DBMS Week 11 TA Session

Backup and Recovery

- A **Backup** of a database is a representative copy of data containing all necessary contents of a database such as data files and control files.
    - **Physical Backup:** A copy of physical database files such as data, control files, log files, and archived redo logs.
    - **Logical Backup:** A copy of logical data that is extracted from a database consisting of tables, procedures, views, functions, etc.
- **Recovery** is the process of restoring the database to its latest known consistent state after a system failure occurs.

Types of Backup Data

- **Business Data** includes personal information of clients, employees contractors etc. along with details about places, things, events and rules related to the business.
- **System Data** includes specific environment/configuration of the system used for specialised development purposes log files, software dependency data, disk images.
- **Media** files like photographs, videos, sounds, graphics etc. need backing up. Media files are typically much larger in size.

Backup Strategies

- Full Backup
- Incremental Backup
- Differential Backup
- Hot Backup

Full Backup

- **Full Backup** backs up everything. This is a complete copy, which stores all the objects of the database.

A full backup must be done at least once before any of the other type of backup.

Advantages

- It is relatively easy to setup, configure and maintain
- Recovery from a full backup involves a consolidated read from a single backup

Disadvantages

- Longest system downtime during the backup process
- It uses largest amount of storage media per backup

Incremental Backup

- **Incremental backup** targets only those files or items that have changed since the last backup.

A full backup is done once a week, and incremental backups are done for the rest of the time.

Advantages

- Less storage is used per backup
- The downtime due to backup is minimized
- It provides considerable cost reductions over full backups

Disadvantages

- It requires more effort and time during recovery
- It cannot be done without the full backup and intermediate incremental backup
- Recovery cannot be 100%, if any incremeantal backup is lost

Differential Backup

- **Differential backup** backs up all the changes that have occurred since the most recent full backup regardless of what backups have occurred in between

Advantages

- Recoveries require fewer backup sets.
- Provide better recovery options when full backups are run rarely (for example, only monthly)

Disadvantages

- The amount of storage media required may exceed the storage media required for incremental backups
- If done after quite a long time, differential backups can even reach the size of a full backup

Example

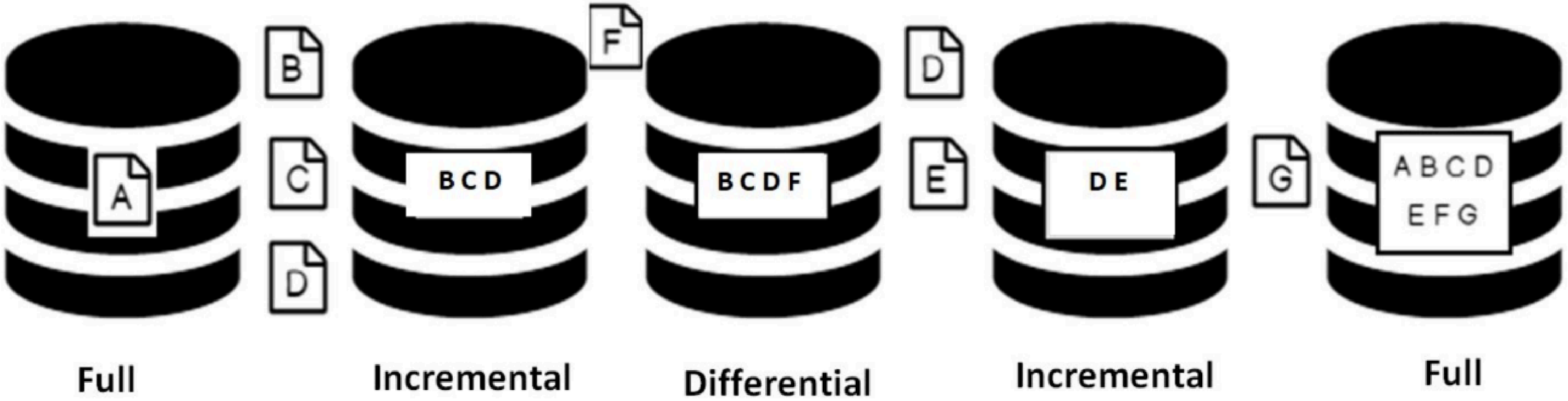


Figure: Backup Types

Hot Backup

- **Hot backup** refers to keeping a database up and running while the backup is performed concurrently

Advantages

- The database is always available to the end user.
- Point-in-time recovery is easier to achieve in Hot backup systems.
- Most efficient while dealing with dynamic and modularized data.

Disadvantages

- May not be feasible when the data set is huge.
- Fault tolerance is less.
- Maintenance and setup cost is high.

Log Based Recovery

- A log is kept on stable storage
  - The log is a sequence of log records, which maintains information about update activities on the database
- When transaction T_i starts, it registers itself by writing a record $< T_i\ start >$ to the log
- Before T_i executes write(X), a log record $< Ti, X, V_1, V_2 >$ is written, where V_1 is the value of X before the write (old value), and V_2 is the value to be written to X (new value)
- When T_i finishes its last statement, the log record $< T_i\ commit >$ is written.

Database Modification Scheme

- The **immediate-modification** scheme allows updates of an uncommitted transaction to be made to the buffer, or the disk itself, before the transaction commits.
- The **deferred-modification** scheme performs updates to buffer/disk only at the time of transaction commit.

Immediate Modification Recovery Example

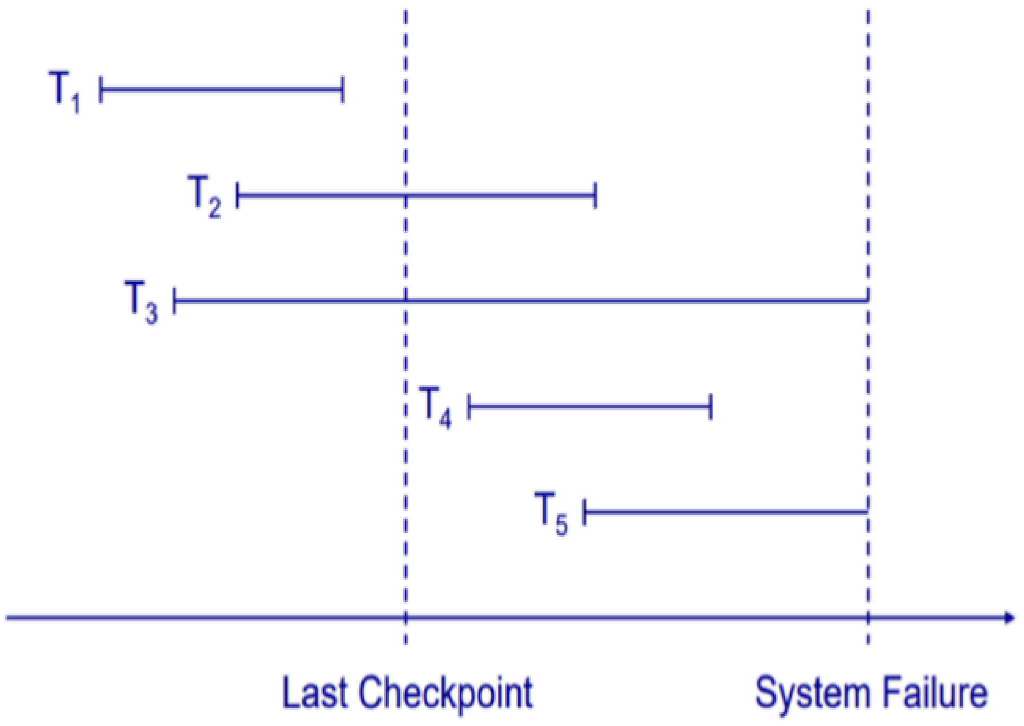
<T_0 start>	<T_0 start>	<T_0 start>
<T_0, A, 1000, 950>	<T_0, A, 1000, 950>	<T_0, A, 1000, 950>
<T_0, B, 2000, 2050>	<T_0, B, 2000, 2050>	<T_0, B, 2000, 2050>
	<T_0 commit>	<T_0 commit>
	<T_1 start>	<T_1 start>
	<T_1, C, 700, 600>	<T_1, C, 700, 600>
		<T_1 commit>
(a)	(b)	(c)

(a) $undo\ (T_0)$: B is restored to 2000 and A to 1000, and log records $< T_0, B, 2000 >$, $< T_0, A, 1000 >$, $< T_0, abort >$ are written out

(b) $redo\ (T_0)\ and\ undo\ (T_1)$: A and B are set to 950 and 2050 and C is restored to 700. Log records $< T_1, C, 700 >$, $< T_1, abort >$ are written out

(c) $redo\ (T_0)\ and\ redo(T_1)$: A and B are set to 950 and 2050 respectively. Then C is set to 600.

Checkpoints

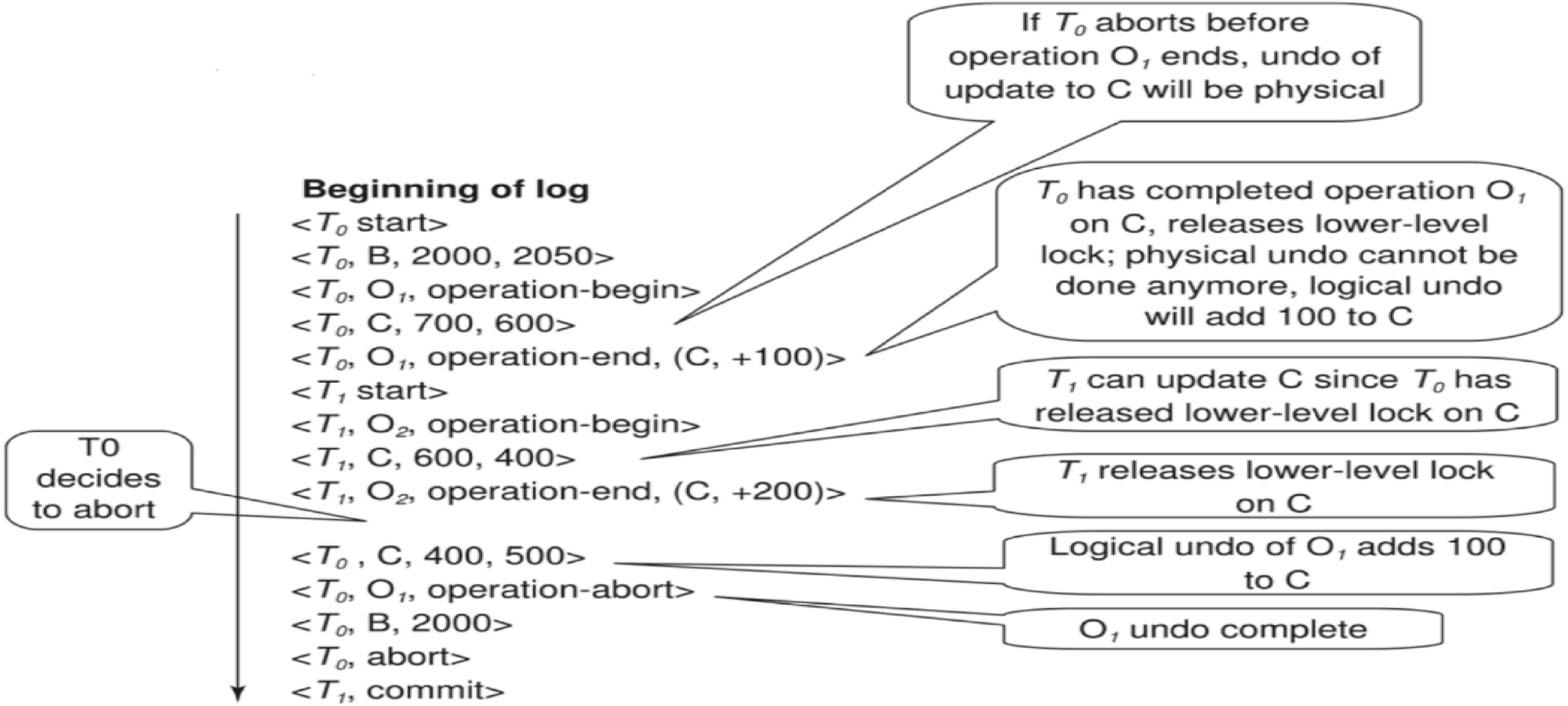


- Ignore the transactions that has been completed before checkpoint
  - T_1 *can be ignored*
- Redo the transactions which has been committed after the checkpoint
  - T_2 *and* T_4 *redone*
- Undo the transaction which is not completed at the time of failure.
  - T_3 *and* T_5 *undone*

Operational Logging

- If crash/rollback occurs before operation completes:
  - the operation-end log record is not found, and the physical undo information is used to undo operation
- If crash/rollback occurs after the operation completes:
  - the operation-end log record is found, and in this case
  - logical undo is performed using U; the physical undo information for the operation is ignored
- Redo of operation (after crash) still uses physical redo information

Example


If T_0 aborts before operation O_1 ends, undo of update to C will be physical
Beginning of log
<T_0 start>
<T_0, B, 2000, 2050>
<T_0, O_1, operation-begin>
<T_0, C, 700, 600>
<T_0, O_1, operation-end, (C, +100)>
<T_1 start>
<T_1, O_2, operation-begin>
<T_1, C, 600, 400>
<T_1, O_2, operation-end, (C, +200)>
<T_0 , C, 400, 500>
<T_0, O_1, operation-abort>
<T_0, B, 2000>
<T_0, abort>
<T_1, commit>
T_0 has completed operation O_1 on C, releases lower-level lock; physical undo cannot be done anymore, logical undo will add 100 to C
T_1 can update C since T_0 has released lower-level lock on C
T0 decides to abort
T_1 releases lower-level lock on C
Logical undo of O_1 adds 100 to C
O_1 undo complete

RAID

- RAID stands for **R**apid **A**rray of **I**ndependent **D**isks
- Disk organization techniques that manage a large numbers of disks, providing a view of a single disk of
  - **high capacity** and **high speed** by using multiple disks in parallel
  - **high reliability** by storing data redundantly, so that data can be recovered even if a disk fails

Mirroring

- Duplicate every disk. Logical disk consists of two physical disks.
- Every write is carried out on both disks but reads can take place from either disk
- If one disk in a pair fails, data still available in the other.

Striping

Bit-level Striping:

- Split the bits of each byte across multiple disks.
- Each access can read data at eight times the rate of a single disk
- But seek/access time worse than for a single disk

Byte-level Striping:

- Each file is split up into parts one byte in size.

Block-level Striping:

- With n disks, block i of a file goes to disk (i mod n) + 1
- Requests for different blocks can run in parallel if the blocks reside on different disks

Parity

- It is a technique to provide fault tolerance and data recovery in storage systems.
- Parity information is calculated and stored along with the data
- Allows the recovery of lost data in the event of disk failure

XOR Gate

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Bit-Interleaved Parity:

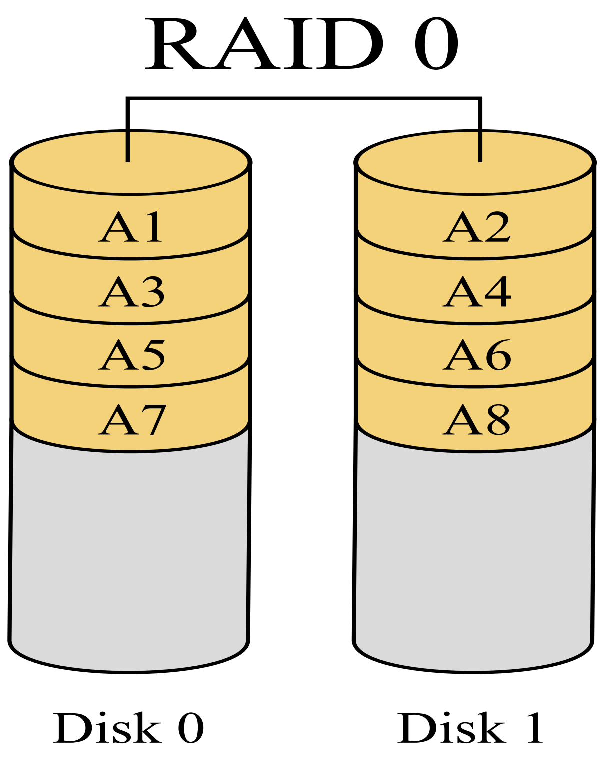
- A single parity bit is enough for error correction, not just detection, since we know which disk has failed
- When writing data, corresponding parity bits must also be computed and written to a parity bit disk
- To recover data in a damaged disk, compute **XOR** of bits from other disks (including parity bit disk)

Block-Interleaved Parity:

- Uses block-level striping, and keeps a parity block on a separate disk for corresponding blocks from n other disks
- To find value of a damaged block, compute **XOR** of bits from corresponding blocks (including parity block) from other disks

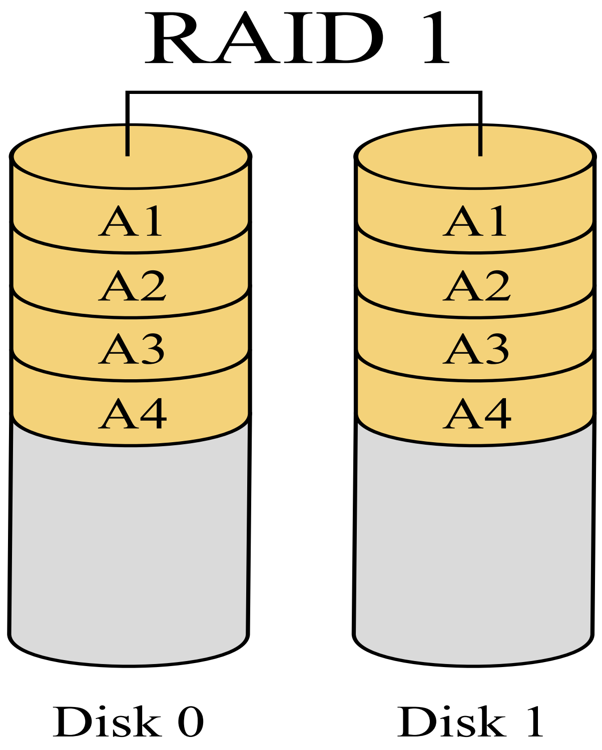
RAID 0: Striping

- It uses data striping
- No redundant information is maintained
- Space utilization is 100 percent
- It has the best write performance of all RAID levels
- This solution is the least costly
- Reliability is very poor



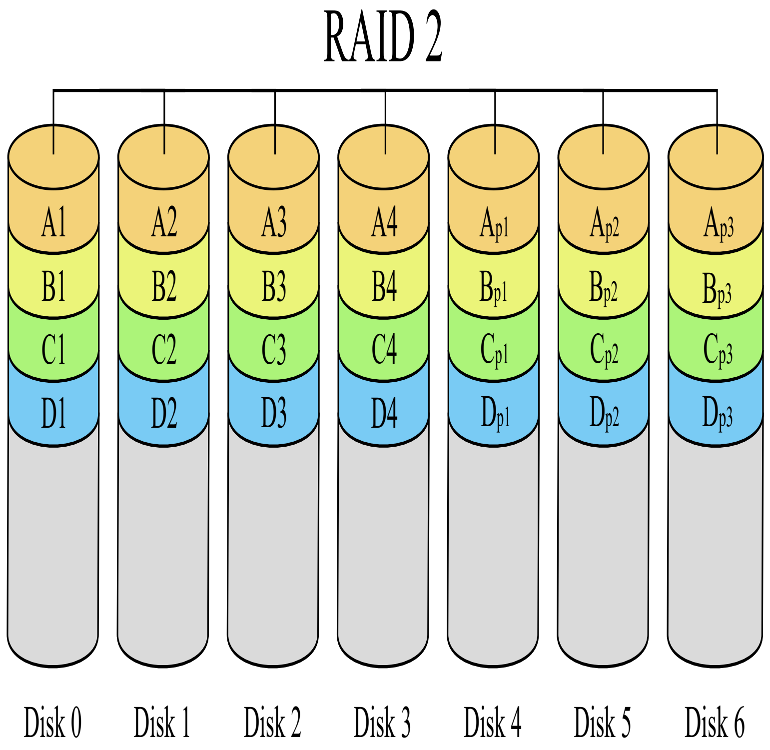
RAID 1: Mirroring

- It maintains two identical copies of the data on two different disks.
- Every write of a disk block involves a write on both disks
- Allows parallel reads
- It does not stripe the data over different disks
- Space utilization is 50 percent
- Most Expensive solution



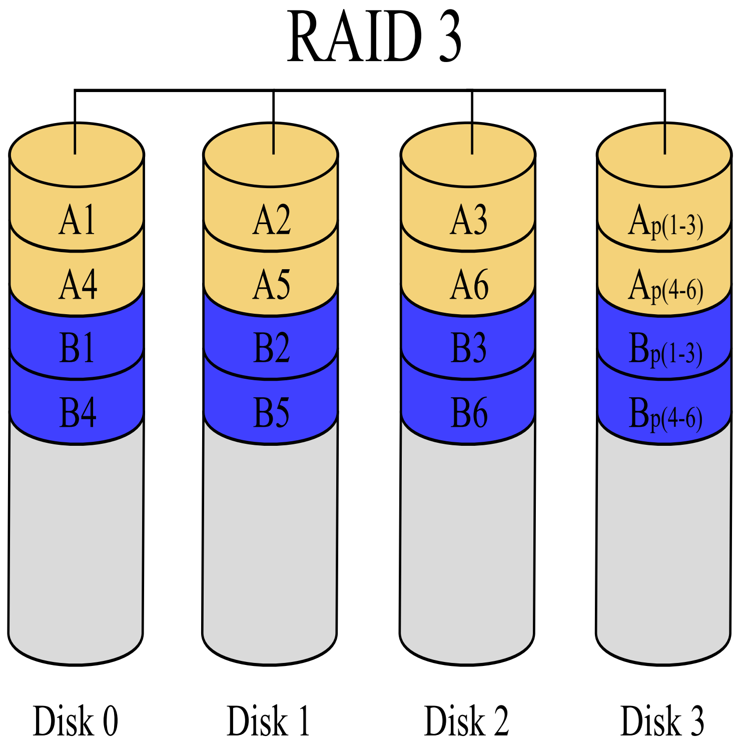
RAID 2: Parity

- It uses designated drive for parity
- In RAID 2, the striping unit is a single bit (Bit-level Striping)
- **Hamming Code** is used for parity
  - Hamming codes can detect up to two-bit errors or correct one-bit errors
  - For a 4-bit data, 3 bits are added



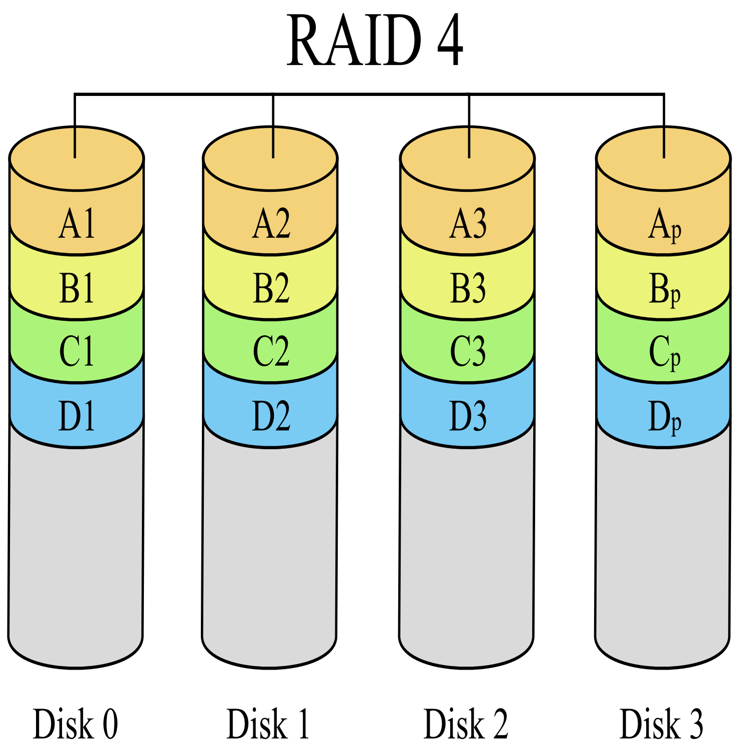
RAID 3: Byte Striping + Parity

- RAID 3 has a single check disk with parity information.
- Reliability overhead for RAID 3 is a single disk, the lowest over-head possible
- It consists of byte-level striping with dedicated parity.
- RAID-3 cannot service multiple requests simultaneously.



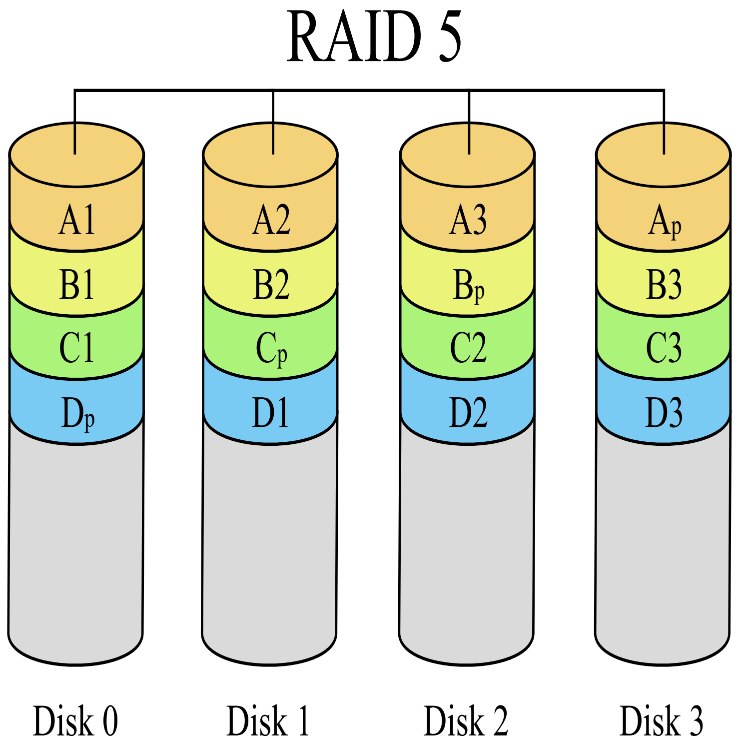
RAID 4: Block Striping + Parity

- RAID 4 has a striping unit of a disk block instead of a single bit, as in RAID 3
- It provides good performance for data reads
- Facilitates recovery of at most 1 disk failure.
- Recovery can be made by simply **XOR**ing all the remaining data bits and the parity bit
- Write performance is low due to the need to write all parity data to a single disk



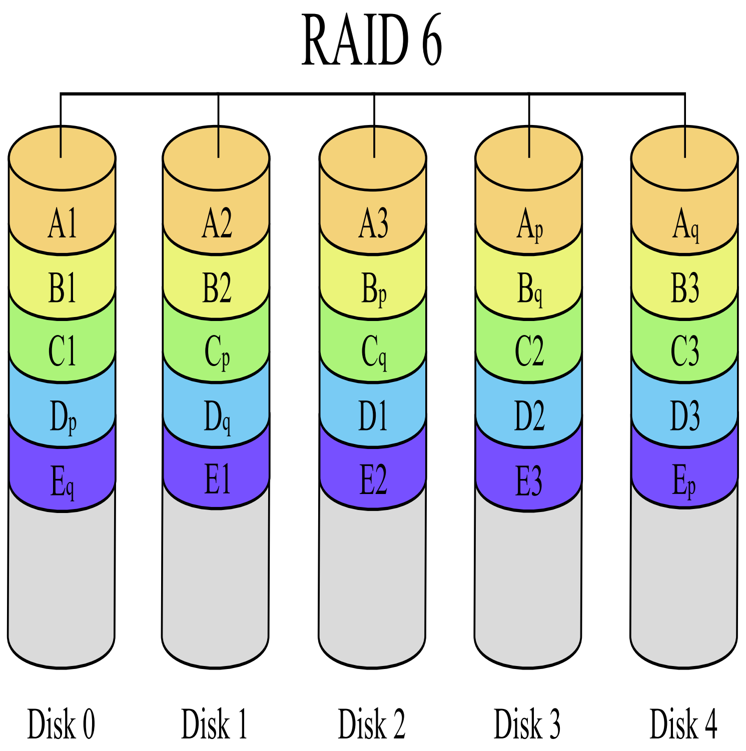
RAID 5: Distributed Parity

- RAID 5 improves upon RAID 4 by distributing the parity blocks uniformly over all disks instead of storing them on a single check disk
- Several write requests can potentially be processed in parallel since the bottleneck of a unique check disk has been eliminated
- Read requests have a higher level of parallelism.
- It allows recovery of only 1 disk failure like RAID 4



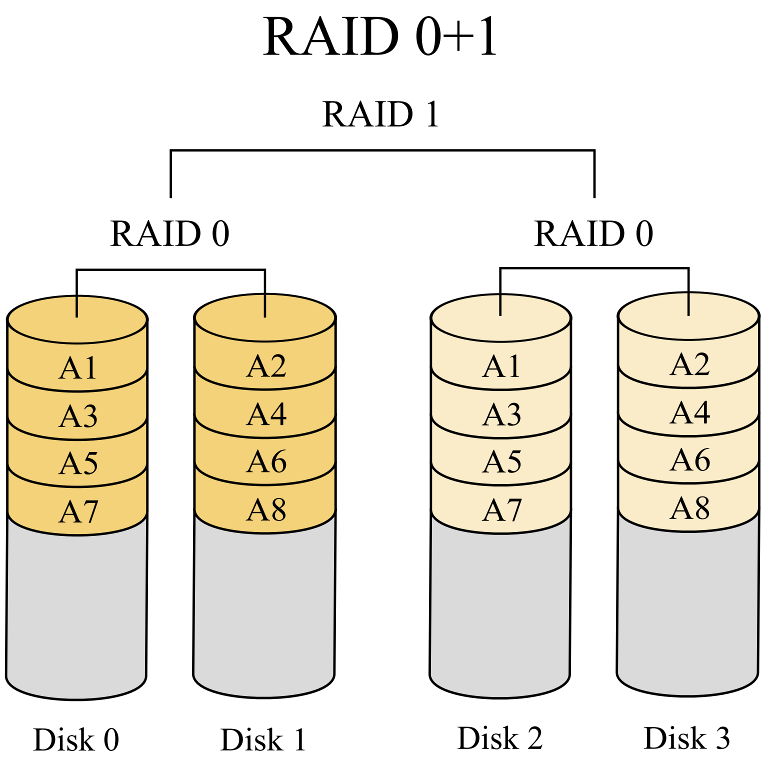
RAID 6: Dual Parity

- It uses block-level striping with two parity blocks distributed across all member disks.
- Write performance of RAID 6 is poorer than RAID 5 because of the increased complexity of parity calculation
- It allows recovery of upto 2 disk failure



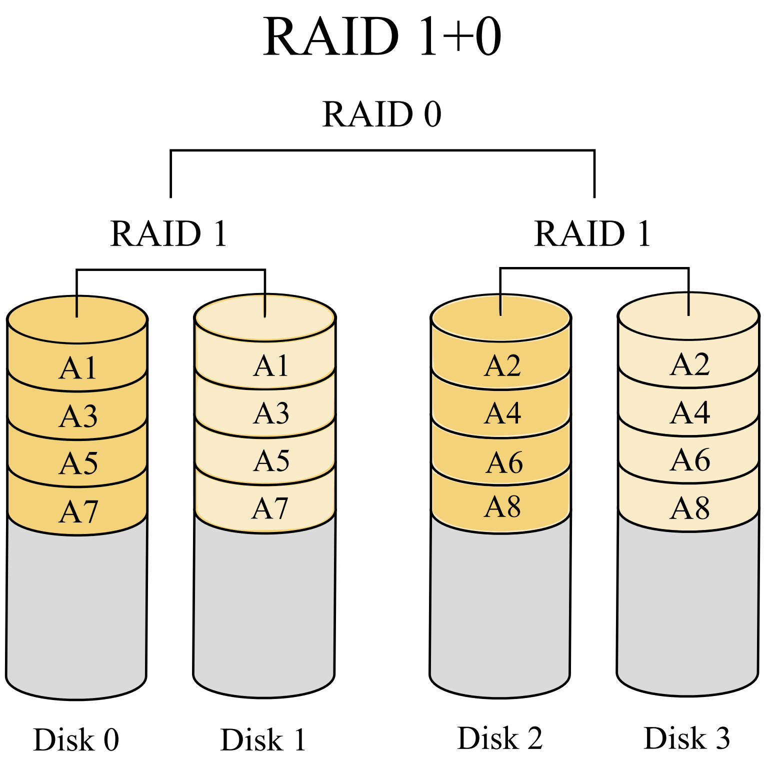
RAID 01 (RAID 0+1): Mirror of Stripes

- RAID 01 is a mirror of stripes
- It achieves both replication and sharing of data between disks
- At least four disks are required in a standard RAID 01 configuration, but larger arrays are also used.



RAID 10 (RAID 1+0): Stripe of Mirrors

- RAID 10 is a stripe of mirrors
- RAID 10 is a RAID 0 array of mirrors, which may be two- or three-way mirrors, and requires a minimum of four drives
- RAID 10 provides better throughput and latency than all other RAID levels except RAID 0



Example

A RAID-5 storage system with similar arrangement of parity blocks as described in slide 55.16 is used for storing the following data:

Disk-1	Disk-2	Disk-3	Disk-4	Disk-5
0100	XXXX	0100	0001	0101
0101	XXXX	0100	0100	0001

Example (Continued)

1. According to the figure disk-2 has crashed. What data is present in the two blocks of disk-2?

Example (Continued)

2. Assume that the binary values represent 8 bit ASCII code. What is the data word present inside this RAID-5 storage system?