Content identification

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Contour

General

1. Physical Vs. digital goods,
2. Classic DRM
   a. Before the fact,
   b. After the fact,
      (i) Fingerprints,
      (ii) Traitor tracing,
3. *New DRM.*

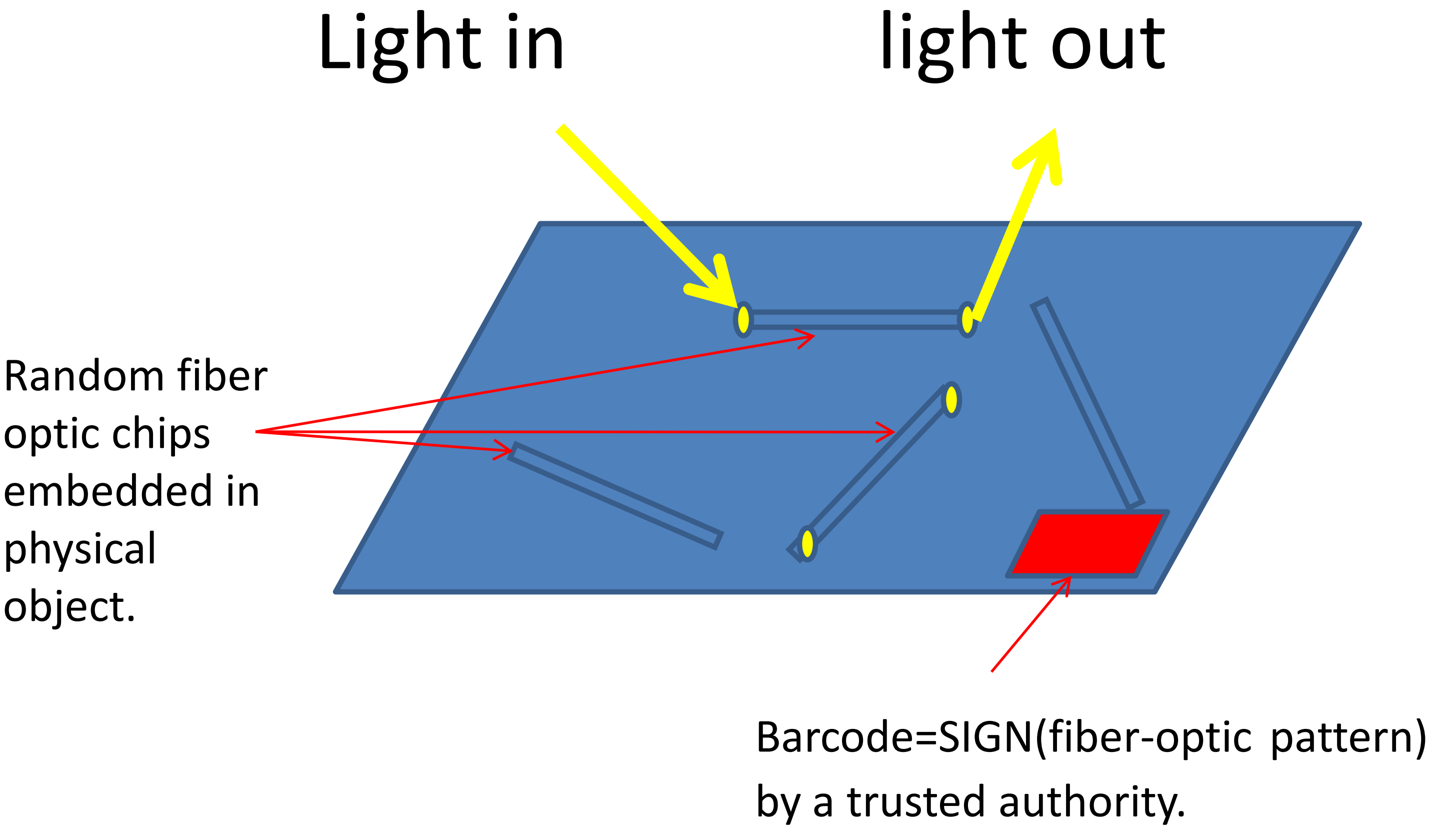
Today's talk

1. Speculate about new DRM,
2. Economics
   a. Piracy
   b. *Counterfeiting*

Damage from Counterfeiting

1. World Economic Forum: Damage from counterfeiting went from $430b in 2004 to $3t in 2007.
2. Physical counterfeiting (medicine, aviation parts, etc.). Solution: *Don Bauder & Gus Simmons* of Sandia National Labs, SALT agreement, 70's.

Physical counter counterfeiting (Bauder & Simmons)



How good can it possibly get?

(new DRM)

DRM for web hosting (“the new DRM”):

Web-host shares ad-revenues w/producer.

Identify the true producer.

Comparison

- The new DRM problem is easier to solve than the classic one. It enjoys numerous *systemic* advantages.

- In addition, replacing watermark technology with media-*hashing* has *operational*, *computational* complexity, and *robustness* advantages.

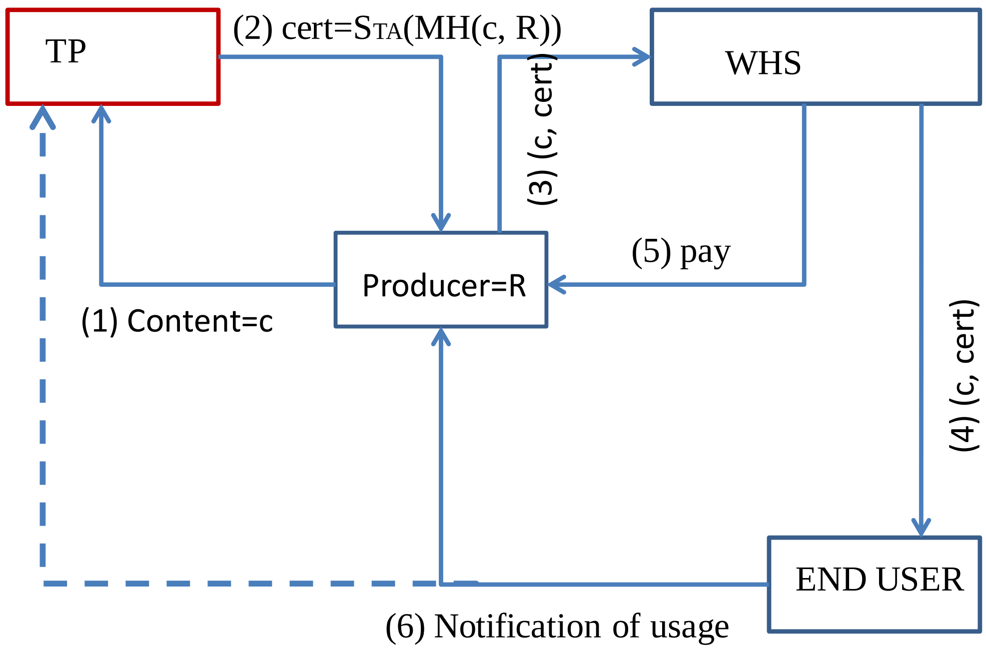
Media hashing

- *Objects* $Ci \cong Cj \rightarrow h(Ci)=h(Cj)$.

  [Ref.: M.H. Jakubowski; M. K. Mihcak; R. Venkatesan]

- Creator *R* created object *c*.
- A ***trusted*** party *TP* issues a certificate $cert=SIGN_{TP}(h(c),R)$, if it hasn't seen $h(c)$ before.

A possible new DRM system



TP=trusted party,
WHS= Web hosting service,
MH=Media hash,
S_{TA} (m)=Signature of TA on m.

Fig. 1: Ad-based revenue generation using media hashing to control fraud.

Systemic advantages of new DRM

- End user is not the enemy;
- Attacker does not know the secret key, and cannot even experiment with the decoder as a black box;
- The assumption that end-user does not modify her player is realistic (since she is not a side in this struggle).

Advantages of hashing over marking

- Operational: Protects the *past*.
- Complexity & Robustness: By def. more efficient & more robust ($\in$ watermarking),
- Example: current image-hash tolerate $\pm 20^0$ rotations. For images, 360/(2*20)=9 trials are enough. For video, after $\pm 20^0$ rotations it is not valuable, so 1 trial.

How good is good enough?

(classic DRM)

REFERENCES

- Banerjee, D.S., 2003, 2006 (“piracy..”),
- YY & Gideon Yaniv in this proceedings.

Counterfeiting Vs. Piracy

- CF looks like original, costs like original, and counterfeiter competes against legal producer in the same market.

Setting

- **Def.:** q = probability to correctly trace (eg, using sting ops), successfully prosecute, and penalize a counterfeiter.

- **Q:** What is the payoff of improving q?

Over simplifications

- Counterfeiter mimic original w/out costs,
- Consumers pay full price for counterfeits,
- Everybody is economically rational.

Reasonable Assumptions

1. Once traced & successfully prosecuted there is a fixed proportion 1/γ between crime and punishment.

2. Audit events are independent,

3. Probability of false positives is negligible (adjust threshold accordingly).

Notations

- x=# illegal copies,
- q=Pr[detection after a single illegal copy],
- $q=\alpha\beta$,
- $\pi(x)$=Pr[det. after x copies]=$1-(1-q)^x$,
- p=price of a copy,
- F=$ punishment,
- $\gamma=F/xp=punish/crime$,
- $P(x)$= gain of the CF,

  $=(1-\pi(x))px- \pi(x)F$
- x^* = optimal CF production,
- Lambert : $L(z)e^{L(z)} = z$,
- $\lambda(\gamma) = L(e \cdot \frac{\gamma}{1+\gamma}) - 1.$

More precisely

$$x^* = \min\{D(p)/n, \frac{\lambda(\gamma)}{\ln(1-q)}\}$$

Market size at price *p*

Number of independent counterfeiting groups.

Henceforth we ignore boundary conditions, and some other details, assuming $x^* < D(p)/n$, and $q > 0$.

The Counterfeiter

Theorem 1:

$$(i)\ \ x^{*} = \lambda(\gamma)/\ln(1-q) \approx -\lambda(\gamma)/q,$$

$$(ii)\ P(x^{*}) > 0,$$

$$(iii)\ \pi(x^{*}) = 1 - e^{\lambda(\gamma)}.$$

i.e. $\pi(x^{*})$ is independent of q and p.

It depends only on γ.

Corollary : $\pi(x_{w}^{*}) = \pi(x_{o}^{*})$.

The economics of the protection

- n=# counterfeiters.
- Subscripts *w,o* denote parameter values *w*ith and with*o*ut improvement (technological, or audit rate),
- For $i \in \{w,o\}$ R_i = revenues of legal producer.
- $P_2 = R_w - R_o$ = payoff of legal producer due to improvement.

Payoff of the legal producer

$$R_w = (D(p) - x_w^*)\,p; \quad R_o = (D(p) - x_o^*)\,p,$$

$$P_2 = \mathrm{R_w} - \mathrm{R_o},$$

For a single counterfeiter:

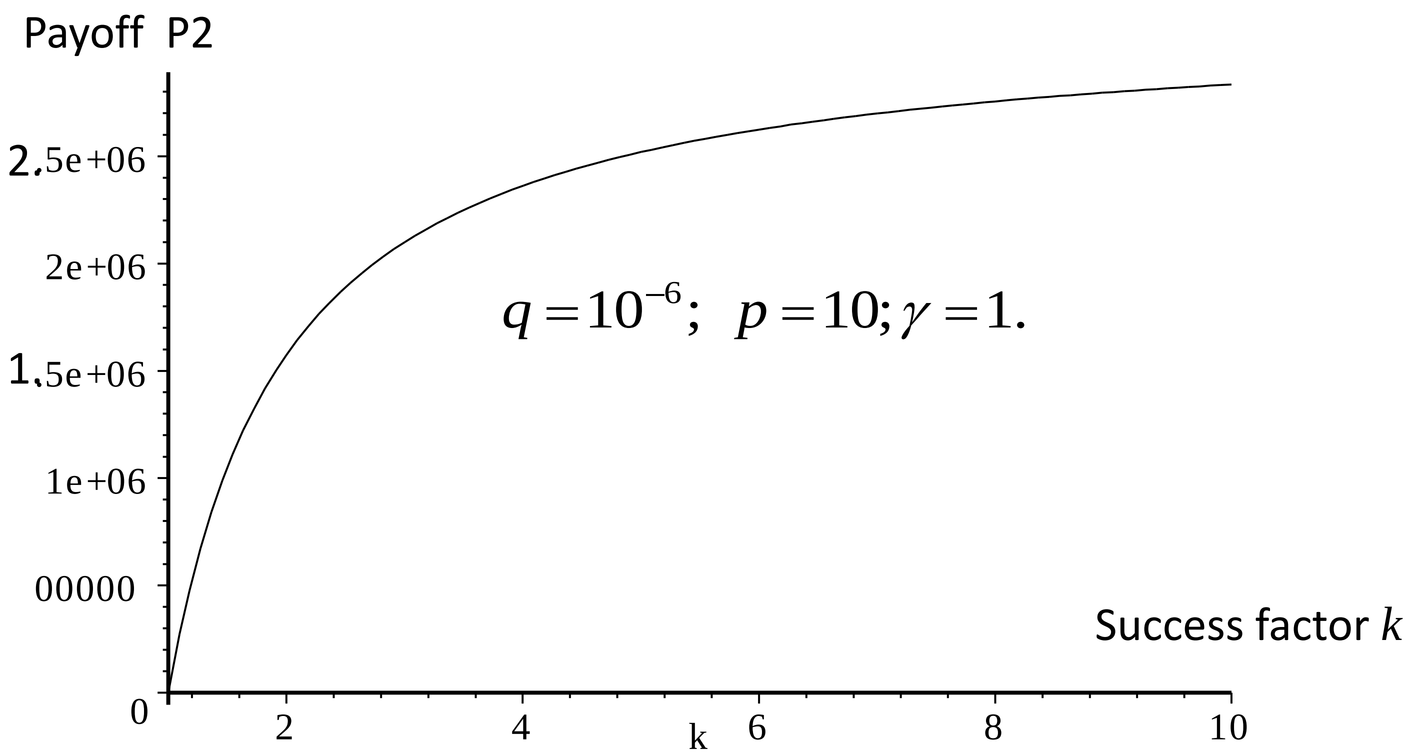
$$P_2 = \lambda(\gamma)\,p\left(\frac{1}{\ln(1-q_o)} - \frac{1}{\ln(1-q_w)}\right),$$

For n counterfeiters:

$$P_2 = \lambda(\gamma)\,np\left(\frac{1}{\ln(1-q_o)} - \frac{1}{\ln(1-q_w)}\right).$$

Success factor $k = q_w / q_o$.

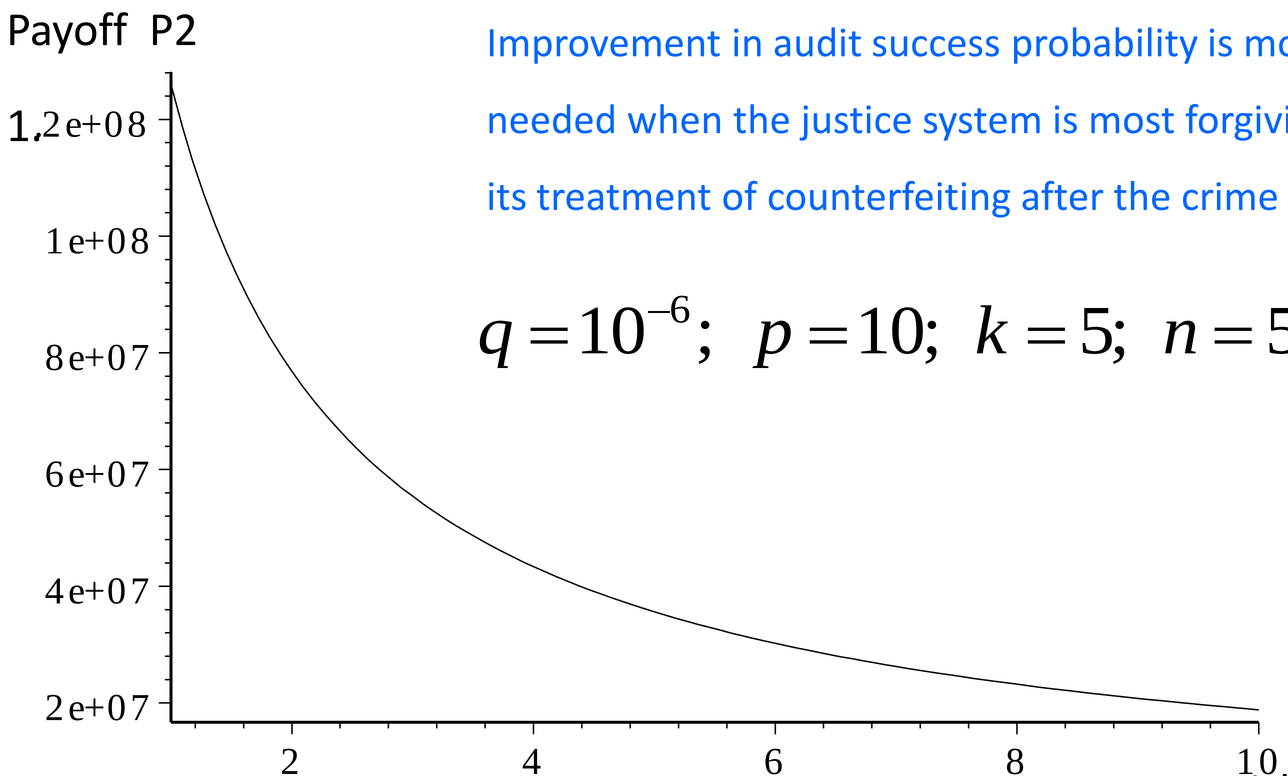
Freeze γ variable k



$$q = 10^{-6}; \quad p = 10; \gamma = 1.$$

K=5 captures most of the payoff (re, how good is good enough).

Freeze k variable γ



Improvement in audit success probability is most needed when the justice system is most forgiving in its treatment of counterfeiting after the crime has been proven.

$$q = 10^{-6};\ \ p = 10;\ \ k = 5;\ \ n = 50$$

$$\gamma = \frac{\text{Punishment}}{\text{crime}}$$

Max # counterfeiters

n counterfeiters crowd the market; each gets $x=D(p)/n<x^*$

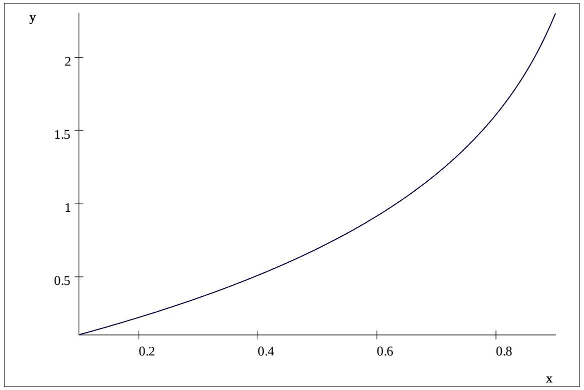
$$\text{Claim}: \quad n_{\max} = \frac{D(p)\ln(1-q)}{\ln(\frac{\gamma}{1+\gamma})}$$

$$\text{Proof}: \ (1-\pi(D/n))\,pD/n - \pi(D/n)F = 0,$$

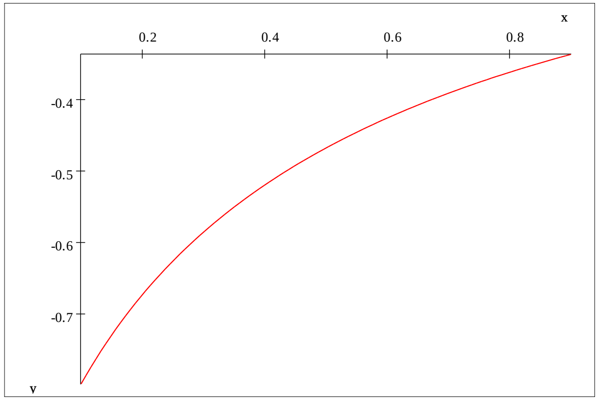
$$F = \gamma pD/n.$$

APPENDIX

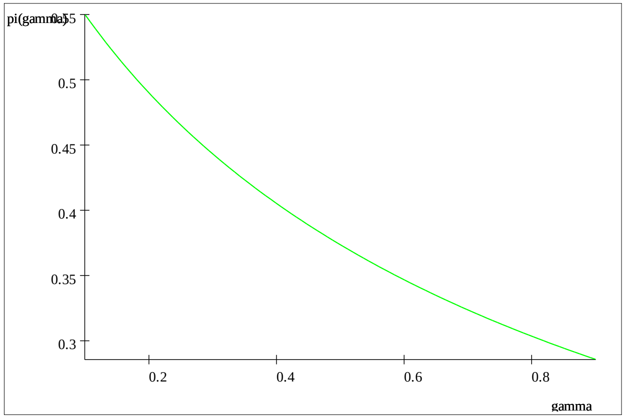
$-\ln(1-q)$



$\lambda(\gamma) = \text{LambertW}(e * \gamma/(1+\gamma)) - 1$



$$\pi(x^*) = 1 - e^{\lambda(\gamma)}$$



$\gamma = 1/2$

$$\frac{n_{\max}}{D} = \frac{\ln(1-q)}{\ln(\gamma/(1+\gamma))}$$