Restricting Intern Access: Ideology and Technology

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***Abstract*—The Internet growth has allowed unprecedent wide spread access to cultural creation including music and films, to knowledge, and to a wide range of consumers' information. At the same time, it has become a huge source of business opportunities. Along with great benefits that this access to the Internet provides, the open and free access to the Internet has encountered large opposition from both political, economical and ethical reasons. An ongoing battle over the control on Internet access has been escalating over all these fronts. In this paper we describe first some of the ideological roots of free access to the Internet along with its main opponents. We then focus on the problem of 'Internet piracy' and analyze the efficiency of efforts to reduce the availability of copyrighted creations that are available for non-authorized free download.**

I. Introduction

As technology allows very high speed access to the Internet to hundreds of millions of people around the world, the pervasive nature of the Internet draws growing opposition. Those who try to restrict, to control or to filter the access to the Internet include a wide variety of actors motivated by quite different reasons ranging from security reasons, political and ideological reasons, economical interests or religion.

This work has been triggered an ongoing legislation battle in France between two opposed approaches for dealing with copyright infringements over the Internet and with non-authorized download of copyrighted material. One approach proposes to ban such downloads and to establish a heavy control on downloads, while the other proposes to establish a general tax on internauts that wish to pursue downloading. The revenues of the tax would be redistributed between the copyright owners.

The Hadopi law can be associated with several types of restriction of the access to the Internet:

- **Content limitation.** The obvious limitation is the legal limitation over the content that can be accessed and exchanged; in absence of such legislation it is not clear whether downloading from the Internet is legal or not.

This direct legal content limitation on the Internet access is accompanied with two other indirect limitations:

- **Disconnecting Subscribers.** As part of the sanctions against unauthorized download by an internet subscriber, the law imposes disconnection of the subscriber.
- **Roaming Access.** Global connectivity for WIFI users is available in practice in many countries in which the individuals who have Internet access through access points located at their home, choose not to restrict the access and do not set a password for connecting to the Internet. The Hadopi law has elliminated the global connectivity and it obliges individuals to secure their access, thus denying access to other roaming users.

Other type of access restrictions that have been implemented in various countries are reducing the bandwidth for accessing P2P sites or blocking the access to them, reducing the bandwidth of subscribers that use P2P traffic and blocking the use of protocols that P2P transfer use.

An alternative proposal to restricting access has been to impose taxes either on the subscriptions to high bandwidth access, or on every one, or on every one except those who declare that they do not download unauthorized files. Among the official reasons that the French government provides for rejecting the last alternative are[1]:
(i) it would increase subscription fees substantially which would reduce the access to the Internet,
(ii) it endangers the very existence of French creation that would not be able to compete against American producers,
(iii) it would require surveillance measures,
(iv) it is not clear how to redistribute the tax.

We shall not deal in this paper with other aspects of Internet access restrictions such as security aspects, efficiency of filtering methods, etc.

The French constitutional Court has rejected some aspects of the original French Hadopi law. In the next Section we discuss the principles and ideology behind this ruling and place it in a wider worldwide context.

We then provide in the following section a mathematical model that examines the impact of measures against unauthorized downloads on file availability and on the download rate.

II. The ideological roots of free Internet access

A. Historical declarations on freedom

There are three very important documents in the history of Human Rights: the Virginia Declaration of Rights 1776[2], the United States Declaration of Independence 1776 and the Declaration of the Rights of Man and of the Citizen 1789[3].

[1] See www.culture.gouv.fr/culture/actualites/index-droits05.html

[2] The Virginia Declaration of Rights 1776 was the model used for the *bill of rights* by other states of the Union.

[3] The Declaration of the Rights of Man and of the Citizen 1789 is considered the first form of positivation of the human rights in Europe[1, 121].

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Whether these texts originated independently of each other, or, on the other hand, there was some influence by one on the remaining, this is a doctrinal discussion in the field of law[2]. However, what is beyond dispute, is that the ideas of the rational natural school[4] are present in these declarations. Since then, life, liberty and equality were recognized in successive western constitutional texts as fundamental rights of every human being. Both, French and American constitutional texts insert the principles considered in the declarations, albeit in different ways: the French through out the preamble, while the USA, on the other hand, does it through amendments:

> "That all men are by nature equally free and independent and have certain inherent rights, of which, when they enter into a state of society, they cannot, by any compact, deprive or divest their posterity; namely, the enjoyment of life and liberty, with the means of acquiring and possessing property, and pursuing and obtaining happiness and safety"... says the Virginia Declaration of Rights 1776.
>
> "That all men are created equal; that they are endowed by their Creator with certain unalienable rights; that among these are life, liberty, and the pursuit of happiness..." says the United States Declaration of Independence 1776.
>
> "Men are born and remain free and equal in rights..." says thirteen years later the Declaration of the Rights of Man and of the Citizen 1789.

Worldwide recognition of these principles was achieved with the first article of the Universal Declaration of Human Rights of 1948:

> "All human beings are born free and equal in dignity and rights."

B. Recognition of Internet as a tool for the exercise of the freedom of speech

Freedom has many forms of manifestation, e.g., freedom of expression and opinion, freedom of press, freedom of thought, conscience and religion, freedom of communication. All these forms in which freedom is manifested, in turn requires guarantees to assure its exercise in all areas, regardless of frontiers and by any means of expression[5]. The European Parliament [European-Parliament: 2009] believes that the Internet is an universal space that now allows the pursuit of all these manifestations of freedom as enshrined in the Universal Declaration of Human Rights, and the International Covenant on the Rights Civil and Political Rights, becoming the most versatile tool for the exercise of freedom of expression globally.

However, the freedom that Internet allows should not be subject to "interference by public authority"[6], neither by the application of limits to access nor by content control. The Spanish Senate[7] recognized that all people have a fundamental right to access the Internet, without any discrimination. As freedom is an inherent condition to the Internet, it admitted the principle that no power can restrict this freedom and that its limits can only come from the Declaration of Human Rights.

The first amendment of the United States Constitution prohibits Congress to pass laws that abridge the freedom of speech or press. Nonetheless, in 1996 the USA Congress approved the *Communications Decency Act* (CDA) to protect minors from "indecent" and "patently offensive" communications that "an international network of interconnected computers that enables millions of people to communicate with one another in "cyberspace" and to access vast amounts of information from around the world", allows [4]. This form of censorship of the freedom of speech was alerted by the *American Civil Rights Union* (ACLU) who filed a civil action against the CDA. The decision of the Special Three-Judge Panel in *ACLU, et al v. Reno* (3/22/1996) was favorable to the freedom of speech, as the "Government may not, thought the CDA, interrupt that conversation. As the most participatory form of mass speech yet developed, the Internet deserves the highest protection from governmental intrusion."[5]. This court says that parents "can install blocking software on their home computers, or they can subscribe to commercial online services that provide parental controls. It is quite clear that powerful market forces are at work to expand parental options to deal with these legitimate concerns. More fundamentally, parents can supervise their children's use of the Internet or deny their children the opportunity to participate in the medium until they reach an appropriate age"[5].

It is interesting what judge Dalzell said before concluding that the CDA was unconstitutional:

> "Just as the strength of the Internet is chaos, so the strength of our liberty depends upon the chaos and cacophony of the unfettered speech the First Amendment protects. The Internet and other online computer networks merit the highest protection from governmental intrusion."[5]

Thus, the Supreme Court upheld the lower court judgement and the CDA was deemed unconstitutional:

> "The interest in encouraging freedom of expression in a democratic society outweighs any theoretical but unproven benefit of censorship"[4].

The CDA was followed by the Child Online Protection Act (COPA), which was called "Congress Decency Act II" by its critics. The Act sought the "restriction of access by minors to materials commercially distributed by means of world

[4]Grocio, Hobbes, Spinoza, Locke, Pufendorf, Leibniz, Tomasio, Rousseau and Kant are considered the most representatives philosophers of the XVII and XIX centuries, who developed the natural law theory based on the reason[3].

[5]Article 19 of the Universal Declaration of Human Rights reminds all States that freedom of speech "includes freedom to hold opinions without interference and to seek, receive and impart information and ideas trough any media and regardless of frontiers." In the same line, Art. 19.2 of the International Covenant on Civil and Political Rights expresses that "[e]veryone shall have the right to freedom of expression; this right shall include freedom to seek, receive and impart information and ideas of all kinds, regardless of frontiers, either orally, in writing or in print, in the form of art, or through any other media of his choice."

[6]Art. 10. 1 of the Charter of Fundamental Rights of the European Union.

[7]See Spanish Senate diary of sessions of 9 December, 1999 at www.senado.es/comredinf/ds/index.html

wide web that are harmful to minors". Besides, it established criminal penalties for any commercial distribution of material harmful to minors. The term "material that is harmful to minors" means any communication, picture, image, graphic image file, article, recording, writing, or other matter of any kind that is obscene or that:

> “(a) the average person, applying contemporary community standards, would find, taking the material as a whole and with respect to minors, is designed to appeal to, or is designed to pander to, the prurient interest;
>
> (b) depicts, describes, or represents, in a manner patently offensive with respect to minors, an actual or simulated sexual act or sexual contact, an actual or simulated normal or perverted sexual act, or a lewd exhibition of the genitals or post-pubescent female breast; and
>
> (c) taken as a whole, lacks serious literary, artistic, political, or scientific value for minors.” [6, Apendix A]

The COPA, like the CDA, reached the Supreme Court [6] which this time did not ruled on its constitutionality, limiting its decision to:

> “hold only that COPA’s reliance on community standards to identify “material that is harmful to minors” does not by itself render the statute substantially overbroad for purposes of the First Amendment. We do not express any view as to whether COPA suffers from substantial overbreadth for other reasons, whether the statute is unconstitutionally vague, or whether the District Court correctly concluded that the statute likely will not survive strict scrutiny analysis once adjudication of the case is completed below. While respondents urge us to resolve these questions at this time, prudence dictates allowing the Court of Appeals to first examine these difficult issues”.

The case was forwarded to the Court of Appeals[7] which stated that the COPA was unconstitutional:

> “to avoid liability under COPA, affected Web publishers would either need to severely censor their publications or implement an age or credit card verification system whereby any material that might be deemed harmful by the most puritan of communities in any state is shielded behind such a verification system. Shielding such vast amounts of material behind verification systems would prevent access to protected material by any adult seventeen or over without the necessary age verification credentials. Moreover, it would completely bar access to those materials to all minors under seventeen – even if the material would not otherwise have been deemed "harmful" to them in their respective geographic communities.”

In France, things have not been very different. The Constitutional Council [8], regarding the HADOPI Act which expected to disconnect the P2P users because they shared copyrights cultural contents, went back to the Declaration of the Rights of Man and the Citizen to say that the freedom of speech could not be trusted to a new nonjudicial authority in order to protect holders of copyrights and neighbouring rights. Because the “free communication of ideas and opinions is one of the most precious of the rights of man”[8]. The Council recognize that Internet is a powerful tool in the exercise of the freedom of speech and this is why only a court of law can restrict a fundamental right. In this decision, the Internet acquire the Fundamental level.

The reaction of the Executive against the Constitutional Council’s decision was almost immediate. Less than fifteen days were enough to present to the Senate a criminal bill [9], in order to complete the mechanism of “graduated response” of the HADOPI Act. In this way, copyrighted content file-sharing becomes a form of piracy that involves the application of penalties: suspension of Internet access for up to a year and a ban on signing a new contract. A criminal offence can only be declared by a court of law, theoretically solving the questions posed by the Council. Nonetheless, the HADOPI II Act has already been challenged in the Constitutional Council as it might violate due process.

C. The Commons in Internet

1) About the Commons: By the term "commons" we refer to the ability to access a resource without someone having the right or power to exclude anyone from using it. But the commons is also used to describe a resource that is shared by a group of people [10]. In regard to whether the commons itself takes place in an open access regime -without regulation- or in a limited access regime -regulated- there is a whole discussion generated from the argument raised by the biologist Garret Hardin [11] to warn the unsustainability of common resources “open to everyone”, that he called *the tragedy of the commons*. Harding uses the commons to portray a commons resource that anybody can access without any restriction to the use. His thesis, has been rebutted by many people who say that metaphor used in the model confuses the commons resource with the open access (*res nullius*) without restrictions[9].

But there is not only regulations on who could use the commons (it was restricted to commoners to whom the lord gave a use right), because as Cox [15] says, in the English commons there was a limitation of the animals that villagers could feed in the summer: they could not exceed the number

[8]Article 11 of the Declaration of the Rights of Man and of the Citizen, 1789.

[9]Bollier argues that the pessimistic attitude regarding the sustainability of the commons is maintained in part “because the commons is frequently confused with an open-access regime—a free-for-all in which a resource is essentially open to everyone without restriction.” [12] According to Capel [13], communal property has been misinterpreted, many times and treated as a free access resource without regulation. Bruce [14] explains that the commons, in the English common law, implies a regulation in the form of access to common resource. Communal property, many times.

that could be fed in the winter. The capacity of the land was used to fix a constraint to the use of the commons.

Ellickson [16] considers that it is necessary to differentiate between the open access resource which every body can use, and common property where the resource use is limited to the community: under a pure or ideal state of open access, each person is authorized to take out resources units, but no person or group of persons have exclusive rights to manage or sell assets. By contrast, the members under a regime of communal property, not only can enter and remove the resource units, but also they have rights to manage the resource and exclude those who are not members of the community.

Finally, Munzer [17] thinks that the problem in a tragedy of the commons is in the absence of cooperation, but not in the restriction of the use, because the members of the community can agree in several ways to the administration of the common resource. This is what Elinor Ostrom [18], [19], [20] has shown in her research about the sustainability of the commons.

2) The open wireless networks as a commons: Yochai Benkler [21] sees Internet as a communication system designed under three layers interconnected and which together make the Internet a commons: The physical layer refers to both the distribution channel as well as the devices to produce and communicate the information. The devices are either controlled by the ISPs or by the Internet users. The logical layer includes the data transmission standards and protocols, e..g. the set of protocols of the TCP/IP model that since its inception was designed and used as a commons. And finally a content layer that includes the cultural expressions that can be stocked and distributed throughout the net, e.g. music, films, books.

All these layers can be free or controlled [22]: they are free when they are organized as a commons and everybody can access under equal conditions, and they are controlled when somebody has the right and the power to exclude anyone from the use. At the same time one layer can be both free and controlled like the content layer. In it we have cultural contents protected by copyright rules and cultural contents under public domain or free access.

Benkler provides a model for a commons based on open wireless networks. Wireless access points in these networks will have capabilities to search neighboring networks, always securing the best route to send traffic. The ISPs under this architecture would provide access to Internet through these wireless access points, and the last mile should be provided by the cooperative action of the Internet local users behaving as a commons. The presence of commons in the cooperative last mile throughout the propietary broadband, removes the bottleneck ISPs set on last miles to control what is send, to whom and what level of productivity and interactivity. However, the network will be as open as the last mile commoners decided.

III. Efficiency of Counter Measures

A. Mathematical model for users' behavior

We consider two types of P2P users: those that upload a given file F and those that are interested in downloading it. The first kind are often called publishers and we shall call the second type consumers. As soon as a publisher arrives, all the present consumers are assumed to rapidly download it.

We consider two categories of consumers. The first, which we call "cooperative", connect and remain some generally distributed time in the system, during which they may download files and let others download from them.

Free riders are those peers that remain just the time they need to download a file. We assume that if the file is not available they immediately disconnect and try to connect at a later time. We assume that these remain in the network a negligible amount of time so that their contribution to the amount of shared file available for the community is negligible.

We shall analyze two extreme cases: the first when there are only cooperative consumers and the second when there are only free riders.

Behavior of cooperative consumers

Assume that publishers and cooperative consumers, respectively, connect according to independent Poisson processes with rates α and β, respectively. A publisher and cooperative consumer, respectively, is assumed to remain connected during some generally distributed time Θ_i with mean σ_i, second moment $\sigma_i^{(2)}$, and Laplace Stieltjes Transform (LST) $\Theta_i^*(s)$, where we use the notation $i = \alpha$ to denote a cooperative consumer and $i = \beta$ to denote a publisher, Let $G_i(u) = P(\Theta_i \leq u)$.

The special case where the above quantities are the same for $i = \alpha$ and $i = \beta$ has been analyzed in [23].

Definition 3.1: (i) The *availability of a file F* is defined as the probability that a peer that does not have the file finds it upon arrival.
(ii) The *probability of future opportunities* is defined as the probability that a cooperative consumer receives F during its connection duration.
(iii) The *DownLoad Rate (DLR)* of F is defined as the rate at which consumers acquire the file F.

Behavior of Free Riders When analyzing the behavior of free riders, we shall restrict to the case where $\beta = 0$, i.e. there are no cooperative consumers.

The reader not interested in the mathematical analysis may go directly to Subsection III-E that describes the qualitative results that we learn from the mathematical model.

B. Mathematical analysis

Theorem 3.1: The number of publishers and the number of cooperative consumers at any given time t are independent and have a stationary Poisson distributions with parameters $\rho_\alpha = \alpha\sigma_\alpha$ and $\rho_\beta = \beta\sigma_\beta$ respectively.

Proof. The statement follows by observing that the process that counts the number of publishers and of the cooperative consumers at time t have the dynamics of $M/G/\infty$ queues with arrival rates and expected service times of (α, σ_α) and of (β, σ_β), respectively. ⋄

We shall need the following, which is a direct consequence of eq (1) in [24]:

Lemma 3.1: Consider an M/G/∞ queue with arrival rate β and with service probability distribution $G_\beta(u)$. Let $B^*_\beta(s,\beta)$ be the LST of the residual busy period at time 0 in stationary regime (we take it to be 0 if the server is idle at that time). We have

$$B^*_\beta(s,\beta) = \frac{1}{\mu(s)} p(\infty)$$

where

$$\mu(s) = \int_0^\infty \exp(-st)p(t)dt$$

$$p(t) = \exp\left\{-\beta\int_0^t (1-G_\beta(u))du\right\}dx$$

Theorem 3.2: The availability probability is given by $1-\zeta$ where

$$\zeta = B^*_\beta(\alpha,\beta)\exp(-\alpha\sigma_\alpha) \tag{1}$$

The stationary probability of future opportunities (i.e. that the peer receives F during his connection, given that he did not receive it upon arrival) is $1-\Theta^*_\beta(\alpha)$.

The download rate is given by

$$DLR = \beta(1-\zeta+\zeta(1-\Theta^*_\beta(\alpha)). = \beta(1-\zeta\Theta^*_\beta(\alpha)).$$

Note that the above quantities are depend on Θ_α only through its expectation.

Proof. The number of connected consumers corresponds thus to the number of customers in an M/G/∞ queue with arrival rate β and i.i.d. service time distributed like Θ_β. Focus on $t=0$ and consider the past busy period. At time $t=0$ no consumer with F if and only if the following two events occur:

- The number of publishers present when the past busy period of consumer begins is zero. The process of arrivals of publishers and of consumers are independent, and therefore the number of publishers when that busy period starts equals to that at steady-state. The probability of this event is $\exp(-\alpha\sigma_\alpha)$.
- No arrivals of peers with F occurred during that past busy period. The probability of this event is $B^*_\beta(\alpha,\beta)$.

This implies the Theorem. ⋄

Example: exponentially distributed Θ_α. Consider an M/M/∞ queue with arrival rate $\hat{\lambda}$ and service rate of 1 unit. Define

$$Q_n(s,u) = \int_0^1 e^{-ux}(1-x)^{s-1}x^n dx, \ n \ge 0$$

Then [25], [26] the Laplace Stieltjes Transform of the residual busy period at stationary regime is

$$B^*(s,\beta) = \frac{Q_1(s,\beta)}{Q_0(s,\hat{\beta})}.$$

We conclude the following:

Theorem 3.3: Assume that the sojourn time Θ_α of a publisher has exponential distribution with parameter 1. Then the availability is given by

$$1-\zeta = 1 - \frac{Q_1(\beta,\alpha)}{Q_0(\beta,\alpha)}\exp(-\alpha).$$

The probability of future opportunities (PFO) is given by

$$PFO = \frac{\alpha}{\alpha+1}$$

The download rate is given by

$$DLR = \beta\left(1-\frac{Q_1(\beta,\alpha)}{Q_0(\beta,\alpha)}\frac{\exp(-\alpha)}{1+\alpha}\right)$$

C. Analysis of Free Riders' Delay

As before, the probability to find F upon connection is $\overline{q}$. We set $S_0 = 0$ and set $\tau_i := S_i - S_{i-1}$. Let ξ_i be the number of the cooperative peers who have the file at time S_i. Without loss of generality we can ignore cooperative peers that do not have the file. Indeed, as we took $r=0$, they will not contribute to the availability of the file. Thus the arrival rate of cooperative peers is $\lambda=\alpha$. We then have $\rho=\alpha\sigma$. Let $\mathcal{S}_c$ be a random variable distributed as the past sojourn time of a cooperative node.

Theorem 3.4: [23] Assume that there is very little interest in F among those that do not have it, i.e. r is taken to be zero. Then

(i) The expected time that it takes for a free rider peer to obtain the file F is given by

$$\begin{aligned} E[S] &= \sum_{i=1}^\infty S_i P(\xi_i > 0, \xi_1 = ... = \xi_{i-1} = 0) \\ &= \sum_{i=1}^\infty S_i(1-\exp(-\rho P(\tau_i < \mathcal{S}_c)) \\ &\quad \times \prod_{j=1}^{i-1}\exp(-\rho P(\tau_j < \mathcal{S}_c)) \end{aligned}$$

(ii) The expected number of samples (probes) of the peer is given by

$$\begin{aligned} E[N] &= \sum_{i=1}^\infty i(1-\exp(-\rho P(\tau_i < \mathcal{S}_c)) \\ &\quad \times \prod_{j=1}^{i-1}\exp(-\rho P(\tau_j < \mathcal{S}_c)) \end{aligned}$$

As an example, assume that the sojourn time of cooperative peers is exponentially distributed with parameter ν. Then $\mathcal{S}_c$ is known also to have exponential distribution with parameter ν, so we obtain:

Corollary 3.1: [23] Assume that the sojourn time of cooperative peers is exponentially distributed with parameter ν. Then

$$E[S] = \sum_{i=1}^\infty S_i(1-\exp(-\nu\tau_i))\exp(-\nu S_{i-1})$$

$$= \sum_{i=1}^{\infty} S_i[\exp(-\nu S_{i-1}) - \exp(-\nu S_i)]$$

If moreover $\tau_i = \tau$ are constant then we get

$$E[S] = \frac{\tau}{1 - \exp(-\rho \exp(-\nu\tau))}$$

and

$$E[N] = \frac{1}{1 - \exp(-\rho \exp(-\nu\tau))}$$

D. Numerical results

For the case of cooperative peers, we investigated the availability and the download rate as a function of α and β. The goal is to understand the impact of an effort by the CPI (Content Providers Industry) to decrease the interest in a file as a function of the rates of offer and of the demand for it. The time unit is chosen such that $\sigma_\alpha = \sigma_\beta = 1$. The numerical results are taken from [23].

Figure 1 depicts the availability probability (y-axis) as a function of β (x-axis) for five values of α: 4, 2, 1, 0.5 and 0.05. β varies in the range $[0.05, \ldots, 8]$ with an incremental increase of 0.5. The curves are decreasingly ordered in α: $\alpha = 4$ corresponds to the curve that dominates all the others (straight line) and the lowest curve corresponds to $\alpha = 0.05$.

In the left subfigure we marked the variation in the availability when α decreases from 2 to 0.05. This large change in α (which decreases by a factor of 40) results in a decrease of only around 10% in the availability if β is high (around 6). It results in a large decrease in the availability for β small ($\beta = 0.5$), namely a decrease from close to 1 to around 0.5.

The right subfigure shows the impact of a large change in β, from 8 to 0, on the availability. This change results in a large decrease of availability when $\alpha = 0.05$ is small: a decrease in around 90%. but it results in a small decrease (around 10%) when $\alpha = 4$.

Figures 2 plots the download rate as a function of α and β.

For the case of free riders, we looked at the impact of sampling frequency on the mean waiting time. Figure 3 plots the mean waiting time of a free rider to download a file (y-axis) as a function of the sampling interval τ (x-axis). In the left figure, $\lambda = \alpha = 1$ is fixed and ν takes three different values: 1, 0.5 and 0.05. In the right figure, $\nu = 1$ is fixed and α takes three values 1, 0.5 and 0.05.

E. On the efficiency of CPI measures: Conclusions drawn from the figures.

Assume that the arrival rate of cooperative peers having F, α, is given and is not controlled by the CPI. The CPI tries to reduce the interest in downloading files. We make the following observations.

1) Impact on availability for cooperative peers:

- For α large (value greater than 1), no matter how much effort is put to discourage the download interest of peers, the file will remain highly available (probability more than 0.8). Thus a huge effort that reduces β from 8.0 to 0.05 will result in minor decrease on file availability. Hence, if $\lambda q \sigma$ is around 1 or more, then the benefit of trying to discourage the download is negligible.
- This conclusion remains true also if the effort is made to decrease α when β is large where a decrease in α will not have much impact on the availability probability.
- However, when both α and β are small, a decrease in β will decrease dramatically the availability of the file in the network. For instance, we observe that by reducing β from $\beta = 1$ to half its value at $\alpha = 0.05$, the availability will decrease from 0.53 to 0.4, i.e. by around 30%.
- Here is another way to view this behavior. Define the slope of the availability curve for a fixed α as the **Availability Decrease Rate (ADR)**. It indicates the decrease of the availability per unit of decrease in β. We observe that the curves in Figure 1 are all concave. This implies that the ADR increases when either β or α increase. Hence for each α the decrease rate is maximized at $\beta = 0$.

We thus conclude that if the effort of the CPI is proportional to the amount by which it can decrease the interest in a file, or more precisely, the arrival rate β, then the largest decrease in the availability for a given effort is obtained for content that has β and α as small as possible.

2) Impact on download rate of cooperative peers: As for the download rate, we observe that it grows with β at a rate that is close to constant and almost independent of the value of α (Figure 2-Left). In fact, the linear behavior occurs when the availability is large (close to 1). There, the download rate is close to β. By reducing β to some β' in this range, the download rate obviously decreases by the same amount. We say that measures for reducing the download rate are effective if by reducing β to $\Delta\beta$, the download rate decreases by a multiplicative factor larger than Δ. We see that this occurs again at low α and β. For instance, we observe in the right part of Figure 2 for $\alpha = 0.05$, that when β decreases from 1 to 0.5 by a factor of 2, the DLR decreases by a factor close to 3.

3) Impact on delays of free riders: As can be expected, we observe that for a given mean sojourn time of cooperative users, the mean waiting time of a free rider increases with larger sampling intervals. Inversely, for a given sampling interval, the mean waiting time decreases when the mean sojourn time increases.

This is illustrated in Figure 3. For a given λ, and as the value of ν becomes large (i.e. cooperative peers stay connected for short time), a small increase in the probing rate τ results in a large increase in the expected time that the free rider has to spend probing until it finds F. The same conclusion is seen to hold when ν is fixed and α becomes small.

We conclude that if CPI can take actions that decrease the probing rates of free riders, then it can affect expected waiting time of free riders dramatically when $\rho = \alpha/\nu$ is already small, otherwise this measure does not have much impact.

IV. CONCLUSION AND RELATED WORK

This paper complements our analysis in [23], [27], [28]. In [23] we have presented an introduction to the interplay

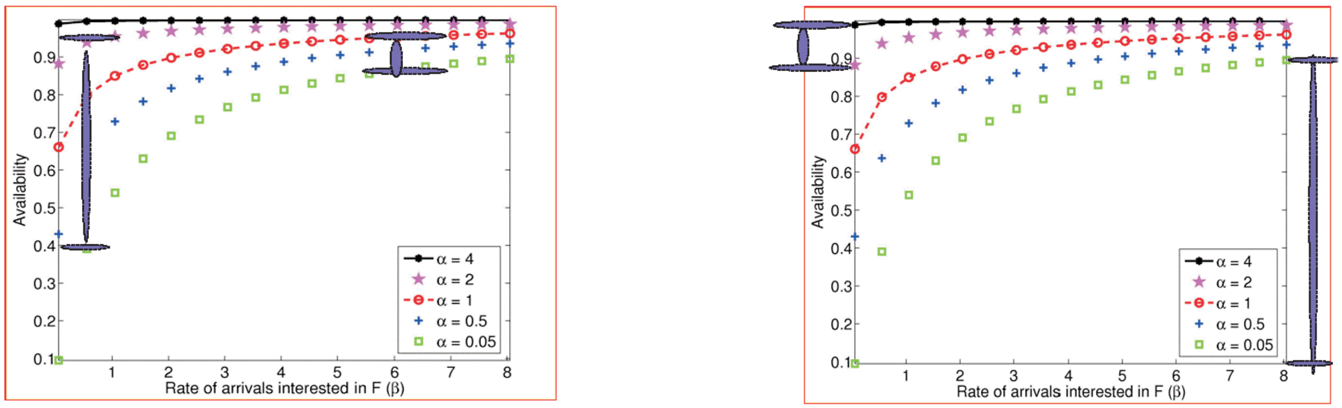

Fig. 1. The availability probability (y-axis) as a function of β for 5 values of α: 4, 2, 1, 0.5 and 0.05. β varies between 0 to 8. The curves are decreasingly ordered in α. $\sigma_\alpha = \sigma_\beta = 1$.

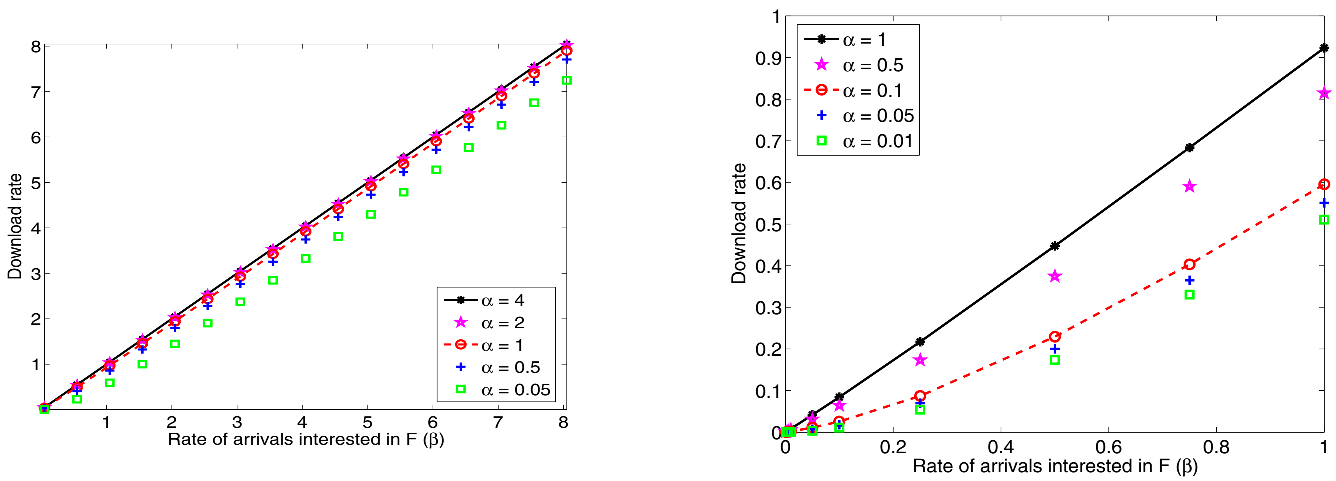

Fig. 2. The download rate (y-axis) as a function of β (x-axis) for 5 values of α. (**Left**): β varies in $[0.05, 8.5]$ with an increment of 0.5 and $\alpha \in \{0.05, 0.5, 1, 2, 4\}$. (**Right**): β varies in $[10^{-3}, 1]$ and $\alpha \in \{0.01, 0.05, 0.1, 0.5, 1\}$. The curves are decreasingly ordered in α. $\sigma = 1$.

between legislation and information technology that accompanied the developments of the Internet along with the possibilities it opened for free access to copyrighted music and films. We have presented in particular the various actors involved, their interests and the interactions between the various actors [23]. Economic modeling of these conflicts along with that of alternative approaches for collaboration between actors was presented in [27]-[28]. In this paper we presented the historical and ideological contexts of the conflicts that are due to the very wide access to culture and knowledge that the internet technology opens. We highlighted the central role that the access to the Internet plays in what many countries understand as basic human rights. We further summarized the economic identification of the Internet with the concept of commons. We ended with a mathematical model that allowed us to study the impact of measures against unauthorized download and upload over the Internet on availability and on other performance measures. We used modeling elements from the theory of infinite server queues, which had already been used in the context of P2P networks by D. S. Menasche et al [29], [30].

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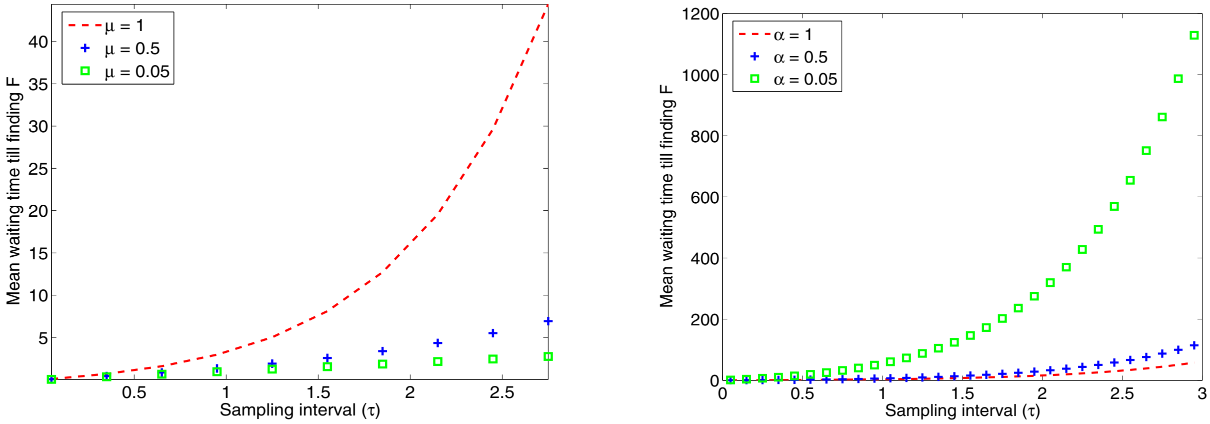

Fig. 3. The mean waiting time for a free rider (y-axis) as a function of sampling interval τ (x-axis). (**Left**): $\lambda = 1$ constant and $\nu \in \{0.05, 0.5, 1\}$. (**Right**): $\nu = 1$ is constant and $\lambda \in \{0.05, 0.5, 1\}$.

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