The Economics of Censorship Resistance

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Outline

A brief history of on-line censorship resistance

Time line:

- `anon.penet.fi` vs the Church of Scientology (1996).
- Napster vs the music industry (2001).
- Notice & Take Down web material on ISPs.

Emergence of the peer-to-peer paradigm:

- Eternity (1996), Freenet (2000), Free Haven (2000)
- Deployed: Kazaa, Gnutella, MojoNation (RIP)
- Peer-to-peer systems and lawsuits.

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An economic model of censorship and resistance

We will create a model that describes:

- Nodes with heterogeneous preferences.
- A particular model of censorship.
- The conflict between the censor and the censored node.

Using this model:

- Compare two ways of achieving censorship resistance.
- Judge the stability of these mechanisms.
- Calculate the resistance nodes will put up and the cost to the adversary.

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Basics

Modelling heterogeneous preferences of nodes:

- There are N nodes in the system.
- Each node can store and help distribute T resources.
- There are two kinds of resources in the system: red and blue .
- Each node prefers to distribute a balanced amount of red and blue resources according to its preferences r_i and b_i ($r_i + b_i = 1$).

Example

A left-leaning node might prefer to help distribute mostly Guardian articles instead of Telegraph articles ($r_i = 0.9$ and $b_i = 0.1$). A node will less partisan views might prefer to maintain a more even balance ($r_i = 0.5$ and $b_i = 0.5$).

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A unimodal utility model

We reflect the balance of red and blue resources a node holds and helps distribute through using a unimodal utility model.
A node that holds R red resources and B blue resources (with $R + B = T$) has a utility of:

$$U_i(R, B) = -T(R/T - r_i - 1)(R/T - r_i + 1) \quad (1)$$

- Maximal utility when $R = r_i T$ and $B = b_i T$.
- Utility decreases as the balance R, B shifts away.

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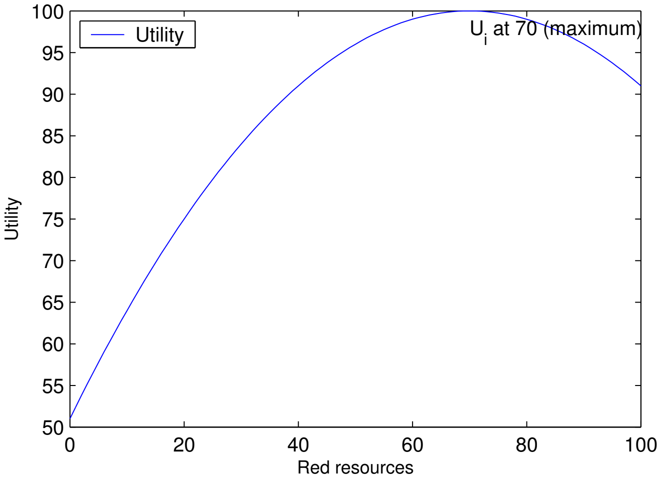

Two paradigms for censorship resistance

The random model:

- Resources are *scattered randomly* across some nodes.
- Censorship would inconvenience everyone.
- Difficult to select target nodes.
- Eternity, Freenet, FreeHaven, Distributed Hash Tables.

The Discretionary model:

- Nodes download whatever they like and *chose what to share.*
- Sharing happens as a by-product of other activities.
- Kazaa, Gnutella, eDonkey (eMule), . . .

Which is better?

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In terms of our model...

- In the *discretionary model* nodes can chose the balance of resources they hold. They will try to maximise their utility by having $R = r_i T$ red resources and $B = b_i T$ blue resources.
- In the *random model* each node receives a sample of all resources stored in the system. If the system stores R red resources and B blue resources, each node will hold $R = r_s T$ red resources and $B = b_s T$ blue resources where r_s and b_s are:

$$r_s = \frac{\mathcal{R}}{\mathcal{R} + \mathcal{B}} \qquad b_s = \frac{\mathcal{B}}{\mathcal{R} + \mathcal{B}} \tag{2}$$

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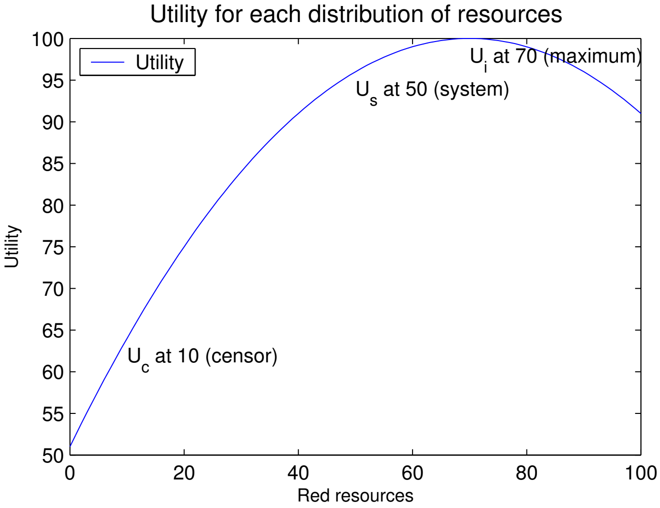

Preliminary comparison

- The utility of a node in the *random model* is lower or equal to its utility in the *discretionary model*.

$$U_i(r_i T, b_i T) \geq U_i(r_s T, b_s T) \quad (3)$$

Unless $r_i = r_s$ and $b_i = b_s$.

- Unless all nodes in the system have equal r_i and b_i there is no set system-wide values r_s and b_s that can maximise the utility of all nodes.

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Preliminary comparison (2)

- In the random model each node has incentives to cheat to shift the system-wide parameters r_s and b_s towards its own preferences.
  Flooding, reputation attacks, denial of service, dropping resources, ... and we have not even talked about censorship yet!
- The system-wide parameters need to be set in a *fair* way: elections, e-cash, reputation, ..., need to resist attacks.
- Even then nodes have incentives to leave the network to join another one with parameters that matches their preferences closer.

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Introducing censorship

Censorship:

- A censor targets a set of individual nodes.
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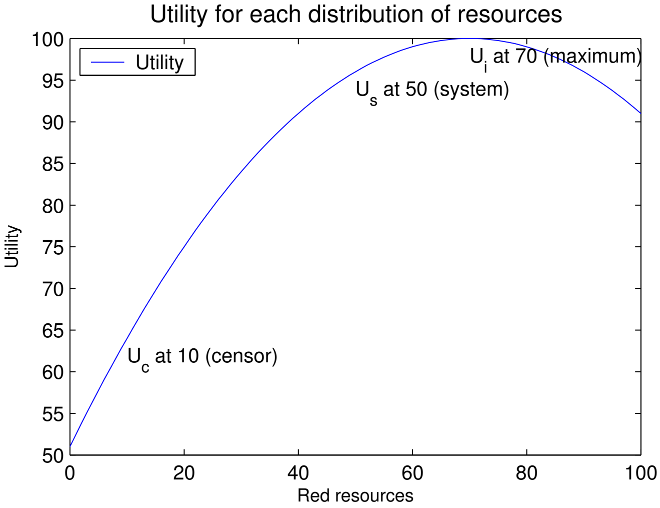

Introducing resistance

A node under censorship can chose to resist:

- It sets aside a *defence budget* t.
- The defence budget is subtracted from its ability to distribute resources $(T - t)$.
- A node has a probability $P(t)$ of foiling censorship depending of its defence budget t.

$$P(t) = \frac{1}{T}t \tag{4}$$

$(P(T) = 1$ and $P(0) = 0)$

- If it foils censorship a node has its previous distribution of resources, otherwise it has the distribution imposed by the censor.

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Utility and defence budget: *discretionary model*

A node in the *discretionary model* has an expected utility of:

$$U = P(t)U_i(r_i(T-t), b_i(T-t)) + (1-P(t))U_i(r_c(T-t), b_c(T-t)) \quad (5)$$

Expected utility is maximised when the defence budget is:

$$t_d = \frac{T}{2}\frac{2U_i(r_c, b_c) - U_i(r_i, b_i)}{U_i(r_c, b_c) - U_i(r_i, b_i)} \quad (6)$$

For the defence budget t_d to be positive it must be that:

$$U_i(r_c T, b_c T) < U_i(r_i T, b_i T) \quad (7)$$

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Similarly for the *random model* the defence budget will be:

$$t_s = \frac{T}{2} \frac{2U_i(r_c, b_c) - U_i(r_s, b_s)}{U_i(r_c, b_c) - U_i(r_s, b_s)} \tag{9}$$

Note that:

$$\forall i \in \mathcal{S}, t_d \geq t_s \Rightarrow \sum_{i \in \mathcal{S}} t_d \geq \sum_{i \in \mathcal{S}} t_s \tag{10}$$

Therefore the defence budget of a node in the random model will be lower than in the discretionary model.

The overall effort in defence of any set of nodes will also be lower.

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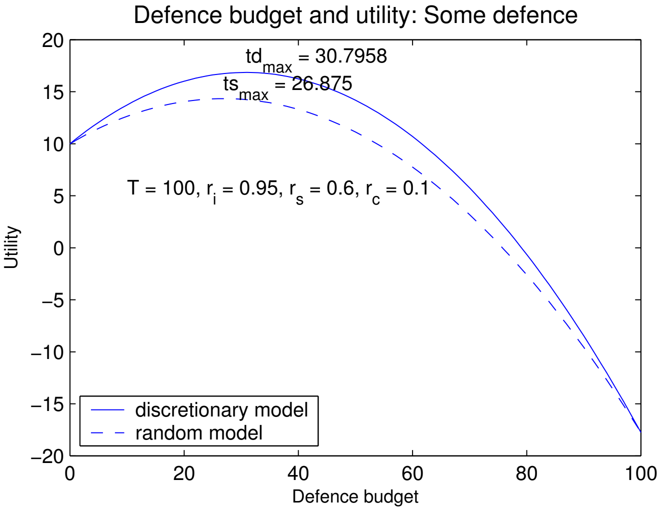
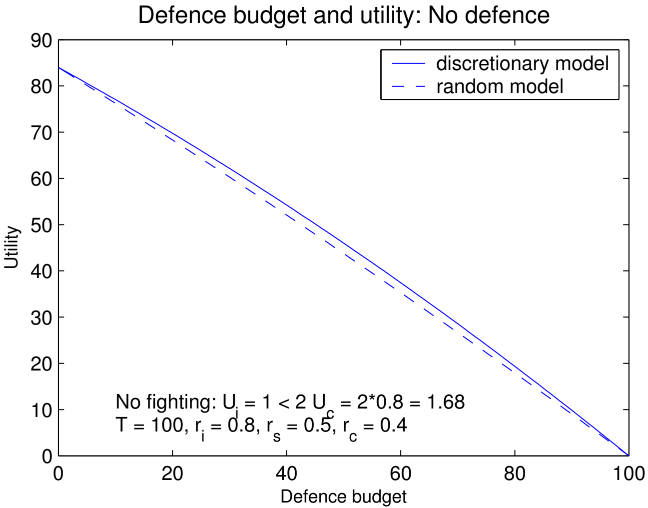


No defence


Defence budget and utility: No defence
discretionary model
random model
No fighting: U_i = 1 < 2 U_c = 2*0.8 = 1.68
T = 100, r_i = 0.8, r_s = 0.5, r_c = 0.4
Utility
Defence budget
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100

A first framework to evaluate censorship resistance

- Utility is about local distribution.
  (What if the red files are globally available?)
- Censorship and defence are local.
  (Censorship resistance is not transformed into a public good)
- Abstract away from real implementation costs.
  (Some random models might be technically more efficient)
- What about the strategy of the censor?

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