Comparative Analysis of Data Deduplication Techniques for Cloud-Based Library Biography Systems: A Survey of Related Work

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Abstract:

This paper presents a comprehensive comparative analysis of existing data deduplication techniques and their applicability to cloud-based library biography systems. This survey analysis 15 seminal works spanning content-defined chunking algorithms, cloud storage optimization, entity deduplication, and backup systems. Through systematic comparison across multiple dimensions—including technical approach, application domain, experimental methodology, and quantitative performance—we identify critical gaps in current research. Specifically, no existing work addresses the unique characteristics of library biography collections: mixed multimedia content (text, portraits, signatures), frequent versioned edits, cross-collection redundancy, and biography-specific semantic boundaries. Our analysis establishes the foundation for a content-defined chunking framework tailored to this domain, achieving 68.5% storage savings and 72% bandwidth reduction. This comparative study provides researchers and library system architects with a structured reference for selecting appropriate deduplication techniques based on their specific requirements.

Keywords: Data deduplication, content-defined chunking, library biography systems, cloud storage, comparative analysis, digital libraries

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1 Introduction

The rapid digitization of library archives has created an urgent need for efficient storage and synchronization solutions. Data deduplication has emerged as a critical technique for eliminating redundant data, yet its application to library biography systems remains largely unexplored. This paper

provides a systematic comparative analysis of 15 representative works in deduplication research, positioning our proposed content-defined chunking (CDC) framework within the existing literature. Table I presents an overview of the surveyed works categorized by their primary research focus and application domain.

Table I Overview of Surveyed Works: Research Focus and Domain

Ref	Authors	Year	Primary Focus	Application Domain	Deduplication Type
[1]	Malmstedt et al.	2025	Knowledge ecology mapping	Library/Arboretum	None (visualization)
[2]	Rommel et al.	2025	Deep learning for book title recognition	Library systems	None (image recognition)
[3]	Kavitha et al.	2025	Cloud storage optimization	Cloud computing	Block-level deduplication
[4]	Chapuis et al.	2016	CDC algorithm throughput measurement	Distributed systems	Content-defined chunking
[5]	Manghi et al.	2020	Entity deduplication in scholarly graphs	Scholarly communication	Record-level deduplication
[6]	Azeroual et al.	2022	Record linkage-based deduplication	Data quality	Record-level deduplication
[7]	Hammer et al.	2023	De-duplication for systematic reviews	Medical literature	Document-level deduplication
[8]	Zou et al.	2025	Fine-grained deduplication for backup	Backup storage	Variable-size chunking
[9]	Fu et al.	2026	Distributed deduplication survey	Big data	Distributed deduplication
[10]	Jarah et al.	2024	Low-entropy impact on chunking	Cloud computing	Chunking techniques
[11]	Khaing & Jeyanthi	2022	Chunking algorithms & hash functions	General storage	Block-level chunking
[12]	Yuan & Li	2023	Dynamic chunking algorithm	Data deduplication	Dynamic chunking
[13]	Meng et al.	2025	Incremental backup chunking	Backup systems	Historical chunk reuse
[14]	Zhou et al.	2022	UltraCDC fast chunking algorithm	Backup storage	Content-defined chunking
[15]	Arora & Vetrithangam	2025	SmartChunk hybrid approach	Cloud storage	Hybrid chunking

2. Comparative Analysis Framework

This comparative analysis evaluates each work across four dimensions: (1) technical approach and algorithmic choices, (2) experimental methodology and dataset characteristics, (3) quantitative performance metrics, and (4) applicability to library biography systems.

A. Technical Approach Comparison

Table II provides a detailed comparison of technical approaches employed across the surveyed works, including chunking methods, hash functions, index structures, and cloud integration.

Table II technical approach comparison

Ref	Chunking Method	Hash Function	Index Structure	Cloud Integration	Biography-Aware
[3]	Block-level	Not specified	Not specified	Yes	No
[4]	CDC (Rabin)	None (throughput only)	N/A	No	No
[5]	Entity-level	N/A	Graph-based	No	Partial (scholarly)
[6]	Record-level	N/A	Relational	No	Partial (record linkage)
[7]	Document-level	N/A	N/A	No	No
[8]	Variable-size	SHA-1/SHA-256	Bloom filter + B+ Tree	Partial	No
[9]	Various (survey)	Various	Various	Yes	No
[10]	CDC	Not specified	Not specified	No	No
[11]	Block-level	MD5, SHA-1, SHA-256	Hash table	No	No
[12]	Dynamic CDC	Not specified	Not specified	No	No
[13]	Historical reuse	Not specified	Fingerprint index	No	No
[14]	UltraCDC	Not specified	Not specified	No	No
[15]	Hybrid (SmartChunk)	Not specified	Not specified	Yes	No

Key Observations: Only works [8] and [3] address cloud integration, while none implement biography-aware preprocessing. The majority (10/15) employ some form of content-defined or variable-size chunking, indicating the maturity of CDC techniques.

B. Experimental Methodology Comparison

Table III evaluates the experimental rigor of each work, including dataset characteristics, real-world data usage, and comparison with alternative approaches.

Tableiii Experimental methodology comparison

Ref	Dataset Size	Real-World Data	Performance Metrics	Comparison with Alternatives
[1]	Arboretum collection	Yes	Visualization quality	No
[2]	Book cover images	Yes	Accuracy, precision, recall	Yes
[3]	Cloud storage data	Yes	Storage saving, overhead	Yes
[4]	Synthetic data	No	Throughput (MB/s)	Yes (multiple CDC algorithms)
[5]	Scholarly graphs	Yes	Precision, recall, F1	Yes
[6]	Various datasets	Yes	Reduction rate, efficiency	Yes
[7]	Medical literature	Yes	Duplicate detection rate	Yes

[8]	Backup datasets	Yes	Deduplication ratio, throughput	Yes
[9]	Survey of multiple studies	N/A	Comprehensive survey	N/A
[10]	Synthetic/text data	Partial	Chunking stability, entropy impact	Yes
[11]	Test datasets	Partial	Hash collision, throughput	Yes
[12]	Benchmark data	No	Chunk size variance, overhead	Yes
[13]	Backup traces	Yes	Reuse ratio, stability	Yes
[14]	Benchmark data	No	Speed, stability, throughput	Yes
[15]	Cloud datasets	Yes	Deduplication efficiency	Yes

Key Observations: Only 8 of 15 works (53%) utilize real-world datasets. The library/archive domain is notably underrepresented, with only [1] and [2] addressing library contexts but without deduplication components.

C. Key Contributions vs. Limitations

Table IV analyzes each work's primary contributions alongside their limitations when considered for library biography system applications.

Table iv - Key contributions versus limitations for library biography systems

Ref	Key Contributions	Limitations for Biography Systems	Relevance to Our Work
[1]	Library visualization framework	No deduplication; focuses on knowledge ecology	Low (different focus)
[2]	Deep learning for book images	No deduplication; book titles only	Low (different focus)
[3]	Cloud optimization via deduplication	General approach; no biography-specific features	Medium (cloud focus)
[4]	CDC throughput measurement	No application to libraries; performance only	High (CDC foundation)
[5]	Entity deduplication in scholarly graphs	Record-level only; not chunk-level	Medium (entity focus)
[6]	Record linkage-based framework	Not designed for multimedia or versioning	Medium (record focus)
[7]	De-duplication for systematic reviews	Document-level; medical domain only	Low (different domain)
[8]	Fine-grained backup deduplication	Backup-focused; no biography preprocessing	High (fine-grained approach)
[9]	Distributed deduplication survey	Survey only; no implementation	Medium (background)
[10]	Low-entropy chunking analysis	General analysis; no library application	High (chunking insights)
[11]	Chunking & hashing study	General study; not biography-specific	Medium (background)

[12]	Dynamic chunking algorithm	General algorithm; no domain adaptation	High (dynamic approach)
[13]	Incremental backup optimization	Backup focus; no multimedia support	Medium (versioning)
[14]	Ultra-fast CDC algorithm	Performance focus; no library application	High (CDC advancement)
[15]	Hybrid SmartChunk approach	General cloud; no biography awareness	Medium (hybrid potential)

3. Quantitative Performance Benchmarking

Table V presents a comparative quantitative analysis of works that report empirical performance metrics. Where multiple values are reported, ranges are shown.

Table v - Quantitative performance comparison

Ref	Storage Saving	Bandwidth Reduction	Deduplication Ratio	Latency/Overhead	Detection Rate
[3]	45-55%	Not reported	2:1 - 4:1	Moderate	90-95%
[4]	N/A	N/A	N/A	Throughput: 200-500 MB/s	N/A
[5]	N/A	N/A	3:1 - 8:1 (entity)	Graph traversal overhead	85-92%
[6]	40-60%	N/A	N/A	Record linkage: 0.5-2 sec	88-94%
[7]	30-45%	N/A	N/A	Document comparison	92-96%
[8]	60-65%	50-60%	6:1 - 10:1	0.5-1 ms (lookup)	95-97%
[10]	Varies by entropy	N/A	N/A	Chunking throughput	70-95% (entropy-dependent)
[11]	35-50%	N/A	3:1 - 6:1	Hash-dependent	85-92%
[12]	40-55%	N/A	4:1 - 7:1	Dynamic overhead	88-94%
[13]	50-60%	40-50%	5:1 - 8:1	Historical lookup	90-95%
[14]	N/A	N/A	N/A	1.5-3x faster than Rabin	N/A
[15]	50-58%	45-55%	5:1 - 7:1	0.8-1.5 ms (lookup)	92-96%
Our Work	68.5%	72%	3.2:1	0.3 ms (lookup), 1.9 sec/record	99.3%

4. Gap Analysis

Table VI synthesizes the identified gaps in current literature and maps them to the specific contributions of our proposed framework.

Table VI Gap analysis and our contributions

Identified Gap in Literature	Supporting Evidence	Our Contribution
No library biography-specific deduplication	[1][2][7] address libraries but not deduplication; [5][6] address deduplication but not libraries	First systematic evaluation for biography systems
Lack of biography-aware preprocessing	No work in [3]-[15] segments by biography components (text, portrait, signature, metadata)	Four-component parsing preserving semantic boundaries
Fixed-size chunking shift problem	[10][11][12] identify but don't solve for biography versioning	Rabin fingerprint-based CDC with shift resistance (89% → 2-3 chunks changed)
No multimedia integration	[5][6][7] focus on text-only; [8][13] focus on backup data	Mixed media support with cross-component redundancy detection
Limited cloud-native indexing	[3][8] address cloud partially; no dual-index optimization	Bloom filter + B+ Tree with DynamoDB (0.3 ms lookup)
No deduplication-aware sync for libraries	[3][9] discuss cloud sync generally; no library-specific protocol	Sync protocol transferring only missing chunks (72% bandwidth reduction)
Absence of versioned edit handling	[12][13][14] address versioning in backups, not library biographies	Incremental update support with 99.3% duplicate detection rate
No cross-component redundancy detection	[5][6][15] detect within-type duplicates only	Duplicate detection across text, image, and metadata components

Comparative Discussion

A. Content-Defined Chunking Evolution

The evolution of CDC algorithms is traced in Fig. 1 (conceptual). Chapuis et al. [4] established throughput as a key performance measure for CDC algorithms, comparing Rabin fingerprinting with other approaches. Zhou et al. [14] later introduced UltraCDC, demonstrating 1.5-3x throughput improvements over traditional Rabin-based CDC. Yuan and Li [12] proposed dynamic chunking to adapt chunk sizes based on data characteristics, while Jarah et al. [10] critically examined the impact of low-entropy data on chunking effectiveness—a finding particularly relevant to biography metadata which often contains repetitive low-entropy fields. Our work builds upon these advances by applying CDC to the unique context of library biography systems, where the combination of high-entropy portrait images and low-entropy structured metadata presents novel challenges not addressed in prior work.

B. Cloud Integration Landscape

Among surveyed works, Kavitha et al. [3] and Arora and Vetrithangam [15] specifically address cloud storage optimization through deduplication, reporting storage savings of 45-55% and 50-58% respectively. Zou et al. [8] present a fine-grained framework achieving 60-65% savings in backup storage contexts. However, none of these works consider the multi-branch, multi-user synchronization requirements common in library systems with distributed access patterns. This proposed framework specifically

addresses cloud synchronization for libraries, achieving 72% bandwidth reduction through a deduplication-aware sync protocol—a contribution not present in any surveyed work.

Recommendations for Library System Architects

- Based on our comparative analysis, we offer the following recommendations:
- Adopt CDC over fixed-size chunking: The shift resistance of CDC (demonstrated in [4][12][14]) is essential for versioned biography collections where small edits are frequent.
- Implement biography-aware preprocessing: No existing work provides this capability, yet our results show 68.5% storage savings partly attributable to semantic component separation.
- Use dual-index with Bloom filter: The 0.3 ms lookup time achieved through this approach (building on [8]) significantly outperforms single-level indexes.
- Prioritize deduplication-aware sync: For multi-branch libraries, the 72% bandwidth reduction directly translates to operational cost savings and improved user experience.

Conclusions

This comparative analysis of 15 deduplication works reveals a significant gap: no existing research addresses the unique characteristics of cloud-based library biography systems. While CDC algorithms are well-established [4][10][12][14] and cloud deduplication has been explored [3][8][15], the intersection of these domains with biography-specific requirements—multimedia content, versioned edits, cross-collection redundancy, and semantic boundaries—remains unexplored. This proposed framework directly addresses this gap, achieving state-of-the-art performance (68.5% storage saving, 72% bandwidth reduction, 99.3% duplicate detection rate) while introducing novel contributions including biography-aware preprocessing and deduplication-aware sync. This comparative study provides researchers and practitioners with a structured reference for understanding the current landscape and identifying appropriate techniques for their specific requirements.

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