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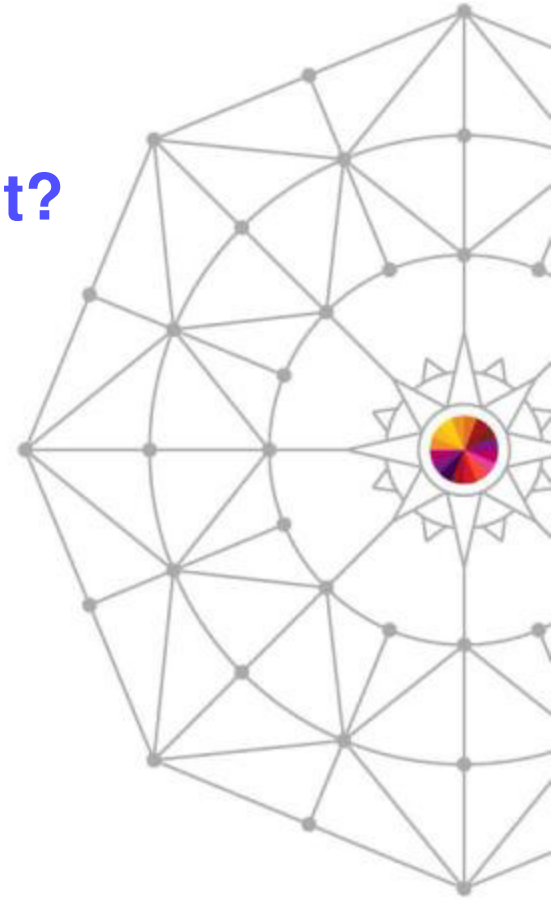
zEnterprise Data Compression

What is it and how do I use it?



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Session 15081

SHARE in Anaheim

Agenda

- Compression Overview
  - Why Compression
  - What is zEDC?
- zEDC Overview
  - What is DEFLATE?
  - Setup and configuration
- Using zEDC
  - zlib
  - Java
  - SMF
  - Sterling Connect:Direct

Other Sessions of Interest

- Session 14948 - Tools for Managing Big Data Analytics on z/OS
  - Presenters: Mike Stebner, Joe Sturonas
  - Wednesday, March 12, 2014 at 11:00
- Session 15207 - System z Batch Network Analyzer (zBNA) Tool
  - Presenter: John Burg
  - Wednesday, March 12, 2014 at 1:30
- Session 15080 - z/OS zEnterprise Data Compression Usage and Configuration
  - Presenter: Cecilia C. Lewis
  - Thursday, March 13, 2014 at 1:30

Explosive Growth In Data
Over 2000 Petabytes of Data Created Per Day

Data Compression will become pervasive

- I/O throughput is struggling to keep up with increasingly data driven applications
- Batch workloads are accessing more data from disk and network connections
- Business opportunities can be lost due to the cost prohibitive nature of keeping data online

Data needs to be shared across platforms

- Data is being exchanged among business partners
- Compression can substantially reduce the amount of data transferred
- Industry standard formats need to be used for transparent peer to peer communication

Compression solves problems in the enterprise

- Improves the effective throughput of data over storage and communication networks
- Allows more data to remain online for increases business value
- Less data to perform encryption operations against
- Makes high cost/byte storage technology such as flash memory more affordable

IBM z Enterprise Data Compression

New data compression offering

What is it?

- ✓ *zEDC Express is an IO adapter that does high performance industry standard compression*
- ✓ *Used by z/OS Operating System components, IBM Middleware and ISV products*
- ✓ *Applications can use zEDC via industry standard APIs (zlib and Java)*
- ✓ *Each zEDC Express sharable across 15 LPARs, up to 8 devices per CEC.*
- ✓ *Raw throughput up to* **1 GB/s** *per zEDC Express Hardware Adapter*

What Changes?

It is time to revisit your decisions about compression.

- **Disk Savings:** Many people are already getting value from CMPSC compression and software compression today
- **Performance:** High throughput alternative to existing System Z compression for large or active files.
- **Industry Standard:** Low cost compressed data exchange across all platforms
- **Pervasive:** Standard APIs allow quick adoption by middleware products running on System Z

What is the Value?

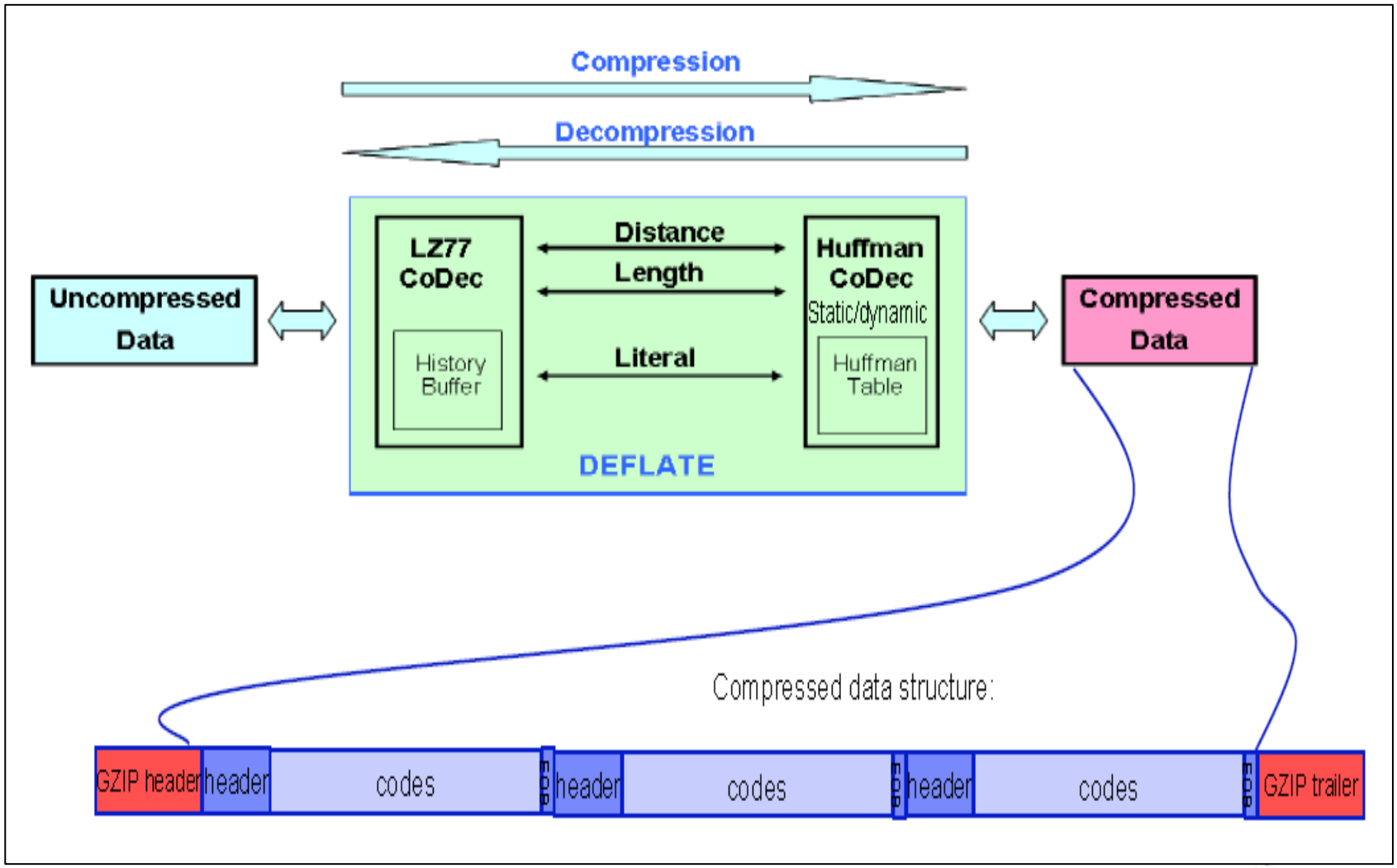
New sources of customer value

- **QSAM/BSAM** compression can save disk cost
- **Business Partner Data Exchange** can have higher throughput with lower CPU cost
- **Sterling Connect:Direct** saves additional link bandwidth, elapsed time.
- **ISV Products** delivery expanded customer value
- **Java** transparently accelerates java.util.zip
- **IBM Encryption Facility** for standard compliant data exchange
- **Improved availability** with SMF compression

What is DEFLATE?

- zEDC uses the DEFLATE file format – defined by the IETF RFC 1951 document
  - How deflate data is generated is up to the program
- The DEFLATE file is generated using the following two algorithms:
  - LZ77 (Lempel-Ziv 1977) – Provide pattern matching via a 32k rolling window in the data. Matches are replaced with a back reference.
  - Huffman encoding - Encodes the symbols into a set of bit patterns where the most frequently symbols get the smallest bit patterns
- Two types of Huffman encoding:
  - Static (Fixed) Huffman – predefined alphabet used to encode the symbols (RFC 1951)
  - Dynamic Huffman – alphabet is defined based on the symbols in the data. The Huffman tree alphabet is imbedded in the DEFLATE block
- The file format is bit aligned, meaning the symbols do not fall on byte boundaries

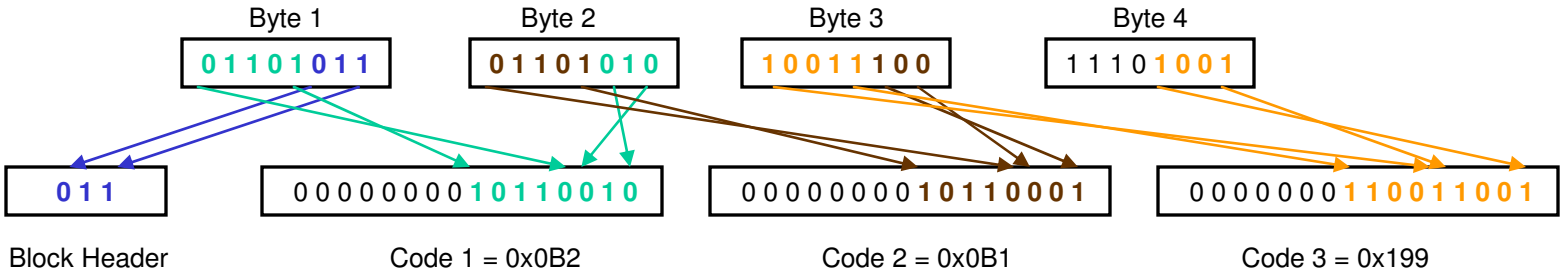
What is DEFLATE (cont)



What is DEFLATE (cont)

The alphabet of codes for the **Fixed Huffman** literals and length values are the following:

Literal Value	Bit Length	Codes
0 – 143 (0x000-0x08F)	8	0x030 – 0x0BF
144 – 255 (0x090-0x0FF)	9	0x190 – 0x1FF
256 – 279 (0x100-0x117**)**	7	0x000 – 0x017
280 – 287 (0x118-0x11F**)**	8	0x0C0 – 0x0C7



The Block Header indicates that **BFINAL** is on and that this is a **BTYPE** of Static Huffman Codes (b'01'). The alignment of the header is such that the right-most bit represents **BFINAL** and the next two bits represent **BTYPE** with the most significant bit in the right-most position.

The DEFLATE RFC defines that each byte is formatted so the most significant bit is in the right-most position. Bits need to be collected until they form a valid code as code lengths vary from 7 to 9 bits.

Using the above example we can now determine the first three Literal Values for this stream.

```
0x0B2 - 0x030 + 0   → 0x82 ('b')
0x0B1 - 0x030 + 0   → 0x81 ('a')
0x199 - 0x190 + 144 → 0x99 ('r')
```

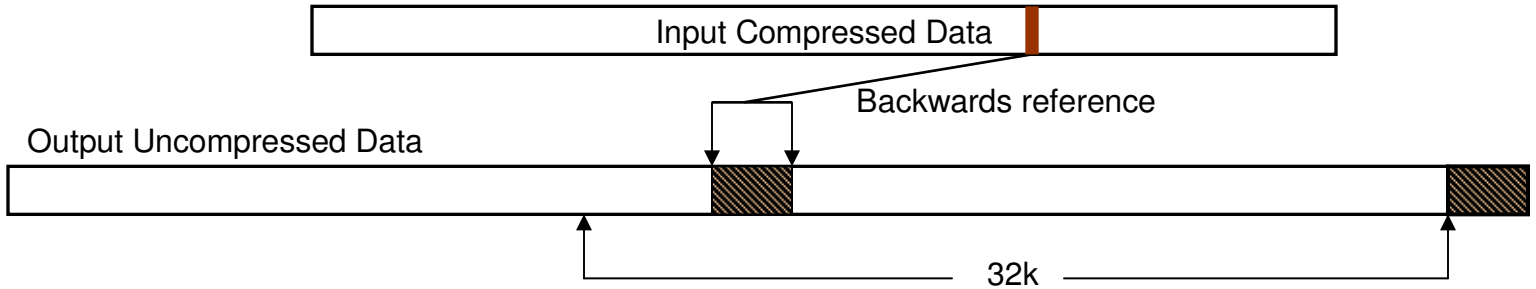
These calculations are done by taking the code, subtracting the start of the code range and adding the start of the literal range.

Example of Inflate (cont)

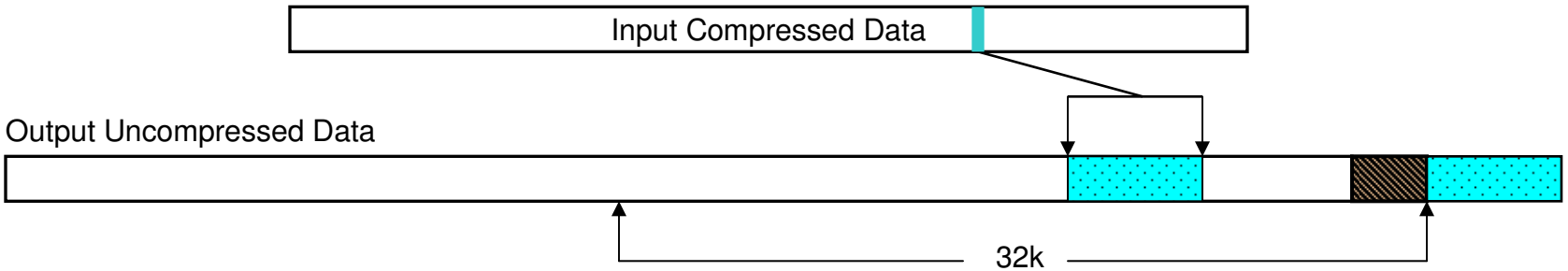
The DEFLATE compression format is considered dictionary-less. That means that the compressor of the file does not have to also save a dictionary of potential string matches.

This is accomplished with DEFLATE because the uncompressed data is the dictionary.

Take for instance a distance/length pair in the input compressed data stream.



After this symbol is decompressed, the rolling window looks like the following for the next symbol evaluation:



Example of Deflate

★The complete example is in the appendix

```
Compressed Data
bar bar bar bar
boo boo boo boo
blah blah blah blah
foo boo blah
blah foo blah
hello
```

The 1st backwards reference length includes symbols that are part of the compressed symbols themselves as shown here:

Byte#	String	Back Reference Len	Back Reference Character
4	bar-b	n/a	n/a
5	bar-ba	1	'a' at byte 1
6	bar-bar	2	'r' at byte 2
7	bar-bar-	3	' ' at byte 3
8	bar-bar-b	4	'b' at byte 4
9	bar-bar-ba	5	'a' at byte 5
10	bar-bar-bar	6	'r' at byte 6
11	bar-bar-bar-	7	' ' at byte 7
12	bar-bar-bar-b	8	'b' at byte 8
13	bar-bar-bar-ba	9	'a' at byte 10
14	bar-bar-bar-bar	10	'r' at byte 11

Start of overlap

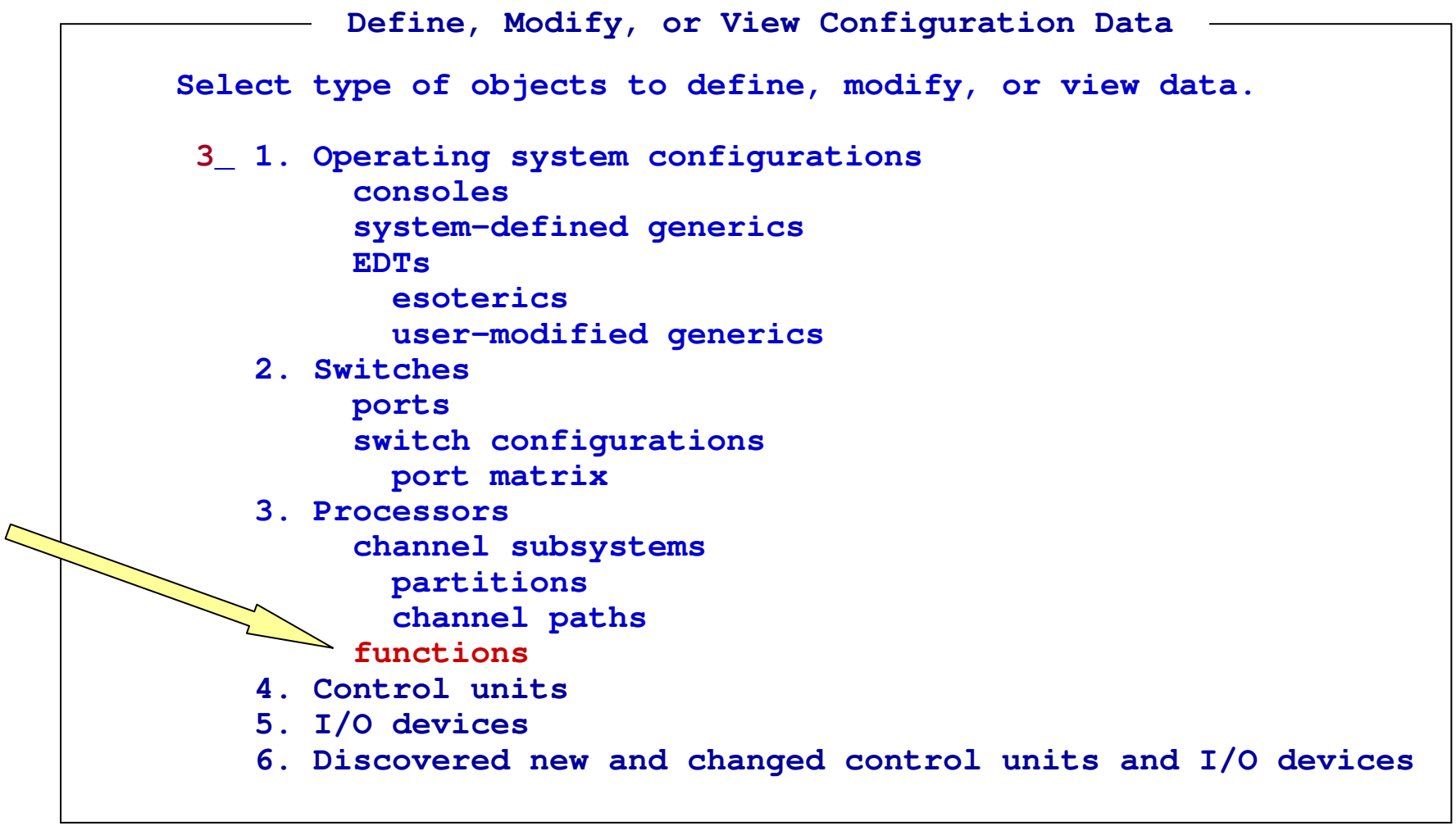
```
Byte #    Codes and Values
00000000 00b2 = 0082 ('b')
00000001 00b1 = 0081 ('a')
00000002 0199 = 0099 ('r')
00000003 0070 = 0040 (' ')
00000004 00b2 = 0082 ('b')    'r'  ' '  'b'  'a'  'r'  ' '  'b'  'a'  'r'
00000005 <000a, 0004> = 0081 0099 0040 0082 0081 0099 0040 0082 0081 0099
00000015 0045 = 0015 ('\n')
00000016 00b2 = 0082 ('b')
00000017 0196 = 0096 ('o')
00000018 0196 = 0096 ('o')
00000019 0070 = 0040 (' ')    'o'  'o'  ' '  'b'  'o'  'o'  ' '  'b'  'o'  'o'
00000020 <000b, 0004> = 0082 0096 0096 0040 0082 0096 0096 0040 0082 0096 0096
00000031 0045 = 0015 ('\n')
...
```

Backward reference: length=10, distance=4 ('a' character at byte# 5)

zEDC Configuration Overview

- **Operating system requirements**
  - Requires z/OS 2.1 and new zEDC Express for z/OS feature
    - PTF Support for BSAM/QSAM in 1Q
  - z/OS V1.13 and V1.12 offer software decompression support only
- **Server requirements**
  - Exclusive to zEC12 and zBC12
  - New zEDC Express feature for PCIe I/O drawer (FC#0420)
    - One compression coprocessor per zEDC Express feature
    - Each feature can be shared across up to 15 LPARs
    - Up to 8 features available on zEC12 or zBC12
  - Recommended high availability configuration per server is four features
    - No additional software cost is incurred by increasing the number of hardware features
    - Provides high availability during concurrent update (half devices unavailable during update)
    - Recommended minimum configuration per service is two features
  - Hot pluggable
  - For best performance, feature is ***needed on all systems accessing the compressed data***
- **Capacity Planning**
  - The **z Batch Network Analyzer** now reports on potential zEDC usage for QSAM/BSAM data sets

HCD - Define, Modify or View Configuration Data



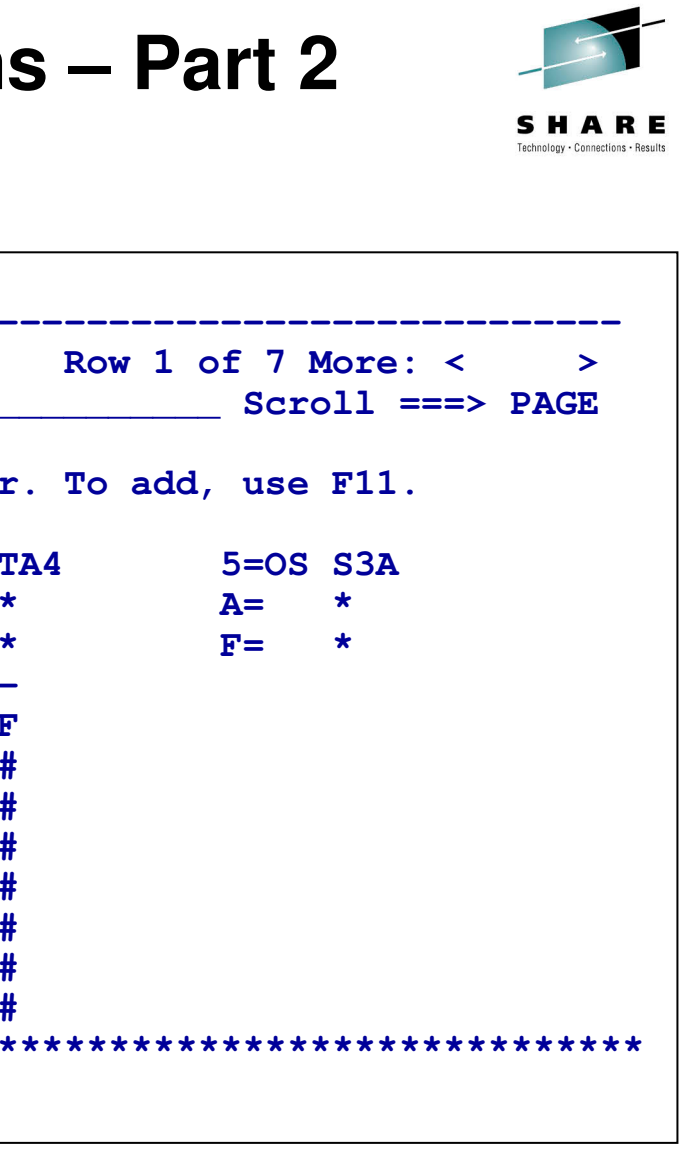
HCD - Displaying the Processor List


```
Goto  Filter  Backup  Query  Help
--------------------------------------------------------------------------------
                               Processor List       Row 1 of 11 More:       >
Command ===> ____________________________________________ Scroll ===> PAGE

Select one or more processors, then press Enter. To add, use F11.


/ Proc. ID Type +   Model +  Mode+ Serial-# + Description
_ D76      2094     S28      LPAR  __________ ICSF z9
_ H87      2097     E40      LPAR  __________ H87 STP Secondary
_ H88      2097     E40      LPAR  __________ H88 STP Primary
_ H89      2097     E64      LPAR  __________ H89 IOS Test z10
_ M32      2818     M10      LPAR  __________ M32 IOS Test zMR
F PBUV4    2827     H43      LPAR  __________ PBUV4 zEC12
_ P87      2827     H66      LPAR  __________ P87 zEC12
_ P88      2827     H66      LPAR  __________ P88 zEC12
_ P89      2827     HA1      LPAR  __________ P89 zEC12
_ P92      2827     H89      LPAR  __________ P92 zEC12 JEMT
_ R89      2817     M80      LPAR  __________ R89 IOS Test z196
****************************** Bottom of data ********************************
```


HCD - Displaying PCIE Functions


```
Goto  Filter  Backup  Query  Help
--------------------------------------------------------------------------------
                              PCIe Function List     Row 1 of 7 More:       >
Command ===> _____________________________________________ Scroll ===> PAGE

Select one or more PCIe functions, then press Enter. To add, use F11.

Processor ID . . . . : PBUV4        PBUV4 zEC12



/ FID    PCHID  VF+  Type+           Description
_ 010    340     1   ZEDC EXPRESS    ____________________________________
_ 011    340     2   ZEDC EXPRESS    ____________________________________
_ 012    340     3   ZEDC EXPRESS    ____________________________________
_ 013    340     4   ZEDC EXPRESS    ____________________________________
_ 014    340     5   ZEDC EXPRESS    ____________________________________
_ 020    360     1   ZEDC EXPRESS    ____________________________________
_ 021    360     2   ZEDC EXPRESS    ____________________________________
******************************* Bottom of data ********************************
```


HCD - Displaying PCIE Functions – Part 2



HCD - Adding a PCIE Function


```
                          Add PCIe Function

Specify or revise the following values.

Processor ID  . . . . : PBUV4          PBUV4 zEC12

Function ID . . . . . . 022
Type  . . . . . . . . . zedc express  +

PCHID . . . . . . . . . 360
Virtual Function ID . . 3_  +

Description . . . . . . ________________________________________

 F1=Help      F2=Split     F3=Exit      F4=Prompt    F5=Reset     F9=Swap
F12=Cancel
```


Enabling the zEDC Express for z/OS Feature

```
PRODUCT OWNER('IBM CORP')
        NAME('Z/OS')
        FEATURENAME('ZEDC')
        ID(5650-ZOS)
        VERSION(*)
        RELEASE(*)
        MOD(*)
        STATE(ENABLED)
```

- Update the IFAPRDxx parmlib member with the new feature
- **Warning** – This must be set at IPL time!!!

```
d prod,state,featurename(ZEDC)
IFA111I 22.18.15 PROD DISPLAY 000
S OWNER              NAME                FEATURE             VERSION   ID
E IBM CORP           Z/OS                ZEDC                * .* .*   5650-Z
```

```
D IQP
IQP066I 22.21.59 DISPLAY IQP 003
zEDC Information
 MAXSEGMENTS:                    0   (0M)
 Previous MAXSEGMENTS:         N/A
 Allocated segments:             0   (0M)
 ...
 Feature Enablement:     Enabled
```

- How to verify that the feature is enabled.

Configuring PCIE Devices to z/OS

CONFIG PFID(nn) command can be used to configure a PFID offline or online to z/OS

```
cf pfid(10),offline,force
IQP034I PCIE FUNCTION 0010 NOT AVAILABLE FOR USE.
 PCIE DEVICE TYPE NAME = (Hardware Accelerator    ).
IQP034I PCIE FUNCTION 0010 AVAILABLE FOR CONFIGURATION.
 PCIE DEVICE TYPE NAME = (Hardware Accelerator    ).
IEE505I PFID(10),OFFLINE
IEE712I CONFIG   PROCESSING COMPLETE
```

```
cf pfid(10),online
IQP034I PCIE FUNCTION 0010 ONLINE.
 PCIE DEVICE TYPE NAME = (Hardware Accelerator    ).
IEE504I PFID(10),ONLINE
IEE712I CONFIG   PROCESSING COMPLETE
```

Note: PFIDs can also be configured offline and online via the SE. z/OS will react to the PCIE availability events that are presented and react accordingly.

Displaying PCIE Devices

Device may appear twice in display after dynamic I/O or config. DP state means device waiting to be cleaned up.

ALLC state does not necessarily mean device is usable. Issue PCIE,PFID=nn command.

```
D PCIE
IQP022I 11.27.32 DISPLAY PCIE 313
PCIE      0010 ACTIVE
PFID  DEVICE TYPE NAME          STATUS  ASID  JOBNAME  PCHID VFN
0000  Hardware Accelerator      DP      013A  FPGHWAM  0380  0001
0010  Hardware Accelerator      ALLC    013A  FPGHWAM  053C  0001
0000  Hardware Accelerator      CNFG                   0380  0001
0013  10GbE RoCE                ALLC    002C  VTAM
0014  10GbE RoCE                STNBY
0099  Hardware Accelerator      ALLC    013A  FPGHWAM  053C  0002
00AA  UNNAMED  (1810 3D03)      CNFG
```

Devices are not necessarily displayed in PFID order.

Device type and vendor id are not known to z/OS

zEDC express devices show up as hardware accelerators. D PCIE,PFID=nn shows type of accelerator.

Address space that allocated device. FPGHWAM allocates all H/W accelerators.

Displaying PCIE Device Details

Application description specifies the type of H/W accelerator (if known)

Detailed device information is displayed only if the device is allocated by FPGHWAM address space.

```
D PCIE,PFID=10
IQP024I 16.33.20 DISPLAY PCIE 157
PCIE     0012 ACTIVE
PFID  DEVICE TYPE NAME          STATUS  ASID  JOBNAME  PCHID VFN
0010  Hardware Accelerator      ALLC    0013  FPGHWAM  053C  0001
 CLIENT ASIDS: NONE
 Application Description: zEDC Express
 Device State: Ready
 Adapter Info - Relid: 000000  Arch Level: 03
                Build Date: 06/12/2013  Build Count: 09
 Application Info - Relid: 000000  Arch Level: 00
```

Device is usable only if in the Ready state. All other states, except intervention required are transient.

Adapter and application info are obtained from the device itself

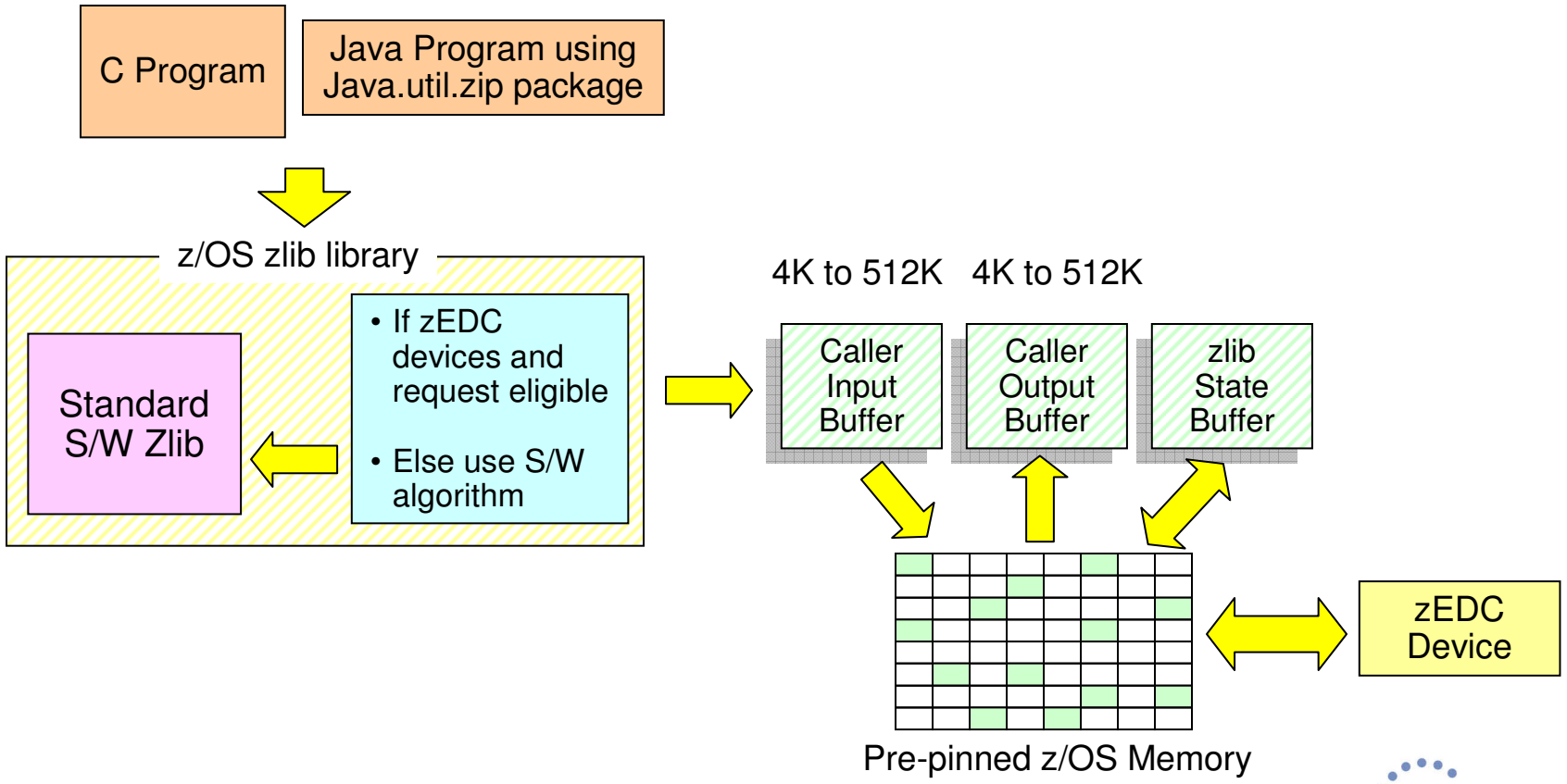
zlib

- zlib is a widely used open source C library that provides compression and decompression
  - Supports RFC 1950, 1951, and 1952
- Streaming model – data can be compressed or decompressed in chunks
- In order to use zEDC for compression/decompression
  - Relink applications with new IBM provided zLIB
  - Address spaces need READ access to the FPZ.ACCELERATORS.COMPRESSION SAF resource
  - First Inflate() or Deflate() must be at least as large as INFMINREQSIZE and DEFMINREQSIZE respectively in IQPPRMxx
  - The window size for deflate must be 32K
  - Note: The _HZC_COMPRESSION_METHOD environmental variable can be used to force S/W compression
- More information can be found in z/OS V2R1.0 MVS Callable Services for HLL

zlib Internal Structure

If the request can not be performed using zEDC then the software zlib code will be used for the request.

The zEDC requests are not done directly from user storage; the input data is copied into pre-allocated buffers and the output data is copied from these buffers back to user storage.



zlib Configuration Options

The IQPPRMxx member in SYS1.PARMLIB can be used to adjust internal settings for zlib behavior. For example

```
ZEDC,DEFMINREQSIZE=5,MAXSEGMENTS=7
```

This member will set the minimum input size of a deflate request via zlib to 5Kb and will set the maximum internal buffer size to 7 16Mb segments. The current settings and buffer usage can be displayed with the D IQP command:

```
D IQP
IQP066I 10.12.37 DISPLAY IQP 364
 zEDC Information
  MAXSEGMENTS:                    7   (112M)
  Previous MAXSEGMENTS:           4   (64M)
  Allocated segments:             1   (16M)
  Used segments:                  0   (0M)
  DEFMINREQSIZE:                  5K
  INFMINREQSIZE:                 16K
  Feature Enablement:    Enabled
```

Updated values from IQPPRMxx

Java and zEDC with java.util.zip

Java 7.1 provides zEDC access via the java.util.zip Inflater and Deflater classes. The same conditions that apply to zlib also apply to Java.

This example (try/catch blocks removed) shows the critical buffer sizes

```
byte buffer[] = new byte[64 * 1024];
byte outputFile[];


input = new FileInputStream(argv[0]);
output = new ByteArrayOutputStream();
gzStream = new GZIPOutputStream(output, 4096);

for(;;) {
    readBytes = input.read(buffer);

    if(readBytes < 0) {
          break;
    }
    else {
          gzStream.write(buffer, 0, readBytes);
    }
}
```

64Kb input buffer for deflate(). This must be >= DEFMINREQSIZE

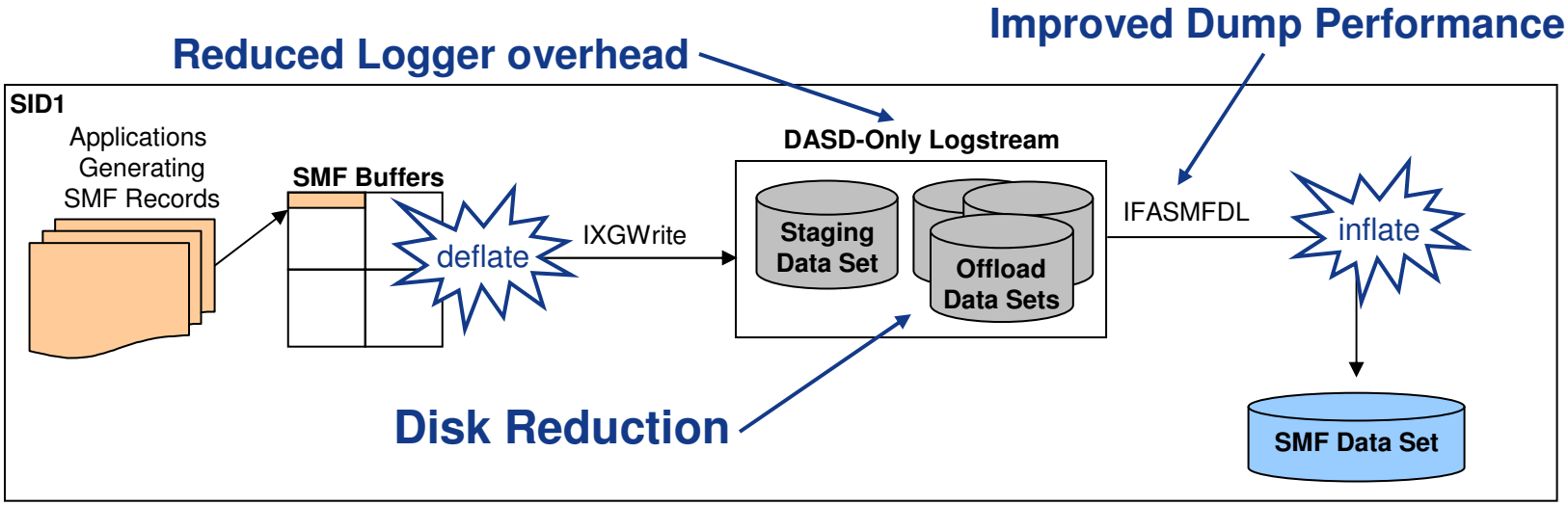
4Kb output buffer for deflate()

Data is read from an uncompressed file and written to a compressed file

When run on Java 7.1 the IBM Encryption Facility can use zEDC to perform compression.

SMF with zEDC

This example shows a DASD-Only logstream used for SMF recording



- Compression SMF logstreams reduce the amount of data in System Logger up to **4x** and reduce the elapsed time to extract IFASMFDL data up to **15%**
- zEDC compression must be available on all systems that will access zEDC compressed SMF logstreams
- Setup from SMFPRMxx either globally or per Logstream

SMFPRMxx in SYS1.PARMLIB
DEFAULTLSNAME(DEFAULT,…,**COMPRESS)**
LSNAME(SMF30,TYPE(30),…,**COMPRESS(PERMFIX(10M))**
LSNAME(RMF,TYPE(70:79)…,**COMPRESS)**

zEDC with IBM Sterling Connect:Direct for z/OS

High performance data compression for Managed File Transfer

- Sterling Connect:Direct can automatically leverage zEDC Express Accelerator for file compression and decompression as files are transferred
- Works with various dataset and file types on z/OS
- File transfers can be z/OS to z/OS, or z/OS to Distributed (UNIX, Linux, zLinux, and Windows)
- Fully compatible with zlib compression used in IBM Sterling Connect:Direct today – no changes required at end points

Up to **5%** compression improvement with zEDC over zlib software compression

44-82% reduction in elapsed time to transfer a file from z/OS to z/OS (results vary by dataset type and characteristics of the data)

Significant improvement in CPU time with zEDC over zlib software compression (sender TCB time and receiver TCB time)

zEDC RMF Reporting

New RMF report shows the utilization of each device.

RMF Postprocessor Interval Report : PCIE Activity Report

RMF Version : z/OS V2R1 SMF Data : z/OS V2R1
Start : 02/24/2014-05.48.00 End : 02/24/2014-05.48.44 Interval : 00:45:000 minutes

Hardware Accelerator Activity

Function ID	Time Busy %	Request Execution Time	Std Dev for Request Execution Time	Request Queue Time	Std Dev for Request Queue Time	Request Size	Transfer Rate T
0013	0.689	7.78	0.417	15.0	0.953	24.3	21.5

Hardware Accelerator Compression Activity

Function ID	Compression Request Rate	Compression Throughput	Compression Ratio	Decompression Request Rate	Decompression Throughput	Decompression Ratio	B
0013	885	11.6	1.14	0	0		64

The percent of this interval where this specific zEDC Express device was executing requests

Compression ratio of all requests serviced by zEDC. This will span all users of this device.

Average request queue time in Microseconds for this device.

Thank You!

Complete your session evaluations online at www.SHARE.org/Anaheim-Eval

Appendix

What is DEFLATE (an example)

This DEFLATE file example shows how each symbol is encoded include back references

Compressed Data

```
bar bar bar bar
boo boo boo boo
blah blah blah blah
foo boo blah
blah foo blah
hello
```

Byte # Codes and Values

```
00000000 00b2 = 0082 ('b')
00000001 00b1 = 0081 ('a')
00000002 0199 = 0099 ('r')
00000003 0070 = 0040 (' ')
00000004 00b2 = 0082 ('b')
00000005 <000a, 0004> = 0081 0099 0040 0082 0081 0099 0040 0082 0081 0099
00000015 0045 = 0015 ('\n')
00000016 00b2 = 0082 ('b')
00000017 0196 = 0096 ('o')
00000018 0196 = 0096 ('o')
00000019 0070 = 0040 (' ')
00000020 <000b, 0004> = 0082 0096 0096 0040 0082 0096 0096 0040 0082 0096 0096
00000031 0045 = 0015
00000032 00b2 = 0082
00000033 0193 = 0093
00000034 00b1 = 0081
00000035 00b8 = 0088
00000036 0070 = 0040
00000037 <000e, 0005> = 0082 0093 0081 0088 0040 0082 0093 0081 0088 0040 0082 0093 0081 0088
00000051 0045 = 0015
00000052 00b6 = 0086
00000053 <0008, 0020> = 0096 0096 0040 0082 0096 0096 0040 0082
00000061 <0004, 000d> = 0093 0081 0088 0015
00000065 <0005, 0017> = 0082 0093 0081 0088 0040
00000070 00b6 = 0086
00000071 <0008, 000e> = 0096 0096 0040 0082 0093 0081 0088 0015
00000079 00b8 = 0088
00000080 00b5 = 0085
00000081 0193 = 0093
00000082 0193 = 0093
00000083 0196 = 0096
00000084 0045 = 0015
```