Chapter #6
External Memory

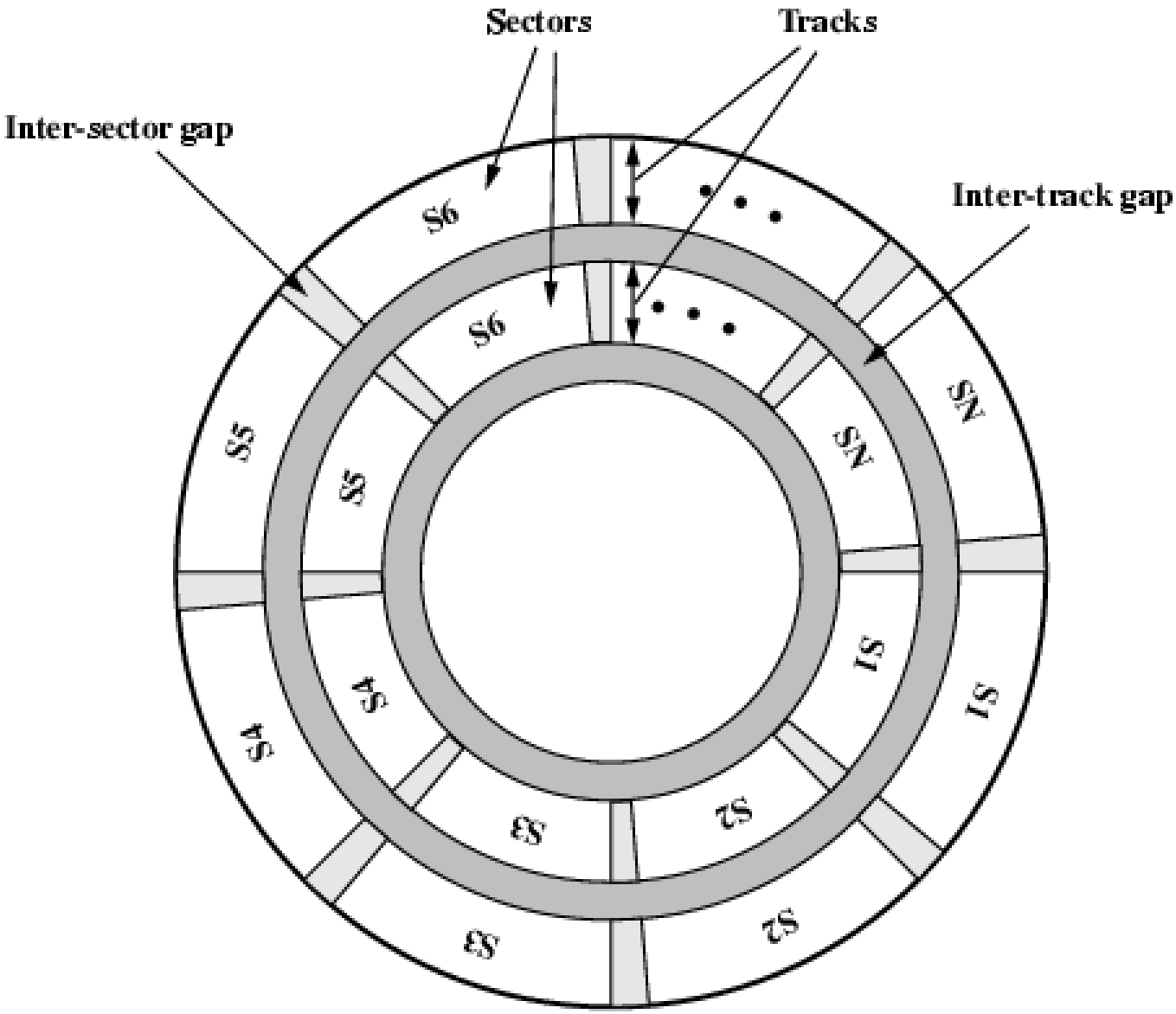
External Memory Overview

- Types:
  - —Magnetic Disk
    - – Floppy disk
    - – Hard disk
    - – RAID
  - —Optical Disk
    - – CD-ROM
    - – DVD-ROM
    - – BD-ROM
- Issues:
  - —Capacity
  - —Speed
  - —Access time

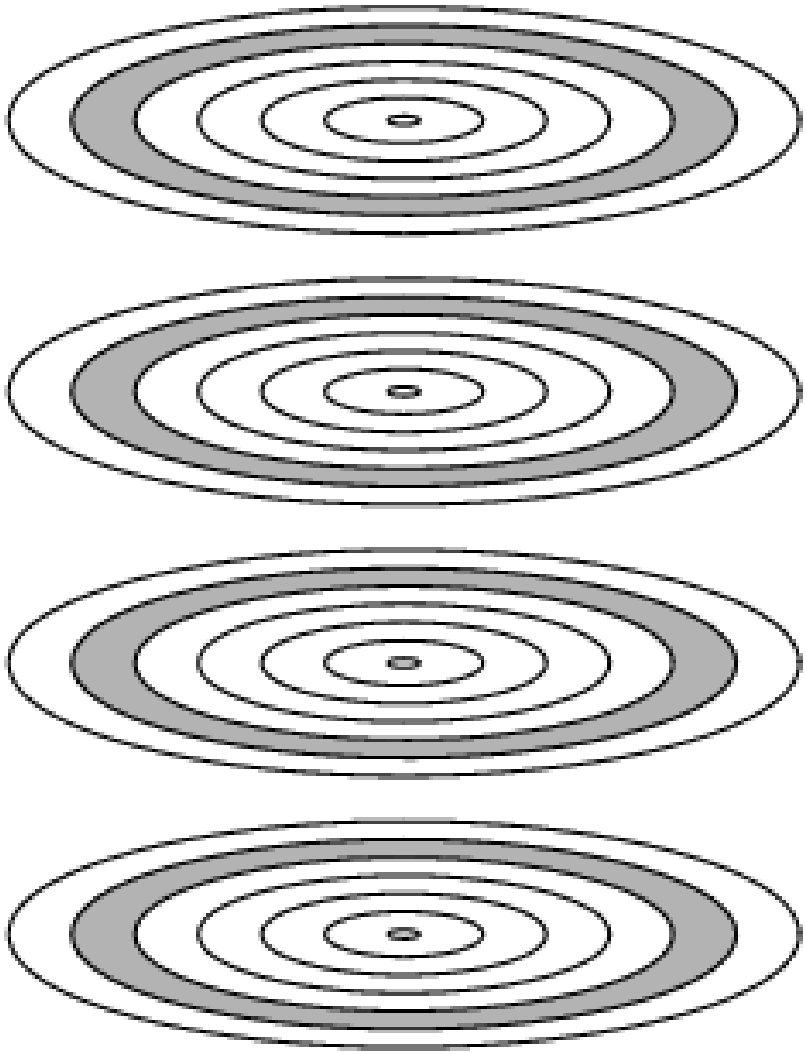
Magnetic Disk Data Organization

- Sector:
  — minimum storage unit in bytes
- Tracks:
  —Concentric rings on disk platter
- Cylinder:
  —Set of tracks in same relative position on platter
- Total capacity:
  —# bytes/sector × sectors/track × # tracks/cylinder × # cylinders

Magnetic Disk Data Layout



Cylinders



Magnetic Disk Performance

- Average seek time in ms (T_s)
- Transfer size in bytes (b)
- Rotation speed in revolutions/minute (r)
- Number of bytes on track (N)
- Transfer time:

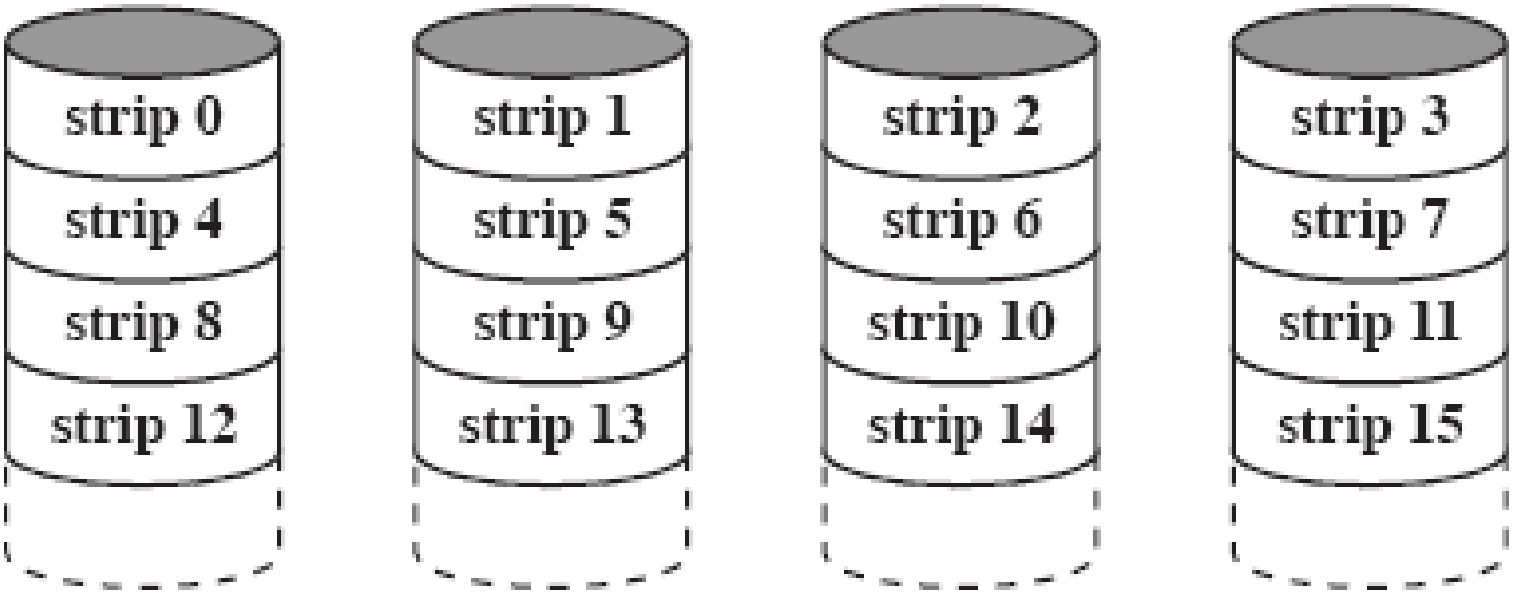
  $T=b/rN$
- Average access time:

  $T_a=T_s+(1/2r)+T$

RAID Overview

- Definition:
  - —Redundant Array of Independent Disks
  - —Term coined at Berkeley in 1988 (orig. I=“Inexpensive”)
  - —Categorized into non-hierarchical 7 levels (0 to 6)
- Characteristics of 7 levels of design architecture:
  - —Set of physical disks viewed by O/S as single logical disk
  - —Data distributed across physical disks of array
  - —Redundant disk capacity used to store parity information to recover data in case of disk failure

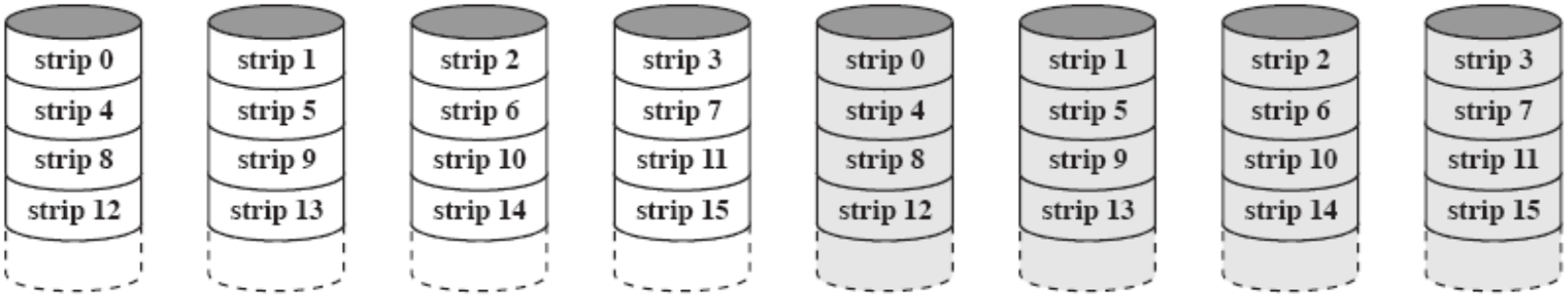
RAID 0 Diagram



RAID 0 Details

- Redundancy:
  - —No redundancy
- Distribution of data:
  - —Round-robin striping of data across disks
- Adv:
  - —Simple, easy, no overhead calculations, improves speed
- Disadv:
  - —No recovery scheme in case of failed disk
- Applications:
  - —Video & image editing
  - —Any appl. requiring high bandwidth

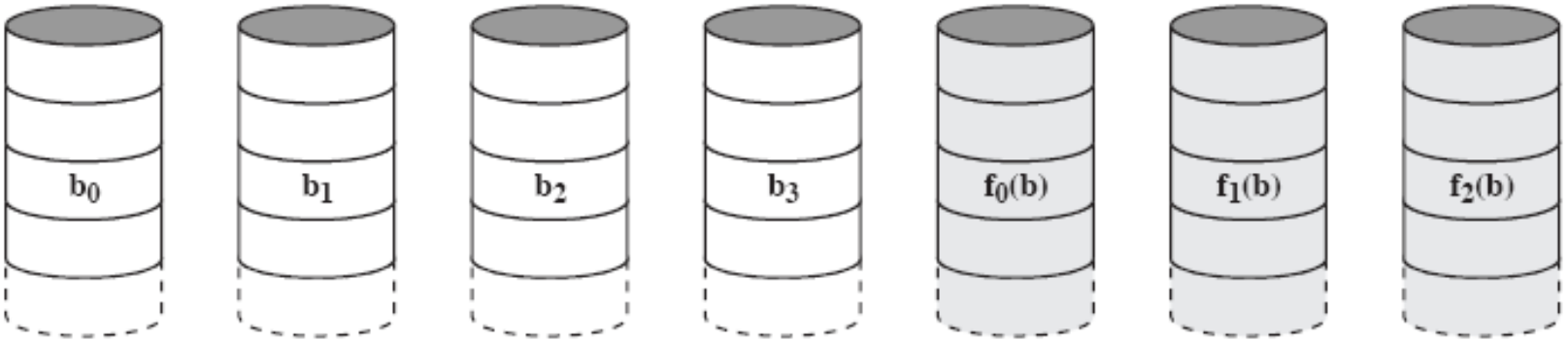
RAID 1 Diagram



RAID 1 Details

- Redundancy:
  - Mirrored disks
- Distribution of data:
  - Round-robin striping of data (2 copies on separate disks)
  - Read from either copy, write to both copies
- Adv:
  - Simple design, recovery is simple for even mutiple failures
- Disadv:
  - Highest disk overhead→expensive & inefficient
- Applications:
  - Accounting, payroll, financial
  - Any appl. requiring very high availability

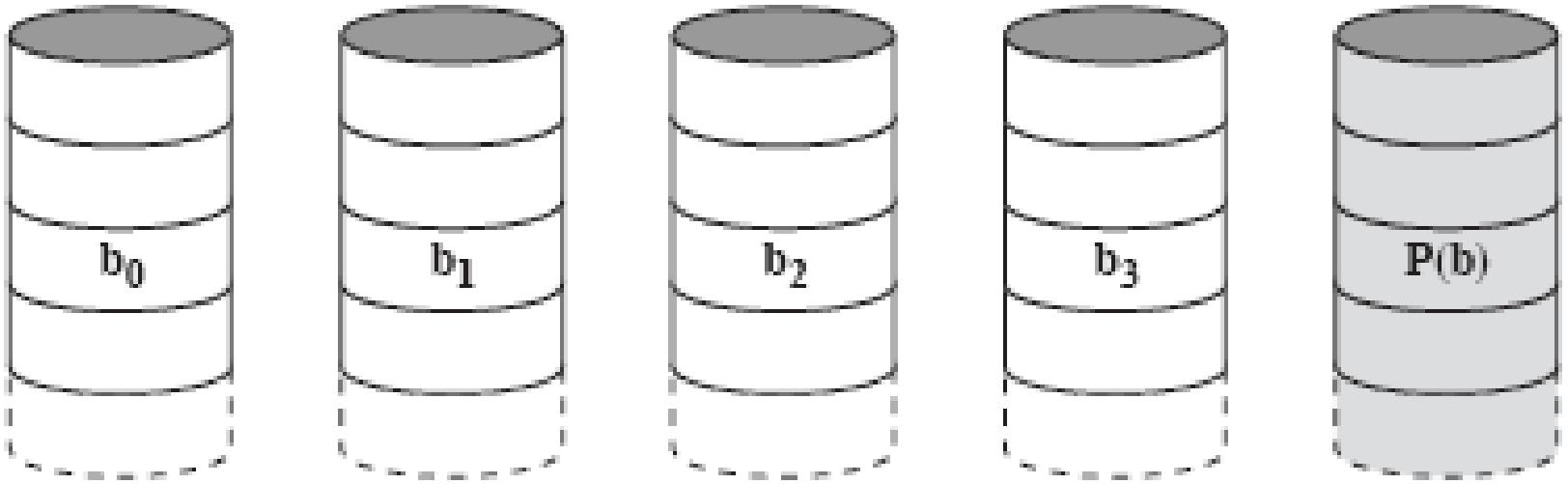
RAID 2 Diagram



RAID 2 Details

- Redundancy:
  - —Hamming code utilizing $\log_2 n$ disks to store parity of corresponding bits across n disks
- Data distribution:
  - —Very small stripes, often single byte/word
- Adv:
  - —High data transfer rate, simple design
- Disadv:
  - —Inefficient & costly (high ratio of parity to data disks)
- Applications:
  - —None→not commercial implementations exist

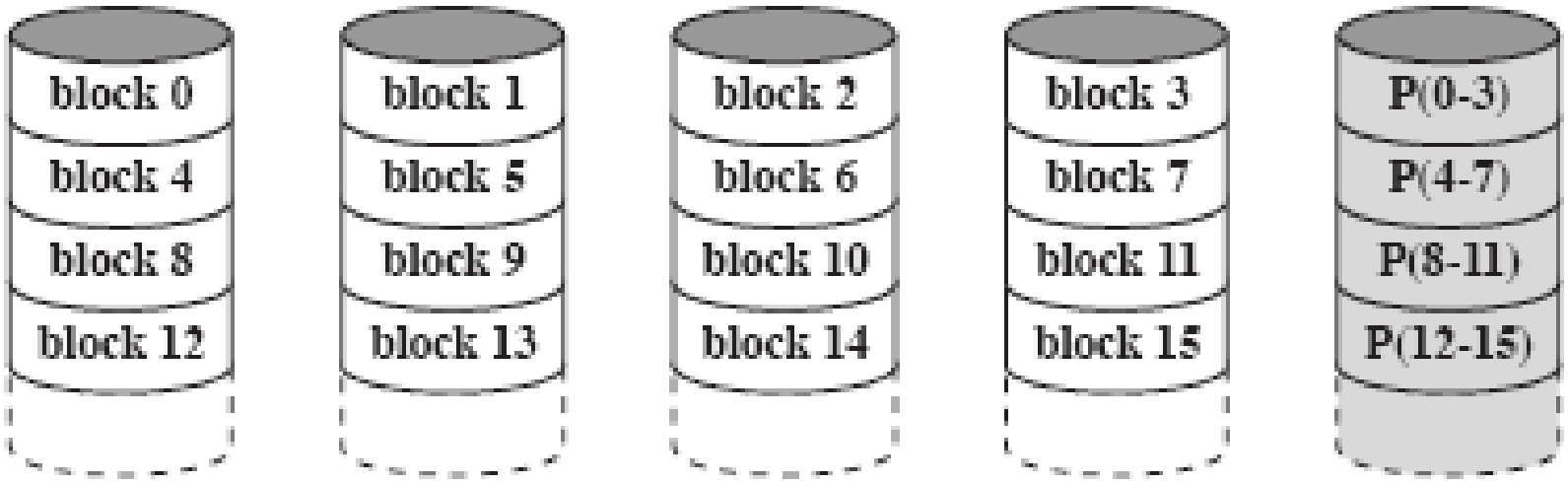
RAID 3 Diagram



RAID 3 Details

- Redundancy:
  - — One disk storing parity information for each set of corresponding bits
  - — Data on failed disk can be recovered from other disks and parity info
- Data distribution:
  - — Bit-interleaved
- Adv:
  - — Very high read/write transfer rates
  - — High efficiency (1 parity disk for any # of data disks)
- Disadv:
  - — Transfer rate equal to single disk at best
- Applications:
  - — Video/image editing
  - — Any application requiring high throughput

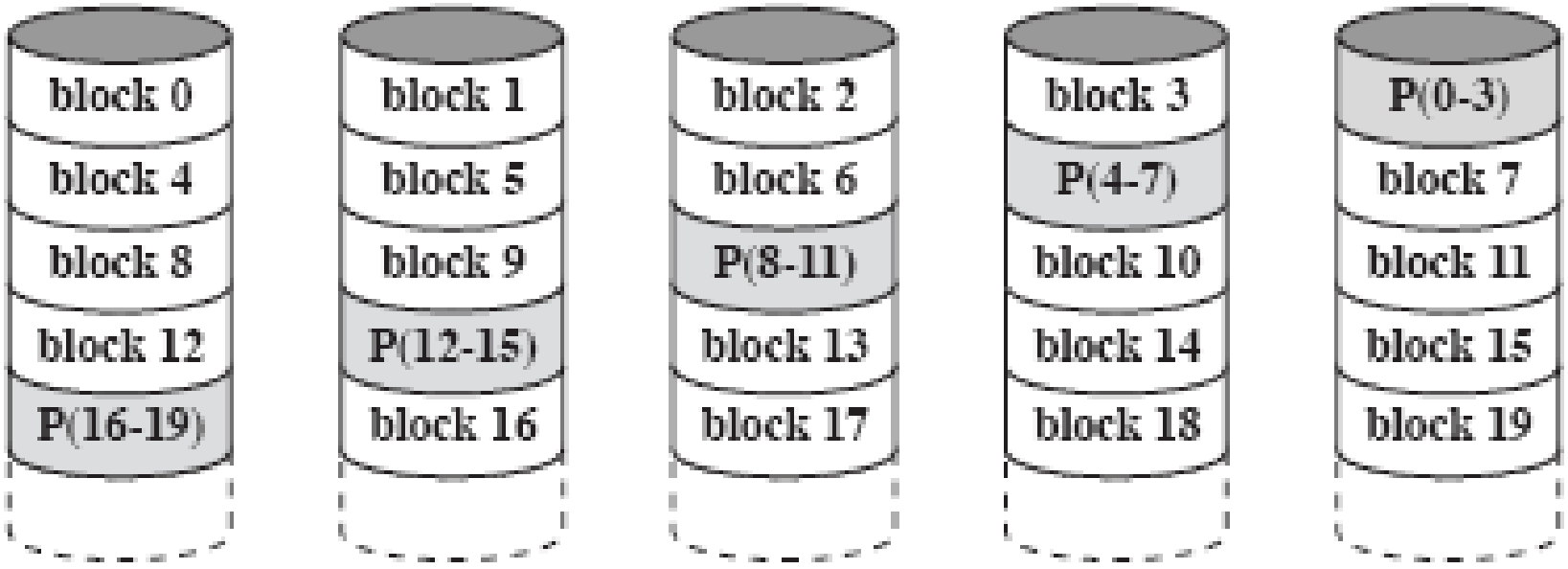
RAID 4 Diagram



RAID 4 Details

- Redundancy:
  - Block-level parity
- Data distribution:
  - Striping of large blocks
  - Each disk operates independently
- Adv:
  - High read transaction rate
  - High efficiency (low ratio of parity to data disks)
- Disadv:
  - Inefficient to recover failed disk, low write transaction rate
- Application:
  - None→no commercial implementation exists

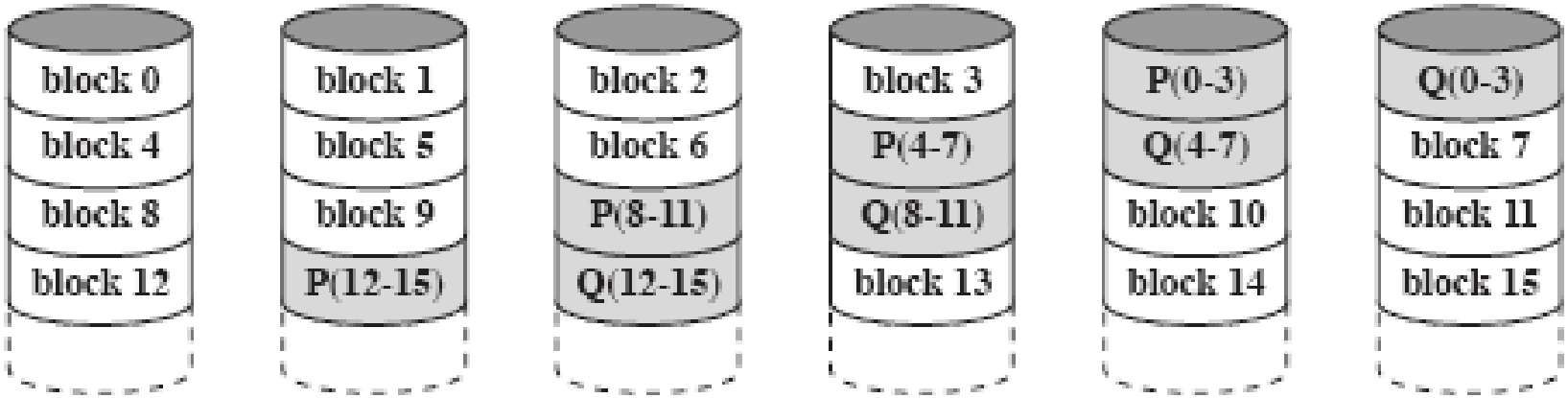
RAID 5 Diagram



RAID 5 Details

- Redundancy:
  - Block-level distributed parity
- Data distribution:
  - Round robin parity striped across all disks
- Adv:
  - Highest read transaction rate
  - High efficiency (low ratio of parity to data disks)
  - Avoids RAID 4 bottleneck at parity disk
- Disadv:
  - More difficult to rebuild data when disk fails
- Applications:
  - Network servers

RAID 6 Diagram



RAID 6 Details

- Redundancy:
  - —Dual block-level distributed parity
- Data distribution:
  - —Round robin parity striped across all disks
- Adv:
  - —High fault tolerance to sustain multiple disk failures
- Disadv:
  - —Parity computation overhead is high
- Applications:
  - —Mission-critical applications