Anti-Collusion Fingerprinting for Multimedia

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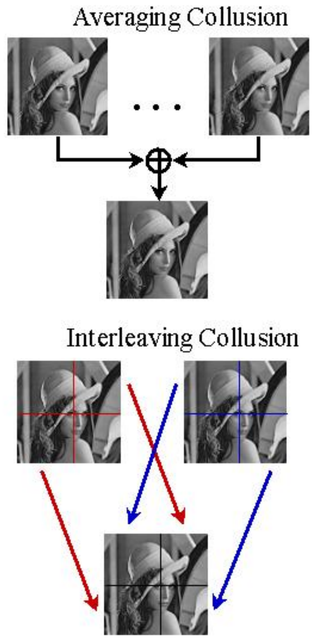
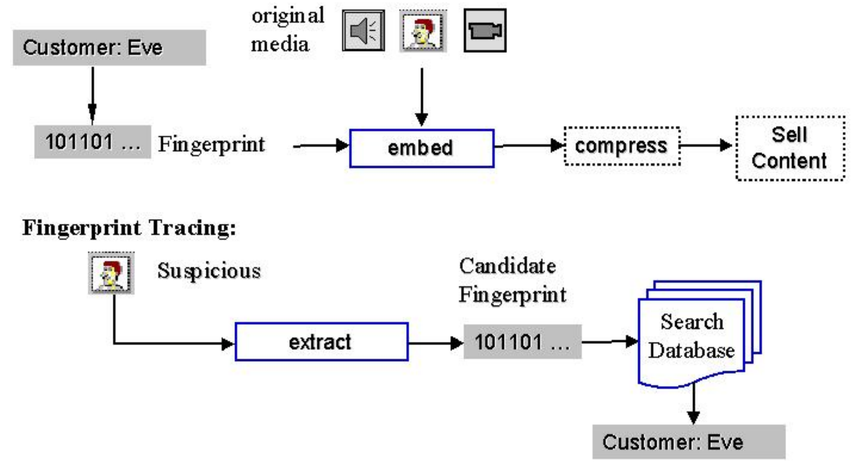
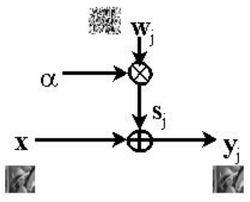
Introduction

- Encryption is useful, but not enough …
  - Protection by encryption vanishes after delivery and decryption
  - Customers may redistribute content in an unauthorized way
- Robustly embed digital fingerprint
  - Insert ID or "fingerprint" to identify each customer
  - Prevent improper redistribution of multimedia content
- Collusion: A cost-effective attack
  - Users with same content but different fingerprints come together to produce a new copy with diminished or attenuated fingerprints
- Anti-collusion fingerprinting
  - Trace traitors and colluders to actively deter collusion/redistribution
  - Rely on joint fingerprint encoding & embedding

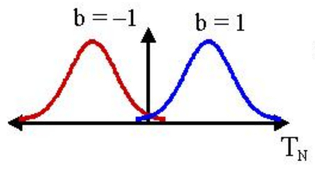




Additive Fingerprint Embedding & Detection



$T_N = y^T s / \sqrt{\sigma_d^2 \|s\|^2}$



- Types of multiple-bit embedding
  - Orthogonal modulation: $w_j = u_j$
  - Coded Modulation: $w_j = \sum_{j=1}^{B} b_{ij} u_j$
- Detection via hypothesis testing
  - Optimal detector for i.i.d. distortion $N(0, \sigma^2_d)$ is a correlator
- Challenge
  - Prefer short code for reliable extraction
  - Also want to trace many users/colluders

Anti-Collusion Fingerprint Codes

- K-resilient AND ACC code
  - A binary code $\mathbf{C}=\{\mathbf{c}_1, \mathbf{c}_2, \ldots, \mathbf{c}_n\}$ such that the logical AND of any subset of K or fewer codevectors is non-zero and distinct from the logical AND of any other subset of K or fewer codevectors
  - **Example**: {(1110), (1101), (1011), (0111)}
- ACC code via combinatorial design
  - Balanced Incomplete Block Design (BIBD)
  - (v,k,λ)-BIBD code is an (k-1)-resilient ACC
    - *Defined as a pair (X,A)*
    - *X is a set of v points*
    - *A is a collection of blocks of X, each with k points*
    - *Every pair of distinct points is in exactly λ blocks*
    - *# blocks* $n = \frac{\lambda(v^2 - v)}{k^2 - k}$

Simple Example

(7,3,1) BIBDcode

- X={1,2,3,4,5,6,7}
- A={123, 145, 167, 246, 257, 347, 356}

ACC code via (7,3,1) BIBD for handling up to 2 colluders among 7 users

$$C = \begin{pmatrix} 0&0&0&1&1&1&1 \\ 0&1&1&0&0&1&1 \\ 1&0&1&0&1&0&1 \\ 0&1&1&1&1&0&0 \\ 1&1&0&0&1&1&0 \\ 1&0&1&1&0&1&0 \\ 1&1&0&1&0&0&1 \end{pmatrix}$$

- Code length for n=1000 users
  - *ours $O(n^{0.5})$ ~ dozens bits*
  - *prior art $O((\log n)^4)$ ~ thousands*

16-bit ACC Example for Detecting ≤ 3 Colluders

User-1 (-1,-1, -1, -1, 1, 1, 1, 1, …, 1)

(-1, 1, 1, 1, 1, 1, …, -1, 1, 1, 1) *User-4*

Collude by Averaging

Extracted fingerprint code (-1, 0, 0, 0, 1, …, 0, 0, 0, 1, 1, 1)

Uniquely Identify User 1 & 4

Detection Statistics For 3-colluder Case