Boosting Enterprise Transaction Processing using Hardware Acceleration

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IBM Research & Development
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IBM LinuxONE™

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Agenda

- IBM LinuxONE System
- Future Trends/Requirements and LinuxONE
- Hardware Acceleration Support on IBM LinuxONE
  - Compression with zEDC card
  - Encryption with CPACF and CEX5S
- Concluding Remarks

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IBM LinuxONE
Combination of Enterprise and Linux

IBM LinuxONE™

Availability
Low unplanned downtime

Scalability
Scale-out with virtualization
Scale-up for large apps/data

Performance
High I/O throughput
4 levels of cache

Security
Dedicated crypto processors
Crypto Cards

Reliability
Embedded error detection
Disaster recovery

Freedom

Customization
Optimize aspects of Kernel

Stability
High uptimes
Regular updates
Worldwide community

Innovation

Software Quality
Multitude of choices
Quick/self updates for open-source

Flexibility

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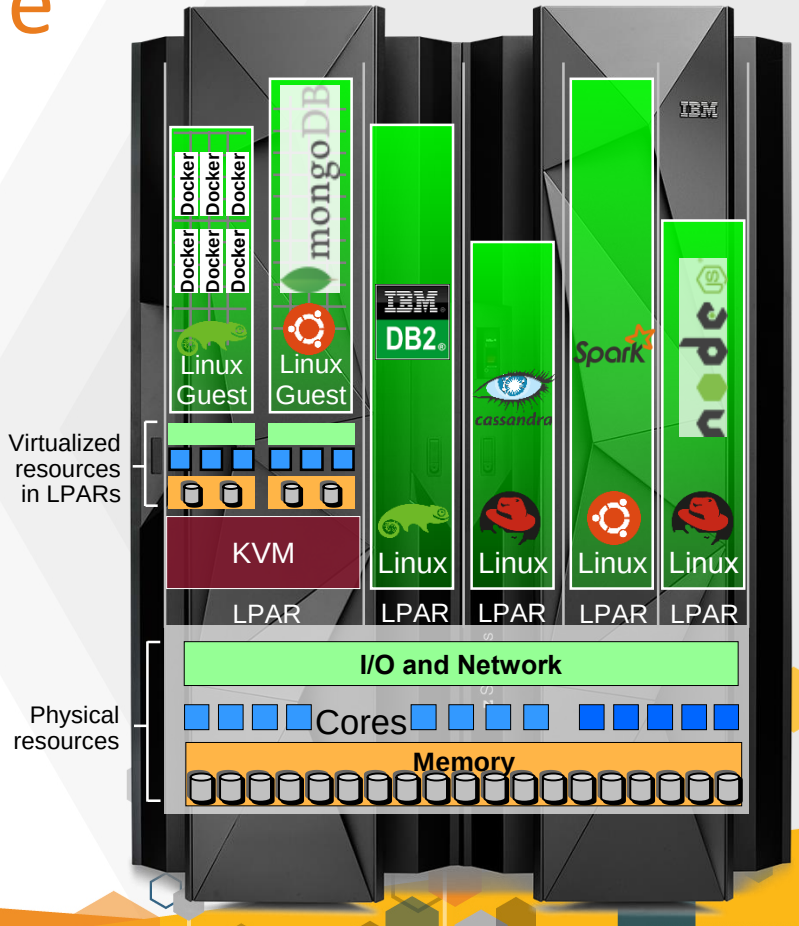
LinuxONE Architecture

- Cores:
  - Up to 141 cores with SMT
- Memory:
  - Up to 10 TB
- LPAR: Logical Partition
  - Subset of hardware resources virtualized as a separate computer with a running Linux OS, up to 85
- Virtualization
  - Linux guests under KVM or z/VM, thousands possible
  - Thousands of Docker containers possible



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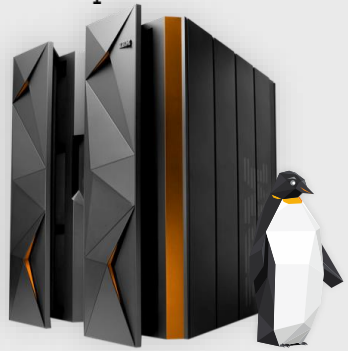
IBM LinuxONE

Open Source & ISV Ecosystem

Distributions	Hypervisors	Languages	Runtimes	Management	Database	Analytics
Supported Versions	KVM	python	nodeJS	docker	MariaDB	Spark
ubuntu (Supported by Canonical)		Ruby		CHEF	PostgreSQL	
SUSE		php	RAILS	puppet labs	mongoDB	hadoop
redhat	LPAR	ERLANG		juju	cassandra	elasticsearch
Community Versions		Scala	OpenJDK	openstack	CouchDB	Apache Solr
debian		Clojure		vmware vRealize	redis	IBM InfoSphere BigInsights
openSUSE		JS		Cloud Manager	ORACLE Diamond Partner	
fedora		OCaml		urban{code}	DB2	BLU Acceleration
CentOS		Java				

IBM LinuxONE Emperor™



IBM LinuxONE Rockhopper™

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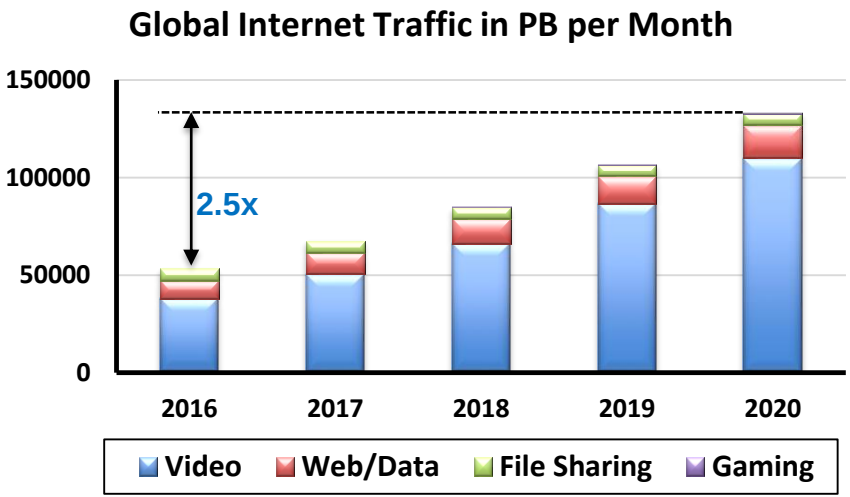
Future Trends



from Cisco Visual Networking Index (VNI) *

IoT by 2020:

- **~30 billion devices will be connected to the networks and possibly to each other**
- **28x more sensor-enabled devices than population of the earth**

Average cost of a data breach is $3.8 – $4 million US dollars! **

Current business infrastructures must be highly reliable, able to cope with high traffic, provide high security to their clients, and enable high availability

* http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.html (Jun 01, 2016)
** http://www-03.ibm.com/security/data-breach/ (Oct. 4, 2016)

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Future Requirements and LinuxONE

High Availability	**Low Unplanned Downtime** - Non-disruptive upgrades, installation, maintenance - “Spare” cores can be turned ON without program interruption
Highly Reliable	**Embedded Error Detection** - Built-in, automated diagnostics, problem identification and isolation **Disaster Recovery** like GDPS appliance **Built-in Redundancy** to eliminate single-point-of-failures
High Security	- FIPS 140-2 Level 4 certified cryptographic hardware - Dedicated crypto cards
Processing Power	- 141 cores, 5GHz clock frequency, 960MB L4 cache - Dedicated I/O processors - Hardware accelerators

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Hardware Acceleration Support

- Compression
  - CMPSC compression coprocessor
  - Enterprise Data Compression (zEDC) card
- Encryption
  - CP Assist for Cryptographic Function (CPACF)
  - Crypto Express Card (CEX)
- I/O
  - OSA-Express card, RoCE cards
  - Flash-Express, FICON-Express cards

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Compression

- Why use compression?
  - 2.5 quintillion (2.5×10^{18}) bytes of data generated per day!
  - Constrained I/O bandwidths
  - Finite storage solutions
- Why avoid compression?
  - Processing power is consumed
  - Energy/battery is consumed
  - Read requires a decompression

Don’t compress frequently accessed data with limited hardware resources

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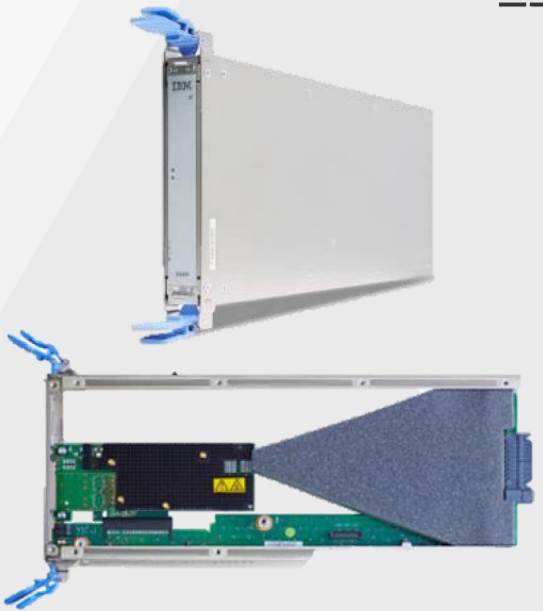
zEDC Compression Card



- PCIe adapter based compression card
- Shareable among 15 LPARs
- Compatible with:
  - zlib
  - Java via java.util.zip
- Provides Customized:
  - Compatible libz.so and API to switch between hardware (zEDC) and software compression transparently from the program
  - gzip/gunzip etc. tools (genwqe_gzip/genwqe_gunzip)

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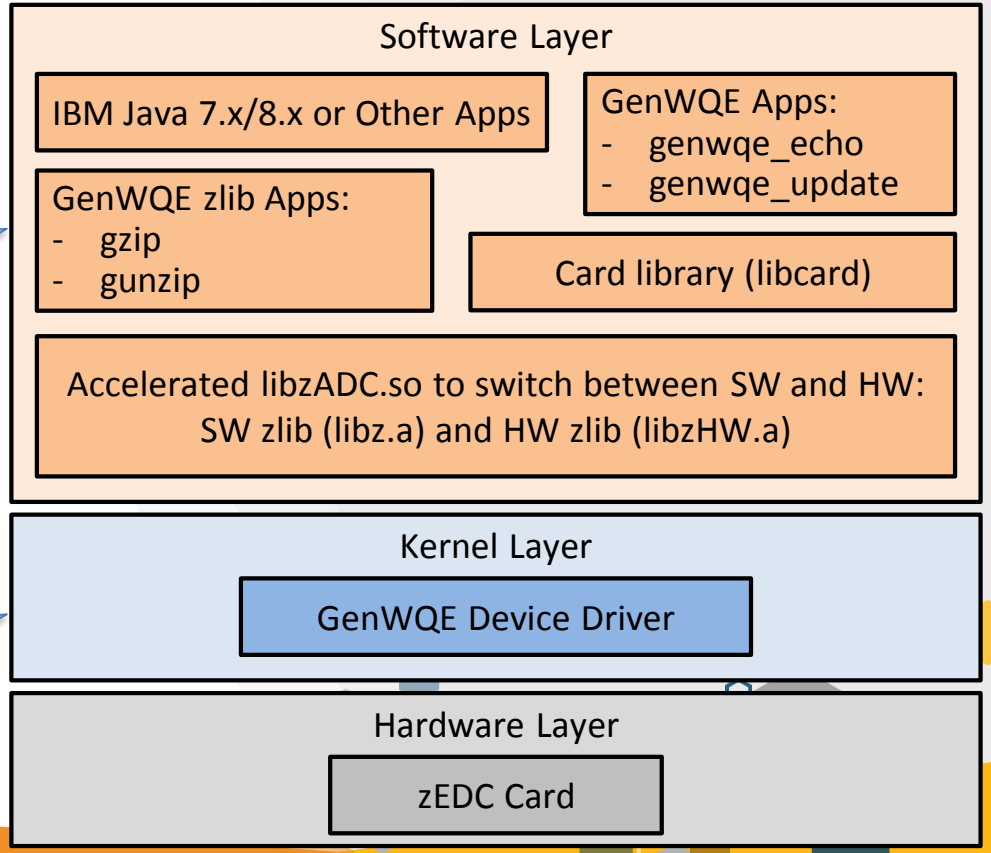
System Stack

- Interface similar to zlib
- Buffering and SW/HW switching
- libcard provides C-style APIs to the device driver

- Serialize requests to the card
- Enables multi-guest and multi-process usage
- Exposes sysfs and debugfs interfaces



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zEDC Compression Card

- Advantages
  - Up to 1 GB/s raw throughput vs 50 MB/s in software
  - Up to 4x data compression → 75% disk saving/link bandwidth savings
  - Minimal CPU overhead, low latency
- Use-Cases
  - Database backup and restore
  - Large files/data transfer over limited bandwidth
  - Cross platform data exchange
  - Batch processing jobs

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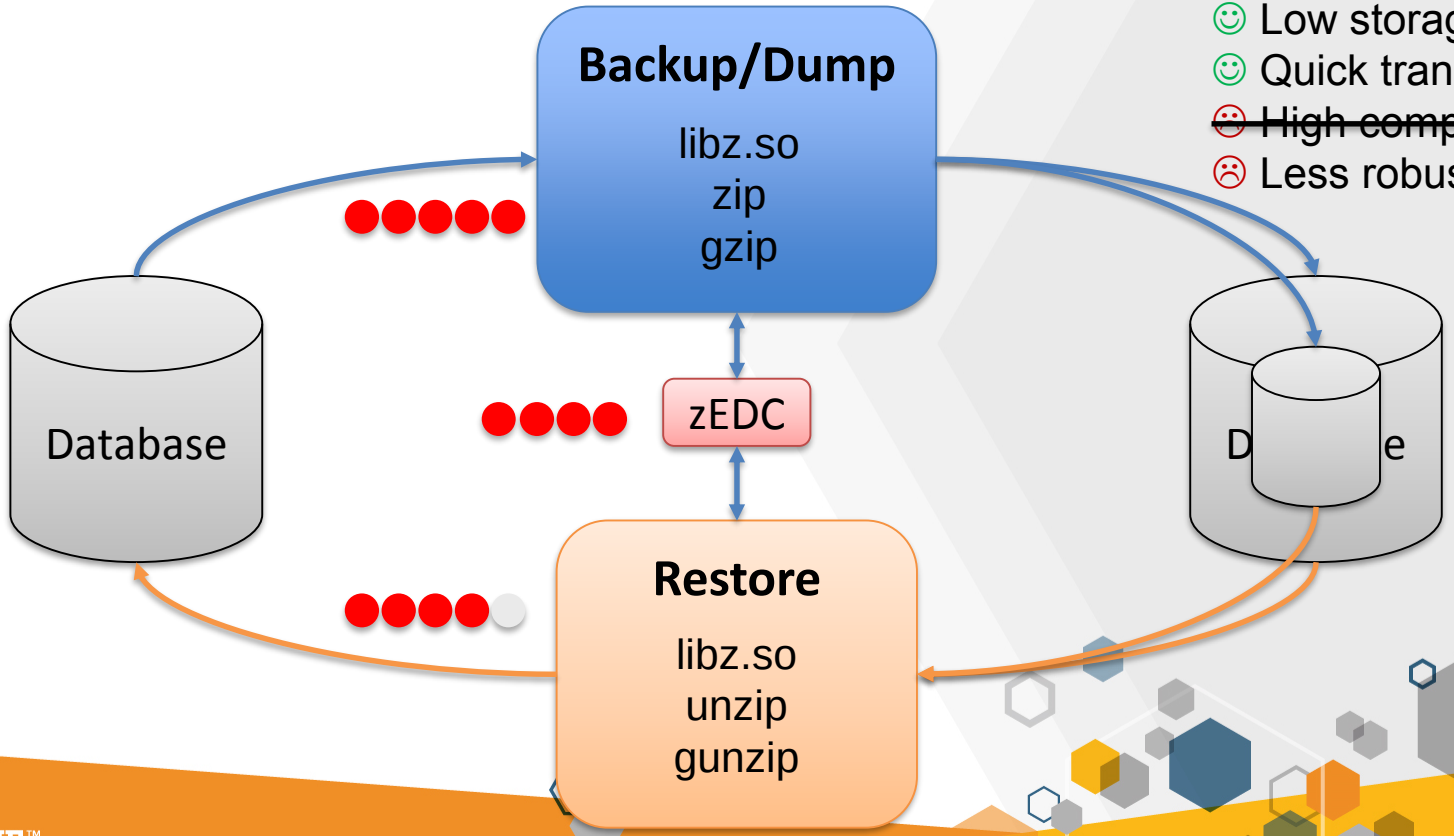
Database Backup and Restore

Compressed DB:
- ☺ Low storage
- ☺ Quick transfer
- ~~☹ High complexity~~
- ☹ Less robust



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DB2 LUW Backup and Restore

- DB2 Database Backup
  - No compression: No compression engine used, least CPU, large backup size
  - Software compression: High CPU, small backup size
  - Hardware compression (using zEDC card on LinuxONE): Low CPU, small/medium backup size
- Multiple User Options
  - PARALLELISM <n>: Number of table spaces which can be read in parallel
  - COMPRLIB <name>: Name of the library used for compression
- db2 backup db *db_name* to *backup_loc* PARALLELISM *parallelism_val* compress comprlib *library_name*

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DB2 LUW Backup and Restore

Config	LinuxONE	x86 Platform
System	1 LPAR	Dedicated Server
Cores	32 dedicated with SMT	36, with HT
Memory	768 GB	768 GB
OS	RHEL – 7.2	RHEL – 7.2
DB2 Version	DB2 v11.1	DB2 v11.1
Database	TPCC (Hammer-DB)	TPCC (Hammer-DB)
Database Size	385 GB	385 GB
Storage	IBM System Storage DS8000	IBM System Storage DS8000

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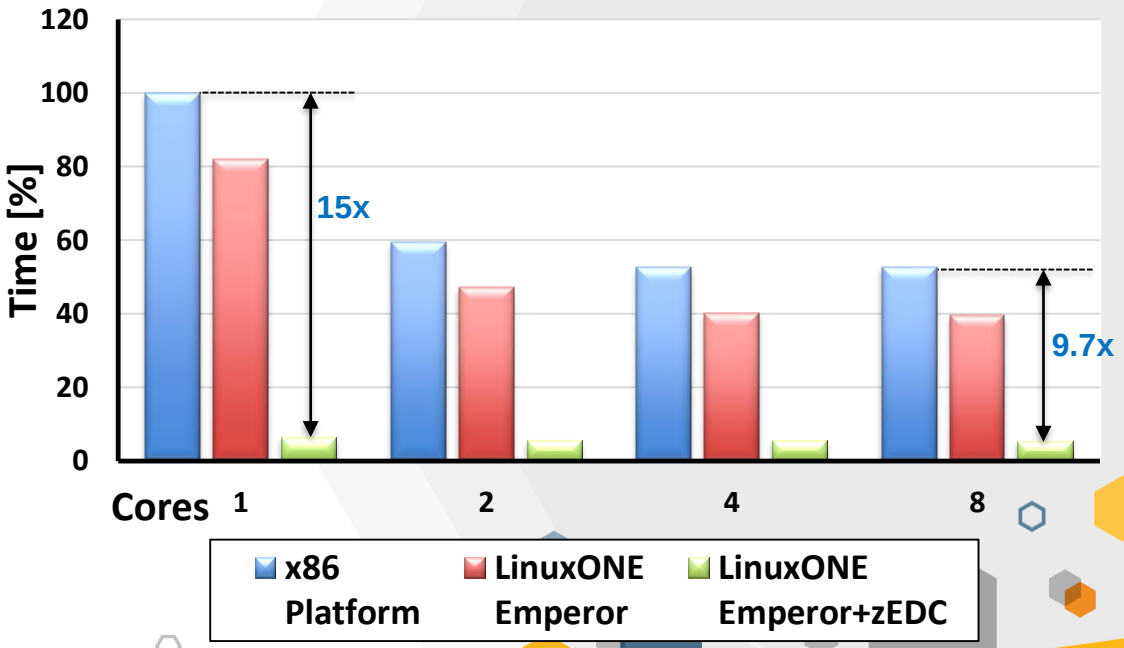
DB2 LUW Backup Performance

Running DB2 v11.1 backup on LinuxONE Emperor with zEDC card is up to 15x faster than on a compared x86 platform using software compression.

Faster backup could mean shorter maintenance windows

DB2 Backup Time with Compression



Disclaimer: Performance results based on IBM internal tests running database backup with compression on DB2 v11.1 to /dev/null. Results may vary. x86 config: 36 Intel E5-2699 v3 cores @ 2.30GHz, 1-8 cores enabled for DB2 v11.1, 768 GB memory, and 80 GB local RAID-5 volume on 15K 12 Gbps SAS drives, RHEL 7.2, 385 GB database on IBM DS8000. LinuxONE config: LinuxONE Emperor LPAR with 32 dedicated cores, 1-8 cores enabled for DB2 v11.1, 768 GB memory, and 40 GB DASD storage, RHEL 7.2 with SMT, 385 GB database on IBM DS8000.

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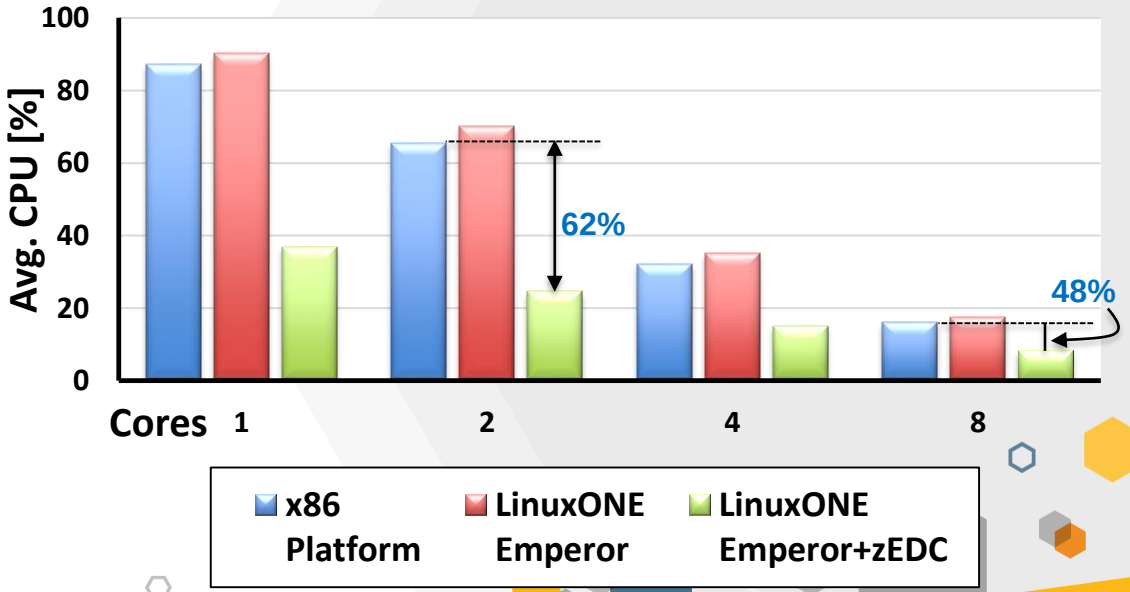
DB2 LUW Backup CPU Utilization

Running DB2 v11.1 backup on LinuxONE Emperor with zEDC utilizes up to 62% lesser CPU than on a compared x86 platform using software compression.

More resources can be allocated to parallel running processing

DB2 Backup CPU Utilization with Compression



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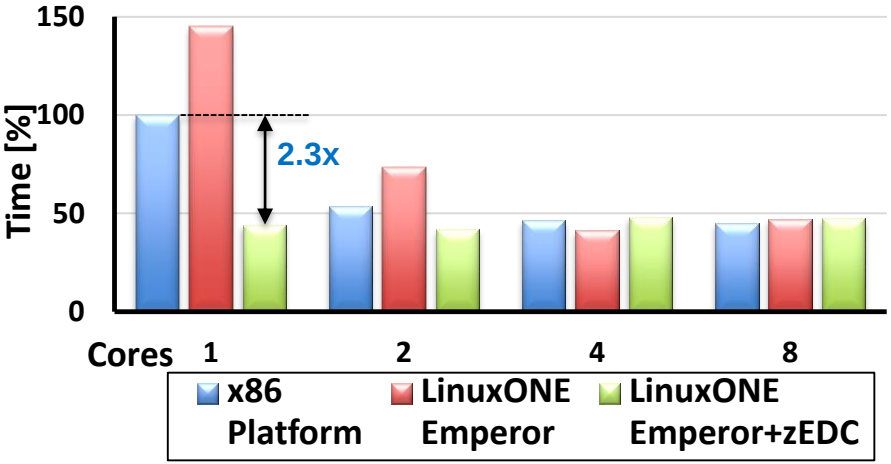
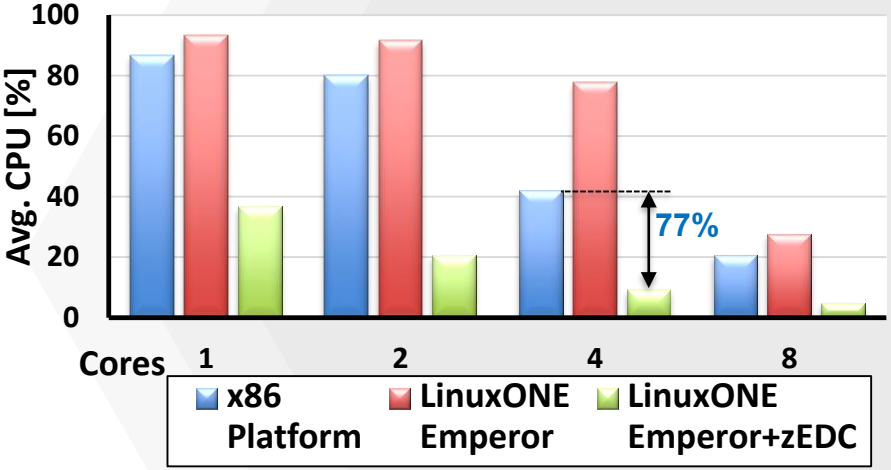
DB2 LUW Restore Performance

DB2 Restore Time



DB2 Restore CPU Util.



Running DB2 v11.1 restore on LinuxONE Emperor with zEDC card is up to 2.3x faster than on a compared x86 platform using software compression.

Running DB2 v11.1 restore on LinuxONE Emperor with zEDC card utilizes up to 77% lesser CPU than a compared x86 platform using software compression.

Disclaimer: Performance results based on IBM internal tests running database restore with compression on DB2 v11.1. Results may vary. x86 config: 36 Intel E5-2699 v3 cores @ 2.30GHz, 1-8 cores enabled for DB2 v11.1, 768 GB memory, and 80 GB local RAID-5 volume on 15K 12 Gbps SAS drives, RHEL 7.2, 385 GB database and backup on IBM DS8000. LinuxONE config: LinuxONE Emperor LPAR with 32 dedicated cores, 1-8 cores enabled for DB2 v11.1, 768 GB memory, and 40 GB DASD storage, RHEL 7.2 with SMT, 385 GB database and backup on IBM DS8000.

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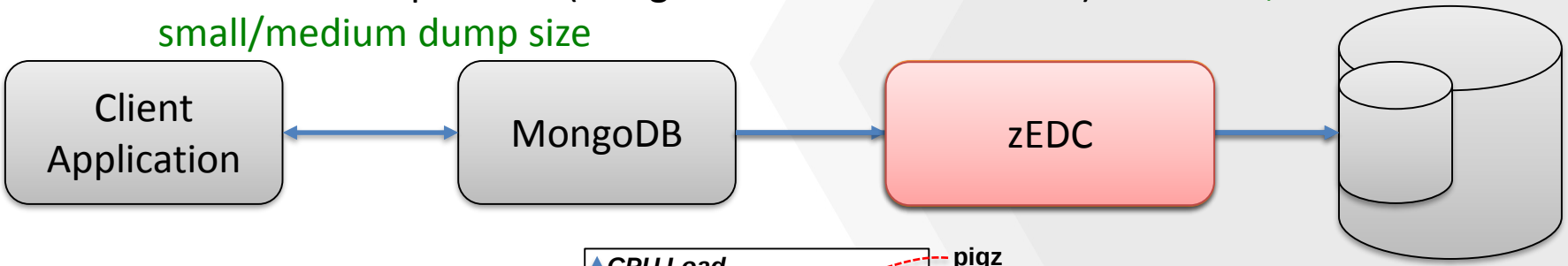
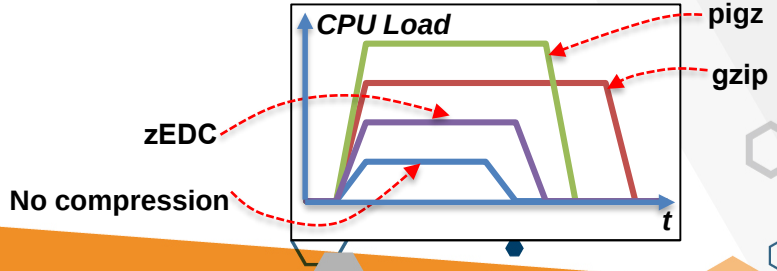
MongoDB Backup (Dump)

- Dump Database
  - No compression: No compression engine used, least CPU, large dump size
  - Software compression: High CPU, small dump size
  - Hardware compression (using zEDC card on LinuxONE): Low CPU, small/medium dump size





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MongoDB Backup

- Options
  - gzip: Compress the dump via gzip tool
    - Single threaded → use pigz for software, genwqe_gzip for zEDC
  - archive: Push to stdout (in order to use pigz or genwqe_gzip)

- mongodump --host *name* --port *mongod_port* --db *db_name* --archive | pigz –p *pigz_threads* > *output_file*
- mongodump --host *name* --port *mongod_port* --db *db_name* --archive | genwqe_gzip > *output_file*

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MongoDB Backup and Restore

Config	LinuxONE	x86 Platform
System	1 LPAR	Dedicated Server
Cores	32 dedicate with SMT	36, with HT
Memory	768 GB	768 GB
OS	RHEL – 7.2	RHEL – 7.2
MongoDB Version	Enterprise v3.3	Enterprise v3.2
Database Size	83 GB	83 GB
Storage	IBM System Storage DS8000	IBM System Storage DS8000

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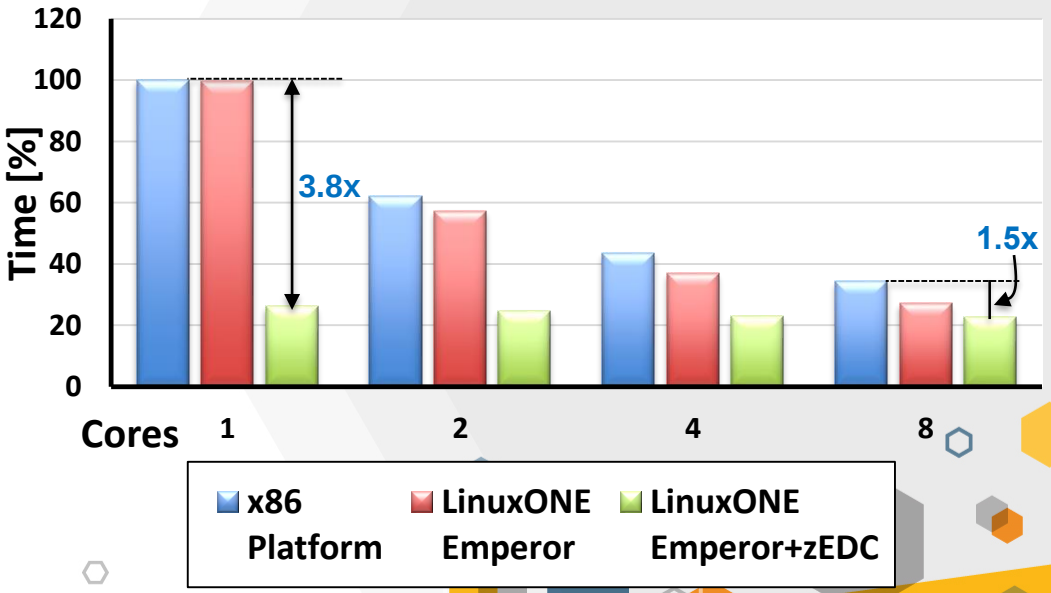
MongoDB Backup Performance

Running MongoDB Enterprise v3 dump on LinuxONE Emperor with zEDC is up to 3.8x faster than on a compared x86 platform using software compression.

MongoDB Dump Time with Compression



Disclaimer: Performance results based on IBM internal tests running database dump with compression on MongoDB Enterprise Release (Database size 83 GB). Results may vary. x86 config: 36 Intel E5-2699 v3 cores @ 2.30GHz, 1-8 cores enabled, 768 GB memory, and 80 GB local RAID-5 volume on 15K 12 Gbps SAS drives, RHEL 7.2, database and backup on IBM DS8000, MongoDB Enterprise Release 3.2, pigz version 2.3.3. LinuxONE config: LinuxONE Emperor LPAR with 32 dedicated cores, 1-8 cores enabled, 768 GB memory, 40 GB DASD storage, RHEL 7.2 with SMT, database and backup on IBM DS8000, MongoDB Enterprise Release 3.3, genwqe-user-4.0.17.

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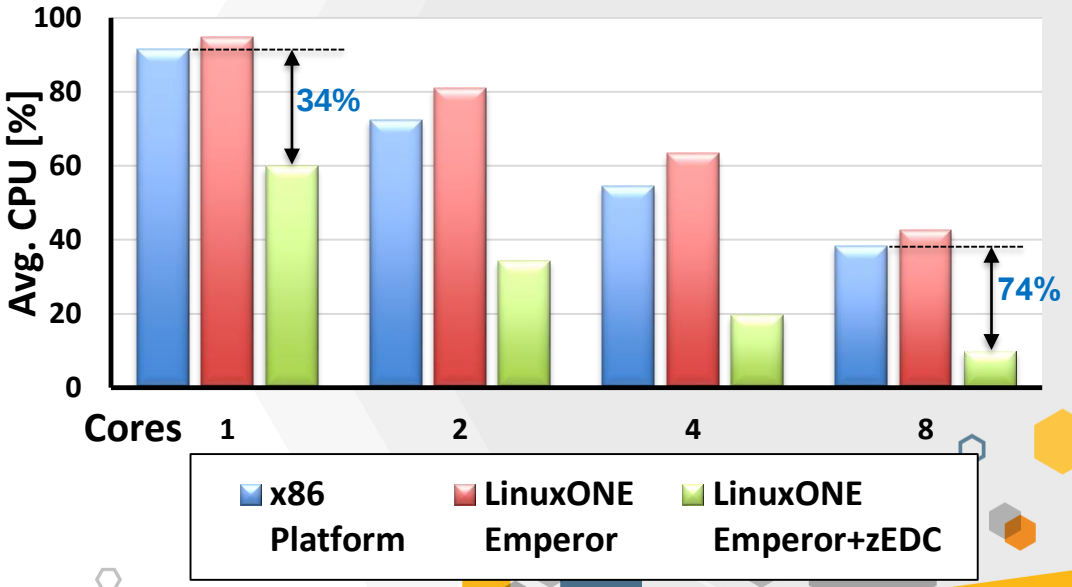
MongoDB Backup CPU Utilization

Running MongoDB Enterprise v3 dump on LinuxONE Emperor with zEDC card utilizes up to 74% lesser CPU than on a compared x86 platform using software compression.

MongoDB Dump CPU Utilization with Compression



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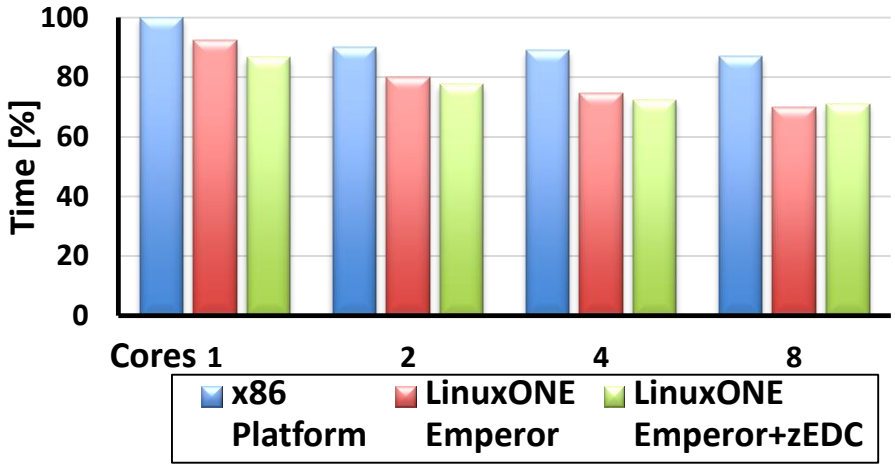
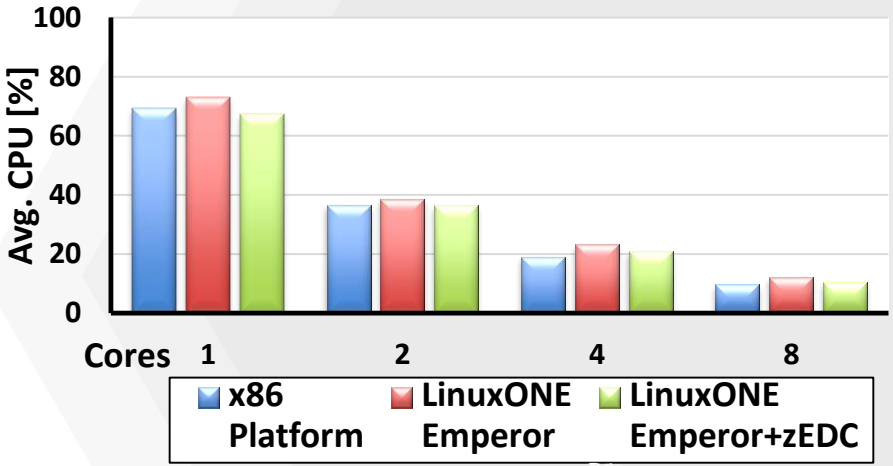
MongoDB Restore Performance

MongoDB Restore Time



MongoDB Restore CPU Util.



Running MongoDB Enterprise v3 restore on LinuxONE Emperor with zEDC card is up to 18% faster than on a compared x86 platform using software decompression.

Disclaimer: Performance results based on IBM internal tests running database restore with compression on MongoDB Enterprise Release (Database size 83 GB). Results may vary. x86 config: 36 Intel E5-2699 v3 cores @ 2.30GHz, 1-8 cores enabled, 768 GB memory, and 80 GB local RAID-5 volume on 15K 12 Gbps SAS drives, RHEL 7.2, database and backup on IBM DS8000, MongoDB Enterprise Release 3.2, pigz version 2.3.3. LinuxONE config: LinuxONE Emperor LPAR with 32 dedicated cores, 1-8 cores enabled, 768 GB memory, 40 GB DASD storage, RHEL 7.2 with SMT, database and backup on IBM DS8000, MongoDB Enterprise Release 3.3, genwqe-user-4.0.17.

IBM LinuxONE™

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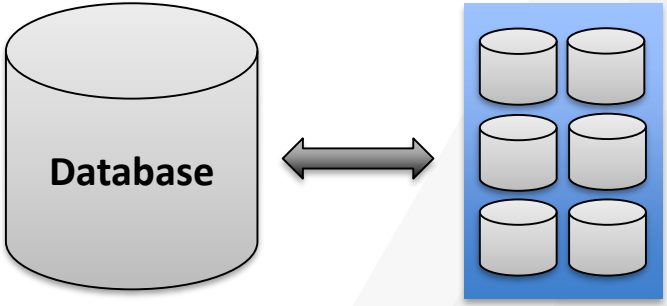
Sharded (Multi-Node) MongoDB Backup

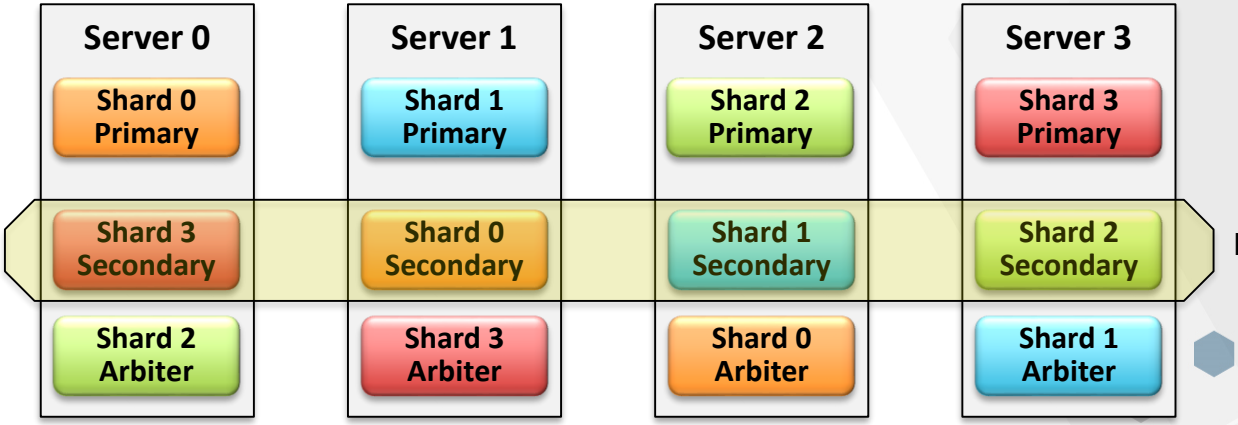
Sharding: A single chunked DB is converted into smaller chunks and distributed over different machines.

Replication: A DB is copied to another location for reliability, accessibility, availability and fault-tolerance.



Sharded DB:

- ☺ Storage scaling
- ☺ Memory scaling
- ☺ CPU scaling
- ☺ Robustness
- ☹ Increased complexity
- ☹ Management



Lock these replica-sets and take their dump

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Sharded MongoDB Config

Config	LinuxONE	x86 Platform
System	4 LPARs on one LinuxONE	4 dedicated servers
Cores per LPAR/server	12 dedicate with SMT	12, with HT
Memory per LPAR/server	512 GB	512 GB
OS	RHEL – 7.2	RHEL – 7.2
MongoDB Version	Enterprise v3.2	Enterprise v3.2
Database Size	400 GB	400 GB
Collections	4, 100 GB each	4, 100 GB each
DB Location	IBM FlashSystem 900	Local SSDs

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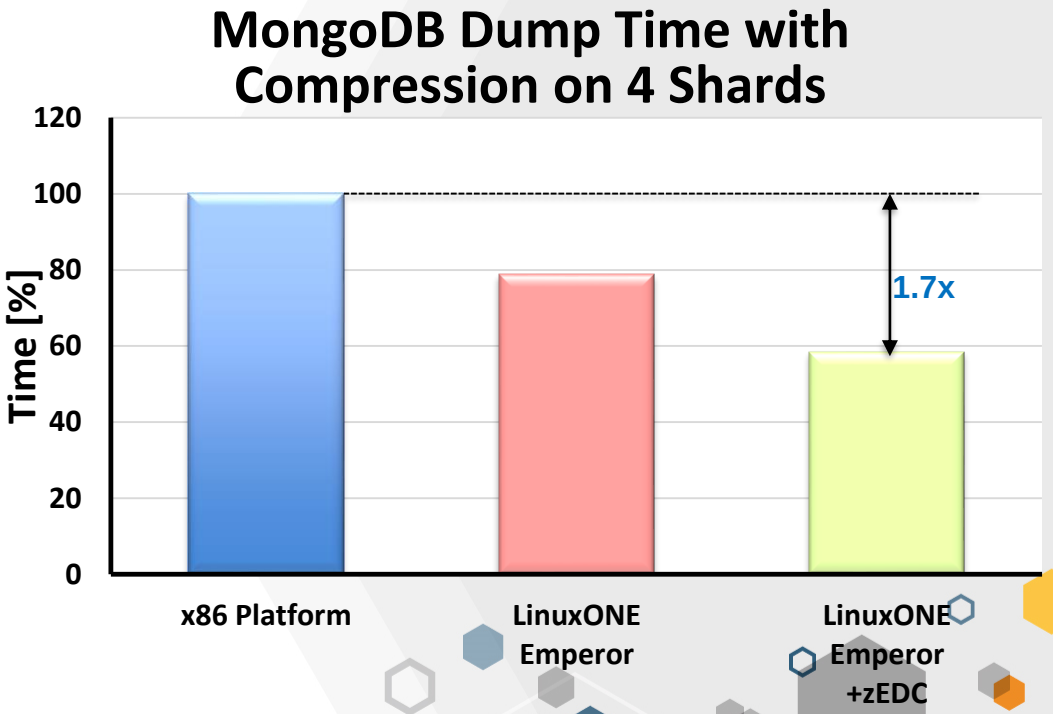
Sharded MongoDB Backup

Running MongoDB Enterprise v3.2 dump on LinuxONE Emperor with zEDC card on 4 shards in parallel is 1.7x faster than on a compared x86 platform using software compression.



Disclaimer: Performance results based on IBM internal tests running database dump with compression on MongoDB Enterprise Release (YCSB database size 400 GB, with 4 collections of 100 GB each, 100 GB DB per shard). Results may vary. x86 config per server: Intel E5-2690 v3 cores @ 2.60GHz servers, 12 cores enabled, 512 GB memory, RHEL 7.2, database on local 1.7 TB SSDs, MongoDB Enterprise Release 3.2, pigz version 2.3.3. LinuxONE config: 4 LinuxONE Emperor LPARs, each LPAR with: 12 dedicated cores, 512 GB memory, 40 GB DASD storage, RHEL 7.2 with SMT, database on IBM FlashSystem 900, MongoDB Enterprise Release 3.2, pigz version 2.3.3, genwqe-user-4.0.17.

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Cryptography

- Why use encryption?
  - Safeguard personal identity and privacy
  - Protecting sensitive data
- When to avoid encryption?
  - Maybe the fear of losing your password ☺

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Crypto Acceleration in LinuxONE

- CPACF – CP Assist for Cryptographic Functions
  - Designed to improve performance of crypto functions
  - Symmetric cryptography, secure hashing

- CEX5S – Crypto Express5S Card
  - PCIe Cryptographic Coprocessor (PCIeCC)
  - Hardware to perform AES, DES, T-DES, HMAC, random number generation, SHA-1, SHA-256, SHA-384, SHA-512, MD5, HMAC, and large number modular math functions for RSA (up to 4096-bit), ECC Prime Curve and other public-key cryptographic algorithms

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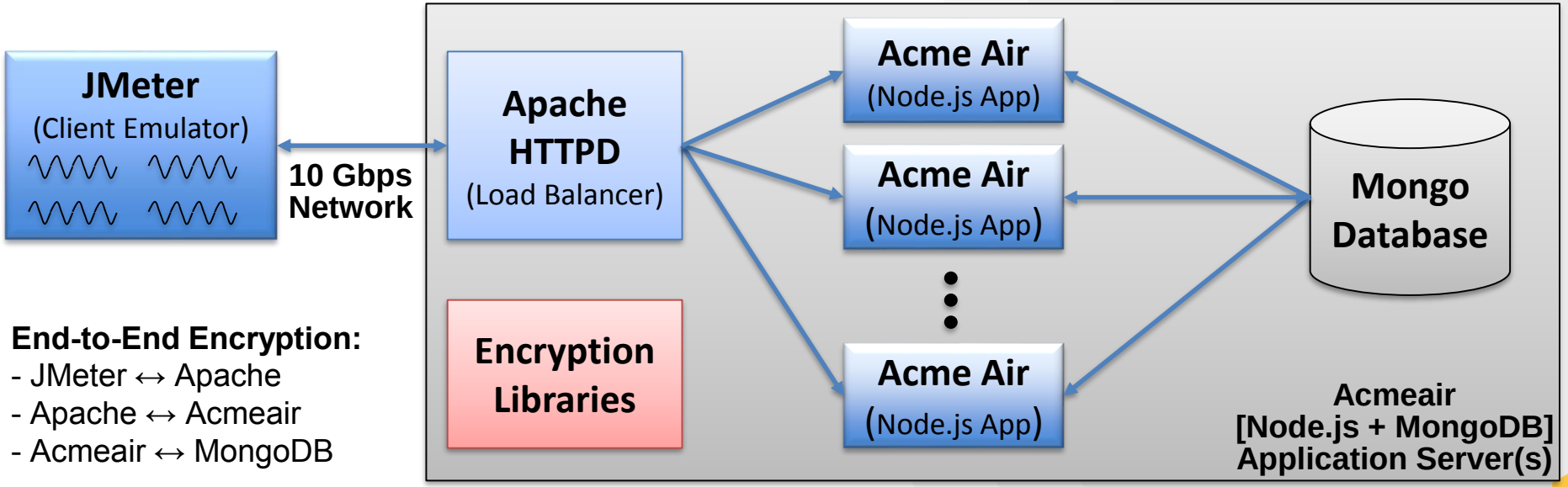
End-to-End Encryption



End-to-End Encryption:
- JMeter ↔ Apache
- Apache ↔ Acmeair
- Acmeair ↔ MongoDB

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Acme Air [Node.js + MongoDB] Config

Config	LinuxONE	x86 Platform
System	1 LPAR	Dedicated Server
Cores	32 dedicated with SMT	36, with HT
Core Assignment	*Apache*: 1 *Node.js*: 1, 2, 4, 8, 16 *MongoDB*: 2 if Node.js 1, 2 or 4 4 if Node.js 8 or 16	*Apache*: 1 *Node.js*: 1, 2, 4, 8, 16 *MongoDB*: 2 if Node.js 1, 2 or 4 4 if Node.js 8 or 16
Memory	768 GB	768 GB
OS	RHEL – 7.2	RHEL – 7.2
MongoDB Version	Enterprise v3.3	Enterprise v3.2
JMeter Version	2.13	2.13
DB Location	RAM disk	RAM disk

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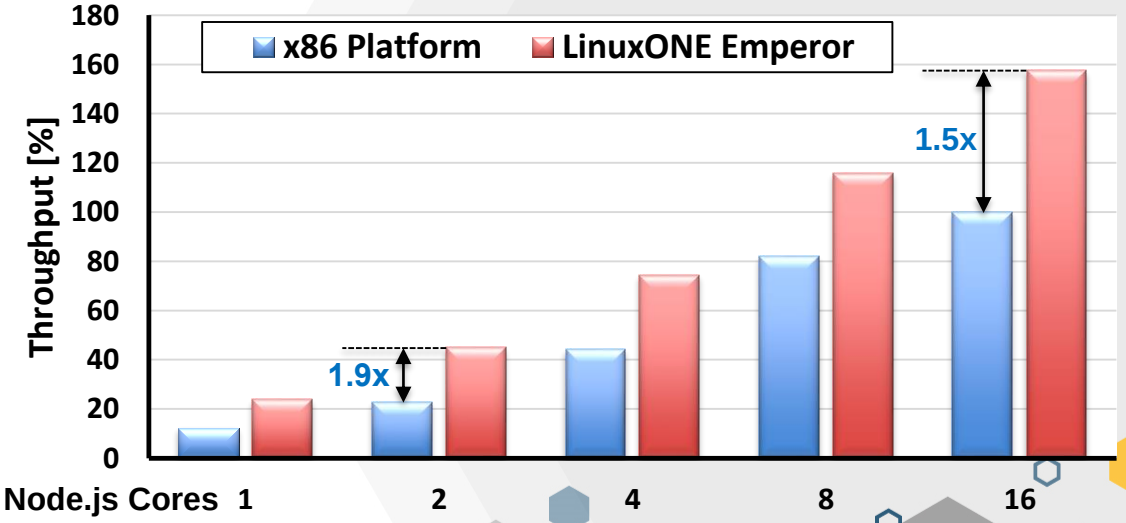
Acme Air [Node.js + MongoDB]

Running Acme Air application with end-to-end encryption on LinuxONE Emperor is up to 1.9x faster than on a compared x86 platform with end-to-end encryption.

Throughput for Acme Air App. with End-to-End Encryption



Disclaimer: Performance results based on IBM internal tests running Acme Air with 10,000 customers on Node.js v6.1 against MongoDB Enterprise v3.3 driven remotely by 250 JMeter 2.13 threads. Apache HTTP server v2.4.6 was used as load balancer. TLS v1.2, DHE-RSA-AES128-GCM-SHA256 cipher was used between JMeter and Apache HTTP, ECDHE-RSA-AES128-GCM-SHA256 cipher was used between Apache HTTP and Node.js, RSA 4096 bit key for SSL configuration of MongoDB. Results may vary. x86 config: 36 Intel E5-2699 v3 cores @ 2.30GHz, Apache HTTP server pinned to 1 core, Node.js pinned to 1-16 cores, MongoDB pinned to 2-4 cores, 768GB memory, and 80 GB local RAID-5 volume on 15K 12 Gbps SAS drives, RHEL 7.2, OpenSSL 1.0.1e-fips 11 Feb 2013, application logs and database on the RAM disk. LinuxONE config: LinuxONE Emperor LPAR with 32 dedicated cores, Apache HTTP server pinned to 1 core, Node.js pinned to 1-16 cores, MongoDB pinned to 2-4 cores, 768GB memory, 40 GB DASD storage, RHEL 7.2 with SMT, OpenSSL 1.0.1e-fips 11 Feb 2013, application logs and database on the RAM disk.

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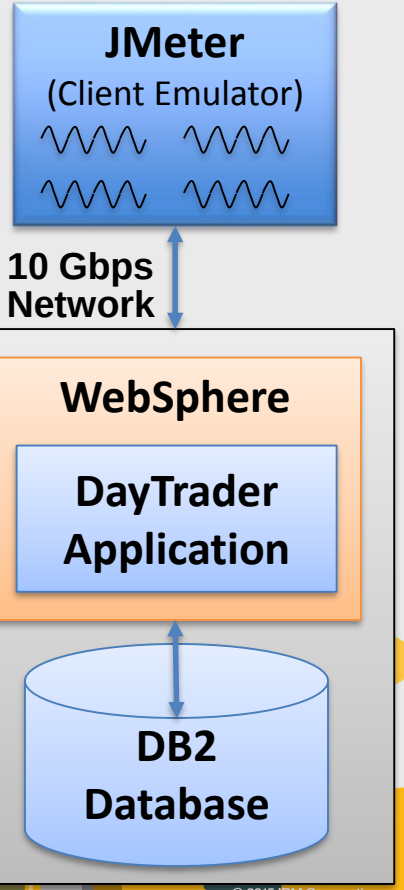
WebSphere Application Sever (WAS)

- **Application Middleware**
  - Provides tools to create and integrate applications
  - Hosts Java based web applications

Config	LinuxONE	x86 Platform
System	1 LPAR	Dedicated Server
Cores	2 – 16 dedicated cores, SMT	2 – 16 cores, HT
Memory	768 GB	768 GB
OS	RHEL – 7.2	RHEL – 7.2
WebSphere Version	v8.5.5.9	v8.5.5.9
DB2 Version	v10.5.7	v10.5.7
Java Version	v1.8	v1.8
DayTrader Version	v3	v3



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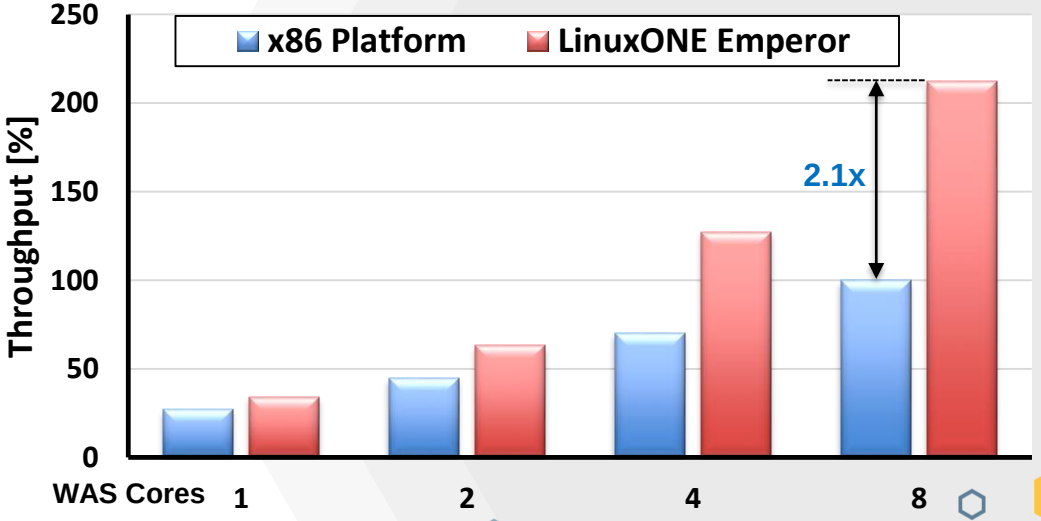
WebSphere Application Server

Running WebSphere Application Server 8.5.5.9 with encryption on LinuxONE Emperor provides up to 2.1x more throughput than on a compared x86 platform with encryption.

WebSphere Application Server Throughput with Encryption



Disclaimer: Performance results based on IBM internal tests running DayTrader v3 with 15000 users on WebSphere Application Server (WAS) v8.5.5.9 driven remotely by JMeter v2.12. DB2 LUW v10.5.7 was used as database system. Results may vary. x86 config: 36 Intel E5-2699 v3 cores @ 2.30GHz, WAS pinned to 1-8 cores, DB2 pinned to 1-8 cores, number of DB2 cores equals number of WAS cores, 768GB memory, and 80 GB local RAID-5 volume on 15K 12 Gbps SAS drives, RHEL 7.2, 177 MB database on local HDDs, IBM Java 1.8.0 (SR2), JMeter threads was 4 times number of WAS cores. LinuxONE config: LinuxONE Emperor LPAR with 32 dedicated cores, WAS pinned to 1-8 cores, DB2 pinned to 1-8 cores, number of DB2 cores equals number of WAS cores, 768GB memory, 177 MB DB2 database on 40 GB DASD storage, RHEL 7.2 with SMT, IBM Java 1.8.0 (SR2), JMeter threads was 2 times number of WAS cores.

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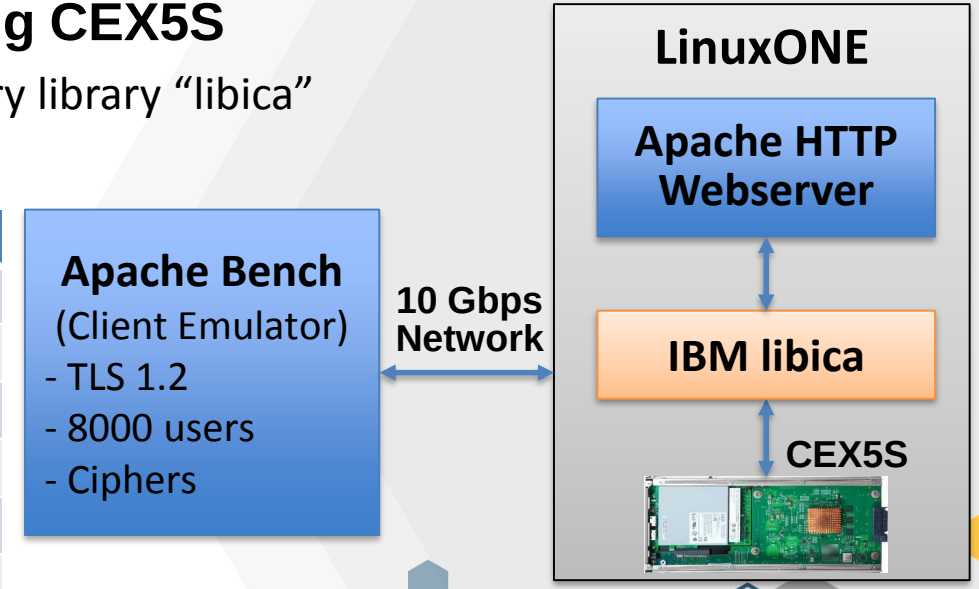
Apache HTTP with Crypto Express5S (CEX5S) Card

- **Apache HTTP Server utilizing CEX5S**
  - Enabled by using IBM proprietary library “libica”

Config	LinuxONE	x86 Platform
System	1 LPAR	Dedicated Server
Cores	2 dedicated, SMT	2, with HT
Memory	768 GB	768 GB
OS	RHEL – 7.2	RHEL – 7.2
Apache Version	v2.4.6	v2.4.6
Apache Bench	v2.3	v2.3
Webpage Size	1024 Bytes	1024 Bytes



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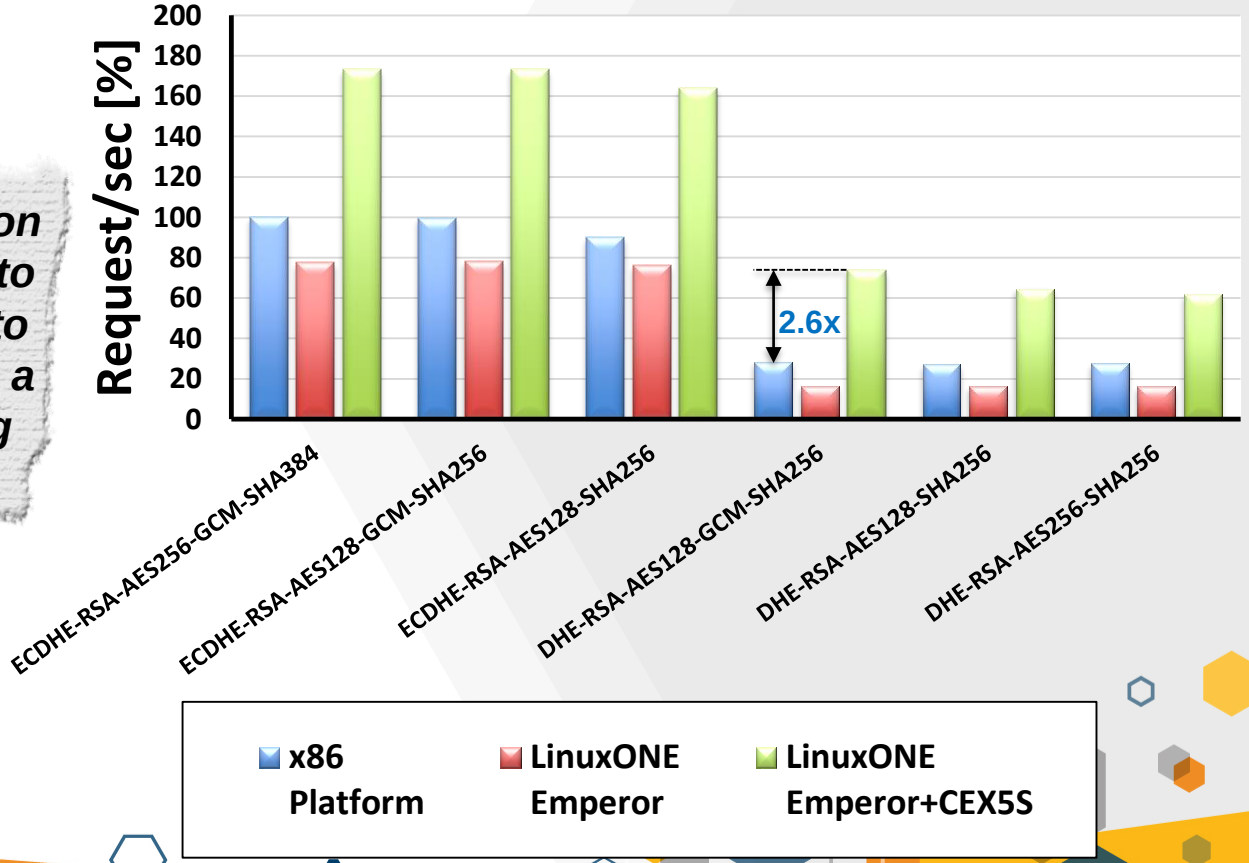
Apache HTTP with CEX5S

Running Apache HTTP v2.4.6 on LinuxONE Emperor with Crypto Express5S card achieves up to 2.6x more throughput than on a compared x86 platform using software encryption.



Disclaimer: Performance results based on IBM internal tests running 32 Apache Bench 2.3 instances (each with 250 users) remotely via 10 Gbps network against Apache HTTP v2.4.6 using 1024 bytes html page, TLS v1.2, OpenSSL 1.0.1e-fips 11 Feb 2013. Results may vary. x86 config: 36 Intel E5-2699 v3 cores @ 2.30GHz, 2 cores enabled for Apache HTTP, 768GB memory, and 80 GB local RAID-5 volume on 15K 12 Gbps SAS drives, RHEL 7.2. LinuxONE config: LinuxONE Emperor LPAR with 32 dedicated cores, 2 cores enabled for Apache HTTP, 768GB memory, and 40 GB DASD storage, RHEL 7.2 with SMT.

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Agenda

- IBM LinuxONE System
- Future Trends/Requirements and LinuxONE
- Hardware Acceleration Support on IBM LinuxONE
  - Compression with zEDC card
  - Encryption with CPACF and CEX5S
- Concluding Remarks

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Concluding Remarks

- New/future businesses must be developed with consideration of the **future constraints and requirements**
- IBM LinuxONE system in collaboration with hardware accelerators can provide **high throughput and security**
- Database **maintenance windows and load** on the system can be reduced using zEDC compression card
- **Encryption performance** can be boosted by exploiting the hardware acceleration support provided by CPACF and CEX5S

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Thank you!

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