Logan: Automatic Management for Evolvable, Large-Scale, Archival Storage

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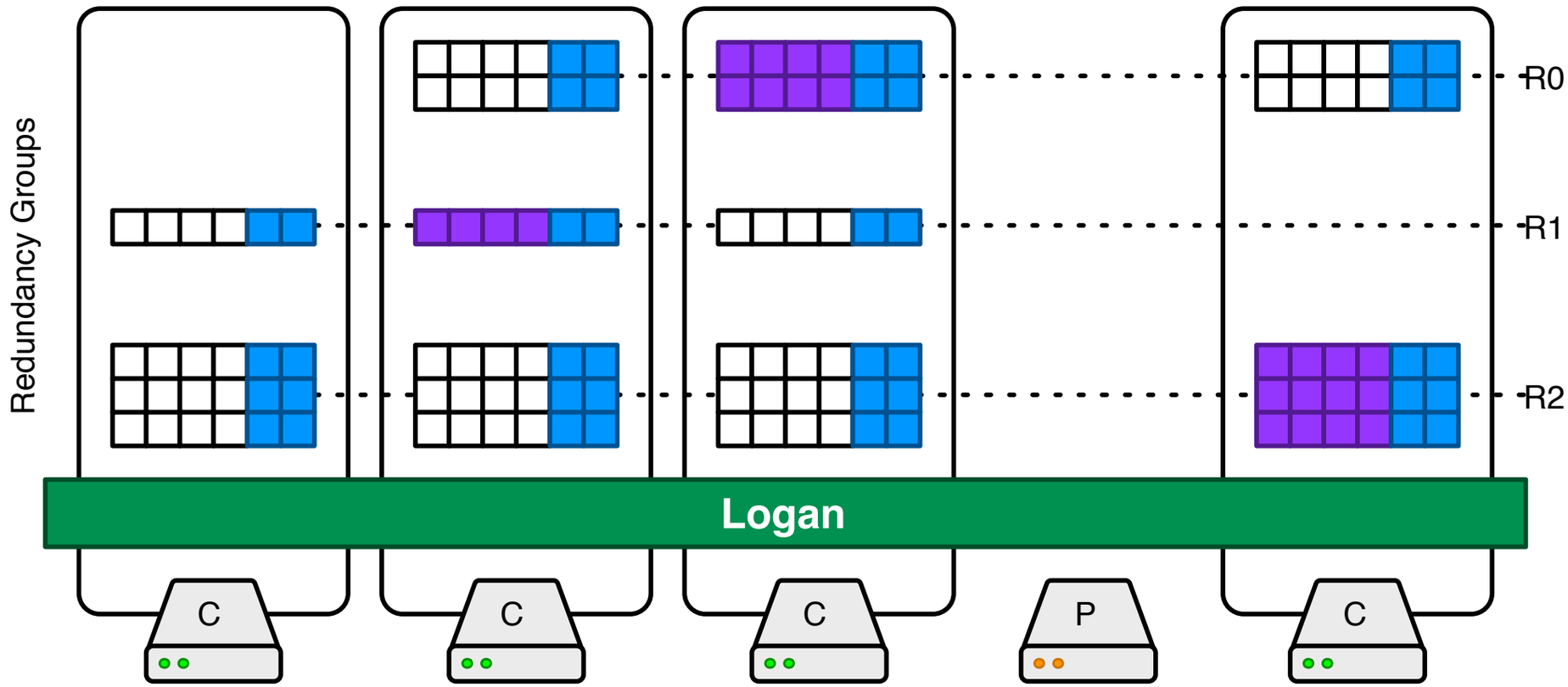
Archival Storage Problem

	Archival Storage	Traditional, Enterprise Storage
Workload	**write once**, (read maybe)	variable
Performance	adequate latency, decent throughput	low latency, high throughput
Cost	cheaper is better	commensurate to performance
Reliability	long-term	short-term
Scalability	time, capacity, technology, vendors	capacity

- Archival storage is a unique class
- Well-suited to a distributed architecture
  - Intelligent devices foster evolution
- How to manage and administer a totally decentralized system?

System Overview

Logan: management layer running on storage *tomes*



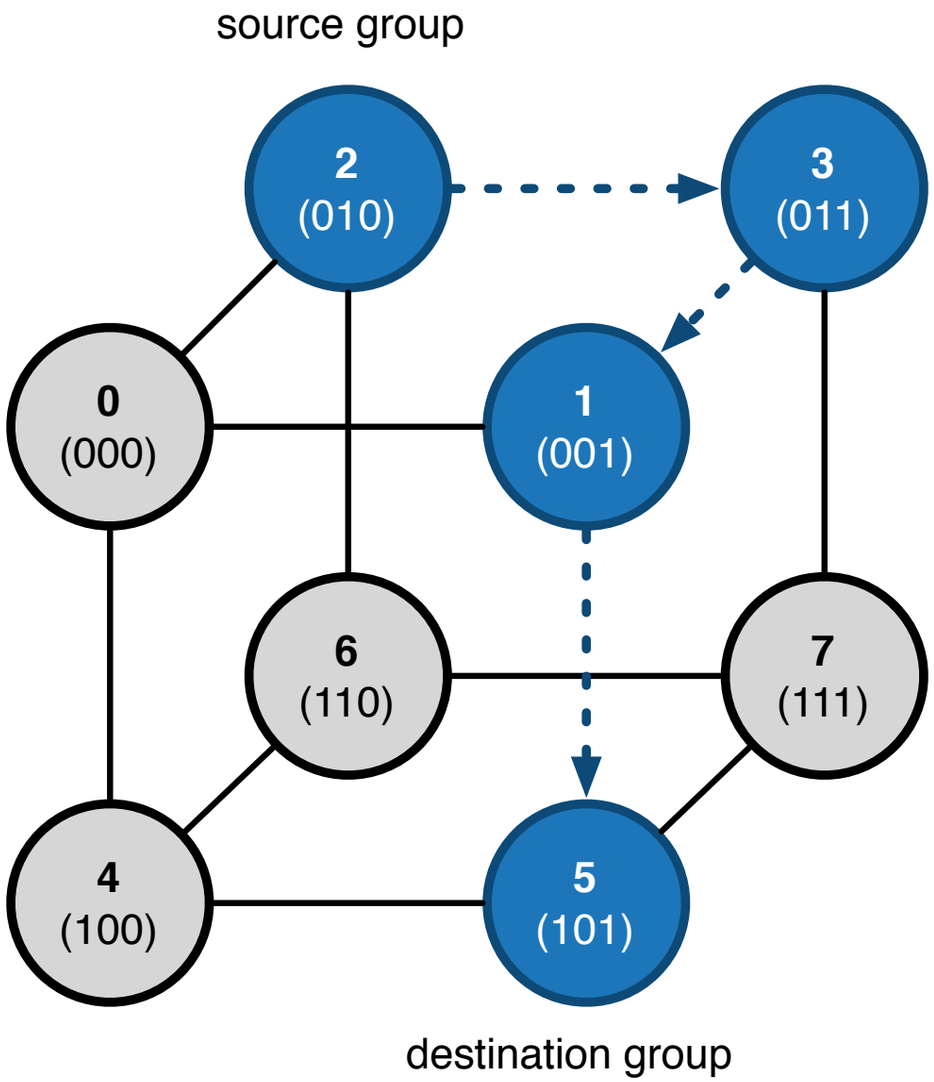
- Fixed-sized blocks arranged in fixed sized segments
- Two level reliability model:
  - Intra: Reliability encoding within segment for media faults
  - Inter: Reliability Groups (RG) across device segments

Management Goals

- Scale to hundreds of thousands (millions?) of tomes
  - Archival storage systems must scale to exabytes
- Avoid the need for global knowledge
  - Even a small amount of information per tome requires too much space
  - Global decisions don't scale well
- Avoid centralized management points
  - Potential single point of failure
  - Don't want to have "specialized" nodes
  - Monitoring issues
    - Potential bottleneck for reliability checking
    - May create problems if network is partitioned

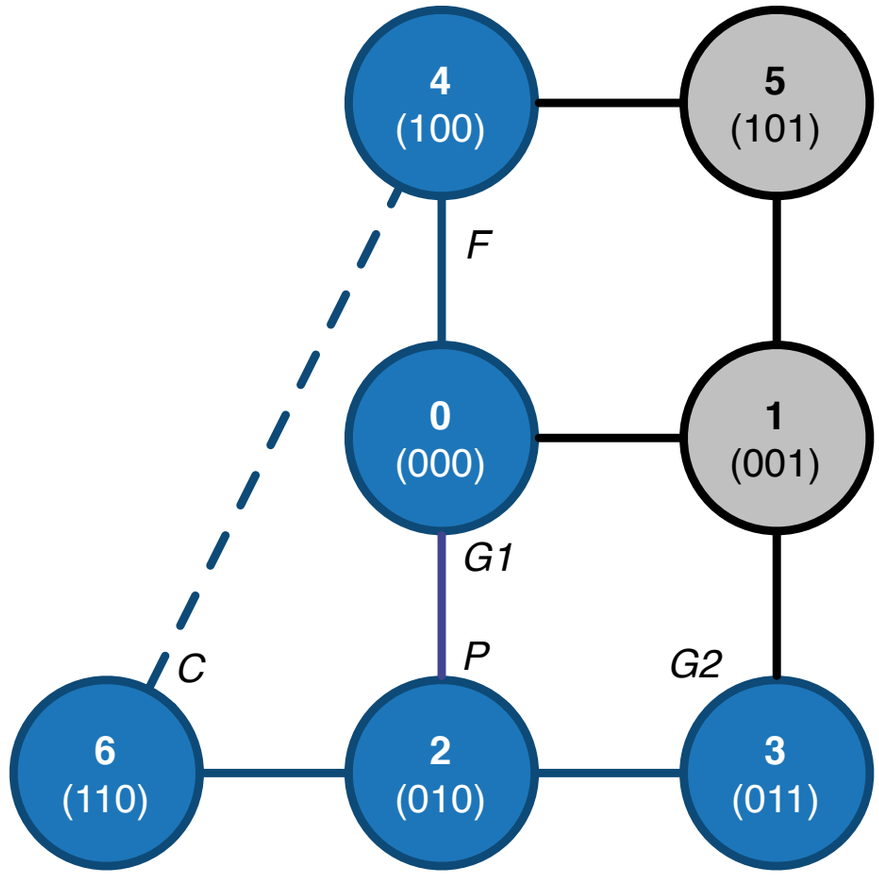
Management Groups

- Approach: group tomes into Management Groups (MG)
  - MG elects a group leader to handle group decisions
- System starts with one MG
- Groups make inter-group edges to form a hypercube
  - Inter-MG routing in log time
- When a single MG gets too large, it splits
  - Scalable hashing using LH*



Management Group Scaling

- Parent P splits to make child C
- P informs C of grandparents G1, G2,...
- C ⊕ P ∨ G = F
  - if F < C, build edge FC

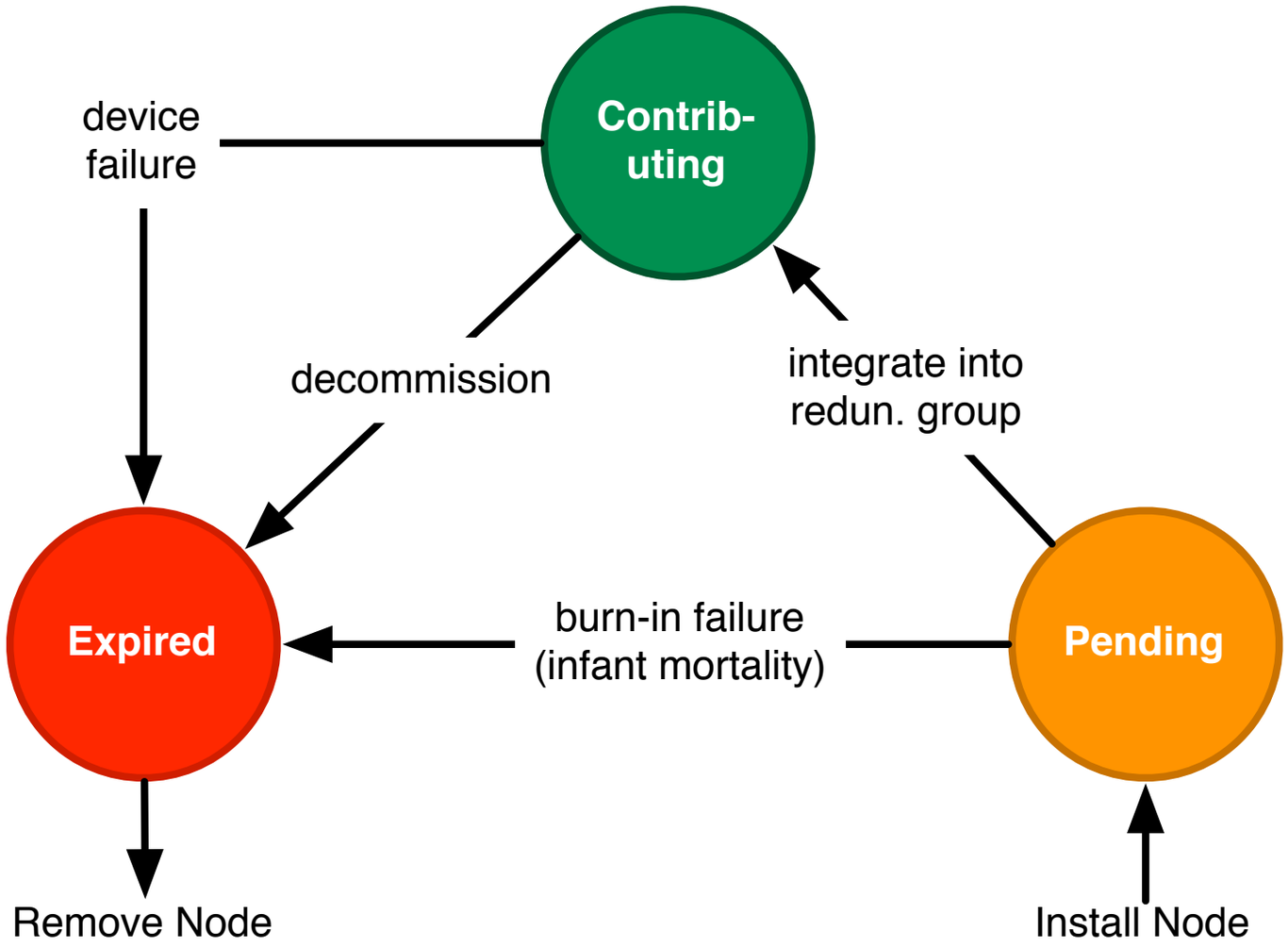


Example: Node 2 (010) splits to form Node 6 (110)

G1: ⑥ ⊕ ② v ⓪ = 100 = ④ < ⑥ build ⑥ ④

G2: ⑥ ⊕ ② v ③ = 111 = ⑦

Device States



New device enters system

1. Broadcast for other nodes
2. Obtain LH* info
3. Calculate MG
4. Contact MG leader
5. Enter MG in pending state

- Nodes progress through three states:
  - **Pending**: alive, known to the system, not in any RGs
  - **Contributing**: active member of one or more RGS
  - **Expired**: failed or decommissioned

Data-Driven Decision Making

- Devices maintain list of self-descriptive attributes
  - e.g.: segment count, power consumption, age, etc.
- Leader collects attributes to develop group statistics
- Heuristic algorithms use statistics to find "good" segment to RG mapping

- Use simulated annealing to make decisions:
  - Solution space (*X*): viable mappings of segments to RGs
    - Either new mappings or replacement mappings
  - Neighbor func. (*N*): randomized segment to RG mapping
    - Differs per management task
  - Objective func. (*P*): minimize cost per segment

Management Tasks

- Scale-out: adding capacity to the system
  - Create new redundancy groups
  - Add device to existing redundancy group
  - *N*: random mapping of unassigned segments to RGs

- Recovery: map new segments to failed segments
  - *N*: random mapping of new, replacement segments

- Maintenance: max. efficiency by decommissioning wasteful devices
  - *N*: randomly swap out wasteful devices and replace them with segments from other devices
  - Maintenance decision can be done opportunistically
    e.g. wait for next scrub cycle to scrub & copy

Status and Future Work

- Current: implementation and experimentation
  - How many devices per management group?
  - How best to weight attributes in heuristic algorithms?
  - Secure leadership elections

- Dealing with network partitions
- Geographically diverse redundancy
- Optimizing device dependency lists
- Recovery schedule

Questions

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