical communities, like WCN, will be willing to contribute more often in non-technical activities. Moreover, those who are already dealing with these tasks can get a higher reward when they need to use the community applications or infrastructure.

In order to evaluate the proposal, we conducted several simulations using an extended version of the Iterated Prisoner's Dilemma (IPD) framework. We modified the payoff matrix of the IPD to include a small *social reward*, which represents a compensation for users involved in non-technical activities.

Next section presents and discusses the related work. Section III describes the extended version of the prisoner's dilemma framework, which helps increase the cooperation of community members, in non-technical activities. Section IV presents the evaluation of the proposed framework, which was done using an evolutionary simulator. The obtained results were compared with different payoffs configurations and users' behavioral rules, for which we provide empirical numbers to build the overall payoff matrix. Section V analyzes and discusses the impact of the proposal on a real technical community. Section VI presents the conclusions and future work.

II. Related Work

This proposal is inspired in the work presented in [8], where the authors analyze the impact of social pressure on the users' cooperation and consensus, using an evolutionary simulator. That work was focused on the community internal pressure caused by users' surroundings, and it modelled the social pressure as an external source. In a recent work Vega et al. [9] analyze the social effort in participatory networks, trying to determine how to provide representative rewards to users devoting time and effort for the community welfare.

In a recent theoretical and experimental study [10] the researchers explored the cooperation engagement in a technical community, by using external sources. The results indicated that the choice of community members between cooperate or defeat, is governed by a death-bird update cycle. However, in our case, we assume a common behavior for the whole community, which is updated by the social pressure of the neighboring nodes (i.e., other community members).

Many other research works have appeared recently trying to model this problem using a two-layers structure of nodes. This approach allows studying the influence that the nodes behavior in a layer has on the other layer. In [11, 12] the researchers built a two-layers network in which nodes play independently and strategically a cooperation game. These works study how cooperation emerges, by allowing some sporadic interactions between the sub-communities.

The study presented in [13], instead, shows how the imitation rules of the nodes can be influenced by strategic choices made in a social network. The work reported in [14] considers two sub-communities that cooperate strategically, and shows how they update their cooperation rules between layers using a learning process. All these works are useful references to realize how the community members interact among them; but they do not consider promoting cooperation between a fraction of the players (e.g., those that are willing to perform non-technical activities in favor of the community). Additionally, they assume that the community – or a fraction of it – acts strategically; however, we assume a social imitation.

Concerning our application domain; i.e., wireless community networks, the access to the shared resources has to be regulated to avoid the potential lack of provisioning or the drop of the quality of service. Direct reciprocity mechanisms are a common way to incentivize users' participation, by rewarding the users proportionally to their contributions. The notion of effort in resource-sharing scenarios has been explored recently in [15], but in that work authors did not consider the tasks related to the non-technical activities. Therefore, the support to some community members depends on the altruistic help of others.

Introducing a social reward to users doing these activities can incentivize to other people to imitate such behavior. In a wireless community network, this work could be measured through users' interactions on the mailing lists [9], while in a peer-to-peer file sharing community can be measured through the users' involvement in developing the software rather than sharing content [16]. Next section describes the proposed model to help address this challenge, which was instantiated by using the Prisoner's dilemma framework [23] for evaluation purposes.

III. Rewarding Model

The Prisoner's dilemma is a well-known framework used in social sciences to evaluate the interactions between people, when they have to decide between to cooperate in favor of the society, or defeat in favor of their self-interest.

The typical payoffs matrix has these two actions (Table I). The relation between the different possible payoffs follow the rule $b > 1 > \varepsilon \rightarrow 0 > c$, which poses the dilemma.

Despite that strategically the defection option is dominant over the cooperation strategy in a two-players game, the consequences for the community in the long-term would change some players' decision. These changes can be a result of the network topological structure [17], the dynamics of the users' interactions and the strategic thinking of individuals [8].

TABLE I. Payoffs Matrix

Player Decision	Co-player Cooperate	Co-player Deflection
Cooperate	(1, 1)	(c, b)
Deflection	(b, c)	$(\varepsilon, \varepsilon) \rightarrow 0$

Without loss of generality, we can fix the values of punishment to defeat (ε = 0.05), and the value received for cooperating (c = 0). Thus, we can study the influence of the other parameters in the game, which would allow performing a simplified analysis of the results [18].

In order to evaluate this proposal, we extended the regular version of the prisoner's dilemma game to include a social reward (α). This should incentivize players who perform useful non-technical activities in favor of the community (Table 2).

TABLE II. Extended Payoffs Matrix

Player decision	Co-player Cooperate	Co-player Deflection
Cooperate	$(1 + \alpha_1, 1 + \alpha_2)$	$(c + \alpha_1, b)$
Deflection	$(b, c + \alpha_2)$	$(\varepsilon, \varepsilon) \rightarrow 0$

Notice that the parameters α_i are applied only to a portion of the community, and only when they decide to cooperate with their neighbors. Additionally, the α value for a single user is a private value, only known locally.

To prevail the dilemma in this game, the punishment parameter ε must take a value in the interval [0,1), and the payoffs rule must be updated to $b > 1+\alpha_i > \varepsilon \rightarrow 0 > c+\alpha_i$ for all *i* nodes. After the simplifications of the reward and punishment values, we can state that the α interval must be (0.005, 0.4). If this relation is preserved, the participants do not need to known the value of their neighbors' social reward *(α_i)* to decide if cooperate or defeat, because such a value does not influence the game. Therefore, the game could be simplified to a symmetric version, where the unknown information does not change the philosophical dilemma.

As our extended version of the game prevails the original Prisoner's dilemma spirit, it is well-known that the rational choice is always to defect, not only to prevent betrayals by other players, but also because it always gives higher payoff, no matter what the other player does (it is a Nash equilibrium [19]). However, it is also clear that the community welfare would be higher if both nodes decide to cooperate, and just here lays the dilemma. In order to address this challenge and understand the consequences of our proposal, we developed two extended versions of the prisoner's dilemma framework.

Extended Prisoner's Dilemma (EPD): This version corresponds exactly to the model described before, where for each interaction between two players, we add a social reward in case of cooperation.

Minimum Extended Prisoner's Dilemma (MEPD): In order to test the consequences of smaller changes into the original prisoner's dilemma game, we modified our extended payoff matrix. In this case the social reward is only added to each node once per round, resulting in smaller increments of the payoff for the cooperating nodes.

A. *Systems dynamic*

During the first round of the IPD game, all nodes make an individual decision between cooperate or defeat against their partners; these alternatives have equal probability to be chosen. During the next rounds, the system dynamic is controlled by the update strategy of the nodes (i.e., the nodes can change their cooperation strategy depending on the results of the past rounds). We evaluated our proposal using several update strategies, which are representative of the way that users make decisions in their real life [20].

Voter Model (VM): When users adopt this strategy, they behave similar to a particular neighbor. This imitation process has shown to be representative of many people during electoral processes [21], and it is a suitable manner to use social imitation mechanisms to deal with a strategy problem.

Unconditional Imitator (UI): This strategy is similar to the previous one, but the user imitates to the neighbor with the best payoff, provided that such value is larger than his own. The UI strategy might resemble the actions of the people in real life, when some neighbor has enough information to make suitable decisions [20, 22].

Replicator Rule (REP): With REP nodes choose a neighbor at random. Then, if the payoff of the chosen neighbor is larger than the node's own, the node adopt the neighbor's strategy with a probability proportional to the difference between both payoffs. In other case, nothing changes. REP is pairwise and stochastic; i.e., a node decides how to evolve, watching only one neighbor per round, and the result of the evolution is not univocally determined.

Moran Rule (MOR): In this case, a node select a neighbor with probability proportional to their payoff, without considering whether it is larger than its own or not [8]. MOR works as a local and stochastic process that allows the individuals to make mistakes; i.e., there is a non-zero probability to imitate a neighbor with bad fitness. This strategy can be considered as a weighted social imitation, where the weight is the success of the observed node.

B. *Simulation model*

The model used in the simulations for evaluating the proposal involved 216 nodes, distributed in a Torus topological network with degree 6. This topology was chosen as an example of network, where nodes share the same topological properties (e.g., clustering or degrees). The number of nodes and degree considered on the model were selected to represent smaller communities with high connectivity.

Each node interacts directly only with its neighbors in the topology, playing one of our extended versions of the Iterated Prisoner's Dilemma game [23]. Therefore, in each round of the simulation, the nodes choose between *cooperate* with others or *defeat.* Then, they collect the payoff of their actions according the game evaluated for each pair of nodes.

Each experiment of this study involved simulations performed over a discrete scenario with 1000 rounds. The first 750 rounds were discarded to be considered transitional. A previous work [8] has shown that this number of rounds is enough to have a stable cooperation density in random and scale-free networks of this size. We evaluated and verified that the stability also holds with our extended versions of the prisoner's dilemma framework, involving 216 nodes that interact through a torus network with degree 6. Additionally, we repeated each experiment 10 times to avoid random effects on the results.

The simulation process starts by randomly placing two sets of nodes in the topology (i.e., users with some social reward and those without it), with a proportion p and $(1 - p)$ respectively. Then, for every combination of values, 10 different simulations were performed, replacing the type of the nodes, and measuring the effect produced by this parameter variation.

IV. Influence of The Social Component

The approach used to validate the proposed incentive schema was based on the observation and analysis of the cooperating nodes density, when the framework arrives to a steady state. First, we studied the influence of both, the incentive parameters and the nodes' update strategy on the whole community. We found that in some cases, the cooperation was broken and never recovered using these strategies; however, in the other cases our proposal achieved at least the same overall cooperation level (i.e., for each node). Second, we analyzed the effect of the social reward on each group; i.e., the rewarded nodes and the rest of the community.

A. *Positive and negative effects on the community welfare*

The most straightforward way to determine the effects of the proposed incentive model, is measuring the average of cooperating nodes density, as function of the parameter α, and then compare the results with the regular PD. Fig. 1 shows the improvement of the EPD for two specific strategies (REP and UI), with a reward to betrayers b = 1.1 and 20% of users socially rewarded from 0.005 to 0.045. The improvement was calculated as the difference between the average cooperation during the last 250 rounds for each individual simulation. Positive values represent improvements produced by our proposal, while negative values represent the opposite.

In Fig. 1 we can also see that when the community uses a UI strategy, it is not clear which of both frameworks – PD or EPD – is more beneficial for the social welfare of the community. However, when the users use a REP approach on the EPD framework, there is a higher probability of improving the cooperation inside the community.

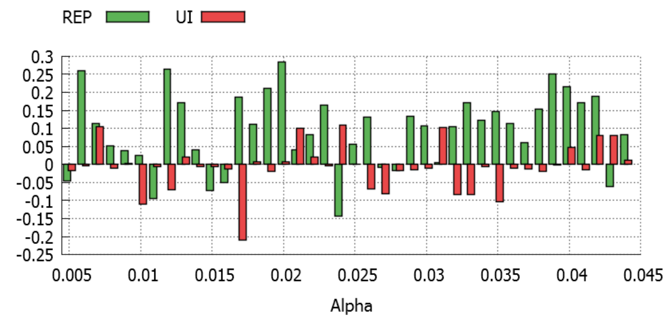

Fig. 1. Average cooperation density using the REP and UI strategy.

The presented results are not enough to make strong conclusions about the existence of minimum values of α that ensure higher incentive using the EPD framework. However, Fig. 1 shows that, as a general rule, higher values of α appear when the EPD framework is used. As an example, less than 9% of the values of α above 0.02, have generated a negative impact higher than 0.03.

Fig. 2 helps us understand how each update strategy influences the cooperation on the three PD frameworks. Comparing the overall behavior of the system, we can state that MOR strategy does not allow the cooperating nodes to survive despite the used incentive mechanism. On the opposite side, the VM and UI update strategies are appropriate for reaching high percentages of cooperating nodes.

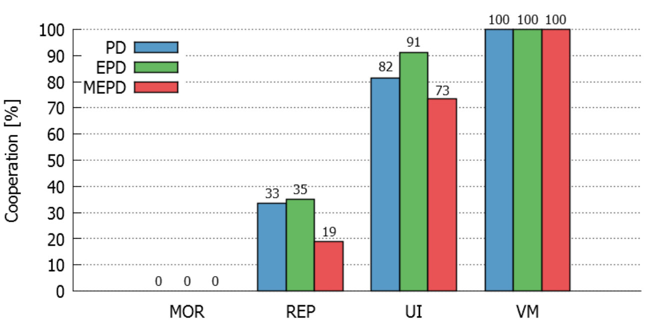

Fig. 2. Average cooperation density using three PD frameworks with different update strategies.

The minimum values of social reward were reached using the MEPD framework. This happens because the small changes introduced in the MEPD payoff matrix played a negative effect in the cooperation level of the system. Therefore, we can argue that when nodes compare their payoff after each round, the contribution of the social reward to nodes' payoff is not enough to surpass the effect of the temptation reward, and hence, most of the socially rewarded nodes decide at some point to imitate some defeater neighbor.

The EPD payoff achieves about 11% of improvement, compared to the regular PD payoff value reached when users' update their cooperation decision using all the information about their neighbors (i.e., a VM strategy). However, the EPD framework does not affect the density of cooperating nodes when decisions are taken locally (i.e., when using VM and REP strategies).

B. Influence in presence of highly defection reward

Provided the previous results have been obtained for a specific combination of payoff values, it is important to check their generalization when the relationship between the payoffs changes. Fig. 3 shows the average cooperation percentage achieved by the community for different simulations, using a VM update strategy, an EPD payoff matrix and a 60% of socially rewarded nodes. The results show that regardless the reward value (α), as the reward to the betrayers (b) increase from 1.1 to 1.4, the overall cooperation drops from 100% to almost 0%. However, it is also noticeable that higher values of social reward can help system designers to maintain the cooperation density between reasonable values.

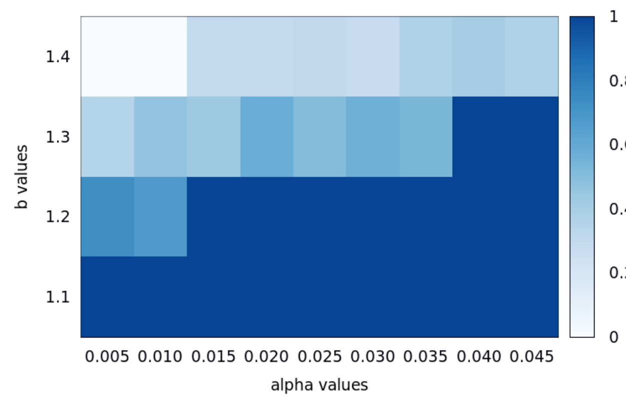

Fig. 3. Average cooperation density of VM strategy, as a function of b and α.

This result has a number of implications about the basic equation that we have assumed for the PD framework. For instance, and additionally of the ratio between the temptation value b and the punishment value ε, the designers have to carefully consider the implications of the α, which – in a limited way – can play a role similar to ε during the game. However, as the social reward only needs to be applied to a fraction of the community, it avoids increasing the payoff to mutual cooperators. Provided the social reward cannot exceed the value of ε, these strategies cannot deal with high values of b, like 1.4.

The relation between both, b and α has also been observed in other combinations of update strategies and percentages of nodes. However, sub-communities involving socially rewarded users need a higher α to counter-balance the increments of b.

C. Impact on the individuals

While there are some advantages for using the proposed framework, it is not clear how much this mechanism improves the willingness of the cooperating nodes. Fig. 4 shows the distribution of cooperation percentages achieved by the nodes of the two studied groups, considering social rewards values higher than 0.025. Each line represents a users group (i.e., with and without reward), using $b = 1.1$ and a REP update strategy.

The results indicate that higher percentage of nodes incentivized by the proposed model, have high cooperation values with their peers. Particularly, when α = 0.45, the socially rewarded users that have over 80% of cooperation, increases 12.5% (see the bottom-right plot in Fig. 4).

However, our findings are counter-intuitive about the nature of the update process. The simulations using the UI strategy show that the distribution of both users groups have no statistical difference, although the EPD strategy increased much more the community welfare. This suggests the need of conducting additional research to understand the differences between the imitation processes taken locally, and those taken considering larger fractions of the community.

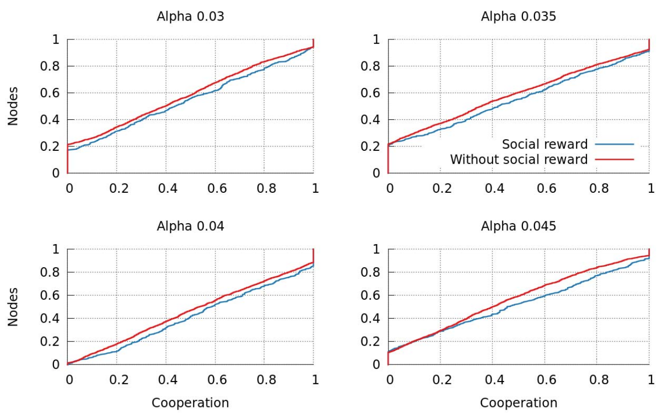

Fig. 4. Users' cumulative cooperation distribution as a function of alpha.

V. Evaluation Using a Real Community

Is apparently clear that rewards should be assigned to people contributing to the community welfare, even if they perform non-technical activities. Through an exploratory study we extended the PD framework in order to consider a social reward for community members doing these activities.

The first observations lead to the conclusion that even small values of social reward, have a direct impact (mostly positive) on the overall community cooperation level. It happens because (1) the risk to be defeated after a cooperation has also been reduced for some nodes, and (2) the reward to users that conduct a mutual cooperation has been increased. This consideration is consistent with the results reported in [24], where it is shown that individuals tend to react more positively to truly rewards on cooperation in the context of a public goods experiment.

Our study also found that there is a threshold (α = 0.02) over which the difference in cooperation using the EPD framework is always positive, even in presence of high rewards to betrayers. The other parameters of the game, such as the users' update strategy and the percentage of rewarded nodes, can drastically modify the impact of α and b. Therefore, it is important to consider that the proposed mechanism only incentivizes the target community, when users' update their strategy using local information.

In [15] the researchers discovered that in cooperative peer-to-peer communities, where people can freely choose their cooperate level, a wide range of ratios can be found. In [25, 26] the authors identified similar situations in online social networks; therefore, we considered these aspects to evaluate the robustness of our proposal.

In order to do that, we used real data from users' behavior gathered from Guifi.net [1], which is (to the best of our knowledge) the largest active Wireless Community Network.

A. *Evaluating the usefulness of the incentive mechanism*

For the evaluation purpose, we analyzed the interactions between users in the Guifi.net mailing lists, and extracted the number of messages sent by each member. The dataset had 776 users and a total number of 2,517 messages. Then, we computed the cumulative distribution function of the interactions between users, and we removed all the values below a given percentile (q). As a result, we have a function that describes the distribution between the different social efforts done (measured as the number of messages sent) by the (1–q) percentage of most active users in the network. Finally, the distribution has been normalized to the range [0.025, 0.045], in which the α values ensure a higher percentage of cooperation for the rewarded nodes.

This method has two clear advantages: (1) it can be adapted to any probability distribution regardless the way used to compute the social effort, and (2) it allows visualizing the heterogeneity of the users' social effort.

B. *Impact on the individuals players*

Fig. 5 shows the distribution of cooperation percentage achieved by the nodes, when some portion of them (p) is rewarded using the proposed motivation mechanism. Each line represents a group of users, considering b = 1.1, and a REP update strategy, to make the results comparable with those presented in Section IV. The cooperation percentage of each node represents, as always, the average number of rounds in which the node decides to cooperate, considering the 250 rounds.

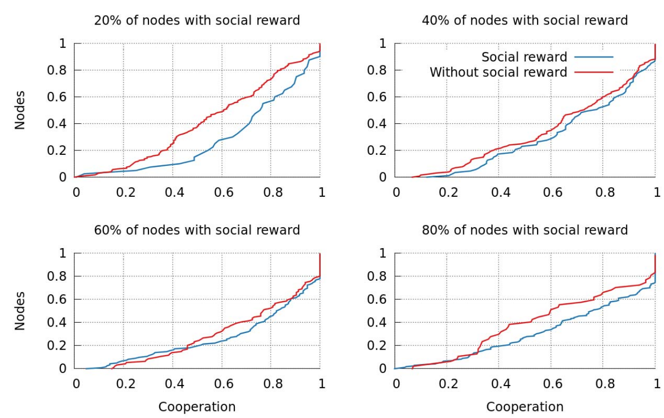

Fig. 5. Users' cumulative cooperation distribution using a realistic distribution of social reward values.

As shown in Fig. 5, a higher percentage of users with positive values of α, produces higher cooperation levels when they play the extended versions of the PD, as we expected according to our framework. Then, we evaluated the system using the same distribution of α, but with higher percentages of rewarded nodes. It was done by adapting the top percentile of messages (q). We found that unlike the theoretical results – where the difference between the PD and the EPD strategies increases proportionally with the number of rewarded nodes –, when we applied a more realistic distribution, the improvement of the cooperation is almost unnoticeable if the size of both nodes groups remain similar. The most intuitive reason to explain such a phenomena is that more scaled social rewards could mask the difference between rewarded and no-rewarded nodes.

VI. Conclusions And Future Work

In this paper we have proposed a model to incentivize community members to perform non-technical activities that contribute to the community welfare. Such a model was implemented as an extension of the prisoner's dilemma framework, and thus it can be evaluated.

The evaluation involved two independent experiments using an agent-based simulator. The first one considered a theoretical scenario and the second one involved traces of real users that participate in the Guifi.net community. The obtained results identified the ratio between betrayers' payoff and social payoff, as the most influencing factor for the social welfare. These results also show that limiting the number of benefited users, to a small percentage of nodes with high social reward, the system leads to higher cooperation ratios.

The article also show the practical usefulness of these findings in a more realistic scenario, by mapping the social reward to the distribution of messages sent by participants in a real wireless community network; particularly in Guifi.net [1].

Concerning the dynamics of the system, we evaluated the proposal using several update strategies, which are representatives of the way in which people make decisions in real social communities. The results indicate that the proposed incentive mechanism only needs to be applied to a small portion of community members.

Several research works report that some participants on resource sharing and volunteer computing systems make decisions strategically, intending to take advantage of the incentive system, instead of imitating the behavior of other members. Studying this aspect of a technical community is part of our future work.

Acknowledgments

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