LUW-05

Recipes for Db2 Backups with Encryption, Compression, Hardware Acceleration and Other Ingredients

Beck Tang, IBM
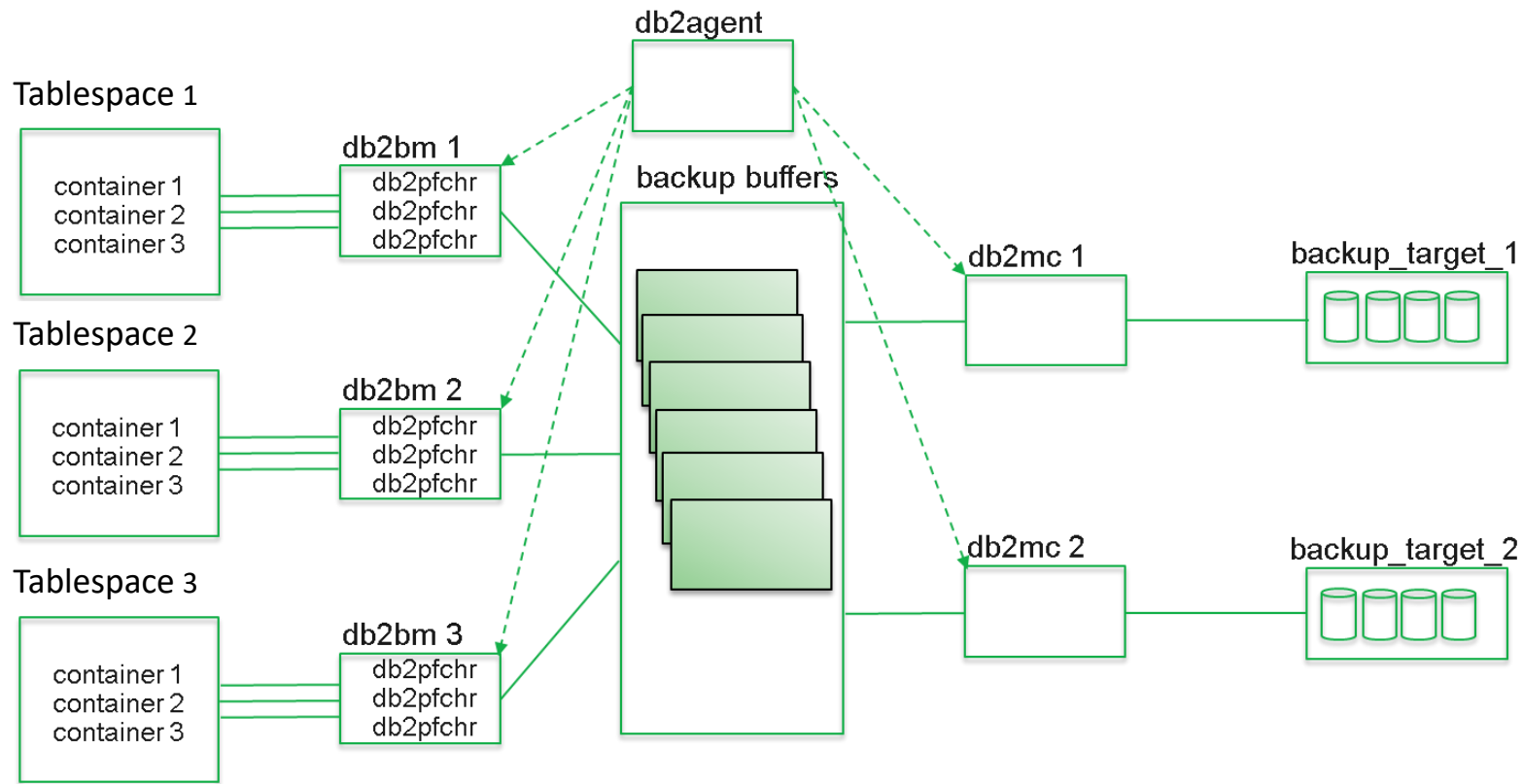
becktang@ca.ibm.com

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Agenda

❖ Using the right bowls to mix the pastry
- The backup process

❖ Choosing best ingredients
- Compression, encryption and other options

❖ Monitoring the baking process
- db2pd and list utilities

❖ Tasting the meal
- Check/validate the backup image

❖ Get feedback from the guests
- Reading the history file

Backup Theory - Process and Involved EDUs ✎

db2agent

Tablespace 1

| container 1 |
| container 2 |
| container 3 |

db2bm 1
db2pfchr
db2pfchr
db2pfchr

backup buffers

db2mc 1

backup_target_1

Tablespace 2

| container 1 |
| container 2 |
| container 3 |

db2bm 2
db2pfchr
db2pfchr
db2pfchr

db2mc 2

backup_target_2

Tablespace 3

| container 1 |
| container 2 |
| container 3 |

db2bm 3
db2pfchr
db2pfchr
db2pfchr

db2 "backup db ABC online to /backup_target_1, /backup_target_2 with 6 buffers parallelism 3"

Note: The backup buffers are coming from the database configuration, Utility memory heap (UTIL_HEAP).   For reference, SAP recommendation for DB2 11.5 for util_heap_sz is AUTOMATIC with an initial value of 50000 X 4KB pages.

Db2 Backup – Using Compression

- Advantages:
  - The size of the backup images will be smaller than without compression
  - This has impact on the time to take backups, the time to transfer the image and the size it allocates in the backup infrastructure

- Disadvantages:
  - Takes more resources to compress the data

- Available compression methods:
  - Common Db2 Compression
    - Software based
  - NX842 on Power
    - Using special accelerator units on CPUs of Power 7+ and later
  - ZLib Compression
    - Either software or using additional accelerators in x86, Power 9 and z CPUs

Backup Theory – HW Acceleration – NX842

```
# amepat

Command Invoked              : amepat

Date/Time of invocation      : Tue Aug 22 16:36:21
CEST 2023
Total Monitored time         : NA
Total Samples Collected      : NA

System Configuration:
---------------------
Partition Name               : db6p021004
Processor Implementation Mode : POWER7 Mode
Number Of Logical CPUs       : 32
Processor Entitled Capacity  : 8.00
Processor Max. Capacity      : 8.00
True Memory                  : 61.00 GB
SMT Threads                  : 4
Shared Processor Mode        : Disabled
Active Memory Sharing        : Disabled
Active Memory Expansion      : Disabled

System Resource Statistics:              Current
---------------------------          ----------------
CPU Util (Phys. Processors)              0.09 [  1%]
Virtual Memory Size (MB)                41752 [ 67%]
True Memory In-Use (MB)                  59719 [ 96%]
Pinned Memory (MB)                        9181 [ 15%]
File Cache Size (MB)                     17905 [ 29%]
Available Memory (MB)                    18812 [ 30%]
```
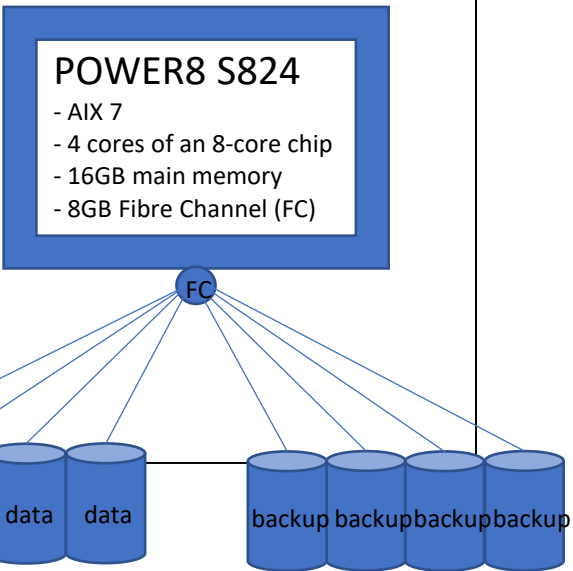
```
1> db2pd -osinfo

Operating System Information:

OSName:   AIX
NodeName: db6p021004
Version:  7
Release:  2
Machine:  00CB85FF4C00
AME     : Disabled
AMS     : Disabled
NX842   : 109:Function not implemented
NXZLIB  : n/a
```
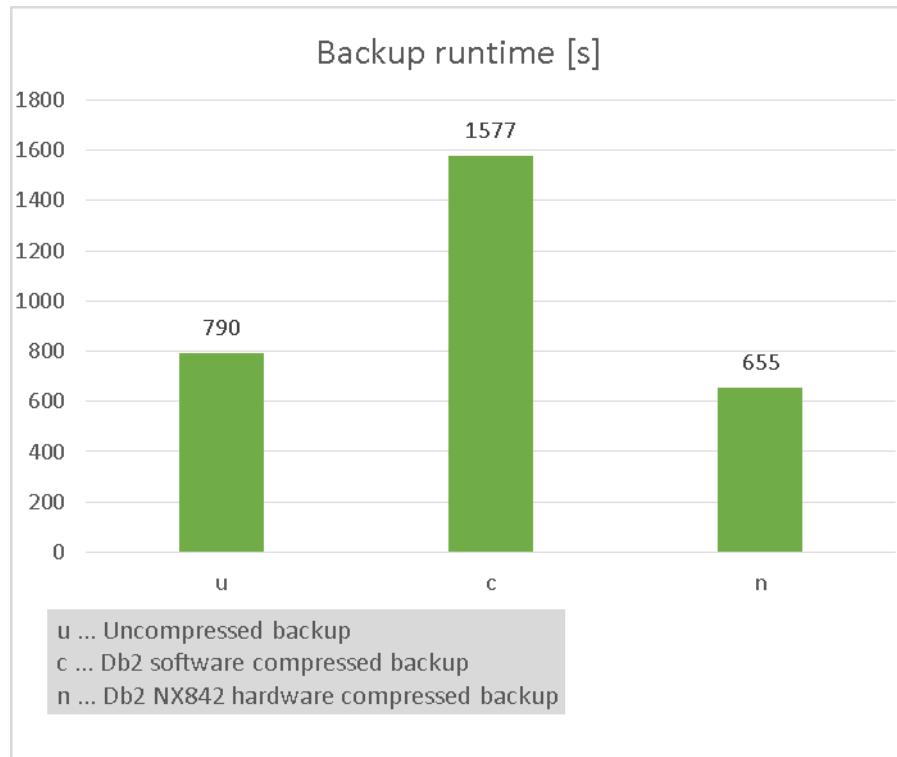
Virtual Fibre Channel Capable	True
Active Memory Expansion Capable	True
Hardware-Accelerated Active Memory Expansion Capable	True

POWER8 S824
- AIX 7
- 4 cores of an 8-core chip
- 16GB main memory
- 8GB Fibre Channel (FC)

FC

data data data data   backup backupbackupbackup

Backup Theory – Compression-Type-Efficency

- Runtime

Backup runtime [s]

	u	c	n
	790	1577	655

u ... Uncompressed backup
c ... Db2 software compressed backup
n ... Db2 NX842 hardware compressed backup

- CPU Usage

Backup user+sys CPU [%]

	u	c	n
	30	48	26

u ... Uncompressed backup
c ... Db2 software compressed backup
n ... Db2 NX842 hardware compressed backup
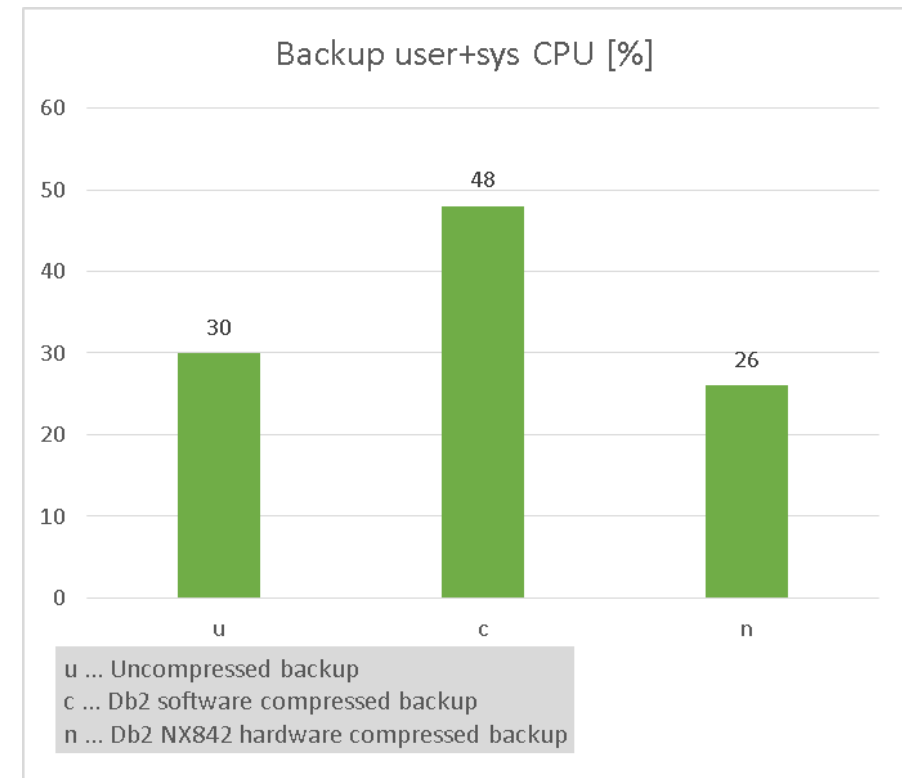
HW-Compression: fast and efficient – use if available

Db2 Backup – Using Encryption

- Advantages:
  - **Data Security**: Encryption helps protect sensitive data in backups from unauthorized access. Even if backup files are stolen or compromised, the data remains encrypted and inaccessible without the encryption key.
  - **Compliance**: Encryption is often required to meet regulatory compliance standards, such as **HIPAA** (Health Insurance Portability and Accountability Act), or **PCI DSS** (Payment Card Industry Data Security Standard), **GIS** (Global Information Security) which mandate the protection of sensitive datal, especially for the finance and health sectors.
  - **Safe Data Transfer**: If you need to transfer backup files to a different location or store them in a cloud service, encryption adds an extra layer of security during transit.

- Disadvantages:
  - **Performance Overhead**: Obviously costs additional resources either on general purpose CPU or on hardware accelerators – up to 10 %.
  - **Complexity**: Requires setting up encryption algorithms, managing keys, and ensuring compatibility with your backup and recovery processes.

Backup Theory - Encryption

Db2 database

Master Key decrypts DEK

DEK decrypts database files

Centralized Key Manager
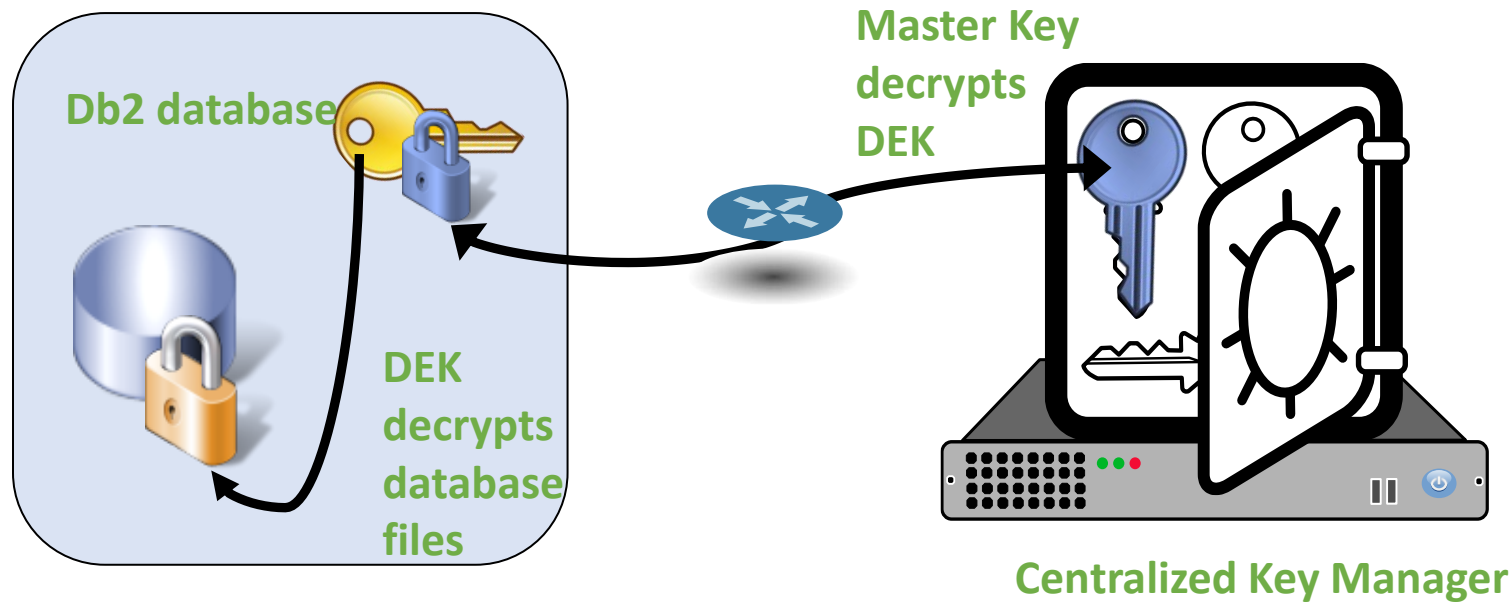
The master key is accessed whenever a DEK requires decryption

- db2start open keystore
- db start (activate, first connect)
- backup /restore
- ...

DEK is generated by Db2 when
    Database is created
    Restore into new database
    Backup is created

Master Key is created
    Manually within the key manager
    Automatically by Db2

Backup Theory – Encryption/Compression Options

- ## COMPRLIB/ENCRLIB options

Operating System	Compression	Encryption	Both
Windows	db2compr.dll	db2encr.dll	db2compr_encr.dll
Linux	libdb2compr.so	libdb2encr.so	libdb2compr_encr.so
AIX	libdb2compr.a	libdb2encr.a	libdb2compr_encr.a

ZLIB without HW acceleration: libdb2zcompr_encr.dll and libdb2zcompr_encr.so

- ## COMPROPTS/ENCROPTS options

Option	Purpose	Values
Cipher	Type of encryption algorithm to use	AES, 3DES
Key Length	Length of the encryption key	AES: 128, 192, 256, 3DES: 168
Master Key Label	Optional name of the Master Key Label used to encrypt the database key	String
Mode	Optional – Cipher Block Chaining	CBC

POWER 7+
AIX NX842 accelerator
   - libdb2nx842.a
   - libdb2nx842_encr.a

POWER 9
AIX NXZLIB accelerator
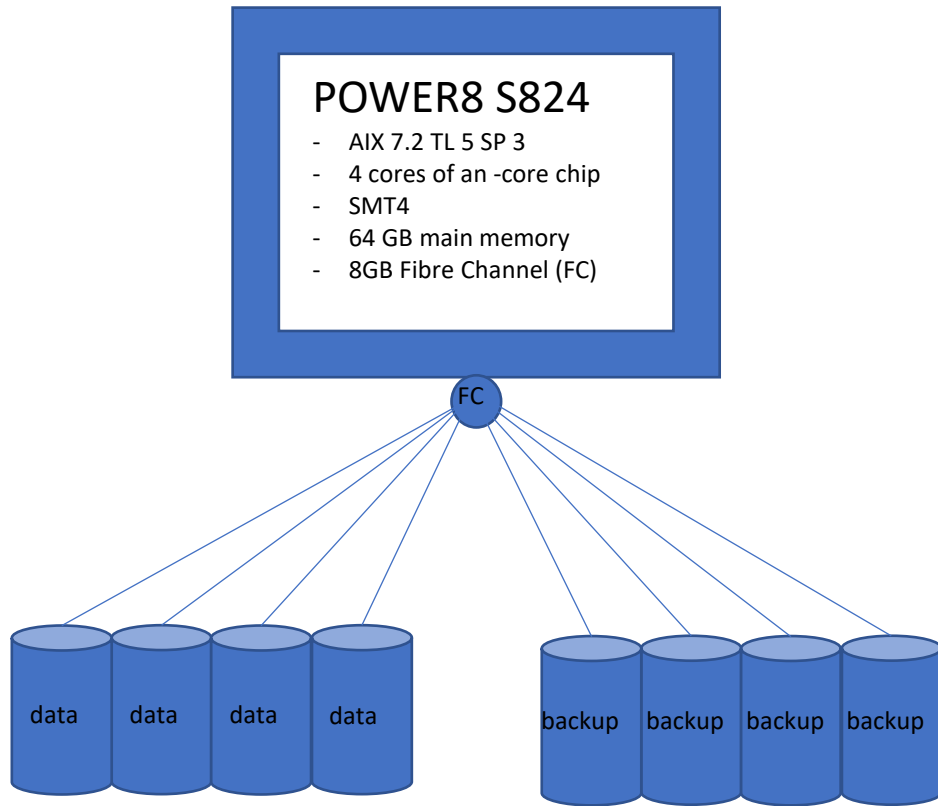   - libdb2zcompr.a
   - libdb2zcompr_encr.a
z15+
Linux NXU accelerator
   - libdb2zcompr.so
   - libdb2zcompr_encr.so

Since Db2 11.5.7+

Backup in Action – Test Environment

POWER8 S824
- AIX 7.2 TL 5 SP 3
- 4 cores of an -core chip
- SMT4
- 64 GB main memory
- 8GB Fibre Channel (FC)

FC

data data data data

backup backup backup backup

- IBM XIV storage system
- Db2: 11.5.6, database size: 270GB
- Database overall compression ratio: 52%
- Number of tablespaces: 48
- Automatic backup settings:
  - Parallelization: 30, buffer: 60 (unencrypted "default" backup)
  - Parallelization:15, buffer: 30 (encrypted backups)

Backup in Action – Encryption

[Malloc heap contention may cause performance degradation when using DB2 on AIX with specific features (ibm.com)](ibm.com) -

Optimized AIX malloc setting for instance owner

- Change the AIX malloc settings
  ```
  export MALLOCOPTIONS=buckets,multiheap:4
  export
  MALLOCBUCKETS=number_of_buckets:128,bucket
  _sizing_factor:64,blocks_per_bucket:1024
  ```

- Unlimt the size of the data area of the instance owner in `/etc/security/limits`:
  ```
  db2vfb:
  data = -1
  ```

- Update the Db2 registry and restart the instance:
  ```
  db2set DB2ENVLIST="MALLOCOPTIONS
  MALLOCBUCKETS"
  db2stop
  db2start
  ```

Reduce parallelization and buffer

- Backup Command
  ```
  db2 "backup db <dbname> to <backup paths>
  with 8 buffers parallelism 4 encrypt
  encrlib libdb2encr.a
  ```

- Manually adapted backup options

  Parallelism: Defines the number of tablespaces backed up in parallel

  Buffer: At least two times the parallelism value

Backup in Action – Create Encrypted DB

Install Keystore using IBM GSKit

- Create keystore directory
  - `su – instance owner`
  - `mkdir <path>/keystore`

- Create keystore
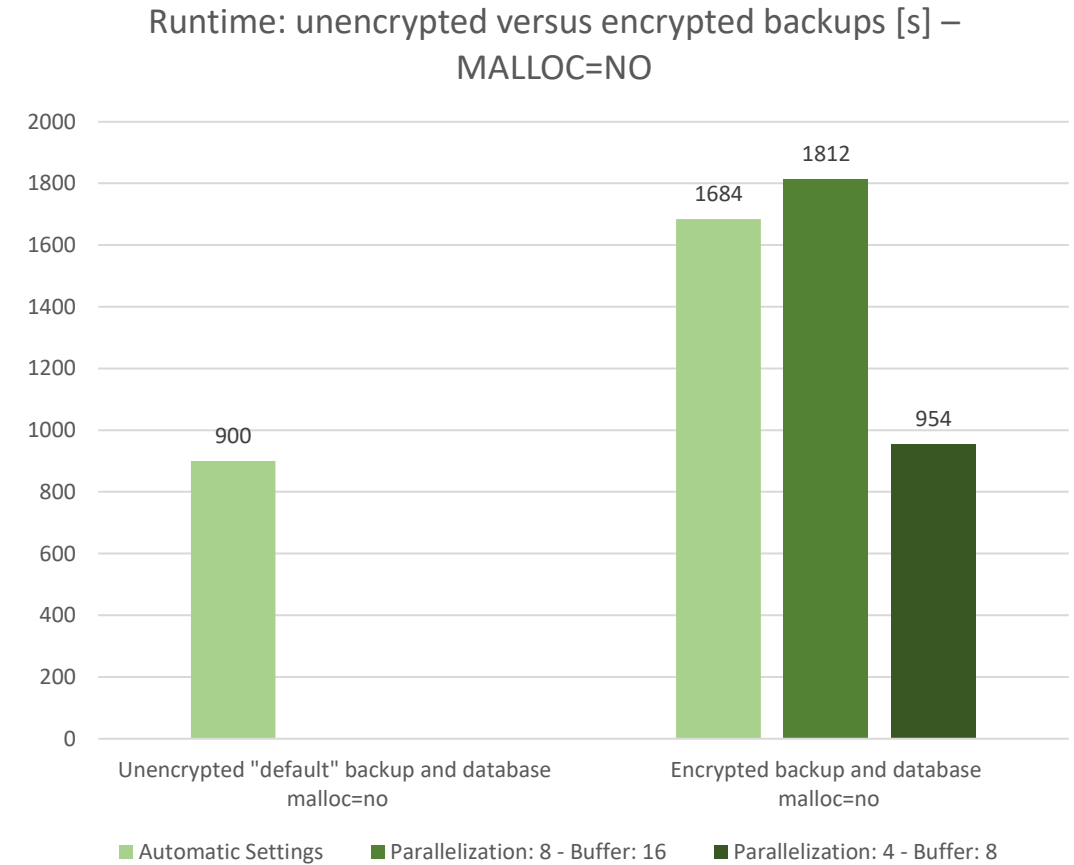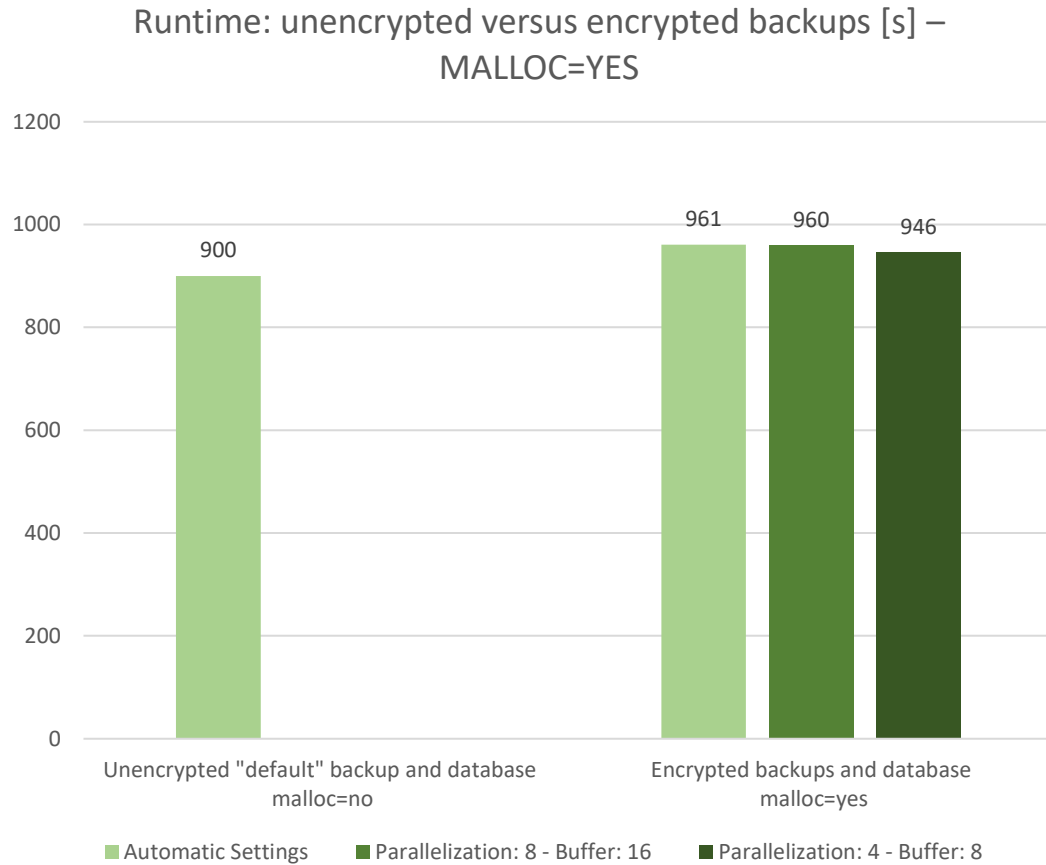 - `gsk8capicmd – keydb -create -db <path>/keystore/<keyfile>.p12 -pw <strong password> -string -type pkcs12 -stash`

Encrypt Database

- Configure instance
  - `db2 update db cfg using keystore_type pkcs12 Keystore_location <path>/keystore/<keyfile>.p12`
  - `db2stop`
  - `db2start`

  - `db2 backup db <dbname> to <backup paths>`

  - `db2 drop db <dbname>`
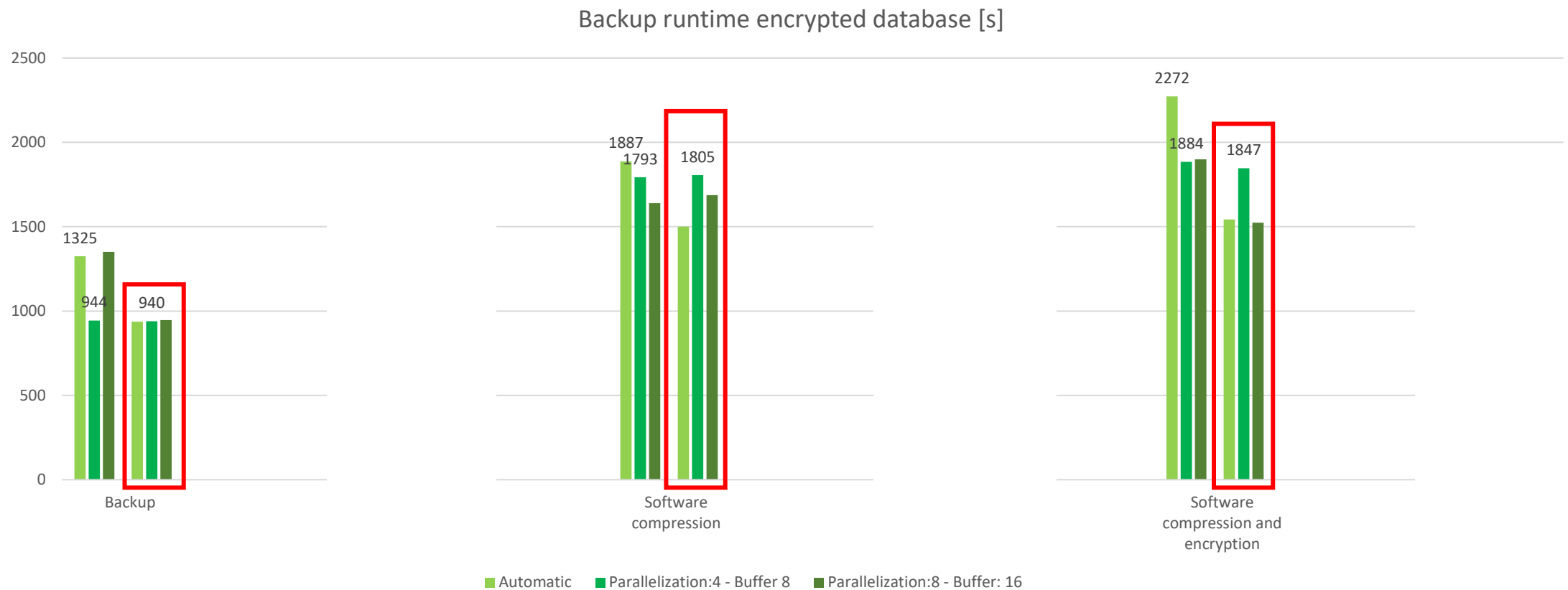
  - `db2 restore db <dbname> from <backup paths> taken at <backup timestamp> ENCRYPT`

You can even use HADR to encrypt the database as described here:

https://blogs.sap.com/2022/05/08/encrypting-an-sap-system-on-a-db2-for-luw-database-reduce-downtime-by-exploiting-the-hadr-feature/
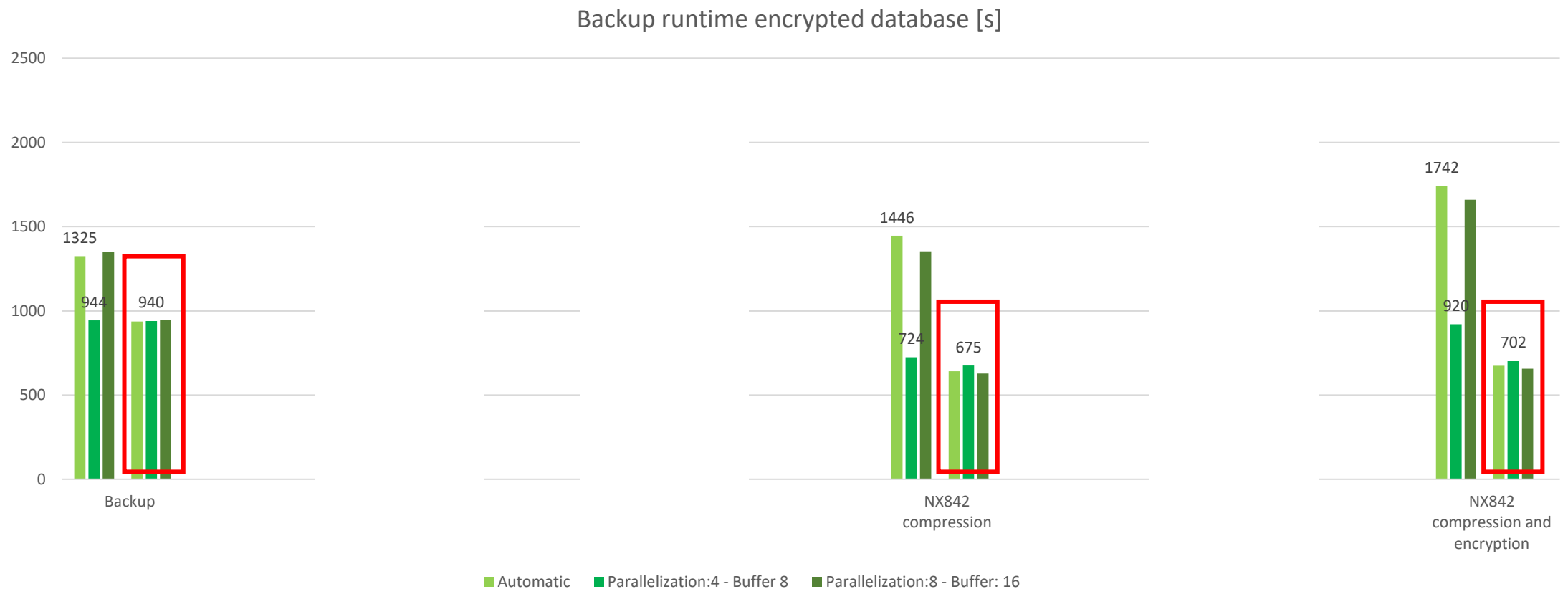
Backup in Action – Encryption

Runtime: unencrypted versus encrypted backups [s] – MALLOC=YES

Runtime: unencrypted versus encrypted backups [s] – MALLOC=NO

Backup in Action – Software Compression & Encyrption

Backup runtime encrypted database [s]

Malloc =yes

Backup in Action – AIX NX842 Compression & Encyrption

Backup runtime encrypted database [s]

Malloc =yes

Backup in Action – Compression & Encyrption
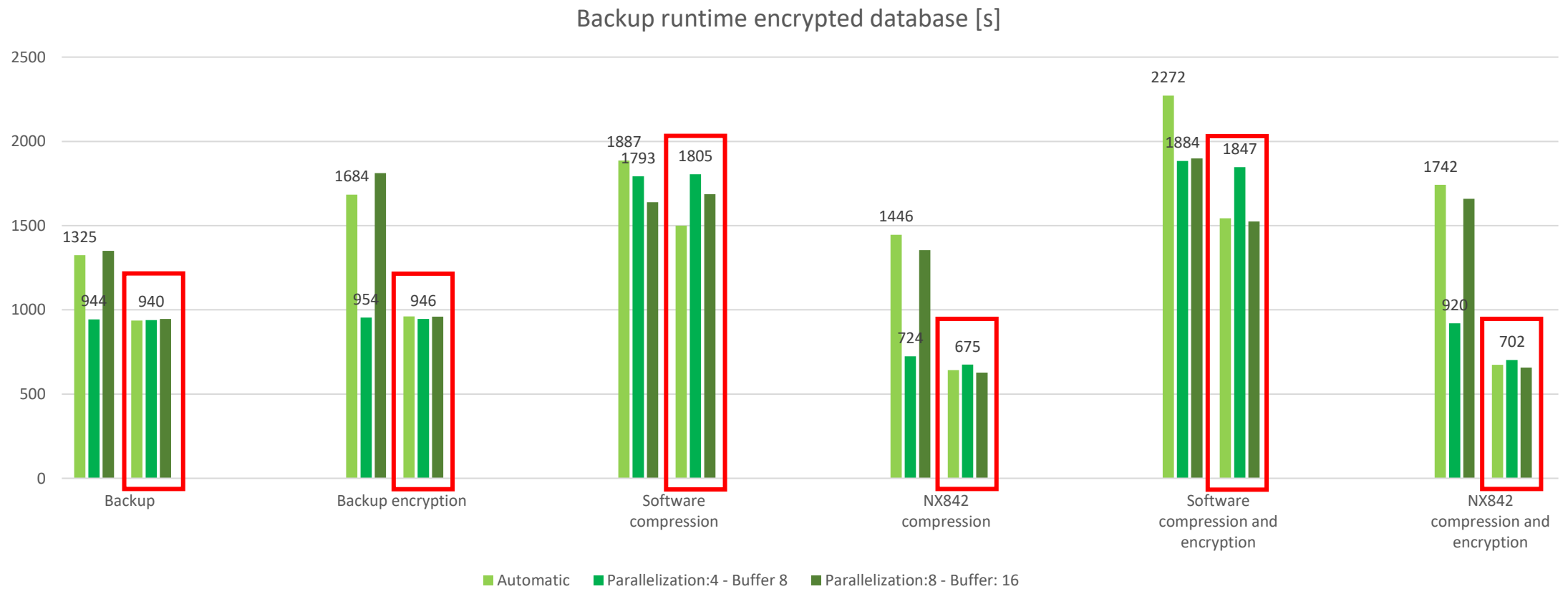
Backup runtime encrypted database [s]

Backup in Action – Unencrypted Databases

Backup runtime - unencrypted database [s]

Legend: Automatic, Parallelization: 4 - Buffer: 8, Parallelization: 8 - Buffer: 16
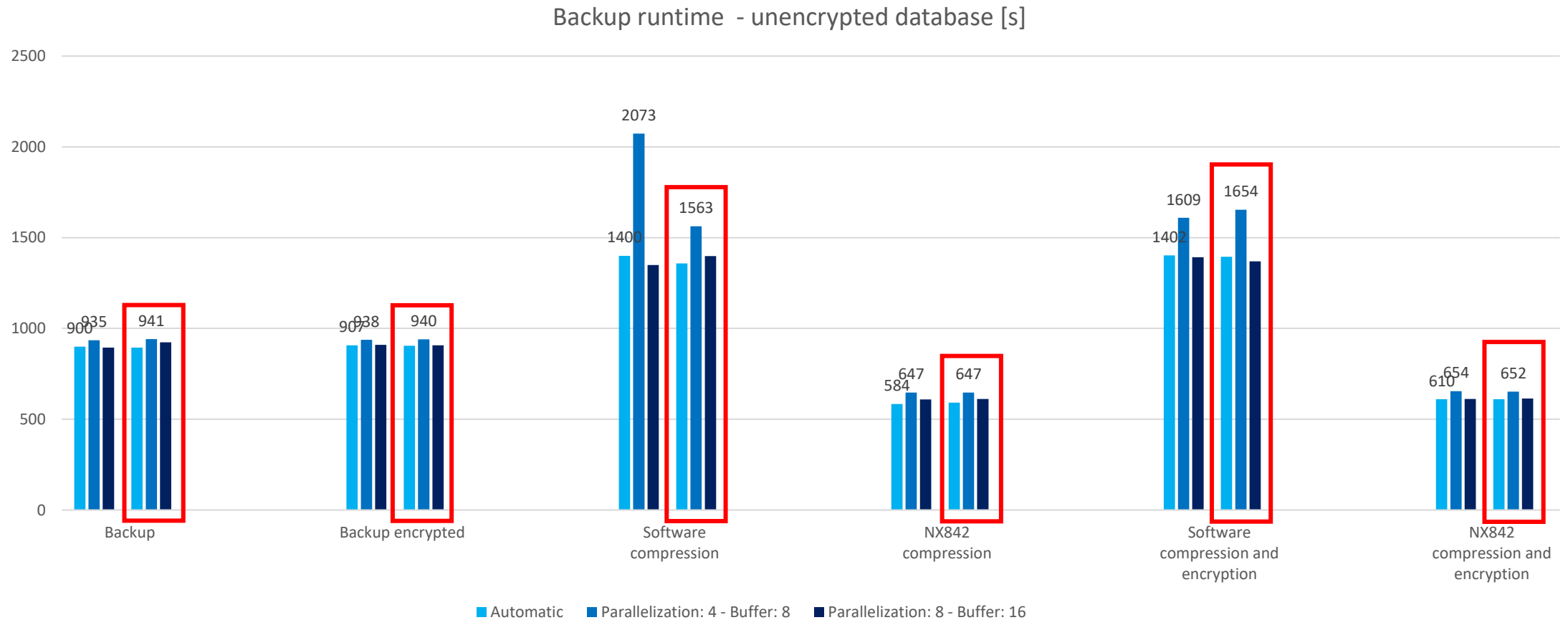
Malloc =yes

Restore of Encrypted Backups

Restore runtime [s]
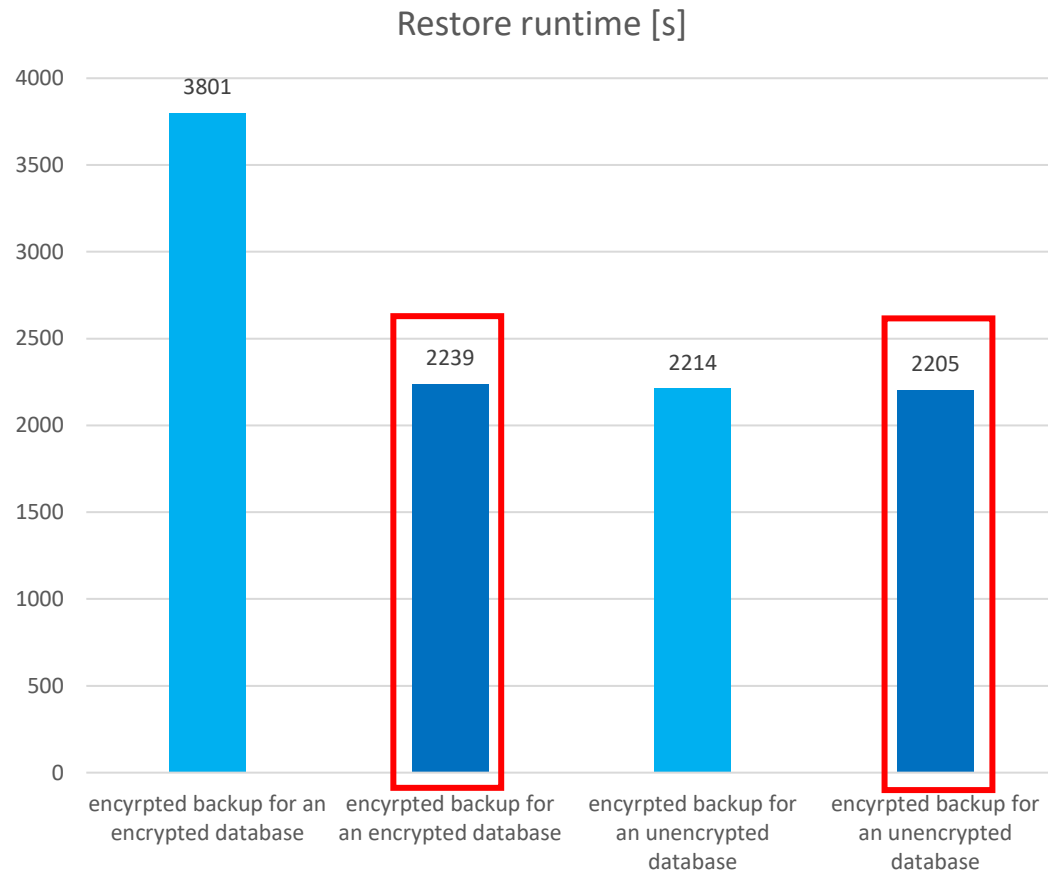
restoring into encrypted database:
- From encrypted or unencrypted backup
- With MALLOC workaround or not

Malloc =yes

ZLib vs. Common Compression on LinuxX86

- Database size: 48.1 GB
- Test sequence:
  - db2 backup db jkl to /target compress
  - db2set DB2_BCKP_COMPRESSION=ZLIB
  - …
  - db2 update db cfg for jkl using encrlib libdb2compr_encr.so
  - …
  - db2 backup db jkl to /target compress

- Common Db2 Compression
  - Runtime: 474 seconds
  - Size: 21.1 GB (43% of orig size)

- ZLib Compression
  - Runtime: 305 seconds
  - Size: 12.75 GB (27% of orig size)

- Backup runtime reduced by 35%

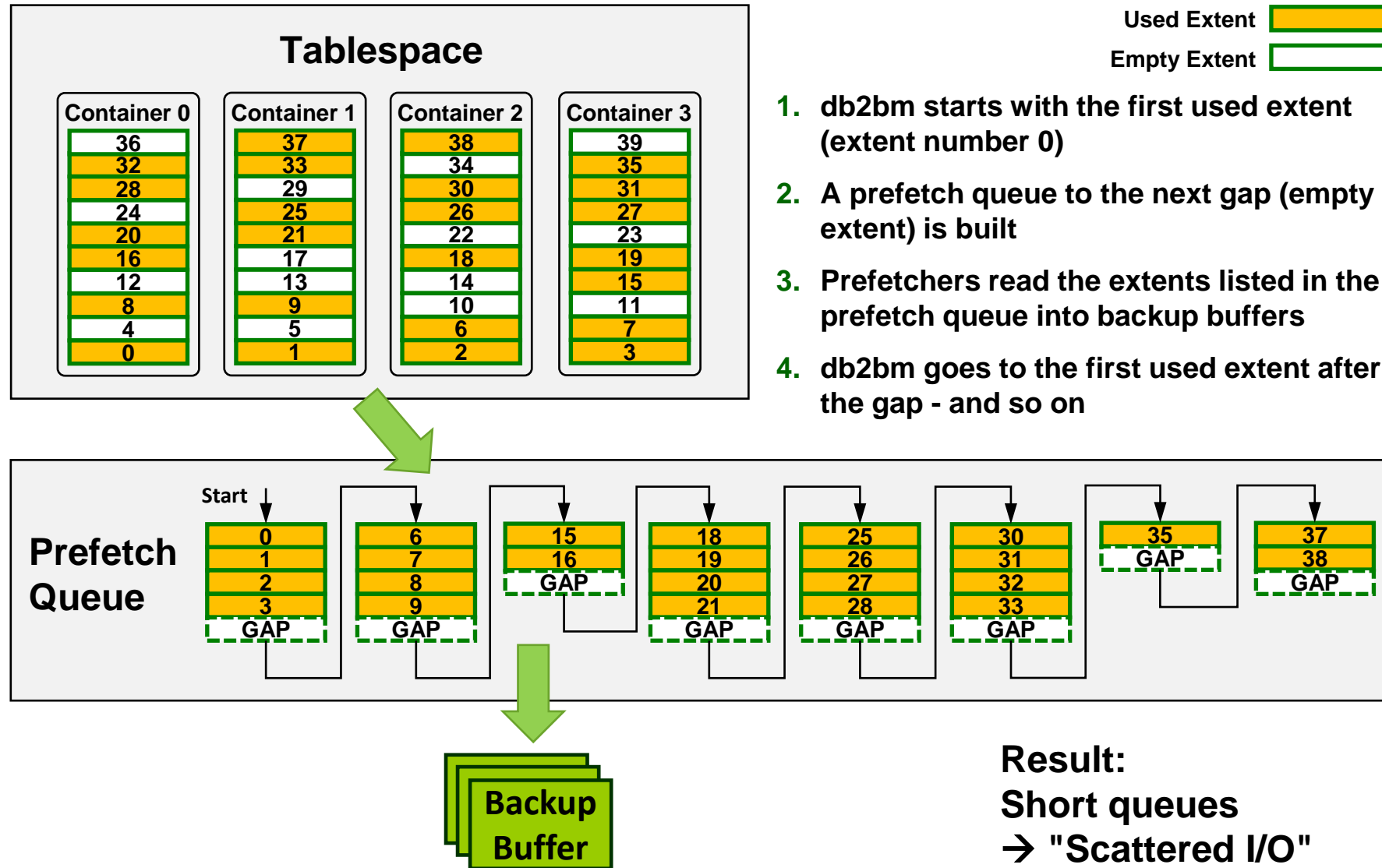- In general, Zlib compressed a little bit better compared to NX842; runtimes are about the same

X86: intel provides a special zlib_next generation library, that uses SIMD instructions, factors 2-4 faster than traditional zlib implementation, uses Vector Units in Intel CPUs (zlib_ng)

Backup Execution: Tablespace Read Sequence
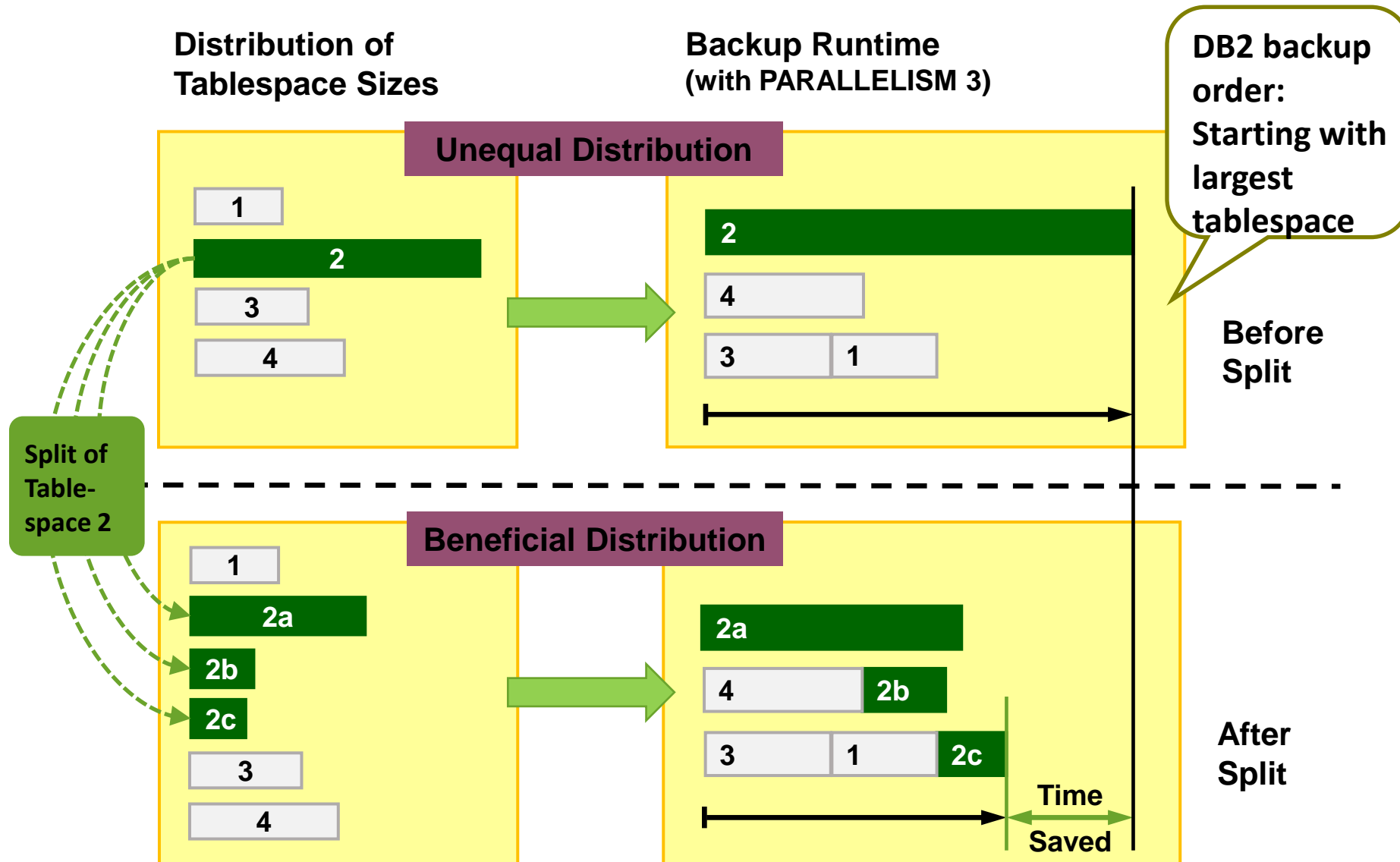
- Can be monitored using WaitQ element of BM section in the BARstats
- Addressed by `ADMIN_MOVE_TABLE` SP or DB6CONV (in SAP, or using tablespace pool) to redistribute tables to tablespaces

Backup Behavior in Case of Fragmentation

Used Extent 🟧
Empty Extent ⬜

Tablespace

Container 0	Container 1	Container 2	Container 3
36	37	38	39
32	33	34	35
28	29	30	31
24	25	26	27
20	21	22	23
16	17	18	19
12	13	14	15
8	9	10	11
4	5	6	7
0	1	2	3

1. **db2bm starts with the first used extent (extent number 0)**

2. **A prefetch queue to the next gap (empty extent) is built**

3. **Prefetchers read the extents listed in the prefetch queue into backup buffers**

4. **db2bm goes to the first used extent after the gap - and so on**

Prefetch Queue

Start ↓

0	6	15	18	25	30	35	37
1	7	16	19	26	31	GAP	38
2	8	GAP	20	27	32		GAP
3	9		21	28	33		
GAP	GAP		GAP	GAP	GAP		

Backup Buffer

Result:
Short queues
→ "Scattered I/O"
→ Increased backup time

To address this, consider using db2 `ALTER TABLESPACE … REDUCE MAX` command

A

Tools – db2pd, …

- db2pd -utilities –repeat
- Or db2 list utilities
- dsmtop/db2top
- db2pd -barstats

```
db6db2:db2jkl 56> db2 list utilities

ID                              = 3
Type                            = BACKUP
Database Name                   = JKL
Member Number                   = 0
Description                     = offline db
Start Time                      = 08/23/2023 09:39:04.915061
State                           = Executing
Invocation Type                 = User
Throttling:
   Priority                     = Unthrottled
Progress Monitoring:
   Estimated Percentage Complete = 20
```

```
db6db2:db2jkl 55> db2pd -uti

Database Member 0 -- Active -- Up 0 days 00:49:23 -- Date 2023-08-23-09.39.08.291886

Utilities:
Address            ID       Type                    State     Invoker    Priority    StartTime            DBName    NumPhases    CurPhase    Description
0x000000020B0EDFE0 3        BACKUP                  0         0          0           Wed Aug 23 09:39:04  JKL       1            1           offline db

Progress:
Address            ID       PhaseNum    CompletedWork             TotalWork                    StartTime             Description
0x000000020B0E9388 3        1           1472074924 bytes          22645651780 bytes            Wed Aug 23 09:39:04   n/a
```

Tools - BARstats

2 forms:
1) Monitor while backup is running: db2pd –barstats
2) Final BARstats in db2diag.log

```
2016-08-25-12.01.57.841616-300 E15769840A2034          LEVEL: Info
PID     : 10092648              TID : 39895            PROC : db2sysc 0
INSTANCE: db2vfb                NODE : 000             DB   : VFB
APPHDL  : 0-2350                APPID: *LOCAL.db2vfb.160825165101
AUTHID  : DB2VFB                HOSTNAME: rubix-lp02.aus.stglabs.ibm.com
EDUID   : 39895                 EDUNAME: db2agent (VFB) 0
FUNCTION: DB2 UDB, database utilities, sqluxLogDataStats, probe:395
MESSAGE : Performance statistics
DATA #1 : String, 1514 bytes

Parallelism     = 4
Number of buffers = 8
Buffer size     = 16781312 (4097 4kB pages)

                                                          Compr
BM#    Total      I/O      Compr     MsgQ      WaitQ     Buffers    MBytes    MBytes
---  --------  --------  --------  --------  --------   --------  --------  --------
000    655.56    588.94    62.05     0.06      0.30       3406     74941    100569    25614
001    655.56    599.01    37.13     0.02     17.29       1665     54944     67462    12509
002    655.34    586.01    48.81     0.03     17.41       2523     62758     81687    18928
003    655.34    588.57    46.71     0.03     17.57       2212     66360     82893    16533
---  --------  --------  --------  --------  --------   --------  --------  --------
TOT   2621.81   2362.55   194.71     0.15     52.58       9806    259004    332613

MC#    Total      I/O                MsgQ      WaitQ     Buffers    MBytes
---  --------  --------            --------  --------   --------  --------
000    655.56    122.44             533.07     0.00       2474     39577
001    655.62    121.34             533.96     0.24       2441     39033
002    655.56    121.34             533.90     0.24       2458     39321
003    655.56    120.33             534.93     0.24       2437     38985
---  --------  --------            --------  --------   --------  --------
TOT   2622.31    485.46            2135.88     0.72       9810    156918

2016-08-25-12.01.57.841914-300 E15771875A477          LEVEL: Info
PID     : 10092648              TID : 39895            PROC : db2sysc 0
INSTANCE: db2vfb                NODE : 000             DB   : VFB
APPHDL  : 0-2350                APPID: *LOCAL.db2vfb.160825165101
AUTHID  : DB2VFB                HOSTNAME: rubix-lp02.aus.stglabs.ibm.com
EDUID   : 39895                 EDUNAME: db2agent (VFB) 0
FUNCTION: DB2 UDB, database utilities, sqlubcka, probe:1070
MESSAGE : Backup complete.
```

- **1** *BM* (buffer manipulator): Number of buffer manipulators launched

- *MC* (media controller): Number of media controllers launched

- **2** *Total*: Time a BM or MC exists which equals the backup runtime

- **3** *I/O*: Time spent for read and write operations

- **4** *Compr*: Time spent for the compression

- **5** *MsgQ*: Time waiting for an I/O buffer

- **6** *WaitQ*: Time waiting for next instruction from the db2agent, can be used to tell if tablespaces are evenly distributed

- **7** *Mbytes*: Amount of uncompressed and compressed data read or written by the different   BM or MC. *Mbytes TOT* shows the size of the uncompressed and compressed backup.

- **8** Compr MBytes: quantity of uncompressed data that was compressed

Example output for backup performance monitoring in Db2 Knowledge Center (Db2 11.5)

Checking Backup Images

- Use `db2ckbkp` to check images on disk

- Use `db2adutl` to check images in TSM

- Use the registry variable `DB2_BCKP_PAGE_VERIFICATION` to check page consistency during the backup

Tools – db2ckbkp

- `db2ckbkp <image>`
  - Checking the image
- `db2ckbkp -H`
  - Reading the header of the image

```
db2jkl 54> db2ckbkp
JKL.0.db2jkl.DBPART000.20230823093905.001

[1] Buffers processed:     ###...###

Image Verification Complete - successful.
```

```
=====================
MEDIA HEADER REACHED:
=====================
    Server Database Name            -- JKL
    Server Database Alias           -- JKL
    Client Database Alias           -- JKL
    Timestamp                       -- 20230823093905
    Database Partition Number       -- 0
    Instance                        -- db2jkl
    Database Configuration Type     -- 0 (Non-shared data)
    Sequence Number                 -- 1
    Database Member ID              -- 0
    Release ID                      -- 0x1500 (DB2 v11.5.8.0)
    AL version                      -- V:11 R:5 M:8 F:0 I:0 SB:0
    Database Seed                   -- 0x78861BF4
    DB Comment's Codepage (Volume)  -- 0
    DB Comment (Volume)             -- SAP database JKL
    DB Comment's Codepage (System)  -- 0
    DB Comment (System)             -- SAP database JKL
    Authentication Value            -- 255 (Not specified)
    Backup Mode                     -- 0 (Offline)
    Includes Logs                   -- 0 (No)
    Compression                     -- 2 (Encrypted)
    Backup Type                     -- 0 (Database-level)
    Backup Granularity              -- 0 (Non-incremental)
    Merged Backup Image             -- 0 (No)
    Status Flags                    -- 0x1
                                       Consistent across all members
    System Catalogs in this image   -- 1 (Yes)
    Catalog Partition Number        -- 0
    DB Codeset                      -- UTF-8
    DB Territory                    -- US
    LogID                           -- 1684329437
    LogPath                         -- /db2/JKL/log_dir/
    Backup Buffer Size              -- 16781312 (4097 4K pages)
    Number of Sessions              -- 1
    Platform                        -- 0x1E (Linux-x86-64)
    Encrypt Info Flags              -- 0x1
                                       Source DB was encrypted

The proper image file name would be:
JKL.0.db2jkl.DBPART000.20230823093905.001


Image header dumped -- NO VERIFICATION PERFORMED.
```

Tools – db2 history file

- `db2 list history backup all for <dbname>`
  - Operation: **B**ackup
  - Object: **D**atabase
  - Type: **F**ull


```
Op Obj Timestamp+Sequence Type Dev Earliest Log Current Log  Backup ID
-- --- ------------------ ---- --- ----------- ----------- -------------
 B   D  20230627111747004    F   N S0000000.LOG S0000000.LOG
 ----------------------------------------------------------------------
   Contains 155 tablespace(s):

00001 SYSCATSPACE
00002 SAPTOOLS
00003 SAPEVENTMON
00004 SYSTOOLSPACE
...
00049 ZTOM#TEST@01D
00050 ZTOM#TEST@01I
00051 ZTOM#TEST@01L
...
00136 D01#ZBWTP@10D
00137 D01#ZBWTP@10I
00138 D01#ZBWTP@10L
...
 ----------------------------------------------------------------------
     Comment: DB2 BACKUP D01 OFFLINE
  Start Time: 20230627111747
    End Time: 20230627115722
      Status: A
 ----------------------------------------------------------------------
EID: 803291 Location: /backup
```

Layout & Configuration – Registry + DB CFG

- DB2_BCKP_INCLUDE_LOGS_WARNING
  - Default: False
  - SAP customers: True

- DB2_BCKP_PAGE_VERIFICATION
  - Default: False

- DB2_BCKP_COMPRESSION
  - Default: Compress
  - Values: NX842, ZLIB

db2 get db cfg for <dbname>

- Encryption Library for Backup (ENCRLIB) = libdb2encr.so
- Encryption Options for Backup (ENCROPTS) = CIPHER=AES:MODE=CBC:KEY LENGTH=256
- Encrypted database = YES
- Keystore type (KEYSTORE_TYPE) = PKCS12
- Keystore location (KEYSTORE_LOCATION) = <PATH/keystore.p12

Settings influence the backup command

More Reading

- [Understanding Db2's Backup and Restore Statistics](#)

- [Db2 backup command in Db2 Knowledge Center (Db2 11.5)](#)

- [Hardware accelerated backup and log file compression in Db2 Knowledge Center (Db2 11.5)](#)

- [Power NX842 Compression for Db2](#)

- [Db2 Encryption overview in Db2 Knowledge Center (Db2 11.5)](#)

- [Example output for backup performance monitoring in Db2 Knowledge Center (Db2 11.5)](#)

- [db2ckbkp – check backup command in Db2 Knowledge Center (Db2 11.5)](#)

SAP on Db2 documentation on SAP Help Portal
https://help.sap.com/viewer/p/DB6
- New/Updated SAP / Db2 guides

SAP on Db2 in der SAP Community
https://www.sap.com/community/topic/db2-for-linux-unix-and-windows.html
-   News about Db2 development
-   Recent Blogs