

# DB2 on S/390 Availability Features and Challenges

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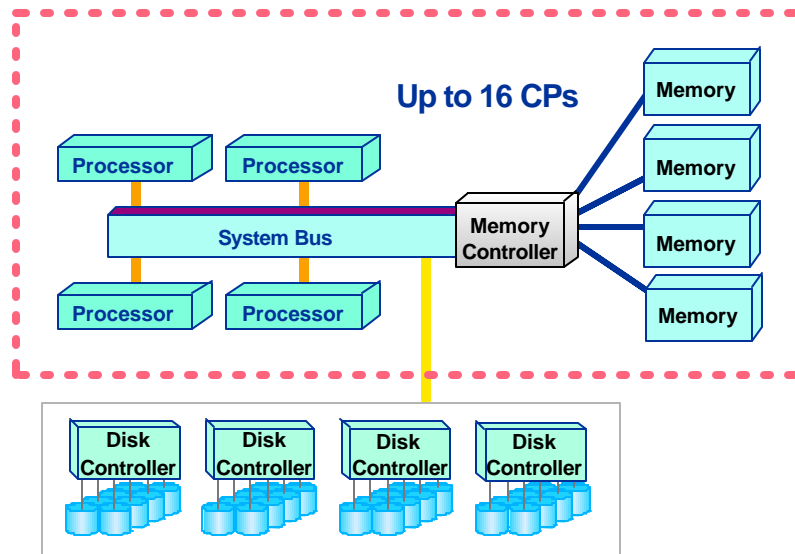
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# Agenda

- System/390 and DB2/390 architectural overview
- Some unique things about System/390 design for availability
- Some key design elements for high availability
- How 390 handles various failure scenarios

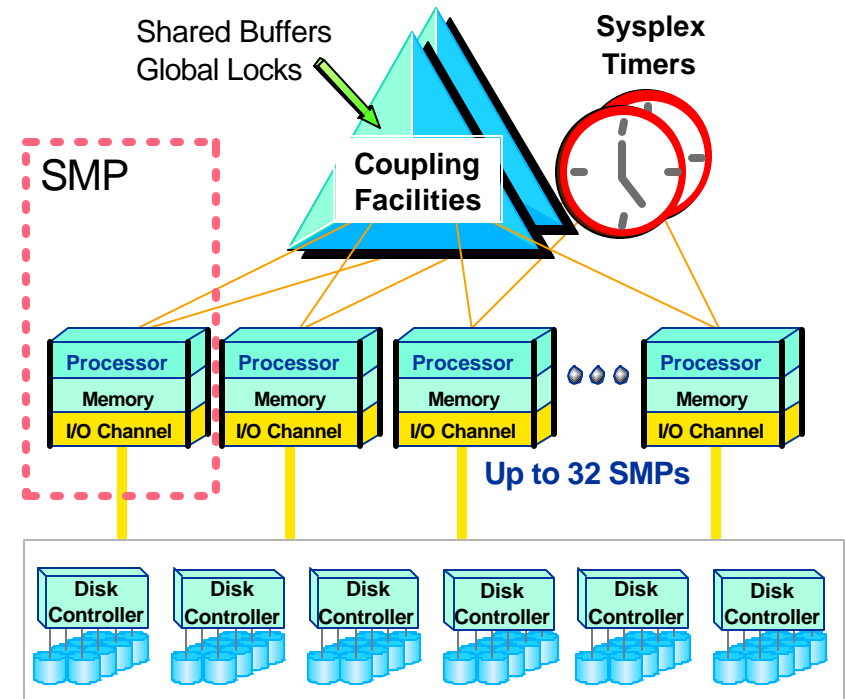
# S/390 Architectural Overview

## Symmetric Multiprocessor (SMP)



- ✓ *Ease of management*
- ✓ *"Shared memory"*
- ✓ *Single OS image or multiple OS partitions*

## Parallel Sysplex Cluster (Data Sharing)



- ✓ *Proven, scalable and ease of management*
- ✓ *"Shared data"*

# DB2 Shared Data Clusters Advantages

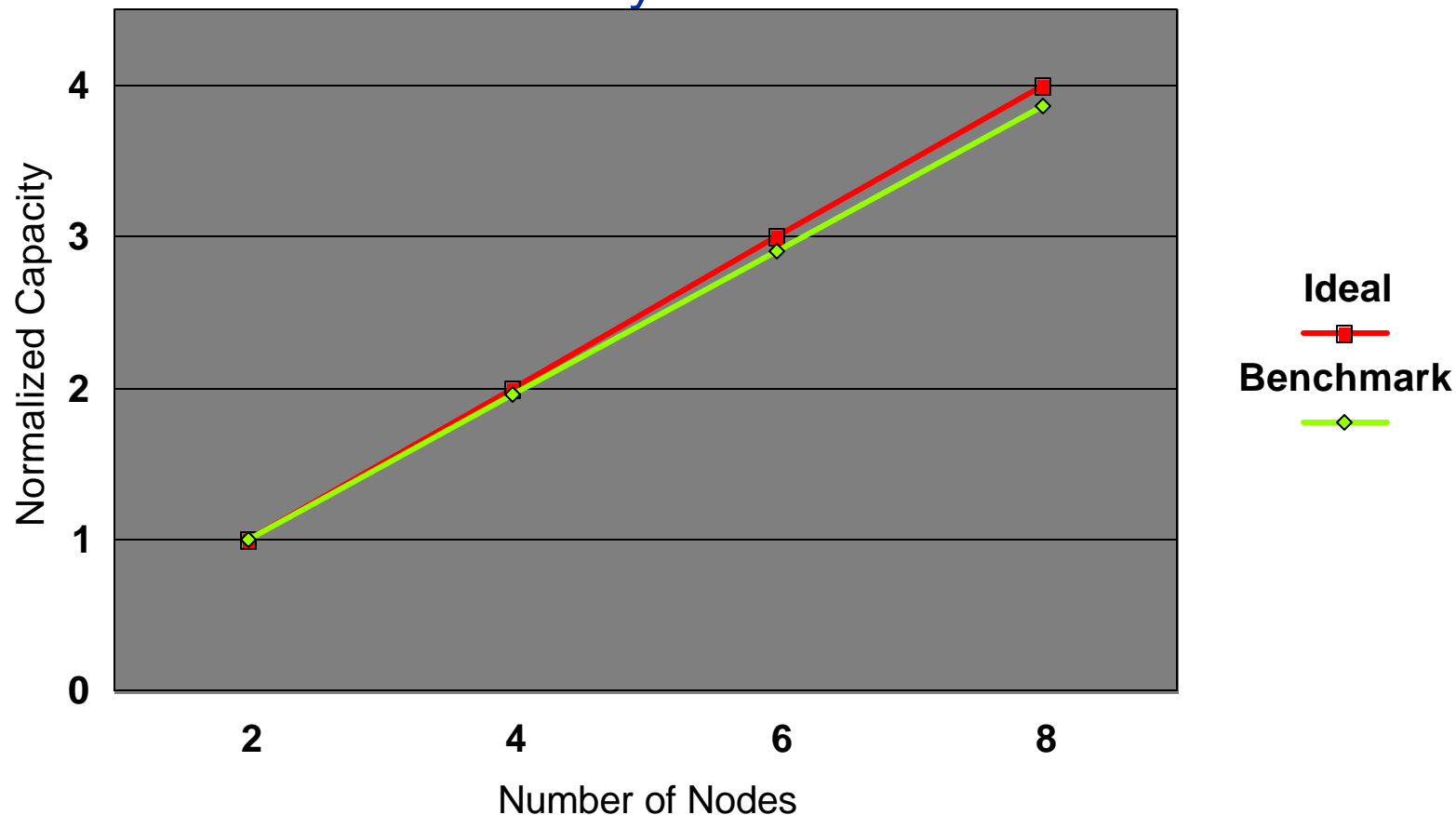
- 390 Parallel Sysplex offers major advantages for customers:
  - no need to balance data across data partitions
  - no need to rebalance partitions across servers
  - no outages to apply maintenance
  - system remains up and running on install of new DB2 release
  - dynamic workload balancing across the members of a parallel sysplex for both CPU and I/O processing
  - superior solutions for disaster recovery (hardware assisted remote site copy)
  - no outages required to modify stored procedures, application packages/plans, or most system parameters
  - highly scalable locking/data currency model
  - single system image for easy operations and application development
- Design point was OLTP and mixed workloads
  - "HPTS" stood for "Highly Parallel Transaction System"

# Scalability: some facts and figures

- Up to 32 systems in a single cluster
  - Up to 150K threads per system = 4.8M threads per cluster
  - Max size of a single table = 16TB
  - Max number of rows in a single table = 1 trillion ( $2^{40}$ )
  - Max buffer pool size = 256GB
  - Some sample DB2 customer stats:
    - 1.4B SQL stmts per day (retail, 4-way data sharing)
    - 24,000 inserts/sec. 150GB log/day (brokerage, 6-way)
      - 40,000 insert/sec. achieved on G4 ('97 vintage) processor
    - 167M inserts/day (UPS, single DB2)
    - 1,000 banking transactions per sec. (4-way data sharing)
    - 5800 stored procedures per sec. (brokerage)
    - Largest data sharing group = 14-way (brokerage)
    - Largest number of DB2 subsystems = 150 (bank)
    - 45 TB mirrored disk (bank)
    - >10 TB warehouses (banking, govt)
-

# DB2 Data Sharing Scalability for OLTP

- 5-15% overhead typically observed for 1-way to 2-way
  - 8-10 CF access per million instr. is typical at customers
- <.5% additional overhead for each member past 2-way
- IMS/TM with DB2 V4 OLTP workload, 100% data sharing
- 96.75% of ideal scalability from 2 to 8 nodes demonstrated



# What is a Coupling Facility?

- "Intelligent" shared electronic storage
- Three structure types supported
  - List: shared queues, messaging
  - Lock: inter-system concurrency control
  - Cache: inter-system buffer coherency control; host-side hardware bit vector for buffer invalidation
- DB2 uses all three structure types
- External or internal, single CP or multiple CPs
- Non volatility provided by battery backup
- Connectivity (can mix and match):
  - ISC (InterSystem Coupling) links: up to 200 MB/sec, 40 km
  - ICB (Integrated Cluster Bus): up to 1GB/sec., 10 m
  - IC (Internal Coupling channel): up to 1.25 GB/sec., "linkless"
- Typical observed command latencies: 10-50 usec.

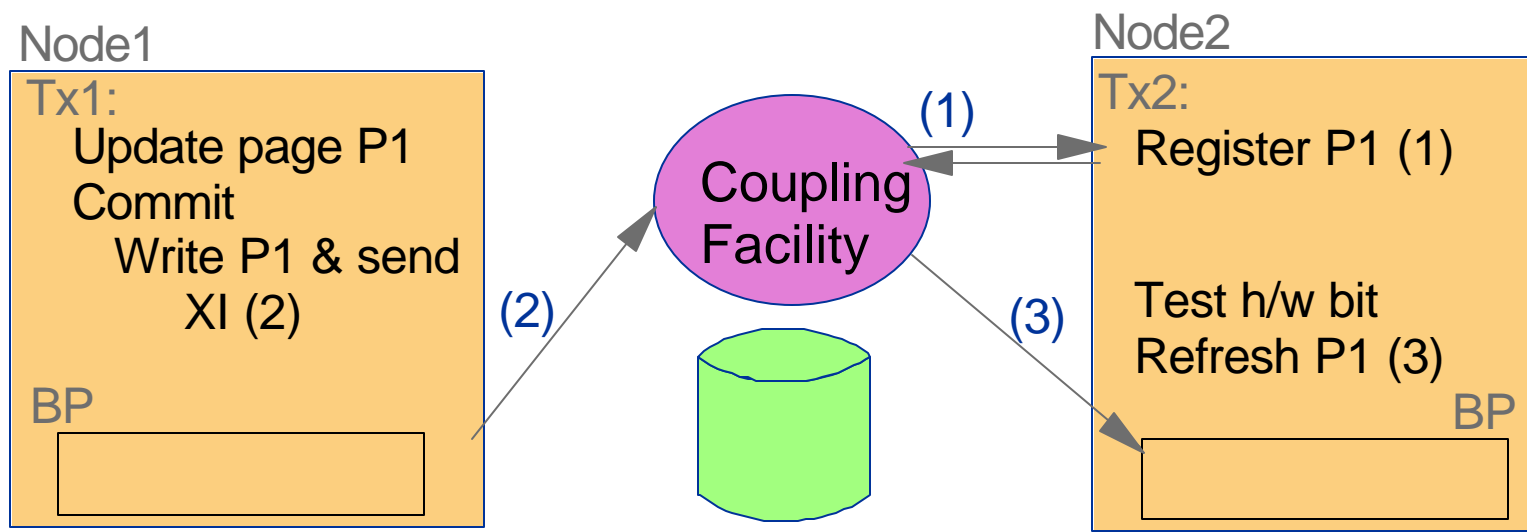
# DB2's Use of the Coupling Facility

- CF Lock Structure
  - Fast inter-system transaction lock conflict detection
  - Fast inter-system page latch conflict detection for cases where sub-page concurrency is allowed (e.g. row level locking)
  - Inter-system read/write interest tracking for DB objects
  - Retained locks in cases of DB2 "instance" failure
- CF Cache Structure
  - Store-in cache by default; "no-data" option provided
  - Register buffers for cross-invalidate (XI)
    - "List" option provided for prefetch
  - Write changed buffers, send XI signals (bundled)
  - H/W instruction to test vector bits for buffer XI
  - Fast refresh of XI'ed buffers
  - Force-at-commit DB write protocol used for writes to CF
- CF List structure: shared status information

# DB2's Use of the Coupling Facility...

- CF technology allows DB2 to do shared disk OLTP clusters avoiding synch. disk I/O and software messaging overheads
- Update example, transaction flow:
  1. Lock page X (0 s/w messages)
  2. Access page in BP (0 s/w messages, no add'l I/O)
    - If BP hit, test h/w bit and refresh page from CF if necessary
    - If BP miss, "read/register" page to CF
      - If CF hit, then pg returned from CF & disk I/O is avoided
      - If CF miss, then read pg from disk as before
  3. Update page in BP
  4. Commit (0 s/w messages, no I/O)
    - Write page to CF. XI signals are sent.
    - Unlock page

# Buffer XI, Refresh Example



## Key points:

- CF interactions are CPU synchronous
  - ▶ Avoid process switching overhead and CPU cache disruptions
- XI signals do not cause processor interrupts
- Force-at-commit fast page cleaning enables fast crash recovery

# Implications of CF as a store-in cache

- Done for performance reasons. Avoid disk I/O under the Tx.
- Pages must be eventually be written to disk. Done asynch. via the "castout" process
  - CF provides feedback on every write request as to the number of changed pages that reside in the structure
  - When threshold is reached, DB2 triggers castout
  - Castout runs in the background
  - Reads changed pages from CF into "private" buffers, writes pages to disk
  - When write I/O completes, DB2 tells the CF.
  - These pages remain cached in the CF as "clean". Clean pages are subject to being stolen (via LRU)
  - Castout is non-blocking. i.e. new version of page can be written while castout is in progress
- If CF fails, pages must be recovered
  - Duplexing (mirroring) avoids recovery outages (later chart)

# Other Important Optimizations

- Sysplex Timer provides efficient means of log record sequencing across systems
- Explicit Hierarchical Locking: transaction locks arranged in parent/child relationships
  - "Tablespace" is the parent; "page"/"row" are the children
  - Local lock managers dynamically track inter-system R/W interest on the parent, using the CF Lock Structure
  - If no inter-system R/W interest on parent, then child locks do not need to be sent to the CF
  - When inter-system R/W interest occurs, children must be "propagated" at that time.
  - R/R, R/W, W/W optimizations
- Buffer Mgr. dynamic tracking of inter-system interest
  - Local buffer managers dynamically track inter-system R/W interest at the "DB object" level using the CF Lock structure
  - If no inter-sys R/W interest, then CF not needed for cache coherency

# The 24x7 Holy Grail

- Given: system h/w and s/w components will incur outages from time to time
  - ▶ Planned and unplanned outages
  - ▶ Processor, OS, DBMS, I/O devices, I/O paths, site disaster, ...
- Goal: end users / apps should perceive that the database is available for read/write 100% of the time
- Design Tenets:
  - ▶ Reliability: components should not fail often
  - ▶ Redundancy with failure isolation:
    - at least 2 of everything
    - isolate failure to lowest granularity - no sympathy sickness
  - ▶ Fast, automatic, non-disruptive recovery
  - ▶ Online maintenance and configuration changes
  - ▶ High concurrency locking/latching
- DB2/390 leverages Parallel Sysplex clusters for high availability

# Some S/390 Availability Features

- Reliability: design point is 40+ years MTBF
- Redundant components (power supplies, AC power input, internal batteries, cooling units, etc.)
- Self-healing
  - Instruction retry: becoming more critical as densities increase
  - Dynamic processor/memory chip sparing
- Concurrent Upgrade
  - Processors
  - Memory, within card boundary
  - I/O, CF, and network adapters
- Concurrent Maintenance
  - uCode
  - Power/cooling
  - I/O, CF, and network adapters

# IBM zSeries z900

## z900 Today

64-bit z/Architecture

25 General Purpose Models

Increased Uni-Processor Performance

16-Way (20 PUs)

Up to 64 GB Memory

Enhanced Parallel Sysplex Connectivity

Intelligent Resource Director (IRD)

Over 1000 units shipped

## z900 Newly Available

HiperSockets ("linkless TCP/IP") - esp. interesting with Linux/390

IRD for Linux partitions

FICON enhancements

zSeries file system, new C++ compiler

Capacity Upgrade on Demand for memory

Capacity Backup nondisruptive return

System managed CF structure mirroring



# **z900 Capacity Backup Upgrade**

## **Who Needs It?**

- **Customers who have a requirement for Disaster Recovery**

## **What Is It?**

- **Nondisruptive addition of one or more engines**
- **Contract between IBM and customer**
- **Needs "spare" PUs**
- **Must plan ahead for memory and connectivity requirements**

## **Improvements**

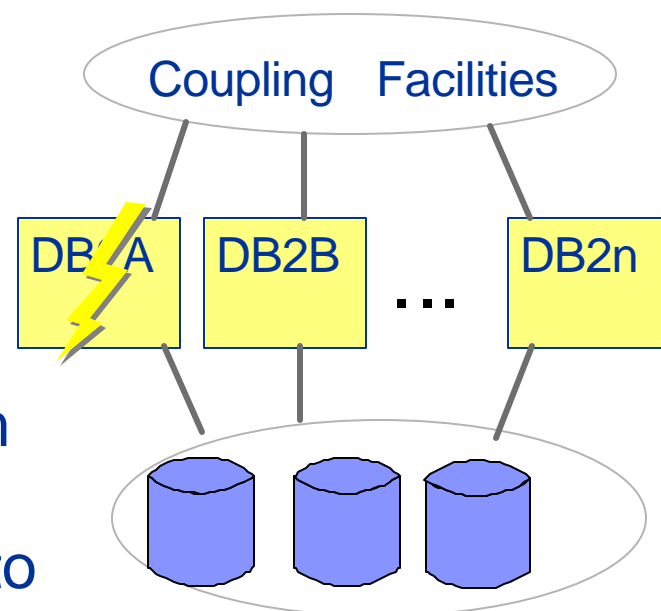
- **1998 - Nondisruptive engine added**
- **1999 - More logical CPs than physical CPs capability**
- **Keeps applications running while engines are added**
- **2000 Fast activation**
- **2001 Nondisruptive downgrade to original configuration**

# Process Failure

- OS/390 Recovery & Termination Manager
  - FRR and ESTAE routines intercept programming exceptions
  - "Percolate" or retry
- OS/390 SubSys Interface used for end-of-task (EOT), end-of-memory (EOM) monitoring
- Isolate failures (abends) to specific threads
- Collect diagnostic info for first failure data capture
  - Dumps, traces, error recording logs
- Maintain integrity of system control structures
- Cleanup shared resources such as latches
- Deferred EOT allows completion of commit/abort if the appl process goes away
- "Must complete" runs under internal, protected execution units
- Extensive debugging tools have been built around OS/390 Interactive Problem Control System (IPCS)
  - Allows for analysis of data on location at customer site

# DB2 Member Failure Recovery

- The other "surviving" members remain up and running
- The architecture allows all members to access all portions of the data bases
- Work can be dynamically routed away from the down DB2 member
- The failed member holds "retained locks" to protect inconsistent data from being locked by other members
- OS/390 Automatic Restart Manager can automatically restart failed DB2 members
- Restart on same or different OS image
- Force-at-commit greatly reduces 'redo' log apply work
- Merged log never needed for restart
- "Restart light" option uses small storage footprint
- Option to defer backout

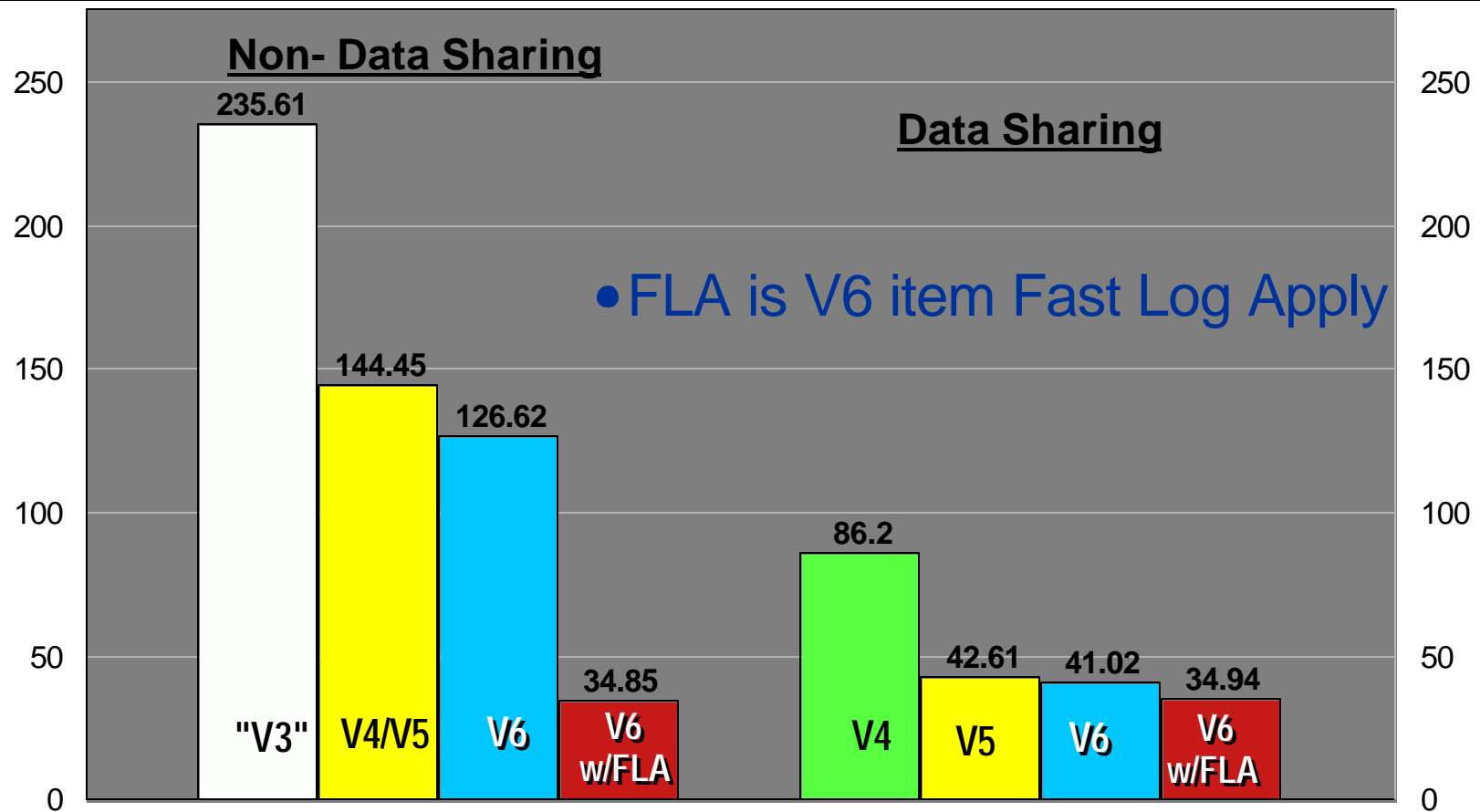


# DB2 Restart Recovery Performance

- Laboratory performance measurements on G5 hardware

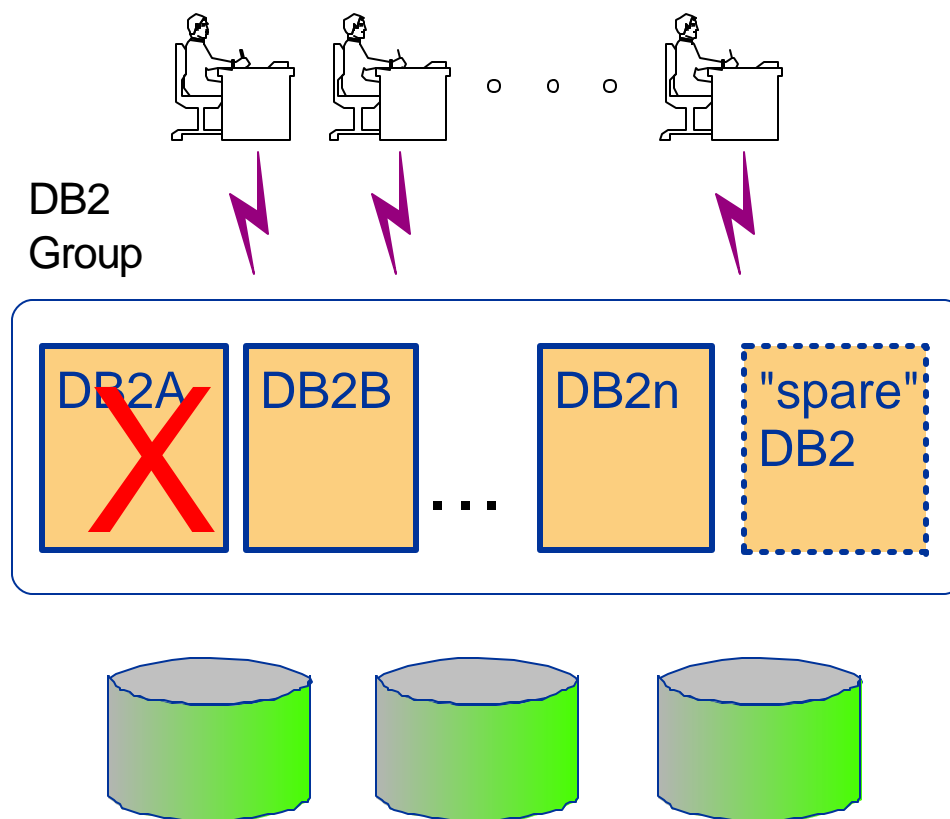
- V5 NDS vs V3 : 39% faster
- V5 2-way vs V4 2-way : 2 times faster

- V6 NDS vs V5 NDS : 4 times faster
- V6 2-way vs V5 2-way : 18% faster



# Online Software Maintenance

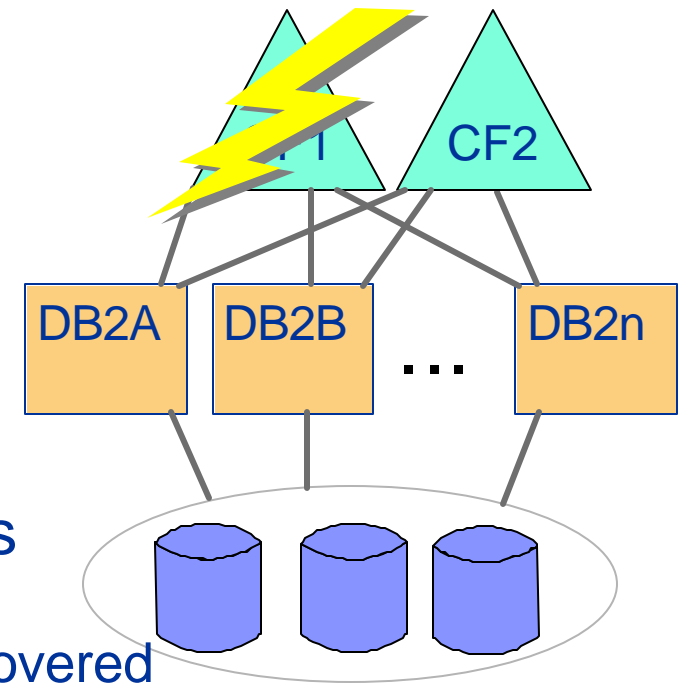
- "Rolling" maintenance with DB2 data sharing
- One DB2 member stopped at a time
- DB2 data is continuously available via the N-1 members
- "Spare" member can be optionally started to maintain full capacity
- Multiple release levels can coexist within a group
- Release fallback support



- ➔ Migrate software releases, apply software maintenance
- ➔ **Without** any user-perceived outage
- ➔ Catalog migration locks portions of the catalog

# Coupling Facility Outages

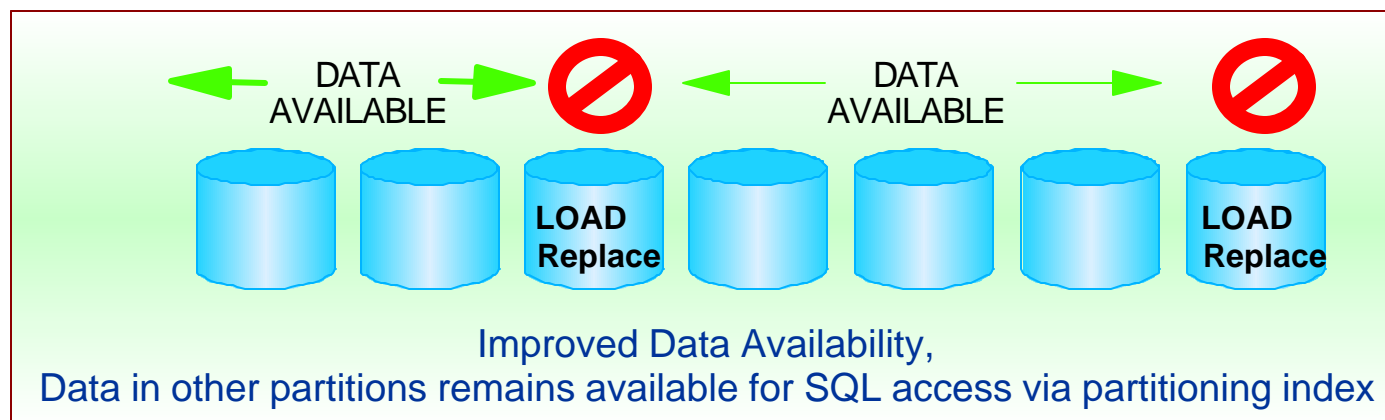
- Planned outages: use the MVS "rebuild" command to move the structures out of the CF that's targeted for maintenance
  - V4: Lock & SCA structures supported, but not group buffer pools (GBPs)
  - V5: support added for GBPs
- Unplanned outages: the system automatically recovers the lost structures
  - V4: Lock & SCA can be automatically recovered, but damaged GBPs must be recovered manually
  - V5: DB2 automatically recovers GBPs from logs
  - V6: GBP duplexing (retro-fitted to V5) via Apars



→ CF failures are extremely rare, but.....

→ As of V6, DB2 can recover from any CF failure within seconds

# Partition Independence

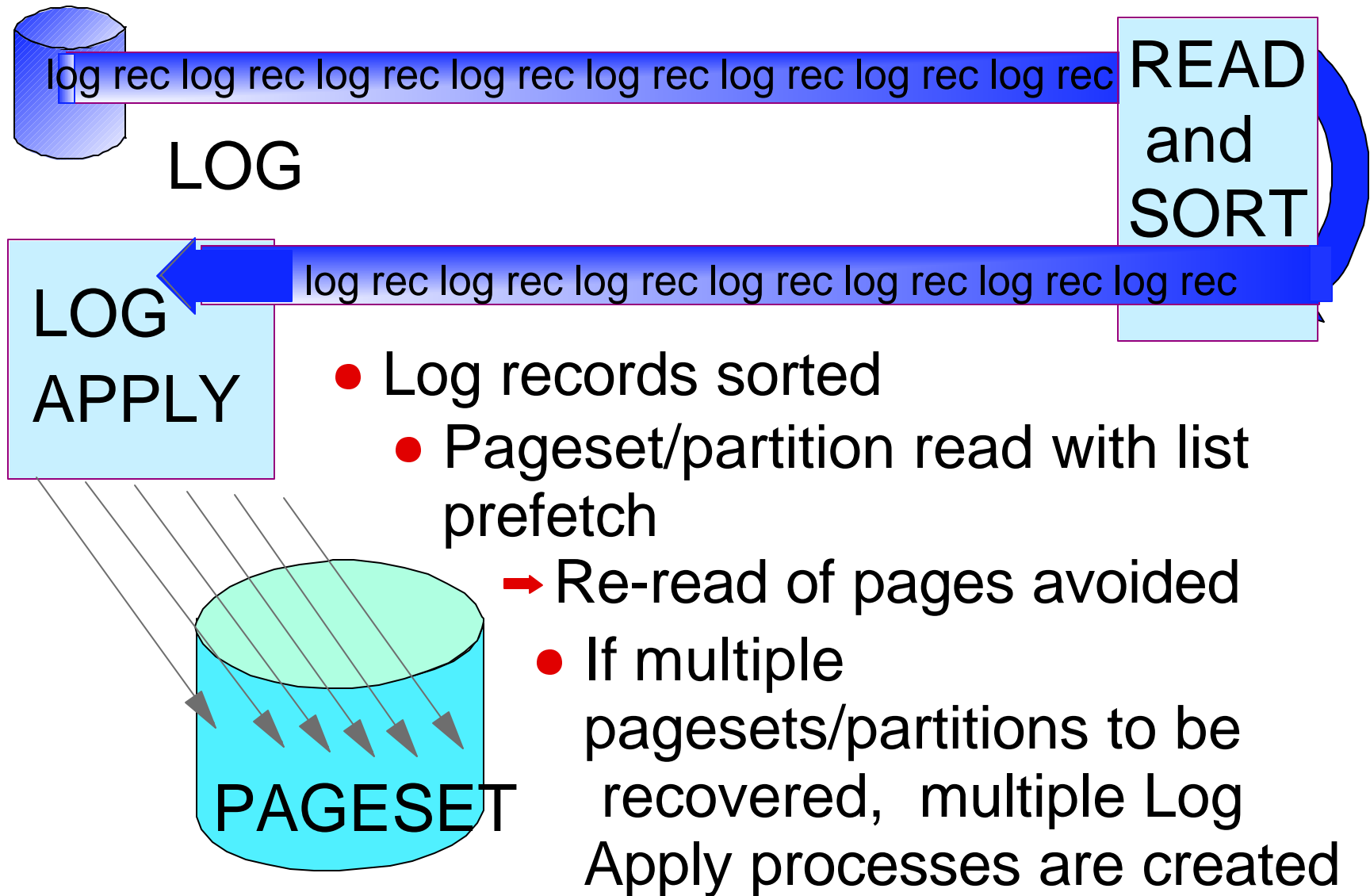


- Improves data availability for utilities and SQL processing
- Reduces elapsed time for utility processing
- Allows you to STOP or START DATABASE on partition level
- Different utilities can run concurrently on different partitions
- SQL runs on partitions not exclusively needed for utilities
- Version 5
  - Up to 254 partitions of 4GB each (1TB for a single table)
- Version 6
  - Up to 254 partitions of 64GB each (16TB for a single table)

# Backup and Recovery

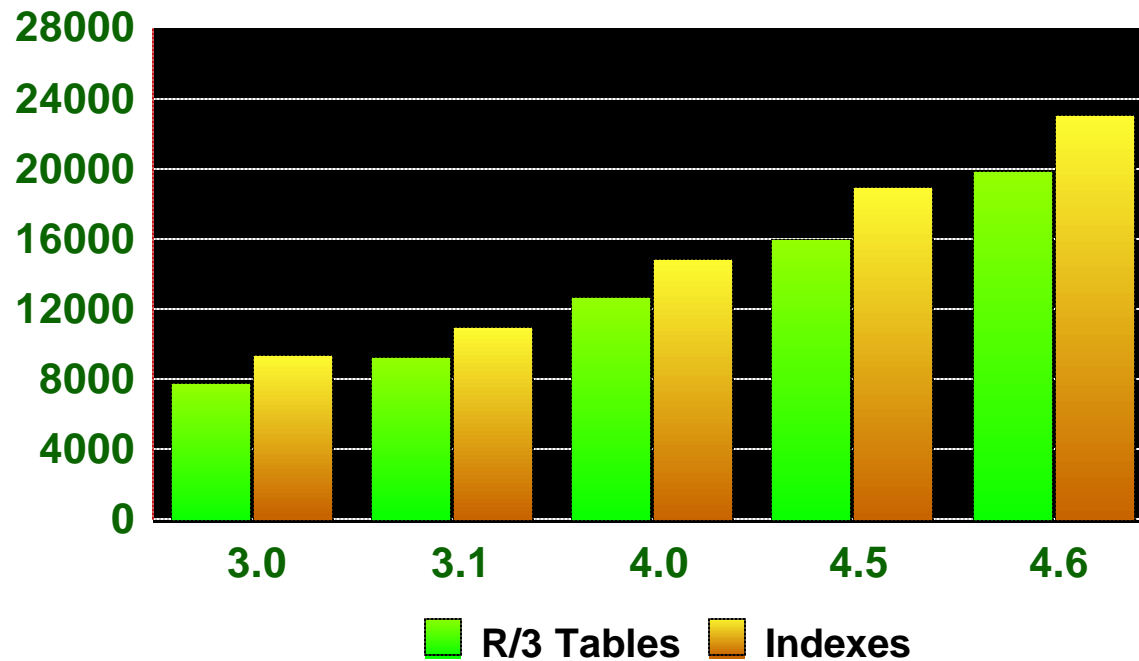
- Backup
  - Incremental or Full
  - Shrlevel(Ref) or Shrlevel(Change)
  - Exploits "fast copy" features of disk subsystems
- Recovery
  - To currency or to a point in time
  - SYSLGRNX directory table limits log scan needed
  - Parallel log apply process
  - LOGONLY recovery - use current database object on disk as the recovery base (instead of image copy)
- Wildcarding and dynamic allocation improves usability
- Partition level
- COPY/RECOVER parallelism for object lists
- Indices can be backed up & recovered independently of data
- System-level backup/recovery features also provided

# Fast Log Apply



# Online Schema Evolution

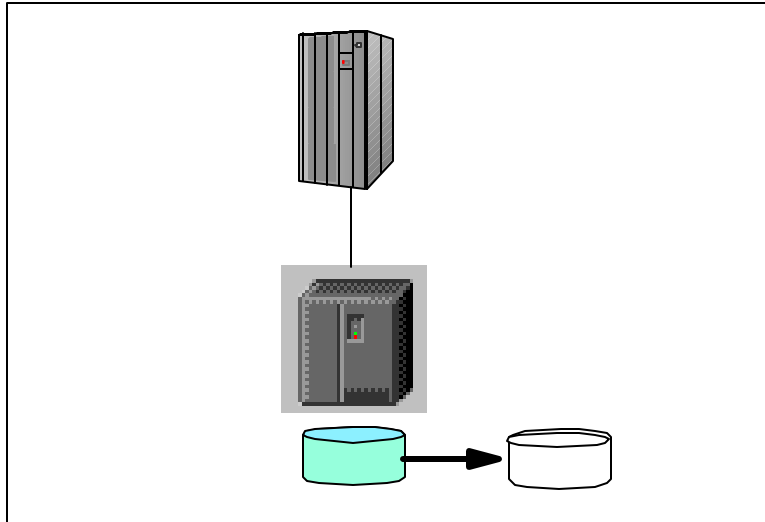
## Example: *SAP R/3 Schema Object Number Growth*



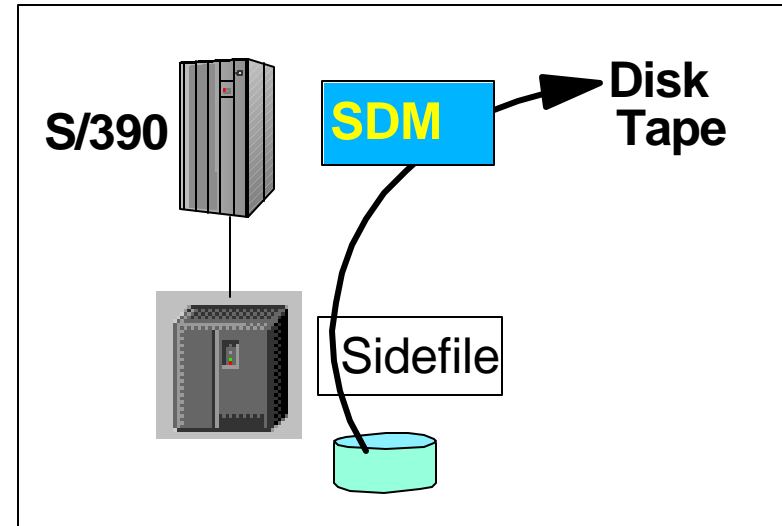
- Add / alter metadata without outages
- Do not invalidate related objects
- Multiple versions of records in same table
  - no changes to data when schema changes
- Change column data types, increase column lengths, ...

# Shark Copy Services

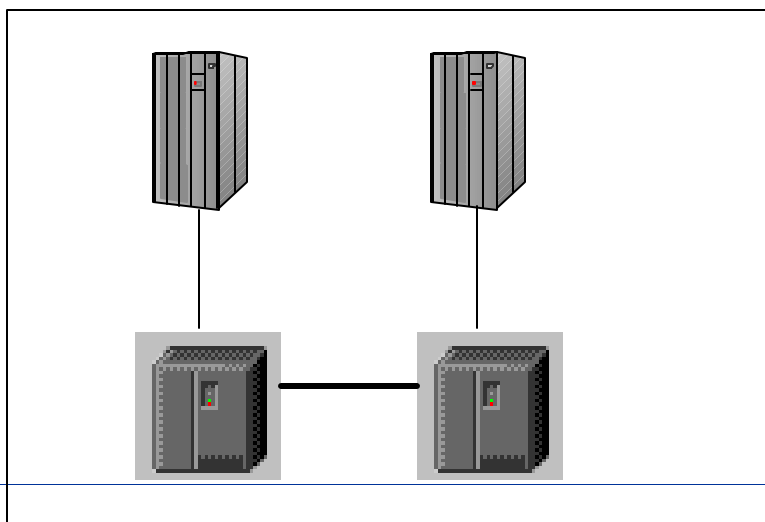
## FlashCopy



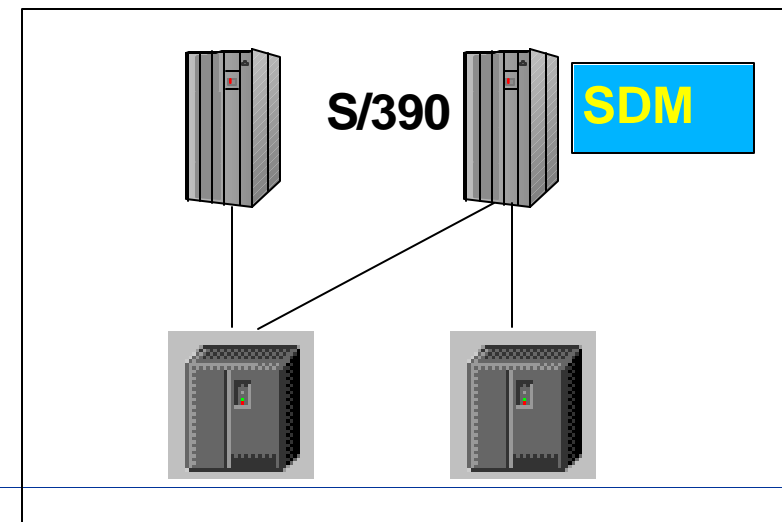
## Concurrent Copy



## PPRC



## XRC



# Shark Copy Services

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## FlashCopy

- S/390 and Open Systems
- Instant T0 copy of a volume for test, backup, temporary copy.....
- Source and Target must be in same logical Subsystem
- Target must have same capacity (or larger) as source
- Invoked by DFSMSdss full volume COPY, TSO command or ESS Copy Services

## Concurrent Copy

- S/390 only
- Instant T0 copy of volume or data set for data backup
- Target can be on tape or DASD volume
- OS/390's System Data Mover is used to move the data
- Sidefiles in cache is used for the updates
- Invoked by DFSMSdss or applications internally call DFSMSdss as the copy program, such as DB2 COPY utility

## PPRC

- S/390 and Open Systems
- Disaster recovery solution
- Synchronous mirror copies of volumes on remote ESS
- Direct connections between ESS systems using ESCON links
- Invoked by TSO command or ESS Copy Services

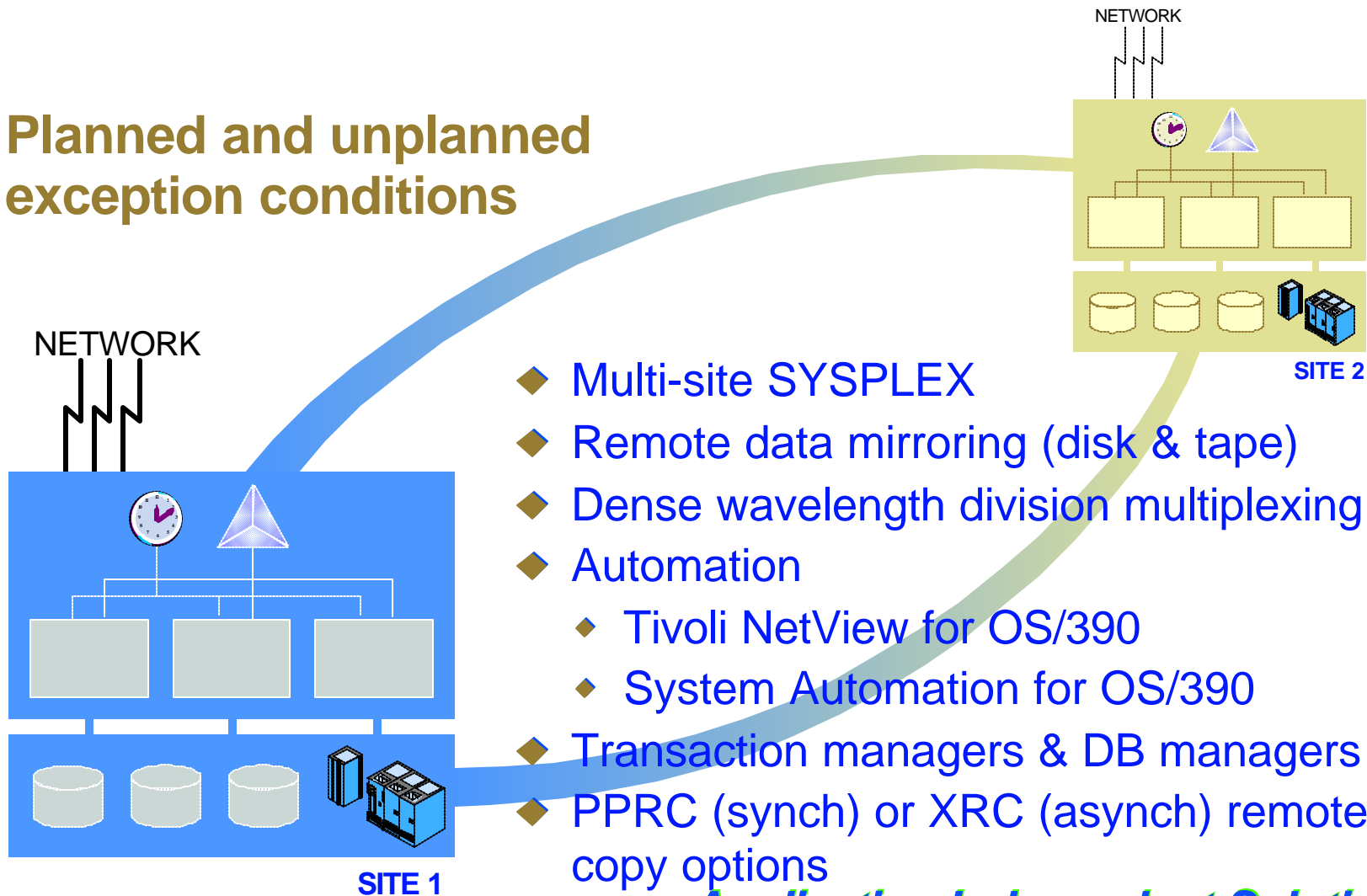
## XRC

- S/390 only
- Disaster recovery solution
- Asynchronous remote mirror copies of volumes
- Supports large distances
- OS/390's System Data Mover is used to move the data
- Invoked by TSO command

# GDPS Disaster Recovery Solution

## *GDPS (Geographically Dispersed Parallel Sysplex)*

Planned and unplanned exception conditions



- ◆ Multi-site SYSPLEX
- ◆ Remote data mirroring (disk & tape)
- ◆ Dense wavelength division multiplexing
- ◆ Automation
  - ◆ Tivoli NetView for OS/390
  - ◆ System Automation for OS/390
- ◆ Transaction managers & DB managers
- ◆ PPRC (synch) or XRC (asynch) remote copy options

*Application Independent Solution*

# GDPS Policy Options

## FREEZE & GO

- ◆ Freeze secondary disk configuration
- ◆ Allow applications to continue
- Optimize for remote restartability
- Least impact on application availability
- May lose data in case of real disaster

## FREEZE & STOP

- ◆ Freeze secondary disk configuration
- ◆ Stop all OS/390 images
- Optimize for remote restartability
- May impact application availability
- No data loss on primary site disaster

## FREEZE & STOP Conditional

- ◆ Freeze secondary disk configuration
- ◆ Determine reason for Suspend
  - ◆ If secondary HW problem then  
FREEZE & GO
  - ◆ Other reason: FREEZE & STOP

# Other Important Availability Features

- Online REORG utility
- Online LOAD RESUME utility
- Inline RUNSTATS and COPY utilities
- LOAD/REORG parallel index build
- Online system parameter change
- Stored procedures run in their own address spaces
  - Failure isolation
- Write I/O errors: isolate failure to page level
  - Logical Page List (LPL)

# Some Challenges

- Dynamic schema change, ongoing work.
- Easier, less disruptive Point-in-time recovery
- Self-healing, self-managing systems

# References

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