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Bimodal Chunking

Erik Kruus
Cezary Dubnicki
Cristian Ungureanu
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Work done at NEC laboratories

Outline

- Content defined chunking
- Motivation, approach
- Introduce bimodal algorithms, transition regions
- Example algorithms
- Results
- Conclusions, Questions

Content Defined Chunking

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- Cut points selected based on values of a function evaluated on local data window
- Produces variably sized chunks
- Effect of small edit operations (replace,insert,delete) likely restricted to single chunks
  - Often used to store backup data (multiple versions)
- Only store one copy of duplicate chunks.
  - Duplicate Elimination Ratio = (input bytes) / (stored bytes)
  - Want high DER

Baseline Chunking Parameters

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To get reproducible chunks, fix various parameters…

- Function evaluated on local window
  - Choice not so important (typically a fast, rolling hash function)
- Average chunk size
  - Depends on predicate used to select cut point
  - Ex. "function of local data window has 10 LSBs zero"
    - Expect 1 match out of every 1024
- Minimum chunk size, Maximum chunk size
  - Random chunk boundary selection ➔ geometric distribution of chunk sizes. Too many small chunks!
- …
  - Perhaps mechanism for reducing # of occurences of non-content-defined cut points as a result of max chunk size

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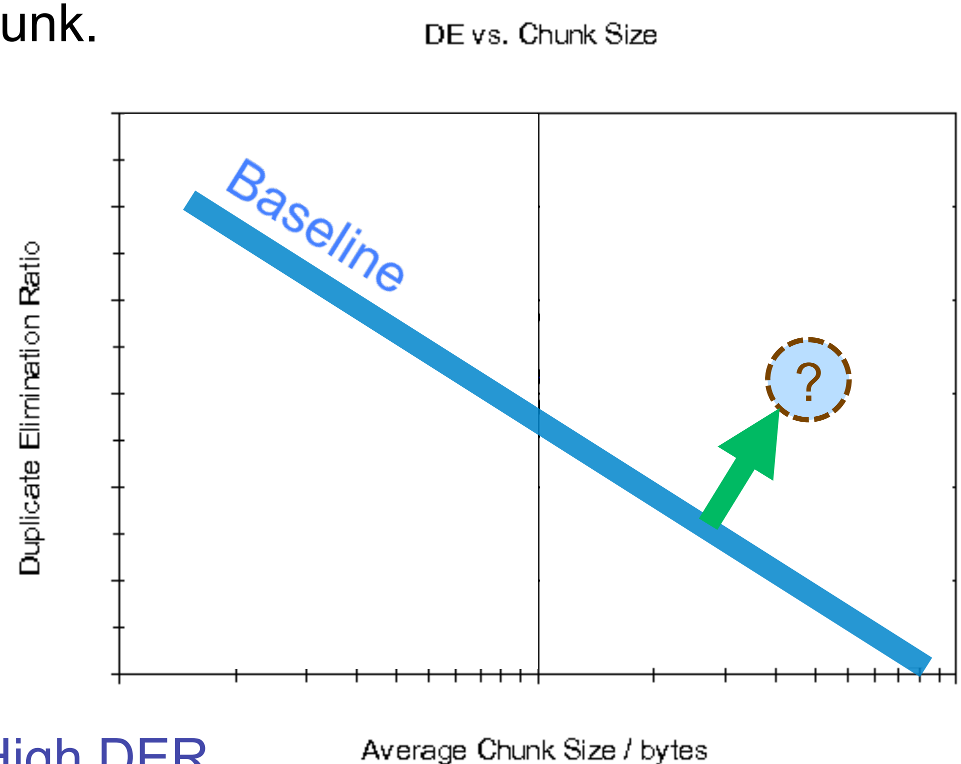
Motivation

- Larger blocks help I/O performance
- Larger blocks reduce metadata storage overhead
  – Large storage systems may have many bytes of metadata associated with each chunk.



- Small block size:
  High DER
- Large Block size:
  Low DER
- Desire Large Blocks and High DER

Approach

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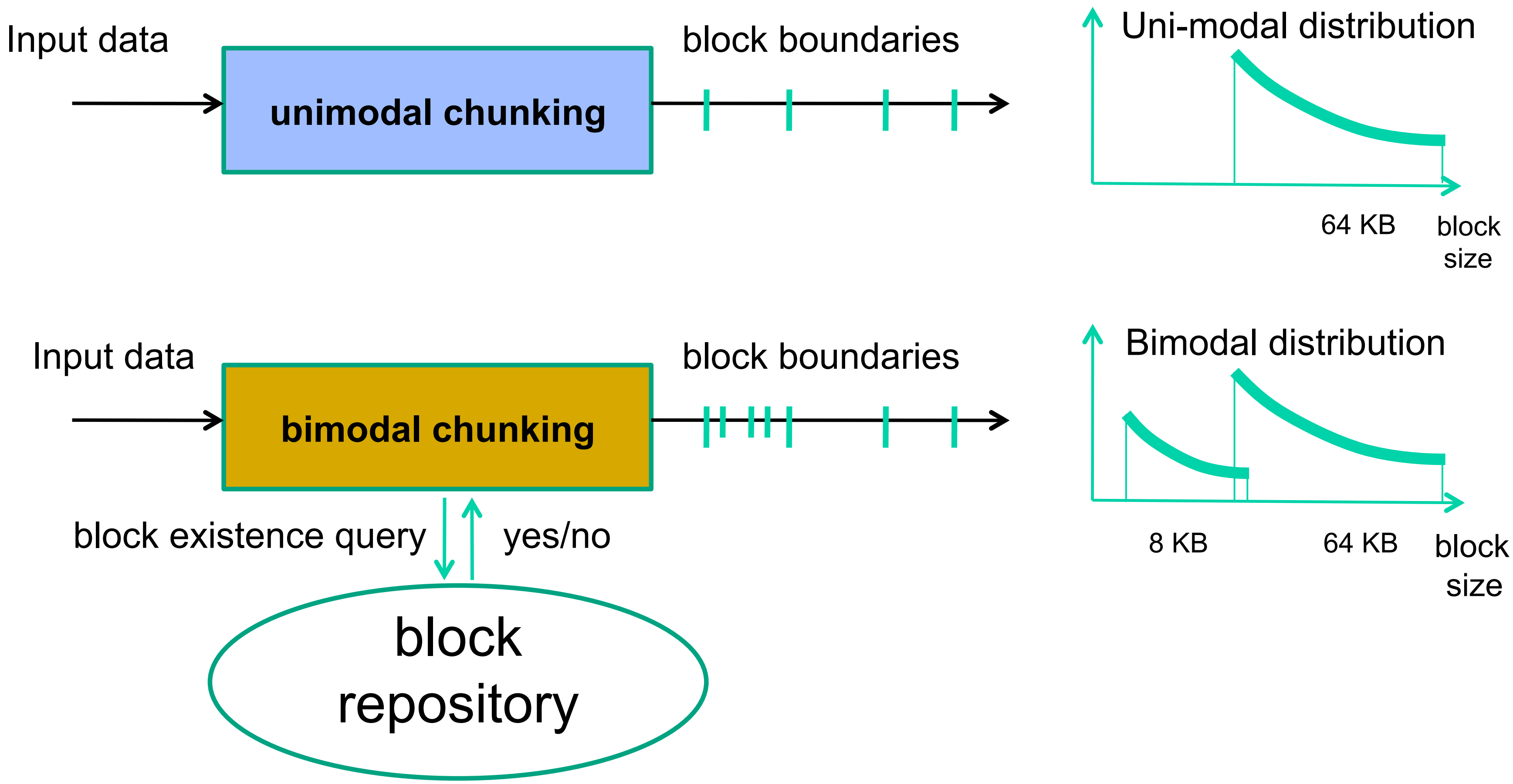
- So what can we do improve the chunking algorithm?
  - Use other easily-available information

- In this work we investigate what can be done if a fast chunk existence query is available.

- NECLA archive data set: 14 backups of the main filesystem used by lab's researchers every day. Full backups done every other week totaled 1.1 TB.
  - Analyses done using smaller chunking summary of the full dataset.

Bimodal Algorithms



"Historical" intuitions

- Intuitive model of file system backups
  1. Long stretches of unseen data should be assumed to be good candidates for appearing later on (i.e. at the next backup run).
     - Original data should have reasonable DER to begin with
     - Long stretches of unseen data should be chunked with large average chunk size.

  2. Inefficiency around "change regions" straddling boundaries between duplicate and unseen data can be minimized by using shorter chunks.

- Inefficiency: short blocks can delineate the beginnings and ends of duplication regions more finely.
- Change regions: existence queries give us a way to detect these transition regions

Why transition regions?

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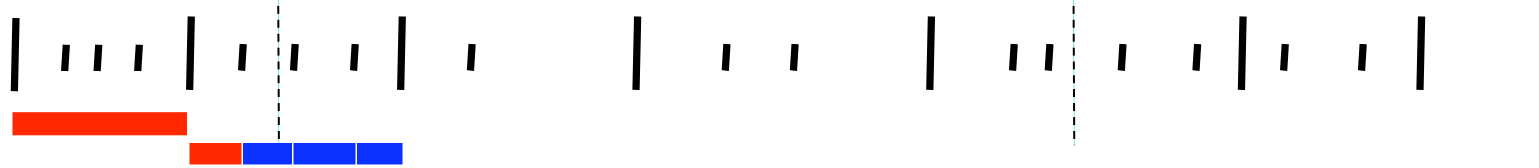
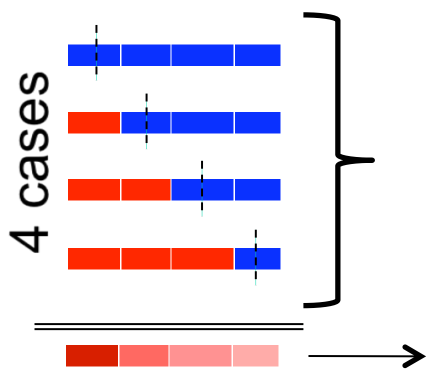
- Duplicate/nonduplicate byte regions in input stream

- Fine-grained and coarse-grained cut points:



- Expect transition point ~ uniformly distributed within the encompassing large chunk



Have been seen before! Should be duplicate eliminated.

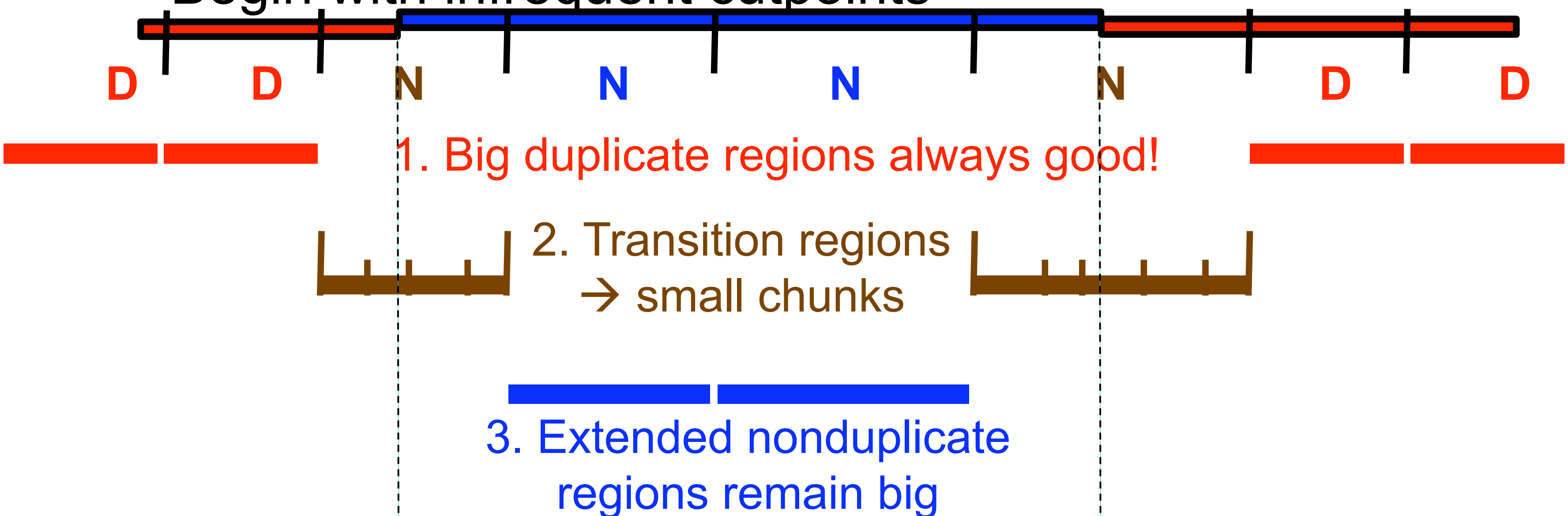
Perhaps a frequent change region? Reduced chance to see again later

Small chunks in transition region could be beneficial

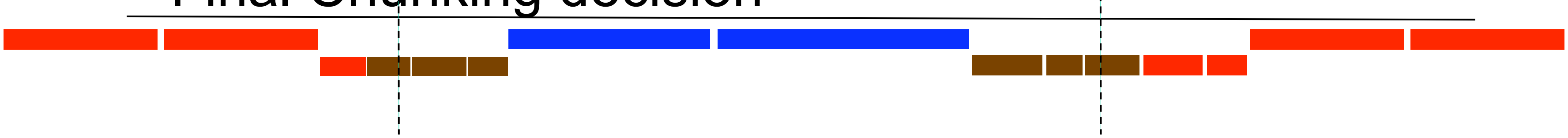
Small chunks in duplication region are bad

Example: breaking-apart

- Assign Duplicate/Nonduplicate byte regions
- Begin with infrequent cutpoints



- Final Chunking decision



- Existence queries required: 1 per large chunk

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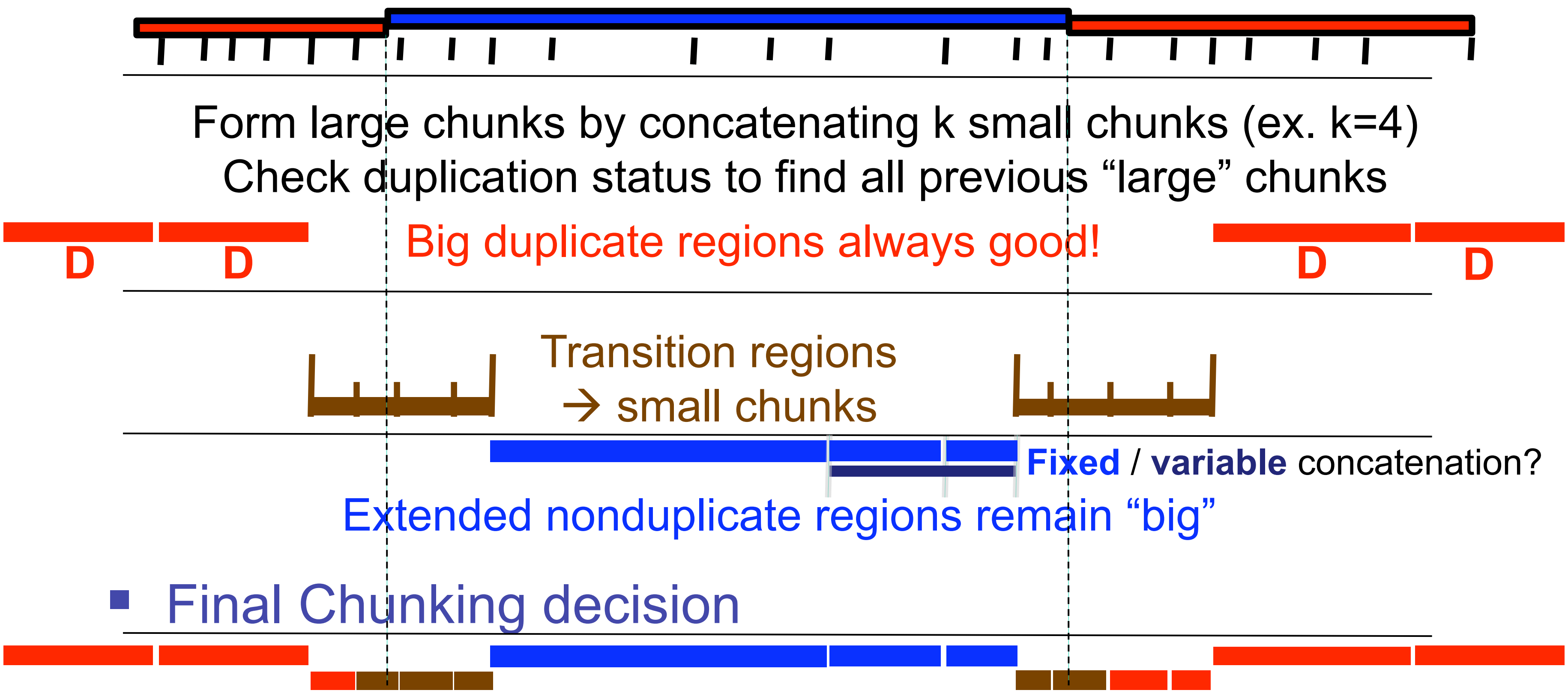
Example: amalgamation

- Assign Duplicate/Nonduplicate byte regions
- Begin with frequent cutpoints



- Existence query bound: k per large chunk
  - Or k(k-1) if 2 to k smalls can generate a big chunk.

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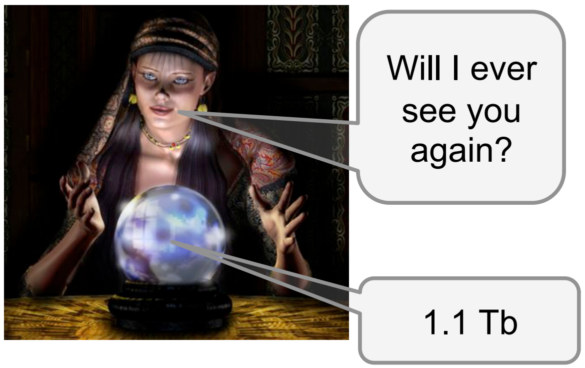
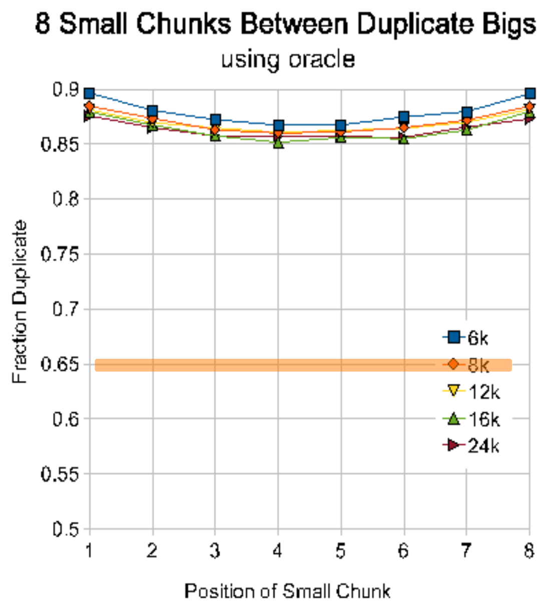
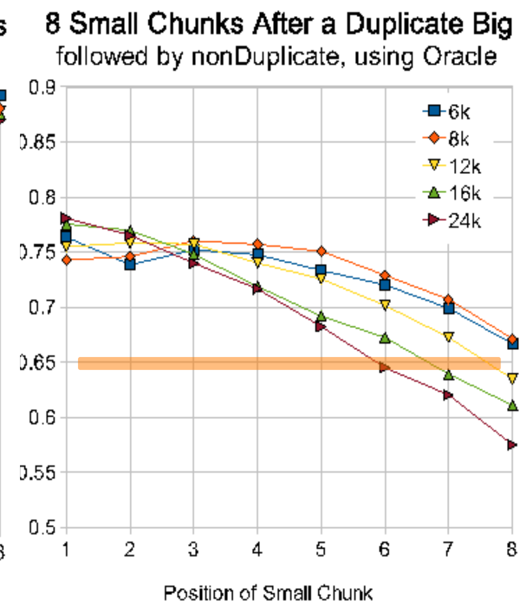
Transition region subcases

Statistics of small chunks for some frequent subcases of fixed-size (8) amalgamation:

Baseline chunkers with average chunk size from 4k to 24k.







- Ask an oracle
  - Using transition regions to guide small chunk output decisions gave future hit rates that were higher than “bulk” expectation

Extend to 32 chunks, see “bulk” 8k small chunk recurrence prob. tailing off to ~65%

A simple, empirical limit

Based on full NECLA data set, how good could it get?

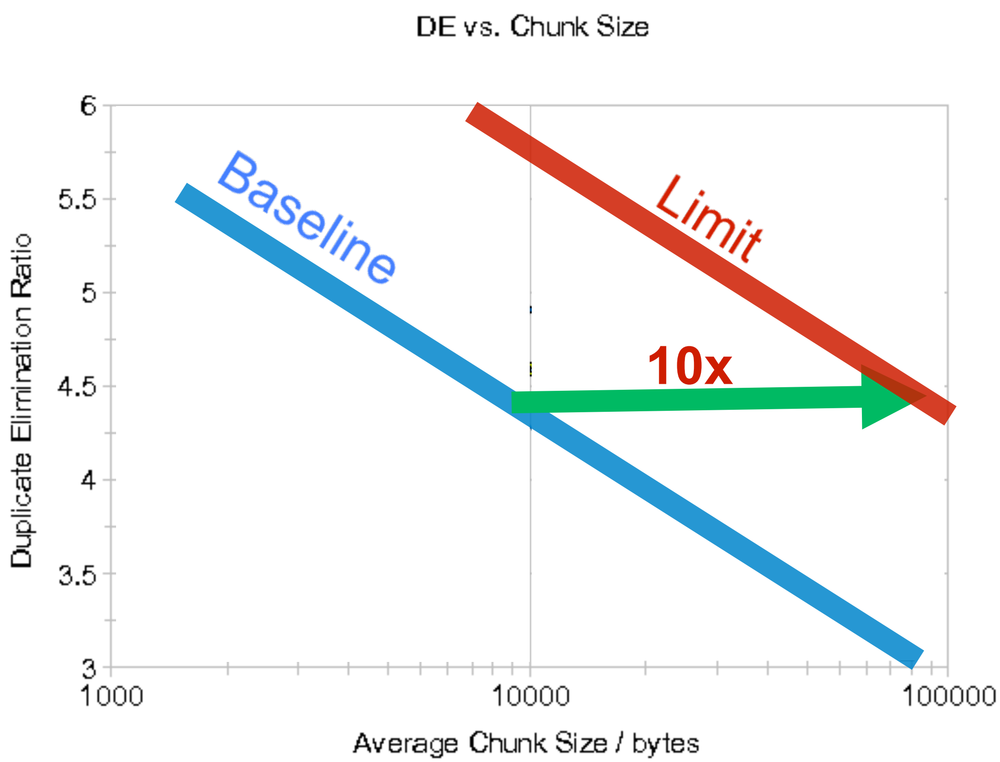
Concatenate all chunks that always occur together

- Whenever a stored item has unique successor, merge!
- For uncompressed storage, DER is unaffected
- Began with 512-byte and 8k baseline chunkings of the full dataset (2 expts)

Result: almost 10x larger average block size

Algorithm not practical

- Uses post-processing
- Computationally very expensive



Comparison to empirical limit

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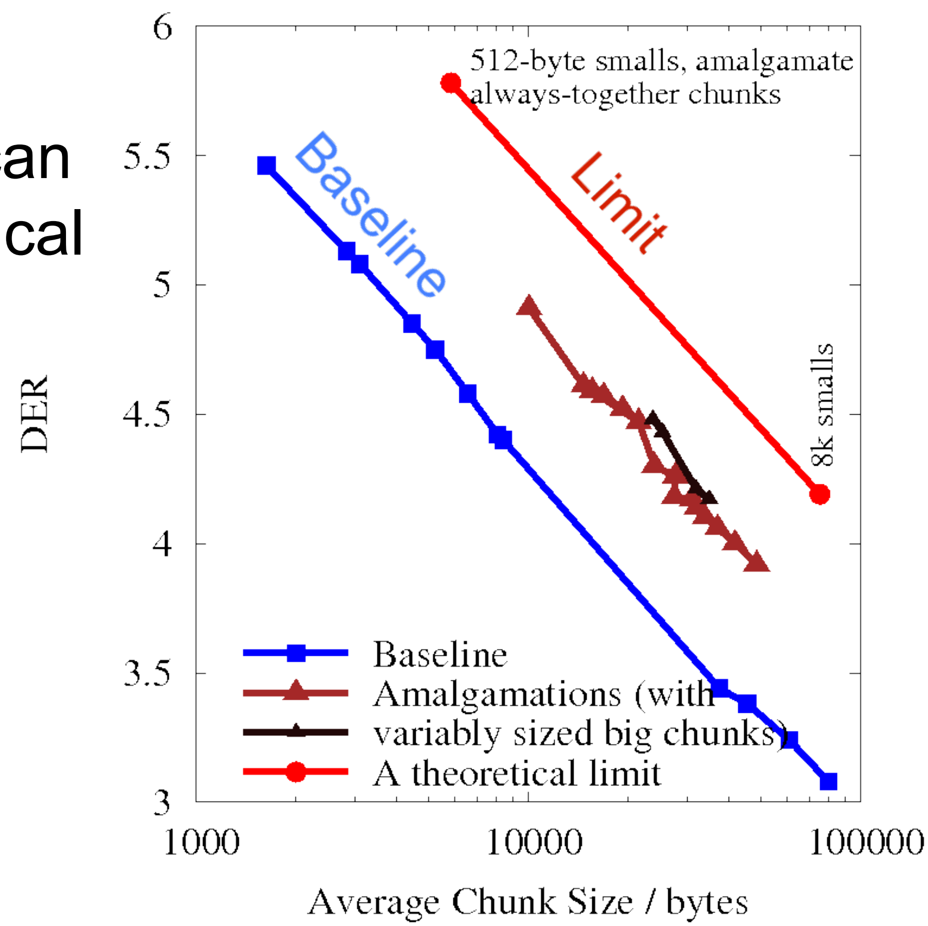
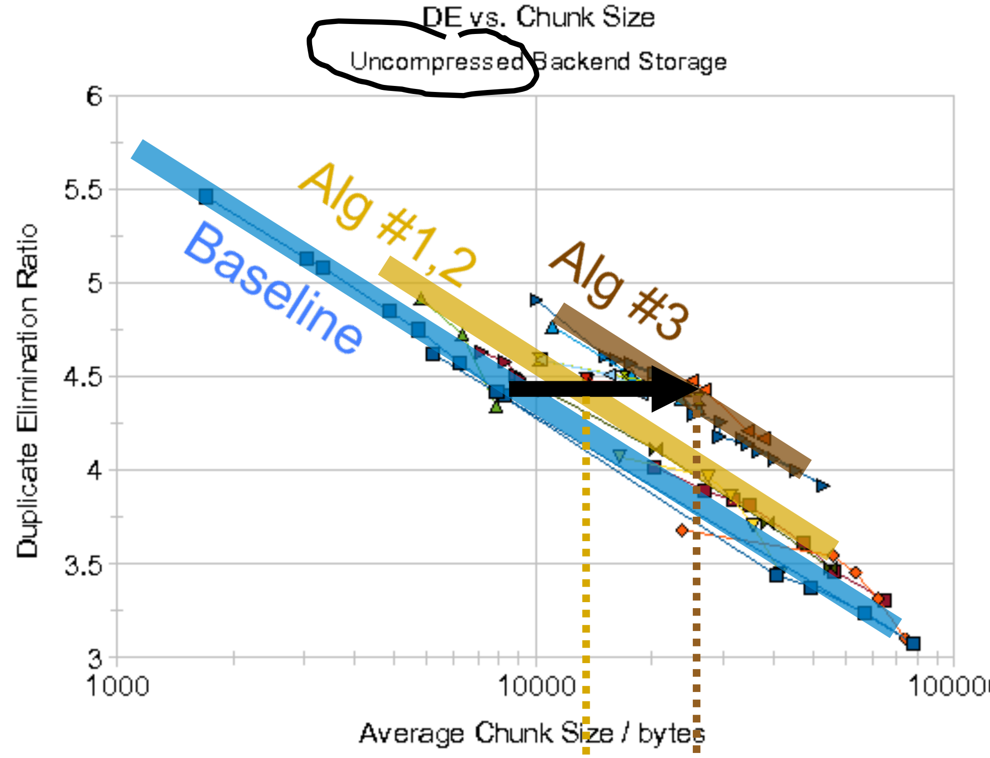
- Using 56-64 existence queries per big chunk, can get ~ halfway to theoretical limit



Results summary

- Simplified storage model assumptions
  – Same data redundancy, No metadata, No compression
- Ran several algorithms, covering a range of parameter settings

- Algorithms 1 & 2
  – Up to 1 or 8 queries per large chunk
  – Chunk size → x1.5
- Algorithm 3
  – Up to 56 or 64 queries per large chunk
  – Chunk size → x3



- "Chunking transition regions small" seems beneficial

Effect of compression

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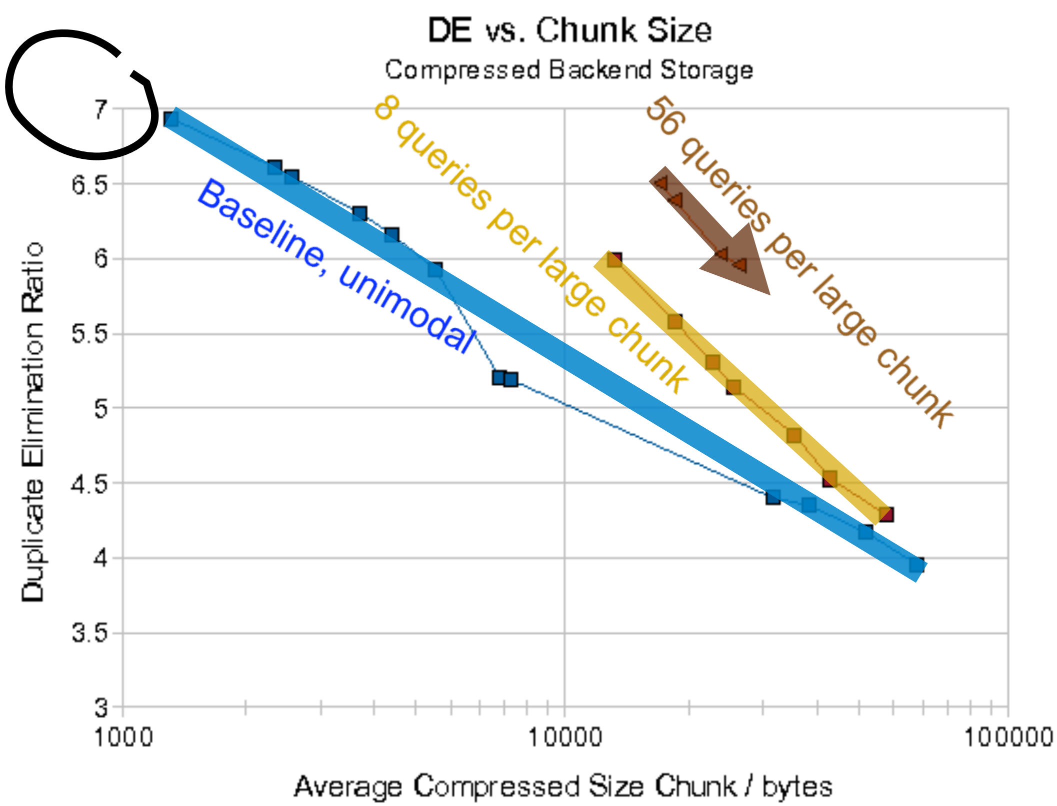
A small subset of these runs used the raw dataset to obtain accurate values including compression.



Amalgamation compression

DER up

Larger blocks compress better.

- Avg blocks size down 64 KB → 45 KB, but little compression at 8 KB
- Increasing chunk size by 50% has enhanced effect at smaller chunk sizes

Effect of Metadata

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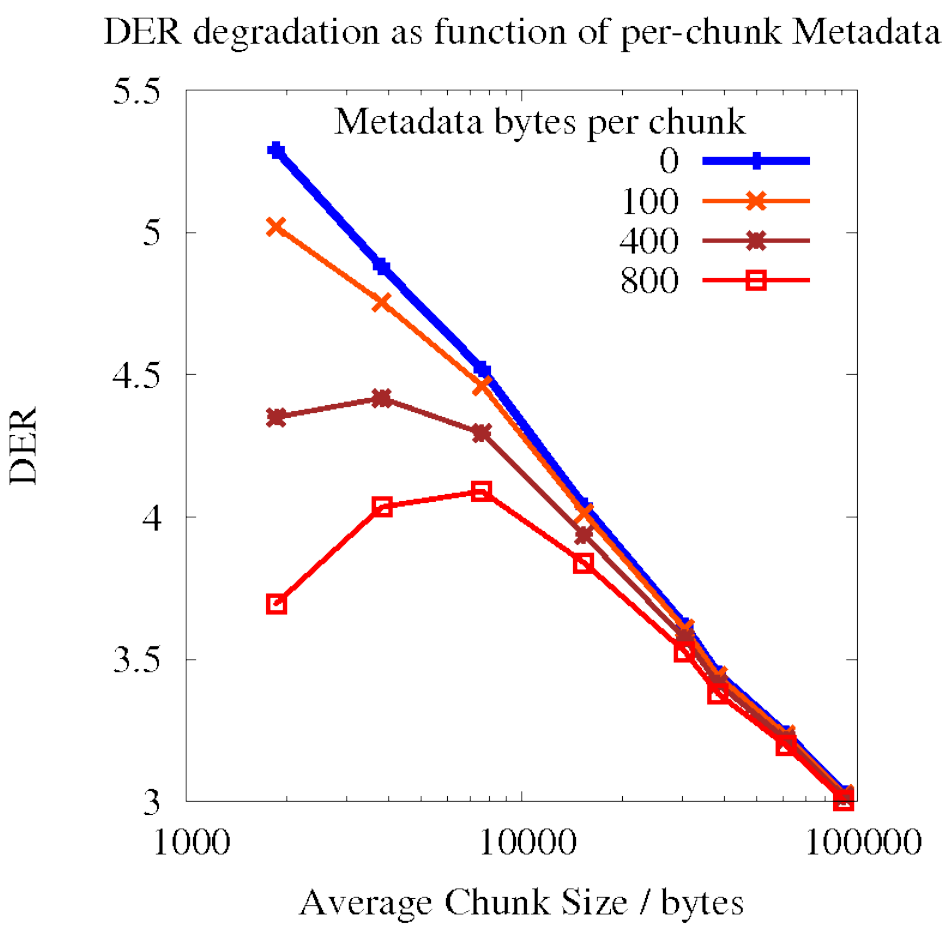
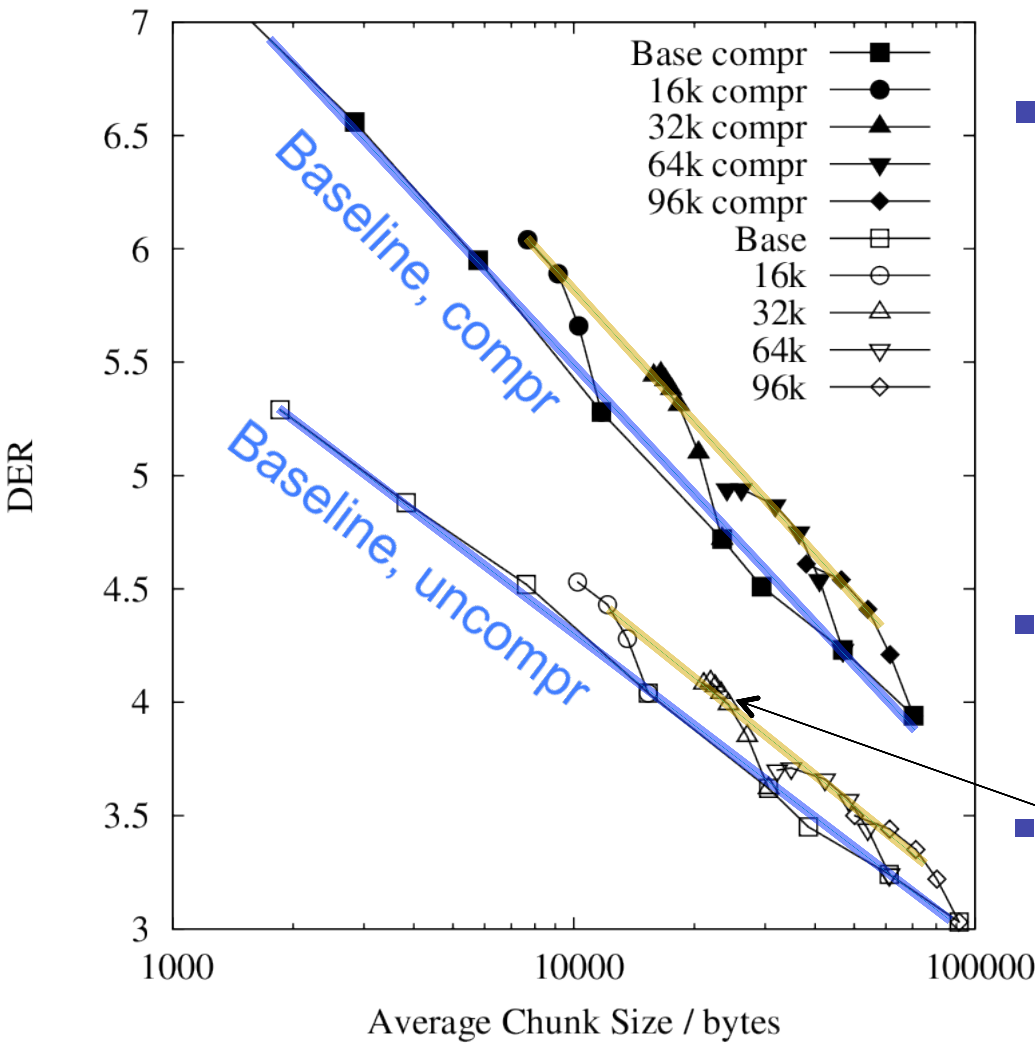


- Consider baseline measurements
- Transform for effect of 100, 400, 800 bytes of metadata per chunk
- Simple transform to new DER' = DER / (1+f), where f=metadata/<chunk size>
- Metadata impact can be severe at low chunk sizes

Detailed results: breaking apart



- Typical settings:
  - Min:avg:max = 1:2:3
  - 3 backup levels
  - Small chunker settings divided by 1:2:4:8
  - 1 existence query per big chunk
- Small chunker 4-8x smaller (on average) was a reasonable choice.
- Variations on min:avg:max had little effect

Detailed results: amalgamation

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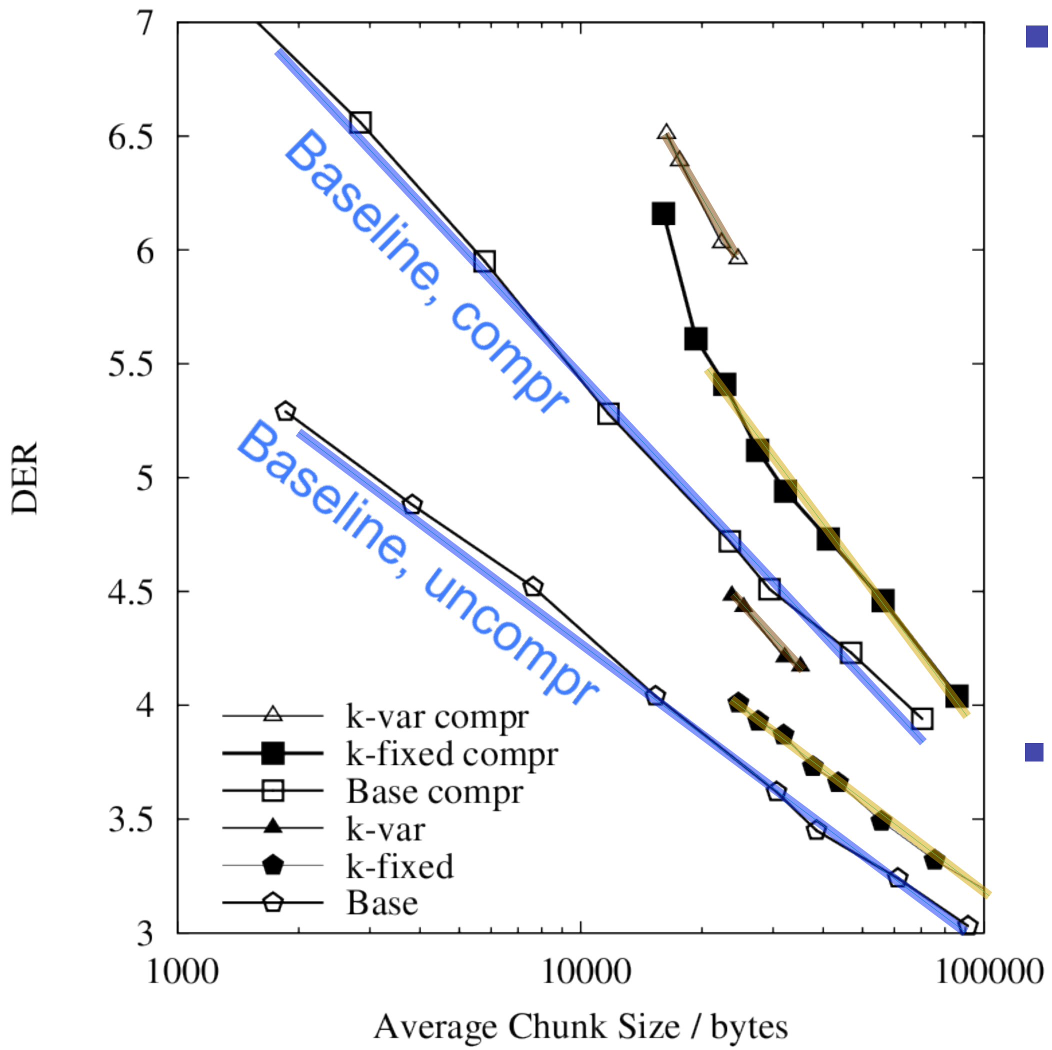
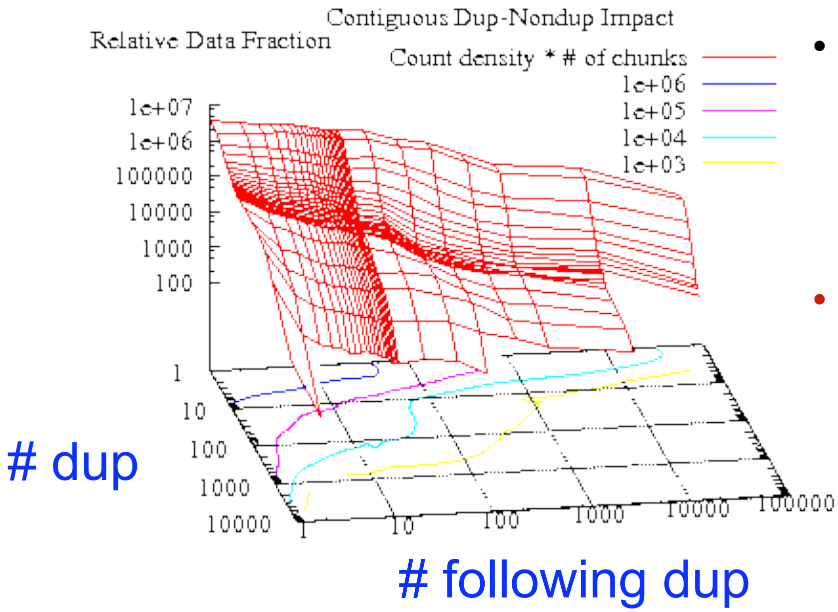


- Typical settings:
  - Min:avg:max = 1:2:3
  - 3 backup levels
  - Big chunk = 8 smalls
  - fixed size big chunks (8 existence queries per big chunk)
  - (or variable, big = 1-8 smalls, 64 existence queries per big chunk)
- Settings robust to minor variations
  - Ex. 8-12 smalls all lying along same curve.

"Historical" intuitions: beware!

- Intuitive model of file system backups
  1. Long stretches of unseen data should be assumed to be good candidates for appearing later on (i.e. at the next backup run).



- Experiment:
  - Run baseline chunker
  - Count (# dup, # following nondup)
  - Weight for # of bytes of input data
- Over these 14 backups, long stretches of unseen data were rather rare.

  2. Inefficiency around "change regions" straddling boundaries between duplicate and unseen data can be minimized by using shorter chunks.
     - Confirmed by "oracle" experiments

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Non-backup archives

- Source code archives, ~ 10 or so versions
  - Ran amalgamation with fixed-size big chunks of k smalls
  - Varied k
- Gcc sources showed some small benefit, while emacs source showed no benefit.
  - Not a universal solution
- DER/chunk size gains definitely depend on nature of archive
  - Expect problems if unimodal DER is low:
    - Ex: emacs uncompressed DER was only ~1.73 for <8k> chunks
    - One of our assumptions is failing --- duplication probability is *never* very high.
- When blocks frequently fail assumption of "high probability to be seen later", bimodal chunking may not be worthwhile.

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Conclusions

- For archival data with DER >3-4, “chunking transition regions small” is a useful mechanism to achieve competitive DER with larger than usual chunk sizes.
- Transition regions can be determined by adding an existence query capability to existing block stores.
- Small chunks in transition regions can show enhanced probability to be seen later.

Questions?