

# Aligning the Incentives for Social Media Distribution

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## ABSTRACT

One of the key challenges in digital media distribution is digital rights management (DRM). DRM is a classic example of a problem that arises due to incentive misalignments that exists among transacting parties in a network. Because of misaligned incentives users have the inclination to break DRM if it becomes technically possible. This paper draws upon work in group lending and social psychology to develop a novel social media distribution scheme. The key objective is to fix the incentive misalignment that exists between the users and media distributors. Using game theoretic modelling, certain conditions that should hold for social media distribution to work are deduced.

## 1. INTRODUCTION

Digital media goods such as movies, books and software are different from non-digital media goods such as paintings. Once a *master* version of a digital good is created it can be copied as many times as needed creating an exact replica of the master each time. This property helps to keep the prices of the digital media items low because the production cost can be recovered over the sales of a large number of items instead of recovering the cost on each item. However, because a buyer is getting an exact replica of the master, the buyer can make copies and illegally resell the item (*content piracy*). Although there are arguments to the contrary [18], piracy is widely believed to reduce the total revenue generated by the producer. Therefore, most digital media goods created by profit seeking institutions are distributed under strict copyright conditions that make redistribution illegal. Over the years many efforts have been made by the producers to enforce the copyright restrictions. We classify these efforts as follows:

- *Digital locking*: Software and hardware techniques (collectively referred to as the *Digital Rights Management* (DRM)) to control the rights end-users have to copy and use digital content [6, 7, 12]. Unfortunately, none of the proposed digital locking techniques are fail proof on commodity hardware.
- *Legal measures*: The DRM techniques are often bolstered by laws [26] that can be used to punish violators. In many instances, the *Recording Industry Association of America* has brought lawsuits against individuals or organizations for consuming or distributing pirated content.
- *Reducing availability*: Increasingly, the Internet is be-

coming the preferred distribution mechanism for pirated content. This also provides another strategy to combat piracy – reducing the availability of pirated content. For example, availability can be reduced by using legal means to take down distribution sites or inject polluted content into the distribution sites [8].

The underlying strategy in the above approaches for anti-piracy is to raise the cost of piracy. For example, by reducing the availability the user is made to spend more time looking for an appropriate copy of the media item. Similarly, legal measures elevate the risk of being prosecuted for consuming or distributing pirated content. The effectiveness of the above techniques lie in the net benefit users gain from piracy. As the cost of purchase for media items increase, the net benefit can be sufficient to influence the users to break DRM.

The above observation has motivated a recent thread of research [5, 25] focused in adjusting the cost of purchase to influence users' to uphold copyrights. For low cost media objects (e.g., songs) this idea is already adopted by media distributors such as iTunes, where the price of a media item is set to elicit the best user behavior. Another approach to adjusting the actual selling price is to provide discounts and tie the discounts to user behavior. Only users who establish their non-pirating behavior should have access to the maximum discount. The key problem with tying discounts to user behavior is tracking user behavior and grouping users.

A straightforward tracking strategy where users' devices are instrumented to provide feedback on their media copying activities (e.g., Sony rootkits) creates significant overhead and privacy concerns. With the current privacy conscious atmosphere on the Internet, deploying any individual monitoring strategy would be almost impossible. Therefore, our research explored alternative approaches for user classification.

One problem that has a similar risk profile as media distribution is money lending. In money lending, a credit union faces risk because it cannot completely observe the actions of the borrowers (i.e., hidden actions). One way the credit union can cope with the risk is to make the repayers subsidize the defaulters (borrowers who do not repay the loan). A similar situation exists in media distribution as well where non-pirating users subsidize pirating users. Making the non-pirating users shoulder the losses caused by the pirating users will only motivate them to switch strategies from non-pirating to pirating. Instead, we need techniques that can isolate pirating users and provide incentives for non-pirating

users. Group lending [10] is one strategy used in money lending that *localizes* the rewards and punishments. Many field studies including the highly successful Grameen Bank have used group lending to provide micro loans to stir economic activity among poor rural peasants.

The *social distribution network* (SDN) we propose in this paper leverages ideas from group lending to create a novel media distribution scheme, where economic incentives and social pressure is used to encourage users to segregate into groups. The groups receive discounts based on their purchase and piracy histories. SDNs can be overlaid on *on-line social networks* (OSNs) such as Facebook. An SDN is rooted at the main content distributor (e.g., iTunes store) and have intermediaries called neighborhood distributors through which the user groups are canvassed.

Various challenges for digital media distribution on the Internet is discussed in Section 2. Section 3 presents the design and rationale for SDNs. In Section 4, we use utility based analysis to establish the necessary conditions for key strategies within the SDN. Section 5 examines related research and highlights the key differences.

## 2. MEDIA DISTRIBUTION CHALLENGES

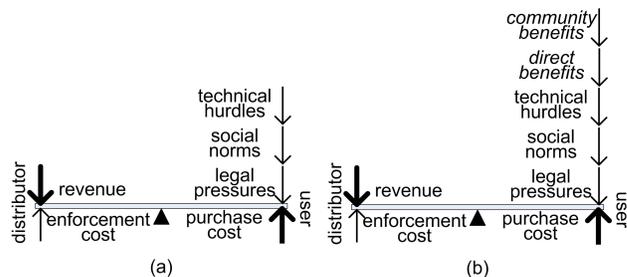
Media distribution on the Internet faces many challenges. The focus in this section, however, is on the challenges emerging from the rights management concerns. Some of these challenges arise from the technical limitations of the Internet, while others have social and economic factors behind them.

**Reliable identification:** Rights management often requires identification of users and content. In particular, when violations of usage rights occur they need to be attributed to the correct users. The Internet lacks a native mechanism to securely associate an action (e.g., packet reception or transmission) to a given user. As a result, tracing the user behind a network activity is a laborious process involving network operators and system administrators that is bound to have errors [22]. The content identification is also a hard problem. Various techniques such as watermarking and fingerprinting are used to detect the origin of a content on the Internet [21].

**Diverse system architectures:** The media distribution on the Internet happens over diverse architectures ranging from general purpose platforms such as PCs to special purpose game consoles. With closed systems (e.g., game consoles), users wanting to breach the rights management schemes protecting media distribution need to perform hardware and software modifications to the underlying platform, which carries a risk of breaking the device.

**Variable user sophistication:** The user sophistication on the Internet is highly variable. One extreme can be users who have very little computer knowledge and need an “appliance” like interface to rights management schemes. The other extreme can be users who are highly skilled and intent on probing the limitations of the rights management schemes.

**Hidden information:** This is a non technical challenge associated with DRM. In a transaction between the media distributor and the user, the distributor does not know the



**Figure 1: Incentives for upholding copyright restrictions (a) without and (b) with social approaches.**

true identity of the user (i.e., pirating or non-pirating), while this information is known to the user. Hidden information based problems are prevalent in other lending problems in the areas of insurance and banking, where several strategies have been developed to handle them. The role hidden information and hidden actions play in network security problems is discussed in [16].

**Social norms against piracy:** Another non technical challenge of DRM is the perception held by many law abiding citizens that piracy is *not* a crime [4]. This means the social stigma typically associated with other crimes (e.g., vandalism) is not associated with piracy.

## 3. SOCIAL DISTRIBUTION NETWORKS

### 3.1 Overview and Objectives

Several studies have examined DRM protection mechanisms, their vulnerabilities, and usability [13]. On general purpose computing systems, DRM protections rely on all software implementations. Once a technique to break an all software DRM protection is developed it can be applied everywhere with very little or zero additional cost. Therefore, to sustain the copyright protection, it is important to ensure that all parties (especially users) have the incentives to uphold the copyright protections. Figure 1(a) shows the incentives a distributor and a user have to uphold (downward arrows) and subvert (upward arrows) the DRM protections.

The popular position taken by the distributors is that piracy hurts their *revenue*. Therefore, distributors want to implement DRM to the fullest. However, *enforcing* DRM comes with significant *costs* including monitoring, legally pursuing offenders, and public relations. The users, on the other hand, are concerned about the *purchase cost*. One strategy given prominence by [5] is *variable pricing*, which depends on setting an appropriately low price to encourage the users to purchase legitimate content instead of consuming pirated content. The *technical hurdles* for circumventing the DRM protections is another incentive for the user to abide by the copyright restrictions. In closed platforms such as game consoles and mobile devices, ‘jail breaking’ the devices might be necessary before removing the DRM safeguards, which adds to overall technical difficulties. Copyright protection, piracy, and fair use have evoked much discussion on the Internet. This means users choice between pirated and non pirated content can be influenced by their

belief (i.e., *social norms*) on what helps the overall welfare. Yet another factor that influences the user behavior is legal pressures applied by distributors or their proxies (e.g., corporations exerting pressure on employees to desist from piracy).

As shown in Figure 1(a), for high purchase cost items (e.g., movies and games) some users can have a net incentive to subvert copyrights while for low purchase cost items (e.g., songs) the same users may readily uphold copyrights. The objective of *social distribution networks* (SDNs) is to add incentives to the user side to address this misalignment.

### 3.2 Elements and Processes of an SDN

An SDN has three major participants as shown in Figure 2: (i) *distributor*, (ii) *neighborhood distributor* (ND), and (iii) *users*. The distributor is the online store (e.g., iTunes) that wants to distribute its content through the SDN. Although our discussion here is limited to a single distributor, a practical deployment can have multiple distributors. The NDs are local agents recruited on the OSN to embed the SDN on the OSN. The NDs play a vital role in the life cycle of user groups: creation, maintenance, and deletion. The NDs are expected to examine group creation requests from users to slow down the creation of bogus user groups. For filtering bogus requests, the NDs can use the hop distance between them and the group creator as a limiting criterion. Some users, depending on the structure of the social network neighborhood, can be connected to more than one ND.

The participants in an SDN use the following tools for effecting rewards and punishments that are fundamental to the operation of the SDN:

**Discount coupons.** As shown in Figure 1(a) one of the causes of the DRM problem is the incentive misalignment that exists between the distributor and user. One of the key objectives of SDNs is to address the incentive misalignment by providing *direct benefits* to the users in the form of discount coupons. Discount coupons are a commonly used marketing mechanism to increase customer loyalty. To use discount coupons as a behavior conditioning mechanism on a user, the SDNs need to use the coupons as a *collateral* and invalidate the coupons if the user engages in piracy. There are two problems associated with using discount coupons as collateral: (i) tracking overhead and (ii) amount of available collateral.

**User groups.** The SDNs use user groups to reduce the tracking overhead and increase the available collateral. The users *self select* their partners to form groups. The *local* distribution network formed by the user groups are managed by the NDs (Figure 2). The required collateral is set such that a user cannot show it using his own coupons. Therefore, a user should collect coupons from other users within the group and stack them to show the minimum collateral. Only transactions with the sufficient level of collateral will be given discounts.

**Sanctions.** Several field studies in group lending [28] have validated the importance of *sanctions* as a borrower disciplining tool. In SDNs, sanctions are designed such that groups controlled by pirates should not get any net benefit from the discounting mechanism. Because non pirating

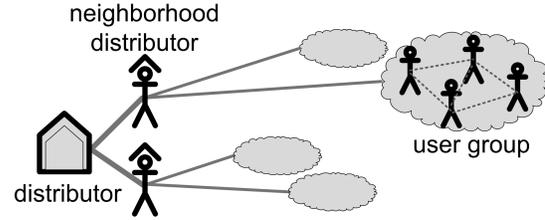


Figure 2: Social distribution network architecture.

users can gain higher benefit by switching to groups not controlled by pirates, they would eventually switch allegiance. If other established groups are reluctant to induct members from a failing group, the non pirating users could establish a new group. Starting a new group will involve an initiation cost and the new group will be initiated when the non pirating users determine that the loss in benefits by staying with the current group is higher than the startup cost.

The SDN formation process consists of two phases. The first phase is the ND selection process. The ND selection is triggered when the distributor receives a request from a user seeking the role of a ND. The distributor is interested in preventing or at least minimizing piracy and simultaneously maximizing its revenue. To achieve this dual objective, the selection process relies on two main factors. The first is called the *distributor potential* (DP). This is a measure of the capacity of a user to be a neighborhood distributor. The DP is governed mainly by the density of connections around the user (i.e., the number of other users in the neighborhood). For instance, a user with connections to many highly connected users can manage large number of groups and therefore, generate high revenue for the distributor. Another factor on which the selection of a ND depends is *piracy rate* (PR). The PR represents the rate at which the content is pirated from the neighborhood of a given ND and is computed by the distributor for each ND. We assume that the distributor tags the digital media objects sold through an ND such that any violations (e.g., piracy incidents) can be attributed to the particular ND.

The content identification in SDNs relies on the state-of-the-art methods available for embedding watermarks or creating fuzzy hashes [21, 2]. Examining or improving the effectiveness of content identification techniques is outside the scope of research in SDN. However, minimizing the overhead caused by content identification is part of SDN design and will be investigated as part of future work.

Once an SDN is setup, the distributor periodically scans distribution channels carrying pirated content to any leaks to those channels from the SDN. If the SDN content is found in the pirated channels, it is matched to a ND using watermarks, fuzzy hashes, or other mapping techniques. Once the pirated content is attributed to an ND, the PR of the corresponding ND is revised. An ND with high PR will eventually be punished by the distributor by revoking its ND status. This provides the ND some incentive to scrutinize the requests from the users.

In the second phase, users wanting to buy movies or music contact their NDs. To get the discounts, a user must belong to a user group that is managed by the contacted ND. To form a new group, users self select their partners

and inform their ND of their group. A newly formed group will also involve an initiation cost. The initiation cost is the price of the coupons the group gets initially from the ND. This depends on the number of coupons the group decides to get but must at least be equal to the minimum number of coupons that needs to be presented to the ND in order to qualify for the group discount. The initiation cost is setup to resist the creation fictitious user groups. Further, NDs can filter group creation requests by checking whether majority of the group’s founders are from its social circle. The initiation cost and other filtering mechanisms from NDs should slow down the creation of fictitious groups.

Once a group is established its members can start receiving discounts by using the coupons within the group. The usage of the coupons are governed by a number of conditions. First, each member of the group is limited to a single coupon (i.e., a member can’t get more than one coupon from the ND). The coupons within the group can be aggregated (stacked) to get higher discounts. Thus, a group member is always better off if he can get more coupons from other members of the group. At the same time, a minimum number of coupons need to be collected in order for any transaction to qualify for the group discount, which is essentially the minimum collateral needed to be eligible for discounts. Because the collateral is generated by coupons held by other users within the group, the purchase and the discount provided for it are associated with the group. A user who is not able to show the minimum collateral will have to get the content from the distributor at the regular price. We assume that the total discount applied towards a particular item cannot exceed the price of that item.

Associated with each coupon is an expiry time and a discount value. Initially all the coupons held by a group start at given discount value. As the group engages in more transactions and avoids any piracy incidents, the group is rewarded by having the value of the discount coupons increase incrementally over time up to a maximum value. The coupon expiry time specifies the duration through which the coupon is valid. A coupon that has been used in transaction as a part of a collateral is replenished after the purchase if there are no sanctions on the group. Therefore, The coupons held by a user indicate the *non pirating* purchase history of the user. By expiring the coupons, SDNs can ensure that collateral presented by a user is actually based on rewards for recent good behavior of the group. Due to the limited validity of the coupons, users have a motivation to use them within the expiry time.

A group that have a piracy incident associated with it is punished by the ND by applying sanctions on the whole group. One way of applying the sanctions is to deny benefits by not accepting the discount coupons for a given period of time or for a specified number of transactions. Either way this will result in losses for the members of the group since they are forced to buy the content at the full price. In addition to the sanction period, another effective form of punishment is the decrease (drop) of the discount coupon values of the group to the initial value. This provides more incentives for the groups that have sustained a good history for a long period to stay away from piracy since the loss in benefit could be high.

### 3.3 Design Rationale

The design of SDNs draws upon a large body of work in group lending in micro finance [17], social psychology [9], game theory [1, 27], and information security economics [3]. The description so far explained the major processes within SDNs and how the incentive misalignment problem [3] is dealt in SDNs. Following paragraphs explain how specific concepts from the background work influenced the SDN design.

Economic [10], social [9], and psychological [9] factors motivate the user groups in SDNs. By grouping users, SDNs hold users *jointly liable* for the piracy incidents. The joint liability idea is successfully deployed by group lending organizations such as Grameen Bank [23]. Various field studies of group lending have identified *self selection* as a key requirement for joint liability to work. The SDNs allow users to select their partners within the groups and exercise discretion on how they collaborate within the group. If it is economically impossible for non pirating users to be bribed (their loss of utility compensated) by a pirating user, non pirating users have no incentive to collude with the pirate by knowingly keeping him in the group. This assortative matching allows SDNs to *screen* users by the “company they keep.” In addition to the economic factors, groups tie in psychological factors [9] such *reciprocity* and *commitment* to influence user behavior with regard to piracy. By contributing her coupons to others’ purchases a user provides benefits to the community and expects the community to reciprocate by providing coupons for her purchases. To successfully reciprocate, the group members should refrain from piracy. When a user joins a group, she affirms her commitment to support other users in their purchases in the SDNs. Therefore, by engaging in piracy a user will let down the whole group.

Following a similar strategy as many group lending [10] schemes, SDNs setup *collateral* in a joint fashion. By setting a minimum required collateral value, SDNs can lower bound the group sizes.

One of the motivations for creating groups in SDNs was to reduce the overhead of tracking the usage of media objects sold to the users. Many deployments of DRM systems track usage at a fine level to exercise greater control over the users. The SDN, however, only tracks incidents that leak content to unauthorized distribution channels. Tracking leakages in SDNs involves determining the source of a media object pushed in unauthorized distribution channels. The media objects (e.g., movies) can be attributed to a source using embedded watermarks or fingerprints of the object. Once a copyrighted media object is detected in an unauthorized channel, its source is determined through an analysis of the embedded watermark or the fingerprint generated from the object. This analysis should point to the group and the incident will be associated with it.

## 4. ANALYSIS OF SDN PROCESSES

The analysis presented in this section considers the effect of the economic factors on the different aspects related to the user groups such as groups formation and user interactions. Based on the SDN model presented in the previous section, we focus on two main issues that are key to the success of the SDN. The first is self selection, which is necessary for the group joint liability to work. In the analysis we show

that if it is economically impossible for non pirating users to be bribed (their loss of utility compensated) by a pirating user, non pirating users have no incentive to collude with the pirate by knowingly keeping him in the group. This will provide the SDN the ability to screen and isolate the pirating users from the non pirating ones. The second issue relates to group stability, a group that suffers from high piracy incidents is constantly under sanctions eventually resulting in the breakdown of the group. Since non pirating users can gain higher benefit by being in groups not suffering from piracy, they would eventually decide to leave a group controlled by pirates. While the non pirating users could establish a new group, starting a new group will involve an initiation cost. Therefore, the new group will be initiated when the non pirating users determine that the loss in benefits by staying with the current group is higher than the startup cost.

Before we present the details of the analysis, we first specify the different notations used throughout this section.

## 4.1 Notations

For the analysis, we will denote the size of a user group with  $n$ . The number of stacked coupons in any user purchase is given by  $m$  and  $m_0$  is the minimum number of stacked coupons (collateral) that required in any SDN transaction. We also note that  $m_0$  represents the minimum number of coupons that must be purchased by a newly formed group (group formation cost). The price of buying a coupon from the ND is  $p_{cp}$ . As mentioned previously, the coupons have a discount value which we denote here by  $d$ . The range for the coupon values is  $d \in [d_{min}, d_{max}]$ . Finally, We assume that the content offered by the distributor have different prices  $p \in [p_{min}, p_{max}]$ .

In addition to the above, the following conditions hold true for the model: The number of coupons used in any transaction must satisfy

$$m_0 \leq m \leq n \quad (1)$$

The total possible discount  $md$  can at most be

$$md \leq p_{min} \quad (2)$$

If  $md > p_{min}$ , then only  $p_{min}$  is granted by the ND. Based on the discount value of the coupons then, when the coupon values are equal to the maximum we have

$$m_0 d_{max} = p_{min}, \text{ when } d = d_{max} \quad (3)$$

This means only the minimum number of coupons is needed in any transaction to obtain the maximum discount. hence, the maximum discount value is  $d_{max} = p_{min}/m_0$ . When the discount value is the at the minimum value  $d = d_{min}$  then,  $m_0 d_{min}$  is the lowest discount obtained in any transaction.

## 4.2 Self Selection Enforcement

SDNs addresses the incentive misalignment problem by providing direct benefit to its users. Therefore, users are mainly compelled to participate in SDNs in order to benefit from the discount provided on the content. At the same time, one of the main goals of the scheme is to reduce or prevent content piracy. To achieve this, it is necessary to show the existence of self selection among the users of the SDN in the group formation process. Using utility based

analysis, we find the necessary conditions under which the non pirating users have no incentive to cooperate with the pirates in the group. For a particular group, we compare the total utility or welfare for the group under two cases: When the group doesn't have any piracy incident (i.e. there are no pirating users in the group) and when there are piracy incidents within the group. While we don't consider the number of pirates in the analysis we assume that they don't form the majority within the group. In both scenarios we let the group size be  $n$ , the price of the content be  $p$ , and the number coupons used to be  $m$  with discount value  $d$ .

We characterize potential buyers from the group by their benefit,  $v$ , from the content. To simplify the analysis, we assume that user benefits are uniformly distributed on  $[0,1]$  (linear demand curve). The assumption of linear demand follows previous research in information goods pricing and other work done mainly for analytical tractability [5].

To keep track of piracy incidents, we assume that the ND will periodically get update reports from the distributor about piracy incidents for his content. If piracy is detected, then the ND will apply sanctions on the appropriate group for a given period of time. The sanctions applied by the ND is represented as follows. First, we partition the transactions from a group into time periods of equal durations. At the end of each cycle the ND evaluates the piracy reports, if piracy is identified then, the group is sanctioned for in the next period. While there are many different ways to set the length of the sanction, In the analysis, we consider sanctioning the group for a single period only. During the sanction period the users can't benefit from the coupons and have to pay the full price to get the content.

Next we analyze the behavior of the non pirating users under the two scenarios. First considering the case when the group doesn't have any piracy incident. Now considering a single period, then a user will buy a given content at price  $p$  if

$$v \geq \frac{p - md}{p_{max}} \quad (4)$$

Equation (4) states that a user will buy the content if his value for the content  $v$  is higher than the total cost (after applying the discount). We normalize the total cost by the maximum price to in order to have the same range as the users benefit. Also the number of coupons and the total discount value satisfy conditions in Equations (1) and (2).

For the second case, we consider when there are  $k$  piracy incidents generated from the group in the previous period. In the next period the group will be sanctioned by the ND and so the users will buy the content during the sanction period if

$$v \geq \frac{p}{p_{max}} \quad (5)$$

Clearly, in this case the number of purchases will go down since the cost for getting the items is higher. In both cases, the fraction of the group members who will buy content is determined by the benefit  $v$  since it obviously affects their decision to buy. Therefore, users who buy the content are those with high benefit, from conditions in Equations (4) and (5) this includes all users with benefit in the ranges

$[\frac{p-md}{p_{max}}, 1]$  when there is no sanction and  $[\frac{p}{p_{max}}, 1]$  under sanction. Next, we compare the group welfare for the two cases. The group welfare represents the net benefit the group gets and it is found by summing up the benefit for all the users who bought content. Based on this, the total welfare for the group in a single period when there is no piracy is

$$W_{normal} = n \int_{\frac{p-md}{p_{max}}}^1 v - \frac{p-md}{p_{max}} dv \quad (6)$$

The total welfare for the sanction period is

$$W_{sanction} = n \int_{\frac{p}{p_{max}}}^1 v - \frac{p}{p_{max}} dv \quad (7)$$

The total loss in welfare for the group due to piracy is  $(W_{normal} - W_{sanction})$ . While for the pirates the benefit gained from utilizing the discounts in  $k$  transactions is

$$k \frac{md}{p_{max}} \quad (8)$$

The equation above represents the benefits the pirates gain from participating in the SDN which are the discounts on the content. Now in order for the non pirating users to collude with the pirates and purposefully keep them in the group, the pirates need to provide enough benefits for the non pirating users to compensate for their losses. Similarly, the pirates will benefit from participating in the SDN if their total utility gained from the discounts is larger than the cost of bribing the non pirating users. Thus, the condition necessary for establishing self selection is

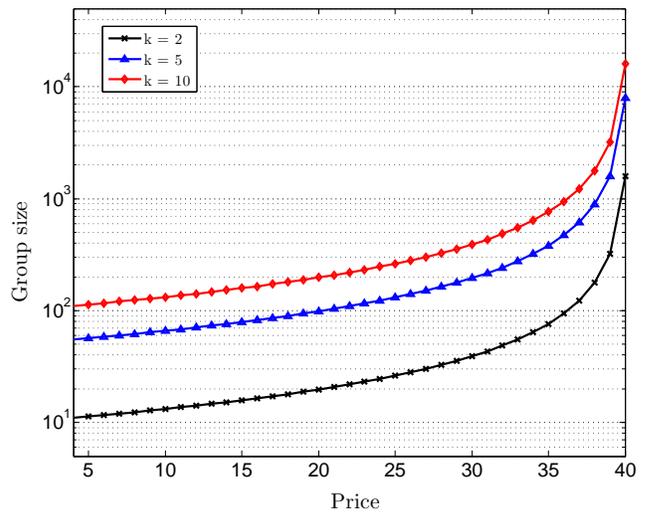
$$k \frac{p_{min}}{p_{max}} < W_{normal} - W_{sanction} \quad (9)$$

To provide the pirates with higher advantage (i.e. worst case scenario for SDN), we will assume that the discount value the pirates are able to obtain in each purchase is the maximum ( $p_{min}$ ). Also for the non pirating members we will assume that they can only get the smallest possible discount ( $m_0 d_{min}$ ) when the group is not sanctioned. Based on these assumptions, and substituting Equations (6), (7), and (8) in Equation (9) we get after some simplifications

$$k \left[ \frac{p_{max} p_{min}}{m_0 d_{min} (p_{max} - p + \frac{1}{2} m_0 d_{min})} \right] < n \quad (10)$$

If condition in Equation (10) holds then the non pirating users have no incentive to cooperate with the pirates. In terms of self selection, the non pirating users will prefer to have non pirating members in their group. At the same time the pirates have no incentive for participating in the SDN because they can increase their utility by getting the content immediately from the distributor at the full price.

The condition above also provides a lower bound on size of the group required to prevent the pirate from colluding with the non pirating members. The value of the group size depends on two variables, the price of the content being considered and the number of piracy incidents in a single period. From the inequality, when the price is fixed then the group size increases linearly in the number of piracy incidents. The number of piracy incidents within a given period is bounded by the number of newly released content because pirates are interested in pirating newly released content. Therefore, by following a staggered release for new content the distributor



**Figure 3: Lower bound on group size based on average transaction price for different number of piracy incidents.**

can limit the number of piracy incidents. The price is also controlled by the distributor, in the model we assume that the price of content ranges between a minimum and a maximum value. Because users can be buying content at different prices, we will consider the average price for a transaction.

Figure 3 shows the lower bound on the group size ( $n$ ) for different average transaction prices ( $p$ ) between  $p_{min}$  and  $p_{max}$ . Each curve represents the (price, group size) combination for a given number of piracy incidents ( $k$ ) in a single period. The values for the remaining parameters were held constant ( $p_{max} = 40$ ,  $p_{min} = 5$ ,  $d_{max} = 1$ ,  $d_{min} = 0.1$ ,  $m_0 = 5$ ). The values of the fixed parameters considered in this example are for illustrative purposes only they have no specific significance. In general for the different number of piracy incidents, the figure shows an increase in the group size as the price increases. We note that the group size grows exponentially with the average transaction price. This increase of the group size with price is due to the effect the price have on the total welfare. Because the user benefit value ( $v$ ) considered in our analysis is uniformly distributed and is independent from content price, then, when the price of the content increases a smaller fraction of users in group are willing to buy the content. This in turn will result in smaller number of transactions and ultimately smaller welfare. In other words, when the price is high a small fraction of user population will get the content and so in small group, the pirate will be successful because he only needs compensate a smaller number of users in order to remain in the group. Therefore, as the group size becomes large the pirate will not be able to succeed in colluding with the group members.

### 4.3 Group Stability

We have shown that the non pirating users don't want to have pirating users in the group. However, when inducting new members to the group the existing members could be admitting pirating users without knowing. A group that ends up having high rate of piracy incidents will sustain

high losses in benefits due to sanctions. Because it is hard for non pirating users to identify pirates in their group, the non pirates would gain higher benefit by leaving the group and establishing a new group. Starting a new group will involve an initiation cost therefore, the new group will be initiated when the non pirating users determine that the loss in benefits by staying with the current group is higher than the startup cost. The analysis here establishes the conditions that results in group breakdown (or instability) when the group suffers from piracy incidents.

Similar to the analysis for the self selection, we focus on the total welfare for particular group when there is no piracy and when there are piracy incidents and then compare the losses in welfare for the group with the initiation cost for a new group. Unlike the previous analysis, the group welfare and the losses are considered over multiple periods of group activities. This accurately accounts for the future losses for the non pirating members if they decide to remain in the current group. In both scenarios we let the group size be  $n$ , the price of the content be  $p$ . For the coupons discount value  $d$ , since we are considering the group welfare over many time periods then the discount values will vary between  $d_{min}$  and  $d_{max}$ . As discussed in the system model, a group that behaves well is rewarded by having its coupons values increased over time. Eventually, after a number of periods the discount values will reach the maximum  $d_{max}$ . If during any time period a piracy incident takes place within the group then, the group is punished by being having their current value for the discount coupons dropped to the minimum value this is in addition to the sanction. Because the number coupons  $m$  used can vary with the discount value, we will discuss how we set its values when we analyze each case.

The total group welfare over multiple period is found by adding the discounted group benefits over the different periods. In the case with no piracy, the group will start with discount value  $d = d_{min}$  and soon have  $d = d_{max}$  and stay that way for the all remaining periods. Thus, we will assume that  $d = d_{max}$  in all periods for this case since the discount values only vary for the initial periods and then stay fixed thereafter. Having the maximum discount value in the group then the number of coupons needed in each transaction is  $m = m_0$  (Equation (3)). The group benefit from a single period when there is no piracy can be found using Equation (6) and replacing  $(md)$  with  $(m_0d_{max})$  to get

$$U^{no\ piracy} = n\left[\frac{1}{2} - \left(\frac{p - m_0d_{max}}{p_{max}}\right) + \frac{1}{2}\left(\frac{p - m_0d_{max}}{p_{max}}\right)^2\right] \quad (11)$$

Using the benefit from a single period, the total welfare for the group over infinitely many periods is given by

$$W_{no\ piracy} = \sum_{t=0}^{\infty} w^t U^{no\ piracy} = \frac{U^{no\ piracy}}{1 - w} \quad (12)$$

In the equation above,  $w$  is the discounting factor with a value between zero and one.

The number of times a group with piracy incidents is sanctioned by the ND depends on how frequent those incidents occur. To represent the frequency of piracy incidents in the analysis, we define  $(q)$  to be the probability in which the group is sanctioned in a given time period. The sanction probability can also be interpreted as a probability of a piracy incident in a given period. Let  $U_{sanction}^{piracy}$  be the

group benefit from a single period when it is sanctioned and  $U_{no\ sanction}^{piracy}$  be the benefit when it is not sanctioned. Then, The group benefit from a single period will equal to  $U_{sanction}^{piracy}$  with probability  $q$  and is equal to  $U_{no\ sanction}^{piracy}$  with probability  $1 - q$ . The total group welfare is then equal to the sum of the discounted expected group benefits.

$$W_{piracy} = \frac{qU_{sanction}^{piracy} + (1 - q)U_{no\ sanction}^{piracy}}{1 - w} \quad (13)$$

The value of the benefit when the group is under sanction for a single period is the same as Equation (7) which can be rewritten as

$$U_{sanction}^{piracy} = n\left[\frac{1}{2} - \left(\frac{p}{p_{max}}\right) + \frac{1}{2}\left(\frac{p}{p_{max}}\right)^2\right] \quad (14)$$

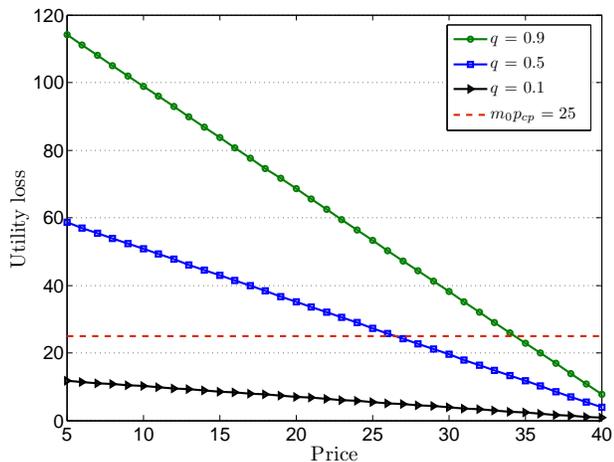
To find the benefit when the group is not sanctioned, we first need to determine the values for the discount coupons and the number of coupons used by the users. As mentioned before, the discount values varies according to the group behavior. A group that continuously keeps a good record will have an increasing values for the discount coupons, however once a piracy incident is detected the coupon values drops to its minimum value as part of the punishment. Thus, the value of the total discounts the members can obtain when the group is not sanctioned depends on the sanction probability because it dictates the average duration between piracy incidents. Similarly for the number coupons used, we assume that the users will try to collect as much coupons as possible in order to maximize their total discount. Based on these arguments, The value of the benefit when the group is not sanctioned is given by Equation (6) by setting  $(md = m'd(q))$  to get

$$U_{no\ sanction}^{piracy} = n\left[\frac{1}{2} - \left(\frac{p - m'd(q)}{p_{max}}\right) + \frac{1}{2}\left(\frac{p - m'd(q)}{p_{max}}\right)^2\right] \quad (15)$$

The value  $d(q)$  in the equation represents the average discounts obtained by the group members for the given sanction probability, and  $m'$  is the average number of coupons the users can find in the group. The total loss in welfare for the group due to the piracy incidents is  $(W_{no\ piracy} - W_{piracy})$  while the initiation cost for a new group is  $m_0p_{cp}$ . Now in order for the non pirating users will decide to leave the current group and start a new one if the following condition is satisfied

$$\frac{n}{(1 - w)p_{max}^2} \left[ (p_{max}m_0d_{min} - pm_0d_{min} + \frac{1}{2}(m_0d_{min})^2) - (1 - q)(p_{max}m'd(q) - pm'd(q) + \frac{1}{2}(m'd(q))^2) \right] \geq m_0p_{cp} \quad (16)$$

In condition given in Equation (16), the losses for the non pirating users in the long term is affected by the group size, content price, and the sanction probability (or piracy probability). A high sanction probability indicates a high rate for piracy incidents which results in higher losses because the group will constantly be sanctioned and also the value of the discount coupons on average will be closer the minimum value due the the punishment. The group size also affects the amount of the losses, a larger group will clearly incur more losses than a smaller one simply because more members suffer from the sanctions in the larger groups. Finally, the average price for the group transactions affects the total



**Figure 4: Long term group welfare loss for different price and sanction probability values.**

group losses, this is due to the same effect discussed in the self selection enforcement part. As the price of the content goes up, the fraction of the users who are willing to buy decrease due to the uniform user benefit function resulting in lower number of transactions and lower welfare.

We illustrate the effect of the average price of the group transactions and the sanction probability on the long term group losses with the following example. Aside from the price and sanction probability, most of the remaining parameters were fixed at following values ( $n = 100$ ,  $p_{max} = 40$ ,  $p_{min} = 5$ ,  $d_{max} = 1$ ,  $d_{min} = 0.02$ ,  $m_0 = 5$ ,  $w = 0.9$ ,  $m' = 10$ ). We use a S-shape function for the average coupon values  $d(q)$ . Then, for a given sanction probability value  $q_0$  we find the corresponding coupon values  $d(q_0)$  and plot the corresponding utility loss curve for the range of prices in  $[p_{min}, p_{max}]$ . Figure 4 shows the utility loss curves for sanction probabilities ( $q = 0.1, 0.5, 0.9$ ). In general for a given sanction probability, the loss of utility decreases linearly in price. Also the loss in utility is higher for higher sanction probability values, this is expected because the group is being sanctioned heavily. The horizontal line represents the initiation cost for the group set at  $m_0 p_{cp} = 25$  (right hand side of condition in Equation (16)). In the figure, the points on the curves that fall above the horizontal line represents an unstable group situation because the long term losses are greater than the initiation cost. For example, the utility loss curve for  $q = 0.1$  always stays below the initiation cost value and so from the users perspective, this indicates that the users will stay in the current group and not seek to form a new one.

## 5. RELATED WORK

One area of related research has focused on how producers should respond to piracy both through pricing and instruments particularly directed at piracy copy protection and enforcement. The effect of content pricing and copyright enforcement on illegal copying and social welfare are discussed in [5]. The work considers how a monopoly publisher should set the price and spending on detection when the gov-

ernment sets the fine for copying, taxes, and subsidy in order to achieve the optimal social welfare. Their analysis shows that content producers consider pricing and enforcement as substitutable strategies that can have the same effect in reducing the expected benefit of copying. At the same time an increase in detection affects social welfare more negatively than price cuts and so society prefers that information goods producers manage piracy through price cuts rather than enforcement. For the government policies, the results indicate that the tax is welfare superior to the fine, and that a subsidy on legitimate purchases results in the social welfare optimum. The work in [25], analyzes the optimal choice of content pricing and level of technology-based protection (i.e., DRM) in a market with digital piracy. It shows that when faced with piracy, the seller's optimal choice is to use a piracy-indifferent pricing which makes all customers indifferent between legal consumption and piracy. In addition, when a seller is able to price-discriminate the content, then the optimal level of DRM protection should be strictly lower than the maximum achievable protection level. Park and Scotchmer [20], explore the effect on content prices when digital rights management is under the control of the content providers. Using economic analysis they show that if protection is imperfect, then the threat of of DRM circumvention reduces prices of content relative to perfect legal enforcement. They support their results by showing that the optimal way to deter circumvention is to use a combination of lower prices (giving up revenue) and protection (paying costs).

The social impact of piracy is discussed in other related work. In [19], the evolution of illegal copying of software in different countries is studied. Analysis of empirical data shows that the major drivers of illegal copying are poorly served markets and software products that don't fit local needs as well as other social characteristics. In addition, the author suggests, based on evidence from the data, that allowing illegal copying, in certain cases, can be an efficient mechanism for market creation. Another study analyzing the effect of file sharing record sales is presented in [18]. The study uses empirical analysis of actual file sharing behavior and album sales and considers the relationship between them. The results from the study concludes that file sharing has only a limited effect on record sales with minimal economic effect. Also, it suggests that file sharing have a differential impact across sales categories where high selling albums may benefit from file sharing.

Alternative content distribution schemes such as superdistribution has recently garnered attention from the content producing industry. Superdistribution is a scheme for the distribution of digital content where buyers are engaged in the distribution process. A buyer receives a small amount as remuneration for making a resale. The remuneration gained from resale is incentive for a buyer to refrain from pirating the content and posting it on the Internet. In [24], Schmidt proposes systematic approach to market mechanisms using superdistribution and technical system architectures supporting it. Kpper *et al.* [14], provides an overview of the origins of superdistribution and explains its different appearances from a technological and business point of view. Furthermore, they provide a market overview of superdistribution-enabled content retail concepts and sketch related business scenarios.

Another related thrust has primarily used game theory to investigate the DRM problem. The work in [11], presents a DRM game to model the strategies associated with various DRM approaches. The DRM game consists of two sub-games, one associated with content acquisition, and the second one dealing with post content acquisition decisions. In the DRM game, the authors consider two strategies. One that punishes users for sharing content and another that rewards users for not sharing content. Analyzing the two strategies, the authors claim that an equilibrium can be established much easier when using a reward based strategy. To implement these strategies, a trust authority middleware infrastructure is suggested in order to rate the behavior of customers and reward them accordingly.

The Secret Incentives-based Escrow System (SPIES) applies game theory to DRM systems where content protection is of interest [15]. This system is suited for applications where a secret must be protected for only a limited period of time and shared between two parties. SPIES is based on providing negative incentive for distribution of digital content beyond authorized possessors. The system consists of three stages: exchange of the secret and placement of funds in escrow; registration of content holders; and release of escrowed funds to registrants. Using a game model of system, the authors show that for the secret provider, the best strategy is to use SPIES when the secret has value and the consumer has incentive to resell the content. The consumer of the content gains the most utility from purchasing the content, placing money in escrow, and not reselling or distributing the content, so that the escrowed funds are returned.

In [29], the authors utilize game-theoretic model, to examine the impact of collaborative structure, content quality, and network environment on the development of pricing scheme and DRM protection policy of digital content. They show that DRM protection level decreases and pirating activities becomes relatively tolerable as the content provider and platform provider operate collaboratively. Depending on the market structure (collaborative or independent providers), higher content quality may strengthen or weaken the adoption of DRM. In addition, the network environment becomes more decentralized and uncontrolled, weaker DRM protection should be a better strategy.

In [31], the authors analyze the different security policies adopted by the various participants of the digital rights management ecosystem using game theory. The paper presents two game models, a cooperative game among digital contents provider, rights/service provider and digital devices provider, as well as a non-cooperative game between providers and consumers. The authors derive the conditions for the existence of pareto optimal equilibrium.

Our work is different from the above in that we focus on the development of a new social media distribution model for selling content on the Internet. Our model is based on previous work in group lending and joint liability and uses economic incentives and punishment strategies to reduce piracy.

Also, there has been a large number of proposals for DRM mechanisms and architectures, we review only a few of them here. In [30], a scheme based on an asymmetric key algorithm to enable DRM mechanisms in BitTorrent P2P systems is proposed. The content distributed via BitTorrent is securely protected by ensuring that no plain pieces of an object can exist in the system. The scheme also assumes the

existence of trusted content players on client sides for decrypting and enforcing usage policies of the downloaded objects without releasing the decryption keys and plain pieces. This allows any peer to take part in the content distribution while only legitimate peers can access the content.

The work in [12] presents a system architecture that uses economic incentives to motivate users to keep the content within the subscription community on P2P file sharing systems. Similar to the previous work, the system makes use of an escrow authority, where the escrow service pays users for sharing content with authorized users. These payments are intended to motivate users to keep content within a subscription community. Users who receive the content outside of the subscription community are not affected by this process.

The authors in [6] propose a protocol to achieve user's fair use rights by using virtual software token in DRM systems. The protocol makes use of asymmetric keys as virtual software tokens which are securely stored on remote trusteeship servers. Additionally, a set of Web service servers are responsible for managing licenses and the access rights of the objects associated with the different clients. The authors claim that this scheme improve the portability of DRM system by allowing users with legal virtual software token to access the content, at anytime and on any compliant device.

The work in [7] presents a rights sharing method for Authorized Domains (AD) based DRM systems to deal with the replay attack when devices leave the AD. The key idea is to use time-stamp and digital signature to encipher the license two times using commutative encryption. This method allows any device in a domain to freely play content but at the same time it blocks playing content in the other domains which guarantees consumers' right and content providers' right at the same time.

## 6. CONCLUSIONS AND FUTURE WORK

The importance of digital rights management is increasing rapidly as digital form becomes the exclusive way of creating and selling content. However, digital rights management remains a hard problem that is unyielding to traditional solutions. In this paper, we approached DRM in a non traditional manner. We highlighted the incentive misalignment that lies between the two major types of players: distributor and user.

A design for a social distribution network that attempts to align the incentives between the distributor and user was presented. Our design draws on wide variety of schemes from micro-economics and social psychology. We used utility-based analysis to show the conditions that should hold for the social approach to work.

This paper presents only a part of the analysis related to social distribution networks. The utility gained by the distributor should be modelled and the configurations that maximize that utility should be examined. While the utility analysis is useful to determine the behavior and pay-off in long term, dynamic characteristics is also important. Simulation studies should be performed to analyze the dynamic behavior under different system configurations.

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