

# Root Cause Analysis on MySQL

The survey will take approximately 30 minutes to complete.

## Introduction of Root Cause Analysis (RCA) toward Database Performance Anomaly Debug

When observing unexpected performance anomalies (too slow queries), developers often want to identify the root causes to debug the anomalies. In the scenario of database, most performance anomalies are caused by abnormal states of certain system events (referred to as KPIs) instead of software bugs. With this regard, our RCA aims to **identify a set of KPIs** (e.g., CPU usage too high) that can **help to infer root causes of database performance anomalies**.

For example, if an I/O delay occurs on a database, and it results in a spike of query processing time, a correct RCA should select several KPIs that are highly related to I/O activity from hundreds of KPI candidates. These selected

## Case study

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Below we present explanation for most of the involved KPIs. Note that some cases stand for multiple KPIs, e.g., MySQL\_Handlers\_xxx may include MySQL\_Handlers\_external\_lock, and MySQL\_Handlers\_commit

1. **MySQL\_Transaction\_Handlers\_xxx:** Including commit and the time of commit and roll back transactions on the MySQL
2. **MySQL\_Handlers\_xxx:** Count the time of different conditions external\_lock, commit, etc.
3. **Current\_QPS:** Current number of queries processed per second
4. **MySQL\_Network\_xxx:** Record the network traffic of MySQL Traffic\_Outbound, Traffic\_Inbound, Usage\_Hourly\_Received Usage\_Hourly\_Sent. If any anomaly influence the network of them will be impacted, **i.e.**, all of them can be used to pre-cause.
5. **MySQL\_Query\_Cache\_Memory\_Free\_Memory:** The amount for the query cache. Query cache stores statements that have run in memory.
6. **MySQL\_Thread\_Cache\_Threads\_Created:** The number of threads to handle connections. If Threads\_created is big, you may want thread\_cache\_size value. In most cases, this metric keeps as 0 exist lots of connection, it will increase.

## 7. MySQL\_Aborted\_Connections\_xxx: Counts aborted connec

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### Workload Spike

**1. Implementation (root cause):**

We greatly increase the number of clients simulated by BenchBase to connect to MySQL server.

**2. Description:**

This anomaly will drastically increase the number of connections to the MySQL server, then increase the workload on the server. This is reflected in the increased number of queries processed by the server, more IO activity and increased network traffic.

**3. Impact on query duration:**

In this case, the query duration is much larger than the normal average value.

- ☐ MySQL\_Transaction\_Handlers\_\_commit
- ☐ MySQL\_Handlers\_\_external\_lock
- ☐ Current\_QPS
- ☐ MySQL\_Network\_Traffic\_\_Outbound
- ☐ MySQL\_Network\_Traffic\_\_Inbound
- ☐ MySQL\_Client\_Thread\_Activity\_\_Peak\_Threads\_Connected
- ☐ MySQL\_Client\_Thread\_Activity\_\_Peak\_Threads\_Running
- ☐ MySQL\_Connections\_\_Connections
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory

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7. **MySQL\_Aborted\_Connections\_xxx:** Counts aborted connections from the server and the client.
8. **Node\_xxx:** This series of KPIs records the corresponding metrics for each node.

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## I/O Latency

### 1. Implementation (root cause):

We create a 100ms delay on the pod (here, "pod" simply refers to the container) of MySQL.

### 2. Description:

Delay caused by this anomaly will lead to a decrease in the MySQL pod's I/O activity, and also lead to the client's current connection timeout or encounter some error, then the client will frequently trying to reconnect the MySQL server, increasing the max used connection count.

### 3. Impact on query duration

In this case, the query duration is much larger than the normal average value.

- ☐ MySQL\_Connections\_\_Max\_Used\_Connections
- ☐ Node\_IO\_Activity\_\_Page\_Out
- ☐ MySQL\_Handlers\_\_write
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Received
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Sent
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ Node\_Memory\_Distribution\_\_Total
- ☐ MySQL\_Client\_Thread\_Activity\_\_Avg\_Threads\_Running
- ☐ Node\_Swap\_Activity\_\_Swap\_In\_Reads
- ☐ Node\_IO\_Activity\_\_Page\_In
- ☐ MySQL\_Aborted\_Connections\_\_attempts
- ☐ MySQL\_Thread\_Cache\_\_Threads\_Created
- ☐ Top Command Counters show slave hosts

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7. **MySQL\_Aborted\_Connections\_xxx:** Counts aborted connections



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## I/O Fault-1

### 1. Implementation (root cause):

We create an I/O fault with error number 1, which can simulate a *Operation not permitted* error in the MySQL pod's file system, this error has 50% probability to happen per operation.

### 2. Description:

This anomaly will have an impact on I/O activity, then decrease the number queries processed per seconds. Further, the usage of network will also get slight impact.

### 3. Impact on query duration

In this case, the query duration is slightly smaller than the normal average value.

- ☐ Node\_IO\_Activity\_\_Page\_Out
- ☐ Node\_IO\_Activity\_\_Page\_In
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Sent
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ Node\_\_Memory\_Distribution\_\_Total
- ☐ MySQL\_Client\_Thread\_Activity\_\_Avg\_Threads\_Running
- ☐ Node\_Swap\_Activity\_\_Swap\_In\_Reads
- ☐ MySQL\_Connections\_\_Max\_Used\_Connections
- ☐ MySQL\_Aborted\_Connections\_\_attempts
- ☐ MySQL\_Thread\_Cache\_\_Threads\_Created
- ☐ Top\_Command\_Counters\_\_show\_slave\_hosts



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5. **MySQL\_Query\_Cache\_Memory\_Free\_Memory:** The amount for the query cache. Query cache stores statements that have run in memory.
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### I/O Fault-5

#### 1. Implementation (root cause):

We create an I/O fault with error number 5, which can simulate an *I/O error* in the MySQL pod's file system, this error has 50% probability to happen per operation.

#### 2. Description:

This anomaly will have an impact on I/O activity, then decrease the number queries processed per seconds. Further, the usage of network will also get slight impact.

#### 3. Impact on query duration

In this case, the query duration is slightly smaller than the normal average value.

- ☐ Node\_IO\_Activity\_\_Page\_In
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Sent
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ Node\_Memory\_Distribution\_\_Total
- ☐ MySQL\_File\_Openings
- ☐ MySQL\_Thread\_Cache\_\_Threads\_Created
- ☐ Node\_Swap\_Activity\_\_Swap\_In\_Reads
- ☐ MySQL\_Connections\_\_Max\_Used\_Connections
- ☐ MySQL\_Aborted\_Connections\_\_attempts
- ☐ MySQL\_Thread\_Cache\_\_Threads\_Created
- ☐ Top\_Command\_Counters\_\_show\_slave\_hosts

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5. **MySQL\_Query\_Cache\_Memory\_Free\_Memory:** The amount for the query cache. Query cache stores statements that have run in memory.
6. **MySQL\_Thread\_Cache\_Threads\_Created:** The number of threads handle connections. If Threads\_created is big, you may want thread\_cache\_size value. In most cases, this metric keeps as 0 exist lots of connection, it will increase.

7. **MySQL\_Aborted\_Connections\_xxx:** Counts aborted connections from the server and the client.
8. **Node\_xxx:** This series of KPIs records the corresponding metrics for each node.

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## I/O Saturation

### 1. **Implementation (root cause):**

We use stress-ng spawns multiple processes that spin on write()/unlink()/sync() system calls on the server where we deploy the cluster.

### 2. **Description:**

This anomaly will have an big impact on memory distribution and I/O activity, then decrease the number queries processed per seconds.

### 3. **Impact on query duration**

In this case, the query duration is much larger than the normal average value.

- ☐ Node\_IO\_Activity\_\_Page\_In
- ☐ MySQL\_Transaction\_Handlers\_\_commit
- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ MySQL\_Handlers\_\_external\_lock
- ☐ Current\_QPS
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Received
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Sent
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ Node\_CPU\_Usage\_Load\_\_iowait
- ☐ Node\_Disk\_Latency
- ☐ Node\_Swap\_Activity\_\_Swap\_In\_Reads
- ☐ MySQL\_Connections\_\_Max\_Used\_Connections
- ☐ MySQL\_Aborted\_Connections\_\_attempts
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### CPU Stress

**1. Implementation (root cause):**

We create an cpu-stress fault with 32 full load threads, which can simulate an *CPU stress test* on the MySQL pod.

**2. Description:**

This anomaly will have a significant impact on the MySQL pod's CPU, then this impact is transmitted to node where the MySQL pod is located. It will also influence the memory distribution and I/O activity.

**3. Impact on query duration**

In this case, the query duration is slightly smaller than the normal average value since the number of queries processed per second drastically decrease.

- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ Node\_CPU\_Usage\_Load\_\_user
- ☐ Node\_CPU\_Usage\_Load\_\_Load\_1m
- ☐ Node\_CPU\_Usage\_Load\_\_Max\_Core\_Utilization
- ☐ Node\_Memory\_Distribution\_\_Total



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5. **MySQL\_Query\_Cache\_Memory\_Free\_Memory:** The amount for the query cache. Query cache stores statements that have run in memory.
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### Memory Stress

#### 1. Implementation (root cause):

We create a mem-stress fault that contains 4 threads each occupied 128 MB in the MySQL pod's memory, which can simulate an *Memory stress test* on the MySQL pod.

#### 2. Description:

This anomaly will have a significant impact on the MySQL pod's memory distribution, then this impact is transmitted to node where the MySQL pod is located. It will also influence the I/O activity.

#### 3. Impact on query duration

In this case, the query duration is larger than the normal average value since the delay of I/O longer the processing times of queries.

- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ Node\_IO\_Activity\_\_Page\_In
- ☐ MySQL\_Connections\_\_Max\_Used\_Connections
- ☐ Node\_CPU\_Usage\_Load\_\_user
- ☐ Node\_Memory\_Distribution\_\_Total
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Received
- ☐ Node\_Swap\_Activity\_\_Swap\_In\_Reads
- ☐ Top\_Command\_Counters\_\_show\_slave\_hosts
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5. **MySQL\_Query\_Cache\_Memory\_Free\_Memory:** The amount for the query cache. Query cache stores statements that have run in memory.
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### Network Delay

#### 1. Implementation (root cause):

We create a network-delay fault that cause 100ms delay on all network connection to the MySQL pod.

#### 2. Description:

Because our MySQL client is outside the cluster, this network delay will delay the traffic between the client and the server, which results in a lower workload on the server, i.e., low QPS and less IO activity.

#### 3. Impact on query duration

In this case, the query duration is much smaller than the normal average value. We think this result from the delay of network decrease the workload on the server, or some queries' duration is missed and be set as 0.

- ☐ Node\_IO\_Activity\_\_Page\_Out
- ☐ Node\_IO\_Activity\_\_Page\_In
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Sent
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Received
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ Node\_Memory\_Distribution\_\_Total
- ☐ MySQL\_Aborted\_Connections\_\_timeout
- ☐ MySQL\_Handlers\_\_read\_rnd
- ☐ Node\_Swap\_Activity\_\_Swap\_In\_Reads
- ☐ MySQL\_Connections\_\_Max\_Used\_Connections
- ☐ MySQL\_Aborted\_Connections\_\_attempts
- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ MySQL\_Thread\_Cache\_\_Threads\_Created

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### Network Partition

#### 1. Implementation (root cause):

We create a network-partition fault that blocks all network connection to the MySQL pod.

#### 2. Description:

Because our MySQL client is outside the cluster, this network delay will block the traffic between the client and the server, which results in a lower workload on the server, i.e., low QPS and less IO activity.

#### 3. Impact on query duration

In this case, the query duration is much less than the normal average value. We think this result from the delay of network decrease the workload on the server, or some queries' duration is missed and be set as 0.

- ☐ Node\_IO\_Activity\_\_Page\_Out
- ☐ Node\_IO\_Activity\_\_Page\_In
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Sent
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Received
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ Node\_Memory\_Distribution\_\_Total
- ☐ MySQL\_Handlers\_\_delete
- ☐ MySQL\_Handlers\_\_read\_next
- ☐ Node\_Swap\_Activity\_\_Swap\_In\_Reads
- ☐ MySQL\_Connections\_\_Max\_Used\_Connections
- ☐ MySQL\_Aborted\_Connections\_\_attempts
- ☐ Node\_Memory\_Distribution\_\_Free
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☐ Top Command Counters show slave hosts

☐ Top Command Counters admin commands

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### Database Backup

**1. Implementation (root cause):**

We run mysqldump on the TPCC database instance to dump the database to the client over the network.

**2. Description:**

Because our MySQL client is outside the cluster, this anomaly will drastically influence the network traffic between the server and the client. Queries will also be influenced because of lock.

**3. Impact on query duration**

In this case, the query duration is larger than the normal average value since the task of backup increase the server's workload.

- ☐ MySQL\_Transaction\_Handlers\_\_commit
- ☐ Current\_QPS
- ☐ MySQL\_Network\_Traffic\_\_Inbound
- ☐ MySQL\_Handlers\_\_external\_lock
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Sent
- ☐ MySQL\_Handlers\_\_read\_next
- ☐ MySQL\_Handlers\_\_read\_rnd\_nex
- ☐ MySQL\_Network\_Traffic\_\_Outbound\_
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ Node\_Swap\_Activity\_\_Swap\_In\_Reads
- ☐ Node\_IO\_Activity\_\_Page\_In
- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ MySQL\_Connections\_\_Max\_Used\_Connections
- ☐ MySQL\_Aborted\_Connections\_\_attempts
- ☐ Node\_Memory\_Distribution\_\_Free

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### Database Restore

**1. Implementation (root cause):**

We dump the history of TPCC database back to the server over the network.

**2. Description:**

Because our MySQL client is outside the cluster, this anomaly will drastically influence the network traffic between the server and the client. Queries will also be influenced because of lock.

**3. Impact on query duration**

In this case, the query duration is larger than the normal average value since the task of restore increase the server's workload.

- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ MySQL\_Network\_Traffic\_\_Outbound
- ☐ Current\_QPS\_\_None
- ☐ MySQL\_Handlers\_\_external\_lock
- ☐ MySQL\_Transaction\_Handlers\_\_commit
- ☐ MySQL\_Handlers\_\_read\_next
- ☐ MySQL\_Handlers\_\_read\_rnd
- ☐ MySQL\_Handlers\_\_write
- ☐ MySQL\_Network\_Traffic\_\_Inbound
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Received
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ Node\_Swap\_Activity\_\_Swap\_In\_Reads
- ☐ Node\_IO\_Activity\_\_Page\_In
- ☐ MySQL\_Connections\_\_Max\_Used\_Connections
- ☐ MySQL\_Aborted\_Connections\_\_attempts

- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ MySQL\_Thread\_Cache\_\_Threads\_Created
- ☐ Top\_Command\_Counters\_\_show\_slave\_hosts
- ☐ Top\_Command\_Counters\_\_admin\_commands



## Case study

Here, we provide 13 encountered performance anomalies when running the MySQL cluster. You are kindly asked to select proper KPIs that you believe high related to the root cause of those anomalies. The root cause of anomalies in each case has been provided in the description of questions.

Below we present explanation for most of the involved KPIs. Note that some cases stand for multiple KPIs, e.g., MySQL\_Handlers\_xxx may include MySQL\_Handlers\_external\_lock, and MySQL\_Handlers\_commit

1. **MySQL\_Transaction\_Handlers\_xxx:** Including commit and the time of commit and roll back transactions on the MySQL
2. **MySQL\_Handlers\_xxx:** Count the time of different conditions external\_lock, commit, etc.
3. **Current\_QPS:** Current number of queries processed per second
4. **MySQL\_Network\_xxx:** Record the network traffic of MySQL Traffic\_Outbound, Traffic\_Inbound, Usage\_Hourly\_Received Usage\_Hourly\_Sent. If any anomaly influence the network of of them will be impacted, **i.e.**, all of them can be used to pre cause.
5. **MySQL\_Query\_Cache\_Memory\_Free\_Memory:** The amount for the query cache. Query cache stores statements that have run in memory.
6. **MySQL\_Thread\_Cache\_Threads\_Created:** The number of threads handle connections. If Threads\_created is big, you may want thread\_cache\_size value. In most cases, this metric keeps as 0 exist lots of connection, it will increase.

## 7. MySQL\_Aborted\_Connections\_xxx: Counts aborted connec

12

### Flush Logs

#### 1. Implementation (root cause):

We flush all logs by invoking mysqladmin commands 'flush-logs'.

#### 2. Description:

Flushing the binary log creates a new binary log file. Whereas flushing the general query log closes and reopens the log file. The same goes with the slow query log and error log, it just closes and reopens the log file. This command has very tiny impact on our cluster.

#### 3. Impact on query duration

In this case, the query duration is slightly larger than the normal average value.

- ☐ MySQL\_Transaction\_Handlers\_\_commit
- ☐ MySQL\_Handlers\_\_external\_lock
- ☐ MySQL\_Network\_Traffic\_\_Outbound
- ☐ MySQL\_Network\_Traffic\_\_Inbound
- ☐ Current\_QPS
- ☐ MySQL\_Handlers\_\_read\_rnd
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Sent
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Received
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ MySQL\_Sorts\_\_Sort\_Rows
- ☐ Node\_Swap\_Activity\_\_Swap\_In\_Reads
- ☐ Node\_IO\_Activity\_\_Page\_In
- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ MySQL\_Connections\_\_Max\_Used\_Connections
- ☐ MySQL\_Aborted\_Connections\_\_attempts

- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ MySQL\_Thread\_Cache\_\_Threads\_Created
- ☐ Top\_Command\_Counters\_\_show\_slave\_hosts
- ☐ Top Command Counters admin commands

## Case study

Here, we provide 13 encountered performance anomalies when running the MySQL cluster. You are kindly asked to select proper KPIs that you believe highly related to the root cause of those anomalies. The root cause of anomalies in each case has been provided in the description of questions.

Below we present explanation for most of the involved KPIs. Note that some cases stand for multiple KPIs, e.g., MySQL\_Handlers\_xxx may include MySQL\_Handlers\_external\_lock, and MySQL\_Handlers\_commit

1. **MySQL\_Transaction\_Handlers\_xxx:** Including commit and the time of commit and roll back transactions on the MySQL
2. **MySQL\_Handlers\_xxx:** Count the time of different conditions external\_lock, commit, etc.
3. **Current\_QPS:** Current number of queries processed per second
4. **MySQL\_Network\_xxx:** Record the network traffic of MySQL Traffic\_Outbound, Traffic\_Inbound, Usage\_Hourly\_Received Usage\_Hourly\_Sent. If any anomaly influence the network of of them will be impacted, **i.e.**, all of them can be used to pre cause.
5. **MySQL\_Query\_Cache\_Memory\_Free\_Memory:** The amount for the query cache. Query cache stores statements that have run in memory.
6. **MySQL\_Thread\_Cache\_Threads\_Created:** The number of threads handle connections. If Threads\_created is big, you may want thread\_cache\_size value. In most cases, this metric keeps as 0 exist lots of connection, it will increase.

## 7. MySQL\_Aborted\_Connections\_xxx: Counts aborted connec

13

### Flush Tables

**1. Implementation (root cause):**

We flush all tables by invoking mysqladmin commands 'flush-tables'.

**2. Description:**

The idea of flush tables is to force all tables to be closed. Relative IO and queries, transactions processing may be influenced, too. Same as flush logs, this command has tiny impact on our cluster.

**3. Impact on query duration**

In this case, the query duration is slightly larger than the normal average value.

- ☐ MySQL\_Handlers\_\_external\_lock
- ☐ MySQL\_Handlers\_\_write
- ☐ MySQL\_Network\_Traffic\_\_Outbound
- ☐ MySQL\_Transaction\_Handlers\_\_commit
- ☐ MySQL\_File\_Openings
- ☐ MySQL\_Handlers\_\_read\_rnd
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Received
- ☐ MySQL\_Network\_Usage\_Hourly\_\_Sent
- ☐ MySQL\_Query\_Cache\_Memory\_\_Free\_Memory
- ☐ Node\_Swap\_Activity\_\_Swap\_In\_Reads
- ☐ Node\_IO\_Activity\_\_Page\_In
- ☐ Node\_Memory\_Distribution\_\_Free
- ☐ MySQL\_Connections\_\_Max\_Used\_Connections
- ☐ MySQL\_Aborted\_Connections\_\_attempts
- ☐ MySQL\_Thread\_Cache\_\_Threads\_Created
- ☐ Top\_Command\_Counters\_\_show\_slave\_hosts

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Top\_Command\_Counters\_\_admin\_commands

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