Management of Information Systems

BME VIK TMIT

Software Engineering, BSc

Management of Information Systems

6. Back-up and Restoration

Back-up and Restoration

- Back-up / archiving definition
- Back-up
  - Tape
  - Back-up systems
  - Back-up methods
    - Full, incremental, differential, progressive
  - Version control systems – Flash Copy
- Archives
  - Archivation requirements
- Design of back-up
  - Example
- Restoration

BACK-UP AND ARCHIVE

"You caught a virus from your computer and we had to erase your brain. I hope you kept a back-up copy."

BACK-UP AND ARCHIVE

Goal of back-up / archiving: recovery safeguard, make copies for preventing data loss

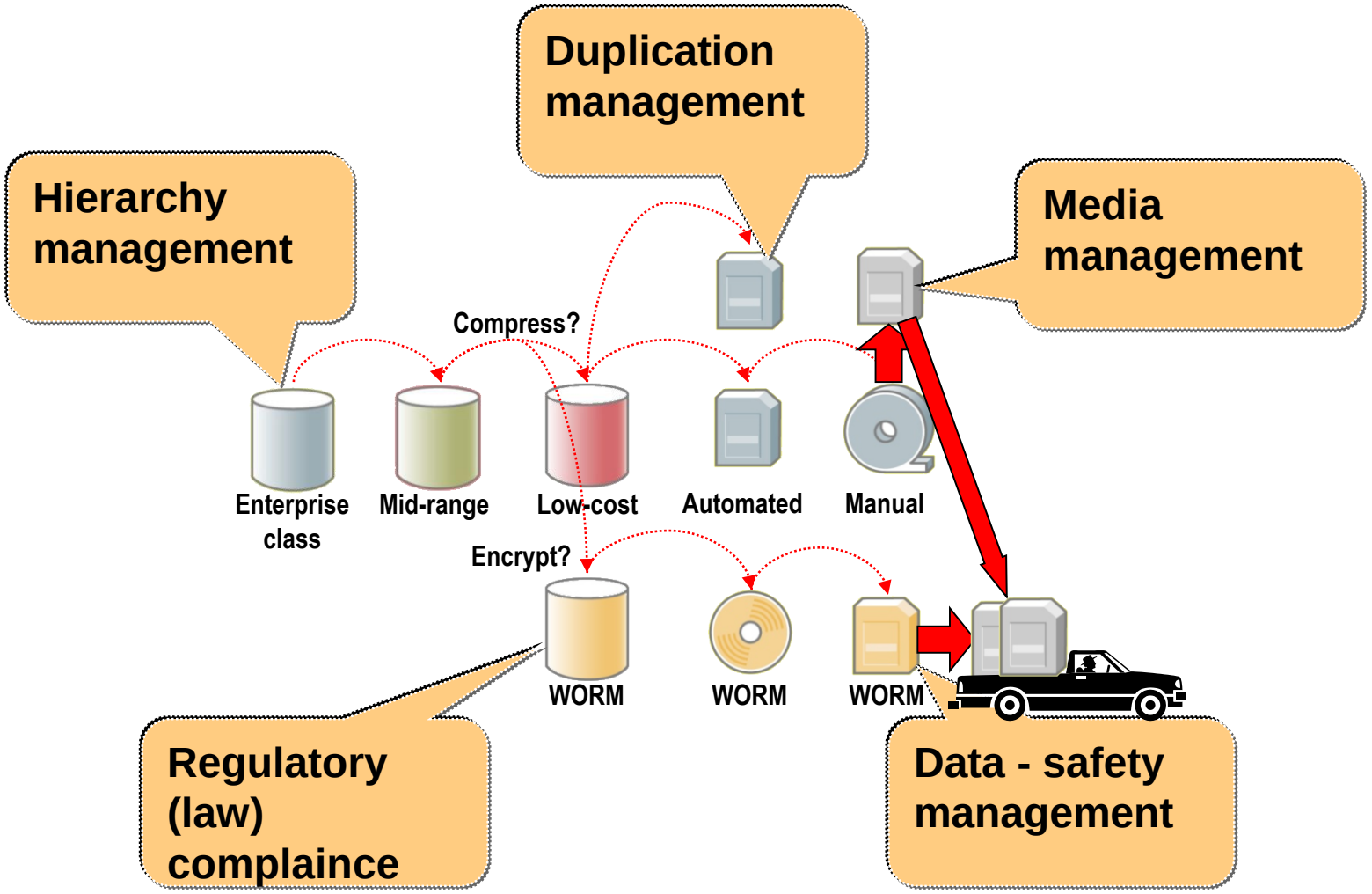
Goal of back-up: to guarantee business continuity

- Delete: the user accidentally / intentionally deletes/overwrites files
- Failure: storage device/system fails

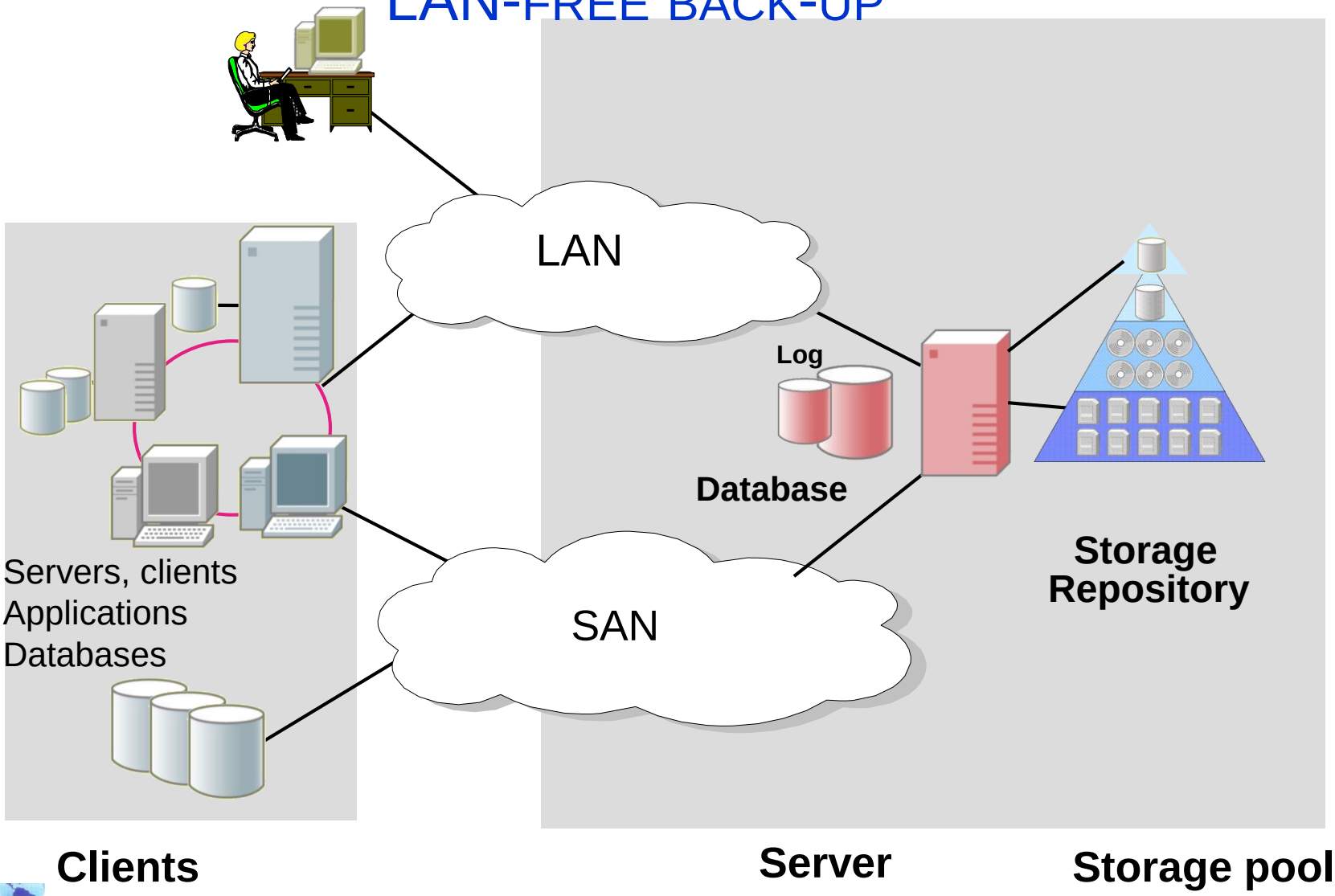
Goal of archiving: to reproduce the entire data of a certain point in time
  - with a granularity of a quarter, half, or full year
- Business, legal etc. reasons: data serves as an evidence, basis for a comparision, reference
- Not used data to be deleted: maintenance / evidence(!!) / legal(!!) reasons

Tipically common base technology for back-up/archiving

Modern Storage System Requirements



Storage System Architecture
LAN-free back-up



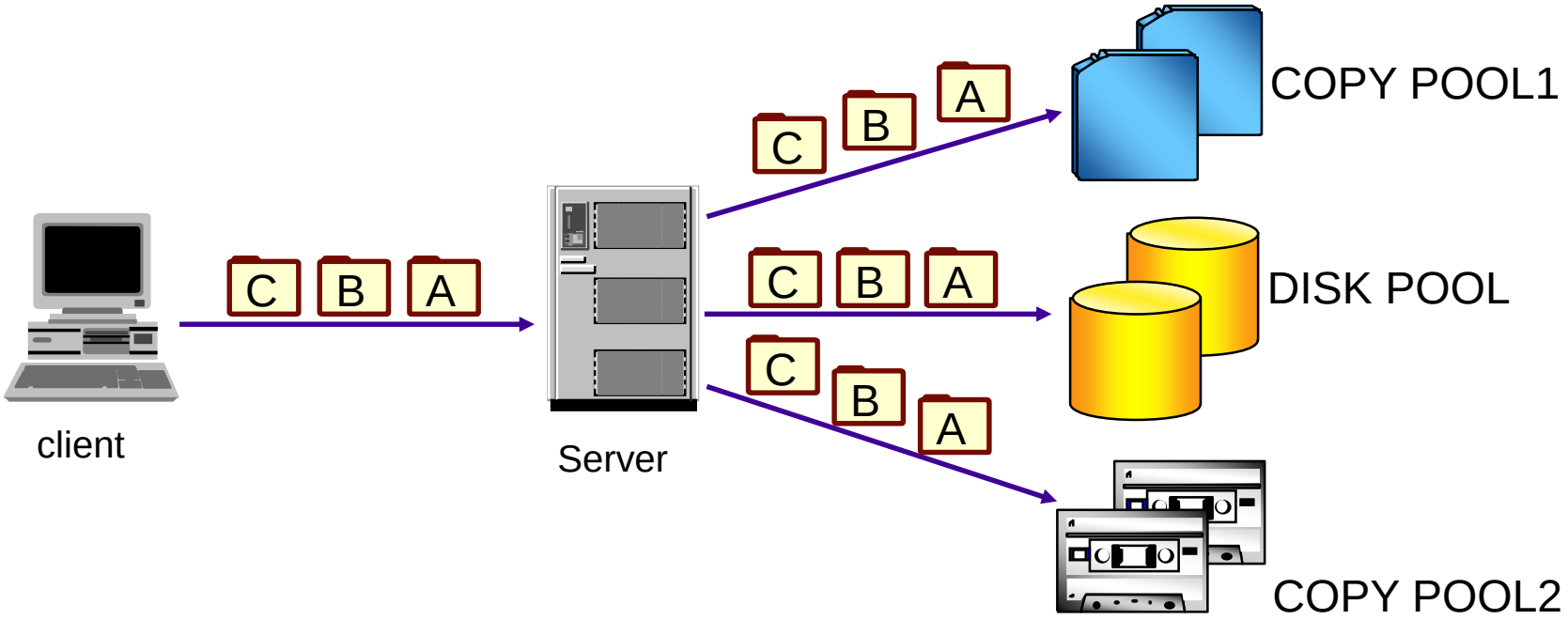
LAN-Free Back-up and Recovery

- LAN-Free data transmission
  - (Back-up) Server manages the internal storage pool
  - The back-ups are typically scheduled (policies)
    - But the client can also initiate data movement / back-up from disk to tape, or to a SAN disk
  - Meta-data (from/to where, how much) transmitted on LAN
  - The back-up data is sent on SAN
    - LAN is not overloaded by heavy data traffic

Data Copying in a Disk System

- Copy (very) large amount of data
- Block level copies
- Fast, firmware-supported back-up processes
- *Volume copies* – real copies of disks
  - Real duplicated file, cloning
  - Real copy for back-up, analyitic, datamining etc.
  - Possibility of migration to other disk types

PARALLEL BACK-UP



More back-up storage pools can be defined, simultaneous writing

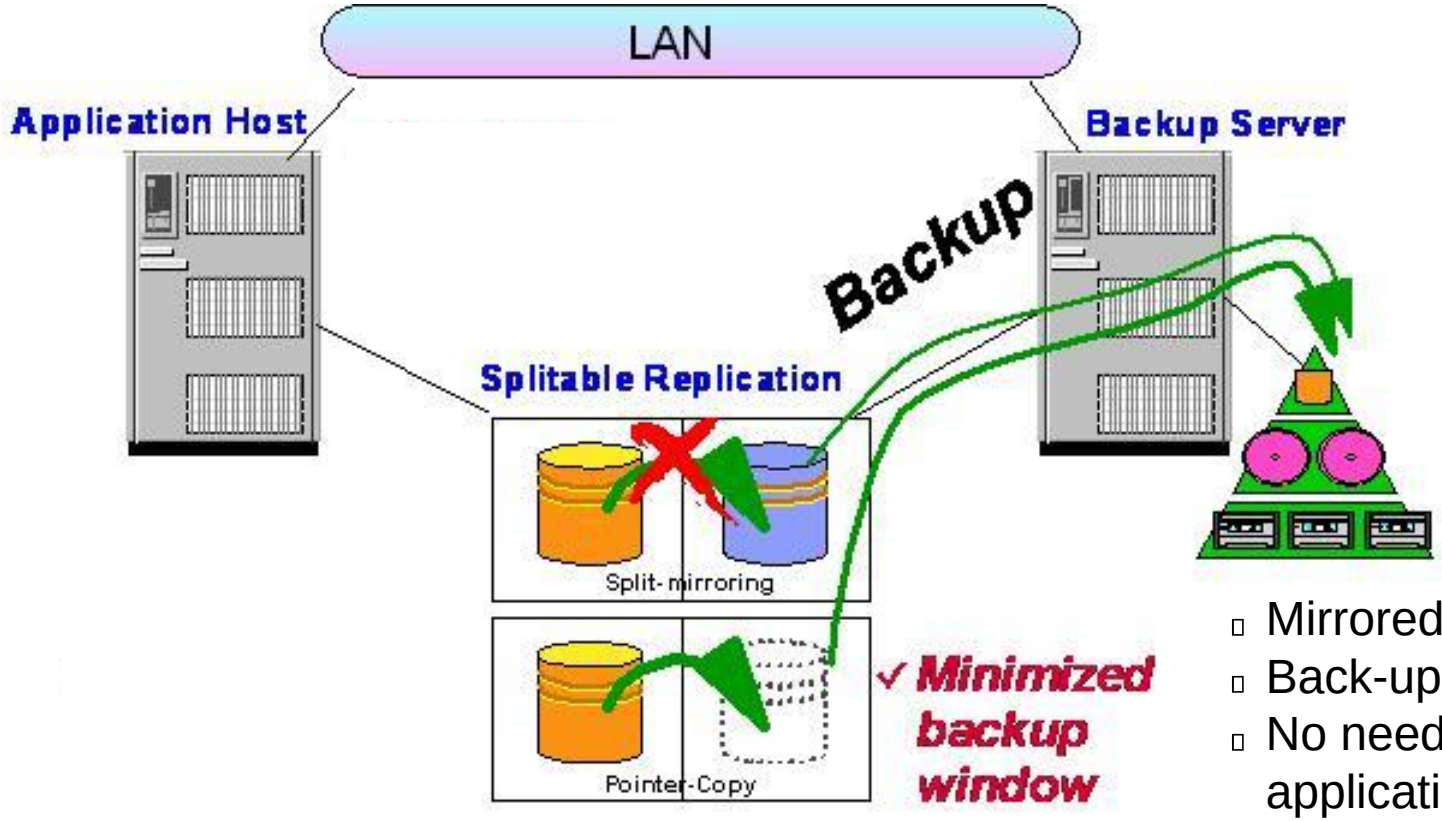
The target storage pools can be of different types (tape, disk)

Disaster tolerant systems

VOLUME COPY - CLONE

- Data-cosistency have to be ensured – stop application during cloning
  - Long time
    - Problem especially in case of DataBase back-up
  - Alternative: split mirror

ZERO DOWN-TIME STORAGE –SPLIT MIRROR



- Mirrored volume
- Back-up from a mirror
- No need to stop the application for a long time
  - Databases

Back-up Methods

- Full Back-up
- Incremental Back-up
- Differential Back-up
- Progressive Back-up Methodology

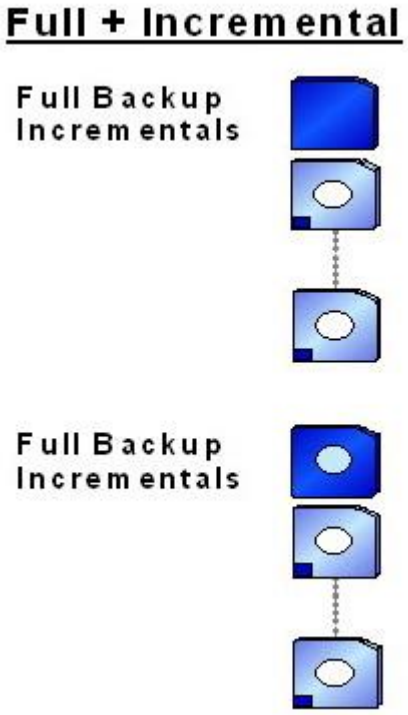
Full Back-up

- Back-up the whole disk content every day
  - Huge amount of data
  - Slow
  - Low utilisation of tapes
    - Backed-up many times, even if not changed
- BUT:
  - Fast restoration (one tape)

INCREMENTAL BACK-UP

- Full back-up only on the first day
- Then only the changes since the previous day
  - Small amount of data

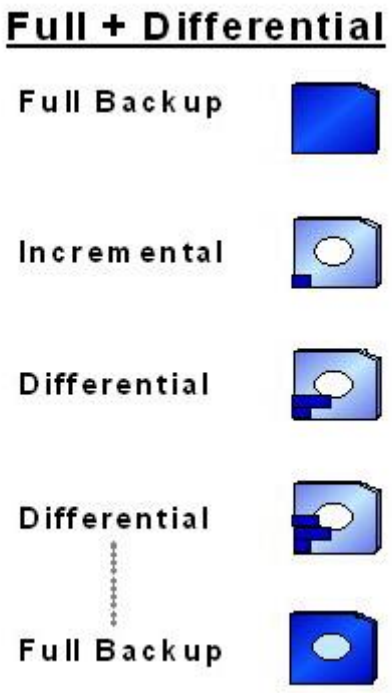
  BUT:
  - Restoration is slow
  - Low utilisation of tapes
    - almost empty



DIFFERENTIAL BACK-UP

- Full back-up only on the first day
- Then only the changes since full back-up
  - Greater, constantly groving amount of data

  BUT:
  - Shorter restoration time (max. 2 tapes)
  - More tapes



Problem of Incremental / Differential Back-up

Day 1	Day 2	Day 3	Day 4	Day 5
File A	File A renamed to File F	File F	File F	File F deleted
File B	File B deleted			
File C	File C renamed to File G	File G	File G	File G
File D	File D moved to new location	File D (new location)	File D deleted	
File E	File E	File E	File E	File E

Files from Day 1 FULL backup		Files from Day 3 INCREMENTAL / DIFFERENTIAL backup		Hard Drive after a restore to Day 3
File A		File F		File A – **wrong** File F
File B	+		=	File B – **wrong**
File C		File G		File C – **wrong** File G
File D		File D (new location)		File D – **wrong** File D (new location)
File E				File E

Progressive Back-up Methodology

- Full back-up only once
- Then only incremental
- But back-up the file system, too
  - A bit (?!) more to back-up
- But at restoration, we can find what is the actual state of a file
  - Valid/deleted/renamed/moved
  - Restoration with backward searching
  - Much faster when restore files that
    - modified several times
    - deleted

Advantage of Progressive Back-up Methodology

Day 1	Day 2	Day 3	Day 4	Day 5
File A	File A renamed to File F	File F	File F	File F deleted
File B	File B deleted			
File C	File C renamed to File G	File G	File G	File G
File D	File D moved to new location	File D (new location)	File D deleted	
File E	File E	File E	File E	File E

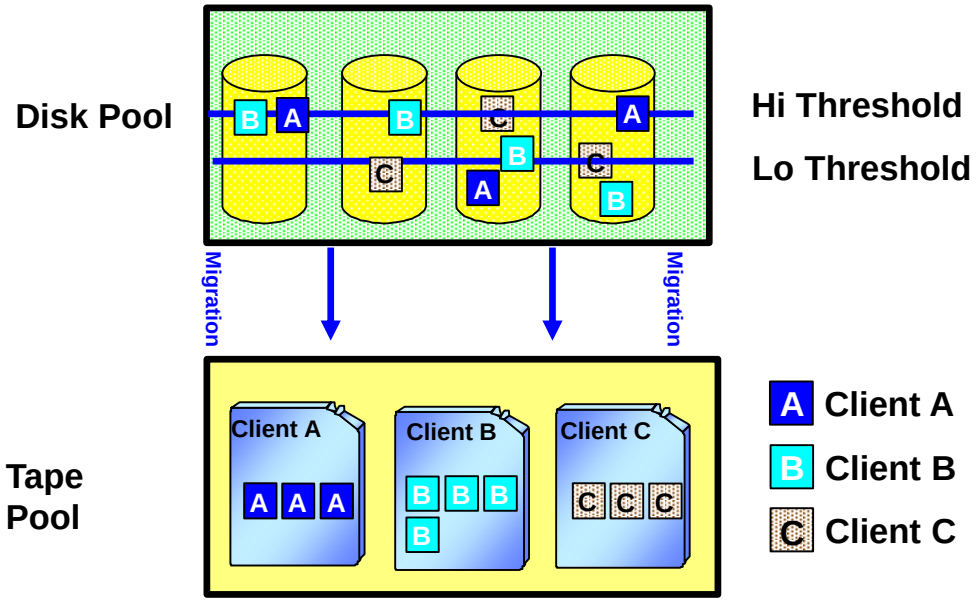
Required files from Day 1 FULL backup		Required files from Day 2 & Day 3 INCREMENTAL backups		Hard Drive after a restore to Day 3
	+	File F	=	File F
		File G		File G
		File D (new location)		File D (new location)
File E				File E

COLOCATION AND TAPE RECLAMATION

Colocation

Data of a client (group) to the same tape

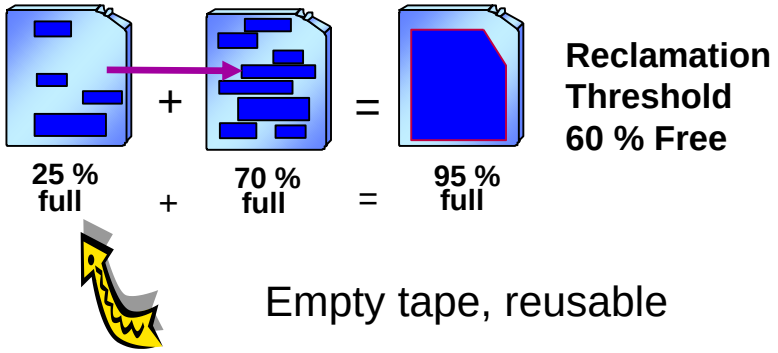
Shorter restoration, fewer tape exchange



Tape Reclamation

Copy valid data to a new tape after a user-specified threshold reached

This copying can be scheduled



Version Handling Systems

- Goal: to store/retrieve any version of a file
- Clone the file after each modification
  - Problem: Most part of the file was not changed
  - Storing the non-modified parts in several copies
  - Solution: Store only the modified parts + descriptor
    - Flash Copy

Flash Copy (Snapshot)

- If we modify a block – no overwrite – store at a different place
- Flash Copy table to point to the blocks of a file
  - „Snapshot”
  - Rollback possible to any time/version
- COW: Copy On Write

- Not suitable for back-up, since no real copy generated!
  - For version handling systems

Flash Copy - Blocks

	Blocks on the disk			Flash Copy table		
Time	**T1**	**T2**	**T3**	**F1**	**F2**	**F3**
	B0		B8	B0		B8
	B1	B1		B1	B1	
	B2		B9	B2		B9
	B3	B3	B3	B3	B3	B3
	B4	B4	B4	B4	B4	B4
	B5	B5	B5	B5	B5	B5
	B6	B6	B6	B6	B6	B6
	B7	B7	B7	B7	B7	B7
Total # of blocks	8			8	8	8
Delta (Flash Copy increment)	0			Virtual Volume A		

Flash Copy - Blocks

	Blocks on the disk			Flash Copy table		
Time	**T1**	**T2**	**T3**	**F1**	**F2**	**F3**
Write t2	B0	**B0>B8**	B8	B0		B8
	B1	B1		B1	B1	
	B2		B9	B2		B9
	B3	B3	B3	B3	B3	B3
	B4	B4	B4	B4	B4	B4
	B5	B5	B5	B5	B5	B5
	B6	B6	B6	B6	B6	B6
	B7	B7	B7	B7	B7	B7
Total # of blocks	8			8	8	8
Delta (Flash Copy increment)	0			Virtual Volume A		

FLASH COPY - BLOCKS

	Blocks on the disk			Flash copy table		
Time	**T1**	**T2**	**T3**	**F1**	**F2**	**F3**
Write t2	B0	**B0>B8**	B8	B0	**B8**	B8
	B1	B1		B1	B1	
	B2		B9	B2		B9
	B3	B3	B3	B3	B3	B3
	B4	B4	B4	B4	B4	B4
	B5	B5	B5	B5	B5	B5
	B6	B6	B6	B6	B6	B6
	B7	B7	B7	B7	B7	B7
Total # of blocks	8			8	8	8
Delta (Flash Copy inctement)	0			Virtual Volume A		

Flash Copy - Blocks

	Blocks on the disk			Flash Copy table		
Time	**T1**	**T2**	**T3**	**F1**	**F2**	**F3**
Write t2	B0	**B0>B8**	B8	B0	**B8**	B8
	B1	B1		B1	B1	
Write t2	B2	**B2>B9**	B9	B2		B9
	B3	B3	B3	B3	B3	B3
	B4	B4	B4	B4	B4	B4
	B5	B5	B5	B5	B5	B5
	B6	B6	B6	B6	B6	B6
	B7	B7	B7	B7	B7	B7
Total # of blocks	8			8	8	8
Delta (Flash Copy increment)	0			Virtual Volume A		

Flash Copy - Blocks

	Blocks on the disk			Flash Copy table		
Time	**T1**	**T2**	**T3**	**F1**	**F2**	**F3**
Write t2	B0	**B0>B8**	B8	B0	**B8**	B8
	B1	B1		B1	B1	
Write t2	B2	**B2>B9**	B9	B2	**B9**	B9
	B3	B3	B3	B3	B3	B3
	B4	B4	B4	B4	B4	B4
	B5	B5	B5	B5	B5	B5
	B6	B6	B6	B6	B6	B6
	B7	B7	B7	B7	B7	B7
Total # of blocks	8			8	8	8
Delta (Flash Copy increment)	0			Virtual Volume A		

Flash Copy - Blocks

	Blocks on the disk			Flash Copy table		
Time	**T1**	**T2**	**T3**	**F1**	**F2**	**F3**
Write t2	B0	**B0>B8**	B8	B0	**B8**	B8
	B1	B1		B1	B1	
Write t2	B2	**B2>B9**	B9	B2	**B9**	B9
	B3	B3	B3	B3	B3	B3
	B4	B4	B4	B4	B4	B4
	B5	B5	B5	B5	B5	B5
	B6	B6	B6	B6	B6	B6
	B7	B7	B7	B7	B7	B7
Total # of blocks	8	10		8	8	8
Delta (Flash Copy increment)	0			Virtual Volume A		

Flash Copy - Blocks

	Blocks on the disk			Flash Copy table		
Time	**T1**	**T2**	**T3**	**F1**	**F2**	**F3**
Write t2	B0	**B0>B8**	B8	B0	**B8**	B8
	B1	B1		B1	B1	
Write t2	B2	**B2>B9**	B9	B2	**B9**	B9
	B3	B3	B3	B3	B3	B3
	B4	B4	B4	B4	B4	B4
	B5	B5	B5	B5	B5	B5
	B6	B6	B6	B6	B6	B6
	B7	B7	B7	B7	B7	B7
Total # of blocks	8	10		8	8	8
Delta (Flash Copy increment)	0	2		Virtual Volume A		

Flash Copy - Blocks

	Blocks on the disk			Flash Copy table		
Time	**T1**	**T2**	**T3**	**F1**	**F2**	**F3**
Write t2	B0	**B0>B8**	B8	B0	**B8**	B8
	B1	B1		B1	B1	
Write t2	B2	**B2>B9**	B9	B2	**B9**	B9
	B3	B3	B3	B3	B3	B3
	B4	B4	B4	B4	B4	B4
	B5	B5	B5	B5	B5	B5
	B6	B6	B6	B6	B6	B6
	B7	B7	B7	B7	B7	B7
Total # of blocks	8	10		8	8	8
Delta (Flash Copy increment)	0	2		Virtual Volume A	B	

Flash Copy - Blocks

	Blocks on the disk			Flash Copy table		
Time	**T1**	**T2**	**T3**	**F1**	**F2**	**F3**
Write t2	B0	**B0>B8**	B8	B0	**B8**	B8
Write t3	B1	B1	**B1>B10**	B1	B1	
Write t2	B2	**B2>B9**	B9	B2	**B9**	B9
	B3	B3	B3	B3	B3	B3
	B4	B4	B4	B4	B4	B4
	B5	B5	B5	B5	B5	B5
	B6	B6	B6	B6	B6	B6
	B7	B7	B7	B7	B7	B7
Total # of blocks	8	10		8	8	8
Delta (Flash Copy increment)	0	2		Virtual Volume A	B	

FLASH COPY - BLOCKS

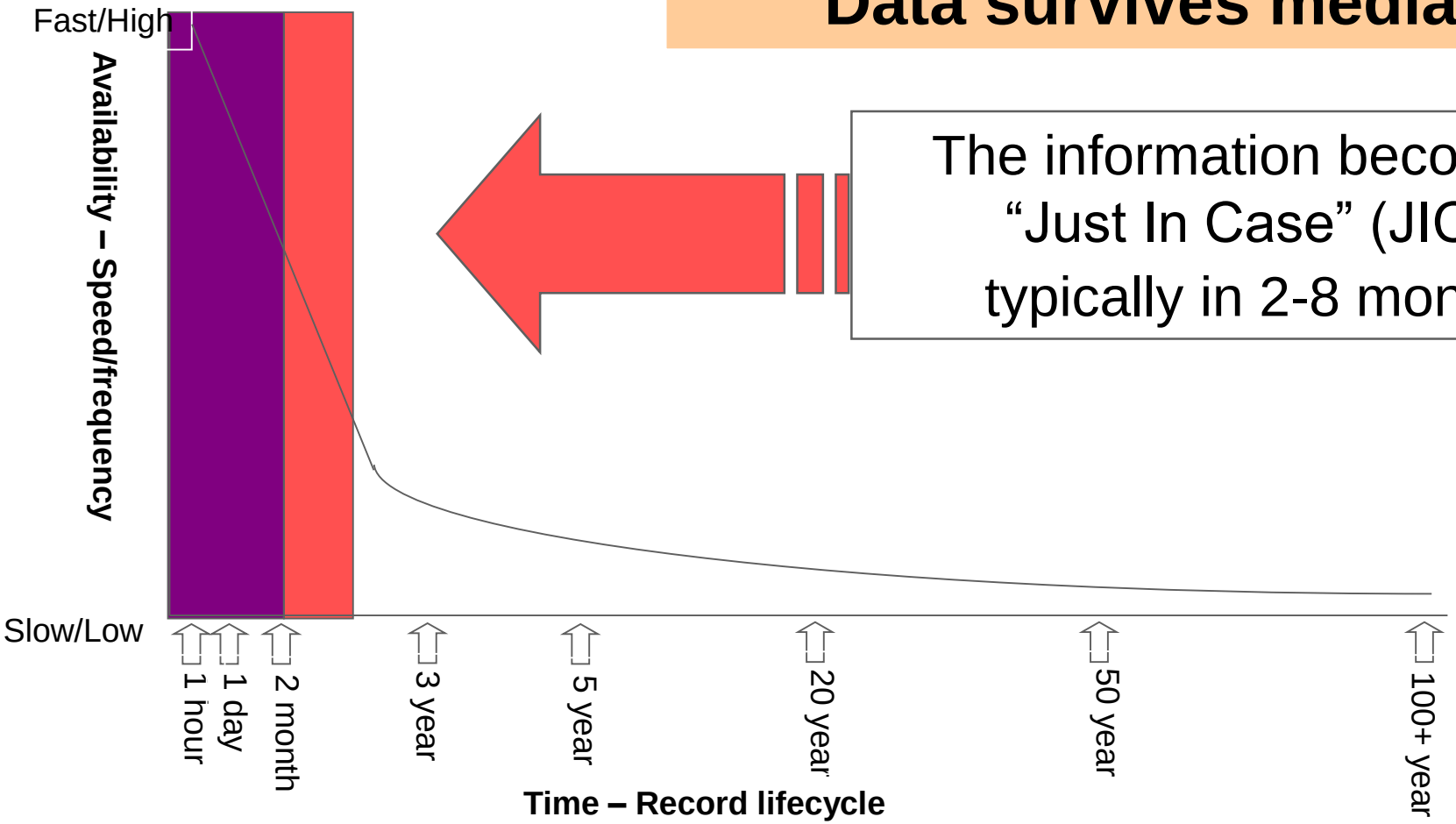
	Blocks on the disk			Flash Copy table		
Time	**T1**	**T2**	**T3**	**F1**	**F2**	**F3**
Write t2	B0	**B0>B8**	B8	B0	**B8**	B8
Write t3	B1	B1	**B1>B10**	B1	B1	**B10**
Write t2	B2	**B2>B9**	B9	B2	**B9**	B9
	B3	B3	B3	B3	B3	B3
	B4	B4	B4	B4	B4	B4
	B5	B5	B5	B5	B5	B5
	B6	B6	B6	B6	B6	B6
	B7	B7	B7	B7	B7	B7
Total # of blocks	8	10		8	8	8
Delta (Flash Copy increment)	0	2		Virtual Volume A	B	

Flash Copy - Blocks

	Blocks on the disk			Flash Copy table		
Time	**T1**	**T2**	**T3**	**F1**	**F2**	**F3**
Write t2	B0	**B0>B8**	B8	B0	**B8**	B8
Write t3	B1	B1	**B1>B10**	B1	B1	**B10**
Write t2	B2	**B2>B9**	B9	B2	**B9**	B9
	B3	B3	B3	B3	B3	B3
	B4	B4	B4	B4	B4	B4
	B5	B5	B5	B5	B5	B5
	B6	B6	B6	B6	B6	B6
	B7	B7	B7	B7	B7	B7
Total # of blocks	8	10	11	8	8	8
Delta (Flash Copy increment)	0	2	3	Virtual Volume A	B	C

THE JIC INFORMATION

Data survives media!

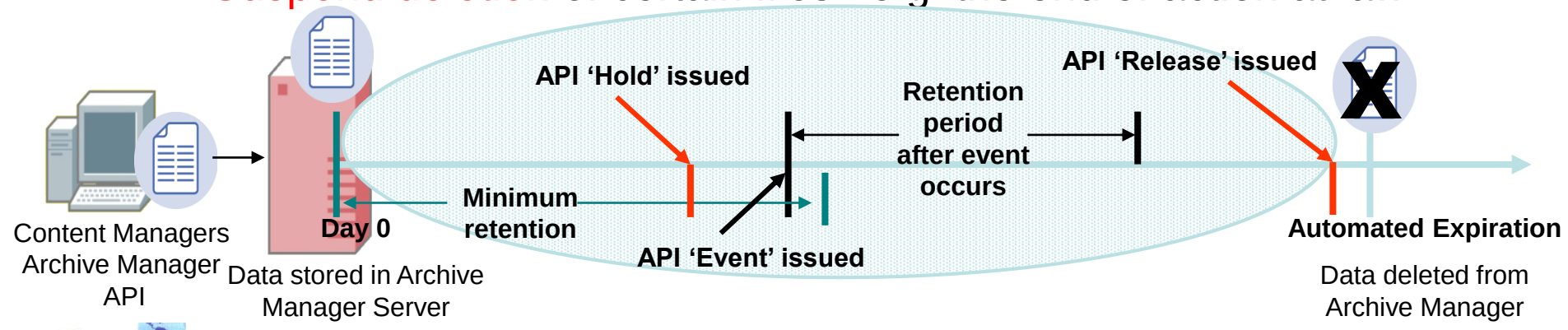


The information becomes
"Just In Case" (JIC)
typically in 2-8 month

SPECIAL ARCHIVING REQUIREMENTS

Protect data from deletion till a predefined time / but deletes immediately after it

Archiving versions
- – Chronological Retention time policy:
  - • Store the objects for a predefined time – e.g. 3 years –
- –Event-based retention protection:
  - • The storage time depends on an event – e.g. 70 years after client death
- – Deletion Suspend / Resume:
  - • Suspend deletion of certain files– e.g. the end of action at law



ARCHIVES

- Goal is different
- On technical level
  - ALWAYS full back-up
  - Archive tapes must be treated separately from „normal” back-ups – duplicating, off-site storing
  - Store at different places
  - Long life (~10 years) so not only the tapes to keep, but
    - Devices creating/reading archives
    - Tools (programs)

WHY TO USE TAPES?

Advantages:

- Cheap
- Tapes can be taken out from archivation equipment (“Jukebox”) – no continuous mechanical stress
- Long life – 30 years
- Stored data can easily be deleted

Disadvantages:

- Serial data access (slow)
- Tape insertation time
- More vulnerable

LINEAR TAPE-OPEN (LTO) STANDARD

- *Tape Format Standard*: IBM, HP and Certance (Seagate) cosortium
  - Open system standard technology
  - 8th generation
  - Backward compatibility
- Since its appearance (2000) wide range of industrial acceptance, leading tape technology
- Actual technology: Ultrium 8
  - 2000: 100 GB
  - 2017: 12 TB (v8)
  - Since v3:WORM
  - Since v4: Encryption
  - Data compression
  - New releases under standardisation

LINEAR TAPE-OPEN (LTO) FEATURES

Type	Year	Capacity	Entire-tape reads/ writes	Approximate years of life assuming one tape filled...	
				per *month*	per *week*
LTO-1	2000	100 GB	200	17	4
LTO-2	2003	200 GB	250	21	5
LTO-3	2005	400 GB	364	30	7
LTO-4	2007	800 GB	200	17	4
LTO-5	2010	1.5 TB	200	17	4
LTO-6	2012	2.5 TB	—	—	—
LTO-7	2015	6 TB	—	—	—
LTO-8	2017	12 TB	—	—	—

BACK-UPS MUST BE PLANNED

- Not enogh: „start at midnight”
  - Several back-up types!
  - *Back-up window* should not be the same
  - Back-up always reduces the performance of the system
  - Do at off-peak hours
    - But when are the peak hours?
  - Back-up outsourcing can lead to problems

Plan of Back-up

- Corporate Guidelines
- Service Level Agreement (SLA)
- Back-up and Restoration Policy
- Back-up Schedule

Corporate Guidelines

- Valid for the whole company
- Defines terminology and requirements for data-recovery systems
  - legal requirements
  - types of data to back-up
- Does not deal with low-level, implementation-close details

SLA

- An SLA is a written document that specifies what kind of services and performance are to be provided
- Created with involving the customers
- Defines:
  - types of back-up
  - requested restoration times
  - how often to back-up
  - how long to keep back-up tapes
  - back-up windows

SLA EXAMPLE

- Customers shall be able to get back any file
  - with a granularity of 1 business day for the past 6 months
  - with a granularity of 1 month for the last 3 years.
- Disk failures shall be restored in 4 hours, with no more than 2 days of lost data
- Archives shall be full back-ups on separate tapes generated quarterly and kept forever
- Critical data will be stored on a system that
  - Creates user-accessible snapshots at every hour from 7 AM until 7 PM,
  - Keeps ‘midnight snapshots’ for 1 week
- Databases and financial systems shall have stricter requirements that shall be determined separately

BACK-UP POLICY

- When SLA approved, determine the policy how to achive the requirements
- Typically obvious:
  - From SLA Example:
    - Daily back-ups
    - Tapes will be retained as specified in SLA
    - The policy determines how frequently to generate full back-ups
      - The rest incremental or differential

Back-up Schedule

- The back-up schedule lists details down to which partitions of which hosts are to be backed-up and when
- SLA changes rarely, but back-up schedule often
- Typically not written – stored in the configuration of the back-up system

Back-up Schedule Example

- Size of a partition: 4GB
- Full back-up: every 4 weeks (28 days)
- Suppose, size of differential back-up grows by 5% every day
  - Day 1: Full back-up, 4 GB
  - Day 2: 200 MB
  - Day 3: 400 MB, etc.
  - Day 10: 2 GB
  - Day 11: 2.2 GB
  - Just these two days require more than a full back-up
  - Worth perform full back-ups at every 10 days!

BACK-UP POLICY – TELL TO USERS

- Back-ups are performed only on data stored on servers (your PC's Z: drive, or UNIX /home directory) every night between midnight and 8 AM.
- *We never create back-ups of your PC's local C: drive.*
- If you need a file recovered, go to [*URL*] for more information, or send email to [*e-mail address*] with the name of the server, the file's complete path, and which date you need the restoration from.
- Access problems, simple restores are done in 24 hours.

EXAMPLE

- We have **2 TB** data on a server
- Use incremental back-up
- Change 10% / day
  - a. In case of a weekly cycle how large amount of data is to be backed-up in 4 weeks?

- Full back-up: 2 TB
- Incrementals: 2 TB * 10% = 0.2 TB (each day)
- One week: 2 TB + 6*0.2 TB = 3.2 TB
- Four weeks: 4 * 3.2 TB = 12.8 TB

EXAMPLE CONT.

b. How large will be the back-up window if the writing speed of the back-up device is 100 GB/h?

- Sunday (full back-up)
  - 2 TB / 100 GB/h = 20 (!!) hours
- Other days:
  - 0.2 TB / 100 GB/h = 2 hours

EXAMPLE CONT.

c. How many devices are needed if the maximal allowed back-up window is 8 hours?

- Worst: Sunday: 20 hours
- 3 devices needed

EXAMPLE CONT.

d. How many tapes are needed if we use new tape(s) every day and the capacity of a tape is 500 GB?

Sunday: 2 TB / 500 GB = 4 tapes

Other days: 0.2 TB (= 200 GB) = 1 tape

Total: 4+ 6*1 = 10 tapes / week

40 tapes / 4 weeks

EXAMPLE CONT.

e. Maximum how many tapes are needed to restore the content of a given day?

Worst: Saturday

Restore: 1 full + 6 incrementals

4 + 6*1 = 10 tapes needed

TAPE REQUIREMENT

- Back-up Policy affects the number of tapes needed

RESTORATION

- Slow...
- Reading and writing speed of a tape often very different + access time!!
  - Often longer than to restore a partition!
- Speed of restoration is typically determined by the writing speed of the file descriptors!!
- Tricks to perform the back-up faster (e.g. incremental back-up) makes the restoration slower
- Hardware limits
  - Tape fast, if the data arrives with exactly the same speed as the writing speed...
- Fastening: typically independent, dedicated network for back-up and Restoration

Restoration: Access rights-related issues

- Who has the right to claim the restoration (and to use) of a given file? – validation!
- File access rights change after restoration?
- File to be restored at the original place with the original access rights or at a different place with probably different access rights?
- Overwrites existing data?

CENTRALIZATION

- Centralization typically reduces costs of:
  - Equipment (expensive, because require high speed and high precision mechanics and high reliability).
  - Tape replacement (expensive, because needs human's work)
- Disadvantages of distributed back-up
  - Back-up device to every server – for high reliability: 2!
  - Tape replacement takes long time
- Network back-up systems
- Jukeboxs

Tape Inventory

- A set of back-up tapes with no index or inventory is only slightly more useful than no back-ups at all…
- Automatic inventory generation
  - No – read every tape backward in time…
  - Partition level
  - File level – fast, but large
  - Compromise
- How to restore if the Restoration system fails?
  - At least minimal info to store on the tape itself

FIRE DRILLS

- The only time to learn the quality of the back-up system is when doing a restoration
  - Restoring a randomly chosen file
  - Restoring a whole disk
    - rarely needed, maybe forget how to do
    - large amount of data – capacity/bandwidth is really enough?

CHANGES IN TECHNOLOGY

- Technology canges are different
  - Disk: almost linear (capacity doubles in ~1.5 years)
  - Tape: capacity remains the same for years and then a ‘big jump’
    - The tape units (jukeboxes) are expensive – not to replace ***them*** often
- When new tape type comes out – retain 1 (2) pieces from the old platform!
  - Equipment
  - Software

Back-up and Restoration - Summary

- Back-up / archive
- Types of back-ups
  - Full, incremental, differential, progressive
- Version handling systems
- Design of back-up
  - Corporate Guidelines, SLA, Back-up policy, Back-up schedule, Time and Capacity Planning, Tape need calculation
- Restoration