Figerprinting digital documents

survey

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1. Government secrets

- Government meeting on Monday to discuss secret plans on hospital reorganizations in face of COVID-19

1. Government secrets

- Government meeting on Monday to discuss secret plans on hospital reorganizations in face of COVID-19
- All the details of the plan are front page news on Index on Tuesday

index

A bezárandó kórházi osztályok listája
- János kórház, belgyógyászat
- Margit kórház, szülészet
- …

2. Industry secrets

Director of engineering compony:

- Good news: We have just sold the thousandth copy of our video on how to build cratoons.

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Director of engineering compony:

- Good news: We have just sold the thousandth copy of our video on how to build cratoons.
- Bad news: this was the last one. Somebody uploaded it to YouTube – now anybody can watch it for free.

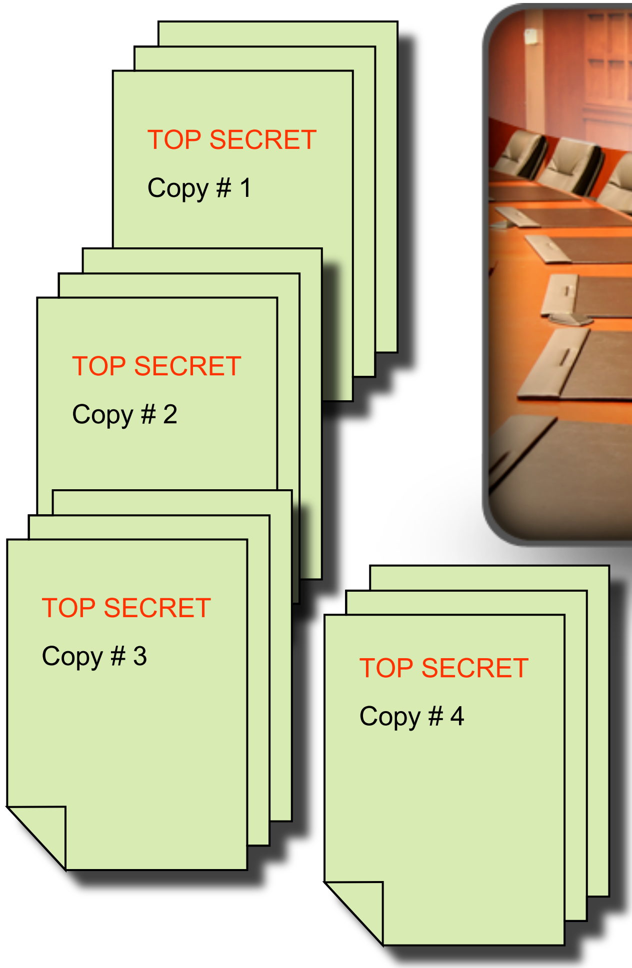
How to protect the secret

- Sue the medium (Index or YouTube) or at least make sure they stop sharing our information
- Sue the illegitimate end user (the guy who builds cratoons with our video but did not pay for it)

How to protect the secret

- Sue the medium (Index or YouTube) or at least make sure they stop sharing our information
- Sue the illegitimate end user (the guy who builds cratoons with our video but did not pay for it)
- In this talk: Find the legitimate user who illegally shared the secret (the cabinet member / one of the thousand customers who payed for the video)

Embed unique ID in every copy of document



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  If user finds it can remove the ID
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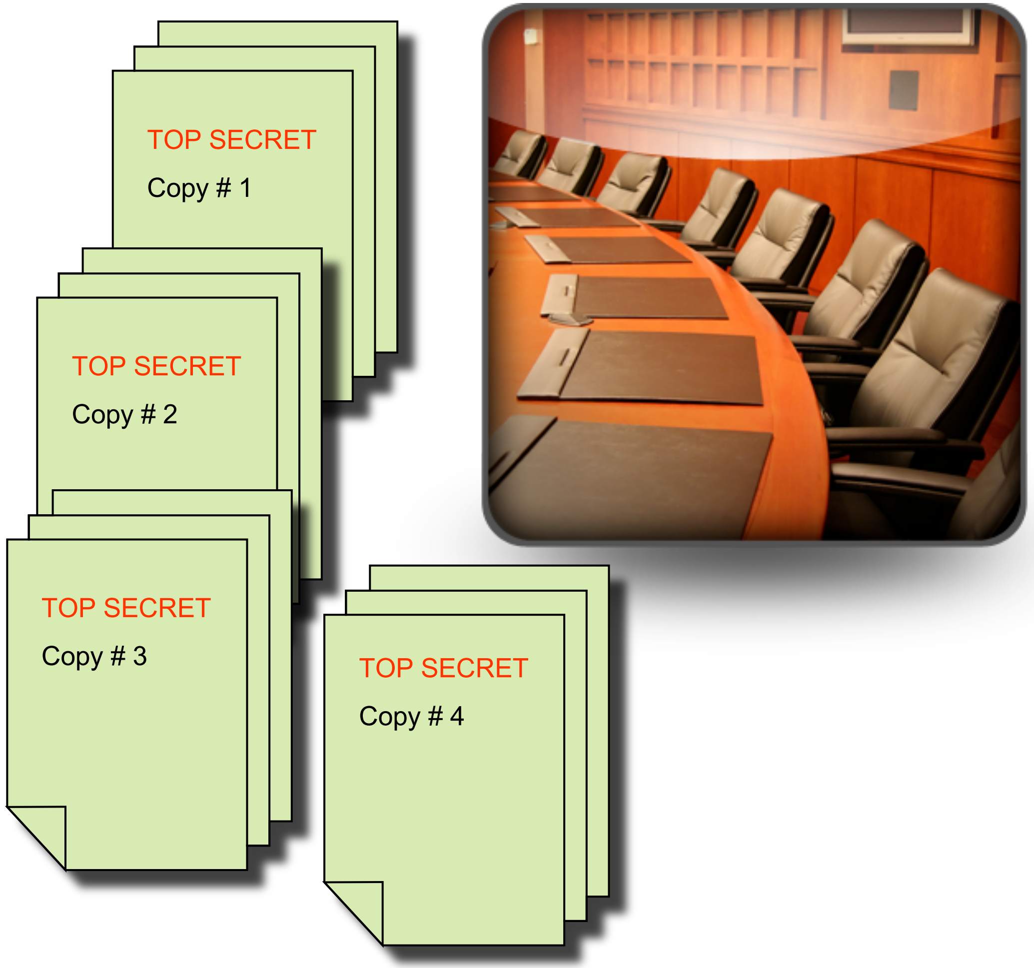

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  harder (but doable) for text.
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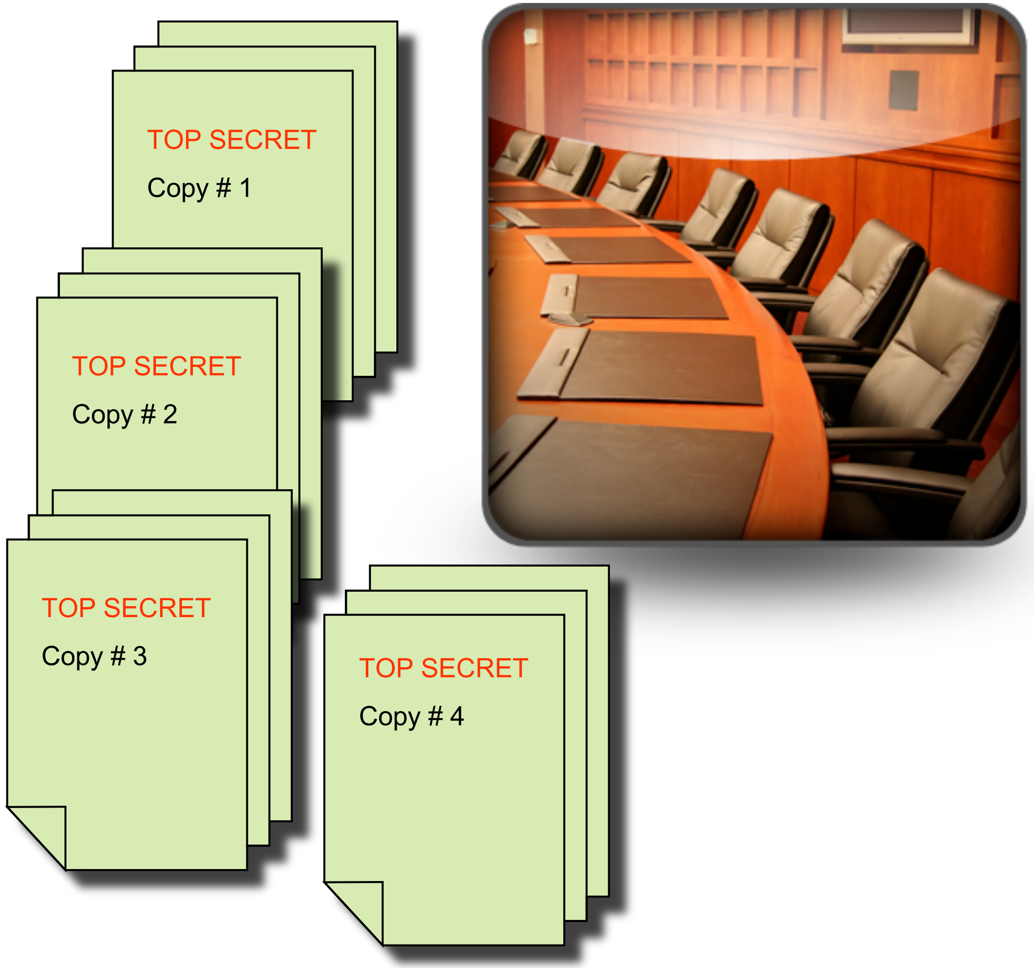

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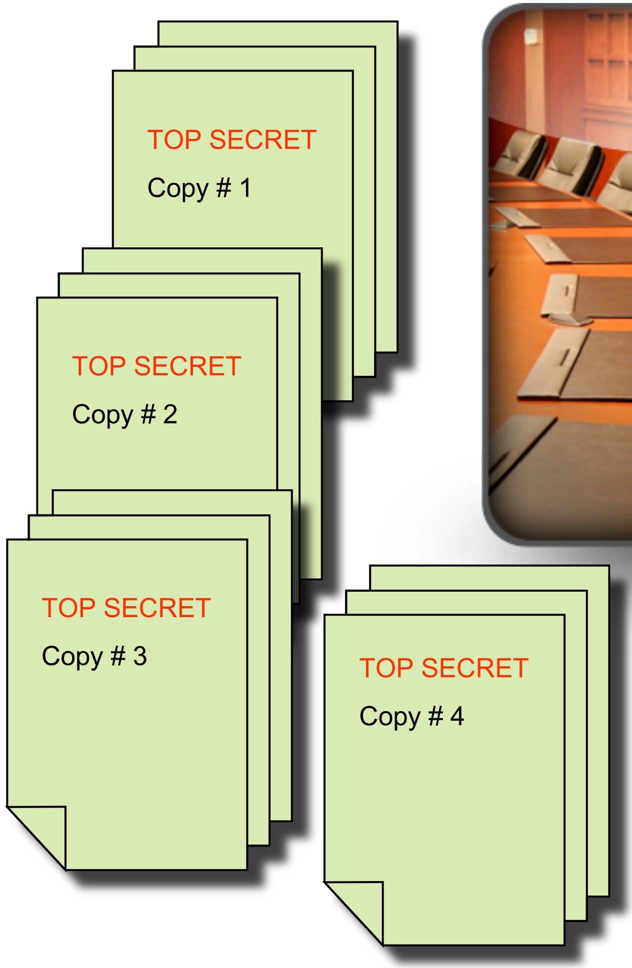
Example: Hollywood movies distributed to the members of the American Academy before the vote for the Oscars.



Example

Digital document:

0010010110101111101010110011010010001010001100110100111111

Example

Find irrelevant positions:

00100101101011111010 101 10011010010001 01000110011010011111

Example

Duplicate:

00100101101011111010 101 10011010010001 01000110011010011111
00100101101011111010 101 10011010010001 01000110011010011111
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Example

Insert distinct code (ID) in every copy:

001001011010111110100101010011010010001001000110011010011111 1

0010010110101111101001010100110100100011010001100110100111111

0010010110101111101001011100110100100010010001100110100111111

0010010110101111101001011100110100100011010001100110100111111

0010010110101111101011010100110100100010010001100110100111111

0010010110101111101011010100110100100011010001100110100111111

0010010110101111101011011100110100100010010001100110100111111

Example

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00100101101011111010**0**101**0**10011010010001**0**010001100110100111111
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- If code position remain hidden
- code is not changed
- leaking participant easily traced

No mathematics?!

$$\int_a^b f(x)dx = \int_{-1}^{1} f\left(\frac{b-a}{2}\xi + \frac{b+a}{2}\right)\left(\frac{b-a}{2}d\xi\right)$$

$$= \frac{b-a}{2}\int_{-1}^{1} g(\xi)d\xi = \frac{b-a}{2}\sum_{k=1}^{n} w(\xi_k)g(\xi_k) + R_n(\xi)$$

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where $\xi = \frac{2x-b-a}{b-a}$, i.e., $x = \frac{b-a}{2}\xi + \frac{b+a}{2}$, $-1 < \xi < 1$,

ξ_k is the kth zero of $P_n(\xi)$,

$$w(\xi_k) = \frac{2}{\left(1-\xi_k^{\,2}\right)\left[P_n{}'(\xi_k)\right]^2},$$

$$g(\xi) = f\left(\frac{b-a}{2}\xi_k + \frac{b+a}{2}\right),$$

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it’s coming…

Collusion attack

Two (or more) participant compare copies:

```
  00100101101011111010010100100110100100010010001100110100111111
  00100101101011111010010100100110100100011010001100110100111111
→ 00100101101011111010010110100110100100010010001100110100111111
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makes tracing much harder (and more interesting!)

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tracing must be based on these

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Limited number of malicious participants (the pirates) collaborate to forge untraceable copy of document.

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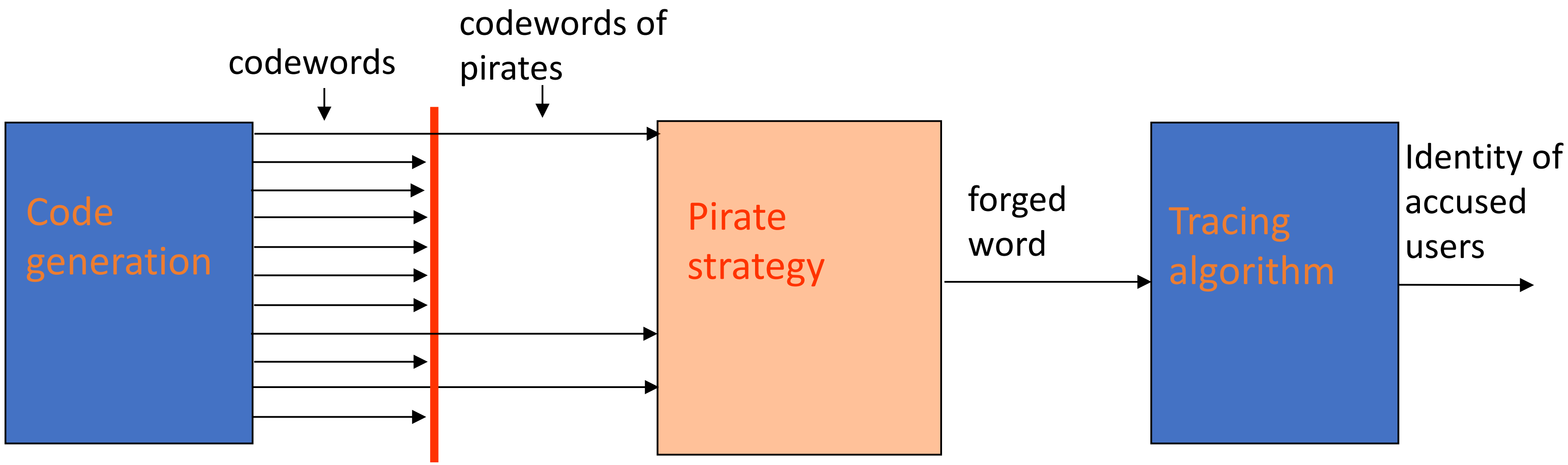
Limited number of malicious participants (the pirates) collaborate to forge untraceable copy of document.

They don’t find / cannot change positions of code that agrees in each codeword they have: the Marking Assumption.

They are not restricted in their output in any other way.

Boneh-Shaw fingerprinting model



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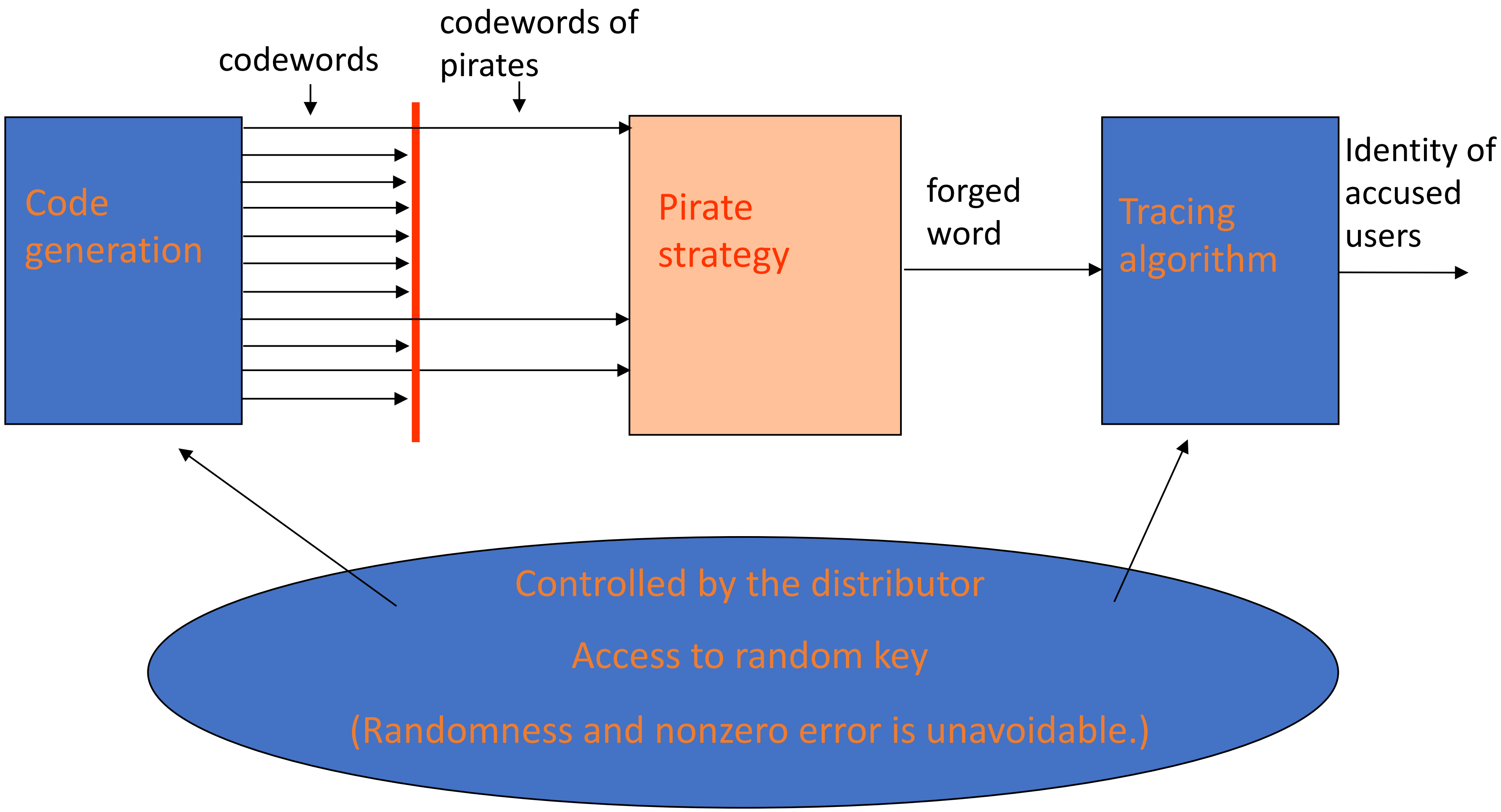

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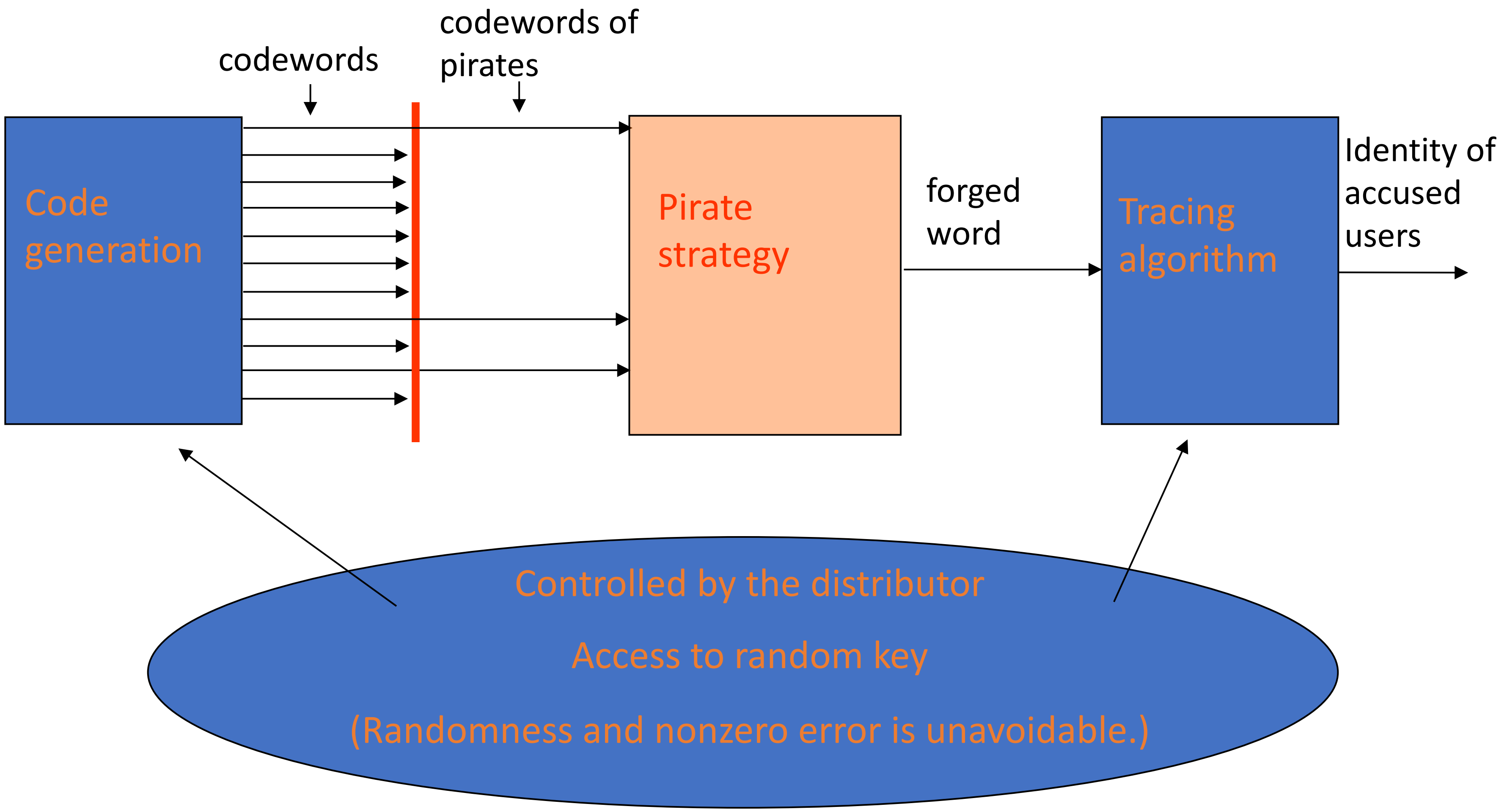

Goal of the distributor: accuse pirate(s)

Error: an innocent user accused

Fail: no pirate is accused

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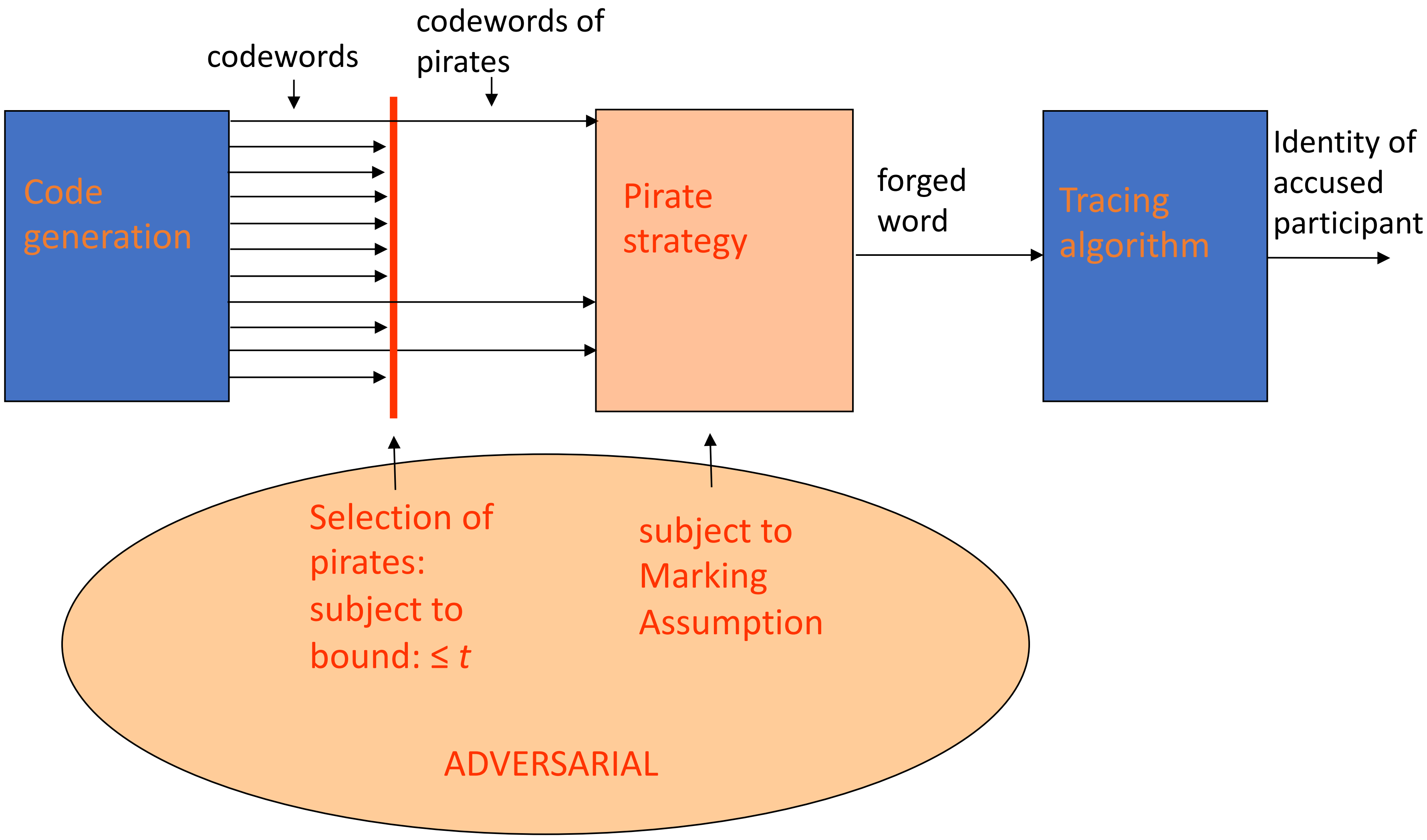

Parameters of fingerprinting code:

- number of participants: *N* considered large
- max number of pirates: *t* considered a constant
- length of code: *n*
- size of alphabet: *s* s=2 for binary, s>2 for non-binary
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Simplification:

Maximize rate subject to error probability going to zero as length grows.

Maximal rate = t-fingerprinting capacity (also depends on s)

Constructions, bounds

Boneh-Shaw 1988: t-secure binary fingerprinting codes with rate: $R = \Omega(t^{-4})$

bound on t-fingerprinting capacity: $O(t^{-1})$

T. 2003, 2008: bias code generation, linear accusation: $R = t^{-2} / 100$

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Huge constant factor between lower and upper bound became subject of intense research:

Skoric-Katzenbeisser-Celik, Skoric-Vladimirova-Celik-Talastra, Blayer-Tassa

While others focused on the capacity for small constant values of t:

Anthapadmanabhan-Barg, Anthapadmanabhan-Barg-Dumer, Barg-Blakeley

Newer constructions, bounds

Amiri-T.: t-secure binary fingerprinting codes with much improved rates:

conjectured to achieve t-fingerprinting capacity for any t.

Improved bound on binary t-fingerprinting capacity.

Both rate of construction and bound is $(1/(2\ln 2) + o(1))\, t^{-2}$

Asymptotical agreement, but do not agree for any fixed t.

Huang-Moulin, Moulin: Similar construction for a much broader class of fingerprinting problems

simpler fingerprinting (T.)

Bias code generation

- find biases $0 < bi < 1, \ i = 1, 2, \dots, n,$ i.i.d from fix distribution D;
- choose bit *i* of binary codeword *x* with bias b_i: $\Pr[x_i = 1] = b_i$;
- every bit of every codeword independent (given the biases)

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- given forged word y accuse user with codeword x if

$$\sum_{i=1}^{n} f(x_i, y_i, b_i) > T$$

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Optimize
– distribution D
– function f
– threshold T

improved fingerprinting (Amiri-T.)

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Advantage:
near-optimal
rate
Disadvantage:
very slow
tracing

GOAL

Combine:

- near-optimal rate
- efficient (linear time) tracing

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First step: doable for $t = 2$ pirates

?????? for $t > 2$???????

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Players: Diana and Pierre.

Parameters: number $t \geq 2$ and finite alphabet S.

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i.i.d. letters from S according to D
and y is another letter from S
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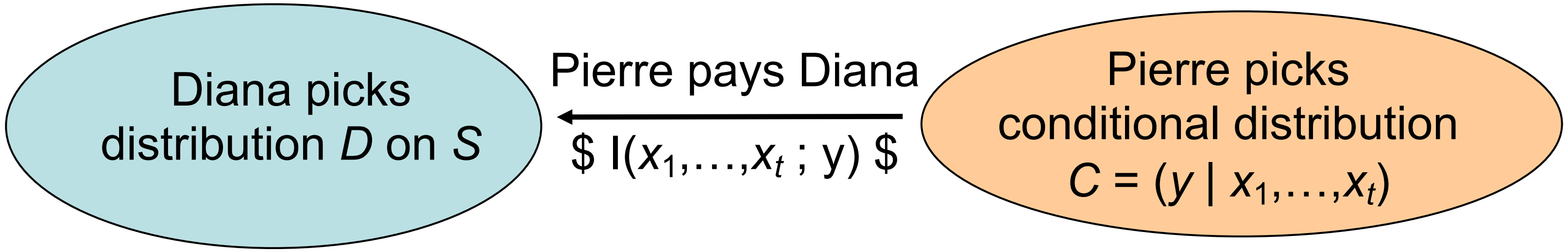

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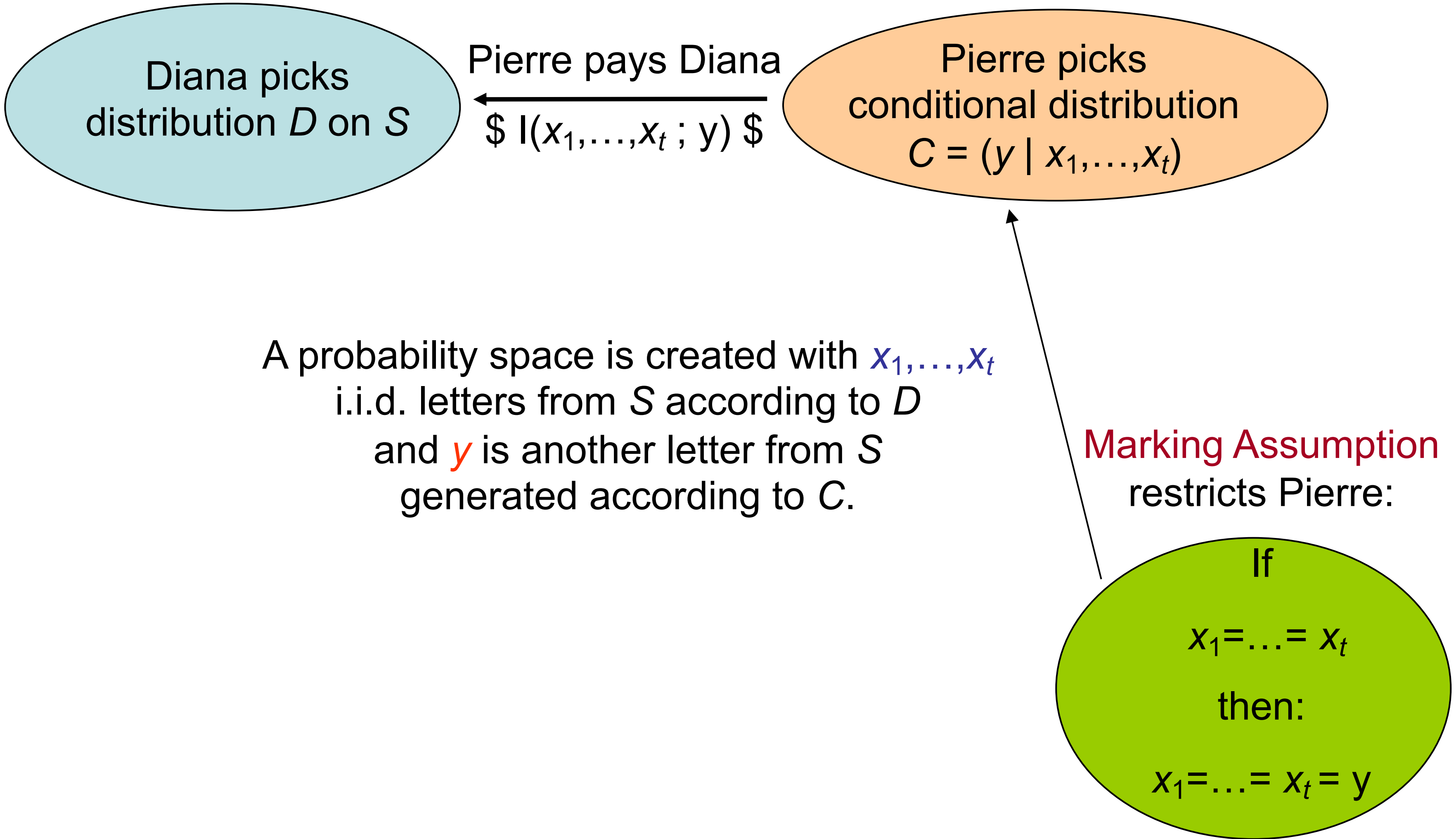

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Marking Assumption restricts Pierre:

If

$x_1 = \ldots = x_t$

then:

$x_1 = \ldots = x_t = y$

Moulin considers other restrictions in place of the Marking Assumption:

Different versions of fingerprinting

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- Diana's optimal strategy is a randomized, but over just a few possible D.
- Rate achieved in fingerprinting = (value of this game)/t

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