

MiVoice MX-ONE

# System Database (Cassandra)- Description

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# Introduction

## Scope

This document describes the general principle for how a distributed system database using eventual consistency is used in the MX-ONE Service Node.

The document also describes the most important files stored in the file system using the system database (Cassandra), and the basic principle of the tree structure used for the data stored in the system database.

## General Cassandra Information

This document provides information only on those aspects of the use of the system database that are unique to the MX-ONE Service Node. For information about general use of the system database (Cassandra), you are recommended to read for example:

- Apache Cassandra web pages, for example, at <http://cassandra.apache.org>
- Datastax tutorial web pages about Cassandra 3.x, for example, at <https://academy.data-stax.com>
- Cassandra: The Definitive Guide (2nd ed.). Carpenter, Jeff; Hewitt, Eben (July 24, 2016). O'Reilly Media. p. 370. ISBN 978-1-4919-3366-4.

## Glossary and Acronyms

### Cassandra Cluster

A collection of system database (Cassandra) data centers.

### Cassandra Node, Node

A Cassandra instance running on a server.

### CQL

Cassandra Query Language, protocol used towards the system database.

### CSV

Comma Separated Values, a data format used for example in .csv files, which store system database data.

### Database

Here a Cassandra database concept which refers to the Apache Cassandra database. Version 3.11 is the latest when this document was written.

### Data Center

A geographical location of one or more Cassandra nodes.

### Keyspace

A Cassandra concept for the control of the replication model(s) and the data in the database nodes

### LIM

Line Interface Module, an MX-ONE Service Node entity, plus at least one media gateway. Can be co-located with a Cassandra node, but does not have to be.

#### Rack

A sub-division of servers within a Data Center, primarily to have separate power supply, or other redundancy.

#### Replication

The copying of data from a database node (replica) to another replica, making the relevant replicas as identical as possible.

#### Replication factor

The amount of copying of data from a database replica to other database replicas. A replication factor of 1 means that there is only one copy of each data in a Data Center, whereas a replication factor of 3 means three copies of the data are stored across the Data Center. Each Data Center has its own replication factor.

#### System Database

The Apache Cassandra <sup>TM</sup>, version 3.11.x is used as system database in the MiVoice MX-ONE Service Node (from version 7.0). It requires Apache License 2.0.

#### Table

A table in Cassandra is a distributed multi-dimensional map indexed by a key, used for the access of database data.

#### Tables

A table in Cassandra is a distributed multi-dimensional map indexed by a key, used for the access of database data.

For a complete list of abbreviations and glossary, see the description for *ACRONYMS, ABBREVIATIONS AND GLOSSARY*.

# Overview

This section provides the architectural details of MiVoice MX-ONE system.

## Architecture

The architectural model is to have at least one system database node accessible in every MiVoice MX-ONE Service Node serving the telephony applications of that Service Node (LIM). Therefore, read requests are directed to one or several system database nodes, either co-located with the Service Node, or located on a separate server as standalone system database node.

Any of the system database nodes can read/write, and all or some other system database nodes can be replicas, depending on the keyspaces defined for the data which is read/written. Write operations need network access to at least one system database node. For full replication, the system needs access to all system database nodes.

In a telephony system with small amounts of configuration changes, one system database node can be located on one of the Service Node servers, as a system database node of that server. Other Service Nodes in the same MX-ONE system may have system database nodes, but they can also share a system database node with other Service Nodes.

In a telephony system with large amounts of configuration changes, the system database nodes may have to be located on a special external server (or servers). Every Service Node must have access to at least one system database node to be working, that is, to be able to read or write system database data.

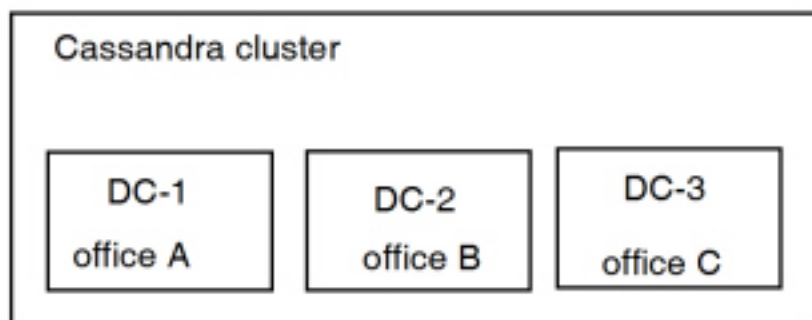
If a system database node is out of service for a long time (for instance due to hardware failure), it is possible to manually reconfigure a new database node to replace the failing one (without loss of data). This is seen as a manual service measure. This process will not be automated.

## Scalability

The system database is designed to have read and write throughput both increase linearly as new machines are added, with the aim of no downtime or interruption to applications.

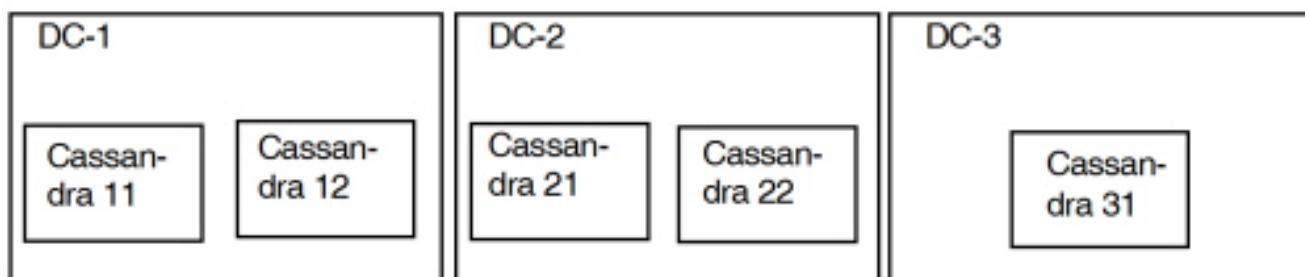
## Cassandra Clusters

A Cassandra cluster holds one or more Data Centers. The MX-ONE system can support up to 40 data centers in a Cassandra cluster. The following figure shows a Cassandra cluster with three data centers, named DC-1, DC-2, and DC-3.

**Figure 2.1:** Cassandra Cluster with Data Center

## System Database Data Centers

A system database Data Center holds one or more system database nodes (servers). In the figure 2, DC-1 and DC-2 have two system database nodes, DC-3 has one system database node.

**Figure 2.2:** Cassandra nodes in each Data Center

Every system database node in a data center can have the same role. There is no single point of failure. Data is distributed across the data center, but there is no master node, as every node can service any request. This does not mean that every node store the same, identical data.

## Data Replication

It is possible to specify to what nodes data should be replicated, that is, replication strategies are configurable. A common approach is to have a complete copy of all data in each Data Center. That is, a complete copy of all data in every geographical location. Internally in a specific Data Center, it is possible to specify on how many nodes a copy of a specific data should be stored. This is specified by the Replication Factor. With a Replication Factor of two, the data will be stored on two different system database nodes within the Data Center.

In a cluster like in figure 2, it is a good idea to have a Replication Factor of 2 for DC-1 and DC-2. With Replication Factor 2, the Data Center has internal redundancy of the data. DC-3 only has one system database node, so the Replication Factor will be one. In a Data Center with more than three nodes it could be useful with a Replication less than the number of nodes in the Data Center. This will give data load



sharing. For example, for a Data Center with four system database Nodes and a Replication Factor two, each node will store half of the data. Each data is stored replicated to two nodes.

The total number of data copies that are replicated is referred to as the replication factor. A replication factor of 1 means that there is only one copy of each row in a Data Center, whereas a replication factor of 3 means three copies of the data are stored across the Data Center.

For ASP113, the data is always replicated to all database nodes in a Data Center.

## Rack

A rack is the physical location of a server (or group of servers) within a Data Center. Servers are spread between racks to get redundancy if rack specific hardware fails. Examples of such hardware are power supplies, access switches and IP networks. system database uses racks to spread replicas to different racks if they are available.

## How Data is Written

When a write request is sent to one system database node, the write request is forwarded to all other system database nodes that hold a copy of that data table row. The system database only waits for a defined number of nodes to be ready with the write, before considering the write successful.

If some nodes are not reachable, the system database has methods to make data consistent when the failed node has recovered. The system database stores a time-stamp for each write to know what the latest write is.

When a write is forwarded to another Data Center, each Data Center distributes the write requests to other nodes in the Data Center holding a copy of the data. This reduces the inter Data Center network traffic.

The system database tries to write to the node that has the shortest response time.

## How Data is Read

When a read request is sent to one system database node, the request is forwarded to one node that holds a copy of the data. The system database also forwards digest requests to other Servers to verify that the data read is consistent with other replicas in the database. If the digest is consistent with the data read it is considered OK.

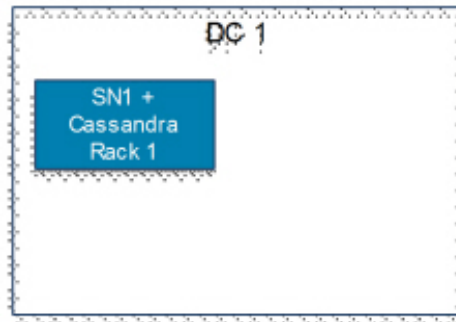
If the read data is not consistent with the digest, a repair action is started that will make this data table row consistent.

The system database tries to read from the node that has the shortest response time.

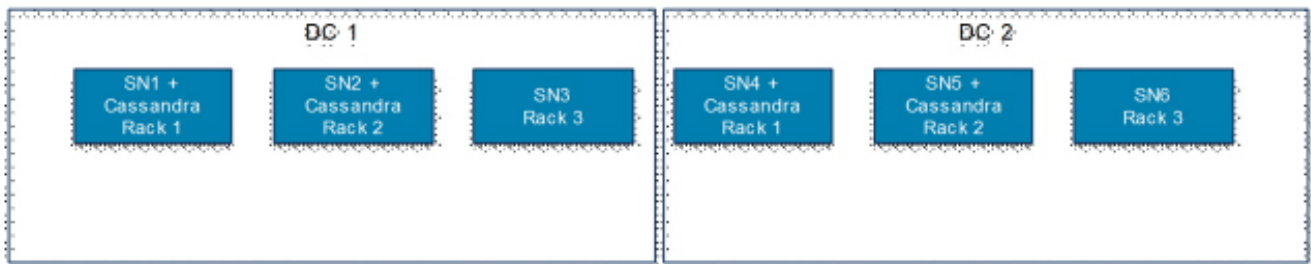
# System Database Deployment Examples in MX-ONE

The system database could when used in the ASP113 system be configured and deployed for example according to the following figures, either as a single Data Center, or as multiple Data Centers, and either co-located with the Service Node(s), or on separate server(s), standalone, and with one or multiple racks within a Data Center:

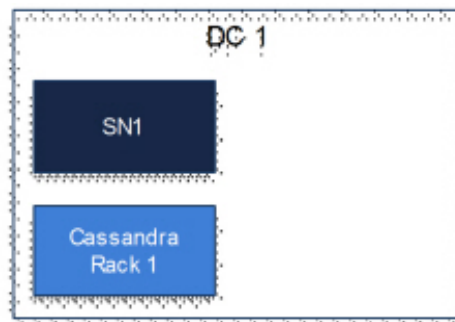
**Figure 2.3:** One Cassandra node co-located with a Service Node. One Data Center, and 1 rack. No redundancy.



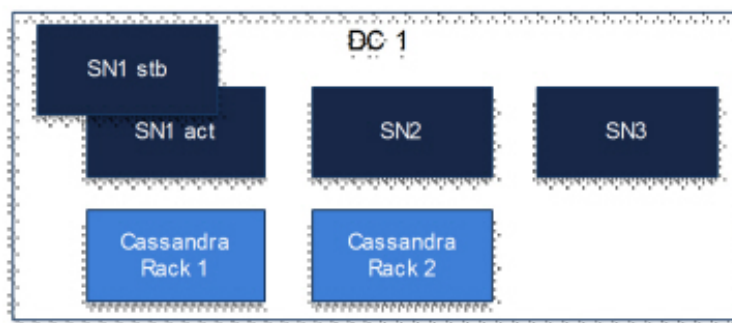
**Figure 2.4:** Four Cassandra nodes co-located and six Service Nodes in one ASP113 system. In two Data Centers (geographical locations), in 3 racks per DC. No server redundancy.



**Figure 2.5:** Cassandra, single site, single database, not co-located with SN. One Data Centre. No redundancy.



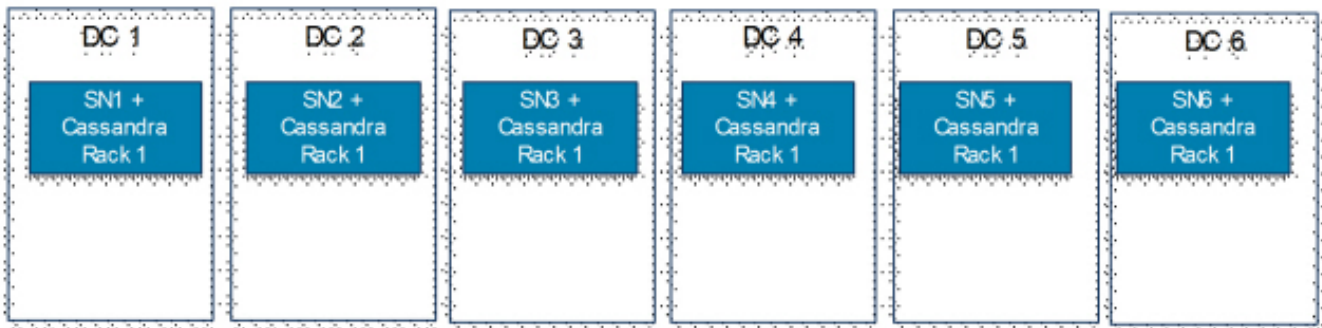
**Figure 2.6:** Cassandra, single site, multiple (2) databases, not co-located with SN. One Data Centre. Server redundancy (1+1) for SN1.



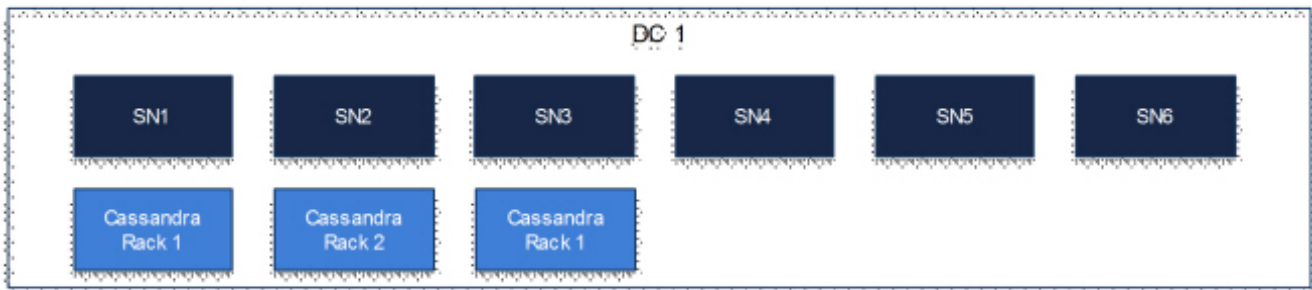
**Figure 2.7:** Cassandra with 2 DCs, 4 databases (2 per DC), standalone, i.e. not co-located with SN. 2 racks used per DC. A total of 7 Service Nodes, 6 active plus 1 standby which serves SN1 in DC1.



**Figure 2.8:** Cassandra in multi-site, co-located with the SNs, but only with one Cassandra node per DC. A total of 6 SNs and 6 DCs (geographical locations). No server redundancy.



**Figure 2.9:** Cassandra in single site, the database is standalone (3 nodes). 1 Data Center with 3 racks, and a system with 6 Service Nodes. No server redundancy.



**Figure 2.10:** Cassandra with 2 DCs (and 2 clusters), where DC2 is remote, and server redundancy is used in both DCs, i.e. SN1 and SN4 have standby servers.



## System Database Data Model Details

### System Database Principles

This section briefly describes the system database data model.

See [References](#) for further details.

### Decentralized Database

Every node in the cluster can have the same role. There is no single point of failure. Data is distributed across the cluster (so each node contains different data), but there is no master as every node can service any request.

Every Service Node must have access to one or several system database nodes. The system database nodes do not have a 1-to-1 relation to the MX-ONE Service Nodes. Instead the number of system database nodes should be kept as low as possible, for example, in a system with 10 Service Nodes, no more than 3 or 4 system database nodes should be used. For redundancy, a minimum of 2 system database nodes is recommended.

### System Database Data Replication

The replication protocol of Cassandra is used. In this way all the necessary information is available locally on every system database node (replica) which is defined to have the particular data.

The concept of a Cassandra database is that it is distributed, built to work decentralized, scalable and with high availability. Replication is done without a master-slave relationship, in a “ring” architecture per Data Center, but not necessarily so that all nodes store the same data, controlled by the used keyspaces.

Replication strategies are configurable. The system database is designed as a distributed system, for deployment of large numbers of nodes across multiple data centers. Key features of the system database’s distributed architecture are specifically tailored for multiple-data center deployment, for redundancy, for failover and disaster recovery.

A Cassandra cluster can have one or more keyspaces, which are analogous to Microsoft SQL Server and MySQL databases or Oracle schema. Replication is configured at the keyspace level, allowing different keyspaces to have different replication models.

The system database is able to replicate data to multiple nodes in a cluster, which helps ensure reliability, continuous availability, and fast management operations. The total number of data copies that are replicated is referred to as the replication factor. A replication factor of 1 means that there is only one copy of each row in a Data Center, whereas a replication factor of 3 means three copies of the data are stored across the Data Center.

Once a keyspace and its replication have been created, the system database automatically maintains that replication even when nodes are removed, or added.

Data is automatically replicated to multiple nodes for fault-tolerance. Replication across multiple data centers is supported. Failed Cassandra nodes can be replaced with no downtime.

Cassandra Query Language, CQL, is used when accessing the database.

# Files

The files related to the use of the system database are data files, system database configuration files, and the start script.

## Data Files for the System Database

Data files related to the system database are located in the directories:

```
/var/opt/cassandra/data  
/var/opt/cassandra/commit  
/var/opt/cassandra/logs
```

## System Database Configuration Files

The system database configuration files are:

```
/var/opt/cassandra/conf/cassandra.yaml  
/var/opt/cassandra/conf/cassandra-env.sh  
/var/opt/cassandra/conf/cassandra-rackdc.properties  
/var/opt/cassandra/conf/cassandra-topology.properties  
/var/opt/cassandra/conf/jvm.options
```

# Backup Strategy

The backup strategy for the system database-based data is integrated with the backup strategy for old style reload data in the MX-ONE Service Node. There is no separate backup or restore done for the system database data. The `data_backup` and `data_re-store` commands affect both reload data and system database data.

## The data\_backup Command

When the `data_backup` command is issued, the Cassandra data is dumped per database table to a number of CSV files, using the CQL protocol. The CSV (.csv) files are stored locally in each LIM, also if the LIM has no local Cassandra node, just as the .D files for reload data.

When a data reload is executed (either as a result of the `data_restore` command, or as a system measure), the data in the master LIM (server) is rolled back to match the CSV files. This is done by running a rollback command behind the scenes. Then it does only the necessary changes to make the data in the Cassandra node(s) match the CSV files.

A Cassandra node can read data from the CSV files. The CSV files are created on every LIM, in case a Cassandra entity has to be moved due to hardware failure.

## Safety Backup

The data dumped to the local hard disk by the data backup function shall be backed up to some external storage as a safety backup. This data will be in CSV format.

This procedure is not described here as it is not Cassandra-specific.

The `config_mirror` script also does the same, plus more.

# Starting and Stopping System Database

To start, restart or stop system database nodes, use the standard SLES/Linux `systemd` commands with the function `mxone_db.service`.

The `mxone_maintenance` script contains functions for add and remove of system database nodes.



# Error and Management Handling on the System Database

The system database has its own dedicated management tools, such as `nodetool`. This standard Linux `systemd` tool has functions for compaction, cleanup, status check, failure detection, flush and repair.

The used Cassandra configuration has certain limitations, which mean it is not allowed to connect the `nodetool` (remotely) from other servers than the one where a Cassandra node is running. See the *`nodetool` online help* in a server with Cassandra.

# Alarms

The system database operation is supervised and alarms are generated for the following error conditions:

- Fault Code (1:53) Cannot read from system database.
- Fault Code (1:55) System database out of order.
- Fault Code (1:56) NTP state is not correct.
- Fault Code (1:57) System database schema version mismatch between hosts.

# References

The following reference documents concerning the system database are relevant:

**Table 8.1:** Reference documents concerning the system database

1.	Cassandra: The Definitive Guide (2nd ed.). Carpenter, Jeff; Hewitt, Eben (July 24, 2016). O'Reilly Media. p. 370. ISBN 978-1-4919-3366-4.
2.	Datastax tutorial web pages about Cassandra 3.x, e.g. at <a href="https://academy.datastax.com">https://academy.datastax.com</a>
3	Apache Cassandra web pages, e.g. at <a href="http://cassandra.apache.org">http://cassandra.apache.org</a>

See also the document *Fault location*, regarding alarms.

