BGP Simulation

This chapter describes how WAE Design models multi-AS networks and simulates basic BGP routing. WAE Design does not directly emulate BGP routing configurations, such as local prefs and MEDs. Rather, it provides a high-level modeling of typical peering policies, such as standard customer, transit, and settlement-free arrangements for service providers. This model lets you quickly and easily evaluate the effects of peering locations and basic policy variations.

Additionally, you can extend these high-level models to significantly more complex policy-based routing situations using *external endpoints* as demand sources and destinations. For information on demands and on external endpoints, see Traffic Demand Modeling and Advanced Routing with External Endpoints.

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Internal and External AS Types

To model a multi-AS network, each node is assigned an AS, and each AS is defined as either *internal* or *external* . A typical multi-AS model in WAE Design consists of the following:

- A single internal AS representing the full topology of your network.
- Individual peering nodes of neighboring external ASes.
- Peering circuits connecting the internal AS to the nodes in the external ASes.

Generally, there are many external ASes in the plan file, but usually only one or a few internal ASes. All nodes in an external AS are typically placed in the same site, although you can place them in any site. Figure 1: Example Multi-AS Model, on page 2 shows an example model with two internal ASes and four external ASes.

AS names and their types are defined in the AS Properties dialog box and listed in the AS table. Nodes are assigned to ASes in the node Properties dialog box.

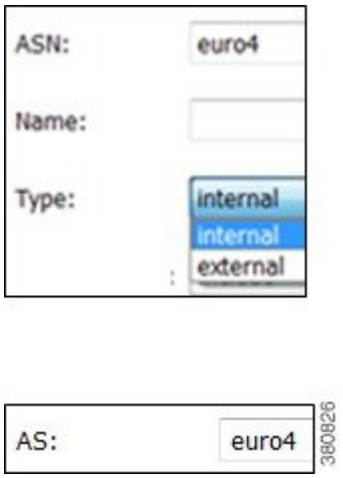
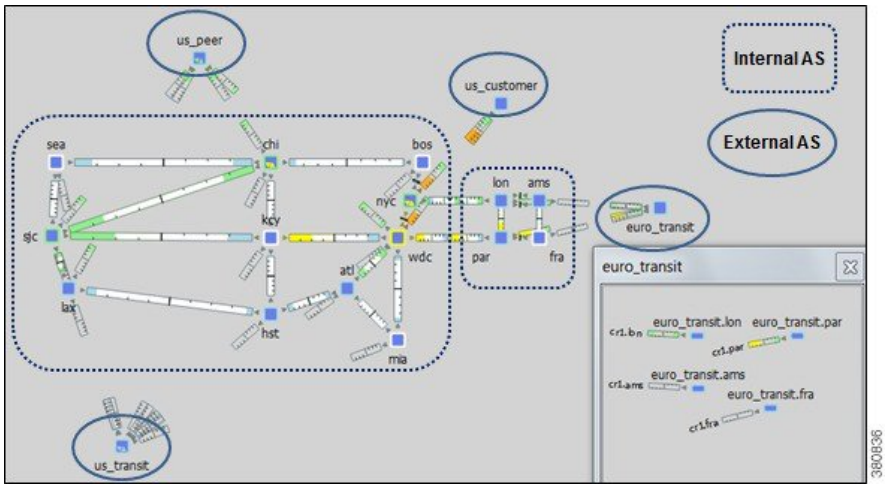


Figure 1: Example Multi-AS Model

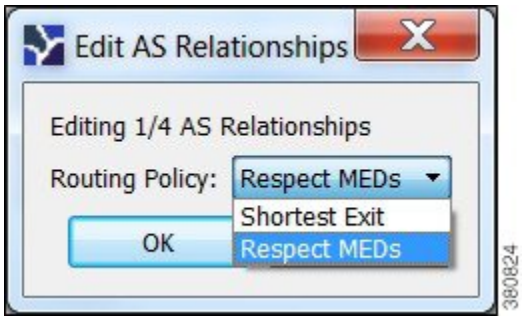


Inter-AS Routing

Route Selection Between Internal ASes

Demands routed within a single AS have a specified source node and destination node where traffic originates and terminates. Demands routed between two connecting internal ASes are specified in the same manner: with a source node in the first AS and a destination node in the second.

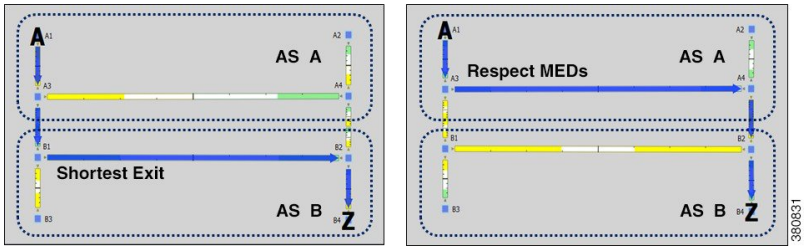
WAE Design routes within an AS, to and from the border exit point, are determined by the IGP protocols. The selection of border exit point is modeled by the Routing Policy, which is set to either Shortest Exit or Respect MEDs. This property is set in the Edit AS Relationships dialog box, which is accessed through the AS Properties dialog box.



- Shortest exit—The border exit node is selected, which is closest to the source node, within the IGP of the source AS. If there is a tie, the exit node with the lowest BGP ID is used.
- Respect MEDs—The border exit node is selected, which is closest to the destination node, within the IGP of the destination AS. If there is a tie, the exit node with the lowest BGP ID is chosen.

Figure 2: Route Selection Based on Routing Policy, on page 3 shows these modeled as two internal ASes: AS A and AS B. The same demand (A1 to B4) is routed using each of the two different routing policies.

Figure 2: Route Selection Based on Routing Policy



Routes Between External and Internal ASes

Table 1: Typical AS Routing Configurations, on page 3 lists typical routing configurations that can be constructed by applying different combinations of Routing Policies for traffic in both directions between two ASes.

- In a peer relationship, routing in both directions is Shortest Exit, which means each controls its own border exit points.
- For a customer relationship, the customer determines the border exit points for traffic in both directions.
- For a transit relationship, the transit AS provides paid transit to the internal AS, so the internal AS determines all border exit points.

Table 1: Typical AS Routing Configurations

Type	Policy to	Policy from
Peer	Shortest Exit	Shortest Exit
Customer	Respect MEDs	Shortest Exit

Type	Policy to	Policy from
Transit	Shortest Exit	Respect MEDs

Like traffic routed within an AS, traffic routed between ASes is represented by demands. However, for demands from and/or to external ASes, the external AS is defined as the source or destination of the demand. Optionally, the specific node in the external AS from which the traffic enters or exits the internal AS is also specified.

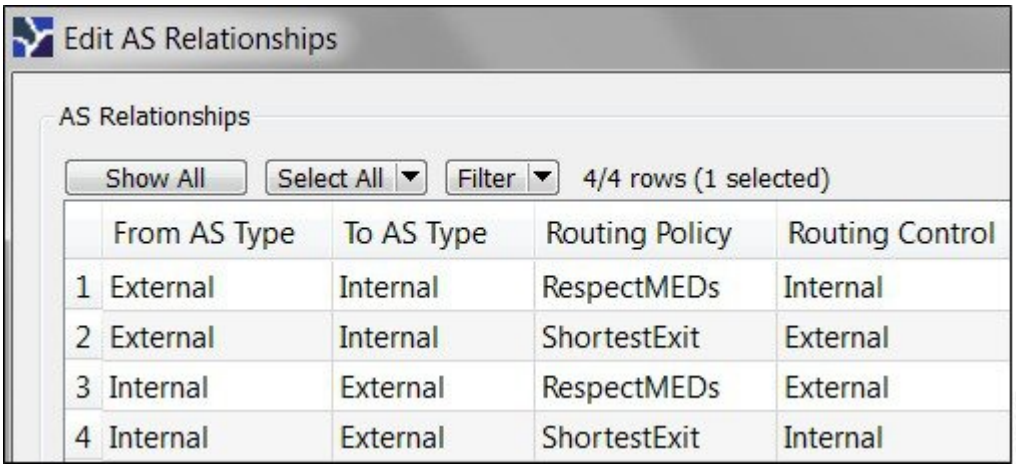
Failover between nodes in the external AS can be modeled. For example, if the traffic is sourced from an external AS and if the peering circuit from which traffic is entering the internal AS under normal operation fails, the traffic can enter the internal AS from a different interface or peering node in the same external AS. In the Demands table, the sources and destinations are represented as follows.

AS{<ASN>}:if{node_name|interface_name}

Example: AS{33287}:if{cr01.newyork.ny|POS3/7/0/0}

For more detailed information on demand sources and destinations, see Traffic Demand Modeling .

The AS that controls the routing chooses which peering node to use. If the internal AS controls the routing, then because the topology of the internal AS is known, you can simulate the routing to the peering node. However, because WAE Design has limited knowledge of the external AS topology, if the external AS controls the routing, you cannot predict how traffic will be distributed among the exit points.



The AS that controls the routing is determined by the AS type, direction of the demand, and the Routing Policy property as described in Table 2: Determining the AS that Controls the Routing, on page 4.

Table 2: Determining the AS that Controls the Routing

Direction	Routing Policy	AS with Routing Control
External AS to Internal AS (Ingress)	Respect MEDs	Internal
	Shortest Exit	External

Direction	Routing Policy	AS with Routing Control
Internal AS to External AS (Egress)	Respect MEDs	External
	Shortest Exit	Internal

Two ASes can be in one of four different routing relationships to one another, depending on which of the two routing policies is chosen in each direction (Table 3: Effects of Routing Policy and Routing Control , on page 5).

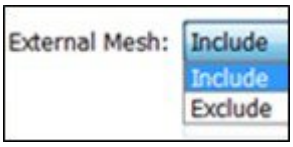
- If traffic is routed to an external AS when it has control and there is no knowledge of its topology, a set of demands is created from the source in the internal AS (or from another external AS), each with a destination set to one of the border nodes in the external AS. This way, any division of traffic between the exit points can be modeled.
- If traffic is routed to an external AS when an internal AS has control, a single demand is created from the source to the AS itself. WAE Design simulations determine the correct exit point for this single demand based on the source.
- If traffic is to be routed from an external AS when it has control, a demand is created from each node in the external AS to each node in the internal AS.
- If traffic is to be routed from an external AS when an internal AS has control, a demand is created to each node in the internal AS using the external AS as the source. The demand originates from one or multiple nodes in the external AS, depending on the topology and the metric cost to reach the destination node. For example, a single demand from an external AS to a specific node could be sourced from two different nodes in the external AS, each carrying 50% of the demand traffic.

Table 3: Effects of Routing Policy and Routing Control

Direction	Routing Policy	AS with Routing Control	Demand Source or Destination Endpoint in Remote AS	Number of Demands
External AS to Internal AS (Ingress)	Respect MEDs	Internal	Entire external AS	One only
	Shortest Exit	External	Border nodes	One for each node
Internal AS to External AS (Egress)	Respect MEDs	External	Border nodes	One for each node
	Shortest Exit	Internal	Entire external AS	One only

External Meshes

An external mesh consists of two or more external ASes with a Type property of External. An internal AS typically restricts advertisement of BGP routes for some external ASes to other external ASes. For example, destinations reachable through the transit network would not be advertised to a peer, or vice versa. In WAE Design, these restrictions are represented by the absence of demands between the two external ASes.



Each AS has a property called External Mesh, which WAE Design uses when inserting demand meshes into a plan. Demands are created for external ASes only if one or both ASes have External Mesh set to Include. If both ASes are set to Exclude, no demands are created for the external AS. For example, in Figure 3: External Mesh Control, on page 6 the peer and transit ASes are both set to Exclude, so no demands are created between those ASes. All other external AS demands are included in the demand mesh. Table 4: External Mesh Settings for Common AS Relationships, on page 6 shows the External Mesh settings for common AS relationships.

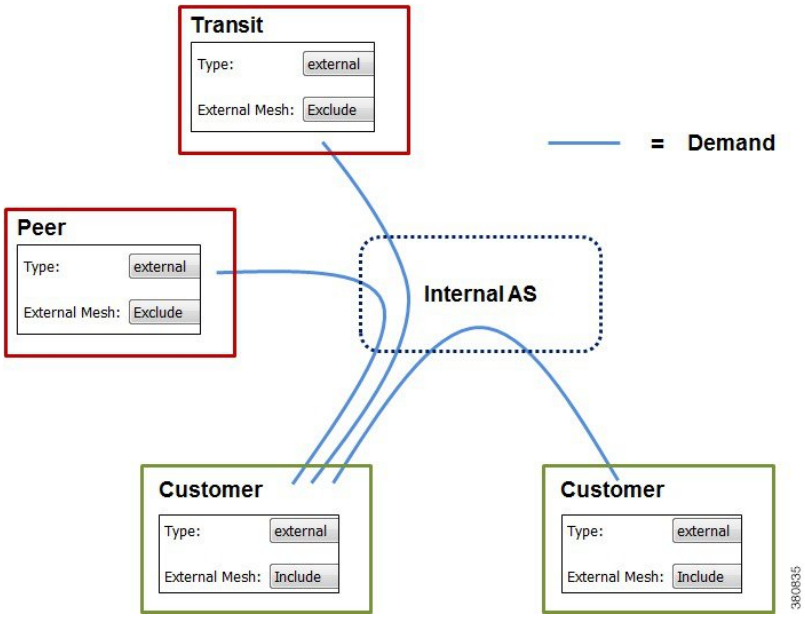
The External Mesh property is set in the AS Properties dialog box.

Table 4: External Mesh Settings for Common AS Relationships

Relationship	External Mesh Setting	Result
Peer	Exclude	Demands permitted to/from customers only
Customer	Include	Demands permitted to/from all external ASes
Transit	Exclude	Demands permitted to/from customers only

For internal ASes, the External Mesh property is ignored. More complex route advertisement policies cannot be represented by these simple External Mesh settings. In this case, demand mesh creation must be performed in several steps, possibly using a script and the dmd_mesh_creator CLI tool.

Figure 3: External Mesh Control



BGP Simulations

As with all WAE Design simulations, AS routing uses demands. An IP simulation for a particular failure scenario and traffic level performs these steps.

Step 1 Demands are routed using the established LSPs (if applicable) and using the specified BGP protocols given the specified failure scenarios.

Step 2 Interface utilizations are calculated from the demand traffic using the specified traffic level.

WAE Design allows routes to be calculated between selected nodes even if no demands are present. In this case, only the first step applies.

BGP demands do not failover between external ASes. That is, all traffic to or from an external AS behaves the same under peering failures to an external AS. You can change this default behavior using external endpoints to simulate specific external AS nodes where traffic goes in and out of the network, as well as set priorities so that if one traffic source or destination goes down, the traffic can still be sourced from or delivered to another external AS node.

BGP Routing Details

BGP Multihop

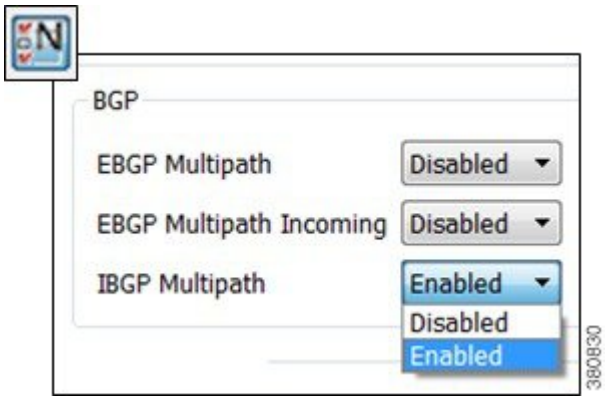
WAE automatically constructs BGP pseudonodes where necessary when BGP multihops are detected.

WAE Design models the nodes in external ASes that are directly connected, for example through eBGP, to nodes in internal ASes. One exception is that you can model BGP multihops by setting the node Type property to psn (pseudonode), such as might occur at a peering exchange. This pseudonode can represent the switch that connects a number of external AS nodes to the same internal AS node. In this instance, multiple external AS nodes are connected by circuits to a BGP psn node, and this node is connected to a node in the internal AS.

Note In all cases, eBGP multipaths across parallel border circuits is assumed.

BGP Load Balancing

BGP load balancing to an external AS uses eBGP multipaths or eBGP multihops. WAE Design models these two eBGP load balancing designs in the same manner, though in the GUI they are identified only as multipaths. BGP multipath options are disabled by default.



To set BGP multipath options globally, follow these steps:

Step 1 Choose **Edit > Network Options** or click the **Network Options** icon in the Visualization toolbar.

Step 2 Click the **Protocols** tab.

Step 3 For each BGP multipath option that you want enabled, choose **Enabled**, and then click **OK**.

- EBGP Multipath—Turns on eBGP multipath within the internal ASes. Demand routings through the internal AS to an external AS are divided among external routes with equal-cost BGP exit routes.
- EBGP Multipath Incoming—Turns on eBGP multipath in all external ASes. Demand routings from external ASes to an internal AS are divided among external routes with equal-cost BGP exit routes.
- IBGP Multipath—Turns on iBGP multipath within the internal ASes. Demand routes through an internal AS to an external AS are divided among internal paths to equal-cost BGP exit routes.

BGP Next Hop

In networks, there are two common configurations for the BGP next-hop IGP metric used in the path selection. One is to set the next-hop self on the iBGP peers (next-hop self = on). The other is to configure IGP metrics on eBGP interfaces, and to inject the interface prefix into the IGP database by setting the interface to be a passive IGP interface (next-hop self = off).

WAE Design does not have an explicit next-hop self setting so it simulates paths as if next-hop self is off. That is, the IGP metric of the egress peering interface is included in the IGP distance to the peering router and is used in the iBGP path selection. However, next-hop self to an external AS can effectively be simulated by setting the metrics on all egress interfaces to that external AS to 0. (You can set the IGP metric in either the Interfaces Properties or Circuit Properties dialog box accessed through the context menu.)

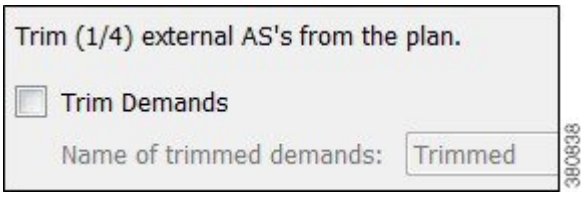
Trimming ASes

A plan file that uses BGP discovery typically has more external ASes in the plot than you are interested in viewing or simulating. Some ASes might have very low traffic levels and others might have only one circuit connecting into the internal AS. You can trim these unwanted ASes to simplify the network. Trimming removes the AS from the plan file, but retains the traffic in and out of the AS for simulation. That is, its interface traffic is still included in the total traffic of connected nodes.

Typically, plan files are trimmed before demands are created. However, you can optionally trim demands in a plan file. If any demand is sourced from a trimmed external AS, the demand source is moved to the first hop on the demand path in the remaining network. Likewise, if a demand has a destination that is a trimmed external AS, the demand destination is moved to the last hop in the remaining network. If two or more demands in the same service class are trimmed so that their resulting source and destination nodes are equal, these demands are aggregated into one demand with their traffic summed. Demands split by ECMPs are converted into multiple demands, each with traffic divided proportionally to the split ECMP.

Note that multicast demands are removed, and cannot be trimmed.

Step 1 Select one or more ASes to trim from the AS table.



For example, sort the ASes by traffic level and then select all ASes that are below the level of interest. Alternatively, filter the table for traffic using the less than operator (<) and the traffic level, and then select the filtered ASes.

Step 2 Right-click one of the selected ASes and choose **Trim**.

Step 3 (Optional) Select the option to trim demands.

By default, the moved demands are named “Trimmed,” though you can enter a different name.

Step 4 Click **Yes**.

Creating ASes

Follow these steps to create an empty AS. After creating the AS, you still need to associate nodes with it and create the relationship between this AS and others. See Associating Nodes with an AS, on page 10 and Editing AS Routing Policies, on page 10.

Step 1 Choose **Insert > AS**, or right-click in the empty plot and choose **New > AS**.

Step 2 Configure the AS properties:

- ASN—AS number, which is a text string that can be a number or name.
- Name—AS name.
- Type—Internal ASes have a full topology. External ASes have a collapsed topology with just border nodes and a virtual node.
- External Mesh—When creating a demand mesh, this option tells WAE Design whether to create external meshes. When one or both ASes are set to Include, WAE Design creates a mesh between the external ASes (default). If both are set to Exclude, no demands are created.
- IGP Protocol—Choose OSPF, ISIS, or EIGRP from the dropdown.

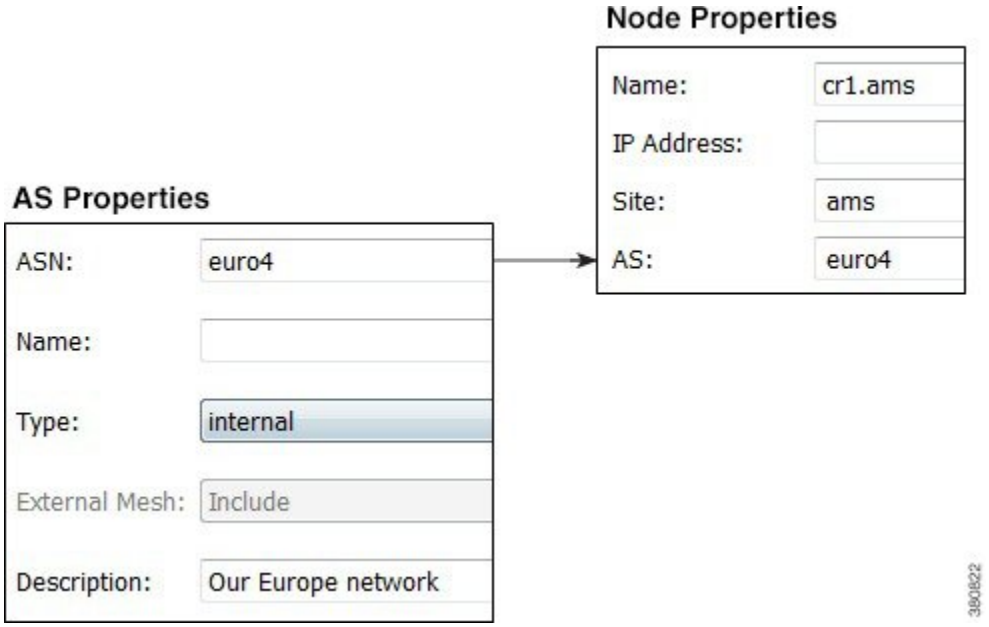
- Description—A text description of the AS.

Step 3 To change the routing policy, click **Edit AS Relationships**. (The default is Respect MEDs.) For information on how these options affect simulation, see Route Selection Between Internal ASes, on page 2.

Step 4 Click **OK** to create an empty AS.

Associating Nodes with an AS

Step 1 Choose one or more nodes, and double-click any one of them to open the node Properties dialog box.



Step 2 In the AS drop-down list, choose the AS to which you want to assign the nodes. Then click **OK**.

Editing AS Routing Policies

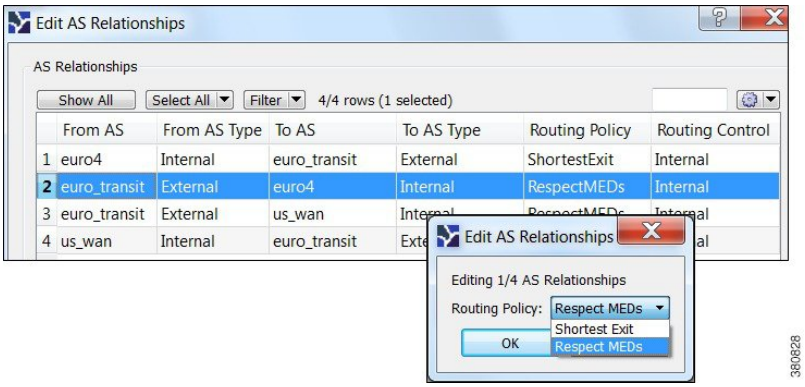
To create AS relationships, set the routing policy.

Step 1 Choose an AS from the AS table.

Step 2 Follow one of these methods to open the Edit AS Relationships dialog box:

- Choose **Edit > AS Relationships**.
- Right-click an AS and choose **Edit AS Relationships**.

- Right-click an AS and choose **Properties**. Click **Edit AS Relationships**.



Step 3 Choose the AS pair that you want to configure. There is a separate line for each direction in the relationship so you can configure them independently.

Step 4 Click **Edit**, set the Routing Policy to **Respected MEDs** (default) or **Shortest Exit**, and click **OK**.

Step 5 Click **OK** again.

Assigning Names to ASNs

WAE Design can assign names to ASNs by looking them up in the $CARIDEN_HOME/etc/ASNs.txt file. This file contains a list of all assigned ASNs with their names and descriptions.

Step 1 Choose one or more ASes from the AS table. If no ASes are selected, names are assigned to all ASes in the plan.

Step 2 Choose **Initializers > Assign Names to ASNs**, or right-click an AS and choose **Assign Names to ASNs**.

Step 3 To assign names only if the ASN does not have one, check **Only those with blank Name fields**.

Step 4 Click **OK**.