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Optical library system for Long term preservation with extended error correction coding

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Hitachi, Ltd.
Yokohama Research lab.

Contents
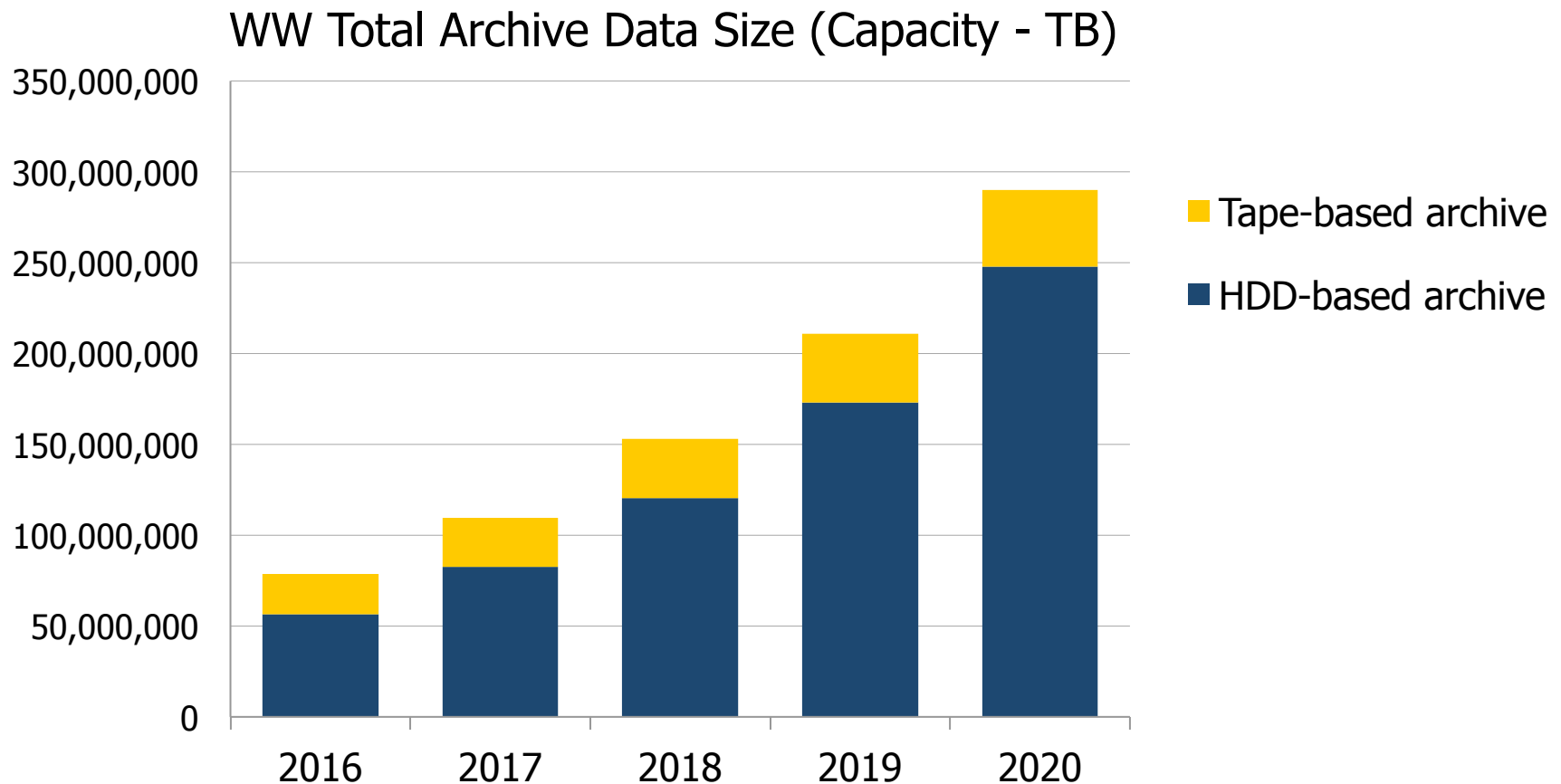
Contents

Archive Data Size Forecast

- Total capacity of archive data will increase x3.7 ('16 → '20)

WW Total Archive Data Size (Capacity - TB)

Legend:
- Tape-based archive
- HDD-based archive

Y-axis: 0, 50,000,000, 100,000,000, 150,000,000, 200,000,000, 250,000,000, 300,000,000, 350,000,000

X-axis: 2016, 2017, 2018, 2019, 2020

Source: ESG (Enterprise Strategy Group Inc.) Custom Report ('12)

3

Background of Data Archiving

■ Archiving "Industry Classified Data"

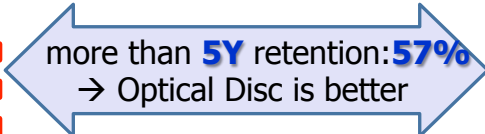**Hospitals**
Medical/
Account data

Research institutes
R&D Data,
papers

Libraries
Significant
literature

Broadcasting stations
Movie,
Audio

State institutions
Official/
Confidential
document

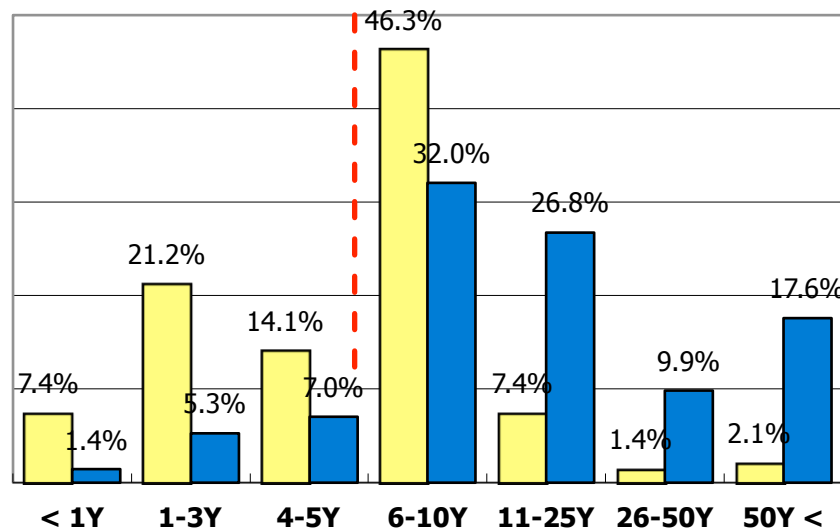**Companies**
Mail, contract,
management info.

■ Preservation terms of digital documents defined in laws

Terms	Target documents	Related laws and regulations
30 Years	**Patient Information**, Electronic Health Chart, Medical Records	USA; HIPPA/OSHA
15 Years	Design Documents	Licensed Architect Act
10 Years	Brokerage; Trade Reports **Manufacturing Drawing** (10 Years after End-of-product)	Cabinet Office Ordinance on Securities Product Liability Act
7 Years	Journal, Account Book (General Ledger) e-Discovery	Income Tax Law, Corporation Tax Law USA; Sarbanes-Oxley Act
5 Years	**Medical**; Medical Records, Midwifery Records, Emergency Medical Records Corporate; Property formation tax exemption savings application	Medical Act etc. Income Tax Law

4

Predominance of Optical Disc

- More than 57% companies have archiving information to be retained at least more than 5 years
  →Optical Disc is preferable from a <u>long-term preservation</u> point of view
- Optical Disc is superior to Tape/HDD from a <u>resilience against disaster</u> point of view, e.g. flood, electromagnetic pulse, and so on.

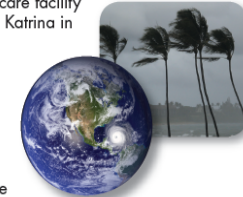HDD-base system migration dead-line (5 Years)

more than **5Y** retention:**57%**
→ Optical Disc is better

46.3%

32.0%

26.8%

21.2%

17.6%

14.1%

7.4%

9.9%

7.4%

5.3%

7.0%

1.4%

1.4%

2.1%

| < 1Y | 1-3Y | 4-5Y | 6-10Y | 11-25Y | 26-50Y | 50Y < |

■ Maximum：20.4 Years(Average)

Source: ESG (Enterprise Strategy Group Inc.) Custom Report ('12)

The Southeast Louisiana Veterans Health Care System (formerly the VA Medical Center, New Orleans) and its outpatient clinics located throughout southeast Louisiana are committed to providing high-quality, compassionate, and safe health care to the more than 220,000 veterans who live in the 23-parish region they serve. The 354-bed acute care facility was affected by flooding following Hurricane Katrina in August 2005.

Situation
Hurricane Katrina, which made landfall near the Louisiana-Mississippi border on the morning of August 29, 2005, and the subsequent flooding caused by the failure of the New Orleans levee system, resulted in one "The media had been exposed to extremely high temperatures and humidity from brackish standing water, they were covered in debris and dust for more than a month," said Allen. "We were able to recover all of the patient images off of the Plasmon libraries. We had just started to migrate to UDO™ (Ultra Density Optical) for an archive solution when the hurricane hit. We are now primarily using the Plasmon UDO Archive Appliance for its long-term recoverability."

"Hospital's Data Survives Hurricane Katrina"
Source: Alliance Storage Technologies, Inc. ("ASTI")
www.alliancestoragetechnologies.com.
"Plasmon" and "UDO" are the Registered Trademarks of ASTI.

E.g. In 2005, Hurricane Katrina in USA
Tape/HDD ： Almost all data were lost
Optical Disc ： 98% data were recovered

5

Use case in Data Center

- Data in Data Center is moved to BD Archiving System when its Access Frequency becomes low.
- BD Archiving System is suitable for the preservation of "Cold Data"
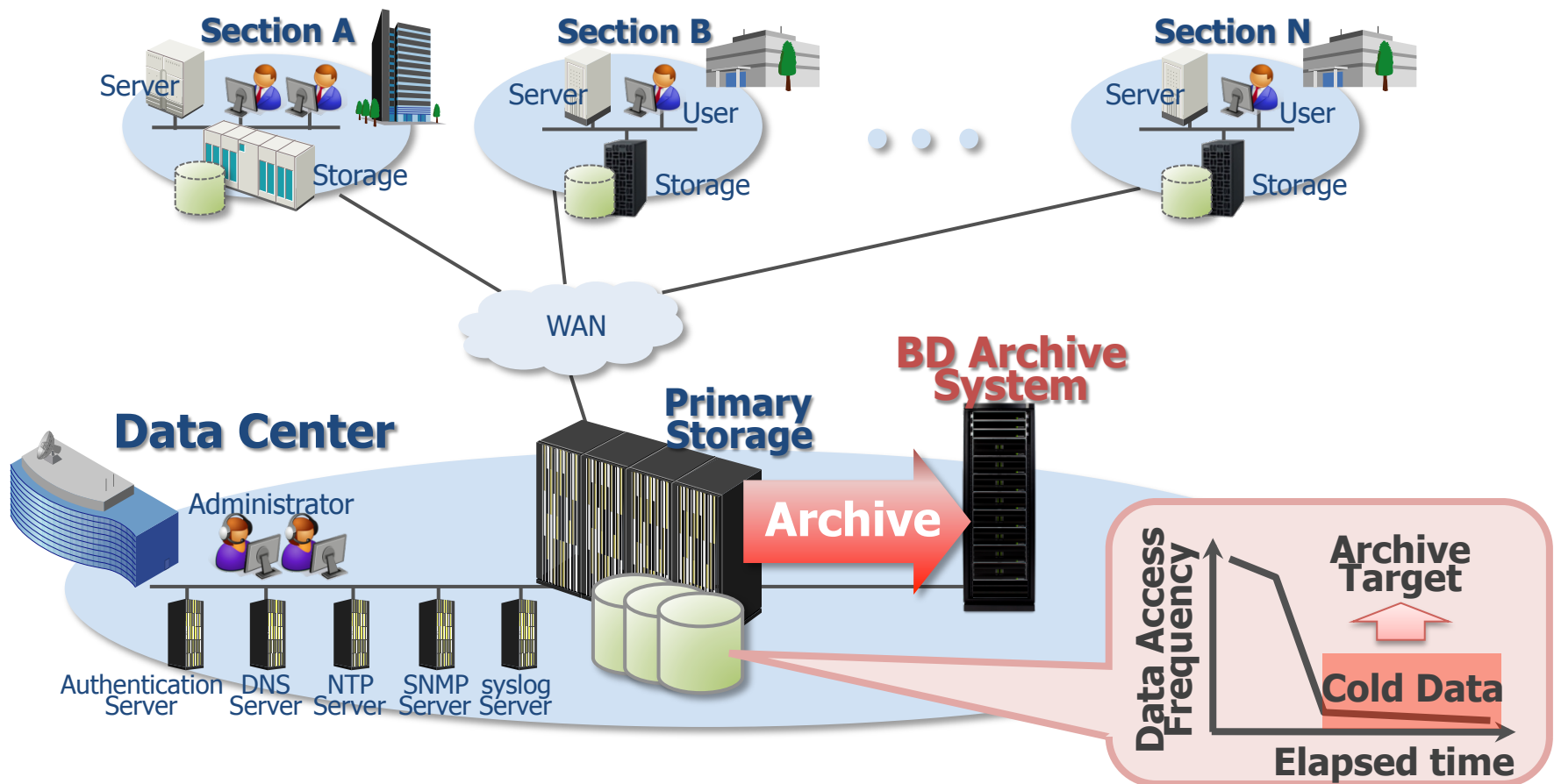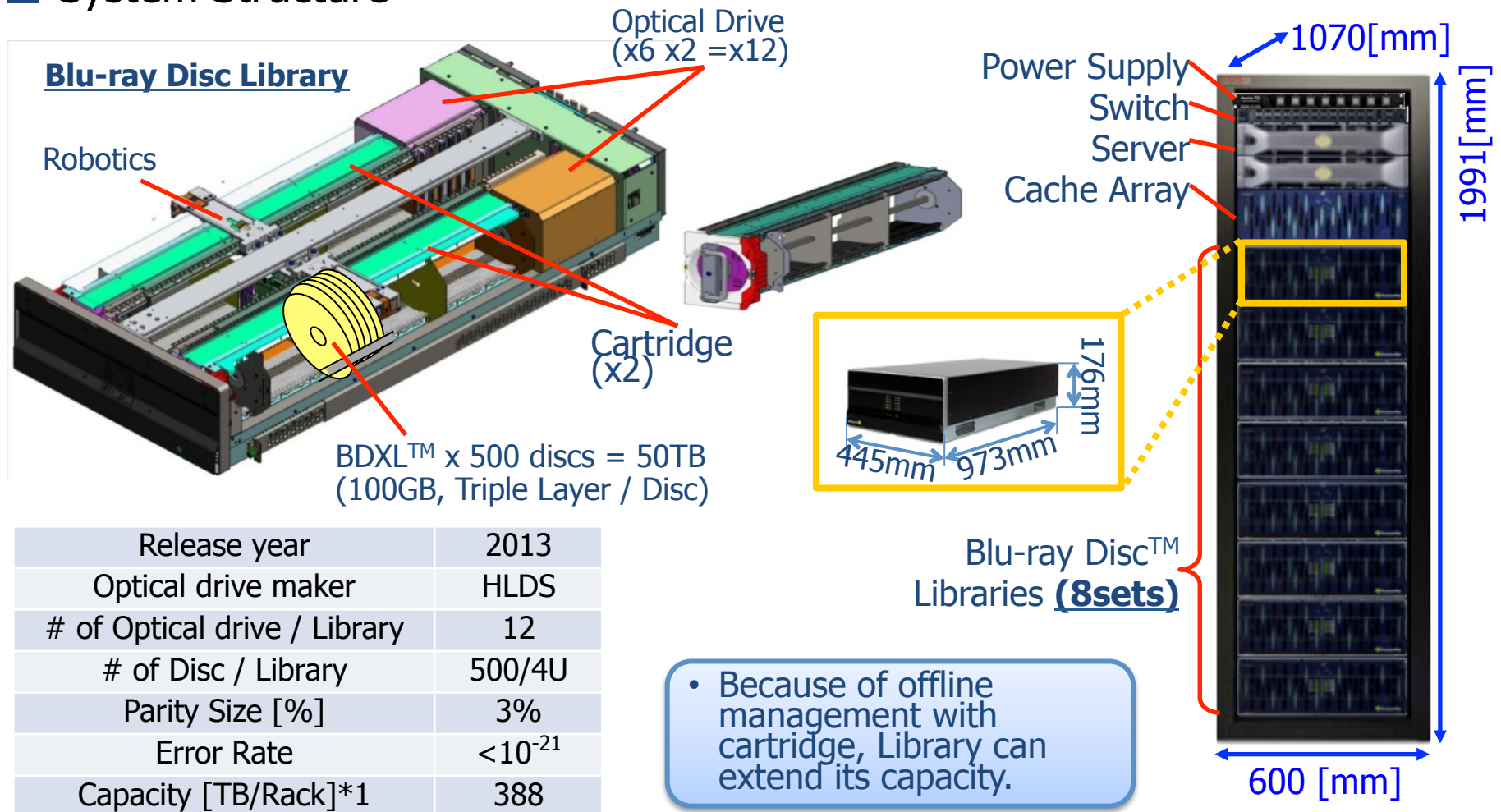
Contents

Blu-ray Disc™ Archiving System

Based on the background, we designed optical library system

■ System Structure

Blu-ray Disc Library

Optical Drive (x6 x2 =x12)

Robotics

Cartridge (x2)

BDXL™ x 500 discs = 50TB (100GB, Triple Layer / Disc)

Power Supply
Switch
Server
Cache Array

1070[mm]

1991[mm]

176mm

445mm 973mm

Blu-ray Disc™ Libraries **(8sets)**

600 [mm]

Release year	2013
Optical drive maker	HLDS
# of Optical drive / Library	12
# of Disc / Library	500/4U
Parity Size [%]	3%
Error Rate	$<10^{-21}$
Capacity [TB/Rack]*1	388

- Because of offline management with cartridge, Library can extend its capacity.

*1; without parity area, 1TB=1,000,000,000,000bytes
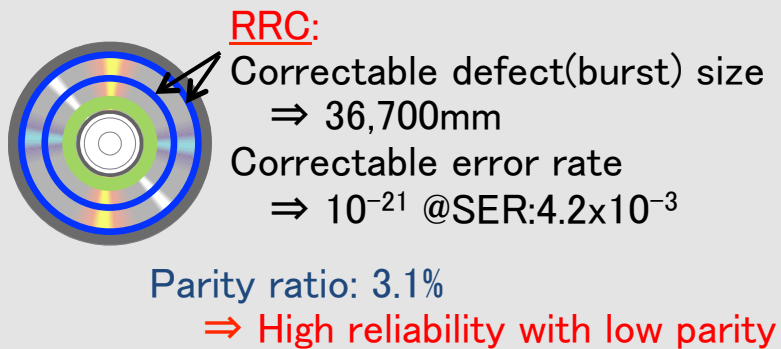
8

HLDS; Hitachi LGE Data Storage

Technologies for Optical Archiving

The technologies for longevity and anti-disaster has been applied.
- <u>RRC</u>; Error correction code improving durability against defects and keeping compatibility with physical specification of optical disc
- <u>ORA</u>; Area management to enhance the data reliability on the disc along with UDF specification

Robustness against defects
- Redundant Recovery Code(RRC) implementation
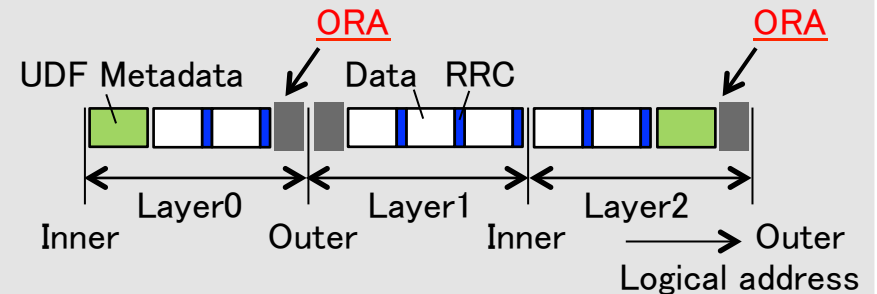- RRC expands the size of correctable defect

RRC:
Correctable defect(burst) size
$\Rightarrow$ 36,700mm
Correctable error rate
$\Rightarrow 10^{-21}$ @SER:4.2×10^{-3}

Parity ratio: 3.1%
$\Rightarrow$ High reliability with low parity

Robustness against scratch
- Outer Reserved Area(ORA) implementation

File system layout
- RRC allocation conforms to specification

ORA   ORA
UDF Metadata   Data   RRC

Layer0   Layer1   Layer2
Inner   Outer   Inner   Outer
                                    Logical address

RRC:Redundant Recovery Code UDF:Universal Disc Format   ORA:Outer Reserved Area
ODD:Optical Disc Drive   SER:Symbol Error Rate

9

Contents

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Large size of "Band" improved tolerance against burst error
- Parity member construction design considering original ECC based on physical specification of optical disc
- Flexibility of designing size of Band and redundancy according to system design policy

■Definition
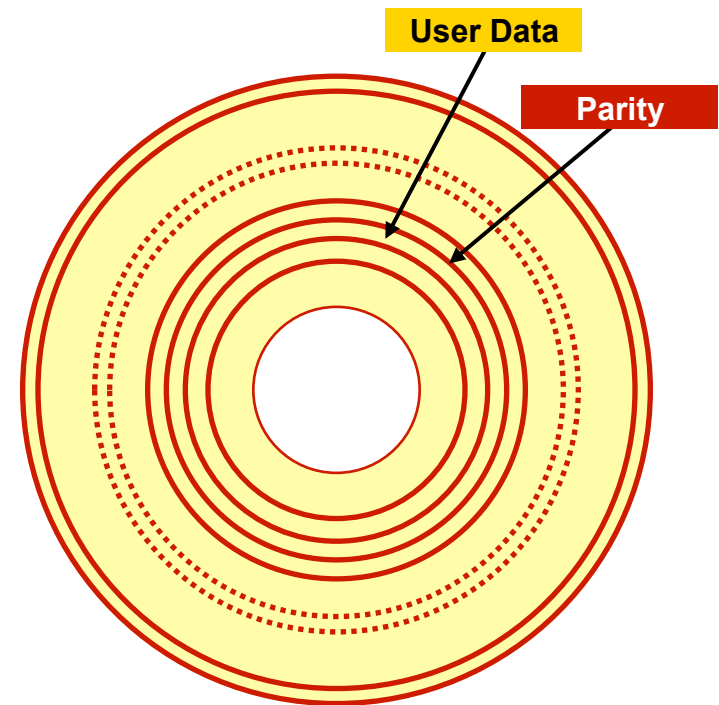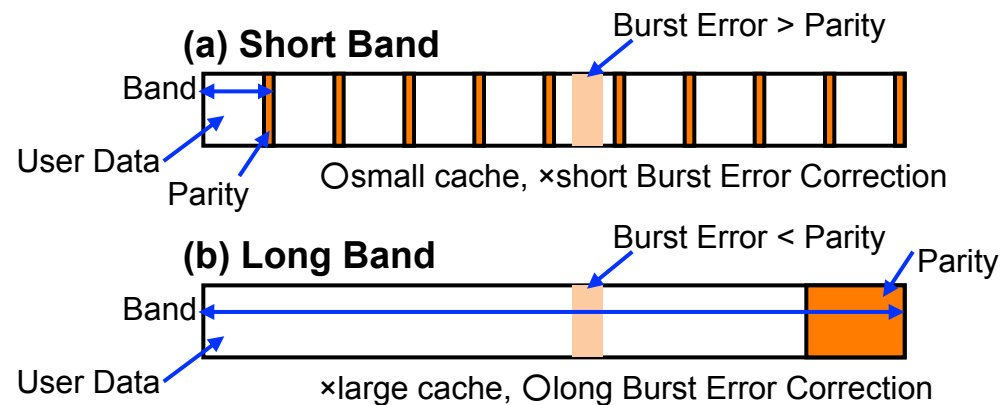"Band" : Group of data unit consist of parity and parity member. User data only

■Design policy
(1) Band Size:
   Optimized to system cache size
   [e.g. 8Lib. x 12_{ODD} = 96_{ODD} Cache Size]
(2) Parity Size:
   Balanced between tolerance and capacity

User Data

Parity

(a) Short Band

Burst Error > Parity

Band
User Data
Parity

○small cache, ×short Burst Error Correction

(b) Long Band

Burst Error < Parity

Parity

Band
User Data

×large cache, ○long Burst Error Correction

11

Comparison about Tolerance for Burst Error

RRC has merits in the following points,
- Radial direction; more than 8 times as long as other method
- Tangential direction; correctable for 33 ~ 82 [um] Burst error
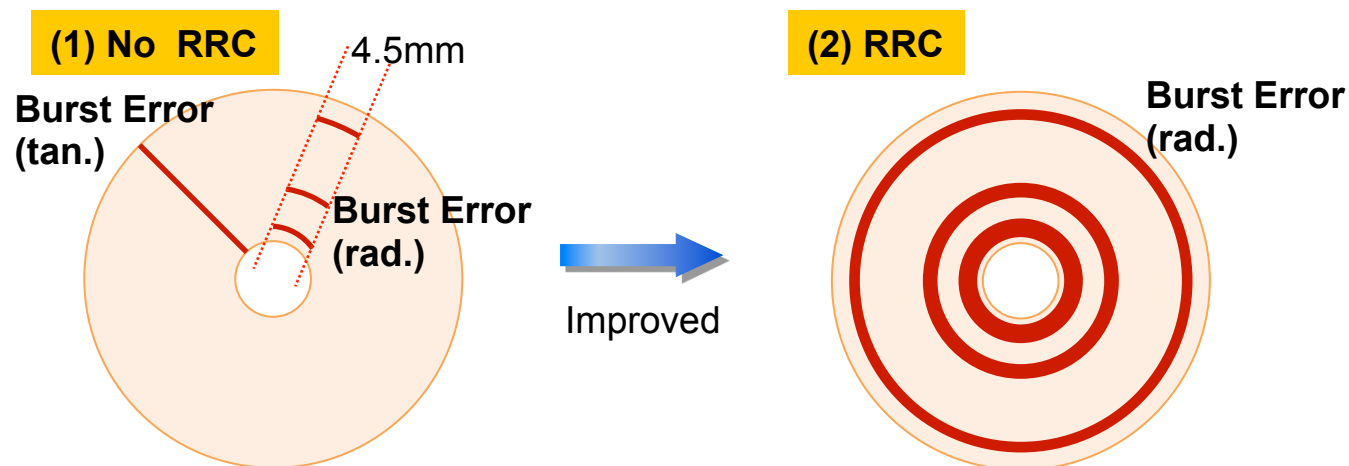
(1) No RRC
   [rad.] Burst error with the length of 4.5mm(rad.max.) within 1ECC(Cluster)
   [tan.] (No capability to correct error)

(2) RRC (in case of 3% parity size)
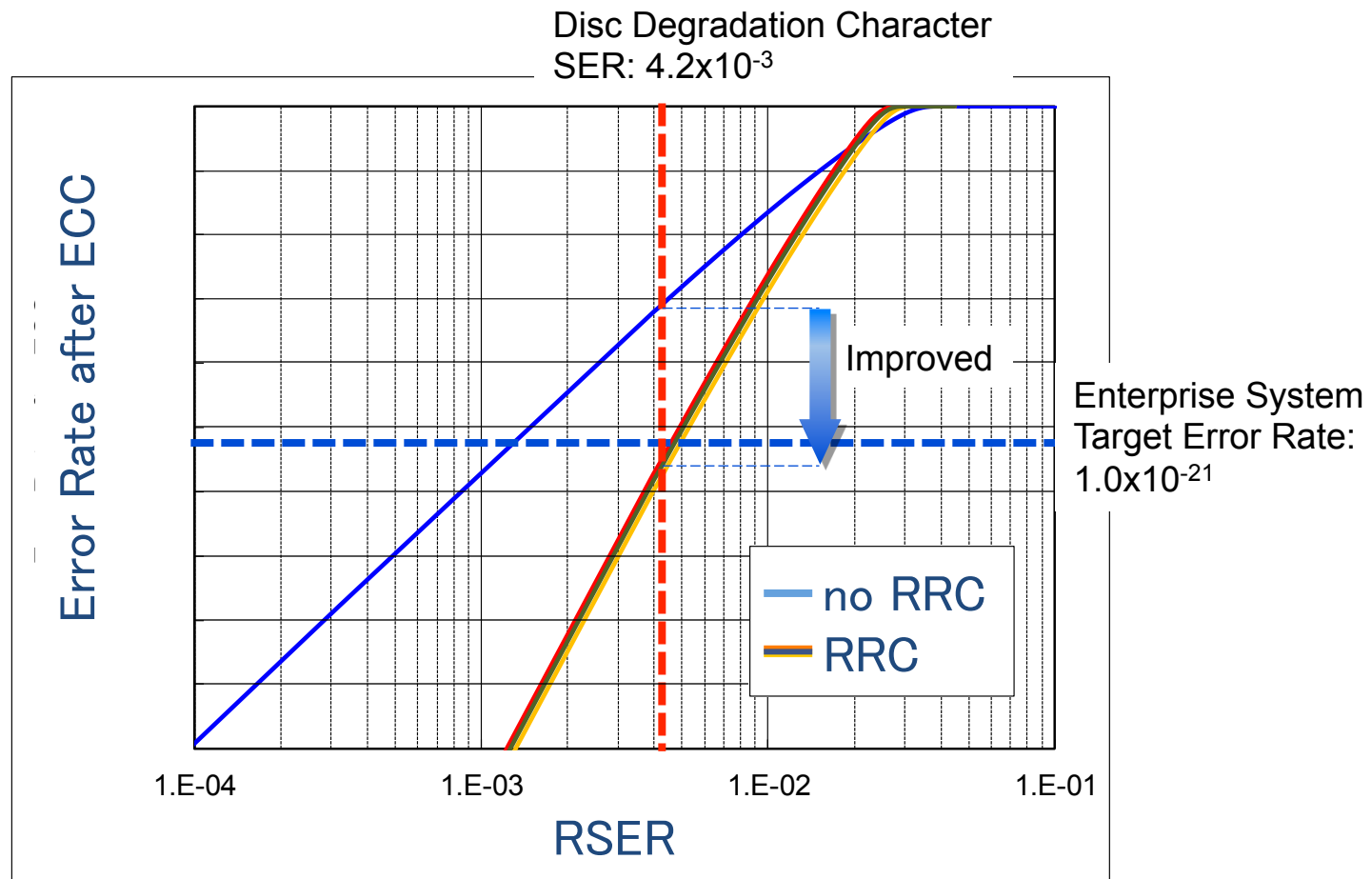   [rad.] Burst error with the length of 1Track
   [tan.] Burst error with the length of 33um (@outer area) (or 82um @ inner area)

(1) No RRC

4.5mm

Burst Error (tan.)

Burst Error (rad.)

Improved

(2) RRC

Burst Error (rad.)

12

Tolerance for Random Error

RRC improves the following points,
- Only 3% parity achieved enterprise system target error rate (1.0×10^{-21})

Disc Degradation Character
SER: 4.2×10^{-3}

Improved

Enterprise System
Target Error Rate:
1.0×10^{-21}

Error Rate after ECC

—— no RRC
—— RRC

RSER

RSER; Read Symbol Error Rate

Overview of "ORA"

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> Purpose;
> • Reduce the risk of data loss caused by the potential low-reliable-area, outer radius area.

■Assumed Risks
  (1) Disc
      ・Outer radius area of optical disc is possible to be lower in reliability.

  (2) Disc Handling in Optical Library
      ・Transporting Disc/Cartridge; Abrasion, Earthly affairs
      ・Holding Disc in Cartridge Slot; Abrasion at Disc edge
      ・Failure of transporting Disc; Scratch on Disc edge

■Countermeasure
      ・Specify the area suspected to be damaged heavily
      ・Measure how to be damaged on the area
      ・According to the result, define ORA area threshold
       considering the balance between the reliability and capacity

RRC Band Assignment

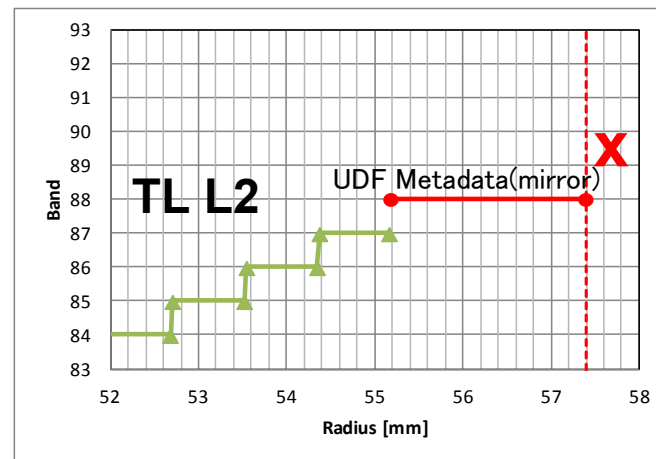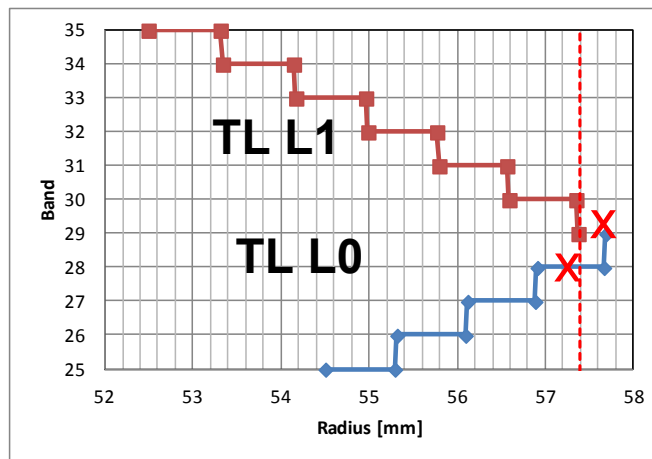- Utilize the size of ORA unit as RRC Band unit
  - TL : ORA needs 3 Bands -> -3N[GB]   (N; Band Size[GB])
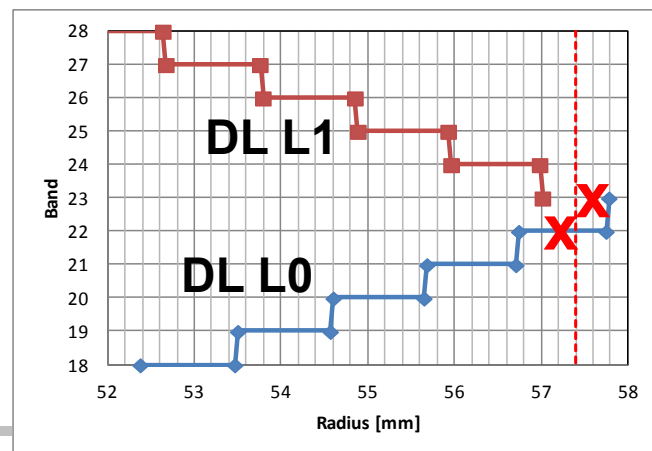 - DL : ORA needs 2 Bands -> -2N[GB]

X : ORA needs these bands marked with X

15
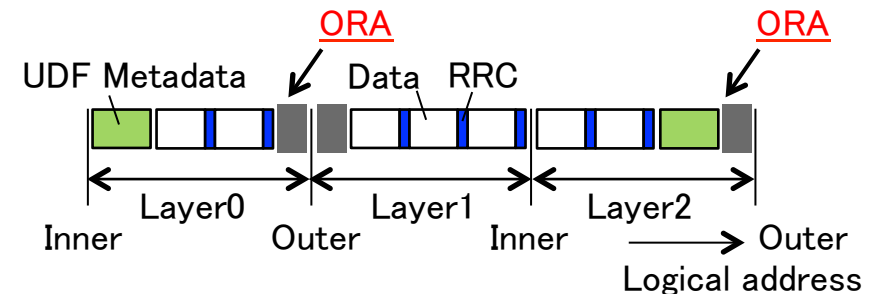
Optical Archiving Overview
- Target of Optical Archiving Market is <u>expanding rapidly.</u>
- Optical storage is suitable for a <u>long-term preservation.</u>

BD Archiving Technologies
- <u>Error correction code (=RRC)</u> improving durability against scratch and keeping compatibility with physical specification of optical disc.
- <u>Outer Reserved Area (=ORA)</u> is allocated complying with RRC, UDF and physical allocation specification.

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