iSeries

Clusters

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Contents

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Clusters let you efficiently group your iSeries(TM) servers together to set up an environment that provides availability that approaches 100 percent for your critical applications, devices, and data. Clusters also provide simplified systems management and increased scalability to seamlessly add new components as your business grows.

“What’s new for V5R2”
Take a look at what is new for this release.“Cluster concepts” on page 2

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“Cluster concepts” on page 2
Get a complete understanding of how clusters work. Read about the benefits of clusters and how they can be important to you, as well as information on important clustering concepts and how they fit together.

“Plan for clusters” on page 18
Find what you need to do before you can set up clusters on your iSeries servers. Find out the prerequisites for clusters as well as hints on designing your cluster. Finally, read tips for setting up your network and some performance hints for clusters.

“Cluster applications” on page 30
Read about considerations for writing and implementing highly available applications within your cluster.

“Configure clusters” on page 34
Understand how to go about creating a cluster.

“Manage clusters” on page 38
Read the cluster management procedures to help you maintain your cluster.

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Find error recovery solutions for problems that are specific to clusters.

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IBM(R) related information contains technical, know-how, and ″how to″ information.

What’s new for V5R2

iSeries Clustering provides the foundations for achieving levels of availability greater than what can be achieved in a single system environment. Cluster resource services in OS/400 has been enhanced in V5R2 to provide support for:

- **Primary and secondary independent disk pools**
  Support for library-based objects through the use of primary and secondary disk pools is present at V5R2. When independent disk pools were introduced in V5R1, they supported user-defined file systems

(UDFS) only. Support for library-based objects allows independent disk pools residing on switchable devices to be composed of library-based objects. See What's new for V5R2 with independent disk pools for details.

- **Cluster CL commands**
  Cluster control language (CL) commands have been added to allow system programmers and system administrators easier access to cluster capabilities.
- **Clustered hash table**
  Non persistent data can be shared and replicated between cluster nodes using the Clustered Hash Table APIs.
- **Failover message queue**
  The failover message queue can be used to control what happens during a failover.
- **Self-starting a cluster node**
  A node can start itself and can rejoin the current active cluster, provided it can find an active node in the cluster.

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Cluster concepts

An iSeries cluster is a collection or group of one or more servers or logical partitions that work together as a single server. Servers in a cluster, called "Cluster node" on page 7, work cooperatively to provide a single computing solution. iSeries clustering supports up to 128 nodes in a cluster. This allows you to efficiently group your iSeries servers together to set up an environment that provides availability that approaches 100 percent for your critical applications and your critical data. This helps ensure that your critical servers and applications are available 24 hours a day, seven days a week. Clusters also provide simplified systems management and increased scalability to seamlessly add new components as your business grows.

For more cluster concepts, see the following:

- "Benefits of clusters" on page 3
- "How a cluster works" on page 3
- "Cluster basics" on page 3
- "The elements of a cluster" on page 6

Benefits of clusters

Clustering offers a continuous availability solution if your business demands operational systems 24 hours a day, seven days a week. By implementing clusters, you can greatly reduce the number and duration of unplanned outages, ensuring that your servers, data, and applications are continuously available.

The major benefits that clusters can offer your business are:

Continuous availability

The “Switchover” on page 13 and “Failover” on page 13 mechanisms provided by clusters ensure that your servers, data and applications remain continuously available.

Simplified administration

You can manage a group of systems as a single server or single database, without having to sign on to individual servers.

Increased scalability

Seamlessly add new components as your business growth requires.

How a cluster works

The cluster infrastructure provided as a part of OS/400, called cluster resource services, provides “Failover” on page 13 and “Switchover” on page 13 capabilities for your servers that are used as database servers or application servers in a client-server environment. If a system outage or a site loss occurs, the functions that are provided on a clustered database server can be switched over to one or more designated backup systems that either:

- Contain a current copy, provided through “Replication” on page 15, of your critical application data.
- Become the primary point of access for the “Resilient devices” on page 12 containing that critical data.

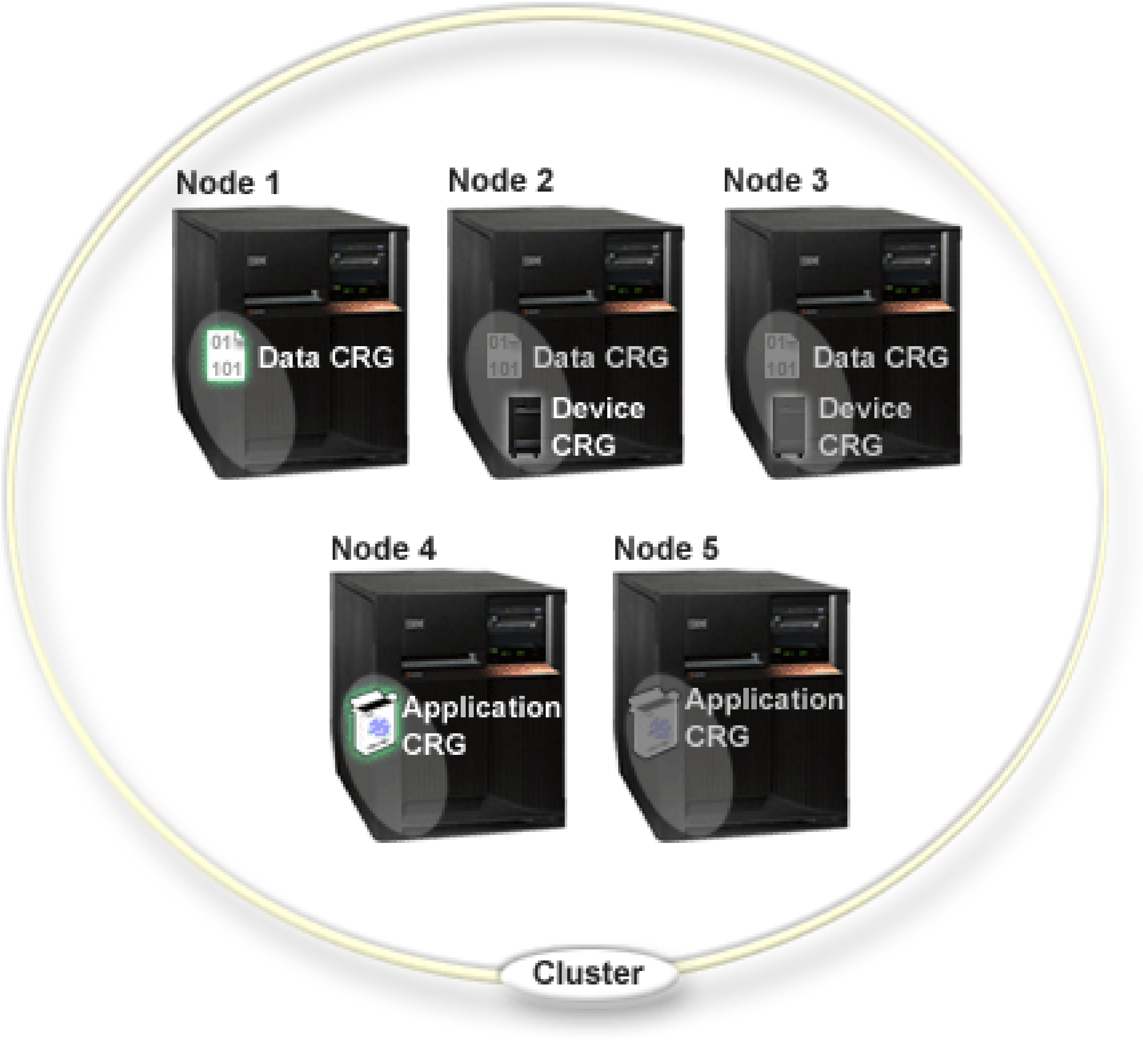
In either scenario, the data and applications remain available. The switching of the access point can be automatic if a system failure, or failover, should happen, or you can control how and when the transfer will take place by manually initiating a switchover.

The switchover and failover will not impact you as a system user or impact applications that you have running on an application server. You can automatically reroute data requests to the new primary node. You can easily maintain multiple replicates of the same data or store the data in a resilient device. If your clusters contain more than two nodes, you can group a system’s “Resilient data” on page 12 (replicated data) together to allow different nodes to act as the backups for each group’s resilient data. Multiple backup nodes can be defined . Once a node has been restarted after a failure, cluster resource services provides the means to reintroduce “Rejoin” on page 13 nodes to the cluster and restore their operational capabilities.

See “Comparing replicated and switchable resources” on page 24 for a comparison of these technologies.

Cluster basics

Before you begin to design and customize a cluster that will satisfy your needs, you need to understand the basic clustering concepts. The example below illustrates the basic constructs of a cluster: its **“Cluster node” on page 7** and **“Cluster resource group” on page 7**.



In this cluster, there are five cluster nodes. Nodes are the iSeries servers or logical partitions that are members of the cluster. When you create a cluster, you specify the servers that you want to include in the cluster as nodes.

There are three **cluster resource groups** (CRGs) present in this example. A cluster resource group serves as the control object for a collection of resilient resources. The CRG defines actions to be taken during a switchover or failover. Each CRG accomplishes this by defining the following:

- “Recovery domain” on page 8 - specifies the role of each node in the CRG:
  - The **primary** node is the cluster node that is the primary point of access for the resilient cluster resource.
  - A **backup** node is a cluster node that will take over the role of primary access if the present primary node fails or a manual switchover is initiated.
  - A **replicate** node is a cluster node that has copies of cluster resources, but is unable to assume the role of primary or backup.
- “Cluster resource group exit programs” on page 8 - manages cluster-related events for that group; one such event would be moving an access point from one node to another node

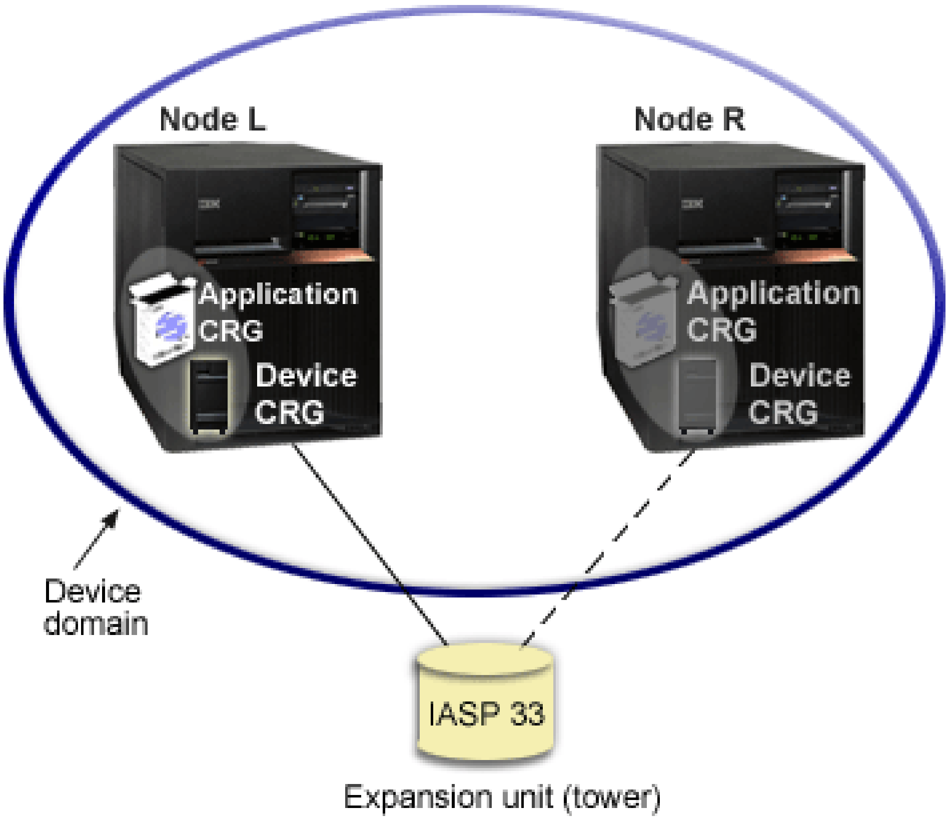
When you create a CRG in a cluster, the CRG object is created on all nodes specified to be included in the recovery domain. However, a single system image of the CRG object, which you can access from any active node in the CRG's recovery domain, is provided. That is, any changes made to the CRG will be made on all nodes in the recovery domain.

An iSeries cluster supports three types of CRGs: application, data and device. In the example above, one CRG of each type is present:

- **Data CRG**: The data CRG is present on Node 1, Node 2 and Node 3. This means that the recovery domain for the data CRG has specified a role for Node1 (primary), Node 2 (first backup) and Node 3 (second backup). In the example, Node 1 is currently serving as the primary point of access. Node 2 is defined as the first backup in the recovery domain. This means that Node 2 contains a copy of the resource which is kept current through replication. Should a failover or switchover occur, Node 2 would become the primary point of access.
- **Application CRG**: The application CRG is present on Node 4 and Node 5. This means that the recovery domain for the application CRG has specified Node 4 and Node 5. In the example, Node 4 is currently serving as the primary point of access. Should a failover or switchover occur, Node 5 would become the primary point of access for the application.
- **Device CRG**: The device CRG is present on Node 2 and Node 3. This means that the recovery domain for the device CRG has specified Node 2 and Node 3. In the example, Node 2 is currently serving as the primary point of access. This means that the resilient device owned by the device CRG can currently be accessed from Node 2. Should a failover or switchover occur, Node 3 would become the primary point of access for the device.

  A device CRG requires a resilient device called an independent disk pool (also called an independent auxiliary storage pool or independent ASP) to be configured on an external device, an expansion unit (tower) or IOP in a logical partition. See Independent disk pools for more complete documentation on switchable independent disk pools.

  The nodes in the recovery domain of a device CRG must also be members of the same device domain. The example below illustrates a device CRG with Node L and Node R in its recovery domain. Both nodes are also members of the same device domain. See “Device domains” on page 10 for more details.



The elements of a cluster

The following are constructs, events, actions, and terms associated with iSeries clustering:

Cluster: An iSeries cluster is a collection of one or more servers that work together as a single server. The following are elements of a cluster:

- "Cluster node" on page 7: A cluster node is an iSeries server or a logical partition that is a member of a cluster.
- "Cluster resource group" on page 7: A cluster resource group (CRG) is an OS/400 system object that is a set or grouping of cluster resources that define actions to be taken during a switchover or failover. The cluster resource group identifies two important elements:
  - "Cluster resource group exit programs" on page 8: Cluster resource group exit programs manage the movement of the access point of a resilient resource.
    "Recovery domain" on page 8: A recovery domain is a subset of nodes in a cluster grouped together to provide availability for one or more resources. A domain represents the nodes of the cluster where a cluster resource exists.
- **cluster resource services**: Cluster resource services is the set of OS/400 system service functions that support iSeries cluster implementations.
- "Cluster version" on page 9: The cluster version identifies the communication level of the nodes in the cluster.
- "Device domains" on page 10: A device domain is a subset of nodes in a cluster grouped together to share device resources.
- **"Resilient resources" on page 11**: A resilient resource is a device, data, or an application that can be recovered if a node in a cluster fails. The types of resilient resources include:
  - "Resilient applications" on page 12: Resilient applications are applications that can be restarted on a different cluster node without requiring you to reconfigure the clients.

- "Resilient data" on page 12: Resilient data is data that is replicated, or copied, on more than one node in a cluster.
- "Resilient devices" on page 12: Resilient devices are physical resources, represented by a configuration object such as a device description, that are accessible from more than one node in a cluster through the use of switched disk technology and independent disk pools.

Cluster events
The following are events, actions, and services that occur within a cluster:

- "Failover" on page 13: A failover is a cluster event where the primary database server, application server, or device server automatically switches over to a backup system due to the failure of the primary server, without any manual intervention.
- "Switchover" on page 13: A switchover is a cluster event where the primary database server, application server, or device server switches over to a backup system due to the manual intervention from the cluster management interface.
- **join**: Join means to become a new member of a cluster.
- **"Rejoin" on page 13**: Rejoin means to become an active member of a cluster after having been a nonparticipating member.
- **"Merge" on page 15**: A merge occurs when a node rejoins the cluster after a cluster partition has occured.
- "Replication" on page 15: Replication is the process of copying objects from one node in a cluster to one or more other nodes in the cluster, which makes the objects on all the systems identical.
- "Heartbeat monitoring" on page 15: Heartbeat monitoring ensures that each node is active by sending a signal around the cluster to detect activity.
- "Reliable message function" on page 17: The reliable message function of cluster resource services keeps track of each node in a cluster and ensures that all nodes have consistent information about the state of cluster resources.
- **"Cluster partition" on page 18**: A cluster partition is a subset of the active cluster nodes that result from a network failure. Members of a partition maintain connectivity with each other.

Cluster node

A **cluster node** is an iSeries server or logical partition that is a member of a cluster.

Each cluster node is identified by an 8-character cluster node name that is associated with one or more IP addresses that represent an iSeries server. When configuring a cluster, you can use any name that you want for a node in the cluster. However, it is recommended that the node name be the same as the host name or the system name.

Cluster communications makes use of the TCP/IP protocol suite to provide the communications paths between cluster services on each node in the cluster. The set of cluster nodes that are configured as part of the cluster is referred to as the **cluster membership list**.

Cluster resource group

A **cluster resource group (CRG)** is an OS/400 system object that is a set or grouping of cluster resources that define actions to be taken during a switchover or failover. The group identifies two important elements:

- "Recovery domain" on page 8
- "Cluster resource group exit programs" on page 8 that manages cluster-related events for that group - one such event would be moving an access point from one node to another node

A collection of related cluster resources that defines actions to be taken during a switchover operation of the access point of resilient resources. The group describes a recovery domain and supplies the name of the cluster resource group exit program that manages the movement of an access point.

Cluster resource group objects are defined as data resilient, application resilient, or device resilient. Data resiliency enables multiple copies of data to be maintained on more than one node in a cluster and enables the point of access to be changed to a backup node. Application resiliency enables an application program to be restarted on either the same node or a different node in the cluster. Device resiliency enables a device resource to be moved (switched) to a backup node.

Each data and application cluster resource group has a cluster resource group exit program associated with it. The exit program is optional for resilient device cluster resource groups.

In iSeries Navigator, cluster resource groups are referred to differently.

- A device CRG is referred to as a **switchable hardware group**.
- An application CRG is referred to as a **switchable software product**.
- A data CRG is referred to as a **switchable data group**.

See Managing the processing of cluster resource groups for more details.

Cluster resource group exit programs

Cluster resource group exit programs manage the movement of the access point of a resilient resource. Cluster resource group exit programs are called during different phases of a cluster environment. These programs establish and manage the environment necessary for data, device, or application resiliency within a cluster. They are called when a cluster event that impacts a cluster resource group occurs to gracefully handle the processing of the cluster event, such as a switchover or a failover. Exit programs are written or provided by cluster middleware business partners and by cluster-aware application program providers.

For detailed information on the cluster resource group exit programs, including what information is passed to them for each action code, see Cluster Resource Group Exit Program in the cluster API documentation.

Recovery domain

A **recovery domain** is a subset of cluster nodes that are grouped together in a cluster resource group (CRG) for a common purpose such as performing a recovery action. A domain represents those nodes of the cluster from which cluster resource can be accessed. This subset of cluster nodes that is assigned to a particular “Cluster resource group” on page 7 either supports the primary point of access, secondary (backup) point of access, or replicate.

The three types of roles a node can have in a recovery domain are:

Primary

The cluster node that is the primary point of access for the resilient cluster resource.
- For a data CRG, the primary node contains the principle copy of a resource.
- For an application CRG, the primary node is the system on which the application is currently running.
- For a device CRG, the primary node is the current owner of the device resource.
If the primary node for a CRG fails, or a manual switchover is initiated, all CRG objects fail or switch over to a backup node.

Backup

The cluster node that will take over the role of primary access if the present primary node fails or a manual switchover is initiated. For a data CRG, this cluster node contains a copy of that resource which is kept current with replication.

Replicate

A cluster node that has copies of cluster resources, but is unable to assume the role of primary or backup. Failover or switchover to a replicate node is not allowed. If you ever want a replicate node to become a primary, you must first change the role of the replicate node to that of a backup node. This can be accomplished by "Change the recovery domain for a cluster resource group" on page 40.

The switchover and failover order is the relationship (or order) that you have defined among the primary node and backup nodes in a recovery domain. In a recovery domain, there can be multiple backup nodes. You specify one node as first backup, another as second backup, and so on. If a primary node fails, the access point for the resilient resources switches to the first active backup node.

Each node in the recovery domain has a role with respect to the current operational environment of the cluster. This is called its **current role** in the recovery domain. As the cluster goes through operational changes such as nodes ending, nodes starting, and nodes failing, the node's current role is changed accordingly. Each node in the recovery domain also has a role with respect to the preferred or ideal cluster environment. This is called its **preferred role** in the recovery domain. The preferred role is a static definition that is initially set when the cluster resource group is created. As the cluster environment changes, this role is not changed. The preferred role is only changed when nodes are added or removed from the recovery domain, or when a node is removed from the cluster. You can also manually change the preferred roles. See "Change the recovery domain for a cluster resource group" on page 40 for details.

Conceptually, you can view the recovery domain as follows:

Node	Current role	Preferred role
A	Backup 1	Primary
B	Backup 2	Backup 1
C	Primary	Backup 2
D	Replicate	Replicate

In this example, Node C is serving as the current primary node. Because it has a preferred role of the second backup, Node C's current role as primary would have to have resulted from two failover/switchover actions. Upon the first failover or switchover action, the primary role moved from Node A to Node B since Node B is defined as the first backup. The second failover/switchover triggered Node C to become the primary node since it is defined as the second backup node.

Note: The role of each node in the recovery domain can also be changed manually. The above example illustrates how the roles in the recovery domain change when switchover/failover actions occur and no manual changes are made to the designation of the roles in the recovery domain.

Cluster version

A **cluster version** represents the level of function available on the cluster. Versioning is a technique that allows the cluster to contain servers at multiple release levels and fully interoperate by determining the communications protocol level to be used. If you are implementing a cluster that will contain servers of varying release levels, see "Multiple-release clusters" on page 22.

There are actually two cluster versions:

Potential cluster version

Represents the most advanced level of cluster function available for a given node. This is the version at which the node is capable of communicating with the other cluster nodes.

Current cluster version

Represents the version currently being used for all cluster operations. This is the version of communications between the nodes in the cluster.

The potential cluster version is incremented on every OS/400 release which has significant new clustering functionality not available in earlier cluster versions. If the current cluster version is less than the potential cluster version, then that function cannot be used since some nodes would not be able to recognize or process the request. To take advantage of such new function, every server in the cluster would need to be at the same potential cluster version and the current cluster version must also be set to that level.

When a node attempts to join a cluster, its potential cluster version is compared against the current cluster version. If the value of the potential cluster version is not the same as current (N) or not equal to the next version level (N+1), then the node is not allowed to join the cluster. Note that the current cluster version is initially set by the first node defined in the cluster using the value specified on the create cluster API or command. See “Configure a cluster” on page 37 for more information.

For example if you want V5R1 nodes to exist with V5R2 nodes you can do one of the following:

- Create the cluster on a V5R1 server and add in the V5R2 node.
- Create the cluster on a V5R2 server specifying to allow previous nodes to be added to the cluster, then add V5R1 servers to the cluster.

In a multiple-release cluster, cluster protocols will always be run at the lowest node release level (N). This is defined when the cluster is first created. N can either be set to the potential node version running on the node that originated the create cluster request or one cluster version previous to the originators potential node version. Nodes in the cluster can differ by at most one cluster version level.

Once all servers in the cluster have been upgraded to the next release, the cluster version can be upgraded so that new functions are available. This can be accomplished by adjusting the cluster version. See “Adjust the cluster version of a cluster” on page 40 for more information.

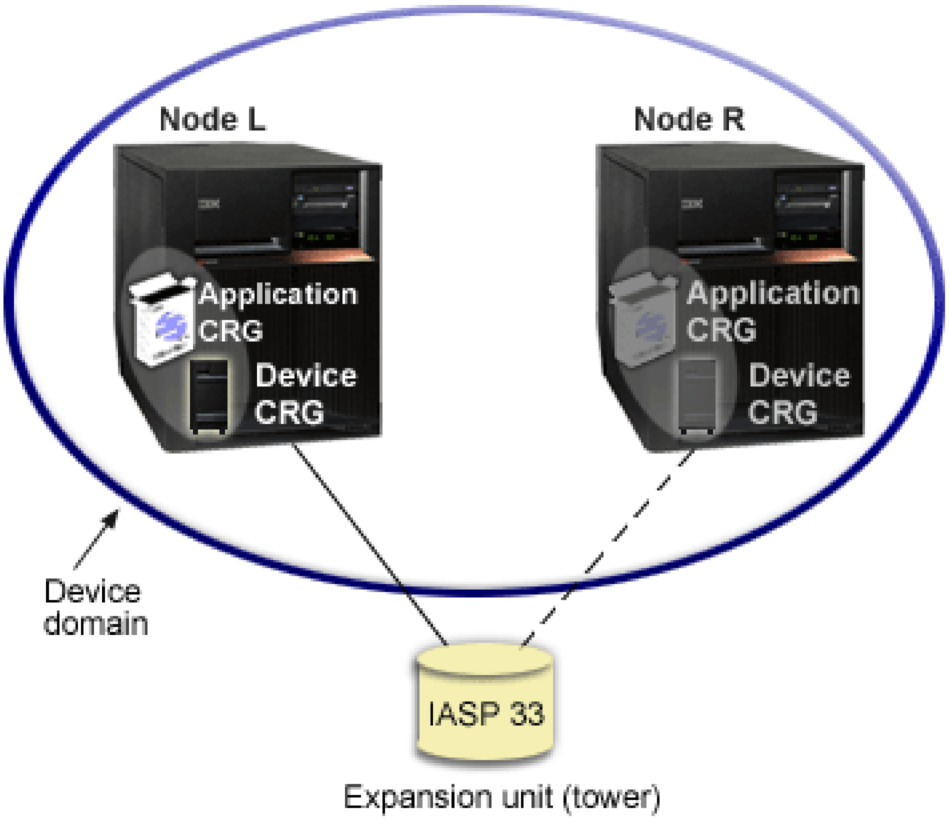
Read more on cluster versions in the Cluster APIs documentation, including information on restrictions and how cluster versions correspond to OS/400 releases.

Device domains

A **device domain** is a subset of nodes in a cluster that share device resources. More specifically, nodes in a device domain can participate in switching action for some collection of resilient device resources. Device domains are identified and managed through a set of interfaces that allow you to add a node to a device domain or remove a node from a device domain.

“Example: A switched disk cluster using independent disk pools” on page 49 contains an example configuration showing a device domain within a cluster.

Device domains are used to manage certain global information necessary to switch a resilient device from one node to another. All nodes in the device domain need this information to ensure that no conflicts occur when devices are switched. For example, for a collection of switchable independent disk pools, the independent disk pool identification, disk unit assignments, and virtual address assignments must be unique across the entire device domain.



A cluster node can belong to at most one device domain. Before a node can be added to the recovery domain for a device CRG, the node must be first defined as a member of a device domain. All nodes that will be in the recovery domain for a device CRG must be in the same device domain.

To create and manage device domains, you must have Option 41 (OS/400 - HA Switchable Resources) installed and a valid license key on your system.

For information on managing device domains, see:

- "Add a node to a device domain" on page 41
- "Remove a node from a device domain" on page 42

Resilient resources

Resilient resources are system resources, such as data, devices and applications, that are highly available if you have implemented clustering on your systems. If a cluster node that is the primary access point for a particular set of resilient resources in the cluster should incur an outage, another cluster node that is defined as the backup for that set of resources now becomes the access point.

The types of system resources that can be resilient are:

1. Data being replicated between nodes.
2. Applications using an IP address, which can be switched from one node to another.
3. Hardware devices which can be switched from one node to another.

The definition of the relationship between the nodes that are associated with a set of resilient resources is found in the **cluster resource group (CRG)** object. "Cluster resource group" on page 7 are replicated and coordinated across the nodes in the cluster through cluster resource services.

For more information see:

- “Resilient applications”
- “Resilient data”
- “Resilient devices”

Resilient applications

A **resilient application** is an application that can be restarted on a different cluster node without requiring you to reconfigure the clients. See “Make application programs resilient” on page 31 to learn about what characteristics make an application resilient.

A resilient application needs the ability to recognize the temporary loss of the Internet Protocol (IP) connection between the client and the server. The client application must be aware that the IP connection will be temporarily unavailable and must retry access rather than ending or initiating a failover. Similarly, if you are performing a switchover, server applications need to be aware that the IP connection is no longer available. Eventually, an error condition is returned to the server application. Once this error condition is received, it is best if the server application recognizes the condition and ends normally.

IP address takeover is a high availability function that is used to protect clients from application server outages. An **application takeover IP address** is a floating address that is to be associated with an application. The concept is to use IP address aliasing to define a floating IP address that is associated with multiple application servers or hosts. When one application server in a cluster fails, another cluster node assumes the responsibilities of the application server without requiring you to reconfigure the clients.

Also introduced in support of IP address takeover is the concept of application cluster resource groups (CRGs). Application CRGs are cluster resource groups that contain an application takeover IP address resource and a “Recovery domain” on page 8. The recovery domain contains the list of application servers within the cluster that support a particular application. If a single resource fails, cluster resource services initiates a failover on the group to which the failing resource belongs.

See “Cluster applications” on page 30 for more information.

Resilient data

Resilient data is data that is replicated (copied) on more than one node in a cluster. Each node in the recovery domain contains a copy of the resilient data maintained through some “Replication” on page 15 mechanism. Nodes that are defined as backup in the recovery domain can assume the role of primary point of access for the resilient data. Nodes that are defined as replicates also contain a copy of the data, but cannot assume the role of primary. Typically, data copied to a replicate node is used to offload work, such as backup or read-only queries, from the primary node.

Resilient devices

Resilient devices are physical resources, represented by a configuration object, such as a device description, that are accessible from more than one node in a cluster. In the event of an outage, the point of access for the resource is switched to the first backup node in the cluster resource group recovery domain. The type of devices that can be defined as resilient are:

Independent disk pools
also referred to as independent ASPs, independent disk pools can go offline or come online independent of the rest of the system storage.

A **resilient device cluster resource group** can contain a list of switchable devices. Each device in the list identifies a switchable independent disk pool. The entire collection of devices are switched to the backup node when an outage occurs. Optionally, the devices can also be varied on as part of the switchover/failover process. There are limitations related to the physical configuration associated with the list of switchable devices. See Independent disk pools for more information on how to set up the appropriate configuration for an independent disk pool defined to be resilient.

A resilient device CRG is very similar to the other types of CRGs. One difference, the list of switchable devices, was mentioned above. Another difference is that the exit program is optional for a device CRG. If environment or data specific processing is needed, an exit program can be used for the CRG. See the Create Cluster Resource Group (QcstCreateClusterResourceGroup) API for additional information on this type of CRG.

Failover

A **failover** occurs when a server in a cluster automatically switches over to one or more backup servers in the event of a system failure. Contrast this with a "Switchover", which happens when you manually switch access from one server to another. A switchover and a failover function identically once they have been triggered. The only difference is how the event is triggered.

When a failover occurs, access is switched from the cluster node currently acting as the primary node in the recovery domain of the cluster resource group to the cluster node designated as the first backup. See "Recovery domain" on page 8 for information on how the switchover order is determined.

When multiple "Cluster resource group" on page 7 (CRGs) are involved in a failover action, the system processes the device CRGs (switchable hardware groups) first, the data CRGs (switchable data groups) second, and the application CRGs (switchable software products) last.

See Example: Failure for different reasons of why a failover might occur.

The failover message queue receives messages regarding failover activity. You can use it to control the failover processing of a cluster resource group. See failover message queue for details.

Switchover

A **switchover** happens when you manually switch access to a resource from one server to another. You would usually initiate a manual switchover if you wanted to perform system maintenance, such as applying program temporary fixes (PTFs), installing a new release, or upgrading your system. Contrast this with a "Failover", which happens automatically when a outage occurs on the primary node.

When a switchover occurs, access is switched from the cluster node currently acting as the primary node in the recovery domain of the cluster resource group to the cluster node designated as the first backup. See "Recovery domain" on page 8 for information on how the switchover order is determined.

If you are doing an administrative switchover of multiple CRGs, the order you specify should consider the relationships between the CRGs. For example, if you have an application CRG that depends on data associated with a device CRG, the steps to an ordered switchover are:

1. Stop the application on the old primary node (to quiesce changes to the data).
2. Switch the device CRG to the new primary node.
3. Switch the application CRG to the new primary node.
4. Restart the application on the new primary node.

Rejoin

Rejoin means to become an active member of a cluster after having been a nonparticipating member. For example, when clustering is restarted on a node after the node has been inactive, the cluster node rejoins the cluster. You start cluster resource services on a node by starting it from a node that is already active in the cluster. Beginning with cluster version 3, a node can start itself and will be able to rejoin the current active cluster, provided it can find an active node in the cluster. See "Start a cluster node" on page 39 for details.

Suppose that nodes A, B, and C make up a cluster. Node A fails. The active cluster is now nodes B and C. Once the failed node is operational again, it can rejoin the cluster when the node is started from any cluster node, including itself. The rejoin operation is done on a cluster resource group basis, which means that each cluster resource group (CRG) joins the cluster independently.

The primary function of rejoin ensures that the CRG object is replicated on all active recovery domain nodes. The rejoining node, as well as all existing active cluster nodes, must have an identical copy of the CRG object. In addition, they must have an identical copy of some internal data.

When a node fails, the continued calling of cluster resource services on the remaining nodes in the cluster can modify the data in a CRG object. The modification must occur due to the calling of an API or a subsequent node failure. For simple clusters, the rejoining node is updated with a copy of the CRG from some node that is currently active in the cluster. However, this may not be true in all cases.

For more details on the rejoin operation, see “Example: Rejoin”.

Example: Rejoin

The following diagram describes the actions taken whenever a node rejoins the cluster. In addition, the state of the rejoining nodes will be changed from *inactive* to *active* in the membership status field in the recovery domain of the CRG. The exit program is called on all nodes in the CRG’s recovery domain and is passed an action code of Rejoin.

Rejoin operation			
Rejoining node		Cluster nodes	
Contains copy of CRG	Does not contain copy of CRG	Contain copy of CRG	Do not contain copy of CRG
(1)	(2)	(3)	(4)

Using the diagram above, the following situations are possible:

1. 1 and 3
2. 1 and 4
3. 2 and 3
4. 2 and 4

If a node in the cluster has a copy of the CRG, the general rule for rejoin is that the CRG is copied from an active node in the cluster to the rejoining node.

Rejoin Situation 1

A copy of the CRG object from a node in the cluster is sent to the joining node. The result is:

- The CRG object is updated on the joining node with the data sent from the cluster.
- The CRG object may be deleted from the joining node. This can occur if the joining node was removed from the CRG’s recovery domain while the joining node was out of the cluster.

Rejoin Situation 2

A copy of the CRG object from the joining node is sent to all cluster nodes. The result is:

- No change if none of the cluster nodes are in the CRG’s recovery domain.
- The CRG object may be created on one or more of the cluster nodes. This can occur in the following scenario:
  - Nodes A, B, C, and D make up a cluster.
  - All four nodes are in the recovery domain of the CRG.
  - While node A is out of the cluster, the CRG is modified to remove B from the recovery domain.
  - Nodes C and D fail.
  - The cluster is only node B which does not have a copy of the CRG.
  - Node A rejoins the cluster.

- Node A has the CRG (although it is down level by now) and Node B does not. The CRG is created on node B. When nodes C and D rejoin the cluster, the copy of the CRG in the cluster updates node C and D and the previous change to remove node B from the recovery domain is lost.

Rejoin Situation 3

A copy of the CRG object from a node in the cluster is sent to the joining node. The result is:

- No change if the joining node is not in the CRG's recovery domain.
- The CRG object may be created on the joining node. This can occur if the CRG was deleted on the joining node while cluster resource services is not active on the node.

Rejoin Situation 4

Some internal information from one of the nodes in the cluster may be used to update information on the joining node but nothing occurs that is visible to you.

Merge

A merge operation is similar to a "Rejoin" on page 13 operation except that it occurs when nodes that are partitioned begin communicating again. The partition may be a true partition in that cluster resource services is still active on all nodes. However, some nodes can't communicate with other nodes due to a communication line failure. Or, the problem may be that a node actually failed, but was not detected as a failure.

In the first case, the partitions are merged back together automatically once the communication problem is fixed. This happens when both partitions periodically try to communicate with the partitioned nodes and eventually reestablish contact with each other. In the second case, cluster resource services must be restarted on the failed node by starting the node from any node in the cluster. See "Start a cluster node" on page 39 for details.

See Example: Merge for examples of how a merge occurs.

Replication

Replication makes a copy of something in real time. It means copying objects from one node in a cluster to one or more other nodes in the cluster. Replication makes and keeps the objects on your systems identical. If you make a change to an object on one node in a cluster, this change is **replicated** to other nodes in the cluster.

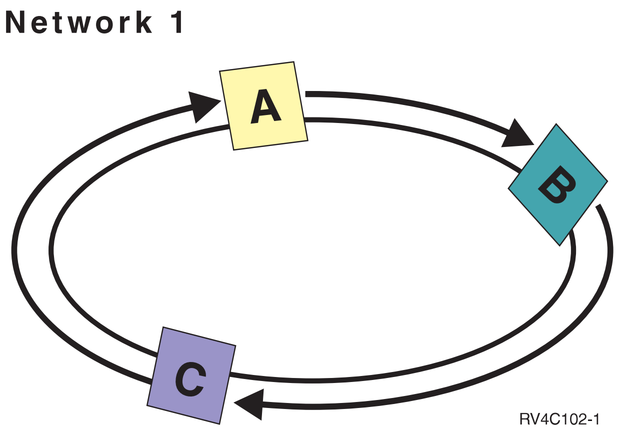
See "Plan for replication" on page 25 in order to determine how to implement replication.

Heartbeat monitoring

Heartbeat monitoring is a cluster resource services function that ensures that each node is active by sending a signal from every node in the cluster to every other node in the cluster to convey that they are still active. When the heartbeat for a node fails, the condition is reported so the cluster can automatically begin the failover process to move resilient resources to a backup node.

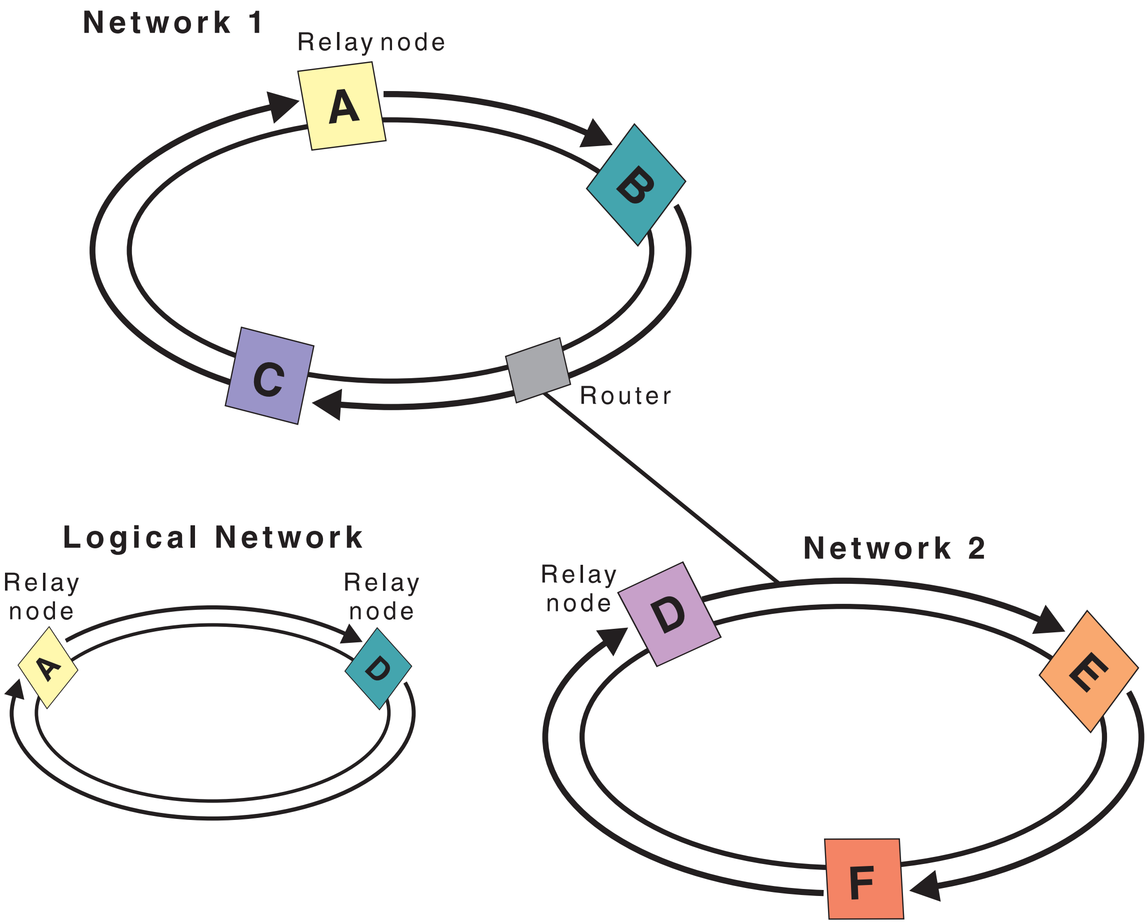
Consider the following examples to understand how heartbeat monitoring works:

Example 1



With the default (or normal) settings, a heartbeat message is sent every 3 seconds from every node in the cluster to its upstream neighbor. For example, if you configure Node A, Node B, and Node C on Network 1, Node A would send a message to Node B, Node B would send a message to Node C, and Node C would send a message to Node A. Node A expects an acknowledgment to the heartbeat from Node B as well as an incoming heartbeat from the downstream Node C. In effect, the heartbeating ring goes both ways. If Node A did not receive a heartbeat from Node C, Node A and Node B would continue to send a heartbeat every 3 seconds. If Node C missed four consecutive heartbeats, a heartbeat failure would be signaled. After this failure is confirmed, the failover process would begin to switch any CRGs with node C as the primary node over to their designated first backup nodes.

Example 2



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Let’s add another network to this example to show how routers and relay nodes are used. You configure Node D, Node E, and Node F on Network 2. Network 2 is connected to Network 1 using a router. A router can be another iSeries system or a router box that directs communications to another router somewhere else. Every local network is assigned a relay node. This relay node is assigned to the node that has the lowest node ID in the network. Node A is assigned as the relay node on Network 1, and Node D is assigned as the relay node on Network 2. A logical network containing Node A and Node D would then be created, thereby letting Node A and Node D send heartbeats to each other. By using routers and relay nodes, the nodes on these two networks can monitor each other and signal any node failures.

Reliable message function

The **reliable message function** of cluster resource services keeps track of each node in a cluster and ensures that all nodes have consistent information about the state of cluster resources. Reliable messaging uses retry and timeout values that are unique to clustering. These values are preset to values that should suit most environments. However, they can be changed through the Change cluster resource services settings interface. The message retry and timeout values are used to determine how many times a message is sent to a node before a failure or partition situation is signaled. For a local area network (LAN), the amount of time it takes to go through the number of retries before a failure or partition condition is signaled is approximately 45 seconds using the default retry and timeout values. For a remote network, more time is allowed to determine whether a failure or partition condition exists. You can figure approximately 4 minutes and 15 seconds for a remote network.

Cluster partition

A **cluster partition** is a subset of the active cluster nodes that results from a communications failure. Members of a partition maintain connectivity with each other.

A cluster partition occurs in a cluster whenever communication is lost between one or more nodes in the cluster and a failure of the lost nodes cannot be confirmed. When a cluster partition condition is detected, cluster resource services limits the types of actions that you can perform on the nodes in the cluster partition. Restricting function during a partition is done so cluster resource services will be able to merge the partitions once the problem that caused.

For more on cluster partitions, see:

- “Avoid a cluster partition” on page 22
- “Partition errors” on page 54

Plan for clusters

This topic covers the requirements that you will need before you can implement clustering. The following topics provide you with the general concepts, requirements, and considerations for designing a clustering solution.

For information on planning for clusters, see the following:

“Cluster requirements”
This topic outlines the hardware, software, and communications requirements for implementing clusters.

“Design your cluster” on page 20
Identify your needs to determine how to design your cluster.

“Cluster security” on page 26
Consider some of the security issues you need to consider when you plan to implement clustering on your systems.

“Cluster configuration checklist” on page 27
Before you begin to configure your cluster, complete this checklist to ensure that your environment is prepared properly.

Cluster requirements

This topic outlines the requirements for implementing clusters. The requirements vary depending upon which cluster capabilities you choose to implement. For example, you may choose to implement a simple, two-node cluster to take advantage of replication. Or you may choose to implement a cluster designed to take advantage of switched disks and switchable independent disk pools. See “Examples: Cluster configurations” on page 47 for details on some common cluster implementations.

Important: When you are ready to order a new server or a server upgrade to implement clusters, IBM will assist you in making sure that your cluster requirements are met. See Planning for Clustering.

Review the following cluster requirements:

- “Hardware requirements for clusters” on page 19
- “Software and licensing requirements for clusters” on page 19
- “Communications requirements for clusters” on page 19

Hardware requirements for clusters

Any iSeries model that is capable of running OS/400 V4R4M0 or later is compatible for implementing clustering.

In addition, you should provide protection from a power loss through an external uninterruptible power supply or equivalent. Otherwise, a sudden power loss on a cluster node could result in a "Cluster partition" on page 18 state rather than a "Failover" on page 13.

Clustering utilizes Internet Protocol (IP) multicast capabilities. Multicast does not map well to all types of physical media. For more information on multicast restrictions that may apply to your particular hardware, see the TCP/IP Configuration and Reference .

You can protect your disks with mirrored protection or device parity protection. Using these solutions on your primary system prevents a failover from occurring should a protected disk fail. It also is a good idea to have these solutions on your backup system in case a failover should occur. See Disk protection for details.

Note: If you plan to use independent disk pools in your cluster, refer to the independent disk pools Hardware requirements topic.

Software and licensing requirements for clusters

In order to implement clustering, you must have the following software and licenses:

1. OS/400 V4R4M0[1] or later configured with TCP/IP (TCP/IP Connectivity Utilities)
2. A cluster configuration and management software solution. This can be any of the following:
   - iSeries Navigator and Simple Cluster Management
   - A cluster middleware business partner solution
   - Your own cluster management application program written using cluster resource services commands and APIs

   See "Solutions for configuring and managing clusters" on page 35 for details on choosing a solution that is best for you.

Important: If you plan to implement independent disk pools to take advantage of switchable devices, there are additional requirements. See Plan for independent disk pools for details.

[1] OS/400 V5R1M0 can be used for implementing independent disk pools containing user-defined file systems (UDFS) only. Support for library-based objects is only available starting with OS/400 V5R2M0. See "Cluster version" on page 9 for a discussion of multiple-release clusters and how to adjust your cluster version.

Communications requirements for clusters

You can use any type of communications media in your clustering environment as long as it supports Internet Protocol (IP). Cluster resource services uses only TCP/IP protocols to communicate between nodes. Local area networks (LANs), wide area networks (WANs), OptiConnect system area networks (SANs), or any combination of these connectivity devices are supported. Your choice should be based upon:

- Volume of transactions
- Response time requirements
- Distance between the nodes
- Cost considerations

You can use these same considerations when determining the connection media to be used to connect primary and backup locations of resources. When planning your cluster, it is recommended that you designate one or more of your backup nodes in remote locations in order to survive a site loss disaster.

To avoid performance problems that might be caused by inadequate capacity, you need to evaluate the communication media that is used to handle the volumes of information that is sent from node to node. You can choose which physical media you prefer to use such as token ring, Ethernet, asynchronous transfer mode (ATM), SPD OptiConnect, High-Speed Link (HSL) OptiConnect, or Virtual OptiConnect (a high-speed internal connection between logical partitions).

HSL OptiConnect is a technology provided by OptiConnect for OS/400 software (OS/400 Option 23 - OS/400 OptiConnect). It can be used to construct highly available solutions. HSL OptiConnect is a system area network that provides high-speed, point-to-point connectivity between cluster nodes by using High Speed Link (HSL) Loop technology. HSL OptiConnect requires standard HSL cables, but no additional hardware. For additional information on HSL OptiConnect, see OptiConnect for OS/400 .

For switchable hardware, also referred to as resilient device CRGs, you need to have an independent disk pool that is switchable in your environment. In a logical partition environment, this is a collection of disk units on the bus being shared by the logical partitions. For a multi-system environment, this is one or more switchable expansion units (towers) properly configured on the HSL loop also containing the systems in the recovery domain. The switchable tower can also be used in an LPAR environment. For more planning information on switchable hardware and independent disk pools, see Plan for independent disk pools.

Note: If you are using 2810 LAN adapters using **only** TCP/IP, and not using Systems Network Architecture (SNA) or IPX, you can increase your adapter performance on a V4R5M0 server by specifying Enable only for TCP(*YES) for your specific line description using the Work with Line Descriptions (WRKLIND) command. Enable only for TCP(*YES) is set automatically in V5R1M0 and later releases.

Design your cluster

Because there are a variety of ways to implement clustering depending on what you are hoping to achieve, it is important to spend some time identifying your needs to determine how to design your cluster. Use the following topics to help you determine exactly how to design your cluster:

- "Design your network for clusters"
- "Multiple-release clusters" on page 22
- "Identify servers to include in a cluster" on page 23
- "Identify applications to include in a cluster" on page 23
- "Plan for data resilience" on page 23

Design your network for clusters

Before you configure your networks for clustering, you need to plan carefully and do some initial pre-cluster configuration involving TCP/IP. It is important that you read these topics before configuring your cluster. They will tell you when or how to:

- "Set up IP addresses"
- "Set TCP/IP configuration attributes" on page 21
- "Avoid a cluster partition" on page 22

For information about setting up redundant communications paths and whether you need to have a dedicated network for clustering, see "Dedicate a network for clusters" on page 22.

See "Tips: Cluster communications" on page 21 for general cluster communications hints.

Set up IP addresses: All the nodes in a cluster must be interconnected using Internet Protocol (IP). Because cluster resource services uses **only** IP to communicate with other cluster nodes, all cluster nodes must be *IP-reachable*. This means that you must have IP interfaces configured to connect the nodes in your cluster. These IP addresses must be set up either manually by the network administrator in the TCP/IP routing tables on each cluster node or they may be generated by routing protocols running on the routers in the network. This TCP/IP routing table is the map that clustering uses to find each node; therefore, each node must have its own **unique** IP address. Each node may have up to two IP addresses assigned to it. These addresses must not be changed in any way by other network communications applications. Be sure when you assign each address that you take into account which address use which kind of communication line. If you have a preference for using a specific type of communication media, make sure to configure the first IP address using your preferred media. The first IP address is what is treated preferentially by the “Reliable message function” on page 17 and “Heartbeat monitoring” on page 15.

Note: You need to be sure that the loop back address (127.0.0.1) is active for clustering. This address, which is used to send any messages back to the local node, is normally active by default. However, if it has been ended by mistake, cluster messaging cannot function until this address has been restarted.

Set TCP/IP configuration attributes: To enable cluster resource services, certain attribute settings are required in the TCP/IP configuration of your network. You must set these attributes before you can add any node to a cluster:

- Set IP datagram forwarding to *YES using the CHGTCPA (Change TCP/IP Attributes) command if you plan to use an iSeries server as the router to communicate with other networks and you have no other routing protocols running on that server.
- Set the INETD server to START. See INETD server for information on starting the INETD server.
- Set User Datagram Protocol (UDP) CHECKSUM to *YES using the CHGTCPA (Change TCP/IP Attributes) command.
- Set MCAST forwarding to *YES if you are using bridges to connect your token ring networks.
- If you are using Opticonnect for OS/400 to communicate between cluster nodes, start the QSOC subsystem by specifying STRSBS(QSOC/QSOC).

Tips: Cluster communications: Here are a few tips when setting up your communications paths:

- Be sure you have adequate bandwidth on your communication lines to handle the non-cluster activity along with the clustering heartbeating function and continue to monitor for increased activity.
- For best reliability, do not configure a single communication path linking one or more nodes.
- Do not overburden the line that is responsible for ensuring that you are still communicating with a node.
- Eliminate as many single points of failure as possible such as having two communication lines coming into a single adapter, same input-output processor (IOP), or same tower.
- If you have an extremely high volume of data being passed over your communication lines, you may want to consider putting “Plan for replication” on page 25 and “Reliable message function” on page 17 on separate networks.
- If you are using Internet Protocol (IP) multicast, you should see the TCP/IP Configuration and Reference for multicast restrictions that may apply to different types of physical media.
- User Datagram Protocol (UDP) multicast is the preferred protocol that the cluster communications infrastructure uses to send cluster management information between nodes in a cluster. When the physical media supports multicast capabilities, cluster communications utilizes the UDP multicast to send management messaging from a given node to all local cluster nodes that support the same subnet address. Messages that are sent to nodes on remote networks are always sent using UDP point-to-point capabilities. Cluster communications does not rely on routing capability for multicast messages.

- The multicast traffic that supports cluster management messaging tends to fluctuate by nature. Depending on the number of nodes on a given LAN (that supports a common subnet address) and the complexity of the cluster management structure that is chosen by the cluster administrator, cluster related multicast packets can easily exceed 40 packets per second. Fluctuations of this nature could have a negative impact on older networking equipment. One example would be congestion problems on devices on the LAN that serve as Simple Network Management Protocol (SNMP) agents that need to evaluate every UDP multicast packet. Some of the earlier networking equipment does not have adequate bandwidth to keep up with this type of traffic. You need to ensure that you or the network administrator has reviewed the capacity of the networks to handle UDP multicast traffic to make certain that clustering does not have a negative impact on the performance of the networks.

Avoid a cluster partition: A "Cluster partition" on page 18 is not aways avoidable. Power loss and hardware failure are two examples. However, the typical network related cluster partition can best be avoided by configuring redundant commuincations paths between all nodes in the cluster. A **redundant communications path** means that you have two lines configured between two nodes in a cluster. If a failure on the first communication path should occur, the second communication path can take over to keep communications running between the nodes, thereby minimizing conditions that could put one or more nodes of the cluster into a cluster partition. One thing to consider when configuring these paths is that if both of your communications lines go into the same adapter on the system, these lines are still at risk if this single adapter fails.

Read "Tips: Cluster communications" on page 21 for general cluster communications hints.

See "Partition errors" on page 54 if you have encountered a cluster partition.

Dedicate a network for clusters: Clustering does not require you to have a dedicated network just for clustering use. During normal operations, base clustering communication traffic will be minimal. It is, however, highly recommended that you have redundant communication paths configured for each node in a cluster. By configuring two lines, you can dedicate one line for clustering traffic and the other line can handle the normal traffic and also be the backup line if the dedicated line for clustering goes down.

See "Avoid a cluster partition" for more information on why configuring two communication paths is a good idea.

Multiple-release clusters

If creating a cluster that will include nodes at multiple "Cluster version" on page 9, then certain steps are required when you create the cluster. By default, the current cluster version will be set to the potential cluster version of the first node added to the cluster. This approach is appropriate if this node is at the lowest version level to be in the cluster. However, if this node is at a later version level, then you will subsequently be unable to add nodes with a lower version level. The alternative is to use the target cluster version value on create cluster to set the current cluster version to one less than the potential cluster version of the first node added to the cluster.

For example, consider the case where a two-node cluster is to be created. The nodes for this cluster are:

Node Identifier	Release	Potential Cluster Version
Node A	V5R1	2
Node B	V5R2	3

If the cluster is to be created from Node B, care must be taken to indicate that this will be a mixed release cluster. The target cluster version must be set to indicate that the nodes of the cluster will communicate at one less than the requesting node's potential node version.

Identify servers to include in a cluster

In order to identify the iSeries servers that you want to include in a cluster, you need to decide which servers are capable of providing adequate backup for the data and applications you need to run your business. You need to determine:

- Which servers contain your critical data and critical applications?
- Which servers will be the backup for those systems?

Once you have determined this, these are the servers that you will want to include in your cluster.

Identify applications to include in a cluster

Not every application will give you the availability benefits of clustering. An application must be resilient in order to take advantage of the switchover and failover capabilities provided by clustering. Application resilience allows the application to be restarted on the backup node without having to reconfigure the clients using the application. Therefore your application must meet certain requirements to take full advantage of the capabilities offered by clustering.

See the “Cluster applications” on page 30 topic for more information on resilient applications.

Plan for data resilience

Data resilience is achieved when data is always available to an end user or application. You can achieve data resilience through the use of replication or switchable independent disk pools. The following topics will help you prepare your cluster for data resilience:

“Determine which data should be made resilient”
Understand what types of data you should consider making resilient.

“Comparing replicated and switchable resources” on page 24
Determine which technology is right for your cluster.

“Plan for replication” on page 25
Multiple copies of the data are maintained with replication. Data is replicated, or copied, from the primary node in the cluster to the backup nodes designated in the recovery domain. When an outage occurs on the primary node, the data remains available as a designated backup node takes over as the primary point of access.

“Plan for switchable independent disk pools” on page 26
A single copy of the data is maintained on switchable hardware; either an expansion unit (tower) or an IOP in a logical partition environment. When an outage occurs on the primary node, access to the data on the switchable hardware switches to a designated backup node.

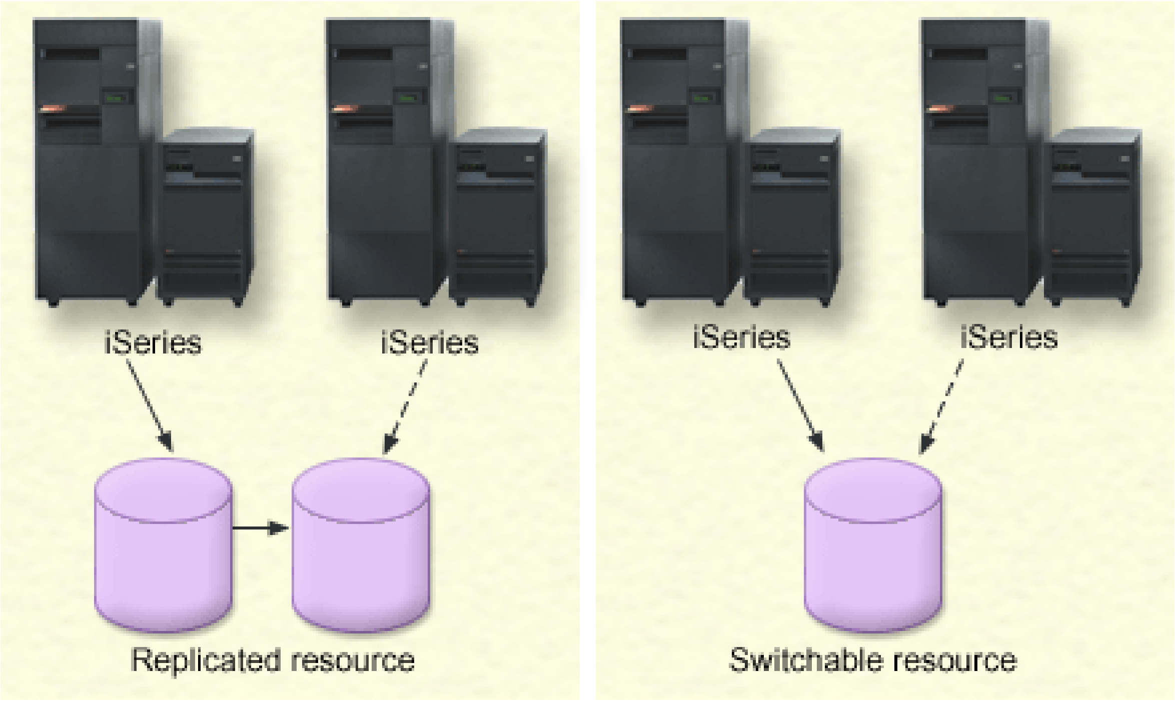
Determine which data should be made resilient: Determining which data you need to make resilient is similar to determining which kind of data you need to backup and save when you prepare a back up and recovery strategy for your systems. You need to determine which data in your environment is critical to keeping your business up and running.

For example, if you are running a business on the Web, your critical data may be:

- Today’s orders
- Inventory
- Customer records

In general, information that does not change often or that you do not need to use on a daily basis probably does not need to be made resilient. See Plan a backup and recovery strategy in the Backup and recovery topic for more information on what types of data should be made resilient.

Comparing replicated and switchable resources: The primary advantages a clustered environment provides are those of replication and switchability.



Replicated resource

Replication is the process of copying objects from one node in a cluster to one or more other nodes in the cluster, which makes the objects on all the systems identical. In the figure above, two identical copies of the data are kept on two separate cluster nodes.

A replicated resource allows for objects, such as an application and its data, to be copied from one node in the cluster to one or more other nodes in the cluster. This process keeps the objects on all servers in the resource’s recovery domain identical. If you make a change to an object on one node in a cluster, the change is replicated to other nodes in the cluster. Then, should a failover or switchover occur, the backup node can seamlessly take on the role of the primary node. The server or servers that act as backups are defined in the recovery domain. When an outage occurs on the server defined as the primary node in the recovery domain and a switchover or failover is initiated, the node designated as the backup in the recovery domain becomes the primary access point for the resource.

Replication requires the use of either a custom-written application or a software application written by a cluster middleware business partner. See “Plan for replication” on page 25 for details.

Switchable resource

Switchable resources enable the resources, such as data and applications, residing on an expansion unit or on an input-output processor (IOP) on a shared bus in a logical partition, to be switched between a cluster’s primary node and backup node. This allows for a set of disk units to be accessed from a second server, a server defined as a backup node in the cluster resource group’s recovery domain, when the server currently using those disk units experiences an outage and a failover or switchover occurs. In the figure above, there is only one copy of the data for which both nodes can serve as the primary access point.

Taking advantage of switchable resources in your cluster requires the use of independent disk pools. See “Plan for switchable independent disk pools” on page 26 for more information.

Use the following table to help you understand the benefits and advantages of replication and switched disk technology.

Factor	Replication	Switched disk
Flexibility	10s of systems	2-3 systems
Single point of failure	None	Disk subsystem
Cost	Additional disk capacity required. Replication software.	Switchable I/O expansion unit (tower)
Performance	Replication overhead	Little impact
Real time coverage	Journaled objects	Objects contained in independent disk pool
Geographic dispersion	Limited by performance considerations	Limited attach distance as servers and expansion units must be attached to HSL OptiConnect loop (250 meters maximum)
Disaster recovery protection	Yes	No
Concurrent backup	Yes	No
Setup	Replication environment. Determining what to replicate.	Independent disk pool environment. Populate independent disk pool

Plan for replication: **Replication** makes a copy of something in real time. It is the process of copying objects from one node in a cluster to one or more other nodes in the cluster. Replication makes and keeps the objects on your systems identical. If you make a change to an object on one node in a cluster, this change is replicated to other nodes in the cluster.

You must decide on a software technology to use for replication. The following solutions are available for achieving replication in your cluster:

- **“Cluster middleware business partners and available clustering products” on page 36**
  Data replication software from recognized cluster business partners enables you to replicate objects across multiple nodes.
- **A custom-written replication application**
  IBM journal management provides a means by which you can record the activity of objects on your system. You can write an application taking advantage of journal management to achieve replication. See iSeries journal management for details on how journal management works.

Once you have chosen a mechanism to achieve replication, you must also:

- “Determine which systems to use for replication”

Determine which systems to use for replication: Key considerations for determining which systems to use for replication are:

- Performance capacity
- Disk capacity
- Critical data
- Disaster prevention

If your system fails over, you need to know what data and applications you have running on your primary system and your backup system. You want to put the critical data on the system that is most capable of handling the workload in case it fails over. You do not want to run out of disk space. If your primary system runs out of space and fails over, it is highly likely that your backup system is also going to fail over due to lack of disk space. To ensure your data center is not completely destroyed in case of a natural disaster, such as a flood, tornado, or hurricane, you should locate the replicated system in a remote location.

Plan for switchable independent disk pools: Careful planning is required if you plan to take advantage of switchable resources residing on switchable independent disk pools. The requirements for implementing independent disk pools, as well as a general overview of independent disk pools and how they work, are detailed in the Independent disk pools topic.

Cluster security

This topic discusses some of the security issues you need to consider when you plan to implement clustering on your systems.

- "Enable a node to be added to a cluster"
- "Distribute cluster-wide information" on page 27
- "Maintain user profiles on all nodes" on page 45

Enable a node to be added to a cluster

Before you can add a node to a cluster, you need to set a value for the Allow add to cluster (ALWADDCLU) network attribute. Use the Change Network Attributes (CHGNETA) command on any server that you want to set up as a cluster node. The Change Network Attributes (CHGNETA) command changes the network attributes of a system. The ALWADDCLU network attribute specifies whether a node will allow another system to add it as a node in a cluster.

Note: You must have *IOSYSCFG authority to change the network attribute ALWADDCLU.

You can pick one of these values:

<u>*SAME</u>
The value does not change. The system is shipped with a value of *NONE.

***NONE**
No other system can add this system as a node in a cluster.

***ANY** Any other system can add this system as a node in a cluster.

***RQSAUT**
Any other system can add this system as a node in a cluster only after the cluster add request has been authenticated.

The ALWADDCLU network attribute is checked to see if the node that is being added is allowed to be part of the cluster and whether to validate the cluster request through the use of X.509 digital certificates. A **digital certificate** is a form of personal identification that can be verified electronically. If validation is required, the requesting node and the node that is being added must have the following installed on the systems:

- OS/400 Option 34 (Digital Certificate Manager)
- Cryptographic Access Provider licensed program (5722-AC2 or 5722-AC3)

When *RQSAUT is selected, the certificate authority trust list for the OS/400 cluster security server application must be properly set up. The server application identifier is QIBM_QCST_CLUSTER_SECURITY. At a minimum, add certificate authorities for those nodes that you allow to join the cluster.

See Digital Certificate Management for more information.

Distribute cluster-wide information

The Distribute Information (QcstDistributeInformation) API can be used to send messages from one node in a cluster resource group recovery domain to other nodes in that recovery domain. This can be useful in exit program processing. However, it should be noted that there is no encrypting of that information. Secure information should not be sent using this mechanism unless you are using a secure network.

Non persistent data can be shared and replicated between cluster nodes using the Clustered Hash Table APIs. The data is stored in nonpersistent storage. This means the data is retained only until the cluster node is no longer part of the clustered hash table. These APIs can only be used from a cluster node that is defined in the clustered hash table domain. The cluster node must be active in the cluster.

Other information distributed via cluster messaging is similarly not secured. This includes the low level cluster messaging. As such, when changes are made to the exit program data, there is no encrypting of the message containing that data.

Cluster configuration checklist

Before you begin to configure your cluster, complete this checklist to ensure that your environment is prepared properly.

TCP/IP requirements

____ TCP/IP must be started on every node you plan to include in the cluster using the Start TCP/IP (STRTCP) Command.

____ The TCP loopback address (127.0.0.1) must be configured and must show a status of *Active*. Verify using the Work with TCP/IP Network Status (WRKTCPSTS) Command on every node in the cluster.

____ The IP addresses used for clustering to a given node must show a status of *Active*. Verify using the Work with TCP/IP Network Status (WRKTCPSTS) Command on the subject node.

____ All cluster IP adresses must be defined with contiguous-bit subnet masks.

A contiguous-bit subnet mask is one where the binary representation of the subnet mask consists of a series of contiguous 1 bits followed by a series of contiguous 0 bits. For example, the binary representation of the subnet mask 255.255.255.0 is 11111111 11111111 11111111 00000000. This is considered contiguous because all of the 1 bits are contiguous, followed by the 0 bits, which are also contiguous. The binary representation for 255.255.240.240 is 11111111 11111111 11110000 11110000. This is not considered contiguous because the 1 bits and the 0 bits are not contiguous..

____ INETD must be active on all nodes in the cluster (STRTCPSVR *INETD). This can be verified by the presence of a QTOGINTD (User QTCP) job in the Active Jobs list on the subject node. See INETD server for details on starting the INETD server.

____ The local and any remote nodes must be able to PING using the IP addresses used for clustering to ensure network routing is active.

____ Ports 5550 and 5551 are reserved for IBM clustering and must not be used by other applications. Port usage can be viewed using the Work with TCP/IP Network Status (WRKTCPSTS) command. Port 5550 will be opened and in a 'Listen' state by clustering once INETD is started.

Resilient device requirements

If you plan to implement switchable devices in your cluster, the following requirements must be satisfied:

____ Option 41 (OS/400 - HA Switchable Resources) must be installed and a valid license key must exist on all cluster nodes that will be in the device domain. Note that any use of the “iSeries Navigator and Simple Cluster Management” on page 35 interface requires this option.

____ In order to access disk management functions in iSeries Navigator, you must configure the service tools server (STS) with DST access and user profiles. See Set up communication for details.

____ If resilient devices are to be switched between logical partitions on a system, Virtual OptiConnect must be enabled for the partitions. This is done at dedicated service tools (DST) signon. See Virtual OptiConnect for details.

____ If a tower on an HSL OptiConnect loop is switched between two systems, and one of the systems has logical partitions, HSL OptiConnect must be enabled for the partitions. This is done at dedicated service tools (DST) signon.

____ When switching resilient devices between logical partitions that are on a system bus, the bus must be configured as ″own bus shared″ by one partition, and all other partitions that will participate in the device switching must be configured as ″use bus shared″.

____ When switching a tower on a HSL loop between two different systems, the tower must be configured as switchable. See Make your hardware switchable for details.

____ When a tower is added to an existing HSL loop, all servers on that same loop must be restarted.

____ The maximum transmission unit (MTU) for your communication paths must be greater than the cluster communications tuneable parameter, message fragment size. MTU for a cluster IP address can be verified using the Work with TCP/IP Network Status (WRKTCPSTS) command on the subject node. The MTU must also be verified at each step along the entire communications path. It may be easier to lower the message fragment size parameter once the cluster is created than raise the MTU for the communications path. See Tunable cluster communications parameters for more information on message fragment size. You can use the Retrieve Cluster Resource Services Information (QcstRetrieveCRSInfo) API to view the current settings of the tuning parameters and the Change Cluster Resource Services (QcstChgClusterResourceServices) API to change the settings.

Security requirements

____ The ALWADDCLU (Allow Add to Cluster) network attribute must be appropriately set on the target node if trying to start a remote node. This should be set to *ANY or *RQSAUT depending on your environment. If set to *RQSAUT, then OS/400 option 34 (Digital Certificate Manager) and Cryptographic Access Provided Product (AC2 or AC3) must be installed. See “Enable a node to be added to a cluster” on page 26 for details on setting the ALWADDCLU network attribute.

____ The status of the QUSER user profile must be enabled, and it must not have *SECADM or *ALLOBJ special authorities.

____ The user profile invoking the cluster resource services APIs must exist on all cluster nodes and must have *IOSYSCFG authority.

____ The user profile to run the exit program for a cluster resource group (CRG) must exist on all recovery domain nodes.

Job considerations

____ Jobs can be submitted by the cluster resource services APIs to process requests. The jobs will either run under the user profile to run the exit program specified when creating the a cluster resource group, or under the user profile that requested the API (for varying on devices in resilient device CRGs only). The user must ensure that the subsystem which services the job queue associated with the user profile is configured as: *NOMAX for the number of jobs it can run from that job queue.

____ Jobs will be submitted to the job queue specified by the job description which is obtained from the user profile defined for a CRG. The default job description will cause the jobs to be sent to the QBATCH job queue. Since this job queue is used for many user jobs, the exit program job may not run in a timely fashion. Users should consider a unique job description with a unique user queue.

____ When exit program jobs are run, they will use routing data from the job description to choose which main storage pool and run time attributes they will use. The default values will result in jobs that are run in a pool with other batch jobs with a run priority of 50. Neither of these may produce the desired performance for exit program jobs. The subsystem initiating the exit program jobs (the same subsystem that is using the unique job queue) should assign the exit program jobs to a pool that is not used by other jobs initiated by the same subsystem or other subsystems. In addition, the exit program jobs should be assigned a run priority of 15 so that they will run before almost all other user jobs.

iSeries Navigator and Simple Cluster Management considerations

There are several software solutions available for configuring and managing your cluster. One of these solutions is “iSeries Navigator and Simple Cluster Management” on page 35. If you choose to use iSeries Navigator, the following requirements must be satisfied:

____ Option 41 (OS/400 - HA Switchable Resources) must be installed and a valid license key must exist on all cluster nodes that will be in the device domain.

____ All host servers must be started using the STRHOSTSVR (Start Host Server) Command: STRHOSTSVR SERVER(*ALL)

____ The Management Central server must be started using the STRTCPSVR (Start TCP/IP Server) Command: STRTCPSVR SERVER(*MGTC)

Cluster applications

A key element of a clustered environment is application resilience. By taking advantage of “Resilient applications” on page 12 in your cluster, an application can be restarted on a different cluster node without requiring you to reconfigure the clients. In addition, the data that is associated with the application will be available after switchover or failover. This means that the application end user can experience minimal, or even seamless, interruption while the application and its data switch from the primary node to the backup node. The user does not need to know that the application and data have moved on the back end.

In order to achieve application resiliency in your cluster, applications that meet certain availability specifications must be used. Certain characteristics must be present in the application in order for it to be switchable, and therefore always available to the end users of the application in the cluster. Because these requirements exist, you have the following options for implementing a switchable software product in your cluster:

1. **Purchase a ClusterProven^{R} software application**
   Software products with the ClusterProven branding meet certain high-availability requirements. See “IBM ClusterProven” for more details.
2. **Write or modify your own application to make it highly available**
   Independent software vendors and application programmers can customize applications to allow them to be switchable in an iSeries clustered environment. See “Writing a highly available cluster application” on page 31 for details.

Once you have a resilient application, it must be managed within your cluster. See “Application CRG considerations” on page 33 for more information.

IBM ClusterProven

ClusterProven^{TM} is the IBM brand that identifies an application as highly available, recognizing applications that continue to be available in the event of an outage, planned or unplanned. It is an IBM designation that defines certain high-availability requirements that are applied to a software product either by itself or in combination with other software products. A solution that satisfies the technical criteria of these requirements can be validated with IBM and licensed to be marketed with IBM’s ClusterProven trademark. What it means to you is that a purchased application with the ClusterProven for iSeries brand is enabled as a partner in the cluster solution.

The ClusterProven for iSeries program offers a branding logo for developer applications that have demonstrated highly available characteristics. These applications meet the following criteria:

- The application can switch over to a backup cluster node when the primary node becomes unavailable.
- The application defines the resilient environment in the Resilient Definition and Status Data Area to enable automatic configuration and activation of the application by a cluster management application.
- The application provides application resilience by means of an application CRG exit program to handle cluster related events, taking advantage of the capabilities of the OS/400 cluster resource services.
- The application provides an application restart function that repositions the user to an application menu screen or beyond.

The Advanced ClusterProven for iSeries program offers a branding logo for developer applications that have demonstrated more stringent availability characteristics. These applications meet the following criteria:

- The application meets all of the criteria for ClusterProven for iSeries as listed above.
- The application provides enhanced application resilience through more robust handling of cluster events (action codes) by the application CRG exit program.
- The application provides a greater level of application restart support. For host-centric applications, the user will be repositioned to a transaction boundary by commitment control or checkpoint functions. For client-centric applications, the user will experience a seamless failover with minimal service interruption.

For more information, see the IBM ClusterProven web site.

Writing a highly available cluster application

A highly available application is one that can be resilient to a system outage in a clustered environment. Several levels of application availability are possible:

1. If an application error occurs, the application restarts itself on the same node and corrects any potential cause for error (such as corrupt control data). You would view the application as though it had started for the first time.
2. The application performs some amount of checkpoint-restart processing. You would view the application as if it were close to the point of failure.
3. If a system outage occurs, the application is restarted on a backup server. You would view the application as though it had started for the first time.
4. If a system outage occurs, the application is restarted on a backup server and performs some amount of checkpoint-restart processing across the servers. You would view the application as if it were close to the point of failure.
5. If a system outage occurs, a coordinated failover of both the application and its associated data to another node or nodes in the cluster would take place. You would view the application as though it had started for the first time.
6. If a system outage occurs, a coordinated failover of both the application and its associated data to another node or nodes in the cluster would take place. The application performs some amount of checkpoint-restart processing across the servers. You would view the application as if it were close to the point of failure.

   Note: In cases 1 through 4 above, you are responsible for recovering the data.

For further considerations for application resiliency, see the following topics:

- “Make application programs resilient”
- “Restart highly available cluster applications” on page 32
- “Calling a cluster resource group exit program” on page 32

Make application programs resilient

A resilient application is expected to have the following characteristics:

- The application can be restarted on this node or another node
- The application is accessible to the client through the IP address
- The application is stateless or state information is known
- Data that is associated with the application is available after switchover

The three essential elements that make an application resilient to system outages in a clustered environment are:

The application itself

How tolerant is the application to errors or to system outages, and how transparently can the application restart itself?
The application can handle this through the use of new clustering capabilities.

Associated data

When an outage occurs, does it affect the availability of any associated data?
A "Cluster middleware business partners and available clustering products" on page 36 replication product which takes advantage of the clustering capabilities can handle this. Alternatively, the data can be stored in a switchable independent disk pool (switchable independent ASP).

Control capabilities and administration

How easy is it to define the environment that supports the availability of the data and the application?
A Cluster Middleware business partner cluster management product that uses the clustering APIs and also combines resilient applications with resilient data can handle this.

Restart highly available cluster applications

To restart an application, the application needs to know its state at the time of the failover or switchover. State information is application specific; therefore, the application must determine what information is needed. Without any state information, the application can be restarted on your PC. However, you will have to reestablish your position within the application.

Several methods are available to save application state information for the backup system. Each application needs to determine which method works best for it.

- The application can transfer all state information to the requesting client system. When a switchover or failover occurs, the application uses the stored state on the client to reestablish the state in the new server. This could be accomplished by using the Distribute Information API or Clustered Hash Table APIs. See "Distribute cluster-wide information" on page 27 for details.
- The application can replicate state information (such as job information and other control structures that are associated with the application) on a real-time basis. For every change in the structures, the application ships the change over to the backup system.
- The application can store pertinent state information that is associated with its application in the exit program data portion of the cluster resource group for that application. This method assumes that a small amount of state information is required. You can use the Change Cluster Resource Group (QcstChangeClusterResourceGroup) API to do this.
- The application can store state information in a data object that is being replicated to the backup systems along with the application's data.
- The application can store state information in a data object contained in the switchable IASP that also contains the application's data.
- The application can store the state information on the client.
- No state information is saved, and you need to perform the recovery.

Note: The amount of information that is required to be saved is lessened if the application uses some form of checkpoint-restart processing. State information is only saved at predetermined application checkpoints. Restart then takes you back to the last known checkpoint which is similar to how database's commitment control processing works.

Calling a cluster resource group exit program

The cluster resource group exit program is called during different phases of a cluster environment. This program establishes and manages the environment necessary for data, application, or device resiliency within a cluster. The exit program is optional for a resilient device CRG but is required for the other CRG types. When a cluster resource group exit program is used, it is called on the occurence of cluster-wide events, including when:

- A node leaves the cluster unexpectedly.
- A node leaves the cluster as a result of the End Cluster Node (QcstEndClusterNode) API or Remove Cluster Node Entry (QcstRemoveClusterNodeEntry) API.
- The cluster is deleted as a result of the Delete Cluster (QcstDeleteCluster) API.
- A node is activated by the Start Cluster Node (QcstStartClusterNode) API.
- Communication with a partitioned node is re-established.

This exit program:

- Runs in a named activation group or the caller's activation group (*CALLER).
- Ignores the restart parameter if the exit program has an unhandled exception or is cancelled.
- Provides a cancel handler.

When a cluster resource group API is run, the exit program is called from a separate job with the user profile specified on the Create Cluster Resource Group (QcstCreateClusterResourceGroup) API. The separate job is automatically created by the API when the exit program is called. If the exit program for a data CRG is unsuccessful or ends abnormally, the cluster resource group exit program is called on all active nodes in the recovery domain with an action code of Undo. This action code allows any unfinished activity to be backed out and the original state of the cluster resource group to be recovered.

If the exit program for an application CRG is unsuccessful or ends abnormally, cluster resource services will attempt to restart the application if the status of the CRG is active. The cluster resource group exit program is called with an action code of Restart. If the application cannot be restarted in the specified maximum number of attempts, the cluster resource group exit program is called with an action code of Failover. The restart count is reset only when the exit program is called with an action code of start, which can be the result of a start CRG, a failover, or a switchover.

When the cluster resource group is started, the application CRG exit program called on the primary node is not to return control to cluster resource services until the application itself ends or an error occurs. After an application CRG is active, if cluster resource services must notify the application CRG exit program of some event, another instance of the exit program is started in a different job. Any other action code other than Start or Restart is expected to return.

When a cluster resource group exit program is called, it is passed a set of parameters that identify the cluster event being processed, the current state of the cluster resources, and the expected state of the cluster resources.

For complete information on cluster resource group exit programs, including what information is passed to the exit program for each action code, see Cluster Resource Group Exit Program in the Cluster API documentation. Sample source code has been provided in the QUSRTOOL library which can be used as a basis for writing an exit program. See the TCSTAPPEXT member in the QATTSYSC file.

Application CRG considerations

An application cluster resource group manages application resiliency. Consider the following topics when using resilient applications in your cluster.

- “Manage application CRG IP addresses”
- “Example: Application cluster resource group failover actions” on page 34

Manage application CRG IP addresses

There are two ways to have the application takeover IP address associated with an application CRG managed. The easiest way, which is the default, is to let cluster resource services manage the IP address.

This method will direct cluster resource services to create the IP address on all nodes in the recovery domain, including nodes subsequently added to the recovery domain. When this method is selected, the IP address cannot currently be defined on any node in the recovery domain.

The alternative way is to manage the IP addresses yourself. This method directs cluster resource services to not take any steps to configure the IP address; the user is responsible for configuration. You must add the takeover IP address on all nodes in the recovery domain (except on replicate nodes) prior to starting the cluster resource group. Any node to be added to the recovery domain of an active CRG must have the IP address configured prior to being added.

Multiple subnets

It is possible to have the application takeover IP address work across multiple subnets, although the default is to have all recovery domain nodes on the same subnet. See Enabling application switchover across subnets for the steps to configure the application takeover IP address when the nodes in the recovery domain span subnets.

Example: Application cluster resource group failover actions

The following happens when a cluster resource group for a resilient application fails over due to exceeding the retry limit or if the job is cancelled:

- The "Cluster resource group exit programs" on page 8 is called on all active nodes in the recovery domain for the CRG with an action code of failover. This indicates that cluster resource services is preparing to failover the application's point of access to the first backup.
- Cluster resource services ends the takeover Internet Protocol (IP) connection on the primary node. For more information on the takeover IP address, see "Manage application CRG IP addresses" on page 33.
- Cluster resource services starts the takeover IP address on the first backup (new primary) node.
- Cluster resource services submits a job that calls the cluster resource group exit program only on the new primary node with an action code of Start. This action restarts the application.

The above example shows how one failover scenario works. Other failover scenarios can work differently.

Configure clusters

IBM and IBM cluster middleware business partners have teamed together to provide state-of-the-art cluster resource services functions along with a graphical user interface (GUI) for cluster management. OS/400 cluster resource services provides a set of integrated services that maintain cluster topology, perform heartbeating, and allow creation and administration of cluster configuration and cluster resource groups. Cluster resource services also provides reliable messaging functions that keep track of each node in the cluster and ensures that all nodes have consistent information about the state of cluster resources. In addition, cluster resource services provides a set of control language (CL) commands and application program interfaces (APIs) and facilities that can be used by iSeries application providers or customers to enhance their application availability. Cluster resource services functions can also be accessed via graphical user interface solutions provided by iSeries Navigator and Simple Cluster Management and cluster middleware business partner products.

Getting started
Follow these steps to configure a cluster:

1. **Select a software solution.**
   See "Solutions for configuring and managing clusters" on page 35 for complete look at the options for configuring and managing clusters.
2. **Satisfy the hardware, software and communications requirements.**
   Review the cluster requirements in "Plan for clusters" on page 18.
3. **Set up your network and server environment for clusters.**
   Use the "Cluster configuration checklist" on page 27 to make sure that you are prepared to configure clusters in your environment.

4. **Configure your cluster.**
   See “Configure a cluster” on page 37 for details.

If you need help during the configuration process, see “Who to call for cluster suppport” on page 65 for a number that you can call.

Solutions for configuring and managing clusters

OS/400 cluster resource services on the iSeries provides the basic infrastructure that allows you to implement a cluster. Cluster resource services provides a set of integrated services that maintain cluster topology, perform heartbeating, and allow creation and administration of cluster configuration and cluster resource groups. Cluster resource services also provides reliable messaging functions that keep track of each node in the cluster and ensure that all nodes have consistent information about the state of cluster resources.

While cluster resource services provides the basic cluster infrastructure, there are several methods that will allow you to take advantage of these clustering capabilities. Each has distinct benefits and capabilities. Depending upon your clustering needs, one of the following solutions will be the best fit for configuring and managing your cluster environment:

> “iSeries Navigator and Simple Cluster Management”
> IBM offers a Simple Cluster Management graphical user interface that allows you to create and manage a simple cluster, including one that uses switchable independent disk pools (switchable independent ASPs) to ensure data availability.
>
> “Cluster commands and APIs” on page 36
> OS/400 cluster resource services provides a set of control language (CL) commands, application program interfaces (APIs) and facilities that can be used by iSeries application providers or customers to enhance their application availability.
>
> “Cluster middleware business partners and available clustering products” on page 36
> You can purchase a product from an IBM cluster middleware business partner that provides the replication functions that are integral to clustering and simplifies cluster creation and management.

Important: IBM recommends that you use only one of these solutions exclusively. Conflicts, problems and unpredictability can arise when attempting to use more than one solution to create and manage a cluster. The information you will find in the iSeries Information Center documents procedures specific to iSeries Navigator and the cluster resource services CL commands and APIs. If you use a cluster middleware business partner solution, see the documentation provided with the product for procedural information on performing tasks.

iSeries Navigator and Simple Cluster Management

IBM offers a Simple Cluster Management interface that is available through iSeries Navigator and accessible through Option 41 (OS/400 - HA Switchable Resources). This interface allows you to create and manage a cluster that uses switchable independent disk pools (switchable independent ASPs) to ensure data availability. See iSeries Navigator for more information on the iSeries Navigator interface.

Important: The iSeries Navigator and Simple Cluster Management interface does not contain all of the capabilities provided by cluster resource services. While iSeries Navigator provides many functions necessary to configure and manage a cluster, be aware that there are some capabilities that are only available through the cluster commands and APIs, or perhaps through a cluster middleware business partner application, depending upon the particular application. For example, the iSeries clustering architecture supports up to 128 nodes in a cluster, however the iSeries Navigator interface only supports up to four nodes in a cluster. With iSeries Navigator, you can create a simple cluster consisting of one or two nodes. Once you have established a cluster in iSeries Navigator, you can then add a node to an existing cluster, up to as many as four total nodes. If your clustering needs exceed this, you should consider using the "Cluster commands and APIs" or "Cluster middleware business partners and available clustering products".

Simple Cluster Management features a wizard which steps you through the creation of a simple, two-node cluster. Additional cluster management can be accomplished using this interface, including tasks such as:

- Adding a node to an existing cluster
- Adding a switchable hardware group to a cluster
- Adding a switchable software product to a cluster
- Adding a switchable data group to a cluster
- Changing the cluster description
- Changing the exit program name for a cluster resource group
- Changing the takeover IP address for a switchable software product
- Deleting a cluster
- Starting clustering
- Stopping clustering
- Switching cluster resources from the primary node to the backup node
- Viewing messages about cluster activity

The online help available in iSeries Navigator provides step-by-step procedures on how to accomplish these tasks.

For more information on Simple Cluster Management, see "Frequently asked questions about iSeries Navigator Simple Cluster Management" on page 59.

Cluster commands and APIs

You can write your own custom application to configure and manage your cluster by utilizing cluster control language (CL) commands and application programming interfaces (APIs). These commands and APIs take advantage of the technology provided by cluster resource services provided as a part of OS/400.

For a complete listing of the capabilities of the cluster commands and APIs, see Cluster CL command and API descriptions.

QUSRTOOL

Cluster resource services also provides a set of example commands in the QUSRTOOL library that map to the CL commands mentioned above. The QUSRTOOL commands might be useful in some environments. For example, you can change heartbeating or send information around the cluster. See the member TCSTINFO in the file QUSRTOOL/QATTINFO for more information on these example commands. An example application CRG exit program is also included in the QUSRTOOL library. The sample source code can be used as the basis for writing an exit program. Sample source, TCSTDTAEXT, in file QATTSYSC contains a source for a program to create the QCSTHAAPPI and QCSTHAAPP0 dataareas, and QACSTOSDS (object specifier) file.

Cluster middleware business partners and available clustering products

IBM cluster middleware business partners provide software solutions for dedicated replication and cluster management functions. If you would like to purchase a product that provides replication functions that are integral to clustering and simplifies cluster creation and management, contact your IBM marketing representative or business partner. They can provide a complete list of clustering enabling products provided by IBM cluster middleware business partners.

The cluster middleware business partner cluster management product:

- Provides the user interface to define and maintain the cluster configuration

- Provides the user interface to define and manage the device, data, and application cluster resource groups
- Maintains the knowledge through the use of cluster APIs, of what cluster resource groups are defined in the cluster and what relationships are required.
- Creates the device, data, and application cluster resource groups.

The cluster middleware business partner replication product:

- Builds the middleware's control structures that identify the data and objects that are required to be resilient.
- Creates the cluster resource group for critical data and associates that object with its control structures.
- Provides the exit program for the data cluster resource group.

Configure a cluster

Before you attempt to configure a cluster, see the "Cluster configuration checklist" on page 27 for details on setting up your environment for clusters.

To configure a cluster, you need to include at least one node in the cluster and you must have access to at least one of the nodes that will be in the cluster. If only one node is specified, it must be the server that you are currently accessing. If you will be creating a cluster consisting of nodes at different cluster version levels, see "Multiple-release clusters" on page 22 before creating your cluster.

If you will be using switchable devices in your cluster, there are additional requirements than that of a cluster that does not use switchable devices. To set up a cluster environment that includes switchable devices, care must be taken so that conflicts are avoided across the cluster. See Create a switchable independent disk pool for step-by-step instructions on how to configure a cluster to use switchable devices.

Using iSeries Navigator
This requires Option 41 (OS/400 - HA Switchable Resources) to be installed and licensed.

"iSeries Navigator and Simple Cluster Management" on page 35 features a wizard that takes you through the steps to create and start a simple cluster consisting of one or two cluster nodes. Once you have created a one- or two-node cluster, you can add nodes to it. A cluster created and managed in iSeries Navigator can contain as many as four nodes. This wizard will guide you through the steps to specify servers to include, create cluster resource groups, and create a device domain if you will be using switchable hardware. When you are creating a simple cluster, the server you are creating the cluster on must be one of the nodes.

To create a simple cluster using the New Cluster wizard in iSeries Navigator, follow these steps:

1. In iSeries Navigator, expand **Management Central**.
2. Right-click **Clusters**, and select **New Cluster..**
3. Follow the wizard's instructions to create a cluster.

Once you have created the cluster, be sure to:

1. Add all of the nodes that you would like to include in the cluster. Up to four nodes can be added to a cluster created and managed in iSeries Navigator.
2. Add desired nodes to device domains (for use with switchable hardware groups and independent disk pools).
3. Create and start the switchable resources (switchable hardware, switchable software, and switchable data).

The online help in iSeries Navigator contains step-by-step procedures on completing these tasks.

Using CL commands and APIs

You can also use CL commands or APIs to configure a cluster:

1. **Create the cluster.**
   Create Cluster (CRTCLU) command
   Create Cluster (QcstCreateCluster) API
2. **Add nodes to your cluster from the active cluster node.**
   Add Cluster Node Entry (ADDCLUNODE) command
   Add Cluster Node Entry (QcstAddClusterNodeEntry) API
3. **Define device domains.**
   If you plan to use switchable devices, you must include the desired nodes in the device domain.
   Add Device Domain Entry (ADDDEVDMNE) command
   Add Device Domain Entry (QcstAddDeviceDomainEntry) API
4. **Create cluster resource groups (CRG).**
   Create Cluster Resource Group (CRTCRG) command
   Create Cluster Resource Group (QcstCreateClusterResourceGroup) API
5. **Start the cluster resource groups (CRG).**
   Start Cluster Resource Group (STRCRG) command
   Start Cluster Resource Group (QcstStartClusterResourceGroup) API

Manage clusters

This topic contains information that covers some of the tasks that involve managing your clusters. If you haven't considered the type of interface you are going to use to manage your clusters, see "Solutions for configuring and managing clusters" on page 35 before going any further.

Some of the changes that you can make to the cluster once you have configured it include the following:

Cluster tasks

- "Add a node to a cluster" on page 39
- Remove nodes from a cluster
- "Start a cluster node" on page 39
- End a cluster node
- "Adjust the cluster version of a cluster" on page 40 to the latest level

Cluster resource group tasks

- Create new cluster resource groups
- Delete existing cluster resource groups
- Start a cluster resource group
- End a cluster resource group
- "Change the recovery domain for a cluster resource group" on page 40
- "Perform a switchover" on page 41
- "Add a node to a device domain" on page 41
- "Remove a node from a device domain" on page 42

This topic will also help you to "Save cluster configurations" on page 46. You may want to read about how "Job structure and user queues" on page 44 are structured and how cluster APIs use user queues. Read about the correct way to "End cluster jobs" on page 44 and how to "Monitor cluster status" on page 43. You also learn how the "Reliable message function" on page 17 and "Heartbeat monitoring" on page 15 keep you updated on the status of your cluster.

Add a node to a cluster

Using iSeries Navigator

This requires Option 41 (OS/400 - HA Switchable Resources) to be installed and licensed.

The simple cluster supported by iSeries Navigator can be made up of a maximum of four nodes. If four nodes already exist in the cluster, the **Add Node...** option is disabled. If your clustering needs extend beyond four nodes, you should use “Cluster commands and APIs” on page 36 or a “Cluster middleware business partners and available clustering products” on page 36 to support up to 128 nodes.

To add a node to an existing cluster, follow these steps:

1. In iSeries Navigator, expand Management Central.
2. Expand **Clusters**.
3. Expand the cluster for which you would like to add a node.
4. Right-click **Nodes**, and select **Add Node...**

Using Cluster commands and APIs

You can also use the following to add a node to a cluster:

- Add Cluster Node Entry (ADDCLUNODE) command
- Add Cluster Node Entry (QcstAddClusterNodeEntry) API

Start a cluster node

Starting a cluster node starts cluster resource services on a node in the cluster. Beginning with cluster version 3, a node can start itself and will be able to rejoin the current active cluster, provided it can find an active node in the cluster.

Using iSeries Navigator

This requires Option 41 (OS/400 - HA Switchable Resources) to be installed and licensed.

When cluster resource services is successfully started on the node specified, the status of the node will be set to *Started*.

To start clustering on a node, follow these steps:

1. In iSeries Navigator, expand **Management Central**.
2. Expand **Clusters**.
3. Expand the cluster that contains the node on which you would like to start clustering.
4. Click **Nodes**.
5. Right-click the node you would like to start clustering on, and select **Cluster > Start...**

Using CL commands and APIs

You can also use CL commands or APIs to start a node. When cluster resource services is successfully started on the node specified, the status of the node will be set to *Active*.

- Start Cluster Node (STRCLUNOD) command
- Start Cluster Node (QcstStartClusterNode) API

Adjust the cluster version of a cluster

The “Cluster version” on page 9 defines the level at which all the nodes in the cluster are actively communicating with each other. Cluster versioning is a technique that allows the cluster to contain systems at multiple release levels and fully interoperate by determining the communications protocol level to be used.

To change the cluster version, all nodes in the cluster must be at the same potential version. The cluster version can then be changed to match the potential version. This will allow the new function to be used. The version can only be incremented by one. It cannot be decremented without deleting the cluster and recreating it at the lower version. The current cluster version is initially set by the first node defined in the cluster. Subsequent nodes added to the cluster must be equal to the current cluster version or the next level version, otherwise they cannot be added to the cluster.

Using iSeries Navigator
This requires Option 41 (OS/400 - HA Switchable Resources) to be installed and licensed.

To adjust the cluster version of a cluster, follow these steps:

1. In iSeries Navigator, expand **Management Central**.
2. Expand **Clusters**.
3. Right-click the cluster, and select **Properties**.
4. Change the Cluster version to your desired setting.

Using Cluster commands and APIs

You can also use the following to adjust the cluster version of a cluster:

- Change Cluster Version (CHGCLUVER) command
- Adjust Cluster Version (QcstAdjustClusterVersion) API

Change the recovery domain for a cluster resource group

You can change the roles of nodes in a “Recovery domain” on page 8 for a cluster resource group, as well as add or remove nodes from a recovery domain.

Using iSeries Navigator
This requires Option 41 (OS/400 - HA Switchable Resources) to be installed and licensed.

To change the role of nodes in the recovery domain for a cluster resource group (switchable hardware, switchable software, or switchable data), or to add or remove nodes to the recovery domain, follow these steps:

1. In iSeries Navigator, expand **Management Central**.
2. Expand **Clusters**.
3. Expand the cluster containing the switchable hardware, software, or data for which you would like to change the recovery domain.
4. Expand the switchable hardware, software, or data.
5. Right-click the switchable hardware, software, or data, and select **Properties**.
6. Select the **Recovery Domain** page.

Click Help on the Recovery Domain page for instructions on how to change roles or add or remove nodes.

Using CL commands and APIs

To change the role of nodes in the recovery domain, or add or remove nodes, use the following CL commands and APIs:

Function	CL command	API
Add node to recovery domain	Add Cluster Resource Group Node Entry (ADDCRGNODE)	QcstAddNodeToRcvyDomain
Remove node from recovery domain	Remove Cluster Resource Group Node Entry (RMVCRGNODE)	QcstRemoveNodeFromRcvyDomain
Change cluster resource group	Change Cluster Resource Group (CHGCRG)	QcstChangeClusterResourceGroup

Perform a switchover

Performing a manual “Switchover” on page 13 causes the current primary node to switch over to the backup node, as defined in the cluster resource group’s “Recovery domain” on page 8. When this happens, the current roles of the nodes in the recovery domain of a cluster resource group change such that:

- The current primary node is assigned the role of last active backup.
- The current first backup is assigned the role of primary.
- Subsequent backups are moved up one in the order of backups.

A switchover is only allowed on CRGs that have a status of ACTIVE.

Note: If you are performing a switchover on a switchable hardware group (also known as a device CRG), you should Synchronize user profile name, UID, and GID for performance reasons.

Using iSeries Navigator
This requires Option 41 (OS/400 - HA Switchable Resources) to be installed and licensed.

To switch a resource - a switchable hardware group, switchable software product, or switchable data group - from the primary node to the backup node in the recovery domain, the resource must have a status of **Started**.

To perform a switchover on a resource, follow these steps:

1. In iSeries Navigator, expand **Management Central**.
2. Expand **Clusters**.
3. Expand the cluster containing the desired resource.
4. Click **Switchable Hardware**, **Switchable Software**, or **Switchable Data**.
5. Right-click the desired resource, and select **Switch...**

Using Cluster APIs

You can also use the following to perform a switchover:

- Change Cluster Resource Group Primary (CHGCRGPRI) command
- Initiate Switchover (QcstInitiateSwitchOver) API

Add a node to a device domain

A “Device domains” on page 10 is a subset of nodes in a cluster that share device resources. Before a node can be added to the recovery domain for a device cluster resource group (CRG), the node must be first defined as a member of a device domain. All nodes that will be in the recovery domain for a device CRG must be in the same device domain. A cluster node can belong to at most one device domain.

To create and manage device domains, you must have Option 41 (OS/400 - HA Switchable Resources) installed and a valid license key must exist on all cluster nodes that will be in the device domain.

Using iSeries Navigator

To add a node to a device domain in iSeries Navigator, follow these steps:

1. In iSeries Navigator, expand **Management Central**.
2. Expand **Clusters**.
3. Expand the cluster that contains the node you would like to add to the device domain.
4. Click **Nodes**.
5. Right-click the node you would like to add to the device domain, and select **Properties**.
6. On the **Clustering** page, specify the name of the device domain you would like to add the node to in the **Device domain** field.

Using CL commands and APIs

You can also use the following to add a node to a device domain:

- Add Device Domain Entry (ADDDEVDMNE) command
- Add Device Domain Entry (QcstAddDeviceDomainEntry) API

Remove a node from a device domain

A “Device domains” on page 10 is a subset of nodes in a cluster that share device resources.

Important

Be cautious when removing a node from a device domain. If you remove a node from a device domain, and that node is the current primary point of access for any independent disk pools, those independent disk pools remain with the node being removed. This means that those independent disk pools will no longer be accessible from the remaining nodes in the device domain.

Once a node is removed from a device domain, it cannot be added back to the same device domain if one or more of the existing cluster nodes still belong to that same device domain. In order to add the node back to the device domain, you must:

1. Delete the independent disk pools currently owned by the node being added to the device domain.
2. Perform a system restart (IPL) on the node.
3. Add the node to the device domain. See “Add a node to a device domain” on page 41.
4. Recreate the independent disk pools deleted in Step 1. See Adding a disk unit or disk pool.

Using iSeries Navigator
This requires Option 41 (OS/400 - HA Switchable Resources) to be installed and licensed.

To remove a node from a device domain in iSeries Navigator, follow these steps:

1. In iSeries Navigator, expand **Management Central**.
2. Expand **Clusters**.
3. Expand the cluster that contains the node you would like to remove from the device domain.
4. Click **Nodes**.
5. Right-click the node you would like to remove from the device domain, and select **Properties**.
6. On the Clustering page, remove the entry in the **Device domain** field.

Using CL commands and APIs

You can also use the following to remove a node from a device domain:

- Remove Device Domain Entry (RMVDEVDMNE) command
- Remove Device Domain Entry (QcstRemoveDeviceDomainEntry) API

Monitor cluster status

Cluster resource services performs basic monitoring of a cluster and its components using the “Reliable message function” on page 17 and “Heartbeat monitoring” on page 15, taking appropriate actions when necessary.

You can also manually monitor the status of a cluster and its components.

Using iSeries Navigator

This requires Option 41 (OS/400 - HA Switchable Resources) to be installed and licensed.

To monitor the status of a cluster in iSeries Navigator:

1. In iSeries Navigator, expand Management Central.
2. Expand **Clusters**.
3. Navigate within the iSeries Navigator folders for the desired cluster to view the status of the cluster, its nodes, and resources using the Status column in the iSeries Navigator list. The online help contains descriptions of the possible values for the Status column. You can also right-click on components of the cluster and select **Properties** to view information about the cluster.

Using CL commands and APIs

You can use the following commands and APIs to monitor cluster status:

Cluster Information

Retrieves information about a cluster, such as the nodes in the cluster, which adapter IP addresses are being used on each node, and the status of each node in the cluster.

- Display Cluster Information (DSPCLUINF) command
- List Cluster Information (QcstListClusterInfo) API
- List Device Domain Info (QcstListDeviceDomainInfo) API
- Retrieve Cluster Resource Services Information (QcstRetrieveCRSInfo) API
- Retrieve Cluster Information (QcstRetrieveClusterInfo) API

Cluster Resource Group information

Generates a list of cluster resource groups and information about the cluster resource group in the cluster, such as the name of the primary node of each CRG in the cluster.

- Display Cluster Resource Group Information (DSPCRGINF) command
- List Cluster Resource Groups (QcstListClusterResourceGroups) API
- List Cluster Resource Group Information (QcstListClusterResourceGroupInf) API

Cluster performance

When changes are made to a cluster, the overhead necessary to manage the cluster can be affected. The only resources that clustering requires are those necessary to perform “Heartbeat monitoring” on page 15, to manage the cluster resource groups and the cluster nodes, and to handle any messaging taking place between cluster resource groups and cluster nodes. Once your clustering environment is operational, the only increase in overhead will be if you make changes to the cluster.

During a normal operating environment, there should be minimal impact to your clustered systems due to clustering activity.

To get the optimal performance out of your clustered servers review these topics:

- “Balance network load for clusters”
- “Tune cluster performance”

Balance network load for clusters

You can balance the network load by splitting your work between the communication lines that you use to connect the nodes in the cluster. The more you can balance the work to keep resource utilization low, the more smoothly your system will run.

See CPU load on backup nodes for more information on keeping your backup systems running smoothly.

Tune cluster performance

Since potentially significant differences exist in your communications environment, you have the capability to adjust variables that affect cluster communications to best match your environment. The default values should normally be acceptable to most common environments. If your particular environment is not well suited for these defaults, you can tune cluster communications to better match your environment. Two levels of tuning are available.

Base-level tuning allows you to set the tuning parameters to a predefined set of values identified for high, low, and normal timeout and messaging interval values. When the normal level is selected, the default values are used for cluster communications performance and configuration parameters. Selecting the low level causes clustering to increase the heartbeating interval and the various message timeout values. With fewer heartbeats and longer timeout values, the cluster will be less sensitive to communications failures. Selecting the high level causes clustering to decrease the heartbeating interval and the various message timeout values. With more frequent heartbeats and shorter timeout values, the cluster will be more sensitive to communications failures.

Advanced-level tuning is also available such that individual parameters may be tuned over predefined ranges of values. This allows more granular tuning to meet any special circumstances in your communications environment. If an advanced level of tuning is desired, it is recommended that you obtain help from IBM support personnel or equivalent. Setting the individual parameters incorrectly could easily result in decreased performance.

See Tunable cluster communications parameters and the Change Cluster Resource Services (QcstChgClusterResourceServices) API for more information on the specific parameters available and the allowed values.

End cluster jobs

You should never try to end a cluster job directly. If you need to stop whatever may be running in a clustered environment, you should:

1. End the cluster node.
2. Fix the problem.
3. “Start a cluster node” on page 39.

Job structure and user queues

Cluster resource services job structure

> Cluster resource services consists of a set of multi-threaded jobs. When clustering is active on a server, the following jobs run in the QSYSWRK subsystem under the QSYS user profile. The jobs run using the QDFTJOBD job description, but with the logging level set such that a job log will be produced.

- Cluster control consists of one job that is named QCSTCTL.
- Cluster resource group manager consists of one job that is named QCSTCRGM.
- Cluster resource groups consist of one job per cluster resource group object. The job name is the same as the cluster resource group name.
- When one or more device list entries in a resilient device CRG have been set to be brought online at switchover or failover, additional jobs will be submitted to perform the vary on function.

The QCSTCTL and QCSTCRGM job are cluster critical jobs. That is, the jobs must be running in order for the node to be active in the cluster.

Most cluster resource group APIs result in a separate job being submitted that use the user profile specified when the cluster resource group was created. The exit program defined in the cluster resource group is called in the submitted job. By default, the jobs are submitted to the QBATCH job queue. Generally, this job queue is used for production batch jobs and will delay or prevent completion of the exit programs. To allow the APIs to run effectively, create a separate user profile, job description, and job queue for use by cluster resource groups. Specify the new user profile for all cluster resource groups that you create. The same program is processed on all nodes within the recovery domain that is defined for the cluster resource group.

Cluster APIs use of user queues

Functions performed by an API that has a Results information parameter operate asynchronously and send their results to a user queue once the API is finished processing. The user queue must be created before calling the API. You can create a user queue by using the Create User Queue (QUSCRTUQ) API. The queue must be created as a keyed queue. The key for the user queue is described in the format of the user queue entry. The user queue name is passed to the API. For more information on user queues, see Cluster APIs Use of User Queues.

When the Distribute Information (QcstDistributeInformation) API is used, the information sent between nodes is deposited on the user queue specified when the CRG was created. This queue must be created by the user on all active nodes in the recovery domain prior to the use of the Distribute Information API. See the Create Cluster (CRTCLU) command and the Create Cluster Resource Group (QcstCreateClusterResourceGroup) API for details on when the distribute information queue must exist.

The failover message queue receives messages regarding failover activity. See Failover message queue for details.

Maintain user profiles on all nodes

Because there is no central security administration to update nodes, user profiles are not automatically updated across cluster nodes. Be sure you update the security information across all nodes to ensure that any public or private authorities associated with any cluster objects, cluster resource groups, applications, or data have the right security level.

One mechanism to achieve this is to use Management Central in iSeries Navigator to perform administrator or operator functions across multiple systems and groups of systems. This support includes some common user-administration tasks that operators need to perform across the multiple systems in their cluster. Management Central allows user profile functions to be performed against groups of systems. The administrator can specify a post-propagation command to be run on the target systems when creating a user profile.

See Manage users and groups with Management Central for details.

Backup and recovery of clusters

If you implement clustering on your systems, it is still important that you create a backup and recovery strategy to protect your data. If you are not familiar with why you would want a strategy and how to go about creating one, see Planning a backup and recovery strategy.

If you are planning on using clustering as your backup strategy so that you have one system up and running while the other system is down when its being backed up, it is recommended that you have a minimum of three systems in the cluster. By having three systems in the cluster, you will always have one system to switch over to should a failure occur.

For more information on backup and recovery procedures, see “Restore a cluster from backup tapes” on page 59.

Saving and restoring cluster resource groups

You can save a cluster resource group whether the cluster is active or inactive. The following restrictions apply for restoring a cluster resource group:

- If the cluster is up and the cluster resource group is known to that cluster, you cannot restore the cluster resource group.
- If the node is not configured for a cluster, you cannot restore a cluster resource group.

You can restore a cluster resource group if the cluster is active, the cluster resource group is not known to that cluster, the node is in the recovery domain of that cluster resource group, and the cluster name matches that in the cluster resource group. You can restore a cluster resource group if the cluster is configured but is not active on that node and if that node is in the recovery domain of that cluster resource group.

Preparing for a disaster

In the case of a disaster, you will need to reconfigure your cluster. In order to prepare for such a scenario, it is recommended that you save your cluster configuration information and keep a hardcopy printout of that information.

1. Use the Save Configuration (SAVCFG) command or the Save System (SAVSYS) command after making cluster configuration changes so that the restored internal cluster information is current and consistent with other nodes in the cluster. See Saving configuration information for details on performing a SAVCFG or SAVSYS.
2. Print a copy of cluster configuration information every time you change it. See Printing system information for details. Keep a copy with your backup tapes to use in case of a disaster where you would need to reconfigure your entire cluster.

For recovery information, see:

- “Recover a cluster after a complete system loss” on page 58

Save cluster configurations

You can use the SAVSYS (Save System) Command which saves your entire system, not just your configured cluster. You can use the SAVCFG (Save Configuration) Command to save your configured system.

You can use the following commands to save your cluster resource group objects:

- SAVOBJ(QUSRSYS/*ALL)

Note: Cluster resource group objects can be saved only for the current release.

See “Backup and recovery of clusters” on page 46 for save and restore considerations for cluster resource groups.

Examples: Cluster configurations

Use these example cluster configurations to understand the possibilities when planning and implementing clusters in your environment.

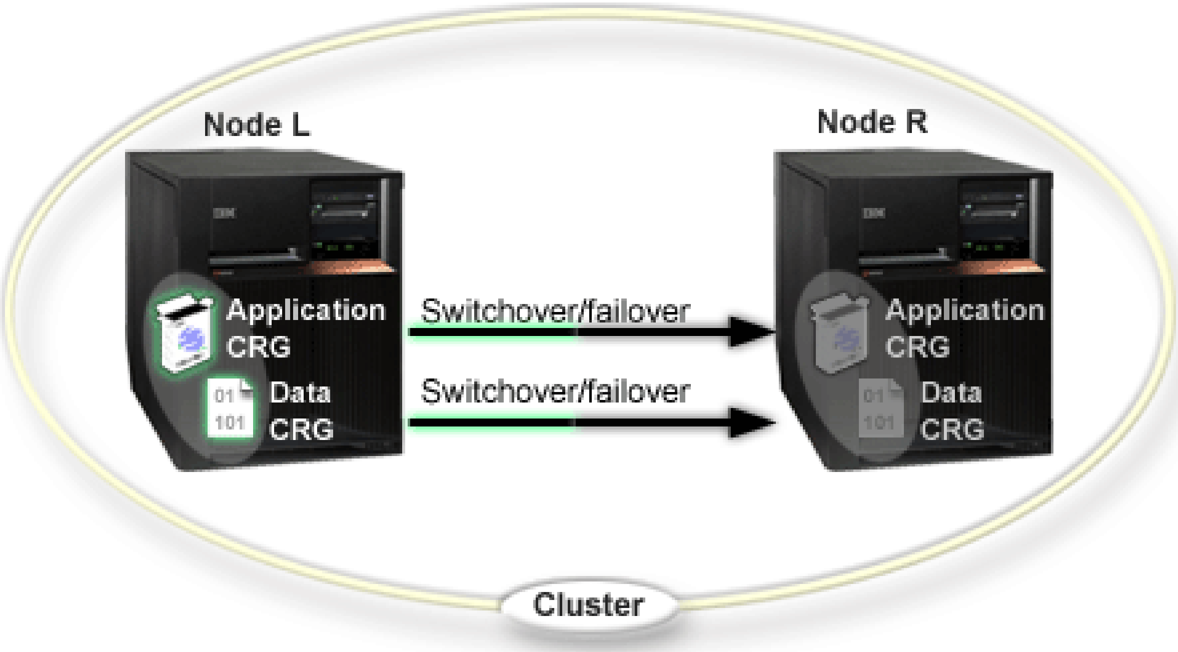
The following configurations are examples of some common cluster implementations:

- “Example: A simple, two-node cluster”
- “Example: A four-node cluster” on page 48
- “Example: A switched disk cluster using independent disk pools” on page 49

Example: A simple, two-node cluster

This example configuration provides the following:

- One-way replication and failover
- Two-tier environment
- Applications and data move together
- Backup used for offine processing of data



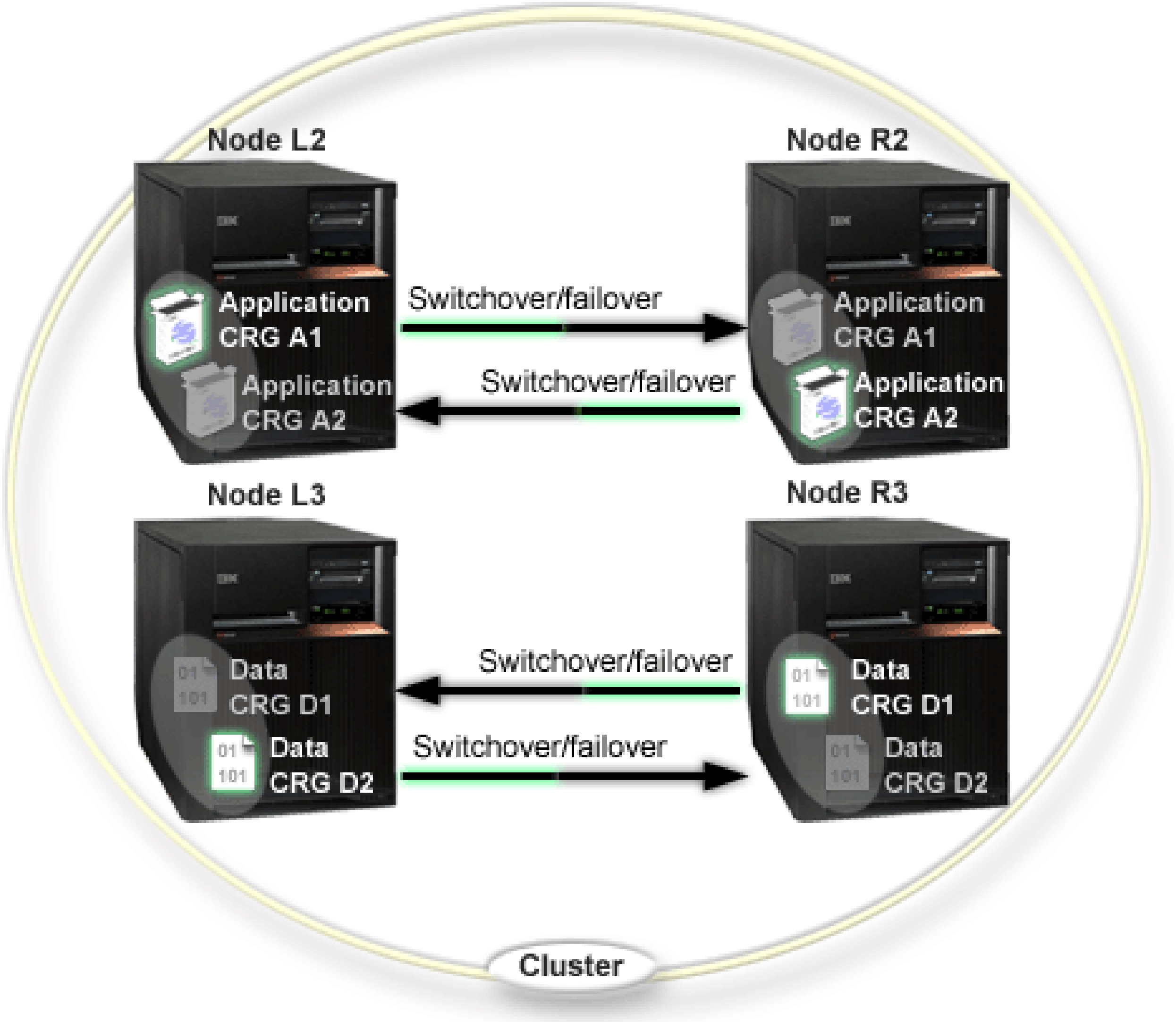
Using this example, Node L is currently operating as the primary node for two cluster resource groups, an application CRG and a data CRG. Two exit programs will be running periodically on Node L for the application CRG. The reason two exit programs may be running at the same time is if you call the Start CRG API, an exit program is started and runs continuously while the application CRG is active. If you should call the End CRG API for the application CRG, another exit program is then started. Node R is the first, and only, backup node designated in the recovery domain of each cluster resource group. Data that is associated with the data CRG and pertinent application information that is associated with the application CRG is being replicated from Node L to Node R. If Node L fails or needs to be taken down for administrative reasons, then a failover or switchover is initiated and Node R becomes the primary node for both cluster resource groups. Node R will take over the Internet Protocol (IP) address defined for the application CRG.

Note: While Node L is down, system availability is exposed because there is no backup should Node R also fail. When Node L recovers and rejoins the cluster, it is made the backup for both cluster resource groups. At that time, replication will be from Node R to Node L. If you would like Node L to resume the role of primary, then an administrative switchover should be performed.

Example: A four-node cluster

This example configuration provides the following:

- Two-way replication and failover
- Three-tier environment
- Applications and data move independently
- Backup is used for normal production of different workload



The four-node example shows the additional flexibility that is possible with an iSeries cluster. There are two application cluster resource groups (A1 and A2) and two data cluster resource groups (D1 and D2).

The data associated with D1 is the critical data for the application associated with A1. The data associated with D2 is the critical data for the application associated with A2. Because this is a three-tier environment, the applications exist on the second tier (Node L2 and Node R2) and the data is separated into the third tier (Node L3 and Node R3).

Cluster resource group (CRG)	Primary	Backup
Application CRG A1	L2	R2
Application CRG A2	R2	L2
Data CRG D1	R3	L3
Data CRG D2	L3	R3

This enables mutual take-over capability at both the application and data levels. All four nodes are being used for normal production. They are also being used to back up other systems in the cluster. The two applications and their associated data should always be available in this cluster. The outage of any single node will not disrupt availability. In addition, the simultaneous outage of a node at the application level with a node at the data level will not disrupt availability.

Note: In either instance, the cluster is running exposed in that some cluster resources will not be replicated while a node is down. You can resolve this by having more than one backup for any critical cluster resource.

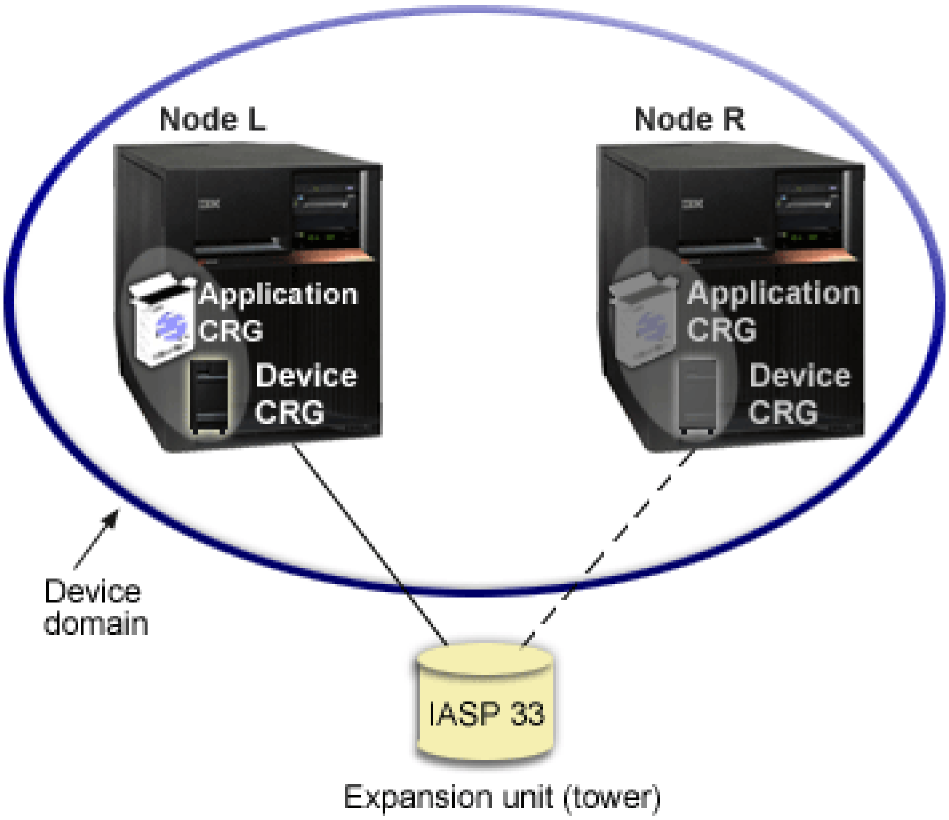
Example: A switched disk cluster using independent disk pools

A cluster using switched disk technology provides an alternative to having the data replicated. In a switched disk cluster, the data is actually contained in independent disk pools (also referred to as independent ASPs).

For more examples of switchable independent disk pool implementations, featuring more sample configurations than the example provided below, see Independent disk pools configurations.

This example configuration provides the following:

- One switchable independent disk pool with an idle standby server. The independent disk pool is contained within a collection of disk units that are switchable.
- Two-tier environment
- Applications and data move together
- Backup used for different work loads not associated with this application's data
- No data replication; only one copy of the data exists in this cluster



Using this example, Node L and Node R belong to the same device domain. Node L is currently operating as the primary node for two cluster resource groups - an application CRG and a device CRG. Node R is the first (and only) backup for both of the cluster resource groups. Data that is associated with the device CRG is contained in a switchable resource such as an external expansion unit (tower). Pertinent application information associated with the application CRG is either stored in that same tower or is otherwise being replicated from Node L to Node R. If Node L fails or needs to be taken down for administrative reasons, then Node R becomes the primary node for both cluster resource groups. Node R will take over the Internet Protocol (IP) address defined for the application CRG. Node R will also assume ownership of the switchable resource defined for the device CRG.

Note: While Node L is down, system availability is exposed because there is no backup should Node R also fail. When Node L recovers and rejoins the cluster, it is made the backup for both cluster resource groups. If you would like it to again take on the role of primary, then an administrative switchover should be performed.

Troubleshoot clusters

At times, it may appear that the cluster is not working properly. This topic covers information about problems that you may encounter with clusters.

“Determine if a cluster problem exists” on page 51
Start here to diagnose your cluster problems.

“Common cluster problems” on page 52
This topic lists some of the most common problems that can occur in a cluster, as well as ways to avoid and recover from them.

“Partition errors” on page 54
Certain cluster conditions are easily corrected. If a cluster partition has occured, you can learn how to recover. This topic also tells you how to avoid a cluster partition and gives you an example of how to merge partitions back together.

“Cluster recovery” on page 57
Read about how to recover from other cluster failures that may occur.

“Frequently asked questions about iSeries Navigator Simple Cluster Management” on page 59
Questions and answers about the iSeries Navigator graphical user interface for creating and managing clusters.

“Who to call for cluster suppport” on page 65
See this topic if you need to contact IBM with your cluster questions.

Determine if a cluster problem exists

At times, it may seem that your cluster is not operating correctly. When you think a problem exists, you can use the following to help determine if a problem exists and the nature of the problem.

- **Determine if clustering is active on your system.**
  To determine if cluster resource services is active, look for the two jobs - QCSTCTL and QCSTCRGM - in the QSYSWRK subsystem. If these jobs are active, then cluster resource services is active. You can use the Work Management function in iSeries Navigator to View jobs in a subsystem or use the WRKACTJOB (Work with Active Jobs) CL command to do this. You can also use the DSPCLUINF (Display Cluster Information) command to view status information for the cluster.
  – Additional jobs for cluster resource services may also be active. See “Job structure and user queues” on page 44 for details.
- **Look for messages indicating a problem.**
  – Look for inquiry messages in QSYSOPR that are waiting for a response.
  – Look for error messages in QSYSOPR that indicate a cluster problem. Generally, these will be in the CPFBB00 to CPFBBFF range.
  – Display the history log (DSPLOG CL command) for messages that indicate a cluster problem. Generally, these will be in the CPFBB00 to CPFBBFF range.
- **Look at job logs for the “Job structure and user queues” on page 44 for severe errors.**
  These jobs are initially set with a logging level at (4 0 *SECLVL) so that you can see the necessary error messages. You should ensure that these jobs and the exit program jobs have the logging level set appropriately. If clustering is not active, you can still look for spool files for the cluster jobs and exit program jobs.
- **If you suspect some kind of hang condition, look at call stacks of cluster jobs.**
  Determine if there is any program in some kind of DEQW (dequeue wait). If so, check the call stack of each thread and see if any of them have getSpecialMsg in the call stack.
- **Check for cluster vertical licensed internal code (VLIC) logs entries.**
  These log entries would have a 4800 major code.
- **Use NETSTAT command to determine if there are any abnormalities in your communications environment.**
  NETSTAT returns information about the status of TCP/IP network routes, interfaces, TCP connections and UDP ports on your system.
  – Use Netstat Option 1 (Work with TCP/IP interface status) to ensure that the IP addresses chosen to be used for clustering show an ’Active’ status. Also ensure that the LOOPBACK address (127.0.0.1) is also active.

  - Use Netstat Option 3 (Work with TCP/IP Connection Status) to display the port numbers (F14). Local port 5550 should be in a 'Listen' state. This port must be opened via the STRTCPSVR *INETD command evidenced by the existence of a QTOGINTD (User QTCP) job in the Active Jobs list. If clustering is started on a node, local port 5551 must be opened and be in a '*UDP' state. If clustering is not started, port 5551 must not be opened or it will, in fact, prevent the successful start of clustering on the subject node.
- **Use the CLUSTERINFO macro to show cluster resource services' view of nodes in the cluster, nodes in the various cluster resource groups, and cluster IP addresses being currently used.** Discrepencies found here could help pinpoint trouble areas if the cluster is not performing as expected. The CLUSTERINFO macro can be invoked from System Service Tools (SST) via the STRSST command as follows:
  - SST Option 1 Start a service tool
  - Start Option 4 Display/Alter/Dump
  - Display/Alter Option 1 Display/Alter storage
  - Select Data Option 2 Licensed Internal Code Data
  - Select LIC Data Option 14 Advanced Analysis
  - Select CLUSTERINFO macro (-h option for parameters if more info desired)

Common cluster problems

The following common problems are easily avoidable or easily correctable.

You cannot start or restart a cluster node.

This situation is typically due to some problem with your communications environment. To avoid this situation, ensure that your network attributes are set correctly, including the loopback address, INETD settings, ALWADDCLU attibute, and the IP addresses for cluster communications.

- The ALWADDCLU network attribute must be appropriately set on the target node if trying to start a remote node. See "Enable a node to be added to a cluster" on page 26 for details on setting this attribute. This should be set to either *ANY or *RQSAUT depending on your environment.
- The IP addresses chosen to be used for clustering locally and on the target node must show an 'Active' status.
- The LOOPBACK address (127.0.0.1) locally and on the target node must also be active.
- The local and any remote nodes must be able to PING using the IP addresses to be used for clustering to insure network routing is active.
- INETD must be active on the target node. When INETD is active, port 5550 on the target node should be in a 'Listen' state. See INETD server for information on starting the INETD server.
- Prior to attempting to start a node, port 5551 on the node to be started must not be opened or it will, in fact, prevent the successful start of clustering on the subject node.

You end up with several, disjointed one-node clusters.

This can occur when the node being started cannot communicate with the rest of the cluster nodes. Check the communications paths.

The response from exit programs is slow.

A common cause for this situation is incorrect setting for the job description used by the exit program. The MAXACT parameter may be set too low so that, for example, only one instance of the exit program can be active at any point in time. It is recommended that this be set to *NOMAX.

Performance in general seems to be slow.

There are several common causes for this symptom.

- The most likely cause is heavy communications traffic over a shared communications line. See "Cluster performance" on page 43 for more information.
- Another likely cause is an inconsistency between the communications environment and the cluster message tuning parameters. You can use the Retrieve Cluster Resource Services Information (QcstRetrieveCRSInfo) API to view the current settings of the tuning parameters and the Change Cluster Resource Services (QcstChgClusterResourceServices) API to change the settings. Cluster performance may be degraded under default cluster tuning parameter settings if using old adapter hardware. The adapter hardware types included in the definition of 'old' are 2617, 2618, 2619, 2626, and 2665. In this case, setting of the 'Performance class' tuning parameter to 'Normal' is desired.
- Another common cause of this condition is problems with the IP multicast groups. If the primary cluster addresses (first address entered for a given node when creating a cluster or adding a node) for several nodes reside on a common LAN, the cluster will utilize IP multicast capability. Using the NETSTAT command, insure the primary cluster addresses show a multicast host group of '226.5.5.5'. This can be seen using option 14 'Display multicast group' for the subject address. If the multicast group does not exist, verify the default setting of TRUE is still set for the 'Enable multicast' cluster tuning parameter by using the Retrieve Cluster Resource Services Information (QcstRetrieveCRSInfo) API.
- If all the nodes of a cluster are on a local LAN or have routing capabilities which can handle Maximum Transmission Unit (MTU) packet sizes of greater than 1,464 bytes throughout the network routes, large cluster message transfers (greater than 1,536K bytes) can be greatly speeded up by increasing the cluster tuning parameter value for 'Message fragment size' to better match the route MTUs.

You cannot use any of the function of the new release.

If you attempt to use new release function and you see error message CPFBB70, then your current "Cluster version" on page 9 is still set at the prior version level. You must upgrade all cluster nodes to the new release level and then use the adjust cluster version interface to set the current cluster version to the new level. See "Adjust the cluster version of a cluster" on page 40 for more information.

You cannot add a node to a device domain or access the iSeries Navigator Simple Cluster Management interface.

To access the "iSeries Navigator and Simple Cluster Management" on page 35 interface, or to use switchable devices, you must have OS/400 Option 41, HA Switchable Resources installed on your system. You must also have a valid license key for this option.

You applied a cluster PTF and it does not seem to be working.

Did you signoff/signon? The old program is still active in the activation group until the activation group is destroyed. All of the cluster code (even the cluster APIs) run in the default activation group.

CEE0200 appears in the exit program joblog.

On this error message, the from module is QLEPM and the from procedure is Q_LE_leBdyPeilog. Any program that the exit program invokes must run in either *CALLER or a named activation group. You must change your exit program or the program in error to correct this condition.

CPD000D followed by CPF0001 appears in the cluster resource services joblog.

When you receive this error message, make sure the system value for QMLTTHDACN is set to either 1 or 2.

Cluster appears hung.

Make sure cluster resource group exit programs are outstanding. To check the exit program, use the WRKACTJOB (Work with Active Jobs) command, then look in the Function column for the presence of PGM-QCSTCRGEXT.

Partition errors

A “Cluster partition” on page 18 occurs in a cluster whenever contact is lost between one or more nodes in the cluster and a failure of the lost nodes cannot be confirmed. This is not to be confused with a partition in a logical partition (LPAR) environment.

If you receive error message CPFBB20 in either the history log (QHST) or the QCSTCTL joblog, a cluster partition has occurred and you need to know how to recover. The following example shows a cluster partition that involves a cluster made up of four nodes: A, B, C, and D. The example shows a loss of communication between cluster nodes B and C has occurred, which results in the cluster dividing into two cluster partitions. Before the cluster partition occurred, there were four cluster resource groups, which could be of any type, called CRG A, CRG B, CRG C, and CRG D. The example shows the recovery domain of each cluster resource group.

Node A	**Node B**	**x**	**Node C**	**Node D**
CRG A (backup1)	CRG A (primary)			
	CRG B (primary)		CRG B (backup1)	
	CRG C (primary)		CRG C (backup1)	CRG C (backup2)
CRG D (backup2)	CRG D (primary)		CRG D (backup1)	
Partition 1			**Partition 2**	

Using this example, read how to “Determine primary and secondary cluster partitions” on page 55 to see what kinds of cluster resource group actions you can take.

A cluster may partition if the maximum transmission unit (MTU) at any point in the communication path is less than the cluster communications tuneable parameter, message fragment size. MTU for a cluster IP address can be verified using the Work with TCP/IP Network Status (WRKTCPSTS) command on the subject node. The MTU must also be verified at each step along the entire communication path. If the MTU is less than the message fragment size, either raise the MTU of the path or lower the message fragment size. You can use the Retrieve Cluster Resource Services Information (QcstRetrieveCRSInfo) API to view the current settings of the tuning parameters and the Change Cluster Resource Services (QcstChgClusterResourceServices) API to change the settings.

Once the cause of the cluster partition condition has been corrected, the cluster will detect the re-established communication link and issue the message CPFBB21 in either the history log (QHST) or the QCSTCTL joblog. This informs the operator that the cluster has recovered from the cluster partition. Be aware that once the cluster partition condition has been corrected, it may be a few minutes before the cluster merges back together.

If the partition condition reported is really a failure condition of one or more nodes, see “Change partitioned nodes to failed” on page 55.

For more information on troubleshooting a cluster partition, see:

- “Avoid a cluster partition” on page 22
- “Tips: Cluster partitions” on page 56

- “Merge” on page 15
- Example: Failure

Determine primary and secondary cluster partitions

In order to determine the types of cluster resource group actions that you can take within a cluster partition, you need to know whether the partition is a primary or a secondary cluster partition. The cluster partition that contains the current primary node in the recovery domain of a cluster resource group is considered the primary partition of the cluster resource group. All other partitions are secondary partitions. The primary partitions may not be the same for all cluster resource groups. The restrictions for each Cluster Resource Group API are:

Table 1. Cluster Resource Group API Partition Restrictions

Cluster Resource Group API	Allowed in primary partition	Allowed in secondary partitions
Add Node to Recovery Domain	X	
Add CRG Device Entry		
Change Cluster Resource Group	X	
Change CRG Device Entry	X	X
Create Cluster Resource Group		
Delete Cluster Resource Group	X	X
Distribute Information	X	X
End Cluster Resource Group	X	
Initiate Switchover	X	
List Cluster Resource Groups	X	X
List Cluster Resource Group Information	X	X
Remove Node from Recovery Domain	X	
Remove CRG Device Entry	X	
Start Cluster Resource Group	X	

By applying these restrictions, cluster resource groups can be resynchronized when the cluster is no longer partitioned. As nodes rejoin the cluster from a partitioned status, the version of the cluster resource group in the primary partition is copied to nodes from a secondary partition.

When a partition is detected, the Add Cluster Node Entry, Adjust Cluster Version, and the Create Cluster API cannot be run in any of the partitions. The Add Device Domain Entry API can only be run if none of the nodes in the device domain are partitioned. All of the other Cluster Control APIs may be run in any partition. However, the action performed by the API takes affect only in the partition running the API.

Change partitioned nodes to failed

Sometimes, a partitioned condition is reported when there really was a node outage. This can occur when cluster resource services loses communications with one or more nodes, but cannot detect if the nodes are still operational. When this condition occurs, a simple mechanism exists for you to indicate that the node has failed.

Warning

> When you tell cluster resource services that a node has failed, it makes recovery from the partition state simpler. However, changing the node status to failed when, in fact, the node is still active and a true partition has occurred should not be done. Doing so could cause a node in more than one partition to assume the primary role for a cluster resource group. When two nodes think they are the primary node, data such as files or databases could become disjoint or corrupted if multiple nodes are each independently making changes to their copies of files. In addition, the two partitions cannot be “Merge” on page 15 back together when a node in each partition has been assigned the primary role.

When the status of a node is changed to Failed, the role of nodes in the recovery domain for each cluster resource group in the partition may be reordered. The node being set to Failed will be assigned as the last backup. If multiple nodes have failed and their status needs to be changed, the order in which the nodes are changed will affect the final order of the recovery domain's backup nodes. If the failed node was the primary node for a CRG, the first active backup will be reassigned as the new primary node.

Using iSeries Navigator
This requires Option 41 (OS/400 - HA Switchable Resources) to be installed and licensed.

When cluster resource services has lost communications with a node but cannot detect if the node is still operational, a cluster node will have a status of **Not communicating** in the Nodes container in iSeries Navigator. You may need to change the status of the node from **Not communicating** to **Failed**. You will then be able to restart the node.

To change the status of a node from **Not communicating** to **Failed**, follow these steps:

1. In iSeries Navigator, expand **Management Central**.
2. Expand **Clusters**.
3. Expand the cluster that contains the node for which you would like to change the status.
4. Click **Nodes**.
5. Right-click the node for which you would like to change the status, and select **Cluster** > **Change Status...**

To restart the node, follow these steps:

1. Right-click the node, and select **Cluster** > **Start...**

Using CL commands and APIs

To change the status of a node from **Not communicating** to **Failed**, follow these steps:

1. Use the CHGCLUNODE command or the Change Cluster Node Entry API (QcstChangeClusterNodeEntry) to change the status of a node from partitioned to failed. This should be done for all nodes that have actually failed.
2. Use the STRCLUNOD command or the Start Cluster Node (QcstStartClusterNode) API to start the cluster node, allowing the node to "Rejoin" on page 13 the cluster.

Tips: Cluster partitions

1. The rules for restricting operations within a partition are designed to make merging the partitions feasible. Without these restrictions, reconstructing the cluster would require extensive work by you.
2. If the nodes in the primary partition have been destroyed, special processing may be necessary in a secondary partition. The most common scenario that causes this condition would be the loss of the site that made up the primary partition. Use the example in "Partition errors" on page 54 and assume that Partition 1 was destroyed. In this case, the primary node for Cluster Resource Groups B, C, and D must be located in Partition 2. The simplest recovery is to use Change Cluster Node Entry to set both Node A and Node B to failed. See "Change partitioned nodes to failed" on page 55 for more information on how to do this.
   Recovery can also be achieved manually. In order to do this, perform these operations:
   a. Remove Nodes A and B from the cluster in Partition 2. Partition 2 is now the cluster.
   b. Establish any replication environments needed in the new cluster. IE. Start Cluster Resource Group API/CL command, etc.

   Since nodes have been removed from the cluster definition in Partition 2, an attempt to merge Partition 1 and Partition 2 will fail. In order to correct the mismatch in cluster definitions, run the Delete Cluster (QcstDeleteCluster) API on each node in Partition 1. Then add the nodes from Partition 1 to the cluster, and reestablish all the cluster resource group definitions, recovery domains, and replication. This requires a great deal of work and is also prone to errors. It is very important that you do this procedure only in a site loss situation.

3. Processing a start node operation is dependent on the status of the node that is being started:

   The node either failed or an End Node operation ended the node:

   a. Cluster resource services is started on the node that is being added
   b. Cluster definition is copied from an active node in the cluster to the node that is being started.
   c. Any cluster resource group that has the node being started in the recovery domain is copied from an active node in the cluster to the node being started. No cluster resource groups are copied from the node that is being started to an active node in the cluster.

   The node is a partitioned node:

   a. The cluster definition of an active node is compared to the cluster definition of the node that is being started. If the definitions are the same, the start will continue as a merge operation. If the definitions do not match, the merge will stop, and the user will need to intervene.
   b. If the merge continues, the node that is being started is set to an active status.
   c. Any cluster resource group that has the node being started in the recovery domain is copied from the primary partition of the cluster resource group to the secondary partition of the cluster resource group. Cluster resource groups may be copied from the node that is being started to nodes that are already active in the cluster.

Cluster recovery

See the following topics to help you recover from failures within your cluster, or even a server failure:

- “Recover from cluster job failures”
- “Recover a damaged cluster object”
- “Recover a cluster after a complete system loss” on page 58
- “Recover a cluster after a disaster” on page 59
- “Restore a cluster from backup tapes” on page 59

Recover from cluster job failures

Failure of a cluster resource services job is usually indicative of some other problem. You should look for the job log associated with the failed job and look for messages that describe why it failed. Correct any error situations. Then, to recover from a failure of a cluster resource services job:

1. End clustering on the node where the job failure occurred. See End a cluster node.
2. Restart clustering on the node. See “Start a cluster node” on page 39.

For more information on cluster jobs, see “Job structure and user queues” on page 44. If you are using a business partner cluster management product, refer to the documentation that came with the product.

Recover a damaged cluster object

While it is unlikely you will ever experience a damaged object, it may be possible for cluster resource services objects to become damaged. The system, if it is an active node, will attempt to recover from another active node in the cluster. The system will perform the following recovery steps:

For a damaged internal object:

1. The node that has the damage ends.
2. If there is at least one other active node within the cluster, the damaged node will automatically restart itself and rejoin the cluster. The process of rejoining will correct the damaged situation.

For a damaged cluster resource group:

1. The node that has a damaged CRG will fail any operation currently in process that is associated with that CRG. The system will then attempt to automatically recover the CRG from another active node.
2. If there is at least one active member in the recovery domain, the CRG recovery will work. Otherwise, the CRG job ends.

If the system cannot identify or reach any other active node, you will need to perform these recovery steps:

For a damaged internal object:
You receive an internal clustering error (CPFBB46, CPFBB47, or CPFBB48).

1. End clustering for the node that contains the damage.
2. Restart clustering for the node that contains the damage. Do this from another active node in the cluster.
3. If Steps 1 and 2 do not solve the problem, remove the damaged node from the cluster.
4. Add the system back into the cluster and into the recovery domain for the appropriate cluster resource groups.

For a damaged cluster resource group:
You receive an error stating that an object is damaged (CPF9804).

1. End clustering on the node that contains the damaged cluster resource group.
2. Delete the CRG (using the DLTCRG command).
3. If there is no other node active in the cluster that contains the CRG object, restore from media.
4. Start clustering on the node that contains the damaged cluster resource group. This can be done from any active node.
5. When you start clustering, the system resynchronizes all of the cluster resource groups. You may need to recreate the CRG if no other node in the cluster contains the CRG.

Recover a cluster after a complete system loss

Use this information in conjunction with the appropriate checklist in the Backup and Recovery manual for recovering your entire system after a complete system loss when your server loses power unexpectedly.

Scenario 1: Restoring to the same system

1.
   a. In order to prevent inconsistencies in the device domain information between the Licensed Internal Code and OS/400, it is recommended that you install the Licensed Internal Code using option 3 (Install Licensed Internal Code and Recover Configuration).
   Note: For the Install Licensed Internal Code and Recover Configuration operation to succeed, you must have the same disk units — with exception of the load source disk unit if it has failed. You must also be recovering the same release.
   b. After you have installed the Licensed Internal Code, follow the *How to Recover Your Disk Configuration* procedure in chapter 5 of the Backup and Recovery manual. These steps will help you avoid having to reconfigure the ASPs.
   c. After you have recovered your system information and are ready to start clustering on the node you just recovered, you must start clustering from the active node. This will propagate the most current configuration information to the recovered node.

Scenario 2: Restoring to a different system

After you have recovered your system information and checked the job log to make sure that all objects have restored, you must perform the following steps to obtain the correct cluster device domain configuration.

1.
    a. From the node you just restored, delete the cluster.
    b. From the active node, perform these steps:

1.
    a. Remove the recovered node from the cluster.
    b. Add the recovered node back into the cluster.
    c. Add the recovered node to the device domain.
    d. Create the cluster resource group or add the node to the recovery domain.

Recover a cluster after a disaster

In the case of a disaster where all your nodes are lost, you will need to reconfigure your cluster. In order to prepare for such a scenario, it is recommended that you save your cluster configuration information and keep a hardcopy printout of that information.

See “Backup and recovery of clusters” on page 46 for details.

Restore a cluster from backup tapes

During normal operations, you should never have to restore from a backup tape. The only time that you need to do this would be if a disaster happened, and you lost all of the nodes in your cluster. If a disaster should occur, you would recover by following your normal recovery procedures that you have put in place after you created your backup and recovery strategy. For more information, see the Backup and Recovery manual.

Frequently asked questions about iSeries Navigator Simple Cluster Management

The IBM graphical user interface for creating and managing clusters is called Simple Cluster Management. It is available in iSeries Navigator and accessible through Option 41 (OS/400 - HA Switchable Resources). See “iSeries Navigator and Simple Cluster Management” on page 35 for details on the interface.

Here is a list of iSeries Navigator Simple Cluster Management questions and answers. If you have a question that is not on this page, please contact us.

General

1. Is there a checklist that outlines the prerequisites to creating a cluster? (See 60)

Simple Cluster Management and iSeries Navigator

1. Where is the Clusters function located in the iSeries Navigator interface? (See 60)
2. How do I create a cluster? (See 60)
3. What is the relationship between the Clusters folder and the Management Central system group? (See 61)
4. I already have a cluster defined on some iSeries systems in the network. How do I add it so I can view and manage it through iSeries Navigator? (See 61)
5. None of the nodes in my cluster have a status of ″Started″. Which node should I start first? (See 61)
6. Why should I care which node is started first? (See 61)
7. What does the ″Current Primary Node″ column mean in the switchable hardware group and switchable software product folders? (See 62)
8. How do I find a device cluster resource group (CRG) in iSeries Navigator? (See 62)

9. How do I find an application cluster resource group (CRG) in iSeries Navigator? (See 62)
10. How do I find a data cluster resource group (CRG) in iSeries Navigator? (See 62)
11. I want to be able to see the switchable hardware group (device CRG) status without having to go back up to the Switchable Hardware folder to see it. How can I do this? (See 62)

Communications

1. What IP address does the Clusters function in iSeries Navigator use to communicate with the nodes in the cluster? Doesn't it use the IP address of the node name? (See 62)

Security

1. Why are most of the context menus in the Clusters folder in iSeries Navigator disabled or disappeared? (See 63)
2. Does the Clusters function in iSeries Navigator use Application Administration values? (See 63)
3. Why does the Clusters function in iSeries Navigator show a signon window to my nodes in the cluster? (See 64)

Troubleshooting

1. Why isn't the Clusters folder showing up under Management Central? (See 64)
2. I already have a cluster, but it doesn't show up in the Clusters folder. Why? (See 64)
3. Why doesn't the latest status show up in the Clusters folder? (See 64)
4. Why didn't a failover of my switchable hardware group or switchable software product occur? (See 64)
5. I received a message for a damaged object. What can I do about it? (See 64)
6. I'm using the ″Browse″ button in the wizards for the nodes to browse for IP addresses.. Why aren't all of the TCP/IP addresses that I expect showing up in the browse window? (See 65)
7. Why are most of the context menus in the Clusters folder in iSeries Navigator disabled or disappeared? (See 63)
8. I was using the ″New Cluster″ wizard and I got a panel titled: ″New Cluster - No Switchable Software Found″. Is this bad? (See 65)
9. One of my nodes has a status of ″Not communicating″. How do I correct this? (See 65)

Warning: Temporary Level 4 Header

General: **Is there a checklist that outlines the prerequisites to creating a cluster?**

Yes. Use the “Cluster configuration checklist” on page 27 to make sure that you are prepared to configure clusters in your environment.

Back to questions (See 59)

Simple Cluster Management and iSeries Navigator: **Where is the Clusters function located in the iSeries Navigator interface?**

The Simple Cluster Management interface is available in iSeries Navigator as a part of the software package IBM iSeries Access for Windows. The Clusters function is located in the Management Central folder in iSeries Navigator. See “iSeries Navigator and Simple Cluster Management” on page 35 for details.

Back to questions (See 59)

How do I create a cluster?

To create a simple cluster using the New Cluster wizard in iSeries Navigator, follow these steps:

1. In iSeries Navigator, expand **Management Central**.

2. Right-click **Clusters**, and select **New Cluster..**
3. Follow the wizard's instructions to create a cluster.

For complete details on creating and configuring a cluster, see "Configure a cluster" on page 37.

Back to questions (See 59)

What is the relationship between the Clusters folder and the Management Central system group?

When you use Simple Cluster Management to create a cluster, a system group is also created on the Management Central server. The system group is given the same name as the cluster name and the endpoint systems in the system group are the nodes in the cluster. The system group also has its own special type so that Simple Cluster Management knows it is a special system group that represents a cluster.

Important: The Management Central system contains the system groups. If you choose to change your current Management Central system in iSeries Navigator, the new management central system will not have the special cluster system groups, and therefore those clusters will not show up in the Clusters folder.

Back to questions (See 59)

I already have a cluster defined on some iSeries systems in the network. How do I add it so I can view and manage it through iSeries Navigator?

To add an existing cluster to appear through iSeries Navigator, follow these steps:

1. In iSeries Navigator, expand **Management Central**.
2. Right-click **Clusters**, and select **Add Existing Cluster...**
3. On the **Add Existing Cluster** window, specify one of the servers in the cluster.
4. Click OK.

Back to questions (See 59)

None of the nodes in my cluster have a status of ″Started″. Which node should I start first?

You should start the node that most recently had a status of ″Started″. For example, say you have two nodes in your cluster: A and B. Node A is currently not started and node B is currently not started. However, node B was the last node to be running with a status of ″Started″. You should start node B first because it will have the most recent information about the cluster.

Back to questions (See 59)

Why should I care which node is started first?

You should care because the node that most recently had a status of ″Started″ is the node that contains the latest information about the cluster. This is important because if you started the other node that had been down the longest, then it may contain outdated information about the cluster. The danger is that the outdated information could get propagated to the other nodes in the cluster when those other nodes are started. For example, say have a two node cluster with nodes A and B. If node B was the most recently active node with a status of ″Started″, then it will contain the latest cluster information. If you choose to start node A first, then it might contain some outdated information, but will still be started. When you then start node B, it will join with a currently active node in the cluster (it joins with node A). The outdated cluster information from node A will get propagated to node B and the result is that both nodes will contain outdated information about the cluster. This is why it is important to start node B first. The outdated cluster information can have an effect on the configuration of the switchable hardware groups. If you find that you have some problems starting up switchable hardware groups because of disk units reporting in on the backup node when the switchable hardware group is showing a different current node, then you will need to change the role of nodes in the recovery domain, making the node which owns the disk units the primary node.

Back to questions (See 59)

What does the ″Current Primary Node″ column mean in the Switchable Hardware, Switchable Software, and Switchable Data folders?

The ″Current Primary Node″ column indicates that the node that is currently serving as the primary node for the switchable hardware group or switchable software product. Or, in cluster API terminology, it means that it is the node with the current role in the recovery domain of primary.

Back to questions (See 59)

How do I find a device cluster resource group (CRG) in iSeries Navigator?

Device CRGs (cluster resource groups) are referred to as Switchable Hardware Groups and found in the **Switchable Hardware** folder in the Clusters folder.

Back to questions (See 59)

How do I find an application cluster resource group (CRG) in iSeries Navigator?

Application CRGs (cluster resource groups) are referred to as Switchable Software Products and found in the **Switchable Software** folder in the Clusters folder.

Back to questions (See 59)

How do I find a data cluster resource group (CRG) in iSeries Navigator?

Data CRGs (cluster resource groups) are referred to as Switchable Data Groups and found in the **Switchable Data** folder in the Clusters folder.

Back to questions (See 59)

I want to be able to see the Switchable Hardware Group (device CRG) status without having to go back up to the Switchable Hardware folder to see it. How can I do this?

As an alternative to navigating to the Switchable Hardware folder every time you want to view status, you can also open a new window with the Switchable Hardware view by right-clicking on the **Switchable Hardware** folder and selecting **Open**. The separate window will show the Switchable Hardware Groups (device CRGs) and their associated status information. This also applies for **Switchable Software** and **Switchable Data**.

Back to questions (See 59)

Communications: **What IP address does the Clusters function in iSeries Navigator use to communicate with the nodes in the cluster? Doesn't it use the IP address of the node name?**

There is a ″Server″ column in the main Clusters folder that displays information about your configured clusters. The server name is also on the properties panel for each cluster. The server listed in the "Server" column is the node in the cluster that the iSeries Navigator interface uses to communicate with the cluster.

It only applies to how iSeries Navigator communicates with the cluster object on the server, not how the nodes in the cluster communicate with one another. The server used by Simple Cluster Management has nothing to do with the current Management Central server.

If the node that iSeries Navigator is using to communicate with the cluster goes down, you can change the communications vehicle to a different node in the cluster to perform cluster actions.

To change the server that will be used by the iSeries Navigator interface to communicate to the cluster, follow these steps:

1. In iSeries Navigator, expand **Management Central**.
2. Expand **Clusters**.
3. Right-click the cluster, and select **Change Server...**.

Back to questions (See 59)

Security: **Why are most of the context menus in the Clusters folder in iSeries Navigator disabled or disappeared?**

Some operations are only available depending on the state of the current configuration of your cluster. For example, you cannot stop a node that is already stopped, you cannot add a node to a cluster that already has the maximum amount of nodes, four, configured. The online help for particlular tasks has explanations of why some of these items are disabled or not available.

Some operations are not available if you don't have enough authority. If you are using Simple Cluster Management and you have *SECOFR userclass authority, you will have access to all cluster operations and administration. Simple Cluster Management uses Application Administration authority from the current Management Central system to determine if you have Application Administration authority for the various Simple Cluster Management operations.

See Application Administration for details on working with Application Administration.

Back to questions (See 59)

Does the Clusters function in iSeries Navigator use Application Administration values?

Yes. Simple Cluster Management uses the Application Administration authority values from the current Management Central system to determine if you have Application Administration authority for various cluster operations.

Simple Cluster Management has two types of authority settings for access: **Cluster Operation** and **Cluster Administration**

With the **Cluster Operation** authority, you can:

- View the status of the cluster
- Start/Stop nodes
- Start/Stop switchable hardware and switchable software
- Perform manual switching of switchable hardware and switchable software

With the **Cluster Administration** authority, you can:

- Create/Delete clusters
- Add/Remove nodes
- Add/Delete switchable hardware, switchable software, and disk pools
- Change the properties of switchable hardware and switchable software

Back to questions (See 59)

Why does the Clusters function in iSeries Navigator show a signon window to my nodes in the cluster?

In some cases, Simple Cluster Management will try to communicate with all of the nodes in the cluster. This depends on the state of your cluster. When Simple Cluster Management needs to communicate with a node, it will first search the existing signon cache in iSeries Navigator to try to find an existing open connection. If it does not find an existing connection, it will then ask the user to sign on. If you cancel the signon window, Simple Cluster Management will make an attempt to allow the user to do cluster operations. Some operations may not be possible if Simple Cluster Management can't communicate with the nodes.

Back to questions (See 59)

Troubleshooting: **Why isn't the Clusters folder showing up under Management Central?**

It is possible that you didn't do a full install of iSeries Access for Windows on your PC. You may have performed a basic install or chosen some custom options. See iSeries Access for details on installation.

Back to questions (See 59)

I already have a cluster, but it doesn't show up in the Clusters folder. Why?

The short answer is this: It isn't showing up because there is not a system group on your Management Central system that represents the cluster. That system group representing the cluster is created by Simple Cluster Management when either the cluster is created or the cluster is added to the Clusters folder by using the ″add existing cluster″ action. You can expand the **System Groups** folder in Management Central to see the system groups. The cluster system groups will show up as ″third party″ system groups, but don't assume all ″third party″ system groups are clusters.

Back to questions (See 59)

Why doesn't the latest status show up in the Clusters folder?

iSeries Navigator displays information about configured clusters as a shapshot by going out to the cluster nodes and getting the latest information about the cluster and then displaying it in the iSeries Navigator window. It does not automatically perform regular updates of the information. The best way to get the latest snapshot of information is to do a manual refresh. You can use the ″View″ menu in iSeries Navigator and then choose the ″Refresh″ option. The alternative is to set up iSeries Navigator to perform automatic refreshes.

Back to questions (See 59)

Why didn't a failover of my switchable hardware group, switchable software product, or switchable data group occur?

The most likely scenario is that you didn't have the switchable resource (cluster resource group) started in the cluster. In other words, before the automatic failover was to occur, the status of the switchable resource was not ″Started″. Your switchable resources must be started for a failover to occur.

Back to questions (See 59)

I received a message for a damaged object. What can I do about it?

You may have received a message like this: `CPF811C User queue QUGCLUSRQ in QCLUMGT damaged`

Option 1: One option is to delete the object and restore it. This is only possible if you previously saved the object.

Option 2: Delete the damaged object. For example, if QUGCLUSRQ in library QCLUMGT is damaged, then delete the object. Then add the existing cluster in Simple Cluster Management. By adding the cluster, the cluster GUI will check if the objects exist and re-create them if they don't already exist. See How do I add an existing cluster so I can view and manage it through iSeries Navigator? (See 61) for details on adding the existing cluster.

Back to questions (See 59)

I'm using the ″Browse″ button in the wizards for the nodes to browse for IP addresses. Why aren't all of the TCP/IP addresses that I expect showing up in the browse window?

The list is only a candidate list of possible IP addresses. You are not restricted to the list of possible addresses shown in the window. You can enter any cluster interface address you want. Be aware, however, that you will receive errors later if Simple Cluster Management can't connect using the IP address you specify as the primary IP address. Simple Cluster Management uses the primary IP address to connect to the nodes in the cluster.

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I was using the ″New Cluster″ wizard and I got a panel titled: ″New Cluster - No Switchable Software Found″. Is this bad?

No, this is not bad and it is not an error. It means exactly what it says; the Simple Cluster Management interface could not find any switchable software that could be automatically installed using the wizard. Simple Cluster Management requires that the any auto-installable switchable software conform to the ClusterProven^{TM} architecture. Additionally, Simple Cluster Management only supports a subset of the ClusterProven architecture, not all of it.

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One of my nodes has a status of ″Not communicating″. How do I correct this?

A cluster partition happens if you lose contact between one or more nodes in the cluster and a failure of the lost nodes cannot be confirmed. See "Partition errors" on page 54 for more information.

Sometimes a partitioned condition is reported when there really was a node outage. This can occur when cluster resource services loses communications with one or more nodes, but cannot detect if the nodes are still operational. When this condition occurs, a simple mechanism exists for you to indicate that the node has failed. See "Change partitioned nodes to failed" on page 55 for details.

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Who to call for cluster suppport

If you need help in deciding whether clustering can benefit your business, or if you run into problems after you have implemented clustering, contact these sources:

- For additional technical marketing assistance or if you would like to hire IBM's consultation services, contact the Continuous Availability Center in the iSeries Technology Center by sending an e-mail to rchclst@us.ibm.com.
- For other problems, contact either the business partner you purchased your clustering software package from or call 1-800-IBM-4YOU (1-800-426-4968).

Related information

Listed below are the web sites and IBM Redbooks^{TM} that relate to clustering:

Web sites

High Availability and Clusters
IBM site for High Availability and Clusters

IBM ClusterProven
IBM site for the IBM ClusterProven^{TM} Program

Redbook

Clustering and IASPs for Higher Availability (about 6.4 MB or 330 pages)
This redbook presents an overview of cluster and switched disk technology available for iSeries servers.

iSeries IASPs - A guide to working with Independent Auxiliary Storage Pools
This redpiece presents a step-by-step approach to independent ASPs on iSeries servers.

Printed in U.S.A.