CS 155 Spring 2006

Digital Rights Management

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Next Tuesday

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Basic Problem

- Joey writes and records a song
  - Song distributed on some sort of media
  - Joey (and music company) want to *sell* recordings
  - But digital info is easy to copy, on most media
- What can Joey (and Music Inc.) try to do?
  - Look for copies?
  - Mark recording to make it easier to find copies?
  - Restrict media so only certain devices can play it?

All of these approaches have problems; no perfect solution (yet?)

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Outline

- Examine or modify content
  - Content hashing and copyright crawling
  - Watermarking
  - Fingerprinting
- Regulate use through special content players
  - Apply complex policies, need tamper-proof platform
  - Some examples
    - MediaMax CD3: restrict access on software players
    - DVDs: CSS encryption and hardware/software players
    - Windows Media Rights Management
    - Office Information Rights Management

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Content hashing

- Suppose we had a "content-aware" hash function:
  H: {music} → {short strings}
  satisfying:
  - 1. If M1 and M2 are two music clips (e.g. MP3 files) that play the "same" song then H(M1) = H(M2)
  - 2. Given a clip M a pirate cannot create an "acceptable" clip M' such that H(M) ≠ H(M')
- Is this realistic?
  - Hash function must resist all signal processing tricks
  - Do not know such hash functions exist
    - some claim to have them

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Copyright Crawler

- Web crawler looks for copyright violations
  - Use list of hashes of all copyrighted content
  - Scans all web sites, Kazaa network, Napster, etc.
  - For every music file found, compute hash and compare
  - If match is found, call the lawyers
- Problems:
  - Hash functions unlikely to exist for music
  - Does not protect against anonymous postings: publius
  - Very high workload

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Examples

- DigiMarc MarcSpider
  - Crawls web looking for pirated images
  - May use watermarking? (next topic)
- MOSS (Measure Of Software Similarity)
  - Detect plagiarism in programming assignments, web pages
  - http://www.cs.berkeley.edu/~aiken/moss.html
- SCAM: N. Shivakumar, Stanford.
  - Crawls web looking for academic plagiarism
  - Several success stories:
    http://www-db.stanford.edu/~shiva/SCAM/scamInfo.html

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Improvement: watermarking

- Embed hidden watermark at the recording studio
  - Embed(M, I): outputs a watermarked version of music M with the information I embedded in it
  - Retrieve(M'): takes a watermarked music file M' and outputs the embedded watermark I
- Watermark requirements (not necessarily achievable):
  - Watermark must be inaudible
  - Watermark should be robust: Given M_1 = Embed(M,I), pirate cannot create an "acceptable" M_2 with Retrieve(M_2) ≠ I
    - To do this, watermark must resist all signal processing tricks - resampling, cropping, low-pass filtering, ...

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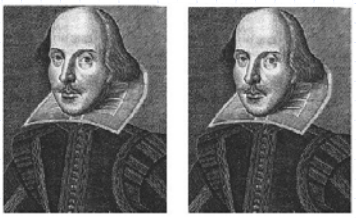
Example Watermarked File



Second image has watermark inserted by DOS software "White Noise Storm"

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Watermark-based enforcement

- Copyright crawler uses "Retrieve" algorithm
- Benefits:
  - Copyright crawler does not need list of all copyrighted material
  - No need for content aware hash
    - Watermarking music "seems" to be an "easier" problem.
- But, some of the same problems as before
  - Does not defend against anonymous postings
  - High workload

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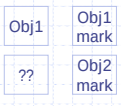
Robust watermarks??

- Embed & Retrieve algs are usually kept secret
  - "Security by obscurity" – not a successful approach
- Do robust watermarking systems exist?
  - We don't know the answer
  - StirMark
    - Generic tool for removing image watermarks
    - Oblivious to watermarking scheme
  - SDMI challenge:
    - Broken: Felten, et al.



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Fingerprinting

- Basic idea:
  - Embed a unique user ID into each sold copy
  - If user posts copy to web or Napster, embedded user ID identifies user
- Problem:
  - Need ability to create distinct and indistinguishable versions of object
  - Collusion: two users can compare their objects to find parts of the fingerprint

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Watermarking Images (>200 papers)

- DigiMarc: embeds creator's serial number.
  - Add or subtract small random quantities from each pixel. Embedded signal kept secret.
- Signafy (NEC).
  - Add small modifications to random frequencies of entire Fourier Spectrum.
  - Embedded signal kept secret.
- Caronni: Embed geometric shapes in background.
- SigNum Tech. (SureSign).

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Watermarking Music (>200 papers)

- Aris Tech (MusicCode):
  - Rate: 100 bits/sec of music
- Solana (E-DNA)
  - Used by LiquidAudio.

Merged to form Verance Used by SDMI

- Argent:
  - Embed full text information.
  - FrameBased: info. inserted at random areas of signal
  - Secret key determines random areas.

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Some other issues

- Digital Millennium Copyright Act (DMCA)
  - Forbids circumvention of copy protection mechanisms, and circumvention tools and technologies
  - Some exceptions for security testing, law enforcement, research that aims to improve security
- Fair Use
  - Copyright law allows regulated use of copyrighted material in certain circumstances
    - Example: quote copyrighted material in a critical review

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Disclaimer: I am not a lawyer. No statements in CS155 are legal advice.

"My Story" by Ed Felten

- Industry consortium (SDMI) considering four technologies for deployment in next-gen music and players.
- We (Princeton, Rice, Xerox researchers) study technologies, find that they don't work very well.
- We write a paper detailing our findings.
- Paper accepted for publication at conference.

3 Slides from: http://csrc.ncsl.nist.gov/ispab/2002-06/Felten-06-2002.pdf

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"Our Paper"

- Music industry claims that our paper is a "technology" whose primary purpose is copyright circumvention
  - Similar claim for oral presentation
- Threatens to sue authors of paper, conference organizers, and employers
- Seeks control over contents of paper

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"My Story (cont.)"

- Music industry (RIAA, SDMI, Verance) threatens lawsuit if we publish.
  - Conference organizers also threatened. We withdraw paper because of threats.
- We file lawsuit seeking right to publish
- After legal wrangling, paper is published
- We managed to publish, but:
  - Months of effort by researchers lost
  - Hundreds of lawyer-hours spent ($$$)
  - Member of our team loses his job
  - Eight-month delay in release of our results

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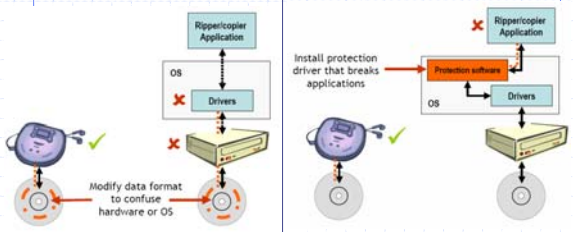
Passive vs Active Protection



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MediaMax CD3 (SunnComm)

- Goal
  - Restrict use of music CD on computer
- Method
  - CD contains autorun file that causes Windows to launch LaunchCD.exe, installs "SbcpHid" driver
  - Driver prevents copying of restricted CDs
- Failures
  - LaunchCD.exe will not run on Linux
  - On Windows: hold shift key while loading CD
- Digital Millennium Copyright Act (DMCA)
  - Forbids circumvention of copy protection mechanisms, and circumvention tools and technologies

http://www.cs.princeton.edu/~jhalderm/cd3/

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Sony XCP

- CD contains copy protection software
- Copy protection software protected by rootkit
- Rootkit detected by RootkitRevealer

http://www.sysinternals.com/blog/2005/10/sony-rootkits-and-digital-rights.html

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Content protection via encryption

- Basic idea:
  - Content distributor encrypts content before releasing it. Release: $C = E_K[\text{content}]$
  - Decryption key embedded in all players.
  - Player will only decrypt if policy is satisfied.
- Note: cannot prevent copying after decryption.
  - User can probe bus to sound card.
  - Unlike watermarking: watermark is embedded in content. Propagates in cleartext copies of content.
- Problem: what if one pirate uses reverse engineering to expose global key k ??

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Example: CSS

- CSS: Content Scrambling System
  - Used to protect DVD movies.
- Each DVD player manufacturer i has key K_i, e.g. K_{sony}
  - Embed same key K_{sony} in all players from Sony.
  - Every DVD movie M is encrypted as follows:
    1. enc-content = $E_K[M]$; K – a random key.
    2. $E_{Ksony}[k]$, $E_{Kphilips}[K]$, ...
  - About 400 manufacturer keys

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Problems with CSS

- DeCSS:
  - Extracted key from Xing software player
  - Could decrypt any DVD playable on the Xing player
  - MPAA revoked Xing key: disabled all Xing players!
- Bigger problem:
  - Encryption algorithm in CSS is based on LFSR's
  - Very fast: video rate decryption on weak DVD player
  - Very weak: given one manuf. Key, can get all keys

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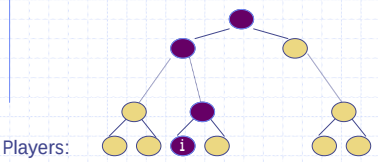
Better revocation technique

- Embed a distinct key in every player



- Every node v has an associated key K_v.
- Every player corresponds to leaf node.
- Key for player i: all keys on path from root to leaf i.

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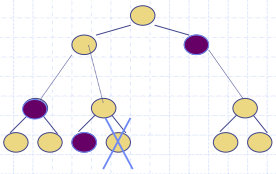
Revocation

- Initially
  - Encrypt all content with key at root
  - Any player can decrypt content.
- When player i is revoked
  - Encrypt content-key so only players other than i can decrypt.



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How to tell which player to revoke?

- When pirate publishes single key on Internet, MPAA knows which keys to revoke.
- What if pirate sells pirated players?
  - How can MPAA tell which keys embedded in player?
- Solution: Tracing systems can interact with player and determine how to revoke that player.
  - How? Take crypto class...

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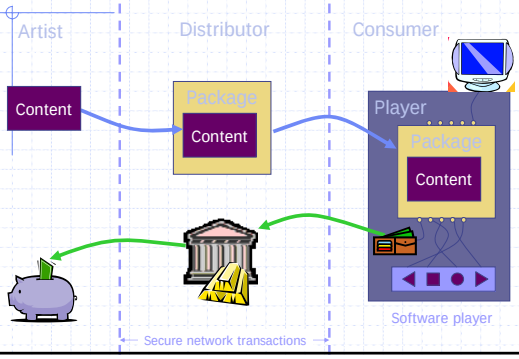
Digital Distribution Dream (Movies Books Music)



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Digital rights management

- Distribute information in specific format
- Player that knows this format controls action
  - Control reading, playing, or copying content
  - Guarantee payment in proportion to use
    - Count number of times content is used
    - Transfer payment to distributor

Problem: Computer files are easy to duplicate
Can software player on general-purpose computer achieve goals?

- No end run
  - Must be impossible to use content without player
  - Player must be tamper resistant

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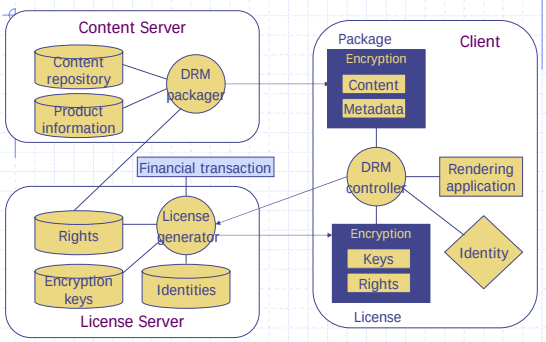
DRM Reference Architecture

Rosenblatt, et al.



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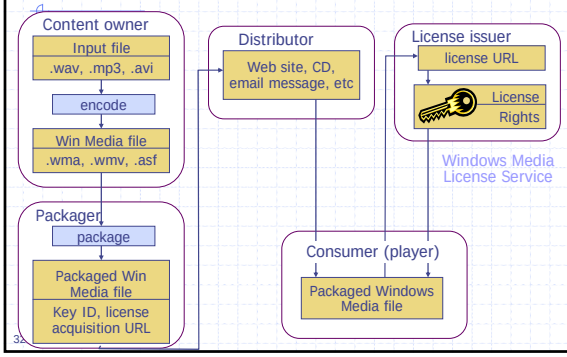
Windows Media Rights Manager



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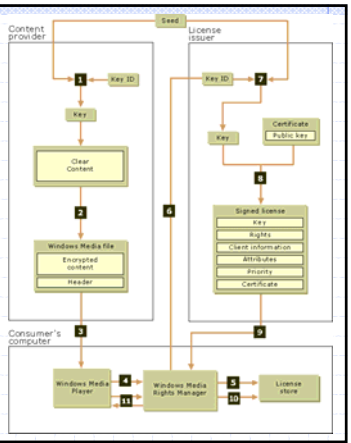
Windows Key and License Management



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HDCP, Secure Audio Path

- High-bandwidth Digital Content Protection
  - HDCP is a specification developed by Intel Corporation to protect digital entertainment content across the DVI/HDMI interface

http://www.digital-cp.com/home

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FreeMe – breaks Windows Media RM

- http://www....com/crypt/drm/freeme/README

  The software distributed with this README file removes content protection from any Windows Media Audio file (.wma file) that uses DRM version 2 (as implemented in Windows Media Player version 7). ...

- http://www...com/crypt/drm/freeme/Technical

  This document describes version 2 of the Microsoft Digital Rights Management (MS-DRM), as applied to audio (.wma files). The sources for this material are varied ...

  The basic components of MS-DRM involve use of elliptic curve cryptography (ECC) for public key cryptography, DES for a block cipher, RC4 for a stream cipher, and SHA-1 for a hash function. There is also a block cipher which I haven't seen before, used in the MS-DRM system to build a MAC, or keyed hash function.

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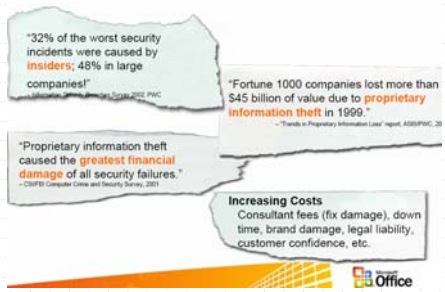
Microsoft Office Rights Management



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www.microsoft.com/rms

Information Rights Management Platform

- Server
  - Microsoft® Windows® Rights Management Services
  - Windows Server 2003
- Application
  - Information Rights Management (IRM)
  - Office 2003, IE Add On
- Protection goes with the file
  - File level, each gets its own protection
  - Persistent, goes wherever the file goes
- Controls Access and Usage
  - Encryption to help restrict access
  - Enforces usage policies in the application, e.g. disables print
  - Can expire content after it is no longer relevant

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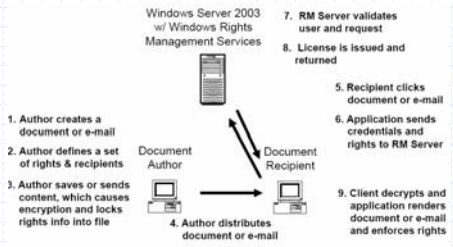
Slide graphics: Johann Kurz, Microsoft Schweiz GmbH, May '04 presentation

System schematic



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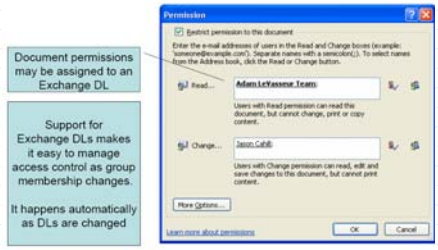
Authorizing user's UI



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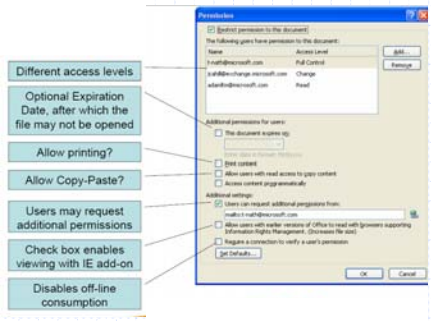

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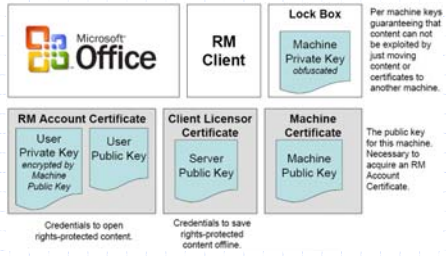
PC system components



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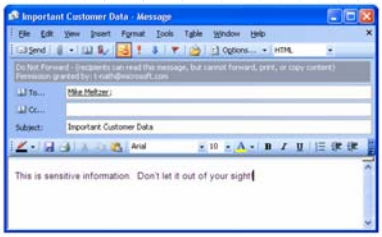
View of restricted email in Outlook



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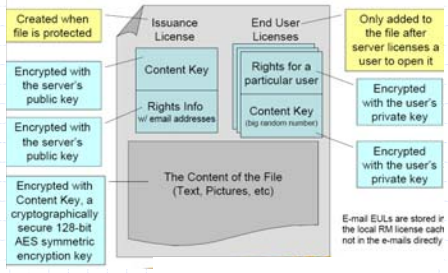
File contents



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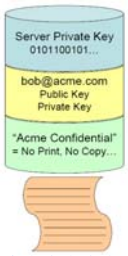
Server components

- Server's Private Key
- User Keys and addresses
  - User keys come from RMS when created
  - User addresses come from Active
  - Directory, which is required for RMS
- Permission Templates
- Logs
  - Logging occurs on creation and issuance of certificates and licenses and is IT controllable. Can be used as an audit trail.



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XrML Summary

- Vocabulary
  - Principals: Alice, Bob
  - Resources: movie, picture, song
  - Rights: play, edit, print
  - Properties: manager, employee, trusted
- Licenses and grants
  - license ::= (grant, principal)
    - Principal p issues/says grant g
  - grant ::= $\forall x1 \ldots \forall xn$ (cond $\rightarrow$ conc)
    - If cond holds, then conc holds
  - conc ::= Pr(p) | Perm(p, r, s)
    - Pr(p) means principal p has property Pr
    - Perm(p, r, s) means p is permitted to exercise right r over resource s

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