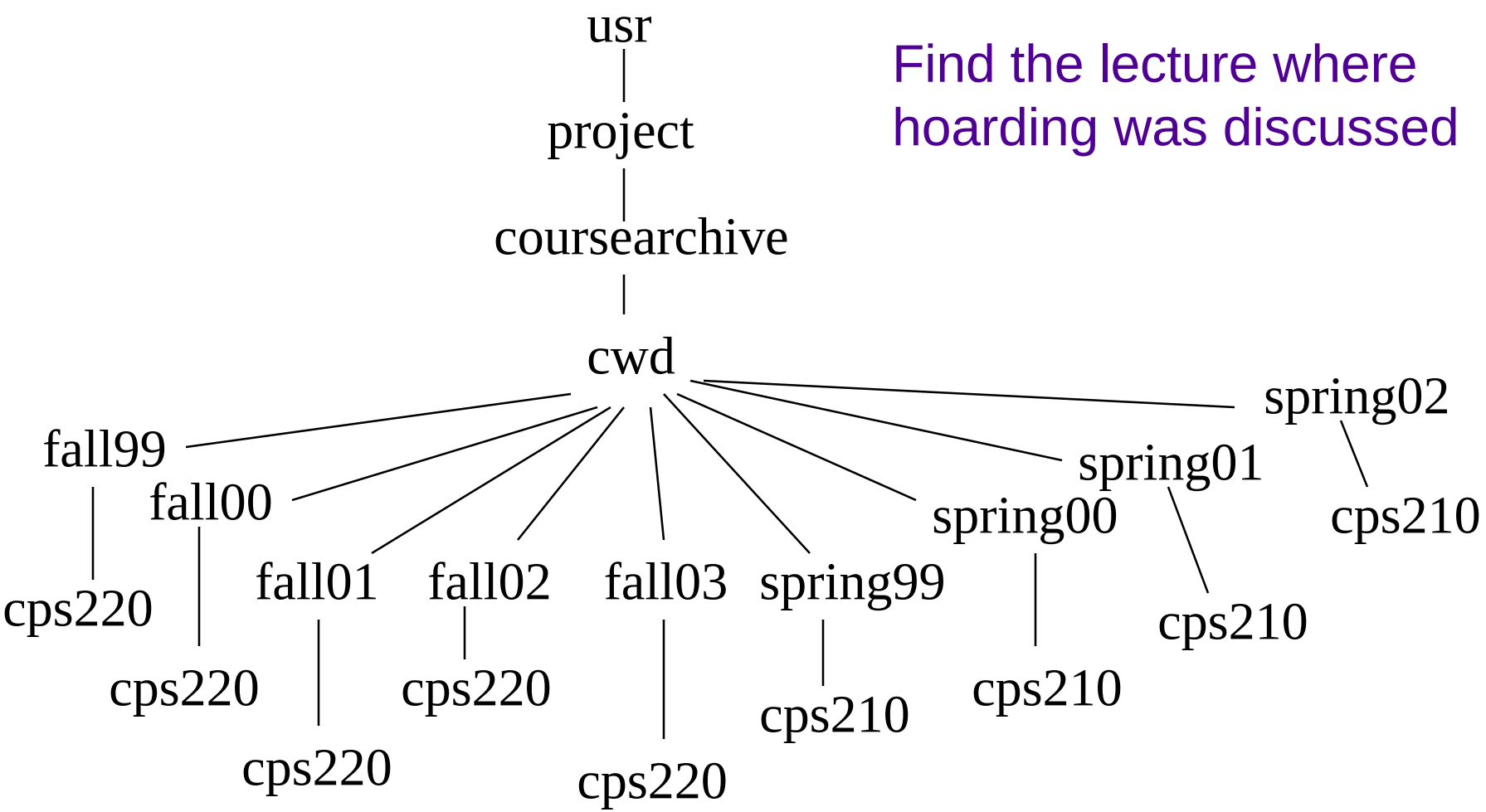
Outline

- Objective
  - Attribute file naming:
    “Why can’t I find my files?”
  - Hoarding techniques and their use in disconnected file systems
- Administrative
  - New programming project up
  - Revisions in schedule – I’m out of town on April 13

An Example of the Problem



Find the lecture where hoarding was discussed

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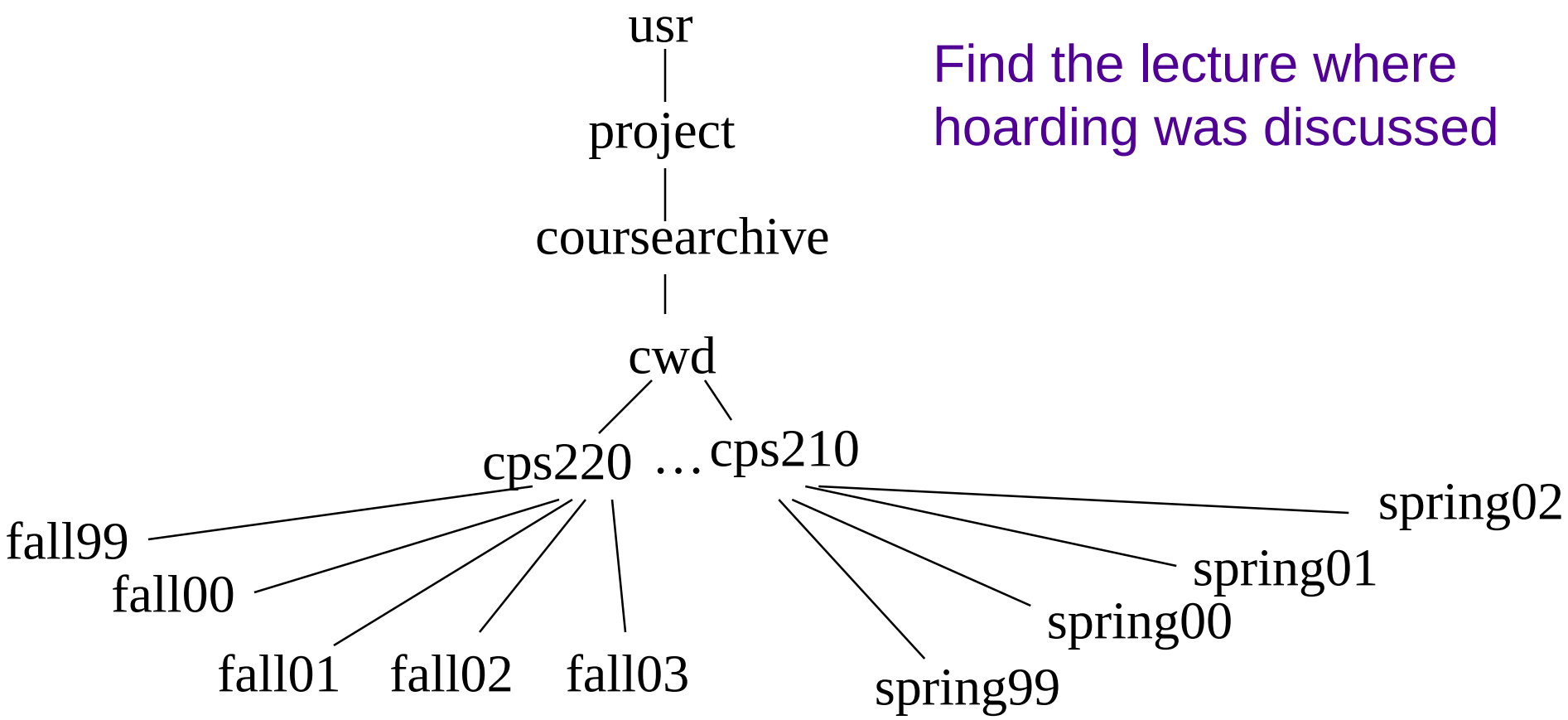

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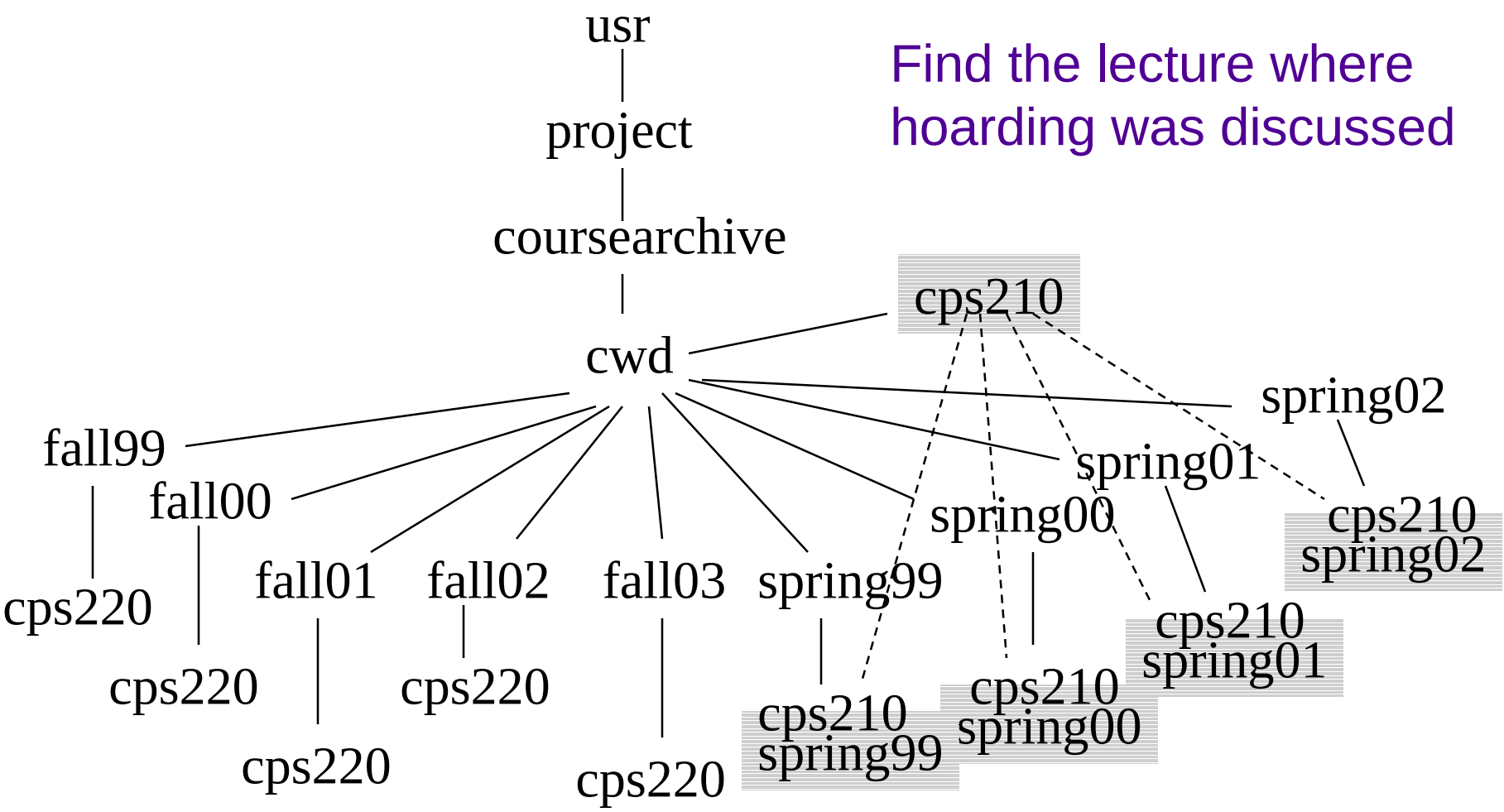


An Example of the Problem

- It gets worse:

  /home/home5/carla/talks

  2 laptops (one lives at work, one at home)

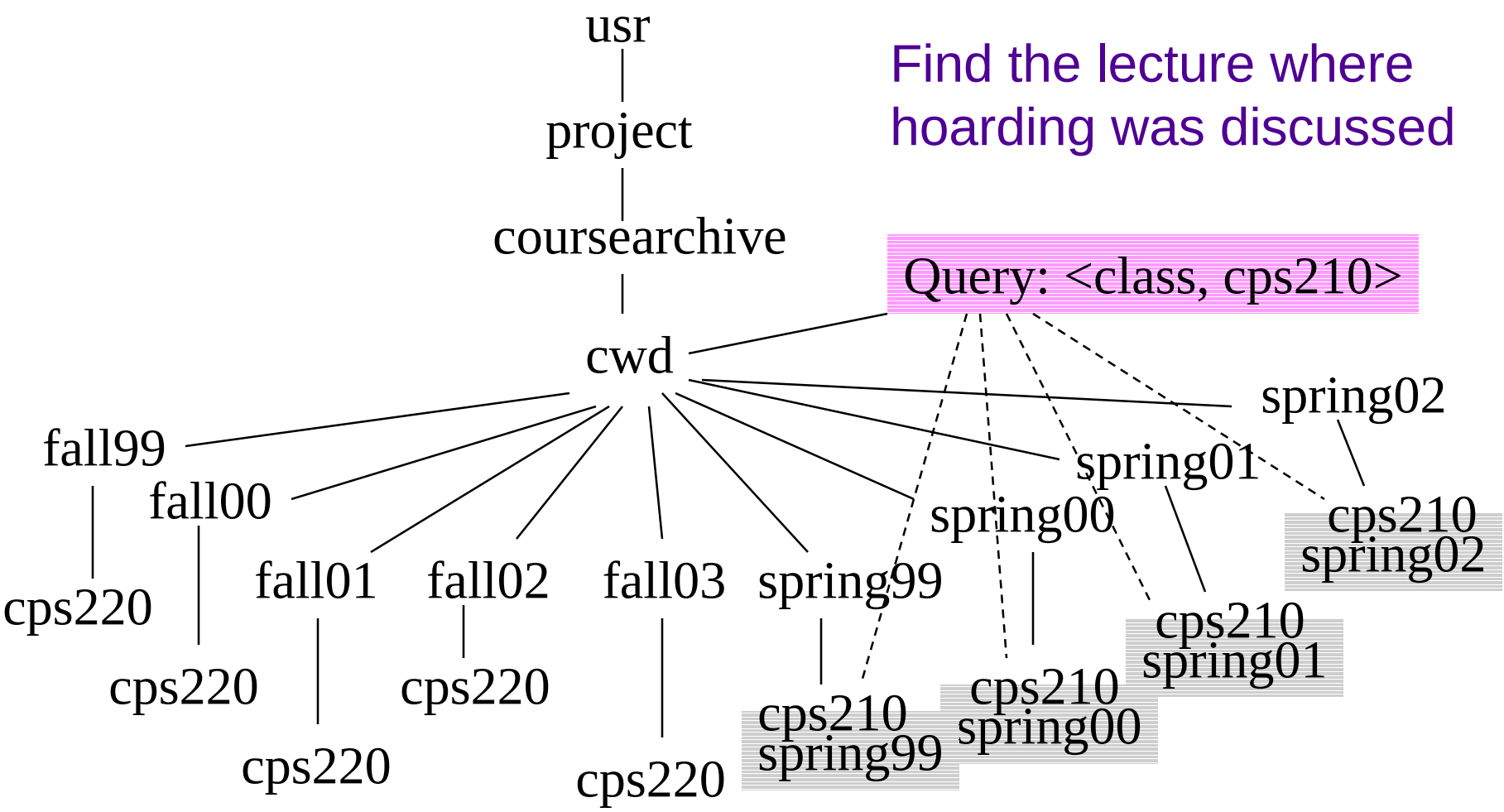
  desktop machine at home

- Forest not a tree!
  - Growing more like kudzu

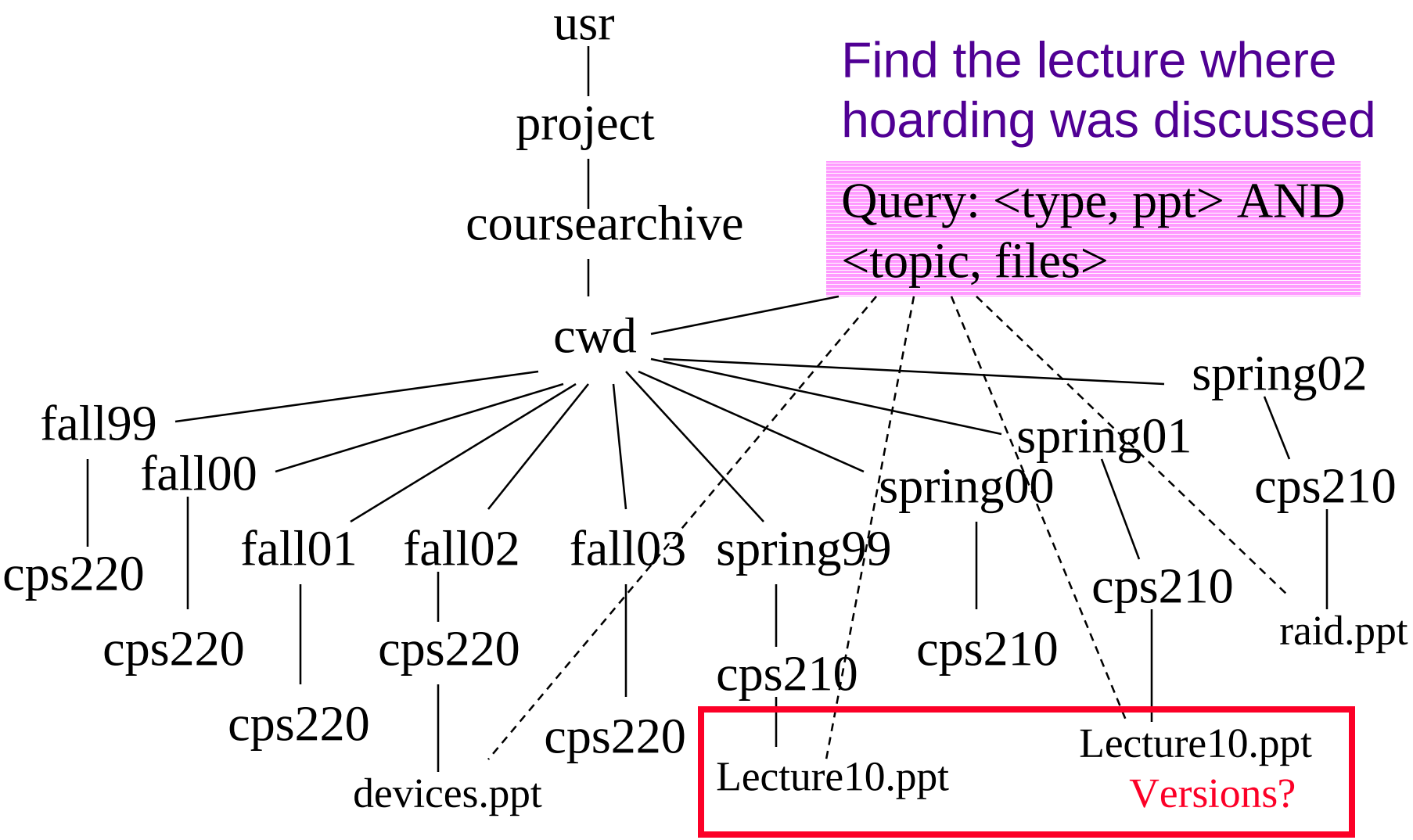
Attributes in File Systems

- Metadata: <category, value>
- How to assign?
  - User provided – too much work
  - Content analysis – restricted by formats
    - Semantic file system provided transducers
  - Context analysis
    - Access-based or inter-file relationships
- Once you have them
  - Virtual directories – “views”
  - Indexing

Virtual Directories



Virtual Directories



Issues with Virtual Directories

- What if I want to create a file under a virtual directory that doesn't have a path location already?
- How does the system maintain consistency? We should make sure that when a file changes, its contents are still consistent with the query.
  - What if somewhere a new file is created that should match the query and be included?
  - What if currently matching file is changed to not match?
- How do I construct a query that captures exactly the set of files I wish to group together?

Example: HAC File System
(Gopal & Manber, OSDI99)

- Semantic directories created within the hierarchy (given a pathname in the tree) by issuing a query over the *scope* inherited from parent
  - Physically exist as directory files containing symlinks
- Creates symbolic links to all files that satisfy query
- User can also explicitly add symbolic links to this semantic directory as well as remove ones returned by the query as posed.
  - Query is a starting point for organization.
- Reevaluate queries whenever something in scope changes.
- Uses Glimpse – an index-based file search tool for content-based queries.

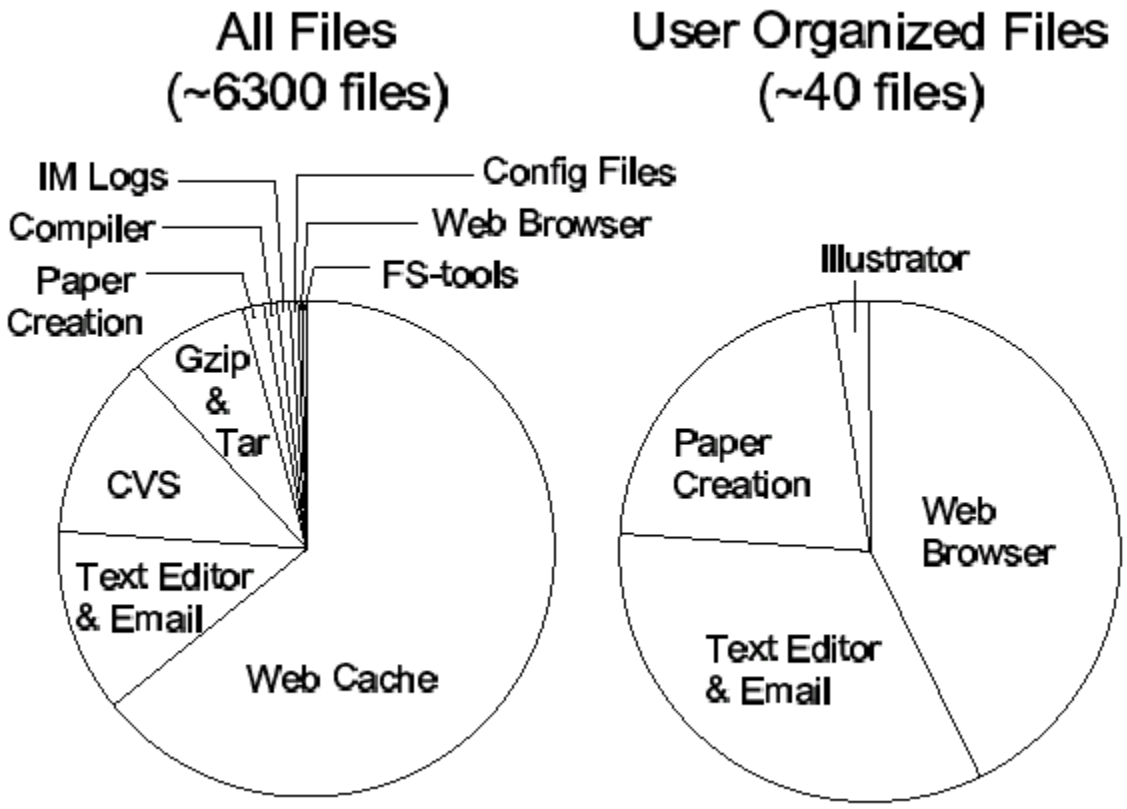
Context-based Relationships

- Premise: Context is what user might remember best.
- Previous work
  - Hoarding for disconnected access (inter-file relationships)
  - Google: textual context for link and feedback from search behavior (assumption of popularity over many users)

Access-based

- Use context of user's session at access time
- Application knowledge – modify apps to provide hints
  - Example: subject of email associated with attached file
- Feedback from "find" type queries
  - Searches are for rarely accessed files and usually only one user – limits statistical info

Traced File Creation Behavior



Inter-file

- Attributes can be shared/propagated among related files
- Determining relationships
  - User access patterns – temporal locality
  - Inter-file content analysis
    - Similarity – duplication -- hashing
    - Versions

Challenges

- Evaluation – issues of deployment for user study
- Mechanisms
  - Storage of large numbers of attributes that get automatically generated
  - User interface
- Context switches
  - Creating false positive relationships

Background:
Inter-file Relationships

Hoarding - Prefetching for Disconnected Information Access

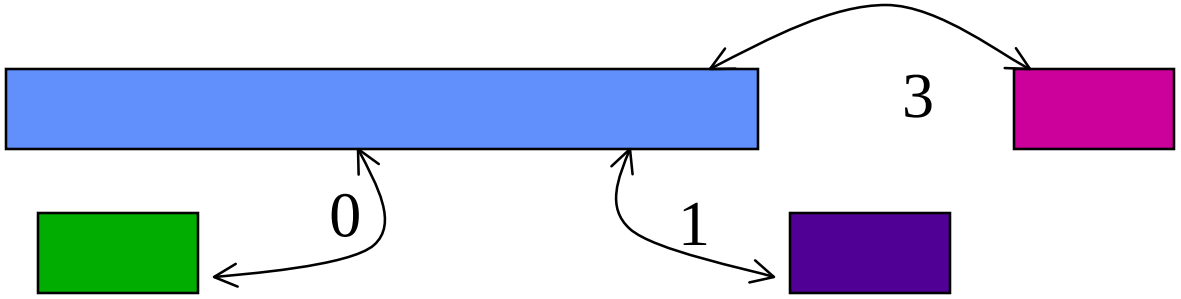
- Caching for availability (not just latency)
- Cache misses, when operating disconnected, have no redeeming value.
  (Unlike in connected mode, they can't be used as the triggering mechanism for filling the cache.)
- How to preload the cache for subsequent disconnection? Planned or unplanned.
- What does it mean for replacement?

SEER's Hoarding Scheme: Semantic Distance

- Observer monitors user access patterns, classifying each access by type.
- Correlator calculates semantic distance among files
- Clustering algorithm assign each file to one or more projects
- Only entire projects are hoarded.

Defining Semantic Distance

- Temporal semantic distance - elapsed time between two file references
  Time scale effects :-(
- Sequence-based semantic distance - number of intervening file references between 2, of interest. At what point? Open? Close?
- Lifetime semantic distance - accounts for concurrently open files - overlapping lifetimes



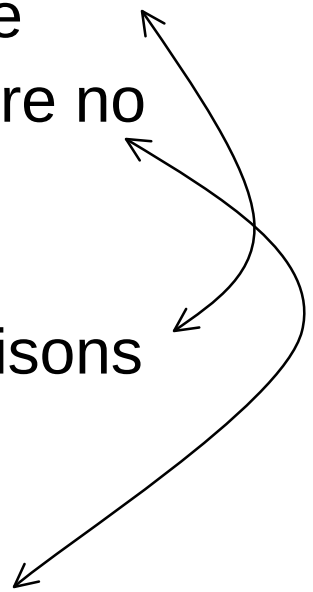
- How to turn semantic distance between two references into semantic distance between files? Summarize - geometric mean.
- Using months of data. Only store n nearest neighbors for each file and files within distance M
- *External investigators* can incorporate some extra info (e.g. heuristics used by Tait, makefile)

Real World Complications

- Meaningless clutter in the reference stream (e.g. find command)
- Shared libraries - an apparent link between unrelated files - want to hoard but not use in distance calculations and clustering
- Rare but critical files, temp files, directories
- Multi-tasking clutter
- Delete and recreate by same filename.
- Examine metadata then open – 1 or 2 accesses?
- SEER tracing itself – avoid accesses by root

Evaluation

- Metric
  - Hoard misses usually do not allow continuation of activity (stops trace) – counting misses is meaningless.
  - Time to 1st miss – would depend on hoard size
  - Miss-free hoard size – size necessary to ensure no misses
- Method
  - Live deployment – difficulty in making comparisons
    - Only long enough disconnections
    - Subtract off suspensions
  - Trace-driven simulation -- reproducible
    - What kind of traces are valid?



Context of Hoarding

Disconnected and Weakly Connected Coda

Satya, Kistler, Mummert, Ebling, Kumar, and Lu, “Experience with Disconnected Operation in a Mobile Computing Environment”, *USENIX Symp. On Mobile and Location-Independent Computing*, 1993.

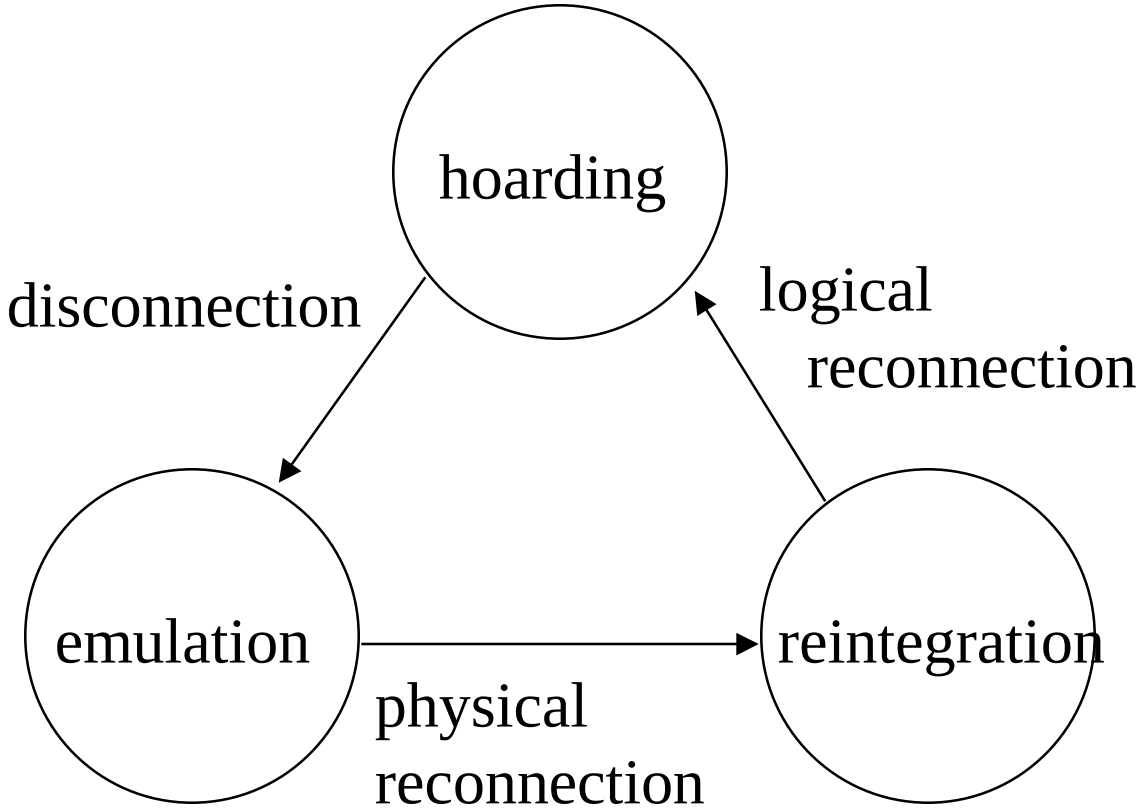
Mummert, Ebling, and Satya, “Exploiting Weak Connectivitiy for Mobile File Access”, *SOSP95*.

Coda

- Single location-transparent UNIX FS.
- Scalability - coarse granularity (whole-file caching, volume management)
- First class (server) replication and second class (client caching) replication
- Optimistic replication & consistency maintenance.

→ Designed for disconnected operation for mobile computing clients

Client-cache State Transitions



Hoard Database

- Per-workstation, per-user set of pathnames with priority
- User can explicit tailor HDB using scripts called *hoard profiles*
- Delimited observations of reference behavior (snapshot spying with bookends)

Coda Hoarding State

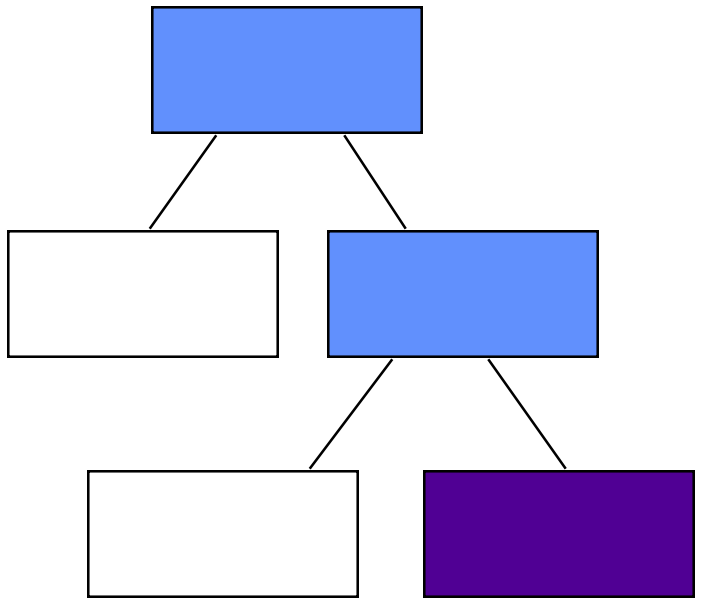
- Balancing act - caching for 2 purposes at once:
  - performance of current accesses,
  - availability of future disconnected access.
- Prioritized algorithm -
  Priority of object for retention in cache is
  f(hoard priority, recent usage).
- Hoard walking (periodically or on request) maintains equilibrium - no uncached object has higher priority than any of cached objects

The Hoard Walk

- Hoard walk - phase 1 - reevaluate name bindings (e.g., any new children created by other clients?)
- Hoard walk - phase 2 - recalculate priorities in cache and in HDB, evict and fetch to restore equilibrium

Hierarchical Cache Mgt

- Ancestors of a cached object must be cached in order to resolve pathname.
- Directories with cached children are assigned infinite priority



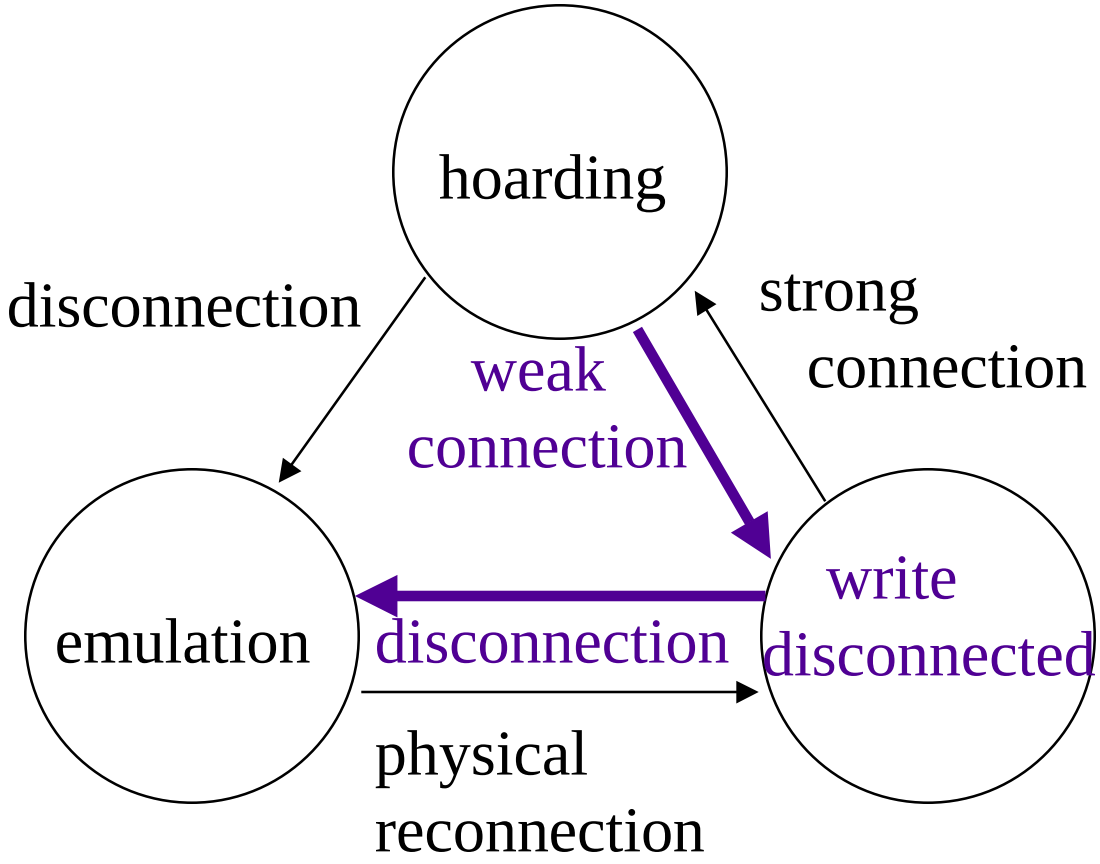
Callbacks During Hoarding

- Traditional callbacks - invalidate object and refetch on demand
- With threat of disconnection
  - Purge files and refetch on demand or hoard walk
  - Directories - mark as stale and fix on reference or hoard walk, available until then just in case.

Emulation State

- Pseudo-server, subject to validation upon reconnection
- Cache management by priority
  - modified objects assigned infinite priority
  - freeing up disk space - compression, replacement to floppy, backout updates
- Replay log also occupies non-volatile storage (RVM - recoverable virtual memory)

Client-cache State Transitions with Weak Connectivity



Cache Misses with Weak Connectivity

- At least now it's possible to service misses but $$$ and it's a foreground activity (noticable impact). Maybe **not**
- User patience threshold - estimated service time compared with what is acceptable
- Defer misses by adding to HDB and letting hoard walk deal with it
- User interaction during hoard walk.